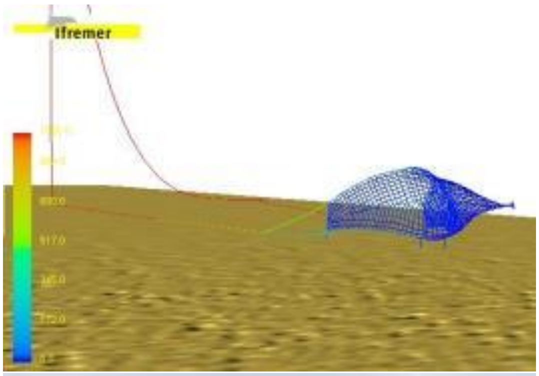
SEPTEMBER 2014

LOT 1:

REDUCTION OF GEAR IMPACT AND

DISCARDS IN DEEP SEA FISHERIES

FINAL REPORT



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EXECUTIVE SUMMARY

OBJECTIVES OF THE STUDY

This report presents the results of laboratory developments, field experiments and data analyses carried out in the contract MARE/2011/07 - "Studies on the Common Fisheries Policy" - Lot 1 "Reduction of gear impact and discards in deep sea fisheries". The contractual objectives were *"(I) to identify and study trawl modification and alternative gear that aim at reducing the impact of the gear on the sea bottom when engaged in deep-sea fisheries, and (II) to identify and study a measure for discard reduction in deep-sea fisheries or fisheries having deep-sea species as a by-catch, pursued with trawls or nets. The measure could consist in gear modifications or catch purification based on the skipper's strategy to avoid unwanted fish*."

METHOD

Objective I

For the first objective, a new light trawl was developed to make it possible to tow a deep-water fishing trawl either off the seafloor or on the seafloor but with minimised contact forces between the gear and the seafloor. Two versions of the trawl were tested by numerical simulations and flume tank experiments: the first, called off-bottom trawl was designed to be a trawl with a positive buoyancy and the second, called light trawl was a trawl lighter than the standard trawl currently in use in the fishery with a lighter groundrope so as to reduce the pressure force on the seafloor. The light trawl was tested with and without tickler chain.

The simulations were used to evaluate the effects of the difference in bridle length and of the swell on the geometry and distance of the trawl from the bottom, the sinking time of the off-bottom trawl as well as the force exerted on the bottom by the light trawl and the effect of the warp length to depth ratio on this force.

A model at the scale 1/40 was made for flume tank experiments. Full details of the scale model are provided in the report. The flume tank experiments were designed to validate the effect of the bridle length difference and towing speed on the trawl geometry and distance off bottom. Once numerical and flume tanks trials were conclusive, the light trawl was tested at sea during two experimental fishing trips operated between September and December in a way similar to standard commercial trip and on the 46-m trawler *Mariette Le Roch II.* This vessel is engaged year round in deep-sea fishing activities defined according to the criteria of the Council Regulation (EC) No 2347/2002 of 16 December 2002 "establishing specific access requirements and associated conditions applicable to fishing for deep-sea stocks".

With respect to objective one (trawl modification), the first experimental trip aimed at testing the light trawl in real conditions and to collect a first set of catch data, in order to compare landings obtained from these new trawls to those from the standard trawl used by the fishery. The distance from the groundrope to the seafloor was measured using a headrope Scanmar sensor (clearance value) and a dedicated sensor based on an angle-meter attached to the trawl (contact sensor). Three riggings were tested: light trawl with or without tickler chain and standard trawl for reference.

The second sea trip aimed at collecting catch data with the optimum gear riggings defined from the first trip. The light trawl with light groundrope and tickler chain, the light trawl without tickler chain towed on the bottom and the light trawl rigged as an off-bottom trawl were used and compared to the standard trawl. The only sensors used during this trial were those from the onboard Scanmar equipment. Those sensors allowed measuring the geometry of the trawls and the distance between the groundrope and the seabed when operating the trawl rigged as an off-bottom trawl.

Details of haul carried out during each trip with the different riggings (i.e. 3 experimental and 1 standard bottom trawl) targeting deep-water species are presented in Table 1 (below). The number of hauls dedicated to deep-water species was limited by the necessity for the fishing vessel to target shallow-water species in each trip.

Catch data were collected according to the protocol for on-board observation of French fisheries, which is used to carry out the sampling required by the Data Collection Framework (DCF)[1]. The landings from the first experimental trip were analysed, and for the second trip, both the landings and discards were analysed. Discards data for the first trip were not used because the trip aimed with priority at testing the fishing gear. Therefore, limited numbers of hauls were made at various depths with different gears and riggings.

First, the catch data collected with the standard trawl during the project were compared to catches observed under similar commercial conditions (*i.e.* same type of vessel, area and season) during on-board observations carried out under the DCF in order to check the consistency of the data collected during the project with average catches of the same fleet.

Then, catches obtained with the standard and light trawls were compared using Mann-Whitney non-parametric statistical test. Observations in both fishing trips were further used to appraise the effect of the light trawl on the working time and fuel efficiency.

Table 1: Catch summary of the hauls carried out during the two deep sea trips. * indicates statistically significant difference with the standard trawl gear (Mann-Whitney test). N/A = not available.

Gear		1st *trip* *setting the experimental gears*	2nd *trip* *collecting catch data*
Standard ground gear trawl	Number of hauls	4	7
	Mean landings (kg/h)	553	496
	Mean discards (kg/h)	N/A	134
Light ground gear trawl with tickler chain	Number of hauls	1	7
	Mean landings (kg/h)	631	589
	Mean discards (kg/h)	N/A	191
Light ground gear trawl without tickler chain	Number of hauls	4	0
	Mean landings (kg/h)	453	Not tested
	Mean discards (kg/h)	N/A	Not tested
Light pelagic	Number of	1	6

[1] French (national) catch observation program on board of commercial vessels. http://archimer.ifremer.fr/doc/00018/12895/9855.pdf

Gear		1st *trip* *setting the experimental gears*	2nd *trip* *collecting catch data*
trawl (off bottom)	hauls		
	Mean landings (kg/h)	28*	23*
	Mean discards (kg/h)	N/A	11*

Objective II

The second objective was studied based on data and knowledge from the French deep-water trawl fishery to the West of Scotland. In this fishery, the two main bycatch species discarded in weight (56 % of total) are smoothheads (Alepocephalids) and greater silver smelt (*Argentina silus*). In decreasing order, the following three species are common rabbitfish, birdbeak dogfish and juvenile roundnose grenadier. However, the bycatch of deep-water sharks, which have a lesser contribution to the discards in number and weight, is considered a more serious problem in deep-water fisheries because deep-water sharks can only sustain a lower fishing mortality than teleost species (Dransfeld et *al*., 2013). Smoothheads are large-bodied species and their size is similar to that of blue ling, roundnose grenadier and black scabbarfish. Although significant, the bycatch of greater silver smelt is small with respect to the commercial catch of this species, mostly used for fish processing. Most deep-water shark species also have similar sizes to that of commercial species. The largest species, like the Portuguese dogfish (*Centroscymnus coelolepis*), the leafscale gulper shark (*Centrophorus squamosus*) and the less abundant kitefin shark (*Dalatias licha*) are slightly larger. As a consequence, little can be achieved in terms of bycatch reduction by regulating the mesh size. The similar size of the target species and the unwanted bycatch also makes it unlikely that any sorting device such as grids or panels would allow reducing the bycatch without a severe loss of commercial catch. However, it cannot be ruled out that the different behaviour in terms of swimming activity and position in the waters column of sharks and other species (Lorance and Trenkel, 2006) could be used to reduce the bycatch of sharks. This approach would require costly behavioural studies of deep-water fish swimming before trawls.

As a consequence, it was considered that objective II could hardly be addressed by developing a technical solution, e.g. a sorting device, and the approach taken for objective II was to analyse available knowledge and data, mostly on-board observations of the French deep-water trawler fleet. Additionally a questionnaire and a plan for skippers' interviews were developed.

Several analyses of on-board observations carried out in application of the regulation 2347/2002 and of the data collection framework (DCF) are presented in the report. A novel spatial method fully based on data, termed nested grid method, appeared to be very relevant to evaluate the spatial distribution of bycatch and investigate management options to reduce them. In this spatial method, cells of variable size are designed to obtain more spatial resolution where more data are available. The discarded proportions are estimated in spatial cells that are small (high resolution) in areas where data are numerous and large (low spatial resolution) where data are scarce. As a result, where data are abundant the method provides estimates in small cell that tend to be homogeneous habitats while large cells might encompass varied habitats. This approach allowed the identification of areas with lower and higher discards. The value in one particular cell should not be over-interpreted as it could be an extreme value obtained by averaging over a small number of hauls, instead it is more appropriate to consider spatial patterns that spread over several cells. This method was applied to the discarded proportion of the total catch, of (undersized) commercial species, of elasmobranch (two categories) and those of the main species found in the discards (greater silver smelt, alepocephalids and roundnose grenadier). All other species are discarded in too small amounts to apply this spatial approach, but they were accounted for in the estimate of the spatial distribution of the total discards.

We also present additional investigations mostly based on raw data plots including (i) the spatial distribution of the discards of a few species caught occasionally by the French deep-water trawl fishery and (ii) the depth and spatial distribution of the discards of six deep-water shark species as well as the blue skate (*Dipturus batis)* complex, using all French on-board observations, *i.e.* deep-water and other fisheries, from 2009 to 2012. The blue skate was included in the latter approach because it was recently identified as consisting of a mixture of two species (Iglesias, 2010). Although these species are considered demersal they are caught down to depths of 1000 m or more and they can only sustain a low fishing mortality, owing to their life history traits; consequently they would be eligible to the FAO definition of deep-sea species (FAO, 2009). The deep-water sharks were studied to investigate which are discarded by deep-water fisheries only[2] and which are also discarded by other fisheries. No other species were investigated: while discards of certain deep-water species from shelf fisheries may be significant for the population of those species, these may represent too small a proportion of the total catch for analysing their distribution.

KEY FINDINGS

Objective I

Current impact on the seafloor

An overall appraisal of the current impact of the French deep-water trawl fishery to the West of Scotland was obtained by overlaying the spatial distribution of seabed types from EmodNet and that of fishing hauls of vessels of the Scapêche fishing company observed in the French on-board observation sampling carried out in application of the DCF and regulation 2347/2002 from 2010 to 2013. The results show that these vessels operate mostly on sandy and muddy sediments and to a lesser extent on coarse sediment. A small proportion of harder substrate occurs in the fished area.

Numerical simulations of off-bottom and light trawls

The light trawl we developed and the standard trawl have identical netting and the main modification applied to the groundrope. For the purpose of experimental trips it was necessary to use a rockhopper as groundrope because of the risk of damage to the net, in particular during the testing phase. The simulated weight in the water of the groundrope for the off-bottom trawl was 1/4 of that of the standard groundrope, which is achievable using existing material. Owing to this light footrope, the complete off-bottom trawl would float in water. Thus whatever the towing speed the trawl would be towed off the bottom. The sinking to the bottom is achieved by the weight of trawl doors. From numerical simulations the shooting time was estimated to be increased by 10% with respect to the standard trawl. Simulations suggested that it was possible to control the height of the off-bottom trawl above the bottom by changing the respective length of the lower and upper bridles.

The effect of the swell was studied by simulating the vessel's motion transmitted to the warp by pure sinusoid motion of 5 and 10 m amplitude and 10 second period. Only extreme swells (10 m amplitude) occasionally drove the trawl to hit the seafloor.

[2] Deep-water fisheries are defined and regulated under Council's regulation 2347/2002.

The light trawl was studied as a trawl with reduced impact on the seafloor, in case the off-bottom trawl, i.e. a trawl that does not touch the seafloor, would not catch fish. An intermediate light footrope was developed for the light trawl. This light footrope remained in permanent contact with the seabed but with minimised pressure force. Similarly to the off-bottom trawl, this pressure force is adjustable by changing the respective bridle lengths. Depending on the latter, the pressure force varies from about half that of the groundrope of the standard trawl to 0. In other words this light trawl can also be operated off-bottom.

With both the gears studied (off-bottom and light trawl), about 70% of the total length of the sweeps were in contact with the bottom.

Flume tank experiments

The main results from the numerical simulations were reproduced in the flume tank and were in agreement with the numerical simulations in terms of trawl geometry and footrope height over the bottom. The effect of adjusting bridles length on the trawl height over the bottom in the flume tank was similar to the simulated effect.

Experimental trips

The footrope modelled for the off-bottom trawl in simulations and flume tank appeared to be too weak and needed to be strengthened, thereby increasing its weight. The resulting footrope of the light trawl used in experimental trips had a weight in water of 5 kg/m (about 400 kg for the whole 81-m footrope) compared to 10 kg/m (810 kg overall) for the standard gear. This light trawl could however be rigged to be towed off-bottom but it could not be stabilised at a constant enough distance from the seafloor. Nevertheless, a sufficient number of hauls off-bottom were towed in both trips combined to conclude that towing a trawl a few metres above the bottom does not allow catching deep-water fish in commercial quantities, at least in the area (West of Scotland) and season (autumn) of the experimental trips. Landings per hour from haul with the trawl off bottom where lesser than 50 kg for all hauls compared to 400 to 800 kg/hour with the standard trawl or light trawl towed on the seafloor.

The catch (landings and discards, all species together) from hauls targeting deep-water species with the standard trawl were not significantly different from the average catches estimated from the French on-board observations program for the deep-water fishing fleet. Further, the catch from the light trawl towed on the seafloor and the standard trawl did not differ significantly. The light trawl exerts a reduced pressure force on the seafloor, owing to its smaller weight in water (half that of the standard trawl), without any reduction in commercial catch nor effect on fishing costs (including working time and fuel consumption). Further, the cost of the light and standard trawls were also estimated to be similar. However, the wear of the light footrope over time is unknown. This lighter device could be more fragile and require more frequent replacement so higher costs.

We compared the economic results of the experimental trip with the light gear to that of four fishing trips observed in the French on-board observation scheme and carried out in the same area and season as the experimental trips. The landed value of a standard sea trip where saithe, hake and deep-water species are each targeted with 10 hauls (30 hauls altogether during the trip) showed no significant difference in the gross sale between the standard or light trawl.

Objective II

Interviews of skippers

Although only four interviews were carried out, they showed that skippers use their knowledge of fishing grounds to avoid locations where high levels of unwanted catch are likely to occur. This avoidance strategy is totally empirical and consists in avoiding locations where high discards were experienced previously. Interviews did not provide options for some other reduction strategies beyond current practices.

Discards of blue skate and deep-water sharks in all fisheries

In French fisheries, catches of the blue skate complex (comprising two species) are fully discarded since 2009 because it is prohibited to retain those two species on board under EU regulations. The bulk of the catch occurs on the Celtic sea shelf in depths shallower than 200 m. For three of the six deep-water sharks species (leafscale gulper shark, Portuguese dogfish and longnose velvet dogfish), the spatial distribution of catches represented well that of the French deep-water trawl fishery, showing that those species are not caught in other fisheries. The situation was different for the birdbeak dogfish, because bycatch also occurs further south down to the Bay of Biscay, where deep-water species are not targeted. Therefore, bycatch of birdbeak dogfish occurs in both deep-water and demersal fisheries. Bycatch of Greenland shark and black dogfish are confined to the northernmost areas visited by French vessels, owing to the boreal distribution of these species. Unlike that of black dogfish (a typical deep-water shark mainly caught between 900 m and 1,000 m), the bycatch of Greenland shark occurs mainly in 600-800 m, that is, both in deep-water and demersal species targeted fisheries. This study suggests that bycatch and discards of some deep-water species occur in both deep-water and other fisheries. Therefore, discards management should apply to all fisheries catching those species.

Other discards: results of the nested grid analysis

Spatial patterns in the discard proportion per grid cell were identified and suggest that higher by-catch proportions occur on relatively flat bottoms at depths of 1,000 to 1,500 m to the North of the Rockall Trough. This applies to total discards, discards of commercial species, to some extend those of elasmobranchs as well as those of Alepocephalids and small roundnose grenadiers. The consistency of the higher proportion of discards of different species is a quite striking result, which was not anticipated from published studies of the geographic distribution of fish species and community in that area. In recent years, less on-board observations were collected in this area, reflecting less fishing pressure, provided that the sampling plan is randomised. We hypothesise that the fleet might have reduced its activity in areas where discards were higher. The potential reasons for this were not investigated but it was noted that substantial reductions in quotas and effort where achieved in most European deep-water fisheries including in the French fishery. Whether vessels avoided areas of higher discards or whether other reasons led to this consequence remains unknown. The area where higher proportion of discards was located to the North of the Rockall Trough between about 58° 40' and 60° North; closing it to fishing would allow the reduction of overall discards and prevent any future increase of effort in this area. The economic effect of such a closure on the French deep-water fishery in future years would presumably be limited or difficult to observe, because at the same time the abundance of the target species (at least that of blue ling and black scabbardfish) is increasing. Other bottom fisheries do not operate in this area to any significant level, so that no known other fishery would be impacted.

RECOMMENDATIONS

Regarding fishing gear modifications to reduce the impact on the seabed, the light footrope needs being installed on one vessel for regular use before generalising it. The objective of this test on one vessel would be (i) to verify on a larger number of hauls and in all seasons that the commercial catches of the light trawl are not significantly smaller than that of the standard trawl and (ii) to test its wear in the long term. Further, additional work to design and test an off-bottom trawl gear could be considered. This would include designing a trawl lighter than the one tested in the experimental trips, with a footrope closer to the one modelled in the numerical simulation and flume tank experiments, i.e. up to half the weight of that used during experimental trips. This trawl would need to be further tested aboard a small vessel, e.g. a 16-18m trawler before building a larger one for a trawler engaged in the deep-water fishery. Test designs could include sweeping chains to adjust the distance between the fishing line and the seabed with no ground gear. The cost of such a project would be in the same order of magnitude as the present project.

A more advanced option would be to develop a truly off-bottom trawl, *i.e.* really without seabed contact. Ongoing controllable doors developments (Poseidon Remote Controllable for instance) could allow an accurate control of the position of the trawl above the seabed. However, such approaches are only at an early stage and their application to fisheries operating in deeper waters may not be possible soon. This development would require chartering a fishing vessel. The cost of such a project would be much higher and is difficult to estimate before controllable doors are fully developed. As the present project showed that the catch of a trawl towed 6 to 10 metres above the sea bottom is very low, the development of an off-bottom trawl would also require testing whether trawling less than 1 m above the bottom is technically achievable and produces commercial catch comparable to those of a bottom trawl.

The spatial analysis carried out in the project allowed delineating an area where levels of discards are significantly higher. The closure of such an area would therefore reduce the overall level of discards, however keeping in mind that the fleet tends to fish less in this particular area. Developing further this analysis by investigating seasonal effects may be useful and can be done in the next few years owing to the accumulation of data collected under the DCF. A similar approach could be developed for other deep-water fisheries operating in other areas and the approach is probably relevant in the wider context of reducing discards in all fisheries. The on-board observers data collected in EU Member States in recent years could be used to investigate the possible existence of areas of higher discard rate as in the present study.

TABLE OF CONTENTS (INCLUDING TABLES OF FIGURES, TABLES)

TABLE OF FIGURES

TABLE OF TABLES

ACKNOWLEDGMENTS

The authors acknowledge the crew and the captain of the fishing vessel for their collaboration and the Directorate for Sea Fisheries and Aquaculture (French acronym DPMA) for the use of the *Obsmer* data.

I GLOBAL METHODOLOGY

I.1 OBJECTIVES OF THE PROGRAMME

The consortium understands the requirements of the tender, its background and context and with this tender proposes the methodology and the work plan that we believe fully answer all the questions and tasks requested in the ToR (Terms of Reference).

The overall purpose of Lot 1 is to contribute to a more sustainable exploitation of deep-sea resources while reducing the negative impacts on the ecosystem. It includes two tasks:

> **Task 1:** The reduction of the impact of the gears on the sea bottom by studying and testing trawl modification and alternative gear configurations;;
>
> **Task 2:** The reduction of discards in deep-sea fisheries or deep-sea species as by-catch (with trawls or nets) by studying and testing gear modifications and identifying skipper's strategy to avoid unwanted fish.

Different approaches or combined approaches are possible to reduce or eliminate physical gear impact on the seabed: gear adaptations, gear restriction, depth restriction, area closure, multi zone approach, for instance light, medium, and heavily fished areas experimented in New Zealand, (Penney et al. 2009).

In the case of gear modification, ongoing MultiSEPT SINTEF project "Development of multirig semi-pelagic trawling" (from beginning of 2012 to end of 2014) proposes to combine pelagic and bottom trawling. They propose to catch fish and shrimps that are very close to or at the bottom, and potentially to avoid physical bottom contact. Thus the project aims at developing a multirig semi-pelagic trawling technology to be used for a sustainable exploitation of deepwater resources such as Northern shrimp in which trawl doors, central clump(s) and sweeps have no physical contact with the seabed. However, in order to ensure a sufficient control of these components, particularly for deep fishing where the inertia of the whole trawl gear including warps makes it difficult to adjust the door depth in real time, it is needed to develop trawl gear control concepts, and also solutions for herding the target species into the path of the trawl in order to compensate for the loss of herding effect when the doors and sweeps are lifted off the bottom. These options are totally out of the scope of the current project regarding time and funding dedicated to the technological part of the project.

The "Active Trawl" system was designed to have a "bottom-contour" mode in which the doors maintain light contact with the bottom or operate at a set height above the seabed. This kind of system is still under development in research projects (ex. CRISP projects, MultiSEPT).

In such "semi pelagic" approach, it is needed to add extra weight at the lower trawl wings end to ensure a good seabed contact of the footrope and stability. The impact due to this additional weight is probably not negligible and comparable to the impact due to correctly rigged and adjusted bottom doors.

When coming to the trawl, number of mitigation measures have been tested: benthos release panel, reducing the weight of foot gear, reducing the bottom impact using sweepless trawl, eventually with drop chains for herding, reduction of the number of foot rope bobbins, replacing tickler chains with brushes, replacing rockhopper footrope with wheels or rolling gears, or with sheering plates gear. Parafoils or kites were tested to replace standard doors but were mainly tested in flume tank.

In DEGREE project, doors were optimized to reduce their action on the seabed (weight reduction and hydrodynamic optimization to reduce drag, increase lift and consequently reduce seize and weight). Low contact door were developed and are still in development (so-celled "Jumper" doors).

I.2 TASK 1: REDUCTION OF THE IMPACT ON THE SEA BOTTOM

I.2.1 State of the art

The Project DEGREE of the European Union (EU), which involved most of the European fishing technology teams in 2005, identified existing research results aiming to mitigate otter trawl seabed impact. These modifications include reducing the weight of the footrope, reducing bottom contact (e.g. semi-pelagic trawling), using sweepless trawls with drop chains and no or limited footrope and more novel approaches such as the use of kites, depressors or other flexible devices and “Active” or “Auto” trawl systems. Concerning light gear, results were positive in terms of trawl geometry and stability, however, reduced catch rates and gear damage were experienced.

Modified semi-pelagic trawl was developed for species such as shrimps, nephrops and fish species such as monkfish which are not herded by bridle/doors sand clouds. Different experiments were undertaken. Door height control was achieved through the shortening of warps and monitored through the use of door height monitoring devices. Results from the trials showed potential for semi-pelagic trawling for shrimps, although it was concluded that further work was required to design a more robust system to better control the doors.

The raised footrope trawl was developed for the Gulf of Maine silver hake *Merluccius bilinearis* fishery to avoid catching flatfish and other bottom-dwelling organisms by raising the height of the fishing line 0.5m above the seabed (Pol, 2003). The fishing line was raised by the attachment of a sweep chain to the fishing line by a number of drop chains. The raised footrope trawl has been very successful and has become mandatory in the fishery. The sweepless trawl has less impact on the seabed, because contact is reduced to a limited number of points. Some fishermen in the United States (US) have adopted the sweepless trawl voluntarily because of its advantages, although concerns have been raised about loss of target species.

The concept of the Active Trawl System was developed by Shenkar (1995, 1996) to actively control the doors. The system is designed to have a bottom-contour mode and to maintain light contact with the bottom or operate at a set height above the seabed. Although this system is still in development stage, it does provide the potential for a doorless otter trawl in certain fisheries, where herding is not a pre-requisite to catch the target species.

I.2.2 Work foreseen in the tender submitted

In order to reduce the impact on the seafloor, a possibility is to test traps, which seem to have a minor impact in comparison with trawls. But that gear has never been used in the concerned fisheries. An intensive work and a large amount of sea trials would be needed before drawing any conclusion on the potential commercial use of that gear in EU deep-water fisheries. Due to the budget available for that study, the consortium concludes that it is not possible to work on that static gear.

Longlines being excluded from the call for tender, the consortium has chosen to concentrate the study dedicated for that task on modifications of standard trawl gears. Off-bottom trawling is an obvious solution to reduce bottom impact, and therefore the goal of that study will be to develop trawl concepts that have no or only minor contact with the seabed.

This task will aim to design and to test an off-bottom trawl at sea. Due to the lack of complete knowledge on technical feasibility and fishing efficiency, a complementary work will be carried out on a light trawl. An initial idea of the partners was to test a plates footrope instead of rockhopper, but such idea has been withdrawn due to the need of R&D to design such a device, which was too expensive for the budget available. This was confirmed – while writing this proposal - by the Norwegian team (IMR, Bergen) who developed the plates footrope concept: They considered that the implementation of that concept on deep-sea trawls with a long fishing line requires a long term development.

The first approach to design the off-bottom trawl concept will be made by numerical simulation. It will be conducted using software DynamiT developed by IFREMER Lorient. Various configurations will be tested to position the trawl off the bottom. The warp length (depth ratio) for different depth, the influence of sweeps length, additional buoyancy and the nature of the footrope will be analysed. Various adjustments will be made to allow a variable height of the footrope from the bottom.

Following the simulation phase, a small-scale model will be calculated and built for trials in Ifremer's flume tank in Lorient. The objective of flume tank tests is to get additional results: stability of the trawl during the shooting of warps and, influence of the towing speed, influence of shooting speed. The stability of the trawl off the bottom is the most important parameter as it is directly linked to the impact.

In order to comply with the conclusions of the technical meeting held the 26th of March 2013, the Consortium added a section describing the effects of removing the rockhopper gear.

I.3 TASK 2: DISCARD REDUCTION

Discards and by-catch have been a major topic in fisheries management, at least over the past 20 years. The two concepts are related but slightly different. Discards are the part of the catch that is releases or return to the sea, dead or alive, whether or not it is brought fully on board a fishing vessel (FAO, fisheries glossary, http://www.fao.org/fi/glossary/). By-catches are the part of a catch taken incidentally in addition to the target species towards which fishing effort is directed. Some or all of it may be returned to the sea as discards, some may also be landed and sold. Discards and by-catch differ in both economical and ecological dimensions. On the economical side, discards are regarded both as a waste of valuable resource and additional costs that generate no profit (Hall *et al.*, 2000, Bellido *et al.*, 2011) while the landed part of the by-catch is not an economical problem. On the ecological side, discards and by-catch are fishing mortalities, as discards may not be well documented, the corresponding mortality may be not be accounted. At the community and ecosystem levels, discards and by-catch may impact vulnerable species and top predators and discards may alter ecosystem functioning impacted by e.g. increased availability of resources to scavengers (Zhou et al., 2010; Bellido *et al.*, 2011). Both discards and by-catch are a matter of sustainable level of exploitation at community and ecosystem levels.

Because of the economical and ecological issues associated to discards, reducing discards is considered a key to the Ecosystem Approach to Fisheries Management (EAFM) and selective fishing is widely promoted (Bellido et al., 2011). It must however be acknowledged, that an alternative to selective fishing, further referred to as the "balanced harvesting", has appeared recently in the scientific literature (Zhou et al., 2010; Garcia *et al.*, 2012). The "balanced a harvesting" suggests that distributing fishing mortality in proportion to the productivity of ecosystem components would better conserve biodiversity, primarily species and size composition in ecosystems and better maintain sustainable fisheries. The approach implies that sensitive species that can only sustain low fishing mortalities should be exploited at corresponding rates, while the "selective fishing" approach may mostly refers to their protection. Nevertheless, starting from the overexploitation levels that lead to the depletion of some elasmobranchs species, both perspectives stress the need to limit the mortality of these species to sustainable levels (Zhou et al., 2010; Bellido et *al.*, 2011). The main difference between the two approaches, is that discards are perceived as an unnecessary mortality in the "selective fishing" while the "balanced fishing" is concerned by disproportionate removal (both overfishing of vulnerable species and low exploitation of productive species) that can result in changes in biodiversity. In the "balanced fishing" approach, discarding of species and catch components that are more productive than the target catch is still a concern (as a waste of resources) but it is addressed as a market issue in order to utilize such catch, rather than as a selectivity issue (Garcia et al., 2012). In the real world both approaches are recognized difficult to implement and there is no final conclusion about which is best suited to manage current fisheries. This might be especially true to deep-water fisheries.

The revised common fisheries policy (CFP) includes a progressive elimination of discards in EU waters. As a consequence, the contractual objectives of the current project were clearly defined in the "selective fishing" approach and this report is written is this perspective. It is clear that for some components of the total catch of deep-water fisheries, the sustainable level of fishing mortality is lesser than that of target species. This applies to orange roughy and some deep-water shark species, which have been overploited in past decades (ICES 2012a,b). For such species, the likely reduced impact of recent fisheries does not allow a fast stock recovery owing to their slow dynamics (Dransfeld et al., 2013) and selectivity fishing to minimize their catch is desirable. On the other hand, small bycatch species and small individuals that have higher productivity and natural mortality (Pauly, 1980; Denney *et al.*, 2002; Andersen *et al.*, 2009; Le Quesne *et al.*, 2012), may sustain higher fishing mortality than target species, including at great depth. Therefore, while, the "selective fishing" approach aims at minimizing their bycatch, the "balanced fishing" approach would aim at developing their utilization.

Although, there are not many studies about the proportion of the total catch that is discarded in deep-water fisheries, some general insight of the situation of gillnet, longline and trawl fisheries can be gleaned. In deep-water fisheries, all fish returned to sea are dead (Koslow et al., 2000; Gordon, 2001) as this result from the high barotrauma suffered by the catch, this applies to all types of fisheries. In gillnet fisheries, Hareide *et al.* (2005) find high level of discards of monkfish and suspected that other species were discarded in high quantities to the West and North of Great Britain, Ireland, around Rockall and Hatton Bank. Their estimate of discards was based upon one single inspection of a gillnetter. The description of the fishery, including bad practices such as long soaking time (8 days on average), the account of lost gears, partly as a consequence of spatial overage with trawl fisheries, and studies suggesting that in the deep water loss gillnet may keep fishing for a long time, a phenomenon known as ghost fishing, played an important role in the regulation, and mostly ban, of deep-water gillnetting from 2006.

Based on surveys carried out on two commercial vessels, one trawler and one longliner, in 1995 to the west of Ireland and Scotland, Connolly and Kelly (1996) estimated that total discards amounted to 941kg for every tonne of roundnose grenadier landed. This figure did not allowed comparing the discarding rates of the two gears, as roundnose grenadier was not caught on longlines. Nevertheless, Connolly and Kelly (1996) detailed the catch by species for both gears during the surveys. In the trawl the total catch and discards were 139kg and 43.8kg per hour fishing. In the longline the catch was 130.58kg, including 110kg of deep-water sharks and the discards were 6.57kg per 1000 hooks. The Irish Marine Institute, carried out a number of other surveys on commercial vessels in the late 1990s and early 2000s. Discards rates from 30% to 43% of the total catch were estimated in three longline surveys from 1997-2000 (Connolly et al., 1999; Clarke et al., 2001; Clarke and Moore, 2002). The main species in the catch was the birdbeak dogfish (*Deania calcea*) and was discarded, while the leafscale gulper shark (*Centrophorus squamosus*) and the Portuguese dogfish (*Centroscymnus coelolepis*) which accounted together for more than 30% of the total catch in two of the surveys were landed. In the last survey, the tusk (*Brosme brosme*) was caught as the second species in weight. This survey was carried in more northern areas than previous ones and covered the Rockall and Hatton Banks. The three above shark species accounted for 43% of the total catch and tusk for 17%. At the time of these surveys, only the birdbeak dogfish was discarded, while all three would be discarded today owing to the zero TAC for all deep-water sharks in EU waters. All shark species made up 58% to 74% of the catch. Durán-Muñoz *et al.* (2011) found even higher proportion of deep-water sharks in the catch of a longline survey on the Hatton Bank. In a trawl survey, on an Irish commercial trawler, the discard rate was estimated for each of 8 small areas sampled in all Irish deep-water surveys. Discard were found to vary from 25 to 75% of the total catch per area (Kelly *et al.*, 1997). Overall, discards were lesser in northern area (the Scottish slope north of 55°N) than in southern areas (Porcupine Bank and Porcupine Seabight slopes). At a larger geographical scale, difference in the discard rates were also found in longlines fisheries for black scabbardfish in southern areas. Based upon a survey carried out on a commercial vessels with the commercial fishing gear, Pajuelo *et al.* (2010) estimated that 45% in weight of the catch was discarded in the fishery around the Canary Islands while Bordalo-Machado *et al.* (2009) found low levels of discards, 6 and 2% respectively in number and weight, from on-board observations of the fishery off Portugal mainland. In the French deep-water trawl fishery to the west of the British Isles, different levels of discarding have been estimated in different Periods. Alain *et al*. (2003) estimated an overall proportion of discards of 48.5% in weight based upon 55 trawl hauls to the West of the British Isles from 47°N to 59°N. In recent years discards of the French trawl deep-water fishery have been estimated from the on-board observation scheme developed under the DCF sampling plan. The proportion of discards, calculated by raising observed haul to the fishing trip and observed trips to the DCF métiers level, was estimated to 20 to 21% in weight from 2010 to 2012 (Fauconnet *et al.* 2011; Dubé *et al.*, 2012; Cornou *et al.*, 2013). The difference may not be an actual change in the discards proportion of the fishery as the estimate from 2003 was not based upon a sampling plan of the whole fishery.

Other factors for discard variation include the target species and season, an extreme case being that of fisheries on spawning aggregation such as those for orange roughy (*Hoplostethus atlanticus*) and blue ling (*Molva Dypterygia*) which were considered to generate lesser bycatch, so lesser discards (Gordon, 2001; Lorance 2012). Discards in the directed orange roughy fishery were assumed to be zero in a trophic web model (Howell *et al.* 2009; Heymans *et al.*, 2011). Lastly depth is a strong factor of the species and size composition and therefore affects the total amount of discards and the discarded proportion of some species which adult are commercial and juveniles are undersized, this applied primarily to the roundnose grenadier (*Coryphaenoides rupestris*). This account of various surveys shows that discards occur with all gears that have been used to exploit deep-water fisheries and discards may vary with several factors and spatially. However, the factors for discards in deep-water fisheries may not be fully understood. The studies reviewed above are probably too much scattered, with various objectives, sampling plans and insufficient overlap in gears, areas, depths and seasons sampled to support a quantitative analysis of discards factors. Lastly, although discards have been pointed out as a serious problem in deep-water fisheries (e.g. Roberts, 2002), little or no published analyses of options for reducing them was found.

TASK 1 – REDUCTION OF THE IMPACT ON THE SEA BOTTOM

II MAPPING OF FISHING GROUNDS IN WEST OF SCOTLAND

In order to identify the type of habitats where deep-water trawlers are operating, a superposition of available information on the position of deep-water trawlers has been made on the latest available seabed mapping produced by EMODnet. Results are presented on the figure bellow (Figure 1).

Deep-water trawlers positions presented are available from tallybooks 2010-2012 for 46 m long trawlers from Scapêche.

Seabed data is available from the EUSeaMap Consortium webGIS data (www.jncc.gov.uk/page-5040) under the pilot project for the European Marine Observation Data Network (EMODnet), funded by the European Commission's Directorate-General for Maritime Affairs and Fisheries (DG MARE).

The Data Owner and EUSeaMap consortium accept no liability for the use of this data or for any further analysis or interpretation of the data.

The seabed is categorised in 7 categories

(1) "Unknown seabed" for seabed nature unkown/unreported; (2) "Mud to sandy mud"; (3) "Sand to muddy sand"; (4) "Coarse sediment"(5)"; "Mixed sediment"; (6) "Till" and (7); "Rock or other hard substrata". The category “Till” did not occur in the study area and so was removed from the map legend.

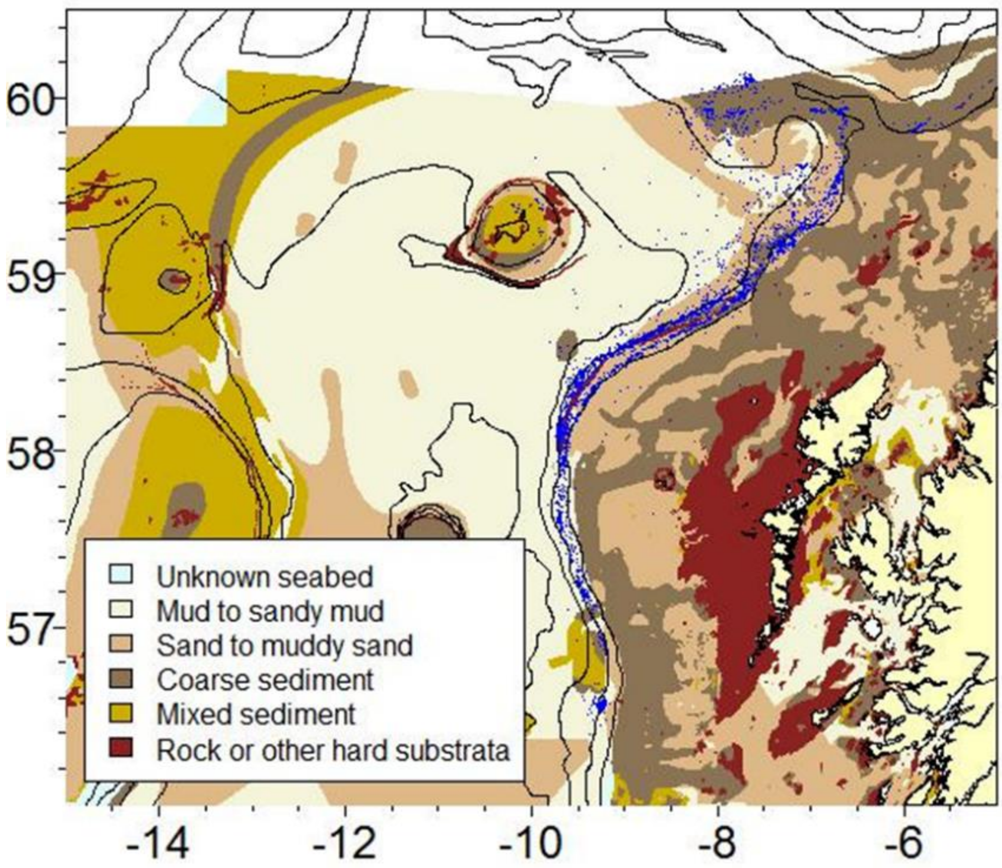


Figure 1: Superposition of the fishing positions of 46 m long trawlers from Scapêche for years 2010-2012 (blue points) on seabed mapping

That figure shows that fishing operations for deep-water species are mainly conducted on sand to muddy sand substrate.

III PRELIMINARY STUDY ON THE TRAWLS MODIFICATIONS

We propose to design and test, by the mean of numerical simulation, an off-bottom trawl of which the main parts in contact with the seabed are door shoes. The forces applied on the sea bottom by the otterboards can be reduced by working on the optimization of the ratio warp length/depth (look at chapter "Effect of warp length/depth ratio on the force applied by doors on the seabed"). Sweeps will be kept off bottom in the area of doors and wings depending on the configuration. The proportion of sweeps on the seabed is calculated for the different options considered hereafter. The trawl is kept off bottom using a very light footrope or eventually, additional floatability on the head rope. Different distances from the seabed to the fishing line are considered and adjustable in order to optimize the commercial catch.

We then present the second option of light footrope lying on the seabed but with very low contact force. Several options are considered to adjust these forces (look at "Force and pressure applied on the seabed for light ground gear concept (Scenario 4)"). The initial objective was to reduce at least by 50 % the forces applied on the sea bed in comparison with the standard footrope.

The sinking speed in two situations (shooting and depth variations) of the light trawl is evaluated to assess the potential time loss in fishing operations. All numerical simulations are done using Ifremer DynamiT software.

III.1 FISHING GEAR DESIGN

III.1.1 Trawl design

Trawl design is presented in Annex 1: Trawl design. It is the design of initial (existing) configuration and also of the modified configuration. Thus it is also the base for scaled model design for flume tank trials.

The existing rigging is described hereafter:

- Warps, sweeps and lower bridles are made of 28 mm steel cable;
- Upper bridles are made of 20 mm cable. Doors are Morgère Oval Foil OF14;
- The footrope is a 81 m long rockhopper with 400 mm rubber disks[3]. Its mean weight in the water is about 10 kg per meter. About 243 disks are used.

  Head rope buoyancy is made of 4 liters floats. 114 on each wing and 30 on the square for a total of 258 floats.

III.1.2 Light trawl design

For the purpose of this study (off-bottom trawl and light trawl) we have to modify the footrope composition to lighter it.

Considering the risk for the trawl of being in contact with the seabed, it is necessary to have a protection of the netting part to minimize the risk of damage. The choice has been made to keep a rockhopper gear like, but modified in order to reduce its weight.

[3] 400 mm is a maximum value, some vessels use 300, 350 and 400 mm disks from the wings to the square.

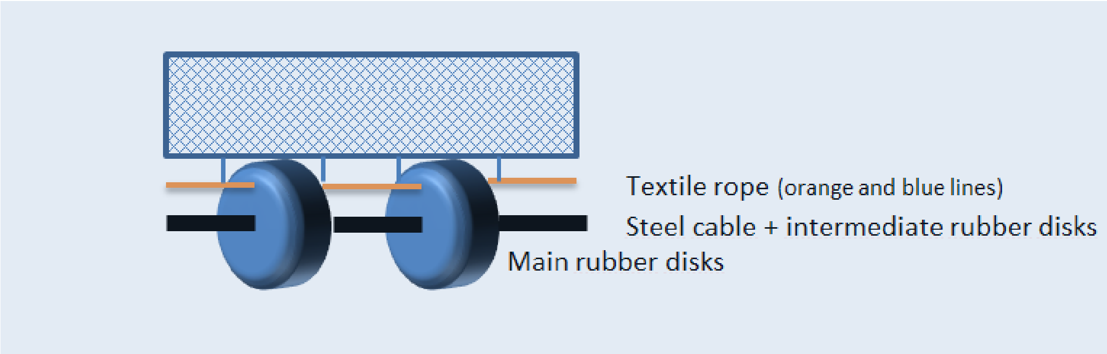


Figure 2: Design of the new rockhopper.

This light rockhopper (Figure 2) is made of steel cable instead of chain. The chain usually found in the edge of the rubber disc is replaced by a textile rope. Connections between this rope and the fishing line are made with textile ropes again. The objective is to divide by 4 the weight in the air compared to initial design.

The table below (Table 2) gives an estimation of the minimum weight in the air and in the water per meter of footrope:

Table 2: Evaluation of the minimum weight of 1 meter of footrope.

Components per meter	Weight in the air (kgf)	Weight in the water (kgf)
Steel cable 18 mm	1.1	0.96
2xRubber risks D400 mmx100 mm	2x12.5	2x1.62 (assuming 13 % for conversion)
Rubber disks D100 mmx800 mm	6.3	0.82
4 liters float	1.5	- 2.5
Total	33.9	2.52

Notice it is possible to add extra floats on the fishing line to adjust the trawl buoyancy or to modify the number of rubber disks, etc.

In the following simulations we assume the weight per meter in the water is 2.5 kg, compared to about 10 kg per meter for original rockhopper design. Some other simulations results are presented in Annex 2: Ground gear height adjustment for 1.3 kg/m using same options. To assess the behaviour of a footrope with apparent weight of 1.3 kg per meter in order to evaluate the sinking speed of the lightest possible gear. Thus, comparison of sinking times is made with the 1.3 kg/m footrope in order to choose the most penalizing configuration (i.e. the lighter configuration that will take more time to sink).

Considering these modifications, the footrope has a total apparent weight of: 2.5 kgf/mx81 m = 202.5 kgf. Headline floatation is made of 774 kgf (consider also “Option 2: Modification of the headline buoyancy”). In this configuration, the trawl is roundly floating. Figure 3 and Figure 4 below illustrate this point at very low towing speeds.

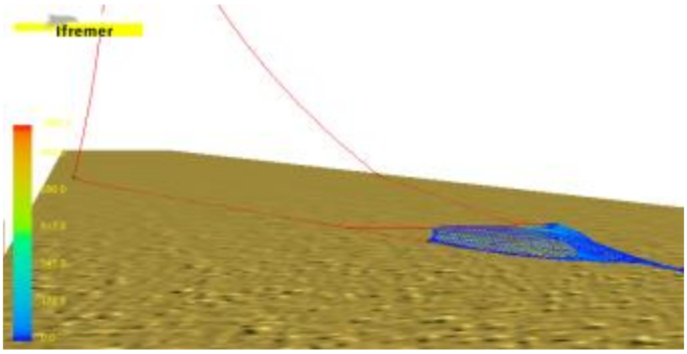


Figure 3: Modified trawl simulation at 3.2 knots.

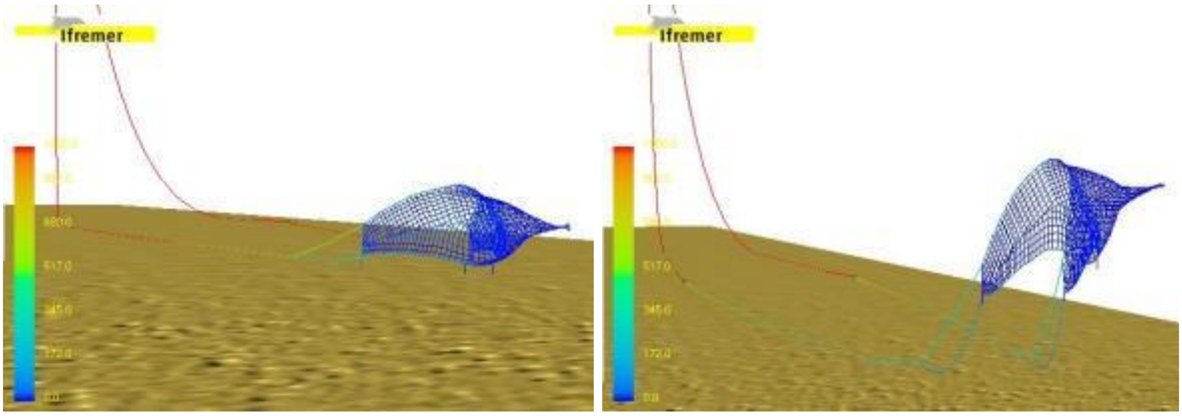


Figure 4: These pictures illustrate the positive floatability of the modified trawl when towing at very low speeds ("unrealistic" 1 knot speed left and 0.5 knot right).

III.2 MATERIAL COSTS

The only difference between the standard and the light trawl was the footrope. Cost of the light footrope is similar to the standard footrope commonly used by the trawler. There is also no differences in all others costs such as other parts of the gear, fuel consumption, catch quality and value and working time for fishermen.

So, we can consider that there is no modification of the costs when using a light trawl instead of a standard one.

III.3 TRAWL HEIGHT ADJUSTMENT (SCENARIO 1)

Following simulations are made assuming the following hypothesis:

- Rockhopper weight in the water is 2.5 kg/m (against 10 kg/m for initial design),
- A 50 kg weight is added at the bridles-sweep connection, except for option 3,
- The number of headline floats is the same than for initial trawl, except for option 2,
- The trawl design (nettings, cutting grates, etc.) is the same than for initial design.

From this modified configuration, three different options are tested to adjust the ground gear height off the seabed:

- option 1 consists in introducing a difference in the bridle length;
- option 2 consists in modifying the headline buoyancy; and
- option 3 consists in modifying the weight at the bridles ends.

For each option, we test 3 different towing speeds: 2.9, 3.1 and 3.3 knots.

III.3.1 Option 1: Introduction of a difference in bridle length

The light trawl is simulated with a difference in length between upper bridle and lower bridle (Table 3, Table 4, Table 5 and Table 6).

Table 3: Option 1: bridle length/No difference (upper bridle equals lower).

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.03	1895	1370	5.4	29.5
3.1	0.02	2103	1563	4.9	29.8
3.3	0.02	2346	1781	4.5	30.2

Table 4: Option 1: bridle length/Difference 0.25 m (upper bridle longer than lower).

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.39	1692	1561	5.9	29
3.1	0.35	1893	1784	5.4	29.7
3.3	0.33	2098	2028	4.9	30

Table 5: Option 1: bridle length/Difference 0.40 m (upper bridle longer than lower).

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.73	1620	1672	6.1	29.3
3.1	0.79	1784	1904	5.6	29.6
3.3	0.80	1974	2175	5.1	30.0

Table 6: Option 1: bridle length/Difference 0.50 m (upper bridle longer than lower).

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	1.2	1562	1733	6.2	29.3
3.1	1.21	1732	1977	5.7	29.9
3.3	1.22	1916	2258	5.2	30.2

Lengthening the upper bridle could lead to distortion in the netting. The pictures below (Figure 5) show that the difference (+ 0.5 m) does not drastically modify the netting shape:

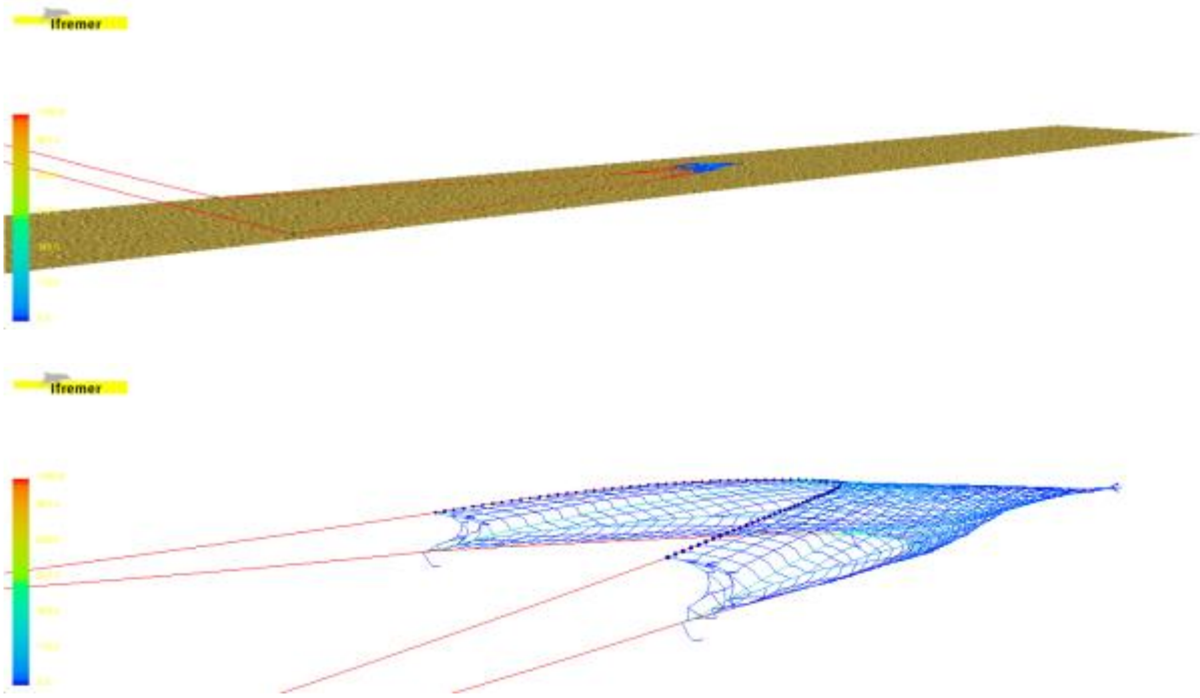


Figure 5: Wings netting is not distorted by the 0.5 m difference of the upper bridle.

Notice the trawl geometry has to be taken into account under the fishing line position.

III.3.2 Option 2: Modification of the headline buoyancy

The initial number of 4 liters and 3 kg floats is 114 on each wing and 30 on the square (258 floats). These numbers are increased in order of reduce the total apparent weight and lift the trawl off the seabed (Table 7, Table 8 and Table 9).

Table 7: Option 2 - Headline floatation/No additional floatation.

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.03	1895	1370	5.4	29.5
3.1	0.02	2103	1563	4.9	29.8
3.3	0.02	2346	1781	4.5	30.2

Table 8: Option 2 - Headline floatation/20 % more floats.

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.18	1968	1365	6.2	29.1
3.1	0.15	2185	1554	5.6	29.5
3.3	0.13	2429	1764	5.2	29.8

Table 9: Option 2 - Headline floatation/20 % more floats and difference of 0.40 m in bridles.

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	1.49	1725	1635	6.6	29.1
3.1	1.53	1892	1868	6.1	29.4
3.3	1.51	2081	2129	5.6	29.7

III.3.3 Option 3: Modification of the weight at the connection bridles – sweep

This simulation shows the reduction of the weight at bridles/sweep connection increases the mean footrope height of about 20 cm (Table 10, Table 11 and Table 12).

Table 10: Option 3 - Weight at the connection bridles – sweep/initial weight: 50 kg.

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.03	1895	1370	5.4	29.5
3.1	0.02	2103	1563	4.9	29.8
3.3	0.02	2346	1781	4.5	30.2

Table 11: Option 3 - Weight at the connection bridles – sweep/Reduced weight: 10 kg.

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.03	1884	1383	5.5	29.4
3.1	0.03	2099	1574	5	29.8
3.3	0.02	2340	1786	4.5	30.1

Table 12: Option 3 - Weight at the connection bridles – sweep/Reduced weight: 10 kg of 0.40 m in bridles.

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	1.00	1614	1669	6.1	29.3
3.1	1.05	1785	1908	5.6	29.7
3.3	1.03	1976	2179	5.1	30.0

III.3.4 Effects of removing the rockhopper footrope

In this chapter, we study the effects of removing the footrope. The objective is to show that the results observed at sea (gear height over the seabed) for a trawl equipped with a footrope will be transposable to the same trawl with no footrope.

The footrope is removed in the simulation by: (1) removing the apparent weight of 2.5 kgf/m of fishing line (thus about 200 kgf are removed) and (2) removing the drag of the footrope, mainly due to rubber disks. Table 13 shows the mean fishing line height over the seabed with and without the footrope. The difference in bridle length is 0.25 m in the case.

Table 13: Fishing line height with and without footrope at different towing speeds. Difference in bridle length is 0.25 m.

Towing speed (knots)	Fishing line mean height (m) with GG	Fishing line mean height (m) with no GG
2.9	0.39	2.25
3.1	0.35	2.19
3.3	0.33	2.00

The effect of weight reduction is quite clear on the fishing line height.

Other adjustments in bridle length difference and modification of floatation could also be tested to compensate it, but the primary conclusion is that the impact of removing the footrope has to be compensated in order to be able to keep the same fishing line height over the seabed with or without the footrope.

We propose 2 ways to compensate the effect of removing the footrope. The first is the easiest to handle: it consists in adding 4 chains (at the wing tips and at the square corners). These 2 meters long chains add a total apparent weight of 200 kgf and will improve the trawl stability as they are partly in contact with the seabed: the higher the fishing line, the heavier the chain weights on the fishing line. According to the simulations, the fishing line height is reduced to approach the ground gear configuration but is still too high (Table 14).

Table 14: Effect of adding 4 compensation chains.

Towing speed (knots)	Fishing line mean height (m) with no footrope and with 4 compensation chains
2.9	1.04
3.1	1.08
3.3	1.07

The second solution to exactly compensate the effect of removing the footrope simply consists in adding a chain with an average apparent weight of 2.5 kgf/m along the fishing line. A length of 105 m of 10 mm chain or a length of 65 m of 13 mm chain or a mixed solution would fit. This chain cannot be considered as a protection as it is attached directly to the fishing line. The effect of the footrope drag seems to be negligible on the footrope height according to the simulations.

III.3.5 Conclusion

This series of simulations shows that some basic modifications (difference in length, buoyancy, weight) permit the adjustment of the mean footrope height. Moreover, these parameters can be combined together to add their effects. Some other options could be studied like the effect of kites on the head rope, the effect of lengthening the bridles to reduce their vertical traction component.

The best solution has to be chosen on the base of the easiness to handle and maintain and also on the base of stability. Difference in bridle length seems to be a good compromise as it only needs slight modification of the rigging. Following simulation (Evaluation of sinking duration (Scenario 3)) give elements about stability of the off-bottom trawl.

III.4 SWELL EFFECTS (SCENARIO 2)

The objective of this part is to assess the stability of the off-bottom configuration against the vessel motion. Thus, we impose the vessel motion rather than a swell height than would need the simulation of the vessel motion, which is out the frame of this study.

Tables below present the ratio (percentage) of sweeps and footrope on the seabed. Zero percent means that the footrope sweeps have no part in contact with the seabed, 100 % means all parts are in contact with the seabed. This ratio is defined by the length lying on the seabed (whatever the force applied on the seabed) divided by the footrope sweep length.

III.4.1 Hypothesis

The effect of the vessel motion is simulated by a pure sinus motion of the block (warp end). This motion is purely horizontal. It could be anything else in the simulation, but the purely horizontal motion seems to be the most sensitive on the trawl behaviour, thus the most penalizing. This motion is superposed to the constant towing speed. Tested towing speeds are 2.9, 3.1 and 3.3 knots. It must be noticed that in bad weather conditions, towing speed is often decreased to 2.9 – 3.0 knots.

The effects of seabed relief are not taken into account, however, the seabed is known to be rather flat.

Towing tension at the block is represented in the graphs below in order to be able to link the vessel motion, difficult to evaluate, to a physical data easy to measure with dynamometers.

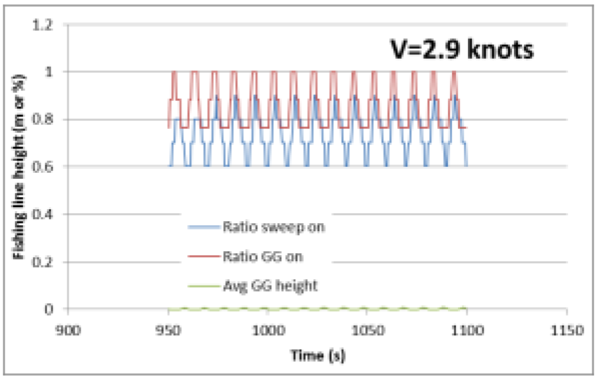
Tested motion amplitudes are 5 meters and 10 meters. Notice that the motion amplitude of 5 meters leads to an overall motion of 10 meters. The amplitude of 10 meters leads to an overall motion of 20 meters. The period of the simulated motion is 10 seconds. This value has been chosen for being rather realistic: longer periods will not impose a sufficient dynamic to the trawl to affect its distance from the seabed and shorter swell periods will lead to a rapid motion that will be damped by the long warps.

