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Report on results of sea trials in the regional seas

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INTRODUCTION

Each of the regional case studies focus on one or more fisheries that are representative of the region and comprise the full range of fishing gears that are widely used in European waters and are highly relevant in the context of mitigating their impact on benthic ecosystems.

Case studies identified are the Baltic Sea (Nephrops trawl, Otter trawls for cod, Blue mussel fishery), North Sea (Beam trawl, Shrimp trawl), Western waters (Nephrops trawl, Scallop trawl, Otter trawl on biogenic habitats), Mediterranean Sea (Otter trawl), Black Sea (Rapa whelk fishery with beam trawls and commercial demersal fisheries with bottom trawls).

In each of the case studies, a full analysis of a selected fishery including the assessment of the current impact on the benthic ecosystem and the assessment of the ecological and economic consequences of technological and management innovations could provide advice, and demonstrate how to mitigate fishery impacts on the benthic ecosystem.

This report collects all the regional case studies reports related to sea trials carried out to date. Particular attention has been paid to the description of the activities carried out. A preliminary presentation of the results obtained has also been included, even if data collected will be further analysed.

BALTIC SEA

Summary

During the period from summer 2014 to summer 2015 a row of bilateral meetings were held with the involved SME's representing the catch industry stakeholders as well as other selected stakeholders to finally plan and implement the experimental sea trials under the Baltic Case Study with 5 sub-case studies. These meetings have functioned as follow-up meetings on technological developments, smart fishing, and effort reduction scenarios in relation to the trial fisheries planned and outlined during the extensive RSE1 workshop in May 2013 in Copenhagen, and also suggested by stakeholders in the sub-group meetings and in the returned questionnaires from this first RSE1 workshop with broad representation of the catch industry, the processing industry, management, environmental NGO's and scientific management advisors.

On basis of the RSE1 workshop a series of pilot field studies have been conducted in the different sub-case studies to test further the recommended methods and technological developments discussed and suggested under the RSE1 in Copenhagen. This has covered fishing tests with light mussel dredges reported in Frandsen et al. (2014), initial creel fishery compared to trawl fishery reported in Frandsen et al. (2013; 2015) and in Hornborg et al. (2015), and fishing with pelagic trawl doors in the Western Baltic cod fishery, during 2013 to 2014. Additional SME meetings during the period from spring 2014 to spring 2015 have mainly been held on bilateral basis with the catch sector SMEs to follow up on the pilot experimental sea trials conducted in relation to each of the Baltic Sea sub-case studies. The aim of these meetings has been to modify the focus of the final sea trials performed in cooperation with the catch sector SMEs for each sub-case study. The resulting, final sea trials have accordingly been conducted during the second half of 2014 and in 2015.

In general the final sea trials in the Baltic Case Study has been delayed because the first extensive sea trials planned for August 2014 both in relation to WP7 and WP3-4 were cancelled at the last minute after extensive planning and communication over the spring because the owners of SME3 passed away in a tragic accident in August 2014 just a few days before the sweep length trials in the Kattegat Nephrops fishery should start. Consequently, the whole series of sea trials had to be re-considered and re-planned, and there had to be an application for approval of the activities and resources to be transferred to another SME. Furthermore, the sea trials have also been delayed due to birth leave of two DTU scientists working on the BENTHIS project.

The final experimental sea trials with smart fishing to avoid hard bottom localities in the Western Baltic cod trawl fishery were designed and conducted in cooperation with SME05 at selected localities in Femern Belt over 6 days in autumn 2014, covering different types of benthic habitats (i.e. sediment types with soft bottom and hard bottom habitats) which were repeated over 6 days in spring 2015. This was compared with the benthic fauna at selected sampling stations from the Femern Belt benthic sampling program as well as with the fishing intensity of the full métier (OT_DMF) for Denmark and Germany where SME05 has been active for several years. Analysis of the results is on-going. The BENTHIS evaluation of fishing pressure and gear impacts on benthic sensitive habitats has also been relevant for the Baltic trawl fisheries and are reported in Bastardie et al. (2015), Eigaard et al. (2015), Thoya et al. (2015) and in Bastardie et al. (in advanced prep).

Smart fishing with a reduction in fishing effort by using side-scan-sonar search and monitoring technology in the mussel fishery, has been tested in cooperation with SME04 (Wittrup Seafood A/S) during pilot sea trials in 2015. Here, side-scan sonar monitoring and test tracks have been recorded with the system acquired by E04. It has taken some time to make the system function properly.

Subsequently, much effort has been put into testing different software programs to evaluate the side-scan-sonar data and obtain adequate contrast in the data to enhance their analysis. During these processes several bilateral meetings with SME04 has been conducted as well as contacts to companies producing side-scan sonar technology and software for reading and analysing such sonar data. Final sea trials are on-going and planned for the rest of 2015 with a running evaluation of the sampled data on different types of mussel seabeds in cooperation with SME04.

The final sea trials with Nephrops creels were conducted during a 10 day survey in May 2015 in the Swedish area of the Kattegat with cooperation between DTU Aqua and SME02 (VG86 ATLAS). The final sea trials investigated the physical (and biological) seabed impact of creeling, and the fate of discards, as well as monitoring of Nephrops catch rates and behaviour in relation to hagfish occurrence in the creels. This was done by use of cameras, frames with cameras, DST Tags, and GPS loggers. In relation to the final sea trials, a mathematical-physical program for calculating the benthic impact of creels when they are hauled, given different directions of the creel strings, are produced. SME02 will continue to collect some additional data in the rest of 2015. The data collected from the final sea trials with creels have been compiled and processed and are now in the process of being analysed.

The first results are expected in early 2016. Final sea trials, testing short and long sweep length catch rates were conducted in a 7 day period finishing in August 2015 with participation of SME05, DTU Aqua and SLU. Here a number of comparative trawl hauls with short and long sweep lengths on a standard Nephrops trawl was conducted in the southern Kattegat to compare catch rates by species and size group. This covered comparable, repeated hauls with the two gear set-ups in both night and day fishery conducted in different areas where relatively high catches of Nephrops, roundfish (cod), and flatfish (plaice, sole) were likely. The experiments were completed successfully, and the data are compiled. During the coming months the catch rates and associated cost-benefit-analysis (CBA) will be analysed according to sweep length and trawl dimensions measured with sensors (amongst others, DST tags). Initial results of the sea trials are expected to be available in early 2016.

Physical and biological benthic impacts on the seabed and on benthic organisms associated with aphotic mud have further been investigated in sea trials with respect to different sweep lengths both in an area that is heavily fished and in an area closed to the fishery. These surveys have used a BACI design with sediment profile imaging (SPI) and core samples (Haps corer) for measures of sediment grain size composition, SPI index values, pigment profiles (HPLC), depth of H_2S free zone, and species abundance, biomass and diversity and biological traits composition. Furthermore, side scan sonar and UW video were used. To the extent possible, laser profiling has been carried out to evaluate the physical impact of different trawl elements.

Several bilateral planning meetings related to the sea trials in the Northern Kattegat were initially conducted with SME03 (FN370 Susanne H) and the Danish Marine Home Guard to conduct this trial in late summer 2014 from the SME03 and Home Guard vessels. However, due to the above mentioned accident the sea trails planned for between 24/8 – 6/9 2014 in the area open to fishery (Ålbæk Bay) and the closed fishing area (the Sound, northern Øresund) were cancelled. Follow-up bilateral meetings were then conducted from autumn 2014 to summer 2015 with SME05 (SG92 GiBri) and the Danish Marine Home Guard to conduct alternative sea trials in the same areas.

The final sea trials for this part of the sampling were successfully completed in two parts with the Danish Marine Home Guard Vessel “Apollo” and the DTU Aqua vessel “Havfisken” in Ålbæk Bay during 5 days in March 2015, and then in the Northern Sound with SME05 (SG92) during 5 days in August-September 2015. The laboratory and data analyses of the material collected during the two latter sea trials have been initiated in April and September 2015, respectively. Initial results from the sea trials are expected to be available in 2016. Other relevant results in the present context are initially reported in Hansen et al. (2015) and Pommer et al. (2015).

Results from sea trials in the western Baltic Sea

Western Baltic Cod and Mixed Consume Demersal Trawl Fishery sub-case-study

Based on the RSE1 workshop and previous pilot studies, the plans for the sea trials in this sub-case study were to test reduced benthic impact by use of pelagic trawl doors compared to standard demersal trawl doors in the Baltic cod trawl fishery. Pilot investigations with initial sea trials with pelagic doors and alternative gear riggings to reduce bottom contact in the western Baltic trawl mixed cod trawl fishery have been conducted during 2013-2014 by SME05. It was considered that an effective method to reduce trawl door impact on the seafloor is to lift the doors off the bottom in the Baltic cod trawl fishery. This measure, however, has a technical as well as a catchability disadvantage and will therefore not work in all fishing situations. Pelagic trawl doors are mainly an option for target species that are not herded by doors and sweeps/bridles along the bottom, such as shrimp and Nephrops. For such target species the mouth area of the trawl itself is the key parameter for catching efficiency (Eigaard et al., 2011).

For species such as cod and plaice, which are herded by the sweeps/bridles, an off-bottom door rigging where these other gear components are on the bottom, may be a solution to maintain catchability and eliminate the seabed impact of the doors. The technical challenge with such rigging is to keep the trawl door distance above bottom nearly constant. He et al. (2006) reported on the development and testing of such semi-pelagic rigging in the shrimp fishery in the Gulf of Maine (USA). In these experiments the door height was set above the seabed by adjusting the length of the warps where the distance of the doors to the bottom was monitored with acoustic instruments. Similar catch rates were obtained with this semi-pelagic trawl door rigging as with traditional trawl doors. Monitoring the height of the trawl doors above the bottom requires appropriate instruments which can be used to adjust the door height by altering trawl warp length or, alternatively, towing speed. An active control of the trawl door depth can also be achieved technically by adjusting the towing point and back strops of the doors while towing (FAO Techn. Report 2007).

The initial results of pilot investigations indicate that there seems to be area differences in the catch efficiency of the gear when using pelagic doors, possibly due to substrate or seasonal related behavioural differences of cod in reaction to the gears. In a national development project (Gemba, 2011), results from other test trials with the same trawl rigged with pelagic or bottom doors, respectively, demonstrated similar catch rates. However, the gears were tested using alternate gear configurations shifting on a trip basis, and the temporal and spatial variation is not accounted for in the comparison, so the figure values in the results should be treated with caution. Further testing is needed.

Based on additional pilot sea trial tests with pelagic trawl doors conducted in cooperation with SME05 during 2013-2014, the fishermen concluded that the catch rates of the targeted cod and flatfish were much lower when the trawl doors did not have seabed contact and accordingly generated visible sediment plumes behind the doors, compared to the pelagic trawl door set-up. The water whirlpool from the pelagic trawl doors without the sediment plume was not considered to create adequate herding effects of the fish into the trawl. The results from these additional pilot sea trials and gear tests have resulted in high scepticism for this method by the cod trawl fishermen (SME05) who expressed reluctance to continue with such sea trials (considered a waste of time). On this basis, alternative methods to reduce benthic impacts in the western Baltic cod trawl fishery were discussed and considered in relation to the final sea trials under this sub-case study.

In the period from summer 2013 to winter 2014-15 4 separate meetings have been held with SME05 on board the vessel SG92 Gi-Bri to discuss alternative methods to reduce benthic impacts in the Baltic cod demersal trawl fishery and to plan alternative, final sea trials in detail for this sub-case-study. One option considered realistic by the fishermen to reduce benthic impacts and still obtain adequate catch rates to maintain economic sustainability of the fishery, was to re-allocate more fishing effort away from the hard-bottom localities in certain seasons of the year to more soft-bottom seabed. The hypothesis is that in the 4th quarter of the year, and also in the 1st quarter of the year, catch rates of targeted flatfish and cod in the Western Baltic mixed demersal consume trawl fishery can be kept high at soft bottom localities under a smart fishing set-up and effort allocation program. Accordingly, compared to standard fishery the commercial fishery would, to a higher extent, avoid effort allocation on hard seabed habitats which are considered to be more sensitive habitats to demersal trawl fishing than soft bottom localities with respect to benthic impacts of the trawling.

It was agreed to set up an experimental fishing design with smart fishing where the final at sea trials were conducted with standard trawl gears and fishing methods respectively, at soft seabed habitats and at hard seabed habitats among known fishing grounds in the 4th quarter of the year. The same stations would then be repeated in the following 1st quarter to compare catch rates of target and by-catch species between types of localities and habitats and seasons. This final trial fishery was carried out in the Femern Belt area of the Western Baltic Sea in autumn 2014 and spring 2015 (see below). Furthermore, an extensive data analysis was undertaken of effort allocation and catch rates according to seabed and habitat type for the whole OTB métier (OT_DMF) for both Denmark and Germany, which SME05 represents and belongs to, in the Femern Belt area to test the proportion of effort allocation and associated catch rates between soft and hard bottom habitats and localities on a seasonal basis. The historical data analyses included the years 2009 and 2010 where there had been extensive benthic fauna sampling in the Femern Belt area (both on the Danish and German sides) in the Western Baltic Sea on a seasonal basis in relation to the baseline monitoring and environmental impact assessment of the fixed link planned between Denmark and Germany in the Femern Belt Area (Figure 1 and Figure 2; Source DHI Denmark).

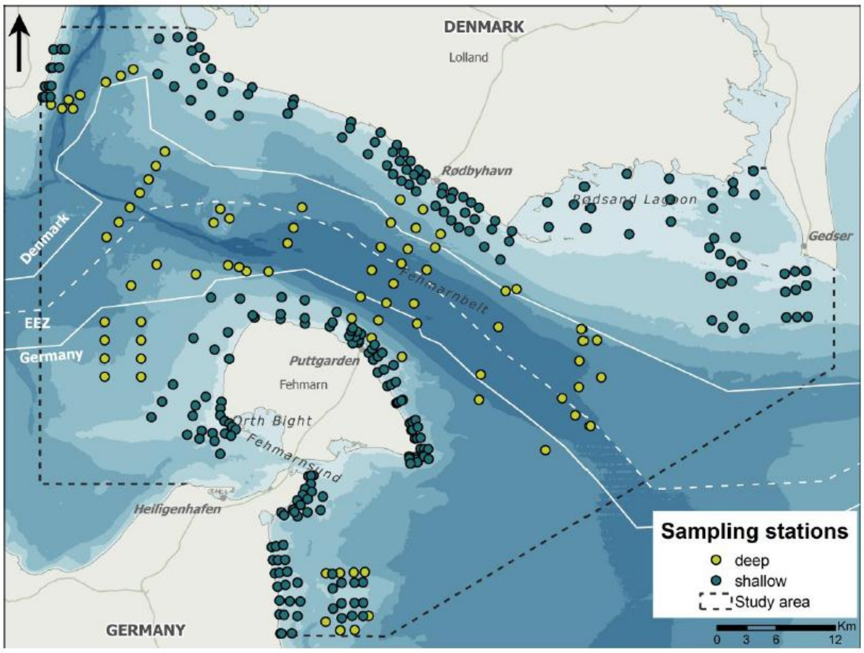


Figure 1. The geographical positions of the sampling stations for the benthic fauna baseline sampling campaign. The dark-coloured symbols denote shallow stations, whereas the light-coloured symbols denote deep stations.

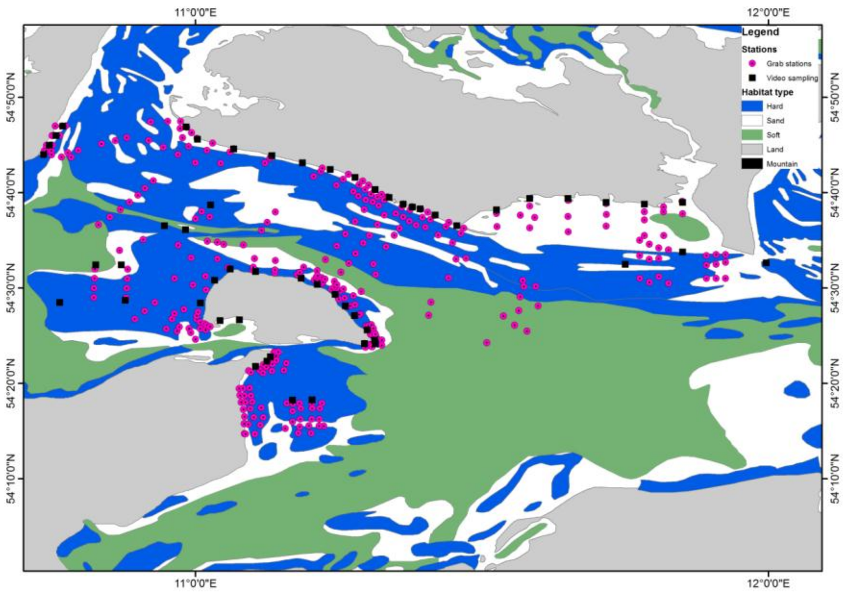


Figure 2. Benthic sampling stations with partly grab sampling stations and video monitoring stations repeatedly sampled in spring 2009, autumn 2009, spring 2010, and autumn 2010, as well as different habitat types and benthic sediment types in the Femern Belt area of the Western Baltic Sea.

In relation to the above extensive sampling program of benthic fauna and flora in the Femern Belt area there have been meetings held (both physical and phone meetings) with the Danish Hydrological Institute (DHI) and with the Femern Belt A/S Consortium to obtain these data for use in the BENTHIS Project. The benthic monitoring and data sampling program covering benthic fauna stations and associated faunistic classification has been conducted under a carefully planned survey design with intensive, standardized, and repeated grab sampling (and video monitoring) on a seasonal basis (both spring and autumn) in 2009 and 2010 covering a dense grid of carefully selected sampling stations. Furthermore, the data sampling, subsequent phylogenetic and species determination, as well as estimation of benthic group abundance, etc., have been quality checked and controlled by several independent parties to ensure a very high quality of the resulting data (perhaps one of the best benthic faunal data sets with extensive coverage in time and space and with quality control checked data, at present in the world for the time being according to DHI).

In the present project these data are compared with effort allocation of Danish and German OTB trawlers and different demersal trawl fishing intensities according to different seabed habitats (sediment types) to investigate impacts on the benthic fauna of different fishing pressures in different habitat types in those periods. The German fishery data has been obtained through contact with the national German fishery research institute (vTI institute) which have applied the BENTHIS WP2 fishing pressure software to their relevant fishery data to calculate fishing pressure during 2009-2014 in area by hauled gears. In this context, the final experimental sea trials were designed and conducted in cooperation with SME05 at selected localities in Femern Belt over 6 days in autumn (November/December) 2014 covering different types of benthic habitats (i.e. sediment types with soft bottom and hard bottom habitats) which were repeated over 6 days in spring (first half of March) 2015.

This is compared with the benthic fauna at selected sampling stations from the above described benthic sampling program as well as with the fishing intensity of the full métier (OT_DMF) for Denmark and Germany which SME05 belongs to.

The final experimental sea trials in autumn 2014 and 2015 are shown with start and end positions in Figure 7. The data from the sea trials have been quality checked, computerized, and compiled, and data analyses are now on-going in the context of the above described investigations and broader context hypotheses. The results of the analyses are expected to be available in early 2016.

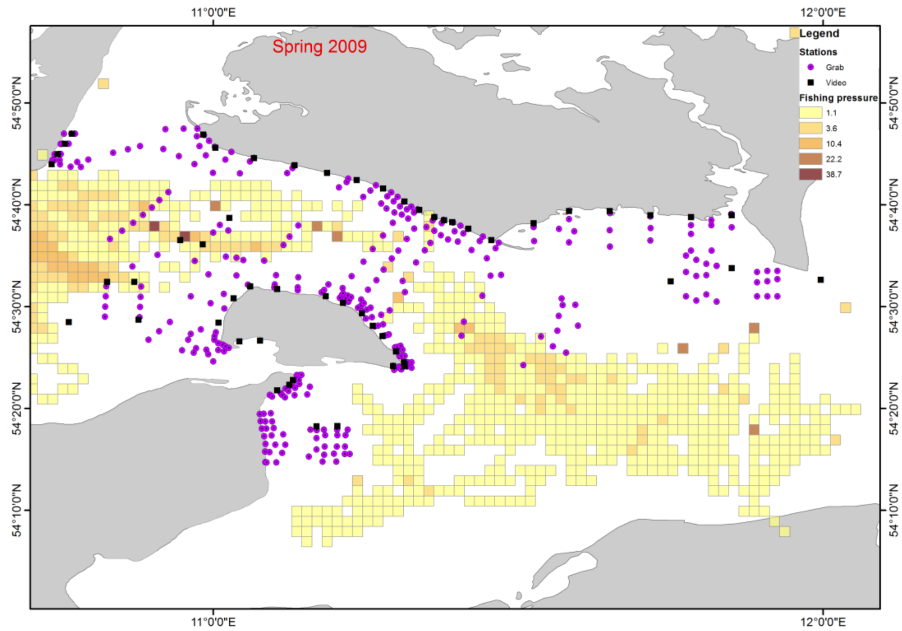


Figure 3. Effort allocation and fishing intensity of the Danish demersal otterboard trawl fishery (OT_DMF métier) in **spring 2009** as well as overlapping benthic sampling with partly grab sampling stations and video monitoring stations sampled in **spring 2009** in the Femern Belt area of the Western Baltic Sea.

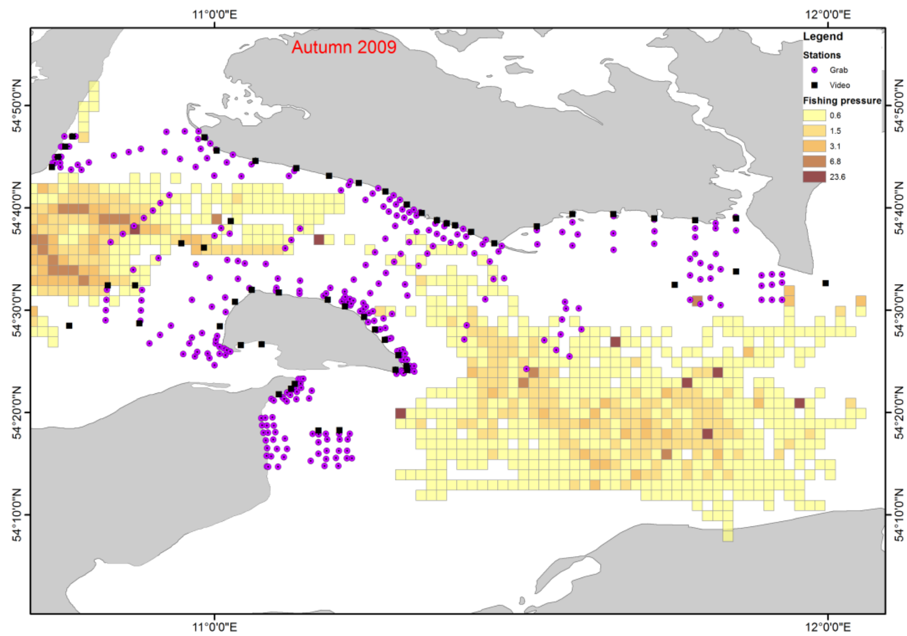


Figure 4. Effort allocation and fishing intensity of the Danish demersal otterboard trawl fishery (OT_DMF métier) in **autumn 2009** as well as overlapping benthic sampling with partly grab sampling stations and video monitoring stations sampled in **autumn 2009** in the Femern Belt area of the Western Baltic Sea.

