WORKSHOP 2 ON INNOVATIVE FISHING GEAR (WKING2)

VOLUME 5 | ISSUE 97

ICES SCIENTIFIC REPORTS

RAPPORTS
SCIENTIFIQUES DU CIEM

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ISSN number: 2618-1371

ICES Scientific Reports

Volume 5 | Issue 97

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Recommended format for purpose of citation:

ICES. 2023. Workshop 2 on Innovative Fishing Gear (WKING2). ICES Scientific Reports. 5:97. 290 pp. https://doi.org/10.17895/ices.pub.24299146

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Contents

i Executive summary

The EU Commission (EU DG MARE) has requested ICES advice on progress that has been made, or impact arising, from the use of innovative fishing gears within EU waters. Specifically, and to the extent possible, EU DG MARE seeks information on the type and range of innovative gears that are being used in commercial fisheries in the EU, the rationale or objective for their use, and their technical specificities and impact on target species, non-target species, and the environment in which they have been deployed. Fundamentally, this advice should also assess to the extent practicable, the reported benefits or negative effects of these innovations on gear selectivity, sensitive habitats, and marine ecosystems.

In response to this request, the first Workshop on Innovative Fishing Gear (WKING) report[1] produced a catalogue of 42 factsheets that described innovative fishing gears potentially viable for EU fisheries. Factsheet detail was generally provided by fishing technologists or other individuals involved in the development of the innovative fishing gear. A framework to assess the performance of an innovative fishing gear was also described in the WKING report, using catch efficiency, selectivity, and impact on the environment as "Criteria of Assessment". For each criterion an innovation matrix was conceived to enable comparison of innovations and provide a preliminary assessment of the benefits each gear. The "Performance improvement" and "Technological Readiness Level" (TRL) of each innovative fishing gear was also evaluated.

In preparation for a Workshop 2 on Innovative Fishing Gear (WKING2) in August 2023, fishing technologists or other individuals involved in the development of the innovative fishing gear were requested complete a new factsheet for any newly developed innovative fishing gear. The purpose of WKING2 was to:

a) Evaluate/endorse the catalogue of gears considered 'innovative';
b) Assess the level of uptake of innovative gears by the EU industry (per sea basin and fishery) that are ready for deployment, investigate aspects that impact the uptake of innovative gears including finance, user-friendliness, health, and safety;
c) Discuss the main drivers that prevent their use if known, and where possible, include analysis of the socio-economic trade-offs and propose ways to facilitate their implementation;
d) Produce a report detailing the process taken and presenting the results;
e) Draft summary advice based on the report produced.

This report describes the findings associated with a), b) and c). It represents d) and includes advice consistent with e). In this report we also convey on additional performance criteria that were included in the factsheets, based on review of the WKING report and discussions arising from WKING2. These include the perceived level of "Complexity", "Capital cost", and "Return on Investment". Questions were also included that sought information related to operational and health and safety considerations, while others were based on the PESTEL framework, designed to evaluate the political, economic, social, technological, environmental, and legal factors that may play a role in the uptake of innovative gear. Collectively, these additional performance criteria were an attempt to better understand main drivers that may influence the uptake of the innovative gear. We contacted members of the Joint ICES/FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) and other relevant individuals seeking advice on

[1]ICES. 2020. ICES Workshop on Innovative Fishing Gear (WKING). ICES Scientific Reports. 2:96. 130 pp. http://doi.org/10.17895/ices.pub.7528

innovative fishing gears. These individuals were invited to complete a revised factsheet with details describing an innovative gear they had developed and/or tested, including performance details.

The WKING2 report is based on the innovative gear catalogue containing an additional 75 factsheets which includes two updated innovations of gears (e.g. shrimp pulse trawl and Flemish panel) present in the previous WKING report.

The EU projects, *Discardless, Minouw, SmartFish, GearingUp,* and *EveryFish* were also reviewed to identify innovative gear, and to the extent practicable a factsheet was produced. Limited STECF (*Scientific, Technical and Economic Committee for Fisheries*) plenary meeting and EWG reports were also consulted.

Based on information provided in the factsheets, it was found that:

- Almost 80% of innovations were categorized as having a *high* level of technological readiness and only 4% were categorized as having a *low* level of technological readiness. Almost half (47%) the innovations were perceived to have a *minimal* level of complexity, and most (80%) of those gears were also deemed to have a high level of technological readiness. Almost one-third of the remaining innovations were perceived to have a *medium* level of complexity and moderate or high technological readiness level.
- Most (80%) innovative fishing gears were considered to result in a positive effect (incremental, transformative, or disruptive improvement) in *catch efficiency*, and most (80%) of these were also considered to have a high level of technological readiness. Those gears considered to result in a negative improvement in catch efficiency require further development, and despite their medium to high level of technological readiness it is unlikely fishers will adopt these gears unless they provide substantial improvement elsewhere, i.e. reduce fuel costs.
- When considering gear *selectivity,* most (80%) innovative fishing gears were deemed to result in a positive effect (incremental, transformative, or disruptive). Most (78%) of these innovations were also considered to have a high level of technological readiness. Five gears were considered to result in a negative improvement in selectivity and require further development or discarding, despite their high level of technological readiness.
- Most (64%) innovative fishing gears were considered to result in a reduction (incremental, transformative, or disruptive) of the impact on the marine ecosystem. Most (77%) of these innovations were also considered to have a high level of technological readiness. There were zero innovations with an increased impact compared to the baseline gear, and 27 with no effect.
- The PESTEL framework, based on six factors (e.g. political, economic, social, technological, environmental, and legal), was used to provide additional performance criteria to better understand the main drivers that influence the uptake of innovative gear.
- Initial use of PESTEL questions in the factsheets, and feedback received during the workshop, indicate that numerous, and often combined, factors are likely to influence gear uptake. More thorough and systematic collection of these data, based on an improved framework as developed in the workshop, is required before any conclusions can be drawn as to what factors encourage or impede uptake of innovative gears.
- Most factsheet responses (53%) indicated that *deployment and retrieval* of the innovative gear was not expected to be any different from the baseline gear, while 28% of innovative gears were considered to make deployment and retrieval of the gear more difficult. Less than 10% of innovative gears were thought to be easier to deploy and retrieve.
- Most (44%) innovative gears were likely to be more difficult for fishers to *maintain and repair* compared to the baseline gear while one-third were thought to make no difference, and 12% to be easier to maintain and repair.

- Almost three-quarters (72%) of innovative gears were thought to have similar impact on fisher *health and safety* as the baseline gears and only 1% to present a higher risk to health and safety.
- Reference to the innovative gear reducing fuel consumption and or greenhouse gas emissions was apparent in 19 (25%) factsheets.

The report concludes that most innovations reported in the factsheets were deemed to be ready for adoption by industry, subject to minor alteration to suit operational and design differences between vessels.WKING2 attempted to understand where impediments may be delaying the uptake of these gears by industry, although the data only permits identification and analysis of trends and indications. Some recommendations to improve data collection in future are also included.

ii Expert group information

Expert group name	Workshop 2 on Innovative Fishing Gear (WKING2)
Expert group cycle	Annual
Year cycle started	2022
Reporting year in cycle	1/1
Chairs	Antonello Sala, Italy
	Julia Calderwood, Ireland
Meeting venue and dates	23–25 August 2023, online meeting (30 participants)

iii Core group experts

Core group	Antonello Sala (CNR, Italy)
	Julia Calderwood (BIM, Ireland)
	Stephen Eayrs (Smart Fishing Consulting, Australia)
	Katell Hamon (WUR, The Netherlands)
	Nathalie Steins (WUR, The Netherlands)

iv Abbreviations and acronyms

ACOM	ICES Advisory Committee
ADG	Advice Drafting Group
AI	Artificial Intelligence
ALDFG	Abandoned, lost or otherwise discarded fishing gear
BRD	Bycatch reduction device
CFP	Common fisheries policy
CQM	Catch quota management
CPUE	Catch per unit effort
DG-MARE	EU Commission Directorate-General for Maritime Affairs and Fisheries
EC	European Commission
EMFAF	European Maritime Fisheries and Aquaculture Fund
EMFF	European Maritime and Fisheries Fund
EOSG	ICES Ecosystem Observation Steering Group
EPM	Electropositive metal
ETP	Endangered, threatened, and protected species
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAD	Fish aggregating device
FDF	Fully documented fishery
FRSG	ICES Fisheries Resources Steering Group
GFCM	General Fisheries Commission for the Mediterranean
GHG	Greenhouse gas
HAPISG	ICES Human Activities, Pressures and Impacts Steering Group
ICCAT	International Commission for the Conservation of Atlantic Tunas
IFR	Ideal Final Result
IUU	Illegal, unreported and unregulated fishing
ISO	International Organization for Standardization
L25, L50, L75	Length at 25%, 50% and 75% retentions
LO	Landing Obligation
MARPOL	International Convention for the Prevention of Pollution from Ships
MCRS	Minimum Conservation Reference Size

MLS	Minimum Landing Size
MSFD	Marine Strategy Framework Directive (2008/56/EC)
NGO	Non-governmental organization
PESTEL	Political, Economic, Social, Technological, Environmental and Legal factors
RFMO	Regional fisheries management organization
ROI	Return on Investment
SCICOM	ICES Science Committee
SMEs	Small and medium-sized enterprises
SR	Selection Range
STECF	Scientific, Technical and Economic Committee for Fisheries
SWD	Staff working document
T90	knotted diamond mesh netting turned 90°
TAC	Total Allowable Catch
TRL	Technology Readiness Level
UUC	Unwanted unavoidable catches
UWC	Unwanted catches
WGECON	Working Group on Economics
WGFTFB	ICES-FAO Working Group on Fishing Technology and Fish Behaviour
WGSOCIAL	ICES Working Group on Social Indicators
WKING	ICES Workshop on Innovative Fishing Gear

v Technical terms

Bycatch	The catch of non-target species and undersized fish of the target species. Bycatch of commercial species may be retained or discarded along with non-commercial bycatch.
Discards	Any fish or other living matter caught when fishing that is not retained but returned to the sea – alive or dead.
Endangered	Species, stock or population is 'endangered' if it is facing a high risk of extinction in the wild in the near future.
Fish stock	Scientifically, a population of a species of fish that is isolated from other stocks of the same species and does not interbreed with them and can, therefore, be managed independently of other stocks. In the Regulation (EU) 1380/2013 (2013), the term 'stock' is used to mean a species of fish living in a defined sea area; the two are not always synonymous.
Mesh selection	The process by which fish above a certain size are unable to pass through the meshes of a fishing net but fish below that size can do so. It works most successfully in free-hanging nets such as driftnets and gillnets, but trawls are also regulated by minimum mesh size (MMS). The efficiency of trawl mesh selection varies enormously with mesh shape.
Minimum Conservation Reference Size (MCRS)	In the Regulation (EU) 1380/2013 (2013), the term MCRS is the size of a living marine aquatic species taking into account maturity, as established by Union law, below which restrictions or incentives apply that aim to avoid capture through fishing activity; such size replaces, where relevant, the minimum landing size.
Minimum Landing Size (MLS)	The smallest length at which it is legal to retain fish or offer it for sale. In theory, it is the minimum length at which no less than 50% of a given species first reach sexual maturity. In practice it tends to be set at a level influenced by market acceptability, and is frequently less than the biological optimum.
Minimum Mesh Size (MMS)	The smallest size of mesh that can be used legally in any given type of net. It is measured either down one side of the mesh (knot-to-knot) or across the diagonal under tension (stretched mesh). The MMS is set to allow at least 50% of the target species at their MLS to pass through the mesh.
Non-target species	Any species that form part of the bycatch but are not (one of) the principal species that the fishery is exploiting.
Selectivity	A measure of a gear's ability to target and capture a species of fish while allowing juveniles and non-target species to escape.
Technical conservation measure	Technical measure that regulates the composition of catches by species and size and the impacts on components of the ecosystems resulting from fishing activities by establishing conditions for the use and structure of fishing gear and restrictions on access to fishing areas. Fishery management measures involve primarily the fishing equipment used rather than fishing time, place, or catch, e.g. minimum mesh size (MMS), engine power, width of individual (*e.g.* scallop) dredges, and number towed by one boat.

1 Introduction

Workshop 2 on Innovative Fishing Gear (WKING2)

1.1 Terms of reference

The purpose of this report is to catalogue and assess innovative gears based on selected criteria in support of the following terms of reference:

2022WK/FRSG38 **Workshop 2 on Innovative fishing gear** (WKING2), in response to the EU DG-MARE request for ICES advice on the progress and impact that has been made in innovative gear use within EU waters, chaired by Antonello Sala, Italy, and Julia Calderwood, Ireland, will be established and meet online 23–25 August 2023 (see Annex 1 for workshop agenda) to:

a) Evaluate/endorse the catalogue of gears considered 'innovative', including their objectives, technical specificities, and known impacts/benefits (in terms of selectivity and catch efficiency on target and non-target species and environmental impact in terms of benefits for, or negative effects on, marine ecosystems and sensitive habitats);

b) For innovations ready for deployment, assess the level of uptake of innovative gears by the EU industry (per sea basin and fishery). Investigate what aspects impact the uptake of innovative gears. Depending on data and knowledge availability, assess the impact of finance, user-friendliness, health, and safety. For those innovations which are already taken up, present the results for the fleets;

c) For those innovations not implemented, discuss the main drivers that prevented their use if known. Where possible, include analysis of the socio-economic trade-offs and propose ways to facilitate their implementation;

d) Produce a report detailing the process taken and presenting the results;

e) Draft a summary advice based on the report produced.

f) A Core Group of members from the ICES Working Group on Fishing Technology and Fish Behaviour (WGFTFB) will work by correspondence to address ToR (a). The Core Group, with input from other experts in the ICES community, will facilitate information collection and discuss the Innovative Gears conceptualization. The Core Group will also collect information on the types of innovative gear that have been used in EU fisheries in recent years. At the WKING2 meeting, the Core Group will present results for review and deliberate the findings to date. ToRs (b) and (c) will be addressed here. Following this, a report and associated advice will be drafted. This workshop will be followed up by a meeting between experts and ACOM Leadership. WKING2 will report by 15 September 2023 for the attention of FRSG, ACOM, and SCICOM.

Supporting information

Priority	High, in response to a specific request from the EU Commission to ICES to prepare the report described in Art. 31.1 of the EC Regulation 2019/1241.
Scientific justification	The EU Commission seeks ICES advice on the progress that has been made, or the impact arising from innovative gear within EU waters. This advice should provide the scientific knowledge basis to assess the benefits for, or negative effects on, marine ecosystems, sensitive habitats and selectivity. The following EU projects should be considered:

	Discardless (http://www.discardless.eu/); Minouw (http://minouw-project.eu/); SmartFish (https://smartfishh2020.eu/); and Gearing Up (https://gearingup.eu/). STECF plenary meeting and EWG reports will also be consulted.
Resource requirements	ICES Secretariat support with meeting logistics and advisory process.
Participants	The Core Group is expected to comprise few members. Other members of WGFTFB will be consulted. Where relevant, stakeholder (NGO, fishing industry, gear industry) input will be sought during the process. Stakeholders will be invited to the final workshop. DG-MARE will also be consulted for feedback on the initial suite of criteria. The requestors should be also engaged in the process through online meetings towards the end of the scoping and final meetings to ensure the product is fit for purpose.
Secretariat facilities	None.
Financial	Covered by DG-MARE special request to ICES.
Linkages to advisory and science committees	ACOM, SCICOM.
Linkages to other groups	EOSG, FRSG, HAPISG, WGFTFB.
Linkages to other organizations	GFCM, EU DG-MARE, STECF.

1.2 Background

In 2021 the European Commission, in line with Article 31(1) of the Regulation (EU) 2019/1241 (2019) ("the Regulation"), reviewed in a *Report to the European Parliament and the Council* how the Regulation is currently being implemented in EU fisheries (European Commission, 2021). This report built upon the contributions and assessments from the WKING report (ICES, 2020c) and the STECF Review of Technical measures (STECF, 2020). It also took full account of the opinions received from 23 Member States, 8 Advisory Councils[2], and 37 stakeholders by means of a targeted online consultation.

According to that report, inadequate time had passed since its inception to fully assess if the Regulation had met its principal objectives, and it therefore focused on analysing: 1) the impact of previous technical measures; 2) the current situation; and 3) the actions planned for the near future to implement the Regulation.

The Report also presented the basis under which the Common Fisheries Policies (CFP) will contribute to the "*Action Plan to conserve fisheries resources and protect marine ecosystems*" as announced in the EU Biodiversity Strategy for 2030 (Communication COM(2020) 380, 2020). The Staff Working Document SWD(2021) 268 (2018) accompanied the *'Report from the Commission to the European Parliament and Council on the implementation of the Technical Measures Regulation'*. It investigated in greater depth: 1) The objectives and targets of the Regulation and how to measure progress towards these objective and targets; 2) General considerations regarding sensitive

[2] https://oceans-and-fisheries.ec.europa.eu/fisheries/scientific-input/advisory-councils_en

species and habitats; 3) Overview of the implementation of the Regulation and the consultation of Member States, Advisory Councils, and stakeholders, looking with detail to commonly applicable measures; 4) Implementation and consultation on regional technical measures, by sea basin, and considering the main findings since the Regulation came into force, and; 5) Research and innovation. 6. Final considerations, including some reflections on the implementation.

Most recently the European Commission published the Marine Action Plan *'Protecting and restoring marine ecosystems for sustainable and resilient fisheries'* as part of the set of measures aiming to improve the sustainability and resilience of the EU´s fisheries and aquaculture sector, in which the innovation and adoption of technology is underlined (Communication COM(2023) 102, 2023).

1.3 Information collection and factsheets

Consistent with the Terms of Reference, this report describes the progress and impacts arising from the development and testing of innovative fishing gears in EU waters, in particular the benefits of these gears on marine ecosystems, sensitive habitats, and selectivity. The following EU projects were considered: *Discardless, Minouw, SmartFish, GearingUp,* and *EveryFish*. Limited STECF plenary meeting and EWG reports were also consulted.

We also contacted members of the ICES/FAO WGFTFB seeking advice on innovative fishing gears. These individuals were invited to complete a factsheet (see Annex 2) with details describing an innovative gear they had developed and/or tested, including performance details.

The factsheet was modified from that reported in the first WKING report (ICES, 2020c) and requested information relevant to various criteria deemed to influence the adoption of innovative fishing gear (*sections §3.5*). New criteria included the capital cost associated with the purchase of the innovative gear and the return on investment resulting from use of the innovative gear. It also included ranking the perceived impact of the innovative gear on deployment and retrieval of the gear, ease of maintenance and repair, risk to health and safety of fishers, and if the gear resulted in higher costs relative to the potential economical, operational, environmental financial costs associated with using the innovative gear. The factsheets also sought feedback to understand to what extent any or all of the six factors of the PESTEL framework, i.e. **P**olitical, **E**conomic, **S**ocial, **T**echnological, **E**nvironmental and **L**egal factors, influenced the adoption of the innovative fishing gear (see *section §3.5.1*).

2 Innovative fishing gear: definition, uptake, and assessment

2.1 General definition of innovation

There have been considerable efforts in recent years to modify fishing gears and practices to improve selectivity, reduce mortality of discards, and reduce seabed impact. Bycatch considerations are an important motivation driving regulations in many fisheries, and new innovative gear modifications are continuously being proposed and tested to mitigate problems.

In April 2020, Strategic Innovation Ltd (UK), published a report titled "*A global state-of-the-art review of seafood*" (Techau *et al.*, 2020), presenting technologies and innovations from around the world that are relevant to the fisheries, aquaculture and seafood industries in UK. According to Techau *et al.* (2020) innovations can be thought of as ***"any new ideas, creative thoughts,*** **[or]** ***new imaginations in the form of technology or method"***. The rationale for developing an innovation is typically to improve the effectiveness of products, processes, services, technologies, or business models relative to that that currently exists. In effect, a successful innovation results in a more ideal or beneficial solution compared to what currently or had previously existed.

The evolution process of innovation usually takes place through a series of discontinuous evolutionary jumps from one way of doing things to another (Mann, 2002) (Figure 1). The goal of innovation is to achieve increased ideality, whereby increased benefits are received with minimal or no cost or harm:

$$Ideality = \frac{\sum positive\ effects}{\left(\sum costs\right) + \left(\sum harms\right)}$$

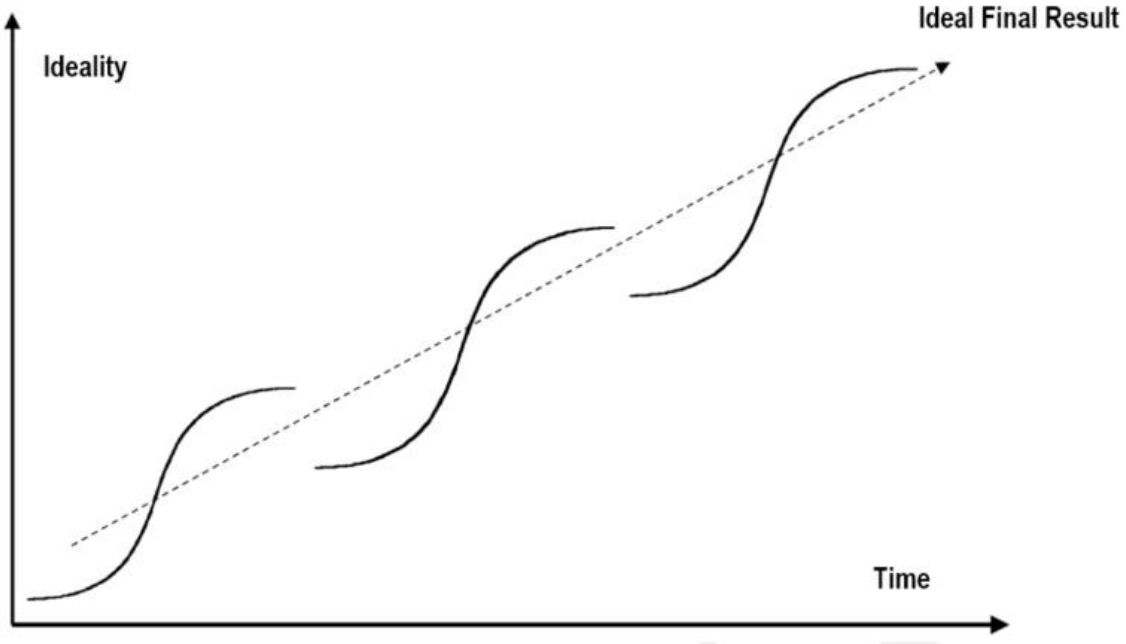

Figure 1. Evolutionary dynamics of innovation. Systems jump from one S-curve to another in the direction of Ideal Final Result (IFR) outcomes. ***Source: adapted from Mann (2002).***

Innovation that is transformative or disruptive can provide outcomes closer to desired ideality sooner than that resulting from incremental innovation (Figure 2). So-called disruptive innovation may initially appear less ideal than the incumbent innovation and may even initially appear further from ideality due to a variety of reasons including lack of scale and limited market presence.

However, such innovation rapidly starts to outperform the incumbent technology and may eventually dominate the market. So-called innovation failures are short lived efforts to realize ideality that struggle to achieve mainstream success. Over time multiple innovation failures can cumulatively realize improvement but this occurs over a relatively long time period. Techau *et al.* (2020) reported that many such failures are not due to deficiencies in the technical idea itself but due to marketing or operational failure, of from simply being ahead of their time and suffering lack of interest.

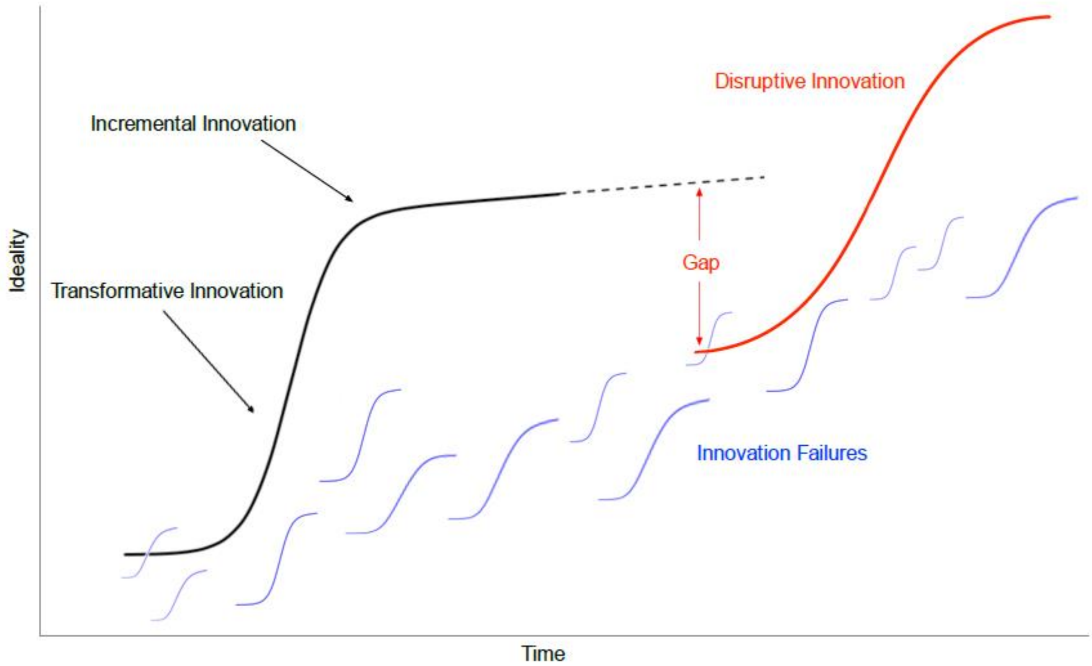

Figure 2. Innovation evolution dynamics. Systems jump from one S-curve to another in the direction of Ideal Final Result (IFR) outcomes (Mann, 2002). Source: adapted from Techau *et al.* (2020).

2.2 Innovative fishing gear

In this report an innovative fishing gear is defined as a new gear or a new or significantly different component of an existing gear that has not previously been used commercially in a specific EU sea basin (Annex 3) and/or is sufficiently different from the baseline gear, which may or may not be described in the current European Regulations. A fishing gear used regularly in one sea basin may be considered innovative in another where the gear has not previously been used. Innovative fishing gears are typically developed to achieve a stated fisheries management or ecosystem objectives, such as a reduction in discards or seabed impact.

In EU fisheries, the baseline gear is often derived either from existing technical measures specified in the European Regulations or from unregulated, commonly used commercial practice. Examples of these parameters are mesh sizes, headline length specifications, restrictions on groundgear. These are often introduced as conservation measures to mitigate against catches of sensitive species in certain areas or impact on sensitive habitats.

2.3 Uptake behaviour

The uptake of innovative fishing gears or nets involves a deliberate change in behaviour. To consciously change behaviour, a number of steps need to be followed: (1) Knowing, (2) Wanting, and (3) Doing (Fisher and Fisher, 1992).

Step one, "knowing" means that people, in this case fishers, first need to understand and recognize why the current behaviour is problematic, for example their fishery is associated with unwanted bycatch of vulnerable or protected species. Once this is agreed, alternative behaviours can be presented, and the relative merits of different alternative options can be discussed. This first step is very much a dialogue between fishers and other stakeholders, including scientists. It should not be a top–down dumping of information as this is unlikely to result in change. This dialogue needs to be built on trust relationships to increase acceptance and legitimacy of the information shared.

"Knowing" that there is a problem and what potential solutions are is, however, not a guarantee that a person will change. While fishers may cognitively be aware that change is necessary and important, affectively (emotionally) they may think otherwise and be unprepared to change (Steins *et al.*, 2022; Jenkins *et al.*, 2023; Pol and Maravelias, 2023). Affective readiness is considered possibly more important that cognitive readiness (Lawton *et al.*, 2009) and yet has seldom been studied, although (Eayrs, 2023) retrospectively considered both the affective and cognitive readiness of fishers to change in an Australian prawn trawl fishery.

"Wanting" to change, the second step in changing behaviour, involves two levers: "ability" and "willingness" (Steins *et al.*, 2022). Fishers need to be able to change and also willing to adopt an alternative behaviour. Once all the intentions are aligned, the "doing" is the next step. From the literature on innovations in fishing gear technology, that fishers' "doing" in taking up gear with a high level of technological readiness (proven gear) often does not meet expectations from gear technologists and managers (Eayrs and Pol, 2019).

Research shows that fishers' decisions to voluntarily adopt proven fishing gear are driven by a complex interplay of social, policy and science-related factors (Steins *et al.*, 2022). These factors can be attributed to the second step of behavioural change "wanting" and its two levers "ability" and "willingness". Ability is associated with knowledge, skills, economic and legal possibilities to enable voluntary uptake, and tends to be the focus of science and policy. Willingness is closely linked to: (a) intrinsic motivations and beliefs about sustainable fishing as well as perceptions about the motivations and behaviour of other fishers; (b) the extent to which fishers consider policy goals and regulations as legitimate; and (c) strong normative beliefs among fishers about the presence (or absence) of a level playing field, in terms of both the same rules applying to all and trust in compliance and enforcement (Steins *et al.*, 2022).

Fishers may have different motives to change practices and apply new technologies. Such motives are often directly related to business operations and include: (i) increasing revenue by catching more, (ii) increasing revenue by raising the value of the catch, (iii) reducing the costs of fishing, and (iv) enhancing comfort and safety onboard (Hall and Mainprize, 2005; Jennings and Revill, 2007; Eigaard *et al.*, 2014; Hamon *et al.*, 2017; Eayrs and Pol, 2019). Fishers may also be intrinsically motivated to reducing un-intended side effects of fishing on the marine environment in terms of improved sustainability of fishing, given their livelihood relies upon a healthy environment. In addition to economic and environmental drivers, social, regulatory, technological, and environmental drivers play a role in the successful uptake of new technology (Hamon *et al.*, 2017; Nielsen *et al.*, 2018; Steins *et al.*, 2022). Social factors that influence investment decisions in innovative technology are the sharing of information and the long-term perspective on the future of the company, the social practice associated to operating the alternative gear and the social licence to operate any innovative technique (van Putten *et al.*, 2018). Other social factors include community norms such as negative perceptions of innovative behaviour by fellow fishers, resistance to change, historical mistrust between parties involved, and ineffective outreach to inspire fishers to innovate (Eliasen *et al.*, 2014; Eayrs *et al.*, 2015; Penas Lado, 2016; ICES, 2018c; Eayrs and Pol, 2019; Steins *et al.*, 2022).

Technological factors are related to the possible constraints of the vessel to implement the innovation. Regulatory and policy factors comprise for instance the room for experimentation, legal support, access to the fishery, and control and enforcement, but also lack of appropriate incentives or presence of disincentives and top–down and 'one size fits all' approaches of policy implementation and lack of support for policy goals (Hall and Mainprize, 2005; Graham *et al.*, 2007; Jennings and Revill, 2007; Catchpole *et al.*, 2008; Eliasen *et al.*, 2014; Kraan *et al.*, 2015; Penas Lado, 2016; Eayrs and Pol, 2019; Barz *et al.*, 2020; Kraan and Verweij, 2020; Calderwood *et al.*, 2021; Steins *et al.*, 2022). Factors impacting fisher behaviour in relation to gear innovation and uptake do not stand alone, i.e. there usually is a combination of factors and it is very possible that positive conditions are negatively impacted by other factors as will be shown in some of the case studies in *section §4.9*.

3 Criteria of assessment

3.1 Ecological performance

The impact of implementing an innovative fishing gear, whether it is a modification to an existing gear or a completely new gear, can be evaluated differently depending on criteria used for the evaluation. In this report we used three ecological performance criteria to evaluate the impact of the innovative fishing gear on target and non-target species and the marine ecosystem compared with the existing (*baseline*) gear. These criteria were 1) catch efficiency, 2) selectivity, and 3) impact of the gear on the marine ecosystem (these criteria were collectively referred to as criteria of assessment in the first WKING report). The improvement (or otherwise) of the innovative gear with respect to each criterion was ranked as incremental, transformative, or disruptive, while the technological readiness of each gear was assessed by the Technology Readiness Level (TRL).

Changes in the catch efficiency and selectivity of a fishing gear can alter the abundance and structure of target and non-target fish stocks. Thus, the adoption of innovative fishing gear can lead to the exploitation of larger or smaller quantities of target and non-target species, the extraction of new species that were not previously impacted by fishing gear, and greater or lesser impact on non-target species including vulnerable and endangered, threatened, and protected (ETP) species. Some innovative fishing gear can also have greater or lesser impacts on the seabed. Considering the impact of an innovative gear on fish stocks and the marine ecosystem is therefore an important step in evaluating the gear and assessing its potential adoption by industry.

3.1.1 Catch efficiency

The main purpose of a fishing gear is to land commercially viable catches of target fish, crustaceans, molluscs, or other species (collectively called "fish" in this report). Therefore, an important criterion for the evaluation of an innovative fishing gear is an assessment of its impact on the catch efficiency of the target species compared with the existing baseline gear. Catch per unit effort (CPUE) is a commonly used metric to evaluate catch efficiency, thus for an innovative fishing gear to be acceptable and adopted by industry its CPUE would likely need to be similar or higher than that of the baseline gear, unless it surpasses the baseline gear in other criteria so that a reduction in CPUE can be justified.

3.1.2 Selectivity

The selection of fish by a fishing gear can be considered the process which causes the landed catch to have a different size and species composition to that of the fish population in the geographical area in which the gear is being used. Thus, the impact of an innovative gear that aims to improve the selection of fish can be evaluated by assessing differences in the size and species composition of the catch between the innovative gear and the baseline gear.

3.1.2.1 Catch of target species

The desirable catch of target species is composed of, i) all individuals of these species retained by the gear that are of a size equal to or above the Minimum Conservation Reference Size (MCRS), and ii) all marketable individuals of those target species without an MCRS that are retained by the gear. Ideally the catch should also be composed of no target species of a size below the MCRS and no non-target species.

The selectivity of a fishing gear is a measurement of the selection process (Wileman *et al.*, 1996). The size selective properties of a fishing gear are often measured by *population-independent* selectivity parameters.

This includes the 50% retention length (L50), the length at which a fish has a 50% chance of being retained by the gear on condition that it enters or interacts with the gear, and the Selection Range (SR), the difference between the 75% (L75) and 25% (L25) retention lengths. The size selective property of a fishing gear may also be evaluated by means of *population-dependent* indicators such as the proportion of retained fish above and below the MCRS.

3.1.2.2 Bycatch

In its broadest sense bycatch includes all non-target animals and non-living material (debris) that are caught and retained in the fishing gear (Eayrs, 2007). Bycatch may include general discards, retained, released or discarded species, sold ''by-product'' species, juvenile fish, so-called trash fish, pre-catch losses, slipped fish, mortalities due to ghost fishing, fish offal, and discarded fish heads and frames. (FAO, 2015). Discard species are the most common focus of studies that seek to report, assess or to reduce bycatch, including the capture of vulnerable and ETP species (Gray and Kennelly, 2018).

3.1.3 Impact on marine ecosystems

All fishing activities have impacts on the marine ecosystem to a greater or lesser extent and these impacts can vary in magnitude and nature (Amoroso *et al.*, 2018). Criteria commonly used to assess the impact of a fishing gear on marine ecosystems are:

- seabed impact;
- gear loss and associated potential for ghost fishing and pollution; and
- impact on endangered, threatened, and protected (ETP) species.

3.1.3.1 Seabed or benthic impact

Demersal fishing gear is designed to be operated very close to, in direct contact with, or to penetrate the seabed in order to harvest target species. These gears include bottom trawls, Danish or Scottish seines, and dredges, and innovations altering the design, configuration, and operation of these gears should be carefully evaluated with respect to potential changes in benthic impact. Such an evaluation should consider physical alteration of the seabed, sediment suspensions, and the welfare and survival of bottom-dwelling epifauna and infauna species.

3.1.3.2 Gear loss, ghost fishing and marine plastic pollution

Abandoned, lost or otherwise discarded fishing gear (ALDFG) is a source of marine litter that contributes to marine pollution and has the potential for ghost fishing, where the gear continues to retain and possibly kill animals over a period of time.

Ghost fishing is primarily an issue for static fishing gear, such as gillnets, traps or pots, but it may apply to demersal or other fishing gear that is lost, discarded or abandoned. The potential introduction of innovations that can influence the risk of gear loss and/or gear impact on marine ecosystems should be evaluated carefully.

3.1.3.3 Impact on endangered, threatened, and protected (ETP) species

The bycatch of vulnerable and ETP species is a substantial threat to many species of megafauna such as sea turtles, marine mammals, seabirds, and sharks and rays. Many studies have investigated the impact of fishing gears on these species; for example, see reviews by (Lucchetti and

Sala, 2010). While this work continues, ongoing reports of interaction between these species and fishing gear, including their mortality, suggests the issue remains in need of additional effort.

3.1.4 Additional criteria

The evaluation of an innovation may also contain information on its impact with respect to additional parameters such as marine pollution, energy consumption or atmospheric contamination associated with fishing activities. Marine pollution includes all types of pollution in the marine environment related to fishing activities, from plastic pollution (e.g. macro-, micro-, and nano-plastics) due to regular gear use and due to disintegration of ALDFG, to garbage, wastewater discharge, and oil spills from fishing vessels.

Energy consumption and the consequent gas emissions from combustion engines contribute to the release of greenhouse gases (GHG) and atmospheric contamination (Sala *et al.*, 2011a; Sala *et al.*, 2022). There are innovations that directly aim at reducing energy use and environmental impact of fishing gear in general. These may also need to be considered when assessing the overall impact of a potential innovation, although these are not the focus of the innovation that is being assessed in this report.

3.1.5 Performance improvement

To facilitate the evaluation of an innovative fishing gear, a grading system was necessary to provide insight into how the performance of this gear may differ compared to the baseline gear. In this report we applied a grading system to the three ecological performance criteria, catch efficiency, selectivity, and impact on marine ecosystem, using a four-level grading system:

1. **Incremental performance.** Performance improvement that can be considered relatively minimal or modest improvement compared to the performance of existing baseline fishing gear;
2. **Transformative performance.** Performance improvement that can be considered a substantive improvement compared to the performance of the existing baseline fishing gear;
3. **Disruptive performance.** Performance improvement that can be considered radically and significantly superior compared to the performance of the existing baseline fishing gear;
4. **Not applicable (*interpreted as no effect*).** No effect on the performance improvement compared to the performance of existing baseline fishing gear;
5. **Negative performance.** Performance improvement that can be considered to provide negative improvement compared to that using the existing baseline fishing gear. Innovations that result in negative performance are likely to be quickly rejected.

3.2 Levels of technological complexity

Technological complexity can be defined as *"the degree to which an innovation is perceived as relatively difficult to understand and use"* (Rogers and Shoemaker, 1971), and it usually indicates the relative technological sophistication associated with the design and manufacture of an innovation or product, considering its characteristics and performance (FAO, 2018).In this report we classified technological complexity into three levels:

- **Minimal complexity** - This level represents a low degree of complexity. Innovative fishing gears belonging to this level usually do not require radically new knowledge or technology, and they can be readily adopted and used with minimal difficulty compared to the existing baseline fishing gear;
- **Medium complexity** - This level represents fishing gears that are sufficiently different from the baseline gear that limited training or knowledge may be required to operate successfully. The use of these gears may also require modest change in vessel design, processes, operations, and handling;
- **Significant complexity** - This level represents fishing gears that are radically different from the baseline gear and their operation requires considerable training or knowledge. They may also require considerable change in traditional vessel design, processes, operations, and handling.

3.3 Technology Readiness Level (TRL)

Technology readiness levels (TRLs) are a measure that enables consistent, uniform evaluation of the maturity of a particular technology (Héder, 2017). The primary purpose of TRLs is to assist decision-making concerning the development and transitioning of a technology by end-users. Some of the advantages of using TRLs include:

- Providing a common understanding of technology status;
- Aiding risk assessment and management;
- Assisting decision-making concerning potential funding for further development of the technology;

Supporting decision-making concerning transition and adoption of technology by end-users.

The use of TRL in EU policy was proposed in the final report of the first High Level Expert Group on Key Enabling Technologies (European Commission, 2011), and was implemented in the subsequent EU Horizon 2020 framework program (Héder, 2017).

In this report, the TRL of innovative fishing gears was classified into three categories - low, moderate, and high (Table 1). This classification was based on Techau *et al.* (2020), which provides guidelines for assessing technical readiness of innovations in the aquaculture and fisheries sector.

To refine this classification, each innovative gear was assigned a score from 1 to 9, with 9 being considered the most mature technology. An innovative fishing gear with a high TRL score was therefore assumed to be sufficiently well developed that it is ready for adoption by industry, perhaps with minor modification to suite operational and design differences between vessels. An innovation with low technological readiness was assumed to be in an early stage of development and requires significant additional development. Such an innovation is not likely to be ready for adoption by industry.

Table 1. Technology readiness levels adopted in the European Union (European Commission Decision C(2014)4995, 2015), and tailored TRL categories for the assessment of the technical readiness of innovative gears.

TRLs category	European Union TRLs scale		
Low	TRL 1	–	Basic principles observed
	TRL 2	–	Technology concept formulated
	TRL 3	–	Experimental proof of concept
Moderate	TRL 4	–	Technology validated in lab
	TRL 5	–	Technology validated in relevant environment
	TRL 6	–	Technology demonstrated in relevant environment
High	TRL 7	–	System prototype demonstration in operational environment
	TRL 8	–	System complete and qualified
	TRL 9	–	Actual system proven in operational environment

3.3.1 Technological readiness and ecological performance matrices

In this report, matrices were produced to assess the relationship between technical readiness level and catch efficiency, selectivity, and impact on marine ecosystems, as reported in the factsheets (see Table 2 for example). The purpose of these matrices was to help identify the potential of each innovative fishing gear for adoption by the fishing industry, and this approach was consistent with that used by Techau *et al.* (2020). The technical readiness of each innovative gear was evaluated using criteria described in *section §3.2* and the ecological performance of innovative gear was rated using criteria described in *section §0*. The colour coding of the cells of the matrix were based on the following:

- **Yellow**: Innovations that deliver incremental performance gains and have a moderate to high level of technological readiness. They may be worthy of adoption by industry.
- **Light red**: Innovations that offer an incremental performance gain but considered unlikely to be worthy of adoption by industry because of their low level of technological readiness.
- **Dark red**: Innovations that offer no improvement or produce worse outcomes compared to the baseline gear. They are unlikely to be adopted by industry.
- **Green**: Innovations that offer potential for transformative or disruptive performance gains and have a moderate to high level of technological readiness. They may be attractive to industry and readily adopted.
- **Sky blue**: Innovations that offer potential transformative or disruptive performance gains, but may not be attractive to industry due to low technological readiness.
- **Blue**: Innovations that have shown to have disruptive performance gains and have a high technological readiness. They are very relatively rare (‘Unicorns’) but are a “no brainer” for speedy adoption.

Table 2. Innovation matrix layout for the assessment of innovative fishing gears.

Performance				
	Disruptive	Probably worth considering	Highly promising	Unicorn “no brainer”
	Transformative	May be worth considering	Some potential	Very promising
	Incremental	Not worth considering	Probably not worth considering	Possibly worth considering
	No effect	Not worth considering	Not worth considering	Not worth considering
	Negative	Negative outcomes	Negative outcomes	Negative outcomes
		Low	Moderate	High
		Technology readiness level		

3.4 Economic costs associated with the purchase and use of an innovative fishing gear

We considered the capital cost and return on investment to assess the economic costs associated with the purchase and use of an innovative fishing gear. These in turn affect the potential these gears to be adopted by commercial fishers.

3.4.1 Capital cost

This is a one-time estimated cost to purchase and install (if required) the innovative fishing gear (a) relative to the baseline fishing gear (b). We developed the following capital cost categories:

Low	a < 1.1 x b
Moderate	a ≤ 1.1 to 1.25 x b
High	a > 1.25 x b

The above multipliers are based on our experience working with the commercial fishing industry. Each fisher is different and their perception regarding what constitutes a low, medium, and high capital cost will be personal and circumstantial. However, in the absence of countervailing evidence, we feel it not unreasonable to categorize an innovative gear as low if it is less than 10%

more expensive than the baseline gear. This category also includes innovative gear that is cheaper than the baseline gear. We also feel it not unreasonable to categorize an innovative gear as high if it is over 25% more expensive than the baseline gear.

3.4.2 Return on Investment (ROI)

Return on Investment (ROI) is defined as the profit fishers derive from catch landings following investment in an innovative gear (i.e. revenue of landings minus the costs associated with the operation of that gear, fixed costs and depreciation costs) divided by the cost of investment[3]. Operational costs include fuel consumption, labour requirements, repair costs, landing costs and other variable costs.

Negative	Profit is negative and the innovative gear is not economically viable.
Minor	Profit is positive but remains low compared to the investment costs, ROI up to 5% on average as a result of operating the innovative gear. This means that the innovative gear is economically profitable but with low return.
Substantial	Profit is positive and up to 10% of the investment costs on average as a result of operating the innovative gear. The investment in the innovative gear is more comparable to long-term investment, with a return between 5 to 10%.
Significant	Profit is positive and high, more than 10% of the investment costs on average as a result of operating the innovative gear. The investment in the innovative gear is clearly profitable.

The above ROI categories are based on our experience working with the commercial fishing industry. Each fisher is different and their perception regarding minor, substantial, and significant ROI can be personal and circumstantial. However, in the absence of countervailing evidence, we feel it not unreasonable to categorize any investment that leads to return on investment of less than 5% as minor. A substantial ROI results from an average profit up to 10% of the investment costs and ROI is significant if profit is higher than 10% of the investment costs.

3.4.3 Cost matrix

Based on data in the factsheets a cost matrix (Table 3) was produced to assess the potential of an innovative fishing gear for adoption by commercial fishers. The matrix assumes that fishers considering using an innovative gear will first consider the capital cost of that gear and if deemed attractive will then consider the potential return on investment associated with using that gear. It also assumes that the capital cost may be sufficient to deter purchase of the gear by fishers, regardless of the return on investment.

[3] For a full definition of ROI, see https://stecf.jrc.ec.europa.eu/documents/43805/1489224/2016_AER_8_ANNEXES.pdf

Table 3. Cost matrix for the assessment of Return on investment (ROI) associated with Capital cost.

Return on Investment (ROI)		Capital cost: High	Capital cost: Moderate	Capital cost: Low
	Significant	Promising	Highly promising	Unicorn "no brainer"
	Substantial	May be worth considering	Promising	Highly promising
	Minor	Probably not worth considering/Refine	May be worth considering	Promising
	Negative	Discard / Seek alternatives	Discard / Seek alternatives	Discard / Seek alternatives
		High	**Moderate**	**Low**
		Capital cost		

3.5 Operational and other factors influencing uptake of innovative fishing gear

To assist a structured assessment of factors influencing uptake of the innovative gears in this report, several questions in the factsheets were included to better understand potential operational and other considerations that may impede such uptake. This included questions related to the impact the innovative gear may have on *i)* ease of gear deployment and retrieval, *ii)* ease of maintenance and repair, *iii)* impact on health and safety, and *iv)* if the perceived costs of the innovative gear may were considered to be disproportionally higher than the benefits of using the gear. We also developed an initial tool to be included in the innovative gear factsheets (Annex 4). This tool is based on the so-called PESTEL framework.

3.5.1 PESTEL Framework

A PESTEL analysis is a strategic framework that was originally developed for business environments (Aguilar, 1967). PESTEL can also be used to evaluate which external factors play a role in the adoption of innovative fishing gear and it provides a way to structuring data collection about factors impacting fishers' decisions in relation to gear adoption. Subsequent evaluation can then point to potential actions for addressing issue(s) that are a barrier to the adoption of innovative fishing gear.

PESTEL is an acronym for six groups of "umbrella factors:" **P**olitical, **E**conomic, **S**ocial, **T**echnological, **E**nvironmental and **L**egal. Individuals who completed the factsheets were asked to what extent they thought each of the six factors influenced the adoption of the innovative fishing gear. These individuals were provided a multiple-choice response option: (a) has encouraged uptake; (b) is a barrier; (c) do not know; and (d) not applicable. They were also provided with the following examples of each PESTEL factor, to increase their familiarity with PESTEL, and mentioned that these are examples to add context and not an exhaustive list. The examples were:

Political factors	Level of fishers' support for policies, top–down regulations, absence of a level playing field when gears are adopted voluntarily.
Economic factors	Cost of purchasing the gear, changes in marketable catch composition, change in running costs, priority to short-term benefits over longer term benefits of using the new gear, presence of grants or subsidies.
Social factors	Resistance or reluctance to change, social norms, peer pressure, effectiveness of outreach about the new gear, demotivation because of policy developments, different understanding of the problem between fishers and other stakeholders (e.g. discards, bottom-trawl impacts).
Technological factors	Technical knowledge, gear is difficult to deploy or requires specialist knowledge or training, extent of the adaptability of the gear to different vessel designs.
Environmental factors	Fuel reduction, reduced unwanted bycatch of fish, reduced unwanted catch of other marine species (benthos, marine mammals, birds), lower seabed impact
Legal factors	Gear is currently not allowed (e.g. tested under a derogation, regional restrictions), having to meet minimal legal gear standards.

Recognizing that experts filling out the factsheets may not necessarily be the ones that have full or direct understanding of factors influencing uptake of the particular gear, the WKING2 workshop (August 23–25, 2023) provided an opportunity for social scientists and gear technologists to work together on developing a more comprehensive PESTEL framework. This framework was included in the factsheets.

Prior to the workshop, social scientists working on WKING2 conducted a literature review to identify the main factors that have previously been recognized as influencing gear uptake. A total of 31 factors were originally identified from the literature. Each factor was taken in turn to consider if it could be classed as Political, Economic, Social, Technological, Environmental or Legal, in-line with the PESTEL framework. It was possible for a factor to fall under multiple PESTEL categories. For each factor an example was provided under relevant PESTEL categories, to provide context and examples of how factors influencing gear uptake could be categorized. Further consideration was given as to whether each factor was linked to 'Knowing', 'Wanting – ability', 'Wanting – willingness' and 'Doing' (*section §3.5.1*).

3.5.2 PESTEL analysis of the innovative gears

A spreadsheet was produced and used as a basis for discussions together with gear technologists during WKING2. Specifically, discussions centred on how data on what is influencing gear uptake could be best collected. It was noted that there are usually multiple factors at play in influencing gear uptake, but it was agreed that having a framework to work through, to better evaluate which factors are likely to be the primary barriers to uptake would be useful. The original spreadsheet required some revision to produce a more useable and useful framework for this purpose. The group, therefore, spent time consolidating factors that were similar, refining the original list down to 24 factors.

These factors were then grouped into eight broad categories; Policy related aspects, Social aspects, Economic aspects, Health and Safety, Resource Access, Carrot and Stick!, Collaboration and Outreach, Sustainability. Questions were formulated under the relevant PESTEL categories for each factor that an expert filling in a gear factsheet could run through to determine which categories have and do influence gear uptake. A second group also spent time to review the spreadsheet and add anything they felt to be missing.

The final version of the spreadsheet can be found in Annex 4**.** Following presentation of the framework to the wider group at WKING2 we looked to review how the PESTEL section of the gear factsheets could be completed. We took the example of Factsheet 36 for quad-rig trawling in the *Nephrops* fishery as we had three experts in the group with direct experience of this gear. Together, the original factsheet was reviewed, and more detail added, as guided by the new PESTEL framework developed.

A comparison of the two PESTEL sections (completed prior to sharing the new framework and completed together following review of the framework) are shown in Box 1. As a result, greater detail was provided, with many of the additions being linked directly to factors identified in the framework. While it was acknowledged that the current spreadsheet could be further refined or converted into a flow chart, to aid in identifying which PESTEL factors may influence gear uptake, it is clear the by providing the current spreadsheet much more valuable information is provided in the factsheets to aid in the analysis of what influences gear uptake.

Factsheet 36. Quad-rig trawling to improve selection in *Nephrops* fishery.

PESTEL. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Not Applicable

Except in Scottish waters where 2-trawls configuration is the legal maximum.

PESTEL. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake

- *Irish law introduced in 2015 – max 4 nets can be towed at once, so quad rig is max allowable.*
- *Scotland – quad rigs banned, partly in response to Danish boats using 8 nets and subsequent worries of overfishing and market collapse.*
- *Multiple political factors = different impact in different areas* ***(multi-level governance issues).***

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know

- *Quad rig does allow fishing at night to catch Nephrops resulting in increased catches* ***(changes in commercial catches).***
- *Catch more Nephrops because cover more ground with the net set up* ***(changes in commercial catches).***
- *Effects on market when fishing 'too' much* ***(changes in commercial catches).***

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know

- *Lots of fishers understand that this gear is very destructive but feel have to keep pace with everyone else as no legislation banning this in Irish waters* ***(level playing field).***

Overall, what impacts do you think have **technological factors** had on uptake of this gear?................. Has encouraged uptake

- *Some smaller vessels don't have power to tow 4 nets so still twin rig (NI)* ***(functionality/workability)***

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake

- *Very efficient at catching Nephrops, can catch quota quickly and afford to tie up for a bit* ***(sustainability).***
- *Lower headline reduced whitefish catches therefore lower unwanted catches/discards* ***(changes in commercial catches).***
- *Deploy nets so quickly can result in not enough time to process catches, resulting in discards from unprocessed codends!*

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................ Has encouraged uptake

Box 1. A comparison of the PESTEL section of the innovative gear in Factsheet 36 *(Quad-rig trawling to improve selection in Nephrops fishery)*. The first PESTEL section was completed based on the original information supplied along with the factsheets regarding the framework. The second PESTEL section was filled out collectively with experts who had experience of testing the gear and working with relevant industry after having been presented with the improved PESTEL framework.

4 Findings

Three EU projects were considered to evaluate progress that has been made, or impact arising from innovative fishing gear within EU waters: **Discardless**[4], **Minouw**[5], **SmartFish**[6]. A fourth EU project, not included in the Terms of Reference, **EveryFish**[7] (was examined to explore the ongoing technological advances and research developments in European waters. Despite mentioned in the Terms of Reference, the **GearingUp** database holding information on studies and comparative trials regarding gear modifications is offline and therefore currently unavailable. General information on the GearingUp project is provided in *section §4.6*.

The STECF plenary 20-03 report was also consulted to understand the innovations and developments that have been supported by the Member States. Unfortunately, the short time available prevented the examination of other STECF plenary and EWG reports. Finally, we considered detail from a total of 75 factsheets describing innovative gears that were developed by fishing technologists and other researchers in the region.

The use of a broad range of sources was necessary to ensure that the review covered all major types of innovation and research developments.

4.1 STECF PLEN 20-03

STECF Plenary meeting PLEN 20-03 reported several initiatives and developments that have facilitated or supported the development of innovative gears. Many were analysed and discussed in the first WKING report (ICES, 2020c); more recent developments are included in this report and described in the attached factsheets.

4.1.1 A netting-based alternative to rigid sorting grids in the small-meshed Norway pout (Trisopterus esmarkii) trawl fishery in the North Sea

This innovation, sometimes referred as 'The Excluder', is a 30 m long netting-based sorting system developed in Eigaard *et al.* (2021) to reduce bycatch and improve on board gear-handling and safety (see **Factsheet 20**).

STECF PLEN 20-03 reported that 'The Excluder' significantly reduced the number of larger herring, mackerel, whiting, long rough dab, and witch flounder bycatch by 30–95% depending on species compared with the currently required grid design. Specifically, the bycatch of 21–26 cm whiting, herring and mackerel and 15–17 cm long rough dab and witch flounder were significantly reduced by number. However, STECF PLEN 20-03 also concluded that for Norway pout and comparable bycatch species of similar size and morphology (e.g. gadoids smaller than 15 cm), 'The Excluder' can be expected to result in increased catches of around 32% by number (CI: 3–95%).

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[4] http://www.discardless.eu

[5] http://minouw-project.eu

[6] https://smartfishh2020.eu

[7] https://everyfish.eu/

4.1.2 Remedial measures for cod in the North Sea and Skagerrak

Article 14 of Council Regulation (EC) 2020/900 (2009) (the fishing opportunities regulation) introduced remedial measures to support the recovery of North Sea and Skagerrak cod. The regulation provides a number of options for Member States to use specific highly selective gears or as an alternative, for Member States to introduce alternative gears (Article 14.2.c) - provided it could be demonstrated that these alternatives result in at least a 30% reduction in cod catches compared to the legal minimum requirements set out in Regulation (EU) 2019/1241 (2019). Furthermore, Member States, as an alternative to the selective gears, can implement national cod avoidance plans to ensure that realized cod catches are in line with the intended catch as per national quota allocations.

4.1.2.1 Alternative gear designs proposed by Sweden

STECF PLEN 20-03 was requested to assess whether alternative gear designs proposed by Sweden met the objectives of reducing cod catches by at least 30% compared to the legal minimum requirements set out in Regulation (EU) 2019/1241 (2019).

A document entitled "*An assessment of the estimated reduction of cod catches by the introduction of an 120 mm square mesh codend as an alternative gear in the North Sea and Skagerrak*" was submitted by the Swedish University of Agricultural Sciences, Department of Aquatic Resources (SLU Aqua).

STECF noted that this document reported reductions in cod catches in numbers of fish. According to the analysis by STECF, the alternative gear (120 mm square mesh codend) would only lead to a 13.2±2.6% (avg±95% CI) reduction in cod catches in numbers in the North Sea, thereby not meeting the threshold of a 30% reduction in cod catches. For the Skagerrak, STECF could not conclude whether the alternative gear design met this threshold.

This gear design is a common codend mesh alternative and identifiable as sufficiently similar to other alternatives trialled in other fisheries, e.g. **Factsheet 22**, **Factsheet 55** and **Factsheet 56**,, and therefore a specific factsheet has not been developed.

4.1.2.2 Measures contained in the national Danish and UK plans to maintain cod catches in line with available quota

STECF PLEN 20-03 was requested to provide a qualitative assessment on whether the measures contained in the national Danish and UK cod plans would help maintain cod catches in line with available quota, based on previous experience in the assessment of the cod recovery plan (Regulation (EC) 1342/2008, 2009) and other relevant reviews.

The aim of the Danish National Cod Plan was to ensure maintain access by the Danish fleet to defined areas of the North Sea and the Skagerrak, contribute to the recovery of the cod stock in these areas, and reduce the mortality rate of juvenile cod below the minimum conservation reference size, which is 35 cm for North Sea cod and 30 cm for cod in the Skagerrak.

According to the Danish National Cod Plan, and relevant to the current WKING2 report, vessels shall be allowed to fish in the prohibited areas under the following conditions:

- Vessels which do not have the required adequate quota left or vessels wishing to use more selective gear in the fishery of 120 mm or more must use one of the following gears to fish in the prohibited areas:
    - a) trawls with a minimum lower belly mesh size of 600 mm;
    - b) increased fishing line (0.6 m);
    - c) 140 mm square mesh panel.
- Vessels which do not have the required adequate quota left or vessels wishing to use more selective gear in the fishery with more than 70 mm in the North Sea and more than

90 mm in the Skagerrak, but less than 120 mm, must use one of the following gears to fish in the prohibited areas:

a) Horizontal sorting grid with a maximum bar spacing of 50 mm separating flatfish and round fish, with an unblocked opening where round fish can escape;
b) Seltra panel of mesh size of 300 mm (square meshes);
c) Sorting grid with a maximum bar spacing of 35 mm, with an unblocked opening where fish can escape;
d) Scaring floats
e) Scaring lines

All of these innovations were analysed and discussed in the first WKING report (ICES, 2020c).

With regards to the prescribed gear, several of them are already listed as derogated gear in Council Regulation (EC) 2020/900 (2009). For the fishery with a mesh size of 120 mm or more, an additional gear modification is proposed: of the use of a 140 mm square mesh panel. STECF noted that using the 140 mm square mesh panel mounted at 6–9 m above the codline in a 120 mm trawl reduced the cod catches by 12.6% in numbers (all sizes) and 9.5% in weight (fish larger than 40 cm). No information on the positioning of the square mesh panel was provided in the plan so it is not clear whether these results are comparable to the 140 mm square mesh panel gear option proposed.

For the fisheries with mesh sizes of less than 120 mm and, in the North Sea, more than 70 mm and in the Skagerrak more than 90 mm, two other gear modifications are proposed: the use of scaring lines and scaring floats.

The Danish document provides no information about the selective properties regarding cod of these gears. STECF noted, two publications testing scaring lines (Melli *et al.*, 2017; Feekings *et al.*, 2020) in the Nephrops fishery. These trials indicated that scaring lines can reduce the capture of larger cod but the results for smaller cod is mixed, with one set of trials showing an increase in their capture and another showing a reduction. With regards to scaring floats, also to be used in the Nephrops fishery, two Danish cruise reports about trials where they are used in combination with different selectivity devices, show contradictory results: in Savina *et al.* (2022) the catches of cod of certain length classes were reduced, but in Feekings *et al.* (2020) the scaring floats did not have a significant effect.

While STECF noted that using a 140 mm square mesh panel may reduce the cod catches by around 10%, without further information, (e.g. on the uptake), STECF could not assess to what extent allowing vessels using that gear to fish in the restricted area would help maintain cod catches in line with available quota. STECF further highlighted that this gear option is unlikely to reduce cod catches to the same extent as the other cod avoidance gear included in the Regulation. For instance, as observed by STECF PLEN 20-01, trawls constructed with netting panels of very large mesh sizes (between 300 and 800 mm) have been tested in the North Sea and shown to decrease cod catches by between 30–75% depending on the construction of the trawl (Campbell *et al.*, 2010; Kynoch *et al.*, 2011). Additionally, STECF PLEN 20-01 showed that a trawl fitted with a raised fishing line can reduce cod below 35 cm in length by about 65% by number.

STECF was not able to assess whether using scaring lines or scaring floats in the Nephrops directed fisheries in the restricted area would lead to a significant reduction in cod catches, sufficient to maintain them in line with available quota. The results of the few studies that have been carried out are inconsistent.

4.1.3 Spanish exemption request under Paragraph 2 of Article 13, Council Regulation (EU) 2020/123 (2009)

Both cod and whiting in the Celtic Sea are regulated as target stocks under the Western Waters Multi-annual plan (WWMAP) (Regulation (EU) 2019/472, 2017), but since 2019, only the incidental catch of these stocks is allowed, a targeted fishery being prohibited. In 2019, ICES catch advice showed that cod and whiting stocks in the Celtic Sea are below Blim. Following Article 8 of the WWMAP, the EU was legally obliged to adopt remedial measures as safeguards to help rebuild these stocks. The ICES advice estimated that without any changes in exploitation, catches of cod would have been 2,055 t in 2020, and while ICES advised zero catch a TAC for 2020 was agreed at 805 t.

The Fisheries Council of December 2019 adopted the "Remedial measures for cod and whiting in the Celtic Sea" under Article 13 of the 2020 Fishing Opportunities Regulation (EU) 2020/123 (2009). The basis for these measures was the need to improve selectivity by increasing mesh sizes and the requirement for bottom trawlers to use fishing gear that avoids cod bycatch. Article 13 requires vessels fishing in the Celtic Sea cod protection zone with more than 20% haddock catches to use certain gear configurations (paragraph 1a) and, as of 1 June, a "raised fishing line" configuration or another dispositive equally selective for avoidance of cod (paragraph 1b).

It also provides for the use of selective gear as alternatives to the above if they result in catches of less than 1% of cod (paragraph 4). Similarly, vessels whose bycatch of cod have been historically below 1.5%, can be exempted under paragraph 2.

In 2020 the STECF received a request from the Spanish Government asking if their vessels, as detailed in the request, can be exempt from Article 13 of Regulation (EU) 2020/123 (2009). Specifically, the request sought an exemption from the requirement to use 100 mm mesh size in demersal fisheries in the Celtic Sea, based on a report by Velasco *et al.* (2020) presenting historical evidence that cod bycatch in area 7 was below 1.5%, and claims that using the mandatory 100 mm (D100) as required in Article 13(2) would result in lower catches of megrim and reduce vessel profitability. STECF noted that a derogation to Article 13(2) requires first that the trips-catch composition does not exceed 20% of haddock. In a second step, a threshold on cod on trip-catch composition can trigger an exemption to allow vessels not to use a D100 mesh size gear.

The study by Velasco *et al.* (2020) provided a map of sampled hauls during 2016–2019 obtained from the Spanish DCF onboard observers. According to the study, the sampling covered from 2.0 to 4.2% of annual fishing trips, and 23.1 to 53.8% of the 14 vessels of the Spanish fleet conducting mixed fishery with OTB_DEF_70-99 in ICES area 7.

The study describes the main fishery conducted by the Spanish fleet in ICES area 7. This is a directed OTB fishery targeting Hake, Megrim, and Monkish (HKE-MEG-MON) involving 13 to 14 vessels (métier OTB_DEF_70-99_0_0), and 5 vessels targeting hake (métier OTB_DEF_100-119_0_0). The study also provided a tabulation of total catches (landings + discards) per area and annual percentages of cod in those catches (0.31% to 1.05% of cod catch, all areas confounded, from 2016 to 2019). It emphasized that the annual percentage over the period 2016–2019 aggregating the sampled trips is below the 1.5% cod threshold, and therefore, justifies an exemption under Art.13(2). Finally, the study describes selectivity trials of the project RAPANSEL (Valeiras *et al.*, 2019), where a range of gear combinations including 100 mm T90 codends, 80 mm codends and 80 mm codend with various SMPs were tested. The study concludes that the design T0_80_T45_04_150, named "*Coppo 2*", (i.e. 80 mm with a 150 mm square panel), is the most promising design for decreasing catch of small megrim and hake when compared to the baseline gear, which for the purposes of these trials was taken as a D100 codend (**Factsheet 42**).

STECF noted that this supporting study referred to ongoing selectivity trials testing alternative gear combinations to the D100 required by Article 13(2). However, also STECF noted that these catch comparison trials mainly focused on the selectivity for the targeted stocks (hake, megrim and monkfish) but were not designed to assess the level of bycatch of cod and whiting with the control and test gears.

STECF is not aware of any other selectivity studies showing the 80 mm and 150 mm square mesh panel, here considered the best combination tested, to be effective in reducing catches of cod. STECF also noted that based on previous studies (Santos *et al.*, 2016b), it is unlikely that the addition of a square mesh panel in the top panel would reduce the catches of undersized megrim given the morphology and behaviour of this species. STECF concluded that no documentation has been provided that allows evaluating whether the proposed gear designs are likely to reduce possible bycatch of cod to less than the 1.5% threshold. Further, STECF was unaware of any other studies showing that the proposed gear combinations are selective for cod.

4.2 Horizon 2020 project DiscardLess

The 2013 reform of the EU's Common Fisheries Policy (CFP) aimed to gradually eliminate the wasteful practice of discarding caught fish that are unwanted, by introducing the so-called landing obligation (LO).

The Horizon 2020 DiscardLess (*Strategies for the gradual elimination of discards in European fisheries*) project was established to address the short-term challenges and potential benefits to support successful LO implementation. The focus was on preventing the unwanted catches from being caught, making best use of any unavoidable unwanted catch, and evaluating impacts of discarding on the marine environment, economy and society as a whole. Fundamentally, the DiscardLess project aimed at assisting the fishing industry to successfully adapt to the landing obligation (Veiga *et al.*, 2016; Eliasen *et al.*, 2019).

Project partners developed a series of tools, freely accessible online (www.discardless.eu) that gathered, synthesized, and disseminated knowledge produced by the DiscardLess project. These tools included a manual of existing selective gear devices and their effectiveness, proposed solutions based on interviews featuring fishers' responses to LO regulations, and a catalogue containing over 30 valorisation products and a methodology to guide their selection for use. It also included a report on onboard handling of unwanted catches and a simple cost–benefit tool to estimate the economic feasibility of investing in gear solutions.

Partners have also assembled a selectivity manual which provide brief descriptions of many of the catch comparison and selectivity trials that have taken place in the North Atlantic and adjacent seas (O'Neill and Mutch, 2017). The manual describes the different stages of the fish capture process, highlight how different parts of the gear may influence selection and identify possible design changes which can alter the selectivity of the gear. The intention is to make fishers, netmakers and fisheries managers more aware of the possible innovations that can be made to their gears so that they can design and develop gears with a selective performance suitable for their particular fishery. This is again to highlight the potential gear modifications that can be made and to provide an indication of their likely effect (O'Neill and Mutch, 2017). Several of these innovations were analysed and discussed both in the current document and the previous WKING report (ICES, 2020c).

Arguably the most significant output of this project was to mobilize, pool, and expand the vast multidisciplinary biological, technological, economic, political, and institutional knowledge of all aspects linked to discarding and sharing it with all key fishery stakeholders. As a result of this effort, a variety of new, innovative gears were developed and are included in this report and described in the attached factsheets.

4.2.1 Available alternatives for processing and storing unwanted unavoidable catches (UUCs) onboard fishing vessels

Viðarsson *et al.* (2017) provided an overview of the work achieved by the DiscardLess project including suggested solutions to the onboard handling of unwanted, unavoidable catches. This includes a series of three-dimensional drawings depicting potential solutions (presented in the **Factsheet 21**) and a simple cost–benefit tool that allows stakeholders to estimate the economic feasibility of investing in such solutions.

The suggested solutions are first and foremost intended to provide fishers with realistic alternatives for meeting the requirements of the landing obligation and for the implementation of the discard ban. The solutions focus largely on separating target catches and the unwanted catches, and to provide alternatives for processing and storing under size catches, which cannot be utilized for direct human consumption according to the landing obligation. Available alternatives for handling unwanted unavoidable catches (UUCs) onboard fishing vessels are primarily dependant on the vessels size, catch composition and how long the vessel is out at sea in each fishing trip.

4.2.2 "Challenge" experiments

Reid (2017) described the results of the three "Challenge" trials carried out in three different countries and across several fisheries. In these trials fishers were challenged to reduce their discards by whatever legal means available. Each vessel could fish alternately with their normal gear and test gear with the aim to minimize the discards over a predetermined period, reporting the decisions and the rationale behind them. Observers were placed onboard to collect catch and discard data and train the crew in self-sampling of the catch. Skippers were asked to set themselves a discard reduction target and this was the core of the "challenge". The targets could be in terms of reducing discards of TAC species in general, or of those that represent the major "choke" species in their fishery. Catch data were analysed to determine success at reaching this target. The trials occurred in:

a) Ireland. One demersal trawl vessel targeting whitefish (cod, haddock and whiting) and one targeting Nephrops with additional catches of the same fish species.
b) Denmark. Twelve vessels mainly fishing cod and saithe, with three Nephrops targeting vessels. The vessels towed a mix of single- and twin-rigs, and were distributed between the North Sea, the Skagerrak, and the Baltic Sea.
c) France. Three vessels targeting a mix of species including cod, whiting, squid cuttlefish and some pelagic species. The vessels were all trawlers, two under 18 m, and one over 18 m.

In Denmark the main option explored by fishers was gear modification, and the data were mostly collected by the fishers themselves, supplemented with Fully Documented Fishery (FDF) methods. In France and Ireland, the approaches included both gear and tactical modifications, with full observer coverage.

The "challenge trials" were moderately successful and improvements were generally quite small.

4.2.2.1 Gear based changes in the challenge trials

Changes to fishing gear figured strongly in the choices by Danish fishers in all three trials, with the aim of improving selectivity and reducing unwanted catches. The fishers chose a range of different approaches:

- seven of the vessels used some form of changed mesh size in the codend. Usually this involved larger mesh size, but in the Baltic vessels they also trialled reduced mesh sizes;
- three vessels inserted escape panels into the net.
- two vessels trialled separator panels with two codends;
- one vessel used a topless trawl, and
- one used a modified mesh in the Bacoma panel.

The trials successfully improved collaboration and the new fishing gear showed some potential. Nine vessels were able to reduce the discard ratio in the test fisheries (three in the North Sea, three in Skagerrak and three in the Baltic Sea), while two vessels (from the North Sea) increased their discard ratio, and one North Sea vessel showed no difference in discard ratio. The improvements ranged from less than 2% for four of the vessels, 2–7% for four others, and, in one case, a 17.6% improvement (Mortensen *et al.*, 2017). For full details, see **Factsheet 22** for the challenge trials in the North Sea, Factsheet 55 for trials in the Skagerrak area, and Factsheet 56 for the rest of Baltic Sea.

In the French trials, a number of gear changes were tested:

- the inclusion of a larger square-mesh cylinder in the extension. The vessel using the mesh cylinder (CMC) approach reported little loss of commercial catch, and in some cases reductions in discard volume. See **Factsheet 34** for full information;
- separator panels with two codends. The separator panel with two codends could not be evaluated, but the skipper was still very positive and felt it had value. *No other information are available in Reid (2017)*;
- increased mesh size in the codend and extension, and T90 mesh. In general, the fishers did not feel that the changes in codend meshes achieved the results they had hoped for small fish, and there were concomitant losses in commercial sized fish. *No other information are available in Reid (2017)*.

One of the Irish vessels (the Nephrops targeting vessel) decided to opt for a quad-rigged Nephrops trawl system, with large mesh square mesh panels in all extensions in each trawl **(Factsheet 36**). The use of square-mesh panels in the quad rig allowed the vessel to keep fishing significantly longer before 'choking' on the cod.

4.2.2.2 Tactical and Strategic changes used in the "Challenge trials"

Tactical and strategic changes were principally tested in the Irish and French "Challenge trials". In the Irish trials, a vessel targeting whitefish aimed to use changes in both the time of day and depths fished to avoid discards, as well as movement between management areas to optimize fishing time. The results of this effort were inconclusive.

The French vessels were mainly focused on the potential for avoiding "sensitive" areas, characterized by high catch rates of quota species under MCRS. The outcomes of this behaviour on the large vessel was limited as it was found that this was already normal practice. For the smaller vessels, they were also limited because their main operating area was within the three-mile zone along the Channel coast, where almost 70% of their catch was usually discarded. Avoiding this area would help with their LO mitigation but at significant economic cost.

4.2.2.3 Highlights

- Based on the "challenge" trials there appears to be scope for fishers to reduce their catches of unwanted fish both in terms of under Minimum Conservation Reference Size quota species, and "choke species" fish.
- The "challenges" allowed fishers to develop their own solutions or approaches to the problems raised by the Landing Obligation.

- Fishers were able to utilize both gear-based approaches (mesh sizes, escape panels and other modifications), and tactical changes (e.g. change of location, fishing deeper, or moving between areas, or changing the time of day of fishing).
- Most of the “challenge” trials showed that the improvements in selectivity, either through gear or behavioural changes, were generally small, and would not alone prevent unwanted catches under the LO.
- The time-scale of the "challenge" trials did not all allow the fishers to make all the changes they might have wished, both gear and behavioural, but many expressed a desire to continue using, and developing, these methods in future.
- There were clear indications that all solutions were local in their application. All fishers in the "challenges" used different methods of gear or behaviour, which were adapted to the particular fisheries in which they worked. No single approach can then be expected to provide a global solution.

4.2.3 Meta-analyses and predictive methods to estimate gear selectivity in terms of gear design parameters and vertical distribution of fish

Selection by the codend has been widely investigated around the world over the past thirty years or more. These studies typically test only a few gears, driven partly by logistic and/or economic limitations and partly to ensure there is sufficient data to estimate the selection of each gear with reasonable precision. To explore a broad range of selective gear options for use in a fishery, and to better understand the relative influence of the important variables related to gear design, it can be useful to develop models that predict selection across all variables. Such empirical models can be constructed based on a meta-analysis that combines the data from many trials, such as that by Fryer *et al.* (2017) and O’Neill and Noble (2017).

Such analyses can be useful to provide relevant information and advance a-priori understanding of the potential of new, “innovative” gears. **Factsheet 23** summarizes the findings of the study by Fryer *et al.* (2017) and O’Neill and Noble (2017). The analysis considers the effect of explanatory variables such as the height of s selection panel and the distance of the panel from the groundgear based on trials conducted in the North Sea, the Grand Banks, the Barents Sea, the Baltic Sea and the Skagerrak between 1970 and 2015. Results are presented for eight species: the gadoids cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*) and whiting (*Merlangius merlangus*), the flatfish lemon sole (*Microstomus kitt*) and plaice (*Pleuronectes platessa*), and monkfish (*Lophius piscatorius*) and Nephrops (*Nephops norvegicus*).