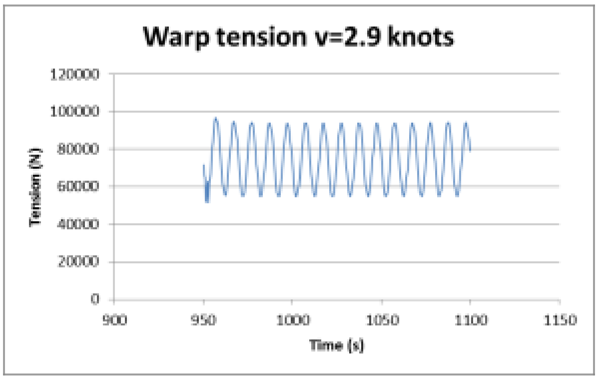
For some graphs, transient phase is represented. They could illustrate speed reduction consequences, for any reason.

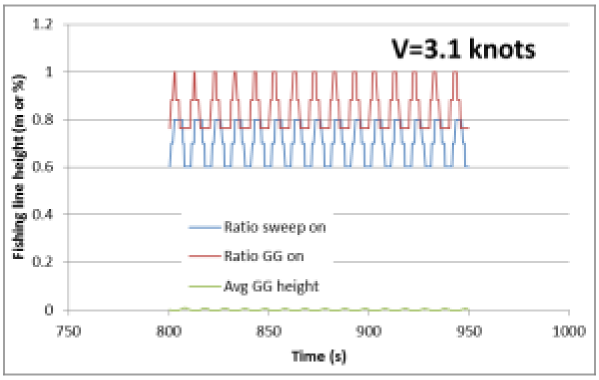
III.4.2 Standard trawl with a 5 m/10 s period vessel motion

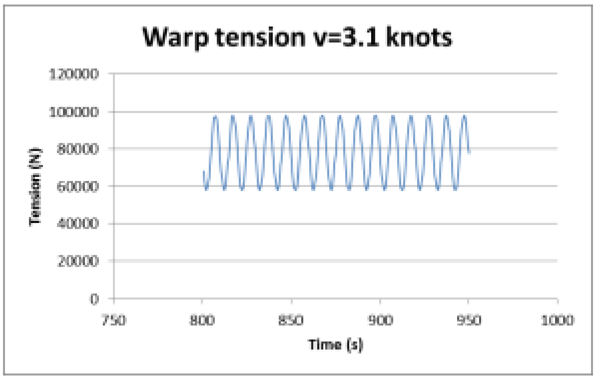
First, we present the standard trawl, submitted to vessel motion, in order to compare the footrope and sweep lines behaviour of modified (light) and standard trawl. In this configuration, the standard trawl can be compared to the modified trawl for case 1 and case 3 (Table 15).

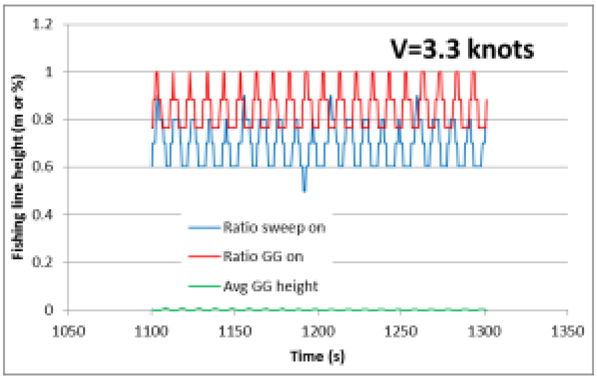
Table 15: Standard trawl results (5 m/10 s period vessel motion).

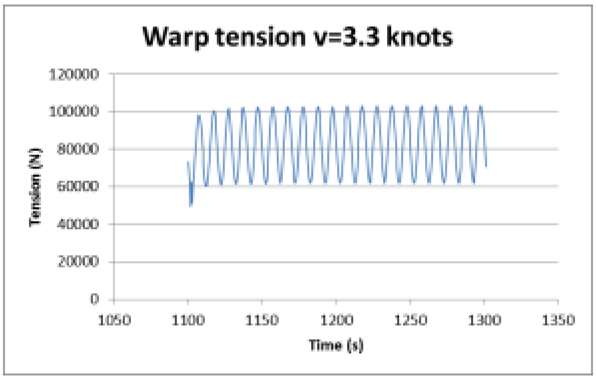










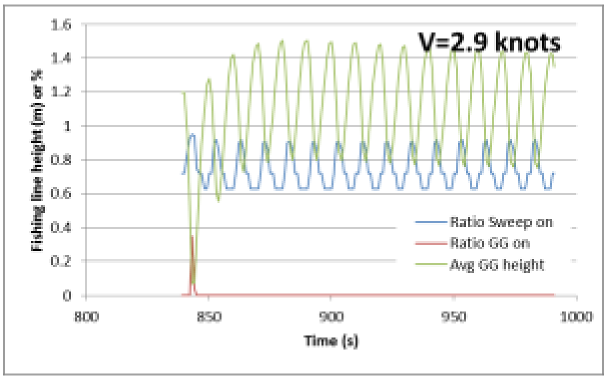


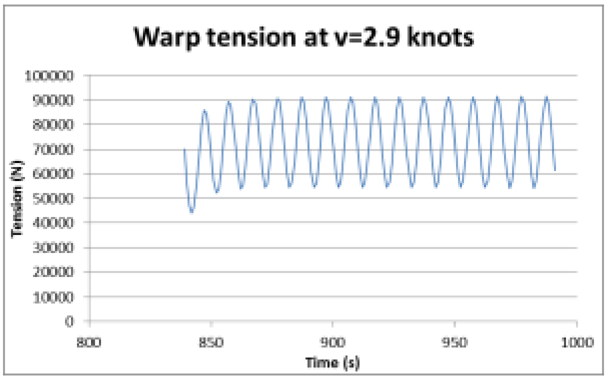
The main conclusion is that the standard trawl, in this configuration motion, always has its footrope in contact with the seabed, with an averaged ratio of about 90 %. About 70 % of sweep lines are in contact with the seabed, and even a bit more for higher trawling speed, due to the wing tip being in contact with the seabed, as it is not the case for light trawl.

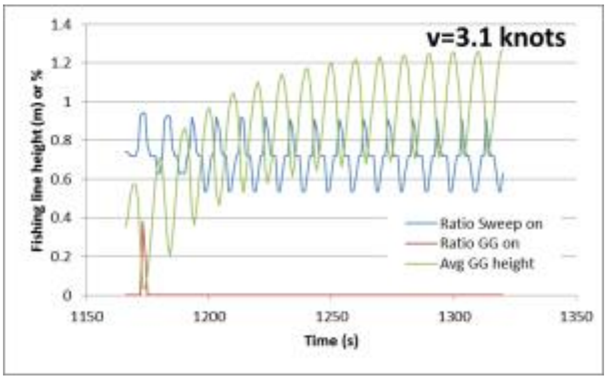
III.4.3 Case 1: 5 M/10 S period vessel motion

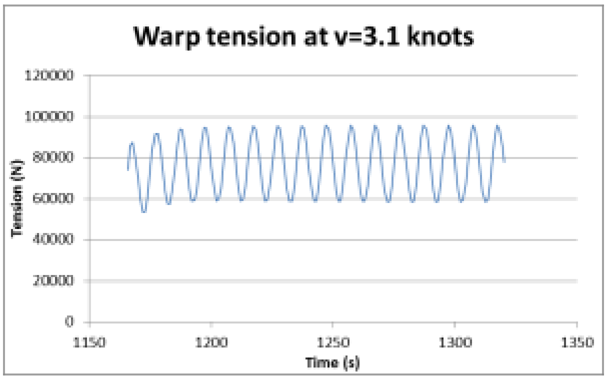
The first case described the following situation: 5 meters amplitude/10 seconds period vessel motion applied to option 1/Upper bridle 0.50 m longer. The simulation results are shown in Table 16.

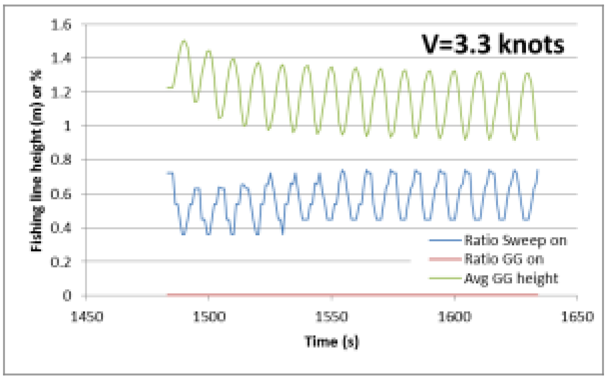
Table 16: Case 1, results (5 m/10 s period vessel motion).

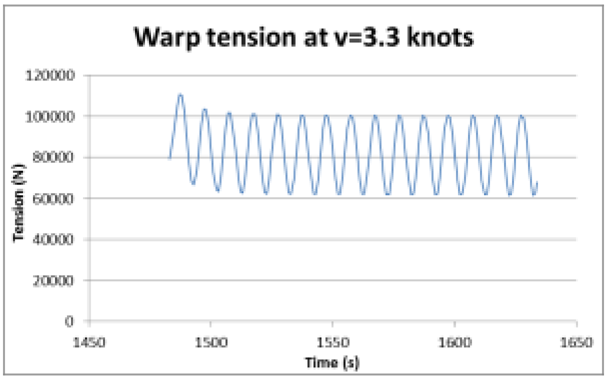










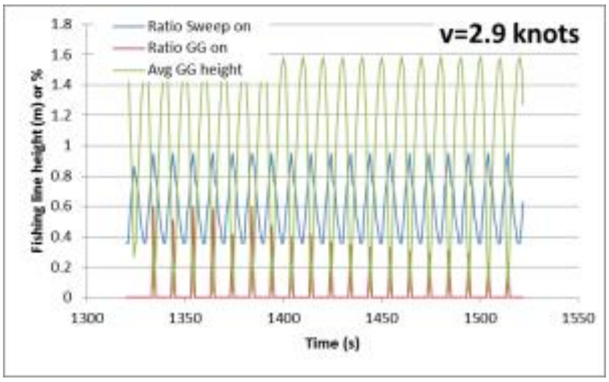


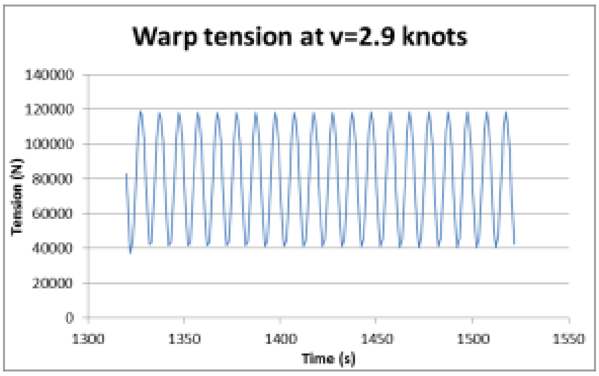
Tested rigging is the option 1 with a difference of 0.5 m. These simulations never show any footrope contact with the bottom. The footrope height varies between 0.8 m and 1.3 m over the bottom, depending on the towing speed and the vessel motion.

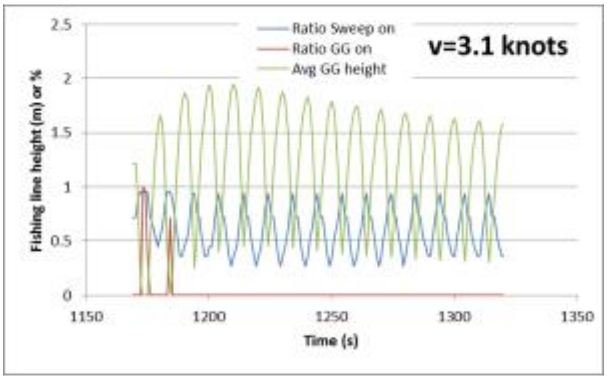
III.4.4 Case 2: 10 M/10 S period vessel motion

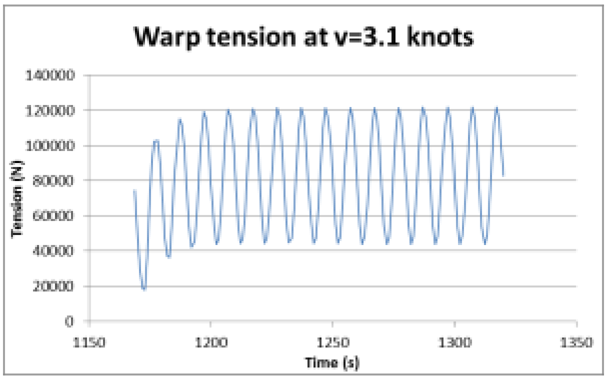
The second case described the following situation: 10 meters amplitude/10 seconds period vessel motion applied to option 1/Upper bridle 0.50 m longer. The simulation results are shown in Table 17.

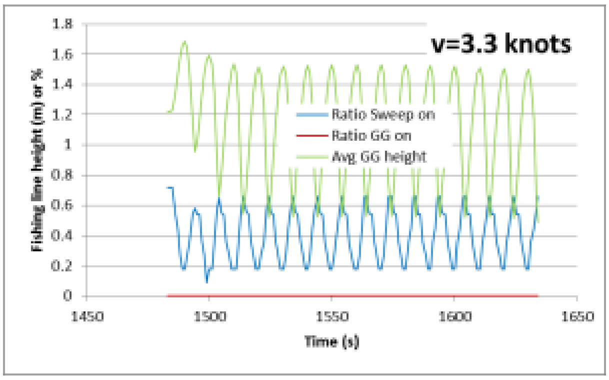
Table 17: Case 2, results (10 m/10 s period vessel motion).

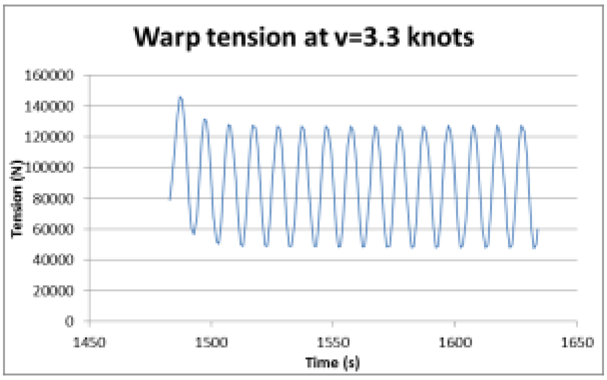










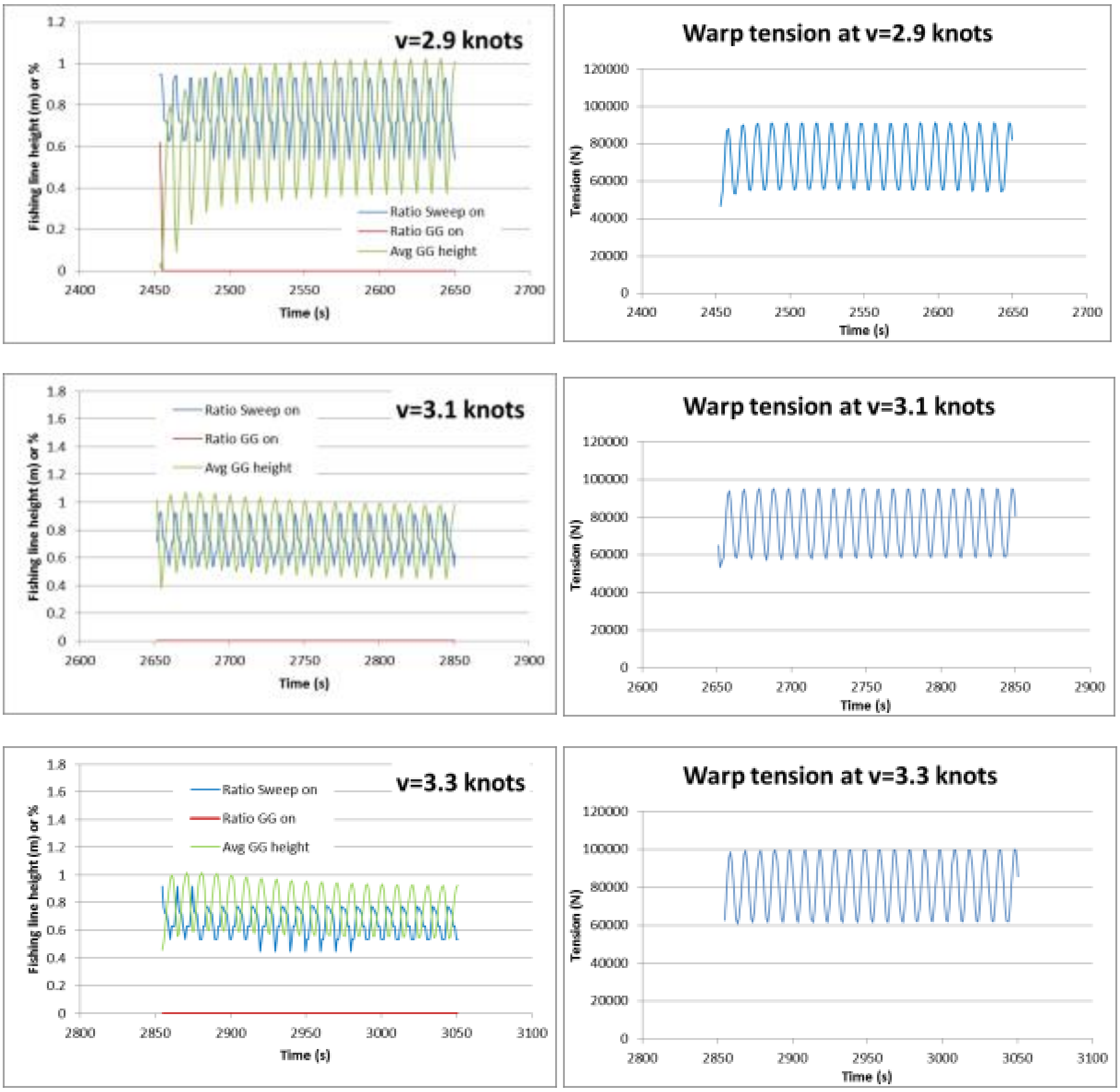


The same rigging is simulated with motion amplitude twice larger. These simulations show slight footrope contact for the lower speed (2.9 knots). Periodical contacts up to 30 % of the footrope (once the transient phase ended) leads to an equivalent 3 % permanent contact (averaged in time).

III.4.5 Case 3: 5 M/10 S period vessel motion

The third case described the following situation: 5 meters amplitude/10 seconds period vessel motion applied to option 1/Upper bridle 0.40 m longer. The simulation results are shown in Table 18.

Table 18: Case 3, results (5 m/10 s period vessel motion).



Tested rigging is still the option 1 with a difference of 0.4 m. These simulations never show any footrope contact. The footrope height varies between 0.4 m and 1 m over the bottom, depending on the towing speed and the vessel motion. The 10 m amplitude excitation has not been tested, but would lead to stronger contact than for case 2.

For a lighter footrope, additional simulations are presented in the Annex 3: Swell effects for lighter ground gear (1.3 kg/m in the water).

III.4.6 Conclusion

One will observe the mean footrope height presented in continuous situations (Trawl height adjustment (Scenario 1)) are a bit higher that mean height in periodic motion (example: mean height for 0.5 m difference is about 1.2 m in continuous situation and is about 1 m with 10 m/10 s motion).

According to simulation results, it is possible to rig the trawl in order to avoid any footrope contact with the bottom, provided the motion transmitted to the warp is lower than 10 m (motion of 5 m amplitude). For vessels equipped with tension auto-regulation system, this condition should be easy to reach. The standard trawl simulation (5 m/10 s) shows that its footrope remains in contact with the bottom most of the time.

The 10 m/10 seconds motion is an extreme value as such a motion would lead to negative speed (maximum speed due to the backward vessel motion greater than the towing speed). Once again, even if realistic, this extreme motion would not be fully transmitted to the warps thanks to tension regulation system. However, in this configuration, the footrope will occasionally be in contact with the seabed.

The measurement of warp tensions will be helpful to verify these hypotheses.

III.5 EVALUATION OF SINKING DURATION (SCENARIO 3)

The sinking duration is a crucial parameter when fishing at great depth. The modification of the trawl footrope could increase the sinking duration, thus it is important to assess this parameter.

III.5.1 Hypothesis

In order to simulate the shooting phase of the fishing operation, we have simulated the following scenario: the whole trawl gear (warps, doors, sweeps, trawl) is supposed to be fully spread at the sea surface (Figure 6), the vessel is supposed to tow the warps at an equivalent speed being the difference between actual vessel speed and the warp speed (winch speed). Thus if vessel speed equals winch speed, the equivalent speed is null (this option is not considered for being unsafe for doors). This equivalent speed represents the relative speed of the fishing gear against the water.

This speed is combined to the vertical sinking speed by the simulator. We test 2 different equivalent speeds: 1 knot and 2 knots. This simplified approach allows a relative comparison between the two trawls design. A more detailed and complex analysis would need to take into account the actual winch speed, warp length and door behavior but is out of the frame of this study. Thus, it must be noticed that the door behavior is not taken into account in the simulation. The door is supposes to keep a vertical position (roll angle = 0). The depth is 800 m (600 m tested in

Annex 4: Sinking time for 600 m depth), the warp length is 1 760 m (ratio of 2.2).

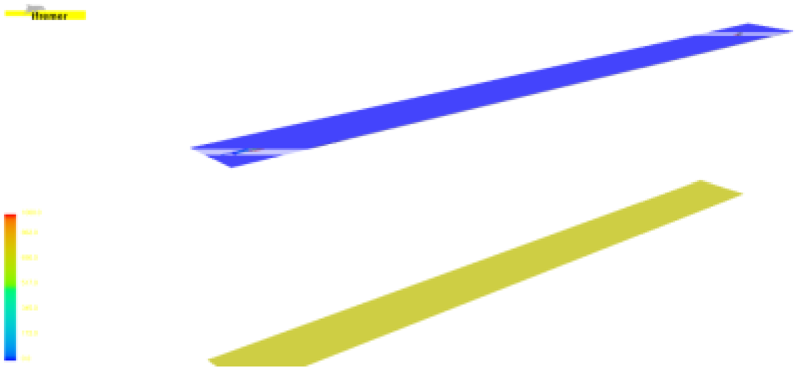


Figure 6: Initial trawl gear shape lying at the sea surface (blue) to assess the sinking duration (Seabed is represented in yellow).

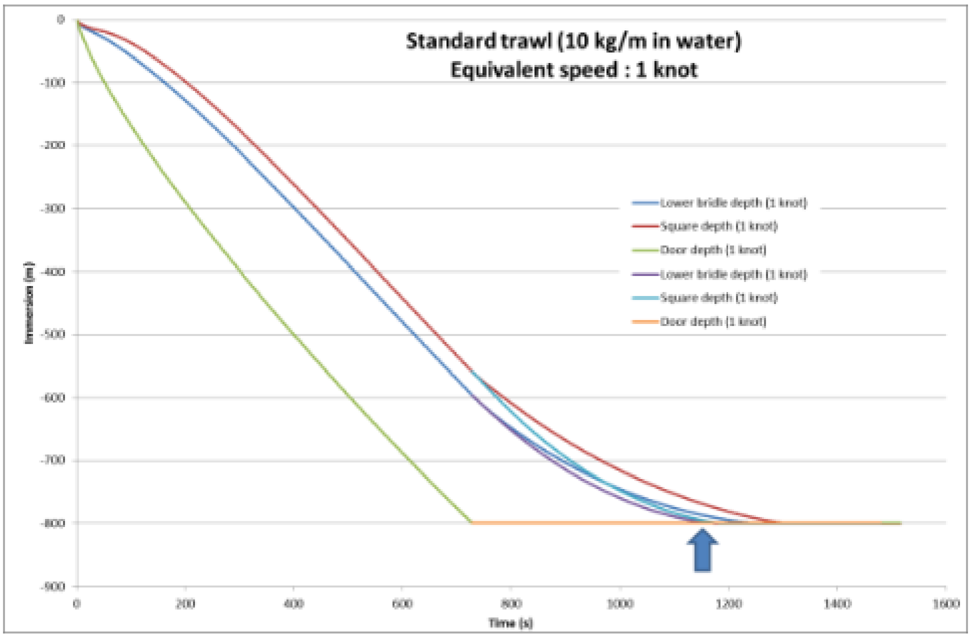
The following graphs (Figure 7 and Figure 8) show the immersion of the doors, the middle of the lower panel square and the middle of the lower bridle against time.

Once the doors on the seabed, two different options are tested:

1) the equivalent speed remains the same or,
2) the vessel increases the speed to 3.1 knots.

The option (2) allows a reduction of the time needed to get the trawl on the sea bottom of about 1 or 2 minutes. Then, when the footrope is stabilized, the trawl is usually supposed to be fishing. One can verify on the graphs below that option (2) does not lead doors to lift off bottom.

For each graph (Figure 7 and Figure 8), the blue arrow indicates the time when the footrope is lying on the seabed or is stabilized off the seabed. Initial trawl design and modified light design are presented on 2 different graphs.



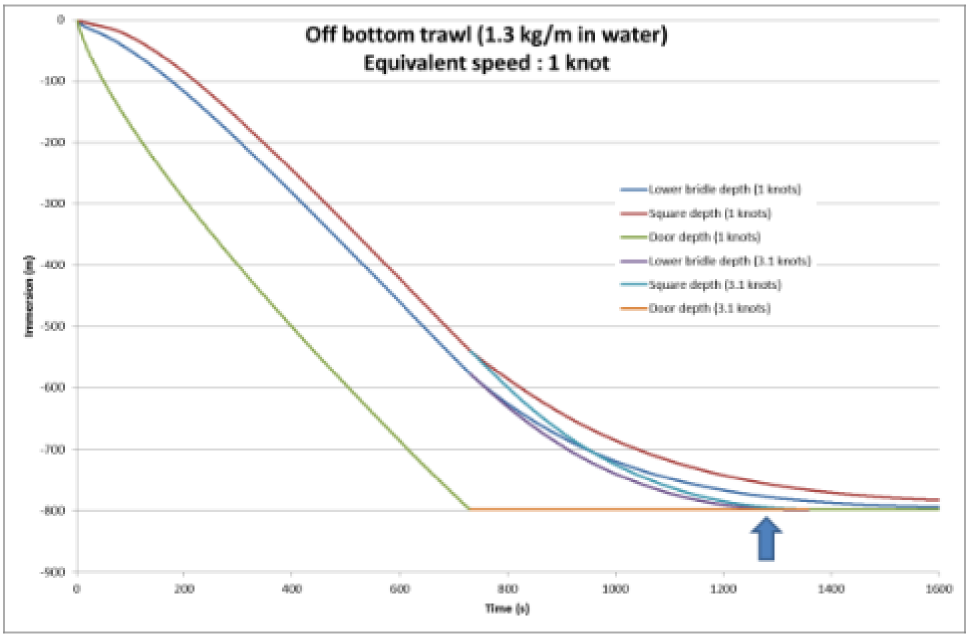
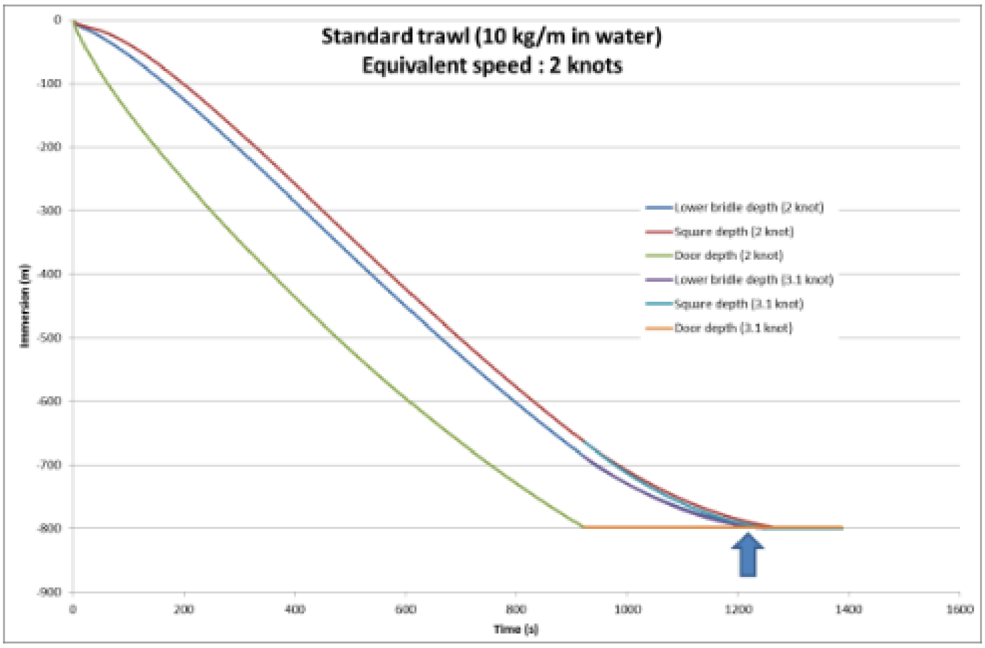


Figure 7: Immersion of different parts of the rigging for original trawl and modified design at an equivalent speed of 1 knot.



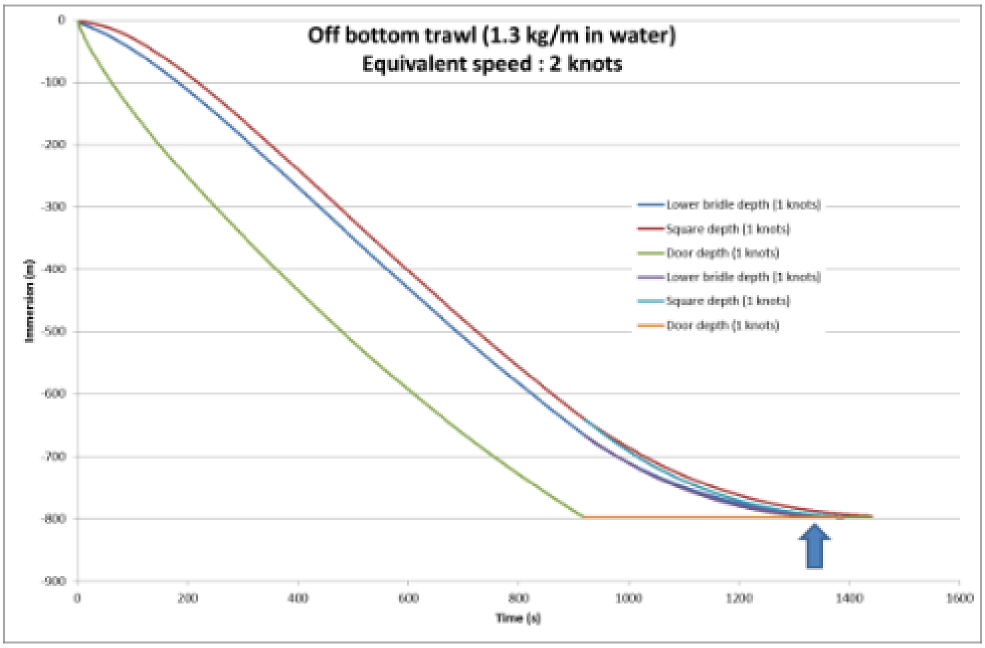


Figure 8: Immersion of different parts of the rigging for original trawl and modified design at an equivalent speed of 2 knots.

When considering an equivalent speed of 1 knot (Figure 7), the time needed to get the footrope on the seabed is about 1 150 seconds (19min10sec) for the initial trawl design and 1 270 seconds (21min10sec) for the modified design, about 10 % longer. The time needed to get doors on the seabed does not seem to be affected by the footrope modifications (about 910 seconds).

For the equivalent speed of 2 knots (Figure 8), the time needed to get the standard trawl on the seabed is about 1 250 seconds (20min50sec) and 1 350 seconds (22min30sec) for the modified trawl, about 8 % longer. The time needed to get doors on the seabed does not seem to be affected by the footrope modifications (about 910 seconds).

As the equivalent speed decreases (vessel speed decreases or winch speed increases), the time needed to get the footrope on the seabed decreases (about 10 %). Alternatively, the doors being the motor of the sinking phase, there weight could be increased to reduce the sinking time.

III.5.2 Conclusion

Simulations of sinking time have been undertaken using the lightest footrope configuration (1.3 kg/m in the water). Thus we present the most penalizing configuration. Field tests will be performed with heavier off-bottom footrope (around 2.5 kg/m).

We can conclude according to these simulations that the modified footrope with 1.3 kg/m in the water (whatever the objective off-bottom or light trawl) does not drastically increases the sinking time. It should take about 10 % longer to get the fishing gear in fishing configuration than for the initial design. More over this time can be reduced by adapting the vessel and/or winch speed and/or the doors weight.

III.6 FORCE AND PRESSURE APPLIED ON THE SEABED FOR LIGHT TRAWL CONCEPT (SCENARIO 4)

We now discuss a light trawl concept which lies on bottom (i.e. is not off bottom). This case study is justified if the off-bottom trawl leads to a too important loss of catch. We propose to use the configuration described in the section "Light ground gear design" with same apparent weight of 2.5 kg/m. This choice is justified by the easiness to modify the rigging (bridle length difference for example) compared to modification the GG weight. Thus, in the following pages, the adjustment for the footrope height is made by tuning the bridles length difference. However, any other options could be used to keep the trawl on the seabed (additional floatation, etc.).

III.6.1 Static case

III.6.1.1 Standard trawl

The objective of this section is to divide by 2 the total force exerted by the footrope on the seabed for reference trawl. The force exerted on the seabed by the standard trawl footrope at various towing speeds are shown below (Table 19).

Table 19: Force on the seabed for the standard trawl footrope.

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)	**Total GG force on seabed (daN)**	**Force for 1 bobbin (daN)**
2.9	0	1820	1580	5.5	28.7	**542**	**2.23**
3.1	0	2040	1782	5	29.3	**549**	**2.26**
3.3	0	2280	2001	4.6	29.6	**558**	**2.29**

III.6.2 Case 1: Simulation with equal bridles and light footrope

In Table 20 is shown the result of this simulation with equal bridles and light footrope.

Table 20: Case 1, simulation with equal bridles and light footrope.

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)	**Total GG force on seabed (daN)**
2.9	0.03	1895	1370	5.4	29.5	**86**
3.1	0.02	2103	1563	4.9	29.8	**80**
3.3	0.02	2346	1781	4.5	30.2	**91**

III.6.3 Case 2: Upper bridle 0.10 m shorter than lower and light footrope

In Table 21 is shown the result of this simulation with upper bridles shorter (0.1 m) and light footrope.

Table 21: Case 2, simulation with upper bridle shorter (0.1 m) and light footrope.

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)	**Total GG force on seabed (daN)**

2.9	0.01	1968	1316	5.1	29.5	**190**
3.1	0.01	2193	1495	4.7	29.8	**203**
3.3	0.01	2447	1698	4.2	30.2	**222**

III.6.4 Case 3: Upper bridle 0.20 m shorter than lower and light footrope

In Table 22 is shown the result of this simulation with upper bridles shorter (0.2 m) and light footrope.

Table 22: Case 3, simulation with upper bridle shorter (0.2 m) and light footrope

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)	**Total GG force on seabed (daN)**
2.9	0.01	2038	1260	4.9	29.6	**288**
3.1	0.00	2274	1432	4.4	29.9	**313**
3.3	0.00	2545	1630	4	30.2	**353**

III.6.5 Effect of rockhopper disks on the seabed

Notice the footrope geometry has to be taken into account under the fishing line position. Considering the fishing line height calculated, the lower part of the footrope lies on the seabed for this configuration.

The comparison of static cases (Table 20, Table 21 and Table 22) shows that it is possible to control the force applied on the seabed by the footrope with a simple action on the bridles length: according to simulations, a difference of 10 cm leads to an increase of forces on the sea bed of about 250 % (Table 21).

Pressure applied on the seabed can be estimated from the geometry of the footrope elements. Assuming the footrope design (Figure 2: Design of the new rockhopper.): the fishing line length is 81 m, the force is split in 162 rubbers disks.

Each has an estimated contact surface of 100 mmxPenetration Length, with Penetration Length = 2e(R - e) where 'e' is the penetration depth and 'R' the rubber disk radius (Figure 9).

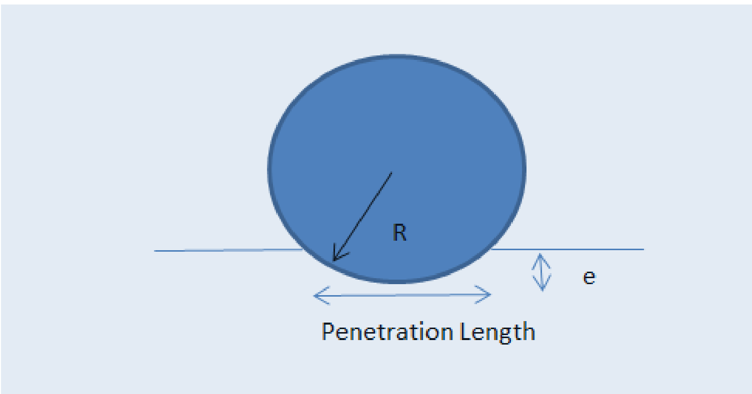


Figure 9: Simplified view of rockhopper disks contact surface.

For an hypothetical penetration depth of 5 mm, Penetration Length = 44 mm. Contact surface of footrope is: 162x44x100 = 7 128 cm².

Thus estimated pressure is 0.06 kg/cm² for case 2 and 0.02 kg/cm2 for case 1.

These figures can be compared to case study calculated by François Théret (2012)[4]. Notice the seabed relief is not taken into account, neither the effects of footrope dynamics.

Many questions and options could be discussed: for instance, considering we keep the footrope apparent weight constant, if number of disks is increased (with same disk thickness), the pressure will decrease but the impact on epyfauna will probably increase, due to increased contact surface. Sediment resuspention will also increase.

On the other hand, from technical point of view, adding more disks will result in reduced risk of damage and reduced fish escapement. In order to illustrate this point, we present in Table 23 an approximation of force and pressure applied on the sea bed for 2 options: 1 or 2 bobbin(s) per footgear meter.

Table 23: Rough estimation and comparison of force and pressure applied on the seabed by rubber disks for two options (case 2 at 3.1 knots).

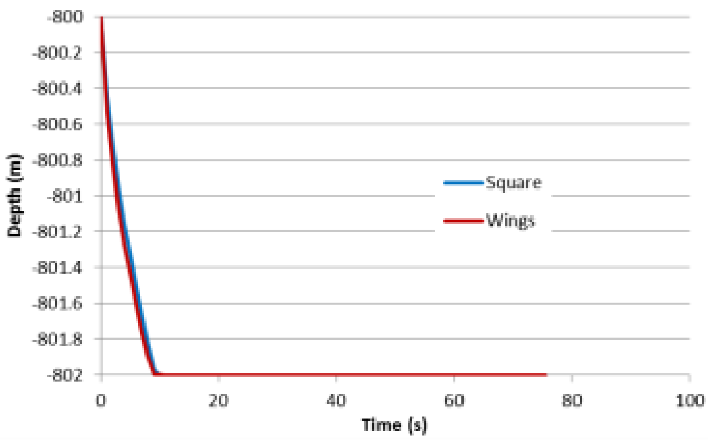
	Force per disk (daN)	Pressure per disk (kg/cm²) assuming 5 mm penetration	Swept surface
1 disk 400x100 mm per meter	203/81=2.5	2.5/(44x100)=0.06	
2 disks 400x50 mm per meter (conception Figure 1)	203/162=1.25	1.25/(44x50)=0.06	double

Initial objective to divide the force by 2 with the new trawl is roundly reached (Table 19) as this value can be divided by 6 when no difference in bridle length is used.

III.6.6 Simulation of a depth increase for the light trawl

We propose to assess the effect of a local depth increase of 2 m. The objective is to compare the time needed by the two footropes (standardl and light) to be in contact again with the seabed once, for any reason, the contact has been lost.

First, we simulate the fishing action. Then, at the time t=0 the depth increases of 2 m (800 m → 802 m). Finally, we report the immersion of the square middle and of the wings middle against time (Figure 10 and Figure 11).



[4] Prediction of the vertical forces applied on the seabed by a trawl gear" F. Théret (Scapêche Lorient), B. Vincent (Ifremer Lorient). ICES WGFTFB 2012.

Figure 10: Sinking time for initial gear (10 kg/m).

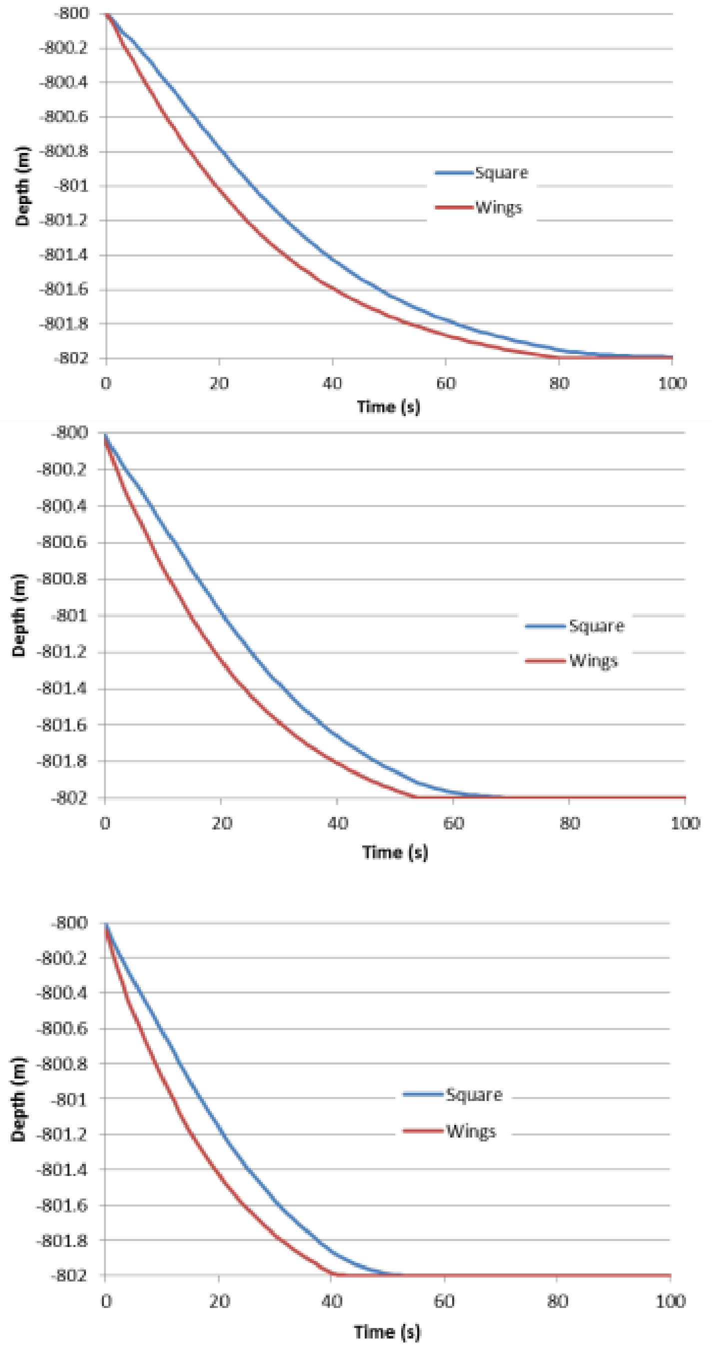


Figure 11: Sinking time for initial light gear (2.5 kg/m) and different bridle adjustments (+ 0 cm, + 10 cm, + 20 cm for lower bridle).

Graphs show that the time needed by the initial design to reach the seabed is around 9 seconds. Time needed by modified configurations is between 80 and 40 seconds. From these results, we can conclude that in the case of a seabed with significant relief, the contact between foot gear and seabed will be often lost.

However, considering configuration of fishing grounds this kind of relief seams rather unlikely.

III.7 EFFECT OF WARP LENGTH/DEPTH RATIO ON THE FORCE APPLIED BY DOORS ON THE SEABED

In order to minimize the impact of door shoes on the seabed, we propose to study the effect of the warp length/depth ratio. We test the light gear configuration but there is no sensitive effect of trawl adjustments on doors behaviour. So these results can also be applied to the off-bottom trawl concept. The Table 24 below presents the force applied by door shoes on the seabed for different warp length and different towing speeds. The fishing depth is 800 m.

Table 24: Door force on the seabed for different shooting ratio and different towing speeds.

Ratio warp length/depth	Towing speed (knots)	Force on the seabed (daN)	Door to door distance (m)
2.09 (- 5 %)	2.9	342	169
	3.1	95	172
	3.3	off	177
2.2 (+ 0 %) Reference ratio	2.9	612	171
	3.1	364	175
	3.3	25	178
2.31 (+ 5 %)	2.9	881	172
	3.1	634	177
	3.3	315	181

Notice the added lifting force due to substratum action on the door shoes is not taken into account by these simulations. Thus door to door distance is probably underestimated for large forces on the seabed. However, the objective is to minimize this force.

Results (Table 24) show that the 2.2 ratio is good compromise: doors are just about lifting off when towing at maximum speed. This situation will reduce shoes friction and consequently shoes wear. It will also reduce the fuel consumption as the friction force reduces. For instance, towing force reduces of about 4 % between ratio 2.31 at 3.1 knots and ratio 2.09 at 3.1 knots. Increasing the ratio will lead to large, useless and detrimental friction. Reducing the ratio will lead doors to leave the bottom before 3.3 knots.

III.8 CONCLUSION OF THIS SECTION

The objective of the study was to design and test by the mean of numerical simulations a concept of trawl that has reduced impact on the seabed for deep fishing. Off-bottom trawling has been chosen as an obvious solution to reduce the seabed contact.

In order to simplify the technology used onboard, the netting part of the trawl remains unchanged (i.e. reference trawl) and the modification only relates to the footrope. The new footrope is designed so that its weight in the water makes the whole fishing gear floating. Its weight in the water is around 25 % of the standard footrope weight in the water. Thus, whatever its towing speed, in a permanent configuration, the footrope always remains off bottom. Simulations show the footrope distance to the seabed can be continuously adjusted from 0 to 1 meter and more. Adding floatation can help to increase this distance.

In particular dynamic configuration, due to vessel motion, a proportion of the footrope can occasionally be in contact with the seabed. However, simulations show this situation could only be reached in extreme weather conditions. A comparison with the reference trawl shows that its footrope remains in contact with the seabed for reasonable vessel motion, in the meantime the off-bottom trawl always remains off bottom. Seabed relief is not simulated. The question of deployment, particularly the time needed to get the off-bottom trawl stabilized over the seabed is studied: simulations show the “shooting time” is about 10 % longer than for the standard trawl.

In the case the off-bottom trawling is not satisfactory in term of fishing efficiency; an intermediate light trawl solution has been studied. This light trawl always remains in contact with the seabed but with a minimum pressure. Once again, this pressure is adjustable by adjusting the difference between bridle lengths. Depending on this adjustment, the average footrope weight on the seabed can continuously be adjusted from about half the footrope weight of the standard trawl to an off-bottom configuration, where the trawl hass no contact with the bottom.

In both configurations (off-bottom and light trawl), sweeps have about 70 % of their length in contact with the seabed. Warp length/depth ratio has been examined in order to minimize the pressure of door shoes on the seabed.

IV FLUME TANK REPORT

The objectives of these flume tank tests are to validate simulation results obtained in task 1.1 with the software DynamiT. The trawl model is made according to the original plan and the rigging adaptations are made according to the numerical results of simulation.

The tests were realized in variable trawling speeds, and with a different length difference between upper and lower bridles, according to option 1 described in the simulation report. We have observed the influence of those parameters on the trawl net geometry, as well as on the footrope height over the bottom (photos in Annex 5: Particular behaviours of the fishing gears in flume tank (photo).

IV.1 IMPLEMENTED MEANS

IV.1.1 Flume tank

The tank (Figure 12 and Figure 14) has a capacity of 180 cubic meters of fresh water with a maximum speed of 1.2 meters per second. The 10 meters long observation area (Figure 13) has a 6 meters long rolling belt and is 2.6 meters wide with a depth of 1.6 meters.

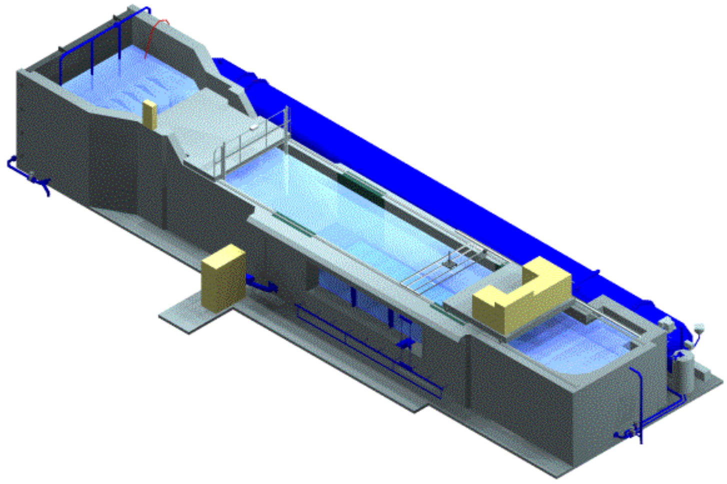


Figure 12: General view of the flume tank.

Figure 13: Observation area.

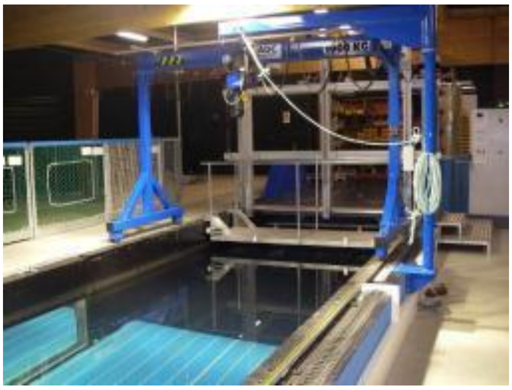


Figure 14: Upper part of the flume tank.

As the flume tank's width is 2.6 meters, model scale has been set to 1/40. This reduction allows the gear (trawl, bridles, first part of sweeps) to position itself correctly in the tank.

IV.1.2 Trawl scale model characteristics

The Figure 15 below presents trawl model characteristics:

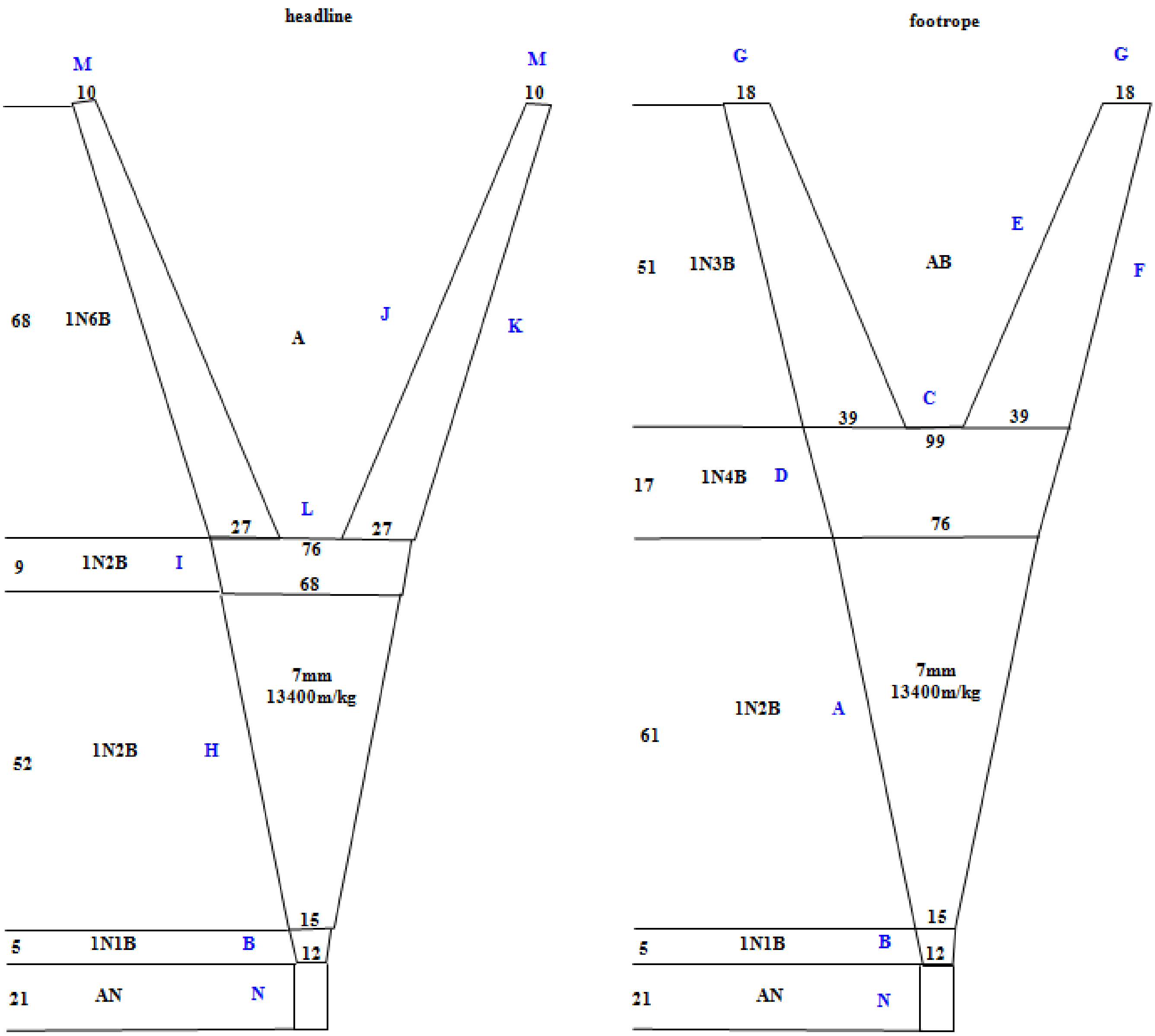


Figure 15: Trawl scale model characteristics.

IV.1.3 Rig characteristics

The Figure 16 below presents rig characteristics and Table 25 gives the meaning of different symbols used in the figure.

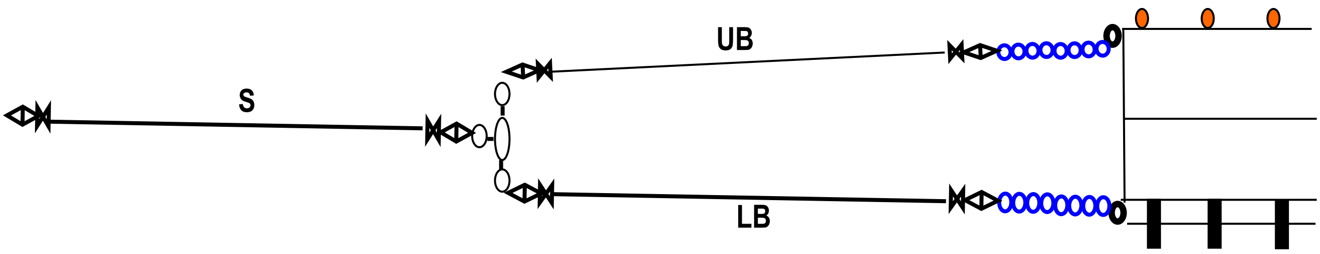
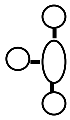


Figure 16: Rig characteristics.

Table 25: Descriptions of the symbol used to describe the rig characteristic.

Description	Symbol	Characteristics
Triple swivel		Between bridles and sweep Weight in water = 0.55 g
Length adjustment plastic chain		Upper chain = 14 links (5 mm each) Lower chain = 15 links (5 mm each)
Ring		Between bridles and trawl
Rubber bobbin		D = 10mm Weight in water = 0.05 g
Clip-swivel		Fixed at each extremity of bridles and sweeps
Float		F = 0.29g for D = 9 mm F = 0.70g for D = 12 mm
Upper bridle	UB	Steel rope R = 9 kg
Lower bridle	LB	Steel rope R = 12 kg
Sweep	S	Steel rope R = 12 kg

Moreover:

- Upper bridle length (with clip-swivels and without adjustment chain) = 1.0 m. Total weight in water = 1.0 g.
- Lower bridle length (with clip-swivels and without adjustment chain) = 1.0 m. Total weight in water = 1.1 g.
- Sweep length (with clip-swivels) = 3.0 m. Total weight in water = 2.25 g.

- Headline buoyancy: 18 floats (9 mm) on each wing, 5 floats (9 mm) and 2 floats (12 mm) on headline bosom. Total buoyancy = 13.29 g. Total buoyancy amounts for the real trawl net = 850 kg.
- Lateral buoyancy (trawl body): the flume tank model is made of nylon netting, while the experimental trawl is made of polyethylene. To balance the difference of specific gravity between nylon netting and polyethylene netting, lateral buoyancy has been added. 2 floats (12 m) and 9 floats (9 mm).
- Footrope: 4 bobbins on footrope bosom, 24 bobbins on each wing. Total footrope weight in water = 2.6 g. Total footrope weight amounts for the real trawl net = 166 kg.

IV.2 TEST RESULTS

Taking into account the 1/40 reduction scale (Table 26), the whole sweep length cannot enter the flume tank. Thus only a sweep portion has been deployed in the flume tank: 3 m scaled sweeps (corresponding to 120 m real scale). The distance between these sweeps portions ends is 2.4 m (96 m real scale). The simulations show that the sweeps are on bottom when observing them at a distance of 120 m from the bridle connexion.

Table 26: Reduction scale between the model and the real trawl.

	Scale model	Real trawl
Bridle length (m)	1.0	40
Sweep length (m)	3.0	120
Distance between first parts of sweeps (m)	2.4	96

IV.2.1 Influence of bridles length difference

To evaluate different length influences of the bridles (Table 27) the speed was constant to 3.1 knots.

Table 27: Influence of bridles length difference.

Difference (upper bridle – lower bridle) (cm)	Middle footrope's height (cm)	Wing's footrope height (cm)	Vertical opening (cm)	Horizontal opening (cm)
- 2	0	0	14	80
- 1	0	0 – 0.5	15	80
0	0 – 0.5	0.5	17	80
+ 1	0,5	0.5 - 1	18	80
+ 2	1 – 1.5	1.5 - 2	18.5	80

At a constant speed, footrope height and vertical opening increase when bridle difference increase. We can observe same behaviour in simulation when using software DynamiT.

IV.2.2 Speed influence

Table 28: Speed influence: Difference (upper bridle – lower bridle) = + 2 cm.

Speed (knots)	Middle footrope's height (cm)	Wing's footrope height (cm)	Vertical opening (cm)	Horizontal opening (cm)
2.0	0.5	1 – 1.5	22	78
2.5	0.5 - 1	1 – 1.5	20	80
3.0	1	1.5 - 2	19	80
3.5	1.5 - 2	2 - 3	18	80
4.0	2	2.5 – 3.5	16	80

Table 29: Speed influence: Difference (upper bridle – lower bridle) = 0 cm.