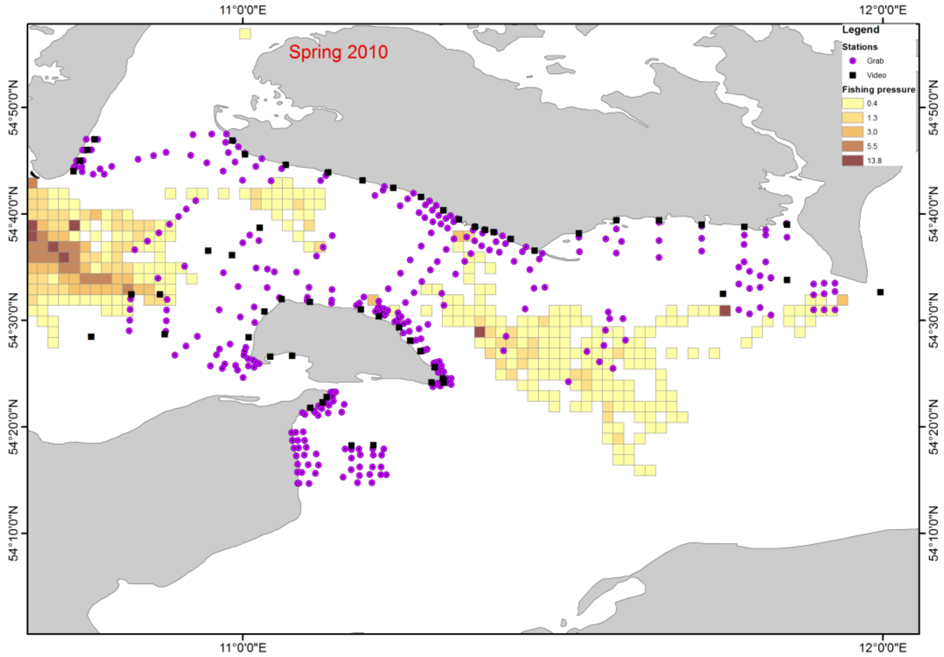


Figure 5.Effort allocation and fishing intensity of the Danish demersal otterboard trawl fishery (OT_DMF métier) in **spring 2010** as well as overlapping benthic sampling with partly grab sampling stations and video monitoring stations sampled in **spring 2010** in the Femern Belt area of the Western Baltic Sea.

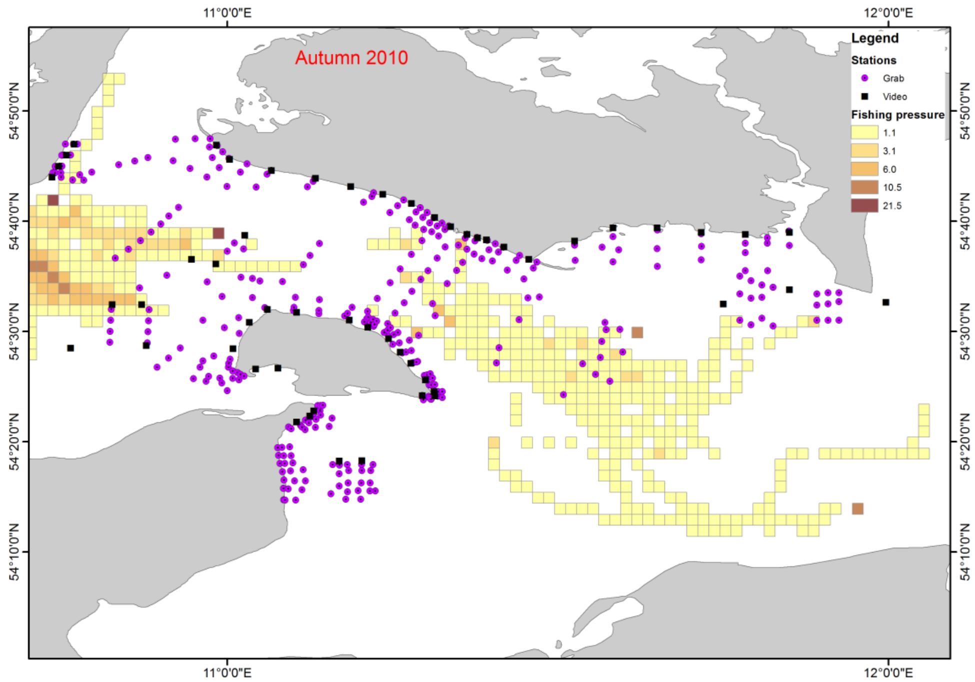


Figure 6.Effort allocation and fishing intensity of the Danish demersal otterboard trawl fishery (OT_DMF métier) in **autumn 2010** as well as overlapping benthic sampling with partly grab sampling stations and video monitoring stations sampled in **autumn 2010** in the Femern Belt area of the Western Baltic Sea.

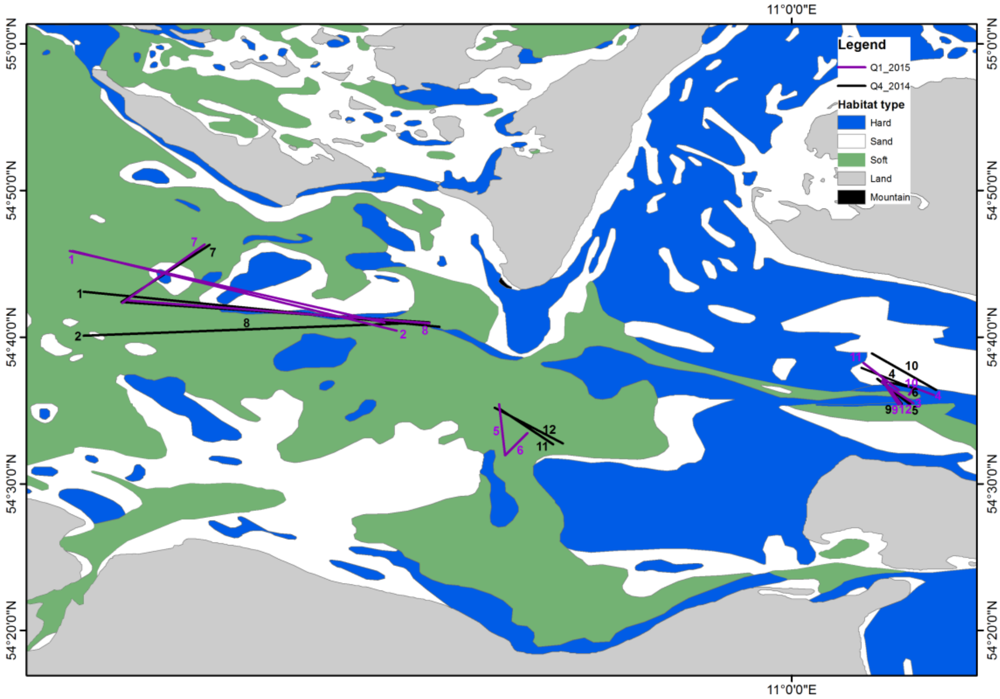


Figure 7. Start and end positions of trawl hauls under the final sea trials in the Western Baltic cod sub-case-study in autumn 2014 and spring 2015, respectively.

The above investigations are followed up by evaluation of different scenarios of effort allocation and fishing intensity in the Western Baltic demersal trawl fishery (OTB métier) on different types of benthic habitats and seabed types (hard bottom and soft bottom localities) using the bio-economic model DISPLACE (Bastardie et al. 2013; 2014; 2015) with respect to evaluation of catch, profit, and energy efficiency in relation to fuel consumption in the fishery. One focus for the Baltic cod-fishery is scenario evaluation of different effort allocation schemes according to season with respect to benthic impacts and catch efficiency of the Western Baltic trawl fishery, evaluated through effects of potential fishing closures in relation to more sensitive habitats.

The Western Baltic waters offer a unique opportunity to evaluate the benthic impacts of fishing closures from comparative studies of habitats and catches inside and outside potential closures according to season. In a pilot study certain fishing closures in the Western Baltic Sea have already been evaluated with respect to large marine constructions (fixed Femern Belt link between Denmark and Germany) in Miethe et al. (2014), and in relation to NATURA 2000 conservation areas and windmill farm sites (Bastardie et al. 2015). Under the BENTHIS project, evaluation of fishing pressure and gear impacts on sensitive habitats have been made, relevant to the Baltic Sea trawl fisheries with respect to effort pressure in Bastardie et al. (2015), Thoya et al. (2015), Thoya (2015) and Bastardie et al. (in advanced prep) and with respect to gear impacts in Eigaard et al. (2015). Furthermore, the different fishing options and related catch efficiency on different types of habitats will be followed up by a cost-benefit analyses (CBA) on individual an vessel basis scaled up to métier in relation to the Western Baltic cod trawl fishery.

Mussel scraper fishery sub-case study in the Belt Sea of the Western Baltic Sea

Based on the RSE1 Workshop and pilot experimental sea trial studies in Denmark, the plan for this sub-case study was to test reduced benthic impact by use of a light mussel scraper compared to the standard heavy mussel scraper. The results from these pilot sea trials are presented in Frandsen et al. (2014). Here the focus was on developing a mussel dredge with reduced ecosystem impact, which can be implemented without compromising commercial viability of the fishery. The aims of the gear development were to: (1) reduce re-suspension of sediment in order to reduce impact on water transparency; (2) increase catch efficiency in order to reduce the affected area; and (3) reduce the force needed to tow, in order to improve energy efficiency and potentially reduce energy transfer to the sediment. The implementation of the dredge in conservation areas is discussed in relation to reduced impact on the ecosystem and the economic efficiency of the fishery.

The highlights of the pilot sea trials of dredging blue mussels, *Mytilus edulis* were the following (Frandsen et al. 2015):

i. With respect to ecosystem impacts of mussel dredging, impacts included: a) removing structural seabed elements, b) inducing re-suspension of sediment, c) reducing filtration capacity;
ii. Reducing fishing impacts: development of new Light Dredge with stakeholders;
iii. Tested against a standard dredge on commercial vessels using different experimental setups;
iv. Results from use of light dredge included: a) the weight of sediment retained and re-suspension of sediment at the surface were lower, b) the drag resistance was significantly lower indicating a reduction in energy transfer to the sediment, c) catch efficiency increased – reducing area of impact and reducing fuel consumption - and accordingly increasing economic efficiency;
v. Sea floor tracks made by the two dredges could be distinguished by use of a side-scan sonar and the tracks were still detectable two months after fishing.

Figure 8. Different types of mussel dredges – light at the left and standard heavy at the right hand side.

During the period summer 2014 to summer 2015 activities included: many SME meetings with SME04 (Wittrup Seafood A/S), internal case study and project meetings, and contacts to companies producing acoustic side-scan sonar technology. These have involved extensive discussions on the extent of the reduced benthic impacts with the light mussel scraper given it is operated with another type of ground gear and gear design, and set-up with extensive seabed contact compared to the standard mussel scraper. Discussions also noted that the benthic impacts of the two gears will be very different according to current conditions and wind speed, as well as to wave influences in relation to boat movements all influencing differently the benthic impacts of the two different types of gears because of their different design. Furthermore, it has been discussed that it will be very difficult and resource demanding (most likely unrealistic) to estimate the actual changed benthic impacts of the two types of scrapers with overlapping experimental fishery using the two scrapers taking all the above influencing factors into account.

This is also seen form the associated diver investigations and measurements using, amongst other, imported equipment from Scotland (demanding Scottish diver participation) to evaluate different impacts of the two gears under the sea trials. Side-scan sonars are not considered sensitive enough to evaluate the different impacts and footprints between the two types of gears to an adequate level of detail. This is the case for both evaluating the impacts on short and long-term basis. Given the reasonable doubts whether such further sea trials with the alternative light mussel scraper would actually provide significant results, which are useful to the project, concerning changed benthic impacts of use of the different mussel scrapers, then alternative investigations were explored and discussed during a series of bilateral meetings with SME04. This also involved contact with companies producing side-scan sonar technologies to explore other methods to reduce benthic impacts of the mussel scraping fishery and for its evaluation.

An alternative focus is on smart fishing with more efficient previous (or real time) search and monitoring of optimal fishing grounds, as well as better mapping of the mussel banks and optimal fishing areas before actual fishing is conducted. The purpose is to obtain a better fishing plan by optimizing fishing effort and to obtain a better area usage in order to reduce the benthic impact of the fishery. That is, to reduce the total fishing effort to catch the same amount of mussels of the targeted size groups as in the previous standard fishery and to avoid areas where there are no mussels or only mussels of non-target size groups and quality. Such optimized effort allocation is obtained by only fishing on pre-monitored mussel bank areas organized from a detailed fishing plan and to avoid fishing in areas outside the mussel banks and on bank areas with non-targeted size groups (or quality) of mussels. Several meetings have been conducted to find technical solutions for a more efficient monitoring of the underlying fishery resources, amongst others, with SMEs which have also included contacts with companies producing side-scan sonars.

SME04 (Wittrup Seafood A/S) have always used video cameras in a smart fishing process for making pre-fishery monitoring of the seabed and the underlying mussel resources with respect to detection of mussels presence, their density, and their size composition. However, this initial resource monitoring using video sledges are very resource demanding in time and handling with respect to setting up, deployment, steaming at very slow speed, and for data analysis. It demands very calm weather to operate, and most importantly, it can only cover a very narrow monitoring band (around 1 m) operated with very low speed. Also, other activities (i.e. fishing) are not possible at the same time as the video sledge monitoring. Consequently, it is not a real time monitoring method when fishing, but the data needs to be checked before actual fishing is conducted afterwards. Overall this intelligent fishing method to select fishing areas and effort allocation (re-allocation) is very resource demanding, slow, and rather inefficient.

In the BENTHIS project since autumn 2014 pilot sea trials have been made with tests of more efficient monitoring, search, mapping and pre-assessment methods before (or real time during) fishing which are more cost-efficient than the video sledge monitoring method. The method tested is acoustic monitoring with a side-scan sonar, using acoustic transects in an optimal search survey design. The occurrence and delineation of the mussel banks are registered and mapped with the side-scan sonar to monitor location of mussel sea beds, mussel densities, as well as potentially the main size classes of the mussels. This previous and online mapping of the fishing areas, as well as surrounding low yield areas, can also be done on a continuous basis during fishing operations to make a more precise fishing plan and to monitor changes in the underlying resource abundance with respect to changes in locations and densities of the mussel banks over time. Furthermore, it is possible in a higher degree to avoid fishing on localities where there are no mussels and in areas between the mussel banks to reduce the benthic impacts in non-mussel-bank areas compared to the standard mussel fishery, which has no or limited previous monitoring and pre-registration of the mussel sea beds. Furthermore, commercial trial fishing operations to test and evaluate occurrences and densities of the mussels can be reduced when using this smart fishing method.

A side-scan sonar has much larger coverage surface than a video monitoring sledge (around 25-50 m wide bands at 4-12 m depth) and can more easily be operated, and can also be operated with higher speed and under worse weather conditions. Besides being operated in optimal survey transects in an optimal survey design, which is repeated on an e.g. two year basis, the side-scan sonar methodology and monitoring can also be used continuously and on a real-time basis. Accordingly, it can monitor and up-date underlying resource abundance maps when fishing and when steaming between mussel banks as well as when steaming between harbour and fishing grounds. Consequently, actual monitoring and pre-registration time is reduced significantly compared to video monitoring giving relatively more time to conduct actual fishing on optimal high density mussel banks which will reduce overall effort and time the gear is in contact with the seabed in order to obtain the same catch rates as in a standard fishery.

Figure 9. The system consists of a Humminbird Onix plotter, a side-scan transducer and a 360 degrees transducer (which can be hull mounted or mounted on towed bodies), as well as of a PC with the program AutoChart Live Pro. Onix can only show maps, but cannot make them. Real time maps and other mapping are therefore made on the PC with AutoChart.

This enables more cost-efficient monitoring and pre-registration of the locations of underlying resources compared to video camera monitoring from a sledge which need to be set and heaved when the vessel lies still, and it also needs to be towed at low speed. The transducers from the side-scan sonar can be hull mounted and as such, the side-scan sonar can continuously monitor at any speed. Consequently, it is much easier to map resources.

The side-scan sonar system acquired by SME04 under the BENTHIS project in 2014 is a combined single beam echo-sounder and wideband side-scan sonar system with a GPS system included for positioning. Seabed side-scan data are visualized on the plotter together with electronic sea maps according to the position obtained from the GPS system. The system has different standard plotter settings, and both echo-sounder and side-scan data, as well as electronic sea maps with position, course and speed of the vessel and seabed depth (the latter from the echo-sounder) and seabed hardness are visualized at the same time in real time monitoring. Onix can only show maps, but cannot make them. Real time maps and other mapping, e.g. historical data mapping, are therefore made on the PC with AutoChart software.

SME04 mainly fish on hard bottom localities in fjords located at 4-12 m depth and they primarily target high quality mussels which are relatively large in size and which are exported and sold as fresh and live mussels in European markets. Wittrup Seafood A/S has for a long period fished with initial camera monitoring of rather limited areas because of the limitations mentioned above in this pre-registration and smart fishing method. The hypothesis is that the more efficient side-scan monitoring and previous and continuous up-dated registration of the underlying resources is reducing overall fishing effort and limit the benthic impact through reduced time of seabed contact of the gear, and as such reduce the fishery impact on non-mussel bank sea beds, as well as at the same time maintaining high catch rates and catch values.

Based on the previous camera monitoring it will be possible to compare time series between the camera monitoring method and the new side-scan monitoring method within the same areas, and at the same time to compare efficiency of the different monitoring methods. Furthermore, it is possible to compare time series of fishing effort, catch rates, and catch values with the same 2-4 vessels under the company in the same area using the different monitoring and pre-registration methods (video camera vs. side-scan) to compare their impact with respect to effort reduction and effort re-allocation compared to catch efficiency.

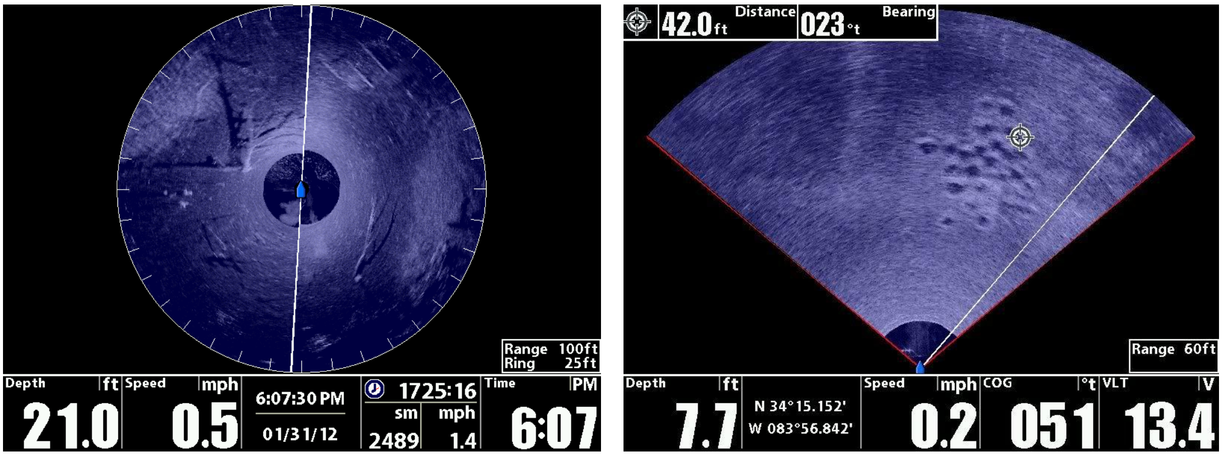


Figure 10. The 360 degrees imaging can be used to 360 degrees, up-dating with the vessel lying still, but the monitoring sector can also be limited to a smaller angle so the up-dating is faster and can be done when the vessel is steaming. As such, the system can function as a forward directed sonar during fishery.

The resolution on the side-scan sonar is approximately 2 degrees and 7 cm range resolution. Chirp pulse compression is used. The resolution on 360 degrees is of the same magnitude. This is not an overwhelming resolution, but experiences have shown that this is adequate for mapping of mussel seabeds. The aim is to optimize the fishery with such a system with more efficient pre-monitoring technologies and the actual fishing effort can be reduced and accordingly the actual benthic impact using the same standard fishing gears and fishing methodology can be reduced. The reduced effort will be a result in itself, and actual registration of changed benthic impact of the actual gear is as such not necessary which would be very complicated and resource demanding as described above with respect to comparison of effects of a light mussel scraper and a standard mussel scraper.

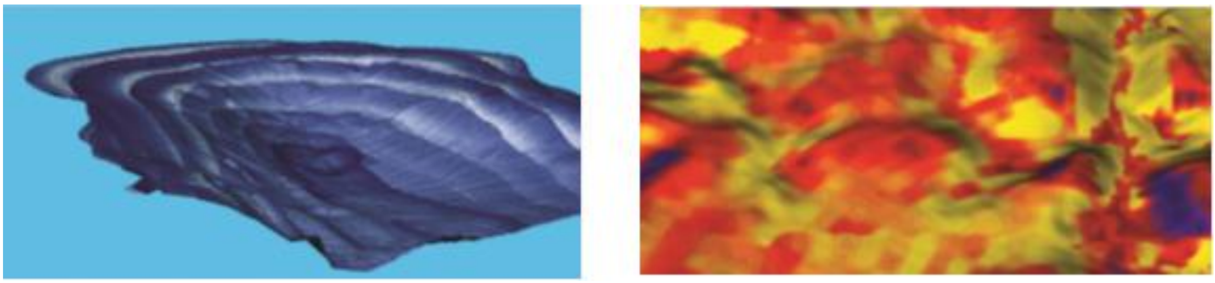


Figure 11. Auto chart can make real time maps over depth, seabed hardness, side-scan and 360 degrees imaging.