Another way of obtaining new insights into gear technology is through the analysis and modelling of data collected in trials. Mixed models are well suited for analysing these data because they estimate the effects of practical importance while accounting for the different sources of variation in the data (O’Neill *et al.*, 2019). The past decade has seen many advances in the statistical methods and software available for fitting mixed models, and they are now routinely used to analyse standard gear trials, such as estimating the selection of a trawl from a covered codend or paired tow experiment, or to compare the catch of one gear with that of another (Millar *et al.*, 2004; Holst and Revill, 2009). They also offer exciting possibilities for analysing the data from nonstandard trials, and recently, Browne *et al.* (2017) used a multinomial mixed model to analyse a quad-rig catch-comparison trial where four test codends were fished simultaneously. The main purpose of the trials was to assess the catch performance of the quad-rig, which is increasingly used in Irish Nephrops fisheries. However, the trials, and the methods for analysing them, suggest how more efficient experiments might be designed in future, with multiple codends being fished in each haul. Mixed models are also a standard approach to synthesising the results of multiple trials and were used, for example, in the meta-analysis of haddock described in the previous section. A challenge moving forward is to make better use of sparse data, particularly for choke species. In single trials, simplifying assumptions are often needed to get models to converge and the power to detect effects can be low. One possibility might be to combine data across multiple trials and to exploit or assume correlations in selection between a data-sparse species and data-rich species that have similar behavioural or morphological characteristics.

4.2.3.1 Highlights

- codend selection depends on codend mesh size, the number of open meshes around the circumference, and twine diameter;
- panel selection depends on panel mesh size;
- For gadoids, panel contact probability depends on where the panel is positioned and the time of year when fishing takes place;
- the relationship of L50 with number of meshes in circumference and twine thickness can be opposite between roundfish and flatfish;
- it should be possible to separate the three categories of (i) haddock, whiting and saithe; (ii) cod, plaice and lemon sole; (iii) monkfish and Nephrops using vertical separation.

4.3 Horizon 2020 project Minouw

The MINOUW project (*The Science, Technology and Society Initiative to Minimise Unwanted Catches in European Fisheries*; 2015–2019) involved over 15 different maritime science institutes and bodies from across Europe (https://cordis.europa.eu/project/id/634495), bringing together scientists, fishers, NGOs and policy-makers. The aims of this project were to encourage the adoption of fishing technologies and practices that reduce unwanted catches and contribute to the eventual elimination of discards in European fisheries. A total of 17 case studies across 7 countries were developed to test solutions to minimize discarding of fish (https://minouw-project.eu/case-studies-new).

The project delivered a portfolio of innovative solutions reduce the problem of discards. It advanced specific technologies and techniques designed to help avoid unwanted catches, minimize effects of fishing on sensitive habitats and species (pre-harvest), and promote the survival of unwanted catches (post-harvest).

The project explored enhancing the selectivity of fishing gears using a variety of both tried and tested techniques and recent innovations, from already proven but underutilized technologies (e.g. sorting grids and large mesh panels) through to an improved understanding and application of novel stimuli (e.g. artificial light) to manipulate the behaviour of marine organisms during the capture process. The project demonstrated and developed observational technologies to reduce pre-catch losses, by testing systems such as *Deep Vision* on pilot vessels in different fisheries (**Factsheet 1**). The following case studies – relevant to the WKING2 report – have been then reviewed and factsheets produced.

4.3.1 Factors that lead to discarding practices, and their impact, in the Aegean Sea bottom trawl (Greece), and assessing the impact of pre-catch monitoring technologies

Trials with the Deep Vision system were conducted in Saronikos Gulf to explore an effective pre-catch monitoring method in the Mediterranean, providing near real-time and non-destructive information of potential catch composition at high spatial resolution and to adapt Deep Vision system on the multispecies Mediterranean bottom-trawl fisheries. Comparisons of Deep Vision results with physical measurements of the catch were in general agreement regarding mean length by species / species group. Deep Vision was also useful in providing information on the spatial distribution, overlap and catch rates of species/sizes along the trawl path. Similar experiments have been already described in **Factsheet 1**.

4.3.2 New technologies to reduce the large quantities of bycatch in bottom-trawl fisheries (Catalonia, Spain)

Experiments were performed to establish whether a new T90 trawl improved species selectivity and reduced unwanted catches, with special attention to European hake and red mullet (Factsheet 70). The results showed an important reduction in the undersized catch of European hake (52%). In essence, the modification of the net is simple and practical to adopt and contributes to the implementation of the landing obligation. Experiments were also performed with artificial lights (blue and green) deployed on Norway lobster trawl fishery. A decrease of biomass of both commercial and discarded catches was detected when comparing control hauls with hauls with lights. Similar experiments have been already described in **Factsheet 6, Factsheet 39,** and **Factsheet 40**.

4.3.3 Evaluating whether use of light technology and alternative fishing gear can improve catch efficiency and reduce bycatch in deep-water crustacean fisheries (Portugal)

Researchers experimented with off-the-shelf CENTRO fishing lights, modified by MINOUW partner SNTECH, by substituting the original lamp with a blue one (about 470 nm) able to pulse at different chosen rates, 10, 20 and 30 Hz. Significant losses of blue-and-red shrimp were seemingly related with the use of the lights and the number of hauls was insufficient to establish the existence of an effect on blue whiting. Similar experiments have been described in **Factsheet 6, Factsheet 39,** and **Factsheet 40**.

4.3.4 Combining work with local fishers to find practical solutions to reduce discards, alongside scientific modelling on the impacts of discarding practices and solutions on marine ecosystems (Sicily, Italy)

The crustacean trawl fishery in the Sicilian Channel targets deep-waters shrimp. In this area the unwanted catches ranges between 25 and 40% of the total catch. The trials performed in collaboration with professional bottom trawlers and research vessels to evaluate the effectiveness of sorting grid separators are described in **Factsheet 69**. A comparison between the catches retained by an experimental trawlnet with grid (JTED) and without grid (control) was conducted to assess the potential reduction of juveniles/unwanted catches. The use of grids demonstrated a potential reduction of unwanted catches up to 30%.

4.3.5 Impact of light technologies in the crustacean bottom trawl Ligurian and North Tyrrhenian Sea fisheries (Italy)

To assess the impact of light technologies in bottom-trawl crustacean fisheries in Porto Santo Stefano (Italy), artificial lights (green/blue/white lights) were mounted around the headrope and the upper panel of the net body to reduce fish bycatch, without any loss on target crustaceans. The trials resulted in a significant reduction (-57%) in the capture of European hake under the

MCRS in the fishery targeting deep-water pink shrimp. Similar experiments have been already described in **Factsheet 6, Factsheet 48,** and **Factsheet 40**.

4.3.6 Impact of different hook types in longline swordfish fisheries in the Aegean Sea (Greece) on catch rates of target species and bycatch

Mediterranean swordfish longline fishing fleets are traditionally employing J-type hooks baited either with mackerel or squid. The fisheries are typically mono-specific but minor catches of sensitive species, such as sharks and sea-turtles occur, depending on the area and season. In certain swordfish fisheries outside the Mediterranean, such as the US longline fisheries in the Atlantic and Pacific Oceans, circle hooks have been shown to be an effective tool to mitigate bycatch of certain unwanted species and the use of such hooks is mandatory. Experimental longline sets using circle and J-type hooks in swordfish targeting fishery were performed during the Minouw project on a Mediterranean-wide level (**Factsheet 74**). Proportionally less catches of undersized swordfish individuals in circle hooks were observed.

4.3.7 Nature of discards in bivalve dredge fisheries in Algarve (Portugal), and the impact of using a bycatch reduction device (BRD)

Along the West coast of Portugal, experiments were performed on commercial vessels to evaluate the possible reduction of bycatch, discards and debris collection in bivalve dredges using a Bycatch Reduction Device (BRD) inside the dredge (**Factsheet 49**). It has been seen that using BRDs in dredges can reduce significantly bycatch, discards and debris in the catch. Notwithstanding, it was also observed a decrease of the fishing yield and consequently a loss of income, higher than it was expected, probably due to the decrease of the dredge efficiency during the tow.

4.3.8 Methods for improving pre-catch identification and survival rates of unwanted catches in purse-seine fisheries (Algarve, Portugal)

Off the Algarve coast, methods to minimize slipping and delayed mortality of sardines after purse-seine capture were tested. **Factsheet 48** summarizes the methods and results achieved in this case study. Survival, scale loss, physiological and biological (weight, length) parameters were measured. The results of this survival assessment demonstrate that using a modified slipping technique may decrease scale loss of escapees and significantly improve survival of slipped pelagic fish.

4.3.9 Gear modifications in trammelnet fisheries targeting lobster, cuttlefish, and red mullet in Mallorca (Spain)

In this case study - published in Catanese *et al.* (2018) - it compared the catching performance of three trammelnet designs targeting the spiny lobster (*Palinurus elephas*) in terms of biomass, species composition and revenue from commercial catches and discards. Each trammelnet design was constructed using a different fibre type - standard polyfilament (PMF) or polyethylene multi-monofilament MMF - and the use of a guarding net or *greca*, a mesh piece intended to reduce discards. **Factsheet 71** summarizes the findings of Catanese *et al.* (2018). The number of marketable species captured indicated that the lobster trammelnet fishery has multiple target species that contribute significantly to total revenue. The discarded species ranged from habitat-forming species to elasmobranchs, but the magnitude of gear-habitat interactions on the long-term dynamics of benthos remains unclear. No relevant differences in revenue and weight of discards were detected. However, the species composition of discards was different when using *greca*.

4.3.10 Impact of discards in trammelnet fisheries in Catalonia (Spain) and evaluate the effectiveness of possible solutions

Two solutions have been tested in trammelnet fisheries in Catalonia to minimize discards and fishing impact on marine ecosystems (Martínez-Baños and Maynou, 2018). Trammelnets used have 40-mm square mesh inner panel and made of 30 pieces of net 50 m long and 1.2 m high. The target species are Cuttlefish, sole, caramote prawn, purple-dye murex, and Golden sea bream.

1. Artificial lights in trammelnet fisheries. Martínez-Baños and Maynou (2018) assessed the effects of lights in reducing unwanted bycatch and improve catch of target species. A conventional trammelnet of 1500 m without lights was contrasted to a similar trammelnet fitted with artificial lights of two colours (white or green) mounted on the floating ropes at 25 m interval. The lights did not prove to be a viable solution to reduce unwanted catches in this fishery **(Factsheet 72)**. However, lights produced a low, but significant, increase in total catches of cuttlefish of 13–14%, with no differences due to light colour.
2. Guardian net in trammelnet fisheries. A "guarding net" consisting of a 2.5-mesh-high (200 mm stretched mesh) net between the footrope and the trammelnet was studied in Martínez-Baños and Maynou (2018). The addition of the guarding net produced 32% higher catches of commercial species and as much as 95% higher catches of the target cuttlefish. Discards were 6% with the use of the guardian net, ca. 1/4 of the amount produced by the conventional trammelnet. See Factsheet 73 for further information.

4.4 Horizon 2020 project SmartFish

The SmartFish project (*Smart fisheries technologies for an efficient, compliant and environmentally friendly fishing sector*; 2018–2023) funded by the Horizon 2020 programme (https://smartfishh2020.eu) involved 18 partners. The goal of the SmartFish project was to develop and introduce high-tech systems to improve automatic data collection, optimize resource efficiency, provide evidence of compliance with fishery regulations, and reduce the ecological impact of the sector on the marine environment (https://cordis.europa.eu/project/id/773521). By leveraging developments in machine vision, camera technology, data processing, machine learning, artificial intelligence, LED, ROV, and other technology, this project aims to (Birch *et al.*, 2022; Krag *et al.*, 2022) 1) assist commercial fishers in making informed decisions during pre-catch, catching, and post-catch phases of the fishing operation; 2) provide new data for stock assessment purposes and improve the quality and quantity of data that comes from traditional data sources; and 3) permit the automatic collection of catch data.

Partners of the SmartFish project have developed a system for pre-catch size and species recognition in purse-seine fisheries based on optical and hydroacoustic technologies, known as *SeinePreCog* **(Factsheet 52)**. SmartFish enabled the development of an acoustic algorithm for fish size estimation and species recognition and tested the performance of a three-dimensional camera for fish size estimation named "UTOFIA". The partners also completed testing of a size discrimination algorithm for anchovy by including acoustic and biological data.

This was followed up by the development of the first prototype of a cable based real-time camera system. SmartFish also developed and tested software to view and analyse the data collected by this system, independent of the three-dimensional embedded smart camera. In combination with this, SmartFish developed and tested an operational concept named *FishFinder* (**Factsheet 63),** which delivered high quality images even in turbid water and could document both Nephrops burrows and Norway lobster, and they completed tests in a series of both on-land and at-sea experiments on the cable-based two-dimensional real-time monitoring system (RTM) named *TrawlMonitor* (**Factsheet 31**). The underwater footage from the Nephrops scanner was processed using photogrammetry, to provide a three-dimensional reconstruction of the seabed. This reconstruction was orthographically projected to provide a digital elevation map and colour map in the same coordinate system.

Another line of work focused on the development of a system that uses LED technology (SmartGear) to optimize the catching performance of trawl fishing gear (**Factsheet 6**). Based on the reaction of fish to light, SmartFish integrated a programmable LED light pod with an acoustic modem. This is an important development, since project partners had determined in previous laboratory experiments that it was possible to change fish behaviour with the use of artificial light and had completed sea trials that demonstrated this in a trawl gear as well (Birch *et al.*, 2022). With this new addition, it was possible to control the light settings in real time from the wheelhouse. The resulting system has since tested successfully at sea.

SmartFish also continued the work on the three-dimensional machine vision system for catch analysis on onboard conveyor belts – the *CatchScanner* (**Factsheet 16**). This system was initially coded for weight estimation and species identification of only a few species, but later refined to include species and weight estimation. The *CatchSnap* (**Factsheet 11**), a versatile, hand-held three-dimensional machine vision unit for inspecting catch samples on smaller fishing vessels, has been further developed with imaging and sampling methodologies. The *CatchMonitor* (**Factsheet 54**) – a system for automatic monitoring and analysis using CCTV cameras, used on larger vessels – had an early prototype for species identification, which has since been upgraded and tested for count estimation algorithms.

Each of these systems were tested, demonstrated, and promoted in at least one regional sea and within appropriate commercial fisheries and systems, including in the Norwegian and Barents seas, and the Mediterranean and Black seas. The *CatchSnap* technology was used to inspect catch samples measured and photographed by cell phone in the seas around Turkey. In the southern North Sea, Celtic Sea and Bay of Biscay, project partners evaluated automated image analyses algorithms to assess the performance of different light technologies and their effect on the behaviour of fish during the catching process. In Kattegat and Skagerrak fisheries, SmartFish completed practical testing and demonstration of *FishFinder* and *TrawlMonitor*.

4.5 EveryFish project

The overall goal of the EveryFish project (*Digital transition of catch monitoring in European fisheries*) is to develop and introduce AI technology in the fisheries sector to fully document catches and improve the accuracy of reporting, consistent with the EU's publicly announced objective of 100% of landings controlled by 2030 (https://everyfish.eu/). Project objectives include:

- Facilitating the introduction of AI in the fisheries sector;
- Improving the accuracy of catch reporting;
- Standardizing catch data;
- Detecting unusual fishing events and changes to the marine ecosystem.

This project started only in 2023, but it hopes to contribute to long-term sustainable fisheries and a healthy marine environment, informing management decisions that have the confidence of all stakeholders. Fishers associated with this project have started using the automatic catch reporting technologies. EveryFish are developing the following concepts:

- CatchScanner: A three-dimensional machine vision system for analysis of catch on onboard conveyor belts. It will be developed and tested in large-scale pelagic and demersal fisheries (**Factsheet 31**).
- CatchMonitor: A system for automatic monitoring and analysis of a catch using CCTV cameras. It will be developed and tested in mid-scale demersal fisheries (**Factsheet 54**).
- CatchWAM: A compact image acquisition system for analysis of discards. It will be developed and tested in mid-scale demersal fisheries.
- CatchWatch: A species recognition system using an IP (*Internet Protocol*) camera. It will be developed and tested in large- and mid-scale demersal and small-scale fisheries.
- CatchHawk: A monitoring and automatic analysis system for use in tuna fisheries. It will be developed and tested in large-scale pelagic fisheries.
- CatchS3ID: An automated species, sex, and size identification device for analysis of crustaceans and molluscs. It will be developed and tested in small-scale demersal fisheries.
- CatchSnap-Commercial and CatchSnap-Recreational: A mobile product which will aid in the automatic registration of catch information in commercial and recreational fisheries. It will be developed and tested in small-scale demersal fisheries and recreational fisheries (**Factsheet 11**).
- AQMPelicalc: A camera system to analyse catch that is pumped from the net onto the vessel. It will be developed and tested in large-scale pelagic and demersal fisheries.

4.6 GearingUp project

The GearingUp project (*Fishing into the future*) was initiated with the aim to make information on fishing gear selectivity trials more accessible to fishers. The developed online GearingUp tool launched in 2017, presented gear trial information in a user-friendly format and could enable transitioning towards more selective fishing gear in order to meet the requirements of the Landing obligation introduced under the EU Common fisheries Policy and UK 2020 Fisheries Act.

Unfortunately, the tool is not online anymore, however, the gearing up database behind the tool still exists off-line and holds information extracted from 159 studies containing 364 comparative trials regarding gear modifications and the influence on the catch. Most of the data are focused on North Sea and Northwestern Waters although trials deployed outside these areas have also been entered.

The database is maintained by Cefas and is being updated regularly with the most recent available manuscripts (Skirrow *et al.*, 2020; 2021). Although the tool was originally developed for fishers, the database has proven to be also very useful as a repository for science advisors, researchers, and policy officials.

A collaboration between Cefas and Seafish will further investigate feedback from the fishing industry and stakeholders on the utility, functionality and demand for the GearingUp tool and also the Seafish gear database (https://www.seafish.org/responsible-sourcing/fishing-gear-database/). Based on this feedback, the GearingUp database will be further developed, and the tool might become available online again in future.

4.7 Broader scientific literature review and in-depth evaluation of innovative gears ready for deployment

A comprehensive review of scientific papers and technical reports was performed searching for innovative fishing gears in demersal and pelagic fisheries. The review included a critical evaluation of the quality and findings of the published research.

4.7.1 Typical mitigation measures to improve species- and size-selectivity

The capture of undesirable species is a recognized problem with all fishing methods (STECF, 2015). Bycatch can include species that may be targeted in other fisheries, undersized fish in the target fishery as well as accidentally caught endangered or protected species. In all cases, these fish and shellfish are part of a species population and an ecosystem. The wide range of developments in fishing gear technology continues to have a significant impact on bycatch, and consequently on discarding (Sala et al., 2008b; Sala et al., 2015; Brčić et al., 2016; Sala et al., 2016; Brčić et al., 2017b; 2018; Mytilineou et al., 2018; Sala et al., 2018; Mytilineou et al., 2021; Mytilineou et al., 2022; Mytilineou et al., 2023). Much of this bycatch consists of juvenile and low-value fish that are often discarded, usually dead. Therefore, removing them affects the food chain and ultimately the economic and social aspects of the fishery in many ways. The management of a multispecies fishery is difficult since most of fishes and invertebrates caught attain different sizes when fully grown, have different shapes and behaviours, and finally have different Minimum Landing Sizes (MLSs) making it hard to target only one of them in their shared habitat. At present, the management of fishing stocks is mainly based on defining closed areas and seasons, minimum landing sizes, minimum mesh sizes, and limiting fishing effort. In the last twenty years, several studies showed that technical modification of traditional fishing gears might improve the release of undersized fish and unwanted bycatch (STECF, 2015). For example, there have been many initiatives to improve selectivity of fishing nets or more correctly to reduce the capture and discard of non-target fish, but it has also become clear that the natural behaviour patterns of many species prevent effective selection (**Factsheet 3, Factsheet 25**). Improved selectivity can be achieved by modifying gear design and/or operation, and by using alternative fishing gears.

The changes usually involve modifying the size, shape and twine thickness of the codend meshes **(Factsheet 15, Factsheet 41, Factsheet 42, Factsheet 64**) or inserting square-mesh windows (**Factsheet 34, Factsheet 42, Factsheet 43**), sorting grids (**Factsheet 20, Factsheet 24**,**Factsheet 59**, **Factsheet 66**, **Factsheet 69**), fish eye or escape hole (**Factsheet 60**), separator panel (Grimaldo et al., 2022), etc. either in the codend or in the aft part of the extension piece (for the successful separation of targets and non-targets species. In general, these devices aim at reducing the catch of juveniles as well the incidental catch of unwanted species (Brčić *et al.*, 2015). In the latter case, they are known as Bycatch Reduction Devices (BRDs). BRDs are commonly used in trawl fisheries allowing fish that are not targeted by the fishers to escape from the net before it is hauled back into the boat (**Factsheet 49**, **Factsheet 68**). To minimize the biological impacts on bycatch and to promote ecologically sustainable fisheries, fishing gears should be modified to address both the size and species selectivity issues.

In longline fisheries, there is considerable concern over the ecological effects of pelagic longlines, which extends throughout tropical and temperate regions of the world's oceans. Several management agencies have mandated bycatch mitigation measures, such as bird-scaring "tori" lines, to reduce the mortality of seabirds that dive for longline bait. Some of these innovations were analysed and discussed in the WKING report (ICES, 2020c). Sharks (*Elasmobranchii*) are another group of vulnerable animals that interact with longlines. To reduce shark bycatch, attempts have been made to ban the use of wire leaders (**Factsheet 53**). However, there are few published studies of the effects of wire leaders on catches, and most results are ambiguous because of small sample sizes or inappropriate experimental design.

4.7.2 Sound technologies and measures to reduce interactions of marine cetaceans with fishing operations

The life histories of many of marine mammal species make them highly vulnerable to human exploitation or unintended mortality, including as incidental bycatch in fishing gears (Rihan, 2010).

ICES (2022) WGBYC reviews and summarizes the annual national reports submitted to the European Commission under Regulation (EU) 2019/1241 (2019) - *repealing Council Regulation (EC) 812/2004 (2004)* - in order to evaluate the impact of cetacean bycatch in fisheries by gear and region. Member States are obliged to implement monitoring schemes for incidental catches of cetaceans using onboard observers, on boats with an overall length of 15 m or over, for the fisheries in defined métiers and areas. Member States are also obliged to establish pilot or scientific studies on smaller vessels operating in the defined métiers and to report their monitored effort to the Commission yearly.

Of the mitigation measures identified for reducing marine mammal bycatch, acoustic alarms, excluder devices, and simple modifications to fishing gears are by far the most used globally (Corrias *et al.*, 2021). The sporadic nature of marine mammal bycatch hampers the development of avoidance solutions. A better understanding of the behavioural interactions of marine mammals with fishing gears is therefore needed. The STECF (2019) report of the EWG 19-07 provided a catalogue of bycatch mitigation methods and attempted to draw out the important issues identified and where possible, proposed follow-up actions. These include:

- The implementation and enforcement of pingers in Member States is low. Requirements to use pingers must be coupled with a requirement for MS to put in place enforcement. The Commission must follow-up on perceived infringements as judged through the reporting process;
- The restrictiveness of legislations may lead to suboptimal use of pingers, with a higher use often reported in métiers with low bycatch and lower use in métiers with high bycatch;
- Although it has been proven that pingers can reduce the rate of incidental bycatch, their broad scale use is affected by costs, enforcement, and the unpredictability of cetacean and fishery overlap;
- Better information is needed in order to use pingers more effectively on a broad scale. Monitoring programmes are needed to improve the information;
- The development of new pingers or other acoustic deterrent devices should not be constrained by a technical specification; rather Member States should be required to provide evidence that the devices they are using are in fact reducing bycatch;
- Other mitigation measures such as closed areas and gear modification may be required for species where pingers are of limited value. Member States should be required to provide evidence that these mitigation measures are effective at reducing bycatch.

While some mitigation measures are widely tested and used, such as pingers (**Factsheet 67**), there is still a need to fully assess the cost implications of bycatch reduction technology before they are introduced into legislation (Rihan, 2010; Puente *et al.*, 2023).

There have been many advances of parametric sound technology where a 'beam' of sound is transmitted directionally and focused at high intensity on to a relatively small area (Gan *et al.*, 2012). There are also passive approaches where the acoustic reflectivity of the gear is enhanced by treating the netting material or attaching acoustic reflectors to the gear so that they are more easily detected by echo-locating species (He and Pol, 2010).

4.7.3 Enhancing the capacity to make real-time decisions

Camera technologies have improved and become miniaturised and less expensive (O'Neill *et al.*, 2019) and are more frequently being used by researchers and fishers to obtain footage of fish reactions to their gears (Struthers *et al.*, 2015). The ability to view fishing gear, observe how fish react to them, and observe the effects of design changes may inspire fishers to find tailored solutions to the specific catch and quota restrictions they are subject to under the Landing Obligation (Feekings *et al.*, 2019).

Developments in camera technology and image processing will improve the ability to make direct observations of fish and fishing gears (e.g. **Factsheet 1, Factsheet 33**). three-dimensional camera systems employing methods such as stereo imaging (Rosen and Holst, 2013) or 'time of flight' (which measures the time taken for a light pulse to reach the object and return) are being improved and developed, for example in the H2020 Project *"Underwater Time Of Flight Image Acquisition system (Utofia)"* (https://cordis.europa.eu/project/id/633098), and may soon permit position and size measurement even in turbid environments. These systems, coupled with advances in image analysis, artificial intelligence and machine learning, have the potential to allow the skipper or a control system to make real-time decisions based on real-time species identification and automatic analysis of acquired images (H2020 Project *"Smart fisheries technologies for an efficient, compliant and environmentally friendly fishing sector (Smartfish)"*, http://smartfishh2020.eu).

An underwater robotic sorting device (named Smartrawl) which helps trawlers prevent bycatch by identifying and sizing fish and other marine life in real time is being developed by scientists from Heriot-Watt University, in partnership with Fisheries Innovation and Sustainability (FIS) and funded by the UK Seafood Innovation Fund (**Factsheet 32**). Smartrawl is an in-water sorting device with three components: a stereo camera, taking images of fish and other animals in the trawl; an AI computer using to determine species and size of animals; and a gate controlled by the computer to retain valuable fish or release unwanted catch. It then releases or retains each marine animal depending on whether it qualifies against a trawler's intended catch using a computer-controlled robotic gate.

Components of the project have already been tested at sea, and further trials are scheduled for later this year in Shetland using the research vessel Atlantia, operated by the University of the Highlands and Islands. It is able to fit into existing nets of all sizes of vessels and requires no additional cables due to the device's patented gate system, which works with the force of the water to rotate between open and closed states. Using the system, fishers will be able to programme trawls to catch specific marine animals according to their size and species, market conditions and allotted quotas, resulting in no discards or bycatch.

Current systems that provide real-time footage generally require transmission cables to the surface which can be difficult to handle and are expensive. Nevertheless, such an ability would allow fishers to make real-time decisions regarding their fishing operation (and potentially inspire their development of innovative gears). These could be as simple as deciding to continue or stop fishing, based on observations of what fish are on the ground or entering their gear; or they could be used in conjunction with remotely controllable instruments that, for example, open/close a codend or operate flaps/doors that direct fish into different compartments of a fishing gear.

Acoustic systems have been used in pelagic fisheries, from estimating the size and density of fish schools to tracking individuals, and more recently, to differentiate between and within species (Trenkel *et al.*, 2016). Such developments are likely to be particularly useful for catch identification during the early hauling stages of purse-seine fisheries (**Factsheet 3**).

At present direct methods such as hand-lining and dipnetting are used to determine the species and size profile of the catch, but these can often only be used during the latter stages of hauling **(Factsheet 48**) when overcrowding may have occurred and the survival of released catches is likely to be low (Marçalo *et al.*, 2018; Marçalo *et al.*, 2019). Sampling methods, can be used during the early stages of a haul, such as shooting a 'mini-trawl' (**Factsheet 4**) into a purse-seine (Isaksen, 2013).

4.7.4 Alternative technologies to improve species and size selectivity

While a lot can be done to develop more selective gears with existing technologies and knowledge, it is also important to consider alternative approaches and new developments (O'Neill *et al.*, 2019). The selective performance of a fishing gear depends on design parameters such as mesh and hook size, and on the response of the species under consideration to the various optical, acoustic, magnetic, electric, hydrodynamic and/or chemical stimuli the gear generates (Popper and Carlson, 1998; Jordan *et al.*, 2013; Løkkeborg *et al.*, 2014). In recent years, due to technological developments which can generate and/or modify these stimuli, and improved understanding of how fish react to them, there has been an increasing focus on harnessing such stimuli to modify fishing gear selectivity (see **Factsheet 5**).

The gustatory and olfactory senses are of particular importance in baited gears Løkkeborg *et al.* (2010) and Thomsen *et al.* (2010) highlighted the potential of artificial baits, longer-lasting baits and a better understanding of species-specific differences in bait performance to improve the selective performance of longline and pot fisheries. Gilman *et al.* (2008) have shown that using fish instead of squid for bait reduced shark bycatch in pelagic longlines, while Stroud *et al.* (2014) have shown that a necromone produced from putrefied shark tissue (**Factsheet 8**) was 100% repellent to competitively feeding Caribbean reef sharks (*Carcharhinus perezi*) and blacknose sharks (*Carcharhinus acronotus*).

Light has long been used by fishers to capture squid and pelagic species (Arimoto *et al.*, 2010) and, with the onset of robust low-powered LED light sources, it is being considered again in many contexts. Bryhn *et al.* (2014) increased the catch efficiency of larger cod (*Gadus morhua*) in pots by using green lights, while (Nguyen *et al.*, 2017) improved the catchability of snow crab (*Chionoecetes opilio*) by using LED lights in their traps (**Factsheet 62**). In trials on the Mediterranean Sea, artificial lights mounted on the headrope trawlnet (**Factsheet 6**) yielded higher catch of deep-water rose shrimp (*Parapenaeus longirostris*), while Hannah *et al.* (2015) were able to reduce the capture of some fish species by up to 90% with no loss of ocean shrimp (*Pandalus jordani*) by placing LED lights on the fishing line of their shrimp trawls. There have also been successful trials with luminous netting materials, fibre optic cables and lasers (**Factsheet 6**, **Factsheet 39, Factsheet 40, Factsheet 62**, and **Factsheet 65**) to direct fish into or within a trawl (O'Neill *et al.*, 2022). To fully exploit the potential of light to improve the selective performance of commercial fishing gears, more research needs to be done on how parameters such as the wavelength, intensity, polarization and strobing of light can be used to modify the behavioural reaction of fish (Königson *et al.*, 2002; Marchesan *et al.*, 2005; Arimoto *et al.*, 2010).

In longline fisheries there have been attempts to take advantage of elasmobranchs' ability to detect weak electromagnetic fields (**Factsheet 7**) to reduce their capture by using electropositive metals and magnets (Kaimmer and Stoner, 2008; Robbins *et al.*, 2011; O'Connell *et al.*, 2014). While success has been limited thus far, and there are issues related to manufacturing costs, deterioration in water and large-scale deployment (Favaro and Côté, 2015), there is the possibility that alternative metals and compounds will offer cheaper and cost-effective solutions (O'Connell *et al.*, 2014).

In trawl fisheries, electricity has been used to increase catchability by stimulating benthic species from the seabed (**Factsheet 26**), to direct and aggregate fish so that they can be caught more easily by conventional means and to improve the performance of selective devices by exploiting species and size differences in their behavioural responses (Polet, 2010). In the southern North Sea flatfish fishery, electrodes produce an electric field which induces a cramp response that bends fish in a U-shape, making it easier for the groundgear to get underneath them so they enter the trawl (van Marlen *et al.*, 2014; Depestele *et al.*, 2019).

Other examples of using electricity in trawl fisheries include the Belgian and Chinese shrimp fisheries (Polet *et al.*, 2005b; Yu *et al.*, 2007) and the razor clam (*Ensis* spp.) fishery in the West of Scotland (Murray *et al.*, 2016).

There are several examples where the hydrodynamics of towed gears have been exploited to improve selectivity. Attempts to develop low-injury mesh trawls for cod and haddock have met with mixed success in terms of the trade-off between creating a benign in-trawl environment vs. achieving an acceptable level of size selectivity (Millar *et al.*, 2023; Moran *et al.*, 2023). Millar *et al.* (2023) tested an inflatable membrane-like fabric tube with escapement holes that replaces the mesh codend of a trawl - *namely Modular Harvesting System (MHS)* - designed to reduce damage to catch by providing fish a low-flow, low-turbulence environment that allows them to maintain swimming control and avoid compaction during trawling and haulback (**Factsheet 27**). They demonstrated that there are new pathways to design trawl gear that can simultaneously increase catch quality and fish survival by reducing known causes of fish damage with no effect on selectivity.

Veil nets in shrimp fisheries, rising panels in codend extensions and the flex deflector modify the flow in the gear to direct fish and crustaceans onto or closer to grids and square mesh panels (Graham, 2003; Santos *et al.*, 2016a). The Hydrodredge deflects a water flow on to the seabed to raise great scallops (*Pecten maximus*) from the seabed (Shephard *et al.*, 2009), and Jordan *et al.* (2013) suggest that water jets directed downwards, ahead of a trawl gear could elicit an early response from elasmobranchs, allowing them to avoid capture (**Factsheet 35**). There is also potential to create regions of low flow behind screens and bluff bodies and turbulent regions which, if the associated vortices are an appropriate strength and size, can be used to encourage fish to hold station and perhaps increase their probability of contact with a selectivity device (Liao, 2007; Laird *et al.*, 2016).

It is evident that there is great scope to better exploit the senses of target and bycatch species. O'Connell *et al.* (2014) provide a very useful summary table which identifies new and existing technologies that should undergo further testing for use in elasmobranch bycatch mitigation. They classified potential solutions for a range of gear types in terms of the sensory modality that the fish will use (Table 4), as this serves as an example of how it could be extended to other species.

Table 4. Potential applications of new and existing bycatch reduction technology by fishing gear and elasmobranch sensory modality. Source: modified and adapted from Jordan *et al.* (2013) and O'Neill *et al.* (2019).

Sensory modality	Hook and lines	Gillnet	Trawl	Purse-seine
Olfaction	Surfactants, semiochemicals	Surfactants, semiochemicals	-	Remote attraction/bait stations
	Bait type			
	Dead sharks			

Sensory modality	Hook and lines	Gillnet	Trawl	Purse-seine
Hearing	Not recommended	-	-	-
Vision	Light sticks: wavelength and flicker	Net illumination	Flashing lights	-
	Bait colour	Net colour		
	Leader type/colour	Predator models		
	Dead sharks			
Mechanosensory lateral line/pit organs	-	-	Water jets	-
Electrosensory	Magnets, lanthanide metals, battery-powered devices	Electric or magnetic field 'barrier'	Electric pulse generators	-

4.7.5 Innovative gears to mitigate the fishing seabed impact

Solutions and technological innovations to reduce the spatial footprint of demersal fishing gear on the seabed have been intensively investigated by the scientific community (Eigaard *et al.*, 2011; Eigaard *et al.*, 2016a; Rijnsdorp *et al.*, 2016; Rijnsdorp *et al.*, 2017), with some successful cases, the so called "proven fishing gears" (Eayrs and Pol, 2019). Technological innovations can include major improvements in fishing gear and vessel design, propulsion systems, fish finding, and catch handling, resulting in a significant increase in effective fishing effort when they are adopted throughout a fishing fleet (Palomares and Pauly, 2019). However, the voluntary uptake of such innovations by fishers often remains low (Steins *et al.*, 2022; Pol and Maravelias, 2023), and is guided by the interplay between a variety of social, policy, and science-related factors influencing the readiness, willingness, and ability of fishers to adopt proven fishing gear (Steins *et al.*, 2022; Jenkins, 2023; Jenkins *et al.*, 2023).

4.7.5.1 Shifting gear (from towed- to passive-gears)

A significant reduction in seabed impact can be expected when bottom trawls are replaced by passive (static) gear such as traps and gillnets which have a hugely reduced footprint (Jennings *et al.*, 2001). However, to be a viable alternative, the catch and economic efficiency of passive gears must be sufficient to offset the relatively high catch volumes derived from bottom trawling. In Europe, trap fisheries that have successfully replaced bottom-trawl fisheries include those that target *Nephrops*. There are now well-established trap fisheries in Western Scotland and the Swedish West Coast which account for up to a quarter of the total *Nephrops* landings in those areas (Ungfors *et al.*, 2013). Recent analysis has found that the Swedish trap fishery for *Nephrops* is more profitable than the Swedish trawl fishery targeting the same species (Hammarlund *et al.*, 2018), while experimental work in the Kattegat has found that the profitability of small creel vessels with two persons on board was comparable to small Danish trawlers (but not to larger mixed fishery trawlers). Leocádio *et al.* (2012) observed that trawling for *Nephrops* off Portugal was not profitable, whereas a *Nephrops* trap fishery was due to a superior revenue to cost ratio. In the Adriatic Sea, the *Nephrops* creel is increasingly being used in Croatian fishing grounds where bottom trawling is banned (Brčić *et al.*, 2017a).

The transition from mobile to passive gears is not with challenges and risk. There is a need for agreement to be reached, either voluntarily or regulated, over spatial or temporal allowance for such activity, particularly in regions where bottom trawling and/or other fishing methods already exist. Otherwise conflicts among mutually-exclusive gears may arise, which could deeply impair development of a new métiers, e.g. in the bay of Biscay (Raveau *et al.*, 2012) or may happen even in well-developed fisheries (Pieraccini and Cardwell, 2016). A study in Kattegat showed that a shift from towed to passive gears will also involve significant changes in fleet structure, overall catch rates, and possibly economic efficiency of the fishery overall (Frandsen *et al.*, 2015; Hornborg *et al.*, 2016). Trawling and passive gear such as traps and gillnets are very different fishing techniques that usually require different vessels; the conversion of an existing trawler to operate traps is uncommon and generally considered not economically viable. An ability to fully utilize existing quotas may also be challenged given the difficulty of matching catch volumes and rates from bottom trawlers (Frandsen *et al.*, 2015).

Replacing bottom-trawl gear with traps will most likely contribute to a substantial reduction in seabed impact. However, passive gear will not be able to replace bottom trawls in all bottom-trawl fisheries. The target species may not occur in dense enough aggregations to yield viable catch rates using traps and the catch entangled in the gillnet may be predated and lost before hauling, e.g. by seals (Koningson *et al.*, 2010; Cosgrove *et al.*, 2015). Using traps or gillnets requires different skills than with bottom trawls, and crews may not be willing to change their traditional *métier*. In fact, in some regions fishers may identify with their own gears as part of long family tradition. Other factors that may influence a transition to traps include existing fishery regulations and limits on gear type, the depth and topography of the seabed, weather conditions, tides.

The risk of gear loss and ghost fishing (Jennings *et al.*, 2001) and bycatch issues and interactions with marine mammals or other non-target animals is also a consideration (Žydelis *et al.*, 2009; Koningson *et al.*, 2010; van Beest *et al.*, 2017), although notably Adey *et al.* (2008) reported that *Nephrops* traps cease to fish once all the bait has been consumed. Ghost fishing with lost bottom trawls is also generally not perceived to be a major issue, although the potential for entanglement of some species may still exist. Finally, there are few current regulations that limit the size and weight of trap gear; hence this is an issue that could be addressed in future if trawling was to be reduced in favour of passive gears.

4.7.5.2 Electrical stimulation

The use of electrical stimulation has much potential to reduce seabed impacts (**Factsheet 26**), including the common sole fisheries which traditionally require heavy groundgear to stimulate sole into the net (ICES, 2020b; Rijnsdorp *et al.*, 2020a). The flatfish pulse trawls have higher catching efficiency for sole than traditional gear and are towed at a lower speed. The penetration depth of the pulse trawls is also reduced, resulting in reduced sediment resuspension (O'Neill and Ivanović, 2016). Compared to a conventional beam trawl, the flatfish pulse trawl reduces benthic impact by 62% (Rijnsdorp *et al.*, 2020a). The replacement of beam trawling with tickler chains trawling with electric *PulseWing* trawling substantially reduces impact on benthic biogeochemical processes and declines in benthic community metabolism (Tiano *et al.*, 2019). Hence, they offer the opportunity to reduce the footprint of the fishery on the seabed, all else held equal. The use of electrical stimulation in shrimp fisheries is thought to reduce the bycatch of fish and undersized shrimps, as well as seabed impact (Polet *et al.*, 2005a; b).

The use of electrical stimulation is illegal under the EU-legislation and concern has been raised about possible adverse effects on marine organisms and the benthic ecosystem (Soetaert *et al.*, 2016b). The sensitivity to injury and harm of fish and other organisms in response to electrical stimulation differs between species (Soetaert *et al.*, 2015b; Desender *et al.*, 2016; Soetaert *et al.*, 2016b). It was shown that the muscle cramp response induced by the sole pulse trawl may lead to fractures and haemorrhages in cod and whiting (van Marlen *et al.*, 2014; de Haan *et al.*, 2016; Soetaert *et al.*, 2016b), although no fractures were observed in invertebrates or fish exposed to an electrical pulse while shrimp trawling (Soetaert *et al.*, 2015a; Desender *et al.*, 2016).

Van der Reijden *et al.* (2017) studied the survival of sole and plaice discards caught using a pulse trawl and reported survival rates of approximately 30% and 15%, respectively, providing first indications of higher survival rates than reported for the traditional beam trawl fishery of <10% (Van Beek *et al.*, 1990; Uhlmann *et al.*, 2016). No effects of pulse stimulation have been reported on the food detection ability of small-spotted catshark (Desender *et al.*, 2017). A comparison between areas where pulse trawlers are permitted and where they are not revealed a 57% reduction in species richness and a 21% reduction in biomass in the former area compared to the latter (Ford *et al.*, 2019). While the cause of these reductions was not entirely clear, the authors did not rule out pulse trawling as one of the main causes. Studies on the effects of electrical stimulation on marine organisms and the benthic ecosystem are ongoing, with a goal to build understanding and strengthen the scientific basis to assess the impact of pulse trawling on the environment.

In contrast to other technological innovations, electrical stimulation has been quickly implemented in the beam trawl fishery targeting flatfish in the Netherlands, although not in the flatfish fishery in Belgium or in the brown shrimp fishery. This difference is somewhat related to the specific operational conditions of each fishery, whereby the Dutch fleet could take full advantage of this gear as the fleet fishes year-round in the North Sea while the Belgium fleet fishes only in the North Sea during part of the year and would only be allowed to pulse fishing in that restricted time period. Hence, the full implementation requires governmental support as well as the appropriate fishery management framework to introduce a technological innovation and make it operational.

Despite the potential for seabed impact reduction (ICES, 2018a; b; 2019), its uptake by the Dutch industry and its support at national level, the experimental licensing of pulse trawling ended in 2021 following the political decision of the European Parliament (see case study Pulse fisheries in *section §4.9.5*).

In conclusion, electrical stimulation has a high potential to reduce seabed impacts by bottom-trawl fisheries. The technique also may improve the selectivity of the gear, as it is expected that the electrical stimulation may target marketable size classes (Verschueren *et al.*, 2019), even if improvement in selectivity for several species still remains uncertain and requires further investigations. Electrical stimulation may also be applied in the fishery for razor clams (Murray *et al.*, 2016), and could have a potential application in the fishery for *Nephrops*. Soetaert *et al.* (2016a) showed the potential application of electrical stimuli in combination with an escape panel to reduce the bycatch of benthic invertebrates while maintaining the commercial sole catch. Further impact assessment studies could be carried out on other fisheries using electric stimulation to determine if the seabed impact reduction occurs relative to traditional fishing techniques, such as the razor clam fishery currently using hydraulic dredges (Hall *et al.*, 1990; Lucchetti and Sala, 2012; Lucchetti *et al.*, 2017; Sala *et al.*, 2017; Vasapollo *et al.*, 2020). ICES (2020b) and Rijnsdorp *et al.* (2020a; 2020b) highlighted the reduced spatial footprint and impact on the fish community and benthic ecosystem when pulse trawling. Furthermore, Depestele *et al.* (2019) reported increased catch efficiency for sole, and reduced fuel consumption and associated CO2 emissions. Compared to a conventional beam trawl benthic impact by 62% and results in at least 37% less CO_2-emissions (Rijnsdorp *et al.*, 2020b).

4.7.5.3 Gear modifications

There have been many studies of gear modifications to reduce seabed impacts (e.g. **Factsheet 29, Factsheet 30, Factsheet 35, Factsheet 51**) such as groundgear modifications, for example, drop chains, raised footrope trawls, sweep-less trawls, use of rollers (He and Winger, 2010; Polet and Depestele, 2010). The actual reduction in total sediment disturbance is much larger as standard otterboards penetrate deeper (up to 35 cm) than any of the other gear components (Eigaard *et al.*, 2016b). As the hydrodynamic drag of the otterboards is reduced, the lifting of otterboards will also contribute to a reduction in the resuspension of sediment (O'Neill and Summerbell, 2011).

The Jumper boards tested in the Bay of Biscay resulted in an 85% decrease in sediment resuspension. Removing a tickler chain (seabed cutting wire) from the Rapa whelk beam trawl will reduce the penetration of the gear into the seabed over the full width of the gear.

4.8 Factsheets

In 2020, ICES has published a WKING report on innovative fishing gears based on a catalogue of 42 factsheets that described innovative fishing gears potentially relevant to EU fisheries (ICES, 2020c). The current report is based on the innovative gear catalogue containing an additional 75 factsheets (Table 5) which includes two updated innovations of gears (e.g. shrimp pulse trawl and Flemish panel) present in previous ICES (2020c) WKING report. The criteria used by these individuals to rank the performance of each gear was deliberately coarse because: *i)* widely agreed and accepted criteria in a commercial fishing context do not exist, and *ii)* there is no individual sufficiently knowledgeable and understanding of all submitted gear innovations to be able to rank them all accurately and consistently. Therefore, by necessity we relied on the opinion of individuals that were involved in the development and/or testing of each innovative gear. This means the rankings, while subjective and inconsistent, were usually derived by individuals with at least some knowledge of the environment and context in which the innovative gear was intended.

Based on information provided in the factsheets, almost 80% of innovations were categorized as having a *high* level of technological readiness and only 4% were categorized as having a *low* level of technological readiness. Almost half (47%) the innovations were perceived to have a *minimal* level of complexity, and most (80%) of those gears were also deemed to have a high level of technological readiness (Figure 4). One-third of the remaining innovations were perceived to have a *medium* level of complexity and moderate or high technological readiness level (Figure 3). Most innovations categorized as having a medium (Moderate) level of technological readiness were reported as TRL 6, meaning they were deemed to be close having a high level of readiness, presumably because addition research and development was felt necessary. An obvious conclusion from these findings is that most innovations reported in the factsheets were deemed to be ready for adoption by industry, subject to minor alteration to suit operational and design differences between vessels.

Most (80%) innovative fishing gears were considered to result in a positive effect (incremental, transformative, or disruptive improvement) in *catch efficiency*, and most (80%) of these were also considered to have a high level of technological readiness. Those gears considered to result in a negative improvement in catch efficiency require further development, and despite their medium to high level of technological readiness it is unlikely fishers will adopt these gears unless they provide substantial improvement elsewhere, i.e. reduce fuel costs.

When considering gear *selectivity*, most (80%) innovative fishing gears were deemed to result in a positive effect (incremental, transformative, or disruptive). Most (78%) of these innovations were also considered to have a high level of technological readiness. Five gears were considered to result in a negative improvement in selectivity and require further development or discarding, despite their high level of technological readiness.

Most (64%) innovative fishing gears were considered to result in a reduction (incremental, transformative, or disruptive) of the impact on the marine ecosystem. Most (77%) of these innovations were also considered to have a high level of technological readiness. There were zero innovations with an increased impact compared to the baseline gear, and 27 with no effect.

Table 5. Summary of information collected in the Factsheets, including: Description of gear; Area of development; Technology Readiness Level (TRL); Level of Complexity (Compl.); Ecological performance - Catch efficiency (C), Selectivity (S), and Environmental Impact (I); and Economic performance - Capital Cost and Return on Investment (ROI); and PESTEL Framework. See *section §3* for full details.

Area: Non-Specific (Global), North Sea (NS), North Western Waters (NWW), South Western Waters (SWW), Baltic Sea (BS), Mediterranean and Black Sea (Med). **TRL Category**: High (3), Moderate (2), Low (1). **Complexity**: Significant (3) Medium (2), Minimal (1). **Environmental improvement Performance**: Disruptive (3), Transformative (2), Incremental (1), Negative (-1), Not applicable, *interpreted as no effect* (0). **Capital cost**: High (3), Moderate (2), Low (1). **Return on Investment (ROI)**: Significant (3), Substantial (2), Minor (1), Negative (0), Unknown (-). **PESTEL framework**: "Do not know" (NK), "Not Applicable" (NA), "Has encouraged uptake" (+), "It is a barrier" (-).

Factsheet	Description	Area	Gear type	TRL		Compl.	Performance					PESTEL Framework					
							Ecological			Economic							
				Category	Scale		C	S	I	Cost	ROI	P	E	S	T	E	L
1	Deep Vision harvest control in-trawl imaging	Global	Trawl	3	TRL7	3	2	2	2	3	3	+	–	+	+	+	–
2	Autotrawl systems	Global	Trawl	3	TRL9	3	2	0	2	3	3	+	–	+	+	+	NA
3	Broadband acoustics to sizing fish-like target	Global	Purse-seine	3	TRL9	3	3	2	1	3	3	NK	+	+	+	+	NK
4	Fish sampling by shooting a "mini-trawl"	Global	Purse-seine	3	TRL7	2	1	2	0	2	2	+	–	+	+	+	–
5	Alternative baits to improve longline efficiency	Global	Longline	3	TRL7	2	-1	1	1	2	0	NK	–	+	–	+	+
6	Artificial lighting to improve catchability in trawl	Global	Trawl	3	TRL7	2	1	1	1	1	-	+	NK	+	+	+	–
7	Electrosensory deterrents to reduce shark bycatch	Global	Longline	3	TRL7	2	0	2	2	2	1	NK	–	+	NK	+	NK
8	Chemical shark necromone repellent	Global	Longline	2	TRL6	2	1	1	3	2	2	NK	NK	+	NK	+	NK
9	Waste heat recovery to increase energy efficiency	Global	Trawl	2	TRL6	2	0	0	1	3	2	+	+	+	–	+	NA
10	Lobster condos	Global	Pots	3	TRL7	1	1	1	1	2	2	+	NK	NK	+	+	NA
11	*CatchSnap*	Global	All gears	3	TRL7	2	0	0	1	1	-	NK	+	NK	NK	+	NK
12	Passive excluder device (*ExFED*) to limit trawl catch	Global	Trawl	3	TRL7	1	2	0	2	1	3	NK	+	+	+	+	–
13	Rigid codend with triggered drafting gate	Global	Trawl	3	TRL7	3	2	2	2	3	3	NK	–	+	–	+	–
14	Biodegradable nets to improve ALDFG and recycling	Global	All gears	3	TRL7	3	-1	-1	2	3	0	NK	–	NK	NK	+	–
15	Larger mesh size to reduce bycatch in skate fishery	Global	Trawl	3	TRL9	1	2	3	2	1	3	+	+	NK	+	+	+
16	*CatchScanner*	Global	All gears	3	TRL7	3	1	0	0	2	2	NK	NK	NK	NK	NK	NK
17	Lobster anti-ghost fishing device (*Eco-trap*)	Global	Pots	2	TRL4	2	2	2	1	3	1	NK	NK	NK	–	NK	NA
18	Modified gillnet to reduce ghostfishing lost gear	Global	Gillnet	3	TRL7	1	1	1	2	2	2	+	–	NA	+	+	NA
19	Modified crab pot to reduces ghostfishing	Global	Pots	2	TRL6	1	1	1	2	1	1	+	NK	+	+	+	NA

Factsheet	Description	Area	Gear type	TRL		Compl.	Performance					PESTEL Framework					
							Ecological			Economic							
				Category	Scale		C	S	I	Cost	ROI	P	E	S	T	E	L
20	Netting-based alternative to rigid sorting grids	NS	Trawl	3	TRL9	1	0	3	3	2	2	+	NK	NK	+	+	+
21	Alternatives for processing and storing UUCs	NS	Trawl	1	TRL2	3	1	0	0	3	3	NK	NK	NK	NK	NK	NK
22	Alternative codend in unrestricted trawl	NS	Trawl	3	TRL7	1	1	1	1	1	1	NK	NK	NK	NK	NK	NK
23	Predictive methods to estimate gear selectivity	NS	Trawl	2	TRL6	1	1	1	1	1	1	NK	NK	NK	NK	NK	NK
24	Sorting grid to improve size selection of shrimp	NS	Beam trawl	3	TRL9	2	1	1	0	2	1	NK	NK	NK	NK	NK	NK
25	Multibeam sonars application	NS	Purse-seine	3	TRL7	3	3	2	2	3	3	NK	NK	NK	NK	NK	NK
26	Pulse trawling	NS	Beam trawl	3	TRL9	3	3	2	2	3	3	–	+	–	+	+	–
27	Modular Harvesting System (*MHS*)	NS	Trawl	3	TRL8	3	3	3	3	3	1	NK	NK	NK	NK	NK	–
28	Shrimp pulse trawl	NS	Trawl	3	TRL9	3	1	1	2	2	3	–	+	NA	NA	NA	–
29	Self-adjusting semi-pelagic doors	NS	Trawl	2	TRL5	3	-1	0	2	3	2	+	–	+	–	+	+
30	Sea stars HydroTrawl	NS	Beam trawl	3	TRL8	1	2	2	2	1	2	NK	NK	NK	NK	NK	NK
31	*TrawlMonitor*	NS	Trawl	3	TRL7	3	2	2	0	3	2	+	–	+	–	+	+
32	Intelligent fishing (*Smartrawl*)	NS	Trawl	1	TRL2	3	2	3	3	2	3	+	NK	+	NK	+	NK
33	*CatchCam*	NS	Trawl	3	TRL9	3	2	2	2	3	3	NA	–	NK	NK	NK	NA
34	Square-mesh cylinder in the extension (CMC)	NWW	Trawl	3	TRL7	1	-1	1	0	1	1	NK	–	NK	NK	NK	–
35	*Hydrodredge*	NWW	Dredge	3	TRL7	1	-1	1	2	1	0	NK	–	NK	+	+	NK
36	Quad-rig trawling to improve Nephrops fishery	NWW	Trawl	3	TRL9	2	1	1	1	3	2	+	+	+	+	+	NA
37	Black sea bream fish pot	NWW	Pots	3	TRL7	1	1	1	1	2	1	NA	–	+	+	+	NA
38	Selective Beam Trawl	NWW	Beam trawl	3	TRL9	1	1	2	2	1	2	NK	+	+	+	+	NK
39	Artificial LED lights on leadline in trawl	NWW	Trawl	3	TRL9	1	2	2	0	1	2	NA	NA	NK	NK	NA	NA
40	Artificial LED lights on raised fishing line	NWW	Trawl	3	TRL9	1	2	2	0	1	0	NA	NA	NK	NK	NA	NA
41	Modified rigging to reduce of unwanted catches	NWW	Trawl	3	TRL9	1	2	2	0	1	2	NA	NA	NK	NK	NA	NA
42	Alternative codend to reduce unwanted catches	NWW	Trawl	3	TRL7	2	2	2	1	1	1	NK	+	+	+	+	+
43	Flemish panel	NWW	Beam trawl	3	TRL8	1	1	2	2	1	1	+	NK	NK	NK	NK	+
44	Raised Trammelnet (Aranha)	NWW	Set-nets	2	TRL6	2	2	2	2	2	1	+	–	+	+	+	NA
45	Four-Panel Nephrops trawl	NWW	Trawl	3	TRL7	2	2	2	-	2	1	NK	–	–	NA	NK	NA
46	Raised fishing line trawl	NWW	Trawl	3	TRL9	1	2	2	2	1	1	NK	–	–	NK	NK	NA
47	Dual codend with net separator panel	NWW	Trawl	3	TRL9	2	2	2	2	2	3	NK	–	–	–	+	NA

Factsheet	Description	Area	Gear type	TRL		Compl.	Performance					PESTEL Framework					
							Ecological			Economic							
				Category	Scale		C	S	I	Cost	ROI	P	E	S	T	E	L
48	Mitigation methods to reduce slipping mortality	SWW	Purse-seine	3	TRL8	1	1	1	1	1	1	NK	NK	NK	+	+	+
49	BRD to reduce discards in dredge fisheries	SWW	Dredge	2	TRL6	1	-1	1	0	1	0	NK	–	NK	NK	NK	NK
50	Intelligent trawls based on Artificial Intelligence	SWW	Trawl	3	TRL7	3	2	3	2	3	1	–	–	+	+	+	NK
51	Reducing door impact (Connect system)	SWW	Trawl	3	TRL7	2	0	0	2	2	1	–	–	–	+	+	NA
52	*SeinePrecog*	SWW	Purse-seine	3	TRL7	1	1	3	0	2	2	NK	NK	NK	NK	NK	NK
53	Nylon leaders to reduce shark longline bycatch	SWW	Longline	3	TRL7	1	1	2	1	1	2	NK	NK	+	NA	+	+
54	*CatchMonitor*	SWW	All gears	3	TRL7	3	0	0	1	2	-	NK	NK	NK	NK	NK	NK
55	Alternative codend in unrestricted Nephrops trawl	BS	Trawl	3	TRL8	1	1	1	0	1	1	+	+	+	+	+	–
56	Alternative codend in unrestricted demersal trawl	BS	Trawl	3	TRL8	1	1	1	0	1	1	+	+	+	+	+	–
57	Increase T90 codends circumference	BS	Trawl	3	TRL8	1	1	-1	0	1	0	–	–	–	+	–	–
58	Changing codend from polyethylene to polyester	BS	Beam trawl	3	TRL8	1	1	-1	0	1	0	–	–	–	+	–	–
59	Flexible grids to release flounder in cod fishery	BS	Trawl	3	TRL8	2	1	-1	0	1	1	–	–	–	+	–	–
60	Flex tunnel to reduce flounder catch in cod fishery	BS	Trawl	3	TRL8	2	1	1	0	1	1	–	+	+	+	+	–
61	Divided codend in the Nephrops trawl fishery	BS	Trawl	3	TRL7	2	1	-1	0	1	1	NA	NA	NA	NA	NA	NA
62	Visual stimuli to improve efficiency in pot fisheries	BS	Pots	3	TRL7	2	1	1	0	2	2	+	+	+	+	+	+
63	*FishFinder*	BS	Trawl	2	TRL6	2	1	1	0	3	1	NK	NK	NK	NK	NK	NK
64	T90 codend and 30% shortening lastridge rope	BS	Trawl	1	TRL3	1	1	1	2	1	2	–	+	NK	+	+	NK
65	Visual deterrents to reduce sea turtles bycatch	Med	Set-nets	2	TRL5	1	1	1	1	2	1	–	–	NK	+	+	NA
66	Juvenile Selection Grid (*JSG*)	Med	Trawl	2	TRL5	1	1	1	0	1	1	NA	NK	–	+	+	NA
67	Pinger to reduce cetacean-fishery conflicts	Med	Set-nets	3	TRL8	2	1	0	2	2	2	+	–	+	+	NK	+
68	*FLEX-TED* to mitigate sea turtle bycatch	Med	Trawl	3	TRL7	1	1	1	1	1	1	–	+	+	+	+	–
69	Sorting grids to reduce undersized crustacean	Med	Trawl	2	TRL6	1	1	2	0	1	2	+	+	+	+	NK	+
70	T90 in the extension piece to reduce bycatch	Med	Trawl	3	TRL9	1	-1	1	0	1	0	+	NK	NK	+	NK	+
71	Alternative materials and new design in trammelnet	Med	Set-nets	3	TRL8	1	1	1	0	1	1	+	+	+	+	+	+
72	Artificial lights to reduce discards in trammelnet	Med	Set-nets	3	TRL7	1	1	1	0	1	1	NK	+	+	NK	+	NK
73	Guardian net to reduce discards in trammelnet	Med	Set-nets	3	TRL9	1	1	1	0	1	1	NK	+	+	NK	+	NK
74	Circle hooks on swordfish longline	Med	Longline	3	TRL9	2	-1	1	2	1	1	+	–	+	NK	+	+
75	Lighter trawl gear to reduce impact	Med	Trawl	2	TRL6	2	0	1	1	2	1	NK	–	+	+	+	NK

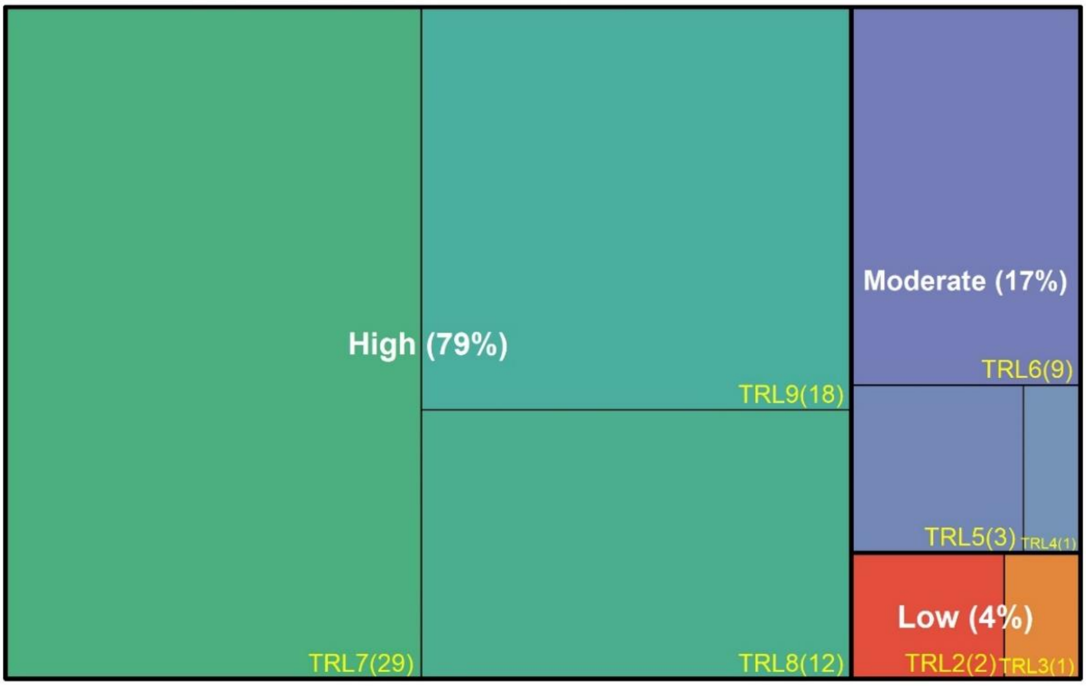


Figure 3. Treemap of Technology Readiness Level (TRL) for all innovations reported in the factsheets, grouped by TRL category (High, Moderate, Low) and TRL scale (TRL1-TRL9). The proportion of innovations represented by each TRL category, and the total number of innovations represented by each TRL scale are shown.

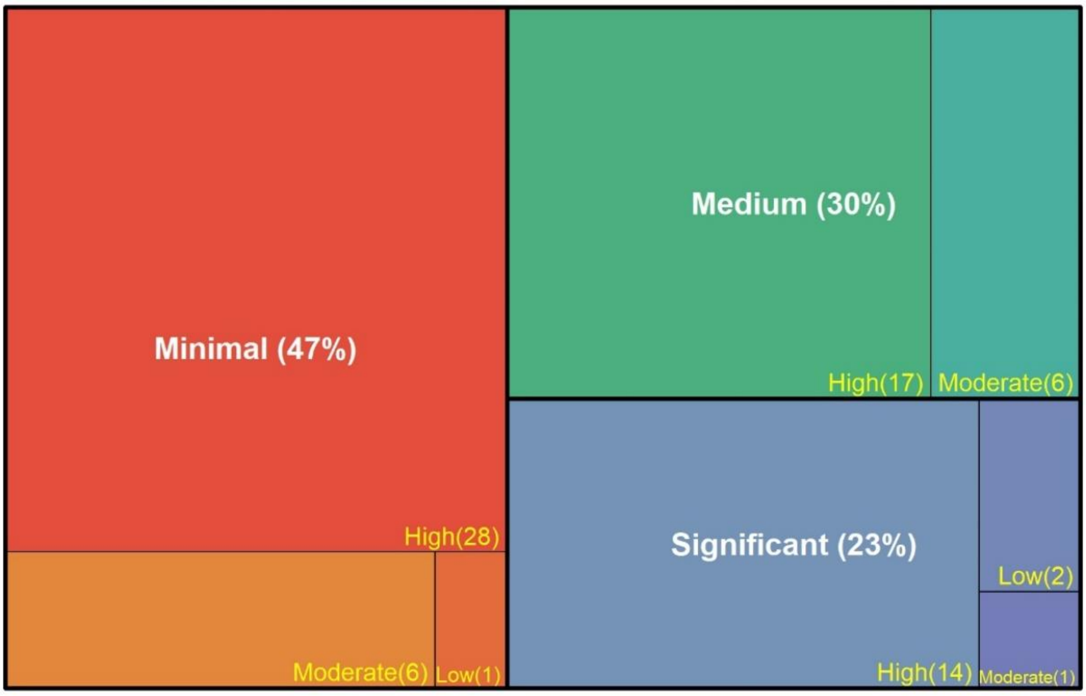


Figure 4. Treemap of technological complexity for all innovations reported in the factsheets, grouped by perceived level of complexity (Minimal, Medium, Significant) and TRL category (High, Moderate, Low). The proportion of innovations represented by each level of complexity and the total number of innovations represented by each TRL category are shown.

4.8.1 Innovation matrix: criteria of assessment and technological readiness

Innovation matrices were developed to visualize the relationship between each criterion of assessment (CA) and technological readiness level as reported in the factsheets (Figure 5, Figure 6 and Figure 7).

4.8.1.1 Catch efficiency

Based on information provided in the factsheets, most innovative fishing gears were considered to result in an incremental or transformative improvement in catch efficiency (Figure 5). Most of these gears were also considered to have a high level of technological readiness. Four gears were considered to result in a disruptive improvement in catch efficiency and all were considered to have a high level of technological readiness. Those gears considered to result in a negative improvement in catch efficiency require further development, despite their medium to high level of technological readiness; it is unlikely fishers will adopt these gears unless they provide substantial improvement elsewhere, i.e. reduce fuel costs.

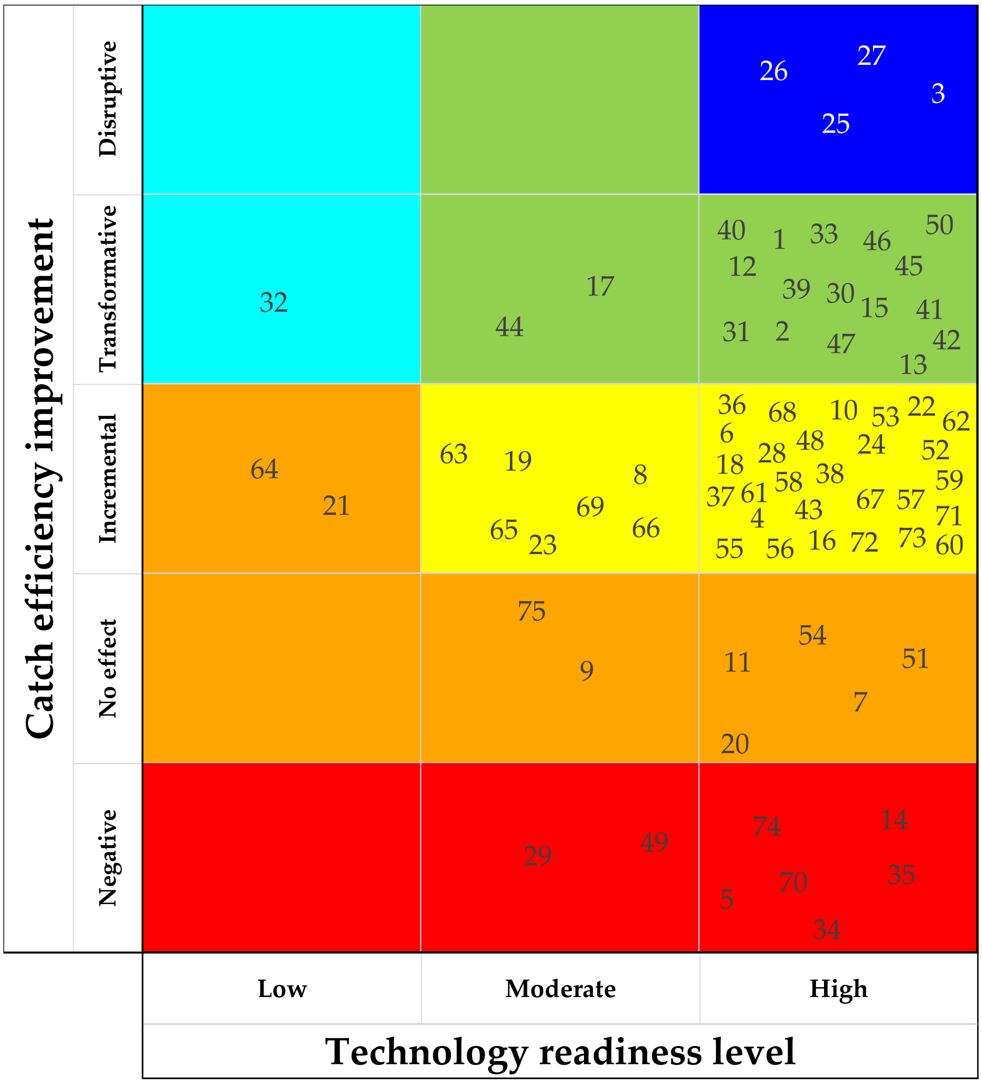


Figure 5. Innovation matrix highlighting the relationship between improvement in catch efficiency and technological readiness level for each innovative fishing gear. Each numbers represents a Factsheet ID number (*see section §6).*

4.8.1.2 Selectivity

Similarly, most innovative fishing gears were considered to result in an incremental or transformative improvement in selectivity and were considered to have a high level of technological readiness (Figure 6). Five gears were considered to result in a disruptive improvement in selectivity and were considered to have a high level of technological readiness. Ten gears were considered to result in a negative improvement in selectivity and require further development or discarding, despite their medium to high level of technological readiness (*except Factsheet=21*).

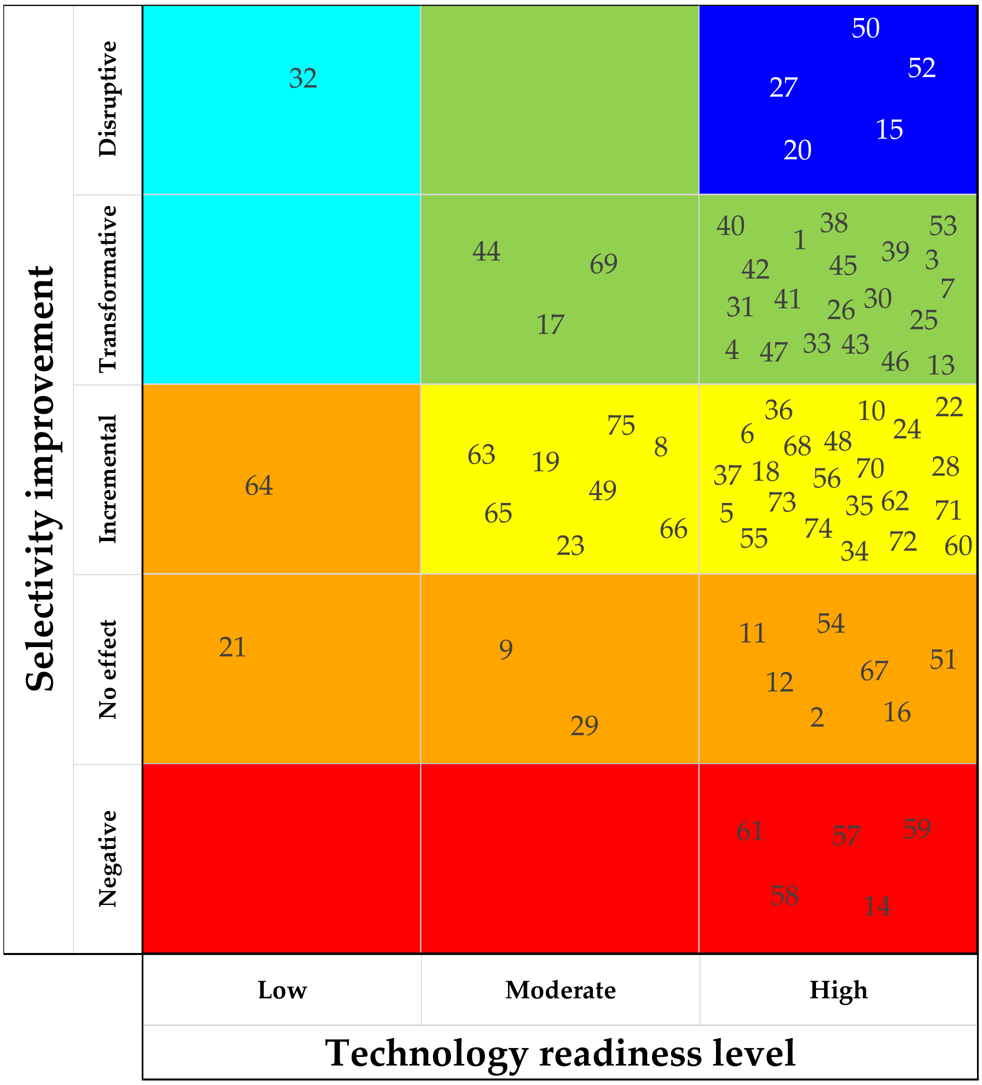


Figure 6. Innovation matrix highlighting the relationship between improvement in selectivity and technological readiness level for each innovative fishing gear. Each number represents a Factsheet ID number (*see section §6).*

4.8.1.3 Impact on marine ecosystems

All but four innovative gears were considered to result in an incremental or transformative reduction of the impact on the marine ecosystem, i.e. they reduced the deleterious impacts of fishing on the ecosystem compared to the baseline gear, and they were considered to have mostly a high level of technological readiness (Figure 7). The four outstanding innovative gears were considered to result in a disruptive impact on the marine ecosystem, i.e. they substantially reduced the deleterious impacts of fishing on the ecosystem compared to the baseline gear. Except **Factsheet 32**, they were considered to have a medium-high technological readiness. Notably, there were no gears considered to result in a negative relative impact on the ecosystem.