Speed (knots)	Middle footrope's height (cm)	Wing's footrope height (cm)	Vertical opening (cm)	Horizontal opening (cm)
2.0	0	0 – 0.5	22	78
2.5	0	0 – 0.5	19	79
3.0	0 – 0.5	0.5	17	80
3.5	0.5	0.5 - 1	15	80
4.0	0.5	0.5 - 1	13	80

Table 28 and Table 29 show that when the speed increases, we can observe more distance between footrope and see bottom. In a same way vertical opening is decreasing. With difference 0 (same length for lower and upper bridles) the trawl net works close to sea bottom. With difference set to + 2 cm (80 cm in real conditions). The trawl net is clearly distant from the sea floor.

IV.2.3 Conclusion of this section

The objective of these flume tank tests was to confirm and validate results obtained with the numerical simulations (described above).

In the Table 30 below, we have compared in same conditions results obtained with flume tank model and with the simulations:

Table 30: Scale model behaviour.

Difference Model/simul	speed	Fishing line mean height from scale model (cm)	Fishing line mean height simulation (cm)	Vertical opening from scale model (m)	Vertical opening simulation (m)	Lower wings opening from scale model (m)	Lower wings opening Simulation (m)
0/0	2.9	0 – 20	3	7.0	5.4	31.6	29.5
0/0	3.1	0 – 20	2	6.8	4.9	32.0	29.8
0/0	3.3	0 – 20	2	6.4	4.5	32.0	30.2
1 cm/40 cm	2.9	20 – 40	73	7.6	6.1	31.6	29.3
1 cm/40 cm	3.1	40 – 60	79	7.2	5.6	31.6	29.6
1 cm/40 cm	3.3	60 – 80	80	6.8	5.1	32.0	30.0

Differences observed between scale model in flume tank and DynamiT simulations may come from several reasons:

- It is difficult to find materials for model (net, cables, floats, bobbin, etc.) exactly adapted for a very small scale fishing gear, with constant weight and volume properties. Thus it is difficult to respect to scale ratio for the weight in the water and the weight ratio is the most important parameter when it comes to floatability consideration.
- The tank bottom to fishing line length is not easy to measure as its mean value is between 0 and one centimetre. Moreover, all different parts of the footrope are not equally distant from the tank bottom.
- DynamiT has a known tendency to under estimate trawl vertical opening.

However, global comparison between tank trials and simulation are rather satisfactory as tendencies are well reproduced:

- Bridle length adjustment lead to comparable effect on the footrope and netting behaviour.
- Trawl behaviour for very low towing speed is well reproduced by tank trials (Table 30).

Thus, we can think that experimental trips will permit to validate this way to easily get an off-bottom trawl.

In addition, a number of papers about the modelling of nets for trawling have been written (Theret, 1993; Makarenko et al., 1998; Bessonneau and Marichal, 1998; Priour, 1999) and commercial codes for net design and simulation are available (e.g. DynamiT). However, even where these models take the seabed into account for the deformed shape of the net, they do not provide information on the detailed interaction of the gear components and the seabed. Moreover, they all consider the seabed is a flat and horizontal plane. In order to simulate the interaction of the fishing gear and the actual seabed with eventual relief, it is needed to simulate the sediment deformation (cutting, digging, moving processes).

Some researchers have examined the interaction between a tool and a granular material. Bohatier and Nouguier (2000) looked at a problem related to cutting processes using numerical simulations. Research undertaken by Zhao and Miedema (2001) concentrated on the finite element method where the cutting forces in saturated soils were simulated.

Later in the UE DEGREE project (2010), two models were coupled to solve (i) the deformation of the sediment (penetration depth of the gear and and pressure filed in the substrate) and (ii) the dynamics of the fishing gear components to predict it movement, only at the interface gear/substrate (Ivanovic, Neilson, O'Neill [5]). This model was applied to a roller clump and a door shoe and compared to sea trials with reasonably good success. These recent advances only concerns a small part of the fishing gear (and consequently a small portion of the sea bed) and is not yet applicable to completely solve the dynamic of the whole fishing gear.

Therefore this kind of simulation, out of the state of the art, was not used in the current project. However, in our simulations, the distance between the seabed and the footrope was the distance between the sweeps and the footrope. Consequently, in case of relief, this distance would be observed from the top of the cretes.

From the flume tank facilities point of view, different researches were undertaken. Laboratory based experiments were carried out in the EU-funded study TRAPESE (Paschen et al., 2000). A series of tests using the laser measurement technique were undertaken on a purpose-built test bed where investigation on the interference of the upper sediment layers by towed elements of beam trawl. Once again only individual trawl components were tested and these tests are not extensible to entire trawl gear.

[5] Ivanovic, A., Neilson, RD. & O'Neill, FG. (2011). 'Modelling the physical impact of trawl components on the seabed and comparison with sea trials'. Ocean Engineering, vol 38, no. 7, pp. 925-933.

V GEARS TO BE TESTED AT SEA

Two sea experiment trips were undertaken. These were dedicated to engineering trials and fishing efficiency evaluation (described hereafter) as well as to study the catchability and the discards in the conditions of deep-water fishing trips.

During the first experimental trip, two options were tested (i) the off-bottom trawl and (ii) the light ground or light contact gear. The first part of the experimental trips was dedicated to the technical aspects of operating such gears. To optimize the time planned at sea, some trials were conducted in shallow waters (between 200 and 400 m depth) in order to reduce the time of shooting and hauling the trawl.

When technical aspects have been solved the second experimental trip has been spent only to study the catch efficiency of those different gears on deep-water species at depthbetween 500 and 1 000 m depth.

V.1 OFF-BOTTOM TRAWLING

Different configurations have been tested during the study in order to manage two contradictory objectives (i) operating at a large distance from the seabed to ensure to avoid any contact with the bottom and (ii) operating very close to the seabed to ensure an efficient enough catchability on demersal species concerned.

In order to solve this problem three configurations have been tested related to different distances between the lower part of the gear and the seabed.

1. **Large distance from the seabed**

   The gear has operated at a large distance from the seabed. The intention was to achieve a distance of at least 10 m. If possible to stabilize the gear during the fishing operation, such a distance should prevent any damage with the bottom.

2. **Moderate distance from the seabed**

   Due to the demersal behaviour of deep-water species, it was expected that it was necessary to try to operate at a smaller distance from the bottom. We have considered moderate a distance approximately between 1 and 2 m. Such a distance should prevent damages in soft bottom, but a risk of accidental contact still exists in case of rock or container for example.

3. **Short distance from the seabed**

   That third configuration intended to stabilize the gear at a distance around 50 cm above the bottom. Using such a distance should ensure that the gear had no contact with the bottom but only in very soft and flat seabed. An important risk existed that the lower part of the gear sometimes had a contact with the seabed.

   The same gear has been used, so a gear with a weight equally distributed all around the footrope.

   If problems appeared during the fishing operation to stabilize the trawl at such a distance, an option has been to use the raised footrope already tested in for the Gulf of Maine (Pol, 2003) where the fishing line was raised by the attachment of a sweep chain (Figure 17) to the fishing line by a number of drop chains as illustrated below:

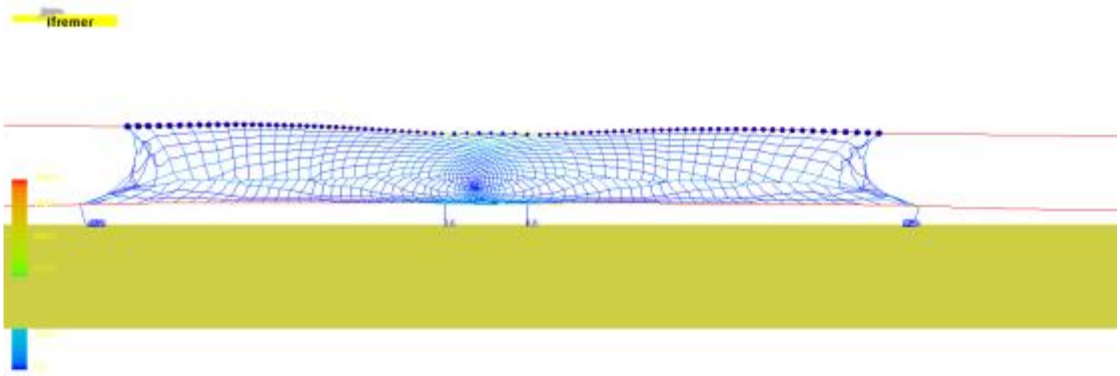


Figure 17: illustration of the use of drop chains used to stabilize the foot rope

Those different configurations and distances from the seabed could be adjusted depending on their feasibility and the results of the first part of the experimental trips (technical aspects).

The gear tested has been rigged with a very light footrope in order to prevent, during the experiments any damage in case of accidental contact with the bottom. That did not affect the catchability of the gear which was linked with its distance from the seabed and the results, as studied in precious section, have been applicable to most type of trawls, included trawls with no rockhopper or bobbins.

V.2 LIGHT TRAWL

V.2.1 General concept

The objective was to reduce impact by reducing force applied on the seabed and to have the possibility under special rigging arrangements to work with the gear off the bottom. The idea was to reduce at the lowest as possible the weight in the water of the rockhopper used on bottom trawl. Of course, the rockhopper has to be strong enough to be used in working conditions.

The main components of a rockhopper are rubber and iron. Due to the differences in density of those two materials: 7.87 for iron and 1.15 for rubber (the rubber commonly used for rockhopper) we can determine the multiplying coefficients to calculate the weight in the water from the weight in the air for each material which are respectively 0.87 and 0.13. For example the weight in the water of 10 kg of iron is 8.7 kg and the weight in the water of 10 kg of rubber was 1.3 kg.

For practical reasons, the rockhopper was divided in separate sections, the length of each of those sections being 9 m long. One section will be called “element” in the following text.

In order to produce an as light as possible footrope, the internal chain has been replace by Dyneema rope, and all the connections between the rockhopper and the trawl were also made with thin ropes. The weight and volume of rubber discs was also reduced. iron just rubber and Dyneema. In practice a few elements in iron were still used where it was impossible to substitute it by Dyneema or other synthetic fibers, for example for the connection between the different footrope elements.

The rockhoppers were built by Ets Le Drezen, a netmaker located in Le Guilvinec, France.

V.2.2 Standard rockhopper

A standard 9 m long element was made with 30 large discs (diameter 35 cm; thickness around 8 cm), smaller discs between the large and chain inside.

Another chain was used located trough the holes in the discs and the connection between the footrope and the netting was made by using connectors or shackles between the bolch line and that additional chain. The weight in the air of such footrope was 412 kg. Measured with the same sensor the weight in the water of that element was 126 kg.

In the water, and in absence of trawl, the vertical force applied on the seabed by each disc was 4.2 kg. When the trawl was connected to the rockhopper, during the fishing operation, it induced a vertical force on the footrope which could be estimated by using DynamiT software, around 0.5 kg.

We could conclude that for the standard footrope the vertical force applied on the seabed by each disc during the tow could be estimated at 3.7 kg.

V.2.3 Light rockhopper

V.2.3.1 Preliminary tests at sea of a very light footrope

Firstly, a very light footrope (Figure 18) was preliminary tested in June 2013 on a trawler in order to know if it was enough strong and resistant on the trawls commonly used at sea. It was made with thin rubber discs as shown below:

Figure 18: First version tested of light footrope.

Every meter there was a large standard disc and three thin discs. The thickness of the large elements was 7.4 cm and only 1 cm for the thin one. The diameter of the discs was 35 cm. A Dyneema rope was used instead the chain in the center of the rockhopper.

The intention, when building that rockhopper, was to be as closed as possible to the weight (in the water) tested during simulation made with DynamiT software in the first part of the project which was 2.5 kg per meter.

But after one fishing trip most of the thin discs presented damages and were more of less destroyed during fishing operations and handling on the net drum. The conclusion was it is not possible to use such footrope under commercial fishing conditions. Concerning Dyneema, no problems appeared when using the Dyneema rope instead the standard chain.

V.2.3.2 Choice of the model to be tested during the experimental trips

After exchanges with the netmaker, it was decided for practical reasons to strengthen the rockhopper. For an 9 m element, it was built with 27 discs (diameter 35 cm), 14 with a thickness of 7.4 cm and 13 with a thickness of 3.6 cm. There were set alternatively. Dyneema was used in the axis of the rockhopper. The rockhopper was linked with the gear by using small ropes.

The total weight in the air for a 9 m long element was 251.8 kg: 237.4 kg of rubber, 4 kg of Dyneema and 10.4 kg of iron. In the water, the predicted weight calculated using the density of the different material was only 40 kg. The rockhopper and its attachments with the trawl can be seen on the photos below (Figure 19 and Figure 20):

Figure 19: Light rockhopper.

Figure 20: Connection between the rockhopper and the bolch line with ropes.

V.2.3.3 Vertical force applied on the seabed by the discs

In the water, and in absence of trawl, the force applied on the seabed by each disc is approximatively 1.5 kg (weight in the water – 40 kg - of the footrope divided by the number of discs: 27). When the trawl was connected to the rockhopper, during the fishing operation, it induced a vertical force on the footrope which could be estimated by using DynamiT software, around 0.5 kg by disc.

We could conclude that for the light footrope the vertical force applied on the seabed by each disc during the tow could be estimated at 1.0 kg.

V.2.4 Reduction of impact in comparison with the standard footrope

The forces applied on the bottom by each disc being 1.0 kg for the light footrope and 3.7 kg for the standard rockhopper, we can consider that in comparison with the standard footrope the light version reduces the vertical force applied on seabed by 73 %. In addition by using 27 discs instead of 30 for one element, we also reduced the number of contact points with the seabed by 10 %.

V.3 PLAN FOR THE EXPERIMENTAL TRIPS

The Table 31 below details the objectives of the experimental trips and the way to get them.

Table 31: Plan for trials at sea during experiment trips

	Objective	Protocol	Sensors/monitoring
Engineering trials (200 to 500 m)	Determine the rigging adjustment to get the distance between footrope and sea bed between 1 and 2 m. Assess stability.	Iteratively modify the bridle difference (5 cm steps, following the simulation conclusions). Shoot the trawl and wait till it stabilizes.	Scanmar headrope, depth sensors mounted on the footrope.
	Determine the rigging adjustment to get the distance between footrope and sea bed at about 0.5 m. Assess stability.	Idem.	Idem.
	Determine the rigging adjustment to get the distance between footrope and sea bed at 0 m. In this case the light trawl is on the bottom. Assess stability.	Idem.	Scanmar headrope, depth sensors mounted on the footrope. Additional light chain will be mounted on the footrope to assess effective contact on the seabed (when in contact chains are shining).
	Repeat previous tests to fill possible lack of technical data where needed.		
Fishing efficiency trials Deep waters (1 000 m)	Test fishing efficiency trawling 10 m off the bottom. Assess sinking duration.	Keep the footrope about 10 m off the bottom by the mean of warp length during the haul duration. This test will not have been done for shallow waters. Observe catches Repeat for 3 hauls	Scanmar headrope sensor is used to monitor the distancebetween the footrope and the seabed. 4 additional depth sensors are attached along the footrope.
	Test fishing efficiency of trawling 1-2 m off the bottom. Assess sinking duration.	Adjust rigging length determined in shallow-water trials. Observe catches during 3 hauls.	Scanmar and depth sensor monitoring.

	Objective	Protocol	Sensors/monitoring
	Test fishing efficiency of a trawling half a meter off the bottom.	Adjust rigging length. Observe catches during 3 hauls.	Scanmar and depth sensor monitoring. Contact chains on foot gear.
	Test fishing efficiency of an on bottom light gear trawl.	Adjust rigging length. Observe catches during 3 hauls.	Scanmar and depth sensor monitoring. Contact chains on foot gear.
	Repeat previous tests to fill possible lack of catch data where needed	3 hauls	Scanmar and depth sensor monitoring.

Scanmar sensor had to be mounted at the vertical of the footrope to maximize chances to get the foot gear echo.

Notice catch data were probably be relatively poor regarding the available number of hauls. The idea to assess catch efficiency was to rely on fishermen expertise in such deep-water fishing, comparison with previous fishing trips and comparison with another trawler from the same company fishing in the same area.

V.4 CONCLUSION OF THE TWO PRELIMINARY STUDY PHASES

The objective of the two preliminary study phases (numerical simulation and flume tank trials) was to design and test a concept of deep-water fishing trawl that has reduced impact on the seabed. Compared to the standard trawl, this new trawl was simply equipped with a light footrope which weight in the water was about a quarter of the standard one.

The numerical simulation tool offered the possibility to adjust any parameter of the trawl, but in order to simplify the work onboard, the adjustment of bridle lengths difference had been chosen. Thus it was possible to continuously adjust the distance between the seabed and the footrope.

The flume tank trials were undertaken in order to validate the simulation and to offer a didactic mean of description and discussion to fishing company. The difficulty to get particular materials such as thin netting and scaled rubber pieces or floats, made it tricky to build perfectly scaled trawl model. Some additional floats were added on the riblines to correct the floatation of the netting for instance. The scaled trawl model footrope distance off the bottom had a length ratio of about 100 which made it uneasy to accurately measure the footrope distance off the flume tank bottom.

However, tank trials were in good agreement with simulations: the footrope distance off the bottom increased when the upper bridle length was increased. The whole footrope was off the bottom whatever the towing speed. Other options could be used to control this distance:

- additional floats,
- additional weight,
- use of synthetic ropes rather than steel cable,
- etc.

The next steps were experimental trips in order to validate the process. All information was available from these 2 preliminary phases to optimize the engineering trial protocol.

VI DEEP-WATER EXPERIMENTAL TRIPS ABOARD "MARIETTE LE ROCH II"

VI.1 OBJECTIVES AND METHODOLOGY OF THE EXPERIMENTAL TRIPS

A light trawl has been designed and evaluated by the mean of numerical simulation and flume tank trials (results presented above). During these tests, it was shown that this light trawl can be adjusted so that its footrope is lifting off the seabed to avoid physical impact on habitats and sediment. It can also be adjusted to keep its footrope on the seabed, but with lower pressure and consequently lower impact than for the standard trawl.

Following the design and modeling phase, two experimental trips have been organized to realize field tests.

- The objective of the first experimental trip was to validate the capacity to operate a trawl with an adjustable distance of its footrope over the seabed.
- The objective of the second experimental trip was to validate the catchability of the light trawl and to increase the number of fishing operation in order to collect more data.

The first experimental trip was conducted from September 30th to October 6th 2013 aboard the fishing vessel *Mariette Le Roch II* (LO924826), a 46 m trawler owned by Scapêche and fishing for deep-water species. The team embarked on the vessel was composed by the three following persons:

- François Theret (Scapêche),
- Benoit Vincent (Ifremer),
- Fanchon Varenne (as observer - COFREPECHE).

The second experimental trip was conducted from November 23rd to December 1st 2013 aboard the same fishing vessel. The team embarked on the vessel was composed by the two following persons:

- François Theret (Scapêche),
- Quentin Le Bras (as observer - COFREPECHE).

In both experiments, the vessel started from Lochinver (Scotland).

VI.1.1 Trawls

The so called "light trawl" was a standard trawl where the standard footrope has been replaced by a light footrope. This light footrope compares to the standard footrope as follows:

- The central rope is made of a dyneema rope instead of steel chain;
- The number of rubber disks has been reduced, so as to reduce the weight and drag; and
- The links from the footrope to the fishing line is made of textile ropes instead of chains.

The mean weight in the water (apparent weight) of the light footrope was 5 kg/m instead of 10 kg/m for standard footrope. This light trawl can be used with or without tickler chain.

The standard trawl has standard footrope, which apparent weight in water was about 10 kg/m. The tickler chain was always used with the standard trawl.

The tickler chain was made of 13 mm chain covered with 100 mm rubber disks.

The so called off-bottom trawl was the light trawl operated off the seafloor.

VI.1.2 Sensors and measurement

VI.1.2.1 Door angle meters

Inclinometers were attached to each door in order to measure their depth and attitude (pitch and roll angles). The objective was to verify and control doors behaviour to explain possible difficulties observed at the trawl level. No particular anomaly was observed about door behavior.

VI.1.2.2 Footrope to seabed distance monitoring

Two devices were used to monitor the distance between the footrope and the seabed: the headrope Scanmar sensor and a dedicated contact sensor mounted on the footrope.

VI.1.2.2.1 Scanmar sensor

The Scanmar headrope sensor was used the measure the so called clearance, which is the distance between the footrope and the seabed, with a resolution that can be estimated to 10 cm. This sensor was positioned at the vertical of the footrope, instead of the usual place on the headrope.

VI.1.2.2.2 Dedicated sensor

A dedicated sensor was attached in the middle of the square (mid part of the footrope) to indirectly measure the distance of the footrope to the seabed:

Figure 21: Dedicated sensor used to measure the distance between the footrope and the seabed. One of the steel bars was twisted once (for tow 21, bottom right picture). The lead mass appeares to be used regularly which ensures its contact with the seabed (top right picture).

This sensor (Figure 21) consisted in a 2 m long bar weighted with a plumb at an end and equipped with an autonomous angle meter at the other end. The system was designed so that the plumb was in contact with the seabed. The distance was deduced from the angle and the bar length. This system was particularly suitable for short distances measurement (80 cm maximum).

The measurement of the distance on the bridge was done to calibrate the sensor before the trawl was shoot. This calibration value was used to correct the measurements during the tow.

This sensor was based on accelerometers. Thus, it naturally produced very noisy measurements. In order to present a smooth signal, a mobile average was performed on 20 measurements (i.e. 20 seconds as one measurement is done every second). This number of measurements has been chosen so that the "reference tow" (tow 20, Figure 21) showed a realistic behaviour with non-negative distance over the seabed. The choice was confirmed with occasional realistic footrope landing during other tows with light trawl. The footrope square motion period observed with this smoothing method also seems to be realistic. Thus, the seabed nature (soft or hard) could also significantly affect the information logged by this sensor.

VI.1.3 Organisation of the first experimental trip

Commercial and meteorological constraints led us to start the cruise in the area where the fleet carry out deep-water hauls. As it was decided before the experimental trip, sensors range was chosen so that privileging the precision against the maximum reachable depth. It was also decided to operate trawl modifications/measurements during the part of the experimental trip in shallow waters, when tow duration is much shorter than in deep waters.

21 fishing operations have been performed. The detailed of the testing process is shown in the following table (Table 32). Thus, no measurement was done during the first part of the cruise. The second part of the cruise (tow 11 to 21) was used to carry out measurements.

Table 32: Summary of tows made during the first experimental trip.

Tow #	Light trawl	Standard trawl	Tickler chain	Instrumentation	Landings weight (kg)
1	X add weights		X		2 060
2	X				2 130
3		X	X		3 355
4		X	X		5 038
5	X			(S)	2 092
6	X		X		3 224
7	X			S	1 921
8	X off-bottom			S	51
9		X	X	S	1 706
10	X		X		2 857
11		X	X		19 985
12	X		X	S P	4 186
13	X		X	S P	425
14	X diff 60 cm			S C P V	6 445
15	X		X	S P	3 259

Tow #	Light trawl	Standard trawl	Tickler chain	Instrumentation	Landings weight (kg)
16		X	X		16 615
17		X	X		451
18	X			S C P V	235
19	X diff 100 cm			S C P V	230
20		X	X	S C V	11 293
21		X	X	S C	16 604

S = sounds, C = contact, P = depth, V = video

VI.1.4 Organisation of the second experimental trip

The second experimental trip was conducted between the 22th of November and the 1st of December of 2013. Half a day has been spent the first day to prepare the light trawl by changing the footrope.

The gears tested were the off-bottom and the light trawls. The goal was to study the catchability of those gears in comparison with the standard trawl. The fishing operations were conducted under usual commercial conditions. No specific measurement were done and the only sensors used were those from the onboard scanmar equipment. Common standard measurements concerned the door spread, the vertical opening and the clearance (distance between the footrope and the seabed).

When leaving the harbour the vessel received information from the UK authorities. A part of the fishing grounds was closed because there were exercises of the UK navy in that area. So, it was impossible to work in the southern part of the common fishing grounds where most of the catches of roundnose grenadier are commonly conducted. As usual in that period of the year, most of the trip was conducted under bad weather conditions. During one day, the vessel was in the obligation to lie to, due to stormy conditions. It was not possible, for safety reasons, to operate the gears with a wind speed of more than 50 knots and waves more than 8 meters.

In spite of the bad weather 39 fishing operations have been performed. The detailed elements of the tows are presented in the following table (Table 33):

Table 33: Summary of tows made during the second experimental trip.

Tow #	Light trawl	Off-bottom (distance from seabed)	Standard trawl	Haul targeting deep-water species	Haul duration	Landings weight (kg)
1	X			X	7h00	3 706
2	X				3h15	6 158,5
3			X		4h05	7 454,5
4		X (3m)		X	3h15	118,5
5		X (4-5m)		X	2h	39

Tow #	Light trawl	Off-bottom (distance from seabed)	Standard trawl	Haul targeting deep-water species	Haul duration	Landings weight (kg)
6	X			X	5h25	3 383
7	X			X	4h20	1 405
8	X			X	4h15	2 449,5
9		X (10 m)		X	2h20	23,5
10		X (7 m)		X	2h30	0
11	X			X	3h55	1 671,5
12	X				3h00	6 303
13	X				2h25	4 917,5
14	X				1h55	1 635,5
15		X (6 m)		X	2h30	25
16			X	X	6h25	1 411
17			X		2h45	1 974
18			X		3h20	6 489,5
19			X		2h55	3 646
20			X		2h30	1 391,5
21		X (6 m)		X	2h20	23,5
22	X			X	6h10	1 870
23			X		3h40	1 297,5
24			X		2h55	2 911
25			X	X	6h00	4 155,5
26			X	X	6h00	2 631
27	X			X	6h55	2 626,5
28			X	X	6h00	3 617
29	X				1h35	151,5
30			X	X	5h30	1 535
31			X	X	6h00	1 624
32			X		2h20	1 638
33			X		3h25	3 960
34			X		2h25	1 092,5
35			X		2h20	731

Tow #	Light trawl	Off-bottom (distance from seabed)	Standard trawl	Haul targeting deep-water species	Haul duration	Landings weight (kg)
36			X		2h15	368,5
37			X	X	5h40	1 555,5
38	X			X	3h55	4 782
39	X				2h30	2 016,5

The Annex 7: Détails des résultats de la deuxième campagne en mer) presents all the details of this second trial at sea.

VI.2 RESULTS OF THE FIRST EXPERIMENTAL TRIP

Data collected with sensors are analysed to evaluate the distance from the seafloor to the footrope. Scanmar sensor provides a coarse indication which simply confirms the values given by the dedicated sensor.

VI.2.1 Scanmar sensor

For each trial with the off-bottom configuration (using bridle length adjustment), Scanmar sensor always showed a non-zero clearance value (Figure 22).

Figure 22: Scanmar screen showing the clearance value ("C 0.0" meaning clearance = 0 meter, also illustrated by the white line that would be off the red line in case of non nul clearance) during a trial with the light trawl adjusted to be towed off the bottom. On this diagram, the vertical trawl opening decreases of about 1 meter with no influence on the clearance.

This result is confirmed by the data collected with the dedicated contact sensor.

VI.2.2 Contact sensor

Five tows (tows number 14, 18, 19, 20 and 21) were monitored with the contact sensor (Table 33) for tows chronology). Tow 21 is not valid for this measurement because the contact sensor was damaged during the tow.

Four graphics are presented hereafter to show the averaged footrope height (distance between the lower part of the footrope and the seabed).

- The time axis starts before the trawl is shoot so that the contact senor can be calibrated while it is on the vessel deck.
- The red line shows the depth of the footrope in meters (right scale in meters). This depth measurement is useful to find the different tow phases and their duration (start shooting, trawl sinking, trawl landing on the seabed, and trawl taking off the bottom when hauling, etc.).
- The green line shows the distance between the lower part of the footrope disks and the seabed (left scale en meters). The distance has been corrected using calibration on the vessel deck. This line is quite noisy as it is based on accelerometers, sensitive to vibrations. Thus it is needed to smooth these measurements.
- The blue line is a 20 seconds (20 measurements) mobile average of the footrope to seabed distance. One can find the effect of the calibration at the beginning of the time line: distance is around 0 m on the deck.

Tow 20 used as reference tow was made with the standard trawl (Figure 23). Thus, we expect a distance close to zero for the standard trawl. One can observe a slight drift of the zero value after 22h40. This drift of about 10 cm is probably due to the sensor attachment creep on the footrope. For this tow, we assume the footrope is in contact with the seabed most of the time with vertical average motion amplitude of about 10 cm.

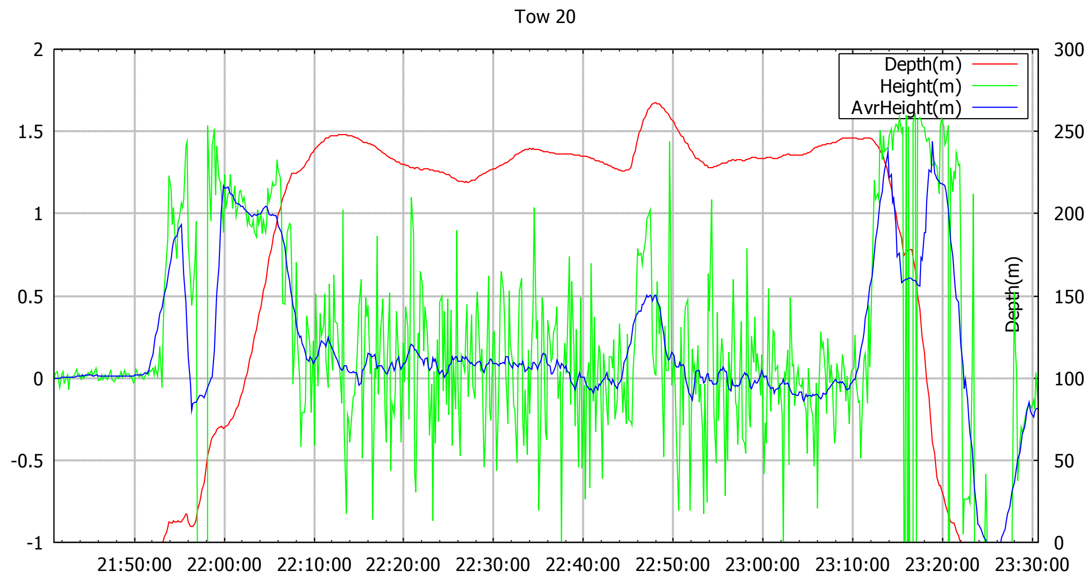


Figure 23: Reference tow with the standard trawl, distance off the bottom of the footrope (green line, left axis), moving average of the distance (blue line,left axis) and depth (red line, right axis) logged for tow 20.

The tow number 18 was made with the light trawl and no difference in the rigging, i.e. no attempt to lift it up by adjusting the bridles length (Figure 24). The trawl seems to be off the bottom most of the time for the average method used to calculate this average distance. A lower number of points to calculate the average height would bring to different conclusion (more contacts with the seabed).

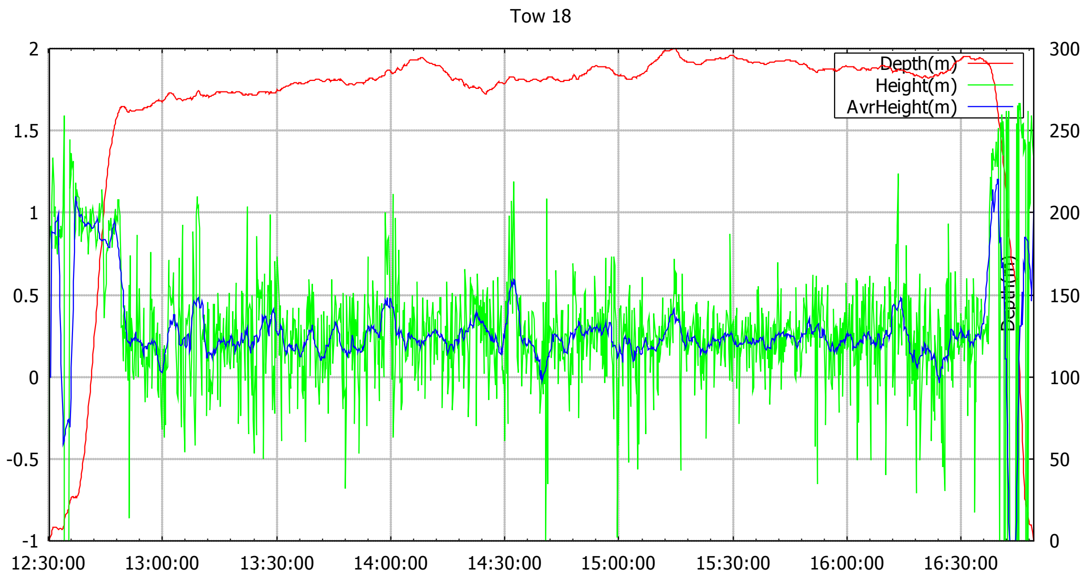


Figure 24: Light trawl with standard rigging, distance off the bottom of the footrope (green line, left axis), moving average of the distance (blue line,left axis) and depth (red line, right axis) logged for tow 18.

The next two tows (tow 14 and tow 19) are attempts to lift the trawl off the seabed. For tow 14, the lower bridle is lengthened of 60 cm. For tow 19, it is lengthened of 100 cm. These adjustments should have led the ground gear to lift off the bottom from several tens of centimeters, with amplified effect for tow 19 (Figure 25, Figure 26). Occasionally, when the trawl falls in a canyon, the contact sensor shows the ground gear losing its contact with the seabed (e.g. 21:30 on Figure 25, with a fast increase in depth of 42 meters).

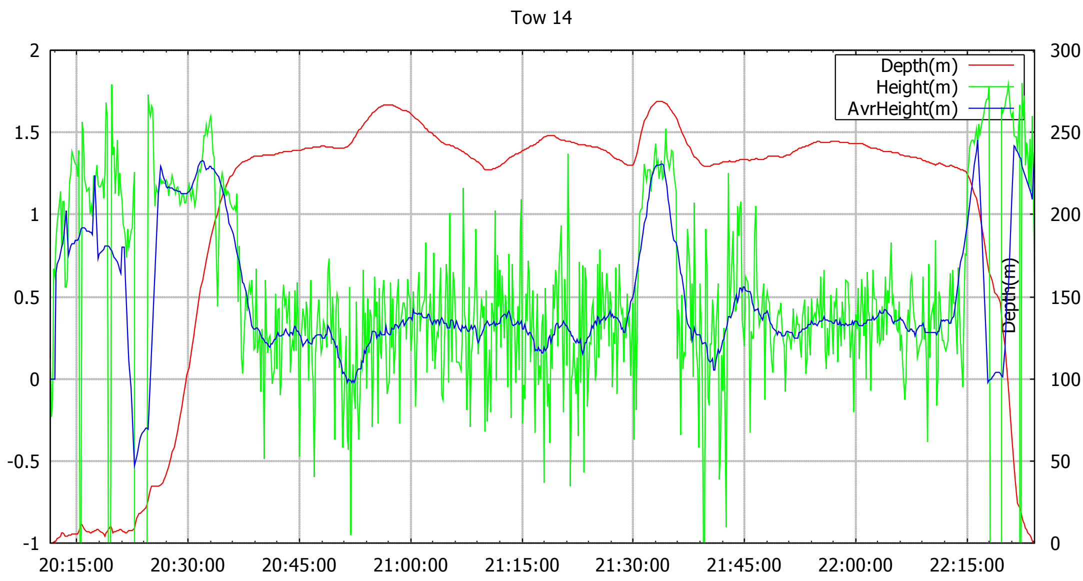


Figure 25: Light trawl with attempt of lifting off (bridle difference 60 cm), distance and depth logged for tow 14 (legend as in previous figures).

Figure 26: Light trawl with attempt of lifting off (bridle difference 100 cm), distance and depth logged for tow 19 (legend as in previous figures).

However, one will observe there is no significant difference in distances for these two tows. Surprisingly, two 14 seems to show a ground gear higher than for tow 19. We can conclude the adjustment of bridle length does not make it possible to adjust the ground gear height over the seabed in the tested configuration, particularly with the higher weight of the actual footrope compared to the weight of the numerically simulated and scaled model footropes.

VI.2.3 Conclusions

A part of the first experimental trip was dedicated to engineering trials to validate the possibility to control the height of the footrope over the seabed. Different trials with different adjustments of the novel light trawl were done during the experimental trip, and compared to the standard trawl behavior.

Trusting the measurement means, we observed that the footrope of the light trawl has an erratic behavior over the seabed with probably less frequent contacts on the seabed than for the standard trawl, even when bridles are not adjusted to lift the trawl off the bottom.

When trying to lift the footrope off the seabed, we observe there is no significant difference between the footrope heights over the seabed for the standard rigging and increased bridle difference. We obviously observe that the light trawl s towed at an unstabilised distance over the seabed with possible periods off bottom and on bottom. It is clear that the height of the footrope cannot be controlled with such a trawl configuration and footrope weight. The information given by the Scanmar sensor confirms the low distance between the footrope and the seabed.

However, the lighter footrope has reduced impact on the seabed compared to the standard footrope due to lower contact time on the seabed and its lower weight.

It must be noticed that the trawl initially tested by the mean of numerical simulation and flume tank trials hhad a significantly lighter footrope than that built and tested during this experimental trip. This difference in weight in the water, by a factor of close to 2, probably explains the impossibility to control the distance between the seabed and the footrope.

Sizing and simulations of the off-bottom trawl were done several months (around November of 2013) before the first sea trials.

Sizing was done with the collaboration of the net maker to be sure weights used for the footrope were suitable with practical use. Later (June of 2013), a series of trials aboard a Scapeche vessel were done to test the mechanical resistance of a single portion of the light footrope. After these trials it was decided to resize the footrope to make it stronger. We naturally got a heavier footrope. Some additional simulations were done to verify the new gear was still light enough to be lifted off the seabed. Simulation showed there still was a potential to lift the gear off the bottom, but with lower distance from the seabed. Finally, during the first experimental trip (October of 2013) we were not able to observe a significant distance. We assume this difference between simulations and field observations comes from uncertainties originated in the theoretical model and/or in the trawl characteristics (weights not taken into account or weight information not valid).

VI.3 RESULTS OF THE SECOND EXPERIMENTAL TRIP

The main part of the experimental trip was dedicated to fishing for deep-water species. Close to 100 h of fishing has been spent on deep-water fishing grounds. Fishing time must be understood as the time when the gear is in contact with the seafloor when using bottom trawls or close to the seafloor when using the off-bottom trawl.

Following the results of the first experimental trip, it was decided to give the priority to test the catchability of the off-bottom and light trawl in comparison with standard trawl.

VI.3.1 Technical comments

Off-bottom trawl trials:

Six tows have been operated during the experimental trip with the off-bottom trawl.

Generally it was difficult to stabilize the gear close to the seabed. During the 2 first tows the skipper tried to work with a distance of 3 to 5 m above the bottom. In practice, that distance was too low and some contact of the footrope with the seabed occurred during the fishing operation (during around 15 mn during the first and around 10 mn during the second tow). Following those observation, during the 4 other tows the skipper has tried to operate the gear at a distance of 6 to 10 m of the bottom. Operating with such distance, no more contact with the bottom appeared during the tests.

Due to bad weather conditions, it was not possible to tow the trawl off the bottom durign the second part of the trip. In those conditions, such as at the end of the last off-bottom haul, the trawl would be moving from 0 to 20 m from the bottom. If the use of such gear was required, it should be necessary to have onboard automatic equipment regulating the length of the warps and/or the towing speed based on constant measurement of the distance between the footrope, or at least the otterboards, and the seafloor.

Light trawl:

Concerning the use and the geometry of the gears, no difference appeared between the light trawl and the standard trawl. The only difference between the two trawls being the footrope the unknown was the resistance of the Dyneema rope used instead of the chain inside the light footrope.

After the two experimental trips where the light gear was used approximately half the fishing time, no one problem or damage has been observed. Due to the lighter weight, it is easier for the crew to manipulate the Dyneema footrope in comparison with the standard, but that point is not important for such size of trawler.

If the light or Dyneema footrope seems to have the same resistance than a standard one, the longevity should be tested during at least half a year before deciding any definitive conclusion.

VI.3.2 Catch analysis of the gears tested

Results concerning the catches are analyzed in section VII "Catch and economic Analysis".

VI.4 DIFFERENCES BETWEEN TESTED GEARS AND STANDARD GEAR IN TERM OF COST

Following this two experimental trips, it was possible for the vessel owner to compare the impacts in term of "working time", "fuel consumption" and "cost of gear". These differences are detailed below. It is also important to interpret these differences with caution. Indeed two experimental trips carried out during an experimentation cannot be compared to traditional fishing campaigns.

VI.4.1 Differences in term of working time

The modified gear (footrope) changes nothing in term of working time for the crew on board. Thus, no change in the time spent to repair trawls was observed. Furthermore, the working time following a tow depends mainly on the volume of catches which are highly variable from one tow to another. Overall, during the experimental trips the modified trawl did not change the volume of catches. At the end, we can consider as equivalent the working time between the light trawl and the standard trawl.

In general, the working time information is not precisely recorded during fishing trips. It is anyway very variable from one trip to another, and depends on both the catches variations during the year and on the weather conditions. Studying working time on a single trip doesn't make sense; there should be data from a significantly larger period of time to be able to draw any conclusion.

VI.4.2 Differences in term of fuel consumption

The modified gear does not modify fuel consumption. Except a light reduction of the friction on the bottom, all the other parts of the gear were the same than those of the standard trawl. On the other hand, the bad weather conditions encountered make it impossible, to draw any detailed analysis on this point. Globally, we can consider that the fuel consumption is not changed with the light trawl in comparison with the standard trawl.

VI.4.3 Differences in term of cost of gear

The cost of the footrope tested on the light version of the trawl was the same as a standard footrope. So, concerning the gear we can conclude that the cost of the modified trawl is the same as the standard trawl.

VI.4.4 Specific case of the off-bottom trawl tested during the experimental trips

When towing the light trawl off the bottom, alterations of working time for fishermen and cost of gear are highlighted:

"Working time": we can estimate that due to the very low level of catches the working time is reduced by a factor at least of 20 when fishing for deep-water species.

"Cost of gear": for a trawler similar to the trawler used during experimental trips if an off-bottom trawl had to be bought, the cost, including the otterboards and the rigging, could be estimated around 75 000 €. In addition it is not possible on such a trawler to use both an off-bottom and a bottom trawl, because only one type of otterboard can be used during the same fishing trip. Finally, as observed during the experimental trips, it is very difficult to stabilize the off-bottom trawl closed to the seabed when fishing in the deep water, especially in bad weather conditions. The use of an automatic system (so called "active trawl"), which can stabilize the gear in order to maintain a fixed distance between the footrope and the seafloor appears necessary. Such device is not currently available on the market and is in an early development stage so its cost is not known.

VI.4.5 Conclusion of this comparison

All the above points being the same for both bottom trawls (standard and modified), comparisons between the two trawls must be based only on the catches realised by each of them. However, considering the case of a trawler in particular is not representative, especially during an experimental trip. It would be more relevant to compile and compare data from the entire deep-water fishing fleet.

So we do not have the elements to make a comparative table and if we had we could not draw any conclusions because those elements do not represent fleet fishing for deep-water species (very bad weather conditions, trawler non representative of all the French or European fleet fishing for deep-water species, specific behavior of the vessel during the experimental trips). At this stage, we can only conclude the modifications made on the bottom trawl tested do not affect the cost of the fishing gear, the working time of the crew or the fuel consumption.

VII CATCH AND ECONOMIC ANALYSIS

VII.1 INTRODUCTION

New riggings of trawls used in deep-water fisheries were proposed to reduce their impact on the seafloor. The analysis presented in this report aims at describing and comparing the catches realised with the various settings in order to assess the potential loss and/or benefit in terms of catch volume and composition.

VII.2 MATERIAL AND METHOD

VII.2.1 Data collection

VII.2.1.1 Sampling scheme

Two experimental trips were conducted, the first from September 30th to October 06th of 2013, was dedicated to the technological settings of the modified trawl gear (but catch data were also collected on the landing fraction). Four gear configurations were tested and compared:

1. the standard gear with tickler chains;
2. the modified light trawl without tickler chain used as a bottom trawl;
3. the modified light trawl with tickler chains used as a bottom trawl; and
4. the modified light trawl used as an off-bottom trawl, i.e. towed a few meters above the seafloor.

The second experimental trip, from 23/11/2013 to 01/12/2013, was dedicated to the sampling of the catch for three gear configurations:

1. the standard trawl with tickler chains;
2. the modified light trawl with tickler chains used as a bottom trawl; and
3. the modified light trawl used as an off-bottom trawl, i.e. towed a few meters above the seafloor.

In both experimental trips, hauls were categorised according the depth and main target species. Some hauls were towed in deep waters (usually > 600 m) and targeted deep-water species (e.g. *Aphanopus carbo, Coryphaenoides rupestris and Molva dypterygia*), whereas some others were conducted in shallower waters, either targeting saithe (*Pollachius virens)* or hake (*Merluccius merluccius)* (Figure 27 a and b).

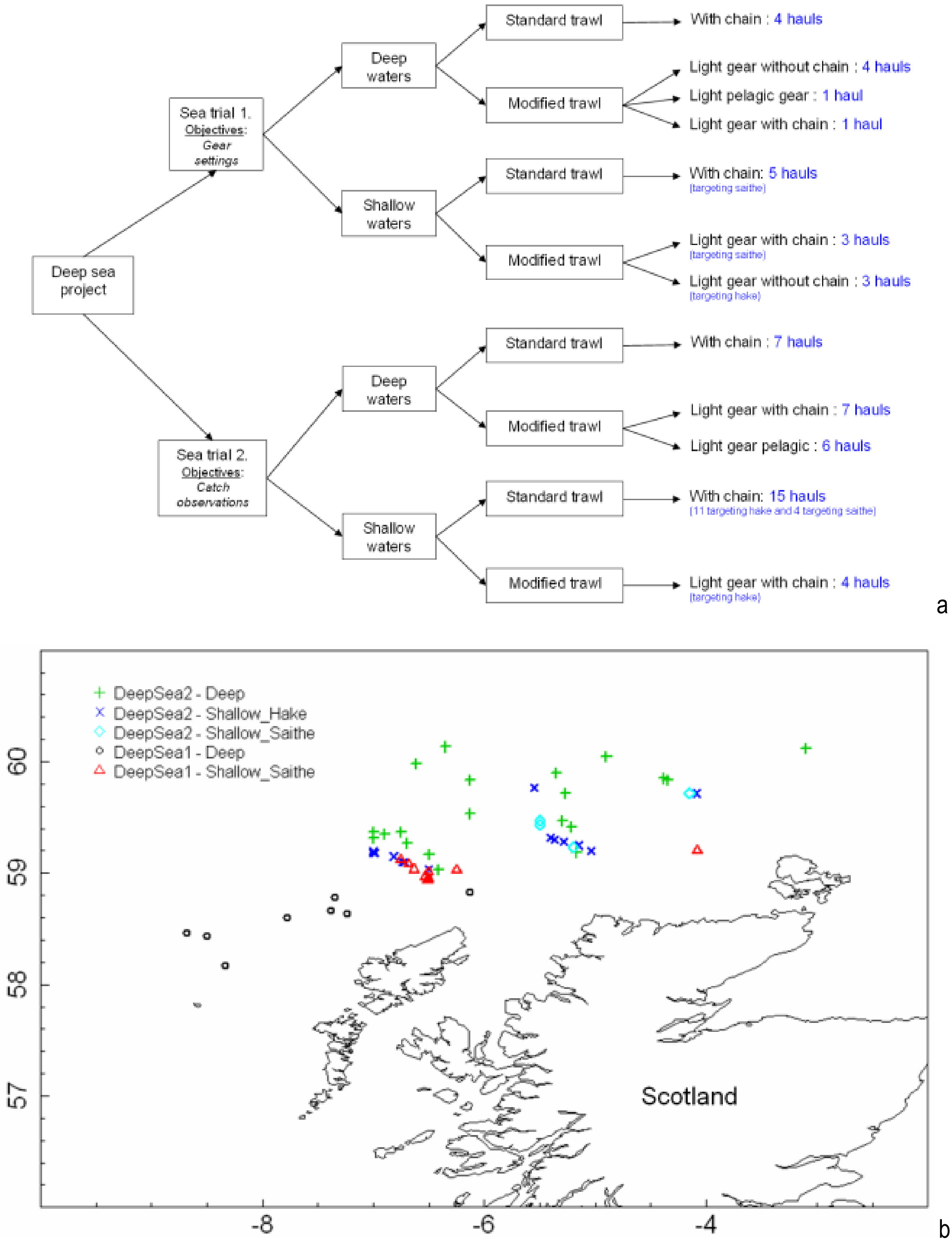


Figure 27: a: Sampling scheme of the two experimental trip: number of hauls carried out according to the gear configuration and target species. b: location map of all hauls carried out during the two experimental trips.

VII.2.1.2 Onboard observations

Durinf the first trial, the priority was given to the settings of the new gears. Various options were tested in order to keep only the most satisfactory ones for the second trial. This first trial, dedicated to technical tests, resulted in a small number of hauls per configuration. Landings data were collected from logbook, but unfortunately, sampling problems occurred and discards data could not be collected rigorously. Therefore they were not used in our analysis.

For the second experimental trip, the sampling scheme enabled to conduct more hauls with the selected configurations (light trawl used as an off-bottom trawl, light and standard trawls towed on the seafloor) (Figure 28). During the second trip, special attention was given to the catch and both the landed and discarded fractions were observed.

The catch observations were done according to the *Obsmer* protocol, i.e. the protocol defined under the national catch observation program[6]. Basically, the commercial fraction was sampled once crew members finished sorting out the catch. For each haul and commercial species, a sample was weighed and the total weight of each landed species was recorded. For the discarded fraction, a representative sample of mixed species was observed. However, the large volume of catch combined to the sorting process onboard of the vessel entailed a specific discards sampling methodology. The dicards were sampled from the end of the fish conveyer once commercial fish were removed by the crew. The time necessary to fill up a basket of discards was recorded, as well as the time required by the crew to sort all the catch. Assuming the discards were homogeneously spread on the fish conveyer, the total discards weigth per haul was obtained from the following equation:

$$Total\_Discards\_Weight = \frac{Duration\_of\_total\_catch\_sorting}{Duration\_of\_discards\_sampling} * Weight\_of\_discards\_sample$$

Species were then sorted and weighed from the sample. The species proportions as well as the species weight in each fraction of the catch were obtained from sampling ratios and total weights (Figure 28). Data relative to the haul such as mean depth, duration and position were also recorded.

6 *http://sih.ifremer.fr/content/download/5587/40495/file/Manuel_OBSMER_V2_2_2012.pdf.*

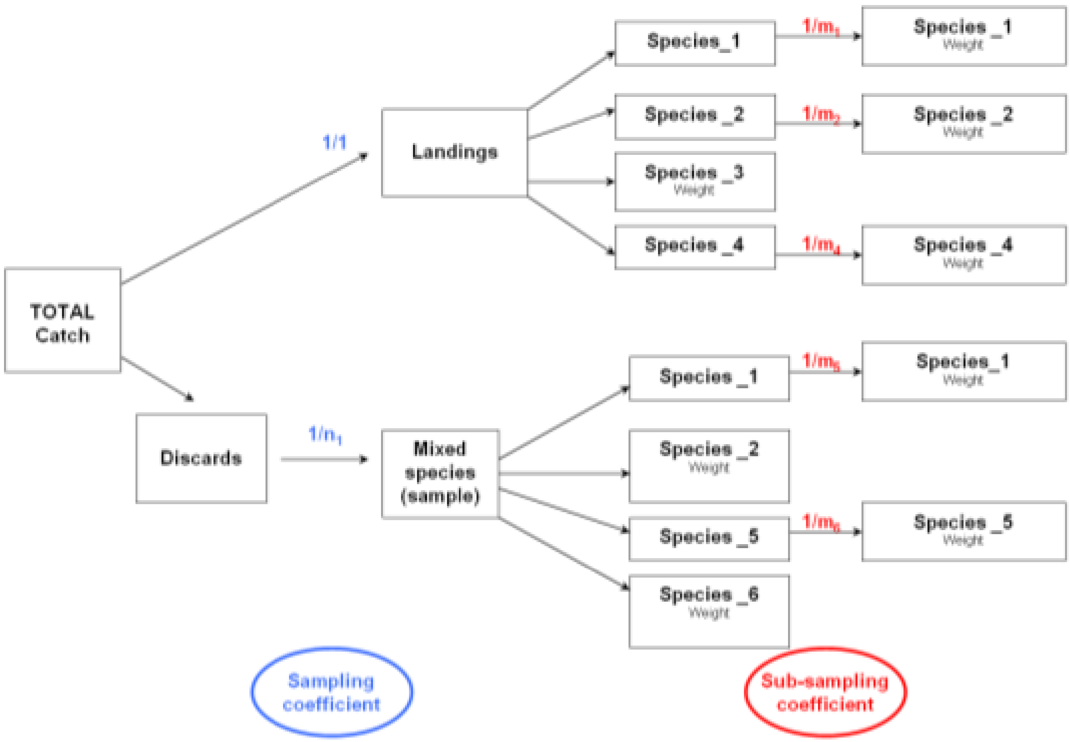


Figure 28: Sampling procedure onboard for landed and discarded fractions, 1/n and 1/m being respectively sampling and sub-sampling coefficient.

VII.2.2 Data analysis

The data were analysed separately for the two experimental trips. Each gear configuration was compared to the standard one, for both hauls targeting deep-water species and hauls carried out in shallow waters targeting hake and saithe separately.

VII.2.2.1 Data preparation and exploration

Weights per species were collected on board for each species and fraction (either discards or landings). Contrary to discards, landed individuals were gutted. Therefore, a conversion factor was applied to the gutted weight to get fish total weight (Table 34).

In order to compare landings' and discards' weights of commercial species caught during the experimental trips, conversion factors available from the EU list were used[7]. The calculation of conversion was necessary to compare landings' and discards' weights of commercial species.

[7] *http://ec.europa.eu/fisheries/cfp/control/conversion_factors/index_en.htm.*

Table 34: Coefficients of conversion between entire weight and weight of commercial presentation.

Common name	Scientific name	Conversion factor
Saithe	*Pollachius virens*	1.19
Black scabbardfish	*Aphanopus carbo*	1.48
Roundnose grenadier	*Coryphaenoides rupestris*	1.11
Blue ling	*Molva dypterygia*	1.17
Ling	*Molva molva*	1.14
Hake	*Merluccius merluccius*	1.11
Rabbit fish	*Chimera monstrosa*	1.18
Ray	*Raja sp.*	1.21
Rockfish	*Sebastes sp.*	1.19

The haul duration was not constant along the sea trials, therefore catch data were standardised, presented and compared per unit of hour (catch/haul duration = kg/h). For that, the total weight of the landed fraction (i.e. gutted weight x conversion factor) and the observed discards weight were used.

The species compositions of the discarded and landed fractions were described graphically. Hauls carried out in deep waters were pooled to calculate species proportion in each fraction of the catch. The same was done for hauls carried out in shallow waters.

VII.2.2.2 Catch comparison

The catch comparison between gears was carried out at two levels: mean total catch per hour were compared statistically across gear tested, and then, mean catch per hours were plotted per species and gear.

i) Comparison of total catch weight between gears (experimental trips 1 and 2)

Because of the variability occurring in the catches and the non-normal distribution of their weight, the non-parametric test Mann-Whitney was used to test any significant difference between gears in terms of total catch weight (for both landed and discarded fractions, all species together).

ii) Comparison of main species weight between gears (experimental trip 2)

The mean species catch weight was computed over all hauls carried out separately with the light and standard gears. This was done only with data from the second sea trip since discards data were not available from the first one. The mean catch weights per hour were plotted for the 20 main species caught during that sea trip. This operation aimed at checking any trend, if exists, of the capacity of the tested gears to catch demersal or benthic species.

NB: All hauls were taken into account even if a given species was not present in the catch. However, it is not known if the absence of the species was due to its absence on the fishing ground or if it is because the gear was not efficient in catching it.

VII.2.2.3 Obsmer comparison

Catch data obtained from the standard trawl were compared to the data collected under the national observation program on board of commercial vessels (*Obsmer*).

This comparison aimed at validating the representativeness of the hauls carried out during the two experimental trips (*ie.* is the order of magnitude of catch observed with the standard gear used during the *DeepSea* trips consistent with the ones observed usually with the same gear under the *Obsmer* program). Therefore, to make consistent comparison and to avoid bias due to fishing area, fishing season and type of vessel, commercial trips observed from the French on-board observation scheme were selected based on the following criterias :

- commercial vessels with size equivalent as the *Mariette Le roch II* (2 such were vessels availablein the data base. This criteria was used to make catch volume comparable);
- commercial fishing trips operated in the West Scotland (ICES Division VIa);
- commercial fishing trips from the fourth quarter (only years 2009 to 2012 were available).

As assumptions of normality of the data were almost always violated, non-parametric Mann-Whitney statistical test was used to compare catch from experimental trips and those from observed commercial trips. The test was performed on catches per hour, separately for hauls targeting hake, saithe and deep-water species.

VII.2.2.4 Economical analysis

This section aims at comparing the mean gross sales generated from each gear type for each target species.

The *Obsmer* data used for the above comparison were used to define a usual sea trip in terms of mean number of hauls per target species and mean haul duration (Table 35). From this information, we propose to consider as a 'usual' sea trip pattern, a trip in which 10 hauls would target hake, 10 hauls would target saithe and 10 hauls would target deep-water species. We also consider that a deep-water species haul last about 6 hours and shallow-water hauls last about 3.5 hours.

Table 35: Distribution of number of hauls and mean haul duration (minutes) for each target species during the hauls selected from the on-board observation programme.

Target species	Saithe		Hake		Deep-water species	
Obsmer sea trip code	Mean haul duration (*min*)	Number of hauls	Mean haul duration (*min*)	Number of hauls	Mean haul duration (*min*)	Number of hauls
2298249			208	19	378	11
2298257			296	30		
4461947	203	11	187	10	330	12
7196228			214	10	359	10

Gross sales (GS) were calculated for every experimental trips carried out in the present project and every selected observed commercial trip . The prices used are those observed at the fishmarket of Lorient for *Mariette Le Roch II*. They were averaged accross the period January-November 2013 (Table 36) and were then multiplied by the landings weights (Equation 1:).

Equation 1:

$$GS_h = \sum_{i=1}^{n} (p_i * w_{i,h})$$

Where:

GS is Gross Sale,

h is the haul number,

p the mean price of species *I*, and

w the weight of species *i* in haul *h.*

Table 36: Mean price of the species landed during the *DeepSea* trips, from January to November 2013 at Lorient fishmarket for the *Mariette Le Roch II* vessel.