Table 1. Specifications of the system

	Humminbird Onix
Forward Directed Sonar	
Type	Scanning 180
Beam angle	3 grader
Axial resolution	7 cm
Chirp	Yes
Max Range	100 m
Sidescan Sonar	Humminbird
Type	Hull mounted
Beam angle	2 degrees
Axial resolution	7 cm
Chirp	Yes
Max Range	100 m
Echosounder build in	Yes (single beam)
Processing	
Maps in real time	Yes
Hardness	Yes
General	
Operational / practical	Reasonable
Robust	No
Mature technology	No
Reliable	No
Maintenance costs	Low
Duration – lifetime	3 years
Price	4800 Euro
Price per year in lifetime	1600 Euro

This equipment was acquired in 2014 by SME04 (Wittrup Seafood A/S) under the BENTHIS project, and mounted and tested on one of the mussel fishing vessels owned by SME04. During pilot sea trials in 2015 side-scan sonar monitoring and test tracks have been recorded with the system. It has taken some time to make the system function properly. Subsequently, much effort has been put into testing different software programs to evaluate the side-scan-sonar data and obtain adequate contrast in the data to enhance their analysis. During these processes several bilateral meetings with SME04 has been conducted as well as contacts with companies producing side-scan sonar technology and software for reading and analyzing such sonar data. Final sea trials are on-going and planned for the rest of 2015 with running evaluation of the sampled data on different types of mussel sea beds in cooperation with SME04.

Nephrops creel fishery sub-case study in the Kattegat of the Western Baltic Sea

During the period 2014-2015 several meetings with BENTHIS SME02 (VG86 ATLAS) as well as stakeholder workshops have been held in order to follow up on the pilot sea trials with creel fishery investigations and the recommendations from the RSE1 stakeholder workshop, as well as to explore economic efficiency of the Danish creel fishery compared to the trawl fishery, based on follow up experimental at sea trials in Kattegat. The meetings have involved bilateral meetings with SME02 to plan the fishing trials with creels conducted in the Kattegat in autumn 2013 and in May 2015. The meetings for planning the final sea trials with creels and to discuss cruise details and agreeing on distribution of work tasks between DTU Aqua and SME02 have been held in December 2014 and in early March and late March 2015. A stakeholder workshop was held in Hirtshals (DK) 12-14 November 2014 which has followed up on the additional investigations of economic efficiency in Danish creel fishery evaluated under the EU InterReg Sustainable Nephrops Fishery (OBJ Fish) (EU InterReg Project Iva, The Sound, Kattegat, Skagerrak) in cooperation with the EU-FP7-BENTHIS project with respect to the comparative economic analyses between the creel and trawl fisheries. The participants in the workshop were DTU Aqua (DK), IFM-AAU (DK), FOI-KU (DK), The Danish Fishery Association (DK), SLU (S) and IMR (N).

Initial pilot investigations and sea trials with creels in the trawl fishery closed area in the Kattegat reported in (Frandsen et al., 2013) indicate that i) creels sank into the soft sediment (camera monitoring); ii) creels were not directly lifted off the bottom, but were dragged for several minutes making a scrapemark (camera monitoring); iii) the bait attracted Hagfish (*Myxine spp.*) which scared the Nephrops in the creels => some escapement; iv) all by-catch thrown overboard immediately went to the bottom, and no predation from sea birds was observed, and there were no visible observed deviations in the cod discard behaviour when they swam to the bottom; v) catch rates were about 180 g/creel per day; vi) CBA indicates a profit of about 3800 DKK per day which is comparable to the trawl fishery for trawlers < 12 m with a profit of about 3050 DKK per day, however, larger trawlers have higher profit.

During a follow up creel experimental fishery in Swedish creel fishing areas over a week in September 2013 on soft bottom localities by SME02, cameras were used to obtain a preliminary understanding around the scraping issue of creel fishery. The video obtained revealed that creels were not directly lifted off the bottom but were dragged for several minutes http://www.youtube.com/watch?v=-EL2G1sMXZUo). Quantification of the physical disturbance which occurs from the creel fishery was not possible from the video obtained and therefore needs to be measured. However, it should be noted that dragging of creels over the seabed during the relatively limited hauling time interval is physically impacting a smaller area than a trawl haul with impact from doors, sweeps and footrope over long periods, covering a larger area.

This issue was followed up in the final trial fishery with creels in May 2015 in the Kattegat. Here the investigations focussed on the evaluation of the video of the creels when hauled on different types of sea beds, the fate of discards, and evaluation of different Nephrops catch rates and profitability of the creel fishery on soft bottom sea beds involving monitoring of catch rates in relation to occurrence of hagfish in the creels (and establishment of tube shelters in the creels). See also below.

The additional creel sea trials conducted in September 2013 in the Swedish fishing area on soft bottom sea beds, which are similar to typical Danish soft bottom fishing areas, also involved an evaluation of the potential economy in the Danish creel fishery compared to trawl fishery first reported in Frandsen et al. (2015). Creel fishing for Nephrops is common practice in, for example, Sweden and Scotland, but not in Denmark. The sea trials and investigations of economic efficiency have been performed in cooperation with the EU InterReg Project OBJ Fish and the EU-FP7-BENTHIS project. This new sea trial indicated that high catch rates with creels on soft mud bottom sea beds can be maintained – also on soft sea bed and habitat types occurring in Danish waters.

Frandsen et al. (2015) investigated the profitability of the Swedish type of creel fishing in areas comparable to Danish waters and fishing areas. It compared the results with the profitability of equivalent Danish trawlers/gill netters of similar size and type. The results from this investigation indicate that a creel fishery for Nephrops may be profitable for smaller vessels (<12 m) using 1400 creels and with home harbour relatively close to fishing localities, i.e. with 2 men on board to handle that number of creels. These estimates are in accordance with the size composition of the creel fleet in Sweden and Scotland. Sensitivity analyses pointed out that an uncertain estimate of catch rates could alter this result. The economy is very dependent on catch rates similar to the Swedish fishery catch rates. More knowledge on the expected catch rates in the fishing areas in question is therefore important prior to investment. Furthermore, higher price for live Nephrops is essential as a buffer. Close fishing areas assure low steaming costs and sufficient time at the fishing locality to handle a high number of creels. Expenses need to be low, i.e. keeping fuel expenses low. Besides having the harbour close to the fishing areas this can also be ascertained with an adjusted size engine with economic fuel consumption. Furthermore, the creel fishery demands that there is not too much wind making it more attractive in seasons with average low wind speeds compared to other seasons. There are better possibilities for optimizing the number of fishing days on fishing localities, which are in close vicinity of the home harbour. The investigations covered 4 scenarios:

(i) One-man vessel < 12 metre
(ii) Two-man vessel < 12 metre
(iii) One-man vessel > 12 metre
(iv) Two-man vessel > 12 metre

Accordingly, a creel fishery seems equally profitable for smaller vessels with respect to creel and trawl fishery, however, a creel fishery is less profitable compared to the profit for larger Nephrops trawlers. Comparison of trawl and creel fisheries in the Kattegat under the BENTHIS project is also reported in Hornborg et al. (2015). The initial results indicate that:

1) Creeling catches larger Nephrops (undersized individuals in the catch is 11.5 % in weight compared to 42%, no difference between mixed and grid, more females (40 % compared to 32%*)* and more females bearing eggs (23% compared to 5 %) compared to trawls;
2) The creel fishery catches and discards considerably less fish than the trawl fishery (grid trawling mainly flatfish;
3) Per tonne Nephrops landed, mixed trawling sweep 40 sq-km, grid trawling 21 sq-km whereas creeling utilize 0.003-1.3 sq-km depending on extent of drag and drift;
4) Fishermen receive higher prices for creel-caught Nephrops than trawl-caught (20%), but mixed trawling has an additional income from fish catches (between 1-2 euro extra per kilo of Nephrops landed).

Table 2. Estimated profitability in the creel fishery (dependent on the number of creels) compared with the profitability in the Danish commercial Nephrops fishing fleet (in DKK) – (From Frandsen, Jensen and Feekings, 2014-15.

	i	Ii	Iii	Iv
Vessel size	<12 m	<12m	>12m	>12m
Crew	1	2	1	2
Creel days per year	150	150	150	150
Fishing days per year	150	150	250	250
Turnover (DKK/day)	3180	5565	3180	5565
Costs (DKK/day)	1634	1968	2534	2868
Profitability (DKK/day)	1545	3597	645	2697
	Data from “FiskerietsØkonomi 2012”			
Yearly profitability	407.500*	407.500*	699.500**	699.500**
Profitability/fishing day	2.717	2.717	2.798	2.798

* Informed average for the group ”Jolle/ruse” for vessels < 12 meter;

** Informed average for the group ”trawl” for vessels > 12 meter and < 16 m.

The Hornborg et al. (2015) report discusses alternative management for trawl and creel fisheries where creels may introduce:

1) Considerable decrease in total catch of juvenile Nephrops and flatfish;
2) Substantial reduction in demersal trawling pressure on seafloor habitats and an increase in trawl-free areas;
3) Potential risk of recruitment overfishing from catching more females with eggs expected to be low;
4) Increased landing quota for Nephrops may be allowed without increasing fishing mortality;
5) Adaptive management recommended: will size composition of Nephrops be affected? Crowding conflicts?

The final sea trials with creels were conducted during a 10 day survey in May 2015 in the Swedish area of Kattegat as an cooperation between DTU Aqua and SME02 (VG86 ATLAS). The final sea trials investigated the physical (and biological) seabed impact of creeling, and the fate of discards, as well as monitoring of Nephrops catch rates and behaviour in relation to hagfish occurrence in the creels. This was done by use of cameras, frames with cameras, DST Tags, and GPS loggers. In relation to the final sea trials a mathematical-physical program for calculating the benthic impact of creels when they are hauled given different directions of the creel strings was produced. SME02 will continue to collect some additional data in the rest of 2015. The data collected from the final sea trials with creels have been compiled and processed and are now in the process of being analysed. The first results are expected in early 2016.

Mixed Nephrops trawl fishery sub-case study in the Kattegat of the Western Baltic Sea

A gear technological efficient option to reduce benthic impacts of the Kattegat Nephrops trawl fishery suggested by fishermen and gear manufacturers at the RSE1 workshop is shortening of the sweep lengths. Accordingly, a traditional Nephrops twin-trawl with benthic doors and 2 different sweep lengths (standard, around 50 m, compared with short sweeps around 15 m) was to be evaluated in an experimental fishery in the Aalbæk Bay, Northern Kattegat, which is a standard Nephrops trawl fishery area (open). This experimental fishery was planned in detail with SME03 (FN370 Sussanne H) to be conducted in August 2014.

The gear development and experimental fishery design was developed and planned in detail based on a long series of meetings and close cooperation with SME03 and gear manufactures during 2013-2014, in advance of the experimental fishery based on the stakeholder recommendations from RSE1. However, very sadly the owners of SME03 passed away in a tragic working accident in August 2014 just a few days before the sweep length trials in the Kattegat Nephrops fishery. Consequently, the sea trials had to be re-considered and re-planned, and there had to be an application for approval of the activities and resources to be transferred to another SME. Later in the year, the possibilities for carrying out the experimental fishery with standard (long) and short sweep lengths with SME05 (SG92 Gi-Bri) were investigated. SME05 usually fishes Nephrops in the Kattegat with standard Nephrops trawl gear in the summer. After obtaining acceptance and approval in BENTHIS to transfer the remaining resources between the respective SMEs (from SME03 to SME05) a series of bilateral planning meetings were held with SME05 on board SG92 GiBri and by telephone during spring and summer 2015 to plan and conduct the final sea trials with SME05 (SG92 GiBri) in August 2015.

The rationale behind the modified gear is that the shorter sweeps will not change the selectivity and catch of Nephrops, because Nephrops are not herded by the fishing gear, while the (un-wanted) by-catch of fish, especially roundfish like cod and flatfish like plaice and sole, will be reduced because there will not be as much herding of these fish from the shorter sweeps compared to the longer standard sweeps. Sweeps are known to herd most fish, especially roundfish and flatfish. Fish by-catch is often un-wanted in the Nephrops fishery because it may restrict the fishery either because of overall TAC- and/or effort- restrictions based on fish catch (especially cod), or because of lack of individual quotas for certain fish species for the Nephrops fishermen because these quotas are very expensive. Un-wanted by-catch and discard will be reduced by shortening the sweeps. The shorter sweep lengths will as such also meet a coming discard ban in the fishery. Shorter sweeps are also considered to have less benthic contact and cause less benthic impact.

Final sea trials, testing short and long sweep length catch rates, were conducted over a 7 day period in August 2015 with the participation of SME05, DTU Aqua and SLU. Here a number of comparative trawl hauls with short and long sweep lengths on a standard Nephrops trawl was conducted in the southern Kattegat to compare catch rates by species and size group. This covered comparable, repeated hauls with the two gear set-ups in both night and day fishing conducted in different areas where relative high catches of Nephrops, roundfish (cod), and flatfish (plaice, sole) were likely. The experiments were completed successfully, and the data have been compiled. During the coming months the catch rates and associated cost-benefit-analysis (CBA) will be analysed according to sweep length and trawl dimensions measured with sensors (amongst others, DST tags). Initial results of the sea trials are expected to be available in early 2016.

Physical and biological benthic impacts on the seabed and on benthic organisms associated with aphotic mud have further been investigated in sea trials with respect to different sweep lengths both in an area that is heavily fished and in an closed fishery area.

These surveys have used a BACI design with sediment profile imaging (SPI) and core samples (Haps corer) for measures of sediment grain size composition, SPI index values, pigment profiles (HPLC), depth of H_2S free zone, and species abundance, biomass and diversity and biological traits composition. Furthermore, side scan sonar and UW video were used. To the extent possible laser profiling has been carried out to evaluate the physical impact of different trawl elements. Several bilateral planning meetings related to these sea trials in the Northern Kattegat were initially conducted with SME03 (FN370 Susanne H) and the Danish Marine Home Guard to conduct this trial in late summer 2014 from the SME03 and Home Guard vessels. However, due to the above mentioned accident the sea trails planned for between 24/8 – 6/9 2014 in the area open to fishery (Ålbæk Bay) and the closed fishing area (the Sound, northern Øresund) were cancelled.

Follow-up bilateral meetings were then conducted from autumn 2014 to summer 2015 with SME05 (SG92 GiBri) and the Danish Marine Home Guard to conduct alternative sea trials in the same areas. The final sea trials for this part of the sampling were successfully completed in two parts with the Danish Marine Home Guard Vessel "Apollo" and the DTU Aqua vessel "Havfisken" in Ålbæk Bay during 5 days in March 2015, and then in the Northern Sound with SME05 (SG92) during 5 days in August-September 2015. The laboratory and data analyses of the material collected during the two latter sea trials have been initiated in April and September 2015, respectively. Initial results from the sea trials are expected to be available in 2016. Other relevant results in are initially reported in Hansen et al. (2015) and Pommer et al. (2015).

NORTH SEA

Assess the current trawling impact (Task 7.2.1)

Summary

The sea trials have been successfully completed. The methods used, data collected and number of sea trials are significantly higher than anticipated in the contract thanks to collateral national funding. Data have been provided for WP2, WP5 and WP6. The tasks for the economic work and for the alternative management scenarios have been initiated, partly carried out and planned.

Clearly significant results

Sea trials, data collection and delivery according to plan. 2 national reports, 1 publication, 4 submitted publications.

Deviations

None.

Failing to achieve objectives

None.

Use of resources

No exceptional deviations.

Options for mitigation (Task 7.2.2)

Summary of progress

A review report on different options for mitigation in the region has been delivered and has been compiled into a report for all case studies combined. The options for mitigation in the North Sea, as an alternative to the present day flatfish directed fisheries, are in principle manifold but few of them are easy to implement. It is, however, very clear that electric pulse fisheries for flatfish as well as for brown shrimps have successfully been implemented into the commercial fisheries. There also are indications that these alternatives have benefits in terms of discards and seafloor impact.

Deviations

None.

Failing to achieve objectives

None.

Use of resources

No exceptional deviations.

Testing alternative gears (Task 7.2.3)

Summary of progress

A total of 4 sea trials have been carried out, 2 for the flatfish pulse and two for the shrimp pulse gears. The aim of the sea trials was to study selected gear alternatives (such as pulse trawl for flatfish and brown shrimp) in several field trials. New experiments to estimate direct mortality of alternative and traditional gears have been conducted in relevant habitats to validate the model developed in WP4. Commercial vessels, available through the participating SME's, have been involved. The effect of trawling has been studied in a number of plots.

For each of the experiments, the contract foresees that direct mortality would be studied. As such, sampling with a benthos dredge according to a BACI scheme must be carried out. Because such an experiment requires that several days are spent at sea, it was decided (similar to the previous reporting period) to use the time at sea to expand the experiment so more information could be collected that can be used to validate the models developed in the generic work packages.

The following extra tasks were scheduled:

- SPI (sediment profile + fishing gradient)
- Resuspension with sediment sledge
- Penetration depth with laser
- Multibeam for alien fish tracks + penetration depth
- Catch comparison
- Injuries (IIM)
- Stomach content (scavenging)
- Box corer (depth distribution, traits)
- Gear characteristics for model on physical impact

Clearly significant results

1 publication, 4 submitted.

Deviations

None.

Failing to achieve objectives

None.

Use of resources

No exceptional deviations

Innovative management scenario’s (Task 7.2.4)

Summary of progress

This task is being carried out. Coordination with WP5 and WP6 has taken place during the project coordination meeting and a follow-up Skype meeting early 2015. Relevant management scenarios have been selected and are being explored.

Deviations

None.

Failing to achieve objectives

None.

Use of resources

No deviations.

Effect of bottom trawling on the food for flatfish (Task 7.2.5)

Summary of progress

This task has been carried out, has been published and has been integrated in an IMARES PhD work.

Clearly significant results

Publications.

Deviations

None.

Failing to achieve objectives

None.

Use of resources

No deviations.

Summary report of the sea trips

Flatfish fisheries in the North Sea

Background and methodology

During the BENTHIS field trials carried out in June 2013 and June 2014 the effects of trawl gear (specifically beam trawl and pulse trawl) on the seabed and benthic organisms were assessed using a BACI-design experiment. As the impacts of trawl gear can be expected to be context-dependent and variable depending on the natural characteristics of the habits, two sites of contrasting characteristics were selected for the two years of trials. In 2013 the research was carried out in the northern part of the Dutch Voordelta (southern North Sea coastal zone area, 15–22 m depth, sandy habitat). In 2014 the trials were carried out on the Frisian front in the proposed Natura 2000 area. In both experimental areas, fishing disturbance was considered to be low (according to VMS data) so interference with the experiment was minimalized.

Within the experimental areas, 3 sub-areas (each 150 m x 1000 m, Figure 12) were established for the BACI experiment: 1) a pulse trawl area; 2) a beam trawl area; 3) a reference area. The pulse and beam trawl areas of the BACI experiment were trawled for one day aiming to achieve complete trawl coverage of the areas. The nets were hauled for sampling of the catch (injury assessment of fish, by-catch estimates). Before and after trawling, all 3 sub-areas were sampled with a multibeam, a sediment profile imaging (SPI) camera and a benthic sledge. Boxcore sampling was carried out after trawling.

In 2013 six hauls were carried out with the pulse trawl (SCH18) on 15 June 2013 (7h25–15h20) with a mean towing speed of 4.4 (SD = 0.8) knots. The swept area trawled in the pulse site was 0.361 km^2 resulting in a fishing intensity of 240% (=0.361/0.149 km^2) or 40 trawl passages. Nine hauls were conducted in the tickler site (RV Isis) on 18 June 2013 (10h47–17h37) with a mean towing speed of 4.2 (SD = 1.0) knots. The swept area was 0.205km^2 which gave a fishing intensity of 140% (=0.205/0.151 km^2) or 25 gear passages. Note therefore that the intensity of tickler disturbance was <60% of the pulse disturbance, looking either at swept area or at the number of gear passages.

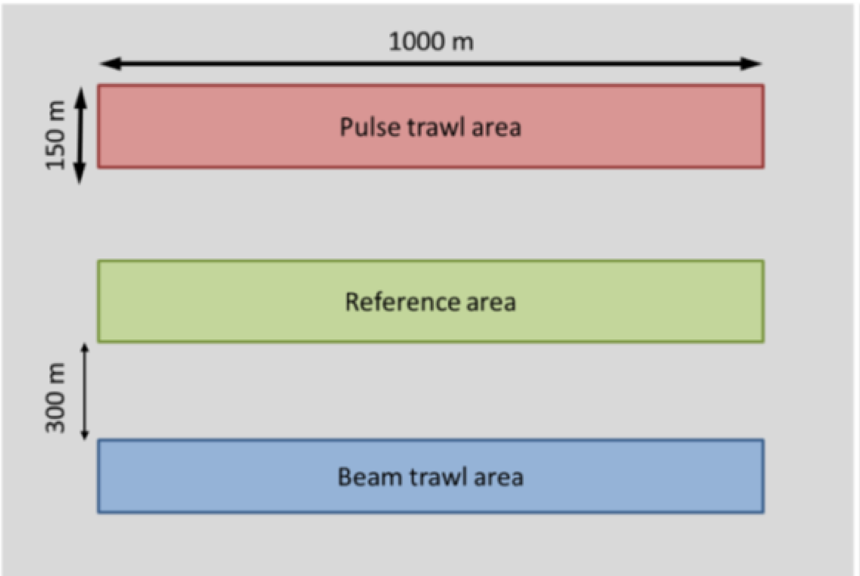


Figure 12. Diagram of experimental setup and area dimensions

In 2014 TX29 (tickler) and TX43 (pulse) were both fished in the same way. A total of 13 passages across the area were conducted. Each vessel towed two beam trawls of 12m wide (24 m wide for each passage). The width of the area was 150m, or thus 24 * 13 (312 m) for trawling. The total fishing intensity was 200% for each of the experimental areas. An approximate surface of 624,000 m² (or 0.624 km²) was fished (in an area of 300,000 m² (0.3 km²)).

Details of the full methodology and approach of 2013 can be found in Teal et al. (2014) and Depestele et al. (2015). Full methodology of 2014 is pending publication.

Preliminary results

Physical impacts

Multibeam data (2013 data only, 2014 data still pending)

The experimental sites were monitored with a Kongsberg EM2040 MBES mounted on the Research Vessel Simon Stevin, which has a very high precision (Degrendele and Roche, 2013) and the relative centimetre accuracy of this acoustic system is a perfect fit with the purpose of this research. Detailed methodology of the 2013 field trials can be found in Depestele et al. (2015) but the most important results are summarized here:

- penetration of the seabed is obvious for both the tickler chain trawl gear and the pulse trawl gear;
- overall the tickler chain gear penetrates deeper into the sediment than the pulse trawl gear;
- trawl marks fade over time, with the pulse trawl marks fading faster.