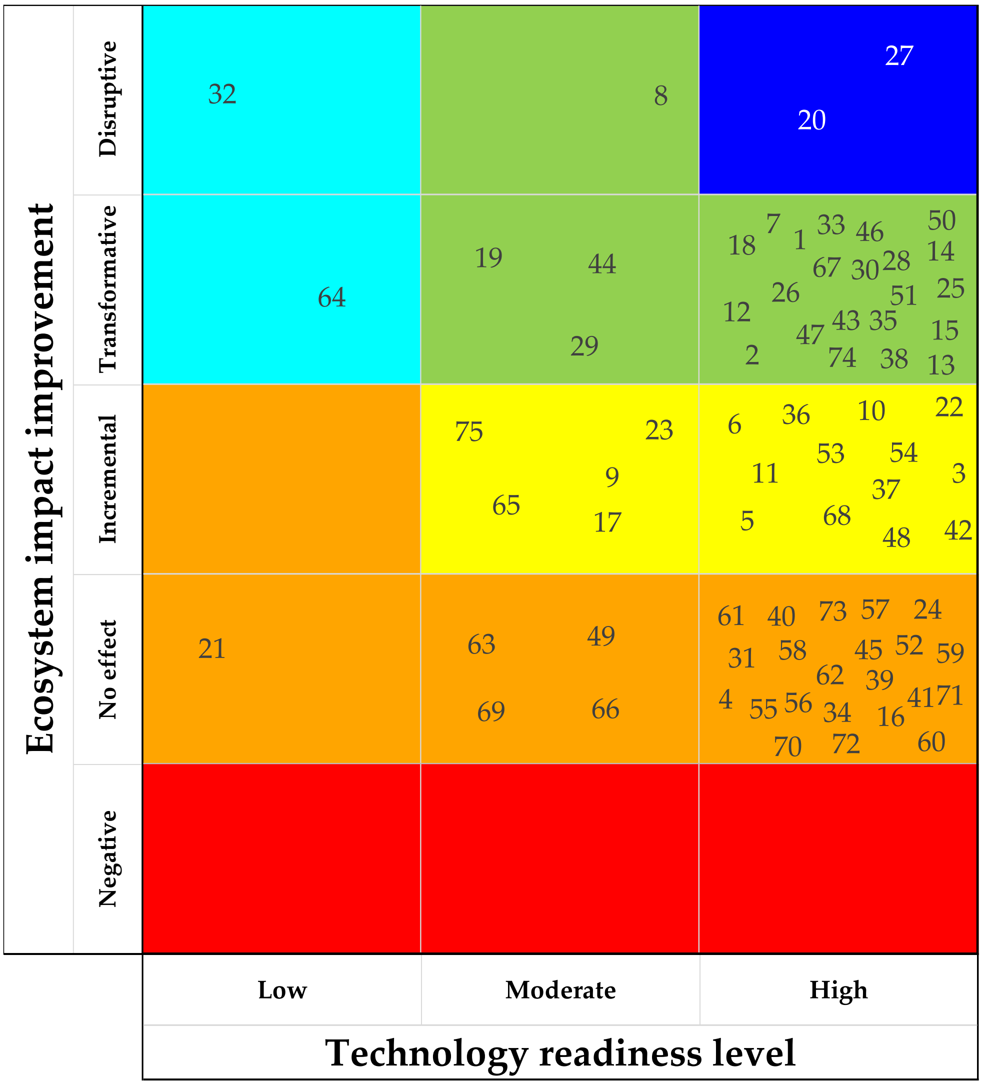


Figure 7. Innovation matrix highlighting the relationship between improvement in marine ecosystem impact and technological readiness level for each innovative fishing gear. Each numbers represents a Factsheet ID number (*see section §6).*

4.8.1.4 Capital cost/Return on Investment (ROI)

The capital cost of 36 (48% of the total number of gears) innovative fishing gears were deemed to be low (Figure 8). Nineteen (53%) of those 36 gears were considered to provide minor (less than 5%) return on investment, i.e. minor profit after accounting for costs, seven (19%) to provide substantial (5–10%) and two (6%) to provide significant (more than 10%) return on investment, and six (17%) to provide negative return on investment. Overall, more than 77% of low-cost innovative gears were considered to provide a positive return on investment, and thus could be considered as reasonable replacement of the currently used gears.

The capital cost of 22 (29% of the total number of gears) innovative fishing gears were deemed to be moderate. Eight (36%) of these gears were deemed to provide minor return on investment, 12 (54%) were deemed to provide substantial or significant return on investment, and 1 (5%) was deemed to provide negative return on investment. In contrast, of the 17 (23% of the total number of gears) innovative fishing gears where the capital cost was deemed to be high, 4 (24%) of these gears were deemed to provide minor return on investment, 12 (71%) were deemed to provide substantial or significant return on investment, and 1 (6%) was deemed to provide negative return on investment. Overall, information provided in the factsheets implies that a significant return on investment is more likely to be expected when the capital costs of an innovative gear are high, and a minor return on investment when the capital costs are low.

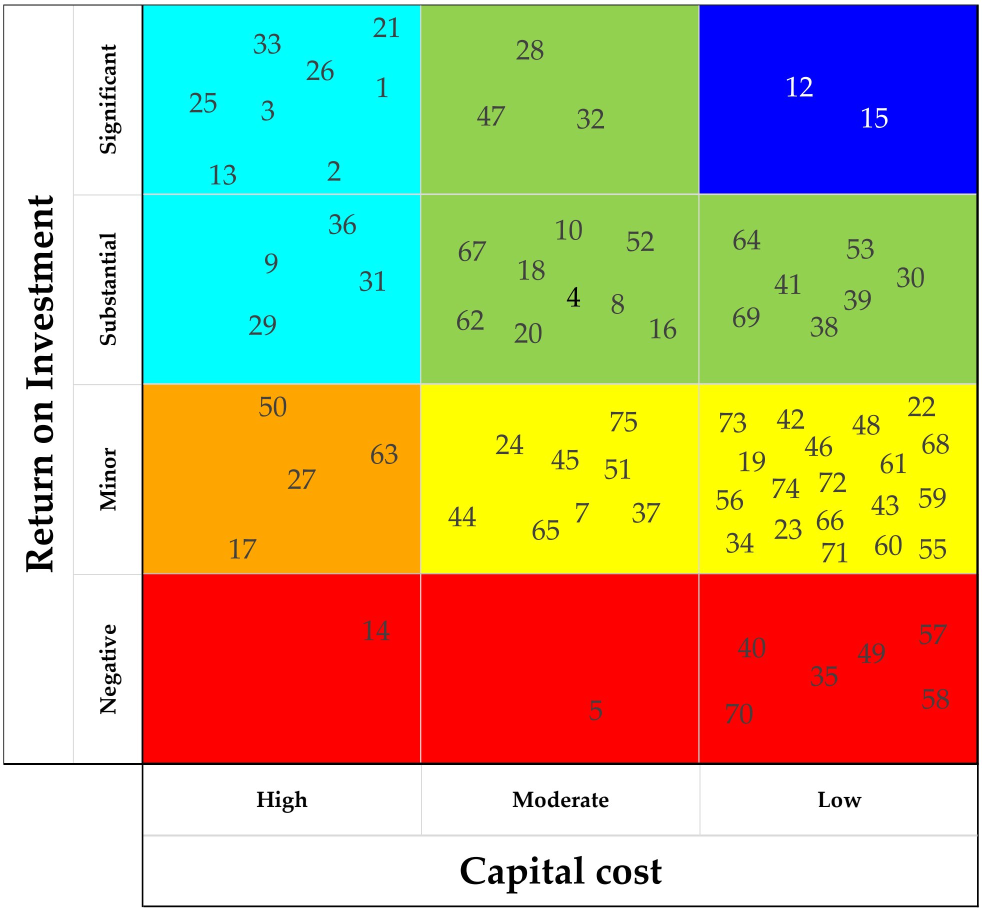


Figure 8. Cost matrix highlighting the relationship between capital cost and return on investment associated for each innovative fishing gears. Numbers correspond to the Factsheet IDs reported in the Catalogue of Innovative gears (*section §6*).

4.8.2 Operational and other considerations

Most factsheet responses (53%) indicated that deployment and retrieval of the innovative gear was not expected to be any different from the baseline gear, while 28% of innovative gears were considered to make deployment and retrieval of the gear more difficult (Table 6). Less than 10% of innovative gears were thought to be easier to deploy and retrieve. Most innovative gears were more likely to be more difficult for fishers to maintain and repair compared to the baseline gear while one-third were thought to make no difference and 12% were thought to be easier to maintain and repair. Almost three-quarters (72%) of innovative gears were thought to have similar impact on fisher health and safety as the baseline gears and only 1% were thought to present a higher risk to health and safety. It was thought the broader economic, operational, and environmental benefits of almost 40% of the innovative gears was higher than the financial costs associated with using the innovative gear, while the impact of half of the innovative gears was unclear. for 10% of the innovative gears, the financial costs associated their use was considered disproportionately higher than the potential economical, operational, environmental benefits. Reference to the innovative gear reducing fuel consumption and or greenhouse gas (GHG) emissions was apparent in 19 (25%) factsheets, i.e. **Factsheet 2, Factsheet 4, Factsheet 9, Factsheet 15, Factsheet 26-Factsheet 29, Factsheet 31, Factsheet 32, Factsheet 35, Factsheet 38, Factsheet 45, Factsheet 48, Factsheet 66, Factsheet 68,** and **Factsheet 75.**

Table 6. Summary of responses from the factsheets (*n = number of responses*).

Factor	Response		Factsheet ID
	n	%	
Deploy and retrieve			
Yes, easier	6	8.0	2, 4, 10, 17, 26, 33
No, more difficult	21	28.0	1, 7, 13, 16, 22, 24, 29, 31, 35, 36, 47, 50, 51, 54, 59, 60–63, 65, 72
Unsure	5	6.7	3, 11, 21, 52, 75l
Maybe	3	4.0	9, 33, 49
No difference	40	53.3	5, 6, 8, 12, 14, 15, 17–19, 23, 25, 27, 28, 30, 34, 37–46, 48, 53, 55–58, 64, 66–71, 73, 74
Maintain and repair			
Yes, easier	9	12.0	10, 17, 33, 38, 55, 56, 59, 60, 61
No, more difficult	33	44.0	1–4, 6, 7, 9, 13, 16, 24–29, 31, 32, 35, 36, 42, 47, 50, 51, 53, 54, 62–68, 72
Unsure	5	6.7	11, 14, 21, 52, 75,
Maybe	3	4.0	15, 20, 44
No difference	25	33.3	5, 8, 12, 18, 19, 22, 23, 30, 34, 37, 39–41, 43, 45, 46, 48, 49, 57, 58, 69–71, 73, 74
Health and Safety			
Yes, lower	6	8.0	2, 12, 20, 24, 38, 44
No, higher	1	1.3	69

Factor	Response		Factsheet ID
	n	%	
Unsure	12	16.0	4, 11, 13, 26, 27, 35, 48, 50, 52, 63
Maybe	2	2.7	10, 31
No difference	54	72.0	1, 3, 5–9, 14–19, 21, 22, 23. 25, 28–30, 32–34, 36, 37, 39, 40–3, 45–47, 49, 51, 53–62, 64–75
Costs higher			
Yes, higher	8	10.7	14, 25, 26, 35, 37, 40, 57, 65,
No, lower	29	38.7	10, 12, 15, 18–20, 29, 30, 32, 33, 36, 38, 39, 41, 43, 44–46, 49, 53, 58–62, 64, 67–69
Unsure	35	46.7	1–9, 11, 13, 16, 21–24, 27, 31, 34, 42, 48–52, 54–56, 63, 70–75
Maybe	3	4.0	17, 29, 66

4.9 Case studies on technological innovation uptake

There are four intrinsic motivations for a fisher to change practices and apply new technologies: (i) to increase revenue by catching more, (ii) to increase revenue by raising the value of the catch, (iii) to reduce the costs of fishing, and (iv) to enhance comfort and safety onboard (Eigaard *et al.*, 2014). Most fishers also have the interest in reducing un-intended side effects of fishing on the marine environment in terms of improved sustainability of fishing, given their livelihood relies upon a healthy environment. However, despite these motivations, many fishers remain unwilling or unable to change (Eayrs and Pol, 2019). While fishers may cognitively be aware that change is necessary and important, affectively (emotionally) they may think otherwise and be unprepared to change (Steins *et al.*, 2022; Jenkins *et al.*, 2023; Pol and Maravelias, 2023). Affective readiness is considered possibly more important that cognitive readiness (Lawton *et al.*, 2009) and yet has seldom been studied, although (Eayrs, 2023) retrospectively considered both the affective and cognitive readiness of fishers to change in an Australian prawn trawl fishery.

Fishers' behaviour towards gear innovation and uptake is driven by a complex interplay of Political, Economic, Social, Environmental and Legal (PESTEL) factors (see *section §2.3*). From the factsheets in this report, there is some evidence that technological innovations that reduce environmental impact but also reduce the cost of fishing (fuel savings) or improve the catch efficiency may be more readily adopted by fishers. For example, the use of innovative echosounders (**Factsheet 3**, **Factsheet 25**) to map the distribution of fishery resource allows fishers to reduce the time spend searching for fish and may reduce their seabed and carbon footprint. For these cases, the improved profitability may be a strong incentive for the uptake of the new technology, as shown for instance by the uptake of the experimental pulse trawl in the sole fishery in the North Sea (Haasnoot *et al.*, 2016). In this instance the uptake of an experimental gear by the majority of the Dutch-beam trawl fleet was linked to reduced impact on the seabed, since dragging heavy gear on the seabed can increase drag and associated fuel consumption (Rijnsdorp *et al.*, 2020a; Delaney *et al.*, 2023). The giant scallop *Hydrodredge* (**Factsheet 35**) or Sea stars *HydroTrawl* (**Factsheet 30**) may be other examples where improved profitability provides incentive to adopt the new gear.

Shifting from traditional to new innovative otterboards could realize reduced environmental impact and positive economic benefits (**Factsheet 29**, **Factsheet 51**). The implementation of novel otterboards has been found to increase the energy efficiency of vessels through the reduction of fishing gear drag and consequently of fuel consumption (Sala *et al.*, 2008a; Sala *et al.*, 2022), which is a major operating cost for fishers. The adoption of such otterboards may also improve the resilience of fishers to increased costs (including fuel) and reduced landing prices or catch volume. Despite their traditional culture, semi-pelagic otterboards have successfully been introduced in Italian fisheries, with a firm interest from the fishers. Similarly, Jumper otterboards (discussed in the WKING report) showed a limited contact with the seabed and a reduction in sediment resuspension (10 times lower) compared to traditional boards (ICES, 2020c).

Within the limited time available for compiling this report, it was not possible to perform a comprehensive analysis of PESTEL factors for individual case studies and how they are interconnected nor for cross-comparison (see *section §3.5.1*). The aforementioned examples are hence initial illustrations of how factors in the PESTEL domain are interlinked. The use of the PESTEL framework demonstrates that there can be many, and multiple, factors that influence the uptake of an innovative gear. The factsheets presented in this report now capture some information to demonstrate which categories of factors may be influencing gear uptake (*section §3.5.1*). The workshop also presented the opportunity for several experts, with first-hand experience of developing and testing gears and who have close working relationships with industry, to provide more detailed insight into the factors at play in gear uptake for specific case studies. The six case studies presented below (see *sections §4.9.1-4.9.6*) provide details of what has (or may) encourage on prevent the uptake of specific gear innovations, which include gears highlighted in gear factsheets produced by WKING and WKING2, in addition to other appropriate examples.

We include these case studies to demonstrate what type of information a more comprehensive application of PESTEL would result in. In doing so, we can show that different PESTEL factors interact and can either positively or negatively influence each other and hence up-take. The information from the case studies highlights that gear innovation and uptake is a complex social process. To fully understand motivations of fishers to take up new gears (or not), in-depth information is needed. This information one can only get from dedicated case study research.

4.9.1 Limiting the use of multi trawls in Scottish Nephrops fisheries

Multi-trawl gears, including quad-rigs as described in **Factsheet 36**, are adopted in a number of fisheries. In the case of the Scottish North Sea *Nephrops* fishery, however legislation is in place to prevent the use of multi trawls with greater than two nets. This legislation, that prevented the use of multiple gears, clearly indicated that there was a legal barrier that prevents relevant innovative gears. Many more factors were at play, however, during the process of introducing this legislation.

During 2002 Marine Scotland (MS) policy division were approach by Scottish Nephrops fishers about the increasing use of multi (>2 trawls) Nephrops trawls in Scottish North Sea Nephrops areas. A number of industry meetings were held around NE Scotland involving MS policy/science with agreement from Scottish industry to bring in legislation preventing the use of >2 trawls.

A number of concerns were raised in allowing expansion of multi trawl within the Scottish NS Nephrops areas.

Political/Legal factors

- Legislation needed to apply to all vessels targeting Scottish NS areas therefore, creating a level playing field (**need for level playing field**).

Economic factors

- A continued expansion of multi trawl would lead to market collapse (**profitability**).

- The significant increase in vessel rigging costs would become unsustainable and lead to a loss of earnings (**profitability, investment costs**).

Social factors

- Scottish Nephrops vessel would become unviable and lead to bankruptcy and job losses in remote Scottish coastal communities.

Technological factors

- The swept-area by >2 trawls would significantly increase fishing effort.

Environmental factors

- Increased effort would lead to the eventual collapse of NS Nephrops stocks.

The legislation came into force early 2003 but at this time and under EU regulations it only applied to Scottish vessels. Further negotiations to apply the legislation to all vessels targeting Scottish NS Nephrops fisheries continued during 2003 but became protracted and ultimately failed. The main reason was an increase in non-Scottish registered vessels (mostly Danish) adopting multi trawl and the Commission view was a unanimous agreement to legislation would not be obtained. The Scottish legislation continued to be applied only to Scottish vessels until 1 February 2020.

4.9.2 Dual codend in Irish Nephrops fisheries

The dual codend (**Factsheet 47**) was proposed as a method in the Irish Nephrops fishery to reduce unwanted fish catches while maintaining Nephrops (Cosgrove *et al.*, 2016). The dual codend is a modified section with two codends and an inclined panel to separate prawns from fish. Further technical details on the dual codend can be found at https://bim.ie/wp-content/uploads/2021/02/5987-BIM-Stella-Nova-Trial-Brochure.pdf.

There are a number of factors at play that have limited the uptake of this gear.

Economic factors

- The dual codend is a complete redesign of the posterior section of the trawl. Typically, a trawl tapers to about 9.6 m circumference (120 meshes at 80 mm) the dual codend starts at 28.8 m (360 meshes at 80 mm) in circumference meaning large sections of existing trawl need to be cut out. The Dual codend is likely to be 4–5 times more expensive than a standard single codend. Most vessels operate a minimum of two nets for Nephrops (**profitability, investment costs**).
- Substantial reduction in catch sorting times (most prawns and fish already sorted in the trawl)
- Substantial improvement in quality of fish and Nephrops landings (prawns are not damaging fish and vice versa)
- Major potential to increase catch value for vessels targeting Nephrops and fish species (better quality prawns and fish)

Social factors

- Most fishers hone the operation of their fishing gear over many years and are often reluctant to change because it might mean that their catches are reduced while they perfect the use of the new gear. Using the dual codend would mean (for most fishers) swapping from 4 nets to 2 with a different bridle configuration and are likely to worry that the gear is not performing as well as a quad rigged vessel (**behaviour towards change)**.

- One fisher commented that one of his (main) reasons for not purchasing a newer vessel was the time it would take him to get his existing gear working on the new vessel (**impacts on profitability**).
- Another skipper commented on how he moved his gear from one vessel to another and has been months getting it to work well, although the new vessel has a similar configuration to the other one (**impacts on profitability**).
- The dual codend has (likely—untested) a greater drag (**fuel costs**)

Technological factors

- The dual codend is heavier than a standard codend and more care is needed when deploying and retrieving, but there is minimal difference in the methods needed (**health and safety**).
- To fully benefit from the dual codend fishers would need to separate their fish hopper, to have a section for fish and Nephrops (**investment costs**).
- Repairs are likely to be a little more difficult.

Environmental factors

- The upper codends mesh size is greater than the lower codend which allows unwanted catches to escape.
- Some fishers have suggested using very large upper mesh so that they only retain large individuals (e.g. monkfish)
- Technically if a fisher swaps from quad to a single or twin rig with a dual codend they are reducing the footprint of their gear and are reducing the seabed impact.

Legal factors

- The gear is legal in Ireland but only on single- or twin-rig vessels. The S.I.No. 518 of 2015 Sea-Fisheries (Multi-rigged fishing gear) Regulations states Irish vessels cannot simultaneously tow fishing gear where the number of nets is greater than 4 or the total number of codends utilized is greater than 4. Most Irish Nephrops vessels two four nets in a quad rig configuration so if they adopted dual codends on a quad rig they would be operating with eight codends, which would be illegal. Thus, for the majority of the fishery this adaptation would currently be illegal unless they changed their gear to twin or single rigs.

4.9.3 Modified rigging in Nephrops fisheries

A modified rigging, as described in **Factsheet 41**, was developed to reduce catches of small whiting, haddock, and large individuals of other species while maintaining Nephrops catches. The modified rig comprised a modified half quad-rig sweep configuration where two middle sweeps were joined fore and aft by two 3.6 m lengths of combination rope. The key results are increase in Nephrops catches with a reduction in skate and ray catches. There was no reduction in small whiting or haddock catches. Further technical details can be found at https://bim.ie/wp-content/uploads/2022/12/BIM-Testing-of-modified-rigging-nephrops-fishery.pdf.

There are several factors at play that may influence the uptake of this gear:

Economic factors

- The modified rigging is likely to cost less than €100 per two nets. Most vessels operate a minimum of two nets for Nephrops. The low costs of this modification means that many fishers will likely not bother with looking for grants, subsidies, etc (**low investment cost)**.
- There is likely to be a reduction in large individuals as they escape between the trawls, which will impact on income. However, fish caught in Nephrops trawls often command

a lower price (than from fish trawls) because of their lower quality (**change in catch composition**).

Social factors

- Most fishers hone the operation of their fishing gear over many years and are often reluctant to change because it might mean that their catches are reduced while they perfect the use of the new gear. Using the modified rigging would mean adding a gap between the nets, which is an escape route that could reduce catches and creates doubt (**behaviour towards change).**
- One fisher commented that one of his (main) reasons for not purchasing a newer vessel was the time it would take him to get his existing gear working on the new vessel (**impacts on profitability**).
- When we trialled this gear, the skipper commented on how it improved his catches and continued using it after the trial. However, the skipper soon began to doubt the gear and not being able to compare it directly to their normal configuration it was changed back to the standard configuration (**behaviour towards change**).

Technological factors

- The modified rigging is very similar to a standard rig, but some additional care is needed when deploying and retrieving to avoid tangles, but there is minimal difference in the methods needed.
- Having hooks on either end of the 3.6 m rope means that it can be removed (or added) easily.
- The modified rigging can work on any pair of trawls with minimal modification to the existing configuration.

Environmental factors

- There is a significant reduction in catches for some species (usually those that seek escape or have the swimming ability to escape—larger individuals) Some of the large fish escaping are likely to be unwanted (and vulnerable) species (e.g. skates and ray) (**change in catch composition)**
- Some fishers have suggested that the modified rigging gives the individual trawls greater autonomy to operate (e.g. less influenced by its adjacent trawl)
- There is no difference in seabed impact between the modified rigging and a standard configuration.

Legal factors

- There is no legal obstacle to this gear.

4.9.4 Raised fishing line trawl

The raised fishing line trawl (**Factsheet 46**) was initially developed as a method to reduce unwanted (low quota) species (e.g. cod, plaice) in fish trawls (McHugh *et al.*, 2017). Raising the fishing line involved lengthening the droppers (toggles) between the fishing line and groundgear on one net to 1.00 m. The key results of this gear are a reduction in cod, flatfish, and skates and ray catches. Further technical details can be found at https://bim.ie/wp-content/uploads/2021/01/6495-BIM-Raised-Fishing-Line-report.pdf.

There are several factors at play that may influence the uptake of this gear.

Political factors

- Some fishers have criticized the gear because while it works to reduce unwanted individuals it does not support other agendas. For examples it isn't effective in reducing fuel usage because there is potential for significant amounts of quota to be left available after fishing with this gear and extra trips using other gears may be required to catch other species. This is exacerbated by Ireland's monthly rationed quota system that does not allow trades or transfers of quota and any quota left over at the end of a month is returned to the overall quota 'pot' (**quota availability**).
- This gear is classified as a conservation measure for cod and its use means vessels can fish in otherwise restricted areas, however, many fishers do not understand that without this gear many areas would be closed to fishing **(access, communication).**

Economic factors

- The raised fishing line is a cheap modification likely to be less than €500 per trawl. Irish vessels operate a maximum of two nets for fish (**investment**).
- This gear is unlikely to reduce the gear's drag (**fuel costs**).
- The raised fishing line will change the catch composition (most benthic orientated species will not be caught). This reduction will have an impact on the overall profitability and the maximization of allocated quota under the Irish rationed quota system (**change in catches**).

Social factors

- The raised fishing line is a minor adjustment to the fishing gear and while it allows them to fish in areas with low cod and plaice quotas it does mean that they might also miss out on other species (e.g. monkfish). Missing out on other species means that they will not maximize their monthly quota allocation if using the raised fishing line (**quota availability**).
- One fisher commented that the raised fishing line was similar (but with a greater gap between the fishing line and groundgear) to a gear they used to reduce debris in their trawl when fishing on certain grounds (**fisher involvement**).

Technological factors

- Some additional care is needed when deploying and retrieving the raised fishing line to avoid tangles of the extended droppers, but there is minimal difference in the methods needed.
- Repairs are not likely to be any different from normal gear.

Environmental factors

- There is no increase in drag.
- There is a significant reduction in catches for some species (usually those close to the seabed)
- There is no difference in seabed impact between a raised fishing line trawl and a standard trawl.

Legal factors

- There is no legal obstacle to this gear, the gear is legal in Ireland.

4.9.5 Pulse trawl for flatfish

In pulse fishing for flatfish the tickler chains of the conventional beam trawls are replaced by electrical currents to startle the fish (**Factsheet 26, Factsheet 28**). The pulse trawl reduces, compared to a conventional beam trawl, benthic impact by 62% and results in at least 37%% less

CO2-emissions. The gear improves the selectivity of the sole fishery, reduces unwanted bycatch of most undersized fish species and benthic invertebrates. There is no additional direct mortality of marine organisms caused by the gear, except for cod where spinal injuries can occur. At population level, these injuries do not have an effect on the reproductive capacity. Besides, catch numbers of cod in pulse trawls are lower (ICES, 2020b; Rijnsdorp *et al.*, 2020a). The development of the gear was initially led by science and a manufacturer, but its initial commercial application was done by one fishing vessel that received compensation for catch loss, followed by a group of five fishers (investment grant only) who together accelerated the technological readiness level. As the use of electricity in marine fisheries was prohibited, the EC gave all North Sea Member States a derogation to use the pulse trawl on maximum 5% of their fleet. The 5 Dutch vessels involved in the trials demonstrated profitability under lower catches due to reduced fuel use. This triggered interest of other vessels in the fleet, which was suffering from heavy economic losses due to rising fuel prices. This resulted in successful requests of the Dutch government to the EC to expand the derogation to 42 vessels in 2010, followed by another 42 in 2014. While research showed positive economic, environmental, and economic performance, growing resistance against the pulse gear was taking place in the European arena. Following a successful campaign by a French NGO (Non-governmental organization) joined by small-scale fishers, the European Parliament voted to ban pulse fishing in 2019. All pulse fishing gears had to be phased out, resulting a situation where a proven (but under derogation) innovative gear that was embraced by the fleet ended in zero uptake.

The factors that play a role in the uptake of this proven (yet legally experimental) gear and subsequent demise have been studied (Haasnoot *et al.*, 2016; Kraan and Verweij, 2020; Steins *et al.*, 2022; Delaney *et al.*, 2023).

Political factors

- The EU banned the use of electricity in marine fisheries in 1988, which paused initial developments of gear using electric currents by gear technologists that had taken place since the 1950s. Interest was renewed in 1990 with an EU funded project.
- In 2006, a financial and image crisis led to a roadmap for sustainable flatfish fisheries agreed upon by government, industry, and NGOs. This included establishing innovation framework with a bottom–up approach to innovation and funding and including the further development of the pulse gear as a promising alternative to conventional beam trawling following experiments that had started in 1999. Five vessels received a grant for the investment cost of the pulse trawl with the objective of making the gear fully operational in a commercial setting.
- Concerns were raised about potential broader ecosystem impacts and after precautionary advice by ICES and STECF, the EC gave each North Sea member state a derogation to use the pulse trawl on maximum 5% of their fleets.
- With a fishing fleet in a financial crisis, the increased profitability of the five vessels using pulse and subsequent pleas from the industry, led the Dutch government to successfully convince the EC to expand the derogation to 42 vessels in 2010, followed by another 42 in 2014 as part of the provisions under the new Landing Obligation. The latter (phased implementation) was supposed to incentivise fishers to transition towards more selective gear avoiding discards that should be counted against quota (**profitability**).
- In 2019 the European Parliament voted for a ban on pulse fishing following successful lobby by a French NGO joined by small-scale fishers (**legitimacy**); their campaign questioned the credibility of the scientific research about the ecological impacts of the pulse gear. The ICES advice that was planned for 2020 upon completion of the comprehensive impact analysis was not awaited in the subsequent decision-making in the trialogue between Commission, Council and Parliament. The ban was implemented despite the

expenditure of many million Euros of public and private funds invested in research that showed positive outcomes.
- An appeal by the Dutch government to the European Court of Justice was not upheld.

Economic factors

- In 2004, a commercial vessel was commissioned to continue developing the gear to make it operational for the fishing practice. Catchability of the target species Dover sole and plaice was initially lower, but this was compensated for by a significant reduction in fuel use (**profitability**). Also, under NGO pressure Dutch retailers had banned flatfish caught with beam trawls as this was not considered sustainable and had pledged to "MSC certified only" (**market access**).
- As part of the innovation framework agreed by all stakeholders (**political**), investment grants were made available for five pulse vessels.
- The 5 Dutch vessels involved in the trials demonstrated profitability under lower catches due to reduced fuel use. This triggered interest of other vessels in the fleet, which was suffering from economic losses (**profitability**). The fishing industry successfully lobbied the government to expand the number of licences under derogation (**political**).
- Initial investment costs are high but are set off by increased profitability due to lower fuel consumption (lower towing speed, less drag, less penetration).
- Increased quality and consequently market value of landed sole.
- As selectivity of Dover sole increased, some fishers were experiencing quota shortages. Quota leasing is allowed, and high demand resulted in high lease prices for quota. On the one hand, this affected profitability of small(er)-scale fishers who often rely on leased quota. On the other hand, it incentive fishers to participate in scientific research projects into survivability and fully-document fisheries, as they were granted so-called scientific quota.
- Following the pulse fishing ban, pulse fishers had to revert to beam trawling and profitability dropped.

Social factors

- As part of the innovation framework accompanying the Dutch roadmap to sustainable fisheries (**political**), 5 vessels started further trials to resolve outstanding operational issues with the gears. The skippers were from different ports and exchanged experiences to accelerate gear development.
- By 2014, following second expansion of licences (**political**), growing resistance against the pulse gear was taking place in the European arena (**legitimacy**). There was dislike of the way the Netherlands had arranged more licences and concerns about the socio-economic and ecological impacts of pulse trawling (**social license to operate**). The Dutch government set up an international stakeholder engagement process (**political**) but it turned out to be difficult to change opinions.
- The late start of the comprehensive ecological impact study that was agreed as part of the license expansions (political), further contributed to resistance to the pulse trawl. International stakeholders were consulted about the contents and approach for the comprehensive ecological impact study (**salience, legitimacy**), and an international peer-review committee was set up (**credibility**).
- Shifts in effort and more intensive trawling of new accessible grounds together with the possibility of catching more sole in these areas further accelerated the disagreement and competition between colleagues (**economic**).
- Ther was an unequal international level playing field as the Dutch-registered fleet had access to additional licenses beyond the 5% threshold, while other fleets did not have immediate access or could only equip 5% of their fleet with pulse trawls (**political**).

- The ban of pulse fishing resulted in demotivation among fishers towards innovation (**uncertainty about political process, technological development).**

Technological factors

- Initially gear development into the commercial phase took place one vessel. Gear development was accelerated by five fishers working jointly on improving technological readiness supported by scientists and manufacturers (**outreach, communication**).
- The gear is more vulnerable to damage compared to the conventional beam trawls and more costly to maintain but this is set off by reduced fuel costs (**profitability**).
- There are no additional health and safety issues.
- Lighter gears means that pulse fishers can access areas with "softer grounds". This results in competition with fishers who traditionally fished in these areas (**area access, profitability, resistance**).

Environmental factors

- Research into effects of pulse trawling had always been a part of the gear's development, but a comprehensive research project into wider ecological and environmental impacts, which was part of the agreement with the EC about the license expansions in 2010 and 2014, did not start until 2016. By this time, growing resistance against the pulse gear was taking place in the European arena (**political, social**).
- Compared to a conventional beam trawl, benthic impact is reduced by 62% and CO2-emissions by at least 37%%. Selectivity of the sole fishery is reduced unwanted bycatch of most undersized fish species and benthic invertebrates. There is no additional direct mortality of marine organisms, except for cod where spinal injuries can occur. At population level, these spinal injuries do not have an effect on the reproductive capacity.
- Survivability of undersized sole and plaice is higher compared to conventional beam trawling.

Legal factors

- Use of electrical fishing in marine fisheries or pulse fishing is banned under EU regulations.

4.9.6 SepNep

The *SepNep* was developed to reduce unwanted bycatch of juvenile flatfish in the North Sea *Nephrops* (*Nephrops norvegicus*) fishery. This innovation was analysed and presented in the previous WKING report (ICES, 2020c). The gear separates catch of Nephrops from fishes into different code-ends using a sorting grid. Its development was industry-led: a fisher came up with the idea, did some initial trials on his vessel and then entered into a collaboration with Dutch and German gear technologists for elaborate testing and improving the gear on a research vessel, after which it was further improved to operational status on his fishing vessel. The SepNep leads to significant reduction of unwanted bycatch of plaice (*Pleuronectus platessa*; 65%), dab (*Limanda limanda*; 79%) and undersized Nephrops (53–56%) with marginal loss of commercial catch (Molenaar *et al.*, 2016). Although the *SepNep*'s benefits are recognized by fishers, there is no sign of its voluntary uptake; even the fisher who developed it is no longer using it.

The factors that play a role in lack of uptake of this proven gear have been studied (Steins *et al.*, 2022).

Political factors

- The Netherlands have adopted a bottom–up, industry-led approach to gear innovation. The innovation process was facilitated by fisheries managers who made funding available for Dutch scientists to facilitate gear development and impact research and German scientists who offered free use their research vessel for the trials (**innovation framework**). This innovation approach did however not include testing of *SepNep* on other vessels and sharing experiences, as was done in case of the pulse fishery (see *Case study section §4.9.5*).

- The son of the fisher who developed the *SepNep* used it a few weeks, but decided to revert to his old nets as he did not get a better market price for his sustainability improvements while he still had some catch loss of valuable Dover sole, which in prices when fuel prices go up is not desirable (economic). As no-one else was using *SepNep* why would he "suffer losses for doing the good thing?" (**level playing field**).
- Dutch Nephrops fishers who use the *SepNep* get an exemption for plaice under the EU landing obligation (**incentive**). Dutch fishers do not support the landing obligation (**legitimacy**): (a) they experience healthy target stocks in a system of discarding; (b) they feel that landing all undersized fish results in increased fish mortality and loss of nutrients to the ecosystem, affecting stocks while resulting in increasing operational costs (Kraan and Verweij, 2020). As the landing obligation throughout Europe is difficult to enforce, the exemption for plaice when using *SepNep* does not function as a reward (**stick and carrot).** Fishers who do not use the *SepNep* (exemption) and who do not fully with landing undersized plaice catch, are not blamed or judged by their colleagues (**social norms**).

Economic factors

- There is no higher market price or improved market access for Nephrops caught with the *SepNep*.
- Initial investment costs are low, although adapting the gear to specific vessel conditions and optimize performance will result in initial revenue loss (and hence wages of the crew).
- There is no funding in support of investments and transitioning to using the *SepNep* available.
- As catchability of Dover sole, a valuable bycatch, is lower fishers using the *SepNep* may not be able to fully use their quota share. Quota leasing is allowed and hence this in theory could compensate partly for underuse. Currently, however, the quota lease market for sole has collapsed due to a combination of factors.

Social factors

- The SepNep was developed by a respected Nephrops fisher facilitated by scientists. Outreach was done in the Dutch Fishing News, fisheries associations' newsletters, and presentations at meetings of the producers' organizations with Nephrops fishers among their members (**outreach)**. Direct peer-to-peer information exchange was limited and there was no wider group of fishers who were involved in the development of the gear. This would, according to a recent focus group meeting with 10 Nephrops fishers from different ports, have contributed to more speedy and targeted development for different vessel-builds and fishing areas (**innovation framework**), as well as have contributed to intrinsic motivations and ambassadorship (**peer norms, outreach**).
- Sorting and grading catch takes less time due to reduced levels of unwanted catch, and this positively impacts crew's time for resting.
- There is a strong belief in level playing field, i.e. "*why should I do this and not be rewarded, if other's don't*". This influences voluntary up-take.
- Lack of support for the landing obligation combined with poor enforcement facilitates risk-taking behaviour. Fishers who do not use the *SepNep* (exemption) and who do not

fully with landing undersized plaice catch, are not blamed, or judged by their colleagues (**social norms**).

Technological factors

- Different vessel builds may require adaptations to allow use of the *SepNep*. The net configuration itself, however, should not be an issue.
- Repairs are not likely to be any different from normal gear.
- There are no additional health and safety issues. Sorting the catch (less unwanted catch) goes much faster, meaning that crew gets more time to rest.

Environmental factors

- There is a significant reduction in unwanted bycatches of undersized plaice (65%), dab (79%) and Nephrops (53%).

Legal factors

- There is no legal obstacle to using this gear.

4.9.7 What can we learn from these case studies and other examples?

It was commented on in discussions during WKING2, that a comprehensive toolbox already exists for the fishing industry to draw from to alter and upgrade fishing gears, yet a relatively small number of gear types and innovations are in regular use. In a number of the case studies detailed above it was noted that fishers were reluctant to change the gear they use as they have spent a long time tweaking it, so it works well for them, on their vessels, in the areas they fish and to obtain the catches to meet quota available to them. For many there seems little incentive to disrupt their regular fishing operations to try something new, even if there is potential for reduced workload and increased economic returns, with even less incentive being provided by the potential wider ecosystem benefits of adopting more innovative gears.

Regulation has been shown to drive uptake of new gears. Investment in new fishing gears and selective devices in the *Nephrops* trawl fishery of the Bay of Biscay, for example, has been mainly the result of regulation drivers such as fishing permits allocated only to vessels with selective devices. In Sweden, grid trawls and creels have increased due to regulatory drivers such as days-at-sea exemptions, closed areas, beneficial quota allocations (Hornborg *et al.*, 2016). Conversely, there have been cases where regulation has prevented the uptake of new gears. This is the case in the Scottish *Nephrops* fishery, as detailed in *section §4.9.1*, where limits were placed on the use of multi trawls. The uptake of dual codends in the Irish Nephrops fishery is also unlikely as no more than four codends are permitted in the fishery, but most vessels already adopt quad rigs (Case study *section §4.9.1 and 4.9.2*).

Economic factors, such as the profitability of a fishery, are obviously very important in influencing the uptake of new gears. In the cases where reduced seabed impact, for example, coincides with a reduced profitability, there will be no incentive to implement a technological innovation. Here, external incentives are required either by technical management measures (spatial management and gear restrictions) or by market driven incentives such as eco-labelling (Thrane *et al.*, 2009; Hornborg *et al.*, 2016) or subsidy. It is advisable to proceed through incentives that capture fishers' engagement (such as getting better market access through eco-labelling) rather than top–down regulations, which may lead to compliance issues if fishers do not support. For instance, meeting the sustainable fisheries certification criteria set by the Marine Stewardship Council (MSC) may stimulate fishers to adopt more environmentally innovative techniques, as it occurred for the Scotland's Loch Torridon *Nephrops* creel fishery (Petetta *et al.*, 2021). Also, in the case study of the *SepNep* (*section §4.9.6*), fishers agreed that getting a market reward for Nephrops caught with the *SepNep* would incentive them to use this more selective gear voluntarily even their colleagues would not use it.

There are numerous other conditions that may affect the adoption of technological innovations, as detailed in Annex 4 have shown that in addition to economic drivers social, regulatory, technological, and environmental drivers play a role in the successful uptake of new technology. Social factors that influence investment decisions in innovative technology are the sharing of information and the long-term perspective on the future of the company, the social practice associated to operating the alternative gear and the social licence to operate any innovative technique (van Putten *et al.*, 2018). Improving communication between those developing gears (often scientists) and the industry, to encourage uptake of innovative gears was a significant factor that was recognized during WKING2 discussions. There were examples where fishers only adopted new gears after it was recommended by netmakers, despite scientists having produced publications aimed at industry to publicize new gears. Improving communication channels and publicizing new gears appropriately could be a key stage to improving uptake.

Technological factors are related to the possible constraints of the vessel to implement the innovation. The dual-codend case study (*section §4.9.2*) demonstrates how a net can be harder to operate, and without further alterations to a vessel to introduce a dual hopper, the separation of catch in the two codends is not particularly useful. There are gears, however, that require minimal change to a vessel, and that are easy to use and operate, that still are not readily adopted (see Case study *section §4.9.3*). More data collection is also required to determine how environmental factors and the issues around sustainability impact upon gear uptake.

Overall, however, we have learned that there are likely to be multiple factors at play that influence gear uptake. Often, fishing vessels are operating in complex and interacting political, economic, and social settings (see Case study *section §4.9.5*). Only through improved data collection will we start to gain a better understanding of how factors interact to influence gear uptake.

5 Conclusions and recommendations

This report represents a second attempt to document innovative fishing gears across the European Union and understand the main drivers that may influence the uptake and adoption of innovative fishing gear. Consistent with the terms of reference, this report describes progress made in the type, range, and development of innovative fishing gears and their impacts (both measured and perceived). We attempt to describe or infer in general terms the rationale for the development of these gears, the technical details of each gear, and the environment in which they have been deployed. We also describe the limitations of this report and make several recommendations to overcome these limitations in future.

A total of 75 factsheets were completed describing innovative fishing gears potentially viable for EU fisheries, to complement the 42 that were documented in the first WKING report (ICES, 2020c). New performance criteria were added to the factsheets including perceived level of “Complexity”, “Capital cost”, and “Return on investment” in the hope of better understanding main drivers that may influence the adoption of the innovative gear. Questions also sought information related to operational and health and safety considerations, while others were based on the PESTEL framework, designed to evaluate the political, economic, social, technological, environmental, and legal factors that may play a role in the adoption of innovative fishing gear.

The ranking of each performance criteria in the factsheets was deliberately coarse and limited to categories such as low, moderate, and high, or minimal, medium, and significant. The rational for these ranks were that: *i)* widely agreed and accepted performance criteria and associated ranks do not exist in a fishery context, *ii)* there is no individual sufficiently knowledgeable and understanding of all innovations to be able to rank each one accurately and consistently, and *iii)* the individuals who completed the factsheets may not understand the pace of uptake of the innovative gear or reasons for the gear’s uptake or rejection. By relying on these individuals to compete the factsheets we recognize the subjective nature of the data and associated limitations, and for these reasons we limited our data analysis to the provision of data trends and indications.

In recognizing the limitations in the data, we recognize this may also reflect a limited involvement or interest by individuals in encouraging the uptake of the gear by fishers. It many instances these individuals have little capacity to do so given the nature of their employment, or, they may have limited ability to mount a dedicated effort and engage with fishers over a period to time and build situational awareness and understanding of the context influencing fisher decision-making. However, it should be noted that such decision-making is also often deeply personal, influenced by context, and sometimes difficult to comprehend, thereby further challenging an ability to build understanding (this assumes of course that uptake is voluntary and not forced by regulation). Conclusions drawn within this report must therefore take these limitations into account, especially when extrapolating conclusions across a fishery or more widely.

In future, it is recommended that a core group of individuals are tasked with investigating the suitability of the performance criteria and associated ranks used in this report and attempt to reach a consensus on their efficacy or otherwise. If deemed necessary, modified, or new performance criteria and ranks can then be developed, a useful outcome prior to any future attempt to collect similar data and report on the uptake of innovative fishing gear. Having an ability in logbooks and within national records to better document when and where innovative gears are being used could also be useful to inform gear uptake.

Currently, other than ensuring legal minimum standards are being implemented, there is often no requirement for European fishers log the exact gear type or innovation being used on each fishing trip. Encouraging management authorities to collect this information and encouraging fishers to provide this information would provide much greater insight into the uptake of innovative gears

5.1 Improving the PESTEL framework for future evaluation of innovative gear uptake

This report describes the first time that the PESTEL tool has been used to understand impediments to the uptake of innovative fishing gear. The limited time available to undertake this work and complete this report allowed an initial review of the framework as part of the WKING2 workshop for the development of a more comprehensive and tested framework, as well as for additional data collection to address knowledge gaps. This problem was particularly acute given the timing of our efforts coincided with the height of summer when for at least part of this time key researchers and others are away enjoying summer holidays. More time is necessary to provide a more substantial, comprehensive and tested framework, as well as for additional data collection to address knowledge gaps.

As well as the use of the improved PESTEL framework, workshop participants identified other changes that could be made to the gear factsheet to facilitate data collection to provide better understanding of the barriers to gear uptake in future. These included:

- Requesting mandatory information in the factsheet to further elaborate how or why a factor influences gear uptake.
- Making it clear that individuals should be certain when filling in the PESTEL framework questions and to not make educated guesses. Those filling out the questions should indicate how they have come to these conclusions (e.g. clear examples in the literature, personal experience, having talked to industry)
- Asking those who are filling in the factsheet to provide information on degree of gear uptake by the fleet (if applicable and if they have access to this information).
- Recording contact details for the individual who has filled out the factsheet so they can be contacted in future to provide any further updates regarding the gear.
- Treating the factsheets in the WKING and WKING2 reports as living documents with the ability to revisit them and update them regarding new information on gear uptake.
- Ensuring adequate time and other resources are allocated to bringing together experts to refine the PESTEL framework prior to any future attempts to document innovative fishing gears in the region.

5.2 Other next steps

The outputs of this report support previous research to show there are many factors, often acting in unison, that influence gear uptake by fishers. The economic performance of the innovative gears can be important, with several technological innovations potentially reducing fuel consumption and reducing costs, both of which may enhance uptake by fishers. However, several other factors having direct consequences on the development and adoption of innovation have also been identified, and many fall within the PESTEL framework. These factors can help better understand the willingness and ability of an individual to make changes to fishing practices and adopt innovative gear. They can also lead to better management measures designed to improve the adoption of more sustainable fishing practices. To gain such understanding there is a need for regular, systematic data collection regarding both current uptake rates and information from all relevant stakeholders involved in gear development and deployment on the factors which do and are likely to influence uptake. Funding will be required to engage in this work.

To successfully develop and adopt sustainable innovative gears, collaboration between managers, fishers, scientists, gear manufacturers, policy-makers and society is important (Rijnsdorp *et al.*, 2008; Steins *et al.*, 2020). Such a collaboration can also be leveraged to improve the dissemination of information to fishers and others with regards to the development and performance of new innovative gears. While scientists may produce reports and factsheets on new gears these may not be easily accessible, or of perceived interest to industry. Developing appropriate communication channels and utilizing science-industry collaboration to better communicate is an essential step to encourage uptake. Ensuring managers, conservationists, and other informed is also wise, particularly if an innovative gear is considered contentious and/or requires political support.

What is clear from this report is that a lot of work is being conducted across Europe, and beyond, to develop innovative fishing gears to reduce negative environmental effects of fishing. More regular data collection is required, however, to determine at what rate these gears are being used by industry, what may be influencing such uptake, and how this may change over time. Such regularity also potentially identifies when timely interventions are necessary to influence gear uptake. Regular, systematic data collection is required to achieve this outcome, with appropriate administrative and financial supports being put in place as required.

At the WKING2 workshop, reference was made to proposing at the forthcoming ICES-FAO WGFTFB24 (www.wgftfb.org/annual-meeting) a need for an *ad-hoc* multiyear Topic Group on Innovative fishing gear to provide: *i)* understanding of recently developed innovative fishing gears, *ii)* opportunities for collaborative collection of information in a public database, *iii)* informing the refinement of the factsheet including agreed metrics of performance, from 2024 to 2026. However, moving forward there is also a need to identify individuals and/or institutions to engage in more regular and systematic data collection regarding the development of innovative gears, the status of uptake by fishers, and the factors that may have encouraged or prevented such uptake. This includes a mechanism to regularly collect factsheets as new innovative gears are developed. The use of improved factsheets (as detailed in *section §***3.**) to capture more information on uptake, could be adopted by a group wider than those involved in WKING and WKING2 in an interdisciplinary approach, i.e. in collaboration with ICES Working Group on Social Indicators (WGSOCIAL) and Working Group on Economics (WGECON). The improved PESTEL framework that proposes questions that can be asked in evaluating factors influencing the uptake (Annex 4) will aid with this data collection, but collab-oration between gear technologists and social scientists will be important in this process.

5.3 Recommendations

To improve upon and build on the findings in this report, we propose the following recommendations:

1. Future initiatives designed to document and describe developments in innovative fishing gear need to provide adequate time to engage with these researchers and others, allow time for individuals to submit factsheets, and then allow time for review and report on factsheet details. Adequate time is also needed to investigate the content of some factsheets more fully, particularly when the individuals completing the factsheet may not necessarily have full or direct understanding of factors influencing the adoption of the innovative gear. This situation can occur when the individuals are involved in technical development but not in related outreach activity and/or have limited engagement with fishers.
2. The performance criteria used in this report, their definition, and their underlying assumptions must be considered more deeply from a wider audience before any future

steps are taken to replicate this report. We made several assumptions based on our knowledge and long history of experience with the commercial fishing sector. While we are comfortable with the assumptions, and have justified them, they are subject to our personal bias. A dedicated effort such as a meeting or workshop with key individuals would be a useful next step, perhaps involving individuals associated with the ICES/FAO WGFTFB, other select ICES Working Groups (e.g. WGSOCIAL, WGECON) and the expert working groups of STECF working on technical measures. Such an effort could also be responsible for deliberating on appropriateness or otherwise of the array of criteria used in this report, their definition, and the coarse and limited ranking of each performance criteria.

3. Similarly, the adequacy and efficacy of the PESTEL framework needs to be considered and reviewed if deemed necessary. A core group of individuals that were involved in WKING2 could establish a PESTEL working group to complete this review prior to any future attempts to use the factsheets. This group may need to leverage additional external expertise to guide this revision.
4. While we found that most innovations reported in the factsheets were deemed to be ready for adoption by industry, we have no evidence that they are being widely used. In fact, we surmise that most are not being used widely at present, being limited at best to a handful of individuals. At present it remains unclear how best to collect information on levels of actual uptake and factors influencing uptake. Given that the individuals responsible for the factsheets are not necessarily well placed to collect this information, alternative methods need to be applied, such as interviews with fishers, focus groups with fishers or fleet wide surveys.
5. Greater effort and understanding of the factors that influence the uptake of innovative fishing gears is necessary. There is a significant and growing body of literature that can be leveraged to better understand human decision-making including the uptake of such gears. However, we stress that there are not generic explanations or blueprint approaches for innovative gear uptake, as decisions to do so are context-dependent, as was shown in our case studies. Furthermore, much of this work is not being fully applied, in part because researchers and other practitioners do not have the knowledge or understanding to apply such information and work in close collaboration with fishers. This also implies that information on innovative gears provided to fishers may be inadequate with respect to frequency, style, and content of messaging.

6 Catalogue of innovative gears

The present catalogue of factsheets together the former WKING report (ICES, 2020c) is by no means exhaustive, indeed, it is a base that needs to be updated to and built upon. The gear performances (selectivity, catch efficiency, and impact) differ at a fishery level, it may also vary at a vessel-by-vessel level. As individual fishers may wish to tailor their gears to the specific catch and quota restrictions they may face and optimize their response to the prevailing market forces.

Concerning the PESTEL framework assessment, in case no further details on information sources were provided validation was not possible. The information should therefore be regarded as provisional and should not be used for analysis or conclusions. This is an initial start of collection of these data, and moving forward more context would need to be provided to allow a robust analysis of the collected PESTEL information

6.1 Non-specific area

6.1.1 Factsheet 1. *Deep Vision* harvest control in-trawl imaging: real-time sampling and analysis of marine life in four dimensions

General information	
Year 2013-ongoing	**Source supplier**............Antonello Sala, *with text adapted from Rosen and Holst (2013) and Allken et al. (2021). Revised by Robin Faillettaz, Melanie Underwood, and Raymon Van Anrooy.*
Region..............................*Non-specific area*	**FAO-Area** ....27.2 *(developed by IMR and Scantrol AS, Norway)*
Gear sub-category ....*Any trawl gear*	**Gear code** ....BT, TB, TM
Target species..................*Not applicable*	**Bycatch species**...........*Not applicable*
Baseline gear	
Any conventional trawl gear without an in-trawl harvesting control.	

Technical information
Definition of the Innovative gear
Scantrol AS and the Institute of Marine Research, Bergen, Norway have developed an in-trawl stereo camera system, Deep Vision, which images passing organisms inside a chamber before they enter the codend.
Technical specificities
Deep Vision is a subsea vision system that can identify and measure fish underwater. A subsea camera attached to the trawl makes it possible to identify and measure fish for the first time without bringing the catch onboard. Marine researchers have already tested Deep Vision (Rosen and Holst, 2013; Underwood *et al.*, 2014; Underwood *et al.*, 2018; Allken *et al.*, 2021) and the system will be launched to the commercial fishing industry in 2024. In order to enhance trawl control, Deep Vision can be integrated with echo sound data and data from SYM 7 Autotrawl symmetry control (see **Factsheet 2**). One of the main benefits of using the system is the improved size- and species-selectivity. It will be necessary to determine what affect, if any, in-trawl imaging systems have on the catching efficiency of the trawl. It is likely that stimuli such as artificial light and reduction of the trawl's cross-section necessary to guide all fish in front of the cameras will affect the passage of fish, and possibly retention inside the trawl. Deep Vision consists of the following main components: <u>*Camsounder*</u>: 1) combined real-time fish echo sounder and fish imagery data sensor; 2) real-time fish sampling and analysis; 3) embedded algorithms and ML functionality for automatic identification of species and size; 3) send critical data in real-time to the Deep Vision Control Station on the bridge.

Control Station: 1) Real-time visualization of Deep Vision *CamSounder* data such as fish species and size distribution for the target catch and by-catch; 2) combine echo sound data, fish images, depth, and catch positioning data; 3) set automatic alerts for target fish and bycatch levels.

Deep Vision Insight: aggregated Deep Vision data for the whole fleet.

Outcomes expected

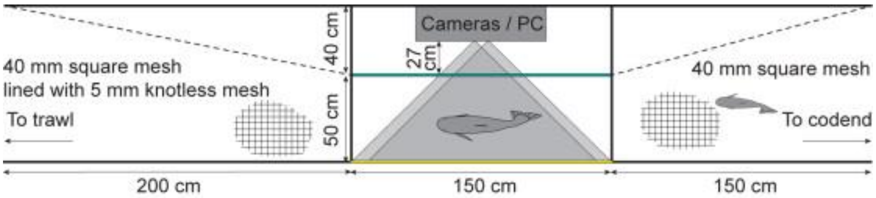
During a haul, fish and organisms passing through the trawl are photographed by the stereo camera. Using Deep Vision software, species are registered, and lengths are measured automatically. Furthermore, images are logged with depth and time information.

Other relevant information

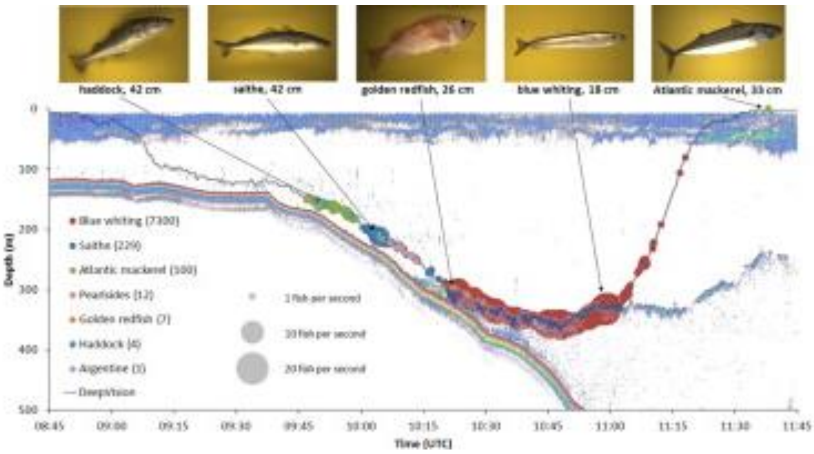
Rosen and Holst (2013), Underwood *et al.* (2014), Underwood *et al.* (2018), Allken *et al.* (2021).

Website: https://www.deepvision.no

Drawing / picture of the Innovative gear



Rigging of Deep Vision trawl section and camera chamber. Illustration at top shows Deep Vision section viewed from above. The photograph shows the Deep Vision section and camera chamber in the trawl just after being taken onboard following towing (Rosen and Holst, 2013; Allken *et al.*, 2021).



GPS and echosounder data used to locate fish along a haul relative to the water column. *Modify and adapted from Rosen and Holst (2013) and Allken et al. (2021).*

Technological Performance assessment

Main criteria............... Species and size-selectivity, catch efficiency.
Additional criteria ..... Increase fishing efficiency and profitability.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level		
Significant complexity		
Performance improvement		
Catch efficiency .... Transformative	**Selectivity** .... Transformative	**Impact**......... Transformative
Comparison with the baseline		
Is the innovative gear easier to deploy and retrieve? .... No, more difficult		
Is the innovative gear easier to maintain and repair? .... No, more difficult		
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference		
Economic Performance assessment		
Capital cost category........ High		
Return on Investment .... Significant		
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure		

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ It is a barrier

6.1.2 Factsheet 2. Autotrawl systems to enhance trawl gear performance

General information

Year 2023	**Source supplier**............Antonello Sala. *Revised by Robin Faillettaz, Melanie Underwood, and Raymon Van Anrooy.*
Region..............................*Non-specific area*	**FAO-Area** ....*Not applicable*
Gear sub-category ....*Any trawl gear*	**Gear code** ....BT, TB, TM
Target species..................	**Bycatch species**...........

Baseline gear

Any conventional trawl gear without an autotrawl system.

Technical information

Definition of the Innovative gear

The Autotrawl systems are used by the commercial fleet and are purported to improve fishing performance by stabilizing trawl geometry over varying environmental conditions, such as rough weather when vessel heave produces an upward lift on the trawl door resulting in loss of ground shear and wing spread, or over rough bottom when doors and nets have a greater probability of snagging. If Autotrawl systems are able to reduce some of the variability in gear efficiency that is due to environmental variability, such as sea state and currents, then including the use of Autotrawl systems may improve catching efficiency and energy saving.

A set of sensors attached to the gear feeds back real-time information to a computer onboard, which helps to monitor the trawl as it is towed underwater. Originally designed to improve trawl efficiency, it has since been suggested that auto trawl systems may also be beneficial in mitigating marine mammal bycatch. Auto trawl systems help to ensure that the entrance of the net remains open during all phases of the trawl, which allows animals that swim into the net (for example dolphins) a chance of escape. This technology can also help to maintain the effective operation of trawl excluder devices and can additionally eliminate any sharp turns and subsequent twisting of the net.

Technical specificities

There are two styles of Autotrawl systems currently marketed.

The first is a tension-controlled system that reacts to the difference in warp tension between winches by equalizing hydraulic pressure (*equal tension*). When the tension on either side exceeds that of the other side (a user-defined threshold) due to factors such as increased drag, currents, sediments, or steep slopes, the system lengthens that warp to equalize the pressure between the two winches. Conversely, when the tension decreases on one warp, the system compensates by shortening that warp to equalize pressure between the two winches (Kotwicki *et al.*, 2006).

The second Autotrawl style is a symmetry-controlled system that actively adjusts warp length in response to cross flow signals from a sensor mounted on the headrope. This system operates on the principle that net skewing can be caused by a crosscurrent. If the net is pulled square to the direction of flow, then its geometry will be symmetrical and trawl performance optimized.

Outcomes expected

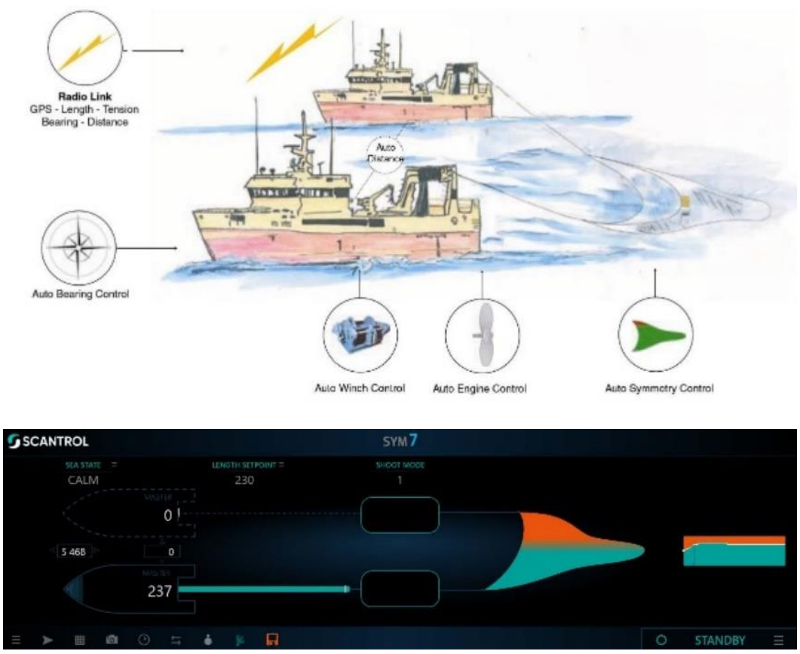
Although further verification is required, the use of auto-trawl systems is suggested as a bycatch mitigation technology to reduce dolphin mortality in trawl nets. During observations in trawl fishery it was noted that dolphins, once in the net, preferred to seek the known exit at the mouth of the net rather than use the trawl-excluder device exit (Wakefield *et al.*, 2017). Using auto trawl systems improves the stability of towed fishing gear which keeps the net fishing effectively and could in turn help maintain an "exit" for non-target animals that enter the net.

Other relevant information

Specific technical information of the autotrawl systems and sensors can be found on the websites of the industries and suppliers. Some examples can be found here:

- https://www.scantrol.com/sym-7-autotrawl
- https://www.trawlmotion.com/
- https://www.kongsberg.com/maritime/products/deck-machinery-and-cranes/deck-machinery/fishing-vessels/synchro-rtx-control-system-fishing/
- https://www.naustmarine.com/winch-control-system-solutions/atw-trawl-winch-control

Drawing / picture of the Innovative gear



Application of an Autotrawl system in a pair-trawl fishery. The skippers on the master and the partner vessel have full overview and control of towing one or several nets in a pair trawl configuration. *Modified and adapted from Scantrol AS (https://www.scantrol.com/sym7-symmetry-control).*

Technological Performance assessment

Main criteria............... Catch efficiency, impact on ETP species.
Additional criteria ..... Increase fishing efficiency and profitability, improved fuel use.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Not applicable **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Yes, easier
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... Yes, lower

Economic Performance assessment

Capital cost category.......... High
Return on Investment.......... Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.......... Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?.......... Not Applicable

6.1.3 Factsheet 3. Broadband acoustics application to sizing fish-like targets in pelagic trawling and seine fishing

General information

Year 2020-ongoing

Source supplier ....Antonello Sala, *with text adapted from Kubilius et al. (2020). Revised by Robin Faillettaz, Melanie Underwood, and Raymon Van Anrooy.*

Region....*Non-specific area*

FAO-Area ....*Not applicable*

Gear sub-category ....Purse seines
Midwater trawls

Gear code ....TM, PS

Target species....*Pelagic species*

Bycatch species....*Undersized individuals*

Baseline gear

Any conventional gear without a broadband acoustic system.

Technical information

Definition of the Innovative gear

Broadband echosounders applied to pelagic trawling or purse seine fishing. Normally a pre-catch inspection of schools with omnidirectional fisheries sonars is routine: the vessel circles the school a few times at some distance in order to determine the size, depth and shape of the school (Vatnehol *et al.*, 2017). A laterally observing, narrow acoustic beam could be aimed at the school at the same time and resolve single fish echoes in the outskirts of the school. A variety of fish orientations would be observed, and a distribution of apparent fish sizes obtained. The extremities of this distribution are anticipated to correspond to the fish body width and length. This approach may be practicable for vertically-oriented echosounders such as on the hull of fishing vessels, on a trawl headline, or on probes deployed from research vessels (Kubilius *et al.*, 2020).

Technical specificities

Broadband echosounders with simultaneous frequency-modulated pulses. Broadband echosounders can improve species discrimination in fisheries.

Outcomes expected

Sizing of fish with broadband acoustic pulses has a realistic potential, as demonstrated by the measurements on fish-like targets presented in this paper. The slow pulse taper will likely be most useful when measuring fish with gas-filled swimbladders despite the lower range resolution. The higher the echosounder frequency the higher the available bandwidth and hence higher range resolutions can be achieved. However, these higher frequencies have a shorter operating range. The further the distance to the fish, the lower the sounder frequency that is needed to achieve an adequate signal-to-noise ratio in the echo and hence only larger fish can be sized. For example, Kubilius *et al.* (2020) anticipated that there is potential to size fish such as Atlantic herring (*Clupea harengus*) and mackerel (*Scomber scombrus*) by using a sideways-pointing narrow beam-width transducer operating with a frequency bandwidth that achieves adequate range resolution to the necessary range.

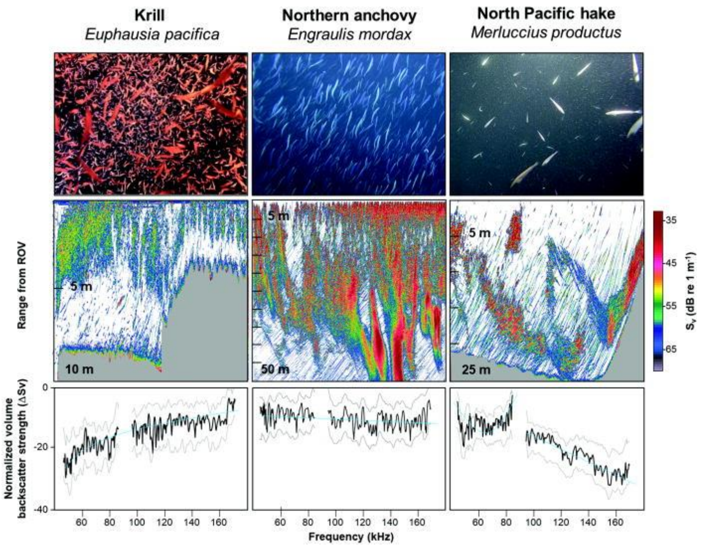
Other relevant information

Specific technical information of the system and sensors can be found on the websites of the industries and suppliers. Some examples can be found here:

- https://www.kongsberg.com/maritime/products/commercial-fisheries/fisherysonar/cs90/
- https://www.japan-marina.co.jp/
- https://www.lowrance.com/en-eu/

Relevant references: Kubilius *et al.* (2020), Vatnehol *et al.* (2017), Benoit-Bird and Waluk (2020), Trenkel *et al.* (2016).

Drawing / picture of the Innovative gear



Observations of three species from broadband acoustic backscatter measurements. *Modified and adapted from Benoit-Bird and Waluk (2020).*

Technological Performance assessment

Main criteria............... Catch efficiency, fishing selectivity, reduced impact on ETP species.
Additional criteria ..... *None*

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Disruptive **Selectivity** .... Transformative **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Unsure
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.......... High
Return on Investment.......... Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................ Do not know

6.1.4 Factsheet 4. Fish sampling by shooting a "mini-trawl" into the purse seine

General information

Year 2013-ongoing	**Source supplier** ....Antonello Sala, *with text adapted from Isaksen (2013). Revised by Robin Faillettaz, Melanie Underwood, and Raymon Van Anrooy.*
Region..............................*Non-specific area*	**FAO-Area** ....*Not applicable*
Gear sub-category ....Purse seines	**Gear code** ....PS
Target species..................*Pelagic species*	**Bycatch species**...........*Not applicable*

Baseline gear

Any conventional purse seine without a mini-trawl system.

Technical information

Definition of the Innovative gear

When purse seining for pelagic species, it is often desirable to get a sample of the catch during the early phase of pursing. The Institute of Marine Research and SINTEF have now jointly developed a method that may revolutionise that sampling process: using a modified line thrower to shoot a mini-trawl into the purse seine. To help avoid triggering closure of fishing ground (RTC) rules, the purse seiners are very keen to find out the size distribution of fish during the early phase of pursing, while it is still legal to release the catch.

Technical specificities

The mini-trawl is held open by "kites" fitted to the head rope and wings of the net, and by having leaded rope attached to the foot rope. The mouth of the mini-trawl is approximately 1.5 x 1.5 metres. The mini-trawl is stuffed into a plastic pipe that in turn is put into the barrel of a modified pneumatic line thrower. When the pressure in the air chamber (back part of the line thrower) is 10 bar, the pipe containing the trawl is shot around 30 m into the net. The line thrower is ready to shoot the pipe containing the sampling trawl. The mini-trawl is shot around 30 metres into the purse seine, and sinks to the desired depth at a speed of approximately 20 cm/sec. It is hauled in at a speed of 1.5-2.0 knots.

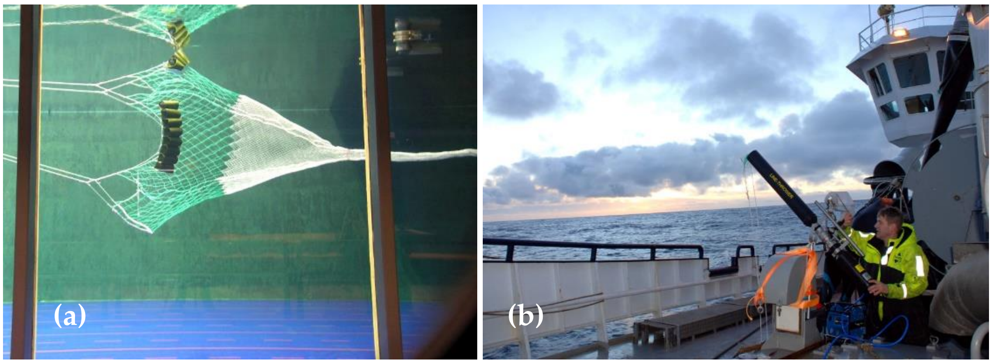
Outcomes expected

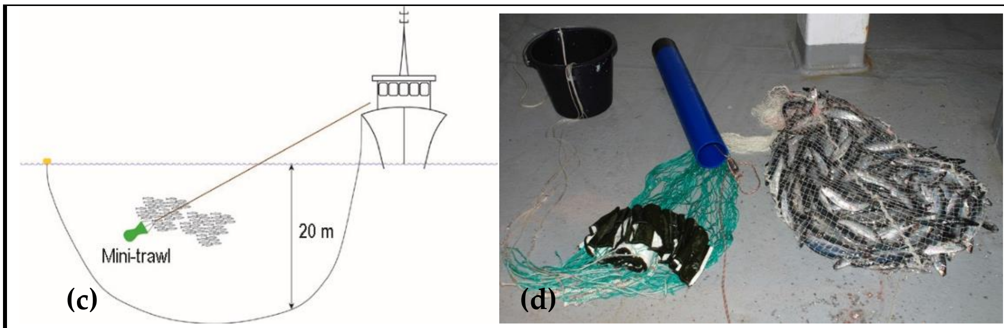
Since size and quality have a big impact on the price obtained for pelagic species, it is important to determine the contents of the catch at an early stage of each haul. Given new knowledge about how crowding can harm pelagic species and raise their mortality rates, there is every reason to believe that traditional sampling techniques may be prohibited, as they involve crowding the fish, taking a sample and then discarding the catch after determining the size and quality of the target species.

Other relevant information

Isaksen (2013)

Drawing / picture of the Innovative gear





(a) Testing the sampling trawl for purse seines in a tank at SINTEF Fisheries and Aquaculture, Hirtshals; (b) Few seconds before the mini-trawl is fired into the purse seine; (c) the sampling trawl is shot around 30 metres into the purse seine; (d) sampling trawl example containing 135 North Sea herring in the size range 21-25 cm. *Source: modified and adapted from Isaksen (2013).*

Technological Performance assessment

Main criteria............... Species- and size-selectivity, catch efficiency.
Additional criteria ..... Reduce discarding, reduced fuel costs and improved catch quality and prices.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Transformative **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Yes, easier
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category.......... Moderate
Return on Investment.......... Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... It is a barrier

6.1.5 Factsheet 5. Alternative artificial baits to improve longline efficiency

General information

Year	2014-ongoing	**Source supplier**	Antonello Sala, *with text adapted from Løkkeborg et al. (2014). Revised by Robin Faillettaz, Melanie Underwood, and Raymon Van Anrooy.*
Region	*Non-specific area*	**FAO-Area**	*Not applicable*
Gear sub-category	Longlines	**Gear code**	LH, LL, LV
Target species	Not applicable	**Bycatch species**	Vulnerable species, sharks

Baseline gear

Any conventional longline.

Technical information

Definition of the Innovative gear

The chemical compounds that elicit food search behaviour differ from species to species, and species selectivity could be improved by incorporating specific feeding attractants in manufactured baits (Løkkeborg *et al.*, 2014). The unique properties of **chemical** stimuli and odour dispersal form the basis for improving longline efficiency through the development of a long-lasting bait. **Vision** is important in prey capture, and manufactured baits can be made more visible than natural baits by increasing the contrast (e.g., via fluorescent or polarising coatings) and creating motion through buoyancy. **Physical** properties such as size, shape, texture and strength can also be manipulated in a manufactured bait to improve catch efficiency (Løkkeborg *et al.*, 2014).

Two main methods to develop an alternative longline bait have been tried: one based on natural resources (e.g. surplus products from the fishing industry) and the other on synthetic ingredients (chemicals) as attractants (Løkkeborg *et al.*, 2014). In both cases, the bait is based on three main components: attractants, binder (*gelling agent*) and reinforcement. All these components must meet important requirements if they are to form an efficient longline bait. The **attractants**, whether natural or synthetic, must include the stimulatory compounds that elicit the food-search behaviour in the target fish species. The purpose of the **binder** is to ensure that attractants are released over a fairly long period of time. As the binder does not add sufficient physical strength to the bait, a **reinforcement** is needed to ensure bait is not lost (e.g., during shooting, sea birds, benthic bait scavengers or the target species).

Technical specificities

Norbait. Manufactured by the Norwegian company Norbait DA is based on surplus products (e.g. waste fish and fish offal) from the fish-processing industry. The technology used to manufacture the Norbait bait is similar to that used for production of sausages. Baits based on several types of surplus products (e.g. herring, mackerel, horse mackerel) have been developed, and species-selective effects have been demonstrated in fishing trials. Increases in catch rates of two to three hundred per cent compared with natural bait have been obtained for haddock, although Norbait compared poorly for cod. Compared to natural bait, minced herring enclosed in a nylon bag resulted in a 58% higher catch rates for haddock, and a considerably lower catch rate for cod.

Artificial bait invented by William E.S. Carr. This bait comprises a water-insoluble, hydrophilic matrix (a polyurethane foam) which is permeable (by diffusion) to the release of attractants incorporated into the matrix. On immersion in water the attractants are released at a predetermined rate over a prolonged period of time. The matrix is a semi-rigid and flexible material that in texture resembles common fish prey. Any fish attractants in liquid form can be incorporated in this artificial bait. Useful attractant mixtures that can be tailored for specific target species are described by the inventor of this artificial bait (Carr *et al.*, 1996).

Bait bags. The "bait bags" are produced by the Icelandic company Bernskan ehf. This bait is based on frozen natural raw material such as capelin, herring, sand eel, squid, extract from Calanus species and mixtures of fish waste products. In field experiments in Norway, the bait bags were compared with saury and mackerel baits, and the bags produced a higher catch rate of haddock, but poorer catches of cod. The bait bags have also been tested in deep-water (300-400 m) longline fishing for halibut with limited success (Løkkeborg *et al.*, 2014). However, the bait bags have several advantages for fishers using traditional hand-baited longlines, including the elimination of the need to cut the bait, cleanliness, a rapid baiting process, and reduced hook entanglements during setting. Another advantage is that seabirds showed no interest in the bags, thus mitigating the seabird bycatch problem.