Comon name	Scientific name	Mean prices (€)
Blackbelly rosefish	*Helicolenus dactylopterus*	1.5
Rockfish	*Sebastes sp.*	1.5
Black scabbardfish	*Aphanopus carbo*	3.37
Arctic skate	*Amblyraja hyperborea*	1.86
Ray	*Raja sp.*	1.65
Rockling	*Gaidropsarus sp.*	2.05
Common mora	*Mora moro*	1.36
Hake	*Merluccius merluccius*	2.6
Ling	*Molva molva*	2.45
Blue ling	*Molva dypterygia*	2.45
Witch flounder	*Glyptocephalus cynoglossus*	1.26
Saithe	*Pollachius virens*	1.38
Roundnose grenadier	*Coryphaenoides rupestris*	1.7
Greenland halibut	*Reinhardtius hippoglossoides*	4.19

Comon name	Scientific name	Mean prices (€)
Squid	*Loligo vulgaris*	2.73
Haddock	*Melanogrammus aeglefinus*	1.8
European conger	*Conger conger*	0.89
Rabbit fish	*Chimera monstrosa*	0.55
Megrim	*Lepidorhombus whiffiagonis*	1.8
Black cardinal fish	*Epigonus telescopus*	1.54
Tusk	*Brosme brosme*	1.5
Angler	*Lophius sp.*	4.9

The gross sales per haul was then re-sampled randomly with replacement 10 times for each combination of *gear type x target species*, to simulate a fishing trip with 10 hauls targeting each of the 3 species (deep-water species, hake and saithe). The gross sale of the 30 hauls were then summed. This procedure was repeated 1000 times in order to compare the gross sales according to gear type and target species (Figure 29).

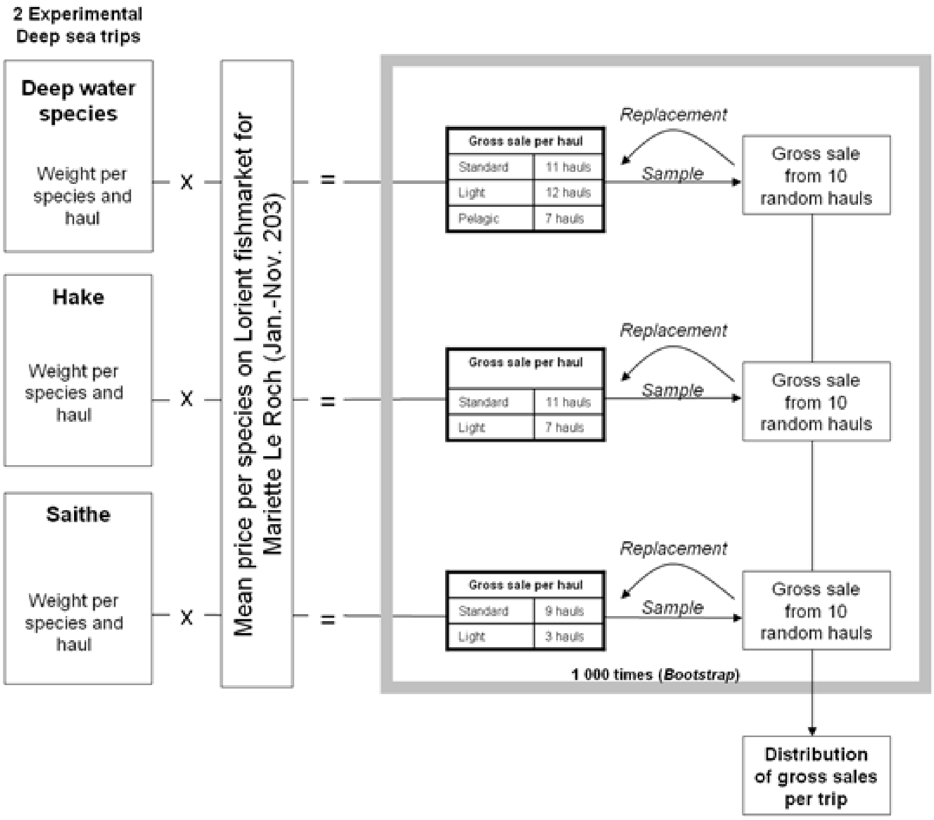


Figure 29: process of gross sale calculation and re-sampling method considering standard sea trip made of 10 hauls targeting deep-water species, 10 hauls targeting Hake and 10 hauls targeting saithe.

VII.3 RESULTS

VII.3.1 Catch analysis

VII.3.1.1 First experimental trip

VII.3.1.1.1 Haul summary

21 hauls were carried out during the first experimental trip (Table 37). 10 of them targeted deep-water species and the 11 others targeted saithe. Since this trial was dedicated to technological settings, several trawl configurations were tested (off-bottom, light with tickler chain, light without tickler chain and standard).

Table 37: Summary of hauls carried out during the first experimental trip. Gear type: L = Light trawl, P = Pelagic for off-bottom trawl, S = Standard trawl. Target species: Sa = Saithe, D = Deep-water species. * = absence of tickler chain on the trawl.

Haul Number	Gear type and target species	Duration (h)	Depth (m)	Gutted commercial catch (kg)	Commercial catch total weight
1	S-D	7:23	1074	2060	2725
2	L*- D	7:00	1074	2131	2869
3	S- D	5:15	1030	3356	3719
4	S- D	7:05	1030	5038	5620
5	L*- D	6:25	1002	2092	2499
6	L- D	5:50	922	3224	3683
7	L*- D	7:05	925	1921	2707
8	P*- D	2:45	914	52	76
9	S- D	6:10	1119	1707	2108
10	L*- D	6:30	773	2858	4104
11	S-Sa	2:20	215	1996	2375
12	L- Sa	2:35	282	4186	4980
13	L- Sa	2:50	299	425	475
14	L*- Sa	1:30	222	6450	7676
15	L- Sa	1:25	218	3259	3869
16	S- Sa	1:25	212	16616	19772
17	S- Sa	3:10	264	452	284
18	L*- Sa	3:40	257	236	269
19	L*- Sa	2:25	203	230	263
20	S- Sa	0:55	232	11294	13439
21	S- Sa	1:25	246	16605	19758

VII.3.1.1.2 Commercial catch summary and gear comparison

The landings per hour are presented for each haul carried out in deep (Figure 30) and shallow (Figure 31) waters. In deep waters, the mean landings per hour for the light trawl with and without tickler chain, the standard trawl with tickler chain and the off-bottom trawl were respectively 631, 453, 553, and 28 kg/h (Table 38).

In shallow waters, the mean landings per hour for the light gear without chain, the light gear with chain and the standard gear were respectively 1 766 kg/h , 1 609 kg/h and 8 735 kg/h Table 38). Hauls N°16, 20 and 21 presented high catch values for a short duration of tow, mainly due to the presence of saithe aggregation in shallow waters.

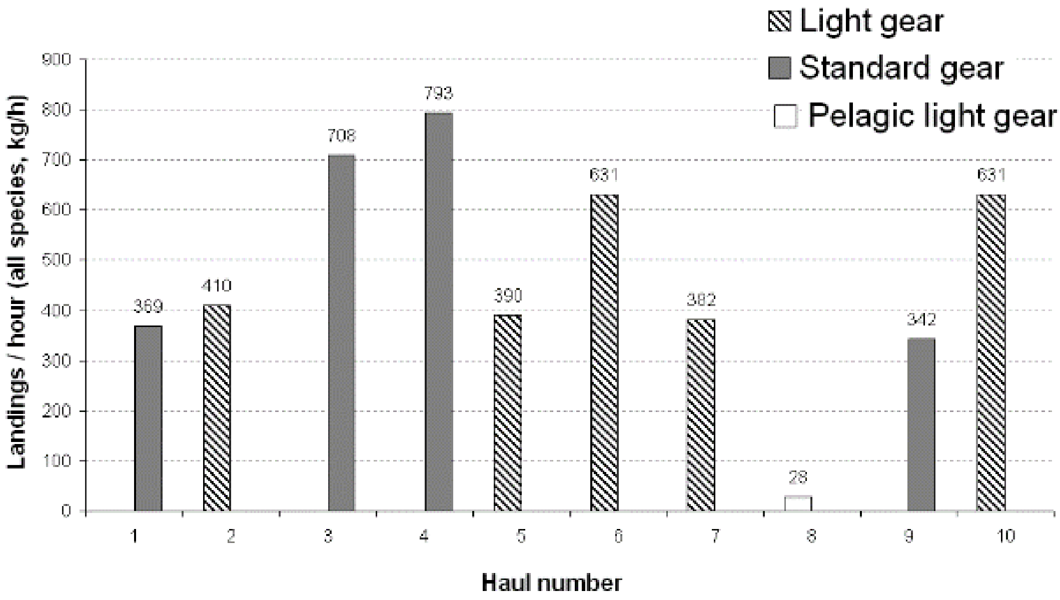


Figure 30: Landings (kg) per hour per fishing haul (deep-water hauls only) during the first experimental trip

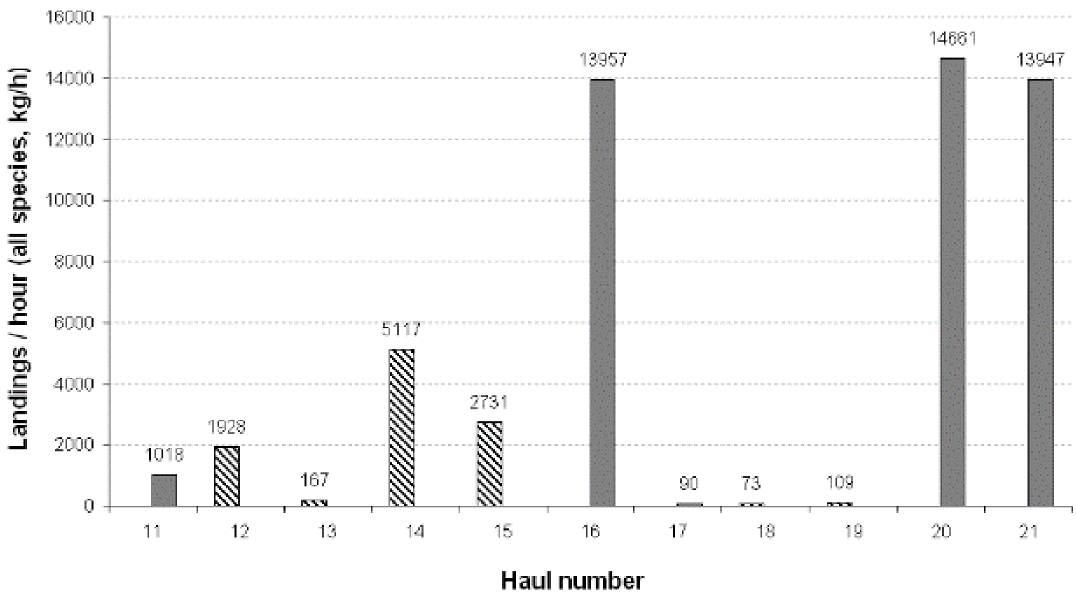


Figure 31: Landings (kg) per hour per fishing haul (shallow-water hauls only) during the first experimental trip

The Mann–Whitney test indicated that there is no significant difference between catches from the light gear without chain and the standard gear, neither for deep- or shallow-water hauls ($p > 0.05$). However, the high variability observed and the small numbers of hauls do not guaranty high robustness of the test.

Table 38: Summary of landed fraction according to the various trawl configurations tested during the first experimental trip.

	Light gear with chain	Light gear without chain	Standard gear with chain	off-bottom trawl
Deep waters				
Mean commercial catch/hour (kg/h)	631	453	553	28
Standard deviation	NA	119	231	-
Number of hauls	1	4	4	1
Shallow waters				
Mean commercial catch/hour (kg/h)	1609	1766	8734	-
Standard deviation	1311	2902	7481	-
Number of hauls	3	3	5	-

VII.3.1.1.3 Landed fraction - Species composition

The landings from deep-water hauls were mainly composed by *Coryphaenoides rupestris* and *Aphanopus carbo*, which represented respectively 56 and 36 % of the cumulated landed fraction. The other 8 % were composed of 7 commercial species (Figure 32).

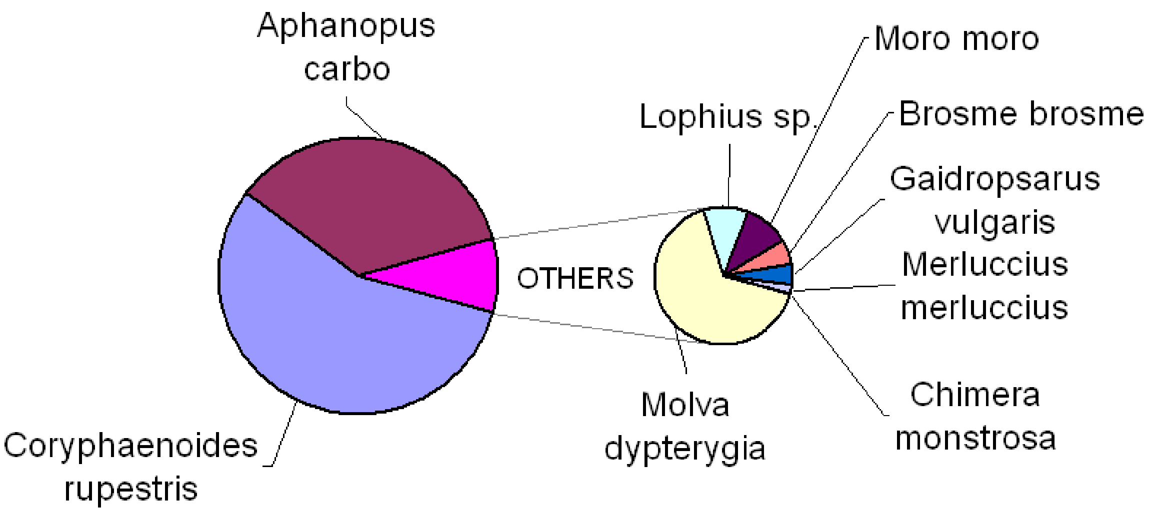


Figure 32: Species composition of landed fraction from deep-water hauls during the first experimental trip.

98 % of the landings from shallow-water hauls were *Pollachius virens*. The other 2 % were composed of 7 commercial species (Figure 33). The discard fraction data were not collected during this first experimental trip, only the by-catch of a basking shark (*Cethorinus maximus*) was recorded in haul 6.

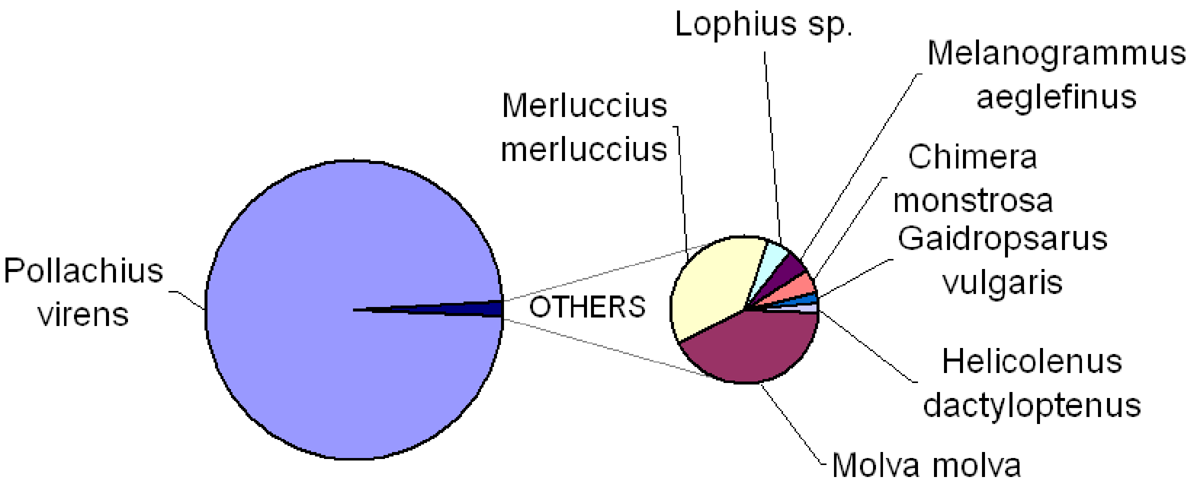


Figure 33: Species composition of landed fraction from shallow-water hauls during the first experimental trip.

VII.3.1.2 Second experimental trip

VII.3.1.2.1 Haul summary

39 hauls were carried out during the second experimental trip (Table 39). 20 of them targeted deep-water species and the 19 others targeted shallow-water species either hake (15 hauls) or saithe (4 hauls). Three gear configurations were tested: 13 hauls were conducted with the light trawl, 9/13 targeted deep-water species and 4/13 targeted hake. 22 hauls were conducted with the standard trawl: 8/22 targeted deep-water species, 10/22 targeted hake and 4/22 targeting saithe. 4 hauls were conducted with the light trawl operated as an off-bottom trawl and only deep-water species were targeted with this trawl rigging. The mean discard rate observed was 27 % (standard deviation σ = 16) for the deep-water species hauls, 7 % (σ = 6) for hake hauls and 22 % (σ = 13) for saithe hauls.

Table 39: Summary of hauls from the second experimental trip. Gear type: L = Light trawl, P = Pelagic (for off-bottom trawl), S = Standard trawl. Target species: H = Hake, Sa = Saithe, D = Deep-water species. * = absence of tickler chain on the trawl.

Haul Number	Gear type and target species	Duration (h)	Depth (m)	Gutted commercial catch (kg)	Commercial catch total weight (kg)	Discarded fraction (kg)	% of discards
1	L-D	07:00	800	3706	4113	1308	24
2	L-H	03:15	290	6169	6963	300	4
3	S-H	04:05	330	7455	8356	2501[1]	23

Haul Number	Gear type and target species	Duration (h)	Depth (m)	Gutted commercial catch (kg)	Commercial catch total weight (kg)	Discarded fraction (kg)	% of discards
4	P*-D	03:15	620	119	129	67	34
5	P*-D	02:00	850	75	83	30	27
6	L-D	05:25	675	3383	3716	1536	29
7	L-D	04:20	600	1405	1531	1664	52
8	L-D	04:15	625	2499	2785	1251	31
9	L-D	02:20	750	25	28	30	52
10	L-D	02:35	1050	0	0	0	0
11	L-D	03:55	900	1672	1915	556	23
12	L-H	03:00	280	6303	7155	200	22
13	L-H	02:25	305	4918	5474	177	3
14	L-H	02:00	290	1635	1831	80	4
15	P*- D	02:35	815	25	30	37	55
16	S-D	06:25	800	1411	1637	979	37
17	S-H	02:45	260	1974	2310	190	8
18	S-H	03:20	290	6490	7308	262	3
19	S-H	02:55	325	3646	4054	170	4
20	S-Sa	02:30	250	1391	1599	100[1]	39
21	P*-D	02:20	690	25	30	10	25
22	L-D	06:10	850	1870	2172	415	16
23	S-H	03:40	230	1298	1490	127	8
24	S-H	02:55	290	2911	3284	139	4
25	S-D	06:00	600	4156	4622	435	9
26	S-D	06:00	580	2631	3030	144	5
27	L-D	06:55	625	2627	2829	309	10
28	S-D	06:00	580	3617	4207	176	4
29	S-Sa	01:35	195	152	157	50	24
30	S-D	05:30	765	1535	2180	1221	36
31	S-D	06:00	720	1624	2167	1866	46
32	S-H	02:20	260	1638	1715	100	6
33	S-H	03:25	300	3956	4327	228	5
34	S-H	02:25	325	1093	1181	57	5
35	S-Sa	02:20	225	775	797	105	12
36	S-Sa	01:45	185	369	384	50	12

Haul Number	Gear type and target species	Duration (h)	Depth (m)	Gutted commercial catch (kg)	Commercial catch total weight (kg)	Discarded fraction (kg)	% of discards
37	S-D	05:40	790	1556	2159	711	25
38	S-H	03:55	520	4269	4721	319	6
39	S-H	02:30	300	2017	2173	66	3

VII.3.1.2.2 Landed fraction – Species composition and quantities

The landings from shallow-water hauls were mainly composed by *Merluccius merluccius* and *Pollachius virens*, which represented respectively 69 and 22 % of the cumulated landed fraction from all shallow hauls. The other 9 % were composed of 13 commercial species (Figure 34).

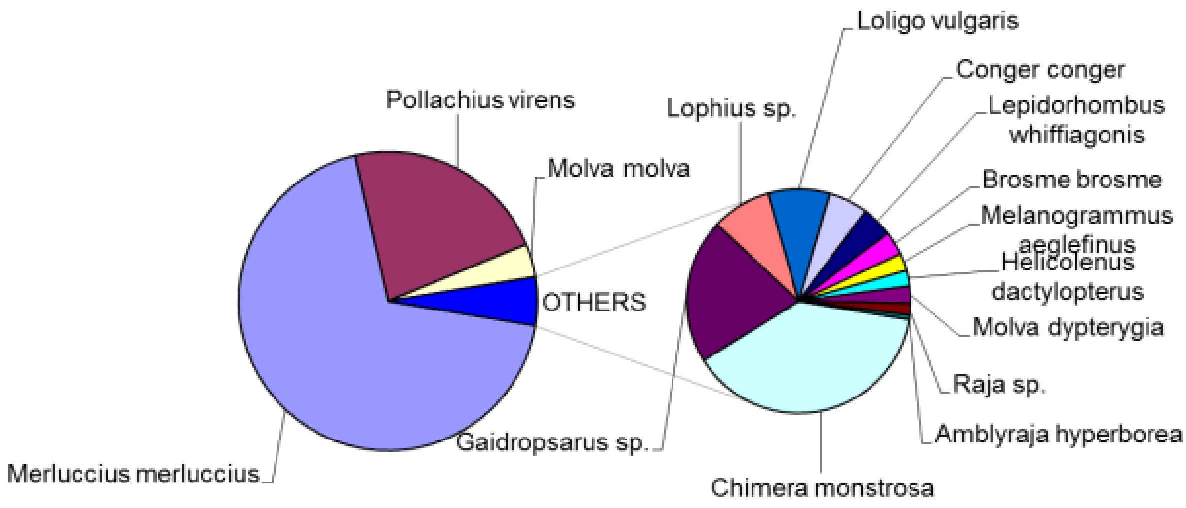


Figure 34: Species composition of landed fraction from shallow-water hauls during the second experimental trip.

In shallow waters, the mean landings per hour for the light gear with chain and the standard gear were respectively 1 927 kg/h and 940 kg/h (Figure 35). The Mann-Whitney test indicates that there is a significant difference between the landings weight from the light and standard gear, but it is dificult to conclude due to the small number of hauls performed with the light gear and the variability observed.

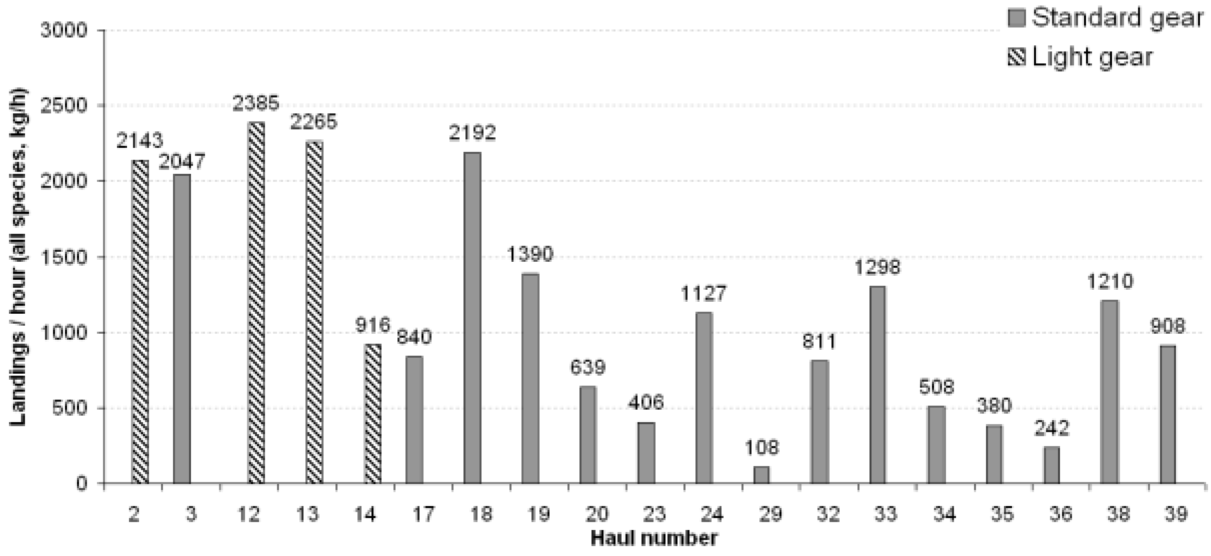


Figure 35: Landings per hour in shallow-water hauls, targeting either hake or saithe, - during the second experimental trip.

The landings from deep-water hauls were mainly composed by *Aphanopus carbo* and *Molva dypterygia*, which represented respectively 44 and 27 % of the cumulated landed fraction. The other 29 % were composed of 16 commercial species (Figure 36).

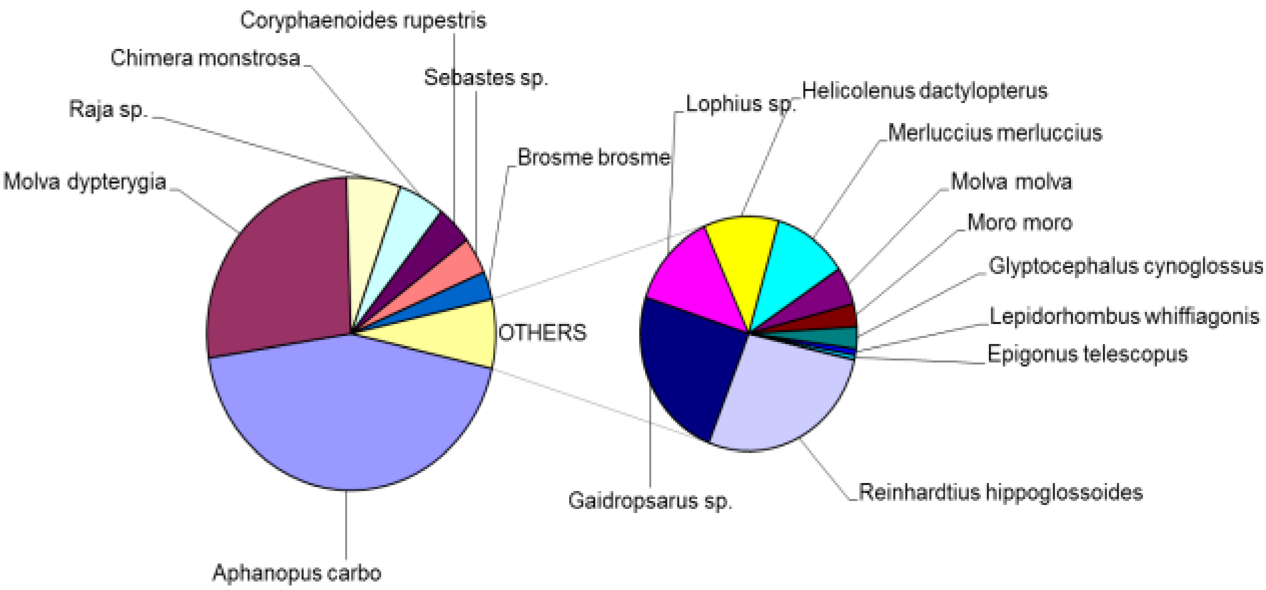


Figure 36: Species composition of the landed fraction from deep-water hauls during the second experimental trip.

In deep waters, the mean landings per hour for the light gear with chain, the standard gear and the off-bottom trawl were respectively 589 kg/h, 496 kg/h and 23 kg/h (Figure 37). The Mann-Whitney test indicates that there is a significant difference between landings from the off-bottom trawl and from the standard gear ($p = 0.003$). Despite the small number of hauls, the order of magnitude of catches from the off-bottom trawl is always inferior to the standard gear ones. The same statistical test indicates that there no significant difference between landings weight per hour from the light gear and the standard gear (p = 0.2).

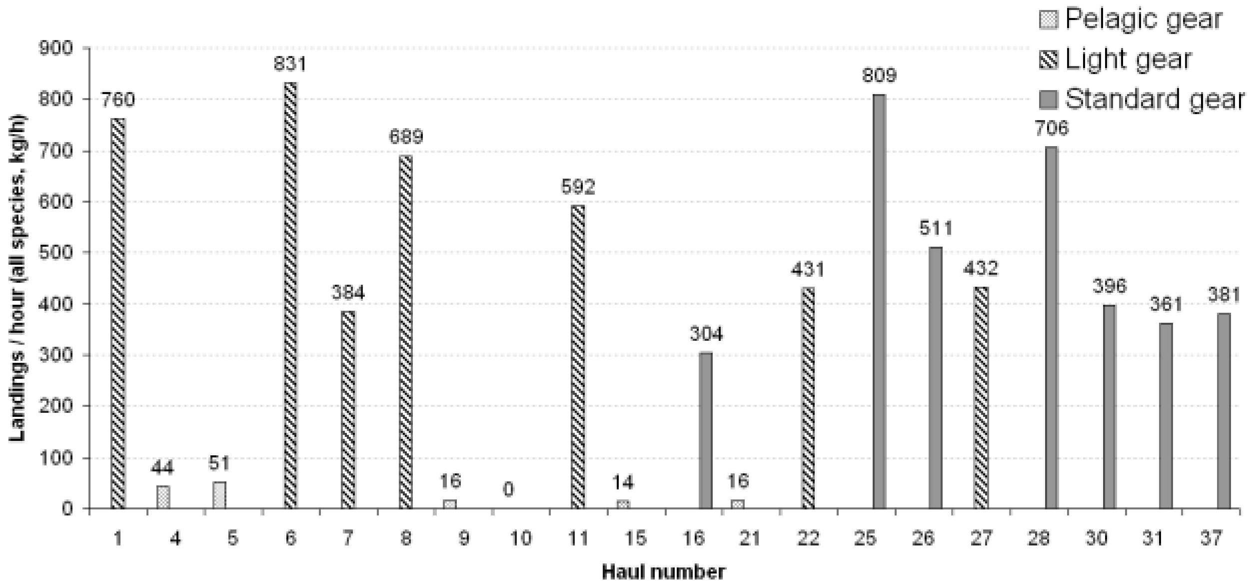


Figure 37: Landings per hour in deep-water hauls during the second experimental trip.

VII.3.1.2.3 Discarded fraction – Species composition and quantities

The discards rate from the 19 shallow-water hauls reached 3 % of the total cumulated catches. The discards were composed of a high variety of species. *Merluccius merluccius* (discarded for quality presentation reason), *Gadus morhua* (discarded for quota reason), *Trachurus trachurus* and *Chimera monstrosa* were the main species discarded, though 35 species were discarded in total (Table 40).

Table 40: Total landings and discards (kg) and percentage of discards in the 19 hauls carried out in shallow waters during the second experimental trip (all gear types together).

Species	Landings (kg)	Discards (kg)	Total_Catch (kg)	Discards (%)
Merluccius merluccius	45309	517	45826	0.76
Gadus morhua	0	392	392	0.58
Trachurus trachurus	0	215	215	0.32
Chimera monstrosa	1327	213	1540	0.31
Micromesistius poutassou	0	143	143	0.21
Argentina silus	0	140	140	0.21
Aphanopus carbo	0	80	80	0.12
Centrocimnus crepidater	0	72	72	0.11
Cancer sp.	0	58	58	0.08

Species	Landings (kg)	Discards (kg)	Total_Catch (kg)	Discards (%)
Deania calcea	0	52	52	0.08
Phycis blennoides	0	47	47	0.07
Nezumia aequalis	0	42	42	0.06
Pollachius virens	14701	35	14736	0.05
Lepidorhombus whiffiagonis	154	34	188	0.05
Scyliorhinus canicula	0	32	32	0.05
Loligo vulgaris	305	28	333	0.04
Molva molva	2369	25	2394	0.04
Galleus sp.	0	21	21	0.03
Conger conger	197	13	209	0.02
Centroscymnus coelolepis	0	10	10	0.02
Rajella fyllae	0	9	9	0.01
Lepidion eques	0	6	6	0.01
Leucoraja naevus	0	6	6	0.01
Dipturus batis	0	5	5	0.01
Chelidonichthys lucernus	0	4	4	0.01
Gadiculus argenteus	0	4	4	0.01
Coryphaenoides rupestris	0	3	3	<0.01
Rajella kukujevi	0	2	2	<0.01
Molva dypterygia	86	2	88	<0.01
Hydrolagus sp.	0	2	2	<0.01
Helicolenus dactylopterus	0	1	1	<0.01
Octopus sp.	0	1	1	<0.01
Amblyraja radiata	0	1	1	<0.01
Lophius sp.	296	1	298	<0.01
Merlangius merlangus	0	1	1	<0.01

Species	Landings (kg)	Discards (kg)	Total_Catch (kg)	Discards (%)
Amblyraja hyperborea	22	0	22	0.00
Brosme brosme	119	0	119	0.00
Gaidropsarus sp.	718	0	718	0.00
Melanogrammus aeglefinus	86	0	86	0.00
Raja sp.	56	0	56	0.00
Helicolenus dactylopterus	78	0	78	0.00
Total	**65821**	**2219**	**68040**	**3**

In shallow waters, the mean discards per hour for the light gear with chain and the standard gear were respectively 68 kg/h and 49 kg/h (Figure 38). The Mann-Whitney test indicates that there is no significant difference between discards weight from the light gear and the standard gear (p = 0.1). The species compositions of shallow- and deep-water hauls show that *Chimera monstrosa*, *Aphanopus carbo*, *Molva molva*, *Coryphaenoides rupestris* and *Helicolenus dactylopterus* could be found in both types of hauls.

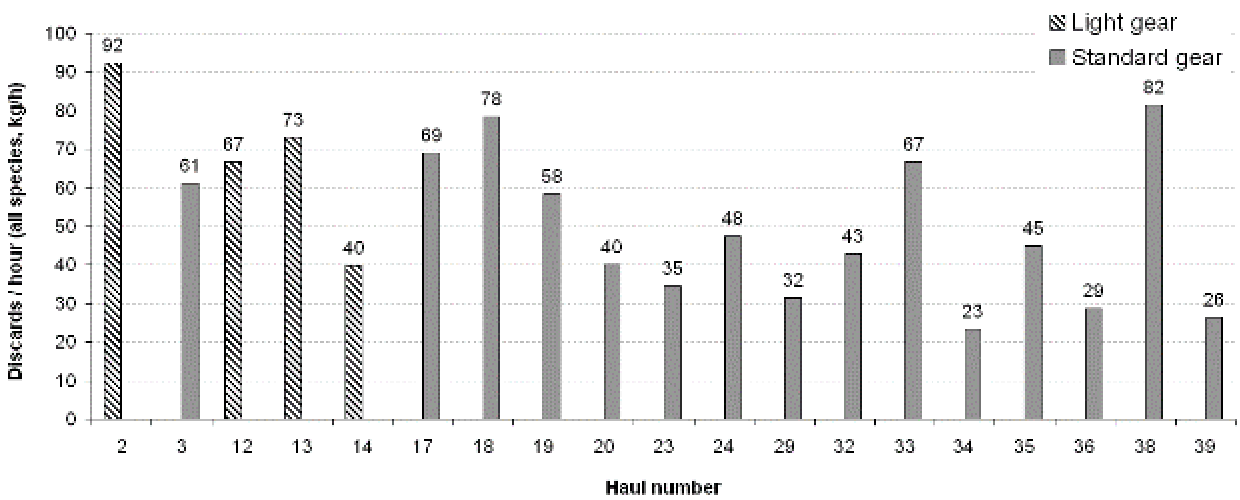


Figure 38: Discards per hour (kg) in shallow-water hauls targeting eiher saithe or hake during the second experimental trip.

The discards rate from the 20 deep-water hauls reached 23 % of the total cumulated catches. The discards were composed of a high variety of species. *Centrophorus squamosus*, *Argentina silus* and *Centroscymnus coelolepsis* were the main species found in the discard fraction, though 39 species were discarded in total (Table 41).

Table 41: Total landings and discards by species (kg) and percentage of discards in the 20 hauls carried out in deep waters during the second experimental trip with either the light or standard trawl.

Species	Landings (kg)	Discards (kg)	Total_Catch (kg)	Discards (%)
Centrophorus squamosus	0	3191	3191	5.69
Argentina silus	0	3057	3057	5.45
Centroscymnus coelolepsis	0	1349	1349	2.41
Aphanopus carbo	19079	877	19956	1.56
Deania calcea	0	777	777	1.39
Centroscymnus crepidater	0	766	766	1.37
Chimera monstrosa	2254	584	2838	1.04
Merluccius merluccius	344	448	792	0.80
Dipturus linteus	0	272	272	0.49
Amblyraja radiata	0	180	180	0.32
Bathyraja spinicauda	0	178	178	0.32
Alepocephalus bairdii	0	142	142	0.25
Rajella fyllae	0	123	123	0.22
Lepidion eques	0	118	118	0.21
Micromesistius poutassou	0	112	112	0.20
Hydrolagus sp.	0	102	102	0.18
Loligo vulgaris	0	58	58	0.10
Molva dypterygia	11679	52	11731	0.09
Nezumia aequalis	0	51	51	0.09
Coryphaenoides rupestris	1740	49	1789	0.09
Lepidorhombus whiffiagonis	25	43	68	0.08
Galeus sp.	0	41	41	0.07
Mora moro	99	24	123	0.04
Phycis blennoides	0	21	21	0.04
Centrolophus niger	0	18	18	0.03
Brosme brosme	1257	17	1274	0.03
Reinhardtius hippoglossoides	845	16	861	0.03
Pollachius virens	0	13	13	0.02
Dipturus oxyrinchus	0	8	8	0.01
Molva molva	161	6	166	0.01
Trachyrincus murrayi	0	5	5	0.01
Helicolenus dactylopterus	345	4	349	0.01
Leucoraja naevus	0	4	4	0.01

Species	Landings (kg)	Discards (kg)	Total_Catch (kg)	Discards (%)
Sebastes sp.	1645	2	1648	<0.01
Trachurus trachurus	0	1	1	<0.01
Scyliorhinus canicula	0	1	1	<0.01
Octopus sp.	0	1	1	<0.01
Cancer sp.	0	1	1	<0.01
Etmopterus spinax	0	1	1	<0.01
Epigonus telescopus	20	0	20	0.00
Gaidropsarus sp.	739	0	739	0.00
Glyptocephalus cynoglossus	92	0	92	0.00
Lophius sp.	407	0	407	0.00
Raja sp.	2623	0	2623	0.00
Total	43354	12712	56066	23

In deep waters, the mean discards per hour for the light gear with chain, the standard gear and the off-bottom trawl were respectively 191 kg/h, 134 kg/h and 11 kg/h (Figure 39). The Mann-Whitney test indicates that there is a significant difference between the discards from the off-bottom trawl and the standard gear ($p = 0.003$). Despite the small number of hauls, the order of magnitude of catches from the off-bottom trawl is always inferior to the standard gear ones. The same statistical test indicates that there no significant difference between discards weight from the light gear and the standard gear ($p = 0.5$). However, the small number of hauls and the variability observed do not permit to draw robust conclusion.

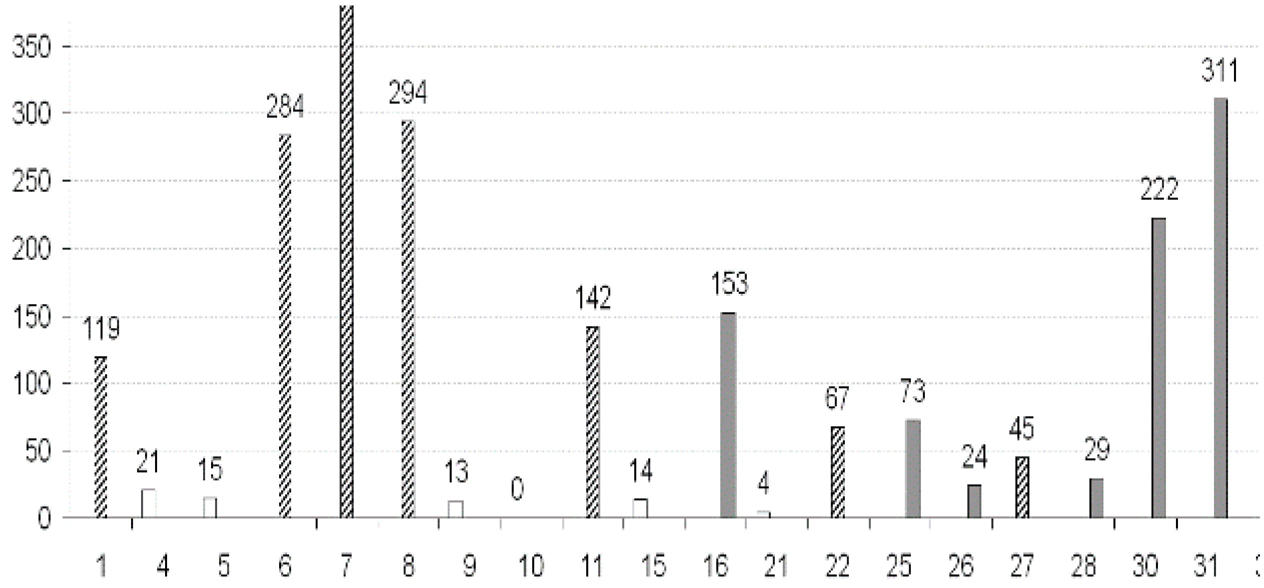


Figure 39: Discards per hour (kg) in deep-water hauls during the second experimental trip.

VII.3.1.2.4 Comparison of gear configurations in terms of species catch

The 20 most abundant species present in the standard trawl were selected for both shallow- and deep-water hauls. A few shallow-water species were caught in the standard trawl but not in the light trawl (Figure 40). This was the case for *Melanogramus aeglefinus, Molva dypterygia and Raja sp.* which were present in 2 shallow standard hauls over 15. Other species, such as *Chimera monstrosa*, *Lophius sp.*, *Conger conger* and *Lepidorhombus whiffiagonis* were more abondant in the standard gear than in the light one.

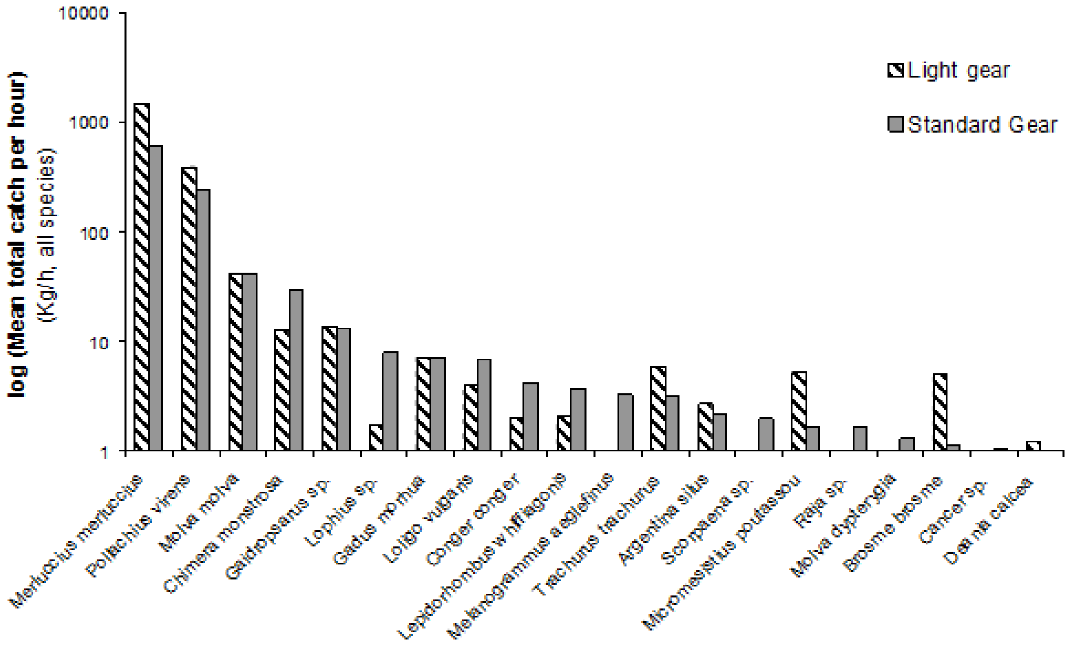


Figure 40: Total catch (landings+discards) per hour (kg) of the 20 main species caught by the standard trawl in shallow waters during the second experimental trip.

The mean catch rates per species in deep waters show that the off-bottom trawl was poorly efficient in catching the two main species targeted and caught by the standard gear, *Aphanopus carbo* and *Molva dypterygia* (Figure 41), even if *A.carbo* may be found off the bottom. The standard gear was the most efficient in catching *Molva dypterygia, Cantrophorus squamosus* and *Raja sp*. Onthe other hand, *Aphanopus carbo, Arhentinus silus, Sebestes sp., Coryphaenoides rupestris* and *Chimera montrosa* were more abundant in the light gear than in the standard gear.

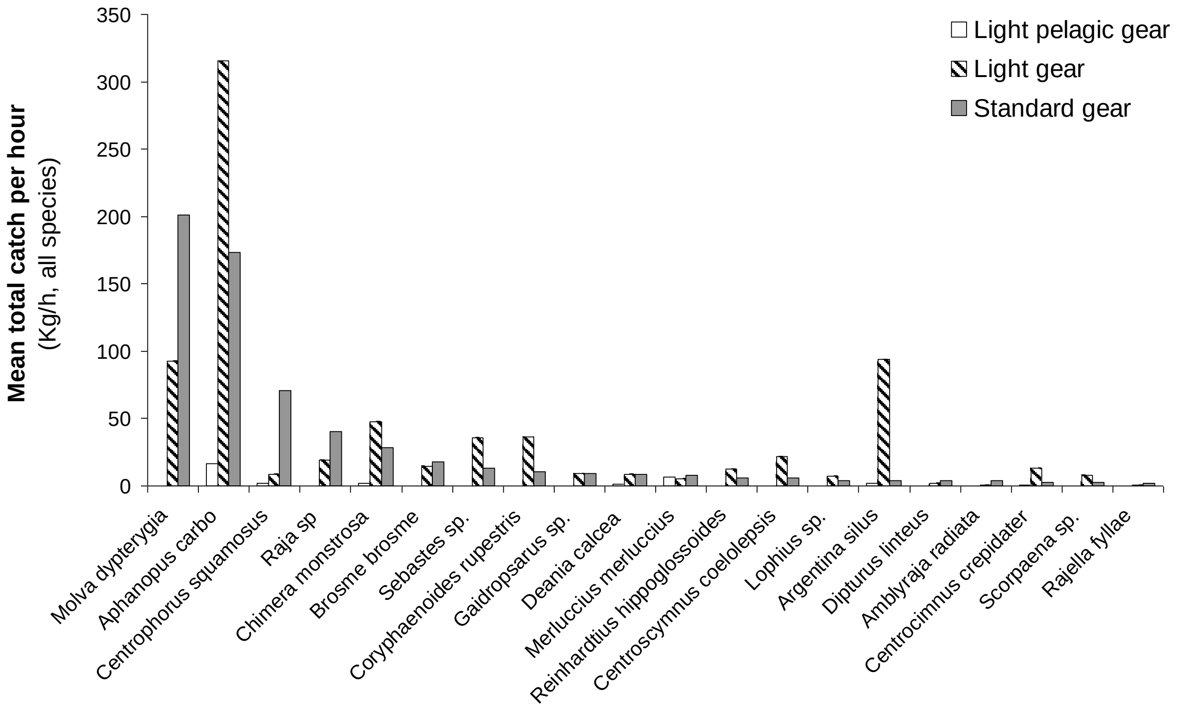


Figure 41: Total catch (landings+discards) per hour (kg) of the 20 main species caught by the standard trawl in deep waters during the second experimental trip.

VII.3.2 Comparison with usual commercial trips observed during the on-board observation scheme

The Mann-Whitney test indicates that the catch from the deep and shallow hauls targeting saithe during the two experimental trips are not significantly different from those from observed commercial trips ($p > 0.05$). However, three shallow hauls targeting saithe from the first experimental trip (hauls N°16, 20 and 21) produced catches much above the average (respectively more than 16, 11 and 16 tonnes of landings) (Figure 42 and Figure 43). The same statistical test indicates that landings of hauls targeting hake during the second experimental trip are significantly higher than those from observed commercial trips (Figure 44).

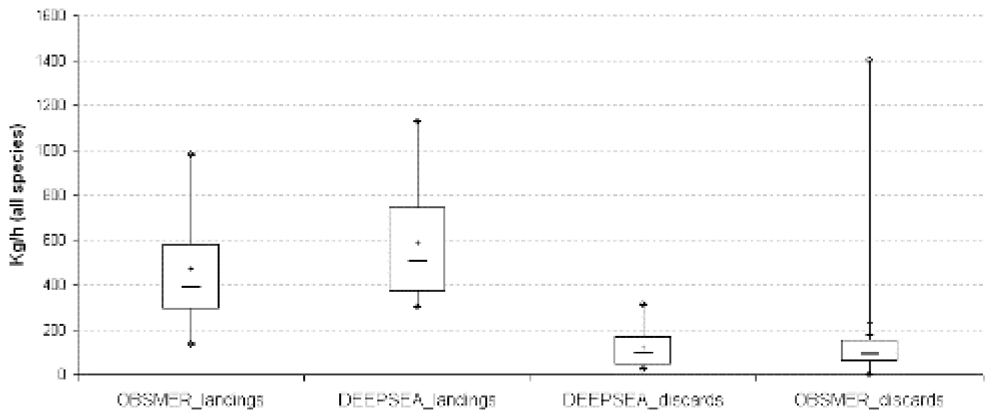


Figure 42: Comparison of catches (landings and discards separately) in hauls targeting deep-water species from observed commercial trips and from the two experimental trips combined. Box: first and

third quartiles (q1 and q3), +: mean – median. NB: The extreme discard value in one commercial trip is due to one haul with a large catch of *Alepocephalus bairdii*.

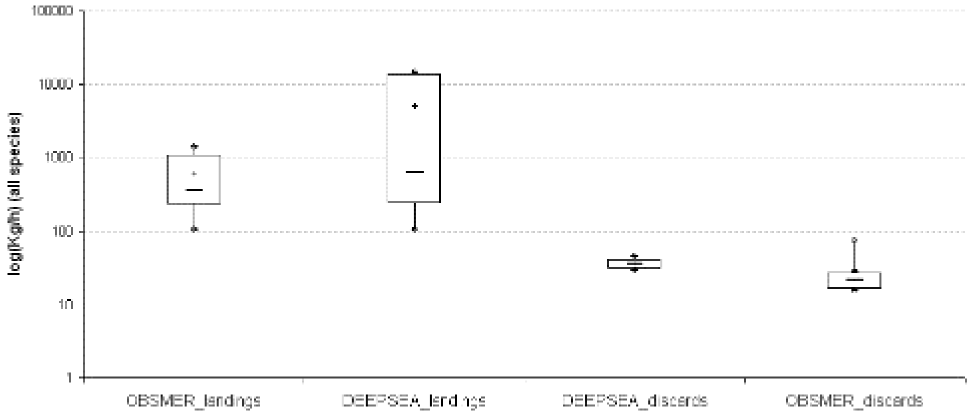


Figure 43: Comparison of catches (landings and discards separately) ofin hauls targeting saithe from observed commercial trips and from the two experimental trips combined. Box: first and third quartiles (q1 and q3), +: mean –median, ° = minimum and maximum.

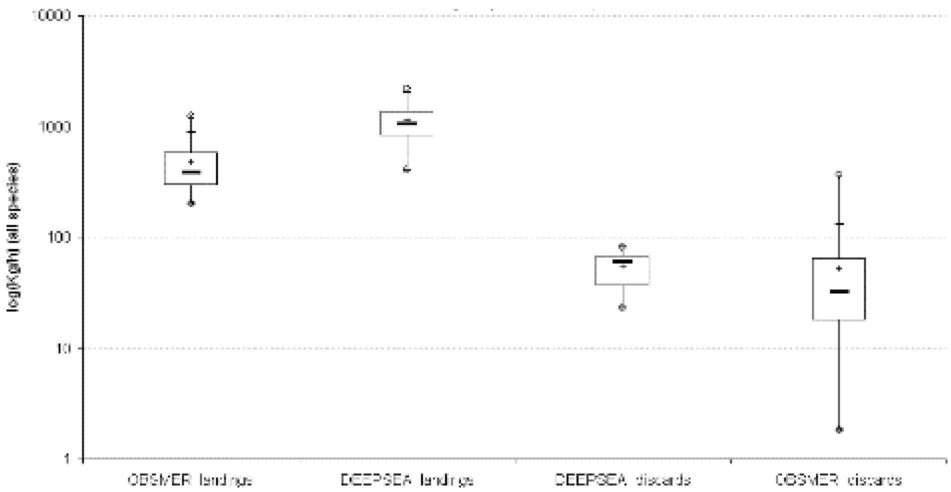


Figure 44: Comparison of catches (landings and discards separately) in hauls targeting hake from observed commercial trips and from the two experimental trips combined. Box: first and third quartiles (q1 and q3), +: mean - median, ° = minimum and maximum.

VII.3.3 Economical analysis

For deep-water hauls, the resampling procedure was based on 11 hauls with the standard trawl, 8 with the light trawl and 6 with the off-bottom trawl from experimental trips. These were compared to 33 hauls for on-board observations (usual commercial trips) carried out with the standard trawl. The Student t-test indicates that the mean gross sales generated from 10 hauls with the light trawl (mean $\mu = 70\,330$ €) is significantly higher than the one generated from 10 hauls with the standard trawl ($\mu = 51\,480$ €, $p < 0.001$). In the same way, the test indicates that the mean gross sales generated from the off-bottom trawl ($\mu = 3\,669$ €) is significantly lower than the one generated from the standard trawl ($p < 0.001$) (Figure 45).

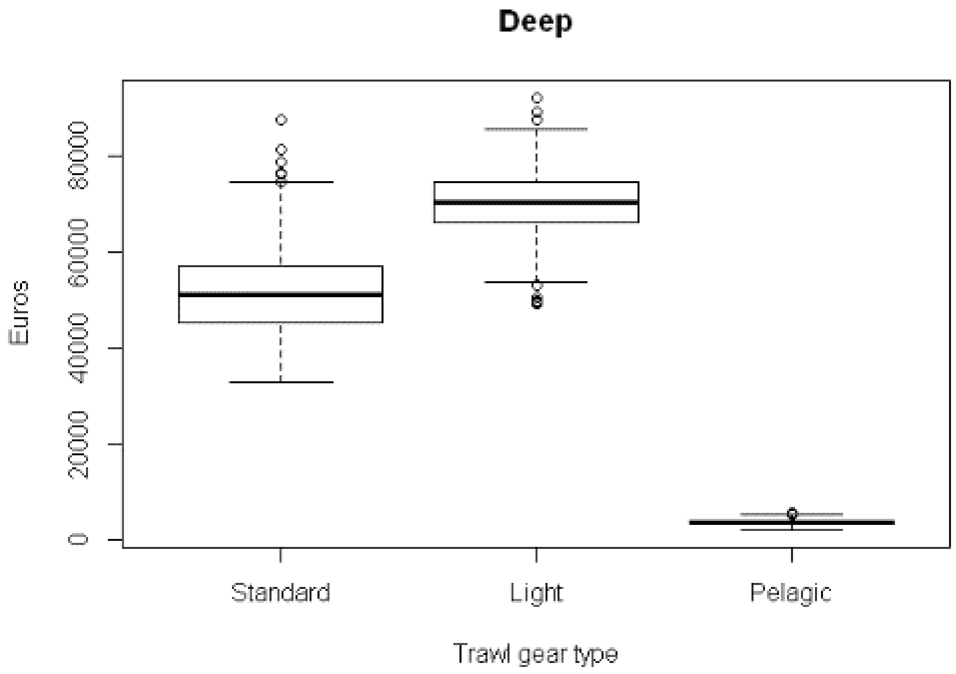


Figure 45: Distribution of gross sales generated from 10 hauls of 6 hours targeting deep-water species. Based on 1 000 iterations re-sampling of usual commercial and experimental hauls for the standard trawl, and of experimental hauls only for the light and off-bottom (labelled pelagic) trawls.

For hauls targeting hake, the re-sampling procedure was based on 11 hauls from the two experimental trips and 69 hauls from usual commercial trips for the standard trawl and 4 hauls from experimental trips for the light trawl (Figure 46). The off-bottom trawl was not tested in shallow waters. The Student t-test indicates that the mean gross sales generated from 10 hauls with the light trawl (μ = 140 010 €) is significantly higher than the one generated from 10 hauls with the standard trawl (μ = 40 523 €, $p < 0.001$). The landed gutted catches observed with the light trawl (μ = 4 756 kg, 4 hauls) and the standard trawl (μ = 3 340 kg, 11 hauls) during experimantal trips were larger than those during observed commercial trips (μ = 1 577 kg, 69 hauls).

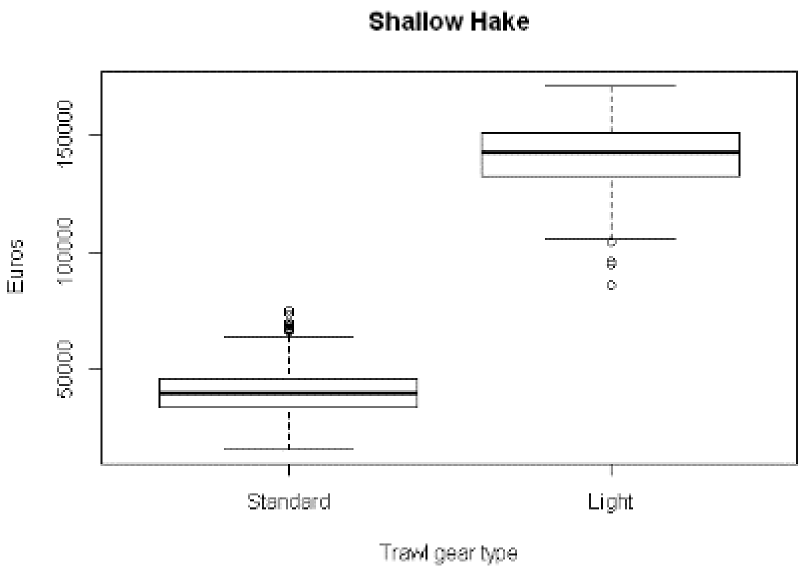


Figure 46: Distribution of gross sales generated from 10 hauls of 6 hours targeting Hake in shallow waters. Based on 1 000 iterations re-sampling of usual commercial and experimental for the standard trawl, and of experimental hauls only for the light trawl.