Figure 13 shows the cumulative probability of occurrence of the range of penetration depths for the two different gears at two time points following trawling. The steeper the curve the less likely deep penetration will occur. It is evident that the pulse trawl shows lower probability of deeper penetration compared to the tickler chain trawl (the curves are steeper and further to the left of the figure). Furthermore there is a clear shifting of the pulse curve to the left over time, showing that the trawl tracks start to fade within a time period of 107 hours. The tickler chain penetrates deeper into the sediment showing maximum penetration to be around 10-12 cm. There is no evidence for the tickler chain tracks fading within 55 hours, however, no measurements were available at 107 hours (comparable to the pulse) and as such the rate of fading cannot be compared between the gears. For more in depth details see Depestele et al. (2015).

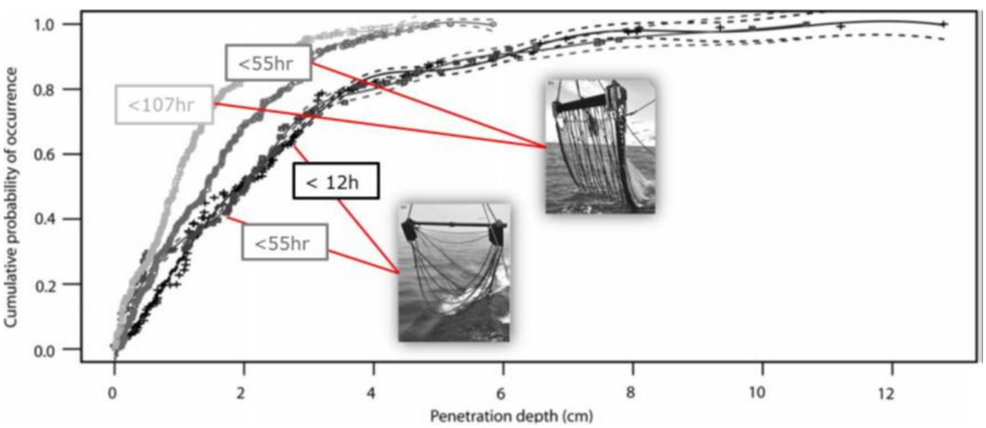


Figure 13. Cumulative distribution functions of alterations to seabed bathymetry measured at 320 kHz after multiple trawling passages: multiple passage of a pulse trawl at two time steps: 55 h after trawling (trt f, open grey circles), 107 after trawling (trt g, open light grey squares). Trawl marks fade over time. The dark grey squares CDF (trt e) can directly be compared with pulse trawling and indicates higher probabilities of higher alterations to seabed bathymetry. The black crosses CDF (trt d) illustrates the alterations to seabed bathymetry at 12 h. Dashed lines indicate the lower and upper limits of 95 % confidence intervals.

Sediment resuspension (2013 data only, not carried out in 2014)

Pulse beam trawl sediment re-suspension work was carried out on board the commercial fishing vessel Boeier (SCH18) on 14th of June, and for the conventional beam trawl on the research vessel ISIS on 19th June. Overall fourteen tows were conducted during the re-suspension experiments. Pulse or conventional beam trawls were in place for six of these each and there were two control tows without any beam trawl present. The data obtained from the instruments has been cropped so that only the sections one minute after the start to one minute before the finish of each haul is utilized. This is to allow time for the fishing gear/instrumentation to settle down and remove any discrepancies in synchronization between instrument and ship time. Full details of sampling methods can be found in Depestele et al. 2015.

Each beam trawl was sampled at 25, 45 and 65m behind the beam by two tows in opposite directions, with and against the tide. Both mean volume concentrations were added together for each distance and the background concentrations deducted to give the true concentration of sediment mobilized at distance by each beam trawl type (Figure 14, Figure 15, Figure 16). Figure 14 and Figure 15 show how the sediment concentrations decrease with distance from the beam trawls. Figure 15 and Figure 16 indicate the pulse and conventional beam trawls mobilize similar quantities of sediment, but the pulse trawl had higher values for more size bins and the total concentrations at 25 and 45m behind the beam.

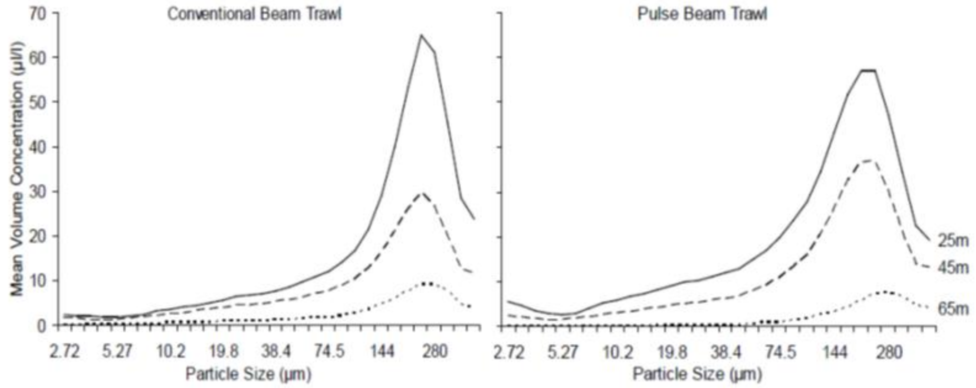


Figure 14. Particle size distributions within sediment plumes at different distances behind the beam.

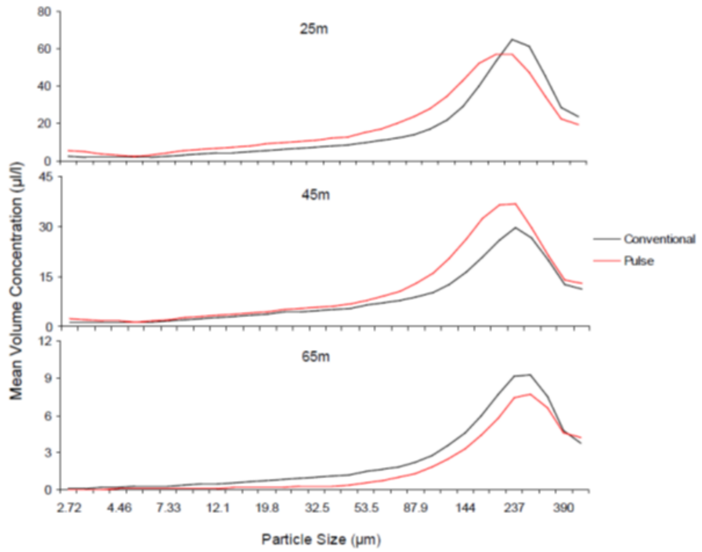


Figure 15. Particle size distributions within sediment plumes at different distances behind the gear.

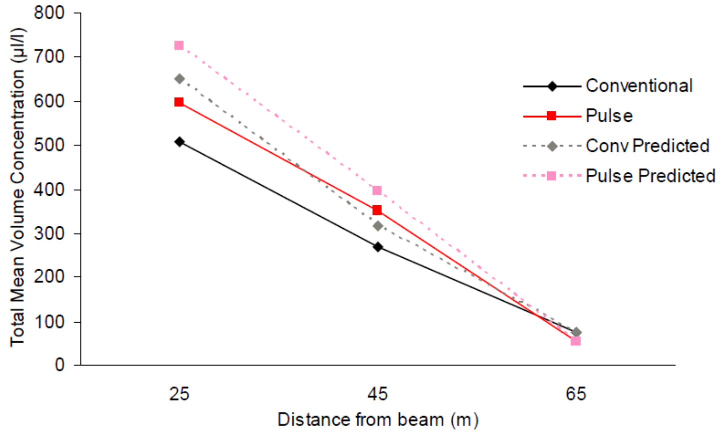


Figure 16. The total mean volume concentration within sediment plumes at different distances behind the beam (dashed lines are predicted by assuming obscured LISST records have a total volume concentration of 780.26 µl/l).

Sediment Profile Imaging (2014 data only)

A sediment profile imaging (SPI) camera (for general principles, see Rhoads and Cande (1971)) was used to obtain in situ images (15 × 21.5 cm = 322.50 cm^2) of the sediment profile. A surface video camera was attached to the SPI frame to record surface images of the seabed, as well as to track the camera in real-time and check the expected quality of each deployment. The camera was deployed in each experimental area before and immediately after (within 2 hours) and 24 hours after trawling impact (T0, T1, T2). Within each area and at each time-point (T0, T1, T2), the camera was dropped at 10 locations and two photos (~5 m apart) were taken (n = 20 per area per time).

The sediment profile generally shows a change in sediment colour with depth. This colour change can be directly related to the biogeochemistry (ecosystem function) of the sediment (for details see Teal et al. (2009; 2010) and references therein). Lighter (reddish-brown) sediment indicates an oxidised environment, which overlies darker (grey-black) sediment indicating a reduced environment. Biogeochemical cycling rates are much higher in the oxidised part of the sediment and it can therefore be said that where this lighter sediment (known hereafter as the mixed layer) extends deeper into the profile the sediment function in terms of nutrient recycling back into the water column is higher than in areas with a very shallow mixed layer (Teal et al., 2010).

In soft sediment environments, the depth of the sediment mixed layer is strongly related to the biological community and the amount of bioturbation. Large burrowing infauna draws oxygen deep into the sediment leading to a deeper mixed layer. However other factors such as sediment type and season (e.g. amount of carbon reaching the seabed from plankton blooms) also play a role. It has been estimated that the global average depth of the mixed layer is 9.8 cm (Teal et al., 2008).

The main conclusions drawn from the SPI sampling of the experimental areas are:

- in T0 the mixed depth appears shallower (~3 cm, pending some image analysis) compared to the global average and indicates a biological community lacking large bioturbation;
- beam trawl area: In T1 (immediately after trawling) a thick layer (~3 cm, pending accurate data form image analysis) of what appears to be loose sediment appears on the sediment surface (Figure 17). The mixed layer is still visible beneath this loose layer. In T2 the loose layer has all but disappeared but the mixed layer appears to be shallower than during T0, likely caused by an increase in oxygen use;

- pulse trawl area: In T1 (immediately after trawling) on some of the images a layer of loose sediment appears which is less compared to the beam trawl area (~1 cm, pending accurate data form image analysis). The mixed layer is still visible beneath this loose layer (Figure 17). In T2 the loose layer has all but disappeared and there is no consistent decrease in the depth of the mixed layer across the images.

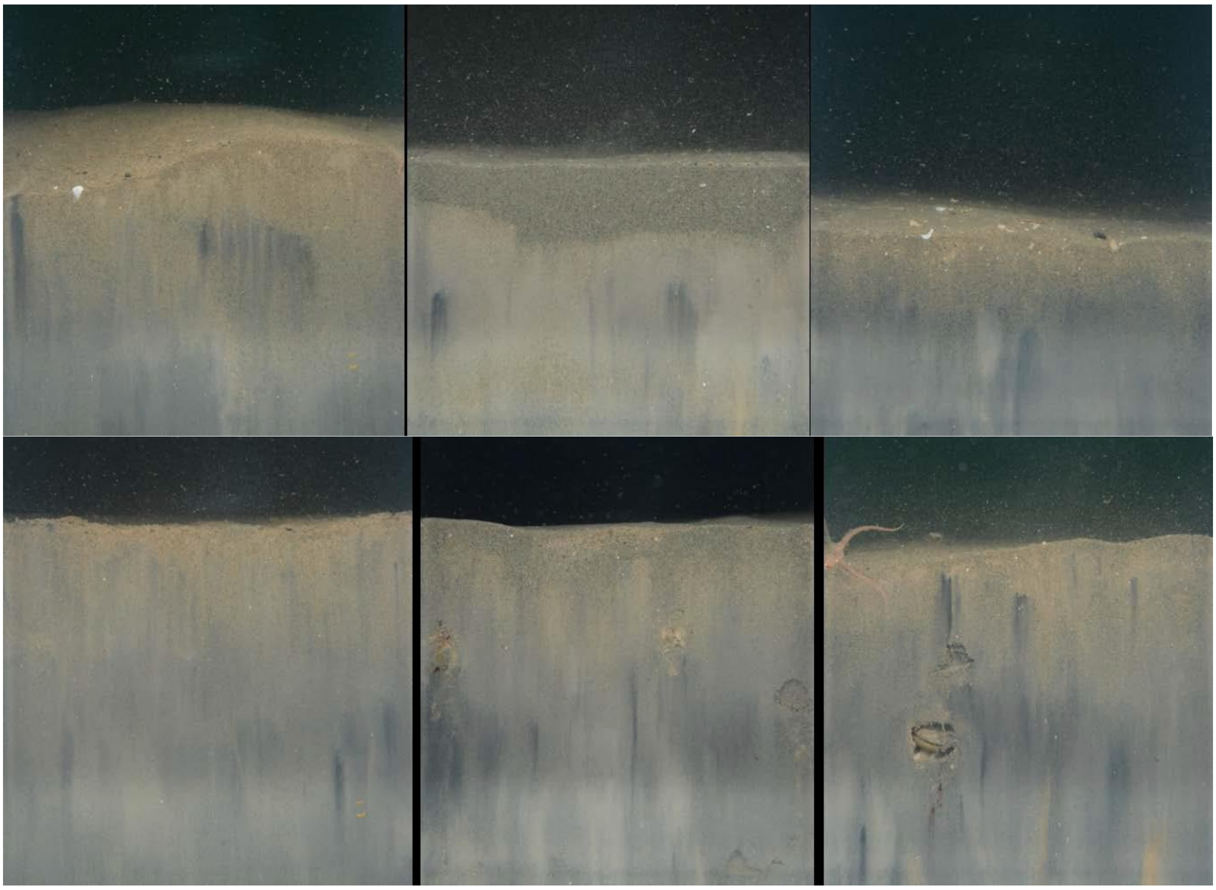


Figure 17. SPI images from the beam trawl area (top row) and the pulse trawl area (bottom row) during T0 (left), T1 (middle) and T2 (right).

Biological impacts

Benthic sledge data (2013 and 2014 data)

In both 2013 and 2014 a benthic sledge (mesh size = 5 mm) was used to sample the benthic fauna found on and within the top 10 cm of the sediment. The sampling was carried out at an angle across each of the three sub-areas in both T0 and T1. The T0 and T1 sampling was carried out perpendicular to each so as to avoid resampling the same strip of sediment. The samples were sorted and identified on-board. Both abundances and biomass were recorded.

The main conclusions drawn from the benthic sledge data can be summarised as follows:

- Trawl path mortality is difficult to detect which may be due to:
    a) Relative high abundance of resistant species. Abundance of vulnerable species found was significantly lower. The community may already be adapted to trawling.
    b) Low power of sampling design: High variability in benthic data requires many more samples.

Figure 18 shows the abundances (log-transformed due to the spread in the data) of overall densities of benthic fauna before and after trawling in the three sub-areas in the Voordelta (2013 results). For a clear conclusion to be drawn on mortality caused by the two trawl gears, the patterns observed in the reference area (b) should be different to those in the tickler area (a) and pulse area (c).

Despite potential declines in both the tickler and pulse area, no clear pattern is evident however. Statistically abundances were shown to be lower overall in T1 compared to T0 but no distinctions could be made in this pattern across the different areas and as such it could not be definitely attributed to trawling effects. Figure 8 shows the same as Figure 4 for the Frisian front (2014 results). Again no clear patterns of mortality could be observed for the trawl areas in comparison to the reference area. The absence of significant effects of trawling may be related to the type of species caught and their susceptibility to trawling effects. All species were therefore categorised into either “resistant”, “intermediate” or “susceptible” to trawling and the same analysis was performed at this grouped level. The grouping of species into the different groups followed the methodology of Bolam et al. (2015) using different species traits as a basis for their vulnerability to fishing. In this case only traits affecting the acute vulnerability of the species were taken into account as the experiment does not deal with long term vulnerability.

Figure 19 shows the log-transformed abundances from the 2013 trial in the Voordelta split into the three categories: resistant, intermediate and vulnerable to trawling. It is clear the community is dominated by species resistant to or with intermediate sensitivity to trawling; the abundances of vulnerable species are significantly lower overall. The same is observed at the Frisian front (Figure 20). Based on this finding it can be said that although currently these areas do not show high trawling impacts (based on VMS data, pers. comm. Niels Hintzen), the communities sampled appear to already be adapted to trawling effects based on the long history of trawling in these areas. This may explain in part why it is difficult to detect mortality in the trawl paths as most species encountered are fairly robust.

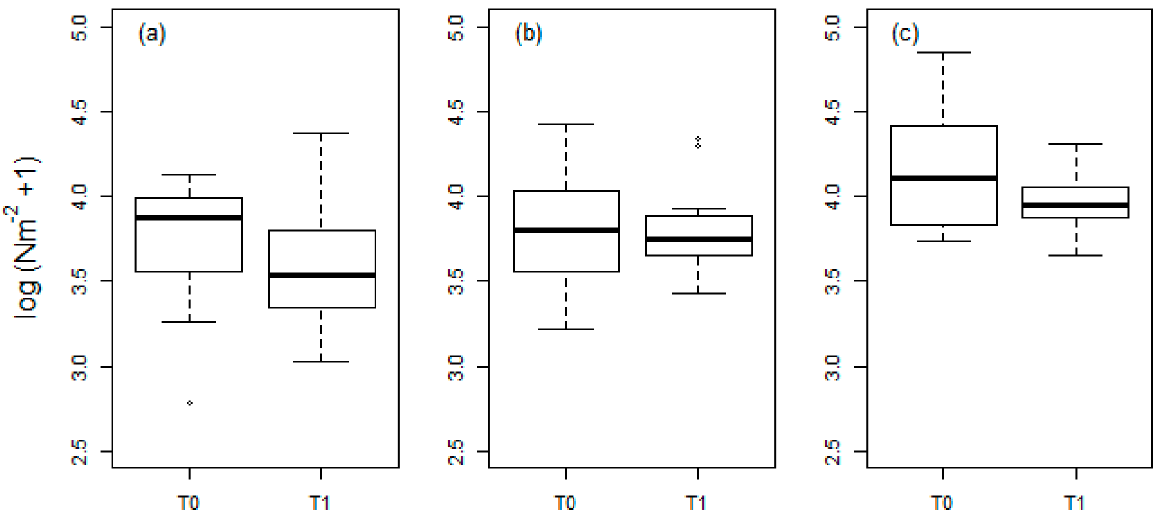


Figure 18. Boxplots (showing the median (thick line), upper and lower quantiles (edge of boxes) and the min and max, excluding the outliers (dots)) of log-transformed densities of all benthic species combined. Data from the Voordelta (2013) in subareas (a) tickler chain, (b) reference and (c) pulse trawl.

Another reason for the inability to identify clear trawling effects may be related to the high variability encountered in the benthic samples. Benthic communities are notoriously patchy within the environment and even on a small spatial scale the variability between the samples can be high. Due to this variability sampling effort was maximised but can still be considered low.

A post-hoc power analysis was performed on the data (currently only the 2014 data) to identify the statistical power of the dataset in showing differences (Table 3). The power analysis revealed a higher chance of detecting an effect in the tickler chain area versus the reference area as opposed to in the pulse area versus the reference area. This is some indication that the chances of detecting significant mortality (given higher sampling effort) in the tickler area is higher than that in the pulse area. The chances of detecting differences in the intermediate sensitivity group is also higher compared to the resistant group. The probability of detecting change in the vulnerable group is low, but this can be related to the very low numbers of vulnerable species caught.

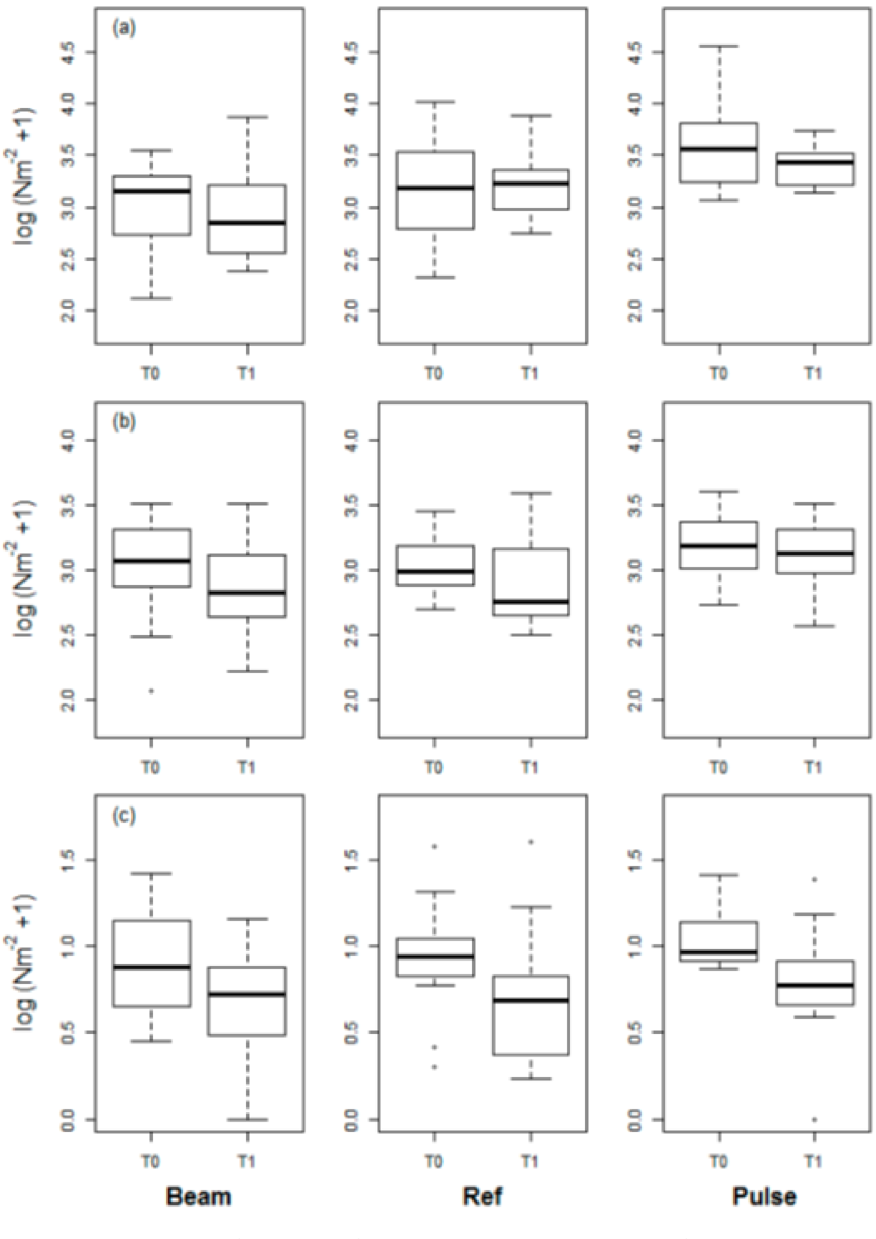


Figure 19. Boxplot of log-transformed summed densities of all species categorised as (a) resistant, (b) intermediate and (c) susceptible to trawling before (T0) and after (T1) experimental trawling in the three treatment areas. Data from the Frisian front trials (2013).