Arom Bait. This artificial bait is manufactured by the Spanish company Arom Bait (www.arombait.com). The bait is made from natural and biodegradable products and is moulded into rectangular and flexible boards that can be cut into suitably sized pieces. Bait types have been developed for both longlining and recreational angling. This product can be stored without freezing.

Other artificial baits. Other examples of artificial baits include a latex and vinyl chloride artificial bait that was developed in order to eliminate the need to freeze bait on Japanese tuna longliners (Januma *et al.*, 2003). Liver of squid was used as the main attractant and combined with seaweed products. The catch rate of the artificial bait was lower than that of natural baits, which may have been partly due to neglecting the importance of the shape of the bait (Januma *et al.*, 2003). The fabricated baits fished as well as or better than herring for sablefish and Pacific halibut, while reducing bycatch of spiny dogfish shark (*Squalus acanthias*), skate (*Raja* spp.), arrowtooth flounder (*Atheresthes stomias*) and Pacific cod (*Gadus macrocephalus*) by more than an order of magnitude. Several new industry-driven initiatives on developing artificial baits for longline fishing are under way. Their bait is based on polymer composites in combination with natural attractants or on the use of extruded starch as binder. These initiatives reflect the high prices of traditional baits and the demands for stable supplies of bait.

Outcomes expected

Longline efficiency could be improved by taking the unique properties of a chemical stimulus into account and develop a long-lasting bait that attracts fish from a large area over a long period of time.

Other relevant information

Løkkeborg et al. (2014), Carr *et al.* (1996).

Drawing / picture of the Innovative gear

Alternative longline baits and their main constituents. (*) Information unavailable. *Source: Løkkeborg et al. (2014).*

Name	Producer	Main attractants	Binder	Reinforcement
Norbait	Nortbait DA	Minced surplus products	Alginate	Cotton stocking
Artificial bait	William E.S. Carr	Any liquefied attractant	Polyurethane foam	Fabric substrate
Bait bags	Bernskan ehf.	Frozen fish or surplus products	*	Cellulose fibre
Arom Bait	Arom Bait	*	*	*

Technological Performance assessment

Main criteria............... Catch efficiency, species selectivity, reduced bycatch of ETP species, sharks in particular, and seabirds.
Additional criteria ..... None

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Negative **Selectivity** .... Incremental **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment........ Negative
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ It is a barrier
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Has encouraged uptake

6.1.6 Factsheet 6. Artificial lighting to improve catchability in trawl fisheries

General information

Year	2015-ongoing	**Source supplier**	Antonello Sala and Marieke Desender, *with text adapted from 11 case studies. Revised by Robin Faillettaz, Melanie Underwood, and Raymon Van Anrooy.*
Region	*Non-specific area*	**FAO-Area**	37.1,2,3, *and other areas*
Gear sub-category	Bottom trawls	**Gear code**	TB *(all trawls in general)*
Target species	DPS *and other shrimp (e.g., PJK)*, NEP	**Bycatch species**	HKE, JAX, RED, HAD, EUL, *and juvenile groundfish species*

Baseline gear

Any conventional demersal or bottom trawl gear.

Technical information

Definition of the Innovative gear

Addition artificial lights in the trawl net (e.g., along the fishing line, or in the vicinity of BRD) to alter fish bycatch and shrimp catch. *Several studies have revealed that the effects of artificial light on catch are highly variable, as they are dependent on many factors. Therefore, despite presented in the Mediterranean section, other case studies have been reported in the present factsheet.*

Technical specificities

Eleven case studies are presented here to illustrate the effect of lights on catchability in trawl fisheries:

1) *Geraci et al. (2021) tested g*reen and white LEDs placed alternately and symmetrically along the headrope, with green and white LEDs alternating at approximately 50 cm from each other. The green and white LEDs peaked at wavelengths of 520 and 460 nm, respectively, with an intensity of 3.5 cd.
2) Larsen *et al.* (2018) tested green Lindgren-Pitman Electralume® LEDs attached to the lower part of the Nordmøre grid with LEDs pointing in towing direction and downwards (at a 45° angle).
3) Hannah et al. (2015) tested Lindgren-Pitman Electralume® LED lights (colours green or blue) in locations around the rigid-grate BRD and attached 10 green lights along the trawl fishing line.
4) Lomeli *et al.* (2018a), *same experiment of Hannah et al. (2015).*
5) Melli *et al.* (2018) investigated potential phototactic responses, mounting 10 Electralume LED lights in two experiments. Experiment 1: to the lower netting panel in the aft part of the tapered section; Experiment 2: in the upper netting panel.
6) Green LED fishing lights (Lindgren-Pitman Electralume) were used to illuminate the headrope in flatfish trawl fishery was tested in Lomeli *et al.* (2018b). The lights were grouped into clusters of three, with each cluster attached ~1.3 m apart along the 40.3-m-long headrope.
7) Lomeli *et al.* (2019) and Lomeli and Wakefield (2019) tested Lindgren-Pitman Electralume® blue LED fishing lights, wavelength centred on 464 nm. Blue coloured LEDs were selected as this wavelength transmits the furthest in water and the predominant spectral component of coastal and continental shelf waters in this region is blue-green light. Lights were grouped into clusters of two and attached to the trawl netting in a horizontal position with the light-emitting end pointing forward upon deployment.
8) Karlsen *et al.* (2021) tested the effect of a novel luminous netting, *VISIONET*, on vertical behaviour of commercial species in a Nephrops trawl fishery. Trawl was manufactured using netting twine with white monofilaments containing a phosphorescent metal called strontium aluminate ($SrAl2O4$), which emit a low intensity green glow that fades over hours after being exposed to sunlight or artificial light (*Euronete Portugal SA*). These luminous monofilaments were integrated 50/50 with green polyethylene monofilaments to give maximum luminous effect while still producing a functional netting of 90 mm diamond meshes (4 mm double twine).
9) Cuende *et al.* (2020a) and Cuende *et al.* (2020b) tested white and blue LED lights (*Centro Power Light*, model SW2) placed over a SMP to attract fish towards the panel and increase contact probability.
10) O'Neill *et al.* (2022) tested fibre optic cables attached to the grid allowing the illumination of the top and bottom halves of the grid independently. The grid was made from 25 mm High Density Polyethylene (HDPE) and measured 1.2×0.75 m. It was divided in half by a horizontal bar and had vertical bars set 0.145 m apart. Two 5 mm multi-strand side emitting fibre optic cables

housed in 12 mm clear PVC tubing were cable tied to the grid, one to the upper half and the other to the lower half of the grid. The cables could be illuminated by PhotoSynergy Ltd PSL5000 units which housed a single green (530 nm wavelength) LED and were powered by a 12 V DC supply. 11) Birch *et al.* (2023) observed that in the presence of light catches-at-length of haddock were lower during the night. Also, the vertical separation was affected with more haddock being retained in the lower codend during the day and night. Lights also increased the proportion of catches in the lower codend for grey gurnard, whiting and Northern squid during the day. Tests subsequently executed in the Smartfish project (Birch *et al.*, 2022) suggest that the application of blue LEDs in the region of the square mesh panel increases the retention of haddock and whiting in demersal trawls. Of further interest is the behavioural response observed for haddock reacting to the approaching lights at some distance by moving downwards in a separator trawl. The SmartGear tested in a beam trawl was technically successful, however the results indicate that the effect of lights on catches were marginal, with only slight significant differences at very narrow length ranges of the target species. Lights were applied in a variety of positions, both ahead of the beam and within the trawl netting, and although it was not possible to draw any firm conclusions it is likely that the light emitted from the technology tested was not bright enough to penetrate the sand cloud generated by the chain mat and fish are more likely to be stimulated by the physical contact, sound and sediment resuspension of the passing trawl. In the North Sea, trials with a Nephrops trawl fitted with a NetGrid selectivity device and two codends resulted as well in increased retention of haddock and whiting in the lower codend with the addition of blue LEDs (Armstrong *et al.*, 2021; Birch *et al.*, 2022). Although, it is not immediately obvious how the observed behavioural reactions can be used to enhance trawl selectivity in these fisheries, the identified reactions and the new technologies invite further investigations to improve selectivity.
Outcomes expected
1) The results from *Geraci et al. (2021)* indicate that bottom trawls equipped with 20 (10 green and 10 white) LED lights increase the overall catch rates during the night, even if they only significantly affected deep water rose shrimp (*Parapenaeus. longirostris*). Catches of this species increased across almost all size classes. This finding could be reflected in a higher profit for fishers. Conversely, for hake and Jack and horse mackerels, the trawl with LEDs caught more undersized species than the control. 2) Larsen *et al.* (2018), who worked with a rigid Nordmøre grid mounted on a shrimp trawl net targeting (*Pandalus jordani*), noted that the addition of green LEDs around the escape exit was ineffective at reducing juvenile fish bycatch. 3) Hannah et al. (2015) and demonstrated that the addition of artificial light appears to have greatly increased the passage of fishes through restricted spaces (between BRD bars and the open space between trawl fishing line and groundline) that they typically would not pass through as readily under normal seafloor ambient light conditions. 4) The addition of artificial illumination along the trawl fishing line tested in Lomeli *et al.* (2018a) significantly affected the average catch efficiency for eulachon, rockfish (*Sebastes* spp.), and flatfish, with LED configurations catching significantly fewer individuals than the unilluminated trawl without impacting ocean shrimp catches. For Pacific hake (*Merluccius productus*), the LED-configured trawl caught significantly more fish than the unilluminated trawl. 5) Significant changes in vertical species separation was identified in Melli *et al.* (2018), but no clear species-specific phototactic response noticed. Neither of the light positions improved fish separation from Nephrops. However, the potential of LED lights as behavioural stimulators was confirmed. 6) Fewer flatfish (sole, flounder), halibut were caught in the illuminated trawl tested by Lomeli *et al.* (2018b) than in the standard trawl. Their findings show that illuminating the headrope of a flatfish trawl can affect the catch comparisons and ratios of groundfishes. 7) Lomeli *et al.* (2019) and Lomeli and Wakefield (2019) verified the effect of artificial illumination on Chinook salmon behaviour and their escapement out a BRD in a hake midwater trawl. The results show that artificial illumination influenced where Chinook salmon exit out of the BRD, but also demonstrated that illumination can be used to enhance their escapement overall. 8) Karlsen *et al.* (2021) evaluated if the presence of VISIONET had the potential to increase the fish capture in the upper compartment. Gadoids entered the lower compartment more frequently than in the control trawl. This was similar to that previously found when applying green LED lights in the tapered section, however opposite for haddock. Large Nephrops significantly increased their preference for the lower compartment. The results show that low intensity light is sufficient to alter the vertical distribution of both fishes and Nephrops. Luminous netting can be integrated in any given trawl design and does not require batteries or electronics. 9) Cuende *et al.* (2020a); Cuende *et al.* (2020b) reported no significant improvement in the release efficiency for either *M. merluccius* or *Micromesisitius poutassou* by testing white and blue LED lights with an SMP. 10) O'Neill *et al.* (2022) demonstrate that the proportion of fish that entered the top codend depends on the grid illumination and has a diel variation. Most species were less likely to enter the upper codend when the grid was illuminated and the results were similar regardless of whether the bottom-half, top-half, or the whole grid was illuminated. There was also a diel effect for all

species with a lower proportion of haddock and whiting and a greater proportion of flatfish in the upper codend at night than during the day. The results are more subtle for some species and for cod, illuminating the grid had no effect during the day, whereas for common dab, there was no effect when the top-half of the grid was illuminated but there was when the bottom-half was illuminated. For long rough dab, illuminating the top-half of the grid had a greater effect than illuminating the bottom-half, and illuminating the whole grid had the greatest effect.

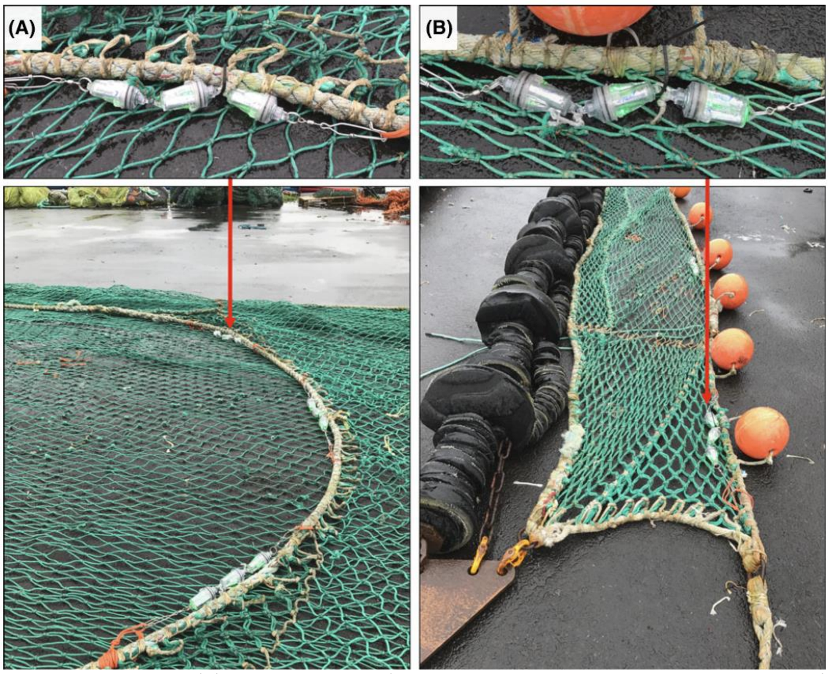
11) The SmartGear tested was technically successful, however the results indicate that the effect of lights on catches were marginal, with only slight significant differences at very narrow length ranges of the target species (Birch *et al.*, 2022). Lights were applied in a variety of positions, both ahead of the beam and within the trawl netting, and although it was not possible to draw any firm conclusions it is likely that the light emitted from the technology tested was not bright enough to penetrate the sand cloud generated by the chain mat and fish are more likely to be stimulated by the physical contact, sound and sediment resuspension of the passing trawl. Other alternative LED units were tested in a demersal trawl fishery in the Celtic Sea, using horizontal separator trawls fitted with square mesh panels, and in the North Sea in a Nephrops trawl fitted with a NetGrid selectivity device and two codends. The results of these experiments were more promising, indicating that LED light induced a behavioural response in haddock and whiting. In both studies, increased retention of haddock and whiting were observed, and the vertical positioning of haddock was affected with the addition of blue LEDs. Although, it is not immediately obvious how the observed behavioural reactions can be used to enhance trawl selectivity in these fisheries, the identified reactions and the new technologies invite further investigations to improve selectivity.

Other relevant information

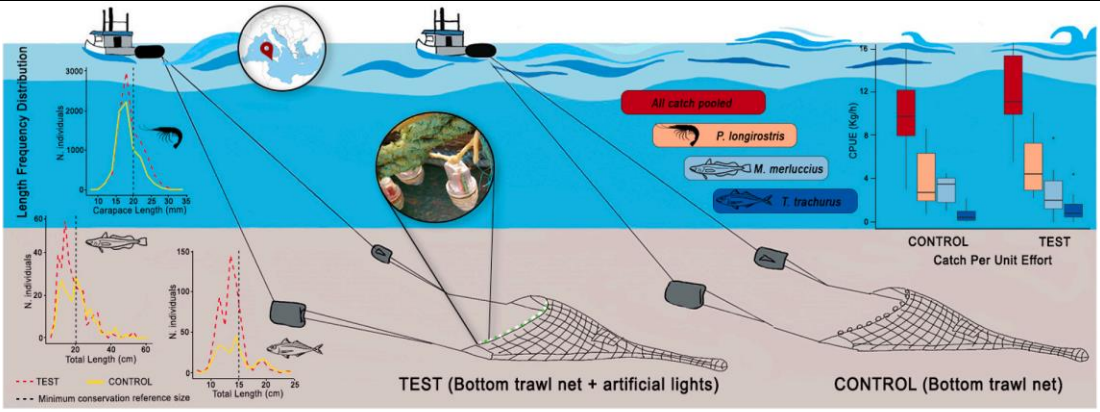
Hannah *et al.* (2015); Larsen *et al.* (2018); Lomeli *et al.* (2018a); Lomeli *et al.* (2018b); Melli *et al.* (2018); Lomeli *et al.* (2019); Lomeli and Wakefield (2019); Cuende *et al.* (2020a); Cuende *et al.* (2020b); Armstrong *et al.* (2021); Geraci *et al.* (2021); Karlsen *et al.* (2021); Birch *et al.* (2022); O'Neill *et al.* (2022); Birch *et al.* (2023).

Drawing / picture of the Innovative gear

Installed on trawl

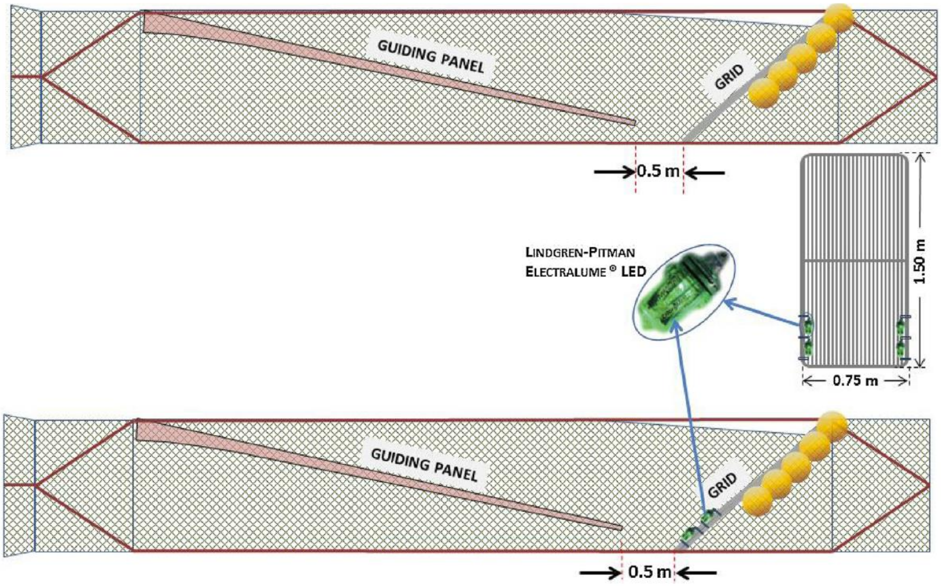


LED cluster attached (A) near the centre of the trawl headrope on the starboard side and (B) along the wing tip on the port side, and their orientations. *Source: adapted from Lomeli et al. (2018b).*

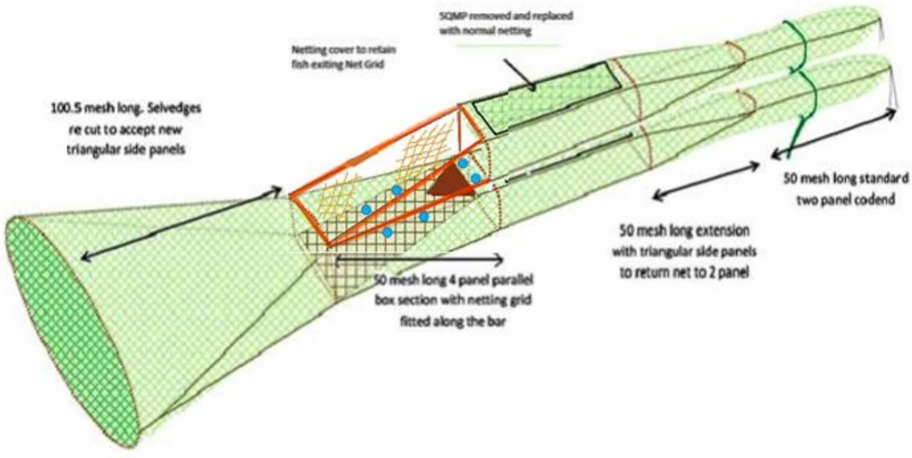


Source: adapted from Geraci et al. (2021).

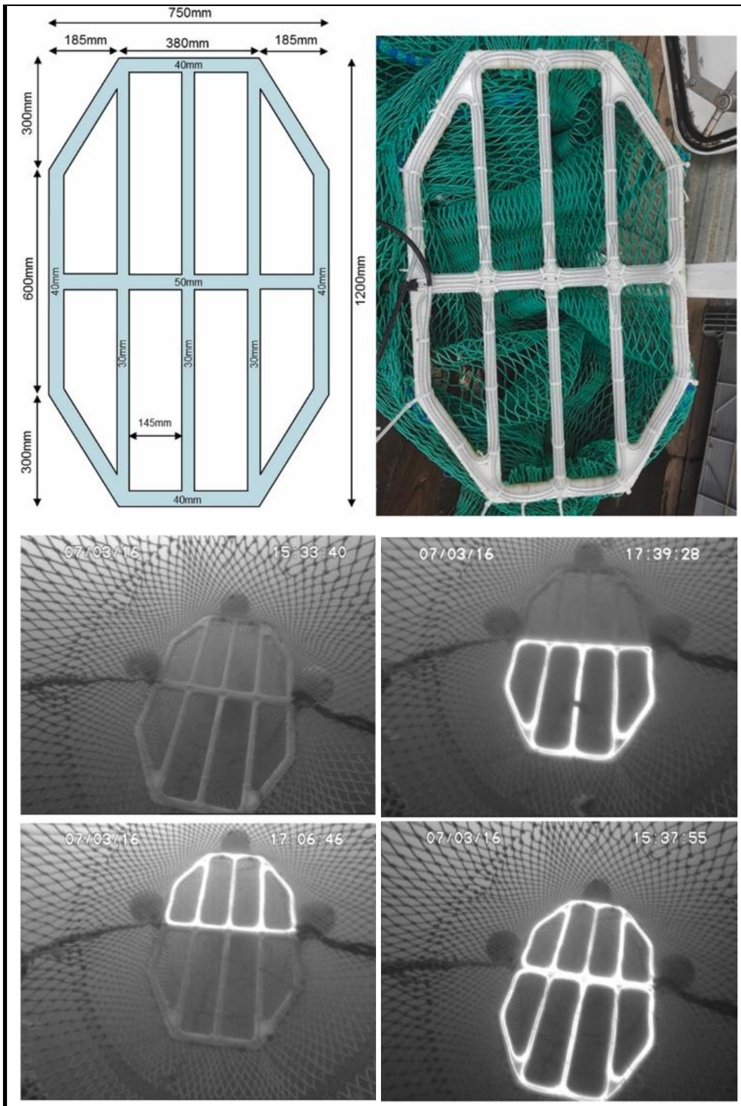
Installed on BRD (e.g., Nordmøre grid)



Standard configuration without LEDs (top) and standard configuration with four Lindgren-Pitman Electralume® LEDs mounted on the lower part of grid (bottom) pointing in the towing direction and 45° downwards. *Source: adapted from Larsen et al. (2018).*



Modified NetGrid insertion with blue Led lights on the inclined panel. *Source: modified and adapted from Armstrong et al. (2021).*



Dimensions of the HDPE grid and mounting configuration of fibre-optic cables. The inclined grid mounted in the extension with (i) none of the grid illuminated; (ii) the bottom-half of the grid illuminated; (iii) the top-half of the grid illuminated; (iv) all of the grid illuminated. *Source: modified and adapted from O'Neill et al. (2022).*

Technological Performance assessment

Main criteria .... Species and size-selectivity, catch efficiency, reduced impact on ETP species (marine mammals).
Additional criteria ..... Decrease escaping stress and fatigue, therefore increase survival.

Technological readiness level (TRL)

TRL category .... High **TRL scale** TRL7

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact** .... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.. Low
Return on Investment.. *Unknown*
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?................... Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. It is a barrier

6.1.7 Factsheet 7. Electrosensory and semiochemical deterrents to reduce sharks bycatch in line-based fisheries

General information

Year 2006-ongoing

Source supplier ....Antonello Sala, *with text adapted from Werner et al. (2006), Kaimmer and Stoner (2008), Robbins et al. (2011), O'Connell et al. (2014). Revised by Robin Faillettaz, Melanie Underwood, and Raymon Van Anrooy.*

Region ....*Non-specific area*

FAO-Area ....*Not applicable*

Gear sub-category ....Longlines

Gear code ....LH, LL, LV *(pelagic lines)*

Target species ....*Pelagic species*

Bycatch species ....*Sharks and elasmobranchs*

Baseline gear

Any conventional longline (*depending on the region*).

Technical information

Definition of the Innovative gear

Sharks possess anterior electrosensory pores (ampullae of Lorenzini), which allow them to detect weak electromagnetic fields. Powerful magnetic fields may overwhelm this sense, and repel sharks, even in the presence of an attractant (Robbins *et al.*, 2011). Electromagnetic fields created in the vicinity of a pelagic longline fishing activity to deter interaction of non-target species with fishing gear, bait, or target species was proposed during the 2006 Smart Gear competition run by the World Wildlife Fund. The judges voted to award Mr Herrmann the grand prize because the concept sets out a novel approach to reducing shark bycatch, is based on sensory perception and addresses a problem which affects shark populations around the world. Recently, other rare-earth magnets and metals have been shown to have deterrent effects on sharks. These effects are likely the result of magnetic or electric fields created by these materials in seawater, which are sensed and avoided by sharks.

Current shark repellent technologies which aim to minimize elasmobranch mortality in fishing gears include: permanent magnets, electropositive metal (EPM) alloys, and semiochemicals. O'Connell *et al.* (2014) reviewed electrosensory and semiochemical shark repellents, the mechanisms of elasmobranch detection and repellency, species-specificity in elasmobranch response to the stimuli, and environmental and biological conditions which may influence repellent success. It is essential to understand: (1) the environmental or physiological characteristics which may be most responsible for electrosensory sensitivity to magnetic repellents, (2) the best applications for each type of repellent with the recreational fishery being a possible candidate for future research due to minimal experimentation thus far, and (3) to understand the physiological effects of these repellents on interacting elasmobranchs.

Technical specificities

Two case studies are presented here to illustrate the effect of electrosensory and semiochemical as a deterrent to sharks bycatch longline fisheries:

1) In 2007, a collaborative laboratory study was conducted by the International Pacific Halibut Commission (IPHC) and the Alaska Fisheries Science Center to test whether the presence of two different rare-earth materials (*neodymium–iron–boride magnets* and *cerium mischmetal, a cerium-richmixture of lanthanide rare-earth metals*) could be used to deter spiny dogfish from attacking baited gear. This research followed from a 2006 "Smart Gear" prize from the World Wild life Fund to Shark Defense LLC for the discovery that various sharks were repulsed by rare-earth magnets and later observations that rare-earth metal alloys had the same effect. Kaimmer and Stoner (2008) tested the potential for using the rare-earth cerium mischmetal material as a deterrent for spiny dogfish and other elasmobranchs in longline fishing for halibut. The mischmetal deterrent alloy comprised of cerium (64.02%), lanthanum (34.22%), neodymium (0.55%), praseodymium (0.11%), and minor amounts of other non-rare-earth impurities (Hefa Rare Earth Canada, Richmond, Canada). This alloy is referred to in metallurgy as a cerium mischmetal (mixed metal). Triangular pieces of mischmetal, ~50 mm on a side and 6.3-mm thick (~50 g), were cut from ingots, and a 6-mm hole was drilled through the center for attachment to a hook with a cable tie.
2) Seven rare earth magnet configurations, two ferrite magnet configurations and two rare earth electropositive metals as means to reduce the rate at which sharks depredated baited lines.

Outcomes expected

1) Fewer dogfish were caught on hooks with mischmetal tested by Kaimmer and Stoner (2008). Reductions in catch of longnose

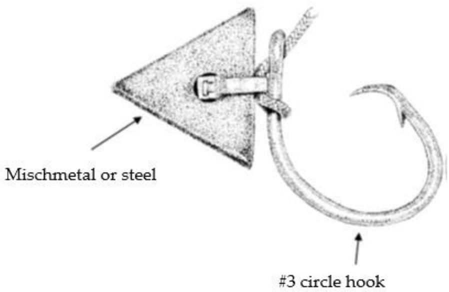
skate (*Raja rhina*) also occurred on hooks protected with mischmetal. However, halibut catch did not increase with protected hooks. However, limitations in using mischmetal in commercial operations are expense, hazardous nature, and relatively rapid hydrolysis in seawater.

2) Although Robbins *et al.* (2011) showed that social interactions between sharks outweighed individual responses to depredation-mitigation devices, magnetic deterrents have high potential for reducing shark bycatch for species that occur in lower densities, or which interact less vigorously with conspecifics than Galapagos sharks.

Other relevant information

Werner *et al.* (2006), Kaimmer and Stoner (2008), Robbins *et al.* (2011).

Drawing / picture of the Innovative gear



Circle hook with metal ~50 mm on a side 6.3-mm thick triangle attached using an electrical tie. *Source: adapted from Kaimmer and Stoner (2008).*

Technological Performance assessment

Main criteria............... Reduce shark bycatch.
Additional criteria ..... Reduce conflicts sharks-fishers.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Not applicable **Selectivity** .... Transformative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair?........ No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment........ Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Do not know

6.1.8 Factsheet 8. Chemical shark repellent: shark necromone effect on feeding behaviour

General information

Year	2014	**Source supplier**	Antonello Sala, *with text adapted from Stroud et al. (2014). Revised by Robin Faillettaz, Melanie Underwood, and Raymon Van Anrooy.*
Region	*Non-specific area*	**FAO-Area**	*Not applicable*
Gear sub-category	Longlines	**Gear code**	LH, LL, LV *(pelagic lines)*
Target species	*Commercial pelagic species*	**Bycatch species**	Shark species

Baseline gear

Any conventional longline *(depending on the region).*

Technical information

Definition of the Innovative gear

A commercially sourced shark necromone produced from putrefied shark tissue. An unambiguous halt in feeding behaviour was observed within 1 min after exposure of the necromone. Stroud *et al.* (2014) experimented that using 150 mL dose of a necromone from a pressurized aerosol canister at the surface is able to halt all feeding activity in a combined population of Caribbean reef sharks (*Carcharhinus perezi*) and blacknose sharks (*Carcharhinus acronotus*).

Technical specificities

All shark repellent aerosol canisters used in Stroud *et al.* (2014) were obtained from Repel Sharks, LLC (Charlestown, Nevis) and were supplied in nominal 177 mL steel aerosol canisters. According to the manufacturer, the model RS-IM-S canister was charged with 150 mL of necromone and pressurized to 150psig with argon gas. The necromone mixture was a composite mixture of extractions from putrefied blue shark (*Prionace glauca*), *C. perezi,* and Galapagos shark (*Carcharhinus galapagensis*) tissue. The canisters are positively buoyant and therefore have a lead metal band near the canister top (i.e. content ejection point) to ensure the can is slightly negatively buoyant and inverted in the water after deployment. The canister was designed to fully evacuate within 60 s, producing a plume in the water column as the can gradually rises to the surface. All aerosols were stored at ambient temperature and out of direct sunlight until testing, per the manufacturer's instructions.

Outcomes expected

Shark necromones induce an alarm response in interacting sharks resulting in a temporary evacuation of an area containing feeding stimuli (Stroud *et al.*, 2014). Habituation to the necromone was not observed for repeated tests. In all experiments conducted by Stroud *et al.* (2014), the presence of a shark necromone did not produce a similar aversion response for teleosts. Experiments demonstrate that the key chemical component responsible for the alarm response is within these amino acids and/or putrefaction products, but further experimentation is needed to identify the active ingredient more accurately. Shark necromones hold promise for use in shark bycatch reduction and conservation. The existence of a putative chemical shark repellent was confirmed.

The necromone active would be immediately relevant in the commercial fishing industry, where high rates of accidental shark catch (bycatch) occur. Stroud *et al.* (2014) envisioned that the necromone active would be incorporated into a time-release matrix and inserted into longline baits, providing a protection window for each baited hook. Since the necromone is selective to sharks, the target fish catch rates should remain unaffected. Ideally, the target fish catch rates would increase, because more hooks would become available for marketable fish given reduced shark capture. Stroud *et al.* (2014) evidenced that even with this minimal introduction of chemicals into seawater, a variety of issues can arise unless the chemicals are derived from natural sources: (1) the chemicals being introduced into the ecosystem are synthetic or superpotent and thus may serve as an environmental pollutant, although components of chemical repellents are compliant with regulations; (2) in addition with chemicals, their success will be heavily dependent on currents and geographical features of the area. In situations where currents are slack or minimal, this will lead to minimal chemical dispersion and may make the chemical nearly ineffective at far distances. Therefore, extensive future research is needed on these aspects.

Other relevant information

Stroud *et al.* (2014), Gilman *et al.* (2008), O'Connell *et al.* (2014).

Drawing / picture of the Innovative gear

Not available

Technological Performance assessment

Main criteria............... Impact on shark bycatch, catch efficiency.
Additional criteria ..... Fish quality.

Technological readiness level (TRL)

TRL category............. Moderate **TRL scale** TRL6

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact** .... Disruptive

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? ....No difference
Is the innovative gear easier to maintain and repair?..........No difference
Does using the innovative gear present a lower risk to the health and safety of crew? ....No difference

Economic Performance assessment

Capital cost category..........Moderate
Return on Investment..........Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? ....Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? ....Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? ....Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? ....Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?..........Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? ....Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?..........Do not know

6.1.9 Factsheet 9. Waste heat recovery system for increasing energy efficiency of fishing vessels

General information

Year 2018

Source supplier ....Emilio Notti (CNR, Italy). *Revised by Robin Faillettaz, Melanie Underwood, and Raymon Van Anrooy.*

Region ....*Non-specific area*

FAO-Area ....*Not applicable*

Gear sub-category ....Bottom trawls

Gear code ....BT, TB, TM

Target species ....*Not applicable*

Bycatch species ....*Not applicable*

Baseline gear

The energy consumed onboard a fishing vessel is produced by internal combustion engines (ICE) burning diesel fuel. The energy layout of a fishing vessel in the Mediterranean Sea commonly consists of an internal combustion engine, in charge of the generation of all the energy requested, by the propulsion system, for navigation (and for trawling in the case of trawlers), by the deck machinery, like winches, water pumps, lights, chillers, and any other energy user. In a more complex layout, two engines are used during fishing activity; a main engine is devoted to propelling the vessel (and trawling the fishing net in case of trawlers), while another engine is used as GenSet for supplying all the other energy users. Only a portion of the energy available is properly transformed into energy used by energy users, such as propulsion systems, electric devices, winches, cranes, etc. A considerable amount of energy is discharged in the form of heat, due to technical constraints, through exhaust gases and the cooling system of the engines.

Technical information

Definition of the Innovative gear

A portion of the heat loss can be re-used to supply a Waste heat recovery System (WHRS), based on the Rankine thermodynamic cycle (ORC), where an organic-based thermodynamic fluid is used to collect the heat waste and generate electric energy through a turbine, which can be used to supply electric devices and reduce the energy requested to the internal combustion engine, lowering the amount of fuel used. The ORC system is based on 4 main components: a high-temperature heat exchanger, that collect heat from exhaust gases or from the cooling system of the engines and transfer it to the fluid; the fluid is overheated, changing from liquid to gas at high pressure and flooded to the turbine, which produces electric energy. The energy produced is sent to all the demanding electric users, determining a lowering of the load. After the turbine, the fluid has loss most of the heat energy absorbed in the high temperature heat exchanger and to conclude the thermodynamic cycle it is sent to a low-temperature heat exchanger to be transformed again in fluid and start another cycle. A devoted pump oversees the motion of the fluid, and it is regulated automatically by the electronic control system of ORC, to adjust the mass flow and the fluid speed according to the heat available and the energy demand from the electric users. The system is totally unmanned and does not require frequent or relevant maintenance.

Technical specificities

An innovative patented ORC system was integrated in a proprietary ORC module, consisting of a high performance microturbine, able to convert low and medium temperature waste heat into electricity with high efficiency. Compared to a standard layout of a fishing vessel, the implementation of the ORC system can contribute to increase energy efficiency of the vessel, which means fuel saving and reduction of pollutant emissions.

Outcomes expected

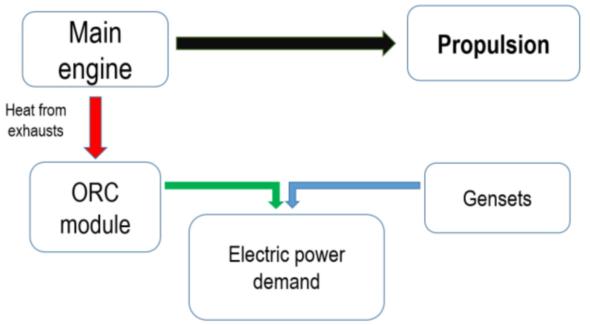
The WHRS based on ORC has the potential to enhance the energy efficiency and environmental performance of fishing vessels by utilizing waste heat for electricity generation. However, successful implementation requires careful consideration of design, fluid selection, and integration to ensure seamless operation and maximum benefits.
Based on the energy demand, a technical plan has been conceived, based on the recovery of heat from the main engine, to produce electricity for the energy supply of three water pumps, normally driven by auxiliary engines. The reduction in such Diesel engine usage could also represent a relevant fuel saving, as well as GHG emission reduction.

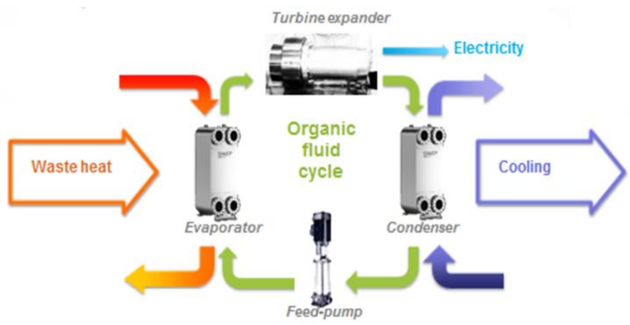
Other relevant information

EU Life+ Project “Efficientship fuel saving in fisheries through heat recovery from main engine” (LIFE13 ENV/FR/000851).
Notti *et al.* (2016), Ng *et al.* (2020), Chen *et al.* (2023).

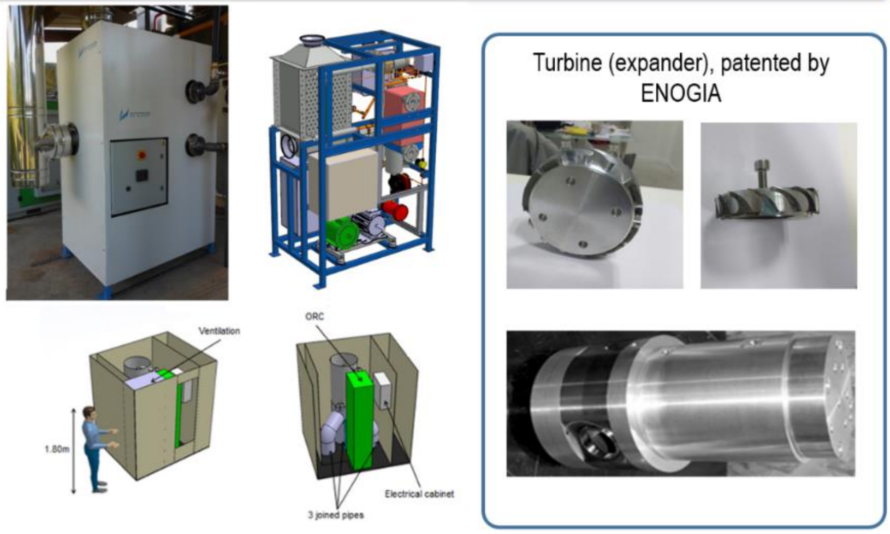
Drawing / picture of the Innovative gear

Design of the ORC module architecture





ORC system design



Evaluation of the expected impact of the ORC module

Nominal consumption onboard

GenSets': Caterpillar 3304B - 106kVa: 50A constant load ⇔ 9.7L/h ⇔5.6€/h (0.58€/L)

Vessel profile: 7500 hours/year

High-low load distribution: 40% / 60%

Economic saving: 6,000 €/year

CBA			
Fuel consumption		9.70	l/h
Fuel cost		0.58	€/l
Working hours		7,500	h/y
High load	60%	4,500	h/y
Low load	40%	3,000	h/y
Hourly cost		5.63	€/h
Fuel cost at high load		25,317	€/y
Money saving		6,000	€/y
Investment		50,000	€
ROI		12	%
PBP		8.3	y

Source: modified and adapted from (Notti et al., 2016).

Technological Performance assessment

Main criteria............... Environmental impact (reduction of GHG emissions)
Additional criteria ..... Energy efficiency, energy savings, compatibility with cold ironing.

Technological readiness level (TRL)

TRL category............. Moderate **TRL scale** TRL6

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Not applicable **Selectivity** .... Not applicable **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Maybe
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ High
Return on Investment........ Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake

The environmental impact of fishing activity is considered a primary constraint, policy makers at national and international levels are sensible to any potential solution to decrease the level of emission of pollutants into the environment.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
The opportunity provided by the WHRS to reduce fuel consumption is a positive factor, especially when the fuel cost rises as occurred during last decades. For the time being, the investment costs of an ORC system are high and detrimental to the return of investment, due to economic scale. However, next years will be characterized by important strategies and directives (e.g., EMFAF, European Green Deal, etc.) which focus on stimulate and support the investments in modernization aimed at reducing environmental impact.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
The positive effect on the environment deriving from the use of a WHRS could be considered as a contribute to promote the fishing products, according to the "willingness to pay approach", where consumers are sensible to market products that can report a more environmental-friendly harvesting process.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ It is a barrier
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Not Applicable

6.1.10 Factsheet 10. Lobster condos

General information

Year 202-2021

Region .... *Non-specific area*
There is interest in some overseas territories of France in the Caribbean in using these new condos. Also in the Dutch BES islands their use is being considered.

Gear sub-category .... Pots

Target species .... MDV

Source supplier .... Raymon Van Anrooy. *Revised by Robin Faillettaz, and Melanie Underwood.*

FAO-Area .... *Western Central Atlantic*

Gear code .... MDV

Bycatch species .... *Not applicable*

Baseline gear

Casitas (or condominiums) commonly called condos are not a fishing gear but act more like Fish Aggregating Devices (FAD) stored on the bottom. They are often made of wood and roof tins and cinder blocks and look like a pallet. The spiny lobster (*Panulirus argus*) likes to shelter under them, and divers can easily collect them with lifting the pallet (condo). Even though other fishing gears like baited pots are also widely used in the Caribbean Region for spiny lobster fishing, the condos are the most important gear used in Mexico, Belize, and the Bahamas for spiny lobster harvesting.

Technical information

Definition of the Innovative gear

The innovative condos are made of one piece of corrugated coated steel sheets with a coating, which does not require construction or repair by the fishers. The dry weight is about 16 -18 kg per condo, which is still easy to carry/lift and sufficient to avoid that they are washed away with the sea current.

Technical specificities

	Traditional condos	Innovative condos
Size	Length 182 cm x width 86 cm. height depending on plank size	Length 223 cm x width 114 cm x height 15 cm
Materials	2 wooden planks (pressure treated, PT), roof tin, nails, cinder block and rope	Corrugated and coated steel sheet (thickness approx. 0.7 mm to 1.0 mm)
Coating/paint	No	*Galvalume* AZ150 (0.02mm per side)

Outcomes expected

The innovative condos are expected to provide shelter to spiny lobsters similarly as the traditional condos or casitas. The benefits of these new type of condos are:

1) Their weight will reduce losses of condos during storm surges and hurricanes.
2) They are easy to transport on small-boats and set at the seabed
3) Replacing the treated wooden planks with the corrugated and coated steel sheets will reduce the release of toxic Chromated Copper Arsenate (CCA) from pressure treated wood in the aquatic environment.
4) The corrugated and coated steel sheets are expected to last longer in seawater compared to roof tin sheets traditionally used. Corrosion should be much slower.
5) The cost price is comparable with or slightly cheaper than the traditional condos USD 30 - 35, and fishers do not have to spent time on construction.

FAO- Government of The Bahamas Technical Cooperation Programme (TCP) project (TCP/BHA/3703) "*Rebuilding fisheries livelihoods in Abaco and Grand Bahama islands following Hurricane Dorian*", introduced the innovative condos in The Bahamas in 2020-2021. A total of 3750 of these new condos were distributed among hurricane affected fishers.

Other relevant information

Website: *https://www.fao.org/jamaica-bahamas-and-belize/news/detail-events/en/c/1413307/*

FAO, 2016. La casita El refugio artificial como una forma alternativa para la pesca responsable de langosta en la Región Autónoma del Caribe Norte de Nicaragua. https://www.fao.org/documents/card/en/c/7f8e143b-20f6-4ba6-8d19-3174d770f9b4/
Website supplier: https://www.nortide.com/

Drawing / picture of the Innovative gear

Condos distribution in June 2021. Courtesy of FAO-NFIFO.

Technological Performance assessment

Main criteria............... Reduced environmental impact from condo construction materials and reduced water pollution from chemicals in treated wood condos when lost.
Additional criteria ..... Increased economic lifespan of gear

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Yes, easier
Is the innovative gear easier to maintain and repair? .... Yes, easier
Does using the innovative gear present a lower risk to the health and safety of crew? .... Maybe

Economic Performance assessment

Capital cost category .... Moderate
Return on Investment .... Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
The Department of Marine Resources of The Bahamas was in favour of this innovation.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
The condos were introduced as disaster risk mitigation tool, to reduce future losses of condos during storms, and to rehabilitate the sector after cat. 5 Hurricane Dorian.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Given that the new condos are fabricated and imported as ready to use from China, there will be a few carpenters that have less work in traditional condo construction. It was however mentioned by fishers that most of the would construct the condos themselves and that they found it a hassle. All the materials for the traditional condos are also imported, but from the USA.

Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Has encouraged uptake
The fact that the innovative condos are easier to transport on small boats and to deploy at sea is positively contributing to their uptake.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
The Department of Marine Resources of The Bahamas promotes these condos because of anticipated less environmental impact.

Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... Not Applicable
Not any relevant legislation has been issued in favour or against the traditional and/or new condos.

6.1.11 Factsheet 11. Versatile hand-held (3D) machine vision unit allowing catch analysis on small fishing vessels (*CatchSnap*)

General information

Year 2018-ongoing

Source supplier .... Marieke Desender, *with text adapted from Birch et al. (2022).*

Region .... *Non-specific area*

FAO-Area .... *Not applicable*

Gear sub-category .... Gears unknown or not specified

Gear code .... *Not applicable*

Target species .... *Not applicable*

Bycatch species .... *Not applicable*

Baseline gear

Small fishing vessels.

Technical information

Definition of the Innovative gear

CatchSnap is a versatile handheld 3D machine vision unit for inspecting catch samples on small fishing vessels. The CatchSnap-Commercial is a mobile product which will aid in the automatic registration of catch information in commercial fisheries. The CatchSnapRecreational is a mobile product which will aid in the automatic registration of catch information in recreational fisheries.

Technical specificities

CatchSnap processes photographs or video material and other data via a machine learning algorithm that can identify fish or shellfish and lengths and weights of the catch. Images are captured with a low-cost small camera or smartphone. Fish are ideally placed on a CatchSnap board within a green area. The technology has been further developed for different sampling methods.

A special purpose variant of CatchSnap, the CatchCam, applies image analysis technology to enable automated catch monitoring for small shellfish potting vessels catching crabs and lobsters. Configuring the low-cost camera and downloading data such as videos and GPS data can be accessed through a WiFi accessible webpage using a tablet, laptop, or mobile phone.

A special application was also developed in the Scottish *Nephrops* fishery utilizing an Intel RealSense L515 Lidar camera to capture depth and colour images of baskets and their caught content.

Outcomes expected

The CatchSnap system was successfully tested onboard bottom trawler, purse seiners and RV in the Bay of Biscay. Pictures taken of blue whiting, hake, anchovy, and sardine using a CatchSnap calibration board were used to enhance the training of AI algorithm image analysis. Coloured and binary images are used to respectively classify the species and estimate the length and weight of the fish. The CatchCam is trained to differentiate between crabs and lobsters, sex of the individuals and to automate the capture of length data. In the Scottish demersal *Nephrops* fishery a CatchSnap system was developed using a 3D camera to estimate the weight and catch composition based on the visible top layer of fish in the basket. Onboard the RV a range of species commercially caught in the North Sea and West of Scotland was also tested. The CatchSnap technology is being further developed in the EU-project Everyfish (https://everyfish.eu/technologies), which will aid towards fully automated catch recording and reporting in commercial and recreational fisheries.

Other relevant information

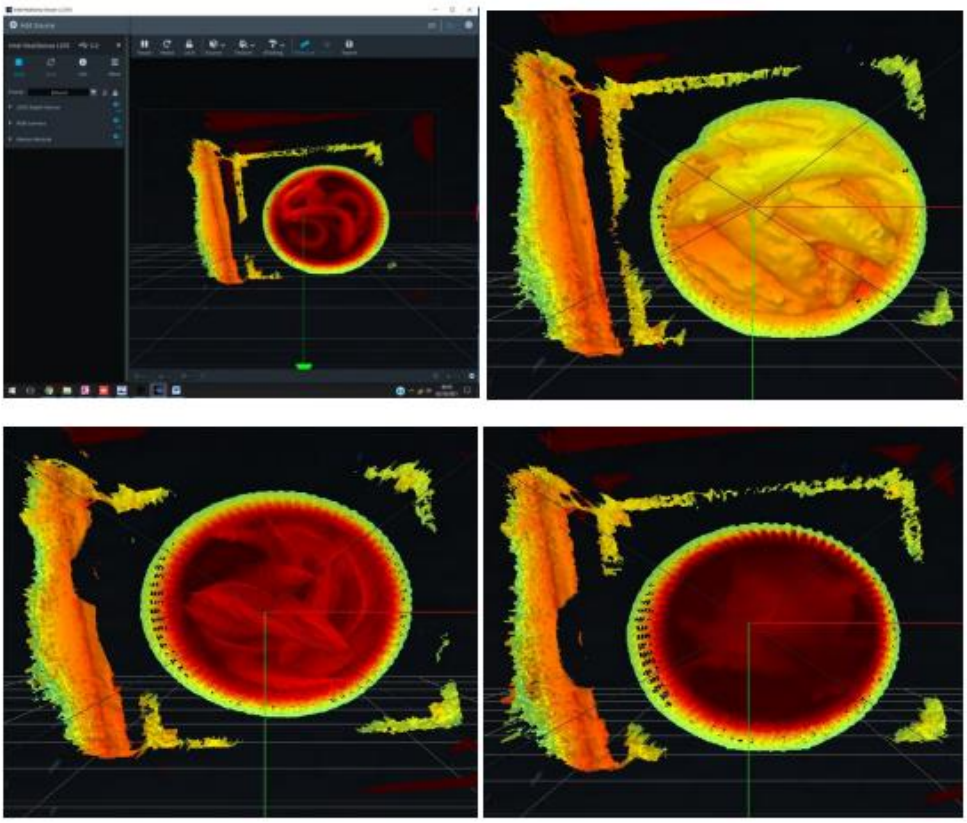
Smart fisheries technologies for an efficient, compliant, and environmentally friendly fishing sector | SMARTFISH | Project | Results | H2020 | CORDIS | European Commission (europa.eu): https://cordis.europa.eu/project/id/773521/results

Digital transition of catch monitoring in European fisheries (EU project EveryFish): https://everyfish.eu/technologies

Calderwood *et al.* (2023).

Drawing / picture of the Innovative gear

Blue whiting and hake on the CatchSnap board.



Depth quality tool software to estimate weight and catch composition in a basket.

Technological Performance assessment

Main criteria............... Impact on vulnerable species.
Additional criteria ..... Catch estimation, size, sex, and species identification.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Not applicable **Selectivity** .... Not applicable **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Unsure
Is the innovative gear easier to maintain and repair?.......... Unsure
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category.......... Low
Return on Investment.......... Unknown
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political** factors had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic** factors had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **social** factors had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological** factors had on uptake of this gear?.................... Do not know
Overall, what impacts do you think have **environmental** factors had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal** factors had on uptake of this gear?.................................. Do not know

6.1.12 Factsheet 12. Passive excluder device (ExFED) to limit the size of the trawl catch and allow excess catch to escape at depth

General information

Year	2012	**Source supplier**	Melanie Underwood, *with text adapted from ICES (2014), CRISP (2016), and CRISP (2019).*
Region	*Trialled in the Barents Sea, but solution is global. Option for wider application.*	**FAO-Area**	27.1
Gear sub-category	*Any trawl gear*	**Gear code**	BT, TB, TM
Target species	*Gadoids*	**Bycatch species**	*Not applicable*

Baseline gear

Any conventional trawl with or without other excluder devices.

Technical information

Definition of the Innovative gear

From approximately 2010, the industry observed excessively large trawl catches due to high populations of cod in the Barents Sea. This resulted in reduced quality when the catch exceeded the vessel production capacity, increasing risk of discarding, gear damage and safety concerns. On the request of industry, Institute of Marine Research. Bergen, Norway, developed a passive excluder device that optimises the catch size and allows excess catch to escape the trawl at depth.

Technical specificities

The Excess Fish Exclusion Device (ExFED) consists of a fish lock just behind a hole in the upper trawl panel covered by a mat attached only at its leading edge. The fish lock prevents the target quantity of fish from escaping during haul back. Initially, the mat lies against the top panel of the trawl sealing the hole. As fish accumulate in the codend and fill up to the fish lock, water flow is diverted out the hole, lifting the mat and allowing excess fish to escape at the fishing depth. The Exfed is mounted at a distance from the codend to achieve the target size catch for the vessel.

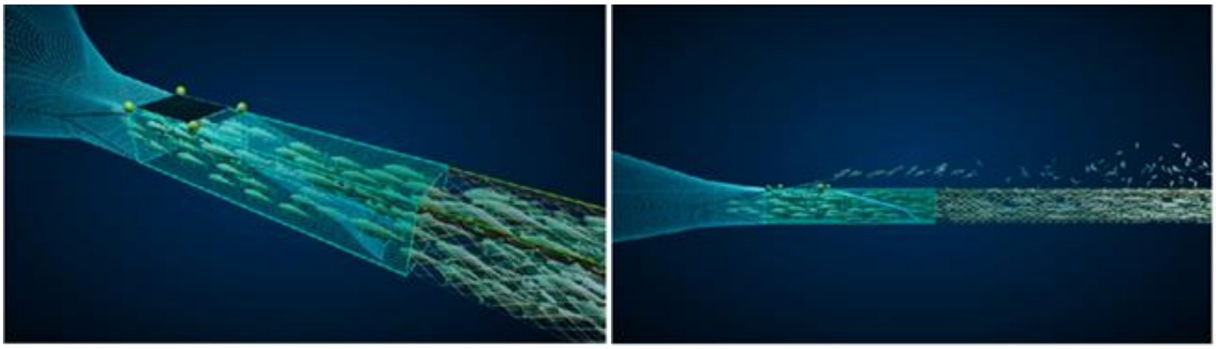
Outcomes expected

Six Norwegian vessels were given approval to use the system during commercial fishing in 2013. The ExFED system reduced the risk of excessively large trawl catches and has been improved based on the feedback from the commercial fleet. In 2019, 21 Norwegian trawlers were given permission to use the system.

Other relevant information

ICES (2014), CRISP (2016), CRISP (2019).

Drawing / picture of the Innovative gear



Source: modified and adapted from CRISP (2016) and CRISP (2019).

Source: modified and adapted from CRISP (2016) and CRISP (2019).

Technological Performance assessment

Main criteria............... Catch efficiency, impact on ETP species.
Additional criteria ..... Increase fishing efficiency and profitability.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Not applicable **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... Yes, lower

Economic Performance assessment

Capital cost category.. Low
Return on Investment.. Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Restricting the size of the catch allows for better quality product and reduces gear damage.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
A very simple system using materials commonly found.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
High cod numbers have driven this innovation.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. It is a barrier
Commercial fleet need to get approval to use the system.

6.1.13 Factsheet 13. Rigid codend with triggered drafting gate

General information

Year 2019

Source supplier ....Emma Jones (NIWA) and Karl Warr (Better Fishing Ltd)

Region....*Developed in New Zealand, but solution is global. Option for wider application.*

FAO-Area ....*Not applicable*

Gear sub-category ....*Any trawl gear*

Gear code ....BT, TB, TM

Target species....Red gurnard, flatfish

Bycatch species....*Undersized target species*

Baseline gear

Any conventional trawl gear with mesh codend.

Technical information

Definition of the Innovative gear

Rigid cage-style codend with prototype of an active, “in-trawl” fish selection system that can detect, unwanted bycatch and then release it ahead of the codend to optimise the trawling process.

Technical specificities

The system consists of a rigid cage style codend for precise selectivity, with a triggered drafting gate mechanism incorporated into the design. A live feed camera system in front of the drafting mechanism allows it to be manually triggered, with an automated fish detection application in development to detect, track and classify the fish viewed by the camera. The system includes:

- real-time video delivered to an inshore fishing vessel via a combination of towed cable and moving wi-fi platform. This allows real-time monitoring of catch rate and catch composition;
- a robust rigid gate that can open and close an escape pathway at the front of the codend, allowing unwanted catch to be released and then continue fishing;
- a codend with rigid apertures to maintain consistent selectivity and release undersized fish. Panels with different aperture dimensions interchangeable depending on target species;
- a fast and robust deep learning pipeline framework for detection, tracking and classification of fish coming in view of an underwater camera that can run in real-time.

Outcomes expected

The rigid mesh panel design of the codend provides precise selectivity and minimizes catches of undersized fish. The triggered drafting gate combined with live feed video allows the catch to be monitored during the tow and manual release of larger non-target or unexpected species. Fishing can be stopped early if the net encounters areas of less fishable grounds. Computer vision technology enables detection, classification and tracking of fish, allowing automated control over which species are caught and which are released.

Other relevant information

Yang *et al.* (2023).

Project: Novel high-tech underwater selection tools for environmentally and economically sustainable fishing (https://tetiniatangaroa.org.nz/projects/novel-high-tech-underwater-selection-tools-for-environmentally-and-economically-sustainable-fishing)

Drawing / picture of the Innovative gear


Courtesy of Emma Jones (NIWA).

Technological Performance assessment

Main criteria............... Catch efficiency, impact on ETP species
Additional criteria ..... Increase fishing efficiency and profitability.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category.......... High
Return on Investment.......... Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
The rigid codend itself is a relatively low cost. High costs of camera and drafting gate technology are currently a barrier to uptake.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
There has been considerable local support for the use of the rigid codend and the perceived improvements in sustainability, with premium prices achieved.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. It is a barrier
The perceived level of technological investment & robustness likely a current barrier to uptake.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................ It is a barrier
The requirement of the industry to fund the demonstration of performance levels of gear to achieve approval is a barrier to uptake, along with limitations on use of third wire onboard vessels.

6.1.14 Factsheet 14. Biodegradable nets to reduce ALDFG and solutions to improve end-of-life recycling

General information

Year	2018-ongoing	**Source supplier**	Marieke Desender, Peter Randall
Region	*Non-specific area*	**FAO-Area**	*Not applicable*
Gear sub-category	*Any fishing gear*	**Gear code**	*Not applicable*
Target species	*Not applicable*	**Bycatch species**	*Not applicable*

Baseline gear

Nets currently used for aquaculture (made of polyester and polypropylene) and fishing activities (polyamide, nylon).

Technical information

Definition of the Innovative gear

Biodegradable nets to reduce ALDFG and solutions to improve end-of-life (EOL) recycling of fishing gear.

Technical specificities

There are several projects covering the development of biodegradable gear(parts) in the marine environment and/or the improved recycling of fishing gear at the end of its life, two are listed below.

The **INdIGO** project (http://indigo-interregproject.eu/en) covers all aspects of net development including the supply chain, manufacturing, prototype development, testing and technical and economic analysis. A lifecycle analysis was also performed. The project also includes an educational aspect through the development of a mobile application to locate gear already lost (Charter and Trevor, 2022). This will enable the mapping of pollution in the cross-Channel zone area and will raise awareness of plastic pollution among divers, walkers, and fishermen. Tasks of the project concerns the development of the prototype of the new fishing gear for the fisheries and aquaculture sectors. The first step is the development of the formulation from biodegradable plastics. This formulation will then be transformed in order to make semi-products: a monofilament and multifilament. These semi-products will then be used for the design and manufacture of prototype nets on an industrial scale.

Also, the Norwegian project **Dsolve** (https://uit.no/research/dsolve-en) is developing a range of biodegradable materials needed for use in fishing and aquaculture industries. These materials are tested for biodegradability and environmental impact. Their performance, catch patterns and efficiency is being analysed via gear trials at sea. Costs, benefits, and public support analysis together with outreach will promote the implementation of these innovations. Additionally, sustainable circular solutions will be considered.

Outcomes expected

In the framework of the **INdIGO** project, two semi-finished products of biodegradable materials in the marine environment, monofilament and multifilament were developed. Subsequently the filaments were implemented in 2 prototype fishing nets. A fine net for the Lorient Gillnet fishing industry and a catenary net for mussel aquaculture was aimed to be produced. For the latter, various knitting tests have made it possible to manufacture a tubular multifilament net that is tested in situ in 2023. The industrial production of fine nets was hampered because of a relocation of production outside of Europe. **Dsolve** project shows that slow deterioration of biodegradable gillnets made of polybutylene succinate co-adipate-co-terephthalate (PBSAT) may be beneficial to reduce ghost fishing (Brakstad *et al.*, 2022). However, biodegradable gillnets significantly retained 25% fewer cod compared to nylon gillnets (Cerbule *et al.*, 2022a). Also, Grimaldo *et al.* (2018a; 2018b; 2019; 2020) noted lower catch efficiency for saith, halibut and cod in biodegradable gillnets. Application of biodegradable materials in snoods used in the longline fishery did not show significant differences in catch efficiency when compared to nylon snoods (Cerbule *et al.*, 2022b).

Other relevant information

INdIGO Project website: http://indigo-interregproject.eu/en/deliverables/
DSolve – Biodegradable plastics | UiT website: https://uit.no/research/dsolve-en

Grimaldo et al. (2018a), Grimaldo et al. (2018b), Grimaldo et al. (2019), Grimaldo et al. (2020), Brakstad et al. (2022), Cerbule et al. (2022a), Cerbule et al. (2022b), INdIGO (2023), Mengo *et al.* (2023).

Drawing / picture of the Innovative gear


Knitting of a tubular biodegradable multifilament net. *Source: modified and adapted from INdIGO (2023).*

Prototype	16/40 version 1
Number of meshes for the whole perimeter	16
Titration of unbleached filament	1380 dtex - 48 filaments
Flat stretched width	64 cm
Diamond side length	40 mm
Weight of stretched mesh	About 16 gr/m

Specifications of the aquaculture multifilament tubular net prototype. *Source: modified and adapted from INdIGO (2023).*

Diameter of monofilament	0,45 mm
Mesh type	Diamond-shaped mesh
Mesh aperture size (stretched dimension)	100 mm
Knot type	Double knot
Dimension of net prototype	Length 50 m Height 60 or 80 MD

Monofilament net specifications. *Source: modified and adapted from INdIGO (2023).*

Technological Performance assessment

Main criteria............... Reduced catch efficiency, reduced environmental impact (*ghost fishing*).
Additional criteria ..... Economic cost benefits, Biodegradability.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Negative **Selectivity** .... Negative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... Unsure
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category .... High
Return on Investment .... Negative
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Yes, higher

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Production costs of gear development in Europe can be high. Catch efficiency lower for tested gillnets. On the other hand, the INdIGO project (see WP1 at http://indigo-interregproject.eu/en/deliverables/) demonstrated an increase in profitability when using Biodegradable fishing gear.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Do not know
It is a promising technology but still being developed and needs to be tested before it can be taken up.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Reduce the impact of ghost fishing and plastic waste.

Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... It is a barrier
A questionnaire revealed that fishers on both sides of the Channel have insufficient awareness about management measures or regulations for EOL fishing gear (Mengo et al., 2023).

6.1.15 Factsheet 15. Larger codend mesh size (400 mm) to reduce by-catch in skate fishery

General information

Year 2021

Source supplier .... Alex Edridge*, with text adapted from Arkhipkin et al. (2023). Reviewed by Emma Mackenzie and Robin Faillettaz.*

Region .... *Trialled in Falkland Islands, but solution is global. Option for wider application.*

FAO-Area .... *Not applicable*

Gear sub-category .... Bottom trawls

Gear code .... OTB

Target species .... BZB, DPV, BZM, BYG, BZS

Bycatch species .... *All finfish.*

Baseline gear

Conventional trawl with 110 mm codend mesh size.

Technical information

Definition of the Innovative gear

Increase of codend mesh size from 110 mm diamond to 400 mm diamond mesh.

Technical specificities

The Falkland Islands skate licence was, until January 2021, held to the same regulatory net standard as other trawl licences: minimum 110 mm diamond mesh in the codend. However, skate-licensed trawlers were permitted to use one or several tickler chains in front of the ground rope to "lift" skates from the sea bottom, increasing the effectiveness of their catches. All Falkland Islands licenced vessels must transmit a daily catch report, which includes midday and midnight positions referenced to a grid of 0.25◦ latitude × 0.5◦ longitude.

The skate licence permits targeting all species of skate, with other fish and invertebrates being classified as bycatch. All catch and bycatch species must be recorded in the daily reports. Commercial non-target bycatch for which a vessel is not licenced to fish must not exceed 10% of the vessel's daily aggregate catch. If bycatch exceeds 10%, The vessel must change fishing position by a minimum distance of one grid square and not return to the original fishing grid position within 10 d. If the bycatch continues to exceed 10%, the vessel owners and master may be prosecuted for breach of this licence condition.

The Falkland Islands Government implemented a regulatory licence condition of 400 mm codend mesh for targeted skate fishing. Besides greater production efficiency, vessel operators are incentivized by possible wider access throughout the fishing zone. Further initiatives are anticipated to develop management measures by individual species

Outcomes expected

The results of the trial confirmed the efficiency of larger mesh codends to decrease finfish bycatch by 97-98%. The Falkland Islands Government implemented a regulatory licence condition of 400 mm codend mesh for targeted skate fishing.

Other relevant information

Arkhipkin *et al.* (2023)*, Regulation (EC) 1386/2007 (2007), repealed by Regulation (EU) 2019/833 (2019).*

Drawing / picture of the Innovative gear

Not available.

Technological Performance assessment

Main criteria .... Reduce finfish, juvenile skate and ray bycatch.

Additional criteria ..... Reduced prosecution from breach of license condition. Possible fuel efficiency.

Technological readiness level (TRL)

TRL category .... High **TRL scale** TRL9

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Disruptive **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?.......... Maybe
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.......... Low
Return on Investment .... Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Vessel operators are incentivized by possible wider access throughout the fishing zone.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
This bottom trawl fishery is characterized by relatively low catch volumes and product yield that challenge commercial profitability. The results of the trial confirmed the efficiency of larger mesh codends to decrease finfish bycatch by 97-98%.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
It is a personal opinion, but given the reported 97-98% bycatch reduction I would think that social factors would encourage uptake.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
It is a personal opinion, but I believe given that changing codend mesh size is just a fairly low-cost alteration to the trawl. This trial was driven by the company that acquired a large proportion of the skate ITQ so I would say it has encouraged uptake.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
This bottom trawl fishery is characterized by relatively low catch volumes and product yield. Skate-target trawling takes substantial amounts of bycatch.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Has encouraged uptake
As a result of the trial, the Falkland Islands Government implemented a regulatory licence condition of 400 mm codend mesh for targeted skate fishing.

6.1.16 Factsheet 16. 3D machine vision system and Machine Learning solutions for onboard catch analysis (*CatchScanner*)

General information

Year 2022-ongoing	**Source supplier** .... Antonello Sala, *with text adapted from Birch et al. (2022). Horizon 2020 project SmartFish (Smart fisheries technologies for an efficient, compliant and environmentally friendly fishing sector).*
Region .... *Non-specific areas*	**FAO-Area** .... *Not Applicable*
Gear sub-category .... Gears unknown or not specified	**Gear code** .... *Not Applicable*
Target species .... *Pelagic and demersal species*	**Bycatch species** .... *Not Applicable*

Baseline gear

Any commercial and conventional fishing gear.

Technical information

Definition of the Innovative gear

The CatchScanner is a 3D machine vision system for catch analysis on onboard conveyor belts. It was developed in the EU project SmartFish, and tested in large-scale pelagic and demersal fisheries (Birch *et al.*, 2022). Real-time information can be collected, along with images for length estimates and species recognition also for quality control. Weight data may be supplied directly from the grader machine, with the CatchScanner facility to estimate weight an option to provide additional quality assurance.

Technical specificities

During the SmartFish project the setup consisted of a 16A-13A power supply conversion, cellular data internet connection, an optional DSLR camera, a high framerate video camera, and a Python-capable microcomputer (Raspberry Pi). The cameras were mounted on a free-standing adjustable scaffold frame 'camera stand' where the Raspberry Pi is contained in aluminium enclosure beside the cellular data internet router, with the high framerate video camera looking down on the grader machine (Birch *et al.*, 2022).

Outcomes expected

The image analysis solution would be "non-invasive," avoiding the risk to business operations posed by modifying grader machines directly (Birch *et al.*, 2022). It could also be transferrable between different manufacturers and models of grader machines, including existing older machines.

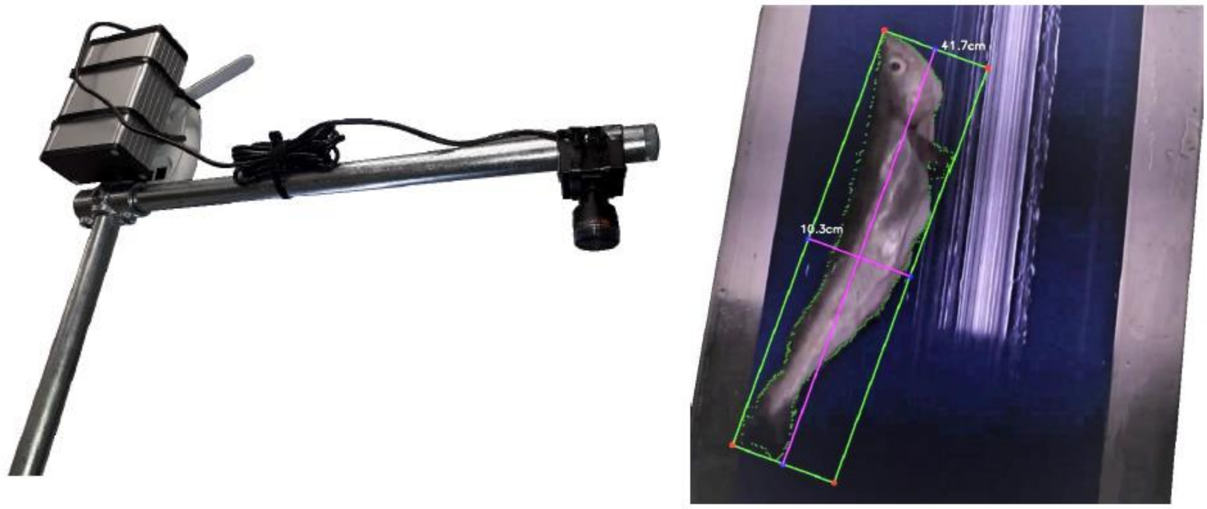
The evaluation by Birch *et al.* (2022) shows that automated onshore market fish grader machines can be used to collect weight data to supplement but not fully replace current sampling for stock assessment and EU data collection requirements. Sample matching be carried out between grader and manual sources, weight and length distributions can be estimated, and spatial information linked from landings records. The grader machine and manual sources have complementary strengths, grader machines producing far more samples at finer time scales, while manual sampling provides coverage of more species, better sampling of the smallest landings and addresses species-specific challenges. A hybrid sampling approach is therefore envisioned as the most effective route for further work. Implementing computer vision methods will enhance the data collected.

The CatchScanner technology developed in the SmartFish project offers a comprehensive solution, while video recording combined with CatchMonitor (Factsheet 54) algorithms was demonstrated as a method to collect data from existing grader machine setups. As automatically collected length and weight data become more common, then developing and deploying calculations for combining these different data sources with appropriate weighting and estimation of uncertainty is required as an area for further work.

Other relevant information

Krag *et al.* (2022), Birch *et al.* (2022).
Project website: http://www.smartfishh2020.eu/
CORDIS website: https://cordis.europa.eu/project/id/773521

Drawing / picture of the Innovative gear



Test prototype for the standalone machine learning camera (CatchScanner). On the right-hand side, video still of a whiting, automatically extracted and outlined from video using computer vision. Lengths and widths were estimated with a basic rectangular bounding box. *Source: modified and adapted from Birch et al. (2022).*

Technological Performance assessment

Main criteria............... Catch efficiency.
Additional criteria ..... Catch quality.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Not applicable **Impact** .... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair?........ No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment........ Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Do not know

6.1.17 Factsheet 17. Lobster anti-ghost fishing device (*Eco-trap*)

General information

Year 2023

Source supplier ....Vanildo Souza de Oliveira and Kelsey Richardson. Glolitter Partnership Project (https://www.imo.org/en/our-work/partnershipsprojects/pages/glolitter-partnerships-project-.aspx)

Region...............................Trialled in Southwest Atlantic *(but solution is global. Option for wider application)*

FAO-Area ....*Not applicable*

Gear sub-category ....Pots

Gear code ....FPO *(single or in strings)*

Target species.................SLC, NUL

Bycatch species...........NUE; SLV; YLA; YLI; YLD; YLF

Baseline gear

Pots or Traps are transportable fishing gear with one or more openings (entry funnel), for the entrance of lobsters or fishes, being very effective in capturing demersal species with little movement that live close to the bottom. Commonly used traps in Pernambuco are wooden-made and quadrangular, with 0.90m on each side and 0.35m in height. The entry funnel is tapered in shape and has a smaller diameter between 20 and 15 cm, and one valve is placed on a single entrance. These funnels can be made of wood, bamboo, wire, or mesh that are attached to the wall of the traps and stretched with rods inside the traps. On the top face or side, there is an opening (view window) to remove the lobster/fish captured.

Technical information

Definition of the Innovative gear

Eco-traps is planned to reduce ghost fishing in lobster traps compared to the 'normal' lobster traps. Eco-traps are collapsible, which facilitates their storage on the deck of fishing vessels. This allows for easy dismantling of the traps. Eco-trap designs include a lobster exclusion device on the bottom side panel and two fish-exclusion devices on the front panel. Eco-traps were built with iron and included cotton yarn and sisal twine as biodegradable materials to fix the one trap panels to the iron frames aiming at preventing and minimizing ghost fishing, namely an 'Anti-Ghost Fishing Device' (AGFD).

Technical specificities

	Traditional trap	Innovative trap
Size	Length 90 cm x width 90 cm x. height 35 cm	Length 90 cm x width 90 cm x. height 35 cm
Materials	Mangrove tree's wooden frame, chicken crop mesh and wire to fix the mesh. The entry funnel is made with local straw	Iron rods and aluminum tubes are used in the construction of the Eco-trap: 6mm, 8mm and 10mm diameter iron rods and 30mm diameter aluminum tubes is necessary to construct the Eco-trap
Coating/paint	No	No

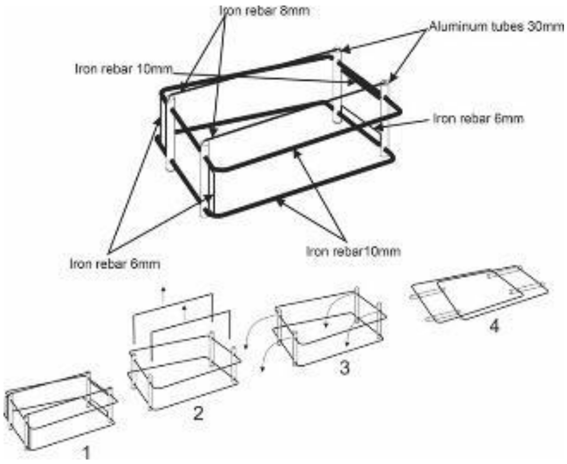
Outcomes expected

An Eco-trap with an Anti-Ghost Fishing Device (AGFD) that uses biodegradable material is developed and tested. Local fishing communities are aware of the need for the proposed Eco-traps, their AGFD modification and performance.