For hauls targeting Saithe, the re-sampling procedure was based on 9 experimental hauls and 11 usual commercial hauls for the standard trawl, 3 experimental hauls for the light gear (Figure 47). The Student t-test indicates that the mean gross sales generated from 10 hauls with the light gear (μ = 67 659 €) is significantly lower than the one generated from 10 hauls with the standard gear (μ = 10 4759 €, p < 0.001). The standard trawl shows some very high gross sales mainly due to 3 hauls of the first experimental trip, hauls number 16, 20 and 21) that caught respectively more than 16, 11 and 16 tonnes of Saithe, whereas the mean catch of saithe was 1049 kg (11 hauls) from usual commercciala trips and 257 kg (4 hauls) from the second experimental trip.

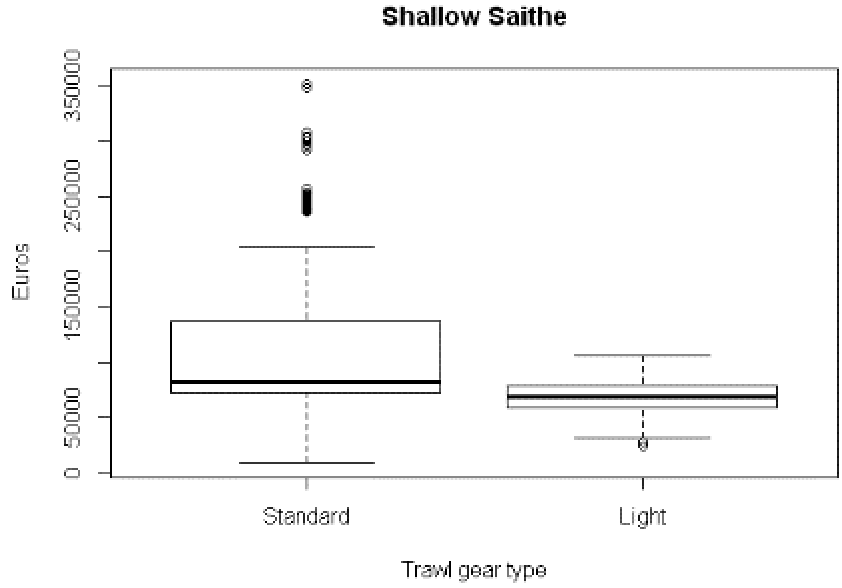


Figure 47: Distribution of gross sales generated from 10 hauls of 6 hours targeting saithe in shallow waters. Based on 1 000 iterations re-sampling of usual commercial and experimental hauls for the standard trawl, and of experimental hauls only for the light trawl.

VII.4 DISCUSSION/CONCLUSION

These experimental trips aimed at reducing the trawl impact on the seafloor. Four gear configurations (light trawl with tickler chain, light trawl without tickler chain, light trawl used as an off-bottom trawl and standard trawl) were tested in three sampling strata (fishing for hake, saithe and deep-water species hauls) during two distinct experimental trips. The catch analysis aimed at assessing any difference in terms of catch weight and composition between the standard and modified trawls.

However, the results should be interpreted with caution. Indeed, a relatively small number of hauls was performed for each trawl/target species combination and a high variability was observed between catches within a same combination. For example, large catches of saithe were observed during the shallow water hauls of the first sea trip, as well as large catches of hake during the second trip. Such situations resulted in a lack of homogeneity in the data and combined to small dataset, may lower the robustness of the statistical tests used. Furthermore, bias in the methodology used to assess the discards fraction may also exist. Indeed, the discards sampling ratio was obtain from the total sorting time on the deck by the crew and the time required to collect the sample of discards.

This methodology relies on the assumption that the discards are homogeneously spread on the conveyer all along the sorting. However, according to the crew members, this may not be always the case, and the total catch weight assessed by the fishermen and by an observer may be different, both being potentially biased. Therefore, catch data presented in that study should be interpreted carefully, especially discards ones.

Looking at global catches and discards rates of deep-water hauls, it appears that the data collected during experimental trips are consistent with the ones collected under the national observation programme on board of commercial vessels. Therefore we are confident that our results are consistent with deep-water fishing trips conducted under commercial conditions by French trawlers.

Some difference in catch composition (species and proportion) were found between the two experimental trips. Thus, the landing fraction of the first trip was mainly composed of *Aphanopus carbo* (56 %) and *Coryphaenoides rupestris* (36 %) whereas the landings of the second trip were composed of *A. carbo* (47 %), *Molva dypterygia* (29 %), *Chimera monstrosa* (6 %) and *C. rupestris* (4 %). The data from the second trip show that the 4 main deep-water species discarded were *Centrophorus squamosus*, *Argentina silus*, *Centroscymnus coelolepsis* and *A. carbo*, representing 15.1 % of the total catch weight. Landings and discards species compositions differ, but they vary between sea trips and season. The second experimental trip for example, showed that 2.8 % of *C. rupestris* caught were discarded, whereas for this species STECF (2013) and Cornou et. al. (2013) reported mean discards rates of 12 % and 9.5 % respectively. It is however important to notice that these latter estilames do not account for possible seasonal variations. In any case, this is lower than what was reported few years ago by Allain et al. (2003), where *C. rupestris* was the main species caught, landed and discarded (more than 20 % discarded). These authors observed that the deeper the hauls, the highest the *C. rupestris* discarding rate. In parallel, Pawlowski and Lorance (2009) found that the French vessels targeting *C. rupestris* tend to fish at smaller depth nowadays with more than 50 % of the fishing time spent at depth 600-1 000 m since 2005. Considering the relatively shallow depth of the deep-water hauls conducted during experimental trips, our results are consistent with the literature as well as with the report of the working group on biology and assessment of deep-sea fisheries resources that indicates a decreasing trend of *C. rupestris* discard rate the recent years (12 % in 2011 and 6 % in 2012, ICES 2013). Cornou et al (2013) reported that *Argentina silus* and *Alepocephalus bairdii* were the main species discarded by the French vessels operating in deep waters. Apart from sharks discarded due to the prohibition of landing or retaining them set by the European regulation (EC, 2009), *A. silus* was the main species discarded during the two experimental trips, whereas *Alepocephalus bairdii* was not a major catch.

Comparisons of catches from the light and standard trawls do not show significant differences, and it may happen that the light trawl was more efficient than the standard one in terms of global catch. There are indications that this light trawl may have caught less benthic species such as *Melanogrammus aeglefinus*, *Raja sp*. or *Lophius sp.* in shallow waters, though these observations are based on a small number of hauls. It is however consistent with the technological observations which showed that the gear could be off the bottom some time to time during the fishing operation. On the contrary, there is no clear indication that the light trawl caught less benthic species in deep waters, which is also consistent with the technological observations since the gear could not be maintained off the bottom at such depths. Generally, more hauls would be necessary to draw robust conclusions on the effect of the light gear on the catches.

Regarding the off-bottom trawllight gear, and though a small number of hauls was realised with that trawl, it clearly appeared that this configuration catches significantly less fish than either the light or standard gear. It caught however some *Centrophorus squamosus*. Deep-water sharks have been observed from ROVs to be active swimmers often swimming well off the bottom while several other deep-water species are little active and stand close to the bottom (Lorance and Trenkel, 2006). The catch of sharks in the trawl towed off the bottom suggests that their habitat extends higher up in the water column than that of target deep-water species.

From an economical point of view, this work focused mainly on gross sales generated from the three trawls: standard, light and off-bottom in deep waters and from the standard and light trawl only in shallow waters. Because of the small number of hauls available, bootstrap re-sampling was necessary to compare the mean gross sales from the three target species and trawls. Even using this procedure, biases remain due to the fact that on-board observations of usual commercial trips were used to assess the gross sales of the standard standard. Indeed, on-board observations cover 4 sea trips and 113 hauls, whereas the two experimental trips include 31 hauls with the standard trawl, 15 with the light trawl and 6 with the trawl towed off-bottom. Compared to hauls from on-board observations selected on vessel type, area and season criteria, hauls from the two experimental trips produced larger catches of saithe during the first trip and larger catches of hake during the second. Comparing catches from the light trawl to those of the standard trawl (from experimental and usual trips pooled), the light trawl catch are higher when targeting hake or deep-water species. However, this result should be interpreted with caution, since it is probably due to the small number of experimental hauls and not because of a higer efficiency of the modified gear. The gross sales generated from the standard trawl targeting saithe is larger than the one from the light trawl, mainly due to the exceptional saithe catches during the first experimental trip. In deep waters, 6 hauls towed off the bottom show significantly lower gross sales with a small variability. As a conclusion, differences of catches and gross sales between the light and standard trawls are not significant, whereas the results from the off-bottom configuration indicate that it is not a viable economic option in deep waters. Though the new light trawl may have a reduced impact on the bottom, it doesn’t show any significant change in global catch and discards rates.

TASK 2 – DISCARD REDUCTION

VIII BYCATCH REDUCTION STRATEGIES

A number of approaches have been developed at several levels to investigate options for reducing discards in deep-water fisheries. In all case the data analyses or the simulations carried out were relevant to the French trawl deep-water fishery to the West of the British Isles.

Conditions where discards occur and practical measures to reducing them in this particular fishery where investigated from interviews of skippers (section VIII.1). These interviews involved only skippers from this particular fishery, interviews of skippers engaged in other deep-water trawl fisheries in the North Atlantic, in particular of skippers of Portuguese and Spanish freezer trawler fleets were not carried out because contacts could not be established with these fleets.

Fish community indicators that can be derived from on-board observations of the deep-water fishing fleet was investigated in order to evaluate how much they can reliably represent the status of the actual deep-water fish community (section VIII.2).

Two descriptive studies of on-board observations were carried out. The first (section VIII.3) is a description of on-board observations of the French deep-water fishing fleet, which shows the number of vessels, fishing trips, hauls, days-at-sea, as well as the weight of catch, landings and discards observed per years from 2004 to 2012 were described together with the list of observed species and their proportion in the catch and discards in 2012. The second (section VIII.4) is a description of the on-board observations of some deep-water sharks and and the blue skate (*Dipturus batis*), using all (i.e. not only those of the deep-water fishing fleet) French on-board observations in 2009-12. Again this analysis is focussed on elasmobranchs, which can only sustain lower fishing mortality than teleosts. The blue skate was included as it was recently identified as a species complex of particular sensitivity (Iglesias et al., 2010). The use of on-board observations from all fleets instead of those from deep-water fishing fleets only allows to appraising the depth and spatial distribution of species which are caught by both demersal and deep-water fleets.

A spatial analysis of the bycatch was made using an innovative method, which allows estimating discard proportions in smaller spatial cells in areas where more data are available.

VIII.1 INTERVIEWS OF SKIPPERS

VIII.1.1 Introduction

Interviews of deep-water fishing skippers were designed to gather their knowledge and ideas about potential technical ways and management options to reducing discards. Stakeholder knowledge and data analysis collected from interviews and other approaches such as cognitive maps has been used for stock assessment and environmental impact management. Such approaches have already been used in deep-water (e.g. Lorance et al. 2011) and shelf fisheries where, for example, environment status diagnostic based upon scientific assessment and stakeholder perception appeared to be mostly consistent (Prigent et al., 2008; Rochet et al., 2008).

In this project, owing to the objective of identifying how in practice bycatch could be reduced, a questionnaire was developed for skippers only who were considered the stakeholders most able to integrate all technical components of the bycatch problem in order to identify solutions that can be practical either at vessels or at fisheries level to reducing bycatch.

A questionnaire was developed in French and English and interviews were carried out from November 2012 to January 2013.

VIII.1.2 Material and methods

VIII.1.2.1 Questionnaire

The questionnaire was elaborated in October 2012 starting with a brainstorming session involving all partners of the project. Some of the questions were refined based on a previous survey carried out in the EU FP7 DEEPFISHMAN project (grant no 227390). The questionnaire from the DEEPFISHMAN project was submitted to various stakeholders including the fish-catching sector (skippers, crewmen, fishing companies representatives and artisanal fishers) as well as the larger fishery sector (e.g. first sale fish markets, fish-processing industry, Producer Organisations), national administrations, Regional Fisheries Management Organisations (RFMOs) and NGOs representatives. The DEEPFISHMAN questionnaire included questions on the management approaches appropriate to address the discards and the environmental impact of deep-waters fisheries. The questionnaire in the current "reduction of gear impact and discards in deep sea fisheries" project was focussed on reasons for discards and the way skippers may suggests to reducing them.

The questionnaire included 12 open questions, with no restriction on the length of the responses, one table where skippers had to identify and comment on measures to reduce discards and one table wher they had to identify the areas, season, depth and associated species of a number of discarded and landed species (Annex 8: Discard reduction strategies questionnaire). The open questions included some simple questions (e.g. which ICES Divisions and which depth do you fish) allowing to identify the relationship between discards and the fishing context as well as some more complex questions (e.g. "what are the ddifferences between trawling fishing vessels with regards to amounts of discards") that where designed to identifying potential subtle factors in discarding rates.

VIII.1.2.2 Plan for interviews

The population of skippers to interview, was considered to include skippers of fishing vessels targeting deep-sea species, as well as skippers of fishing vessels not targeting these species but however holding the deep-seal fishing permit required by regulation 2347/2002 to land bycatch of deep-sea species listed in the Annex 1: Trawl design) of this regulation. Contacts with these skippers have been taken from November 2012 and have been repeated up to early 2014 (Table 42), nevertheless the number of responses collected has remaindedd small owing to several difficulties: (1) the limited number of vessels hodling the deepsea fishing permit, (2) the difficulty in getting in touch with skippers while they are on land, (3) the reluctance of some skippers or that of their fishing company or Producer Organisation to respond to interviews as well as possibly (4) the increasing number of surveys initiated by various sources without sufficiently clearly feeed-back to interviewees.

Table 42: Table of contact for the interviews.

Institution/organism	Date of first contract (specific to the interviews)	Results

Ifremer	October 2012	Definition of the questionnaire and obtaining contacts for RAC long distance
Operator SCAPÊCHE (request for interviews)	November 2012	Two interviews conducted
Operator EURONOR (request for interviews)	December 2012	One interview conducted
Operator DHELLEMMES (request for interviews)	January 2013	Numerous attempts to contact. No result.
Operator ARMEMENT BIGOUDEN (request for interviews)	January2013	One interview conducted
Scottish White Fish Association (request for contacts)	January2013	Numerous attempts to contact. No result.
CEPESCA (request for contacts)	November 2012	Numerous attempts to contact. No result.
OPAGAC (request for contacts)	January 2013	Obtaining additional contacts at CEPESCA
CEPESCA	February 2014	Numerous attempts to contact. No result.
Operator DHELLEMMES	February 2014	Numerous attempts to contact. No result.

Example of an email sent to institutions such as CEPESCA, the SWFA and OPAGAC to obtain information on the operators outside France:

"*COFREPECHE is a consultancy specialised in fisheries and aquaculture management, and as such we are regularly working for the European Commission among other clients (for example, we are undertaking the current evaluations of the protocols to the tuna Fishing Partnership Agreements between the EU and third countries).*

In addition, COFREPECHE is currently undertaking a study in Consortium for the European Commission DG MARE on deep-sea trawler fisheries (>400m) pursued by EU vessels in the North-East Atlantic.

One of the objectives of this study is to identify and study skipper, strategies aiming at the avoidance of catch of unwanted or forbidden deep-sea species (reduction of bycatch).

As I am having some difficulty identifying relevant armaments online, could you please provide me with the names of some UK and/or Irish is applicable deep-sea trawl fishing armaments (>400m) in order for me to contact them? Two or three names would be enough and I would be grateful if you could provide them to me.

I am available, should you wish to obtain further details on my query."

VIII.1.2.3 Implementation phase interviews

Skippers of vessels targeting deep-water species or holding a deep-sea fishing permit pursuant to regulation 2347/2002 were interviewed following a semi-directive interview, which seemed to be the preferred approach by skippers. It was decided to follow this approach following the first interview, which was not conducted directively enough, and produced results difficult to interpret.

A number of maps were provided to skippers together with the questionnaire during the interviews in order to ease responses to questions with spatial aspects. Interviews were conducted in 1-2 hours time.

VIII.1.3 Results and discussion

The small number of interviews (4) limits the conclusions that can be drawn. Nevertheless, interviewed skippers of fishing vessels targeting deep-sea species showed that they had a good knowledge of fishing grounds. This knowledge is primarily empirical and derives from information recorded by skippers in their personal logbooks. In EU logbook skippers record their fishing location at the scale of ICES statistical rectangle, as required by regulation. Fishing information is recorded at a much higher spatial resolution in their own logbooks and on-board navigation systems, where the accurate location of fishing tracks is kept. Although Vessel Monitoring Systems (VMS) allow tracking fishing activities at a much higher spatial resolution than EU logbook data, it does not allow reconstructing trawl track accurately (Skaar et al., 2011; Lambert et al., 2012) so that the exact locations of fishing tracks of a particular vessel are only known to the skipper of this vessel. Skippers also keep data on commercial catch in weight and details such as "large size roundnose grenadier" or "only a small part of roundnose grenadier is of commercial size"; occasional damages to the trawl and the amount of bycatch by broad categories i.e. "several tonnes of smoothhead". Based on this information, they have predictions/expectations about the catch composition that they will obtain from a particular trawl track at a given season.

Thanks to these records skippers are able to come back to the fishing track (same location and depth) at the time of the year where they previously obtained good catch. Therefore, they can avoid locations of poor catch or location where the same commercial catch was caught together with a high bycatch of unwanted species, which implies more work for the crew. All of this means that a long-standing and stabilised fishery would overall generate less discards than a developing fishery or an overexploited fishery, in which case vessels might tend to explore new fishing grounds, where the empirical knowledge, of course, does not exists. Moreover, the implementation of new dedicated, including mapping, softwares has considerably increased the ease of retrieval of this data by skippers.

Previous surveys carried out in the DEEPFISHMAN project and other DEEPFISHMAN stakeholder analysis suggested that most fishermen interviewed and engaged in deep-water fisheries thought that the most suitable technical measures to reduce bycatch/discards are to limit their authorised quantities to an agreed level and to use bycatch-reduction devices (Lorance et al., 2011). Skippers interviewed in the current project did not consider bycatch-reduction devices suitable to reduce discards in their fishery and chose the strategic measure "Limit maximum quantity of discards" in the questionnaire (annex 8). When the questionnaire was drafted, this measure was thought as a level of discards to be defined as tolerable and that skippers would have to cope with. Such an approach is not fully consistent with the updated CFP (EU regulation N° 1380/2013), which took effect on 1 January 2014. The new CFP plans a gradual elimination of discards by setting the landing obligation of all catches of species which are subject to catch limits, i.e. TACs. In the case of deep-water fisheries, the landing obligation will be implemented at the latest in 2019 and, unless a dedicated regulation is set, discarding of species not subject to TACs will remain tolerated.

In the French deep-water trawl fishery, discards of species subject to catch limits occur mainly for roundnose grenadier and greater silver smelt. For roundnose grenadier small, unmarketable fish are discarded, and make up slightly more than 5% of total discards. Greater silver smelt (*Argentina silus*) is discarded in larger quantities, up to 25% of total discards, because there is not market in France although about 22000 tonnes/year (ICES, 2012a) are landed internationally and marketed to fish processing factories, for human consumption purposes. It seems unlikely that this fish processing market will be suitable to small bycatches in deep-water trawl fisheries, then fish landed under the landing obligation will probably be directed to fishmeal or other fish by-products. Although the quantities of greater silver smelt are small compared to international landings, they are about 5% of total catch (25% of current discards) so that landings this bycatch may imply additional costs.

VIII.2 DERIVING INDICATORS FROM ON-BOARD OBSERVATION DATA

VIII.2.1 Introduction

In this section the information content of on-board observation data is evaluated. The underlying question is to what extent these data do allow to obtain a representative view of fish assemblages and their spatio-temporal patterns. It can be expected that assemblage properties might be more robust to trawl type and sampling issues compared to single species abundance indices. Here we will evaluate to what extent community attributes might be representative in on-board observation data from the French deep-water fishery.

VIII.2.2 Material and method

Data from 2004 to 2010 are used, because this analysis was coded before data format change to the COST fomat (Jansen, 2009) made in the on-board observation database. New data extracted under the COST format have not been integrated. Only hauls for which both discards and landings and all species were sampled were retained and any unidentified biomass was removed (recorded as “rest”, “unidentified”, “pisces” in the database) from each haul. Vessel engine powers were checked against the common fleet register and corrected in one case. Overall this study applies to 856 hauls, with unequal distribution between depth categories, quarters and vessel engine categories (Table 43). The depth categories are 250 m depth band centred on 750, 1 000, 1 250, and 1 500 m.

Table 43: Number of hauls used in the analysis.

Category	2004	2005	2006	2008	2009	2010
Total	244	154	81	19	182	30
Depth (m)						
750	16	20	43	8	65	10
1000	99	61	16	7	73	16
1250	91	70	22	2	25	1

Category	2004	2005	2006	2008	2009	2010
Total	244	154	81	19	182	30
1500	38	3	0	2	19	3
Quarter						
1	0	0	50	0	44	30
2	90	0	10	0	81	0
3	99	99	14	0	31	0
4	55	55	7	19	26	0
Power (kW)						
<500	0	9	21	0	3	0
500-1000	91	41	29	6	38	0
1000-1500	111	44	21	0	0	0
>1500	42	60	10	13	141	30

A small study was carried out to investigate the impact of vessel power on vessel fishing efficiency and a correction factor was derived. For obtaining standardised fishing effort, fishing time (in hours) was multiplied by vessel power.

Seven fish assemblage indicators were calculated by depth range by year: total catch weight per standardised unit effort, total catch numbers per standardised unit effort, species richness, proportion of shark (in weight), ratio of roundnose grenadier to blackscabbardfish (in weight), mean weight and mean length. Abundance and mean weight could only be estimated in the case where the species was measured in a given haul as otherwise no counts were available. Length subsamples were raised to the haul level before use.

A simulation study was carried out to investigate the impact of sample size (number of hauls) on total species richness and compare it to published results from scientific surveys. To this end, hauls were resampled (across years and depth strata) with replacement and the total number of species were counted.

VIII.2.3 Results

For studying fishing efficiency, total catch per haul divided by haul duration was plotted against vessel power by depth stratum (Figure 48). It is apparent from this figure that there is no linear relationship between relative fishing power and engin power in this fishery. In particular, vessels between about 600 kW and 1 500 kW had similar fishing powers while smaller and larger vessels differed. Further there was large inter-haul variability. It was decided to created three vessel groups and use the average value within each group as correction factor for standardising fishing effort (horizontal line in Figure 48).

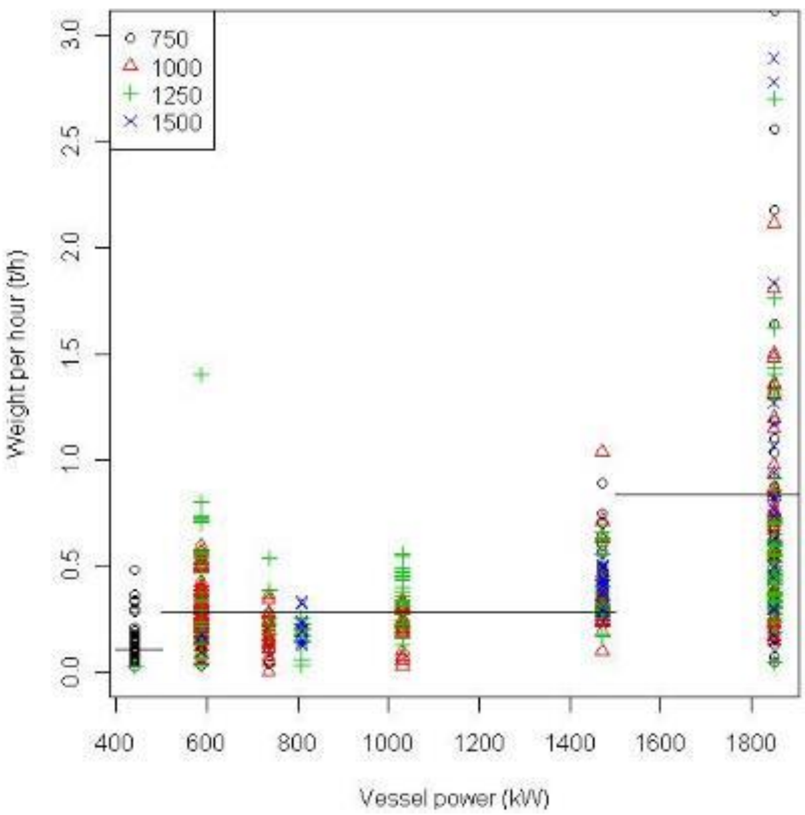


Figure 48: Catch per haul standardised per hour fishing by depth strata. Horizontal lines indicate fishing power correction factors that were used for assemblage indicators.

For most fish assemblage indicators, there were no strong time trends over the study period 2004 to 2010 (Figure 49). Inter-annual variations were strong for all indicators, probably as a result of low sample sizes. For some indicators there was a clear difference between depth strata. For example, mean length decreased with depth while the proportion of shark increased with depth. The time trend of species richness was probably impacted by data quality problems. Mean species richness per haul increased at the end of the period for the two most shallow depth strata (625 – 1 125 m) while it decreased deeper down. These divergent species richness trends seem odd and might be due to species identification problems. As said in the section "Descriptive analysis of deep-water sharks bycatch distribution based upon on-board observations 2009-2012", data quality has improved over time, with dedicated manuals for species identification made available to on-board observer and training of observers.

The ratio of roundnose grenadier to blackscabbard fish decreased slightly in all depth strata while standardised total weight per haul showed no strong pattern with depth (Figure 50).

The resampling study revealed the relationship between observed species richness (total number of species observed) and the number of hauls available (Figure 51).At least 100 hauls would be required to stabilise richness estimates.

Gordon and Bergstad (1982) observed the same number of species in only 10 survey hauls. In the study from these authors, small mesh sized trawled were used. The scientific trawl retain much better small species that selectivity of commercial trawl aim at leaving escaping. Therefore a lot of small species are not often retained by commercial trawls. Thus using onboard observations means that larger sample sizes are required compared to a designed scientific survey to determine species richness and detect changes.

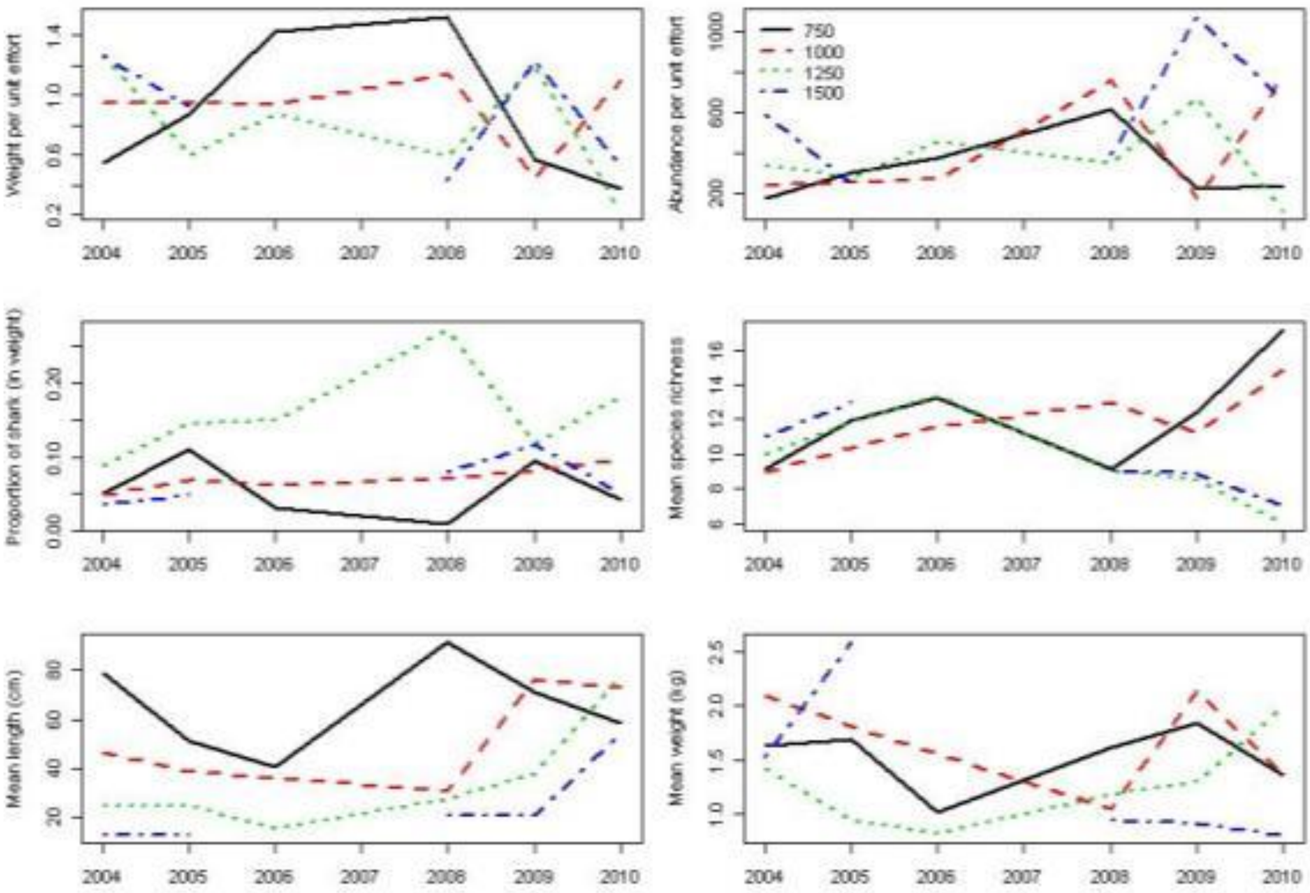


Figure 49: Fish assemblage indicators by depth stratum derived from onboard observations.

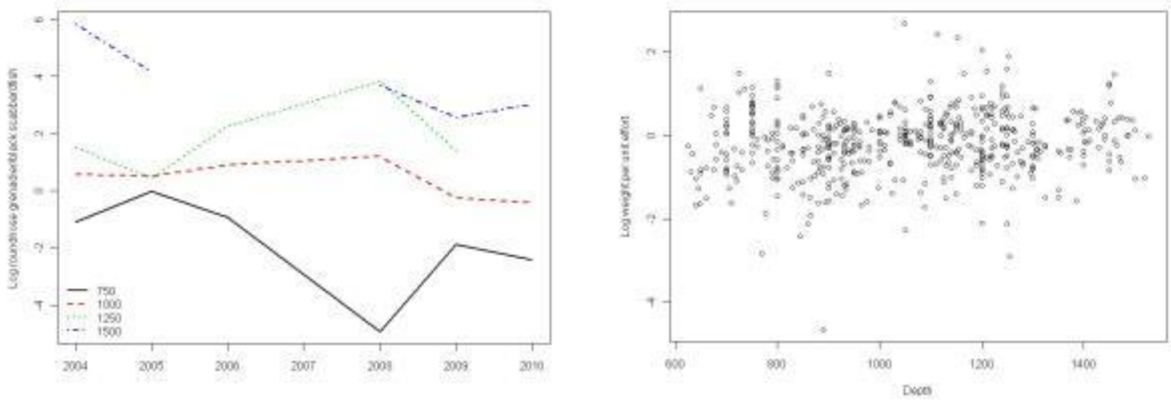


Figure 50: Ratio roundnose grenadier to black scabbardfish derived from onboard observations (left) and distribution of fish assemblage biomass (total biomass per unit effort per haul) with depth (right) derived from onboard observations of French demersal trawl.

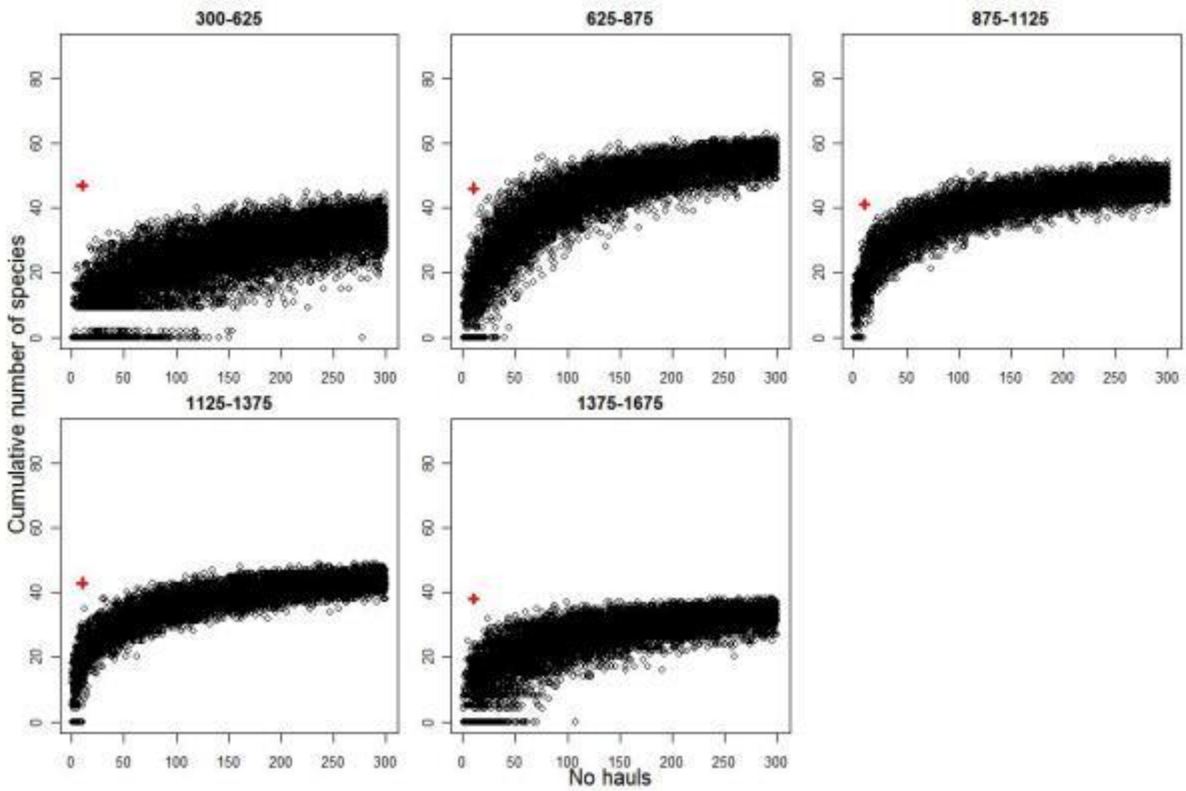


Figure 51: Total number of species (richness) as a function of the number of hauls from onboard observations. The red cross indicates the number of species obtained by e.g. Gordon and Bergstad (1982).

VIII.2.4 Conclusion

Although much richer than landings, onboard observations have a number of short comings as well. First of all species identification is not always reliable.

Second, due to logistic constraints not all species can be measured on board, which means that under the current data registration scheme numbers are not available for species which were not measured.

Third, differences in vessel power and haul duration make it tricky to standardise observations as it is not obvious how to define a standard unit of effort. Fourth, seasonality probably also affects catch quantities and composition, but these could not be investigated here due to too small sample sizes. As result of all these short comings in addition to low sample sizes assemblage indicators showed strong interannual variations but generally no clear time trends. Thus it seems that the exploited fish assemblage (not necessarily all species) to the west of the British Isles might have been rather stable during the period 2004 to early 2010.

Fish community indicators can be derived from on-board observation data. Because of the strong depth effect on species dominance and abundance, the indicators change with depth.

As a consequence, if the distribution of fishing by depth changes over time the indicators will change. This applies to indicators of commercial species, e.g. the ratio of roundnose grenadier to black scabbardfish fish in the catch as well as indicators of non-commercial species such as sharks. Some shark species were commercial during the time period of this study and are now non-commercial. Indicators of sharks, i.e. the proportion of sharks in the catch, were shown here to be sensitive to the fishing depth. This has two complementary consequences (1) changing the fishing depth by management measures may be one approach to reduce sharks discards and (2) changes over time in the discarding on sharks at metier, i.e. of the fishing for deep-sea species, level should not be interpreted without taking into account possible changes in fishing depth. Some other factors may be important too mainly because commercial fishing correspond to a process known as "preferential sampling" (Diggle et al., 2010). These conclusions are highly consistent with the spatial simulation which suggested different proportion of sharks in the fish community and in the catch depending on the fishing strategy scenario.

VIII.3 ON-BOARD OBSERVATIONS OF THE FRENCH DEEP-WATER FISHING LICENSED FLEET

In this section a general analysis of the French on-board observations carried out in application of the Data Collection Framework and regulation 2347/2002 is provided.

The French deep-sea licensed fleet, i.e. vessels holding a deep-sea fishing permit in application of the Council regulation 2347/2002 has been observed since 2004. The deepsea fishing permit is mandatory for vessels that catch and retain on board (or tranship or land) more than 10 tonnes per calendar year or more than 100 kg per fishing trip of deep-sea species. Observed fishing trips of all vessels holding a deep-sea fishing permit were extracted from the on-board observations database held at Ifremer. Overall from 2004 to 2012, 271 fishing trips corresponding to 6939 fishing hauls from vessels holding a deep-sea fishing permit have been observed on a total of 44 fishing vessels from 2004 to 2012 (Table 44). Some of these vessels mostly fished for deep-sea species, i.e. species listed in annex I of the Council regulation 2347/2002 but all vessels also did some fishing for demersal species, in particular for saithe and hake and. Further, for some vessels, deep-sea fishing was only a small part of their activity. These latter vessels held a deep-sea fishing permit because they make a bycatch of deep-sea species while targeting other species. This concern in particular vessels fishing in the Celtic sea where catches in excess of 100 kg per fishing trip of greater forkbeard (*Phycis blennoides*) may be caught on the shelf.

The method to allocate fishing trips to metiers in estimations of catch and discards for all the French fleet was not used because the metiers are defined at the fishing trip level (Dubé et al. 2012) and would exclude e.g. one single deep-water hauls during a fishing trip targeting mainly demersal species. Extracting data based on the list of vessels holding the deep-sea fishing permit defined according to the EU regulation allows instead identifying all vessels that can do deep-sea fishing.

Raised estimations of landings and discards in the métier bottom trawl for deep-water species have been calculated per year (Fauconnet et al., 2011; Dubé et al., 2012).

In 2012, 98 species were discarded, a figure similar to those obtained in 2011 where 100 species were discarded (Dubé et al., 2012) and 2010 where 122 species where discarded (Fauconnet et al., 2011). A few species make up the bulk of the total species in weight. In 2012, the ten first species in discarded weight represented 83 % of the total discarded weight. These species were: *Alepocephalus bairdii, Argentina silus, Centrophorus squamosus, Centroscymnus crepidater, Chimaera monstrosa, Deania calcea, Coryphaenoides rupestris, Centroscymnus coelolepis, Somniosus microcephalus, Etmopterus princeps*. The two first species make up about 45 % of the discards. The 6 shark species make up 28 % of the discards.

Table 44: Summary of French on-board observation data. Number of fishing vessels, trips, haul and days-at-sea observed together with resulting cumulated total landings, total discards, proportion landed, proportion discarded, and landings and discards of deep-water species. All is observed sample without any raising to the total fleet activity. For 2012, analyses are on-going.

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012
Number of vessels	22	13	6	1	10	15	17	11	10
Number of fishing trip	29	15	9	1	11	32	36	27	24
Number of hauls	280	152	118	11	222	586	561	414	352
Number of days at sea observed	333	172	119	14	141	343	455	321	269
Total catch observed (t)	660	341	189	4	378	1438	1300	1162	939
Total landings observed (t)	401	213	108	4	318	1120	1180	990	808
Total discards observed (t)	258	129	81	1	61	318	119	171	130
Proportion of the total catch landed	0.61	0.63	0.52		0.84	0.77	0.90	0.85	0.86
Proportion discarded	0.39	0.37	0.48		0.16	0.23	0.10	0.15	0.14
Catch of deep-water species (t)	378	298	161	1	298	1213	1057	983	776
Landings of deep-water species (t)	201	180	88	>1	254	926	968	827	667

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012
Discards of deep-water species (t)	178	117	72	>1	45	287	89	156	108

The list of species in the landing and discards in these hauls is given for 2012 as an example (Table 45).

Table 45: Percentage of discards by species relative to the total multispecies catch (in decreasing order), together with proportion discarded by species, proportion of the species in the catch, and proportion of the species in the discards.

Scientific_name	Weight discarded as percent of the total catch	Proportion discarded	Percentage of the total catch	Percentage of the total discard
Alepocephalus bairdii	4.578	100	4.578	23.652
Argentina silus	4.124	100	4.124	21.31
Centrophorus squamosus	1.652	100	1.652	8.535
Centroscymnus crepidater	1.395	100	1.395	7.208
Chimaera monstrosa	1.052	47.36	2.222	5.437
Deania calcea	1.007	100	1.007	5.204
Coryphaenoides rupestris	0.865	8.943	9.669	4.468
Centroscymnus coelolepis	0.499	100	0.499	2.581
Somniosus microcephalus	0.468	100	0.468	2.419
Etmopterus princeps	0.448	100	0.448	2.317
Lepidion eques	0.358	100	0.358	1.848
Illex coindetii	0.332	100	0.332	1.717
Centroscyllium fabricii	0.31	100	0.31	1.604
Alepocephalidae	0.224	100	0.224	1.159
Rajella bathyphila	0.219	100	0.219	1.132
Trachyrincus scabrus	0.186	100	0.186	0.96
Aphanopus carbo	0.168	0.598	28.121	0.869
Bathyraja spinicauda	0.124	100	0.124	0.641
Caelorinchus caelorhincus	0.099	100	0.099	0.511

Scientific_name	Weight discarded as percent of the total catch	Proportion discarded	Percentage of the total catch	Percentage of the total discard
Phycis blennoides	0.09	7.892	1.134	0.463
Hexanchus griseus	0.087	100	0.087	0.45
Raja fyllae	0.079	100	0.079	0.408
Amblyraja hyperborea	0.071	100	0.071	0.365
Dipturus linteus	0.059	100	0.059	0.303
Polyacanthonotus rissoanus	0.058	100	0.058	0.301
Helicolenus dactylopterus	0.048	33.861	0.141	0.247
Brosme brosme	0.046	2.297	1.983	0.235
Raja fullonica	0.046	100	0.046	0.236
Loligo forbesi	0.044	100	0.044	0.229
Hydrolagus mirabilis	0.039	100	0.039	0.203
Amblyraja radiata	0.037	100	0.037	0.19
Cottunculus thompsoni	0.036	100	0.036	0.186
Rajella kukujevi	0.034	100	0.034	0.175
Halargyreus johnsonii	0.028	100	0.028	0.144
Schedophilus medusophagus	0.028	100	0.028	0.143
Dipturus	0.026	100	0.026	0.134
Anarhichas denticulatus	0.026	100	0.026	0.136
Micromesistius poutassou	0.026	100	0.026	0.133
Todarodes sagittatus	0.024	100	0.024	0.125
Nezumia aequalis	0.022	100	0.022	0.115
Chaceon affinis	0.02	100	0.02	0.104
Apristurus laurussonii	0.019	100	0.019	0.099
Coelorinchus labiatus	0.019	100	0.019	0.099
Macrourus berglax	0.017	50.473	0.034	0.088

Scientific_name	Weight discarded as percent of the total catch	Proportion discarded	Percentage of the total catch	Percentage of the total discard
Molva dypterygia	0.017	0.056	30.765	0.09
Neolithodes grimaldii	0.017	100	0.017	0.086
Lophius piscatorius	0.015	0.841	1.787	0.078
Mora moro	0.015	3.161	0.467	0.076
Nezumia sclerorhynchus	0.012	100	0.012	0.061
Chimaeriformes	0.011	7.811	0.142	0.057
Etmopterus spinax	0.011	100	0.011	0.057
Centrolophus niger	0.01	100	0.01	0.051
Merluccius merluccius	0.009	1.292	0.699	0.047
Lepidorhombus whiffiagonis	0.008	27.593	0.028	0.039
Harriotta raleighana	0.008	100	0.008	0.042
Reinhardtius hippoglossoides	0.008	0.237	3.453	0.042
Geryon trispinosus	0.008	100	0.008	0.041
Rhinochimaera atlantica	0.007	87.947	0.008	0.037
Galeus melastomus	0.006	100	0.006	0.032
Dipturus nidarosiensis	0.006	100	0.006	0.03
Scymnodon ringens	0.006	100	0.006	0.03
Alepocephalus	0.005	100	0.005	0.025
Hoplostethus atlanticus	0.004	100	0.004	0.019
Lycodes esmarkii	0.004	100	0.004	0.021
Glyptocephalus cynoglossus	0.004	4.635	0.079	0.019
Raja oxyrinchus	0.004	100	0.004	0.021
Galeus murinus	0.003	100	0.003	0.018
Lepidion guentheri	0.002	100	0.002	0.012
Zoarces viviparus	0.002	100	0.002	0.01

Scientific_name	Weight discarded as percent of the total catch	Proportion discarded	Percentage of the total catch	Percentage of the total discard
Malacocephalus laevis	0.002	100	0.002	0.011
Malacoraja kreffti	0.002	100	0.002	0.011
Neoraja caerulea	0.002	100	0.002	0.012
Epigonus telescopus	0.002	0.698	0.29	0.01
Antimora rostrata	0.001	100	0.001	0.006
Beryx decadactylus	0.001	100	0.001	0.004
Nesiarchus nasutus	0.001	100	0.001	0.005
Gaidropsarus vulgaris	0.001	100	0.001	0.004
Rostroraja alba	0.001	100	0.001	0.004
Actinopterygii	0	0	0.009	0
Squalus acanthias	0	100	0	0.002
Lophius budegassa	0	0	0.055	0
Lophius spp	0	0	0.025	0
Lepidorhombus boscii	0	100	0	0.002
Cataetyx laticeps	0	0	0.03	0
Conger conger	0	0	0.01	0
Coryphaenoides guentheri	0	100	0	0.002
Diastobranchus capensis	0	100	0	0.002
Hippoglossus hippoglossus	0	0	0.061	0
Molva spp	0	0	0.229	0
Lycodes squamiventer	0	100	0	0
Gadus morhua	0	0	0.016	0
Raja batis	0	100	0	0.001
Raja circularis	0	100	0	0.002
Sebastes mentella	0	0	1.115	0

Scientific_name	Weight discarded as percent of the total catch	Proportion discarded	Percentage of the total catch	Percentage of the total discard
Sebastes	0	0	0.115	0
Sebastes norvegicus	0	0	0.313	0
Synaphobranchidae	0	100	0	0
Trachyscorpia cristulata	0	0	0.028	0
Total	19.352		99.998	100.002

VIII.4 Descriptive analysis of deep-water sharks bycatch distribution based upon on-board observations 2009-2012

VIII.4.1 Introduction

With the closure of fisheries for sharks, on-board observations carried out in application of regulation 23/47/2002, DCF and addition sampling based on national funding provide the main source of information about the interaction of the deep-water fishery with deep-sea sharks. Here on-board observations from 2009 to 2012 were used to draw the spatial distribution of sharks by-catch using the R-packages COSTcore and COSTeda (COST project, 2009).

VIII.4.2 Material and method

Distribution maps of the catches in weight of deep-water sharks during commercial fishing hauls sampled in the on-board observations from 2009 to 2012, were drawn for 6 species categorised deep-sea according to regulation 2347/2002: leafscale gulper shark (*Centrophorus squamosus*), Portuguese dogfish (*Centroscymnus coelolepis*), longnose velvet dogfish (*Centroselachus crepidater*), birdbeak dogfish (*Deania calcea*), Greenland shark (*Somniosus microcephalus*) and black dogfish (*Centroscyllium fabricii*). All French on-board observations from years 2009 to 2011 and most of observations in 2012 were used, the data included 1754 fishing trips and 7795 hauls (here in the broader meaning of fishing station, including hauls of towed gears and sets of static gears). Data from the year 2012 was not fully used as they were not fully available when this approach was carried out.

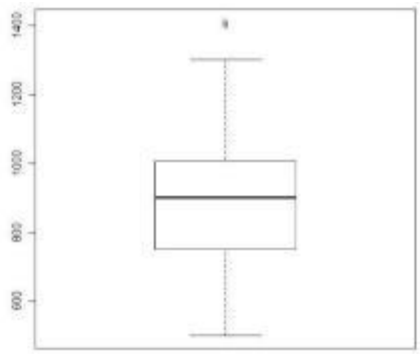
As all French on-board observations were used, occasional bycatch in non deep-water fisheries were included. In addition to maps, the depth of catch of the study species was drawn. Further, the same maps have been drawn for a few other chondrychtyans species, namely *Dipturus batis, Squalus acanthias, galeorhinus galeus, Mustelus asterias* and some comment are provided.

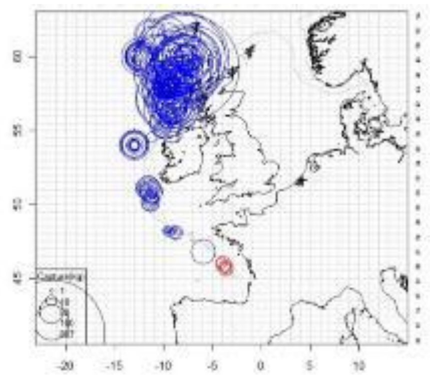
VIII.4.3 Results

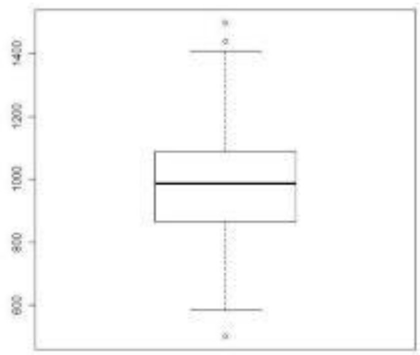
The species with the shallowest depth in the catch was the Greenland shark (Table 46), a species actually known to occur in coastal waters in Northern areas such as Icelandic, Greenland and Faeroes waters. The deepest species was the black dogfish, a species that became of commercial interest in France in the late 1990s, i.e. later than the leafscale gulper shark and Portuguese dogfish.

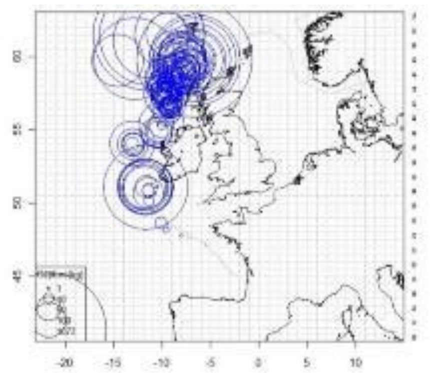
Amongst the six deep-sea sharks species studied, the catching locations reproduce well the spatial distribution of the fishing grounds of the French deep-water licensed fishing fleet for the leafscale gulper shark, the Portuguese dogfish, the longnose velvet i.e. 3 out of 6 species studied (Figure 52 and Figure 53). The 2 species for which the catch distribution is not that of the fishing grounds are the Greenland shark and the black dogfish, which catches are restricted the northernmost part of the fishing ground of the deep-water licensed fleet. This is related to the more boreal distribution of these two species. These 2 species were caught in smaller numbers of fishing trips and hauls, and for the Greenland shark, where the catch consist most often of one large individual, these catches could be qualified incidental catches. Further for 2 species, the leafscale gulper shark and the birdbeak dogfish, the catch distribution extend further to the south in the Bay of Biscay, where some catch in static fishing gears were also recorded. These latter catches were observed at rather shallow depth, some close or shallower to the 200 m depth contour.

The observed catch of the other species occurred mainly of the shelf shallower than 200 m. However for both the spurdog (*Squalus acanthias*) and tope shark (*Galeorhinus galeus*) some catches deeper than 200 m were recorded in northern areas to the North of Scotland. These deepest catches had however only a minor contribution to the total catch of these species. For the blue skate (*Dipturus batis*) the observed catch were concentrated on the Celtic sea shelf and occurred in both towed and static gears (Figure 54). Further North to the West of Scotland and in the Northern North Sea, catches were mostly distributed on the outer shelf (close to 200 m) and upper slope down to 600-800 m.









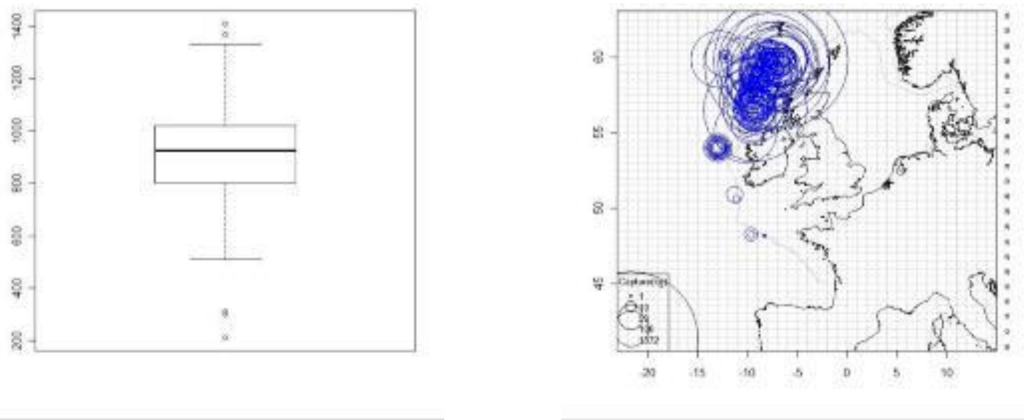
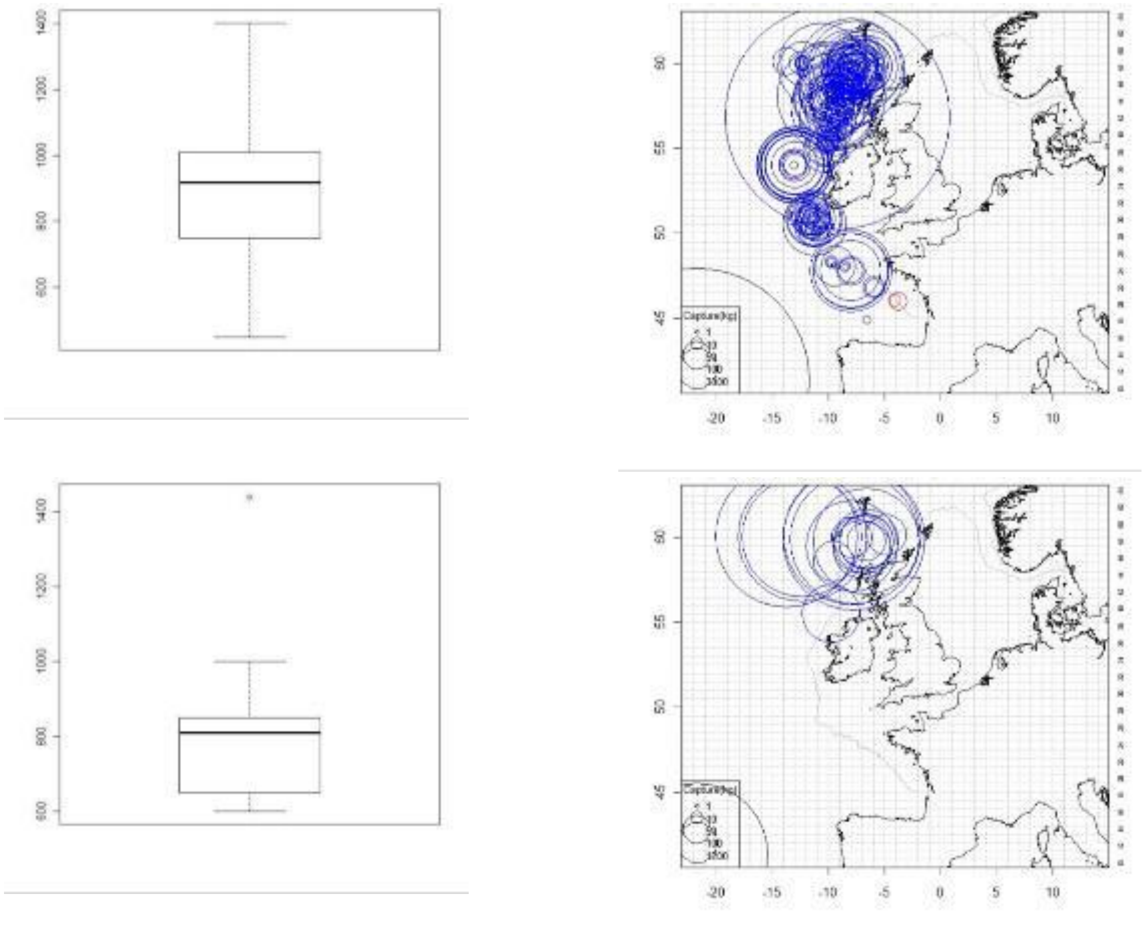


Figure 52: Depth distribution (left) and spatial (right) distribution of the catch of leafscale gulper shark (top), Portuguese dogfish (middle), Longnose velvet dogfish (bottom) in French on-board observation 2009-2012. The depth distribution is depicted as a boxplot where the bold bar represents the median depth in the sample (i.e. no raising to the total fishing activity), the box represents the depth distribution of 50 % of the catch and the whiskers that of 75 %. The depth contour shown is 200 m.



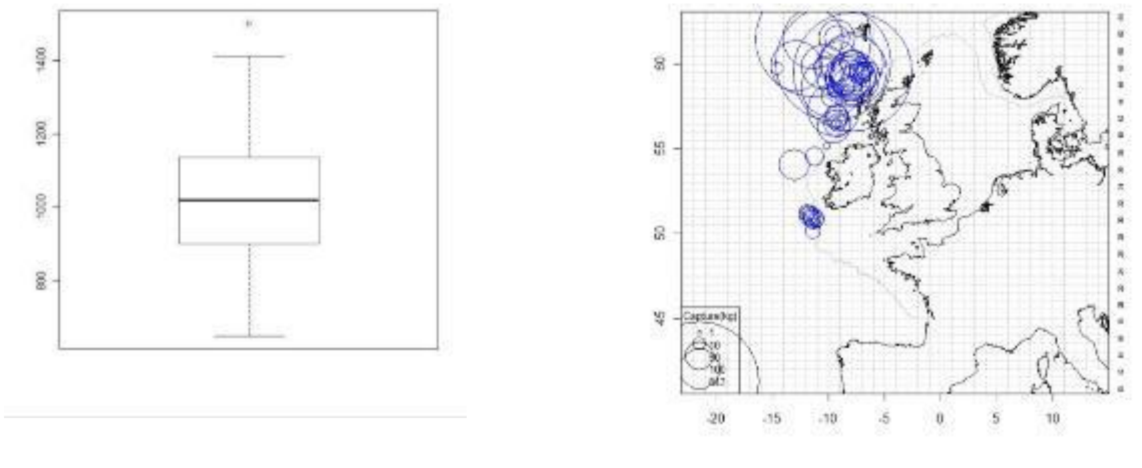


Figure 53: Depth distribution (left) and spatial (right) distribution of the catch of birdbeak dogfish (top), Greenland shark (middle) and black dogfish (bottom) in French on-board observation 2009-2012. The depth contour shown is 200 m (see also legend in Figure 54).