Table 3. Output of power analysis on 2014 benthic sledge data. Numbers show the probability of detecting a change in abundance at the significance level of 0.05, given the current experimental setup and assuming the real effect or data distribution follows the output of the statistical model applied.

Response	Group	Interaction all	Tickler – ref	Pulse – Ref	Tickler - Pulse
Abundance	All	0.91	0.96	0.23	0.64
	Resistant	0.61	0.70	0.11	0.41
	Intermediate	0.95	0.98	0.37	0.67
	Sensitive	0.38	0.42	0.06	0.34

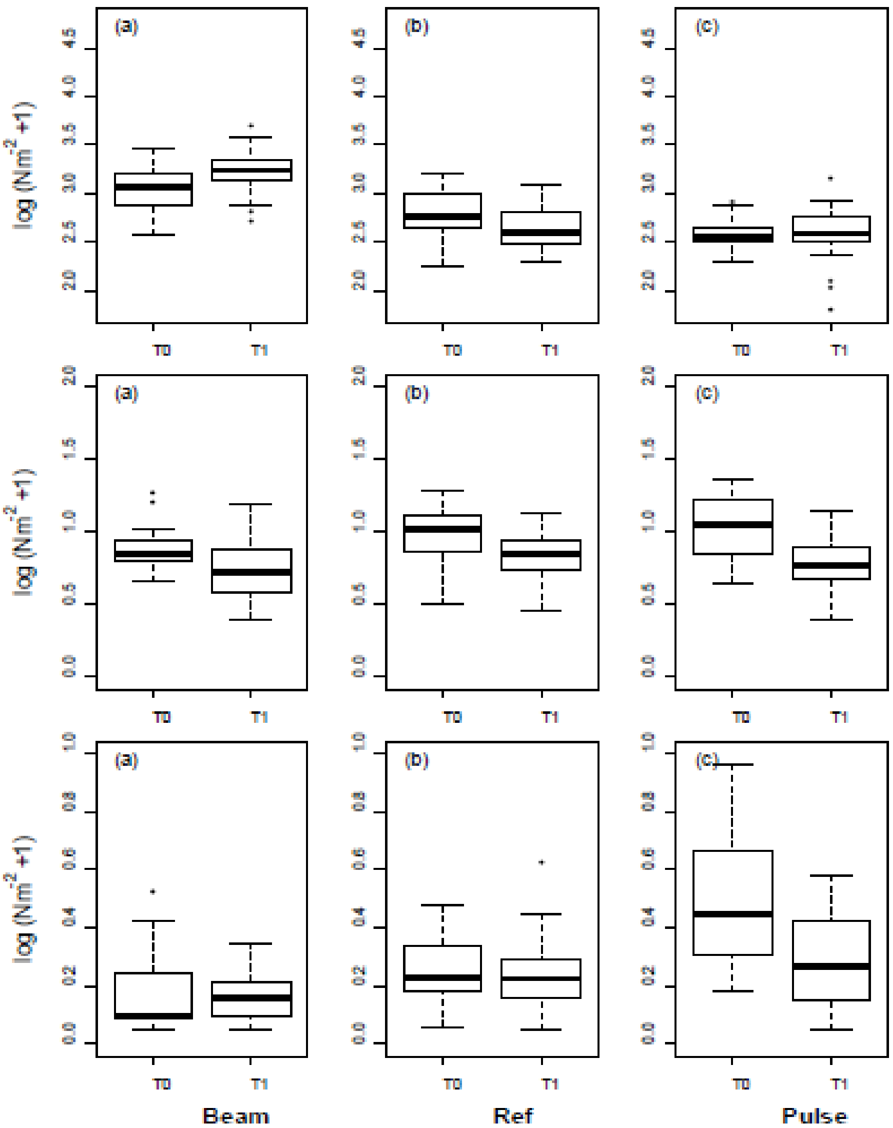


Figure 20. Boxplot of log-transformed summed densities of all species categorised as (a) resistant, (b) intermediate and (c) susceptible to trawling before (T0) and after (T1) experimental trawling in the three treatment areas. Data from the Frisian front trials (2014).

By-catch benthos (2013 and 2014 data)

During the trawling of the experimental areas the catch was collected and sampled for various purposes. The by-catch of benthos within the hauls could also be assessed. The benthos was identified and abundances estimated per area. Note that the number of hauls sampled is very low:

- 2013 beam = 4 / pulse = 3
- 2014 beam = 2 / pulse = 2

Despite the low sample numbers the main conclusion drawn from the benthos discards is that the pulse trawl causes considerably less benthos discards. Figure 21 and Figure 22 illustrate this for the 2013 field trials in the Voordelta. Due to the large numbers of *Ophiura* caught (Figure 21), which masks the data for the other species, the data was log-transformed (Figure 22). Note also that in 2013 a relatively light tickler trawl was used (1065 kg) compared to a relatively heavy pulse trawl (2500 kg). Figure 23 shows the untransformed data for the 2014 trials at the Frisian front. All figure give a clear picture of lower benthic discards in the pulse trawl.

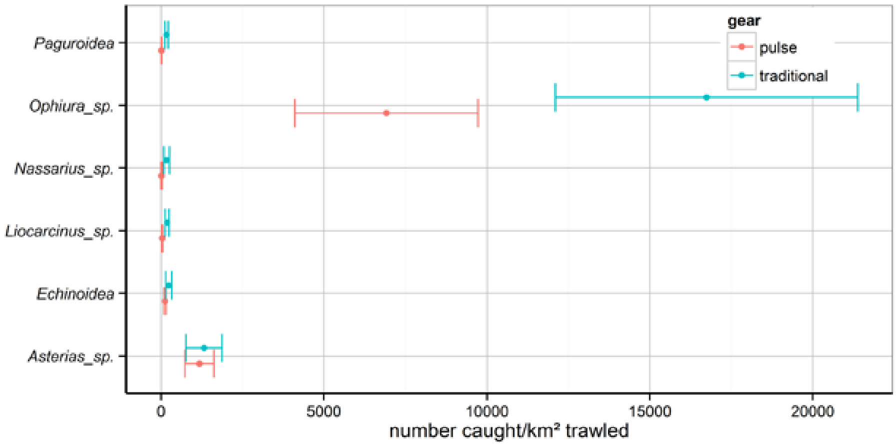


Figure 21. Quantity of discarded benthos (in nrs per area trawled) for the pulse and traditional tickler trawl in the Voordelta (June 2013).

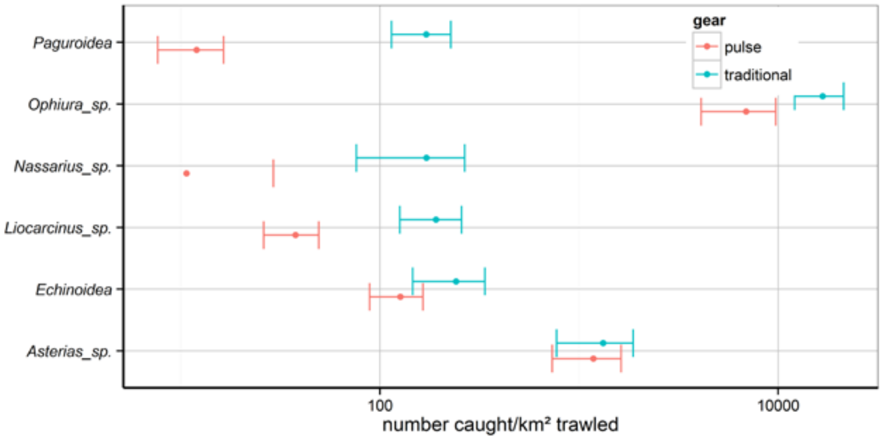


Figure 22. Quantity of discarded benthos (log-transformed numbers per area trawled) for the pulse and traditional tickler trawl in the Voordelta (June 2013).

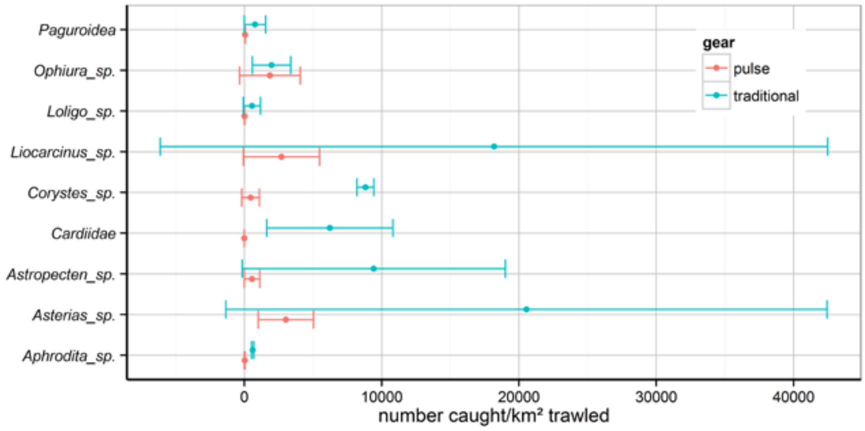


Figure 23. Quantity of discarded benthos (in nrs per area trawled) for the pulse and traditional tickler trawl at the Frisian Front (June 2014).

Shrimp fisheries in the Wadden Sea

In this study we focus on quantifying direct short term effects on the benthic community of experimentally enforced fishing pressure by a shrimp trawl in areas that have been fished for decades. We carried out experiments in the Dutch coastal zone and in the Dutch Wadden Sea in shallow areas. Benthic fauna development was compared between experimentally fished areas and control plots using a trait based approach that classifies species by life-history strategies and their relative sensitivity to bottom disturbance (Bolam and Eggleton, 2014). This latter approach studies the response of individual species, but focusses on the form and function of animals in the ecosystem.

The study consisted of two different experiments each with a different aim:

1) direct short term effects were measured in plots divided over the entire area to include the natural variation in substrate and water depth characteristic for the area. Samples size was optimised in such a way that detectable effects could be measured based on a power analysis using data in similar areas. In 15 plots varying in position, depth and substrate fishing pressure consisted of one passage by a shrimp trawl.

2) the response to varying fishing pressure was measured in one area in the western Wadden Sea both at short term (weeks) and a slightly longer term (months). We exposed different plots to different fishing pressures varying between 1 and 4 times. In both experiments benthos parameters were measured in mid-summer using a bottom dredge a few days before (T0) and two weeks after experimental fishing (T1), and in the second experiment also at a longer term after the first winter (T2).

The first experiment was severely hampered by unplanned fishing in 14 out of 15 plots, thereby changing the fishing pressure from the controlled experiment to a range of different fishing pressures both in the experimentally fished plots and in the control plots. This reduced the possibilities for analyses greatly; therefore we resorted to a correlative analysis of the benthos community in relation to the real experienced fishing pressure. The second experiment was not primarily set up as a statistically sound experiment but was rather intended to study the dose-effect relation between fishing pressure and benthic fauna. Our hypothesis in both experiments is that 1) primarily long-lived, large sized, suspension or deposit-feeding, non-free living, shallow buried, non-swimming species would be affected by the shrimp trawl and that 2) repeated fishing events have a stronger effect than a single passage of the net and 3) short term effects are stronger than long term effects.

Study area

The study area was situated in the shallow shelf sea (maximum depth 25 m) along the Dutch coast and in the Dutch Wadden Sea (Figure 24). For experiment 1 15 plots were divided divided over 6 areas named after their closest geographical reference: Ameland (A1, A2, A3), Schiermonnikoog (S1, S2, S3), Terschelling (T1, T2), Wadden Sea (WA1, WA2, WA3), Petten (P1, P2, P3), Vlakte van de Raan (VR1, VR2, VR3). Every plot consisted of two equally sized (300m x 500m) parts, of which one was experimentally fished and the other served as a control. For experiment 2 one area within the western Wadden Sea (Molenrak) was used measuring 500x1500 m in total and subdivided in 5 plots, with each a specific trawling intensity varying between 1 and 6 times with one control plot.

Benthic sampling

For experiment 1 in every plot five parallel dredge samples were taken of each ca 150 m length at T0 (June/July 2012) and T1 (August/September 2012, Figure 24). For experiment 2 in every plot five parallel samples were taken at T0 (July 2012), T1 (September 2012) and T2 (March 2013). Stations were sampled with a trawled dredge over a distance of 150 m, a width of 0.1 m and a depth of 7 cm, resulting in a total sampled surface of ca 15 m^2.

To make sure the dredge kept on the bottom the fishing line was kept at 3.5 times the water depth. Fished distance was determined using an electronic counter connected to a measuring wheel running over the seafloor. Total distance covered was calculated in number of rotations of the wheel, each measuring 1.5 meter. All samples were sieved through a 5 mm sieve, sorted and counted. All live organisms (except for fish, shrimp, worms and urchin) were taken from the catch. Subsampling took place in case of large quantities. Subsamples consisted of at least 25 individuals. Numbers and fresh weight per species were determined for each sample. Weighing was done using a Marel M2000 series balance. Broken shells were included in the total number if either the ligament and flesh remains or the siphon was present. All intact shellfish were weighed.

Numbers of crabs, brittle star and starfish were determined based on respectively the number of carapaces, the number of disks and the number of arms (1 arm = 0.2 individual). Fresh weight of damaged animals was determined based on the mean weight of intact animals of the same size. Ash-free dry weight (AFDW) was determined from the fresh weight using conversion factors. In the density calculations the efficiency of the different sampling gears was included. Based on 400 stations, sampled both with a box-corer and a trawled dredge in 2004 and 2005 (unpublished data IMARES and Netherlands Institute of Ecology) we estimated the efficiency of the trawled dredge to be 50%.

Trait classification

Ten different traits were selected that are considered important in determining a taxon's sensitivity to trawling (Bolam et al., 2014). Trait information (Table 1) was obtained for all 79 macrobenthic taxa recorded, at genus level or higher taxonomic grouping (e.g. Bryozoa). Biomass per trait modality was calculated as described in (Bolam et al., 2013). Each trait considered was subdivided into multiple modalities. These were summed by modality to produce a biomass-weighted trait modality table for all sampling sites.

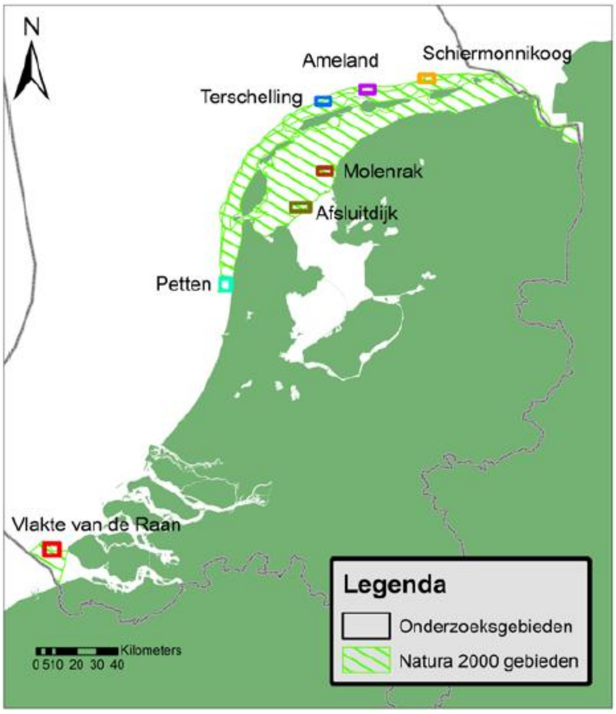


Figure 24. The study area.

Experimental trawling

For the experiments we used a commercial shrimp fishing vessel to carry out the experimental treatment. Hauls were made in such a manner that every square meter of the total surface of 300x500 m was touched by the fishing gear. In experiment 1 every plot was fished once, while the paired plot remained unfished, in experiment 2 the fishing pressure was varied: 1x, 2x, 3x and 4x (and one control) within one week. The treatments were divided randomly over the plots.

In the 15 plots of experiment 1 the actual fishing pressure deviated from the intended treatment because of unplanned fishing activity. The actual exerted fishing pressure in the 15 plots trawling intensity was quantified based on the Automated Identification System (AIS) and radar observations, collected by the Dutch Coastguard. Three indicators of fishing behaviour were identified: the ship type, the speed over ground of the ship and the path sailed by the ship.

The passages by three ship types were selected, namely: vessels with AIS and ship type 30 (fishing vessel) in their AIS message, vessels without AIS but seen by the radar and manually identified as a fishing vessel by the operator on shore and finally vessels without AIS only seen by the radar, without any additional information available. From the passages by these vessels, the passages with an average speed over ground of less than four knots were selected for a more detailed analysis.
The passages were merged into scenarios, where a scenario consists of passages of the plot by one ship for which the time between the passages was very short (i.e. 2 hours). These scenarios were reviewed in corporation with a senior fisherman, especially to interpret the path (behaviour) of the vessel. From the passages carried out by fishing vessels that were classified as actually fishing, the distance sailed through the area was determined.

These results in the total distance fished within the plot. These measures give an indication of the impact of the fishing activities in each plot. Most fishing vessels are equipped with AIS. However since AIS is not compulsory and can be switched off, radar observations recorded from the mainland were also used and analysed in a similar way.

Statistical analyses

Experiment 1

Because of the unintended fishing disturbance (Figure 25), the originally planned data analyses of the experiment with a pairwise comparison of experimentally fished and control plots could not be carried out. Instead of all ten samples per plot (both experimentally fished and control combined) actual trawling intensity was determined and the average value per plot was used as an explanatory variable for benthos characteristics. Actual mean distance trawled varied between 500 and 2300 m (Figure 25).

Firstly, spatial differences in trait composition before the experiment started were determined. A Detrended Correspondence Analyses (DCA) was performed with biomass per modality (data not transformed) at T0. Secondly, we analysed the effects of trawling on trait composition for all areas with a Redundance Analysis (RDA) with trawling intensity as explanatory variable and differences in biomass per modality (T0 – T1) as response variable. Significance of the relation was tested by a Monte Carlo permutation test.

Experiment 2

Spatial differences in trait composition before the experiment started were determined. A DCA was performed with biomass per modality (data not transformed) at T0. Thereafter the effects of trawling on trait composition were analysed. This was done with a RDA with trawling intensity as explanatory variable and differences in biomass per modality (T0 – T1) and (T0-T2) as response variable.

Because of spatial differences in trait composition, a Redundancy Analysis (RDA) was used to test the relationship between differences in biomass per modality (T0 minus T1) and plot, as proxy for environmental differences. We then applied partial RDA to measure the amount of variation that can be explained by differences in trawling intensity. Significance of the relation was tested by a Monte Carlo permutation test. Results are available but are only partially written down.

Shrimp fisheries in the southern North Sea

In June 2015 a sea trip dedicated to comparing traditional shrimp beam trawling and shrimp pulse trawling was carried out in the southern North Sea off the Belgian coast. No report is available yet.

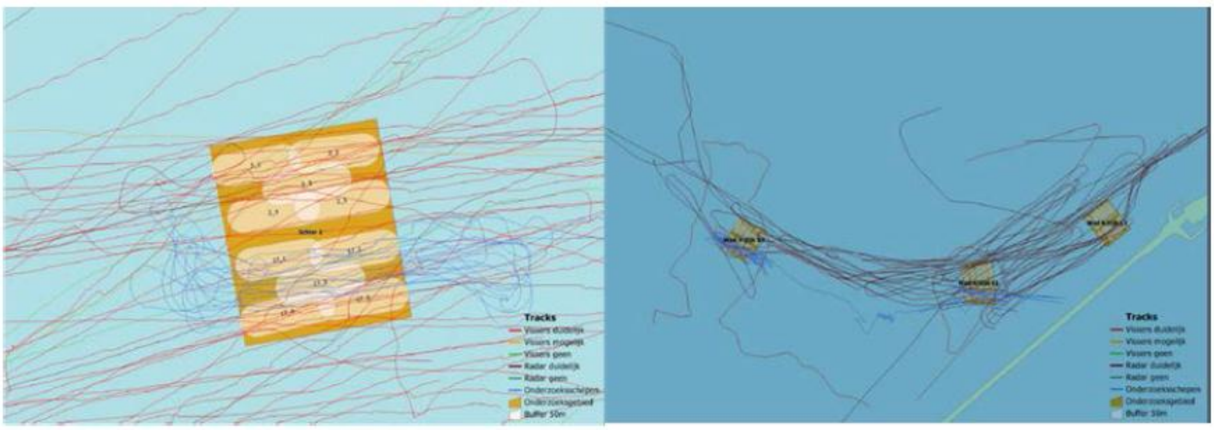


Figure 25. Example of unintended fishing in a plot North of Schiermonniksoog (left) and the Afsluitdijk (right).

WESTERN WATERS

Sub-Case study 1: Hake-Nephrops mixed fisheries in the Bay of Biscay

Benthic community structure under fishing pressure gradients: surveys FEBBE 1 and 2 (2013)

General objectives

Previous studies in the Bay of Biscay have shown that the Grande Vasière (GV) benthic community diversity and size structure appears to follow the classical patterns of trawling impacts described in similar systems: reduction of species richness, loss of sensitive species, increase of small opportunistic species, modifications of size structure of demersal fish population (Blanchard, 2001, Blanchard et al., 2004; Vergnon and Blanchard, 2006; Serrano et al., 2011). Analysis of the long-term evolution of macrobenthic communities in the GV has shown that the patchwork of benthic communities is more homogeneous than the one described 35 years ago (Hily et al., 2008). Those changes could be due to an increase of the fishing pressure during this period but this pressure was still not adequately quantified.

BENTHIS offers opportunity to better analyse benthic community structures and trends under fishing pressure. Specifically acquired biological datasets and newly estimated fishing effort level (Benthis WP2) will ensure to correctly investigate responses of benthic community under fishing pressures gradients. Such results will be helpful to better define strategies in order to reduce unwanted fishing impacts.

The surveys FEBBE 1 & 2 (**F**ishing **E**ffects on bay of **B**iscay **B**enthic **E**cosystem) have been performed in 2013 to better evaluate effects of trawling pressure on benthic community. Sampling strategy has been developed to identify changes in benthic community structure along fishing gradients (Figure 26) as defined from the VMS dataset and utilizing BENTHIS standardized workflow (BENTHIS-WP2). By combining a mix of sampling tools, samples ranging from meio- to megafaunal components have been collected. Data related to sediment structure and hydrological features have been collected as well. The expected final analysis & results aims are:

- to identify fishing pressure signal from macrofauna and megafauna compartments
- to evaluate species and functional (especially trophic linkages through isotopics analysis) changes under fishing pressure gradient and evaluate tresholds
- to establish the impact of those changes to the benthic community functioning

Material and methods

The sampling strategy has been developed to focus on an area with homogeneous habitat typology. It was especially defined from sediment type as described from already existing sediment maps (Bouysse 1985, Figure 26). A total of 21 and 23 stations have been respectively sampled in May and August 2013 (Table 4). Depending on temporal aggregation scale and stations locations, sampled area offers a fishing pressure gradient (swept area in km^2) extending from about 0 km^2 to more than 10 km^2 (Figure 27).