Other relevant information

Eco-traps experiments are being developed in collaboration with the Laboratory of Sustainable Fishery (LAPESU) of the Department of Fisheries and Aquaculture (DEPAq) of the Federal Rural University of Pernambuco (UFRPE): http://www.depaq.ufrpe.br/.

Drawing / picture of the Innovative gear



The Food and Agriculture Organization of the United Nations (FAO) and the *Fundação Apolônio Salles de Desenvolvimento Educacional (FADURPE)* (https://fadurpe.com.br/) signed a Letter of Agreement to conduct the project Testing and promoting fishing gear innovation to reduce ghost fishing of lost lobster traps in Brazil, under the Glolitter Partnerships Project Activity 4.2.1 focuses on supporting the testing of gear modifications in selected small-scale fisheries to reduce ghost fishing. Glolitter is implemented by the International Maritime Organization (IMO) and FAO, with initial funding from the Government of Norway via the Norwegian Agency for Development Cooperation (Norad).

Technological Performance assessment

Main criteria............... Selectivity and environmental impact, through gear innovation to reduce ghost fishing of lost.
Additional criteria ..... Fishers economic losses: material loss; and fish and/or lobster that would be caught to generate income will get trapped and die. Damage to fishing stocks: committing the sustainability of the fishing activity. Damage to the environment - seas and oceans: receive all degraded material (synthetics), which turns to waste.

Technological readiness level (TRL)

TRL category............. Moderate **TRL scale** TRL4

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?.......... Yes, easier
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.......... High
Return on Investment.......... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Maybe

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know

As a first experience in Brazil, political factors to implement an anti-ghost fishing device rely on fishers long standing perceptions of social, economic and environmental benefits and willingness to technological changes.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know

As economic factors rely on the overall catches, target species and bycatch, preliminarily cost-effectiveness will decrease, once small and juvenile specimens will be released, as the eco-trap designs include a lobster exclusion device on the bottom side panel and two fish-exclusion devices on the front panel.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know

Together with the strengthening of institutions involved, improved communication between all stakeholders, and capacity building, this process shall create significant gains in social capital that we believe will allow for sustainable improvement of livelihoods, including the effective introduction of technological innovations.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. It is a barrier

Technological change remains stubbornly hard to come by. The harsh circumstances and the complex reality faced by commercial fishers often make it challenging to undertake technological adoptions. The solutions defined and developed by fisheries scientists and managers do not always meet the reality faced by fishers.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know

Most significant and expected contribution would be the interest from local fishers to reduce ghost fishing, alongside the reduction of fishing operation costs because, in general, they do not believe that their fishery poses a marked threat to the environment.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Not Applicable

The technological innovation meets the current legislation. Nevertheless, improving fisher's uptake will require new lobster fisheries regulations and the construction of public policies regarding grants and economic incentives, enhancing the fishers' voices in the technological change process.

6.1.18 Factsheet 18. Modified gillnet to reduce ghostfishing and to aid recover of lost gear

General information

Year	2023	**Source supplier**	Eric Okuku (Kenya Marine Fisheries Research Institute) and Kelsey Richardson (FAO).
Region	Trialled in Indian Ocean, *Western Subarea 51.5 Somalia, Kenya and Tanzania (but solution is global. Option for wider application)*	**FAO-Area**	*Not applicable*
Gear sub-category	Gillnets	**Gear code**	GNS
Target species	Benthic and demersal species including emperor, rabbitfish, rays, shark, kingfish, tuna, flounder, needlefish, halfbeak and lobster.	**Bycatch species**	Turtle, shark, dolphin, marine mammals and and sea birds

Baseline gear

The baseline fishing gear is conventional multifilament nylon gillnet of various twine sizes and mesh sizes. The gillnets are suspended by floats and held vertically in the water column with lead or stone weights on the bottom. The gillnets are set to fish overnight, anchored to the seabed by boulders and marked by a large float. Fish become entangled in the netting by their operculum and entrap themselves further as they struggle to escape.

Technical information

Definition of the Innovative gear

The widespread and increasing use of gillnets by artisanal fishers in the nearshore/shallow waters poses a risk of ghostfishing when they are abandoned or lost in storms and strong currents. The modified gillnets incorporate biodegradable cotton twines (recommended 2 mm diameter) in the float line attachments to the conventional gillnets commonly used in the small-scale fishery.

When the gear is lost, and continuously exposed to seawater, the float line cotton attachment twines degrade, break, and separate from the netting, causing the rest of the net to collapse to the seafloor while one end of the float line and buoy emerge to the surface (when the water depth is less than the length of the net). The collapse of the gillnets with the float line detached reduces ghostfishing, while the resurfaced end of the float line aids gear recovery, thereby reducing ghostfishing and marine plastic pollution.

Technical specificities

Comparison of specifications

	Conventional gillnets	Modified gillnets
Float line attachment	24-ply nylon twine	1.5/2/3 mm twisted cotton twine (2 mm recommended)
Lines connection	No connection between lead and float lines	Modified float line and unmodified Lead lines are linked in a single line

Outcomes expected

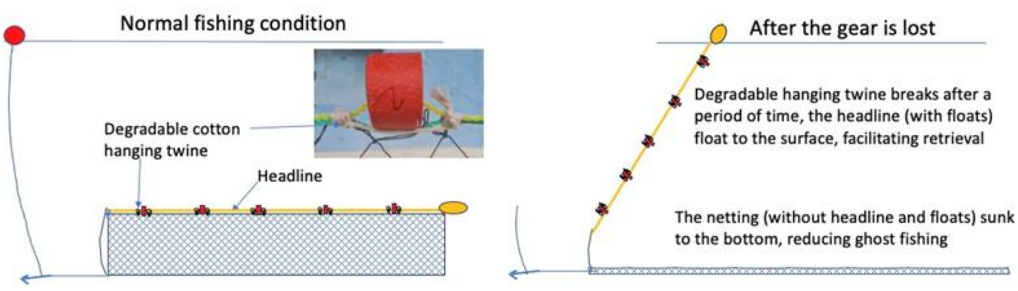
The modified gear is expected to reduce ghost fishing by lost gillnets and will result in the following outcomes:

1. Increased fish catch in artisanal fisheries of Kenya through reduction in ghostfishing and its impact on the fishery resource;
2. Improved livelihoods from better fishery yields;
3. Reduced fishing gear-related litter in the artisanal fisheries of the Kenyan coast due to increased ability to retrieve lost gear;
4. Reduced costs for replacing lost gillnets due to the ability to recover and reuse the lost nets.

Other relevant information

Eco-traps experiments are being developed in collaboration with the Laboratory of Sustainable Fishery (LAPESU) of the Department of Fisheries and Aquaculture (DEPAq) of the Federal Rural University of Pernambuco (UFRPE): http://www.depaq.ufrpe.br/.

Drawing / picture of the Innovative gear



Technological Performance assessment

Main criteria............... Reduced environmental impact through reduced ghostfishing from abandoned, lost or discarded gillnets.
Additional criteria ..... Enhanced sighting and more efficient retrieval of lost gear.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment........ Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
No setbacks of political nature have been encountered.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
The cotton twines used to modify the net are not immediately available in the local markets.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Not Applicable

Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Has encouraged uptake
Modification makes use of existing gear making technology.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Modification promises cleaner seas and reduces the loss of fish to ghostfishing.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Not Applicable
No legal limitations exist with regards to the modified gillnet.

6.1.19 Factsheet 19. Modified blue swimming crab pot to reduces ghostfishing

General information

Year 2023
Source supplier .... Mochammad Riyanto (IPB University) and Kelsey Richardson (FAO).
Region........ Trialled in Pacific, *Western Central, Area 71 (but solution is global. Option for wider application)*
FAO-Area .... *Not applicable*
Gear sub-category .... Pots
Gear code .... FPO
Target species........ SCD
Bycatch species........ TEH, EFX, IGV

Baseline gear

The baseline fishing gear is conventional multifilament nylon gillnet of various twine sizes and mesh sizes. The gillnets are suspended by floats and held vertically in the water column with lead or stone weights on the bottom. The gillnets are set to fish overnight, anchored to the seabed by boulders and marked by a large float. Fish become entangled in the netting by their operculum and entrap themselves further as they struggle to escape.

Technical information

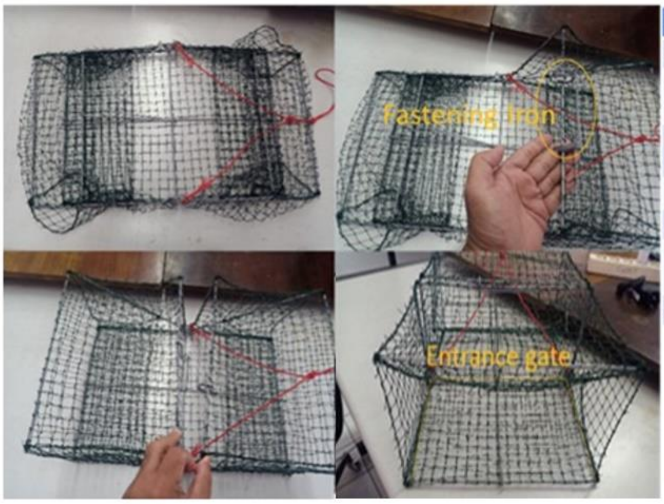
Definition of the Innovative gear

The modified blue swimming crab is a modification to the commercial crab pot incorporating biodegradable twine to reduce ghostfishing when abandoned, lost or discarded. The shape, dimension and specifications of the pot remain unchanged, which is made from PE netting with iron frame. The new modified pot employs biodegradable cotton material for fixing the pot's entrance. When the pot is lost or left in the water for a certain amount of time (nine months maximum), the cotton twine that fastens the entrance

will degrade and opens the pot at the entrance so that the pot will not continue to ghostfish.	

Technical specificities

A polyethylene-covered iron frame forms the base of the pot, which is 39.5 cm long, 26 cm wide, and 17 cm high. The pot is fitted with both bait hooks and iron hooks for closing. The twine that fastens the bottom of the entrance of the pot is replaced by biodegradable cotton twine, from the original polyethylene twine. It is anticipated that the biodegradable twine will break if the fishing gear is misplaced (i.e., abandoned, lost, or discarded), and create a large opening at the entrance to allow crabs and other species to freely and quickly escape from the pot, thus reducing ghostfishing. The pot can function regularly and catch target and bycatch species until its entrance is unfunctional. If the cotton twine at the bottom of the entrance is worn or damaged during the course of operation, fishers can promptly repair it. Modified and conventional pots have the same size and technical specifications. The difference between the two pots lies in lacing twine at the bottom of the pot's entrance. Various sizes of cotton twines were tested in the laboratory, and 1 mm diameter twine was found most suitable for the pots under local conditions.



Specification of Blue Swimming Crab Pot	
Specification	
Collapsible pot frame	Iron (ø 0.35 mm)
Body and entrance gate of pot	PE multifilament 210D/6
Bait hook	Iron (ø 0.27 mm)
Size (L x W x H)	39.5 x 26 x 17 mm
Mesh size	1.25 inch (Square mesh)
Scale 1:10	

Blue Swimming Crab Pot Specification

Outcomes expected

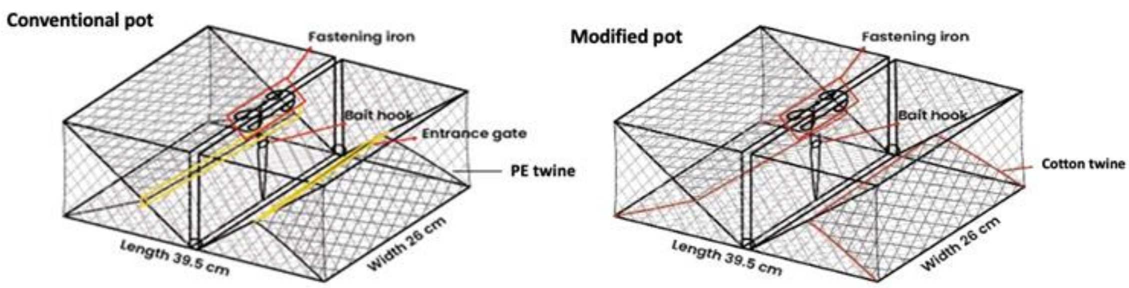
The modified pot is expected to reduce or eliminate ghostfishing if it is abandoned, lost or discarded. The advantages of these modified pots are:

1. Maintaining the same or better catch-efficiency compared to conventional pots;
2. Biodegradable materials, such as cotton thread, are readily available at reasonable prices for fishers;
3. Simple to repair when damaged.

Other relevant information

Not available.

Drawing / picture of the Innovative gear



Technological Performance assessment

Main criteria............... Reduced environmental impact through reduced ghostfishing from abandoned, lost or discarded pots.
Additional criteria ..... Reduced impact to biodiversity, reduced impact to fisheries resources.

Technological readiness level (TRL)

TRL category............. Moderate **TRL scale** TRL6

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.. Low
Return on Investment.. Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
The Directorate General of Capture Fisheries and the Coordinating Ministry of Maritime Affairs and Investment of Indonesia are in favour of this innovation.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?................... Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Not Applicable

6.2 North Sea

6.2.1 Factsheet 20. A netting-based alternative to rigid sorting grids in the small-meshed Norway pout (Trisopterus esmarkii) trawl fishery

General information

Year 2021	**Source supplier**............Ole R. Eigaard (DTU-AQUA, Denmark). Innovation d*iscussed during the STECF PLEN 20-03. Revised by Louisa Sinclair, Alex Edridge, and Gokhan Gokce.*
Region...............................North Sea	**FAO-Area** 27.3.a, 27.4.a
Gear sub-category ....Bottom trawls	**Gear code** ....OTB, OTT
Target species..................NOP	**Bycatch species**...........HER, WHG, MAC, PLA

Baseline gear

Rigid sorting grid for the small-meshed Norway pout (*Trisopterus esmarkii*) trawl fishery.

Technical information

Definition of the Innovative gear

A new bycatch reduction device, termed "Excluder", is presented as an alternative to a traditional rigid sorting grid, mandatory in the small-meshed Norway Pout (*Trisopterus esmarkii*) trawl fishery in the North Sea.

Technical specificities

The Excluder is a 30 m long netting-based sorting system, developed to reduce bycatch (70 mm square meshes) and improving on board gear-handling and safety. The Excluder was tested in Eigaard *et al.* (2021) against a 5.8 m^2 standard sorting grid (35 mm bar spacing) in a twin-trawl experiment from the commercial 70 m trawler "S364 Rockall".

The Excluder is a purely netting-based selectivity device that could be used by all fishing vessels engaging in the directed fishery for Norway pout in the North Sea, as an alternative to the rigid sorting grid described in the provisions on 'mesh sizes', in the EC Technical Measures Regulation (EU) 2019/1241 (2019), Annex V, part B.

Outcomes expected

For all bycatch species analysed, the Excluder had significantly lower catches relative to the grid (Eigaard *et al.*, 2021): herring (21%), whiting (6%), mackerel (5%), American plaice (70%), witch flounder (15%), and lesser silver smelt (71%). For Norway Pout there was a significant increase in the overall catch efficiency of 32%. These results are explained by a 10 cm smaller L50 (the length of fish with 50% probability of being rejected by the sorting system) of the Excluder and a 15 times larger sorting area, which reduces the risk of clogging and loss of function.

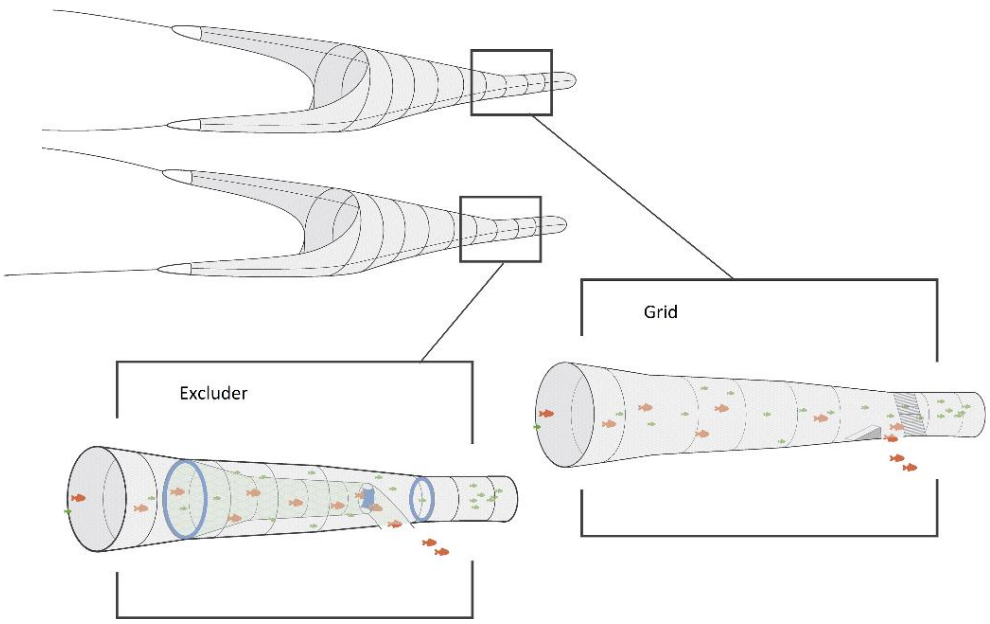
With these documented effects of improved sorting and target species catch efficiency, implementation of the Excluder would improve sustainability and address two main barriers of the current Norway pout fishery that limit quota capitalization; a tendency for Norway pout to mix with herring and whiting and lowered catch rates from grid-clogging. Additionally, gear-handling and safety on board would be improved.

The Excluder tested Eigaard *et al.* (2021), and approved by the EC, is now widely implemented in the Norway pout fishery in Area 27.4. The Excluder is currently being tested in also the sandeel (*Ammodytes marinus*) trawl fishery and it is expected that the Excluder can replace rigid sorting grids in a number of trawl fisheries globally.

Other relevant information

Eigaard *et al.* (2021).

Drawing / picture of the Innovative gear



Experimental setup of the Excluder mounted in one of the trawls and the grid in the other trawl of the twin rig. Both systems sort out the larger (red) fish and retain the smaller (green) but based on different selection mechanisms. (Note that the drawing is not true to scale). *Source: modified and adapted from Eigaard et al. (2021).*

Technological Performance assessment

Main criteria............... Improved size and species selectivity
Additional criteria ..... Ease of handling and safety on board

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Not applicable **Selectivity** .... Disruptive **Impact**......... Disruptive

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Yes, easier
Is the innovative gear easier to maintain and repair? .... Maybe
Does using the innovative gear present a lower risk to the health and safety of crew? .... Yes, lower

Economic Performance assessment

Capital cost category.......... Moderate
Return on Investment.......... Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.......... Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?.......... Has encouraged uptake

6.2.2 Factsheet 21. Available alternatives for processing and storing unwanted unavoidable catches (UUCs) onboard fishing vessels

General information

Year 2017

Source supplier............Antonello Sala, *with text adapted from Viðarsson et al. (2017). Revised by Louisa Sinclair, Alex Edridge, and Gokhan Gokce.*

Region..............................North Sea

FAO-Area 27.4

Gear sub-category ....Bottom trawls

Gear code ....BT, SV

Target species..................Any commercial species

Bycatch species...........undersized individuals

Baseline gear

The baseline fleet segments selected represent a descriptive cross-section of European fisheries in terms of fleet composition and main challenges, i.e., 11-m coastal vessel, 23-m Danish seiner/trawler, 39-m bottom trawler, and 50-m bottom trawler.

Technical information

Definition of the Innovative gear

The suggested solutions are first and foremost intended to provide fishermen with realistic alternatives for meeting the requirements of the landing obligation in Europe, as they are preparing for the implementation of the discard ban. Along with those suggestions we have also included recommendations for improved onboard handling technologies, which are expected to increase the value of catches regardless of the implementation of the landing obligation. The solutions focus largely on separating between the target catches and the unwanted catches, and in particular to provide alternatives for processing and storing under Minimum Reference Size Catches, which cannot be utilised for direct human consumption according to the landing obligation of the EU Common Fisheries Policy.

Technical specificities

The 3D drawings suggested by Viðarsson *et al.* (2017), along with the cost-benefit tool that is now publicly available at the DiscardLess website (http://www.discardless.eu) will enable fish business operators, vessel owners, fishermen, policy makers and other stakeholders to better understand some of the available options that can be used for handling UUCs onboard fishing vessels and as results contribute to a successful implementation of the Landing obligation. There are limited options available for handling the UUC and those options are dramatically reduced as the vessels get smaller. The smallest vessels are only able to store UUC and below MCRS separately and then need to transfer the responsibility for further handling ashore. The larger vessels have more alternatives, such as sorting into differently coloured tubs, bulk storage, mincing, compressing, silage production (FPH/FPC), fishmeal production and other alternatives.

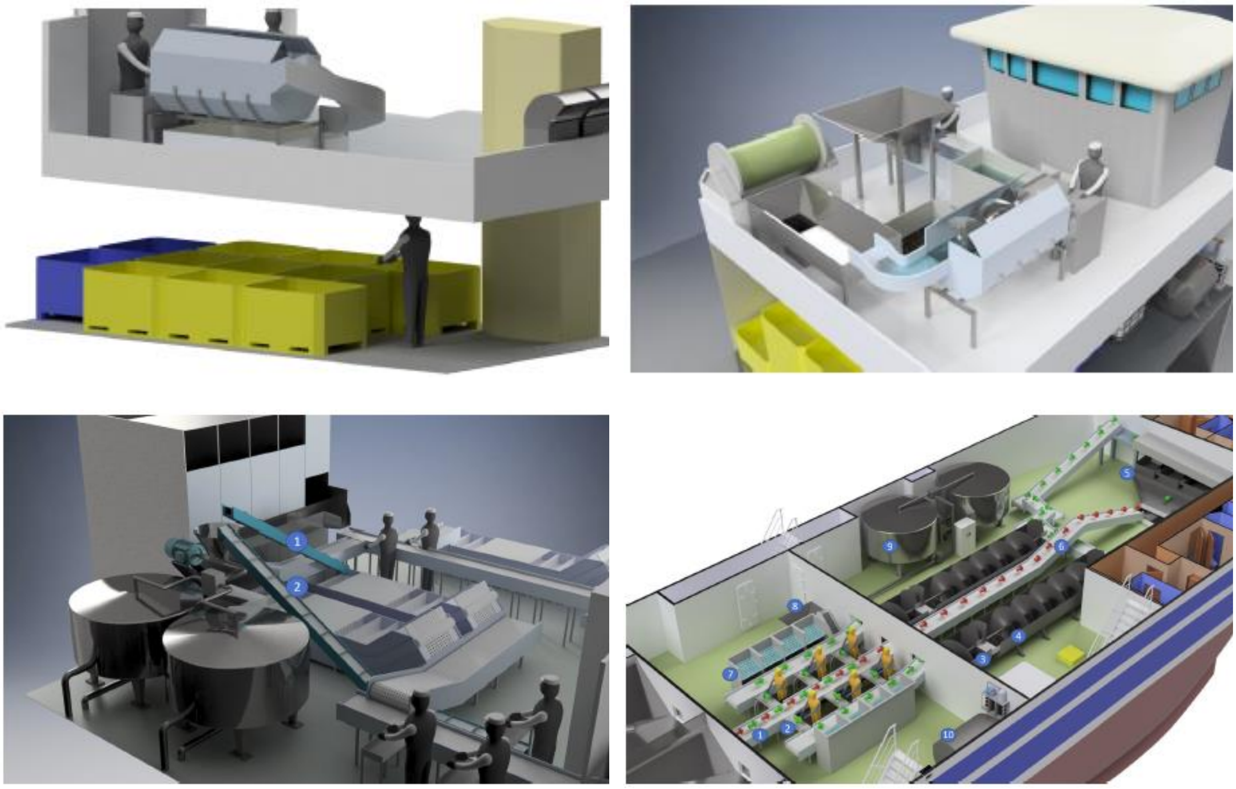
Outcomes expected

The variability in catches and catch composition within this fleet segment is extreme and the suggested solutions presented above are therefore only few of many alternatives. The 3D drawings are available on the DiscardLess webpage where it is possible to get more information on the recommended solutions. A simple cost-benefit tool that allows stakeholders to estimate the cost of installing and operating these solutions, along with expected value creation is also available at the DiscardLess webpage.

Other relevant information

DiscardLess website: http://www.discardless.eu
Viðarsson *et al.* (2017).

Drawing / picture of the Innovative gear



From upper left to bottom right. **Small coastal vessels**. An illustration of the setup in the hold - yellow tubs for normal catch and blue for the UUC. **Small bottom trawlers and Danish seiner**. The suggested setup onboard a small Danish Trawler. (1. Reception; 2. Bleeding; 3. Bleeding / cleaning tank; 4. Gutting; 5. Cleaning/Cooling tank; 6. Down to hold). **Medium sized bottom trawlers in the Bay of Biscay**. The production room. Two employees perform the bleeding and sorting of the catch in front of the reception, they have the alternative to sort whole UUC and or fish under MCRS on to a conveyor belt that leads to the silage unit, or it can be sent straight to packaging. The wanted catch however goes through bleeding and the most valuable catches trough gutting as well. There are three employees performing the gutting beside the two large primary silage tanks. The viscera and the offal's are gathered and utilised into silage. The conveyor (1) receives whole UUC and MCRS while conveyor (2) receives viscera and offal's. **Large wetfish bottom trawlers**. Overview of the production deck. 1. Main conveyor, 2. Gutting board, 3. Bleeding tank, 4. Rotary cooling tank, 5. Automatic sorting unit, 6. Mayn conveyor (no bleeding or gutting), 7. Sorting tubs for MCRS, 8. Silage mincer, 9. Silage Day tanks, 10. Slurry ice buffer tank.

Technological Performance assessment

Main criteria............... Catch efficiency
Additional criteria ..... Fish quality, discard reduction

Technological readiness level (TRL)

TRL category............. Low **TRL scale** TRL2

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Not applicable **Impact** .... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Unsure
Is the innovative gear easier to maintain and repair? .... Unsure
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category.......... High
Return on Investment.......... Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... Do not know

6.2.3 Factsheet 22. Alternative codend designs in unrestricted gears under a catch quota management (CQM) scheme

General information

Year 2015-2017

Source supplier ....Antonello Sala, *with text adapted from Mortensen et al. (2017) and Reid (2017). Horizon 2020 project DiscardLess (Strategies for the gradual elimination of discards in European fisheries). Revised by Louisa Sinclair, Alex Edridge, and Gokhan Gokce.*

Region..............................North Sea

FAO-Area 27.4

Gear sub-category ....Bottom trawls

Gear code ....OTB, OTT

Target species..................POK, COD, PLE

Bycatch species...........NEP, HAD, HKE

Baseline gear

Regulatory 120 mm demersal trawl, with a 120 mm codend

Technical information

Definition of the Innovative gear

Trawlers were challenged to test their own solutions to reduce unwanted bycatch and/or choke species, while maintaining profitable. Different codend design options depending on fishery and type of issues they faced individually.

Technical specificities

Alternatives

i. Inserted a 1 300-mm mesh panel in the top of the codend of a regulatory 120 mm demersal trawl, with a 120 mm codend.
ii. Switched to a BACOMA codend, which was assessed by the fisher to have a negative effect owing to kinking in the rest of the codend.
iii. Switched to a 140 mm codend with circumference 85-90 meshes to avoid "pouching" effect.
iv. Four-sided codend, with bottom and sides of 125 mm diamond mesh and top with 180 mm mesh
v. Codend with 130 mm diamond mesh.
vi. 120 mm topless trawl, with no wings. Opens 1.4-1.5 m vertically.

To incentivize participation, additional quota was offered to compensate for the additional costs and economic uncertainty linked to developing and testing new gears, and to remove the barriers linked to needing enough quota to cover changes in catch composition and not having to lease. During the trials, discarding was allowed, and discards were not counted against quota.

Outcomes expected

Get a better selection in the codend by sorting out other fish, crabs, and other invertebrates. Reduce the amount of small fish. The move towards the landing obligation and thus CQM means in theory that fishers would shift from maximizing the value of the part of the catch that can be sold to minimizing the volume of the part of the catch that cannot be sold, which would lead to a better alignment of the individual objective with the societal and policy objective (Nolde Nielsen *et al.*, 2015). To achieve this, fishers would in theory select the fishing methods and strategies that maximise their profits within the allowed catch frame. The contradiction between the result of the average and the results from the individual fishers highlights a challenge for less restrictive technical regulations in a CQM management scheme, as the overall result would argue against a less restrictive TCM, while the individual results would argue for it (Mortensen *et al.*, 2017).

Average landings (kg), discard (kg) and discard ratio (%) in the North Sea, all alternative gears combined.

	Baseline	Alternatives	Difference
Landings	713	704	+9
Discards	13	18	-5 (*)
Discard ratio	1.9	2.6	+0.7 (*)

Significant differences *(Sig.<0.05)* between alternative and baseline gear are marked with (*).

Average landings (kg), discard (kg) and discard ratio (%) for each individual alternative gear trialled in the North Sea.

Landings	Discards	Discard ratio	Change

	Baseline	Alternative	Baseline	Alternative	Baseline	Alternative	in ratio
1	1,314	1,177	3	3	0.2	0.3	+0.1
2	367	357	8	6	2.2	1.7	-0.5 (*)
3	704	784	5	23	0.7	2.8	+2.1 (*)
4	460	457	13	4	2.8	0.9	-1.9 (*)
5	814	913	24	46	2.9	4.8	+1.9 (*)
6	1,197	948	16	6	1.3	0.6	-0.7 (*)

Significant differences *(Sig.<0.05)* between alternative and baseline gear are marked with (*).

Other relevant information

Mortensen *et al.* (2017), Reid (2017), Mortensen *et al.* (2018), Commission Delegated Regulation (EU) 2020/2014 (2020).

Drawing / picture of the Innovative gear

Not available.

Technological Performance assessment

Main criteria............... Reduce small fish; removes small cod and haddock, along with flatfish; reduce cod landings, including small cod and small plaice; fewer small fish and less discard.
Additional criteria ..... Improve fish quality and reduce catch sorting.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.......... Low
Return on Investment.......... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.......... Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?.......... Do not know

6.2.4 Factsheet 23. Predictive methods to estimate gear selectivity in terms of gear design parameters and vertical distribution of fish

General information

Year 2017

Source supplier .... Antonello Sala, *with text adapted from Fryer et al. (2017) and O'Neill and Noble (2017). Revised by Louisa Sinclair, Alex Edridge, and Gokhan Gokce.*

Region .... *North Sea, Grand Banks, Barents Sea, Baltic Sea.*

FAO-Area .... *All North Atlantic (Non-specific region)*

Gear sub-category .... Bottom trawls

Gear code .... OTB, OTT

Target species .... COD, HAD, POK, MON, NEP, PLE, LEM, WHG

Bycatch species .... *Not applicable*

Baseline gear

Any baseline standard derived from European Regulations.

Technical information

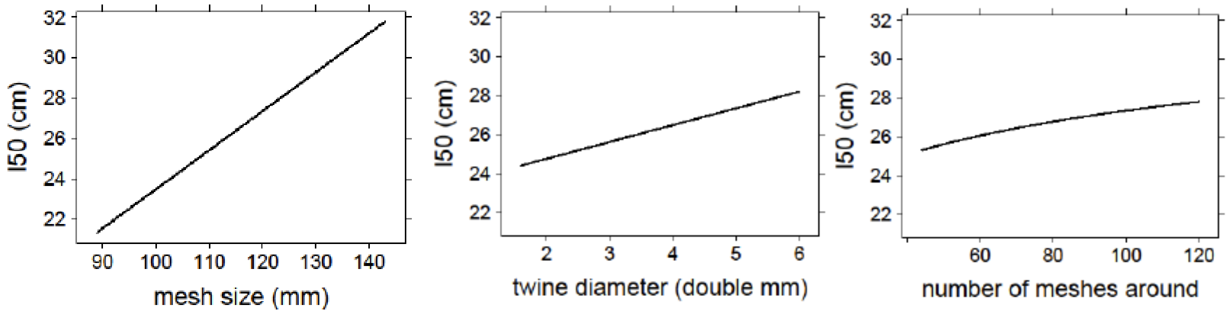
Definition of the Innovative gear

Guidelines for trawl gear selectivity.

Technical specificities

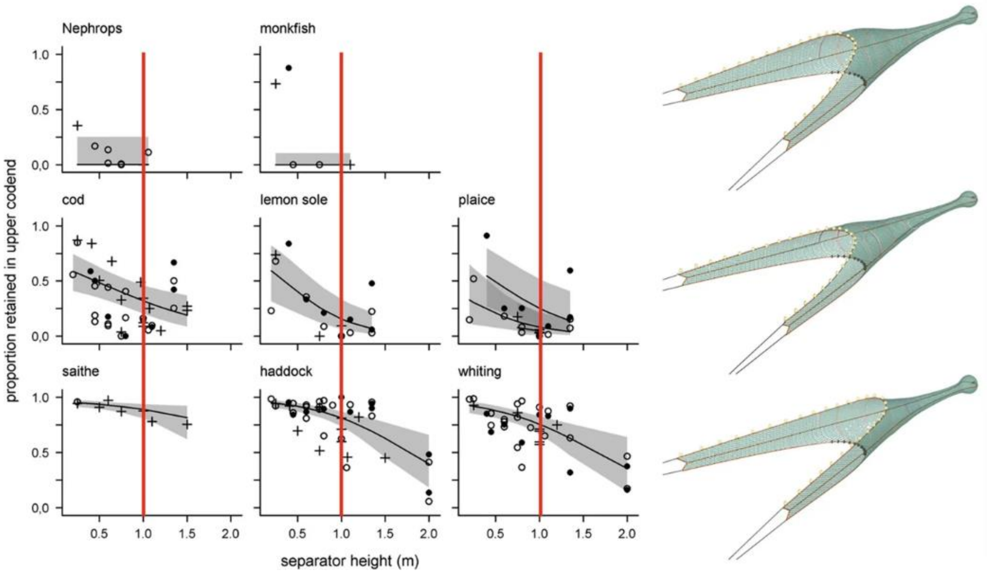
Meta-analyses of plaice codend selection based on codend mesh size, number of open meshes around the circumference and twine diameter. Panel selection: effects of panel mesh size, panel position, and the time of year when fishing takes place. Full information can be found on O'Neill and Noble (2017).

Codend mesh size (range 89-143 mm); number of meshes around the codend circumference (range 44-120); codend twine diameter (range 1.6-6.0 mm).



Dependence of plaice L50 on codend mesh size, twine diameter and number of meshes around the circumference. *Source: Modified and adapted from O'Neill and Noble (2017).*

Fryer *et al.* (2017) suggests that, in the first instance, it should be possible to separate the three categories of (i) haddock, whiting and saithe, (ii) cod, plaice and lemon sole and (iii) monkfish and Nephrops. If these species can be directed to different parts of the gear it may then be possible to further select on a size or species basis. The proportion of fish that rise above the separator panel decreases as the height of the leading edge of the panel increases for six of the eight species. Only monkfish and Nephrops have no significant dependency on panel height. Cod is the only species for which separation depends on the horizontal distance of the leading edge of the panel from the ground gear, with the proportion of cod going above the panel increasing the farther the panel is from the ground gear. The time of day only affects the separation of plaice, with a greater proportion going above the panel at night than during the day.



The proportion of fish that will enter a trawl gear above a given height. The vertical red lines indicate the proportion of each species that would enter above a height of 1 m. The trawl gears on the right illustrate how net makers can make use of this type of information to influence the species profile entering a gear by altering the height and position of the headline. The top net is a standard trawl, the middle one is a low headline trawl and the bottom one is a cutaway trawl. *Source: modified and adapted from O'Neill et al. (2019).*

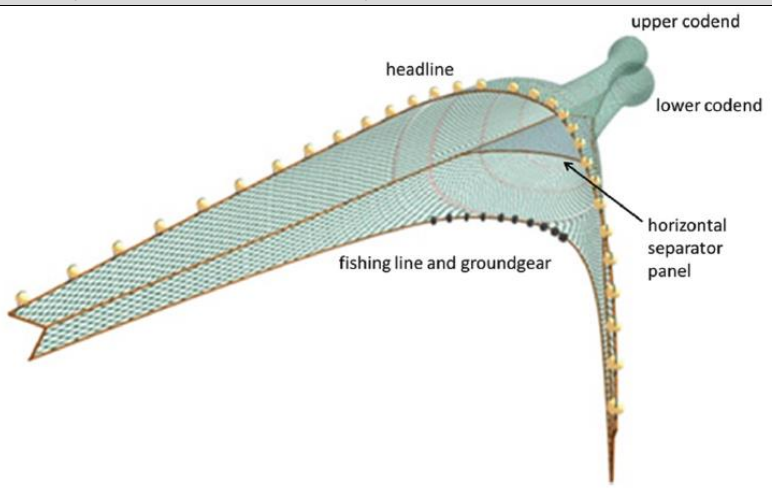
Outcomes expected

- Codend selection depends on codend mesh size, the number of open meshes around the circumference and twine diameter;
- panel selection depends on panel mesh size;
- For gadoids, panel contact probability depends on where the panel is positioned and the time of year when fishing takes place;
- the relationship of L50 with number of meshes in circumference and twine thickness can be opposite between roundfish and flatfish;
- it should be possible to separate the three categories of (i) haddock, whiting and saithe; (ii) cod, plaice and lemon sole; (iii) monkfish and Nephrops using vertical separation.

Other relevant information

Fryer *et al.* (2017); O'Neill and Noble (2017); O'Neill *et al.* (2019).

Drawing / picture of the Innovative gear



Demersal trawl fitted with a horizontal separator panel that directs fish that go above the panel to the upper codend and fish that go below the panel to the lower codend. *Source: modified and adapted from Fryer et al. (2017).*

Technological Performance assessment

Main criteria.............. Gear selectivity knowledge can be used by fishers and net makers to pre-select the likely most appropriate changes in gear design to reduce unwanted catches.
Additional criteria ..... Not applicable

Technological readiness level (TRL)

TRL category............ Moderate **TRL scale** TRL6

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.. Low
Return on Investment .... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Do not know

6.2.5 Factsheet 24. Sorting grid to improve size selection of brown shrimp (*Crangon crangon*) in a beam trawl fishery

General information	
Year 2019	**Source supplier**............Antonello Sala, *with text adapted from* Feekings *et al.* (2019). *Revised by Louisa Sinclair, Alex Edridge, and Gokhan Gokce.*
Region....................North Sea	**FAO-Area** 27.4.b
Gear sub-category ....Beam trawls	**Gear code** ....TBB
Target species..................CSH	**Bycatch species**........... *Undersized brown shrimps*

Baseline gear

Conventional beam trawls

Technical information

Definition of the Innovative gear

A grid with a 6 mm bar spacing allowing small shrimp to escape. To ensure maximum water flow through the grid, special bars were constructed out of glass fiber which were drop formed and only 4 mm thick.

Technical specificities

Brown shrimps are caught with beam trawls in shallow waters. The fishery was MSC certified in 2016 based on a management plan implementing a gradual increase in mesh size from 20 to 26 mm in 2021. Fishers are concerned that the increase will lead to a high loss of marketable shrimp, therefore an alternative to the mesh size increase is investigated. In periods and areas with large amounts of seaweed, the mandatory sieve net is often blocked, resulting in high losses of marketable shrimp. An alternative to the sieve net has therefore also been tested. Furthermore, a reduction in fish by-catch was desired.

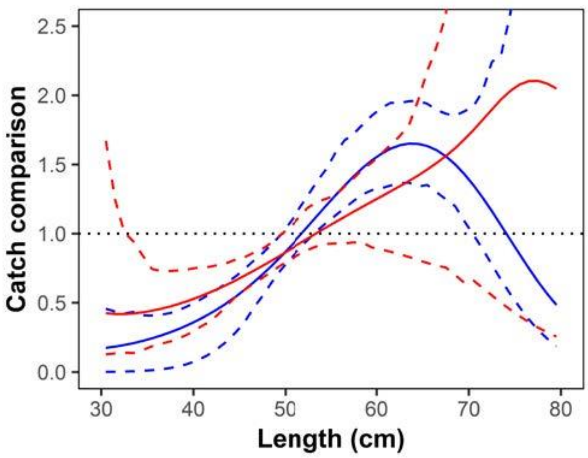
Outcomes expected

Based on preliminary testing, minor adjustments were needed to optimise performance, handling and robustness of the grid. During the preliminary trials, samples were taken to determine whether small shrimp were escaping. Catches of small shrimp under 48 mm were significantly reduced.

Other relevant information

Feekings *et al.* (2019).

Drawing / picture of the Innovative gear



Source: modified and adapted from Feekings et al. (2019).

Technological Performance assessment

Main criteria............... Brown shrimp size selectivity, reduce fish bycatch.
Additional criteria ..... Improve brown shrimps catch quality.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair?........................ No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... Yes, lower

Economic Performance assessment

Capital cost category.. Moderate
Return on Investment.. Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Do not know

6.2.6 Factsheet 25. Multibeam sonars to assess fish behaviour, densities and school biomass in purse-seine fisheries

General information

Year 2018-ongoin	**Source supplier** ....Antonello Sala, *with text adapted from Marçalo et al. (2019). Revised by Louisa Sinclair, Alex Edridge, and Gokhan Gokce.*
Region..................North Sea	**FAO-Area** 27.4
Gear sub-category ....Purse seines	**Gear code** ....PS
Target species...............CAP, MAC, HER	**Bycatch species**...........*Not applicable*

Baseline gear

Conventional Norwegian inshore and offshore purse-seines.

Technical information

Definition of the Innovative gear

Following the introduction of the EU Landing Obligation (LO), slipping practices in EU waters were regulated from 2015 by Commission Delegated Regulations (CDRs), for both North-Western Waters and the North Sea. Skippers use experience and knowledge about the behaviours of different species to evaluate school size and species based on received echoes on their sonar and echo-sounder screens. Having accurate quantitative estimates of school characteristics will further improve catch estimation and reduce unwanted catches (UWC). Avoiding UWC can have significant economic benefits for fishers, through reduced fuel costs and improved catch quality and prices (Marçalo *et al.*, 2019).

Information about the species in a school, school morphology and geographical distribution can, to some degree, be estimated using multi-frequency echo-sounders (Horne, 2000; Korneliussen *et al.*, 2009). The echo strengths at different frequencies are species-specific, due to variation in fish morphology (e.g. presence or absence of a swimbladder) and the relative frequency response, i.e. the ratio of the backscattered energy at frequency to that at 38 kHz, can be used to distinguish between some species. Individual fish size within a school can also be estimated using a high-resolution broadband echo-sounder, if individual targets can be detected.

In recent years, significant progress has also been made in using multi-beam sonars to quantify fish school sizes (Nishimori *et al.*, 2009; Vatnehol *et al.*, 2017) and behaviour (Gerlotto and Paramo, 2003; Holmin *et al.*, 2012). Especially in Norway, research and development in hydro-acoustic pre-catch identification is a well-functioning cooperation between research institutes, the fishing industry and companies delivering fisheries instrumentation (e.g., CRISP; LSSS; DABGRAF; SEAT).

Technical specificities

Pre-catch identification of fish schools (with respect to species, quantity and fish size) using hydro-acoustic methods to prevent catching unwanted fish. Multi-beam sonar has also been used to describe purse seine shape and volume during seine hauling (Tenningen *et al.*, 2015). The authors provided a better understanding of how the volume available for captured fish schools varies under different fishing conditions and the impact that may have on the survival of slipped fish.

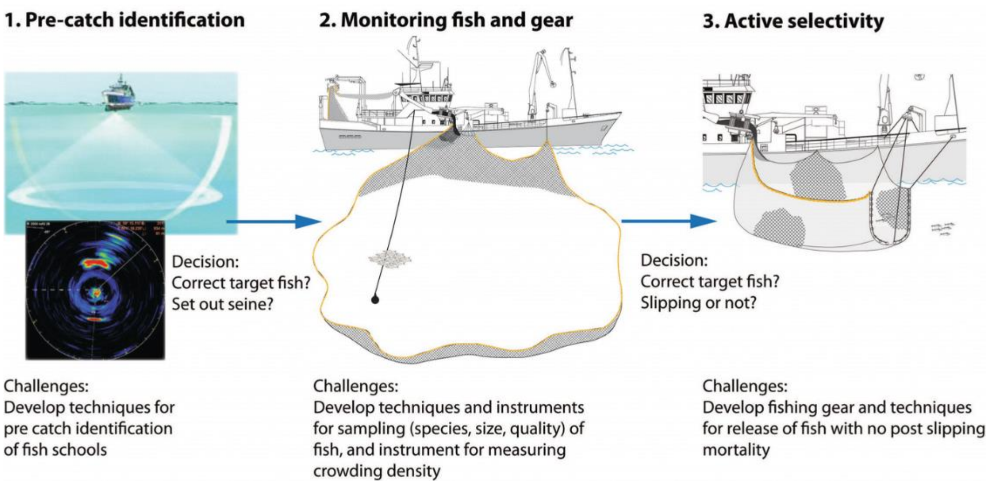
Outcomes expected

Pre-catch identification is not always accurate, especially when schools are large and dense. So, it is also necessary to have tools to monitor and characterise the catch early in the capture process before the fish become too crowded in the net (Marçalo *et al.*, 2019). However, monitoring a school inside the net is challenging, even using acoustic technologies. Omnidirectional sonars are usually retracted into the hull during purse seining to avoid damage, making them unsuitable for monitoring schools during capture. But multi-beam sonar, mounted on a research vessel, has been used to monitor and describe the behaviour of schools captured by purse seine (Tenningen *et al.*, 2017). Multi-beam sonars on fishing vessels, with side-looking transducers are now commercially available (e.g., Kongsberg Maritime SN90) so work is in progress to obtain a better understanding of fish behaviour, densities, and school biomass inside the purse seine.

Other relevant information

Marçalo et al. (2019), Tenningen et al. (2015), Tenningen et al. (2017).

Drawing / picture of the Innovative gear



The three-stage strategy to provide purse seine fishers with the tools and methods necessary for avoiding unwanted catches and reducing slipping-related mortality. *Source: modified and adapted from Breen et al. (2012).*

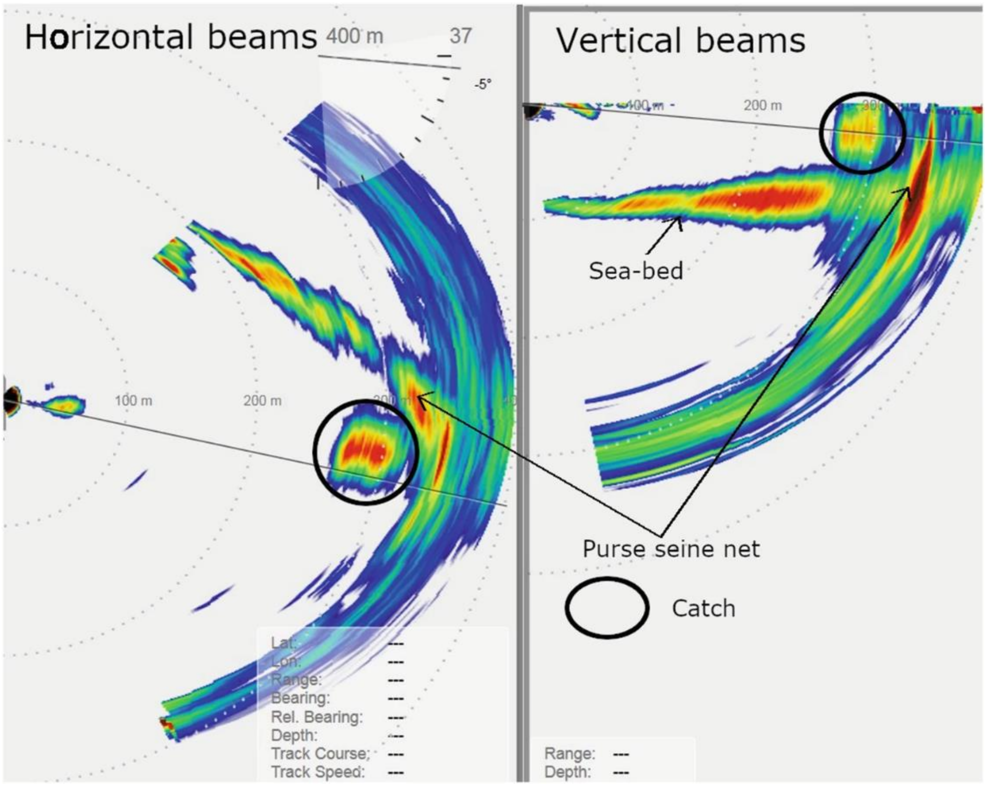


Image from the Simrad SN90 sonar (Kongsberg Maritime AS) of a school of North Sea herring in a purse seine, with the wall of the net clearly visible. Left panel: horizontal view; right panel: vertical view. *Source: modified and adapted from Marçalo et al. (2019).*

Technological Performance assessment

Main criteria............... Catch efficiency, size- and species-selectivity, reduced bycatch of ETP species.
Additional criteria ..... Reduce discarding, reduced fuel costs and improved catch quality and prices.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Disruptive **Selectivity** .... Transformative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve?	No difference
Is the innovative gear easier to maintain and repair?	No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew?	No difference
Economic Performance assessment	
Capital cost category	High
Return on Investment	Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it?	Yes, higher
P.E.S.T.E.L. Framework	
Overall, what impacts do you think have **political factors** had on uptake of this gear?	Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear?	Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear?	Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?	Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear?	Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?	Do not know

6.2.7 Factsheet 26. Pulse trawling

General information

Year 1998-2020

Source supplier .... Adriaan Rijnsdorp, Pim G. Boute, Dick de Haan. *Revised by Antonello Sala.*

Region .... North Sea

FAO-Area .... 27.4 *(with possibility to be used in other areas)*

Gear sub-category .... Beam trawls

Gear code .... PUK, PUL *(with possibility to be implemented in TB)*

Target species .... *Flatfish*

Bycatch species .... *Undersized fish and benthos, benthic invertebrates,* COD

Baseline gear

Any conventional beam trawl and bottom trawl.

Technical information

Definition of the Innovative gear

Instead of chains, that mechanically stimulate flatfish from the seabed, electrodes are used to produce an electric field. The cramp response immobilises the fish for 1-2 seconds during which the fish are scooped up in the net. In the net the fish are outside of the electric field and the cramp ceases. The pulse trawl technique is particularly effective to catch sole because the sole cramp into a U-shape, which enhances the catchability. The pulse system creates a three-dimensional electric field between the wire-shaped electrodes. The pulse technique is often used in combination with a hydrofoil shaped beam ("SumWing").

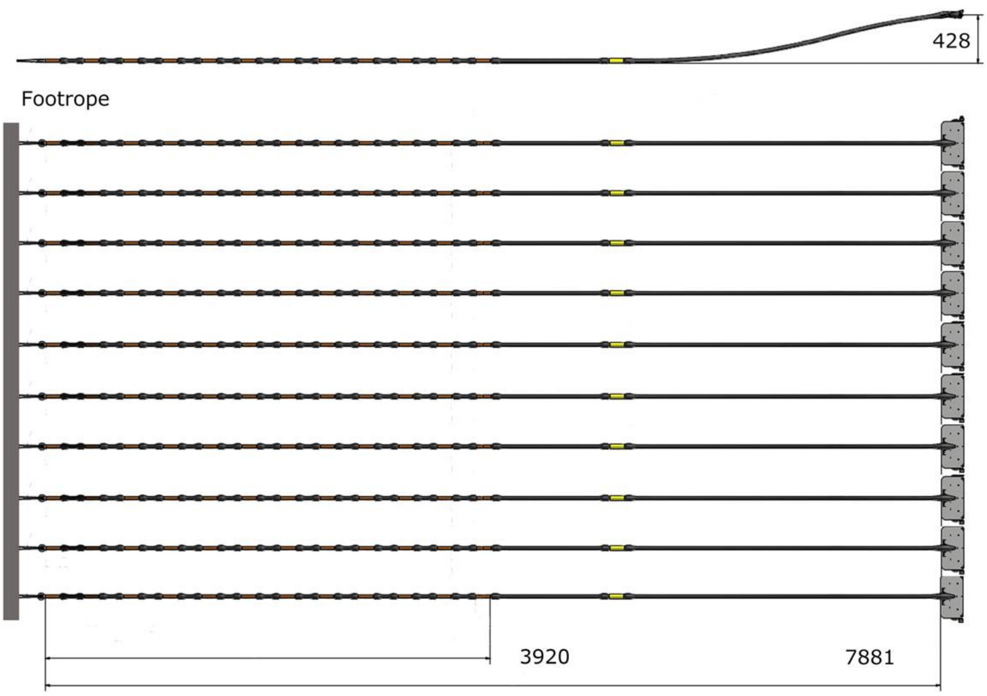
Technical specificities

Two companies have developed pulse systems for the Dutch flatfish fishery: HFK Engineering and Delmeco (previously Verburg-Holland). These pulse systems comply with the legal specifications with regard to the electrical characteristics and dimensions of the gears. The pulse technique is often used in combination with the SumWing technique. The pulse system creates a three-dimensional electric field between the wire-shaped electrodes. The figure below shows the pattern of maximum field strength around the conductor (white) and isolator (grey) parts of the electrodes. The strength of the electric field is strongest close to the conductors and becomes weaker when moving away from the conductors. Outside of the net, the field strength is reduced to values below the threshold field strength that causes cramp. The field strength that an animal will experience depends on the location of the animal in the electric field. Animals that occur on the sea floor close to an electrode will be exposed to the highest field strength. Animals that occur halfway between two electrodes will be exposed to a substantially lower field strength. Also, animals that occur above or below the sea floor will experience a lower field strength. The effect of the sediment hardly affects the field strength in the sandy and muddy sediments fished by pulse trawlers. The time that an organism on the sea bed is exposed to sole pulses is around 1.6 seconds. It can be calculated by dividing the towing speed of the gear (2.5 m/s) by the length of the electrode (4 m). During this exposure, the field strength varies with the passage of the alternating conductor and isolator elements.

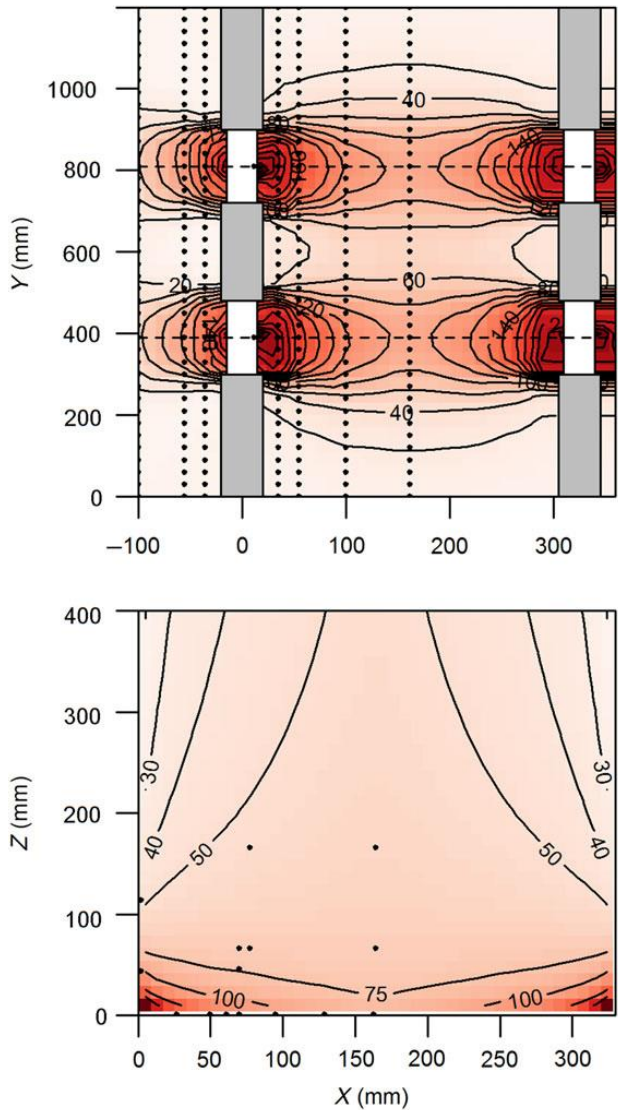
Pulse systems generate alternating positive and negative pulses with a frequency between 40–80 Hz and a pulse width of 100-270 µs. The peak voltage of a pulse is between 45 and 60 V. The total power per unit width of the gear is around 0.7 kW/m. During each pulse electric current runs between paired electrodes. The direction of the current reverses for with the polarity of the pulse (positive or negative). The electrical current flows for about 2% of the full pulse cycle (duty cycle), meaning there is no current running for 98% of the pulse cycle. The effective voltage (root mean square) over the conductors is therefore much lower than the peak voltage. For a peak voltage of 60V, a square shaped pulse and a duty cycle of 2%, the effective voltage is 8.5 V (square root of 0.02*60*60) (de Haan *et al.*, 2016). The figure below shows the rigging of the electrodes of a 4 m HFK Pulse wing (de Haan *et al.*, 2016). The upper panel shows the side view with a vertical net opening of 0.43 m. The lower panel shows the 10 electrodes that run from the wing (left) to the footrope of the net (right). The electrodes create an electric field of about 4x4 meters. Each electrode consists of 12 conductor elements, evenly placed over a length of 3.92 m, that are in contact with the seabed. The conducting part of an electrode ranges between 26% and 40% of the total length that has contact with the sea floor. The isolated joint is used to exchange electrodes. To absorb the tensile forces on the electrode, a disc-protected rope is rigged alongside each electrode between the beam or SumWing and the ground rope.

Outcomes expected
The SumWing is a foil and has been developed to reduce the drag of the gear to reduce fuel consumption (Soetaert *et al.*, 2019). Combining the SumWing design with the pulse technique has resulted in the combined Pulse Wing. Compared to the drag of a conventional 12 m beam trawl the drag of a Pulse Wing of similar length reduced to 33% and so, fuel consumption by more than 40%. By only using a foil (Sumwing) and still using conventional tickler chains, fuel consumption was reduced by 18% (Turenhout *et al.*, 2022). Large pulse trawlers have a lower towing speed (-23%) and catch 17% more sole and 32% less plaice (kg/hour) than conventional beam trawlers (Poos *et al.*, 2020) and 36% less discards (van Overzee *et al.*, 2023). The increased efficiency for sole, in combination with the reduced towing speed and reduced depth of disturbance (Depestele *et al.*, 2019), resulted in a smaller area trawled and a reduction of more than 50% in impact on the benthic ecosystem (Rijnsdorp *et al.*, 2020b). Experiments on the effects of electrical stimulation on marine organisms and biogeochemical processes in the sediment – water interface have not revealed any adverse effects (Soetaert, 2015; Tiano, 2020; Boute, 2022). The main adverse effects shown are the internal injuries caused by the cramp response. These injuries mainly occurred in cod (40%), but not in flatfishes and in low numbers (<2%) in whiting, grey gurnard and greater sandeel (Boute *et al.*, 2023). The reduced towing speed reduces the use of fuel and associated CO_2 emissions. Provided that the sole stock is well-managed, ICES advises that pulse trawling does not impose any increased risk to its sustainable exploitation and that the change from conventional beam trawling to pulse trawling does not increase, and in some cases may reduce pressure on Natura 2000 habitats and species (ICES, 2020a; b).
Other relevant information
van Marlen *et al.* (2014), de Haan *et al.* (2016), Depestele *et al.* (2019), Boute (2022), Boute *et al.* (2023), ICES (2020a), ICES (2020b), Poos *et al.* (2020), Rijnsdorp *et al.* (2020b), Tiano (2020), Turenhout *et al.* (2022), van Overzee *et al.* (2023). Website: https://www.pulsefishing.eu/what-is-pulse-fishing/techniques

Drawing / picture of the Innovative gear



Rigging of a 4 mHFK pulse trawl. The top panel shows the side view with a vertical trawl opening of 0.43 m. The bottom panel shows the top view of 10 electrodes rigged between the wing and the groundrope. Each electrode consists of 12 conductor elements, evenly placed over a length of 3.92 m that are in contact with the seabed. An isolated joint is used to exchange electrodes. *Source: modified and adapted from de Haan et al. (2016).*



Contour plot of peak field strength (V/m) around a pair of Delmeco electrodes positioned at X=0 mm and X=325 mm. The field strength is shown in the horizontal plane (a) and the vertical plane (b). Locations of measurements are indicated by black dots. White parts show the conductor elements. The grey parts show the isolator elements. *Source: modified and adapted from de Haan et al. (2016).*

Technological Performance assessment

Main criteria............... Impact, size and species selectivity, catch efficiency.
Additional criteria ..... Fuel saving, energy efficiency, reduced GHG emissions.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Disruptive **Selectivity** .... Transformative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Yes, easier
Is the innovative gear easier to maintain and repair?... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category .... High
Return on Investment .... Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Yes, higher

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
Despite the promising results of the scientific studies, the EU parliament decided to maintain the ban on pulse trawling and revoked all existing derogation.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Strong reduction in fuel costs resulting in a return to net profitability was a key driver for Dutch beam-trawl fleet (and beam trawlers under UK en German flag owned by Dutch companies) to start using the pulse gear. Belgium beam trawlers did not make the transition because they have insufficient quota to fish in the North Sea for the whole year.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... It is a barrier
Other fishers (in particular small coastal fishers) and some environmental NGOs have heavily criticised pulse trawling.

Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Has encouraged uptake

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Pulse trawling was expected to reduce the adverse side effects of beam trawling on the sea-bed and fuel use (less CO2 emissions). Both were confirmed by scientific research.

Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... It is a barrier

6.2.8 Factsheet 27. Modular Harvesting System (MHS)

General information

Year 2023	**Source supplier**...........Martin de Beer, André Pinkert (*Precision Seafood Harvesting Limited). Revised by Antonello Sala and Nathalie Steins.*
Region..............................North Sea	**FAO-Area** 27.3.a, 27.4.a,b,c
Gear sub-category ....Bottom trawls	**Gear code** ....BT, TB, TM
Target species..................SOL, PLE, COD, POK, HAD	**Bycatch species**...........TUR, BLL, GUU, WHG, DAB

Baseline gear

Any commercial trawl codend and lengthener. *Management objectives required estimates of the absolute size-selectivity of both the Modular Harvesting System (MHS) and conventional gears, and an estimate of their relative selectivity.*

Technical information

Definition of the Innovative gear

The MHS is a membrane-based system that comprises a series of modules to replace the conventional mesh codend and lengthener of a trawl net. The MHS is designed to reduce damage to catch by providing fish a low-flow, low-turbulence environment that allows them to maintain swimming control and avoid compaction during trawling and haul back.

Technical specificities

The MHS is constructed from high strength composite fabric with three components: a cone module, three to six retention modules and a lift bag module. This system provides a low-flow, low-turbulence in-trawl environment that is designed to match the physiological parameters of the fish. The critical mechanism is to control the water velocity within the MHS to within the stamina of the catch, allowing fish to regain control, individualise and look after themselves during the fishing event. The graded water flow inside the MHS is achieved with strategically positioned and sized escapement openings along the length of the MHS to allow water (and undersize or unwanted catch) to escape.

Outcomes expected

The MHS can provide benefits for catch quality (reduced external damage, blood spots and bruising), sustainability (survivability, protected species) and selectivity (species, size, bycatch).

Prototypes of the proposed new technology have already shown their ability to allow juveniles and unwanted fish to escape unharmed at capture depth. Such fish have a very high chance of survival compared with fish that may escape from a conventional trawl and which are often both exhausted and injured.

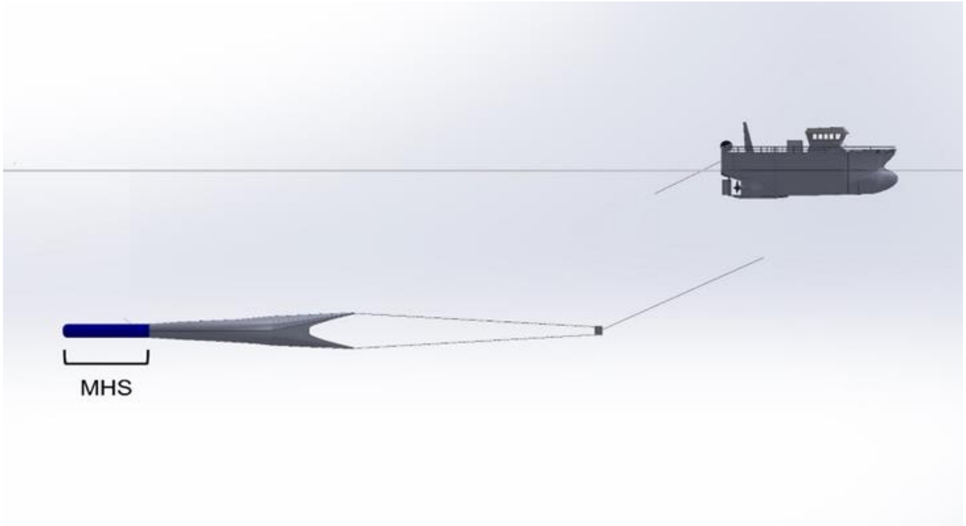
The graded flow reduction and open geometry of the MHS was observed to reduce the impact of factors that cause physical damage and fatigue to the catch in mesh codends. Accelerometery measurements demonstrated the MHS moved less and maintained a more stable position during trawling than conventional codends (Moran *et al.*, 2023).

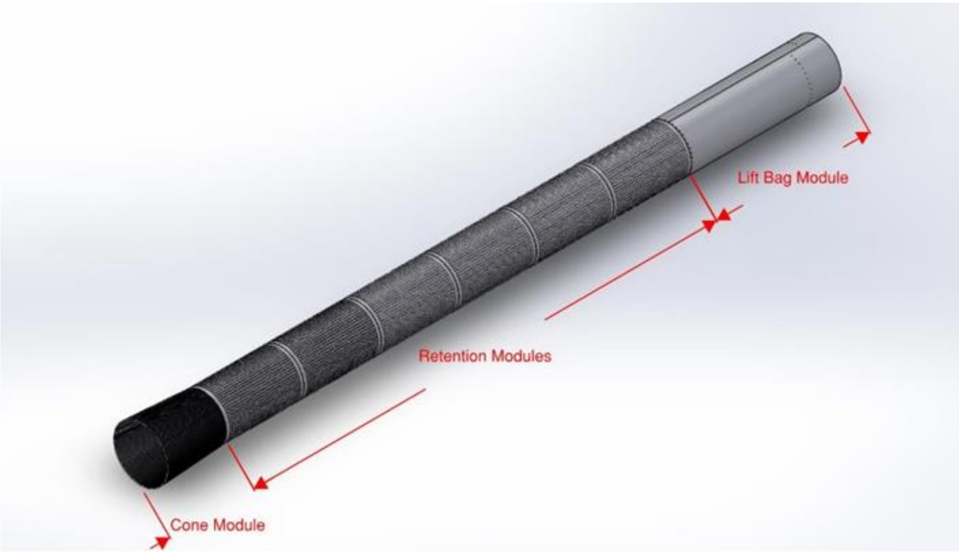
Other relevant information

Supplier information about MHS: www.precisionseafoodharvesting.co.nz MHS is approved for commercial use in New Zealand (NZ): Approved trawl gear | NZ Government (mpi.govt.nz)

Millar *et al.* (2023), Wilson *et al.* (2019), Moran *et al.* (2023).

Drawing / picture of the Innovative gear





Courtesy of Precision food harvesting.

Technological Performance assessment

Main criteria............... Survivability of unwanted species, size- and species selectivity.
Additional criteria ..... Landings quality, fuel saving, openings in MHS do not shrink.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL8

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Disruptive **Selectivity** .... Disruptive **Impact**............ Disruptive

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?........ No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category........ High
Return on Investment........ Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Trials are in an early stage so no information available / factor does not yet apply.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ It is a barrier
The codend is not made of netting and as such as 'no mesh size'. There are no provisions for using 'meshless materials".

6.2.9 Factsheet 28. Shrimp pulse trawl

This innovation was presented in the WKING report (ICES, 2020c). An updated version with new information and PESTEL assessment has been provided by Heleen Lenoir and Mattias Van Opstal (ILVO).

General information

Year	2023	**Source supplier**	Heleen Lenoir, Mattias Van Opstal, and Hans Polet (ILVO). *Revised by Antonello Sala.*
Region	North Sea	**FAO-Area**	27.4.b,c
Gear sub-category	Bottom trawls	**Gear code**	TBS
Target species	CSH	**Bycatch species**	PLE, SOL

Baseline gear

Any conventional shrimp bottom otter trawl.

Technical information

Definition of the Innovative gear

Shrimp pulse trawl.

Technical specificities

The mechanical stimulation to catch shrimp is largely replaced by an electrical stimulus. The shrimp pulse trawl uses a startle pulse (5 Hz) to make brown shrimp jump out of the seabed. The number of bobbins is reduced and set in a straight line perpendicular to the towing direction, making the gear hover over the seabed and reducing the bottom contact.

Outcomes expected

The innovation reduces the environmental impact in the brown shrimp (*Crangon crangon*) trawl. The results illustrate that pulse stimulation enables a discard reduction of small shrimp of up to 35% and a reduction of benthos and fish discards of up to 76%, with no or minor loss of commercial shrimp. In addition, contact of the groundgear with the seabed is reduced by using a straight bobbin rope with less bobbins.

Other relevant information

Verschueren *et al.* (2019).

Drawing / picture of the Innovative gear

Details of the bobbin rope of a traditional trawl with 36 bobbins in a u-shaped bobbin rope (400 kg) and a pulse trawl with 11 bobbins in a straight configuration (150 kg inclusive of electrodes) illustrating the difference in mechanical stimulation and the size and orientation of escape opportunities between the bobbins for by-catch species. *Courtesy of ILVO (Belgium).*

Technological Performance assessment

Main criteria............... Bottom impact, species and size-selectivity.
Additional criteria ..... Fuel saving, higher fish survival.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?........ No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew?.................. No difference

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment........ Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
There is a ban on electric pulse fishing from 2021 in the EU.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Not Applicable
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Not Applicable
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Not Applicable
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. It is a barrier
There is a ban on electric pulse fishing from 2021 in the EU.

6.2.10 Factsheet 29. Self-adjusting semi-pelagic otterboards for demersal trawls

General information	
Year 2022	**Source supplier** ....Barry O'Neill (DTU-AQUA), MLD Aps, Esbjerg (Denmark). *Revised by Antonello Sala.*
Region...............................North Sea	**FAO-Area** 27.3.a, 27.4.a
Gear sub-category ....Bottom trawls	**Gear code** ....OTB, OTT, OTP, TBN, TBS
Target species..................*Not applicable*	**Bycatch species**...........*Not applicable*

Baseline gear

Conventional demersal otterboards contact the seabed and are not self-adjusting.

Technical information

Definition of the Innovative gear

Self-adjusting otterboards (SAO) that have altimeters and adjustable flaps that are controlled by an active Proportional-Integral-Derivative (PID) feedback system. This allows the doors position in the water column to be modified by adjusting the flap openings via actuators, by comparing the altimeter data to a pre-set target height above the seabed during the fishing operation.

Technical specificities

These doors are designed to replace conventional seabed contacting demersal trawl doors.

Outcomes expected

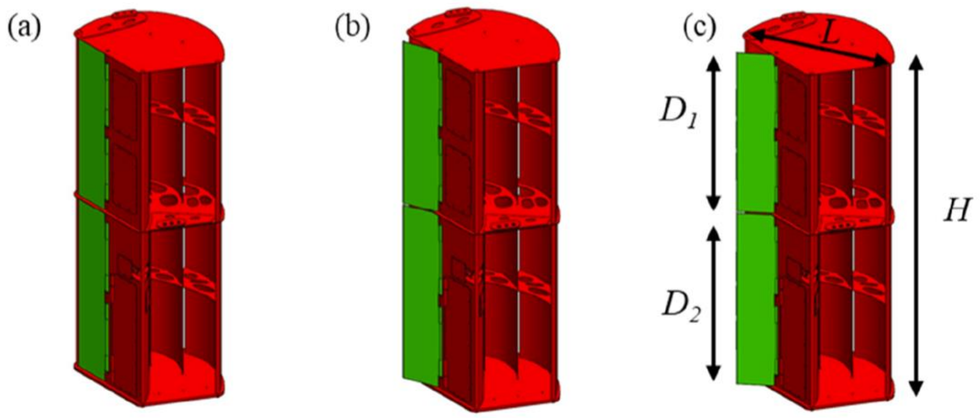
Reduced drag, improved spreading forces, reduced fuel consumption, less contact with the seabed.

Other relevant information

Eighani *et al.* (2023)

Drawing / picture of the Innovative gear

The semi-pelagic self-adjusting, otterboards (SAO) during sea trials. *Source: modified and adapted from Eighani et al. (2023).*



Schematic view of the SAO; (a) when the angle of the lower flap is greater than that of the upper one, the otterboard rolls forward and goes higher in the water column (b) when the angle of the upper flap is greater than that of the lower one, the otterboard rolls backwards and goes lower in the water column, (c) when both flaps are open the horizontal spreading forces increase. Length and height, L and H, are respectively 0.79 and 2.20 m. Length of upper and lower flaps, D1 and D2, are 1.03 and 1.11 m. *Source: modified and adapted from Eighani et al. (2023).*

Technological Performance assessment

Main criteria............... Environmental impact, reduced seabed impact.
Additional criteria ..... Energy efficiency, energy savings, reduction of GHG emissions.

Technological readiness level (TRL)

TRL category............. Moderate **TRL scale** TRL5

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Negative **Selectivity** .... Not applicable **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ High
Return on Investment........ Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Maybe

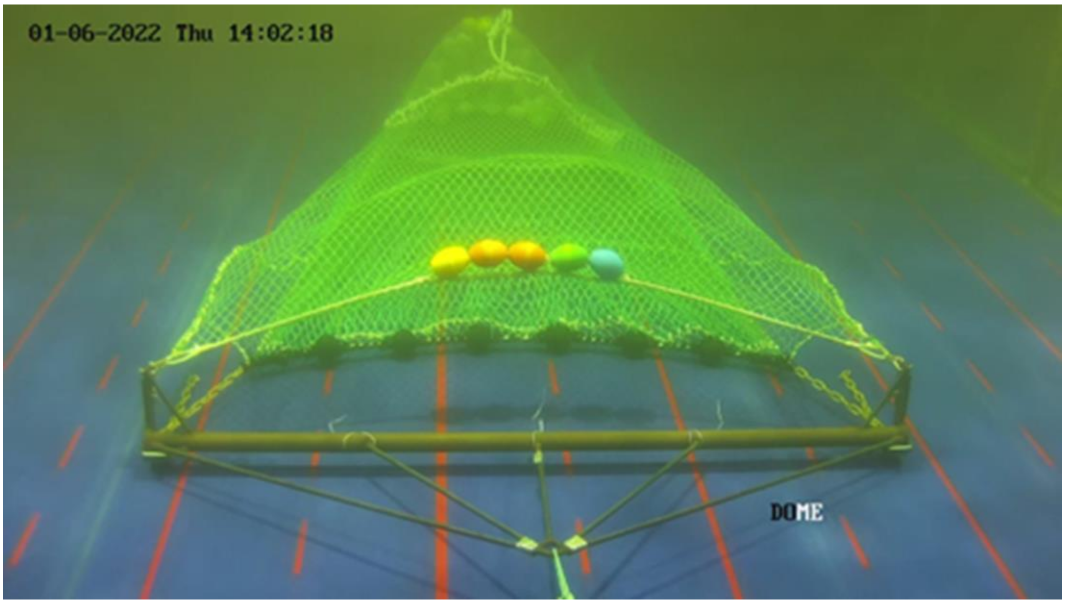
P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ It is a barrier
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Has encouraged uptake

6.2.11 Factsheet 30. Sea stars HydroTrawl

General information	
Year 2022	**Source supplier**............Barry O'Neill (DTU-AQUA, Denmark). *Revised by Louisa Sinclair, Alex Edridge, and Gokhan Gokce.*
Region...............................North Sea	**FAO-Area** 27.3.a, 27.4.a
Gear sub-category ....Beam trawls	**Gear code** ....OTB, OTT, OTP, TBN, TBS
Target species..................STH	**Bycatch species**...........MUS
Baseline gear	
Gear attached to triangular towing frame without shoes.	