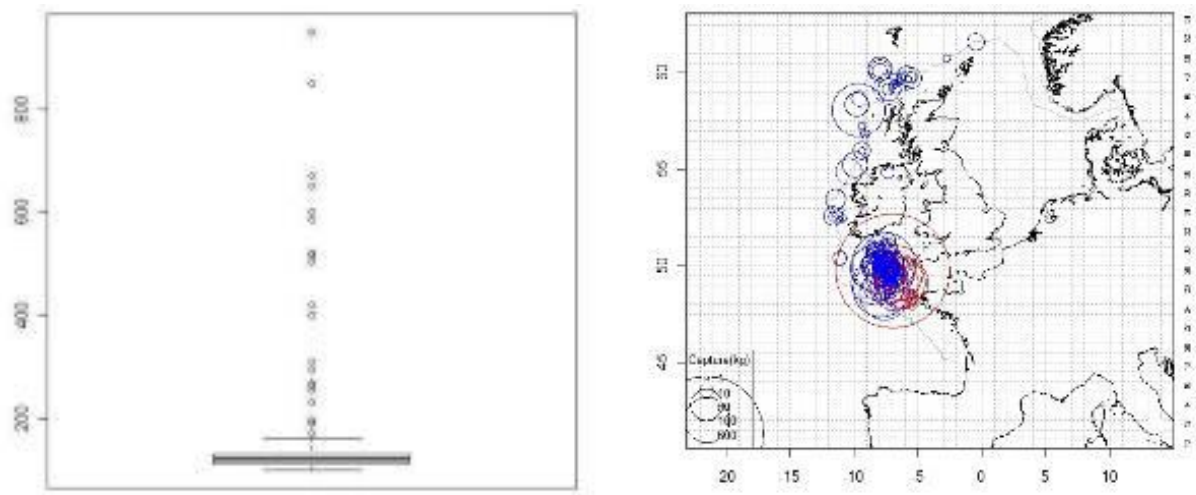


Figure 54: Depth distribution (left) and spatial (right) distribution of the catch of blue skate in French on-board observation 2009-2012. The depth contour shown is 200 m (see also legend in Figure 54).

Table 46: Median depth of catch in the on-board observations by species and occurrence data.

		Median depth	Occurrence (in nb)	
Common name	Scientific name	of catch	Fishing trips	Hauls
Leafscale gulper shark	*Centrophorus squamosus*	880	44	191
Portuguese dogfish	*Centroscymnus coelolepis*	1004	35	118
Longnose velvet dogfish	*Centroselachus crepidater*	901	40	168
Birdbeak dogfish	*Deania calcea*	884	42	209
Greenland shark	*Somniosus microcephalus*	803	12	20
Black dogfish	*Centroscyllium fabricii*	1035	26	60

VIII.4.4 Discussion

The spatial distribution analysis presented here is exploratory and preliminary. More data can be integrated in the analysis including data from 2004 and the whole year 2012, available on the database only in recent days. The same protocol can further be applied species other than sharks and rays, on which we concentrated as those species are more a concern in terms of impact on the fishing mortality on their populations.

For most sharks species studied here these data do not suggest strong spatial pattern in the bycatch. Nevertheless, the approach was univariate and additional approaches are required in order to include other aspect. This is planned to be addressed using statistical models. For two species, there were clear spatial patterns, and they were caught in the northern part of the fishing grounds on the deep-water licensed fleet. For these species in particular, the investigation of the existence of additional effects, e.g. seasonal is of major interest to evaluate whether limited spatio-temporal constraint to the fishing could relax most of the bycatch fishing mortality. This is especially of interest for the Greenland shark, a very large sized species, which therefore could be more vulnerable.

VIII.5 SPATIAL ANALYSIS OF DISCARDS USING A NESTED GRID APPROACH

VIII.5.1 Abstract

In this section a novel approach is used to estimate the geographical distribution of discard rates. Using data from on-board observations of the French deep-water fishing fleet to the west of Scotland from 2004 to 2012, the process starts from large spatial cells and divide them in smaller cells when the contain many observed hauls. Cells may be divided several times so that small cells are drawn where numerous hauls were observed and larger cells are drawn were only a few haul were observed. As a consequence a higher spatial resolution is obtained in areas where there are more observations. Then the mean proportion of fish that is discarded is calculated in every cell. The method is applied to the total discards and to discards of some species and groups of species. The results show a spatial pattern in the rate of discards, which is mostly common to several groups of discarded species (total discards, elasmobranchs, roundnose grenadier, alepocaphalids). An area of higher discarding rate can be delineated to the north of the Rockall Trough. Developing regulation in this area could allow reducing the overall discard rate in the fishery. Outside of this area there are little spatial variations in the discards.

VIII.5.2 Introduction

The purpose of this analysis is to develop a method for estimating the impact of fishing on fish populations, based on on-board observations of commercial fishing. The proportion of the catch that is discarded is estimated in a spatial grid with a variable cell size. The spatial cells are of variable cells smaller cells are defined where there is more data, i.e. in areas where there is more fishing activity provided the on-board observation sampling is representative. The approach is fully based upon available data, it estimates the spatial distribution of the proportion of the catch that is discarded. It is considered highly relevant to the objective of identifying options to reduce discards as it allow to evaluate whether there exist areas where a higher proportion of the total catch or of a particular species or group of species is discarded.

Where the method delineates small enough spatial cells, each cell might encompass only a small range of depth so that this major factor in the species composition and rate of discards is indirectly taken into account. Conversely, it is difficult to account for seasonal factors in this approach because estimating discards proportion by season (e.g. quarter) imply working on small dataset.

VIII.5.3 Material and method

VIII.5.3.1 Data

The dataset is composed of on-board observations from the French deep-water fishing fleet. On-board observations of this fleet are carried out under the Data Collection Framework (DCF, Council regulation (EC) No 199/2008) and the Council regulation (EC) No 2347/2002. Collection and storage of on-board observation data is managed by Ifremer. The sampling fraction of the deepwater fishery, i.e. the proportion of fishing trips of French vessels holding a deep-sea fishing permit was 14.6 % in 2012 (Dubé et al, 2012.).

In on-board observation, for each observed fishing trip, the catch for each fishing operation is sorted by species. For every species, the weight of landings and discards are noted. Length distribution and further biological data, e.g. maturity, are collected for some species based on a subsample where appropriate. Associated data on the vessel (e.g. length and total power) and each fishing operation (e.g. date, time, haul in locations, duration, water depth) are also collected. Data are organised according to a standard format for commercial fisheries data described by Jansen et al (2009). For the French deep-water fishing fleet, On-board observation data were available from 2004 to 2012.

The total fishing activity of the French deep-water fishing fleet extends from the Bay of Biscay to the northern and eastern North Sea, the longitude range of observed fishing hauls is [-17.82°,7.83°] and the latitude range is [43.51°, 62.93°] (Figure 55). Hauls, represented by their mean position in figure 1, are are mainly distributed along the continental slope; however the fleet also fished on shelf fishing grounds, in particularly in the Bay of Biscay and Celtic Sea, to the west of Ireland and on the Porcupine Bank. Further, fishing activity of these vessels in the North Sea correspond to fishing for demersal species, primarily saithe (*Pollachius virens*) along the upper slope of the northern North sea and Norwegian Deep.

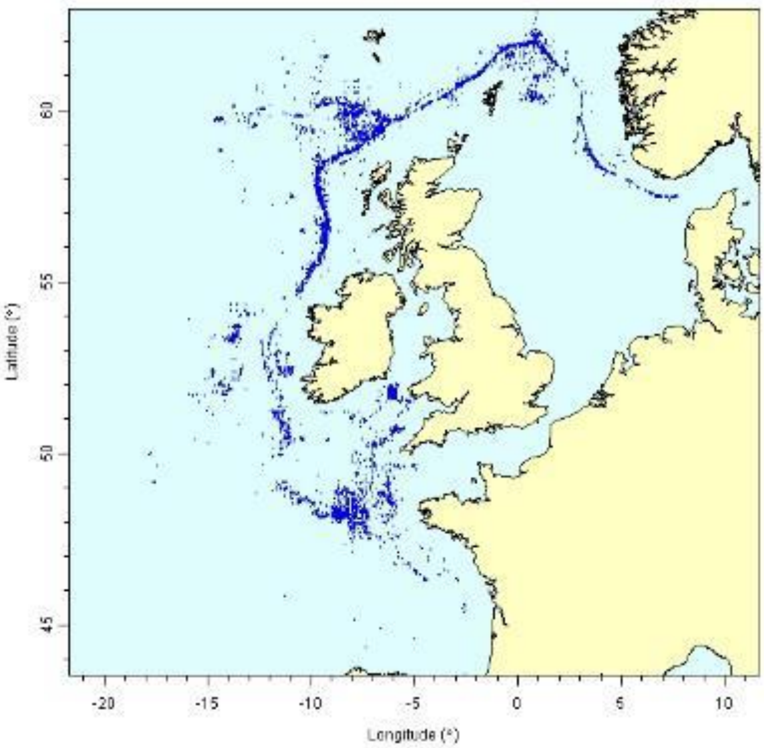


Figure 55: Geographical distribution of observed fishing hauls from the French deep-water fishing fleet from 2004 to 2012.

VIII.5.3.2 Study area

The analysis was restricted to the West of Scotland and Faroe Islands area, corresponding to ICES Divisions Vb, VIa and VIb because outside of this area there number of observed fishing hauls for deep-water species was too low. Hauls to the south and East of the study area were mostly for demersal species The longitude range of observed hauls in ICES Divisions Vb, VIa and VIb was 4.05 to 14.61 decimal degree. West and the latitude range was 54.51 to 62.00 decimal degrees. In this study area, the fishing activity of the vessels holding a deep-sea fishing permit was mainly targeted to deep-sea species. The total number of observed hauls was in the study area was 2610, corresponding to about 40 % of all observed hauls of French vessels holding a deep-sea fishing permit during the years 2004 to 2012 (Figure 56).

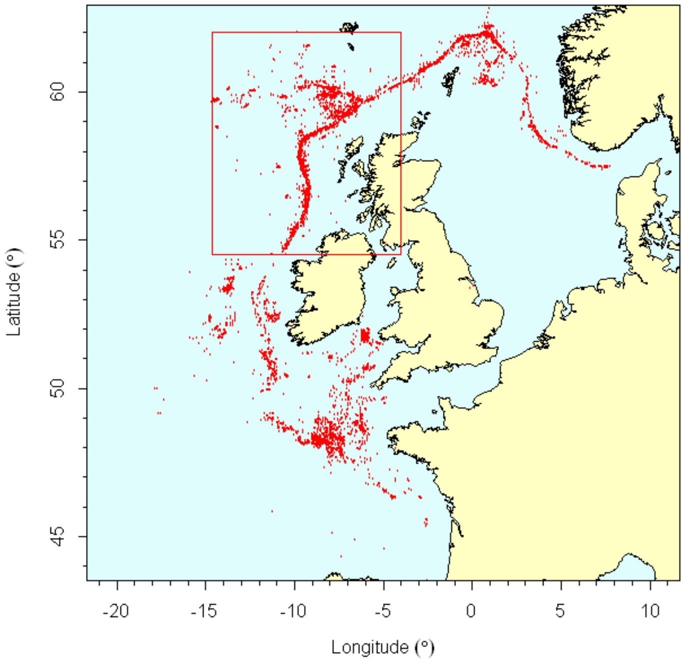


Figure 56: Study area and positions of individual hauls. Hauls to the south and East of the study area were mostly for demersal species.

Observations were concentrated along the West of Scotland slope, with some extension to the south of the Faroe Bank and further west at about 60°N (Figure 57).

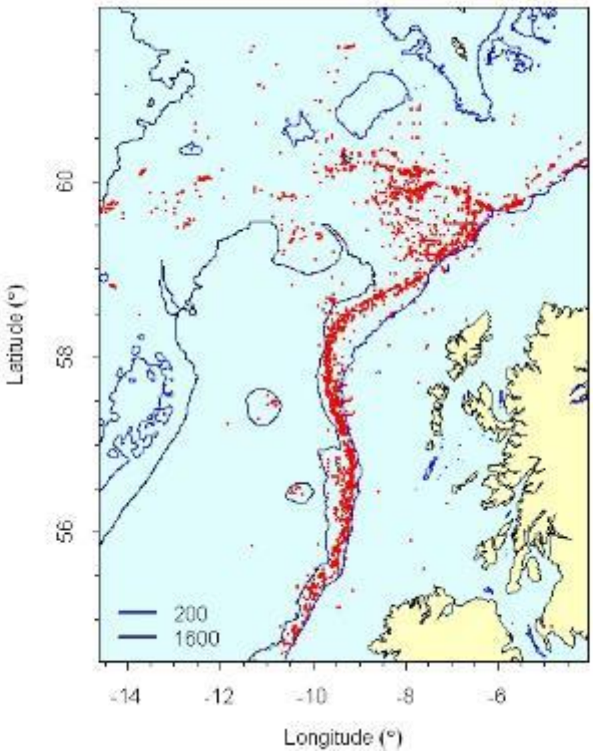


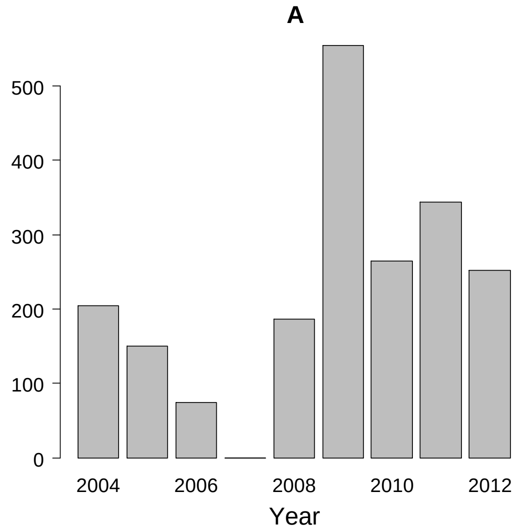
Figure 57: Spatial distribution of observed hauls in 2004 to 2012, in the study area. The depth contours shown are 200 m and 1 600 m.

VIII.5.3.3 Data preparation

Data were selected using the on-board observations database held at Ifremer. Starting from the complete database the data from all the licensed deep-sea fishing fleet was extracted, then the data subset was restricted to hauls observed in ICES Division Vb, VIa and VIb and only to hauls were both the ladings and the discards were registered[8]. The total number of observed hauls of the licensed fleet was 6 939 and the number of haul where both landings and discards were registered was 4 122, of which 2 153 were at more than 500 m depth. Finally, restricting to the West of Scotland area, 2 028 hauls were observed of which 1 629 were deeper than 500 m, reflecting that in this area the fishing was much more targeted toward deep-sea species. Other hauls deeper than 500 m were mainly carried out in ICES Division VIIj, i.e. along the continental slope of the Celtic sea proper. The resulting total number of observed hauls of the fleet was on average more than 200 per year. There was no sampling in 2007 and more sampling in 2009 owing to an addition sampling effort from national fundings in that year (Figure 58 A). The distribution over time of all hauls and hauls deeper than 500 m was similar (Figure 58).

Deep-sea fishing regulation changed over time and might have triggered changed in the fishing strategy susceptible to impact the spatial distribution of the fishing activity, the species composition of the catch and therefore the proportion of the catch that is discarded.

The stronger regulation changes likely to impact on the discarded proportion of the catch were (1) the reduction of the Total Allowable Catch (TAC) over time and the ban of orange roughy and deep-water sharks landings from 2010. Further effects such as the increase in fuel price since 2004 may have impacted fishing strategies in general. The amount of available data was considered insufficient to assess the spatial distribution of discarded proportions by year, which would Therefore the proportion discarded by cell were estimated for all the data (all years 2004 to 2012) and for the three most recent years (2010 to 2012) in order to evaluate the proportion discarded with all the data available and with the most recent data only, which may allow to better estimate proportions discarded under the current regulation and fishing strategies.



[8] On observed trips, on-board observers main not observed all hauls for pratical reasons. The standard format for sampling from commercial fisheries include a variable for catch registration, which specify for every haul which part of the catch (all, landings, discards or none) was registered (Jansen et al., 2009).

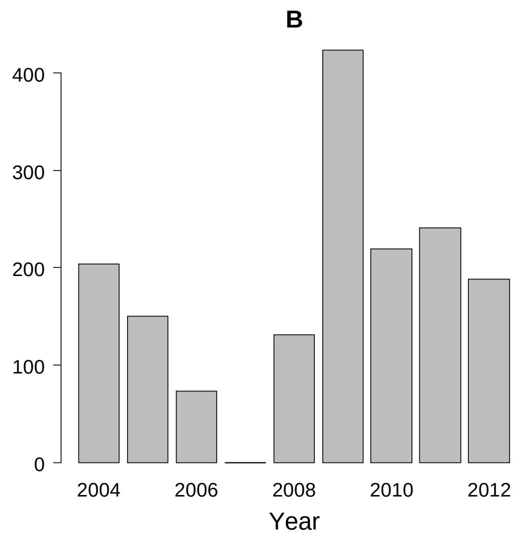


Figure 58: Number of observed hauls in the West of Scotland area per year, (A) all hauls, (B) hauls deeper than 500 m.

The discarding rate may vary with depth, in particular it may be different when fishing for deep-water species and when fishing for saithe and hake along the upper slope. As vessels holding a deep-sea fishing permit do the two type of fishing in most fishing trips, the data include both types of fishing. In order to evaluate the discarding rate when fishing of deep-water species, all proportion where calculated first for all hauls of the observed fishing trips of the fleet and for hauls deeper than 500 m only. The dataset of hauls fished deeper than 500 m was similar to that of hauls were deep-sea species made up more than 10 % of the catch, it was however considered more suitable to select hauls based upon a haul characteristics than based upon the resulting catch.

VIII.5.3.4 Nested grid

To represent the geographical distribution of the proportion discarded of various species and larger taxonomic groups, a “nested grid”, i.e. a grid with variable cell size, was used. The observed hauls in the on-board observation program are geographically unevenly distributed (Figure 59), with clustered points on the main deep-water fishing grounds where the fishing effort is higher, and more spread out points in other areas, where the fishing effort is low. If the data points were studied through a regular grid with a fixed cell size, the number of observations in each cell would vary greatly. As a consequence, the accuracy of data aggregation per cell, such as the mean discard rate, would vary greatly as well. To avoid such a variation in accuracy, a nested grid is applied: in areas with few data points a large cell size is used and in areas with many observations, a smaller cell size is used. This method takes into account the spatial distribution on the observed hauls and adapts the spatial resolution of estimated variables according to it.

The nested grid method was taken from Gerritsen et al (2013). The nested grid was drawn according to 3 parameters: the maximum size of a cell, the maximum number of points allowed in a cell, labelled *N*, and the maximum number of cell divisions. First a grid with the maximum cell size is drawn, then the number of observed hauls per cell is estimated. Cells with no hauls are deleted, cells with less than *N* hauls are kept, and cells containing more than *N* hauls are divided in two smaller cells. The cells are first divided according to their longitude. The number of data points per cell is estimated again, and cells still containing more than *N* hauls are divided in two again. The second cell division is done along the latitude of the cell.

As further divisions go on, the cells are divided alternatively according to their longitude and latitude. The process is repeated until all cells contain less than *N* points or have reached the minimum allowed size (Figure 59).

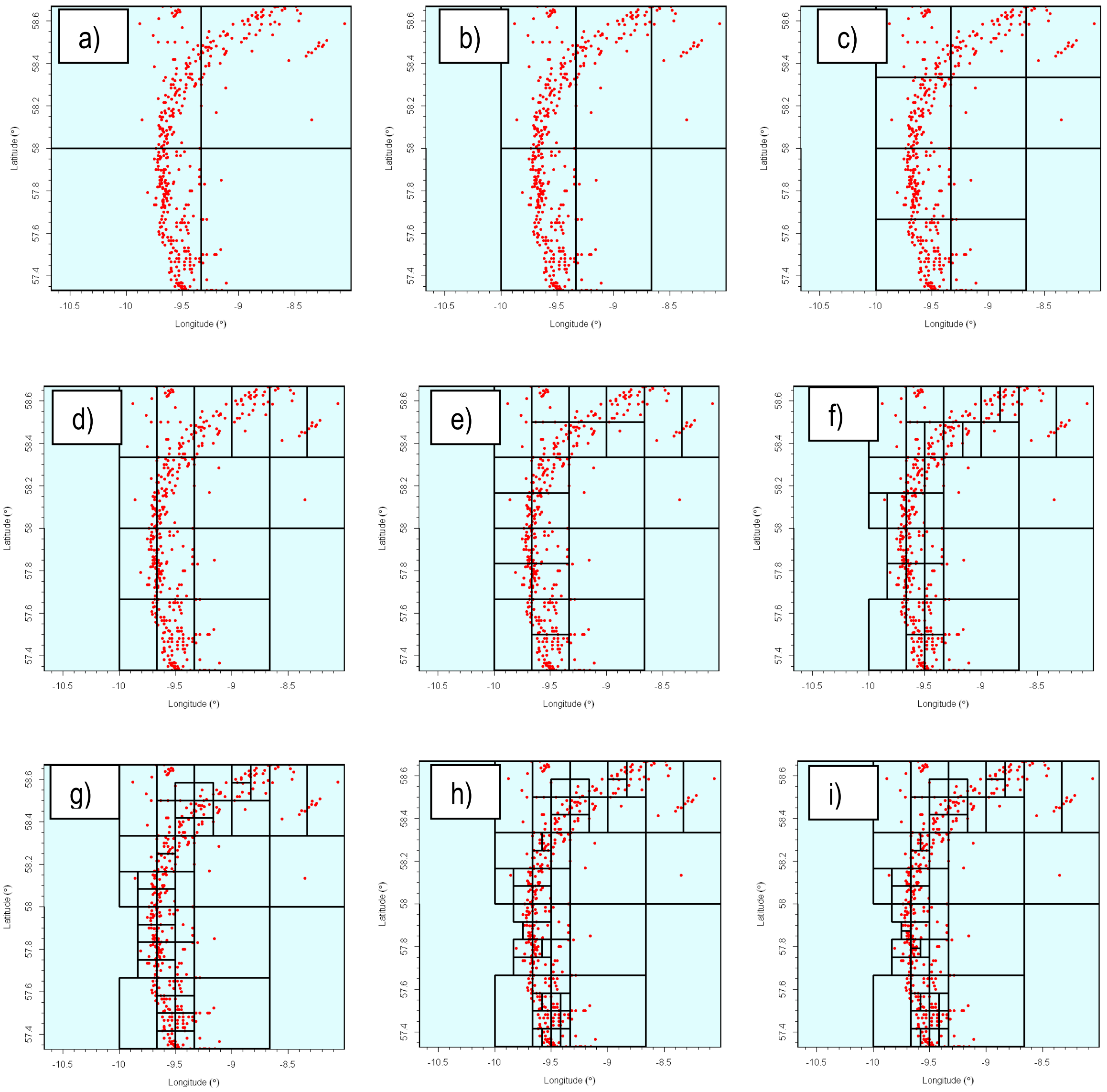


Figure 59: The 9 steps of the nested grid definition process: a) Maximum cell size grid, b) to h) Successive divisions of the cells, alternatively according to their longitude and latitude, according to the numbers of points inside each cells, i) 8th and final divisions of the cell, and final grid.

One single nested grid was drawn based on the spatial distribution of all observed hauls from 2004 to 2012 in the study area. Results for the two set of years (all years and years 2010-2012 only) and the two depth ranges (all depths and depths > 500m) were calculated in the same nested grid for ease of comparisons. The nested grid was drawn using all hauls in all years in the study area. The minimum number of hauls for dividing cells was fixed to *N*=15, which means that if there are more than 15 observations per cell, it is divided in 2 smaller cells. The maximum number of divisions of a cell was set to 8.

The maximum cell size was fixed to 1.33 degrees by 0.67 decimal degrees, corresponding to a size of 80'x40' because this starting size allow keeping entire size in number of minute up to the 7th division where the cell size is 5'x5'. After the 5th division, the cell size is 10'x10'. So that the calculation are done for some hopefully practical sizes to further combine the results of this study to other data, e.g. spatialised effort data derived from Vessel Monitoring System (VMS), in the future. The smaller cells were 5' in longitude and 2.5' in latitude. The larger cells (80'x40') are larger than ICES statistical rectangles (60'x30'). Nevertheless, changing the size of the larger cells to fit with any fixed spatial resolution of other data after a number of divisions is feasible in order to adapt to the cell size of other available.

The spatial distribution of the discards of the following species and species groups was estimated:

- Total discards, i.e. the proportion of the total discards in the total catch per haul;
- Discards of commercial species: commercial species were defined as those which total landings exceeded total discards over the whole data set. These included the main target species such as saithe, (*Pollachius virens)*, blue ling (*Molva dypterygia*), black scabbardfish (*Aphanopus carbo*), hake (*Merluccius merluccius*), roundnose grenadier (*Coryphaenoides rupestris*), monkfish (*Lophius* spp.), haddock (*Melanogrammus aeglefinus*), ling (*Molva molva*), rabbitfish (*Chimaera monstrosa*) and bycatch species such as blackbelly rosefish (*Helicolenus dactylopterus*) and greater forkbeard (*Phycis blennoides*), which quantities landed are larger than quantities discarded;
- Discards of elasmobranchs, this group of species includes all sharks, rays and Chimaerids, i.e. those categorized deep-sea sharks in the EU regulation[9] as well as other species such as the spurdog, *Squalus acanthias*, which may be caught at great depth. Chimaeras are known abundant at upper and mid-slope depths, their vulnerability to fishing, i.e. the rate of exploitation that their populations can sustain is poorly known. In most, if not all marine ecosystems, the most vulnerable species are sharks and rays species (see e.g. Clark et al., 2003; Garcia et al., 2008; Le Quesne and Jennings, 2012);
- Discards of deep-sea sharks, this category includes deep-sea sharks listed in the EU regulation;
- Discards of siki sharks, this category refers to the French commercial appellation "siki" for the two main commercial deep-sea sharks *Centrophorus squamosus* and *Centroscymnus coelolepis*, which landing are currently banned in application of a 0 Total Allowable Catch (TAC);
- Discards of roundnose grenadier, this species is the only target species of the deep-water trawling fleet analysed here because it is the only one which discards are significant. Unlike the two other main target species, black scabbardfish and blue ling, which juveniles do not occur on the fishing grounds, juvenile roundnose grenadier are caught in high numbers and discarded;
- Discards of greater silver smelts (*Argentina silus*). Greater silver smelt is subject to significant landings for reduction purposes in the Northeast Atlantic. It is not commercial for the French trawl deep-water fishery and contribute roughly to 25% of the discards of the fishery (Dubé et al., 2012);
- Alepocephalids, these species are dominant in the slope fish community biomass at depth deeper than 1000 m (Gordon and Duncan, 1985; Gordon and Bergstad; 1992, Gordon et al. 1996). These species are not marketable and have a big contribution to the total discarded biomass at some depths.

9 Annex I of Council Regulation (EC) No 2347/2002 of 16 December 2002 establishing specific access requirements and associated conditions applicable to fishing for deep-sea stocks.

For each the species and groups above, two proportions are considered, the proportion of the discards in the total catch (the weight of the discards of the species or group divided by the weight of the total catch) and the proportion discarded (the weight of the discards of the species or group divided by weight of the catch of the species of group).

Depending on the species or group, the two proportions may be of interest or not. For a not commercial species all the catch is always discarded so that the proportion discarded is 1 and is not of interest. Conversely, for some groups that are partly discarded, the proportion of the discards in the total catch may be of lesser interest than the proportion discarded.

The method appeared not appropriate for species caught only occasionally because the averaging on proportions discarded in cells of the nested grids would mostly be based upon one single catch event per cell. In such cases it is more appropriate to map the raw data, i.e. the individual catch location to see whether these show a spatial pattern or not. This was done here for the Greenland shark (*Somniosus microcephalus*), for large skates of the genus *Dipturus* and could be made for other species in particular large bodies species. A further example was made for the dealfish (*Trachipterus articus*). In other fisheries similar simple mapping could be also made based upon on-board observations for seabirds, marine mammals and turtles, which no bycatch have been registered in on-board observations of the French deep-sea licensed fishery.

VIII.5.4 Results

VIII.5.4.1 Total discards

The total discarded proportion (total discarded weight divided par total catch) for the studied fleet per nested grid cell varied in a range of about 0 to 45 % (Figure 60A). Higher discarded proportions were observed when the hauls taken into account were restricted to depth below 500 m (Figure 60 B). This might be due to lower proportion discarded on the upper slope where vessels fish for saithe and hake. It is therefore important to analyse both the proportion discarded for the whole fishing activity of the fleet to the West of Scotland and the proportion discarded in the deeper hauls. In these deeper hauls, higher discards are observed to the North of the Rockall trough, by latitudes of about 58°30' North to 60°North and West of About 8° West. The discarded proportion seems lower along the Scottish slope. Cells where the estimated discard proportion is high are generally larger than small cells along the West of Scotland slope, which correspond to the most fished area. Larger cells are drawn from areas with lower number of observations; the calculated discarded proportions are then derived from small numbers of hauls. Similarly, caution should be taken about the most northeastern rectangles to the Southwest of the Faroe Islands because in this area two the number of observe hauls was small.

In recent years (2010-2012), some areas of high discarded proportion were not sampled in the on-board observation scheme (grey rectangles, Figure 60C, D). As a consequence, there are overall lesser areas with high discarded proportions. The difference between the discards with all depths included (Figure 60 C) and only hauls deeper than 500 m (Figure 60 D) was minor. Some spatial pattern in the total discarding can be seen with a lower proportion discarded along the Scottish slope to the South of 59°N. One single cell with a high discarded proportion to the south of the study area should be considered with caution as it may come from one single haul.

The absence of observed hauls in some areas in recent years is related to a change in the spatial distribution of fishing effort.

This change may come from changes in the fishing strategy related to the smaller number of vessels and the decline in the total deep-water fishing effort (ICES, 2012a, STECF, 2011). At the same time, stock assessments have shown some recent increase in the abundance of two target stocks, i.e. blue ling and black scabbardfish (ICES, 2012a), which might have a direct effect on the discarded proportion.

Higher catch rates of these two target species may further have allowed vessels to catch their quota closer from the ports, so the lesser fishing activity in the western part of the study area. Other factors such as the price of fuel may also have prompted vessel not to steam far away.

As Alepocephalids, in particular the Baird's smoothhead (*Alepocephalus bairdi*), are known to from a big share of the total discards, the spatial distribution of the total proportion discarded of all other species was calculated (Figure 61). The proportions discarded are of course smaller when Alepocephalids are not included. More interestingly, most of the areas with high, say over 40 %, proportion discarded disappears.

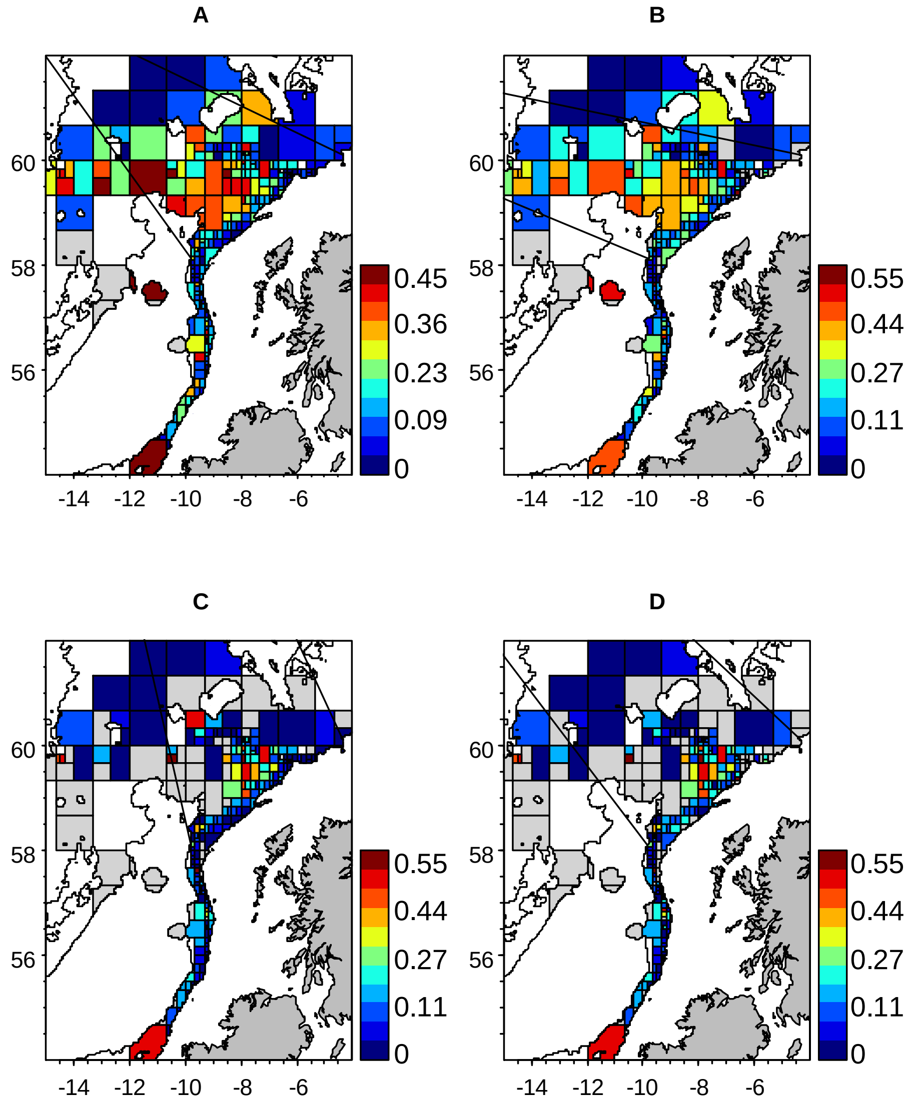


Figure 60: Proportion discarded of the total catch; (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

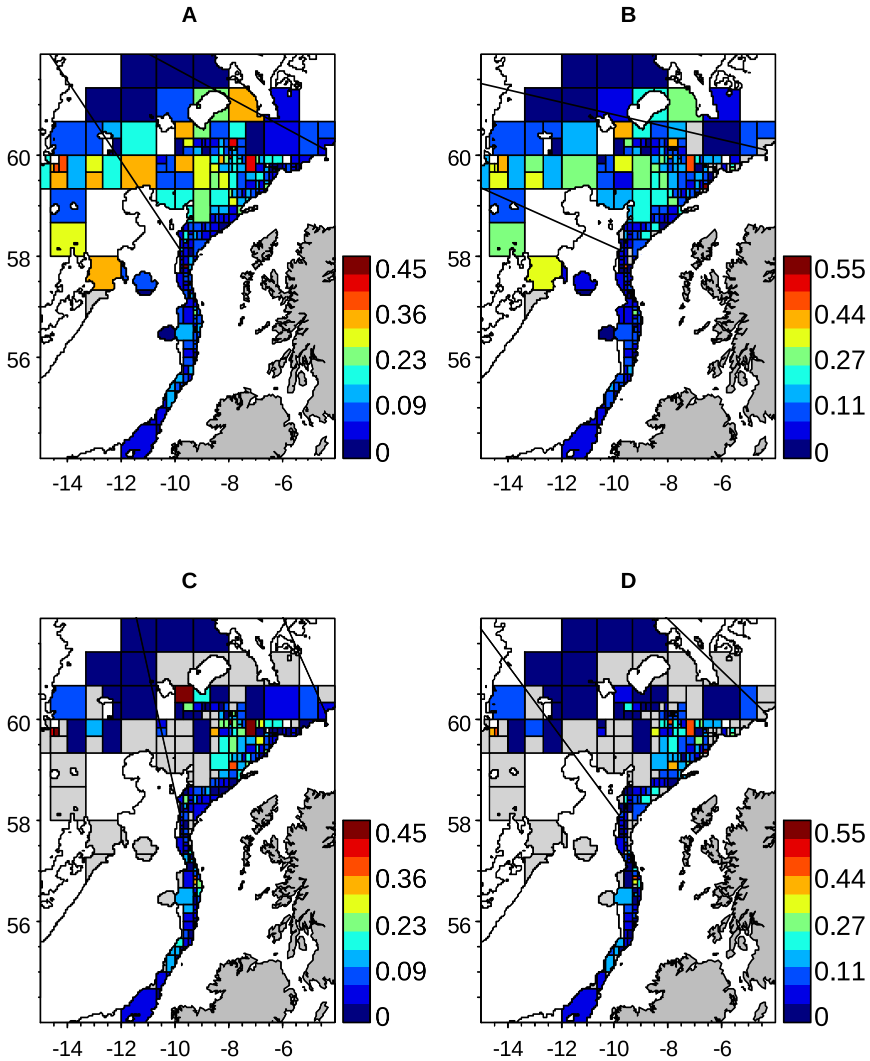


Figure 61: Proportion discarded of the total catch, Alepocephalids excluded; (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

VIII.5.4.2 Discards of commercial species

The proportion discarded of commercial species was low, i.e. less than 5 % of the total catch, in most areas. A zone of higher proportion discarded can be seen between 59° and 60° N and West of 9°W, this zone may extend further south, on the Rockall bank, most western areas of the maps but there was few observed hauls in these areas as can be seen from the size of the grid cell (Figure 62 A, B).

The pattern seen for all species, that higher discards occur to the North of the Rockall trough, by latitudes of about 58°30' North to 60°North and West of About 8° West is also visible for commercial species from the whole study period 2004-2012 (Figure 62 A, B) but not for the recent period (Figure 62 C, D) were discards of commercial species were overall low with a few local exceptions.

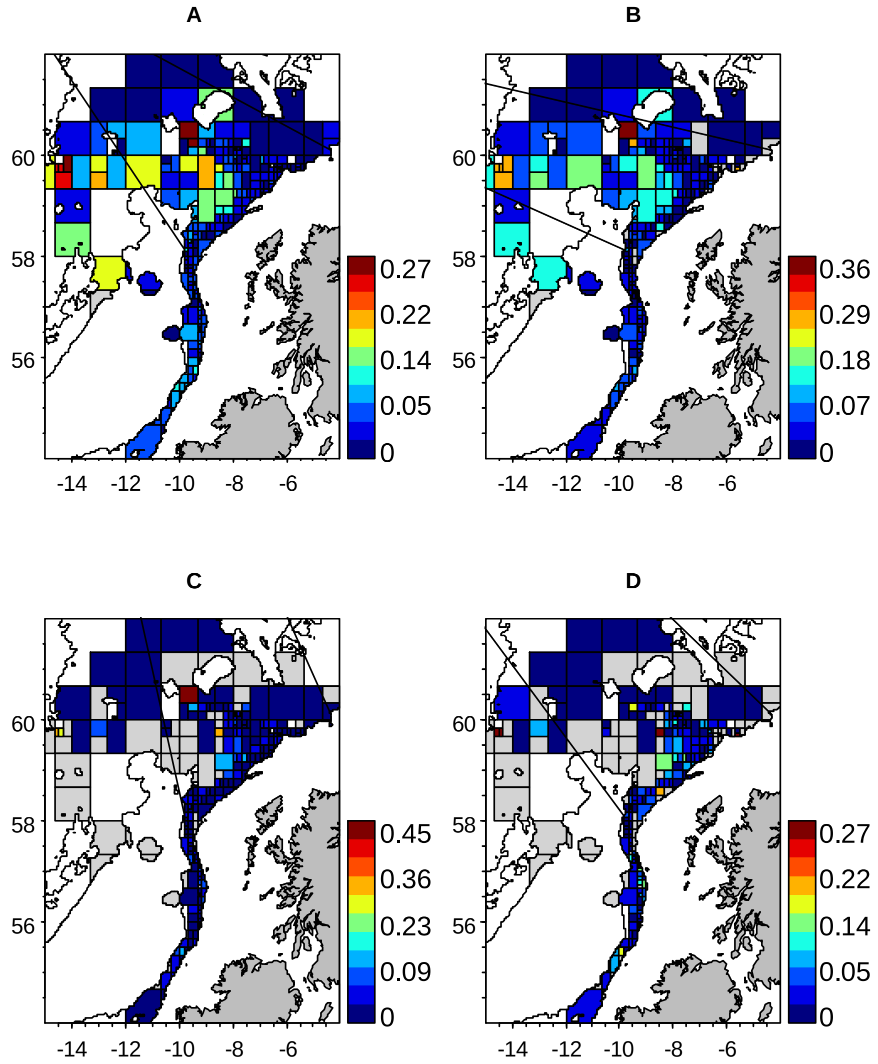


Figure 62: Proportion discarded of commercial species; (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

VIII.5.4.3 Discards of elasmobranchs

Elasmobranchs include sharks, rays and chimaeras. The proportion discarded of all elasmobranches (weight of elasmobranches discarded divided by total catch weight) was mostly lower than 10 % (Figure 63). It should be reminded that the category elasmobranchs considered here included both deep-sea sharks of the Annex I of the regulation 2347/2002 and other elasmobranchs. Further, what is calculated is the proportion discarded, which is lower than the proportion of elasmobranchs in the catch as some elasmobranchs were landed. The proportion of discarded elasmobranchs in the catch does not show clear geographical pattern, and there may not be any spatial pattern because at least 35 species are included in this group and the literature on deep-water communities does not suggest that there are strong spatial patterns in the proportion of elasmobranchs in the slope fish community at the scale of the study area.

The proportion of elasmobranchs discarded (discards of elasmobranch/catch of elasmobranchs) does not show either a clear overall spatial pattern.

There may be a slightly lower proportion discarded along the West of Scotland slope (Figure 64). It appears clearly that the proportion discarded was higher in recent years, 2010-2012 than for the whole study period (Figure 64 A, B).

Significant proportions of elasmobranchs have been discarded as a consequence of several deep-water sharks species been not marketed (Figure 64 A, B). Mostly three species, *Centrocymnus coelolepis, Centrophorus squamosus and Centroscylliumm fabricii*, (see below section VIII.5.4.4) have been marketed and other species have been mostly discarded owing to their smaller size or absence of market. During the most recent three years studied (2010 to 2012), almost all the catch of sharks was discarded and the proportion discarded in cells that continued to be fished in 2010-2012 was much higher for this period (Figure 64 C, D). This is an effect of the O Total Allowable Catch (TAC) for these species. A small proportion was still landed, probably as the allowance of landing 10 % of the 2009 quotas in 2010.

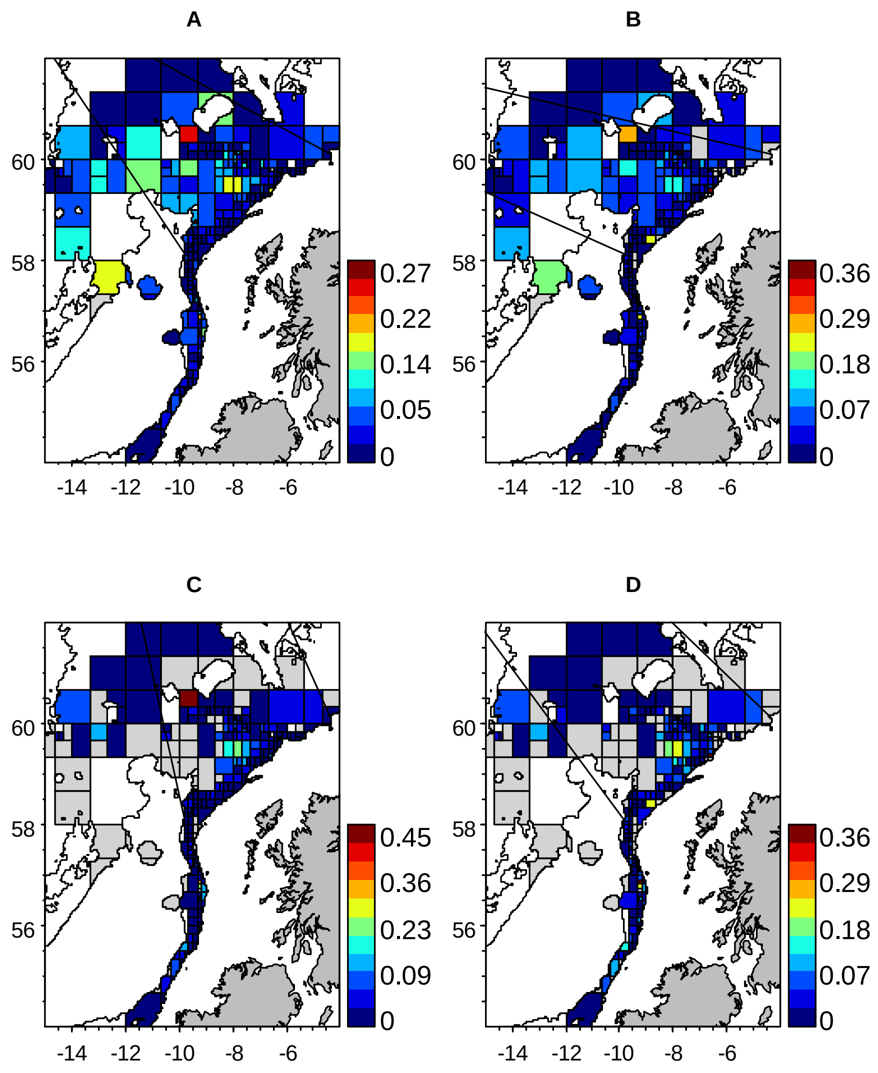


Figure 63: Proportion of discarded elasmobranchs in the total catch; (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

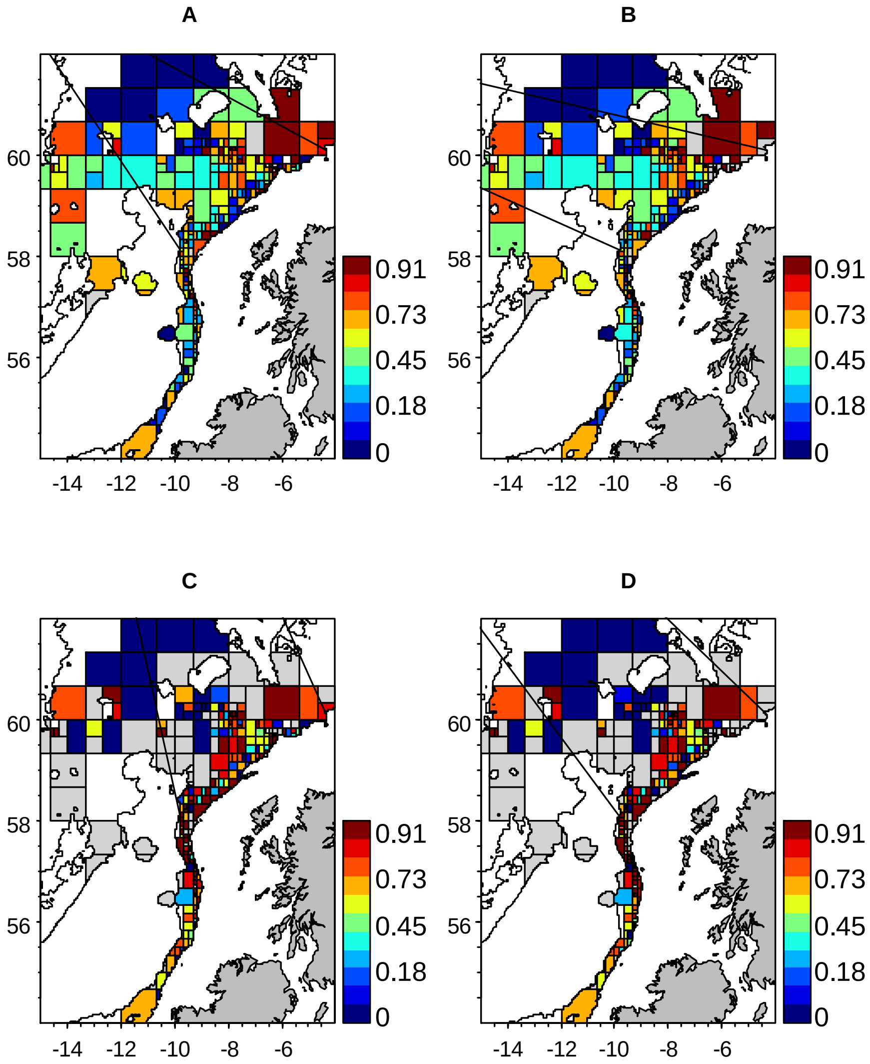


Figure 64: Proportion of elasmobranchs discarded (discards of elasmobranch/catch of elasmobranchs); (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

The same analysis restricted to deep-sea sharks, i.e. species from annex I of Council Regulation (EC) No 2347/2002 of 16 December 2002, returned similar spatial distribution patterns (maps not shown). The proportion of the discards of deep-sea sharks in the total catch was naturally slightly smaller than when considering all elasmobranchs because rays and chimaeras are also subject to discarding. The proportion discarded of deep-sea sharks was similar to that of elasmobranchs up to 2009 and was close to 100 % during years 2010-2012 (see also below sikis sharks).

VIII.5.4.4 Siki sharks (Centrophorus squamosus and *Centrocymnus coelolepis)*

These species were the two main species of commercial deep-water sharks before the reduction of the TAC down to 0 in 2010. In the first year of the 0 TAC (2010) an allowed landing of 10 % of the 2009 TAC was maintained.

Discards of siki sharks were minor before 2010, so that the geographical distribution of the proportion of these discards in the total catch using all the years in the dataset was low in most grid cells (Figure 65). When considering years 2010-2012 only, the proportion of the discards in the total catch, was still always below 10 %.

The proportion discarded of siki sharks was mostly low when all year were included and close to 100 % for recent years (Figure 66).

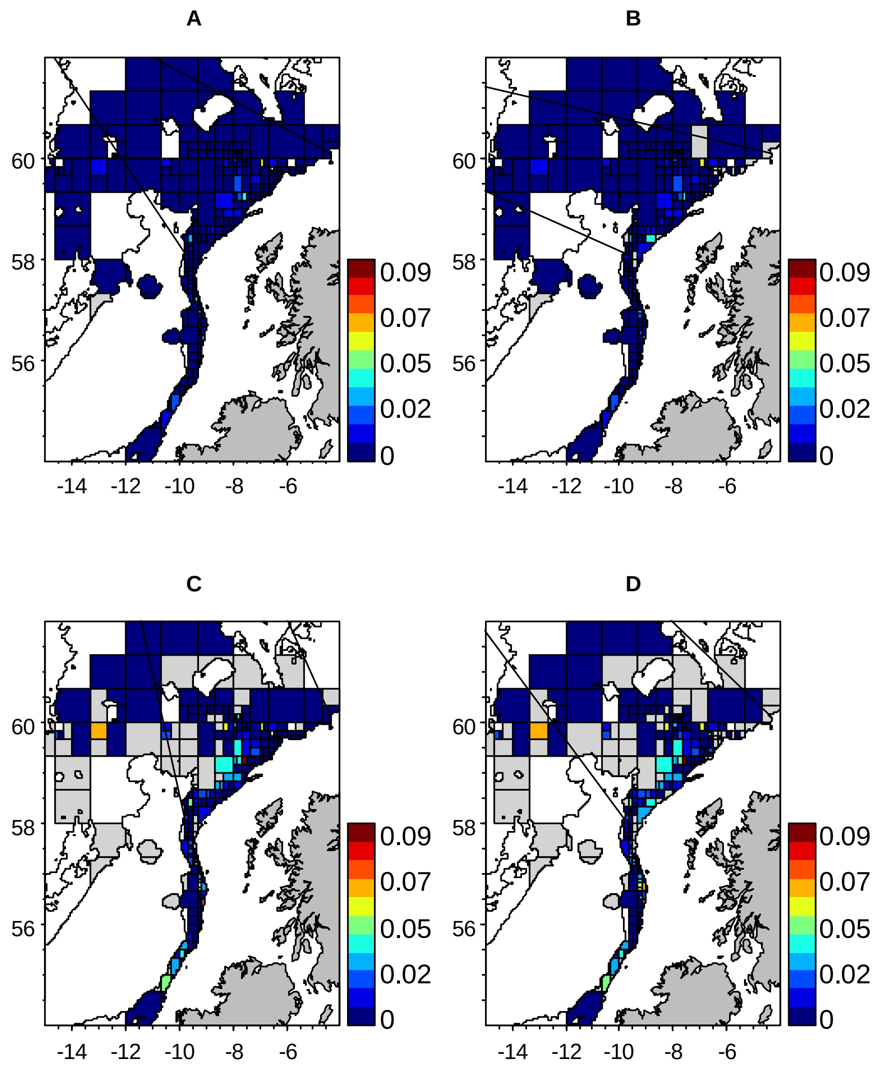


Figure 65: Proportion of discarded siki sharks in the total catch (discarded siki sharks discarded divided by the total catch); (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

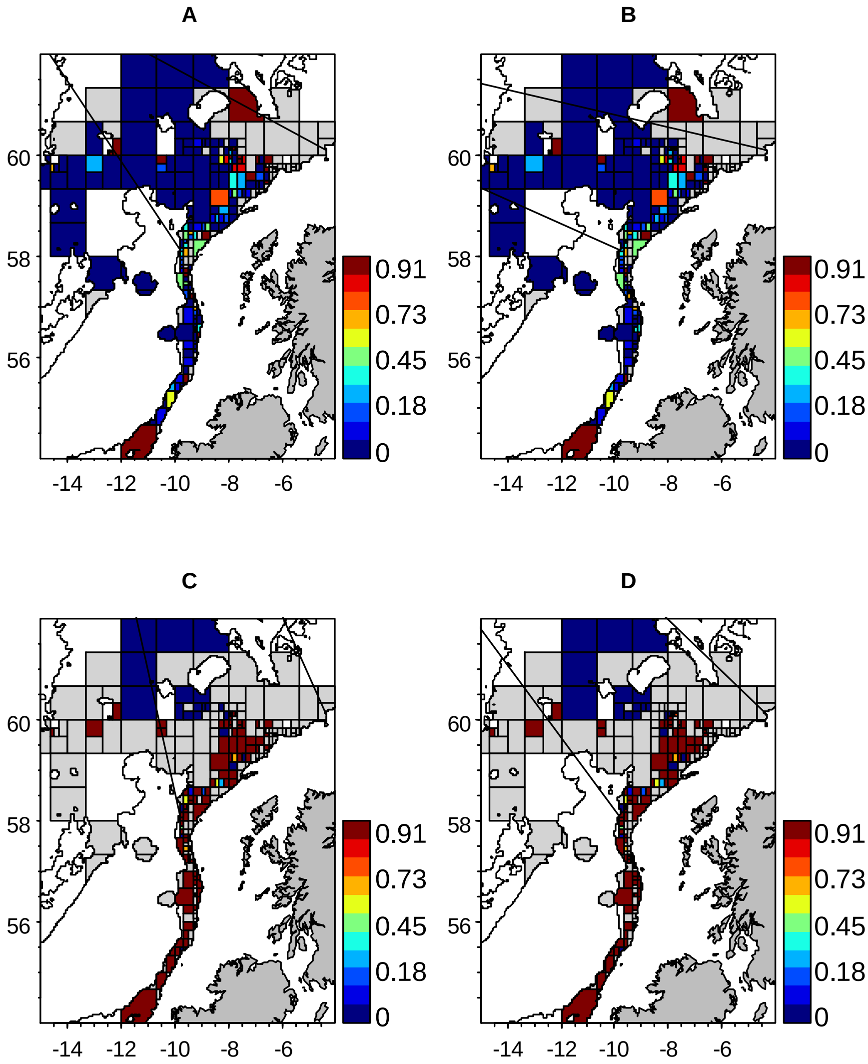


Figure 66: Proportion of siki sharks discarded (discards of siki sharks/catch of siki sharks); (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

VIII.5.4.5 Roundnose grenadier (Coryphaenoides rupestris)

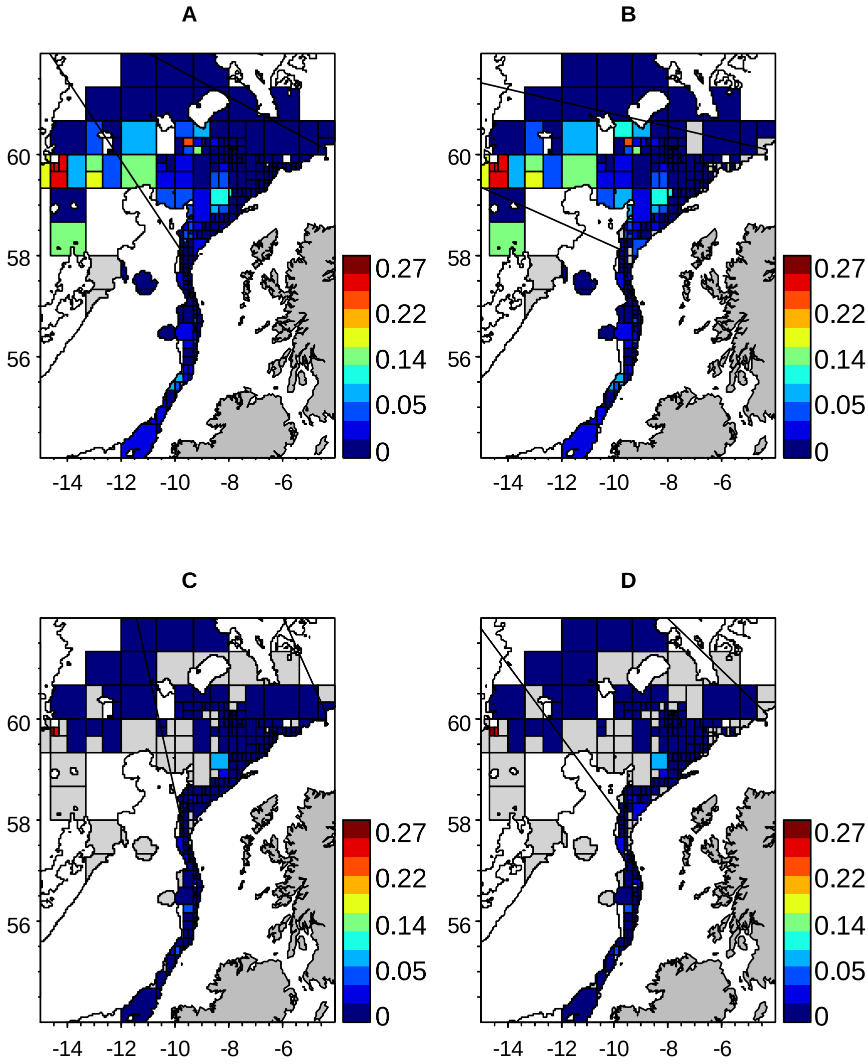


Figure 67: Proportion of the discards of roundnose grenadier in the total catch (discards of grenadier divided by total catch); (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

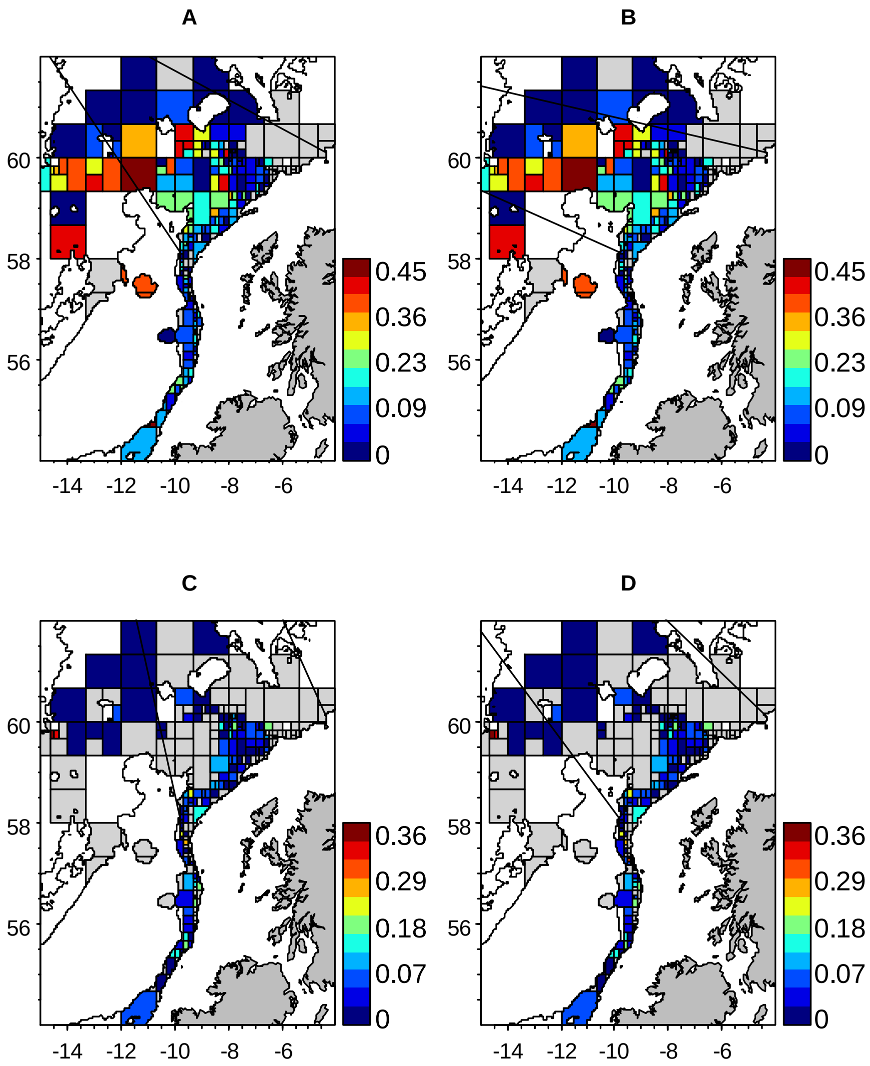


Figure 68: Proportion discarded of roundnose grenadier (discards of roundnose grenadier divided by catch of roundnose grenadier); (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

The proportion of discarded roundnose in the total catch was overall lesser than 5 % (Figure 67). There was clear spatial pattern in this proportion with lower value along the west of Scotland Slope and in Faroe Islands area and higher value to the west of the study area and to the North of the Rockall trough. Striklingly, there was no observation in recent years in areas of higher proportion discarded (Figure 68 C, D). This can be ascribed to the fishery having reduced its fishing in the western part of the study area. Some small areas by about 59°30'N and 14°W still showed high proportion of grenadier discarded.