Table 4. Number of collected samples during surveys FEBBE 1 & 2 for each utilized sampling tool and corresponding ecosystem component.

Sampling gear	Number of stations by survey		Observed ecosystem component
	FEBBE 1 (spring)	FEBBE 2 (summer)	
Day-Grab	18 (94 samples)	23 (149 samples)	Epi and endo-benthic meiofauna to macrofauna
Beam trawl	21	23	Epi-macrofauna to megafauna
Otter Trawl	21	17	Epi-megafauna
Plancton net	15	5	plancton
Multi-corer	13	23	Sediment
Niskin	10 (20 samples)	6 (24 samples)	Water

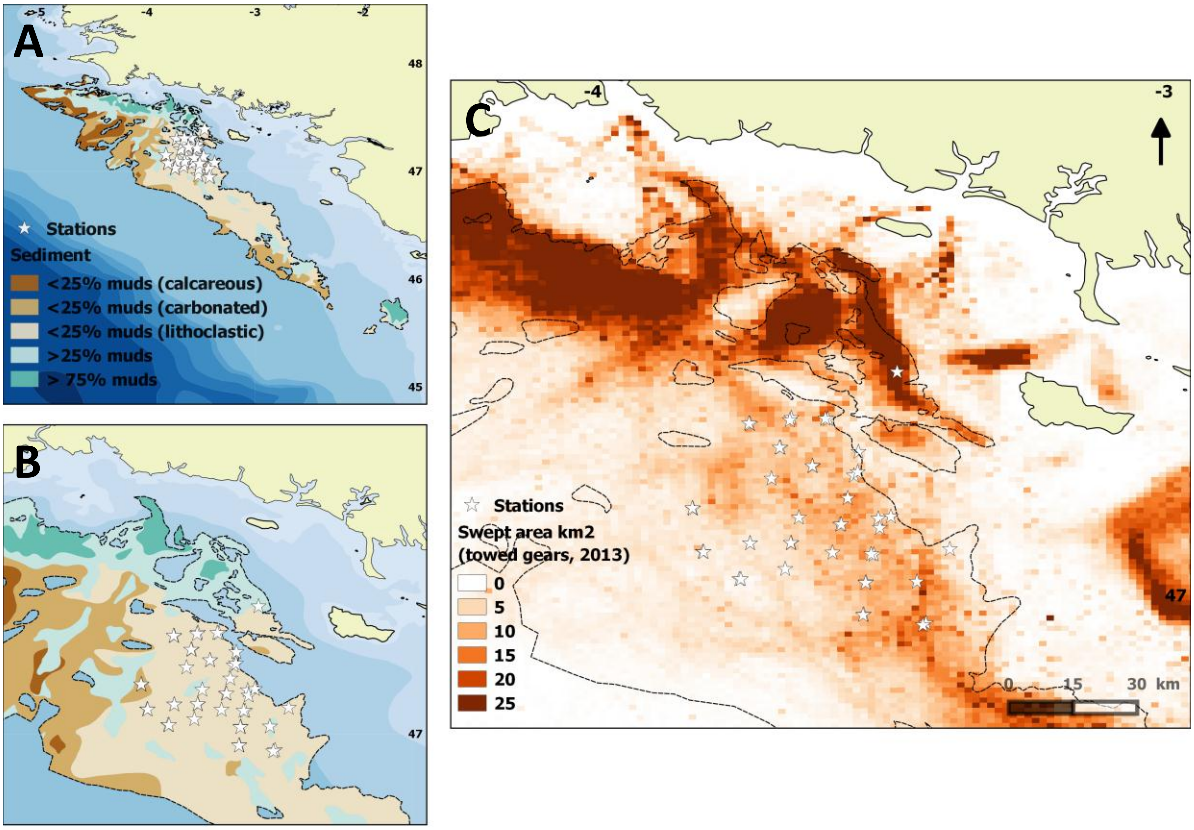


Figure 26. Location of stations sampled during surveys FEBBE 1 & 2. (A) General map showing extent of "Grande Vasière" (GV) area showing sediment characteristics and sampled area, (B) zoom over sampled area with sediment map and (C) same map with fishing effort for towed gears in 2013 (cumulated annual swept area in km^2).

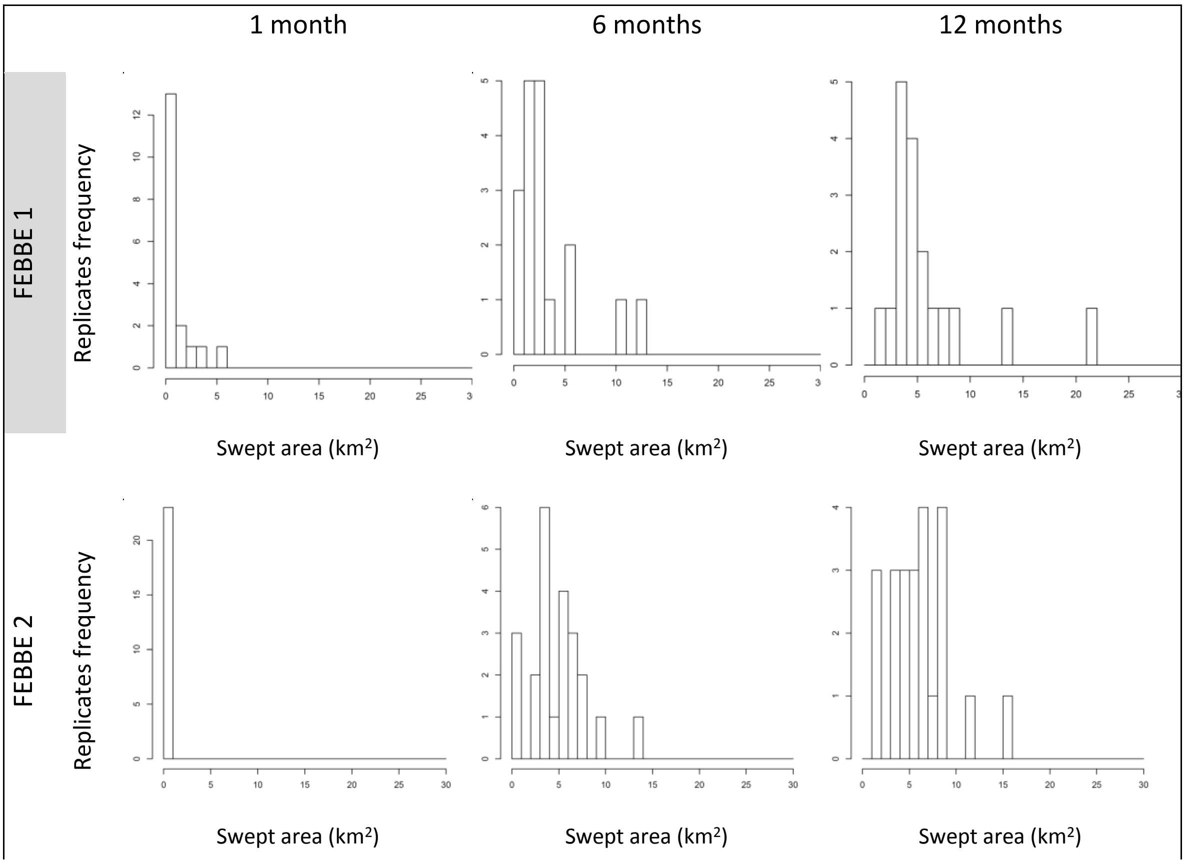


Figure 27. Distribution of fishing effort (towed gears swept area in km^2) for Day-grab replicates of stations sampled during spring (FEBBE 1) and summer (FEBBE 2) surveys. Fishing effort is aggregated at 3 temporal scales from 1 to 12 month from the sampling date.

Preliminary results and further work

A total of 257 distinct macrofauna taxa have been identified from the 2 surveys; 128 species were common between the two seasons. Regarding megafauna, a total of 93 species have been identified from the 2 surveys. Depending on biological compartments (macro or megafauna), and considering equivalent sampling effort, both surveys gave similar species richness (Figure 28). As very preliminary results, species richness displays no relationship with fishing effort level whatever the time scale selected for fishing pressure aggregation (Figure 30).

Further work will be conducted during the BENTHIS project to analyse community structure under a fishing gradient considering ecosystem functions of species. Moreover, to go deeper into benthic community functioning, data will be analysed with a specific focus on the trophic structure as obtained from isotopic qualification of species. Those analyses should help us to evaluate what community response thresholds would be expected under various fishing pressure levels.

Expected results will feed the deliverable 7.10 dealing with "fishing impact on feeding patterns for selected species as indicator of benthic community structure and food webs compared to benthic bio-diversity to establish functional relationships between fish and benthos given fishing intensity". Such results will be essential to quantify what would be the objectives of effort adjustment in order to reduce fishing impact on benthic ecosystem functioning.

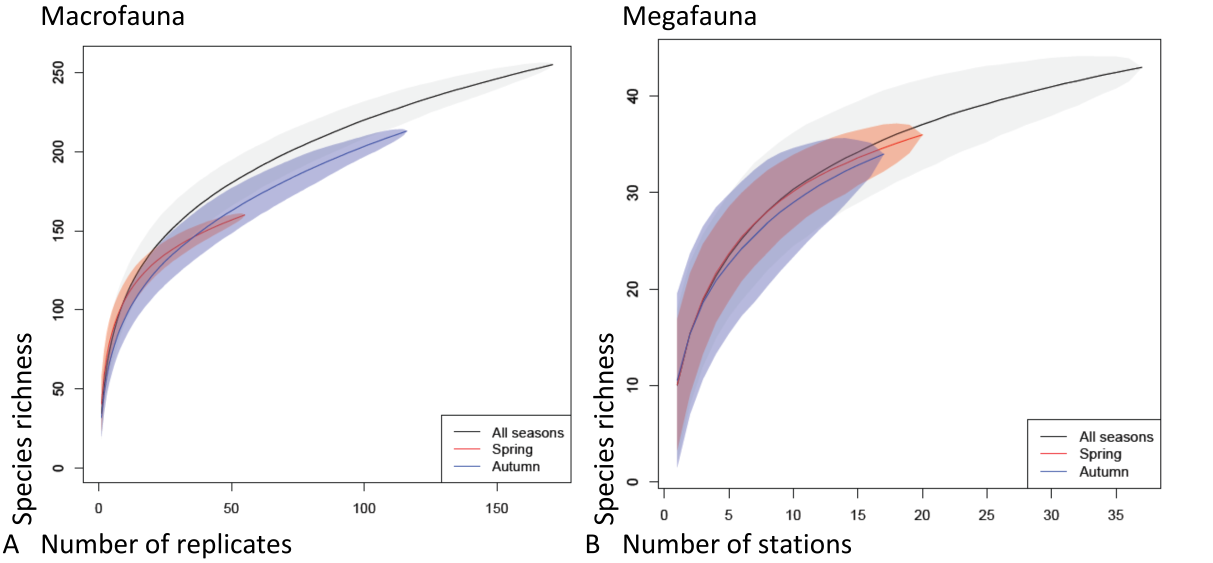


Figure 28. Evaluation of species richness as obtained for both FEBBE surveys, in Spring (FEBBE-1) and Summer (FEBBE-2) for A) macrofauna from grab samples and B) megafauna from trawl samples.

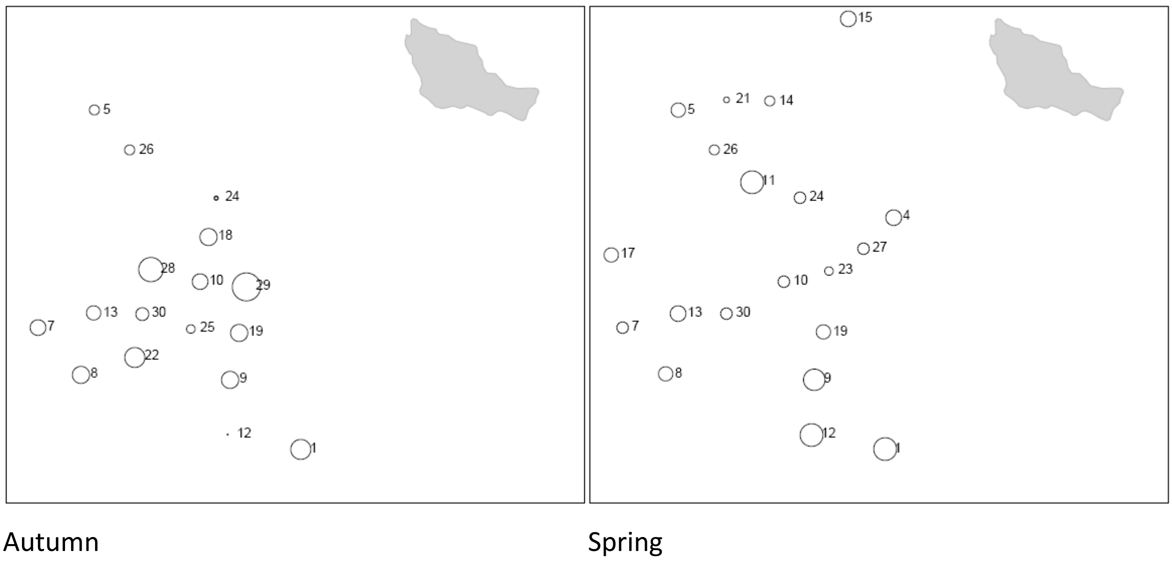


Figure 29. Macrofauna species richness for each sampled stations as obtained from Day-grab for FEBBE surveys in Spring (FEBBE-1) and Summer (FEBBE-2).

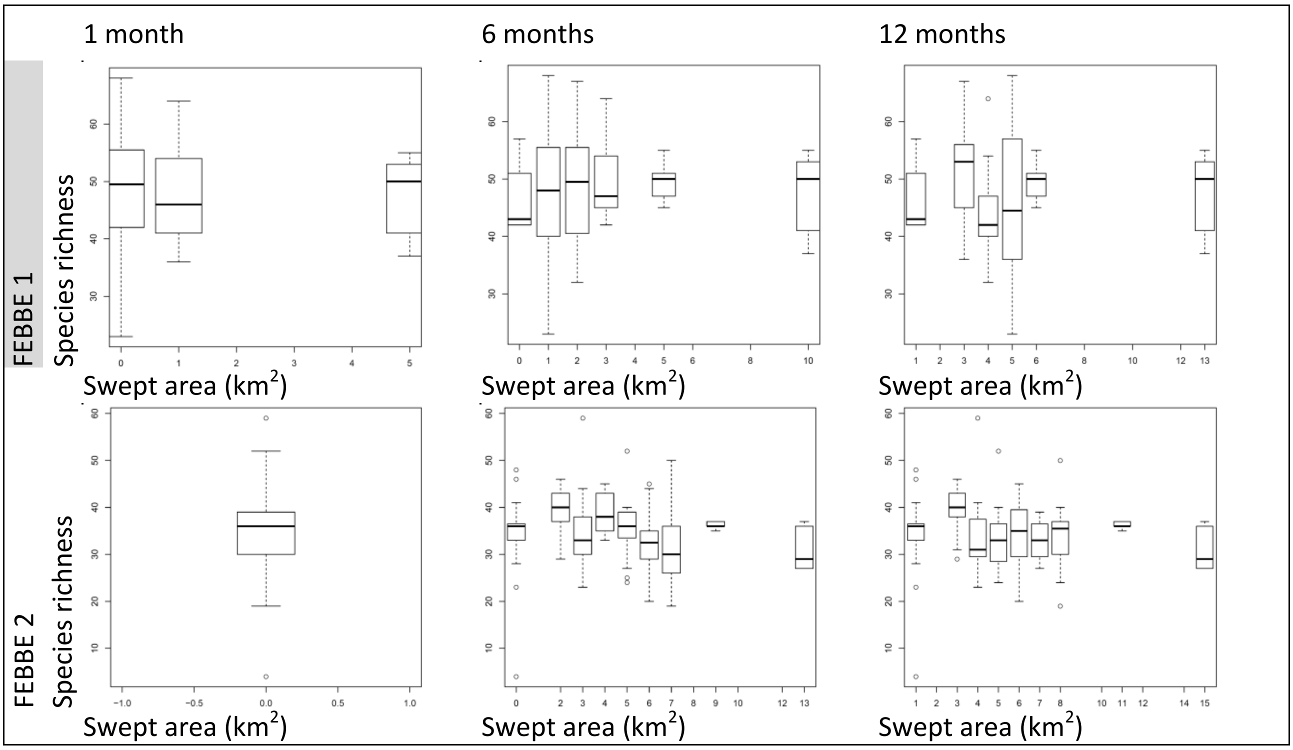


Figure 30. Boxplot of macrofauna species richness for replicates obtained from Day-grab as a function of fishing effort level (total swept area in km^2) aggregated according to 3 time scale (1,6 and 12 months) for FEBBE surveys in Spring (FEBBE-1) and Summer (FEBBE-2).

Fishing impact and alternative "Jumper Gear" tests: surveys FEBBE 3 & 4 (2014)

General objectives

The surveys FEBBE 3 &FEBBE 4 (**F**ishing **E**ffects on bay of **B**iscay **B**enthic **E**cosystem) have been respectively performed in May-June and October 2014 to analyse physical effects of twin Nephrops trawl equipped with current doors ("Thyboron") as compared to alternative "jumper" doors. Surveys have been performed within two muddy areas representative of the Bay of Biscay *Nephrops* fishing grounds. Main objectives and operations realized during both surveys were:

- to run alternative jumper doors operational tests and comparisons with the current gear, and especially to test the utilization of "jumpers" with a *Nephrops* twin trawl that has never been tested before
- to quantify sediment re-suspension processes behind the current and alternative gears.
- to evaluate trawls footprint and modifications of sediment bottom structures due to abrasions effects of the fishing gears

Material and methods

During FEBBE 3 & 4 surveys, two fishing gears have been compared. Both are twin Nephrops trawl but the first one was equipped with current Thyboron doors and the other one with the alternative jumper doors (description of alternative gears is given into BENTHIS deliverable 7.7 and Figure 31). First version of Jumper doors has been developed during the OPTIPECHE project (2007-2010, Ifremer, Region Bretagne). Doors have been modified during the "Jumper project" (2013-2014, CNPMEM, FFP). For the BENTHIS project, that last version of "jumpers" doors were tested (see Figure 31).

Moreover, "Jumpers" were tested for the first time with a Nephrops twin trawl and in operational fishing conditions. Works at sea have been jointly performed by a scientific vessel (R/V Thalia) for the main scientific measurements and sampling (Figure 31: Rosette, day-grab, "Pagure" sledge, corer) and a professional fishing vessel ("Côte d'Ambre", Benthis partner SM09) operating professional trawling gears. Two areas of work (area A and B) have been selected for their contrasting sediment characteristics (Figure 32). Both areas are made of sandy muds with a relative proportion of mud ranging from 25 % in area B up to 75 % in area A. Each one of the tested gears had 4 to 6 experimental hauls, performed in both working areas (A and B, Figure 33 and Figure 34). In order to reach surveys objectives, a combination of sampling devices, both in the water column and on the sea floor, have been utilized to obtain needed measures and samples (Figure 31).

Prior to the sampling process, sonar maps have been produced with a multibeam echo sounder (Klein sonar 3000). Obtained reflectivity maps (Figure 32B, C, D) have been especially helpful to better select observations and sampling stations as compared to the pre-existing trawling footprint. Those sonar maps have also been utilized to analyse and interpret collected data, especially so when analysing the variations of bottom structure under experimental trawl impact as far as we were not able to find any area without pre-existing trawling pressure.

Sediment plumes have been dynamically measured directly behind the F/V trawling path utilizing two types of devices (Figure 35). On the one hand professional gears have been equipped with a "turbidity-line" composed of a series of 3 turbidity meters set along at 20, 40 and 60m behind the attachment point on the fishing gear (Figure 35 A and B). Two attachment points on the fishing gear have been selected: close to the board itself and at the junction part of the two trawls (clump: weight made of chains) of the twin *Nephrops* trawl. On the other hand, the doors themselves were equipped with probes giving high precision measurements of door behaviour (depth, pitch and roll). Another pressure probe, localized on the "fishing line" and giving depth, has been utilized to evaluate board altitude to the bottom (Altitude=$Depth_{board}$-$Depth_{fishinline}$±offset).

Fishing gears and vessels were also equipped with the MARPORT system continuously giving data about gear geometry (especially distance between doors) and door behaviour (depth, pitch and roll). Just behind the F/V trawling path, sediment plume measurements into the water column have been performed with a "rosette" equipped with ADCP, turbidity meter and Niskin bottles (Figure 35B). In order to adequately measure the sediment plume, R/V initial position for rosette deployment was selected outside of the trawling path and downstream from the bottom current (Figure 35B) as obtained from a hydrological 3D model (MARS 3D model, www.previmer.org, Ifremer/Shom/Meteo France). During both survey periods and areas, forecasted bottom currents were rather low with values always below 0.4 $m.s^{-1}$. The "rosette" was deployed near to the bottom (from 1 to 10m from the bottom) and geographic position of the R/V was recorded continously during operations (about 15 to 20 minutes for each measurement sequence). Measurement sequences with the "rosette" have been repeated up to 4 times during each one of the experimental F/V trawling haul.

Both before and after experimental fishing hauls, the "Pagure" sledge equipped with video and laser microtopography system (Figure 36) has been utilized to measure bottom sediment reworking and impact by fishing trawl (bottom abrasion and reworking, penetration depth of different trawl parts). A total of 76 sledge's hauls were undertaken in the two areas and with the two gears (Figure 33, Figure 34 and Table 5). In order to compare effects between current *vs* alternative gear, the positions of the 15 minute sledge's hauls were selected to go diagonally across the experimental fishing gear tracks. In order to get reference measurements, complementary sledge's hauls outside trawling tracks have also been performed.

Others complementary measurements and sampling were also undertaken (Figure 33, Figure 34 and Table 5):

- multi-corers to evaluate sediment characteristics (granulometry, water and organic content) from the bottom surface down to 30 cm penetration.
- day-grab samples to determine benthic community typology.