Technical information
Definition of the Innovative gear
The turbulent flow generated in the wake of a beam towed close to the seabed is used to lift sea stars into the path of the following net. The optimal design increases catches of sea stars and reduces mussel bycatch. The beam is held at a fixed distance from the seabed by small shoes, thus ensuring a consistent fishing efficiency while reducing physical impacts on the seabed.
Technical specificities
On the innovative gear the beam is held off the seabed with small shoes and the positioning of the net to the beam is altered. The size and shape of the beam, its height above the seabed and the position of the net will all influence catching efficiency of sea stars and bycatch.
Outcomes expected
The optimal design increases catches of sea stars, reduces mussel bycatch and physical impacts on the seabed.
Other relevant information
Baastrup Burgaard *et al.* (*in press*)
Drawing / picture of the Innovative gear



Courtesy of Barry O'Neill (DTU-AQUA, Denmark).

Technological Performance assessment

Main criteria............... Environmental impact, reduced seabed impact.
Additional criteria ..... Energy efficiency, energy savings, bycatch reduction.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL8

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.. Low
Return on Investment.. Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?................... Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Do not know

6.2.12 Factsheet 31. Cable-based stereo trawl camera to deliver high-quality live-feed in real-time during demersal trawling (*TrawlMonitor*)

General information

Year 2022-ongoing

Source supplier............Antonello Sala, *with text adapted from Krag et al. (2022). Horizon 2020 project SmartFish (Smart fisheries technologies for an efficient, compliant and environmentally friendly fishing sector).*

Region...............................North Sea *(but viable for other areas)*

FAO-Area ....27.3 *(tested in Skagerrak and Kattegat)*

Gear sub-category ....Bottom trawls

Gear code ....TBN *(but viable for other trawl gears)*

Target species..................NEP

Bycatch species...........*Unwanted finfish species*

Baseline gear

Nephrops trawl gear without trawl camera monitoring systems.

Technical information

Definition of the Innovative gear

TrawlMonitor is a cable-based system that delivers a clear video-feed from the trawl to the vessel's wheelhouse in real-time. The TrawlMonitor is the first fully developed real-time system that delivers quantitative information on the ongoing catching process in demersal trawl fisheries. The system and all the elements in the system integration are specifically optimized for simple and robust commercial use. During the SmartFish EU project, clear video feed from the trawl that quantitatively indicated the catch composition that entered the trawl in real-time were successfully delivered. The tested TrawlMonitor is a cable-based stereo trawl camera powered from the topside through a coax-cable that delivers a high-quality live-feed from the trawl to the wheelhouse in real-time during demersal trawling. According to Krag *et al.* (2022), the developed, tested and demonstrated TrawlMonitor is ready for commercial up-take.

Technical specificities

Krag *et al.* (2022) tested the TrawlMonitor system to monitor the catch rate and catch composition where the SmartGear *(CodEnd closure system)* is used to react on the catching process. Sea trials with TrawlMonitor in combination with SmartGear were conducted in the Nephrops directed demersal trawl fishery and in the deep-water shrimp fishery in Skagerrak.

Outcomes expected

A bi-directional acoustic modem sending data from a sensor on the gear, i.e., the CodEnd Closure System, to the vessel in real-time allowed fishers to directly control the gear, and thus improve catch quality and reduce catch of unwanted catches. The procedure in the Nephrops fishery was to begin towing with the codend open and to use the codend closure system to close the codend in response to observations that there were sufficient Nephrops entering the gear. In this configuration the acoustic modem and codend closure system were attached to the top sheet of the codend as shown in figures below.

The objective of both these sets of trials in the H2020 SmartFish project was to demonstrate how TrawlMonitor used in combination with SmartGear (codend closure system) could be used to alter the selective performance of the gear in real time and in response to observations of the fishing process. While the trials demonstrated that the individual technologies perform well and are very promising, the acoustic path alignment issues need to be addressed before demonstration to the industry. Specifically, the system needs to consistently close when triggered together with a return confirmation on the topside that the system has been triggered.

Other relevant information

Krag *et al.* (2022), Birch *et al.* (2022).

Project website: http://www.smartfishh2020.eu/
Smart fisheries technologies for an efficient, compliant, and environmentally friendly fishing sector | SMARTFISH | Project | Results | H2020 | CORDIS | European Commission (europa.eu): https://cordis.europa.eu/project/id/773521/

Drawing / picture of the Innovative gear

Design of the observation scene with easy-access TrawlMonitor integration in a pocket. System integration in a Norway lobster trawl and system in operation during demersal trawling. *Source: modified and adapted from Krag et al. (2022).*

Technological Performance assessment	
Main criteria............... Catch efficiency, Nephrops selectivity. **Additional criteria** ..... Fuel consumption, catch quality.	
Technological readiness level (TRL)	
TRL category............. High	**TRL scale** TRL7
Technological complexity level	
Significant complexity	

Performance improvement		
Catch efficiency .... Transformative	**Selectivity** .... Transformative	**Impact** .... Not applicable

Comparison with the baseline	
Is the innovative gear easier to deploy and retrieve?	No, more difficult
Is the innovative gear easier to maintain and repair?	No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew?	Maybe

Economic Performance assessment	
Capital cost category	High
Return on Investment	Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it?	Unsure

P.E.S.T.E.L. Framework	
Overall, what impacts do you think have **political factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear?	It is a barrier
Overall, what impacts do you think have **social factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?	It is a barrier
Overall, what impacts do you think have **environmental factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?	Has encouraged uptake

6.2.13 Factsheet 32. Intelligent fishing (*Smartrawl*) to allow in-water identification and grading of fish by species and size

General information

Year	2023	**Source supplier**	Paul G. Fernandes (Heriot-Watt University and Fisheries Innovation & Sustainability). *Revised by Antonello Sala.*
Region	North Sea *(global solution)*	**FAO-Area**	27.4.a
Gear sub-category	Bottom trawls	**Gear code**	TB
Target species	Finfish species, *(e.g., COD, WHI, HAD)*	**Bycatch species**	*Unwanted species, depending on area.*

Baseline gear

Conventional bottom and demersal trawl gears.

Technical information

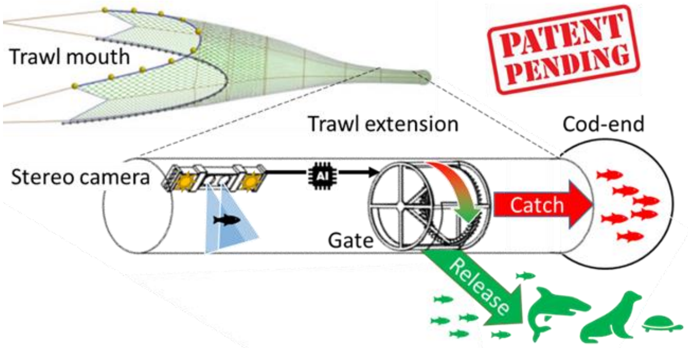
Definition of the Innovative gear

Smartrawl is part of a series of phased projects, to develop a selective device to operate in a demersal trawler allowing for fish to be released in-situ underwater. Smartrawl is an in-water selective device with three components: a stereo camera, taking images of animals in the trawl; a computer, with artificial intelligence to determine species and size of animals; and a gate, controlled by the computer to catch or release animals. Smartrawl was designed with trawl fishers and fits easily into the nets of all sizes of vessels: it needs no cables, and the patented gate system works with the force of the water to rotate between open and closed states. Smartrawl will allow fishers to program their trawls to catch exactly what they want, according to market conditions and their quota, and have no bycatch. Components of Smartrawl have been tested at sea with commercial skippers, and the next stage is to integrate the system and take the next step towards the sustainable future of trawling.

Technical specificities

Smartrawl requires two items to be fitted into the extension of the net: a stereo camera system with lights and an onboard computer; and a gate, which is a cylinder with a diameter equivalent to that of the net at that juncture. Descriptions of the Smartrawl 'Gate Mechanism' were prepared and discussed with the University's Commercialisation manager and the patent attorney (Murgitroyd European Patent and Trademark Attorneys).

Outcomes expected
Ultimately, we anticipate the trawl to be pre-programmed (e.g., via an app on a phone) to catch only what the skipper wants (species and size). Everything else will be released back into the sea, in-situ, alive and unharmed.
Other relevant information
Smartrawl - Fisheries Innovation & Sustainability | https://fisorg.uk/smartrawl/
Drawing / picture of the Innovative gear



Schematic Smartrawl system. *Courtesy of Paul G. Fernandes (Heriot-Watt University and Fisheries Innovation and Sustainability).*

Technological Performance assessment

Main criteria............... Catch efficiency, size- and species-selectivity, environmental impact.
Additional criteria ..... No bycatch, less bulk, more fuel-efficient.

Technological readiness level (TRL)

TRL category............. Low **TRL scale** TRL2

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Disruptive **Impact**......... Disruptive

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Maybe
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment........ Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Still at TRL2, but govt agencies very keen on the idea.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Depends on final cost, which will depend on manufacturer's requirements.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Retailers have indicated they will provide incentives for the buyers to source from boats using this. Has attracted a lot of social attention.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Do not know

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake

Bycatch issue high on biodiversity agenda, especially elasmobranchs.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?.................................. Do not know
Depends on what government decide to do, may well leave it to the market.

6.2.14 Factsheet 33. Wireless underwater camera (*CatchCam*) to monitor fishing gear performance

General information

Year 2022	**Source supplier** ....Ulf Lundvall (Marine CTRL AS) and SafetyNet Technologies (Norway).
Region ....North Sea *(but solution is global. Option for wider application)*.	**FAO-Area** 27.3, 27.4
Gear sub-category ....*Any trawl gear*	**Gear code** ....BT, TB, TM
Target species ....*Not applicable.*	**Bycatch species** ....*Not applicable.*

Baseline gear

Any conventional trawl gear without monitoring camera systems.

Technical information

Definition of the Innovative gear

CatchCam is a small wireless underwater camera that can be attached to all gear types. It is robust and easy to use and can be deployed on all types of fishing gear. The CatchCam has a battery life of up to 21 days, variable frame rates and low light settings and comes with a remote control for easy use on deck. Users access the footage on recovery of the gear, by streaming from the camera to a phone or tablet running the CatchCam App – thus there is no need to remove the equipment and the footage can be accessed while the vessel is operating. The CatchCam is small enough to be deployed anywhere on the fishing gear from the trawl door to the codend and works equally well with mobile and static gears.

Technical specificities

Depth rated – 800 m / Length 180 mm / Diameter 55 mm / Near neutrally buoyant / Operating temp Min: 0°C (32°F) Max: +55°C (131°F) / Format MP4 / Resolution 480p / Field of view 85° +/- 20° / Memory 128 GB.

Outcomes expected

CatchCam allows users to see their fishing gear in action and based on performance take appropriate measures to reconfigure the fishing gear, resulting in better catching performance (reduction in resource inputs / kg of fish) and a reduction in negative impacts (bycatch or environment).

Other relevant information

Supplier website: https://sntech.co.uk/products/catchcam/

Drawing / picture of the Innovative gear

Courtesy of SafetyNet Technologies.

Technological Performance assessment

Main criteria............... Selectivity, catch efficiency, environmental impact. **Additional criteria** ..... Precision fishing, reduced GHG emissions, energy savings.
Technological readiness level (TRL)
TRL category............. High **TRL scale** TRL9
Technological complexity level
Significant complexity
Performance improvement
Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Transformative
Comparison with the baseline
Is the innovative gear easier to deploy and retrieve?............ Yes, easier **Is the innovative gear easier to maintain and repair?**............ Yes, easier **Does using the innovative gear present a lower risk to the health and safety of crew?** .... No difference
Economic Performance assessment
Capital cost category............ High **Return on Investment**............ Significant **Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it?** .... No, lower
P.E.S.T.E.L. Framework
Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Not Applicable Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know Overall, what impacts do you think have **technological factors** had on uptake of this gear?............ Do not know Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know Overall, what impacts do you think have **legal factors** had on uptake of this gear?............ Not Applicable

6.3 North Western Waters

6.3.1 Factsheet 34. Square-mesh cylinder in the extension (CMC)

General information

Year 2015-2017

Source supplier .... Antonello Sala, *with text adapted from Weiller et al. (2014); Balazuc et al. (2016); Reid (2017); Reid et al. (2019). Horizon 2020 project DiscardLess (Strategies for the gradual elimination of discards in European fisheries). Revised by Marieke Desender and Ben Collier.*

Region .... North Western Waters

FAO-Area .... 27.7.d *(Eastern Channel)*

Gear sub-category .... Bottom trawls

Gear code .... OTB, OTT

Target species .... Demersal species (e.g., WHG, MUX), MAC, squid, cuttlefish

Bycatch species .... HER

Baseline gear

Conventional demersal trawls, with an 80-99 mm codend.

Technical information

Definition of the Innovative gear

Square-mesh cylinders *(CMC in French).*

Technical specificities

Alternatives
a) 2-m long 80-mm;
b) 1-m long 80-mm;
c) 2-m long 115-mm;
d) 2-m long 100-mm
e) 2-m long 80-mm + grid *(SELECMER grid 1x0.7 m, bar spacing of 23 mm)*

Outcomes expected

Vessels using the mesh cylinder (CMC) reported loss of commercial catch volume (in some case substantial as for the 100-mm and 115-mm CMC), and in discard volume. While such changes may help fishers comply with the LO, and reduce discards, it is still not sufficient to avoid significant impacts on their economic viability. Notwithstanding this, we consider it desirable to continue working with fishers on both gear and behavioural based responses to the challenges implicit in the LO (Reid *et al.*, 2019). For example, it is worth considering for future investigation the alternative 80-mm CMC+grid, where besides a minor loss of commercial species a valued 8% discard reduction was obtained.

Main outcomes for each individual alternative. Reduction of the overall landings, discards, and economic impact.

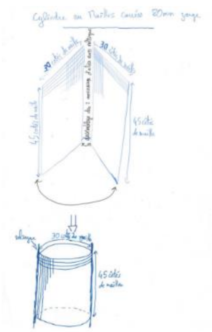
Alternative	Commercial	Discards
a) 2-m long 80-mm;	-10%	-22%
b) 1-m long 80-mm;	-12%	-20%
c) 2-m long 115-mm;	-22%	-37%
d) 2-m long 100-mm	-40%	-36%
e) 2-m long 80-mm + SELECMER grid	-1%	-8%

Source: modified and adapted from Weiller et al. (2014).

Other relevant information

Weiller *et al.* (2014); Balazuc *et al.* (2016); Reid (2017); Reid *et al.* (2019).

Drawing / picture of the Innovative gear



Source: modified and adapted from Balazuc et al. (2016) and Weiller et al. (2014).

Technological Performance assessment

Main criteria............... Reduce undersized animals and unwanted catches while implementing landing obligation.
Additional criteria ..... Minimization of effort, safety to shooting/hauling. Substantial user friendliness, low investment cost.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Negative **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.. Low
Return on Investment.. Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Political factors are not relevant.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
The results from the 100 mm and 115 mm CMC versions indicate a significant reduction of commercial catch.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Do not know
The relatively simple design of this device would not cause any technological challenges.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Reduction of discards.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. It is a barrier
If the device is restricting the meshes in the main part of the trawl from opening this would have legal implications.

6.3.2 Factsheet 35. Hydrodredge, a novel innovation in giant scallop *(Placopecten magellanicus)* dredging to reduce impact on the seabed

General information

Year 2009-ongoing

Source supplier .... Antonello Sala, *with text adapted from Shephard et al. (2009). Revised by Marieke Desender and Ben Collier.*

Region .... North Western Waters

FAO-Area 27.5, 27.6, 27.7

Gear sub-category .... Towed dredges

Gear code .... DRB

Target species .... SCA

Bycatch species .... *Undersized scallops, benthic invertebrates*

Baseline gear

Conventional towed dredges for giant scallops.

Technical information

Definition of the Innovative gear

The novel 'Hydrodredge' was designed for giant scallop (*Placopecten magellanicus*). It has the potential to exert far less damaging effects on the seabed and its biota (Shephard *et al.*, 2009). Instead of mechanical means, the new gear uses four precisely oriented 'cups' (cut from 30 cm trawl floats) that deflect water into a downward jet and create large-scale vorticity, a combination that exerts sufficient force on the seabed to lift scallops into the water column whereupon they can be captured by the trailing net/chain bag. Notably, this is a passive process based on the hydrodynamics of the gear and does not require any mechanical pumping of water.

Technical specificities

The hydrodredge is 2.1 m wide and used four hydrocups (23 cm diameter) placed at regular intervals across the mouth. A single chain bag was used, being 2.1 m wide and 1 m deep and comprised of 10 cm steel rings. The belly chain sagged from its connection points, contacting the seafloor approximately 45 cm behind the outer and 90 cm behind the inner hydrocups. The top of the bag was constructed as a heavy nylon mesh panel to reduce weight (Shephard *et al.*, 2009).

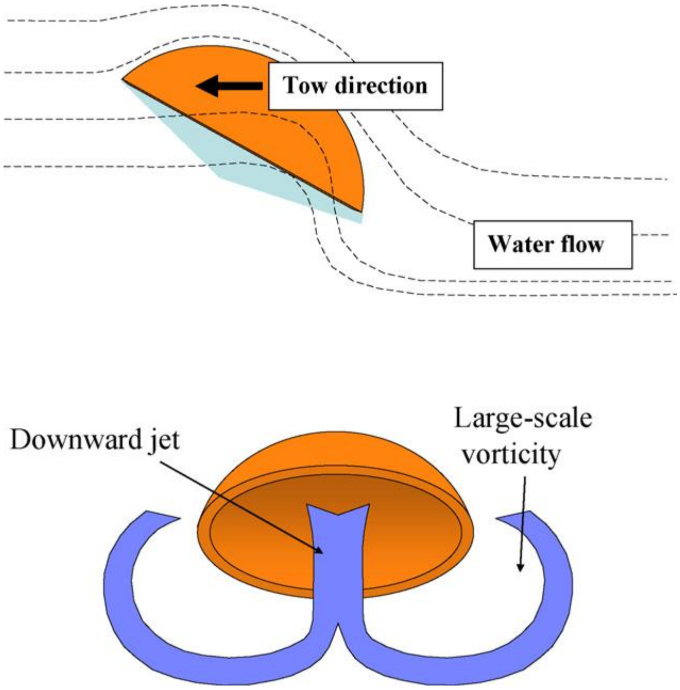
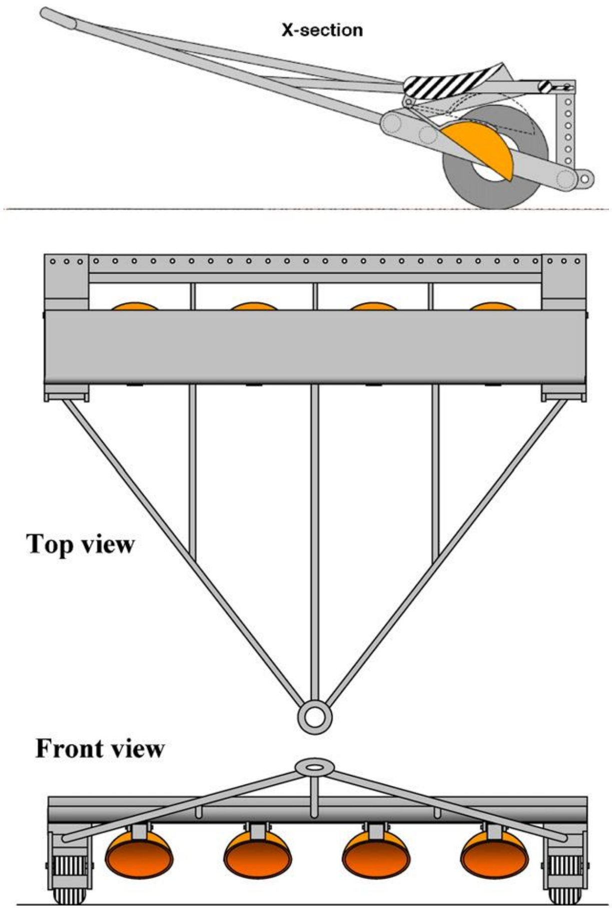
Outcomes expected

Scallop dredges typically use teeth or a cutting bar to dig though the sediment and are associated with detrimental impacts on marine benthos. The lower impact 'Hydrodredge' uses 'cups' to deflect water downward in a turbulent wave sufficient to lift scallops from the seabed. Shephard *et al.* (2009) tested the novel dredge over three different ground types (smooth, medium and hard) and two tow-speeds (2.5 kt, 4.0 kt), the proportion of dead scallops and bycatch in the Hydrodredge was significantly less than in the commercial dredges. This result highlighted the role of the teeth on the tooth-bar in exerting severe (fatal) damage to the catch and bycatch. Rates of non-fatal damage to scallops and bycatch did not differ between gears, suggesting that such damage occurs because of contact with other parts of the gears such as the chain bag.

The hydrodredge was less efficient at catching great scallops compared with the commercial dredges (10-40%). For great scallops (*Pecten maximus*), the cups did not significantly increase catch relative to the dredge fished without cups, which contrasts with results for other surface-dwelling scallop species, e.g., *Placopecten magellanicus* and *Aequipecten opercularis*. Importantly, the Hydrodredge was designed for the giant scallop (*P. magellanicus*), a species typically lighter and less embedded than *P. maximus* and thus potentially more vulnerable to the flow patterns of the Hydrodredge.

Other relevant information

Shephard *et al.* (2009).

Drawing / picture of the Innovative gear
 Diagram showing water flow around hydro cups (upper image is side view and lower image is front view). Water flow is passive and only due to hydrodynamics of the gear. *Source: modified and adapted from Shephard et al. (2009).*  Diagram of hydrodredge incorporating novel cup design. *Source: modified and adapted from Shephard et al. (2009).*
Technological Performance assessment

Main criteria............... Size- and species selectivity, physical impact on the seabed.
Additional criteria ..... Fuel saving.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Negative **Selectivity** .... Incremental **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair?... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category.. Low
Return on Investment .... Negative
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Yes, higher

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
10-40% reduction in the catch of great scallops would cause a financial loss to the fisher.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
Potentially less physical wear compared to a toothed dredge resulting in less maintenance requirements.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Do not know

6.3.3 Factsheet 36. Quad-rig trawling to improve selection in *Nephrops* fishery

General information

Year 2017	**Source supplier**............Daragh Browne. *Revised by Antonello Sala, Marieke Desender, and Ben Collier.*
Region....................North Western Waters	**FAO-Area**....................27.7
Gear sub-category...........Bottom trawls	**Gear code**....................OTP
Target species..................NEP	**Bycatch species**...........undersized NEP and WHG, HAD, COD

Baseline gear

Quad-rig trawling has become ubiquitous in Irish Nephrops fisheries, replacing twin-rig as Nephrops catch rates are higher.

Technical information

Definition of the Innovative gear

Quad-rig trawls using a triple warp and centre clump arrangement with 4 identical Nephrops trawls each fitted with a diamond mesh codend with nominal mesh sizes of 70, 80, 90, or 100 mm.

Technical specificities

Four Nephrops trawls (35.5 m footrope length) in quad-rig configuration comprising:

- 70 m outer sweeps (22 mm ϕ combination rope)
- 50 m split/vee sweeps (22 mm ϕ combination rope)
- 20 m middle sweeps (22 mm ϕ combination rope)

Outcomes expected

Reductions in total catches of up to 61% of cod, 38% of haddock, and 59% of whiting were observed in trials in the Celtic Sea which compared catches in quad and twin-rig trawls with 70 mm codend mesh size (BIM, 2014). These reductions could be associated with lower headline height and altered sweep arrangements. Significantly increased proportions of small Nephrops and cod were retained in the quad-rig compared with the twin-rig. Results suggest that lower catch weight associated with reduced fish catches in quad-rig trawling is likely to increase retention of smaller Nephrops compared with single or twin-rig trawling. Hence, management measures which consider the different catch profiles of single-, twin-, and quad- rig trawling are required in Nephrops fisheries to optimize bycatch reduction and quota utilization under the EU landing obligation. Such an approach would effectively reduce catches of undersize Nephrops, boost sustainability of the Nephrops stock, assist fishers in meeting EU landing obligation requirements, and optimize economic returns from the Nephrops fishery.

The finding by Browne *et al.* (2017) that larger codend mesh sizes retained fewer small Nephrops provides firm biological justification for an increase in mesh size from 70 to 80 mm.

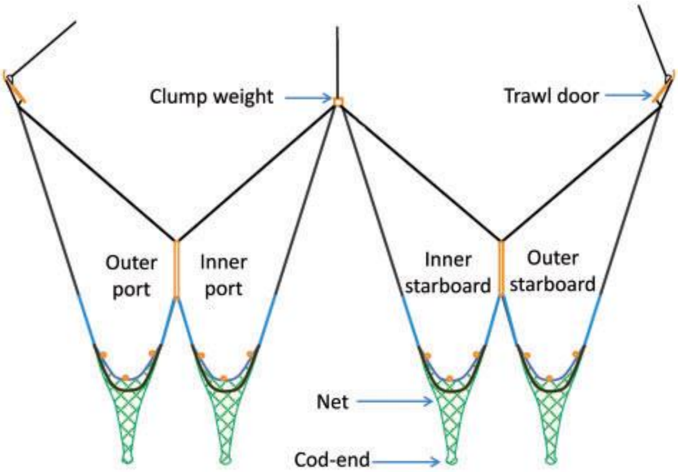
Increases in codend mesh size beyond 80 mm resulted in an approximate doubling of economic loss for relatively small gains in terms of reductions of catches of small Nephrops. In the short term, an increase to 90 or 100 mm mesh codend is unlikely to be economically feasible as a means of reducing catches of small Nephrops (Browne *et al.*, 2017). An 80 mm baseline codend mesh size was implemented first as an Irish measure and then at EU level under Regulation (EU) 2019/1241 (2019).

Other relevant information

BIM (2014), Browne *et al.* (2017).

Other relevant legislations are: Regulation (EC) 850/1998 (1998), Regulation (EC) 2602/2001 (2001).

Drawing / picture of the Innovative gear



Source: modified and adapted from Browne et al. (2017).

Technological Performance assessment

Main criteria............... Nephrops size selectivity, catch efficiency, fish bycatch reduction.
Additional criteria ..... Fuel saving.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair?.......... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.......... High
Four new trawls required along with sweeps and potentially larger trawl doors.

Return on Investment.......... Substantial
Quad-rig catch rates consistently higher than twin-rig.

Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.......... Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?.......... Not Applicable
Except in Scottish waters where 2-trawls configuration is the legal maximum.

6.3.4 Factsheet 37. Black sea bream fish pot

General information

Year 2023	**Source supplier** .... Sonia MEHAULT (IFREMER, France). *Revised by Marieke Desender and Ben Collier.*
Region .... North Western Waters	**FAO-Area** 27.8.a,b
Gear sub-category .... Pots	**Gear code** .... FPO
Target species .... BRB	**Bycatch species** .... *Unwanted and undersized species*

Baseline gear

Technical information

Definition of the Innovative gear

Floating fish pot, conception based on target species behaviour.

Technical specificities

Floated and rotating gear (off the seafloor and oriented in the water current). Foldable to be compact on board but resistant facing the water current when deployed.

Outcomes expected

Catch of black seabream without catch of crustacean. High fish quality. Ergonomic use under commercial conditions. Good resistance to water current. Low contact with the sea floor.

Other relevant information

Méhault *et al.* (2022), National Regulation: 2018-014 Deliberation «*Nasses a poissons-CRPM-A*» du 30 Mars 2018.

Drawing / picture of the Innovative gear

Experimental fish pot device (*left*) and foldable pot legs (*right*). *Source: modified and adapted from Méhault et al. (2022).*

Technological Performance assessment

Main criteria............... Potential for high selectivity since mesh size is adapted to target species and remain open during fishing operation. Low catch rate so far.
Additional criteria ..... High fish quality.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.. Moderate
Return on Investment... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Yes, higher

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Not Applicable

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Fish pot is a significant investment compared to the benefit from the catch.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Adopting eco-friendly fishing gear contributes to a good image of coastal fishers.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?................... Has encouraged uptake
Coastal fishers with vessels already equipped with net-spooler might be prone to test fish pots since they can easily deploy them.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
More and more artisanal fishers are interested by fish pots since they are aware of the need to use sustainable gear.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Not Applicable
The adoption of fish pot is a voluntary act and not driven by the regulation.

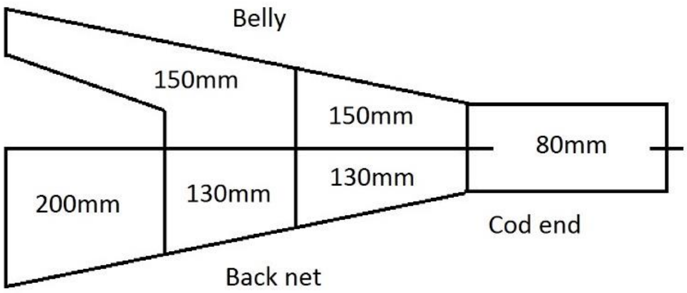
6.3.5 Factsheet 38. Selective Beam Trawl

General information

Year 2010-ongoing
Source supplier............Marieke Desender and Thomas Catchpole (CEFAS)
Region...............................North Western Waters
FAO-Area 27.7.e,f,g,h
Gear sub-category ....Beam trawls
Gear code ....TBB
Target species..................SOL, ANF, LEM, PLE, MEG
Bycatch species...........DAB, GUX, CTC, PLE, SYC

Baseline gear

Conventional beam trawl with 80 mm mesh codend.



Technical information

Definition of the Innovative gear

Incorporation of larger meshes in different sections of the gear design: codend, sleave, batings, lower panel and square section.

Technical specificities

Project 50% trailed 10 designs by 10 vessels developed together with the southwest fishing industry. Results from these trials led to defining two configurations of more selective beam trawls:

Option 1 - most used UK configuration: - Square section: 300 mm - Lower panel: 150 mm - Batings: 150 mm - Sleave: 150 mm - codend: 90 mm single 6 mm.

Option 2 - most selective UK configuration: - Square section: 300 mm - Lower panel: 180 mm - Batings: 180 mm - Sleave: 160 mm - codend: 100 mm.

Outcomes expected

All designs were successful, resulting in significant improvements in selectivity. Significant reductions towards the main quota species caught in the fishery were observed, including an average 28% reduction in the weight of, mostly small size classes of sole, as well as whiting (30%), plaice (2%), and monkfish (2%). Additionally, there were substantial and significant reductions in analysed non-quota species as well, such as bib, lemon sole, tub gurnard, cuttlefish, and dab (Catchpole *et al.*, 2018).

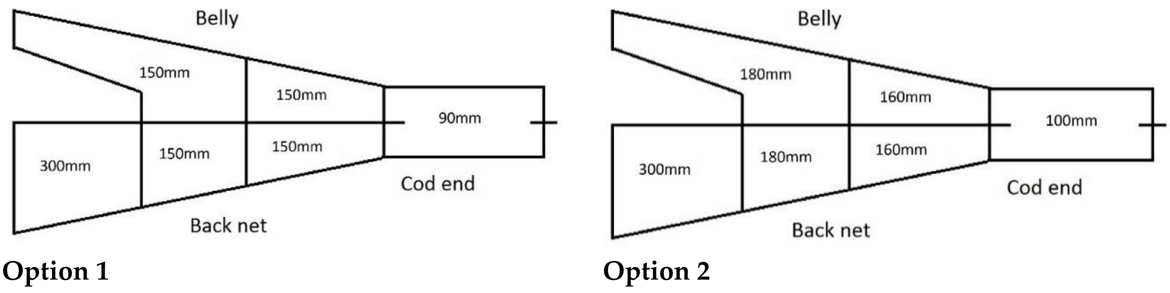
A follow up social study in 2017 revealed that, since the Project 50% trials, none of the participating vessels had reverted to the previous standard trawls, and some UK vessels that did not participate in the original trials had taken up the new more selective designs.

A gear inventory in 2020 showed that the majority (75%) of the UK South-West beam trawl fleet had incorporated meshes similar to or larger than option 1, but also the most selective option 2 is being used by a smaller number of vessels (10%) (Catchpole *et al.*, 2021). The response from the industry was used to define two selective trawl configurations now in use and considered to represent the most selective commercially viable designs that are currently available.

Other relevant information

Catchpole *et al.* (2018), Catchpole *et al.* (2021).

Drawing / picture of the Innovative gear



Technological Performance assessment

Main criteria............... Reducing unwanted catches and discards of fish.
Additional criteria ..... Reduced fuel consumption, improve catch quality, lower gear replacement rate.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Transformative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... Yes, easier
Does using the innovative gear present a lower risk to the health and safety of crew? .... Yes, lower

Economic Performance assessment

Capital cost category........ Low
Return on Investment........ Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
There was a direct economic incentive to offset quota cuts in the valuable sole quota in 2010. It was also mentioned by fishers that fuel consumption was reduced possibly due to lighter gear and less drag. It was mentioned that trawls were lasting longer and the catch quality improved.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
There was a social motivation to improve the environmental credentials of the fishery. The benefits of the trawl have been widely recognised amongst the fleet.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
Easy adaptable from existing gear.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
It is perceived as being more selective and has lower environmental impact. A lighter gear potentially reduces gear/seabed interaction therefore being beneficial to blue carbon habitat and less drag potentially reduces fuel use/ emissions.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................ Do not know
There were no legal barriers with the modifications developed.

6.3.6 Factsheet 39. Artificial LED lights on leadline in trawl fisheries

General information

Year 2023
Region .... North Western Waters
Gear sub-category .... Bottom trawls
Target species .... WHI, HAD, HKE

Source supplier .... Matthew McHugh (BIM, Ireland)
FAO-Area 27.7.j
Gear code .... OTB, OTT
Bycatch species .... COD

Baseline gear

Conventional trawls without lights on headline.

Technical information

Definition of the Innovative gear

Lights attached to the trawl headline.

Technical specificities

14 Lindgren-Pitman® green (LPG) light emitting diodes (LEDs) were attached to the headline of the trawl with ~150 cm spacing between each light.

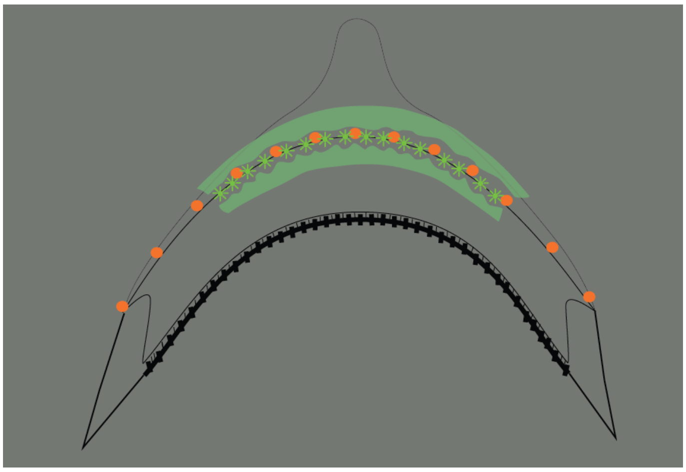
Outcomes expected

Maintain or increase target species, reduce unwanted species. 51% increase in haddock catch weight with lights on the headline during nighttime. 64% increase in the value of haddock caught with lights during nighttime.

Other relevant information

Oliver *et al.* (2023)

Drawing / picture of the Innovative gear



Graphical representation of lights on headline. *Courtesy of BIM (Ireland).*

Technological Performance assessment

Main criteria .... Species and size selectivity, reduced bycatch and discards.
Additional criteria ..... *None.*

Technological readiness level (TRL)

TRL category .... High **TRL scale** TRL9

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact** .... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category .... Low
Return on Investment .... Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Not Applicable

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Not Applicable
The modification is low cost, but fishers are slow to change from gears that are working, even when the new gear might improve catches.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
I do not know but, some fishers like to be seen to try something new but do not want to be seen as foolish for trying new concepts.

Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Do not know
I do not know but, Fishers just need to purchase some lights and try them.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Not Applicable

Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... Not Applicable
I cannot think of a legal reason why this gear could not be used.

6.3.7 Factsheet 40. Artificial LED lights on the raised fishing line in trawl fisheries

General information

Year 2022
Region .... North Western Waters
Gear sub-category .... Bottom trawls
Target species .... WHI, HAD, HKE

Source supplier .... Matthew McHugh (BIM, Ireland). *Revised by Antonello Sala.*
FAO-Area 27.7.g
Gear code .... OTB, OTT
Bycatch species .... COD

Baseline gear

Any trawl gear without lights on the raised fishing line.

Technical information

Definition of the Innovative gear

Lights attached to the trawl's raised fishing line.

Technical specificities

20 Lindgren-Pitmann® green lights were attached to the fishing line centred around the bosom of the trawl at ~ 1 meter spacing between each light.

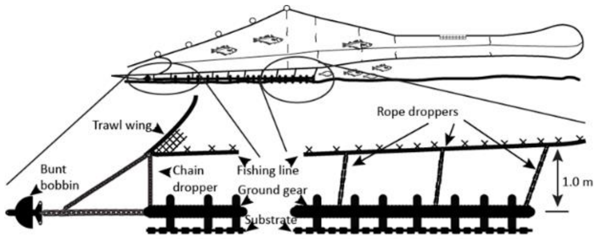
Outcomes expected

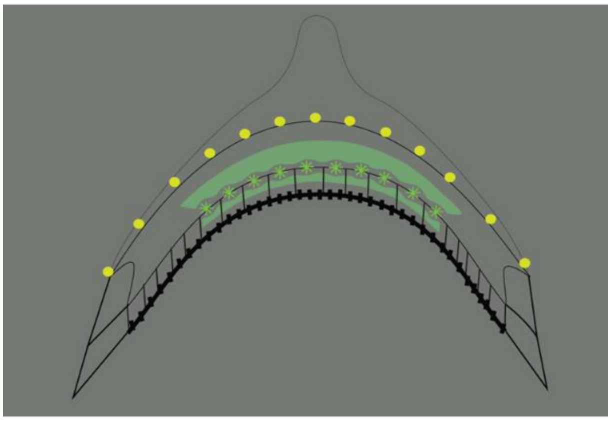
Significant 65% reduction in cod, Substantial reductions in market sized whiting and hake, Lights on the raised-fishing line currently commercially unviable due to loss of marketable catches.

Other relevant information

Oliver *et al.* (2022).

Drawing / picture of the Innovative gear





Graphical representation of lights on the raised fishing line. *Courtesy of BIM (Ireland).*

Technological Performance assessment

Main criteria............... Species and size selectivity, reduced bycatch, and discards.
Additional criteria ..... None.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Low
Return on Investment........ Negative
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Yes, higher

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Not Applicable

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Not Applicable
The modification is low cost but fishers there was a substantial loss to target catches.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know

I do not know but, some fishers like to be seen to try something new but do not want to be seen as foolish for trying new concepts.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Do not know
I do not know but, Fishers just need to purchase some lights and try them.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Not Applicable

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................ Not Applicable
I cannot think of a legal reason why this gear could not be used.

6.3.8 Factsheet 41. Modified trawl rigging towards reduction of unwanted catches in *Nephrops* fisheries

General information

Year...................................2022
Region...............................North Western Waters
Gear sub-category...........Bottom trawls
Target species..................NEP
Source supplier............Matthew McHugh (BIM, Ireland)
FAO-Area.......................27.7.a
Gear code......................TBN
Bycatch species...........WHI, COD, HAD, SKX

Baseline gear

Conventional twin trawls in half-quad configuration, see drawing (A) in the figure below.

Technical information

Definition of the Innovative gear

Two 3.6 m lengths of combination rope (22 mm diameter) were attached between the middle bridles on a half-quad configuration.

Technical specificities

The standard rig is a standard half quad configuration with a 'Y' bridle arrangement (drawing A in the figure below). The modified rig comprised a modified half quad-rig sweep configuration where two middle sweeps were joined fore and aft by 3.6 m horizontal ropes. See drawing (B) in the figure below.

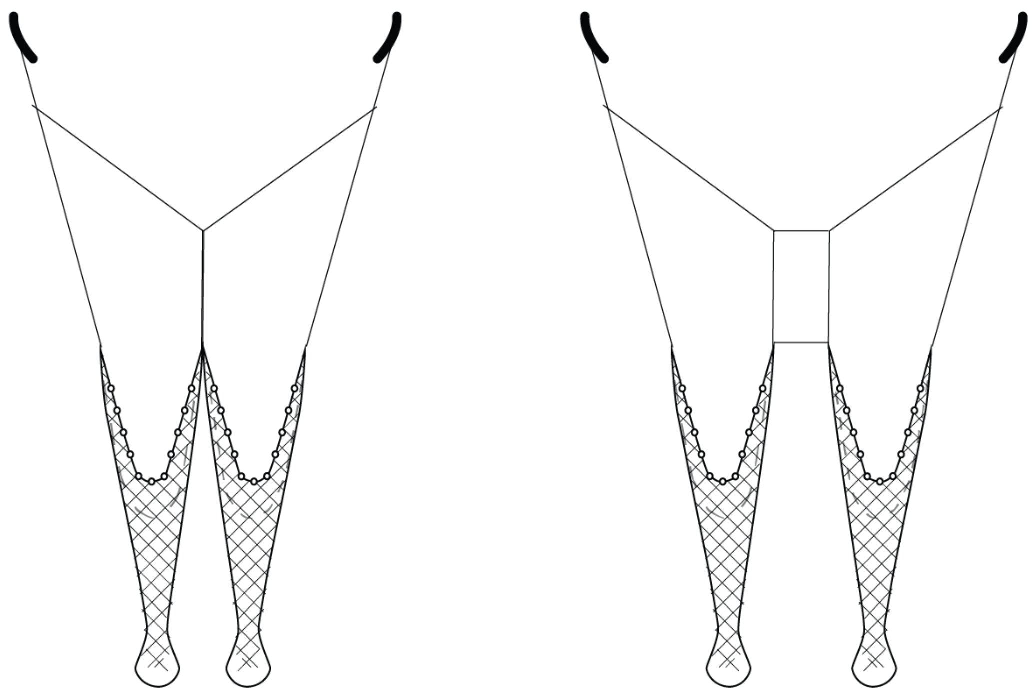
Outcomes expected

Increase in *Nephrops* catches. Reduction in dogfish catches, No reduction in small whiting or haddock catches.

Other relevant information

Browne et al. (2022).

Drawing / picture of the Innovative gear



(A) Standard rigging (half-quad configuration) (B) Modified rigging with gap between trawls.

Technological Performance assessment

Main criteria............... Species and size selectivity, reduced bycatch and discards.
Additional criteria ..... *None*.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?........ No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Low
Return on Investment........ Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Not Applicable

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Not Applicable
The modification is low cost, but fishers are slow to change from gears that are working, even when the new gear might improve catches.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
I do not know but, some fishers are conscious of how they might be perceived for trying something new.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Do not know
I do not know but, Fishers might worry that changing their configuration will alter how it performs and the work they have done to hone their gear will be undone!

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Not Applicable

Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Not Applicable
I cannot think of a legal reason why this gear could not be used.

6.3.9 Factsheet 42. Alternative codend design (MEGRIMSAFE PANEL PLUS) to reduce unwanted catches

General information

Year	2022	**Source supplier**	Julio Valeiras (CSIC, Spain)
Region	North Western Waters	**FAO-Area**	27.7
Gear sub-category	Bottom trawls	**Gear code**	OTB
Target species	MNZ, LEZ	**Bycatch species**	HKE, HAD, COD, WHI, BOC

Baseline gear

Conventional bottom trawls targeting demersal species with codend 100 mm mesh size.

Technical information

Definition of the Innovative gear

Codend with 80 mm mesh size with top-and-side panel of square 180 mm mesh size.

Technical specificities

A codend of 80 mm diamond mesh size (T0) equipped with a square mesh panel of 180 mm mesh size (T45) of 3.4 m long, mounted in the upper half of the codend 5 m away from the end of the codend (segment T0_80_T45_05_180), occupying the entire width of the upper part of the codend and the sides of the lower part.

Outcomes expected

To propose this selective codend to be included in the technical measures regulation for its voluntary use in this fishery in ICES 7 waters. This 80 mm mesh codend equipped with a 180 mm square mesh panel could be a possible solution for the reduction of juvenile discard rates of target species and of several unwanted species in the fishery such as haddock and cod, minimizing economic impact in the fishery of commercial megrim losses using 100 mm mesh size.

Target species:

- Unwanted capture of megrims reduced 68.0%
- Unwanted capture of monkfish reduced 45.2%
- Unwanted capture of hake reduced 72.9%

In the case of the Megrims, with the experimental codend, they were caught 81.6% fewer small fish smaller than 25 cm (fish below the minimum BMS). The number of fish caught in commercial categories 1 and 2 also decreased. However, despite the decrease, the number of fish retained for these categories increased by 10.3% and the unwanted catch was reduced by more than 80%.

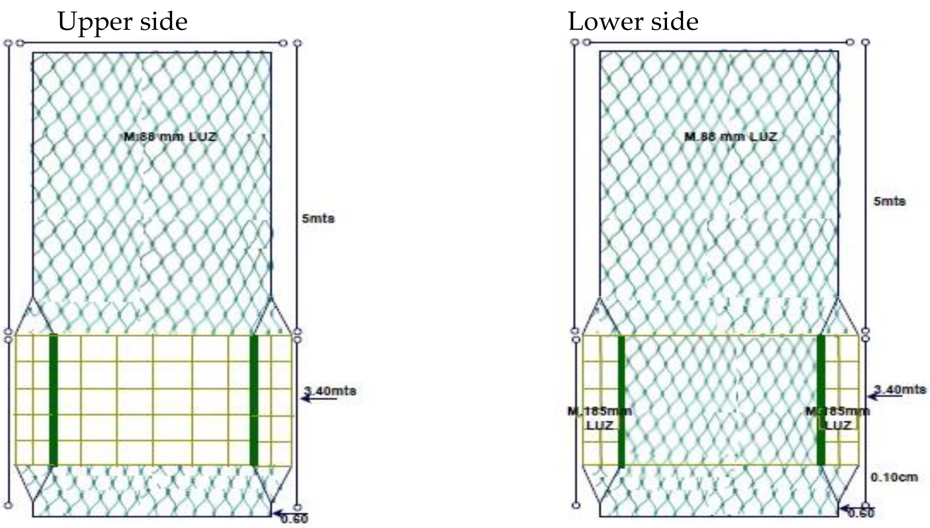
In the case of hake, with the experimental codend, 35% fewer specimens were retained, which affected all commercial categories. Unwanted catch of other species: Significant reduction of unwanted catches of choke species for this fishery.

- Unwanted capture of haddock decreased by 80.9%
- Unwanted capture of cod decreased by 44.0%
- Unwanted capture of blue whiting decreased by 99.4%

Other relevant information

Valeiras *et al.* (2019).

Drawing / picture of the Innovative gear



Courtesy of Julio Valeiras (CSIC, Spain).

Technological Performance assessment

Main criteria............... Species and size-selectivity
Additional criteria ..... Better quality, cleaner and less damaged fish (product valorisation). Savings in workload due to less sorting time for unwanted species and invertebrates (crew works more efficiently, with more time to prepare fish, more rest, greater safety).

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category	Low
Return on Investment	Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it?	Unsure
P.E.S.T.E.L. Framework	
Overall, what impacts do you think have **political factors** had on uptake of this gear?	Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **social factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?	Has encouraged uptake

6.3.10 Factsheet 43. Flemish panel

This innovation was presented in the WKING report (ICES, 2020c). An updated version with new information and PESTEL assessment has been provided by Heleen Lenoir and Mattias Van Opstal (ILVO).

General information

Year 2023	**Source supplier** ....ILVO (Belgium)
Region ....North Western Waters	**FAO-Area** 27.4, 27.7
Gear sub-category ....Beam trawls	**Gear code** ....TBB
Target species ....SOL	**Bycatch species** ....TUR, BLL, DAB, WHG, COD, LEM, MON, GUU, RJH, RJM, RJC, RJE

Baseline gear

Conventional beam trawls.

Technical information

Definition of the Innovative gear

A flatfish beam trawl vessel with a large mesh extension in the tail.

Technical specificities

The net is attached to a beam and is rigged with a chain matrix in the net mouth. The baseline gear has a net extension nominal mesh size of 80 mm while the innovative gear has a net extension nominal mesh size of 120 mm. All other sections of the trawl are identical.

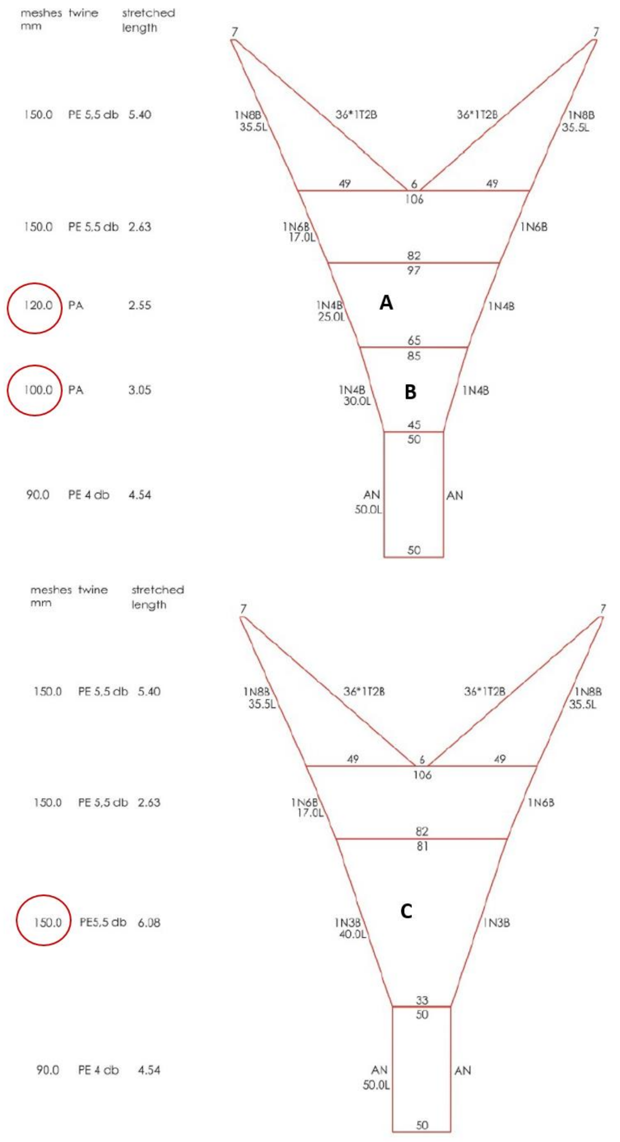
Outcomes expected

Increasing the mesh size of the extension in a beam trawl has shown to be an effective and simple method to reduce the capture of sub-legal sized sole and other species. The application of the large mesh extension trawl in the Belgian beam trawl fishery meets two needs: Reducing fishing mortality of undersized sole and maintaining the economic viability of the Belgian fishing fleet.

Other relevant information

Bayse and Polet (2015).

Drawing / picture of the Innovative gear



Design of lower panel of the standard net (top), and (bottom) lower panel of the experimental net: big mesh extension in the tail. *Source: modified and adapted from Bayse and Polet (2015).*

Technological Performance assessment

Main criteria............... Species- and size-selectivity.
Additional criteria ..... Improved fish survival.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL8

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Transformative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.. Low
Return on Investment.. Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
To maintain a de minimis for sole from the landing obligation, the implementation of a Flemish panel is required.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Has encouraged uptake

6.3.11 Factsheet 44. Raised Trammelnet (*Aranha*)

General information

Year 2020

Region...............................North Western Waters

Gear sub-category ....Entangling nets

Target species..................CTC

Source supplier............Monika Szynaka, Aida Campos, Redelusa, Lda (https://www.redelusa.pt)

FAO-Area 27.9.a,b

Gear code ....GTR

Bycatch species...........MIA, SOL, SKA

Baseline gear

Conventional trammel nets used in the Atlantic and Mediterranean.

Technical information

Definition of the Innovative gear

A standardized trammel net that is raised off the bottom using a thicker line between the bottom of the net and the leadline (soon to test using a buoy line on the bottom of the net to properly raise the net as suggested by the fishers).

Technical specificities

The bottom of the net is no longer directly attached to the leadline. There is an additional line attached to the bottom net and another line is attached between the bottom of the net and the leadline forming a diagonal pattern.

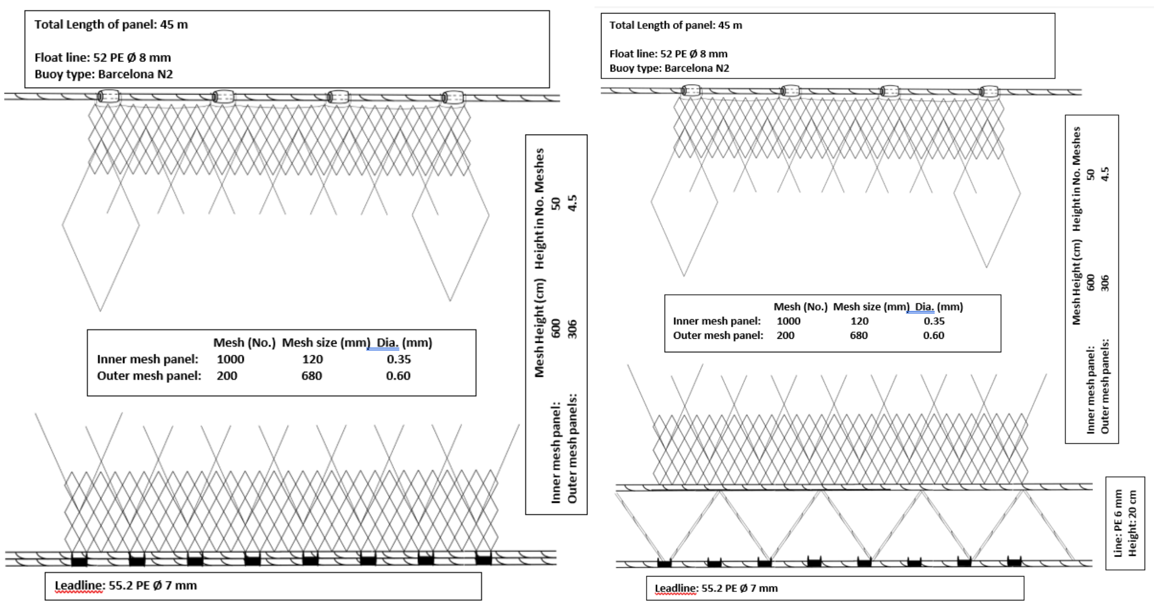
Outcomes expected

The gear has already been tested and there was a significant decrease of 36% of habitat forming species individuals in number and no significant differences in the main target species in numbers and weight. For the upcoming version of the net, it is expected that there will be an additional decrease in the numbers of corals and sponges caught.

Other relevant information

Website: https://www.redelusa.pt. *National Portuguese legislations: No. 1102-H/2000, 22/11. Recent Amendment: No. 594/2010, 29/07.*

Drawing / picture of the Innovative gear



Courtesy of Monika J. Szynaka. Using the free software "Inkscape".

Technological Performance assessment

Main criteria............... Selectivity, catch efficiency, and environmental impact.
Additional criteria ..... Reducing net cleaning and repairing.

Technological readiness level (TRL)

TRL category............. Moderate **TRL scale** TRL6

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?............ Maybe
Does using the innovative gear present a lower risk to the health and safety of crew? .... Yes, lower

Economic Performance assessment

Capital cost category............ Moderate
Return on Investment............ Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Two of the fishers associations' presidents in the Algarve have agreed to encourage uptake of such a gear.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Currently the modified net is more than 10% more expensive than the standard net.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
At least 50% of the local fishers interviewed stated they would uptake the gear due to the significant reduction of invertebrate by-catch and would therefore reduce cleaning efforts.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
The modification is so simple that a fisher could apply it to their own net if needed.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
A significant reduction of catch rates in habitat forming species.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Not Applicable

6.3.12 Factsheet 45. Four-Panel *Nephrops* trawl

General information

Year 2021

Region...............................North Western Waters

Gear sub-category ....Bottom trawls

Target species..................NEP

Source supplier............Matthew McHugh (BIM, Ireland). *Revised by Antonello Sala.*

FAO-Area 27.7

Gear code ....TBN

Bycatch species...........WHI, HAD, COD

Baseline gear

Any conventional two-panel *Nephrops* trawl.

Technical information

Definition of the Innovative gear

The innovative gear is a four-panel Nephrops trawl. The addition of two extra panels allows a modular approach when changing out panels to improve selectivity. For example, it is easier to include large mesh panels in the top sheet of a four-panel trawl than in a two panel.

Technical specificities

The four-panel trawl has larger mesh in the top panel to allow unwanted individuals easier escape and it has a steeper trawl side taper that are likely to reduce drag.

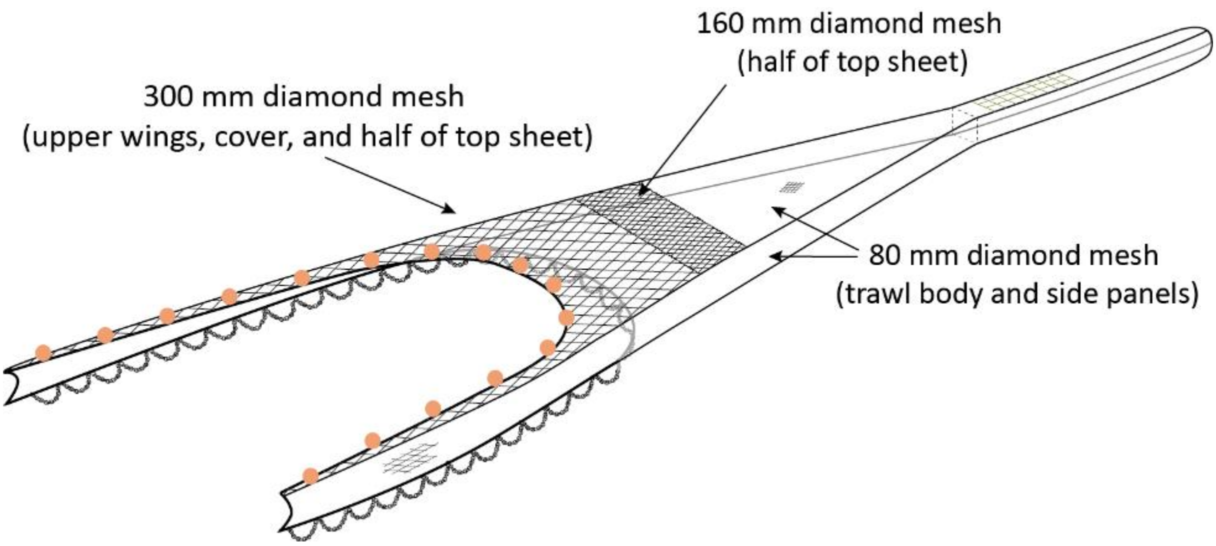
Outcomes expected

Reduced catch of unwanted individuals while maintaining Nephrops catches. 9% increase in wing end spread and swept area.

Other relevant information

McHugh et al. (2022).

Drawing / picture of the Innovative gear



Graphical representation of the four-panel trawl. *Source: modified and adapted from McHugh et al. (2022).*

Technological Performance assessment

Main criteria............... Improved Nephrops catches and selectivity.
Additional criteria ..... Reduced fuel consumption.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? ...... No difference
Is the innovative gear easier to maintain and repair?...... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? ...... No difference

Economic Performance assessment

Capital cost category...... Moderate
Return on Investment...... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? ...... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? ...... Do not know

Overall, what impacts do you think have **economic factors** had on uptake of this gear?...... It is a barrier
There are initial additional costs to constructing this trawl because of the additional work in making and putting together the four panels.

Overall, what impacts do you think have **social factors** had on uptake of this gear? ...... It is a barrier
Two panel trawls are the most common trawl used and it is difficult to change mindsets to a new trawl design.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?...... Not Applicable
The four-panel trawl can be a direct swap for a two-panel trawl.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? ...... Do not know
It has the potential to reduce fuel use, but this comes at the cost of investing in a new trawl (or up to 4 in quad rig) and might not.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?...... Not Applicable
There are no legal barriers to the uptake of this gear.

6.3.13 Factsheet 46. Raised fishing line trawl

General information

Year 2019	**Source supplier** .... Matthew McHugh and Daragh Browne, *with text adapted from McHugh et al. (2017).*
Region .... North Western Waters	**FAO-Area** 27.7
Gear sub-category .... Bottom trawls	**Gear code** .... OTB, OTT
Target species .... WHI, HAD	**Bycatch species** .... COD, SKX, FLX

Baseline gear

Directed fishing for mixed fish must use a mesh size of at least 80 mm must be used with a square mesh panel of at least 120 mm.

Technical information

Definition of the Innovative gear

Droppers are extended to 1 m between the fishing line ground gear and was initially developed as a method to reduce unwanted (low quota) species (e.g., cod, plaice) in fish trawls.

Technical specificities

The raised-fishing-line trawl comprises a standard trawl with 1 m long droppers attached between the fishing line and ground gear. A triple-bridle configuration was found to stabilise the trawl under a variety of towing speeds. The third bridle was attached between the fishing line and the upper bridle with the existing bridle extended by 6 m to allow the third bridle to function correctly (see drawing below). The tested gear had 32×1 m droppers constructed from 14 mm polysteel rope attached between the fishing line and the ground gear. However, droppers can be constructed from rope, and/or chain.

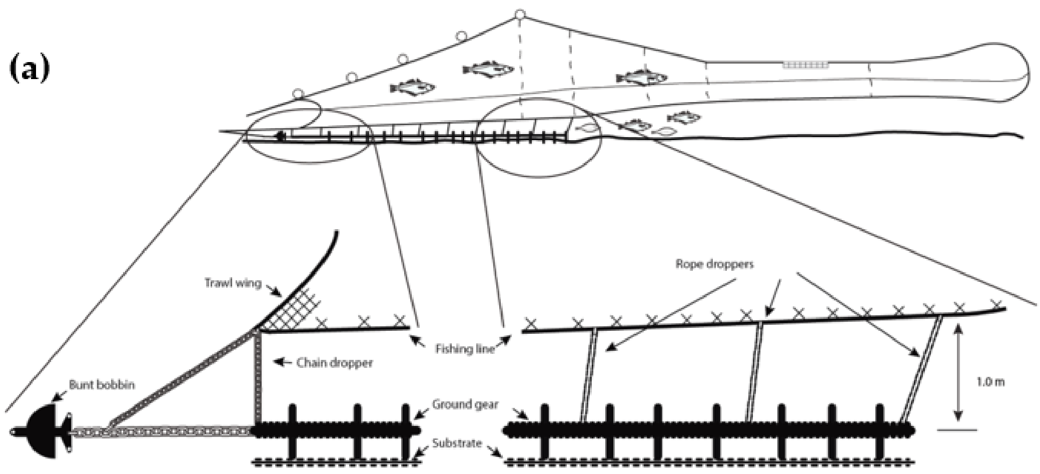
Outcomes expected

Substantial reductions in rays, flatfish, and dogfish with more moderate reductions in haddock and cod. Substantial reduction in undersized whiting with no loss of market sized whiting. Many areas of the Celtic Sea have a bycatch only quota for cod and Plaice with many skate and ray species considered vulnerable. The key results of this gear are a reduction in cod (62%), flatfish (67%), and skate and ray (88%) catches.

Other relevant information

McHugh et al. (2017).

Drawing / picture of the Innovative gear



Raised fishing line (a) and the bridle configuration (b). *Source: modified and adapted from McHugh et al. (2017).*

Technological Performance assessment

Main criteria............... Species- and size-selectivity.
Additional criteria ..... Ability to fish in areas of low cod and/or plaice quota.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Low
Return on Investment........ Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Other factors are likely to have had more influence on uptake.

Overall, what impacts do you think have **economic factors** had on uptake of this gear?......................... It is a barrier
There is a potential loss to bottom fish like flatfish and monkfish.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... It is a barrier
The potential loss of bottom fish will give the impression of losing out.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Do not know
I do not know but similar gears with small er gaps between the fishing line and ground gear are often used to limit the catching of debris.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
The reduction in unwanted by-catch of fish should result in more efficient use of available quota but might mean additional days fishing are needed to catch escaped fish like monkfish and some flatfish.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Not Applicable
Under Regulation (EU) 2019/1241 (2019) this gear has been implemented as an option in North Western Waters, specifically in ICES divisions 7f,g, the part of 7h North of latitude 49°30' North and the part of 7j North of latitude 49°30' North and East of longitude 11° West.

6.3.14 Factsheet 47. Dual codend with net separator panel

General information

Year	2019	**Source supplier**	Daragh Browne and Matthew McHugh, *with text adapted from Cosgrove et al. (2019).*
Region	North Western Waters	**FAO-Area**	27.7
Gear sub-category	Bottom trawls	**Gear code**	TBN
Target species	NEP, ANG	**Bycatch species**	COD, WHI, HAD

Baseline gear

Directed fishing for Norway lobster (*Nephrops norvegicus*) a mesh size of at least 80 mm must be used with a square mesh panel of at least 120 mm or sorting grid with a maximum bar spacing of 35 mm or equivalent selectivity device fitted.

Technical information

Definition of the Innovative gear

A net panel allows *Nephrops* to pass through into a lower codend while fish are deflected into an upper codend. Appropriate codend mesh sizes and mesh orientations are utilised to optimise selectivity. T90 (turned 90°) mesh is used in the upper codend as it is typically more selective than equivalent diamond mesh (T0) for round fish such as cod, haddock and whiting. This gear has been implemented as a remedial measure for cod and whiting in the Celtic Sea Protection Zone (EU 2019/1241) albeit with the upper codend mesh size increased to 100 mm from 90 mm in line with measures for non-Nephrops fisheries.

Technical specificities

- 2 to 4 panel adapter section
- 4-panel separator section
- 4 to 2 panel extension pieces (x2)
- 2 panel upper codend (90 mm T90 mesh) and lower codend (80 mm diamond mesh)

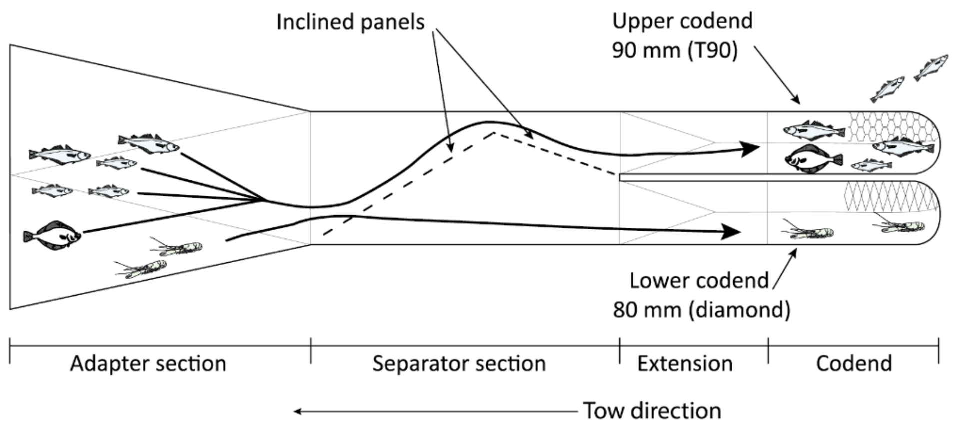
Outcomes expected

Comparing catches from a dual codend with net separator and an 80 mm control codend (Cosgrove *et al.*, 2019) results in: 1) no reduction in catches of Nephrops ≥MCRS; 2) separation of key retained fish species by weight into the top codend consisted of 82% of flatfish, 83% of haddock, 90% of cod and hake, 94% of whiting, and 98% of monkfish; 3) reductions in catches of undersize whiting (-72%) and haddock (-49%); 4) species separation greatly reduced catch sorting times and improved fish quality.

Other relevant information

Cosgrove et al. (2019).

Drawing / picture of the Innovative gear



Dual codend showing the likely behaviour of fish passing over the inclined panels into the upper codend, and Nephrops passing through the inclined panel into the lower codend. *Source: modified and adapted from Cosgrove et al. (2019).*

Technological Performance assessment

Main criteria............... Species- and size-selectivity
Additional criteria ..... Separating fish and crustacean catches improved catch sorting times and catch quality.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Transformative **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair?... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category... Moderate
Return on Investment... Significant
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Other factors are likely to have had more influence on uptake.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
More expensive to purchase and maintain than standard gear.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... It is a barrier
This gear is one of several gear options available to fishers. The most used option is likely the one that fishers are most familiar with as it has been implemented for the longest time, i.e., a square mesh panel fitted between 9 and 12 m from the codline.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. It is a barrier
Significant departure from standard practice. Requires modification of existing gear (cutting back trawl body to accommodate increased circumference) and vessel (dividing hopper).

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Reduced unwanted by-catch of fish results in more efficient use of available quota, less catch sorting time and increased catch quality.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Not Applicable
Under Regulation (EU) 2019/1241 (2019) this gear has been implemented as an option in North Western Waters as it qualifies for the Nephrops survival exemption in ICES 7 and is part of the mandatory remedial measures in the Celtic Sea Protection Zone. National Irish legislation limits fishers to using a maximum of four codends which prohibits uptake by vessels using quad-rigged trawls.

6.4 South Western Waters

6.4.1 Factsheet 48. Mitigation methods to reduce slipping related mortality in Portuguese purse-seine fishery

General information

Year 2018-ongoing

Source supplier............Antonello Sala and Emma Mackenzie, *with text adapted from Marçalo et al. (2018); Marçalo et al. (2019).* Horizon 2020 project Minouw (*Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries*)

Region..............................South Western Waters

FAO-Area 27.9

Gear sub-category ....Purse seines

Gear code ....PS

Target species..................ANE, PIL, HOM, VMA.

Bycatch species...........*Undersized target species.*

Baseline gear

Conventional Portuguese mainland sardine purse seines.

Technical information

Definition of the Innovative gear

Following the introduction of the EU Landing Obligation (LO), slipping practices in EU waters were regulated from 2015 by Commission Delegated Regulations (CDRs), for South-Western Waters.

During meetings with fishers to discuss practical methods to mitigate the slipping problem, it was suggested that during the closed season, sardines could be released from the remainder of the catch through an opening created by putting weights over the float-line (Marçalo *et al.*, 2018). This utilised differences in the behaviour of different species in the catch to selectively release the sardines. That is, sardines when in a mixed catch with other small pelagic species, usually swim close to the surface, while other species (e.g., chub mackerel) swim down in the net. Marçalo *et al.* (2018) carried out experiments to assess the effectiveness of this method in promoting the survival of slipped sardines, compared to the standard method of rolling the fish over the float-line and a control (non-slipped and non-crowded sardines).

Technical specificities

The slipping practice typically occurs at the very end of the fishing operation and involves rolling the fish over the float-line. To effectively reduce slipping-related mortality, it is necessary to release any unwanted catch as early in the capture process as possible, before the fish become fatally stressed. This modification to purse seine design and practice promote the survival of slipped fish.

The results of Marçalo *et al.* (2018) demonstrate that using a modified slipping technique during purse-seine operations can significantly improve survival of released sardines, with minimal disturbance of fishing operations and potentiate the improvement of on-site resource management by fishers. Commercial purse-seining operations typically end with complete drying up and slipping, which constitutes a stressful event, leading to physiological, physical, and behavioural changes, resulting in variable and sometimes elevated delayed mortality of escapees

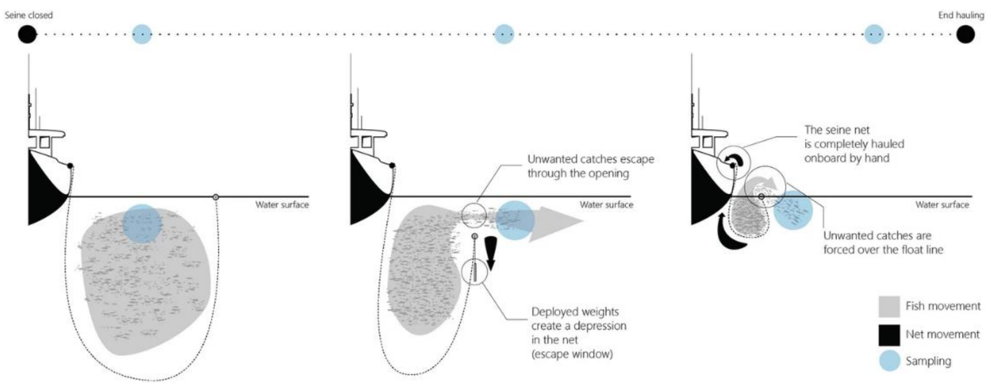
Outcomes expected

The effects on survival, physiological stress and physical damage of a modified slipping technique (using weights to create an escape window and allow unwanted catch to swim freely out of the net) were compared with those of the standard slipping operation (fish rolled over the headline) and non-slipped and non-crowded sardines, treated here as experimental control subjects. The modified slipping procedure did significantly improve survival (survival at asymptote of 44.7%; 39.3-50.1% at 95% CI), which was comparable to the control fish (survival at asymptote of 43.6%; 38.0-49.3 at 95% CI).

Other relevant information

Marçalo *et al.* (2018), Marçalo *et al.* (2019), Regulation (EC) 1224/2009 (2009), Regulation (EU) 1394/2014 (2014), Regulation (EU) 2018/188 (2018).

Drawing / picture of the Innovative gear



Modified and standard slipping techniques in the Portuguese purse seine. *Source: modified and adapted from Marçalo et al. (2018).*

Application of the weights by the crew of the auxiliary boat. Fish escape window in the purse seine floating line by using weights. *Source: modified and adapted from Marçalo et al. (2018).*

Technological Performance assessment

Main criteria............... Catch efficiency, species- and size-selectivity, reduced bycatch of ETP species.
Additional criteria ..... Reduce discarding, improved survival, reduced fuel costs and improved catch quality and prices.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL8

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category.. Low
Return on Investment... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?................... Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Has encouraged uptake

6.4.2 Factsheet 49. Bycatch reduction device (BRD) to reduce discards in bivalve dredge fisheries in Algarve (Portugal)

General information

Year 2015-2019	**Source supplier**............Antonello Sala and Emma Mackenzie, *with text adapted from Gaspar (2019). Horizon 2020 project Minouw (Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries).*
Region..............South Western Waters	**FAO-Area**..............27.9
Gear sub-category..........Towed dredges	**Gear code**..............DRB, DRM
Target species..............Bivalves	**Bycatch species**...........*Undersized bivalves, invertebrates.*

Baseline gear

Commercial Portuguese bivalve dredges made of metallic grid. Dredges are used in a fishery targeting *Spisula solida, Chamelea gallina*, and *Donax trunculus* along the Algarve coast.

Technical information

Definition of the Innovative gear

BRD of rigid grid made of stainless steel mounted inside the bivalve dredge.

Technical specificities

Six types of BRDs were tested and consisted of a rigid grid, made of stainless steel mounted at a 45-50º degree angle in the middle of the retention system of the dredge, aiming to guide part of by-catch individuals and debris to an opening on the top of the dredge. Three of the BRDs had a square mesh grid (mesh size of 31, 41 and 51 mm) whereas the other 3 consisted in a grid with 31-, 41- or 51-mm bar spacing. The use of BRD in dredges implies a slightly modification in the dredges currently used with a cost of around 40 Eur.

Outcomes expected

Although the use of BRD was effective in reducing bycatch, discards and debris it also affected the amount of the target species that entered the dredges, decreasing fishing yields, which is related to the decrease of the dredge efficiency during the tow. The loss of fishing yields by around 40% is certainly outside the limits for fishers to accept the use of BRD in dredgers, even if bycatch reduction is exceptionally good. Notwithstanding, the use of BRDs show promise for bycatch and discards reduction in the Portuguese dredge fishery.