The proportion discarded of roundnose grenadier, show the same patterns. In some areas, a higher proportion of the catch was discarded. Note that the contribution of this area with high discard rate to the total discards as the fishery level was not estimated here. The proportion of discarded grenadier was mainly in the range 0 to 20 % along the west of Scotland slope and further North.

VIII.5.4.6 Greater silver smelt (*Argentina silus*)

Greater silver smelt is a commercial species landed mainly for fish meal. The international landings in ICES Division Vb, VI and VII have been are in the order of 22,000 t per year in recent years, mainly from Faroese and Dutch fisheries (ICES, 2012a). The species is a bycacth in the French trawl deep-water fishery where it is discarded, it is the second species in the overall proportion discarded after Alepocephalids and it formed 25 % of the discards in 2011 (Dubé et al., 2012).

The total amount of Greater silver smelt discarded in the French deep-water trawl fishery is then small compared to the landings for reduction purposes. Further, discards of greater silver smelt occur is other offshore demersal fisheries so that the discards in the studied fisheries might be only a small contribution to the fishing mortality of the stock(s). These discards occur mainly to the southest of the Faroe Islands as a consequence of the area distribution of this species (Figure 69).

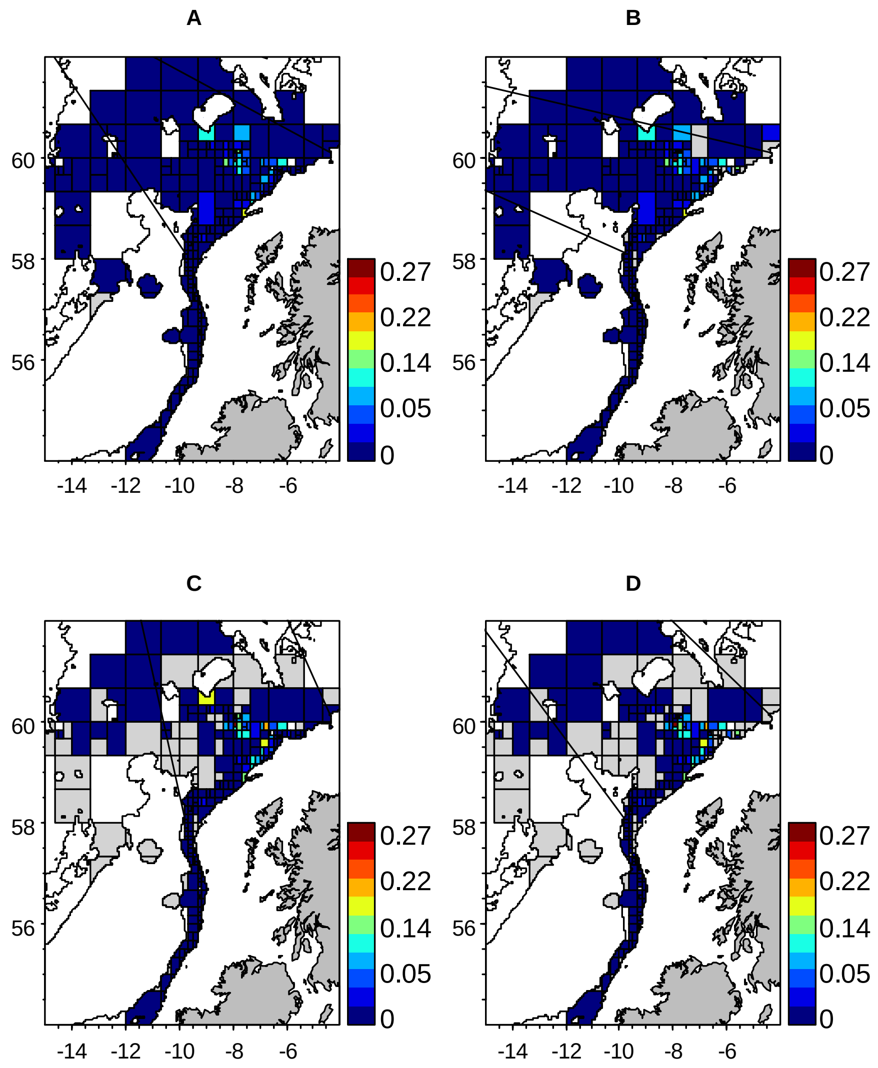


Figure 69: Proportion of the discards of greater silver smelt (*Argentina silus*) in the total catch (discards of grenadier divided by total catch); (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

VIII.5.4.7 Smoothheads, Alepocephalidae

Smoothheads are fish of the family Alepocephalidae. The main species caught in this family is the Baird's smoothhead (*Alepocephalus bairdii*), all smoothheads are however considered aggregated here because other species of smoothheads may not be always reliably identified in the on-board observations. Bycatch of smoothheads seem to be higher to the North of the Rockall Trough (Figure 70).

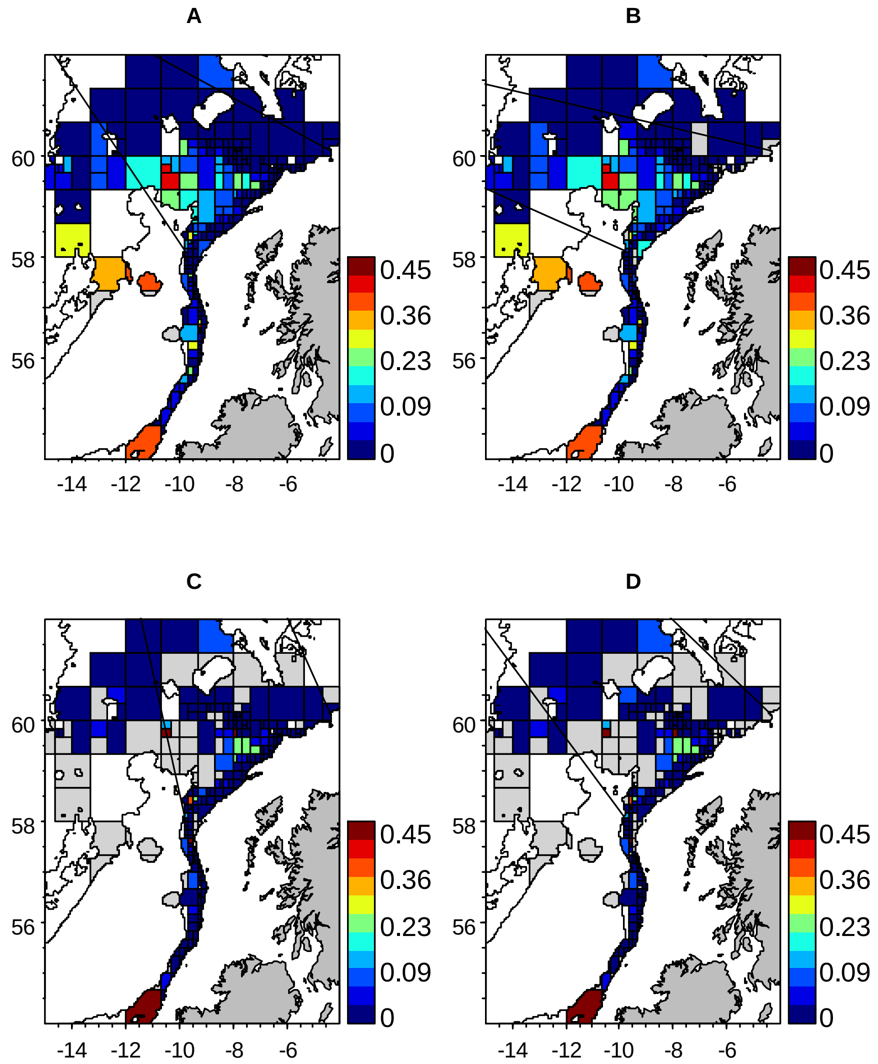


Figure 70: Proportion of the discards of Alepocephalids in the total catch (discards of grenadier divided by total catch); (A) all years, all hauls; (B) all years, hauls deeper than 500 m; (C) years 2010-2012, all hauls; (D) years 2012-2012 hauls deeper than 500 m.

VIII.5.4.8 Species caught occasionally

Occasional catch of Greenland sharks are registered. Two species are recorded in the database, *Somniosus microcephalus* and *S. rostratus*), identification at species level of these large bodied sharks may be uncertain so that the two species are considered combined here.

The occasion catches appear to be mostly concentrated in a restricted area to the south of the Faroe Islands and most between 500 and 1000 m depths, mostly in a latitude range of 59.5-60.5 degrees North and a longitude range of 6-9 decimal degrees West (Figure 71 A).

The mean and the median depth of hauls were Greenland sharks were caught was about 800 m. Further investigation using all French on-board observations yielded 10 more catch events distributed in the same area.

Occasional catches of large skate of the genus *Dipturus* were much more scattered over the whole study area, reflecting that these species occur throughout the fishing grounds (Figure 71 B).

Occasional catches of *Trachipterus arcticus*, were rare and did not show any spatial pattern (Figure 71 C).

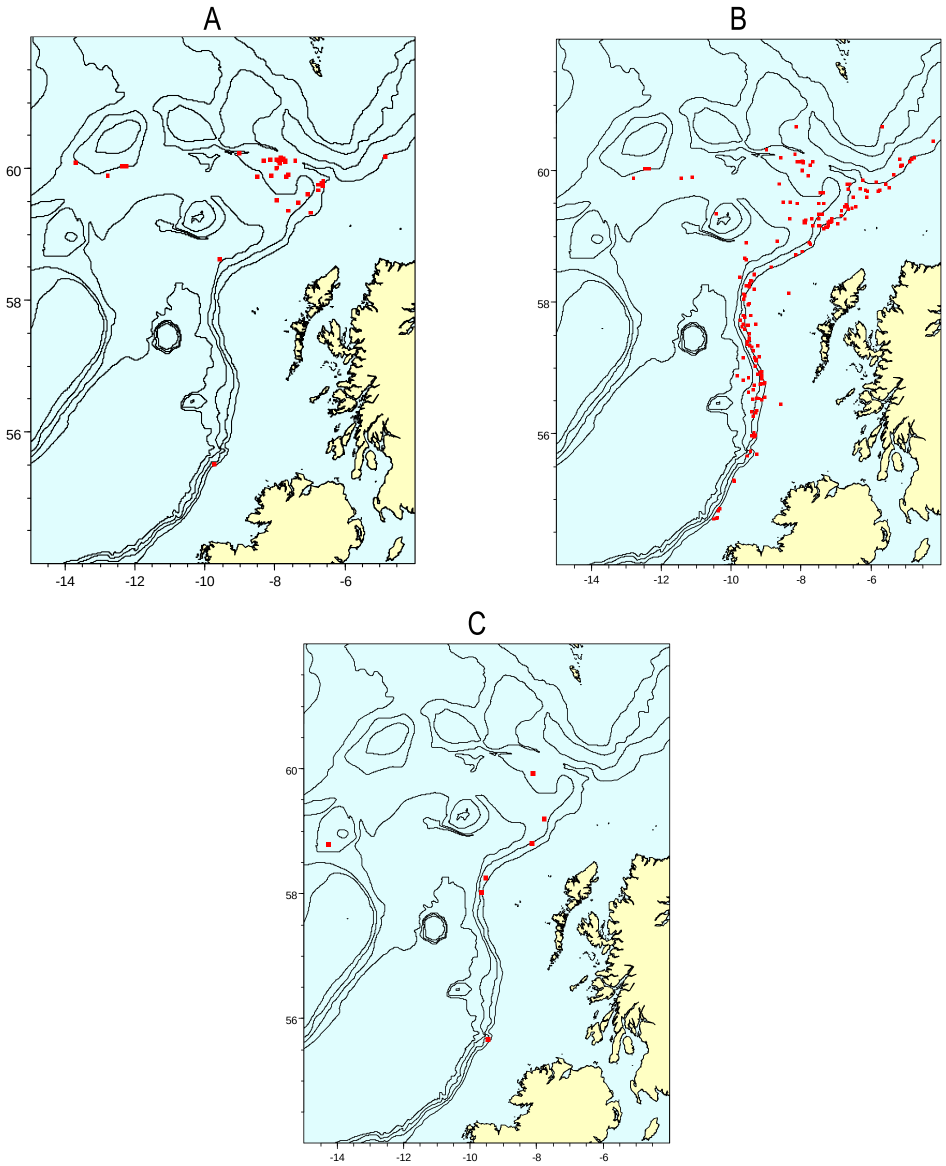


Figure 71: Catch locations of (A) Greenland shark (*Somniosus* spp.), (B) large skates (*Dipturus* spp.) (C) *Trachipterus arcticus*. Depth countour shown are 500, 1000, 1 500 and 2 000 m.

VIII.5.5 Discussion

In this study a spatial approach was used to calculate the proportion of the catch that is discarded in small spatial cells of the fishing areas of the French deep-water fishery to the West of Scotland. The approach is innovative and based on a method published in 2013 (Gerristen et al., 2013). This method was used to draw the proportion discarded registered from on-board observations of the French deep-water trawl fishery. The approach is highly relevant to the investigation of bycatch reduction strategies as is allows detecting areas were the actual fishery discards a higher proportion of the total biomass caught.

The analysis showed some clear spatial pattern where higher discards were observed to the North of the Rockall trough, by latitudes of about 58°30' North to 60°North and West of About 8° West for the total discards, the discards of commercial species, to some extend those of elasmobranches, those of small grenadiers and Alepocephalids. It is a quite striking result to obtain a common pattern for several species and species groups, which may rather mean than in these areas the proportion of the catch that is marketable is lower. In recent years (2010-2012), there were lesser on-board observations in these areas of higher discards with most cells of the nested grid without any observed haul. It is known that the areas fished by the fleet have shrunk and the main factor for this may be management that reduced quotas and fleet size. It is interesting to note here that this management may have indirectly induced a stronger reduction of fishing in areas where discards were higher.

The study focussed on discards, i.e. bycatch in "bycatch reduction strategies" was understood as unmarketable bycatch i.e. discards. Landed bycatch species, i.e. species that are caught and marketed, are not considered as bycatch which management should aim at reducing quantities. Landed bycatch are species that are not enough abundant or have too low prices to be targeted but that contribute to the revenue of the fishery when they are caught. In the French trawl deep-water fishery to the west of Scotland, the main target species, landed bycatch species and unwanted bycatch species are currently as follows:

- main target species: roundnose grenadier, black scabbardfish and blue ling;
- main landed bycatch: monkfish (*Lophius* spp.), chimaeras, greater forkbeard and tusk;
- main unwanted bycatch: greater silver smelt, alepocephalids and elasmobranchs.

Amongst the main commercial species, only roundnose grenadier is subject to discards. Small and large roundnose grenadiers are caught by the fishery and small, not marketable individuals are discarded. This has been reported to represent a significant proportion of the total catch of the species, up to 30 % of the total catch-in-weight of roundnose grenadier (Pawlowski and Lorance, 2009). The proportion of small grenadier in the catch is however sensitive to the depth distribution of fishing, which changed over time. Black scabbardfish fish and blue ling are not subject to discards to any significant level. All the catch of these two species is of marketable size as small juveniles do not occur on the fishing grounds.

Current unwanted bycatch of elasmobranchs include elasmobranchs species that were never commercial. Species that are considered commercial or not may depend on the fishery. For example the blackmouth catshark (*Galeus melastomus*) and the bordbeak dogfishes (*Daenia* spp.) were never commercial for the French trawl deep-water fishery although some quantities have been marketed by Spanish and Portuguese fisheries operating off Iberia (ICES, 2013). Since 2010, unwanted bycatch include of deep-sea sharks as they are subject to a 0 TAC.

This ban naturally generated an increase in a proportion of sharks discarded.

The situation of the two other main unwanted species is different. Several thousand tonnes of greater silver smelt from the Northeast Atlantic are landed annually for reduction purposes but the species has not been marketed by the French trawl deep-water fishery that is aimed to the fresh fish market for Human consumption, so that it has been discarded and is part of the unwanted bycatch here. Discarding greater silver smelt imply a loss of potential yield to fisheries which target this species but the discards of greater silver smelt by the French deep-sea fishing fleet is small with respect to the landings of targeted fisheries. Some landings of Alepocephalids caught in the Northeast Atlantic have been reported in the 2000s (ICES, 2012a) but these species are generally considered not commercial because of their high water content (Okland et al., 2005).

More than the potential loss of yield noted for the greater silver smelt, the problem of discards of deep-water species is to evaluate whether fish populations subject to these discards can sustain the corresponding fishing mortality. In general fishing fleets generate a fishing mortality on non-target species which is less than or equal to that generated on target species (Pope et al., 2000). These lower fishing mortalities might be mostly sustainable to smaller species, which life-history characteristics allow to sustain higher fishing mortality (e.g. Denney et al., 2002). The main problem is therefore for species that can only sustain lower fishing mortality than the target species. Based on a Productivity Susceptibility Analysis (PSA), Dransfeld et al. (2013) suggested that the most vulnerable species to current deep-water fisheries in Irish waters were deep-water sharks while the smaller bodied finfish species *Lepidion eques* was less vulnerable compared to larger commercial species. The groups of species for which the fishing mortality corresponding to discards is most a concern might then be deep-water sharks and elasmobranchs. Dransfeld et al. (2013) further suggested than the susceptibility of orange roughy to fisheries had decreased following the landing ban of this species. It is not known if this may apply also to deep-water sharks in the study area and elsewhere, but the effect of the landings ban is likely to be lesser for deep-water sharks than for orange roughy because the latter forms distinct local aggregations that fisheries have no reason to target anymore. Therefore, amongst the species and groups of species that were studied here, sharks and other elasmobranches might be a priority for actions aiming at reducing bycatch.

The results suggest that some reduction of bycatch throught spatial management is achievable. The area of higher discards proportion mentioned above is depicted more accurately in Figure 72 over the maps of the proportion of the total discards for all years and of on-board observations, i.e. the spatial distribution of total discards shown in Figure 58 A.

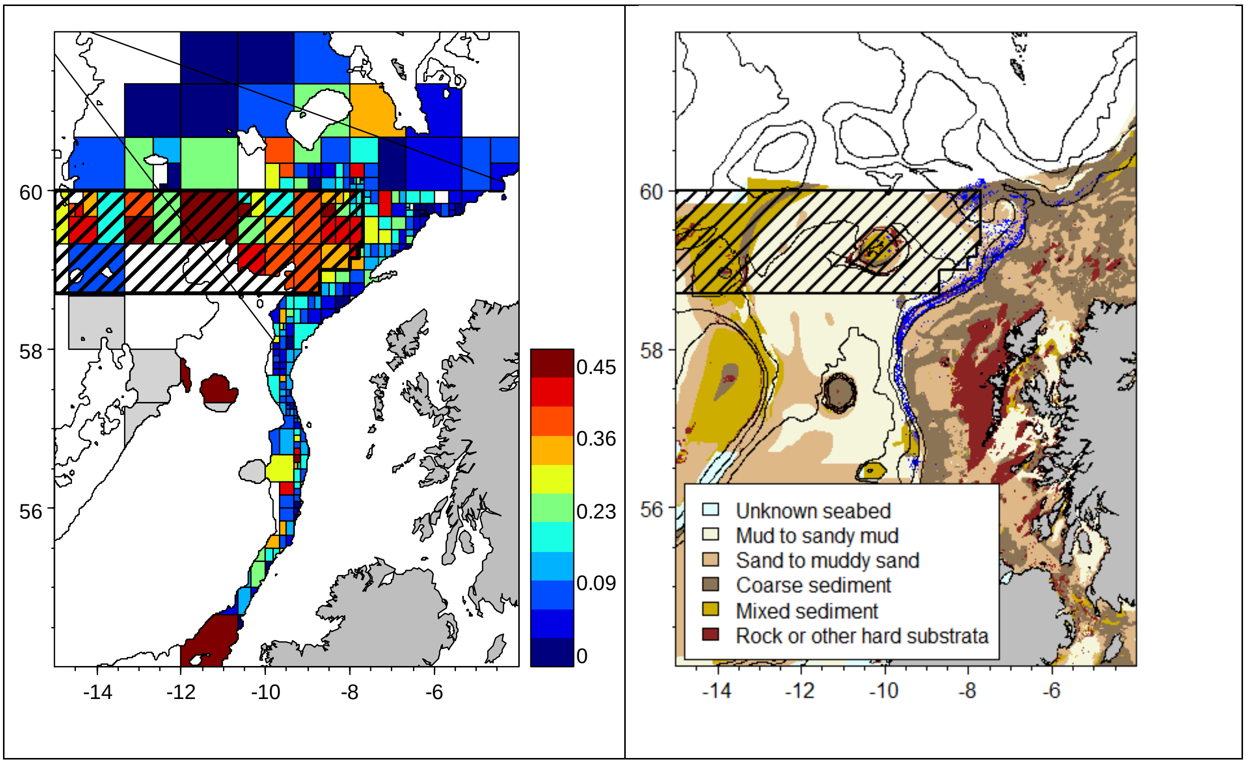


Figure 72: Main area of higher discard rate (box with shading lines), (left) overlayed on the proportion of discards in the total catch and (right) overlayed over the habitat,depth contours and hauls of scapeche vessels in 2010-2012. Depth contours are 500, 1000, 1500 and 2000 m.

A regulation of fishing in the area shown in Figure 72 would allow reducing the overall rate of discard in the fishery. The economic effect of such a closure can hardly be calculated for the following reasons:

- the economical consequences of a closure depends much of the strategies that the fleet will develop to adapt to it;
- the overall fishing effort has been declining since 2003 as a consequence of the EC regulation of deepsea fisheries since 2003. This induced a reduction in fishing mortalities (ICES, 2012). Recent stock assessment work suggests that the biomass of blue ling increased further during 2012 and 2013, while that of roundnose grenadier and black scabbardfish stabilised or slowly increased (ICES, 2014). These higher biomass of the target species, imply that (1) lesser fishing effort is required to catch the same amount of fish and (2) vessels might not need to steam further away to catch their quotas and can instead minimise the distance travelled from ports. Therefore the potential economic cost of closing an area such as that of Figure 1, might be minor.

Nevertheless, results shown in the section were derived from data from the French trawl fishery only and evaluation of the effect of possible management measures to other fisheries, including those for demersal species, as well as the effect on the fish populations will need further evaluation, some of which may require simulations.

The results also showed that, the proportion discarded reduced in recent years. Part of this change may be explained by changes in the fishing strategy. According to tallybook data (own logbooks of volunteer French skipper taking part in the French deep-water trawl fishery, the fishing depth decreased during the period where the proportion discarded were estimated, in particular in recent years, more fishing was targeted to the upper slope depths, 600-800 m (Figure 73). See Lorance et al. (2010) for detail about tallybook data. This estimate of effort covers a larger number of hauls than the on-board observations. This suggests that restricting fishing beyond a given depth may produce similar results as a management by area.

Further, the area of higher discarding rate derived from the nested grid analysis includes a large part of seabed between 1000 and 1500 m to the north of the Rockall Trough (Figure 72).

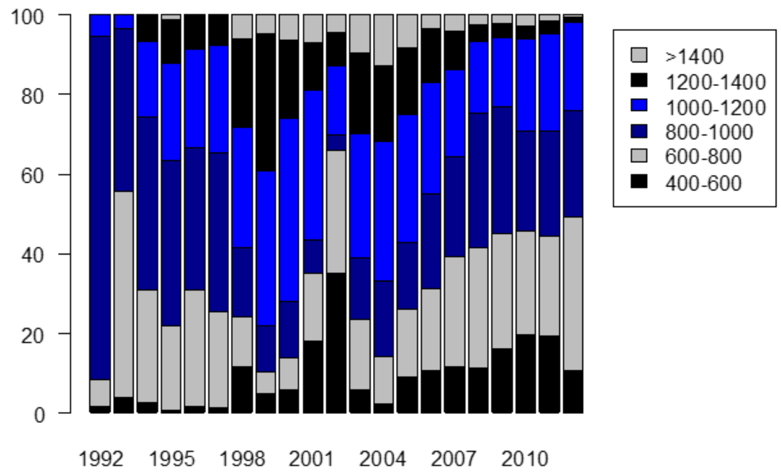


Figure 73: Depth distribution of the fishing effort, as proportion of the effort in kW.h, estimated from tallybook data (i.e. own logbooks from Skippers of volunteer vessels).

The nested grid method is not appropriate to analysing occasional bycatch, i.e. species rarely caught for which the dataset of on-board observations include only a small number of catch events such as the Greenland shark (*Somniosus microcephalus*). For such species discarded proportion per grid cell would have no sense as there would be mostly 0 or 1 catch event per cell. In this case simple maps of all catch events might be the only useful information. This was exemplified for the Greenland sharks, skates of the genus *Dipturus* and the Dealfish (*Trachipterus arcticus*). For the Greenland sharks a clear spatial pattern appeared suggesting that the bycatch of this species in this fishery could be reduced by spatial management measures.

Nevertheless, it is uncertain whether the area where it is caught corresponds to areas of higher abundance of the Greenland shark or to the southern end of the area of distribution of the species, which includes Faroese and Icelandic waters. For large skates, no spatial pattern appears, so that no spatial management can be suggested. In the future, the continuation of the on-board sampling will accumulate more data on these species and the nested grid method might become applicable to these species. Although catch events seem to occur all over the study area there could be grid where the proportion of white skates in catch weight is higher. The dealfish was used as an example of a species rarely caught although is it probably not a species which bycatch may be an issue as it is a pelagic species which occurs in large oceanic areas.

VIII.6 DISCUSSION AND CONCLUSION ON BY-CATCH REDUCTION STRATEGIES

Several approaches were explored to identify possible bycatch reduction strategies. Interviews suggested that skippers engaged in the French deep-water trawl fishery have an extensive experience of the fishery and already deploy a strategy to minimize discards. Clearly, the interest of vessels is to catch the commercial species at the minimum cost, including measurable economical costs such as fuel and working time. It is likely that good skippers are able to make the crew earning their wages with less intensive on-board work and maintain themselves better in the fleet.

A first exploration of French on-board observations described the data available in the French on-board observations database. The deep-water licensed fishing fleet has been observed since 2004, 271 fishing trips corresponding to 6939 fishing hauls have been observed from 2004 to 2012.

The study of indicators derived from on-board observations revealed that the application of indicators used in survey data to on-board observation data may not be straightforward. Some problems were found in data quality. The study did not use the most recent data, so that the improvement in data collection may overcome some of these. More importantly, in commercial trawls small species are caught in smaller proportion that in fisheries survey owing to the large mesh size use for commercial fishing. As a consequence, fish community indicators such as the species richness can only be appraised using large dataset on on-board observations. Some indicators, including the proportion of sharks in the catch and the mean length of the catch vary with depth and other factors of the fishing strategy so that monitoring indicators, including the proportion of discards over time need to account for changes in fishing depth and probably other aspects of the fishing strategy.

The spatial distribution of the bycatch of six deepsea shark species and a sensitive skate was studied, using all French on-board observtions from 2009 to 2012. The skate species was recently identified to be a mixture of two species (Iglesias 2010). Although these species are considered demersal they are caught down to depths of 1 000 m or more and they can only sustain a low fishing mortality, so that they would be eligible to the FAO definition of deepsea species (FAO, 2009). In French fisheries, the bulk of the catch of these species however occur on the Celtic sea shelf. For three of the six deepsea sharks species (leafscale gulper shark, Portuguese dogfish and longnose velvet dogfish) the spatial distribution represented well that of the French deep-water trawl fishery, showing that those species are not caught in other fisheries.

The situation was different for the birdbeak dogfish, which bycatch also occurs further south down to the Bay of Biscay, where fishing targeting deepsea species is not prosecuted. Therefore, bycatch of birdbeak dogfish occurs in both deepsea and demersal fisheries. Bycatch of Greenland shark and black dogfish are confined to the most northern areas visited by French vessels, owing to the boreal distribution of these species. Unlike that of black dogfish, a typical deepsea shark, which is centered by 1 000 m, the bycatch of Greenland shark occurs mainly in 600-800 m so that in both deepsea and demersal species targeted fisheries.

With the nested grid method, a novel spatial approach fully based on data was developed to evaluate the spatial distribution of bycatch and investigate management options to reducing them. In this method, the proportion discarded are estimated in spatial cells that are small (high resolution) in areas where there data are numerous and large (low spatial resolution) where data are scarce. As a result, where data are abundant the method provides estimates in small cell that tend to be homogeneous habitats while large cells might encompass varied habitats. This approach allows appraising whether there are areas where levels of discards are higher or lower. The value in one particular cell should not be overinterpreted as it could be an extreme value obtained by averaging over small number of hauls, instead it is more appropriate to consider spatial patterns that involve several cells. Such patterns where founds and suggest that higher bycatch proportion occur occur relatively flat bottoms by 1 000 to 1 500 m to the North of the Rockall Trough. This applies to total discards, discards of commercial species, to some extend those of elasmobranchs as well as those of Alepocephalids and small roundnose grenadier. In recent years, these areas were less sampled, which implies that they were less fished. Therefore the fleet might have been reducing its activity in areas where discards where higher. It is not known whether vessels avoided areas of higher discards or whether other reasons lead to this consequence. An area which closure would allow to reducing the bycatch level was delineated. The economical effect of such a closure on the French deepsea fishery in future years would presumably be limited or difficult to observed, because at the same time the abundance of the target species, at least that of blue ling and black scabbardfish is increasing. In the future the proportion of the catch that is discarded may therefore be reduced from spatial management measures but also other measures and external factors. It is likely that the slightly increasing biomass of target species (ICES, 2012a) induced a higher proportion of them in the catch, therefore a lower proportion of discarded species. Over time the deep-water fishing effort was also reduced and external factors such as fuel price had an impact on all fisheries. In the case at hand, areas where higher discards occur are also further away from ports, which may explain that they were less fished in recent years.

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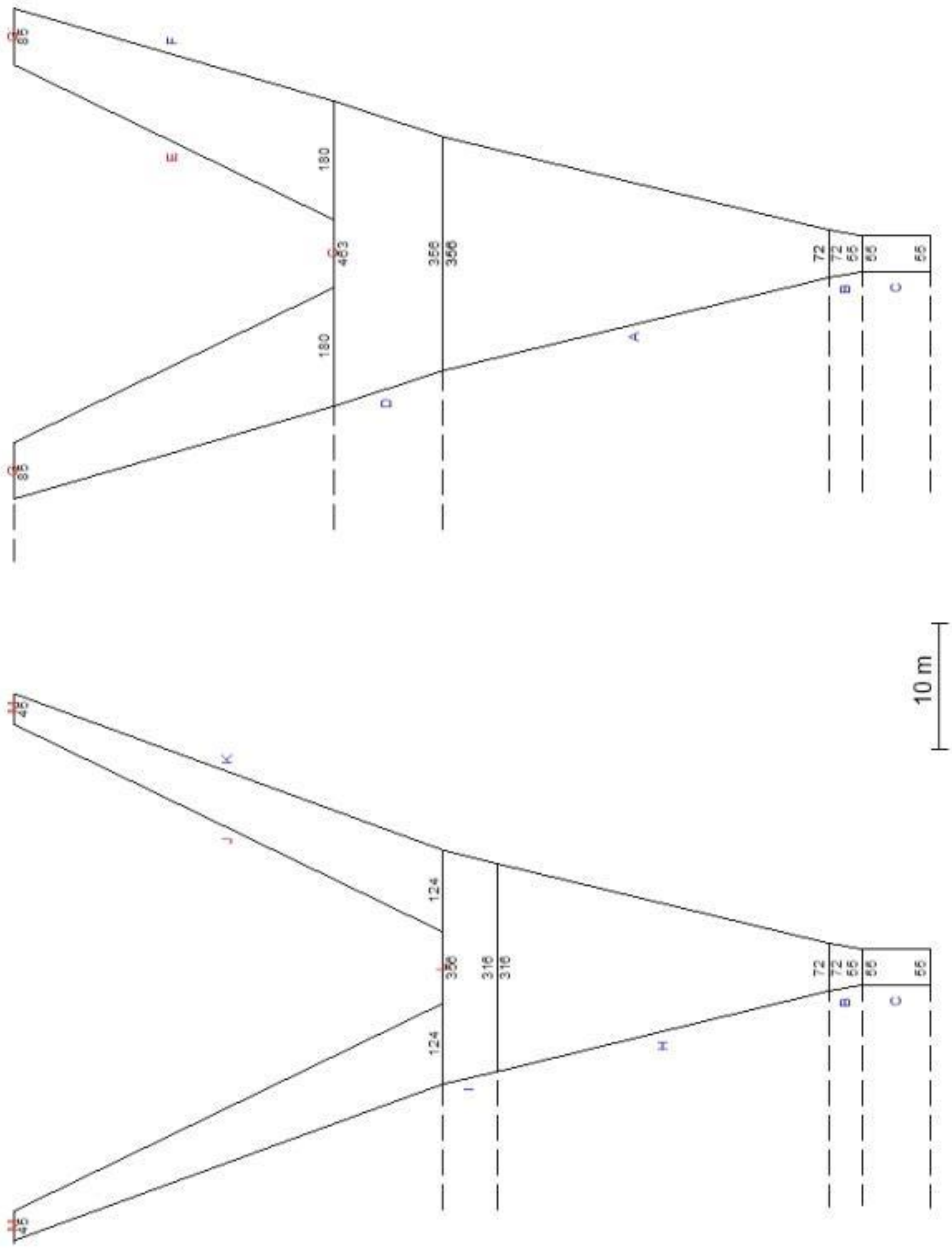
X ANNEXES

Annex 1: Trawl design



ANNEX 2: GROUND GEAR HEIGHT ADJUSTMENT FOR 1.3 KG/M USING SAME OPTIONS.

1. Trawl height adjustment

No difference (upper bridle equals lower)

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.45	1895	1345	5.1	29.5
3.1	0.42	2101	1545	4.6	29.6
3.3	0.35	2342	1761	4.2	30.2

Difference 0.10 m (upper bridle longer than lower)

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.66	1820	1432	5.2	29.5
3.1	0.58	2033	1631	4.7	30.0
3.3	0.54	2240	1854	4.3	30.1

Difference 0.25 m (upper bridle longer than lower)

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	1.10	1712	1536	5.4	29.5
3.1	1.25	1892	1751	5.0	29.6
3.3	1.04	2093	2008	4.5	30.0

Difference 0.5 m (upper bridle longer than lower)

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	2.03	1566	1707	5.7	29.4
3.1	1.90	1722	1986	5.3	29.6
3.3	1.92	1900	2253	4.9	30.0

2. Option 2: headline floatation

The initial number of 4 liters floats is 114 on each wing and 30 on the square (258 floats).

No additional floatation

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.45	1895	1345	5.1	29.5
3.1	0.42	2101	1545	4.6	29.6
3.3	0.35	2342	1761	4.2	30.2

20 % more floats

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.87			5.7	29.2
3.1	0.75			5.2	29.5
3.3	0.71			5.8	29.8

3. Option 3: weight at the connection bridles - sweep

Initial weight: 50 kg in air

Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	0.45	1895	1345	5.1	29.5
3.1	0.42	2101	1545	4.6	29.6
3.3	0.35	2342	1761	4.2	30.2

Reduced weight: 10 kg in air

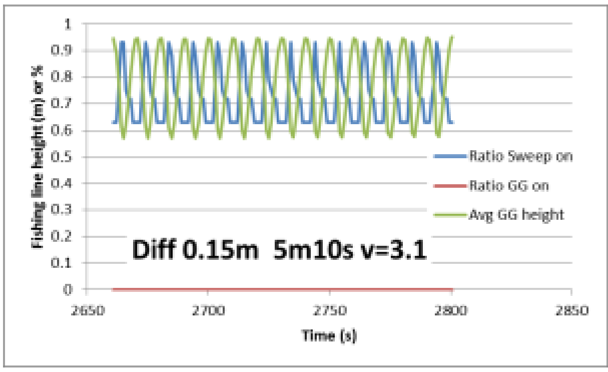
Towing speed (knots)	Fishing line mean height (m)	Upper bridle tension (kgf)	Lower bridle tension (kgf)	Vertical opening (m)	Lower wings opening (m)
2.9	1.151169	1970	1330	5.8	29.1
3.1	0.984394	2181	1523	5.2	29.5
3.3	0.942578	2420	1743	4.8	29.8

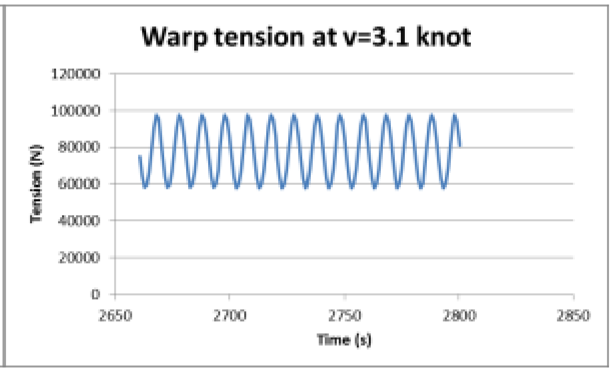
ANNEX 3: SWELL EFFECTS FOR LIGHTER GROUND GEAR (1.3 KG/M IN THE WATER)

The figures below present the ratio of sweeps and footrope (ground gear GG) on the seabed and mean ground gear height for a lighter ground gear at the towing speed of 3.1 knots and a motion of 5 m amplitude and 10 seconds period. The objective is to compare two ground gear motion amplitude.

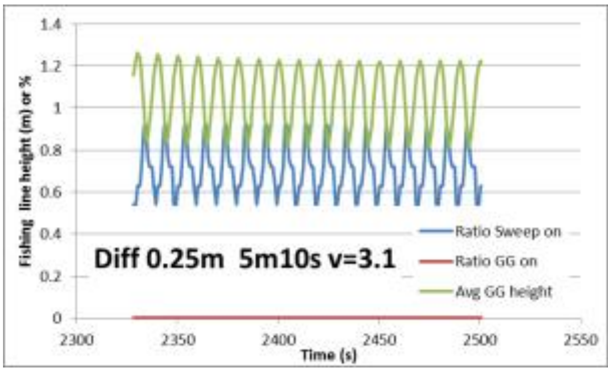
For 2.5 m/kg GG, with a difference of 0.5 m, excitation of 5m/10s the amplitude at 3.1 knots is around 0.55 m. For 1.3 m/kg GG, with a difference of 0.25 m, excitation of 5 m/10s the amplitude at 3.1 knots is around 0.40 m. In both cases, mean GG height is around 1 meter.

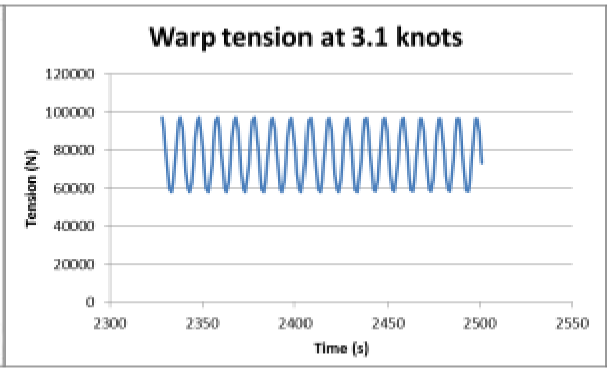
1. 5 meters amplitude/10 seconds periodic vessel motion applied to option 1/0.15 m



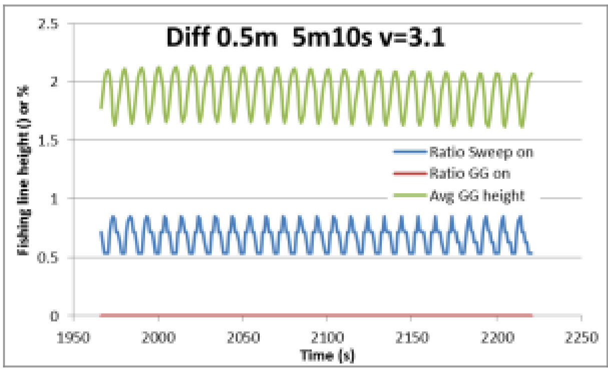


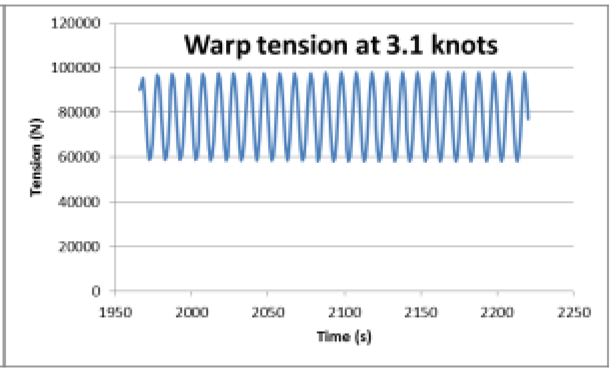
2. 5 meters amplitude/10 seconds periodic vessel motion applied to option 1/0.25 m





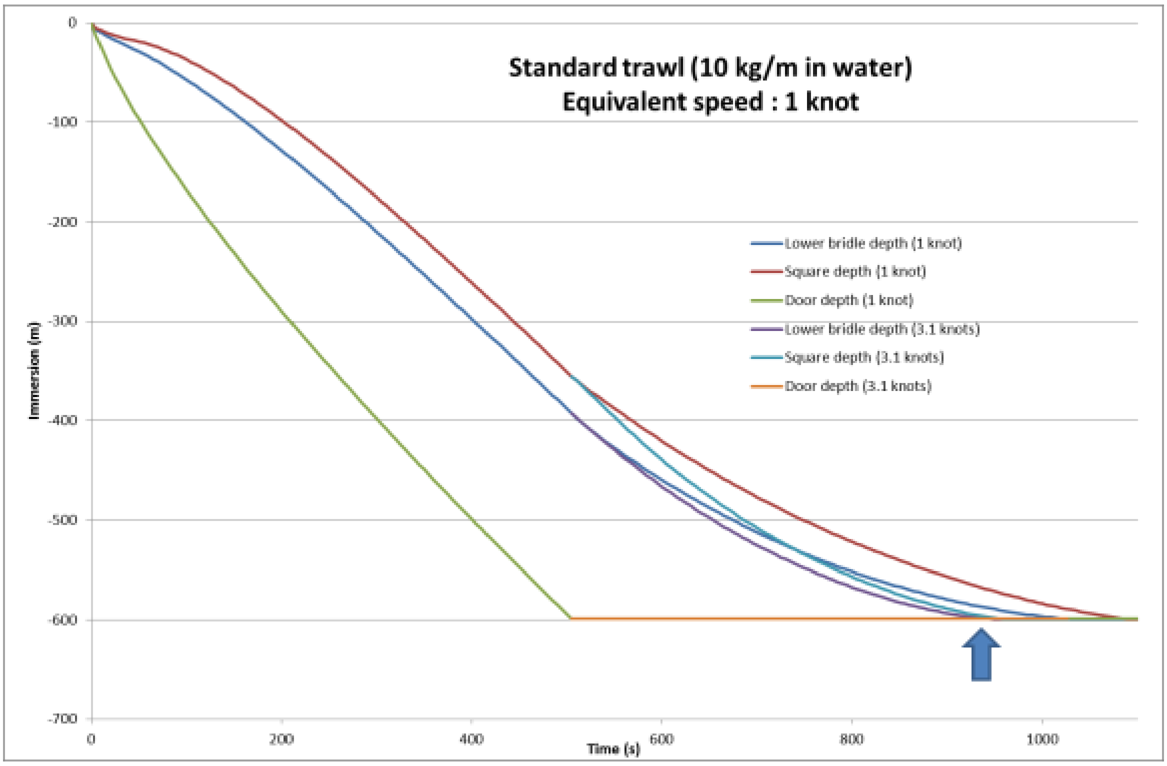
3. 5 meters amplitude/10 seconds periodic vessel motion applied to option 1/0.50 m

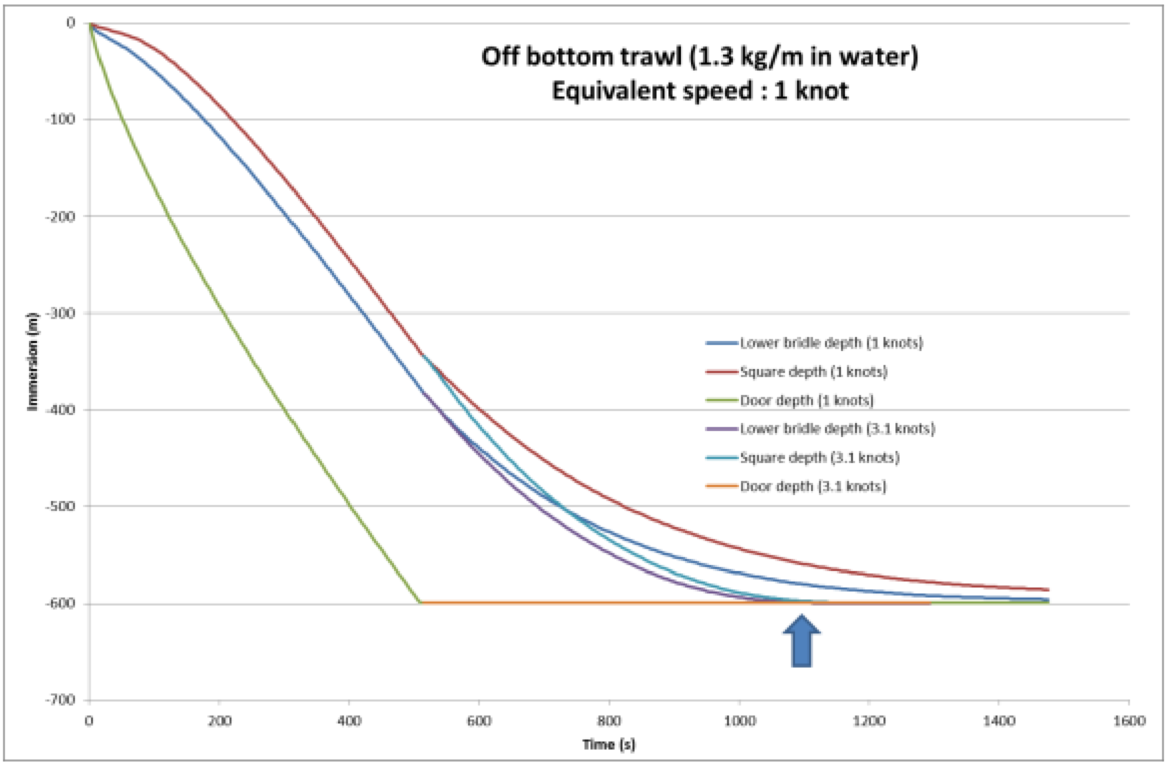




ANNEX 4: SINKING TIME FOR 600 M DEPTH

Protocol is the same that the one developed previously. Sinking time difference is about 15 %.

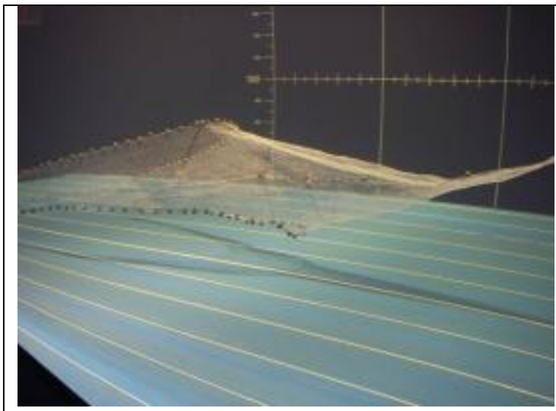
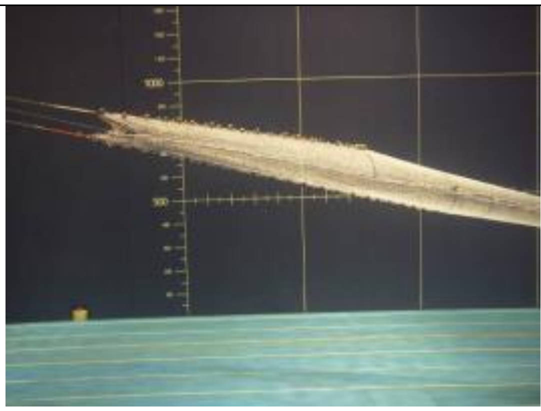




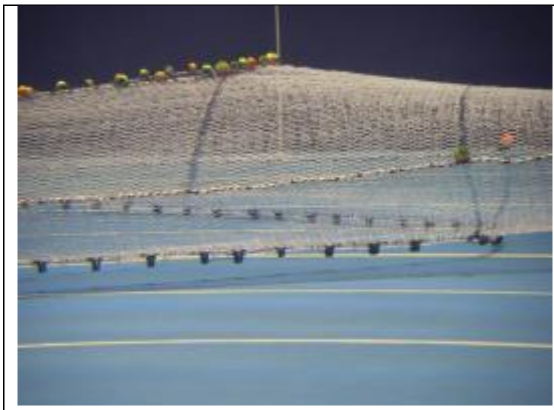
Off bottom trawl (1.3 kg/m in water)
Equivalent speed : 1 knot
Lower bridle depth (1 knots)
Square depth (1 knots)
Door depth (1 knots)
Lower bridle depth (3.1 knots)
Square depth (3.1 knots)
Door depth (3.1 knots)
Immersion (m)
Time (s)
0
-100
-200
-300
-400
-500
-600
-700
0
200
400
600
800
1000
1200
1400
1600

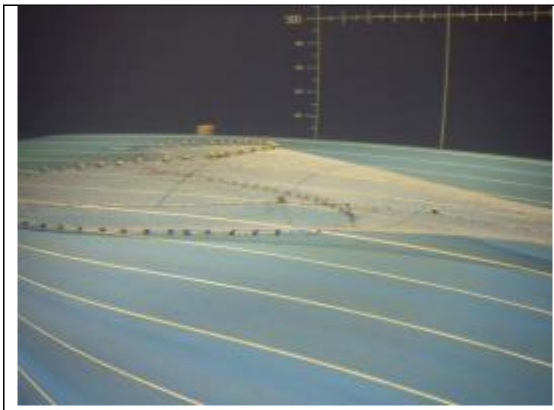
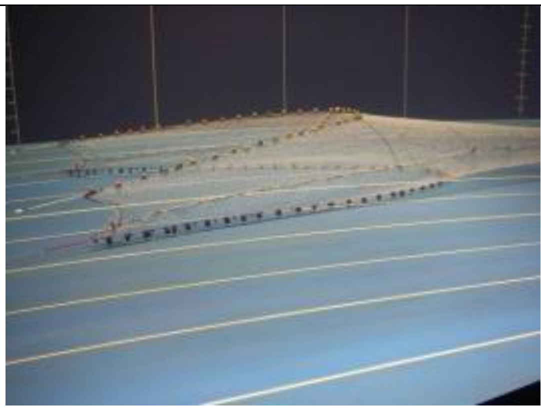
ANNEX 5: PARTICULAR BEHAVIOURS OF THE FISHING GEARS IN FLUME TANK (PHOTO)

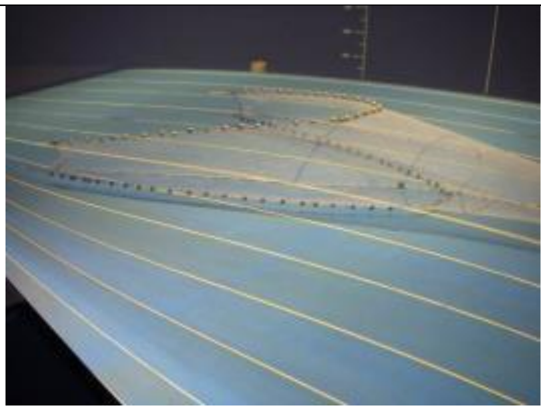
Particular behaviours of the fishing gear in flume tank

	
Trawl behaviour with a speed of 0,5 knots.	Behaviour of trawl during hauling

Trawl behaviour in different conditions

	
Detail of the trawl with 3,1 knots speed	The trawl stabilized with 3,1 knots speed

	
The trawl net stabilized with 3 knots speed and diff = 0	

	
Wing height	Trawl net sharply unstuck from the bottom

Annex 6: Details des resultats de la premiere campagne en mer

1. Trait 1 : lundi 30 soir

Chalut allégé avec des lests ajoutés sur le bourrelet. Racasseur à petites rondelles.

Filage à 23h30, 2250 m. En pêche 23h27.

20 min pour filer les 2 250 m. Ancien chalut met 13-14 min pour arriver au fond une fois treuils freinés. 20 min pour le léger. Vitesse de filage câbles 2 m/sec.

Heure	sonde	VIT	filage	Tens t/b	Ov/cl	Pan	
10H55	1062	2.9	2250	8.4 8.5	6.6/0	198	
11h10	1070	3.4	2250	7.1 7.4	6/0	197	
11h20	1072	3.4	2250	7.3 7.5	6/0	195	
11h30	1074	3.3	2250	6.3 6.6	5.8/0	197	
11h50	1078	3.3	2250	8.7 8.7	5.8/0	195	

Viré vers 6h40

Baudroie	1	24.5
Grenadier	31	749.5
Lingue bleue	3	71.5
Sabre	49	1214.5

TOTAL 2 060 KG

2. Trait 2 : mardi 1er octobre matin

Chalut allégé sans racleur. Les lests de bourrelet ont été retirés.

File les panneaux à 7h47, treuil freinés à 8h07.

Bourrelet posé à 8h25.

Début de traine 58°38.23 8°48.16

Heure	sonde	VIT	filage	Tens t/b	Ov/cl	Pan	
8h30	1082	3.3	2278	7.1 8.0	5.3 0	211	
8h55	1072	3.4	2278	7.1 8.0	5.6 0	204	
9h05	1088	3.3	2278	7.8 8.2	5.4 0	231 ?	
9h15	1069	3	2278	7.8 8.3	5.5 0	210	
11h40	1039	3.5	2278	7.9 8.2	5.4 0	201	
11h50	1041	3.5	2278	7.8 8.3	5.6 0	200	
12h00	1042	3.5	2278	7.9 8.3	5.4 0	203	

Mesures relevées pendant le virage :

Filage	H(dos-fond)/ c	panneaux	Vit gps	Vit scan	
1500	7.6 0	156	1.2	2.2	Sur le fond
1400	7.3 0	156	1.2	2.2	//
1300	6.9 0	159	1.2	2.2	//
1200	9 0.4	150	1.2	2.2	Décollé
1100	19.6 1.2	162	1.2	2.5	//
1000	42 1.8	164	1.1	2.5	//
900	63 3	159	1.2	2.3	//

Vire à 15h30

Grenadier	28	644
Mostelle	1	23.5
Lingue bleue	3	73
Sabre	57	1390

TOTAL 2 130 KG

3. **Trait 3 : mardi AM**

Chalut classique avec un rockhopper neuf (2 chaines).

Début filage panneaux 16h33. Freins serré à 16h50. Virage câbles à 70 m par minute.

Chalut au fond à 17h06. Pos GPS 58°26.37 9°31.47

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
17h15	1069	3	3.3	2310	8.3 8.9	6.4 0	196
17H25	1071	3.2	3.1	2310	8.4 9	6.7 0	200
20H45	1071	3.2	3.1	2350	8.8 9.6	6.4 0	197

Viré vers 22h30.

Baudroie	1	26.5
Grenadier	111	2761
Lingue bleue	18	433
Sabre	5	125

TOTAL 3 355 KG

Problème de treuils de bras.

4. **Trait 4 Refile le même chalut standard**

En pêche 0H10

Baudroie	3	77
Brosme	3	75
Grenadier	169	4089
Lingue bleue	14	348
Mora	7	173
Sabre	11	274

TOTAL 5 038 KG

Vire à 7h15.

5. **Trait 5 : mercredi 2 matin**

Chalut allégé sans racleur. Caméra installée, caisson sono sur corde bête (sensibilité 5), scanmar reculé sur 1er collage.