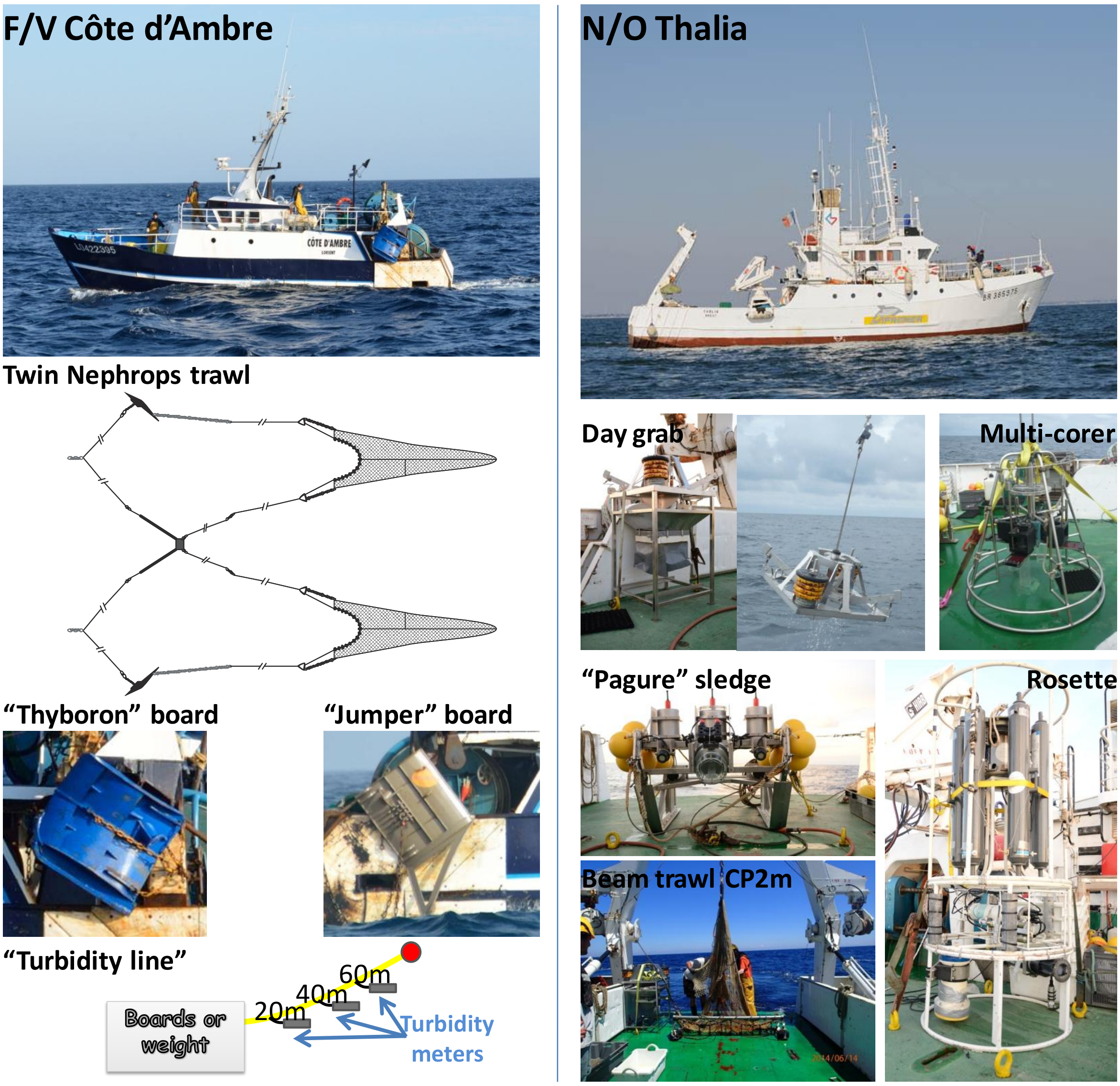


Figure 31. Fishing vessel (F/V) Côte d'Ambre (photo on the left, 16 m overall length, SME09) and research vessel (R/V) Thalia (photo on the right, 24.5 m overall length, Partner SME09) jointly operating during FEBBE-3 and 4 surveys. For each vessel, main utilized devices are shown. On the left side, F/V with the tested twin trawls and the two doors configurations (current "Thyboron" vs alternative "jumper") and "turbidity line". MARPORT system and Probe installed on doors are not figured. On the right side, R/V with day grab, multi corer, "Pagure" laser/video sledge, Rosette and 2m Beam trawl. Klein 3000 multi-beam echo sounder is not figured.

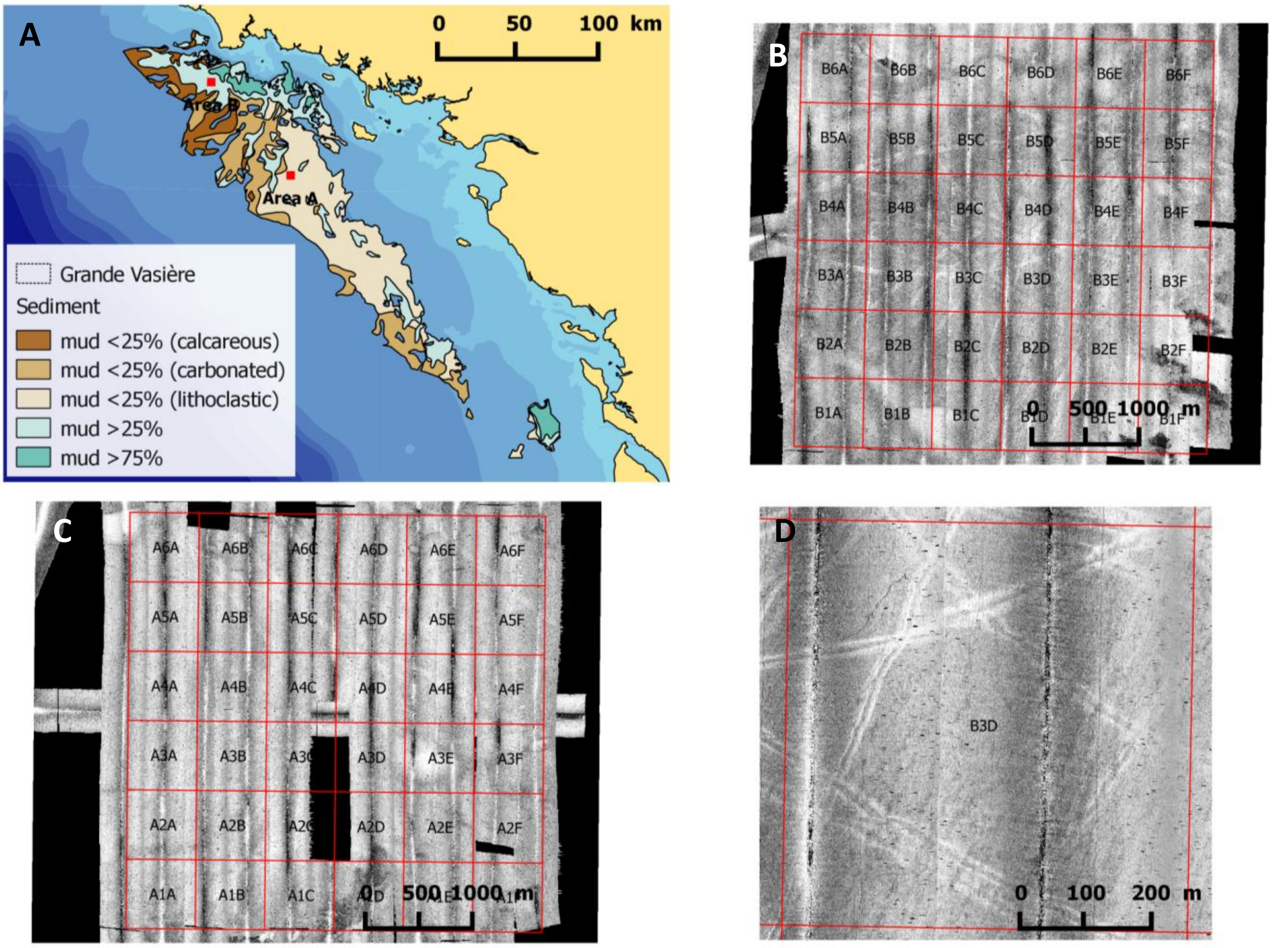


Figure 32. "Grande Vasière" delimitation map (A) showing main sediment features (map derived from Bouysse et al. 1985) and working areas A and B (red squares) during FEBBE-3 & 4 surveys. Reference grids in muddy sands habitats and reflectivity maps before experimental trawling as obtained with "Klein sonar" during FEBBE-3 for (B) Area B in central GV (proportion of mud >75%) and (C) Area A in northern GV (proportion of mud > 25%). (D) Zoom into area B (grid sector B3D).

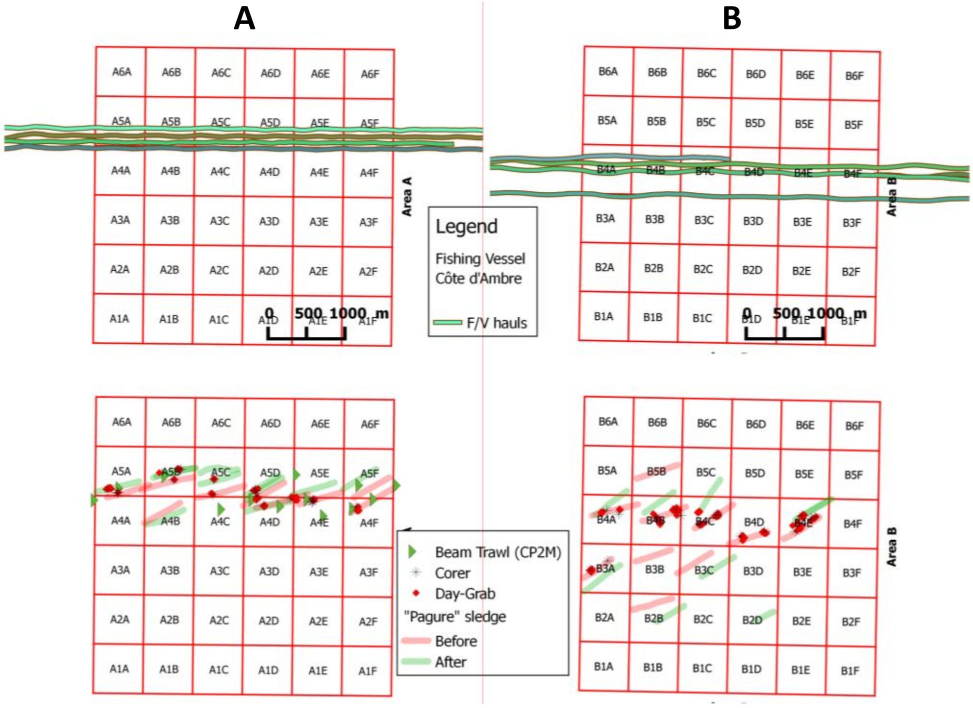


Figure 33. Operations realized during FEBBE-3 sea trials dedicated to impacts evaluation of current fishing gear (twin Nephrops trawl with Thyboron type doors) in A) area A in northern GV (proportion of mud >25 %) and B) area B in central GV (proportion of mud >75 %). For both areas, locations of hauls realized with professional fishing vessel (F/V côted' Ambre, upper maps) as well as sediment and biological sampling (corer, Day-grab and beam trawl) and video/microtopography records ("Pagure" sledge) (lower maps) are indicated.

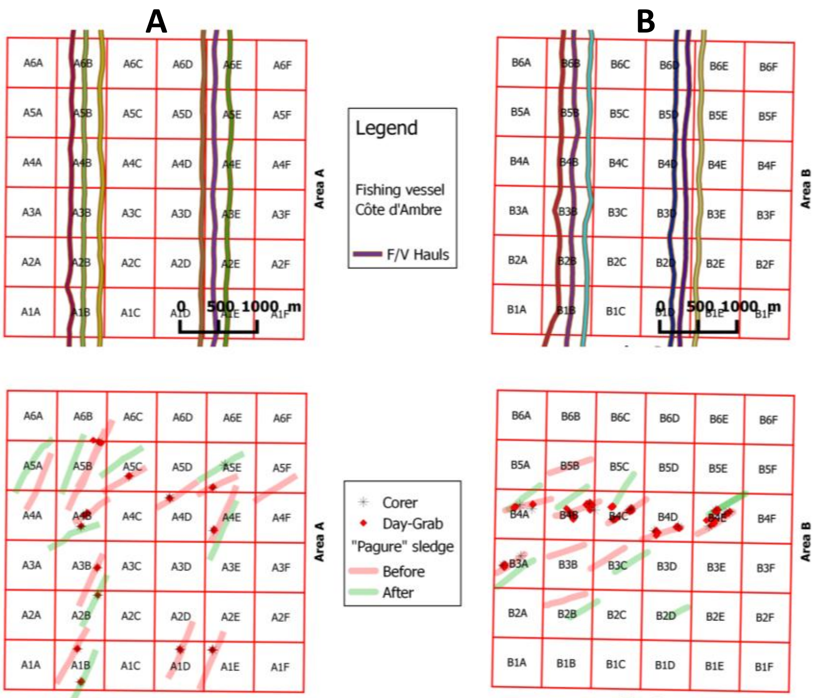


Figure 34. Operations realized during FEBBE-4 sea trials dedicated to impacts evaluation of alternative fishing gear, twin Nephrops trawl with "Jumper" type doors, in A) area A in northern GV (proportion of mud >25%) and B) area B in central GV (proportion of mud >75 %). For both areas, locations of hauls realized with professional fishing vessel (F/V Côte d'Ambre, upper maps) as well as sediment sampling (corer and Day-grab) and video/microtopography ("Pagure" sledge) records (lower maps) are indicated.

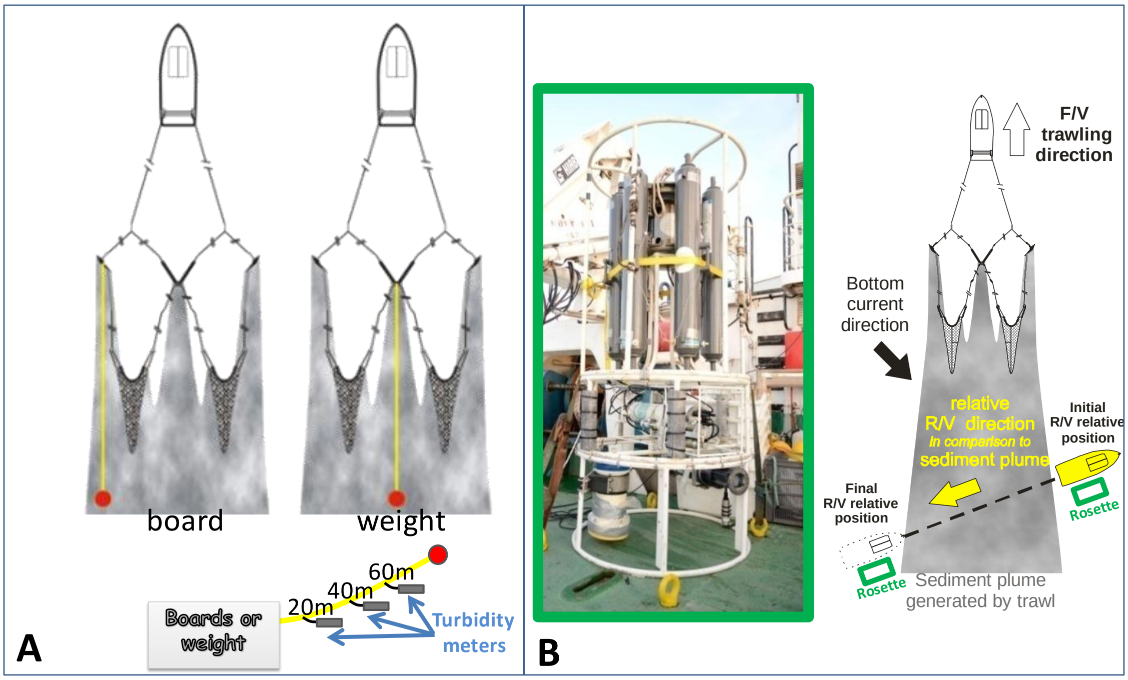


Figure 35. Tools utilized for sediment plume measurements, A) line with 3 turbidity meters (20, 40 and 60m from the attachment point) attached on the fishing gear close to the board or on the weight, B) rosette with ADCP, turbidity meter and Niskin bottles utilized with RV Thalia for transversal plume measurements.

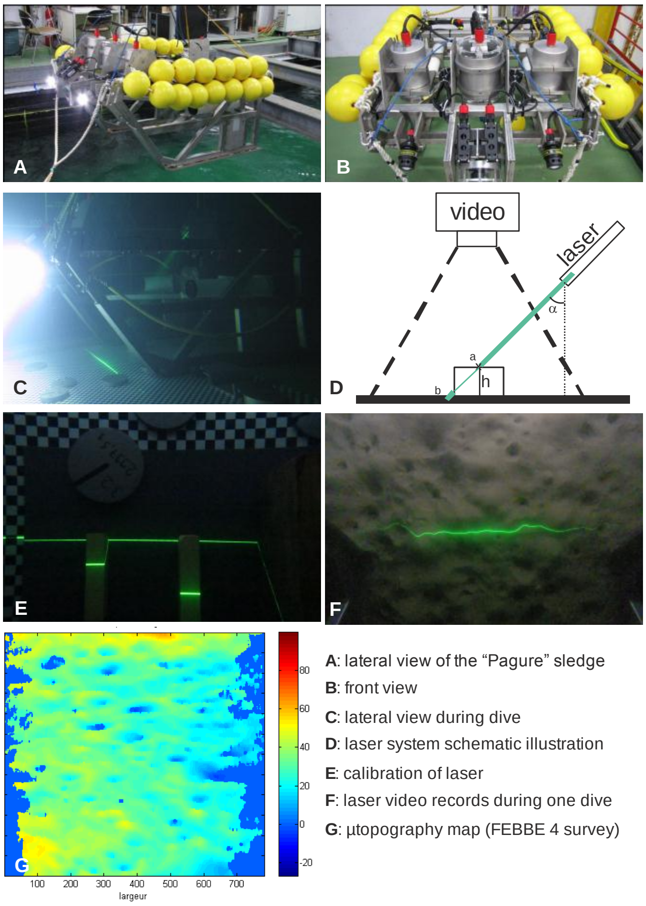


Figure 36. Description of laser microtopography system of "Pagure" sledge utilized during FEBBE-3 & 4 for measurements of bottom structures (G: microtopography colour scale in mm).

Table 5. Summary of realized operations during FEBBE 3 and 4 surveys in both areas (A and B).

- Tested or sampling gear		- Number of sample or haul by survey				- Observed ecosystem component
		- FEBBE 3		- FEBBE 4		
- AREA		- A	- B	- A	- B	
- Current gear "thyboron"doors		- 4	- 4	- -	- -	- -
- Alternative gear "Jumper" doors		- -	- -	- 6**	- 6***	- -
- Day-Grab	- before	- 18	- 6 *	- 15 *	- - *	- Epi and endo-benthic meiofauna to
	- after	- 40	- 55	- 50	- 55	- macrofauna
- Beam trawl	- before	- - *	- - *	- - *	- - *	- Epi-megafauna
	- after	- 4	- - *	- - *	- - *	
- "Pagure" sledge	- before	- 11	- 9	- 8	- 10	- Benthic habitat µtopography
	- after	- 9	- 10	- 13	- 6	
- Multi-corer	- before	- 4	- 1 *	- 4 *	- - *	- Sediment characteristics
	- after	- 6	- 12	- 10	- 11	

- * meteorological conditions and/or technical issues prevent us to realize all planned operations
- ** four-sided trawls net ; *** two-sided trawls net

Preliminary results

Jumper's board behaviour

Due to unexpected technical problems, a modification of the professional fishing gear equipped with "jumper" doors occurred between part 1 and 2 of FEBBE 4 survey:

- 12/10 (**Area B**), "jumper" twin trawl with "2 sides trawl net"
- 24/10 (**Area A**), "jumper" twin trawl with "4 sides trawl net"

Such modification of gears could explain some of the results described below. For alternative gear (equipped with "jumper" doors), mean values of distance recorded between the 2 doors (collected with MARPORT system, Figure 37) gave satisfactory results and varied from 50 m to 57 m. Variations in door distance were higher during the first sea trials (12/10, Area B) as compared to the second one undertaken with the heaviest gear (four sided one, 24/10, Area A). As expected, jumper doors drifted above the bottom, touching it sometimes, at mean altitudes ranging from less than 1 m to more than 3 m depending on hauls and trials (Figure 39). The highest variations in doors altitude have been observed during the second part of FEBBE 4 trials (in area A) and especially for the left board. Such a difference in door horizontal distance and altitudes could be explained by the differences in gear types between both parts of FEBBE 4 sea trials. The gear utilized during the second part was larger/heavier (four sided one) inducing more traction force that would have potentially induced higher destabilization of the jumper doors.

General behaviour and stability of jumper doors were satisfactory but, depending on haul conditions, doors showed differences in behaviours. For some hauls (or parts of hauls), "jumper" doors showed their typical "jumping" characteristics with vertical oscillations close to the bottom and touching it regularly (*e.g.* Figure 38, T2). For others, the doors mainly drifted a few metres above the bottom without touching it (*e.g.* Figure 38, T3). Even if the dynamics of both doors (left and right) was globally similar, differences occurred in altitude above the bottom and pitch values (e.g. lower altitude and pitch for right board as compared to left board during FEBBE 4 haul T3).

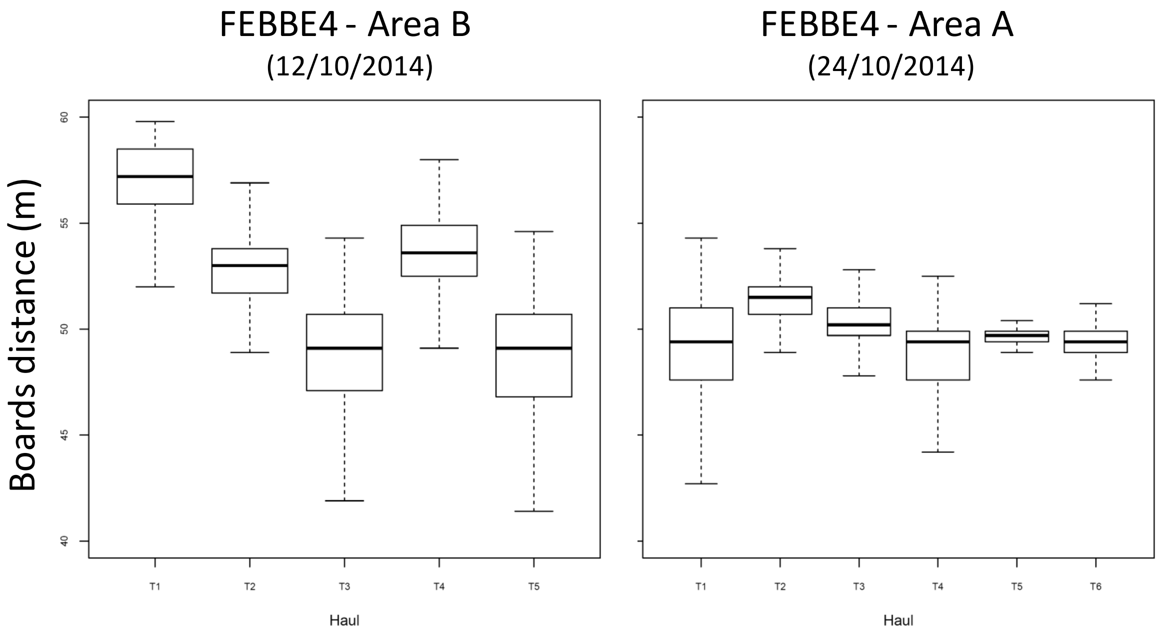


Figure 37. Boxplot of doors horizontal opening values for alternative fishing gear ("jumpers" doors) during FEBBE4 sea trials in Area B (left plot) with small sized twin trawls and in Area A (right plot) with four sided twin trawls.