Other relevant information

Gaspar (2019), Anjos *et al.* (2018)

Drawing / picture of the Innovative gear

Commercial Portuguese bivalve dredge in Algarve area. *Source: modified and adapted from Gaspar (2019).*

Technological Performance assessment

Main criteria............... Improvement in size and species selectivity
Additional criteria ..... Reduction in catch efficiency

Technological readiness level (TRL)

TRL category............. Moderate **TRL scale** TRL6

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Negative **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Maybe
Is the innovative gear easier to maintain and repair?... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.. Low
Return on Investment... Negative
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?................... Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Do not know

6.4.3 Factsheet 50. Automated actively-selective trawl controlled by Artificial Intelligence (AI)

General information

Year	2023	**Source supplier**	Julien Simon (IFREMER, France)
Region	South Western Waters	**FAO-Area**	27.8.a
Gear sub-category	Bottom trawls, Midwater trawls	**Gear code**	OTM, TSP, PTM, OTB, OTT
Target species	*Not applicable*	**Bycatch species**	*Not applicable*

Baseline gear

Any conventional trawl gear.

Technical information

Definition of the Innovative gear

GAME OF TRAWLS *(Giving artificial monitoring intelligence to fishing Trawls)*.

Technical specificities

The trawl is equipped with an underwater camera, an acoustic communication device, actuators and an embedded computer performing AI. One of the most innovative aspects of the intelligent trawl is the system's ability to detect species entering the trawl in real time using AI, inform the skipper on the rate of target and non-target species entering the trawl and switch the trawl in catching or releasing mode. This is particularly suitable for reducing catches of non-target species. The system is composed of:

1) Embedded software performing AI inside the trawl.
2) Acoustic communication sending AI results to the skipper.
3) User interface displays catch information to the skipper.
4) Actuators switch the trawl in catching or releasing mode.

Outcomes expected

Previously blind trawling activities can now be turned into informed and smart fishing using trawls fully operated by artificial intelligences. The artificial intelligence and real-time active selective device developed as part of the GAME OF TRAWLS projects can be adapted to any species. The potential for transferability to new areas and species of interest will be tested in the near future through collaboration between scientists within the Horizon Europe funded project Marine Beacon.

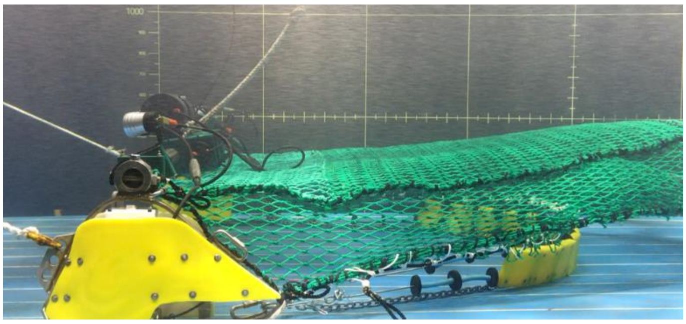
Other relevant information

https://gameoftrawls.ifremer.fr/en/home/

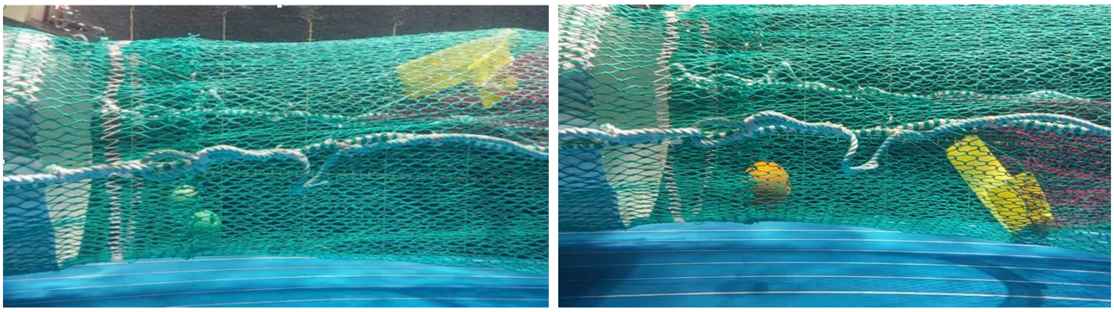
https://www.youtube.com/watch?v=L85FfScjZRs&t=1s

Drawing / picture of the Innovative gear

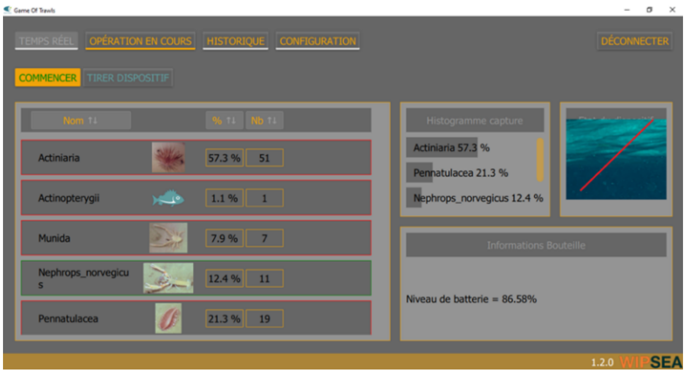
Targeted species entering the trawl (*left*), the AI switch the trawl in catching configuration, an acoustic signal is sent to the skipper. Non-targeted species entering the trawl (*right*), the AI switch the trawl in release configuration, an acoustic signal is sent to the skipper.



Picture of the Game of Trawls bottom trawl system with the controllable footrope made of yellow plates. The camera, GPU and light are set on the beam and the actuators on the side shoes.



The controllable exclusion device in fishing mode (*left*) and exclusion mode (*right*) in the pelagic application of the Game of Trawls system. The change in mode is controlled by either the fisher (manually) or by the AI (automatically, based on the species detected).



A user interface displays the catch information (species and relative composition) and device status to the skipper in real time.

Technological Performance assessment

Main criteria............... Size and species selectivity
Additional criteria ..... Catch efficiency, energy saving, reduced GHG emissions

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Transformative **Selectivity** .... Disruptive **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category.. High
Return on Investment.. Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?................... Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. Do not know

6.4.4 Factsheet 51. Reducing the otterboard impact on the seabed ("Connect" system)

General information

Year 2023	**Source supplier** .... Benoit Vincent (IFREMER, France)
Region .... South Western Waters	**FAO-Area** 27.8.a
Gear sub-category .... Bottom trawls	**Gear code** .... OTB, OTT
Target species .... *Not applicable*	**Bycatch species** .... *Not applicable*

Baseline gear

Any commercially used otterboard.

Technical information

Definition of the Innovative gear

Real time monitoring of the physical otterboard impact.

Technical specificities

Trawl doors (otterboards) are equipped with sensors used to calculate the physical impact of the door on the seabed in terms of shocks and vibrations. The information is transmitted to the wheelhouse and the skipper can adjust the warp length and/or the vessel velocity to lighten the doors and reduce their impact.

Outcomes expected

Reduction of the otterboard impact on the seabed and habitats like friction, crushing, and resuspension.

Other relevant information

https://octech.fr/projet-connect/, https://www.bretagne-peches.org/projets/, https://www.youtube.com/watch?v=TLfq2tFS59g. Prat *et al.* (2008), Sala *et al.* (2009), Mellibovsky *et al.* (2018), Sala *et al.* (2019).

Drawing / picture of the Innovative gear

The door physical impact sensors are located inside the door spread sensor. *Courtesy of Benoit Vincent (IFREMER, France).*

Technological Performance assessment

Main criteria............... Environmental impact, seabed physical impact reduction.
Additional criteria ..... Energy saving, reduced GHG emissions, crew awareness.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Not applicable **Selectivity** .... Not applicable **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.......... Moderate
Return on Investment.......... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
This impact indicator is associated with door spread data which is considered to be a means of increasing trawling efficiency and is therefore not subsidised.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Could be subsidised.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... It is a barrier
In particular fishing conditions (change of the sea depth, of water current) crew will have to be more attentive to the indication of the system and occasionally modify warp length or vessel velocity.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.......... Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?.......... Not Applicable

6.4.5 Factsheet 52. Pre-catch size and species recognition for purse seine (*SeinePrecog*)

General information

Year 2022

Source supplier .... Matthew McHugh and Antonello Sala, *with text adapted from Birch et al. (2022). Horizon 2020 project Smart-Fish (Smart fisheries technologies for an efficient, compliant and environmentally friendly fishing sector).*

Region .... South Western Waters

FAO-Area 27.8.c

Gear sub-category .... Purse seines

Gear code .... PS

Target species .... ANE, HOM, PIL, MAC

Bycatch species .... *Undesized fish*

Baseline gear

Any conventional purse seine without recognizing fish species system.

Technical information

Definition of the Innovative gear

A method to identify species and the estimation of their individual size before hauling in purse seiners.

Technical specificities

The baseline gear is the current purse seine. The innovative gear is a configuration using Zunibal ZSR acoustic equipment to identify species and sizes prior to deployment of the seine. Basically, the idea of these trials was to check whether the data collected in the scientific vessels was representative of the data that is collected by purse seiners.

Outcomes expected

The proper identification of species and the estimation of their individual size before hauling in purse seiners would allow the skipper to avoid unnecessary hauling, saving time during the fishing operation, reducing the workload of the crew, and therefore improving the overall economic efficiency. The Seine Precog will also help with the purse seine fleet's selectivity reducing the unnecessary fishing mortality during the "slipping" and saving quota against the discarded species.

Other relevant information

Birch *et al.* (2022), Regulation (EC) 1224/2009 (2009), Regulation (EU) 1394/2014 (2014), Regulation (EU) 2018/188 (2018).

Drawing / picture of the Innovative gear

SeinePrecog is a system for recognizing fish species, and fish size in purse seine fisheries based on optical and hydroacoustic technologies. The SeinePrecog consists of an acoustic system (sound, software, and filter) and an image system (3D and HD camera). Its purpose is to gain information about fish size and species before setting the fishing net thus enabling the possibility of avoiding unwanted species and sizes. It has been tested successfully for both anchovy and sardine purse seine fishing. Courtesy of AZTI (Spain).

Purse seine operations and ZSR acoustic recordings in the Bay of Biscay trials.

ST	Date	Time	Latitude	Longitude	Catch (kg)	Depth (m)	%ANE	%PIL	%MAC
01	06/04/2022	20:00	~43º32	~3º33	0	0-50	-	-	-
02	06/04/2022	22:45	~43º32	~3º36	200	0-50	-	-	100
03	07/04/2022	00:30	~43º32	~3º36	>50000	0-50	-	-	100

Configuration of the *Zunibal ZSR* acoustic equipment used during the trials.

Frequency (kHz)	200
Power (W)	250
Pulse duration (ms)	0.3
Calibration sphere (mm)	38.1
SaCorrection (dB)	-2.08
MajorAxis3dbBeamAngle (degrees)	20.56
MajorAxisOffset (degrees)	0.01
MinorAxis3dbBeamAngle (degrees)	16.48
MinoAxisOffset (degrees)	-0.03
TransducerGain (dB)	33.08

Technological Performance assessment

Main criteria............... Improved selectivity of target species and catch efficiency.
Additional criteria ..... *None*

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Disruptive **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Unsure
Is the innovative gear easier to maintain and repair? .... Unsure
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment........ Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
There is a need for this equipment, but it is too early to comment on uptake.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
It is not clear if there has been widespread uptake of this gear, but it is stated that it should improve the economic viability of the purse seine fleet. Also, it is not highlighted how much this gear is likely to cost.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Do not know
It is not clear if there has been widespread uptake of this gear.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
It is not clear if there has been widespread uptake of this gear, but it is stated that it should improve by reducing unnecessary fishing mortality during the "slipping".

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................ Do not know
It is not clear if there will be legal barriers to this gear.

6.4.6 Factsheet 53. Nylon leaders to reduce shark bycatch mortality in pelagic longline fisheries

General information

Year	2023	**Source supplier**	Robin Faillettaz, *with text adapted from Ward et al. (2008) and Fauconnet et al. (2023). Reviewed by Emma Mackenzie and Alexius Edridge.*
Region	South Western Waters	**FAO-Area**	27
Gear sub-category	Longlines	**Gear code**	LH, LL, LV *(pelagic lines)*
Target species	*Pelagic and demersal species*	**Bycatch species**	sharks

Baseline gear

Any conventional longline *(depending on the region)*

Technical information

Definition of the Innovative gear

Nylon leaders can be used to replace wire leaders that are too strong to be cut by sharks. An experiment has been conducted in the Australian waters to compare wire versus nylon leaders in longlines (Ward *et al.*, 2008). It shows that although the fate of the animals that escaped remain unknown, their probability of survival is higher. In addition, the economic cost of the increased gear loss due to shark bit and escape is compensated by an increased catch of bigeye tuna, which seem less likely to detect the nylon leaders compared to the wire one. Nylon leaders have thus been proven effective in reducing shark bycatch in pelagic longlines, and the same pattern may occur with bycatch of deep-water sharks. However, despite their strong potential to enhance the survival of shark bycatch, nylon leaders remain understudied, and results are not yet conclusive due to insufficient sample size (Favaro and Côté, 2015).

Technical specificities

The leaders compared in Ward *et al.* (2008) are described as follow: the wire leaders were 30 cm, stainless steel, six-strand wire cable (see figure). A 38 g swivel was attached to the branchline 5 m above the hook. The nylon leaders did not have a weighted swivel. They were 2 mm diameter (250-300 kg breaking strain) nylon. One longline vessel used 30 cm double nylon leaders. The nylon monofilament is a copolymer, with a core of flexible nylon and an outer skin of tougher nylon. Both the nylon and wire leaders were attached to 16 m nylon monofilament branchlines constructed of the same material as the nylon leaders.

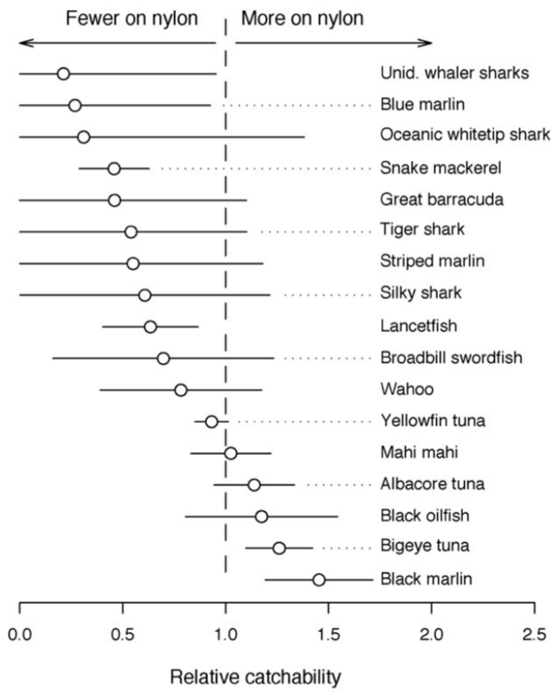
All vessels used 4 mm diameter nylon monofilament mainlines and Japanese tuna hooks (55 mm total length, 28 mm bite, 27 mm gape, 10° offset). They used frozen pilchard (*Sardinops* spp.) or squid as bait. On about 9% of branchlines, crewmembers attached luminescent light sticks 2 m above the hook.

Outcomes expected

Replacing wire leaders by weaker nylon leaders enables to sharks that bite the bait to escape by cutting the leader. Although tested in few areas only, it has shown promising results for reducing shark bycatch in both pelagic and deep-water fisheries (see figure below). The analyses show the benefits of banning wire leaders for most shark species in Australian waters.

Other relevant information

Ward *et al.* (2008), Favaro and Côté (2015), Fauconnet *et al.* (2023).

Drawing / picture of the Innovative gear		
 Wire leader (top) and nylon leader (bottom). Only the type of leader differs. *Source: modified and adapted from Ward et al. (2008).*  Changes in relative catchability using nylon leaders for sharks and pelagic fish species. *Source: modified and adapted from Ward et al. (2008).*		
Technological Performance assessment		
Main criteria............... Impact on shark bycatch, catch efficiency. **Additional criteria** ..... *None*		
Technological readiness level (TRL)		
TRL category............. High	**TRL scale** TRL7	
Technological complexity level		
Minimal complexity		
Performance improvement		
Catch efficiency .... Incremental	**Selectivity** .... Transformative	**Impact**............ Incremental
Comparison with the baseline		

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category .... Low
Return on Investment .... Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Do not have enough information to conclude.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
The case study suggests that the cost of lost gear is compensated by increased catches of commercial species, but no information on the economic factor to conclude.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Personal opinion because of the increased public attention to shark bycatch and the fact that some regulations have been implemented there.

Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Not Applicable
There is nothing complex in implementing nylon leaders.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Personal opinion because of the increased public attention to reduce shark bycatch and protect them, and the fact that some regulations have been implemented there.

Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... Has encouraged uptake
Some jurisdictions in Australia have banned wire leaders to reduce shark mortality from pelagic longline fisheries.

6.4.7 Factsheet 54. Image analysis technology (CatchMonitor) to enable efficiencies in using remote electronic monitoring (REM)

General information

Year	2022	**Source supplier**	Antonello Sala, *with text adapted from* Birch *et al.* (2022). *Horizon 2020 project SmartFish (Smart fisheries technologies for an efficient, compliant and environmentally friendly fishing sector)*
Region	South Western Waters	**FAO-Area**	27.7
Gear sub-category	Gears unknown or not specified	**Gear code**	*Not applicable*
Target species	*Not applicable*	**Bycatch species**	*Not applicable*

Baseline gear

Remote Electronic Monitoring (REM).

Technical information

Definition of the Innovative gear

The CatchMonitor is a system for automatic monitoring and analysis of a catch using CCTV cameras. The process of reviewing REM sensor and video data to quantify fishing effort and generate catch estimates is largely done manually by experienced reviewers but can be a time-consuming process. The SmartFish project, through the creation of CatchMonitor, aimed to create an artificial intelligence (AI) algorithm that could automatically analyse and summarise REM video footage to provide volumes by species in the discarded component of the catch, improving the efficiency of video review.

Technical specificities

Image analysis technology. Image recording with computer vision methods.

Outcomes expected

The ability of the algorithm compared to the reviewers to identify the same individuals as the same species varied between species and vessel. When density was higher, and variability in reviewers also higher, the algorithm performed comparatively better than when reviewer agreement was universally high (Birch *et al.*, 2022).

The CatchMonitor was successfully tested and it demonstrated high potential to enhance data collection and address management and sustainability challenges caused by catch data limitations. There are still improvements to be made including increasing the training data set for some species, and modifying the way the fish are presented on the vessel to reduce the density of fish in the images. The Horizon EveryFish project (https://everyfish.eu/), started in 2023, will provide opportunity to build upon this work, by building systems that can apply the algorithms in situ, then send, capture and disseminate the catch data, by bridging it with other systems developed SmartFish. Overall, having started at the very beginning of this process, the CatchMonitor algorithm has come a long way and shows real promise for improving efficiency in generating catch estimates from REM data (Birch *et al.*, 2022).

Other relevant information

Birch *et al.* (2022), (French *et al.*, 2020).
Project website: http://www.smartfishh2020.eu/
Smart fisheries technologies for an efficient, compliant, and environmentally friendly fishing sector | SMARTFISH | Project | Results | H2020 | CORDIS | European Commission (europa.eu): https://cordis.europa.eu/project/id/773521/

Drawing / picture of the Innovative gear

Not available.

Technological Performance assessment

Main criteria............... Catch efficiency, impact on vulnerable species.
Additional criteria ..... REM automatic control.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Significant complexity

Performance improvement

Catch efficiency .... Not applicable **Selectivity** .... Not applicable **Impact**............ Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair?........ No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment........ *Unknown*
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Do not know

6.5 Baltic Sea

6.5.1 Factsheet 55. Alternative codend designs in unrestricted *Nephrops* trawl gears under a catch quota management (CQM) scheme

General information

Year 2015-2017

Source supplier ....Antonello Sala and Emma Mackenzie, *with text adapted from Mortensen et al. (2017) and Reid (2017). Horizon 2020 project DiscardLess (Strategies for the gradual elimination of discards in European fisheries).*

Region...............................Baltic Sea *(Skagerrak case study)*

FAO-Area 27.3.a

Gear sub-category ....Bottom trawls

Gear code ....OTB, OTT

Target species..................NEP

Bycatch species...........POK, COD, PLE, HAD, HKE

Baseline gear

Regulatory 90 mm Nephrops trawl.

Technical information

Definition of the Innovative gear

Trawlers were challenged to test their own solutions to reduce unwanted bycatch and/or choke species, while maintaining profitable. Different codend design options depending on fishery and type of issues they faced individually.

Technical specificities

Alternatives
1) Inserted a separator panel and two codends. Top codend with 150 mm mesh and bottom codend with 90 mm mesh.
2) Inserted a separator panel and two codend. Top codend with 90 mm mesh and bottom codend with 90 mm mesh.
3) New codend in the regulatory 90 mm Nephrops trawl, with sides and bottom of 90 mm mesh and top 120 mm mesh.

Outcomes expected

Cleaner catch of Nephrops and fewer small fish/undersized fish. Less small fish and less discard. The move towards the landing obligation and thus CQM means in theory that fishers would shift from maximizing the value of the part of the catch that can be sold to minimizing the volume of the part of the catch that cannot be sold, which would lead to a better alignment of the individual objective with the societal and policy objective (Nolde Nielsen *et al.*, 2015). To achieve this, fishers would in theory select the fishing methods and strategies that maximise their profits within the allowed catch frame.

Average landings (kg), discard (kg) and discard ratio (%) in the Skagerrak area (Baltic Sea), all alternative gears combined.

	Baseline	Alternatives	Difference
Landings	172	175	+3
Discards	25	18	-7 (*)
Discard ratio	12.6	9.5	-3.1 (*)

Significant differences *(Sig.<0.05)* between alternative and baseline gear are marked with (*).

Average landings (kg), discard (kg) and discard ratio (%) for each individual alternative gear trialled in the Skagerrak area (Baltic Sea).

	Landings		**Discards**		**Discard ratio**		**Change in ratio**
	Baseline	Alternative	Baseline	Alternative	Baseline	Alternative	
1	193	150	74	17 (*)	27.6	10.0	-17.6 (*)
2	160	173 (*)	16	16	9.3	8.5	-0.8 (*)
3	199	186	32	25 (*)	13.8	11.7	-2.1 (*)

Significant differences *(Sig.<0.05)* between alternative and baseline gear are marked with (*).

Other relevant information

Mortensen *et al.* (2017), Reid (2017).

Drawing / picture of the Innovative gear

Not available.

Technological Performance assessment

Main criteria............... Reduce small fish; removes small cod and haddock, along with flatfish; reduce cod landings, including small cod and small plaice; fewer small fish and less discard. Reduce small fish; removes small cod and haddock, along with flatfish; reduce cod landings, including small cod and small plaice; fewer small fish and less discard. To incentivize participation, additional quota was offered to compensate for the additional costs and economic uncertainty linked to developing and testing new gears, and to remove the barriers linked to needing enough quota to cover changes in catch composition and not having to lease. During the trials, discarding was allowed, and discards were counted against quota (in the Baltic Sea, the LO entered into force for all vessels on 1 January 2015).

Additional criteria ..... Improve Nephrops quality and reduce catch sorting.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL8

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... Yes, easier
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Low
Return on Investment........ Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Engaged with fishers to develop their own solution providing support from the users.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Additional quota available to fishers to incentivise use of the gear, low cost of gear and positive change in catch composition – reducing catch if undersized fish therefore less discards.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
The change has come from within the industry therefore fishers more likely to accept gear.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Has encouraged uptake
Gear easy to deploy, adaptable and easy to transfer to different vessel designs.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Reduces catch of unwanted/undersized catch and reduces discards. Fewer choke species caught.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ It is a barrier
Technical measures need to be changed to allow the uptake of these gears.

6.5.2 Factsheet 56. Alternative codend designs in unrestricted demersal trawl gears under a catch quota management (CQM) scheme

General information

Year 2015-2017

Source supplier .... Antonello Sala and Emma Mackenzie, *with text adapted from Mortensen et al. (2017) and Reid (2017). Horizon 2020 project DiscardLess (Strategies for the gradual elimination of discards in European fisheries).*

Region .... Baltic Sea

FAO-Area 27.3

Gear sub-category .... Bottom trawls

Gear code .... OTB, OTT

Target species .... COD

Bycatch species .... Undersized COD and FLE

Baseline gear

Regulatory 120 mm demersal trawl and Regulatory 120 mm Bacoma trawl

Technical information

Definition of the Innovative gear

Trawlers were challenged to test their own solutions to reduce unwanted bycatch and/or choke species, while maintaining profitable. Different codend design options depending on fishery and type of issues they faced individually.

Technical specificities

Alternatives

1) 105 mm diamond mesh trawl with 105 mm T90 codend mesh. Last 9.4 m constricted to 8 m using straps, to keep mesh open.
2) 105 mm diamond mesh trawl, with steel flounder escape grills (3 pcs.) in the bottom forward part of the codend and straps in the sides to loosen or tighten pull on meshes.
4) 110 mm BACOMA panel but with a wider opening, inspired from flotation trawls, to create a balloon effect in the codend.

Outcomes expected

Catch larger range of sizes to reduce time at sea with a relatively small increase in discards. Less flounders in the codend to clog up the selection of cod. Get at steeper selection curve and higher catch rates with relatively less discard. The move towards the landing obligation and thus CQM means in theory that fishers would shift from maximizing the value of the part of the catch that can be sold to minimizing the volume of the part of the catch that cannot be sold, which would lead to a better alignment of the individual objective with the societal and policy objective (Nolde Nielsen *et al.*, 2015). To achieve this, fishers would in theory select the fishing methods and strategies that maximise their profits within the allowed catch frame.

Average landings (kg), discard (kg) and discard ratio (%) in the Baltic Sea, all alternative gears combined.

	Baseline	Alternatives	Difference
Landings	1,066	1,275	+209
Discards	328	256	-72
Discard ratio	23.5	16.7	-6.8 (*)

Significant differences *(Sig.<0.05)* between alternative and baseline gear are marked with (*).

Average landings (kg), discard (kg) and discard ratio (%) for each individual alternative gear trialled in the Baltic Sea area.

	Landings		**Discards**		**Discard ratio**		**Change in ratio**
	Baseline	Alternative	Baseline	Alternative	Baseline	Alternative	
1	1,004	1,367 (*)	217	184	17.7	11.9	-5.8 (*)
2	615	570	197	130 (*)	24.3	18.6	-5.7 (*)
3	2,024	2,238	665	474 (*)	24.7	17.5	-7.2 (*)

Significant differences *(Sig.<0.05)* between alternative and baseline gear are marked with (*).

Other relevant information

Mortensen *et al.* (2017), Reid (2017).

Drawing / picture of the Innovative gear

Not available.

Technological Performance assessment

Main criteria .... Reduce small fish; removes small cod and haddock, along with flatfish; reduce cod landings, including small cod and small plaice; fewer small fish and less discard. Reduce small fish; removes small cod and haddock, along with flatfish; reduce cod landings, including small cod and small plaice; fewer small fish and less discard. To incentivize participation, additional quota was offered to compensate for the additional costs and economic uncertainty linked to developing and testing new gears, and to remove the barriers linked to needing enough quota to cover changes in catch composition and not having to lease. During the trials, discarding was allowed, and discards were counted against quota (in the Baltic Sea, the LO entered into force for all vessels on 1 January 2015).

Additional criteria ..... Improve fish quality and reduce catch sorting.

Technological readiness level (TRL)

TRL category .... High **TRL scale** TRL8

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact** .... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... Yes, easier
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category .... Low
Return on Investment .... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Engaged with fishers to develop their own solution providing support from the users.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Additional quota available to fishers to incentivise use of the gear, low cost of gear and positive change in catch composition – reducing catch if undersized fish therefore less discards.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
The change has come from within the industry therefore fishers more likely to accept gear.

Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Has encouraged uptake
Gear easy to deploy, adaptable and easy to transfer to different vessel designs.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Reduces catch of unwanted/undersized catch and reduces discards. Fewer choke species caught.

Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... It is a barrier
Technical measures need to be changed to allow the uptake of these gears.

6.5.3 Factsheet 57. Increasing circumference of T90 codends to improve selectivity on Baltic cod trawl fishery

General information

Year 2019	**Source supplier**............Antonello Sala and Emma Mackenzie, *with text adapted from Feekings et al. (2019)*
Region...............................Baltic Sea	**FAO-Area** 27.3
Gear sub-category ....Bottom trawls	**Gear code** ....OTB, OTT
Target species..................COD	**Bycatch species**...........Undersized fish

Baseline gear

Conventional codend with 120 mm T90 mesh and circumference of 50 meshes. The gears currently legislated in the Baltic Sea trawl fishery for cod have been developed to minimize the catches of undersized cod.

Technical information

Definition of the Innovative gear

Codend with 120 mm T90 mesh with a larger circumference of 92 meshes.

Technical specificities

The length classes just above the MCRS (35 cm) now constitute a larger fraction of the landings and are thus increasingly important economically. A need for gears that effectively retain these sizes is presented by the fishers. To observe what effect increasing circumference in a T90 codend has on the selectivity of cod *(Gadus morhua)*. Bycatches of flounder in the directed cod fishery are unwanted. High numbers of flounder in catches hamper codend selectivity and reduce cod quality due to abrasion. A gear that retains round fish and sorts out flatfish is therefore required.

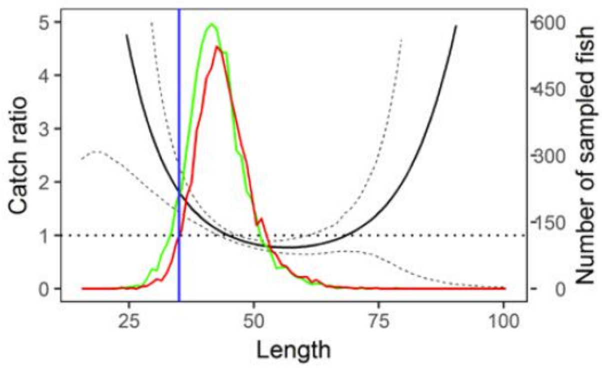
Outcomes expected

The codend with a larger circumference caught significantly more cod under 47 cm. Increasing the circumference is therefore not optimal as it results in significantly more cod under the MCRS (35 cm) being caught.

Other relevant information

Feekings *et al.* (2019).

Drawing / picture of the Innovative gear



Source: modified and adapted from Feekings *et al.* (2019).

Technological Performance assessment

Main criteria............... Cod selectivity, flounder bycatch reduction, improve catch efficiency of cod (above MCRS).
Additional criteria ..... Improve cod catch quality.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL8

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Negative **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?........ No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Low
Return on Investment........ Negative
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Yes, higher

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
Despite the gear being designed by fishers to address issues within their own fishery and uptake incentivised for trial use, the incentive structure for the project led to some gears being insufficiently tested or tested by fishermen for their own personal gain and not for the benefit of the wider fishing industry.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Increased unmarketable catch of cod as more cod below MCRS caught with this gear.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... It is a barrier
Potential demotivation due to poor implementation of the landing obligation scheme paired with a rigid management system.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Has encouraged uptake
Easy to deploy and adaptable between different vessel designs.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... It is a barrier
Increased levels of unwanted catch as more cod below MCRS captured.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ It is a barrier
Gear currently not permitted and rigid management framework causing further issues for new gears to be implemented within the legislation.

6.5.4 Factsheet 58. Changing the codend material from polyethylene to polyester to improve selectivity on Baltic cod trawl fishery

General information

Year 2019
Source supplier ....Antonello Sala and Emma Mackenzie, *with text adapted from* Feekings *et al.* (2019)
Region................................Baltic Sea
FAO-Area 27.3
Gear sub-category ....Beam trawls
Gear code ....OTB, OTT
Target species..................COD
Bycatch species...........FLE

Baseline gear

Conventional codend with T90 120 mm mesh made out of polyethylene material.

Technical information

Definition of the Innovative gear

Codend with 120 mm T90 mesh made out of polyester material.

Technical specificities

Polyester material is cheaper than polyethylene. Effect of polyester had a negative impact on cod selectivity. Same codend design was used during the trials.

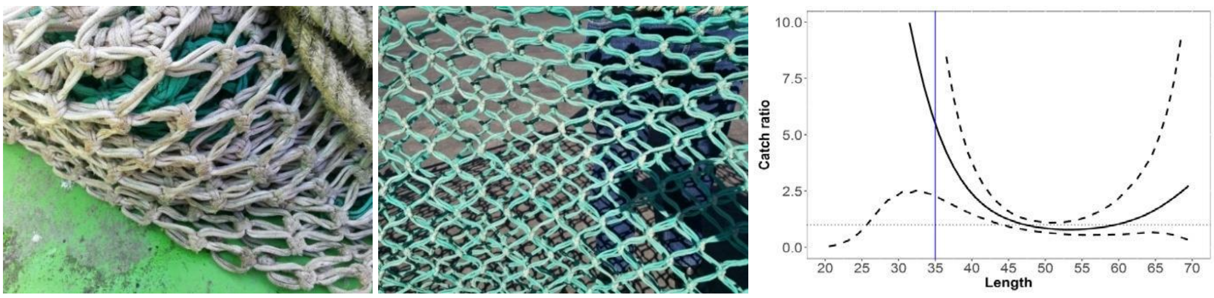
Outcomes expected

The codend constructed out of polyester caught significantly more cod under 44 cm. The use of polyester is therefore not optimal as it results in significantly more cod under the MCRS (35 cm) being caught.

Other relevant information

Feekings *et al.* (2019).

Drawing / picture of the Innovative gear



Source: modified and adapted from Feekings et al. (2019).

Technological Performance assessment

Main criteria............... Cod selectivity, improve catch efficiency of cod (above MCRS).
Additional criteria ..... Improve cod catch quality.

Technological readiness level (TRL)

TRL category............. High
TRL scale TRL8

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental
Selectivity .... Negative
Impact......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?.. No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.. Low
Return on Investment.. Negative
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
Despite the gear being designed by fishers to address issues within their own fishery and uptake incentivised for trial use, the incentive structure for the project led to some gears being insufficiently tested or tested by fishermen for their own personal gain and not for the benefit of the wider fishing industry.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Increased unmarketable catch of cod as more cod below MCRS caught with this gear.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... It is a barrier
Potential demotivation due to poor implementation of the landing obligation scheme paired with a rigid management system.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
Easy to deploy and adaptable between different vessel designs. Polyester material is cheaper than polyethylene therefore economical better and the driver behind the change in netting material.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... It is a barrier
Increased levels of unwanted catch as more cod below MCRS captured.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. It is a barrier
Gear currently not permitted and rigid management framework causing further issues for new gears to be implemented within the legislation.

6.5.5 Factsheet 59. Flexible grids to release flounder in the Baltic Sea cod trawl fishery

General information

Year 2019

Source supplier ....Antonello Sala and Emma Mackenzie, *with text adapted from* Feekings *et al.* (2019).

Region..............................Baltic Sea

FAO-Area 27.3

Gear sub-category ....Bottom trawls

Gear code ....OTB, OTT

Target species..................COD

Bycatch species...........FLE

Baseline gear

Conventional T90 120 mm codend.

Technical information

Definition of the Innovative gear

Flexible grids to reduce flounder catches in the Baltic cod directed trawl fishery. The advantage with the *Vónin* Flexi grid, besides its great sorting abilities, is when trawls need to go on a net drum on board the vessel. The Vónin Flexi Grid is manufactured from strong plastic tubes with *dyneema* twine going through. The advantage with the Vónin Flexi Grid is that there are no crossbars, and that makes it easy to get the grid on the deck and to get it onto the netdrum.

Technical specificities

Fishers designed a grid system consisting of three flexible grids (*Vónin*). Netting was placed behind each grid and held closed with elastic rope designed to slow or stop the catch and facilitate escape. If the catch became too large, the elastic rope could expand so that the catch could continue unobstructed either to the next sorting section or to the codend. Positioned in the bottom of the extension piece, the grid system was designed to guide out flatfish, in particular flounder.

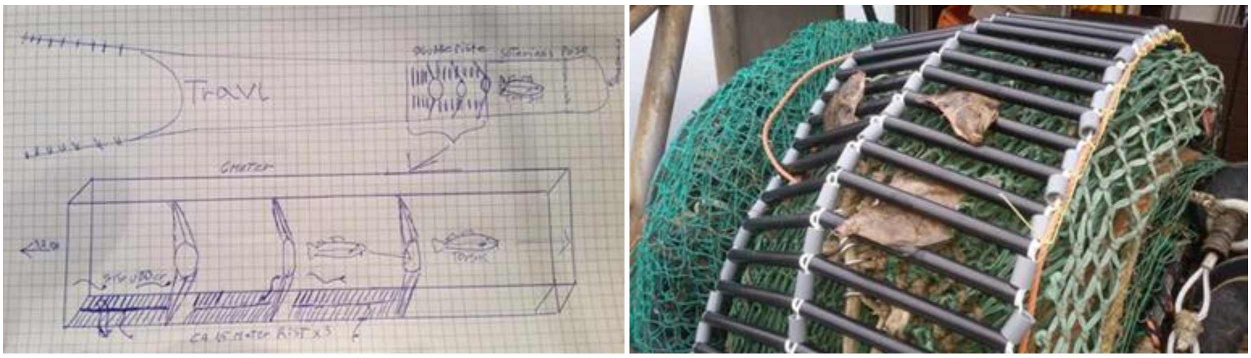
Outcomes expected

Preliminary testing carried out by the fisherman showed mixed results. During some hauls good reductions of flounder were obtained, while others not. Furthermore, the efficiency of the grid was sensitive to the fitness of flounder. In the beginning of the year when fitness was good the catches of flounder were substantially reduced, while towards the end of the season when flounder had spawned the grid was not as effective.

Other relevant information

Feekings *et al.* (2019).

Drawing / picture of the Innovative gear



Source: modified ad adapted from Feekings et al. (2019).

Technological Performance assessment

Main criteria............... Cod selectivity, improve catch efficiency of cod (above MCRS).
Additional criteria ..... Improve cod catch quality.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL8

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Negative **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair?............ Yes, easier
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category............ Low
Return on Investment............ Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
Despite the gear being designed by fishers to address issues within their own fishery and uptake incentivised for trial use, the incentive structure for the project led to some gears being insufficiently tested or tested by fishermen for their own personal gain and not for the benefit of the wider fishing industry.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Uptake may only be seasonal due to reduced effectiveness of the grid later in the year once flounder have spawned.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... It is a barrier
Potential demotivation due to poor implementation of the landing obligation scheme paired with a rigid management system.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
Easy to deploy and adaptable between different vessel designs.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... It is a barrier
Uptake may only be seasonal due to reduced effectiveness of the grid later in the year once flounder have spawned.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................. It is a barrier
Gear currently not permitted and rigid management framework causing further issues for new gears to be implemented within the legislation.

6.5.6 Factsheet 60. Flex tunnel to reduce flounder (*Platichthys flesus*) in the Baltic cod trawl fishery

General information

Year...................................2019
Source supplier............Antonello Sala and Emma Mackenzie, *with text adapted from* Feekings *et al.* (2019)
Region...............................Baltic Sea
FAO-Area.......................27.3
Gear sub-category...........Bottom trawls
Gear code.....................OTB, OTT
Target species..................COD
Bycatch species...........FLE

Baseline gear

Conventional codend with T90 120 mm mesh.

Technical information

Definition of the Innovative gear

Thünen institute has developed a gear (Flex tunnel) with a 25 cm high grid fixed in the lower section of the extension. Horizontal bars have a spacing of 80 mm.

Technical specificities

Fishers designed a grid system consisting of three flexible grids (*Vónin*). Netting was placed behind each grid and held closed with elastic rope designed to slow or stop the catch and facilitate escape. If the catch became too large, the elastic rope could expand so that the catch could continue unobstructed either to the next sorting section or to the codend. Positioned in the bottom of the extension piece, the grid system was designed to guide out flatfish, in particular flounder.

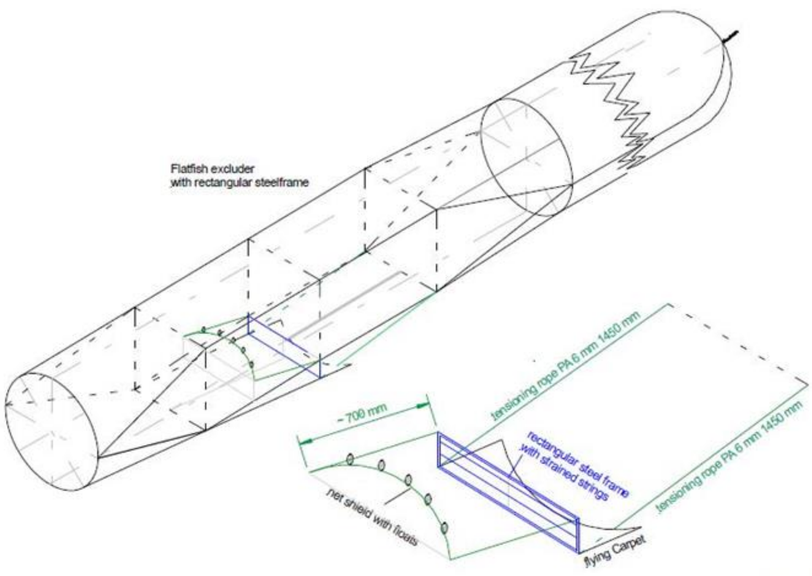
Outcomes expected

Trials on board a German research vessel have demonstrated a reduction in catches of flounder and plaice by 88% and 90% respectively, while no significant reduction for the target species, cod, was found.

Other relevant information

Feekings *et al.* (2019).

Drawing / picture of the Innovative gear



Source: modified and adapted from Feekings et al. (2019).

Technological Performance assessment

Main criteria............... Cod selectivity, improve catch efficiency of cod (above MCRS).
Additional criteria ..... Improve cod catch quality.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL8

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair? .... Yes, easier
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Low
Return on Investment........ Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
Despite the gear being designed by fishers to address issues within their own fishery and uptake incentivised for trial use, the incentive structure for the project led to some gears being insufficiently tested or tested by fishermen for their own personal gain and not for the benefit of the wider fishing industry.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
No change in marketable catch and reduced discards of bycatch.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Gear designed by fishers which is good motivation for uptake.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Has encouraged uptake
Flexible grid should make handling easy for crew.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Significant reduction of bycatch species, flounder 90% and plaice 80% with no change to target catch therefore appealing to fishers for uptake.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ It is a barrier
Gear currently not permitted and rigid management framework causing further issues for new gears to be implemented within the legislation.

6.5.7 Factsheet 61. Divided codend in the Nephrops trawl fishery

General information

Year 2019

Source supplier .... Antonello Sala and Emma Mackenzie, *with text adapted from* Feekings *et al.* (2019)

Region .... Baltic Sea

FAO-Area 27.3

Gear sub-category .... Bottom trawls

Gear code .... OTB, OTT

Target species .... COD

Bycatch species .... FLE

Baseline gear

SELTRA trawl.

Technical information

Definition of the Innovative gear

A divided codend was tested as an alternative to the SELTRA codend. The divided codend consisted of a lower codend (90 mm diamond mesh), an upper codend (140 mm diamond mesh), and a 140 mm square mesh section to replace the SELTRA panel. The lower frame had a height of 300 mm and the upper 400 mm.

Technical specificities

Nephrops are small and consequently small meshes are required to retain the species. This introduces the risk of retaining juveniles of other species living on the same grounds as Nephrops. Traditionally the Nephrops fishery is a mixed species fishery with a large fraction of the income originating from fish.

Outcomes expected

Restrictions of fish quota in combination with a landing obligation has highlighted a need of gears with very low retention of fish. Such a gear option will allow fishermen to decide where and when to spend fish quota.

Other relevant information

Feekings *et al.* (2019).

Drawing / picture of the Innovative gear

Source: modified and adapted from Feekings et al. (2019)

Technological Performance assessment

Main criteria............... Nephrops selectivity, reduce fish bycatch.
Additional criteria ..... Improve *Nephrops* catch quality

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Negative **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair?.......... Yes, easier
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.......... Low
Return on Investment.......... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Not Applicable
Fishers lost interest in the project which resulted in no data being collected.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Not Applicable
Fishers lost interest in the project which resulted in no data being collected.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Not Applicable
Fishers lost interest in the project which resulted in no data being collected.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.......... Not Applicable
Fishers lost interest in the project which resulted in no data being collected.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Not Applicable
Fishers lost interest in the project which resulted in no data being collected.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?.......... Not Applicable
Fishers lost interest in the project which resulted in no data being collected.

6.5.8 Factsheet 62. Visual stimuli to improve fishing efficiency in pot fisheries

General information

Year 2014-ongoing

Region...............................Baltic Sea

Gear sub-category ....Pots

Target species..................COD, CRQ

Source supplier............Antonello Sala and Emma Mackenzie, *with text adapted from* Bryhn *et al.* (2014) and *Nguyen et al. (2017).*

FAO-Area 27.3

Gear code ....FPO

Bycatch species...........*Undersized crustaceans*

Baseline gear

Conventional pots used in the Baltic fisheries.

Technical information

Definition of the Innovative gear

Many aquatic species (e.g. herring, anchovies, mackerel, tuna, squid, cod, largehead hairtail, snow crab, scad and other pelagic species) (Marchesan *et al.*, 2005; Matsushita and Yamashita, 2012; Yamashita *et al.*, 2012) could be lured using artificial light colours. Pots must have the right characteristics to lure the fish to enter the pot (Bryhn *et al.*, 2014). Their fishing efficiency is to a great extent related to fish behaviour when compared to other types of fishing gear.

However, advances in fishing technology including the application of Light Emitting Diode (LED) lights, that last longer are more efficient and have better chromatic performance than other lights, is an important contribution towards improving modern pot fisheries which face increasing demand, higher harvesting costs, and to ensure ecologically responsible methodologies.

Technical specificities

Two case studies are presented here to illustrate the effect of visual stimuli in pot fisheries:

1) Bryhn *et al.* (2014) tested green lamps (electric fishing light) were acquired from www.artisanalfish.com. Each lamp consisted of two LED greenlights, with a peak wavelength of 523 nm (*linewidth at Ee/2=26 nm*). Measured maximum output intensity (*Ee*) was 124 µW. The size of each lamp was 120 mm x 43 mm with a power supply of 3V LR06 (2 AA). The lamps were placed by the bait bag in the middle of the pot.

2) Lindgren-Pitman LED Electralume® fishing lights were used in field experiments of Nguyen et al. (2017). Lights had a forward voltage of 3.2 V, luminous intensity of 4.7 cd, forward current of 35 mA, and power dissipation of 124 mW. The lights had an operating temperature range of -30 to 85°C, a maximum operating depth of 850 m (1270 psi), and a battery life of approximately 300-500 consecutive hours, depending on the type of AA battery used as a power source. Five colours of lights were used: blue, green, purple, red, and white.

Outcomes expected

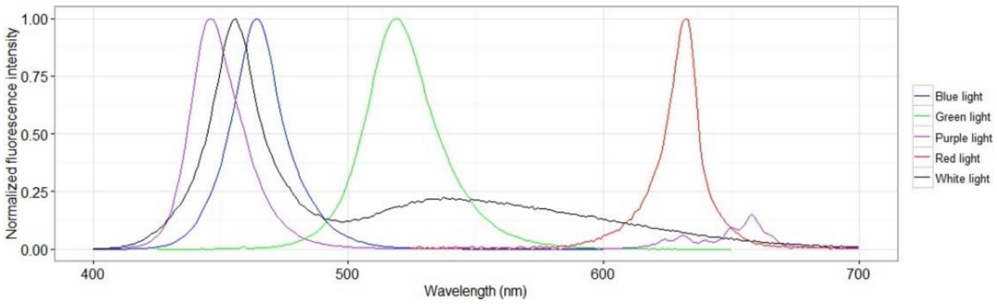
1) Bryhn *et al.* (2014) shows that the Atlantic cod resembles many other pelagic fish species (e.g., herring, anchovies and mackerel) in that it is attracted to light and that the cod catch efficiency of pots equipped with a green lamp was significantly higher than those lacking a lamp. Results showed that green lamps may be used in the commercial pot fishery as the lamp increased the mean catch weight of legal sized cod by 80%. A green lamp inside the pot increased the number and weight of large (>38 cm) cod. However, light could indirectly lure cod to enter the pots by attracting potential cod prey species such as smaller fish or crustaceans.

2) Field experiments in Nguyen et al. (2017) indicated that the catch rate of baited traps significantly increased with the addition of LED lights, and that substantial numbers of crab entered traps when only LED lights were used as the stimulus.

Other relevant information

Bryhn et al. (2014), Nguyen et al. (2017), Regulation (EU) 1396/2014 (2014).

Drawing / picture of the Innovative gear



Normalized fluorescence of Lindgren-Pitman LED *Electralume* lights. Peak wavelengths were 464 nm for blue lights, 519 nm for green lights, 446 nm for purple lights, 632 nm for red lights, and 456 nm for white lights. *Source: modified and adapted from Nguyen et al. (2017)*.

Technological Performance assessment

Main criteria............... Catch efficiency, species selectivity.
Additional criteria ..... None.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair?........ No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment........ Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
It is likely that the significantly increased catch rates observed with this gear would encourage uptake of the use of artificial lights if implemented as a new policy.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Cost of the light source minimal, quantity and quality of catch increase for both case studies.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
The gear innovation brings positive results and therefore it is unlikely there would be any negative factors affecting the uptake of this gear.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Has encouraged uptake
Cheap, easy and effective gear modification.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake

Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Has encouraged uptake
Use of lights not permitted in legislation.

6.5.9 Factsheet 63. Towed system to deliver real-time video-feed of the seabed and quantitative information on the target species prior to the fishing operation (*FishFinder*)

General information

Year 2022

Source supplier .... Matthew McHugh, *text adapted from Krag et al. (2022). Horizon 2020 project SmartFish (Smart fisheries technologies for an efficient, compliant and environmentally friendly fishing sector).*

Region .... Baltic Sea

FAO-Area 27.3

Gear sub-category .... Bottom trawls

Gear code .... TBN

Target species .... NEP

Bycatch species .... *Undersized Nephrops*

Baseline gear

Conventional and legislated *Nephrops* trawl in the specified area.

Technical information

Definition of the Innovative gear

The baseline gear is a trawl/s without a method to know if there are target species available. The innovative gear is a trawl/s with a sledge with camera and LED lights that is powered by a coax-communication towed on the seabed.

Technical specificities

The FishFinder prototype is a metallic sledge with a stabilization tower for fast deployment and retrieval along with stable landing and towing on the seabed. The FishFinder is towed on a coax-communication cable that also powers the systems camera and LED lights. The FishFinder is deployed prior to the catch operation to determine whether it would make sense to start a fishing operation at this location.

Outcomes expected

The gear is expected to inform fishers if it is worth deploying a trawl in certain areas. When FishFinder was deployed and it was possible to count Nephrops, even in challenging weather conditions, but also other categories of individuals such as other crustaceans, flatfish and roundfish.

Other relevant information

Project website: http://www.smartfishh2020.eu/. Krag *et al.* (2022), Birch *et al.* (2022).

Drawing / picture of the Innovative gear

FishFinder deployed at the bottom and FishFinder onboard the DTU research vessel. Source: modified and adapted from Krag *et al.* (2022).

Technological Performance assessment

Main criteria .... Catch efficiency and *Nephrops* selectivity.
Additional criteria ..... Not applicable.

Technological readiness level (TRL)

TRL category .... Moderate **TRL scale** TRL6

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact** .... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... Unsure

Economic Performance assessment

Capital cost category .... High
Return on Investment .... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know

It is an additional piece of equipment that could give users an advantage but might be too complex.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
It is not clear if it will be economically viable, there is a lot of additional equipment to purchase and potentially lost time searching for target species.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
The gear is a prototype and I think most would only want to use/purchase a final proven version.

Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Do not know
The gear is a prototype and I think technologically it might require specialist training to use and maintain. Its durability for everyday use onboard a commercial fishing vessel is also untested.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
It has the potential to limit impact from trawling grounds where there are limited fish.

Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... Do not know
The requirements for deploying and retrieving towed underwater cameras would need to be reviewed.

6.5.10 Factsheet 64. T90 codend of 125 mm mesh and 30% shortening lastridge rope

General information

Year 2021	**Source supplier** .... Juan Santos, Uwe Lichtenstein, and Daniel Stepputtis (Thünen Institute of Baltic Sea Fisheries)
Region .... Baltic Sea	**FAO-Area** 27.3.d
Gear sub-category .... Bottom trawls	**Gear code** .... OTB
Target species .... PLE, FLE, DAB	**Bycatch species** .... COD

Baseline gear

T90 codend with a minimum mesh size of 120 mm and maximum 50 meshes in circumference.

Technical information

Definition of the Innovative gear

Shortened lastridge ropes providing 30% shortening effect (30%SLR). Compared to the legal T90 codend, two modifications were introduced: a) an increase in minimum mesh size (inner mesh opening) from 120 mm to 125 mm; b) the addition of Shortened Lastridge Ropes to force the meshes of the codend to stabilize the opening of the T90 meshes during towing.

Technical specificities

Attachment of 30%SLR and an increase in the minimum mesh size from 120 mm to 125 mm. This selective device represents a further development of the T90 codend, one of the two codends legally used in the Baltic trawl fisheries targeting demersal species. A T90 codend is made of standard netting, turned by 90° to keep the meshes more open.

Outcomes expected

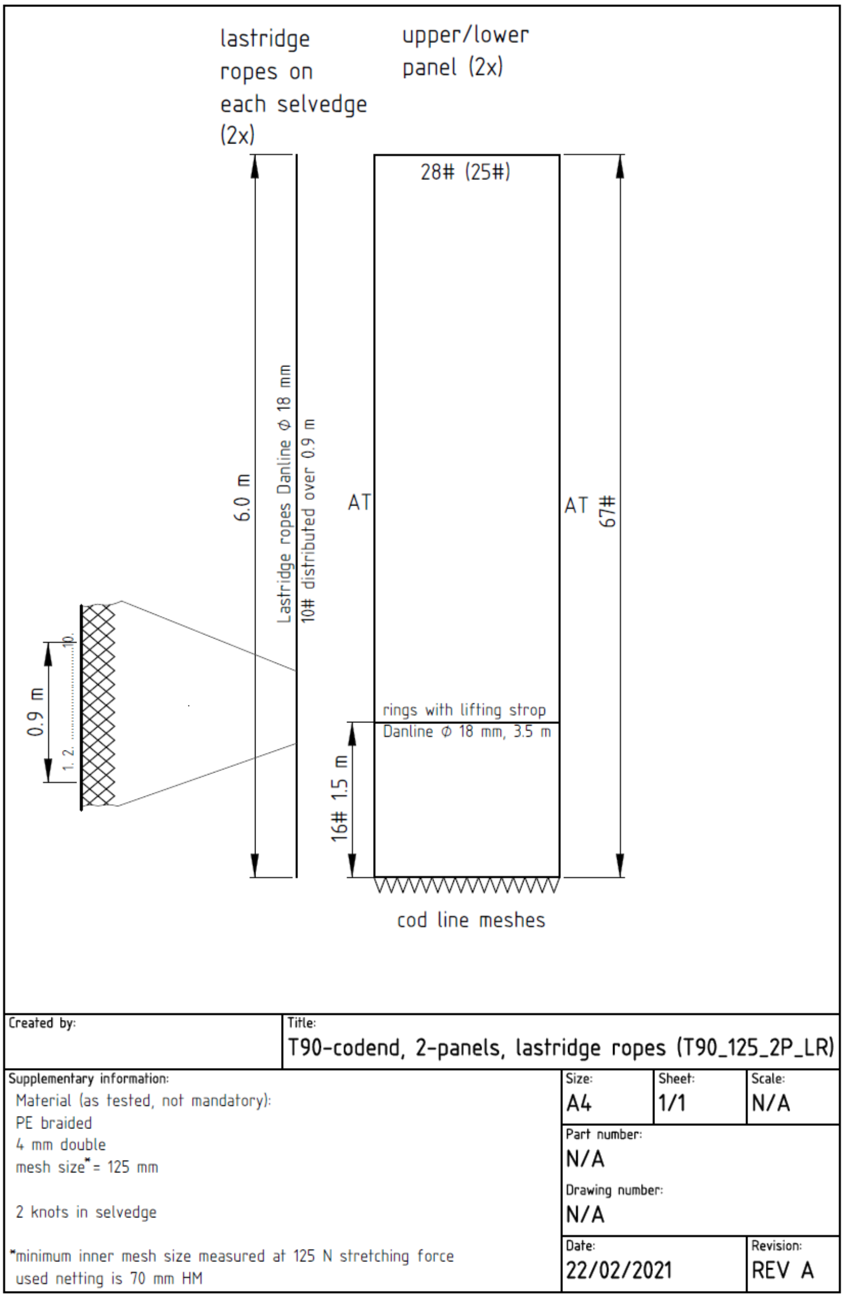
Large bycatch-reduction of cod (since 2021, only a small bycatch quota of cod is available for the fishers) while keeping or slightly increasing catches of flatfish species. The codend is very efficient in releasing cod. As all codend designs, the selectivity of the codend is length dependent and its performance changes when the size structure in the population changes. Therefore, the performance (catch and bycatch reduction) of the codend need to be evaluated regularly.

Other relevant information

https://www.thuenen.de/media/institute/of/Arbeitsbereiche/Forschung/Fischerei_und_Surveytechnik/Factsheets/05_fact-sheet_T90_modified.pdf

Drawing / picture of the Innovative gear

Illustration of the effect of shortened lastridge ropes on the shape of T90 meshes. The left image shows T90 netting under tension (as during towing, here tow direction from left to right). The tension stretches the netting and closes the meshes. The right image shows the same netting with a shortened lastridge rope, which takes the tension and prevents the stretching of netting and closing of meshes to ensure optimal escapement of roundfish, such as cod. *Courtesy of Thünen Institute of Baltic Sea Fisheries*.



Courtesy of Uwe Lichtenstein (Thünen Institute of Baltic Sea Fisheries).

Technological Performance assessment		
Main criteria............... Species- and size-selectivity, catch efficiency. **Additional criteria** ..... Improved catch sorting, better flatfish quota usage.		
Technological readiness level (TRL)		
TRL category............. Low	**TRL scale** TRL3	
Technological complexity level		
Minimal complexity		
Performance improvement		
Catch efficiency .... Incremental	**Selectivity** .... Incremental	**Impact**......... Transformative
Comparison with the baseline		

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category .... Low
Return on Investment .... Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
The process of implementing this technology in the Baltic Sea started in 2021, as an urgent measure to protect depleted Baltic Cod stocks. The proposal was supported by regional stakeholders and passed the technical evaluation made at European level on new technological developments. However, to date (09/2023), the gear has not been yet regulated and therefore it has not been formally implemented in the fishery.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Attaching SLR to a T90 codend already in use (fishers often use mesh sizes larger than 125 mm even with the current regulation) is inexpensive. In contrast, it has been experimentally demonstrated that attaching 30%SLR can greatly contribute to reduce bycatch of cod. In the current status in the Baltic Sea, cod can be considered a choke species in flatfish fisheries. Therefore, avoiding cod bycatch as much as possible will lead to a better use of available quotas of PLE, thus allowing the fishers to catch other flatfish species with no quota, such as FLE and DAB.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know

Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Has encouraged uptake
Attaching SLR to a codend does not suppose any technological challenge for fishers.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Reducing bycatches of cod in Baltic flatfish fisheries can contribute to restore the depleted cod stocks in the region.

Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... Do not know

6.6 Mediterranean and Black Sea

6.6.1 Factsheet 65. Visual deterrents to reduce sea turtles' bycatch in set-net fisheries

General information			
Year	2014-ongoing	**Source supplier**	Virgili Massimo, Lindgren Pitman, Petetta Andrea, Lucchetti Alessandro (CNR, Italy). *Revised by Chryssi Mytilineou and Monika Szynaka.*
Region	Mediterranean Sea	**FAO-Area**	37.2.1
Gear sub-category	Gillnets, trammel nets	**Gear code**	GNS, GTR
Target species	SOL, SKA, *Siganidae*	**Bycatch species**	Sea turtles

Baseline gear

Conventional set nets.

Technical information

Definition of the Innovative gear

Sea turtles rely extensively on visual cues, particularly when foraging, due to their well-developed visual system provided with a wide spectral range. This characteristic has prompted the development of visual deterrents such as Light Emitting Diode (LED) lamps and light sticks to be attached to set net float lines (Wang *et al.*, 2010; Wang *et al.*, 2013; Ortiz *et al.*, 2016). Over the past few years, an appreciable decrease in turtle bycatch rates (ranging from 39.7% to 63.9%) and preservation of target species catch rates have been obtained along the Northern and Southern Pacific coasts by illuminating gillnets with green light (Wang *et al.*, 2010; Ortiz *et al.*, 2016) or UV light (Wang *et al.*, 2013). Therefore, tests have been conducted also in the Mediterranean Sea for loggerhead sea turtle (*Caretta caretta*) and green turtle (*Chelonia mydas*).

Technical specificities

Two case studies are presented here to illustrate the effect of visual stimuli in set net fisheries:

1) Virgili *et al.* (2018) and Lucchetti *et al.* (2019) tested, in the Italian Adriatic Sea, UV LED lamps acquired from Lindgren-Pitman LED Electralume®. UV-LED lamps perform better than common light sticks, because they provide consistent high intensity illumination, they last longer, and their light penetrates deeper into the water compared with chemical light sticks. Each lamp was fitted with two batteries that provide approximately 30 days of function. Lamps were fixed to the gillnet float line. A distance around 15 m (corresponding to 70 lamps/km) was found to maximize gear performance and illumination. Also, fishers complain about the significantly larger amount of time spent to rig the net with the lights when setting and to remove them when hauling.
2) In Snape (2014), green LED lights were used (LP-Electrolume) in Cyprus. The LED lights were fixed to the trammel net float line at 10 m intervals.

Outcomes expected

1) Virgili *et al.* (2018) and Lucchetti *et al.* (2019) showed that no turtles were caught in the illuminated net, whereas 16 individuals were captured by the traditional net (mortality rate, 30%). There were no significant differences in the catch rates of target species. This was the first test of a BRD designed to reduce sea turtle bycatch in a Mediterranean set net fishery. A broad diffusion of these bycatch reducer devices (BRDs) would provide a significant contribution to the conservation of loggerhead turtles while enabling large-scale production and cost reduction. However, until this happens the cost of adopting this BRD cannot be afforded by the fishermen operating SSF.
2) Field experiments in Snape (2014) indicated that LEDs had no significant influence on fish catches. Although the study failed to categorically determine the precise effect of setting LED lights on marine turtle bycatch, target catch seemed to be positively influenced which merits more detailed study, as if target catches are indeed positively affected, then a finalised LEDs product would receive warmer acceptance by the fishery.

Other relevant information

Snape (2014), Sala (2016), Virgili *et al.* (2018), Lucchetti *et al.* (2019), Wang *et al.* (2010) Wang *et al.* (2013), Ortiz *et al.* (2016).

Drawing / picture of the Innovative gear


Courtesy of Massimo Virgili (CNR-IRBIM, Italy)

Technological Performance assessment

Main criteria.............. Sea turtle bycatch reduction.
Additional criteria ..... *None.*

Technological readiness level (TRL)

TRL category............. Moderate **TRL scale** TRL5

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No, more difficult
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment........ Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Yes, higher

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
Until now there is not any measure that promotes the adoption of this device.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
The cost of the device should be covered through economic incentives.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Fishers (Cyprus) expressed interest in using lights on set nets, while other Adriatic fishers did not want to spend further time in using this BRD due to the waste of time in rigging the lights.

Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Sea turtle bycatch was drastically reduced when UV lights were applied.

Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................ Not Applicable
The device is not addressed in any Mediterranean regulations.

6.6.2 Factsheet 66. Juvenile Selection Grid (JSG)

General information

Year 2020-ongoing	**Source supplier**...........Ocean Marine and Fishing Gears A/S (Denmark), *modified by Tecnopesca srl and CNR-IRBIM (Italy). Revised by Chryssi Mytilineou and Monika Szynaka.*
Region..............................Mediterranean Sea	**FAO-Area**.....................37.1, 37.2, 37.3
Gear sub-category..........Bottom trawls	**Gear code**....................OTB, OTT
Target species.................HKE, MUX, DPS, ILL	**Bycatch species**..........*Undersize target species.*

Baseline gear

Conventional demersal or bottom trawls *(40 mm square-mesh codend)* used in Mediterranean.

Technical information

Definition of the Innovative gear

Juveniles Selection Grids are not commercially used in the Mediterranean. The 2-section JSG is a very light grid made of an alloy of high-strength plastic material, which ensures a remarkable elasticity and ability to withstand considerable bends and to resume its natural shape when the mechanical stresses are finished. The upper section is made of narrow bars that allow juveniles of commercially important species (e.g., Norway lobster, European hake, deep-water rose shrimp) to escape from the bar spacing and reach an opening behind the grid. The lower section of the grid has a hole that guides large animals (i.e., the commercial catch) towards the codend. A guiding funnel is used to convey all the catch to the upper section, to enhance the contact probability with the bar spacing of the grid.

Technical specificities

The grid has 110 x 85.6 cm dimension (height x width). In the upper section, it has 24 vertical bars spaced 20 mm each other. The 20 mm bar spacing was made upon the results found in literature for Mediterranean selection grids with this spacing, which proved to be promising at excluding juveniles of commercially important species. It has 3 horizontal bars required to maintain the rigidity of the grid during towing. The lower section of the grid is approximately 25% of the total area.

The grid is mounted on a tubular netting section (6 m in length) with a tilt angle of approximately 46˚ and placed in the extension piece, just in front of the codend. An escape opening has been cut into the upper portion of the net behind the grid to let the juveniles escape from the net. The test configuration is obtained by inserting the grid section between the extension and the codend.

Outcomes expected

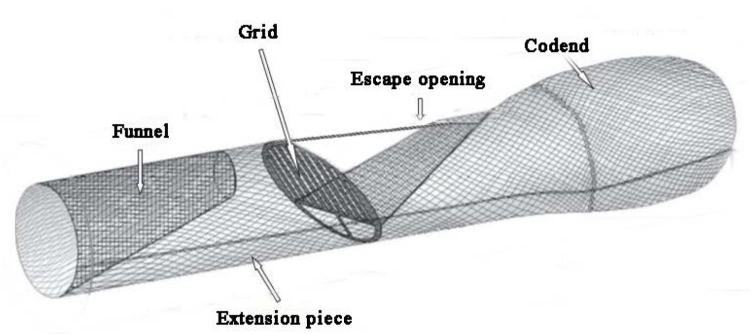
The JSG device does not affect neither bottom trawl technical performances (horizontal and vertical net opening and door spread) nor increase the required towing force, hence fuel consumption remain constant. Preliminary trials showed that the JSG provided a significantly lower retention for juveniles of commercial species, i.e. European hake (*Merluccius merluccius*; <20 cm of minimum landing size) and red mullet (*Mullus barbatus*; <11 cm of minimum landing size) but also for commercial individuals of red mullet (>11 cm) deepwater rose shrimp (*Parapenaeus longirostris*) and cephalopods (*Illex coindetii*; *Eledone* spp.), when compared to a standard net.

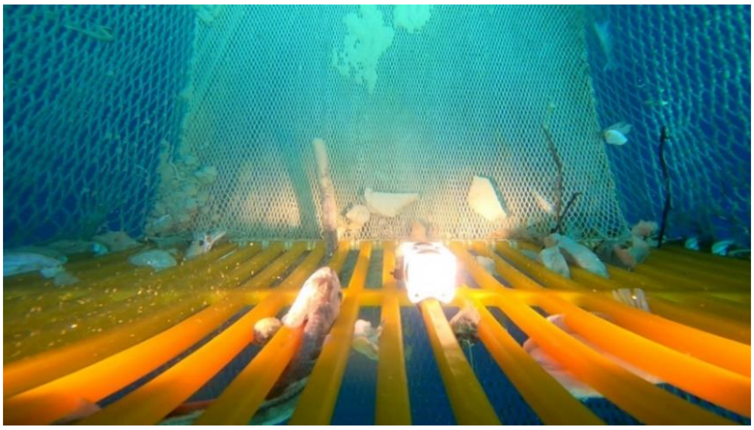
Underwater video camera recordings documented that, regardless of the species, more than 70% of the individuals escaping from the grid bars were alive, with some species (e.g., red mullet, deepwater rose shrimp, 80-100%) being alive more often than others (e.g., European hake, 75% on average). However, some clogging phenomena were observed at the guiding funnel, due to large objects (e.g., logs, plastic bags) that reduce the contact probability with the bar spacings of the grid. The material of which the JSG is made allows it to maintain a stiff configuration during trawling, and safely winding around a standard net winch as the net is hauled onboard.

Other relevant information

Bahamon *et al.* (2007), Sardà *et al.* (2005), Vitale *et al.* (2018b).

Drawing / picture of the Innovative gear





Courtesy of Andrea Petetta (CNR-IRBIM, Italy).

Technological Performance assessment

Main criteria............... Improved selectivity for main commercial species with a minimum landing size in the Mediterranean.
Additional criteria ..... None.

Technological readiness level (TRL)

TRL category............. Moderate **TRL scale** TRL5

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category .... Low
Return on Investment .... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Maybe

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Not Applicable
The device is currently only tested for scientific purposes.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
The cost of the device and of the eventual commercial loss could be covered through some economic incentives from the governments.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... It is a barrier
Fishers that have tested the device are aware that the trawl catch efficiency is reduced.

Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Has encouraged uptake
The gear equipped with the grid is not more difficult to deploy, and do not require specialist knowledge or training. However, the testing of the device is on an early stage.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Reduced catch of undersized individuals of commercially important species.

Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... Not Applicable
The device is not addressed in any Mediterranean regulations.

6.6.3 Factsheet 67. Interactive acoustic deterrent devices (pinger) to reduce cetacean-fishery conflicts and mitigate bycatch

General information

Year 2020-ongoing

Source supplier ....Antonello Sala, *with text adapted from Buscaino et al. (2021). Revised by Chryssi Mytilineou and Monika Szynaka.* Szynaka.

Region ....Mediterranean Sea

FAO-Area 37.1, 37.2, 37.3

Gear sub-category ....Entangling nets

Gear code ....GN, GT, GC *(all set nets)*

Target species ....AMB

Bycatch species ....*Dolphins, cetaceans*

Baseline gear

Any conventional set nets (e.g., gillnets, trammel nets, combined nets) without deterrent devices.

Technical information

Definition of the Innovative gear

Interactive pingers application to reduce bottlenose dolphin (*Tursiops truncatus*) interactions with trammel nets along the coast of Lampedusa Island. The interactive pinger is designed by Daimar Ltd (Italy). It must be placed 1 m above the set nets.

Technical specificities

The power spectral density (PSD) of the pinger signals is shown in Figure 4 with the first peak at approximately 40 kHz and the remaining peaks at 15, 20, 45, and 60 kHz. Power spectral density was obtained using 50 randomly selected pinger events from the recordings collected during the experiment (Buscaino *et al.*, 2021). Pinger sound frequencies were included in the maximum auditory range sensitivity of bottlenose dolphins.

Outcomes expected

The level of interaction between dolphins and the nets was evaluated in Buscaino *et al.* (2021) considering the number of dolphin clicks grouped over time (single acoustic incursion on each net), the duration of every acoustic incursion, and the number of dolphins clicks per incursion. Moreover, the catch rate was measured as the number of fish per hour for each net.

The duration of the interaction between dolphins and nets significantly increased over the study period, with a concomitant reduction in catch rate. The interactive pinger showed efficacy in protecting the nets from dolphin depredation during the first period of 11 fishing days (higher catch rates and lower incursion durations), whereas no differences were found in any interaction parameters between pinger and control nets in the second period (six fishing days). Interactive pingers may be an effective, short-term (2–3 weeks) tool in deterring depredation by bottlenose dolphins in small-scale artisanal fisheries.

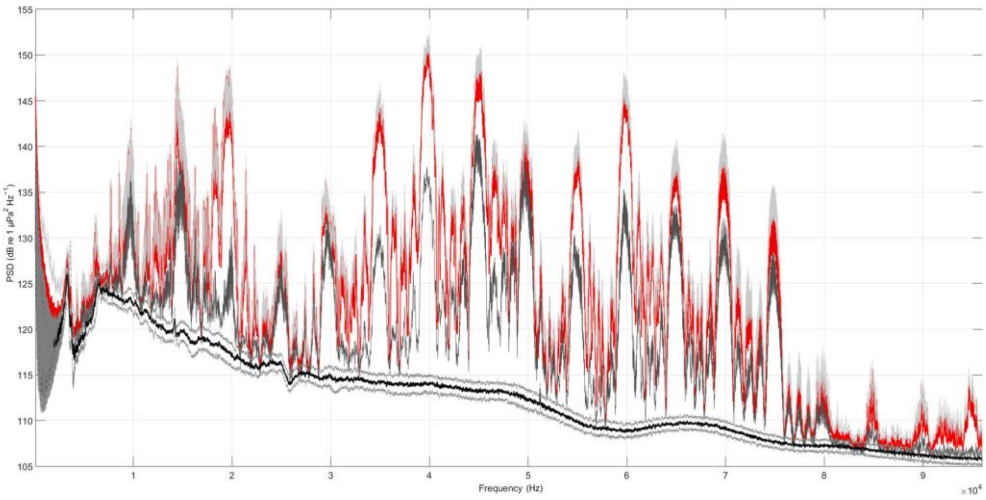
Other mitigation approaches, such as gear modification, lessons learned through outreach, and passive acoustic monitoring of the nets, could improve the management of the interactions between fisheries and bottlenose dolphins.

Other relevant information

Buscaino et al. (2021), Rihan (2010), ICES (2022), STECF (2019), Yan *et al.* (2010).

A list of techniques for reducing non-target species bycatch and results obtained is also provided in Werner *et al.* (2006).

Drawing / picture of the Innovative gear



Median (25th-75th percentile) power spectral density (dB re 1 µPa² Hz⁻¹) of 50 randomly selected pinger events (red curve) and median (25th-75th percentile) power spectral density of 30 randomly chosen recordings of background sea-noise lasting 3 s (black curve). *Source: modified and adapted from Buscaino et al. (2021).*

Technological Performance assessment

Main criteria............... Impact on vulnerable species (marine mammals).
Additional criteria ..... Reduced conflicts cetaceans-fishers, low cost of the investment for the fishing enterprise.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL8

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Not applicable **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.......... Moderate
Return on Investment.......... Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
Usually set netters are small-scale fishers, they have economic difficulties to afford the investment.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... Has encouraged uptake

6.6.4 Factsheet 68. Flexible turtle excluder device (FLEX-TED) to mitigate sea turtle bycatch in Mediterranean demersal trawl fisheries

General information

Year	2014-2020	**Source supplier**	Ocean Marine and Fishing Gears A/S (Denmark), *modified by Tecnopesca srl and CNR-IRBIM (Italy). Revised by Chryssi Mytilineou and Monika Szynaka.*
Region	Mediterranean Sea	**FAO-Area**	37.2.1
Gear sub-category	Bottom trawls	**Gear code**	OTB, OTT
Target species	MTS, HKE, MUT, DPS, MON, WHG	**Bycatch species**	TTL, MYL, MPO

Baseline gear

Conventional demersal or bottom trawls *(40 mm square-mesh codend)* used in Mediterranean.

Technical information

Definition of the Innovative gear

TEDs are not commercially used in the Mediterranean. FLEX-TED is made of an alloy of plastic material, which ensures a lightness of the grid (compared to rigid TEDs made of aluminium), rigid configuration during the tow and the capacity of withstanding considerable bends and resuming its natural shape when the mechanical stresses are finished. Therefore, this grid can be safely winded around a standard net winch, allowing to carry out the normal fishing operations without additional time. Dimension, space between the bars, hole position, flap and cylindrical netting section have been adjusted to fit Mediterranean trawls.