Freins serrés à 8h48.

Bourrelet posé à 9h06, position : 58°28.47 9°20.76

Clearance 0

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
9H30	986	3.2	-	2300	9.0 9.2	5.1 0	210
9H40	987	3.2	-	2300	9.1 9.2	5.0 0	201
9H50	986	3.2	-	2300	9.1 9.3	5.1 0	210
12H40	978	3.5	-	2300	7.6 7.9	5.3 0	199
12H55	979	3.3	-	2300	7.7 7.9	5.0 0	202
13H05	979	3.3	-	2300	7.7 7.8	5.4 0	193
13H15	979	3.5	-	2300	7.7 7.9	5.3 0	201

Vire à 15H45.

Grenadier	64	1546
Lingue bleue	1	26
Mora	1	25
Sabre	20	494

TOTAL 2 092 KG

6. **Trait 6 : mercre**di **AM**

Chalut allégé **avec racleur**, pas de caméra, pas d'enregistreur.

Treuils freinés à 17h12, bourrelet au fond à 17h27.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
17H35	894	3.5	3.3	1980	8.2 7.8	5.1 0	201
18H25	907	3.5	3.1	1980	8.2 7.7	5.4 0	192
18H40	903	3.5	3.1	1980	8.1 7.8	5.3 0	198
19H00	903	3.5	3.0	1980	8.2 7.7	5.3 0	196
20H10	920	3.6	3.0	1980	8.1 8.2	5.3 0	193
20H30	919	3.6	3.1	1980	8.2 8.2	5.3 0	196
20H40	919	3.5	2.9	1980	8.3 8.7	5.3 0	198
22H55	942	3.3	3.0	1980	8.3 8.7	5.3 0	188
23H05	941	3.2	3.9	1980	8.2 8.7	5.4 0	191
23H15	905	3.3	3.0	1980	8.2 8.7	5.3 0	190

Vire à 23h13 (vit Scan = 1.1 nds pdt virage). Chalut décolle à 23h27 câble à 68 m/min, bateau à 1 nd.

Un pèlerin de 4 m.

Baudroie	2	53
Brosme	1	26
grenadier	100	2409.5
Lingue bleue	11	281
mora	1	25
Mostelle	1	24.5
sabre	16	405

TOTAL 3 224 KG

7. **Trait 7 : mercredi soir**

Chalut allégé sans racleur, caméra en place et enregistreur (directement sur le bourrelet, sensibilité 8).

Freins serrés à 00h39. Bourrelet au fond à 1h01.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
1h05	907	3.1	3.0	1990	7.5 8.8	5.6 0	197
1H12	902	3.3	3.5	1990	8.3 8.9	5.6 3.2	203
1H20	923	3.3	3.5	1990	8.5 8.9	5.5 0	200
1H30	933	3.2	3.5	2040	8.8 9.7	5.2 0	210

Il y a eu 2 autres décollements pendant la nuit.

Viré à 7h30. Chalut décolle vers 7h45. Monte la rampe à 8h09.

Grenadier	13	314
Brosme	1	17.5
Baudroie	1	24.5
Sabre	62	1564

TOTAL 1 921 KG

8. **Trait 8 : jeudi matin**

Chalut allégé sans racleur. Pas de caméra, enregistreur laissé depuis le trait 7.

Essai de chalutage en pélagique à quelques mètres au-dessus du fond.

Début filage 8h41. Filage de 1 600 m sur fond de 930 m.

Le scan d'ouverture a été remis sur la corde de dos. Il mesure une ouverture de 10 m40 pendant la descente.

Refile à 1 800 m.

« stabilisation » à environ 10 m du fond à 9h27 oscille entre 8 et 24 m (distance entre fond et corde dos). Bien stabilisé à partir de 9h30.

Mini à 8 m à 10h01 puis 9 m à 10H16. Touche ? Voir enregistreur son.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
10H35	911	3.2	3.3	1810	7.8 8.5	8.8	200
10H55	919	3.2	2.1	1810	7.7 8.8	10.5	201
11H05	936	3.2	3.3	1810	7.9 8.8	11.6	196
11H20	948	3.2	3.2	1810	7.8 8.9	19	198
11H40	935	3.3	3.2	1810	7.7 8 .8	12	186

Vire à 11h45 (2h15 de trait).

Sabre	2	51

TOTAL 51 KG

Les sons enregistrés sont bruités par les mousquetons.

9. **Trait 9 : jeudi 3 AM**

Chalut standard avec racleur, enregistreur.

Frein serrés à 13h23, bourrelet posé 13h43

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
13H50	1121	3.3	3.3	2400	9.1 8.3	6.4 0	208
14H00	1120	3.2	3.1	2400	9.1 8.2	6.4 0	206
16H10	1128	3.3	3.2	2400	9.6 8.3	6.4 0	197
16h35	1127	3.4	3.1	2400	9.5 8.3	6.3 0	196
17h00	1125	3.4	3.2	2400	9.5 8.3	6.3 0	195
17h30	1125	3.3	2.8	2400	9.5 8.2	6.4 0	189
18h45	1117	3.4	3	2400	9.4 8.2	6.3 0	193
19h45	1087	3.5	2.9	2400	9.9 8.2	6.1 0	196

Vire à 19h57.

Grenadier	40	961
Lingue bleue	5	128
Sabre	24	617

TOTAL 1 706 KG

10. **Trait 10 : jeudi soir**

Chalut allège avec racleur sur fond un peu plus dur.

Capteur d'ouverture sur corde de dos.

Treuils freinés à 21h35, bourrelet au fond à 21h53.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
22h00	763	3.5	3	1750	8.2 8.3	5.8 0	189
22H20	764	3.4	3.4	1750	8.4 8.2	6.3 0	193
22H40	764	3.4	3.4	1750	9.8 9.4	5.3 0	195

Vire à 4h10.

Baudroie	1	22
Grenadier	7	165
Lingue bleue	1	24.5
Merlu	2	49
Mostelle	2	49
Sabre	99	2548

TOTAL 2 857.5 Kg

11. Trait 11 / vendredi matin

Chalut classique, Filé à 5h50.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
7h15	216	3	3.7	770	8.7 8.0	7.9 0	109
7H40	221	2.9	4	790	9.5 8.2	6.1 0	118
7h55	223	2.9	3.6	790	9.4 8.3	8.4 0	106

Viré 8h10. Beau coup de lieu noir. Attente avant de refiler.

Brosme	1	22
Lieu noir	748	19 963.5

TOTAL 19 985.5 KG

12. **Trait 12 : vendredi midi**

Chalut allégé avec racleur. Enregistreur de son sans les manilles (première fois).

4 capteurs de profondeur : 2 sur bourrelet, 1 corde de dos, 1 sur le collage. Caméra sur collage.

Ouverture chalut pdt la descente : 7.1 m

Freins serrés à 13h15, bourrelet au fond à 13h20.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
13h25	299	4.0	3.2	900	7.1 7.3	5.3 0	117
13h30	290	3.8	3.2	900	7.2 7.4	5.3 0	113
14H00	304	3.7	3.2	900	7.2 7.3	5.5 0	111
14H10	292	3.8	2.8	900	7.3 7.2	5.8 0	114
14h25	285	3.8	3.3	900	7.4 7.4	5.4 0	115
14H45	276	3.9	3.5	900	7.4 7.6	5.1 0	119
15H05	276	3.8	3.4	900	7.3 7.6	5.3 0	117
15h34	275	3.9	3.3	900	7.2 7.7	5.3	117

Vire à 15h56, bourrelet décolle à 15h57, (filage 775 m vitesse corde dos 3.8 nds).

Brosme	1	22
Lieu noir	156	4 164.5
Lingue Fra	1	21.5

TOTAL 4 186 KG

13. **Trait 13 : vendredi AM**

Chalut allégé avec racleur, enregistreur et capteurs SP2T laissés en place, caméra retirée.

Filé à 16h27. Freins serrés à 16h38. Bourrelet posé à 16h43.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
16h50	297	3.2	3.6	950	7.8 8.0	5.2 0	121
17H10	298	3.2	3.7	950	7.7 7.9	5.6 0	120
17H45	297	3.1	3.5	950	7.8 7.9	5.6 0	117
18H30	306	3.2	2.4	950	7.8 7.9	5.6 0	118

Vire à 19H35, avarie ? Décollé plusieurs minutes avant.

Sonde lue avant virage : 1200 m

Chimère	2	50
Lieu noir	3	79
Lingue Fra	6	154
Merlu	5	117

Mostelle	1	24

TOTAL 425 KG

14. **Trait 14 vendredi soir**

Chalut allégé sans racasseur, bas raccourci de 60 cm. Capteur de contact bourrelet, SP2T, caméra en place.

Treuils freinés à 20H34, bourrelet au fond à 20H37.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
20H40	232	3.9	2.8	830	6.1 7.1	5.6 0	118
20H50	254	4	2.9	830	6.1 7.1	5.5 0	121
20H56	228	4	3.1	830	6.1 7.1	6.1 0	118
21H30	210	4	3	830	6.4 6.8	6.0 0	119
21h36	228	3.9	2.8	830		6.3 0	120
22h05	215	4	3.1	830		5.4 0	121

A 21h31, tombe dans un trou de 10 à 15 de profondeur, reste à voler au-dessus sans se poser. Retouche vers 21h 36

Décolle vers 21h52 puis se repose (40 secondes).

A 22h01 : augmente la vitesse scan à 3.2 pour voir si ça décolle, on ne voit rien sur CLEARANCE scanmar.

Vire à 22h08.

Lieu noir (POK)	240	6445

TOTAL 6 445 KG

15. **Trait 15 vendredi soir**

Chalut allégé sans racleur. Capteur son laissé en place. Capteur contact retiré.

Différence remise à zéro.

Freins serrés à 23h11, bourrelet au fond à 23H16.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
23h25	242	3.9	3.2	850	6.3 6.9	5.3 0	121
23H50	237	3.8	2.9	850	6.1 6.7	6.2 0	111
00H15	226	3.8	3.3	850	6.6 6.9	5.3 0	121
0h35	215	3.9	3.2	850	6.6 6.6	5.6 0	118

Décolle à 23h45 (le même trou). Retouche à 23h46 (la vitesse a été réduite).

Vire à 0h37, bourrelet décolle à 0h39.

Lieu noir	118	3174.5
Merlu	3	64
Rascasse (SCS)	1	20.5

TOTAL 3 259 KG

16. **Trait 16 samedi matin**

Chalut classique.

File 1h55

Vire 3h20

Lieu noir	596	16615

TOTAL 16 615 KG

17. **Trait 17 samedi 5 matin**

Chalut classique.

File à 8h33. Freins serrés à 8h42. Bourrelet au fond à 8h44.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
8h50	284	4.2	2.8	900	6.7 6.6	6.6 0	118
9H25	305	4.1	3.2	900	6.7	6.7 0	123
9H50	285	4	3.1	900	7.0 6.7	6.6 0	120
10H20	284	4.1	3	900		6.3 0	121
10H50	283	3.9	2.8	900	7.1 7.0	6.9 0	120

Vire à 11H58, bourrelet décolle à 12H03

Baudroie	2	43.5
Lieu noir	5	135.5
Lingue FRA	8	224
Merlu	2	48.5

TOTAL 451 KG

18. **Trait 18 samedi 4 midi**

Chalut allégé. Caméra, son, contact, SP2T.

Capteur d'ouverture sur corde de dos.

Freins serrés à 12h44. Contact bourrelet à 12h49. Capteur d'ouverture sur corde de dos.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
12H55	257	3.9	3	900	6.5 7.5	5.8 0	122
13H15	256	3.8	3.1	900	6.8 7.5	5.6 0	122
13h35	265	3.9	3	900	6.7 7.5	5.4	122
14h05	276	3.8	3.3	900	6.7 7. 3	5.3	122
14h35	271	3.9	3.4	900		5.3	121
15h05	289	3.8	1.9	900		5.1	117
16H05	274	3.9	1.8	900		5.4	124
16h28	281	3.8	1.8	900		5.4	119

Courant portant dans deuxième moitié du trait.

Décolle à 12h25 pdt 30 sec. Décolle à 14h31 pdt 1 minute. Décolle vers 14h54. Décolle vers 15h16. Décolle vers 16h12. Décolle à 16h30, recolle.

Vire à 16H30, chalut décolle à 16h38 (bateau à 0.9 nds).

Anon (HAD)	1	26.5
Lieu noir	5	134.5
Merlu	3	75.5

TOTAL 235 KG

19. Trait 19 samedi AM

Chalut allégé sans racleur. Différence de 1 m. Caméra, son, contact, SP2T.

Capteur d'ouverture sur corde de dos.

Freins serrés 17h16. Bourrelet au fond à 17h20

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
17H33	208	3.5	2.1	850	7.4 7.7	5.6 0	124
17H43	198	3.5	2.1	850	7.5 7.7	5.2 0	126
17H53	205	3.4	2.1	850	7.5 7.7	5.6 0	123
18H03	203	3.4	2.1	850	7.5 7.6	5.4 0	125
18H19	197	3.3	1.9	850		5.6 0	123
18h30	198	3.3	2	850	7.5 7.7	6.3 0	123
18H40	199	3.3	2	850		6.1 0	125
18H50	197	3.2	2	850	7.5 7.7	6.3 0	119
19H00	198	3.2	2	850	7.5 7.7	5.4 0	125
19H45	204	3	1.8	850	6.9 6.6	6.3 0	120

Toujours pas de clearance

Vire à 19H45, bourrelet décolle à19h53, (240 m fune, v bateau 2 nds)

Anon (HAD)	1	25
Lieu noir	5	136
Merlu	3	69

TOTAL 230 KG

20. Trait 20 samedi 5 soir

Chalut classique avec racasseur. Caméra, capteur son et capteur contact bourrelet.

Freins serrés à 22h07, bourrelet au fond à 22h09.

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
22h13	212	4	2.4	760	7.2 7.7	6.8 0	120
22H25	225	4.3	2.3	760	7.6 7.6	6.6 0	114
22H35	216	4.2	2.5	760	7.9 7.8	5.4	120
22H45	207	4.1	2.1	760	7.7 6.7	11.2 3	110
23H00	238	4	2.4	760	7.8 7.7	6.4 0	115

Bourrelet décolle à 22h45 (prof augmente). Un détecteur de prise à rouge à 22h55. Deuxième à 23h.

Chalut décolle un peu à 23h06.

Vire à 23h04. Bourrelet décolle à 23h13 fune 150m, vit 1 nd. Capteur contact sorti plié.

Lieu noir	405	11293

TOTAL 11 293 KG

21. Trait 21 Dimanche 6 matin

Chalut classique avec racasseur. Capteur son et capteur contact bourrelet (plié à la mise à l'eau).

Freins serrés à 2h27 bourrelet posé à 2h31

Heure	sonde	VIT GPS	VIS scan	filage	Tens t/b	Ov/cl	Pan
2h50	203	4.1	2.9	760	5.5 9.4	6.4 0	115
3h15	210	3.9	2.7	760	7.4 8.4	5.9 0	119
3h40	219	3.7	2.9	760	7.7 7.4	5.8 0	121

Vire à 3H52. Le bourrelet décolle à 3h58 à 260 m de câble. Vscan 2.5 nds.

Lieu noir	597	16595
Baudroie	1	9.5

TOTAL 16 604 KG

ANNEX 7: DETAILS DES RESULTATS DE LA DEUXIEME CAMPAGNE EN MER

1. Bateau

RPM = 746 tr/min

Shaft = 133 tr/min hélice à 4 pales

Mesures de tension de funes pas significatives (mesurées sur pression hydro treuils).

2. Chaluts

Par la suite on appelle :

« Chalut standard » avec maillage de 75 mm, le chalut avec rockhopper standard (10 kg/m dans l'eau).

« Chalut allégé » avec maille de 60 mm, équipé du rockhopper allégé (4,5 kg/m dans l'eau) et d'un racleur en chaîne de 13 mm (3,7 kg/m) avec rondelles de 10 mm.

« chalut pélagique » le chalut allégé, sans racleur, et travaillant avec le bourrelet et l'ensemble du train de pêche décollés du fond

Bourrelet léger : dans l'eau 57 kg. Moins 13,8 kg d'élingue pour la pesée. Soit 43 kg dans l'eau. S'ajoute le poids des connecteurs (+1,8 kg pour 2 demi-connecteurs). Soit 45 kg pour 9 m ou = 5 kg/m dansl'eau.

3. Capteurs scanmar

Positions standard : sur corde de dos (symétrie en ouverture verticale).

Toujours dans cette position si rien de précisé en commentaire.

4. Contact bourrelet

Scanmar du bord.

5. Chronologie

Départ Lochinver vendredi 22 novembre à 15h00 ; pas de travail dans sud car zones de tirs UK.

6. Trait 1 : vendredi 22 soir

Chalut allégé

Filage terminé à 23h15 position : 59°02/7°35

Sonde : 785 m Filage 1850 m

Espèce recherchée : sabre

Vitesse : GPS 3,5 nds Scanmar 3,0 nds

Tension fune : bd 8,2 td 8,3

Conso : 287 (vieux)/236 (nouveau)

Distance panneaux : 190 m

Ouverture verticale : 5,3 m

Virage : 6h15 position : 59°21/7°07

Captures estimées pont : 140/150 caisses (estimées patron 160 caisses)

[Remarque : 300 kg de sabre maillés (en plus des estimations du pont)]

Captures conservées :

espèce	caisses	Poids (kg)
brosme	2	50,5
chimère	1	23
grenadier	4	92
Lingue bleue	5	119
merlu	1	22,5
mostelle	4	98,5
rascasse	1	23,5
sabre	134	3277
Total	152*	**3706**

*152 caisses réelles, soit 149 si ramené à 25 kg exactement

7. Trait 2 : samedi 23 novembre

Chalut allégé.

Filage terminé à 7h55 position : 59°11/7°01

Sonde : 280 m Filage 870 m

Espèce recherchée : merlu

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
8h15	280	3.8 / 3.5	870	8.0 / 8.0	5.6 / 0	120	290 / 230	70
9h50	293	3.7 / 3.6	870	8.2 / 8.0	5.3 / 0	117	303 / 243	71
10h20	303	3.9 / 3.5	870	8.2 / 8.1	5.4 / 0	115	298 / 237	71
10h30	307	3.9 / 3.7	900	8.9 / 8.5	5.1 / 0	119	300 / 245	71
10h45	317	3.8 / 3.6	900	8.7 / 8.6	5.2 / 0.1	117	275 / 220	67
11h00	308	3.8 / 3.4	899	8.4 / 8.6	5.3 / 0	120	274 / 220	67
11h05	308	3.7 / 3.3	900	8.4 / 7.9	5.2 / 0	118	268 / 216	67

Virage : 11h10 position : 59°17/6°40

Captures estimées pont : 200 caisses

Captures conservées :

espèce	caisses	Poids (kg)
baudroie	1	18,5
chimère	4	89
Lieu noir	62	1409
Lingue franche	4	89,5
merlu	200	4457,5
mostelle	3	70,5

divers	1	24,5
Total	275*	**6158,5**

*correspond à 245 caisses 25 kg

Divers : mélange brosme-mostelle

Remarque : avarie d'ailes ; prochain trait standard pour réparation de l'allégé

8. Trait 3 : samedi 23 novembre

Chalut standard (réparation à faire sur chalut allégé).

Filage terminé à 12h00 position : 59°17/6°43

Sonde : 322 m Filage 900 m

Espèce recherchée : merlu

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
12h15	322	3.9 / x	900	7.3 / 7.3	6.4 / 0	120	270 / 220	68
13h00	330	4.0 / x	920	8.1 / 8.6	6.5 / 0	117	293 / 244	71
13h10	327	3.6	920	8.1 / 8.3	6.3 / 0	123	286 / 228	68
13h20	322	3.9	920	8.2 / 8.3	6.3 / 0	119	306 / 252	72
13h30	330	3.8	920	8.2 / 8.3	6.1 / 0	123	301 / 245	72
13h45	327	3.7	920	7.7 / 8.2	6.3 / 0	117	302 / 247	72
14H15	317	3.8	920	8.2 / 8.1	5.8 / 0	122	311 / 255	74

Remarque : la donnée vitesse scanmar ne fonctionne pas sur ce capteur

Virage à 16h05 position : 59°29/6°33

Captures estimées pont : 250 caisses

Captures conservées :

espèce	caisses	Poids (kg)
baudroie	1	15,5
cardine	1	22
chimère	13	318
lieu noir	36	843,5
Lingue franche	10	233
merlu	253	5901
mostelle	4	97
rascasse	1	24,5
Total	320*	**7454,5**

* 299 si ramené à 25 kg

9. Trait 4 : samedi 23 novembre

Chalut pélagique

Filage terminé à 17h15 position : 59°28/6°42

Sonde : 600 m Filage 1 400 m

Espèce recherchée : sabre / mostelle / lingue bleue / merlu

Pendant descente, ouverture verticale du chalut de 10,5 m à 11,5 m

En pélagique ouverture de l'ordre de 9 m (observé quand capteur capte le bourrelet)

Scanmar pendant trait :

Sur cette photo (ensemble du trait), le capteur ne détectait pas le bourrelet. Quand il le détecte, l'ouverture du chalut est de l'ordre de 9 m.

Le chalut évolue de près du fond, avec quelques contacts (mais tout le gréement est toujours décollé), à 1 à 9 m du fond. Contact de 15 mn en début de trait. Moyenne estimées à 3 m du fond.

Virage : 20h30 position : 59°39/6°38 sonde 630 m

Captures estimées pont : 4 à 5 caisses

Captures conservées :

espèce	caisses	Poids (kg)
chimère	1	24,5
merlu	3	69,5
sabre	1	24,5
Total	5	**118,5**

10. Trait 5 : samedi 23 novembre

Chalut pélagique

Filage terminé à 21h40 position : 59°43/6°44

Sonde : 880 m filage 1750 m

Espèce recherchée : grenadier/sabre

Pendant descente, ouverture verticale du chalut de 10,5 m ; après (stabilisé près du fond) de l'ordre de 9 m.

Scanmar pendant trait :

Sur cette photo (ensemble du trait), le capteur ne détectait pas le bourrelet. Quand il le détecte, l'ouverture du chalut est de l'ordre de 9 m.

Le chalut évolue de près du fond, avec quelques contacts (mais tout le gréement est toujours décollé) et 5 à 10 m du fond. Contact 10 mn en début de trait. Moyenne estimées à 4/5 m du fond.

Virage : 23h40 position : 59°49/6°42 sonde : 820

Captures estimées pont : 2 caisses (sabre)

Captures conservées :

espèce	caisses	Poids (kg)
Sabre	2	39
Total		**39**

11. <u>Trait 6 : dimanche 24 novembre</u>

Chalut allégé

Filage terminé à 0h55 position : 59°54/6°39

Sonde : 700 m Filage 1650 m.

Espèce recherchée : sabre et divers grenadier, lingue bleue

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
1h15	717	3,8 / 1,8	1650	8,3 / 8,2	5,3 / 0	196	310 / 247	73

Virage : 6h20 position : 59°57 / 7°16 sonde 700 m

Captures estimées pont : 140 caisses (estimation patron 180)

Captures conservées :

espèce	caisses	Poids (kg)
brosme	2	51,5
cardine	1	25
chimère	18	452

grenadier	24	587
Lingue bleue	13	315
mostelle	1	25
rascasse	1	24
sabre	76	1903,5
Total	136*	**3383**

*136 caisses ramenées à 25 kg exactement

12. Trait 7 : dimanche 24 novembre

Chalut allégé

Filage terminé à 7h 35 position : 59°59/7°23

Sonde : 590 m Filage 1450 m.

Espèce recherchée : divers

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
9h15	542	3,6 / 1,9	1450	8,6 / 7,6	5,0 / 0	189	303 / 250	73
10h00	600	3,7 / 1.8	1450	8,2 / 7,8	5,3 / 0	181	301 / 245	73
10h30	630	3,6 / 1,7	1480	8,8 / 8,0	5,8 / 0	171	277 / 220	70
11h00	630	3,8 / 1,8	1480	8,8 / 7,8	5,7 / 0	170	298 / 240	72
11h15	600	3,9 / 1,7	1480	8,7 / 8,1	5,6 / 0	170	290 / 250	72
11h30	605	3,8 / 1,6	1480	8,8 / 8,1	5,3 / 0	180	287 / 230	72
11h45	608	3,8 / 1,7	1480	8,7 / 8,2	5,3 / 0	180	291 / 240	72

Virage : 11h55 position : 60°08/7°41 sonde 610

Captures estimées pont : 120 caisses (estimé bosco : 70 caisses à conserver, rejets « gros yeux »

Captures conservées :

espèce	caisses	Poids (kg)
baudroie	1	23,5
brosme	5	121
chimère	12	300
Lingue bleue	13	301
Lingue franche	3	68
merlu	2	46
mostelle	3	73
rascasse	6	148,5
sabre	8	195,5
sébaste	6	128,5
Total	59*	**1405**

*correspond à 57 caisses 25 kg exactement

13. Trait 8 : dimanche 24 novembre

Chalut allégé

Filage terminé à 12h55 position : 60°08/7°39

Sonde : 610 m Filage 1475 m

Espèce recherchée : lingue bleue

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
13h15	630	3,7 / 2,5	1480	8,3 / 8,6	5,6 / 0	190	308 / 247	74

Traine avec beaucoup de « virages ». Nombreuses variations. Données moyennes ci-dessus. Correspondent globalement aux données du trait n°7

Virage : 17h10 position : 60°04/7°42 sonde 650

Captures estimées pont : 50 caisses conservées, présence de « gros yeux »

Captures conservées :

espèce	caisses	Poids (kg)
baudroie	4	96
brosme	4	102
chimère	12	298,5
lingue bleue	44	1071,5
lingue franche	2	53,5
mostelle	3	73
rascasse	2	50
sabre	1	26
sébaste	32	729
Total	104	**2499,5**

*correspond à 100 caisses 25 kg

Remarque : rallonge panneau tribord cassée. Changée (30 mn).

14. Trait 9 : dimanche 24 novembre

Chalut pélagique

Filage terminé à 19h10 position : 59°50/7°52

Sonde : 710 m Filage 1450 m.

Vitesse moyenne GPS : 3,5 nds

Espèce recherchée : sabre, quelques lingues bleues

Scanmar pendant trait (deux dernières heures):

Sur cette photo, le capteur ne détectait pas le bourrelet. Quand il le détecte, l'ouverture du chalut est de l'ordre de 9 m.

Le chalut évolue de 3 à 20 m du fond. Pas de contact avec le fond. Moyenne estimée à 10 m du fond.

Virage : 21h30 position : 59°41/7°55 sonde : 780

Captures conservées :

espèce	caisses	Poids (kg)
sabre	1	23,5
Total	1	**23,5**

15. Trait 10 : dimanche 24 novembre

Chalut pélagique

Filage terminé à 22h55 position : 59°32 / 7°52

Sonde : 1 030 m Filage 1 750 m.

Espèce recherchée : grenadier et sabre

Scanmar pendant trait (deux dernières heures) :

Sur cette photo, le capteur ne détectait pas le bourrelet. Quand il le détecte, l'ouverture du chalut est de l'ordre de 9 m.

Le chalut évolue de 3 à 14 m du fond. Pas de contact avec le fond. Moyenne estimée à 7 m du fond.

Virage : 1h30 position : 59°28/7°x39 sonde : 1 070

Captures conservées :

espèce	caisses	Poids (kg)
néant	0	0
Total	0	**0**

16. Trait 11 : lundi 25 novembre

Chalut allégé

Filage terminé à 3h35 position : 59°22/7°15

Sonde : 900 m

Espèce recherchée : sabre

Virage : 7h30 position : 59°11/7°33 sonde 890

Captures estimées pont : 60 caisses

Captures conservées :

espèce	caisses	Poids (kg)
Baudroie	1	23
Chimère	2	49
Grenadier	11	250,5
Lingue bleue	4	91,5
Mostelle	1	24,5
sabre	50	1233
Total	69	**1671,5**

*correspond à 67 caisses 25 kg

17. Trait 12 : lundi 25 novembre

Chalut allégé

Filage terminé à 9h10 position : 59°09/7°11

Sonde : 270 m Filage 870 m.

Espèce recherchée : merlu

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
10h00	273	3,9 / 2,2	870	6,8 / 8,2	5,6 / 0	118	259 / 209	64
10h40	288	3,7 / 1,8	870		5,9 / 0	114	263 / 211	64
11h00	280	3,8 / 2,0	870		6,6 / 0	114	269 / 215	66
11h20	271	3,7 / 1,8	870		5,8 / 0	110	285 / 225	66
11H40	280	3,6 / 1,9	870		5,6 / 0		283 / 239	68

Virage : 12h10 position : 59°14/6°52 sonde 290

Captures estimées pont : 180/200 caisses

Captures conservées :

espèce	caisses	Poids (kg)
brosme	1	20
chimère	1	24,5
encornet	1	25
lieu noir	81	1980,5
Lingue franche	4	99,5
merlu	172	4128,5
mostelle	1	25
Total	262	**6303**

*correspond à 252 caisses 25 kg

18. Trait 13 : lundi 25 novembre

Chalut allégé

Filage terminé à 12h45 position : 59°15/6°51

Sonde : 290 m Filage 875 m.

Espèce recherchée : merlu

Virage : 15h10 position : 59°19/6°36 sonde 320

Captures estimées pont : 180 caisses

Captures conservées :

espèce	caisses	Poids (kg)
cardine	1	20
congre	1	19,5
lieu noir	8	193,5

lingue franche	6	141
merlu	191	4543,5
Total	208	**4917,5**

*correspond à 198 caisses 25 kg

19. Trait 14 : lundi 25 novembre

Chalut allégé

Filage terminé à 15h50 position : 59°15/6°51

Sonde : 300 m Filage 900 m.

Espèce recherchée : merlu

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
16h30	287	3,9 / 1,7	900	7,7 / 9	5,6 / 0	125	352 / 295	74
17h00	287	3,7 / 1,8	900	7,7 / 8,9	4,8 / 0	122	345 / 285	73
17h30	286	3,7 / 1,9	900	7,6 / 9,1	5,4 / 0	120	348 / 296	73

Bourrelet décolle de temps en temps. Petites « bosses » sur le fond.

Virage : 17h45 position : 59°26/6°33 sonde : 280

Captures estimées pont : 70/80 caisses

Captures conservées :

espèce	caisses	Poids (kg)
encornet	1	15
lieu noir	11	276,5
Lingue franche	2	49,5
merlu	51	1244,5
mostelle	2	50
Total	67	**1635,5**

*correspond à 66 caisses 25 kg exactement

20. Trait 15 : lundi 25 novembre

Chalut pélagique

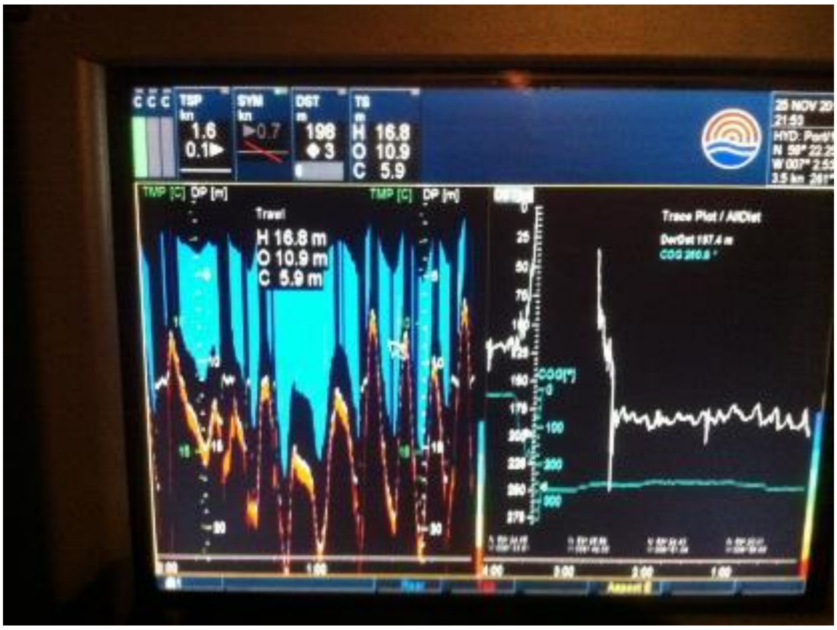
Filage terminé à 19h00 position : 59°25/6°47

Sonde : 800 m filage 1 800 m.

Vitesse 3,3 à 3,5 nds

Espèce recherchée : sabre

Scanmar pendant trait (deux dernières heures) :



Quand bourrelet détecté +/- 10 m d'ouverture chalut.

Peu stable, mer agitée.

Le chalut évolue de 1 à 18 m du fond. Quelque rares (2 ou 3) contacts avec le fond. Moyenne estimée à 6 m du fond (15 - 9).

Virage : 21h30 position : 59°22 / 7°03 sonde : 830

Captures estimées pont : 2 caisses

Captures conservées :

espèce	caisses	Poids (kg)
sabre	1	25
Total	1	**25**

*correspond à 1 caisse de 25 kg

21. Trait 16 : lundi 25 novembre

Chalut standard

Filage terminé à 22h35 position : 59°21/7°06 [+/- même traîne que trait n°1]

Sonde : 800 m Filage 1 850 m

Vitesse : 2,7 à 3 nds

Espèce recherchée : sabre

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
23h45	785	3,3 / 1,5	1850	7,6 / 7,3	6,4/ 0	200	320 / 250	76

Conditions bonnes jusqu'au trait 15, pendant ce trait vent 40 nds, mer plus qu'agitée.

Virage : 5h00 position : 59°07/7°33 sonde : 780/800

Captures estimées pont : 70 caisses dont 60 à conserver

(150 kg sabre maillé)

Captures conservées :

espèce	caisses	Poids (kg)
Baudroie	2	49.5
Brosme	2	46.5
Grenadier	3	65
Limande gauche	1	21
Lingue bleue	2	49
Mora	1	23
Mostelle	4	92.5
sabre	43	1064.5
Total	58	**1411**

*correspond à 56 caisses 25 kg

22. Trait 17 : mardi 26 novembre

Chalut standard

Filage terminé à 6h30 position : 59°06/7°17

Sonde 250 m

Espèce recherchée : lieu noir, divers, merlu

Vent 40 nds

Virage : 9h15 position : 59°11/6°59 sonde : 270

Captures estimées pont : 70 caisses

Captures conservées :

espèce	caisses	Poids (kg)
baudroie	1	23,5
chimère	4	100
lieu noir	55	1369
lingue franche	4	97,5
merlu	15	359
mostelle	1	25
Total	80	**1974**

*correspond à 79 caisses 25 kg

23. Trait 18 : mardi 26 novembre

Chalut standard

Filage terminé à 9h55 position : 59°12/6°58

Sonde : 280 m Filage 870 m

Vent : 35 à 40 nds, creux 3 à 4 m

Espèce recherchée : merlu

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas

10h30	288	3,9 /	870	8,2 / 8,7	6,0 / 0	122	275 / 230	66
10h45	288	3,9 /	870	8,6 / 8,7	6,0 / 0	125	272 / 210	66
11h00	288	3,6 /	870	8,4 / 8,2	5,6 / 0	124	280 / 210	65
11h15	287	3,9 /	870	8,3 / 8,4	6,0 / 0	124	279 / 209	65

Virage : 13h15 position : 59°18/6°36

Captures estimées pont : 200 caisses

Captures conservées :

espèce	caisses	Poids (kg)
Baudroie	1	24,5
Chimère	1	24,5
Congre	3	78
Encornet	1	19
lieu noir	54	1340
Lingue franche	12	295.5
Merlu	194	4661.5
Mostelle	1	24.5
Raie vache	1	22
Total	268	**6489.5**

*correspond à 260 caisses 25 kg

Remarque : plus de grattage comparé à la veille, même traine mais avec chalut allégé + de lotte, congre, lingue).

24. Trait 19 : mardi 26 novembre

Chalut standard

Filage terminé à 14h05 position : 59°18/6°38

Sonde : 330 m Filage 900 m

Vent : 30/35 nds, houle 4 m

Espèce recherchée : merlu

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
14h30	330	3,8 / ---	900	7,7 / 7,2	6,2 / 0	120	272 / 220	65
17h00	325	3,8 / ---	940	8,0 / 8,4	6,1 / 0	124	289 / 230	69

Virage : 17h00 position : 59°28/6°34

Captures estimées pont : 150 caisses

Captures conservées :

espèce	caisses	Poids (kg)
Brosme	1	25
Cardine	1	25
Chimère	5	125.5
Congre	2	49.5

Lieu noir	8	200
Lingue franche	8	202
Merlu	117	2868.5
Mostelle	6	150.5
Total	148	**3646**

*correspond à 146 caisses 25 kg

25. Trait 20 : mardi 26 novembre

Chalut standard

Filage terminé à 17h45 position : 59°27/6°30

Sonde : 260 m Filage 850 m

Vent : 40 nds

Espèce recherchée : lieu noir

Virage : 20h15 position : 59°19/6°33

Captures estimées pont : 50 caisses

Captures conservées :

espèce	caisses	Poids (kg)
Encornet	1	13
Lieu noir	28	705,5
Lingue franche	3	76
Merlu	26	572
Mostelle	1	25
Total	59	**1391,5**

*correspond à 56 caisses 25 kg

26. Trait 21 : mardi 26 novembre

Chalut pélagique

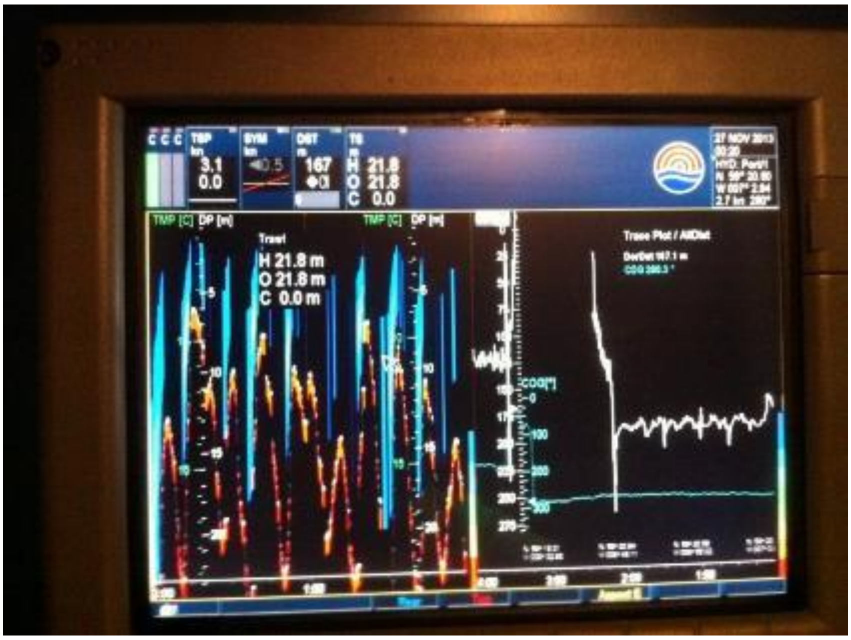
Filage terminé à 21h40 position : 59°21/6°50

Sonde : 650 m à 700 m Filage 1450 m.

Vitesse 3,3 nds

Espèce recherchée : sabre

Scanmar pendant trait (deux dernières heures) :



Très instable, mer très agitée. Vent 40 à 45 nds de face. Houle +/- 5 m. Filage réduit de 30 puis de 20 m pendant le trait (1400 m). De temps en temps l'info scanmar disparait (mauvais temps).

Impossible de maintenir le chalut dans des conditions satisfaisantes par mauvais temps.

Le chalut évolue de 1 m (parfois 0 m) à 18 m du fond. Quelques contacts avec le fond. Moyenne estimée à 6 m du fond (15 - 9).

Virage : 00h00 position : 59°20/7°03 sonde : 780

Captures estimées pont : 1 ou 2 caisses

Captures conservées :

espèce	caisses	Poids (kg)
sabre	1	23,5
Total	1	**23,5**

27. Trait 22 : mercredi 27 novembre

Chalut allégé

Filage terminé à 00h50 position : 59°22/7°00

Sonde : 820 m

Vent : 30/35 nds, houle 4 m.

Espèce recherchée : sabre, grenadier

Virage : 7h00 position : 59°42/6°45 sonde : 880

Captures estimées pont : 70 caisses

Captures conservées :

espèce	caisses	Poids (kg)
Baudroie	2	48
Brosme	1	26,5
Cardinal	1	20

Chimère	2	48,5
Grenadier	2	50
Lingue bleue	1	24,5
Mora	1	24,5
Mostelle	2	50
Sabre	63	1578
Total	74	**1870**

*correspond à 75 caisses 25 kg

28. Trait 23 : mercredi 27 novembre

Chalut standard (sans racleur)

Filage terminé à 8h35 position : 59°46/6°27

Sonde : 230 m filage 700 m

Vent : 30 nds, houle 5 m.

Espèce recherchée : lieu noir

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
9h50	235	3,8 / ---	700	8,0 : 8,4	6,8 / 0	117	267 / 220	65
11h00	225	3,8 / ---	700	7,9 / 8,6	5,9 / 0	125	276 / 202	67

Virage : 12h15 position : 59°41/6°02 sonde : 230

Captures estimées pont : 50 caisses

Captures conservées :

espèce	caisses	Poids (kg)
Chimère	1	21,5
Encornet	1	21
Lieu noir	24	608
Lingue franche	3	72,5
Merlu	24	574,5
Total	53	**1297,5**

*correspond à 52 caisses 25 kg

29. Trait 24 : mercredi 27 novembre

Chalut standard

Filage terminé à 12h55 position : 59°43/5°55

Sonde : 290 m Filage 850 m

Vent : 30 nds, vagues 4/5 m.

Espèce recherchée : lieu noir/merlu

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
13h10	290	3,9 / ---	850	7,9 / 8,2	5,9 / 0	120	280 / 200	66

13h35	295	3,9 / ---	850	7,9 / 8,4	5,9 / 0	120	272 / 200	63

Virage : 15h50 position : 59°45/5°33 sonde 300

Captures estimées pont : 80 caisses

Captures conservées :

espèce	Caisses	Poids (kg)
Cardine	1	21.5
Chimère	14	350.5
Encornet	2	39.5
Lieu noir	17	428
Lingue franche	4	100
Merlu	80	1950
Raie douce	1	21.5
Total	119	**2911**

*correspond à 116 caisses 25 kg

30. Trait 25 : mercredi 27 novembre

Chalut standard

Filage terminé à 17h00 position : 59°50/5°39

Sonde : 590 m Filage 1550 m

Vent : 35 nds, houle 4/5 m.

Espèce recherchée : lingue bleue, flétan, raie

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
17h30	598	3,5 / 2,5	1550	--- / ---	6,7 / 0	194	254 / 113	62
18h15	610	3,7 / 1,3	1570	--- / ---	6,8 / 0	195	250 / 200	61
20h00	620	3.4 / 1.7	1600	--- / ---	5.7 / 0	196	290 / 220	70

Virage : 23h00 position : 60°02/5°06 sonde : 600 m

Captures estimées pont : 100 caisses (patron : plutôt 120)

Captures conservées :

espèce	Caisses	Poids (kg)
Brosme	7	175,5
Chimère	1	24,5
Fletan noir	9	220,5
Grenadier de roche	4	97
Lingue bleue	96	2411
Lingue franche	1	19,5
Rais douce	44	1110,5
Rascasse	1	24
Sebaste	3	73
Total	166	4155,5

*correspond à 166 caisses 25 kg

31. Trait 26 : jeudi 27 novembre

Chalut standard

Filage terminé à 0h00 position : 60°03/5°06

Sonde 580 m

Vent : 30 nds, houle 4 m.

Espèce recherchée : lingue bleue, raies, etc.

Virage : 6h00 position : 59°52/6°34 sonde 580 m

Captures estimées pont : 100 caisses (patron 60)

Captures conservées :

espèce	caisses	Poids (kg)
Brosme	6	150
Chimère	13	329
Flétan noir	1	19.5
Lingue bleue	66	1672.5
Merlu	3	75
Mostelle	3	75.5
Raie douce	7	174
Sébaste	6	135.5
Total	105	2631

*correspond à 105 caisses 25 kg

32. Trait 27 : jeudi 28 novembre

Chalut allégé

Filage terminé à 7h20 position : 59°51/6°37

Sonde : 600 m Filage 1570 m

Vent : 25 nds, houle 3-4 m.

Espèce recherché : lingue bleue, flétan, raies, etc.

Heure	sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
8h45	620	3.7 / 1.4	1570	--- / ---	5.4 / 0	195	288 / 224	68
9h15	625	3.7 / 1.4	1570	--- / ---	5.6 / 0	200	269 / 190	66

Virage : 14h15 position : 60°07/4°59

Captures estimées pont : 80 caisses

Captures conservées :

espèce	caisses	Poids (kg)
Brosme	4	100.5
Chimère	1	20

Flétan noir	24	591.5
Grenadier roche	9	213
Lingue bleue	36	591
Raie douce	30	760.5
Sébaste	2	50
Total	107	2626,5

*correspond à 105 caisses 25 kg

33. Trait 28 : jeudi 28 novembre

Chalut standard

Filage terminé à 15h30 position : 60°07/4°54

Sonde : 580 m Filage 1550 m

Vent : 25 nds, houle 4/5 m.

Espèce recherchée : lingue bleue, flétan, raies, etc.

Heure	Sonde	VIT (gps/s)	Filage	Tens b/t	Ov/cl	Pan	Conso v/n	pas
16h00	580	3,2 / 1,6	1550	--- / ---	6,3 / 0	196	330 / 286	75
16h45	580	3.3 / 1.6	1550	--- / ---	6.0 / 0	200	320 / 260	75

Virage : 21h30 position : 59°56/5°23 sonde 580 m

Captures estimées pont : 100 caisses

Captures conservées :

Espèce	caisses	Poids (kg)
Brosme	5	126.5
Chimère	5	128
Fletan noir	1	13.5
Lingue bleue	114	2887.5
Merlu	3	72
Raie douce	5	123
Sébaste	11	266.5
Total	144	3617

*correspond à 146 caisses 25 kg

Avaries de ventre.

34. Trait 29 : jeudi 28 novembre

Chalut allégé

Filage terminé à 23h45 position : 59°4 3/5°41

Sonde : 200 m

Vent : 40 nds, houle 5 m.

Espèce recherchée : lieu noir

Virage : 1h20 position : 59°41/5°50 sonde 190 m

Captures conservées :

Espèce	Caisses	Poids (kg)
Eglefin	1	15.5
Baudroie	2	25
Lieu noir	2	45
Mostelle	1	24
Raie douce	1	25
Rascasse	1	17
Total	8	151.5

*correspond à 7 caisses 25 kg

35. Vendredi 29 novembre suite

En cape, vent 50/60 nds d'ouest, vagues 8/10 m

36. Trait 30 : vendredi 29 novembre

Chalut standard

Filage terminé à 17h45 position : 59°10/7°30

Sonde : 770 m filage 1750 m

Vent : 40 nds, houle 5/6 m.

Espèce recherchée : sabre noir

Heure	Sonde	VIT (gps/s)	Filage	Tens b/t	Ov/cl	Pan	Conso v/n	Pas
23h00	770	3,3 / 1,9	1750	9,3 / 9,2	6,3 / 0	180	320 / 240	73

Tensions remises en route (reset) après arrêt pendant plusieurs traits. Les valeurs indiquées semblent plus importantes qu'avant le reset.

Virage : 23h15 position : 59°21/7°01

Panneaux à poste à 23h40

Captures estimées pont : 80 caisses

Captures conservées :

Espèce	Caisses	Poids (kg)
Baudroie	1	25.5
Brosme	1	25
Limande gauche	1	25
Lingue bleue	2	50.5
Mora	11	26
Mostelle	2	49
Rascasse	1	26

Sabre	52	1308
Total	61	1535

*correspond à 61 caisses 25 kg

37. Trait 31 : samedi 30 novembre

Chalut standard

Panneaux largués à 0h18 (filage 100 m en 52 s, soit 2 m/s)

Filage terminé à 00h30 position : 59°19/7°00

Sonde : 690 m filage 1700 m

Vent : 25 nds, houle 3/4 m.

Espèce recherchée : sabre noir

Virage : 6h30 position : 59°07/7°32 sonde : 740

Captures estimées pont : 80 caisses (pas possible de faire une grosse erreur d'estimation)

Captures conservées :

Espèce	Caisses	Poids (kg)
Baudroie	2	49
Brosme	4	102
Chimère	7	169.5
Grenadier	1	21.5
Limande gauche	2	46
Lingue bleue	3	74.5
Mostelle	5	127.5
Rascasse	2	48.5
Sabre	40	985.5
Total	66	1624

*correspond à 65 caisses 25 kg

38. Trait 32 : samedi 30 novembre

Chalut standard

Filage terminé à 7h50 position : 59°06/7°16

Sonde : 250 m filage 850 m

Espèce recherchée : merlu, lieu noir

Heure	Sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	Pas
9h30	275	3.8 / 1.6	850	6.8 / 8.1	6.4 / 0	124	267 / 200	64

Virage : 10h10 position : 59°11/7°02 sonde : 270

Captures estimées pont : 60 caisses

Captures conservées :

Espèce	Caisses	Poids (kg)

Baudroie	1	23.5
Encornet	1	21.5
Lieu noir	37	932
Lingue franche	3	75
Merlu	23	560.5
Mostelle	1	25.5
Total	66	1638

*correspond à 65 caisses 25 kg

39. Trait 33 : samedi 30 novembre

Chalut standard

Filage terminé à 10h50 position : 59°11/7°00

Sonde : 270 m filage 865 m

Espèce recherchée : merlu, lieu noir

Heure	Sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	Pas
11h30	270	3.8 / 2.4	870	8.0 / 7.8	6.3 / 0	121	269 / 220	65

Virage : 14h15 position : 59°18 / 6°38 sonde 330 m

Captures estimées pont : 120 caisses

Captures conservées :

Espèce	Caisses	Poids (kg)
Encornet	3	62.5
Lieu noir	22	560.5
Lingue franche	9	227.5
Merlu	128	3088.5
Rascasse	1	16.5
Total	163	3960

*correspond à 157 caisses 25 kg

40. Trait 34 : samedi 30 novembre

Chalut standard + camera [objectif vers l'avant, objectif vertical, 1 m (8 mailles) derrière collage]

Filage terminé à 15h00 position : 59°18/6°38

Sonde : 330 m filage 900 m

Vent : 35 nds, houle 4/5 m.

Espèce recherchée : lieu noir, merlu

Heure	Sonde	VIT (gps/s)	filage	Tens b/t	Ov/cl	Pan	Conso v/n	Pas
16h00	320	3.7 / 2.6	900	7.3 / 7.5	6.1 / 0	120	306 / 233	70

Virage : 17h25 position : 59°27/6°34

Captures estimées pont : 40 caisses

Captures conservées :

Espèce	Caisses	Poids (kg)
Baudroie	1	16.5
Cardine	1	24.5
Chimère	2	50
Congre	1	24.5
Lieu noir	10	250
Lingue franche	2	50.5
Merlu	26	627.5
Mostelle	2	49
Total	45	1092,5

*correspond à 44 caisses 25 kg

41. Trait 35 : samedi 30 novembre

Chalut standard

Filage terminé à 18h10 position : 59°26/6°30

Sonde : 230 m filage 780 m

Vent : 40/45 nds, houle 5 m.

Espèce recherchée : lieu noir

Virage : 20h30 position : 59°19/6°33 sonde 220

Captures estimées pont : 20/30 caisses

Captures conservées :

Espèce	Caisses	Poids (kg)
Baudroie	1	23.5
Encornet	2	36.5
Lieu noir	19	477
Lingue franche	2	48.5
Merlu	5	121
Mostelle	1	24.5
Total	30	731

*correspond à 29 caisses 25 kg

42. Trait 36 : samedi 30 novembre

Chalut standard

Filage terminé à 21h45 position : 59°14/6°48

Sonde : 190 m filage 700 m

Vent : 30 nds, houle 4 m.

Espèce recherchée : lieu noir

Virage : 23h30 position : 59°28/6°34 sonde 180 m

Captures estimées pont : 10/15 caisses

Captures conservées :

Espèce	Caisses	Poids (kg)
Eglefin	3	70
Baudroie	2	49.5
Lieu noir	8	201.5
Lingue franche	1	24
Merlu	1	23.5
Total	15	368.5

*correspond à 15 caisses 25 kg

43. Trait 37 : dimanche 1 décembre

Chalut standard + camera [objectif vers l'avant, objectif vertical, 1 m (8 mailles) derrière collage]

Filage terminé à 1h10 position : 59°16/7°18

Sonde : 780 m

Espèce recherchée : sabre

Virage : 6h50 position : 59°00/7°36

Captures estimées pont : 80 caisses (plus 200 kg maillé)

Captures conservées :

Espèce	Caisses	Poids (kg)
Baudroie	1	25
Brosme	1	25
Chimère	2	44
Grenadier	8	191.5
Lingue bleue	1	24
Mora	1	25
Mostelle	2	50
Sabre	47	1171
Total	63	1555,5

*correspond à 63 caisses 25 kg

44. Trait 38 : dimanche 1 décembre

Chalut allégé

Filage terminé à 8h05 position : 59°02/7°30

Sonde : 530 m filage 1 470 m

Vent : 15 nds

Espèce recherchée : merlu, chimère

Virage : 12h00 position : 59°12/7°12

Captures estimées pont : 150 caisses

Captures conservées :

Espèce	Caisses	Poids (kg)
Baudroie	1	25.5
Brosme	1	25
Cardine	1	23
Chimère	21	534
Congre	1	25
Lieu noir	1	24
Lingue bleue	3	73.5
Lingue franche	7	50.5
Merlu	152	3780
Mostelle	4	100
Total	193	4782

*correspond à 191 caisses 25 kg

45. Trait 39 : dimanche 1 décembre

Chalut allégé.

Filage terminé à 13h10 position : 59°12/7°00

Sonde : 290 m.

Espèce recherchée : lieu noir, merlu.

Virage : 15h40 position : 59°17/6°44

Captures estimées pont : 70 caisses.

Captures conservées :

Espèce	Caisses	Poids (kg)
Cardine	1	17.5
Encornet	2	38
Lieu noir	20	513
Lingue franche	3	73
Merlu	53	1328.5
Mostelle	1	26.5
Rascasse	1	20
Total	81	2016,5

*correspond à 81 caisses 25 kg

FIN DE LA MAREE.

46. Résumé traits

Trait	Chalut allégé	Chalut pélagique	Chalut standard	Racleur	Pêche profonde	Durée du trait	Capture retenue (kg)
1	X			X	X	7h00	3706
2	X			X		3h15	6158,5
3			X	X		4h05	7454,5
4		X			X	3h15	118,5
5		X			X	2h	39
6	X			X	X	5h25	3383
7	X			X	X	4h20	1405
8	X			X	X	4h15	2449,5
9		X			X	2h20	23,5
10		X			X	2h30	0
11	X			X	X	3h55	1671,5
12	X			X		3h00	6303
13	X			X		2h25	4917,5
14	X			X		1h55	1635,5
15		X			X	2h30	25
16			X	X	X	6h25	1411
17			X	X		2h45	1974
18			X	X		3h20	6489,5
19			X	X		2h55	3646
20			X	X		2h30	1391,5
21		X			X	2h20	23,5
22	X			X	X	6h10	1870
23			X	X		3h40	1297,5
24			X	X		2h55	2911
25			X	X	X	6h00	4155,5
26			X	X	X	6h00	2631
27	X			X	X	6h55	2626,5
28			X	X	X	6h00	3617
29	X			X		1h35	151,5
30			X	X	X	5h30	1535
31			X	X	X	6h00	1624
32			X	X		2h20	1638
33			X	X		3h25	3960
34			X	X		2h25	1092.5
35			X	X		2h20	731
36			X	X		2h15	368,5
37			X	X	X	5h40	1555,5

38	X			X	X (?)	3h55	4782
39	X			X		2h30	2016.5

Profond : 20 traits : 6 pélagique, 7 allégé, 7 standard.

ANNEX 8: DISCARD REDUCTION STRATEGIES QUESTIONNAIRE

"Deep sea fish are species with slow growth and low reproduction, that live at depth ranging from 500m to more than 2 500m" IFREMER
"The term deep sea fishing applies wherever the activity is carried out below 400m" CIEM

- **What CIEM zones do you fish in? Please list ICES divisions (e.g. VIa, VIb or preferably ICES rectangles e.g. 39D7) or indicate fishing grounds on the following map of CIEM zones (map supplied).**

- **What depths do you fish at?**

- **Can you list the zones that yield the most discards or indicate them on the following map?**

- **Which of the following technical and strategical measures are most suitable to the reduction of bycatch/discards of deep water species? See following table. Comments/suggestions welcome.**

Technical measures	Detail (depth, season, etc.)		Strategical measures	Detail (depth, season, etc.)
			Stop fishing at depths where discards are highest	Example: limitation of roundnose grenadier catch to 1 100 m instead of 1 500 m where we can find juveniles.
			Closure of zones	
			Seasonal closures	
			Limit maximum quantity of discards	
			Quota reduction when unattained	
			Banning of certain fishing gears	

- **What are the differences between trawling fishing vessels with regards to amounts of discards?**

- **When fishing for deep water species are there differences in discard levels between night and day? Specify zones, seasons, depths, fishing gear (single / twin trawls).**

- **Do you know of specific zones that yield high amounts of discards? What species? Any details are welcome.**

- **Do you know of specific depths that yield low amounts of discards? What species? Any details are welcome.**

- **Is the level of discards linked to the target species?**

- **Are the species discarded linked to the target species?**

- **Can you list the species composition of discards for your fishing methods? Please indicate which species have a major contribution to discards (in weight) and which species you have seen in the discards but are caught in small quantities only.**

	Species caught	Zone	Season	Depth	Associated species
DISCARDED	Greater forkbeard Phycis blennoides				
	Herring smelts Argentina sphyraena				
	Leafscale gulper shark Centrophorus squamosus				
	Portuguese dogfish Centroscymnus coelolepis				

	Other deep-sea sharks				
	Non commercialised grenadiers Coelorinchus caelorhincus or Coelorinchus labiatus or Trachyrincus murrayi or Trachyrincus scabrus				
	Baird's slickhead Alepocephalus bairdii				
	Blue ling Molva dypterygia				
	Black scabbardfish Aphanopus carbo				
	Roundnose grenadier Coryphaenoides rupestris				
	Tusk Brosme brosme				
RETAINED ONBOARD	European hake Merluccius merluccius				
	Orange roughy Hoplostethus atlanticus				
	Beaked redfish Sebastes mentella				
	Blackbelly rosefish Helicolenus dactyloterus				
	Megrim Lepidorhombus whiffiagonis				
	Angler Lophius piscatorius				

- **Can you identify some areas where one or several species are discarded in higher/lower quantities and specify where these specific species are discarded most regularly?**

- **Are there areas where discards of deep-water sharks are higher/lower?**

- **Do Greenland sharks occur in your discards, where, when and how?**