Technical specificities

The FLEX-TED dimensions are: 1,130 mm (height); 845 mm (width); 3,110 mm (circumference); with 20 mm of bar diameter and 96 mm of spacing between bars. This grid is mounted on a tubular netting section (6 m in length) and placed immediately in front of the codend. An escape opening is cut on the lower or upper portion of the net just before the TED and covered by a netting panel with three sides sewn to the net to prevent loss of commercial species. The fourth side is free and function as a valve, as it opens only when it is hit by large and heavy objects, and thus allowing sea turtles and other bycatch species to out the net. TED angle is usually set to 45-48°.

Outcomes expected

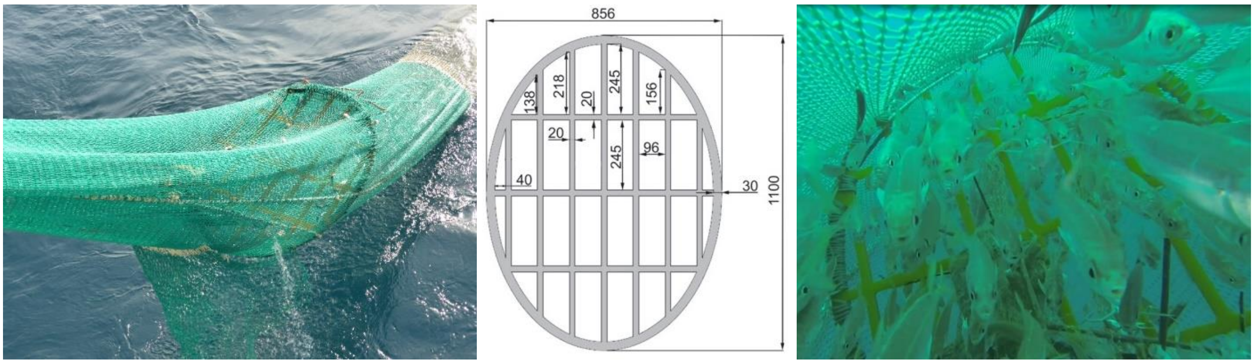
FLEX-TED device does not affect neither bottom trawl technical performances (horizontal and vertical net opening and door spread) nor increase the required towing force, hence fuel consumption remain constant. Comparison of commercial catches for the major species showed that the use of this TED did not affect catching efficiency, while it reduced the amount of debris (Lucchetti *et al.*, 2019; Vasapollo *et al.*, 2019). The device did not influence the size of commercial species, leaving the selective performance of the trawl unmodified. Underwater video camera recordings documented that fish caught in the net swam through the grid and easily reached the codend, missing the TED escape opening. FLEX-TED is a very light grid made of an alloy of high-strength plastic material. The material of which it is made ensures a remarkable elasticity and ability to withstand considerable bends and to resume its natural shape when the mechanical stresses are finished. These features allow the grid maintaining a stiff configuration during trawling, and safely winding around a standard net winch as the net is hauled onboard.

The effectiveness of the FLEX-TED has been already proved under the TartaLife Project (LIFE12 NAT/IT/000937), and allowed overcoming some problems connected with other rigid TEDs tested during the hauling phase (i.e. net and TED breaking and loss of time with handling). The easy storage and handling make the flexible TED a practical and valuable solution to reduce turtle bycatch in coastal Mediterranean demersal multispecies fisheries. In support of the efficacy of the FLEX-TED, some vessels, after having tested this device during the experimentation trials of the TartaLife project, voluntarily adopted the use of the device. Positive results have led to the adoption of a "Turtle safe" label by Friends of the sea".

Other relevant information

Sala *et al.* (2011b), Lucchetti *et al.* (2019), (Pulcinella *et al.*, 2019), Vasapollo *et al.* (2019).

Drawing / picture of the Innovative gear



Courtesy of CNR-IRBIM (Italy).

Technological Performance assessment

Main criteria............... Reduce marine megafauna bycatch.
Additional criteria ..... Reduce marine debris from the catch, better catch quality.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL7

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.. Low
Return on Investment.. Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... It is a barrier
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................ It is a barrier

6.6.5 Factsheet 69. Sorting grids to reduce undersized catches in crustacean bottom trawl fisheries

General information

Year 2017	**Source supplier** .... Michele Geraci, Sergio Vitale (CNR-IRBIM, Italy). *Horizon 2020 project Minouw (Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries). Revised by Chryssi Mytilineou, Monika Szynaka, Antonello Sala.*
Region .... Mediterranean Sea	**FAO-Area** 37.2.2
Gear sub-category .... Bottom trawls	**Gear code** .... OTB, OTT
Target species .... DPS	**Bycatch species** .... HKE

Baseline gear

Conventional demersal or bottom trawls *(40 mm square-mesh codend)* used in Mediterranean.

Technical information

Definition of the Innovative gear

Sorting grids with bars spaced 20 mm and 40 mm square-mesh.

Technical specificities

The test was equal to the baseline trawl net except for a sorting grid mounted in the extension section. Three different sorting grids were tested: the first grid type (G1-SM40) was built with a net of 40-mm square mesh while the second (G2-ST20) and third (G3-ST25) were made from vertical steel bars spaced 20 and 25 mm apart, respectively (see figure below). The first two innovative gears seem to be the best trade-off between selectivity and economic factors.

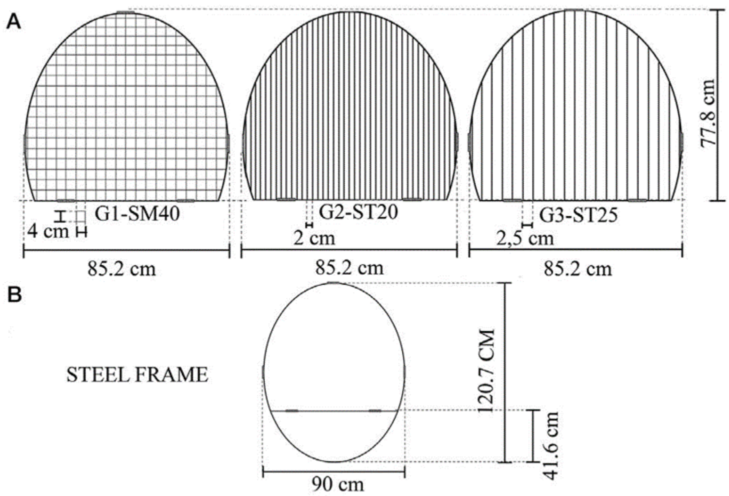
Outcomes expected

G1-SM40, the reduction of undersized individuals in the codend was about 60% and 44% for DPS and HKE, respectively. With G2-ST20, a 34% catch decrease of HKE individuals smaller than 20 cm in total length was observed. Finally, G3-ST25 was efficient at reducing the catch of undersized DPS and HKE but showed a higher loss of marketable fractions than the other grids.

Other relevant information

Vitale *et al.* (2018b), Vitale *et al.* (2018a), (Bonanomi *et al.*, 2020), Geraci *et al.* (2023).

Drawing / picture of the Innovative gear



Courtesy of CNR-IRBIM, Italy.

Technological Performance assessment

Main criteria............... Species- and size-selectivity, catch efficiency.
Additional criteria ..... Reduced catch sorting time.

Technological readiness level (TRL)

TRL category............. Moderate **TRL scale** TRL6

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Transformative **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?........ No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No, greater

Economic Performance assessment

Capital cost category........ Low
Return on Investment........ Substantial
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... No, lower

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
The innovative gears were not implemented but the modelling approach pointed out that the application of the sorting grids would have a positive effect on the biomass of adult DPS and HKE which is a proxy of the economic gain.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Has encouraged uptake
The proposed innovative gears are a simple modification from the technological point of view.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Has encouraged uptake
The innovative gears were not implemented; however, given that the CFP (Regulation (EU) 1380/2013, 2013) stated that the selectivity of the gears should be improved, the legal factors will have a positive impact on the proposed gears.

6.6.6 Factsheet 70. Diamond-mesh turned 90° (T90) in the extension piece to reduce bycatch in bottom trawl fisheries (Catalonia, Spain)

General information

Year 2015-2018

Source supplier Antonello Sala, *with text adapted from Sola and Maynou (2018). Horizon 2020 project Minouw (Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries). Revised by Chryssi Mytilineou and Monika Szynaka.*

Region Mediterranean Sea

FAO-Area *Not applicable*

Gear sub-category Bottom trawls

Gear code BT, TB, TM

Target species *Not applicable*

Bycatch species *Not applicable*

Baseline gear

Conventional bottom trawls with extension manufactured of diamond-mesh (53 mm stretched mesh).

Technical information

Definition of the Innovative gear

Diamond-mesh of 50 mm (stretched size) turned 90º (T90).

Technical specificities

In the new trawl net, the extension netting was replaced with a 50-mm diamond mesh turned 90° (T90). The introduction of modifications to fishing gear that improve fisheries selectivity will be successful only if these modifications are practical (easy to use and inexpensive), can be acceptable to industry and managers, have low environmental impact and are easily enforceable.

It is expected that the economic loss can be partially offset by decreased sorting time and costs and decreased costs related to compliance with the Landings Obligation, but certainly short-term losses of income are a barrier to the adoption of more selective technologies.

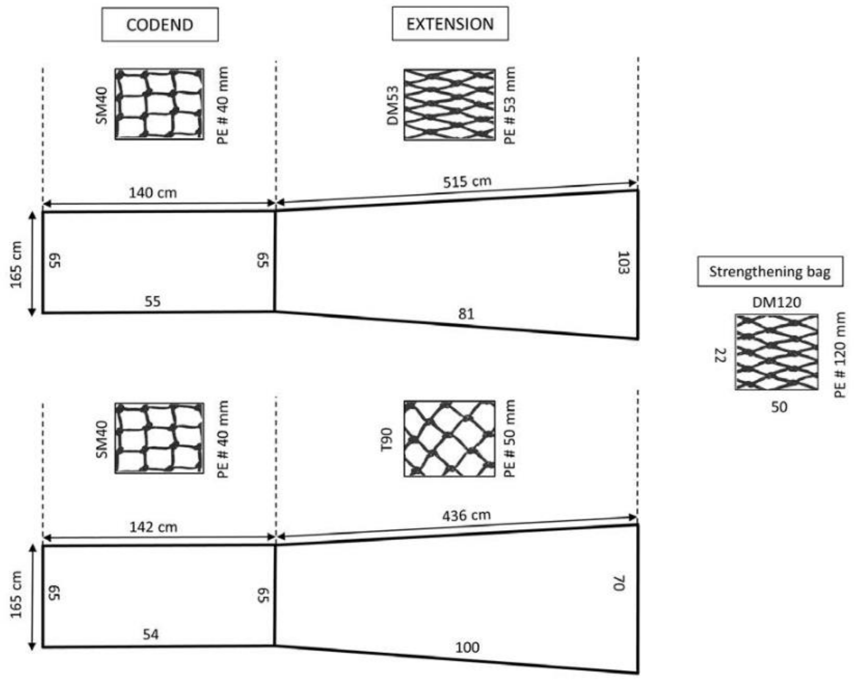
Outcomes expected

- The results show that a simple modification in the trawl extension piece significantly decreases the amount of undersize European hake (*Merluccius merluccius)*, but has a negligible effect on the catches of two red mullets, *Mullus barbatus* and *M. surmuletus.*
- Catch ratio curve estimated for hake shows that the experimental net catches significantly less individuals smaller than 16 cm.
- Proportion of undersize hake (< 20 cm) in the catches of the modified net was 52% of that found in the standard configuration.
- Catch ratio curve for red mullet and striped red mullet did not provide conclusive results, mainly because no undersize red mullets were caught during the experiments.
- Proportion of non-regulated unwanted catches in both nets was similar (47.6 and 48.8% of the total catch).

Other relevant information

Sola and Maynou (2018).

Drawing / picture of the Innovative gear



Characteristics of the trawl with details of the control and experimental aft parts of the net. *Source: adapted from Sola and Maynou (2018).*

Technological Performance assessment

Main criteria............... Size selectivity
Additional criteria ..... *None*

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Negative **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair?........ No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Low
Return on Investment........ Negative
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **technological factors** had on uptake of this gear?........ Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **legal factors** had on uptake of this gear?........ Has encouraged uptake

6.6.7 Factsheet 71. Alternative netting materials and new design in set trammelnet Balearic Islands fisheries

General information

Year 2015-2018

Source supplier .... Antonello Sala, *with text adapted from Catanese et al. (2018). Revised by Chryssi Mytilineou and Monika Szynaka.*

Region .... Mediterranean Sea

FAO-Area 37.1.1

Gear sub-category .... Entangling nets

Gear code .... GT, GC *(potentially viable for GN)*

Target species .... SLO

Bycatch species .... *undersized spiny lobsters, invertebrates*

Baseline gear

Trammel nets with mesh size 120-160 mm for Spiny Lobster. Most of the small-scale vessels in Balearic Islands use trammel nets of varying designs to target both fish and shellfish. The spiny lobster (*Palinurus elephas)* is one of the economically most prized species affected by the Landing Obligation (LO) in Balearic Islands. However, the LO regulations contrast substantially with the management rules currently applied by the local government, which requires releasing undersized juveniles and ovigerous (egg-bearing) female lobsters back to the sea. To-date, local management rules include: (a) open fishing season limited to the time period between 1 April - 31 August to avoid the breeding period; (b) a minimum landing size of 240 mm of total length; (c) capture and retention on board and commercialization of ovigerous females is prohibited at any age and size; (d) soaking time of the nets cannot exceed 48 h to minimize discard mortality; and (e) mesh size of 133 mm and total length of 5,000 m per vessel are regulated.

Technical information

Definition of the Innovative gear

Since 2000s, fishers of the Balearic Islands have introduced changes in the fishing tactics, but the effectiveness of these have not yet been evaluated. For example, exchanging the standard polyfilament (PMF) nets for a new polyethylene multi-monofilament (MMF) net combined with the use of a special design (*greca*), also referred to as a selvedge or guarding net, which is intended to reduce the discards from the sea bottom. While monofilament netting is increasingly used the adoption of a guarding net has only been trialled by fishers that participated in the Minouw EU project (Catanese *et al.*, 2018).

Technical specificities

Testing of trammel nets constructed by two alternative netting materials:

- traditional multifilament polyamide (PMF); and,
- the more recently introduced multi-monofilament ethylene (MMT) netting, in a spiny lobster fishery.

Testing of the performance of trammel nets modified by a "*greca*" (selvedge) as a bycatch reduction device in a spiny lobster fishery.

Testing the performance of two trammel net mesh sizes:

- the traditional 60 mm versus
- 80 mm, in cuttlefish fishery.

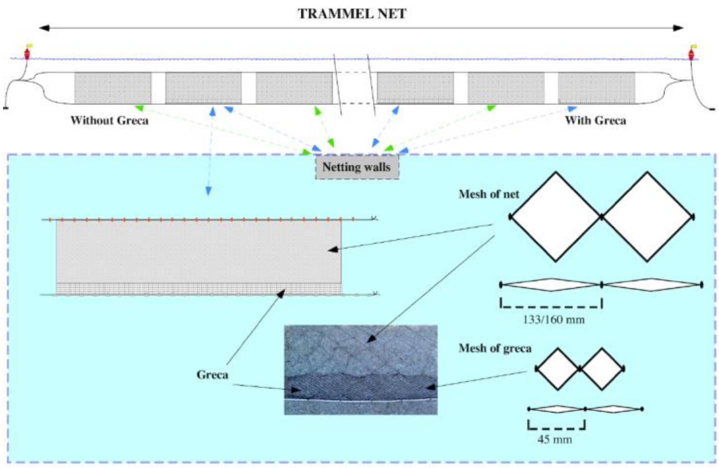
Outcomes expected

Catanese *et al.* (2018) compared three trammel net designs (PMF, MMF and MMF+*greca*) in terms of biomass, species composition and revenue of marketable catches and discards. Regarding the MMF vs PMF comparison, the proportions of netting walls/panels with some marketable catch (PMF=31% vs. MMF=28%), the estimated mean revenue in the netting wall (PMF=41€ vs. MMF=42€), and the mean revenue for an average net (PMF=262€ vs. MMF=242€) were similar. In all three cases, the differences between PMF and MMF were not considered statistically relevant. Concerning the MMF vs PMF comparison at the netting panel level, the proportions of panels with unwanted catch were similar (PMF=50% vs. MMF=49%). Concerning the standard MMF vs MMF+*greca* comparison, the differences in the probability of obtaining some commercial catches were relevant (MMF=52% vs. MMF+*greca*=70%), but the estimated mean discarded weight was statistically relevant in the opposite direction (MMF=1.30 kg vs. MMF+*greca*= 0.62 kg). The estimated mean revenue when marketable items in MMF vs MMF+*greca* comparison were concerned did however not to differ. However, MMF+*greca* netting walls tended to retain some discarded fauna more frequently, but the overall mean weight of discards was smaller. The three trammel net designs (PMF, MMF, and MMF+*greca*) showed no significant differences in revenue and weight for the wanted and unwanted marketable fractions in the spiny lobster fishery. Moreover, although the species composition of discards was different when using *greca* with some discard species being retained more frequently, the overall mean weight of discards in MMF+*greca* was smaller in relation to other trammel nets design.

Other relevant information

Gil *et al.* (2018), Catanese *et al.* (2018).

Drawing / picture of the Innovative gear



Details of the strip added at the bottom of trammel nets (greca). Greca net approximately 20 cm of nylon material with a mesh size of 45 mm that is sown to the bottom of the main net along its entire length. *Source: modified and adapted from Catanese et al. (2018).*

Technological Performance assessment

Main criteria............... Size and species selectivity
Additional criteria ..... catch efficiency, reducing catch sorting time

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL8

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Low
Return on Investment........ Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.................. Has encouraged uptake
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?................................ Has encouraged uptake

6.6.8 Factsheet 72. Use of artificial lights to reduce discards in trammelnet fisheries

General information

Year 2018	**Source supplier** .... Antonello Sala, *with text adapted from Martínez-Baños and Maynou (2018). Horizon 2020 project Minouw (Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries). Revised by Chryssi Mytilineou and Monika Szynaka.*
Region .... Mediterranean Sea	**FAO-Area** .... *Not applicable*
Gear sub-category .... Entangling nets	**Gear code** .... GTR, GTN
Target species .... CTC, MUR	**Bycatch species** .... *More than 30 different species*

Baseline gear

Conventional trammel nets made of 50-m sheets for a total length of 1500 to 2000 m, and 1.5 to 2.5 m high. Inner panel 80 mm polyethylene mesh, 40 meshes high, outer panel 200 mm nylon mesh, 8 meshes high; hanging ratio 0.82) following the usual professional configuration.

Technical information

Definition of the Innovative gear

A conventional trammel net divided into three sections of 500 m each. Two sections were provided with artificial lights fixed on the floatline (12 mm float nylon rope): one section was provided with white lights, the other with green lights (see figure below).

Technical specificities

The artificial lights were units employed in tuna longlining fisheries, commercialized as "LED fishing light, deep sea drop light" manufactured by Ningbo Solar Lighting Electrics (Zhejiang, China). Each unit used two AA batteries with nominal manufacturer's specification 300 h.

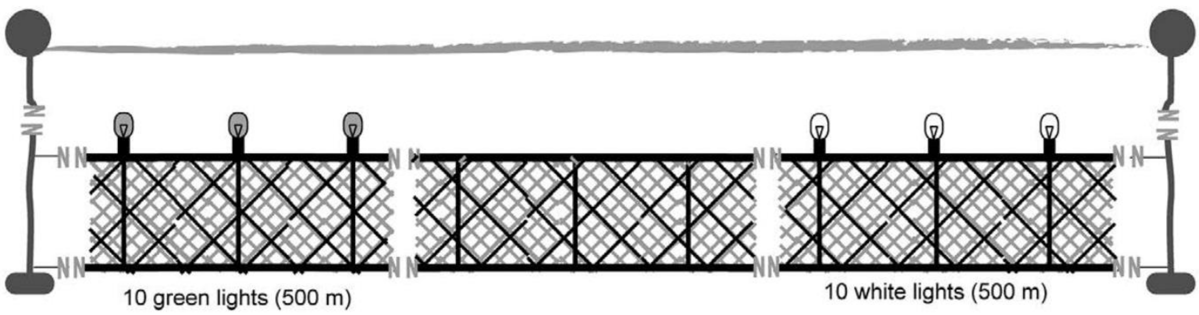
Outcomes expected

Artificial lights produced a low but significant increase in total catches of commercial species of 13%, with no differences due to light colour. This conventional trammel nets produced 19% discards in weight. However, lights produced a low, but significant, increase in total catches of cuttlefish of 13-14%, with no differences due to light colour.

Other relevant information

Martínez-Baños and Maynou (2018).

Drawing / picture of the Innovative gear



Schematic design of the trammel nets. Trammel net was built of 30×50 m panels (total length 1500 m) with a vertical span of approximately 1.6 m, using 80 mm inner meshes and 200 mm outer meshes. The net was divided into 3×500 m sections (10 panels each). Two of the sections were fitted with green or white lights every 50 m and one section was left unmodified. *Source: modified and adapted from Martínez-Baños and Maynou (2018).*

Technological Performance assessment

Main criteria .... Species- and size-selectivity.
Additional criteria ..... Reduced sorting time.

Technological readiness level (TRL)

TRL category .... High **TRL scale** TRL7

Technological complexity level

Minimal complexity

Performance improvement	
Catch efficiency .... Incremental	**Selectivity** .... Incremental **Impact**......... Not applicable
Comparison with the baseline	
Is the innovative gear easier to deploy and retrieve?	No, more difficult
Is the innovative gear easier to maintain and repair?	No, more difficult
Does using the innovative gear present a lower risk to the health and safety of crew?	No difference
Economic Performance assessment	
Capital cost category	Low
Return on Investment	Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it?	Unsure
P.E.S.T.E.L. Framework	
Overall, what impacts do you think have **political factors** had on uptake of this gear?	Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **social factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?	Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?	Do not know

6.6.9 Factsheet 73. Use of guardian net to reduce discards in trammelnet fisheries

General information

Year 2018

Source supplier .... Antonello Sala, *with text adapted from Martínez-Baños and Maynou (2018). Horizon 2020 project Minouw (Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries). Revised by Chryssi Mytilineou and Monika Szynaka.*

Region .... Mediterranean Sea

FAO-Area 37.1

Gear sub-category .... Entangling nets

Gear code .... GTR, GTN

Target species .... CTC, MUR

Bycatch species .... *more than 30 different species*

Baseline gear

Conventional trammel nets made of 50-m sheets for a total length of 1500 to 2000 m, and 1.5 to 2.5 m high. Inner panel 80 mm polyethylene mesh, 40 meshes high, outer panel 200 mm nylon mesh, 8 meshes high; hanging ratio 0.82) following the usual professional configuration.

Technical information

Definition of the Innovative gear

A guarding net fixed to the footrope of the trammel net has revealed effective in reducing unwanted catches in some Mediterranean trammel net fisheries, for instance the caramote prawn fishery of Tuscany (Sartor *et al.*, 2018).

Technical specificities

A conventional trammel net fitted with a guarding net made of 2.5-mesh-high polyethylene mesh (200 mm, twine thickness 4.2 mm) and positioned between the trammel net and the footrope (weighed rope 10 mm diameter).

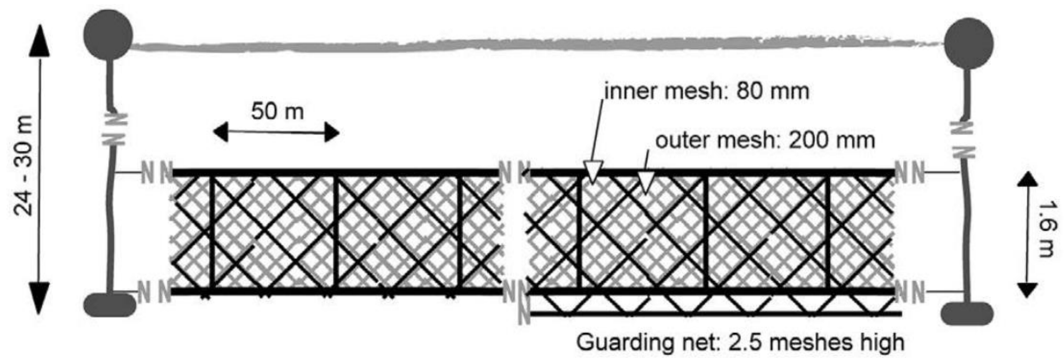
Outcomes expected

The trammel net deployments with guarding net produced 32% higher catches of commercial species and, in the case of the target cuttlefish, as much as 95% higher. The amount of unwanted catches in deployments with guarding net were 6% (i.e., ca. 1/4 of the amount produced by the conventional trammel net).

Other relevant information

Martínez-Baños and Maynou (2018), Sardo *et al.* (2023), Sartor *et al.* (2018).

Drawing / picture of the Innovative gear



Schematic design of the trammel nets. Trammel net was built of 30×50 m panels (total length 1500 m) with a vertical span of approximately 1.6 m, using 80 mm inner meshes and 200 mm outer meshes. The control trammel net is shown in the top left figure. The modified trammel net with a guarding net was created by adding 2.5 meshes (of the external type, i.e., 200 mm) between the footrope and the panel. *Source: modified and adapted from Martínez-Baños and Maynou (2018).*

Technological Performance assessment

Main criteria............... Species- and size-selectivity.
Additional criteria ..... Reduced sorting time, increase net life-durability.

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Minimal complexity

Performance improvement

Catch efficiency .... Incremental **Selectivity** .... Incremental **Impact**......... Not applicable

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category.......... Low
Return on Investment.......... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?.......... Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?.......... Do not know

6.6.10 Factsheet 74. Circle hooks on a Mediterranean-wide longline swordfish fisheries level

General information

Year 2018

Source supplier ....Antonello Sala, *with text adapted from Tserpes (2019). Horizon 2020 project Minouw (Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries); and Carbonara et al. (2023). Revised by Chryssi Mytilineou and Monika Szynaka.*

Region...............................Mediterranean Sea

FAO-Area 37.3

Gear sub-category ....Longlines

Gear code ....LLD

Target species..................SWO

Bycatch species...........*Sharks, sea turtles, and other ETP species*

Baseline gear

Mediterranean swordfish longline fishing fleets are traditionally employing J-type hooks baited either with mackerel or squid. The fisheries are typically mono-specific but minor catches of sensitive species, such as sharks and sea-turtles occur, depending on the area and season.

Technical information

Definition of the Innovative gear

Experimental fishing trials with circle hooks on longline fisheries targeting swordfish. Comparison between J and circle hooks regarding catch rates of the target species (swordfish), as well as species composition of bycatches, including captures of vulnerable species.

Technical specificities

Circle hooks and J hooks are two of the most common types of fishing hooks used by anglers. Both hooks have their advantages and disadvantages and can be used in different situations depending on the type of fish being targeted. Circle hooks are designed to be more efficient at hooking a fish than a traditional J hook. This is due to the shape of the hook, which is designed to catch the fish in the corner of the mouth, rather than the traditional J hook which can catch the fish in the throat or gut. This means that circle hooks are less likely to cause injury to the fish, making them a more humane option for catch and release fishing. Additionally, circle hooks are less likely to be swallowed by the fish, which can cause it to become hooked in the stomach or intestine.

The biggest advantage of using a circle hook is that it is more effective at catching fish than a J hook. This is due to the shape of the hook, which is designed to set in the corner of the fish's mouth. This gives the angler more control over the fish and makes it easier to bring it to the boat. Additionally, the shape of the hook allows it to be used with a variety of baits, including live bait, cut bait, and artificial lures. The biggest disadvantage of using a circle hook is that it is not as effective at catching large fish as a J hook. This is because the shape of the hook makes it more difficult to penetrate the thicker skin of larger fish. Additionally, the shape of the hook can make it difficult to set the hook in the corner of the mouth of a large fish, meaning that the angler may have to use a different technique to set the hook.

In general, J hooks are a better choice for anglers targeting large fish, while circle hooks are better suited for smaller fish. J hooks are more effective at penetrating the thick skin of larger fish and are also better suited for use with heavier lines and larger baits. Circle hooks, on the other hand, are more effective at catching smaller fish and can be used with lighter lines and smaller baits (ref. https://southerncountrycharters.com/circle-hooks-vs-j-hooks).

In Carbonara *et al.* (2023), a pelagic longline targeting swordfish was used during the experiment, with a total mainline length between 30 and 40 km. A hook was attached to a dropline with a length of about 13 m, and each dropline was attached to the main line every ~58 m. The configuration of the longline gear used in this study is the same as the configuration used in commercial fisheries. Usually, the hooks used during the fishing season are J-type hooks that are 76 mm long. The bait used in the study was frozen mackerel (Scombridae), and an artificial light was attached to the middle of each dropline. The dropline was composed of monofilament.

Outcomes expected

Proportionally less catches of undersized swordfish individuals in circle hooks were observed in *Tserpes (2019)*. Employment of circle hooks seems to be promising but given the limited number of the trials and the fact that past works revealed variable results in different fisheries, further field studies are needed to confirm the effectiveness of circle hooks on a Mediterranean-wide level.

Catch rate differences of the target species (swordfish), expressed in terms of kg/1000 hooks, between the traditional (J-hook) and the modified (Circle-hook) gear were not statistically significant. The modified gear caught proportionally less undersized swordfish individuals (MLS = 100 cm LJFL according to ICCAT regulations). However, overall size differences between gear types were not statistically significant. Regarding catches of "sensitive" species, such as sharks, these were comparable among gear types, representing around 10% of the total catch in terms of numbers. Release of unwanted captures was in most cases easier in the modified gear *(Tserpes, 2019)*.

With all species, Carbonara *et al.* (2023) observed no significant difference in catch-per-unit-effort (CPUE) or specimen lengths between the two hook types. In addition, the hook type did not significantly affect the capture condition of swordfish, pelagic stingray, or loggerhead turtle specimens; however, it significantly affected the capture condition of blue sharks. The percentage of blue shark specimens found in healthy condition was higher when using a C-type hook (71.5%) than when using a J-type hook (22.6%). Overall, these preliminary results suggest that the use of a C-type hook improves the condition of bycaught blue sharks without affecting the CPUE or size of the target species.

Other relevant information

Tserpes (2019), Carbonara et al. (2023).

Drawing / picture of the Innovative gear

C-type hook (left) and J-type hook (right) and their dimensions. *Source: modified and adapted from Carbonara et al. (2023).*

Technological Performance assessment

Main criteria............... Species- and size-selectivity, impact on vulnerable species (e.g., sharks, sea turtles).
Additional criteria ..... Bycatch survival (e.g., blue shark found in healthier condition using C-type hooks).

Technological readiness level (TRL)

TRL category............. High **TRL scale** TRL9

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Negative **Selectivity** .... Incremental **Impact**......... Transformative

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... No difference
Is the innovative gear easier to maintain and repair? .... No difference
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category	Low
Return on Investment	Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it?	Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **economic factors** had on uptake of this gear?	It is a barrier
Overall, what impacts do you think have **social factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **technological factors** had on uptake of this gear?	Do not know
Overall, what impacts do you think have **environmental factors** had on uptake of this gear?	Has encouraged uptake
Overall, what impacts do you think have **legal factors** had on uptake of this gear?	Has encouraged uptake

6.6.11 Factsheet 75. Lighter trawl gear to reduce environmental impact on the seabed

General information

Year	2008	**Source supplier**	Chryssi Mytilineou, *with text adapted from Guijarro et al. (2017). Revised by Antonello Sala.*
Region	Mediterranean Sea	**FAO-Area**	*37.1.1*
Gear sub-category	Bottom trawls	**Gear code**	OTB
Target species	NEP, ARA	**Bycatch species**	*Not available*

Baseline gear

Traditional diamond 40 mm nominal codend mesh size. This net was linked by 40 m PP and hemp legs, with *Dyneema* and steel in the upper (ø20 mm) and lower (ø46 mm) part, respectively, and 360 m steel and polypropylene (PP) sweeps (ø43 mm) to metallic oval-shaped bottom doors HIP-SE (2.66×1.55 m= 4.1 m^2; 670kg) and to steel warp ø 14 mm.

Technical information

Definition of the Innovative gear

The novel fishing gear is 100 kg lighter (total weight 800 kg). The gear was lighter because of thinner twines, shorter sweeps, and lighter hydrodynamic doors.

Technical specificities

Square-mesh codend of 40 mm with thinner twine of 3 mm thickness. This net was linked by 40 m PP and hemp legs, with *Dyneema* and steel in the upper (ø20 mm) and lower (ø46 mm) part, respectively, and 310 m steel and polypropylene (PP) sweeps (ø43 mm) to metallic bottom doors MAPSA model EXPLORER S1150 (2.15×1.40 m= 3.01 m^2; 588 kg) and to steel warp ø14 mm.

Outcomes expected

Significant differences between the two gears were found in the abundance of the commercial, discarded, and total catch, being higher with the traditional gear for the upper slope. No difference for the other two depth zones.

Discards reduction for the upper slope in 40 mm square-mesh codend mainly concerning the small-sized Elasmobranchs, *Scyliorhinus canicula* and *Galeus melastomus*). No significant differences between the two gears in terms of biomass in any of the depth zones. Fuel consumption by hour (l/h) showed a reduction of 5% and 11% in the upper and middle slope, respectively.

Other relevant information

Guijarro *et al.* (2017).

Drawing / picture of the Innovative gear

Not available.

Technological Performance assessment

Main criteria .... Seabed impact, catch efficiency, vulnerable species bycatch reduction.
Additional criteria ..... Fuel use, CO2 emissions.

Technological readiness level (TRL)

TRL category .... Moderate **TRL scale** TRL6

Technological complexity level

Medium complexity

Performance improvement

Catch efficiency .... Not applicable **Selectivity** .... Incremental **Impact** .... Incremental

Comparison with the baseline

Is the innovative gear easier to deploy and retrieve? .... Unsure
Is the innovative gear easier to maintain and repair? .... Unsure
Does using the innovative gear present a lower risk to the health and safety of crew? .... No difference

Economic Performance assessment

Capital cost category........ Moderate
Return on Investment .... Minor
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it? .... Unsure

P.E.S.T.E.L. Framework

Overall, what impacts do you think have **political factors** had on uptake of this gear? .... Do not know
I believe there could be negative factors in case of an enforcement of the implementation of such a modification without subsidies.

Overall, what impacts do you think have **economic factors** had on uptake of this gear? .... It is a barrier
I think the cost of investment in new doors and new sweeps is quite high. No information about the cost in the publication.

Overall, what impacts do you think have **social factors** had on uptake of this gear? .... Has encouraged uptake
Fishers involved in the experiment (no purchase needed for the modifications) still use this system.

Overall, what impacts do you think have **technological factors** had on uptake of this gear? .... Has encouraged uptake
The reduced fuel consumption is a promising incentive. Further investigation is needed because several modifications have been applied (net twine, sweeps, doors) that makes suggestions for each modification difficult.

Overall, what impacts do you think have **environmental factors** had on uptake of this gear? .... Has encouraged uptake
The reduced fuel consumption and the reduced gas emissions are promising.

Overall, what impacts do you think have **legal factors** had on uptake of this gear? .... Do not know

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Annex 1: Workshop agenda

Online Workshop, 23-25 August 2023. ***List of participants reported in Annex 5.***

23 August 2023 online meeting starting at 09:00 CEST

09:00 - 10:00 CEST. Plenary session

Introduction by ICES (David Miller, Eirini Glyki)

Update and approval the meeting agenda

Appointment of the WKING2 Chairs

Terms of reference (*section §1.1*)

Present the ***suite of criteria*** *(WKING report) to objectively define 'Innovative gear'*

- *Definition of sea basins*
- *Gear baselines*
- *Conceptualization*

10:00 - 12:30 CEST. Parallel subgroups

Split into two parallel subgroups: social and technology groups

<u>Technology group</u>
Tor (a). Evaluate/endorse the catalogue of gears considered 'innovative'

<u>Social group</u>
Tor (c). Discuss the main drivers that prevented the use of the innovations not implemented (if known)

12:30 - 14:00 CEST. Lunch break

14:00 - 17:00 CEST. Parallel subgroups ***(continue)***

24 August 2023 online meeting starting at 09:00 CEST

09:00 - 12:30 CEST. Plenary session

Meet in plenary to discuss the progress (Social and Technology groups)

Tor (b). Assess the level of uptake of innovations ready for deployment by the EU industry (per sea basin and fishery)

12:30 - 14:00 CEST. Lunch break

14:00 - 17:00 CEST. Parallel subgroups

25 August 2023 online meeting starting at 09:00 CEST

09:00 - 12:30 CEST. Plenary session

Meet in plenary to wrap up the work done and coordinate future report tasks

Only the Core group (Social and Technology chairs and experts by invitation)

12:30 - 14:00 CEST. Lunch break

14:00 - 17:00 CEST. Parallel subgroups

Annex 2: New factsheet template

Technical information			
Title of the Innovative gear / Innovation			
Year		**Source supplier name**	
Region *(click next box for drop-down list)*	Select a Region	**FAO Area** *(Division, L2)*	*See Annex 6*
Gear sub-category *(click next box for drop-down list)*	Select gear sub-category	**Gear code**	*See Annex 7*
Baseline gear	*Define / describe the baseline gear* *(Baseline standards are derived from either existing Regulations or commonly used unregulated)*		
Target species *(click hyperlink)*	Use FAO 3-alpha code	**Bycatch species** *(click hyperlink)*	Use FAO 3-alpha code
Definition of the Innovative gear	*Define/describe the innovative gear / Innovation*		
Technical specificities	*Describe and compare the technical specificities/differences between the baseline gear and the Innovative gear*		
Outcomes expected	*Outline/describe the main outcomes expected and/or tested from the innovative gear*		
Drawing / picture of the Innovative gear	*Expand the row if necessary*		
Other relevant information	*URL / References*		

Performance and technical assessment			
Main criteria *(list the main criteria affected)*	*For example, selectivity, catch, environmental impact*	**Additional criteria** *(additional criteria or benefits from using this gear)*	*For example, reduced GHG emissions, energy savings*
Technological complexity level *(section §3.2)*	Options: Minimal, Medium, or Significant complexity.	**Technology readiness level (TRL)** *(See section §3.2)*	Options for TRL category: High, Medium, or Low. Option for TRL scale: TRL1-TRL9.
Environmental improvement *(section §3.1.5)*	Score the three main Criteria. Options: not applicable, negative, incremental, transformative, disruptive. 1) Selectivity; 2) Catch efficiency; 3) Impact.		
Capital cost category *(section §3.4)*	Options: Low, Moderate, or High.	**Return on Investment** *(section §3.4)*	Options: negative, minor, substantial, or significant.
Is the innovative gear easier to deploy and retrieve compared to the baseline?			Options: no difference, yes easier, no more difficult, unsure, or maybe.
Is the innovative gear easier to maintain and repair compared to the baseline?			Options: no difference, yes easier, no more difficult, unsure, or maybe.
Does using the innovative gear present a lower risk to the health and safety of crew compared to the baseline?			Options: no difference, yes easier, no greater, unsure, or maybe.
Are the financial costs associated with using the innovative gear disproportionately higher than the potential benefits (e.g., economical, operational, environmental) of using it?			Options: yes higher, no lower, unsure, or maybe.

P.E.S.T.E.L. Framework *(section §3.5)*	
Overall, what impacts do you think have **political factors** had on uptake of this gear?	Options: has encouraged uptake, it is a barrier, do not know, not applicable.
Optional: Please provide more details on your above choice	
Overall, what impacts do you think have **economic factors** had on uptake of this gear?	Options: has encouraged uptake, it is a barrier, do not know, not applicable.
Optional: Please provide more details on your above choice	
Overall, what impacts do you think have **social factors** had on uptake of this gear?	Options: has encouraged uptake, it is a barrier, do not know, not applicable.
Optional: Please provide more details on your above choice	
Overall, what impacts do you think have **technological factors** had on uptake of this gear?	Options: has encouraged uptake, it is a barrier, do not know, not applicable.
Optional: Please provide more details on your above choice	
Overall, what impacts do you think have **environmental factors** had on uptake of this gear?	Options: has encouraged uptake, it is a barrier, do not know, not applicable.
Optional: Please provide more details on your above choice	
Overall, what impacts do you think have **legal factors** had on uptake of this gear?	Options: has encouraged uptake, it is a barrier, do not know, not applicable.
Optional: Please provide more details on your above choice	

Annex 3: European sea basins

The sea basins identified in the Regulation (EU) 2019/1241 (2019) when establishing region-specific baselines and innovations (Figure 9):

- North Sea: Area 27.4
- North Western Waters: Area 27.5, 27.6, 27.7
- South Western Waters : Area 27.8, 27.9, 27.10, 34.1.1, 34.1.2, 34.2
- Baltic Sea : Area 27.3
- Mediterranean Sea: Area 37.1, 37.2, 37.3
- Black Sea: Area 37.4

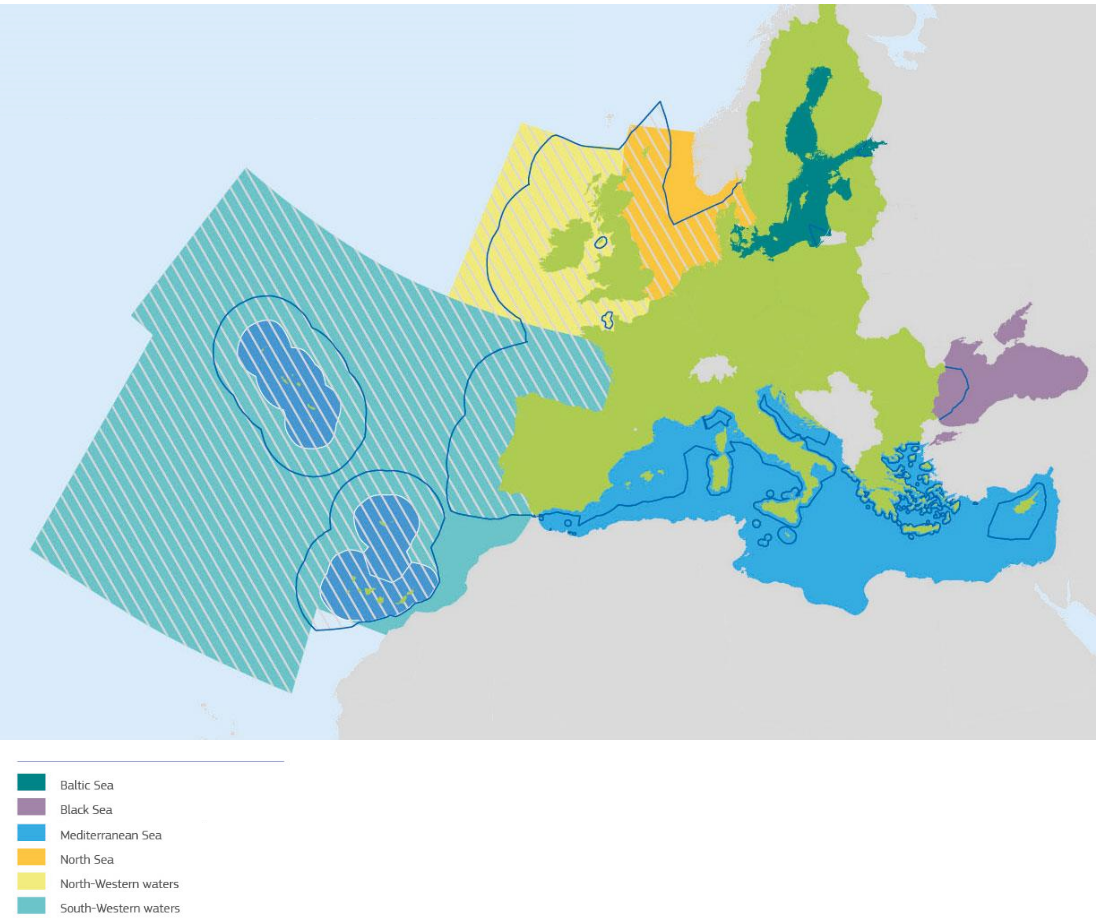

Figure 9. Sea basins identified in the Regulation (EU) 2019/1241 (2019).

Annex 4: Complete PESTEL framework template

		P(olitical)	E(conomic)	S(ocial)	T(echnological)	E(nvironmental)	L(egal)	References	Know-ing	Wanting - Ability	Wanting - Will-ingness	Doing
Policy related aspects	**Regula-tions/Tech-nical measures**	Within what pe-riod could it be made legal to use?	-	Is there oppor-tunity for fish-ers to be in-volved in deci-sion-making?	-	-	Is the adapta-tion currently allowed?	Hamon *et al.* (2017); Steins *et al.* (2022).	-	X	-	X
	Legitimacy of policy de-cisions	Do fishers per-ceive policy deci-sions to be legiti-mate? (e.g., How the exemptions and lack of en-forcement weaken the idea behind the LO). Uncer-tainty due to changing policies.	-	Are fishers less likely to com-ply with a regu-lation that is not perceived as legitimate? LO: lack of common under-standing of the discard issue. Lack of trust between fishers and other stake-holders.		Is there scientific support for envi-ronmental regula-tions?		Hall and Mainprize (2005); Graham *et al.* (2007); Catchpole *et al.* (2008); Eliasen *et al.* (2014); Kraan *et al.* (2015); Penas Lado (2016); Barz *et al.* (2020); Kraan and Verweij (2020); Calderwood *et al.* (2021); Steins *et al.* (2022).	X	-	X	-
	Innovation framework present	Is the innovative process facilitated by governments and policy? Other than providing grants are there supports/struc-tures to encourage fishers to come up with own ideas and learn from each other.	Are fishers compensated for their time, effort and costs as-sociated with engagement?	Do fishers get together to ex-change ideas and learn from each other?	-	-	-	Hamon *et al.* (2017); Steins *et al.* (2022).	X	X	X	X

		P(olitical)	E(conomic)	S(ocial)	T(echnological)	E(nvironmental)	L(egal)	References	Knowing	Wanting - Ability	Wanting - Willingness	Doing
	Level playing field in a multi-level governance setting	Is it worth implementing or changing national policy if it may not align with international policy?		Will a fisher change behaviour if others fishing in the same area or with the same gear do not?	-	-	Is their appropriate enforcement?	Piattoni (2009); Steins *et al.* (2022).	-	-	-	-
	Top–down and 'one size fits all' approaches of policy implementation	Is there limited ability for individual fishers to make adjustments to their own nets that they feel would be beneficial to increase selectivity? This can discourage innovation in the fishing industry. See Technical measures & lack of support for policy.	Can the one size fit all approach integrate the varying economic challenges of the fishers (e.g. level of debts)?	Is it equitable for all fishers to be subject to one size fits all? E.g. regulations that assume boat size is an appropriate proxy for capacity and that discount other important characteristics of fisheries in each region.	Do all fishers have the technological capacity to comply with a one size fits all approach?	-	See Technical measures & lack of support for policy.	Hall and Mainprize (2005); Graham *et al.* (2007); Kraan *et al.* (2015); Penas Lado (2016); Barz *et al.* (2020); Kraan and Verweij (2020); Calderwood *et al.* (2021); Steins *et al.* (2022).	-	X	X	X

		P(olitical)	E(conomic)	S(ocial)	T(echnological)	E(nvironmental)	L(egal)	References	Knowing	Wanting - Ability	Wanting - Willingness	Doing
Social aspects	**Community norms / perceptions (peers and/or others)**	Are fishers discussing regulations, new fishing gears, etc in their fisher association meetings? When is enough enough?	-	How do other fishers perceive the new gear? Are they following what others do? Are fishers meeting community expectations regarding best fishing practice? What is the social status of fishers outside the fishing sector?	-	-	-	Eliasen *et al.* (2014); Hamon *et al.* (2017); ICES (2018c); Steins *et al.* (2022); Jenkins *et al.* (2023).	X	-	X	X
	Behaviour toward risk & change	-	Would financial certainty encourage change and allow for more risk taking? How costly is it to use, maintain and replace if needed?	Is change seen as something positive or are fishers more likely to stick with the status quo? What is the determining factor/s that bring about change by fishers?	How easy is it to use and maintain?	-	-	Eayrs *et al.* (2015); Hamon *et al.* (2017); Eayrs and Pol (2019).	-	-	X	-

		P(olitical)	E(conomic)	S(ocial)	T(echnological)	E(nvironmental)	L(egal)	References	Know-ing	Wanting - Ability	Wanting - Will-ingness	Doing
	Level of trust between par-ties involved	Is there a lack of trust in policy-makers due to previous decision-making or failure to deliver on promises? Can the aspirations of eN-GOs and industry align?	-	Is there mis-trust in people and processes (e.g., mistrust of scientists or management agencies)? Is there mistrust between fish-ers? Are they willing to share information?	-	-	-	Penas Lado (2016); ICES (2018c); Eayrs and Pol (2019); Steins *et al.* (2022).	X	-	X	-
Economic aspects	**Changes in commercial catch**	-	Will adop-tion of new gear result in lower (at least short - term) reve-nue?	Does catch vol-ume influence fishers' status? Are higher catches deemed more important than higher net revenue?	-	Is it possible to maintain catches or revenue and minimize envi-ronmental impact at the same time (win-win)?	-	Hall and Mainprize (2005); Graham *et al.* (2007); Jennings and Revill (2007); Catchpole *et al.* (2008); Steins *et al.* (2022).	-	X	X	-
Economic aspects	**Fuel effi-ciency**	-	How does a gear affect the opera-tional costs related to fuel? Does uncertainty around the volatility of fuel prices mean there is reluctance to change?	-	-	-	-	Haasnoot *et al.* (2016); Hamon *et al.* (2017).	-	X	-	-

		P(olitical)	E(conomic)	S(ocial)	T(echnological)	E(nvironmental)	L(egal)	References	Know-ing	Wanting - Ability	Wanting - Will-ingness	Doing
	Profitability	-	How does the gear perform economically, does it result in changes in revenues and in costs? How does it affect the salary of the crew in a share system?	-	Does adopting a new gear take considerable time to set up and tweak before it is working as well as previous gear used?	-	-	Hamon *et al.* (2017).	-	X	-	-
	Investment costs	Should industry always pay for improvements that reduce environmental impact?	How much does the initial investment cost? Does the fisher have the capital to invest? What is the expected ROI?	Should industry always pay for improvements that reduce environmental impact?	Do fishers always need to invest in the latest developments as the pace of change increases?	-	-	Jennings and Revill (2007); Eayrs and Pol (2019); Steins *et al.* (2022).	-	X	-	-
	Access to funding	Are they grants, loans, or subsidies available? How easy is it to access them?	Are the grants loans, or subsidies easy to access, use and are they timely? Does the fisher have to pay first and get reimbursed later? Will the banks accept to loan the money?	-	-	-	-	Hamon *et al.* (2017).	X	X	-	-

		P(olitical)	E(conomic)	S(ocial)	T(echnological)	E(nvironmental)	L(egal)	References	Knowing	Wanting - Ability	Wanting - Willingness	Doing
	Future perspective	-	What is the economic viability of the fishery/vessel? Can they survive the short-term losses to potentially get the long-term wins? Does the change in catch composition means the fisher has to invest in fishing rights?	What is the future of their company (successor)? Will the catch composition remain the same in future?	-	-	-	Hamon *et al.* (2017).	X	X	X	-
Health & Safety	**Functionality/workability of the gear / net adaptation**	-	Does the new gear reduce compensation claims?	How does the work of the crew change with the new gear? Are there health and safety concerns?	How easy is it to use and maintain?	Does the new gear reduce catches of hazardous animals?	What is risk to scientists or the gear manufacturer if an injury to crew occurs as a result of using the new gear?	Hamon *et al.* (2017).	-	X	X	-

		P(olitical)	E(conomic)	S(ocial)	T(echnological)	E(nvironmental)	L(egal)	References	Know-ing	Wanting - Ability	Wanting - Will-ingness	Doing
Resource access	**Quota (ac-cess)**	Can the fisher have access to the quota that fit your new catch compo-sition?	Can you buy/lease in quota that fit your new catch compo-sition? Is there a choke species risk due to the new catch composition?	Can the fisher have access to the quota that fit your new catch composi-tion (Producer Organization distribution)?	-	-	-	Hamon *et al.* (2017); O'Neill *et al.* (2019); Calderwood *et al.* (2021).	-	X	-	-
	Area access	Are there area ac-cess regulations that require cer-tain gear usage (e.g., MPAs, off-shore renewable energy sites, na-tional waters)?	-	Would fishers shift area of op-erations based on efficiency of fishing gear?	Have you got the suitable technology for the area/envi-ronment you are fishing in?	Is it physically possible to fish with the gear in an area (is it suit-able to use de-pending on sea-bed characteris-tics etc)? What is the impact of any effort shift on the environment?	-	Hamon *et al.* (2017).	-	X	-	-
	Effort re-strictions	Does the gear im-pact upon which fleet segment a vessel is catego-rized as and could this result in less days at sea or greater effort re-strictions?	What is the economic im-pact of such restrictions?	-	-	Would effort re-strictions have positive results on the environment or decrease im-pacts on target fish populations and/or environ-ment?	-	Hamon *et al.* (2017)	-	X	-	-

		P(olitical)	E(conomic)	S(ocial)	T(echnological)	E(nvironmental)	L(egal)	References	Know-ing	Wanting - Ability	Wanting - Will-ingness	Doing
Carrot and stick!	**Incentives**	Is it appropriate to incentives up-take of new gear?	If you use new gear do fishers re-ceive addi-tional bene-fit? Does the market re-ward fishers for using new gear?	Do other fish-ers acknowledge others using the new gear?	-	is special access to select areas an option?	Are there ex-emptions available?	Jennings and Revill (2007); Catchpole *et al*. (2008); Eliasen *et al*. (2014); Penas Lado (2016); ICES (2018c); Eayrs and Pol (2019); Steins *et al*. (2022).	X	X	X	X
	Penalties	Are the rules lead-ing to more selec-tivity enforced? (e.g., Marketing of undersized fish).		Can peer pres-sure or pressure from other stakeholders be leveraged to en-courage uptake of innovative gear? Is there a risk of getting caught for breaking the rules?	-	-	Are the pen-alties en-forced or are there loop-holes?	Hamon *et al*. (2017).	X	-	X	-

		P(olitical)	E(conomic)	S(ocial)	T(echnological)	E(nvironmental)	L(egal)	References	Know-ing	Wanting - Ability	Wanting - Will-ingness	Doing
Collaboration and outreach	**Level of out-reach by sci-entists to in-spire fishers to adopt proven gear**	How does the gear fit in the cur-rent regulation framework?	How does the gear per-form eco-nomically?	How do you communicate results to fish-ers? Is the com-munication ap-propriate and/or effec-tive? Who is the messenger? What was the involvement of fishers in the development? Will scientists or fishers share their knowledge or keep it to them-selves?	-	-	Is the com-municator of the infor-mation liable if an injury to crew occurs as a result of using the new gear?	Hall and Mainprize (2005); Eayrs and Pol (2019).	X	-	-	-
	Levels of meaningful fisher in-volvement in the design, testing and decision-making pro-cess	-	Is there en-gagement with indus-try to ensure economic vi-ability of new gears?	Is there collabo-ration with fish-ing industry in the design, test-ing and result-ant roll out of gears?	Is there collabo-ration with fish-ing industry in the design, test-ing to ensure it is feasible to use on a com-mercial vessel?	-	-	Kennelly and Broadhurst (2002); Hall and Mainprize (2005); Kraan *et al.* (2015); ICES (2018c); Veiga-Malta *et al.* (2019); Calderwood *et al.* (2021).	X	X	X	X

		P(olitical)	E(conomic)	S(ocial)	T(echnological)	E(nvironmental)	L(egal)	References	Know-ing	Wanting - Ability	Wanting - Will-ingness	Doing
	Availability of technical knowledge	-	-	-	Does the fisher know how to use the gear? How to use the gear in prac-tice? IS there adequate tech support (net-makers, gear manufacturers etc) to help the fisher use the gear?	-	Are there copyright or confidential-ity issues?	Steins *et al.* (2022).	X	X	-	-
Sustainability	**Sustainabil-ity**	-	How does it change the access to market?	How does this change the im-age of the fish-ers? Does it in-crease social li-cence to oper-ate?	-	How does this af-fect the environ-ment? (Habitat, Carbon footprint, biodiversity).	-	Hamon *et al.* (2017).	-	X	X	-

Annex 5: List of participants

No.	Surname	Name	Country	Affiliation	E-mail
1	Chopin	Frank	Canada	Independent expert	chopin.frank@gmail.com
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13	Mackenzie	Emma	UK	Marine Scotland Science	emma.mackenzie@gov.scot
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16	Muthupandi	Kalaiarasan	India	TNJFU-Directorate of Incubation and Vocational Training in Fisheries	kalaiarasan@tnfu.ac.in

No.	Surname	Name	Country	Affiliation	E-mail
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20	Ragavan	Velmurugan	India	Fisheries University	rvelmurugan@tnfu.ac.in
21	Roth	Ricardo	Argentina	INIDEP	rroth@inidep.edu.ar
22	Sala	Antonello	Italy	National Research Council (CNR)	antonello.sala@cnr.it
23	Sinclair	Louisa	UK	Marine Scotland Science	louisa.sinclair@gov.scot
24	Steins	Nathalie	The Netherlands	Wageningen Marine Research	nathalie.steins@wur.nl
25	Szynaka	Monika	Portugal	CCMAR	mjszynaka@gmail.com
26	Thangaraji	Ravikumar	India	Fisheries University	ravikumar@tnfu.ac.in
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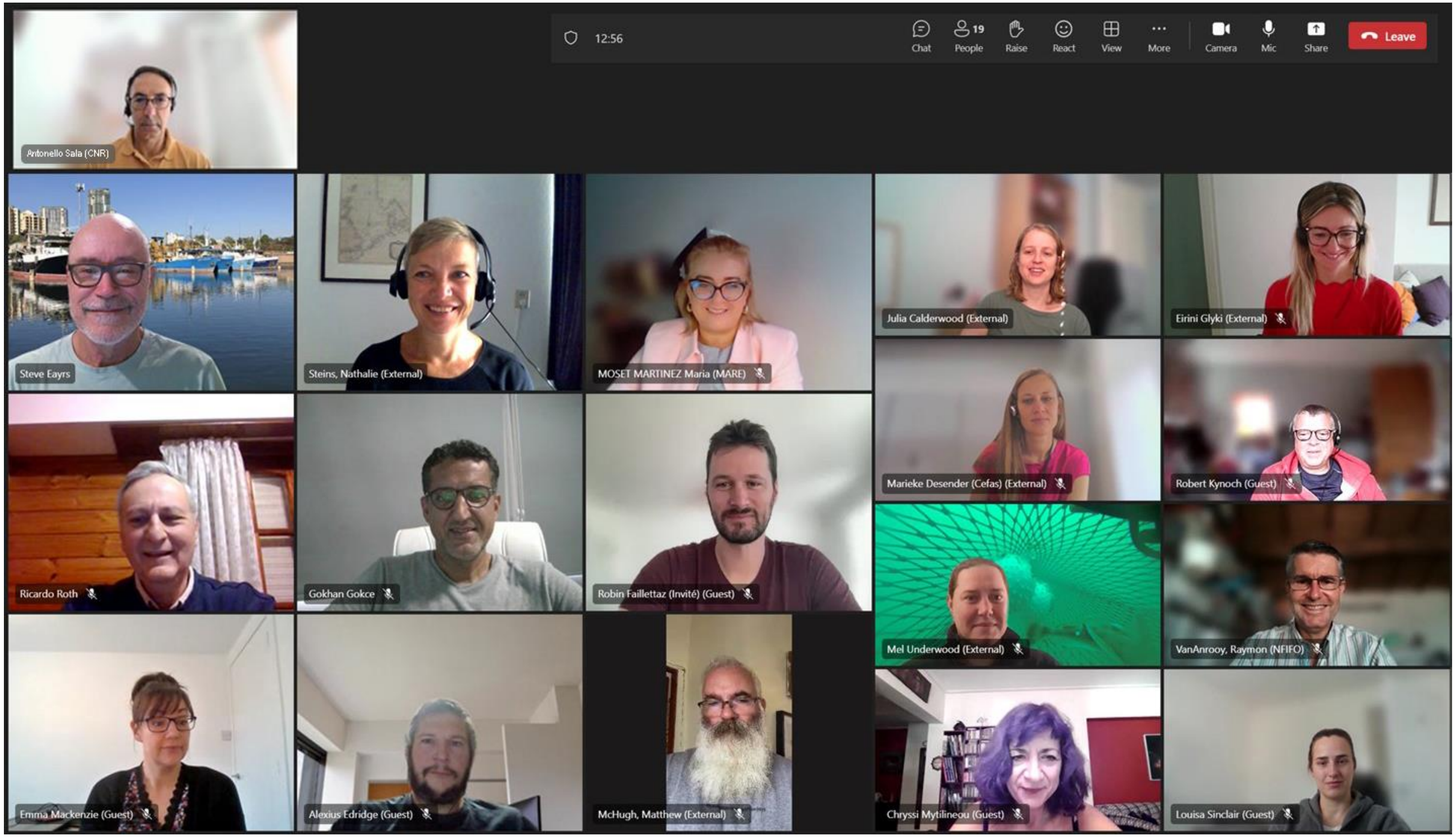
28	van Anrooy	Raymon	Italy	Food and Agriculture Organization of the United Nations (FAO)	raymon.vananrooy@fao.org
29	Vettiyattil	Madhu	India	ICAR - CIFT	madhucift@gmail.com
30	Watson	Dan	UK	SafetyNet Technologies	dan@sntech.co.uk



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Chat
19
People
Raise
React
View
More
Camera
Mic
Share
Leave
Antonello Sala (CNR)
Steve Eayrs
Steins, Nathalie (External)
MOSET MARTINEZ Maria (MARE)
Julia Calderwood (External)
Eirini Glyki (External)
Marieke Desender (Cefas) (External)
Robert Kynoch (Guest)
Ricardo Roth
Gokhan Gokce
Robin Faillettaz (Invité) (Guest)
Mel Underwood (External)
VanAnrooy, Raymon (NFIFO)
Emma Mackenzie (Guest)
Alexius Edridge (Guest)
McHugh, Matthew (External)
Chryssi Mytilineou (Guest)
Louisa Sinclair (Guest)

Annex 6: FAO area codes

Relevant Areas according to the FAO Area classification as provided in the Master Data Register repository. Note that only those areas of interest for the current workshop are included. Areas are specified from Level 1 (L1) to Level 4 (L4).

- North Sea (Annex V): Area 27.4
- North Western Waters (Annex VI): Area 27.5, 27.6, 27.7
- South Western Waters (Annex VII): Area 27.8, 27.9, 27.10, 34.1.1, 34.1.2, 34.2
- Baltic Sea (Annex VIII): Area 27.3
- Mediterranean Sea (Annex IX): Area 37.1, 37.2, 37.3
- Black Sea (Annex X): Area 37.4

Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
27					Atlantic, Northeast
	27.1				Barents Sea (Subarea I)
		27.1.a			Barents Sea - NEAFC Regulatory Area
		27.1.b			Barents Sea - non-NEAFC Regulatory Area
	27.2				Norwegian Sea, Spitsbergen, and Bear Island (Subarea II)
		27.2.a			Norwegian Sea (Division IIa)
			27.2.a.1		Norwegian Sea - NEAFC Regulatory Area
			27.2.a.2		Norwegian Sea - non-NEAFC Regulatory Area
		27.2.b			Spitsbergen and Bear Island (Division IIb)
			27.2.b.1		Spitsbergen and Bear Island - NEAFC Regulatory Area
			27.2.b.2		Spitsbergen and Bear Island - non-NEAFC Regulatory Area
	27.3				Skagerrak, Kattegat, Sound, Belt Sea, and Baltic Sea, the Sound and Belt together also known as the Transition Area (Subarea III)
		27.3.a			Skagerrak and Kattegat (Division IIIa)
			27.3.a.n		Skagerrak
			27.3.a.s		Kattegat

Area	Subarea (L1)	Division (L2)	Subdivision (L3)	Unit (L4)	Description
		27.3.b			Sound and Belt Sea or the Transition Area (Divisions IIIb)
			27.3.b.23		Sound
		27.3.c			Sound and Belt Sea or the Transition Area (Divisions IIIb)
			27.3.c.22		Belt Sea
		27.3.d			Baltic Sea (Division IIId)
			27.3.d.24		Baltic West of Bornholm (Subdivision 24)
			27.3.d.25		Southern Central Baltic – West (Sub-division 25)
			27.3.d.26		Southern Central Baltic - East (Subdi-vision 26)
			27.3.d.27		West of Gotland (Subdivision 27)
			27.3.d.28		East of Gotland or Gulf of Riga (Sub-division 28)
				27.3.d.28.1	Gulf of Riga
				27.3.d.28.2	East of Gotland
			27.3.d.29		Archipelago Sea (Subdivision 29)
			27.3.d.30		Bothnian Sea (Subdivision 30)
			27.3.d.31		Bothnian Bay (Subdivision 31)
			27.3.d.32		Gulf of Finland (Subdivision 32)
	27.4				North Sea (Subarea IV)
		27.4.a			Northern North Sea (Division IVa)
		27.4.b			Central North Sea (Division IVb)
		27.4.c			Southern North Sea (Division IVc)
	27.5				Iceland and Faroes Grounds (Subarea V)
		27.5.a			Iceland Grounds (Division Va)
			27.5.a.1		Northern Reykjanes Ridge
			27.5.a.2		Icelandic Shelf
		27.5.b			Faroes Grounds (Division Vb)
			27.5.b.1		Faroe Plateau (Subdivision Vb1)

Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
				27.5.b.1.a	Faroe Plateau - Part of NEAFC Regulatory Area
				27.5.b.1.b	Faroe Plateau Non-NEAFC Regulatory Area
			27.5.b.2		Faroe Bank (Subdivision Vb2)
	27.6				Rockall, Northwest Coast of Scotland and North Ireland, (the Northwest Coast of Scotland and North Ireland also known as the West of Scotland) (Subarea VI)
		27.6.a			Northwest Coast of Scotland and North Ireland or as the West of Scotland (Division VIa)
		27.6.b			Rockall (Division VIb)
			27.6.b.1		Rockall - Part of NEAFC Regulatory Area
			27.6.b.2		Rockall Non-NEAFC Regulatory Area
	27.7				Irish Sea, West of Ireland, Porcupine Bank, Eastern and Western English Channel, Bristol Channel, Celtic Sea North and South, and Southwest of Ireland - East and West (Subarea VII)
		27.7.a			Irish Sea (Division VIIa)
		27.7.b			West of Ireland (Division VIIb)
		27.7.c			Porcupine Bank (Division VIIc)
			27.7.c.1		Porcupine Bank - Part of NEAFC Regulatory Area
			27.7.c.2		Porcupine Bank - Non-NEAFC Regulatory Area
		27.7.d			Eastern English Channel (Division VIId)
		27.7.e			Western English Channel (Division VIIe)
		27.7.f			Bristol Channel (Division VIIf)
		27.7.g			Celtic Sea North (Division VIIg)
		27.7.h			Celtic Sea South (Division VIIh)
		27.7.j			Southwest of Ireland / East (Division VIIj)

Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
			27.7.j.1		Southwest of Ireland - East - Part of NEAFC Regulatory Area
			27.7.j.2		Southwest of Ireland - East - Non-NEAFC Regulatory Area
		27.7.k			Southwest of Ireland - West (Division VIIk)
			27.7.k.1		Southwest of Ireland - West - Part of NEAFC Regulatory Area
			27.7.k.2		Southwest of Ireland - West - Non-NEAFC Regulatory Area
	27.8				Bay of Biscay (Subarea VIII)
		27.8.a			Bay of Biscay / North (Division VIIIa)
		27.8.b			Bay of Biscay / Central (Division VIIIb)
		27.8.c			Bay of Biscay / South (Division VIIIc)
		27.8.d			Bay of Biscay / Offshore (Division VIIId)
			27.8.d.1		Bay of Biscay - Offshore - Parts in NEAFC Regulatory Area
			27.8.d.2		Bay of Biscay - Offshore - Non-NEAFC Regulatory Area
		27.8.e			West of Bay of Biscay (Division VIIIe)
			27.8.e.1		West of Bay of Biscay - Parts in NEAFC Regulatory Area
			27.8.e.2		West of Bay of Biscay - Non-NEAFC Regulatory Area
	27.9				Portuguese Waters (Subarea IX)
		27.9.a			Portuguese Waters / East (Division IXa)
		27.9.b			Portuguese Waters / West (Division IXb)
			27.9.b.1		Portuguese Waters - West Parts in NEAFC Regulatory Area
			27.9.b.2		Portuguese Waters - West Non-NEAFC Regulatory Area
	27.10				Azores Grounds (Subarea X)
		27.10.a			Azores Grounds (Division Xa)

Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
			27.10.a.1		Azores Grounds - Parts in NEAFC Regulatory Area
			27.10.a.2		Azores Grounds - Non-NEAFC Regulatory Area
		27.10.b			Northeast Atlantic South (Division Xb)
	27.12				North of Azores (Subarea XII)
		27.12.a			Southern mid-Atlantic Ridge (Southern Reykjanes Ridge south to Charlie-Gibbs Fracture Zone) (Division XIIa)
			27.12.a.1		Subdivision XIIa1 - NEAFC Regulatory Area
			27.12.a.2		Subdivision XIIa2 - NEAFC Regulatory Area
			27.12.a.3		Subdivision XIIa3 - Non-NEAFC Regulatory Area
			27.12.a.4		Subdivision XIIa4 - Non-NEAFC Regulatory Area
		27.12.b			Western Hatton Bank (Division XIIb)
		27.12.c			Central Northeast Atlantic - South (Division XIIc)
	27.14				East Greenland (Subarea XIV)
		27.14.a			Northeast Greenland (Division XIVa)
		27.14.b			Southeast Greenland (Division XIVb)
			27.14.b.1		Southeast Greenland - Parts of NEAFC Regulatory Area (Division XIVb1)
			27.14.b.2		Southeast Greenland - Non-NEAFC Regulatory Area (Division XIVb1)
34					Atlantic, Eastern Central
	34.1				Northern Coastal
		34.1.1			Morocco Coastal
			34.1.1.1		El Jadida
			34.1.1.2		Morocco Coastal
			34.1.1.3		Cabo Bojador
		34.1.2			Canaries/Madeira Insular

Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
		34.1.3			Sahara Coastal
			34.1.3.1		Cape Barbas
			34.1.3.2		Cape Timiris
	34.2				Northern Oceanic
	34.3				Southern Coastal
		34.3.1			Cape Verde Coastal
			34.3.1.1		Senegal River (estuary)
			34.3.1.2		Cape Roxo
			34.3.1.3		Subdivision 34.3.1.3
		34.3.2			Cape Verde Insular
		34.3.3			Sherbro
		34.3.4			Western Gulf of Guinea
		34.3.5			Central Gulf of Guinea
		34.3.6			Southern Gulf of Guinea
	34.4				Southern Oceanic
		34.4.1			Southwest Gulf of Guinea
		34.4.2			Southwest Oceanic
37					Mediterranean and Black Sea
	37.1				Western Mediterranean
		37.1.1			Balearic
		37.1.2			Gulf of Lions
		37.1.3			Sardinia
	37.2				Central Mediterranean
		37.2.1			Adriatic
		37.2.2			Ionian
	37.3				Eastern Mediterranean
		37.3.1			Aegean
		37.3.2			Levant
	37.4				Black Sea

Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
		37.4.1			Marmara Sea
		37.4.2			Black Sea
		37.4.3			Azov Sea

Annex 7: Fishing gear classification

Master Data Register (MDR) contains data structures and lists of fisheries codes to be used in electronic information recording and exchanges among Member States and for Member States' communications with Norway with the purpose to record and report fishing activities. The MDR website with data structure and all code lists are publicly accessible at the following link: https://ec.europa.eu/fisheries/cfp/control/codes/.

The current fishing gear classification system is based on the FAO International Standard Statistical Classification of Fishing Gear (ISSCFG) (Nédelec and Prado, 1990; FAO, 2010; 2016). The ISSCFG classification has been readapted to respect the logics and formalisms of database structures. The three levels of classifications, Type, Sub-type, and Gear; are conceived to respect the FAO ISSCFG criteria.

Table 7 is designed to improve the compilation and collection of harmonized information, as well as to provide data correspondence with the FAO ISSCFG.

Table 7. Gear classification system used in the current WKING2 information collection. The classification is based on the FAO International Standard Statistical Classification of Fishing Gear (ISSCFG) and the classification in the Master Data Register repository.

Type	Sub-type	Gear	Description
P			**Surrounding nets**
	PS		**Purse seines**
		PS1	One boat operated purse seines
		PS2	Two boats operated purse seines
	LA		**Surrounding nets without purse lines**
		LA1	Surrounding nets without purse lines *(Lampara)*
S			**Seine nets**
	SB		**Beach seines**
		SB1	Beach seines operated from the shore
	SV		**Boat seines**
		SDN	Danish seines
		SSC	Scottish seines
		SPR	Pair seines
T			**Trawls**
	BT		**Beam trawls**
		TBB	Beam trawls *(Tickler chain and Chain matrix beam trawls)*
		PUK	Electric beam trawls *(Pulse Beam)*
		PUL	Electric sumwing trawls *(Pulse Wing)*
	TB		**Bottom trawls**
		OTB	Single boat bottom otter trawls
		OTT	Twin bottom otter trawls
		OTP	Multiple bottom otter trawls
		TBN	Nephrops bottom otter trawls
		TBS	Shrimp bottom otter trawls
		PTB	Bottom pair trawls
	TM		**Midwater trawls**
		OTM	Single boat midwater otter trawls

Type	Sub-type	Gear	Description
		TMS	Midwater shrimp trawls
		TSP	Semi-pelagic trawls
		PTM	Midwater pair trawls
D		**Dredges**	
	DR		**Towed dredges**
		DRB	Boat dredges
		DRH	Hand dredges
		DRM	Mechanised dredges *(Hydraulic jet dredges)*
L		**Lift nets**	
	LN		**Lift nets**
		LNP	Portable lift nets
		LNB	Boat-operated lift nets
		LNS	Shore-operated stationary lift nets
F		**Falling gears**	
	FG		**Falling gears**
		FCN	Cast nets
		FCO	Cover pots / lantern nets
G		**Gillnets and entangling nets**	
	GN		**Gillnets**
		GNS	Set gillnets (anchored)
		GND	Drift gillnets *(driftnets)*
		GNC	Encircling gillnets
		GNF	Fixed gillnets (on stakes)
	GT		**Entangling nets**
		GTR	Trammel nets
	GC		**Combined nets**
		GTN	Combined gillnets-trammel nets
R		**Traps**	
	FT		**Large stationary nets or barrages**
		FPN	Stationary uncovered pound nets
		FWR	Barriers, fences, weirs, etc.
		FAR	Aerial traps
		FYK	Fyke nets
		FSN	Stow nets
O		**Pots**	
	FP		**Pots**
		FPO	Pots *(single or in strings)*
H		**Hooks and lines**	
	LH		**Pole and lines**
		LHP	Handlines and hand-operated pole-and-lines
		LHM	Mechanized lines and pole-and-lines
		LTL	Trolling lines
	LL		**Longlines**
		LLS	Set longlines
		LLD	Drifting longlines
	LV		**Vertical lines**

Type	Sub-type	Gear	Description
		LVT	Vertical lines
M			**Miscellaneous gears**
	MH		**Hand operated gears**
		HAR	Harpoons
		MHI	Hand implements *(Wrenching gear, Clamps, Tongs, Rakes, Spears)*
		MPN	Pushnets
		MSP	Scoopnets
		MDV	Diving
		MDR	Drive-in nets
	MM		**Mechanized gears**
		MPM	Pumps
		MEL	Electric fishing
		HMX	Harvesting machines
	RG		**Recreational fishing gears**
		RG1	Recreational fishing gears
N			**Gears unknown or not specified**
	NK		**Gears unknown or not specified**
		NKK	Gears unknown
		NKS	Gears not specified