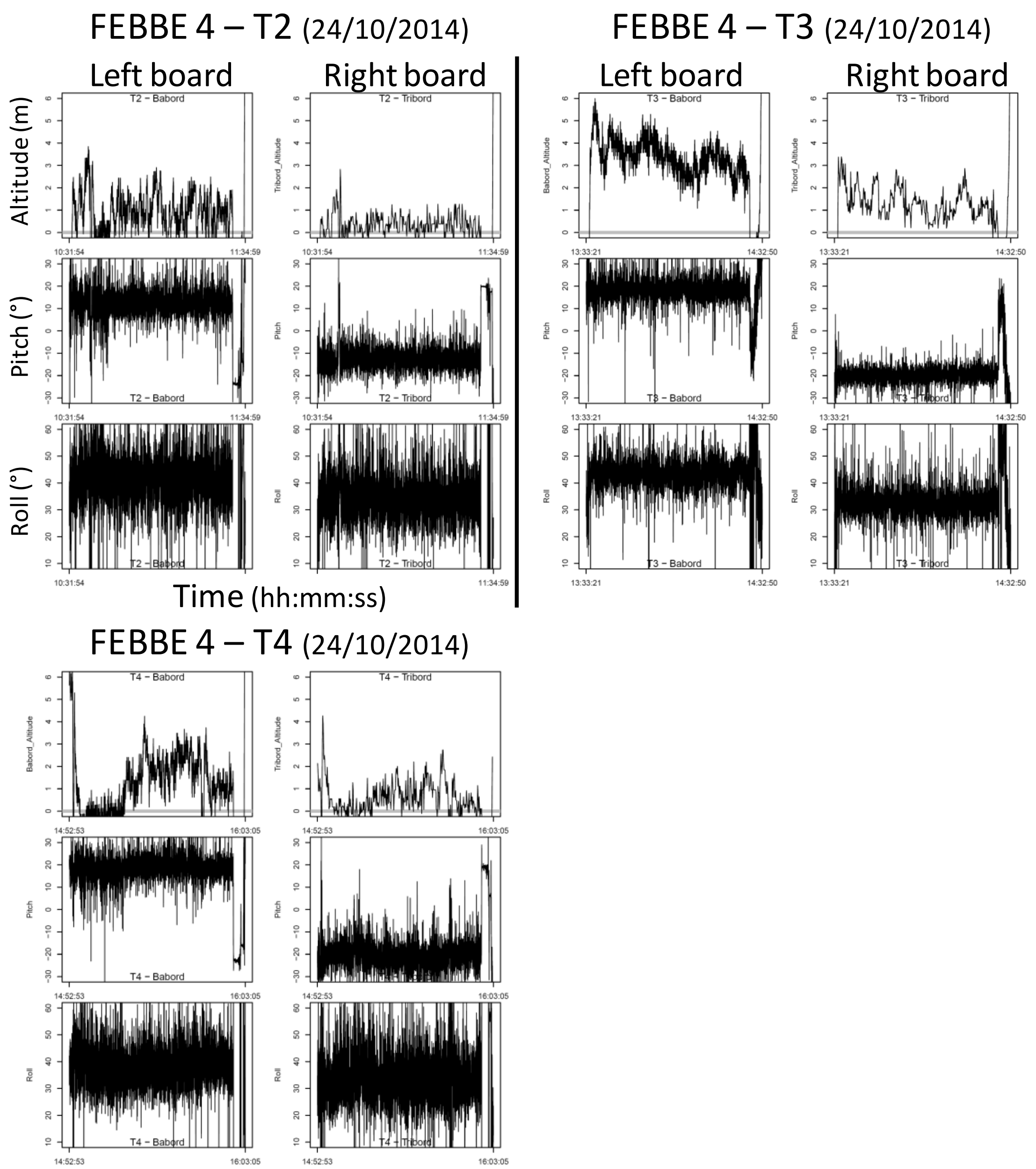


Figure 38. Examples of jumper doors behaviour (depth, pitch and roll) as recorded from3 hauls (T2, T3 and T4) among the 6 realized during the second part of FEBBE 4 sea trials (24/10/2014, Area A).

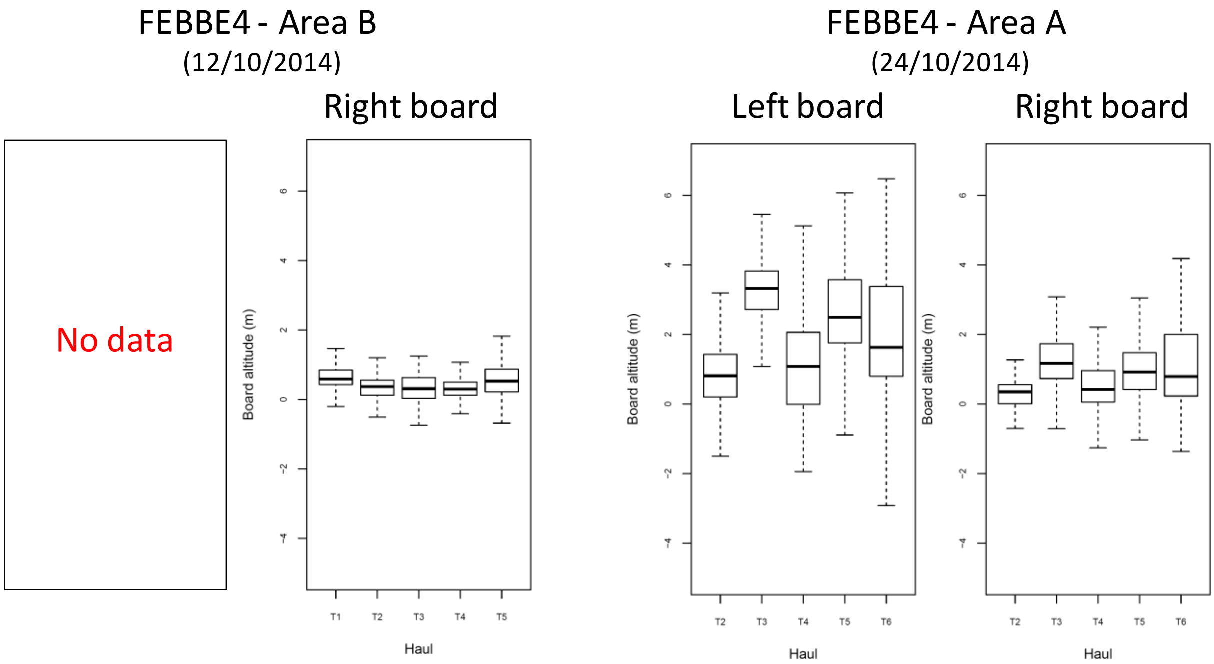


Figure 39. Boxplot of doors altitude from the bottom for alternative fishing gear ("jumpers" doors) during FEBBE4 sea trials in Area B (left plot, 5 experimental hauls) with small sized twin trawls and in Area A (right plot, 6 experimental hauls) with four sided twin trawls.

Comparison of turbidity levels generated by current and alternative gears

Jumper doors' behaviour was well illustrated by the depth of the doors as recorded from the MARPORT devices (Figure 38). Measurements obtained with the "turbidity line" confirmed those observations. As compared to the Thyboron staying at the bottom (Figure 40), the Jumper board showed their specific behaviour with oscillations into the water columns (Figure 41). Thyboron doors generated relatively high turbidity levels (Figure 40) as compared to Jumpers doors (Figure 41). Jumper doors mainly drifted above the bottom but touching it sometimes causing bursts of sediment into the water column (Figure 41) with transient highest turbidity values from 60 to 200 NTU. However, for the most part of the hauls operated with "Jumper" doors, mean sediment re-suspension values remained close to zero (Figure 42) and close to those produced near the clump. That turbidity level was much lower than the one generated by the Thyboron doors (around 150 NTU).

Longitudinal, transversal and vertical turbidity measures from "Rosette" devices (Figure 43 and Figure 44) confirmed the general lowering of re-suspended sediment amounts with the alternative fishing gear ("jumpers" doors). After trawling, turbidity values obtained with "Jumper" doors never get above 20 NTU while values obtained with current "Thyboron" doors reached more than 150 NTU close to the F/V track. Moreover, those values stayed at a relatively high level at a distance from the trawling gear.

Strong differences in sediment amounts sent into the water column by current *vs* alternative gear seemed to indicate that sediment re-suspension is mainly produced by the doors themselves. That conclusion has to be verified as it seems to go against some previous studies describing the effects of gear on sediment re-suspension processes. Indeed such studies pointed out the dominance of hydrodynamic drag on the production of the sediment plume induced by a fishing gear (O'Neill and Summerbell, 2011).

Our results could be explained by the relatively small size of Nephrops trawl (*e.g.* vertical opening reaches a maximum of 0.8 up to 1 m) making the doors the essential fishing gear part to consider in re-suspension processes.

To conclude, those preliminary results gave us some insight about alternative gear behaviour and its capability of reducing unwanted fishing impact:
- strong reduction in sediment re-suspension amounts, and especially from the doors themselves with a mean reduction close to 100% as compared to the current board.
- for the whole gear, at distance from the F/V, the mean reduction of sediment resuspension is about 80 to 90%.

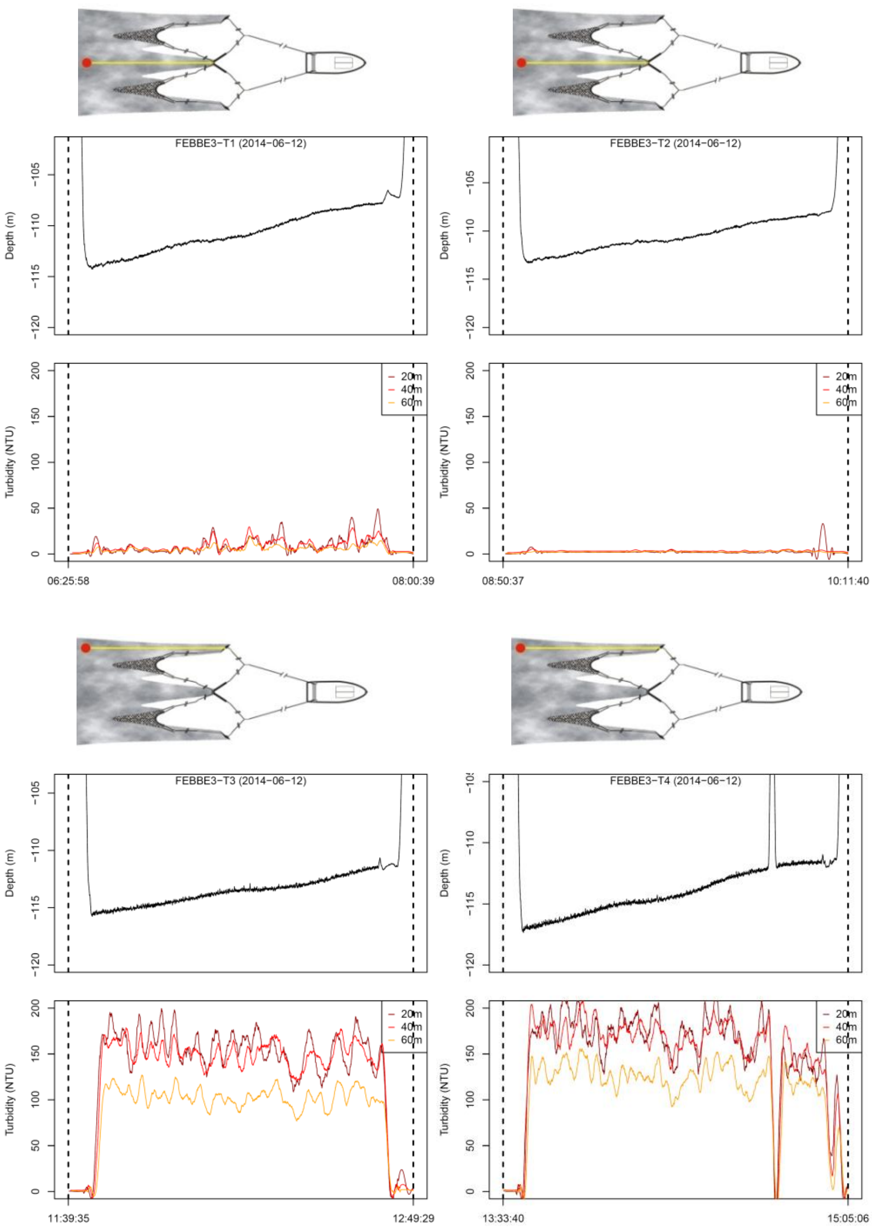


Figure 40. Depth (m) and turbidity (NTU) measurements as obtained from 4 experimental hauls with current gear (twin Nephrops trawl with Thyboron doors) operated during FEBBE 3 survey in the GV area A. Turbidity meters line was alternatively attached behind two different parts of the gear: the clump (upper graphs) and the doors (lower graphs).

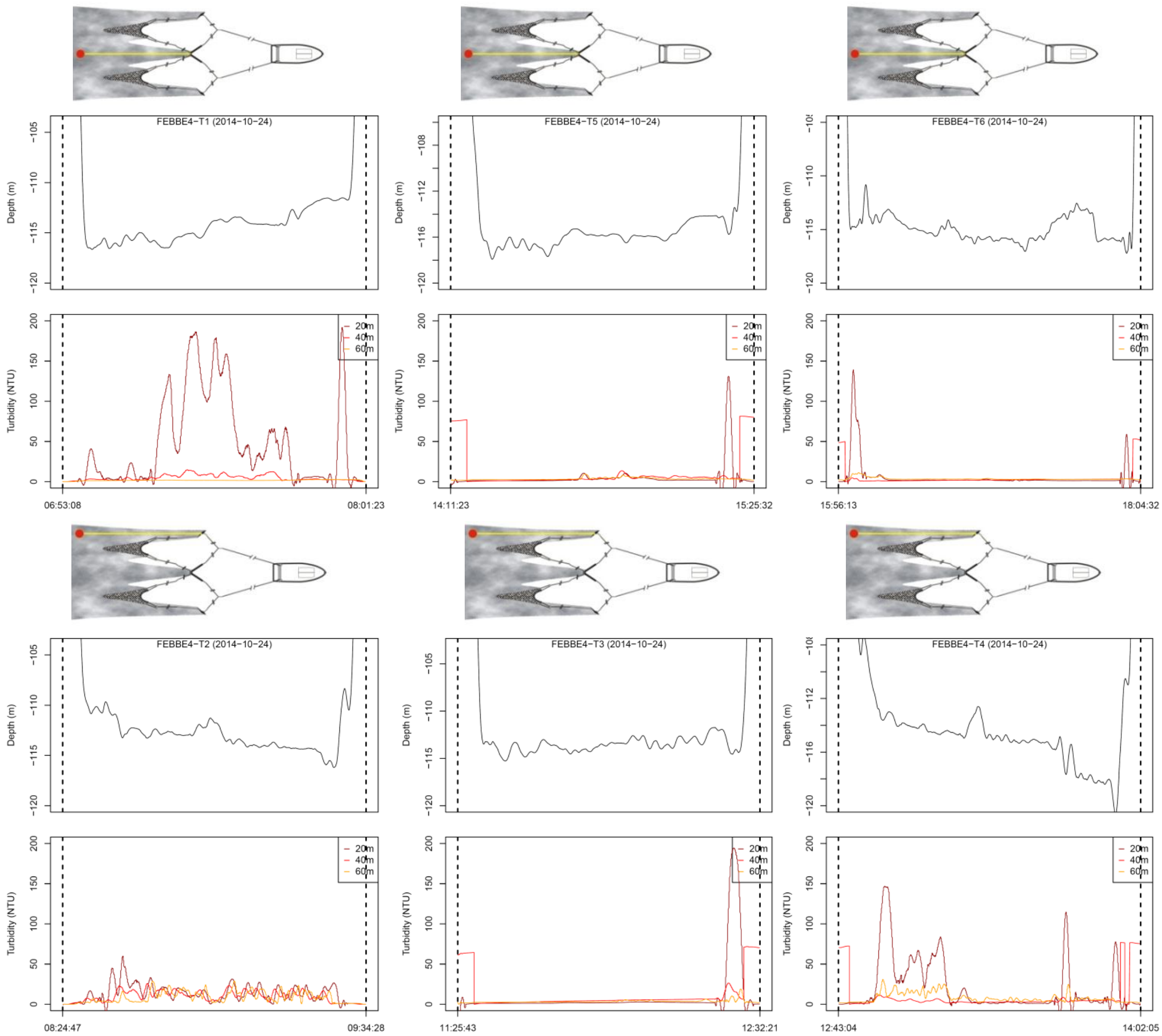


Figure 41. Depth and turbidity measurements as obtained from 6 experimental hauls with alternative gear (twin Nephrops trawl with "Jumper" doors) operated during FEBBE 4 survey in the GV area A. Turbidity meters line is alternatively attached behind two different parts of the gear: the clump (upper graphs) and the doors (lower graphs).

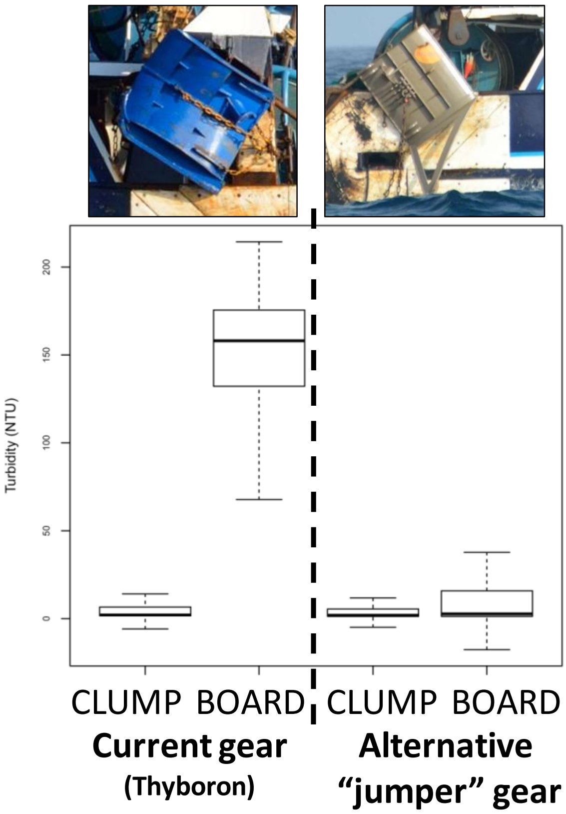


Figure 42. Boxplot of overall turbidity values as recorded with turbidity-line for twin Nephrops trawl equipped with Thyboron (graphs on left side) vs Jumper doors (graphs on the right side). Line was settled at 2 positions on the gear: the clump or the doors.

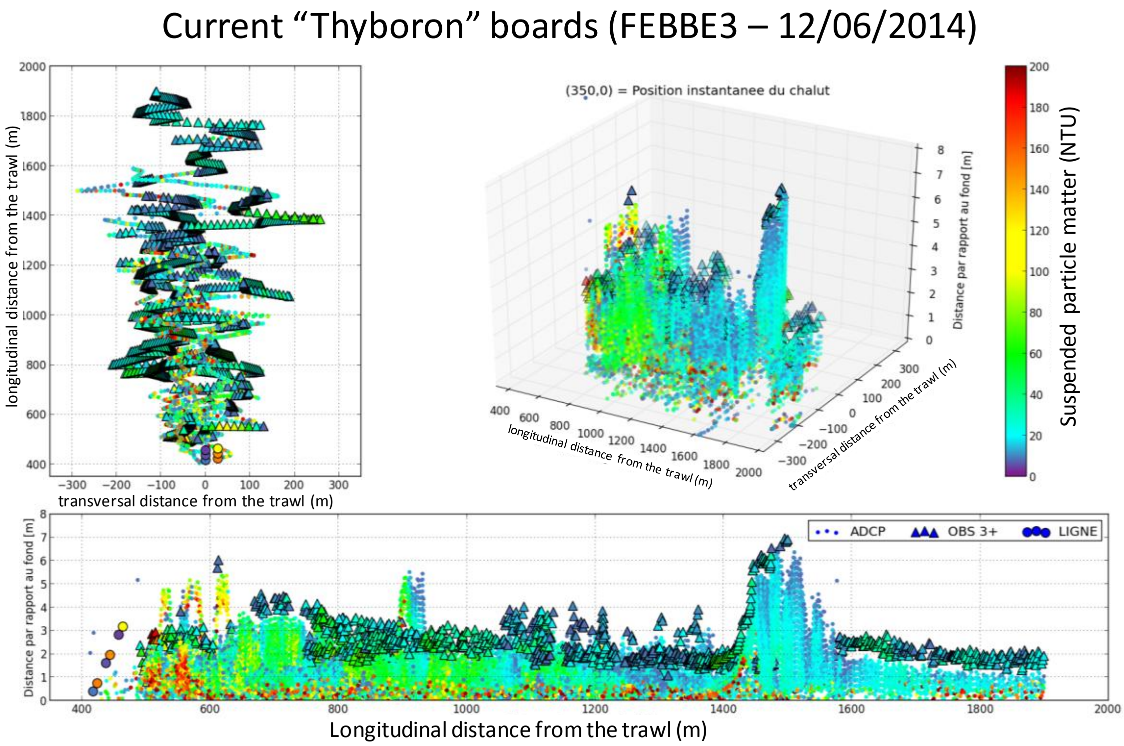


Figure 43. Summary of turbidity measures during FEBBE 3 survey (12/06/2014, Area A) as obtained from Rosette (ADCP and turbiditymeter) and "turbidity line" behind a twin Nephrops fishing trawl equipped with current ("Thyboron") doors. Results for the 6 experimental hauls are included in the graphics.

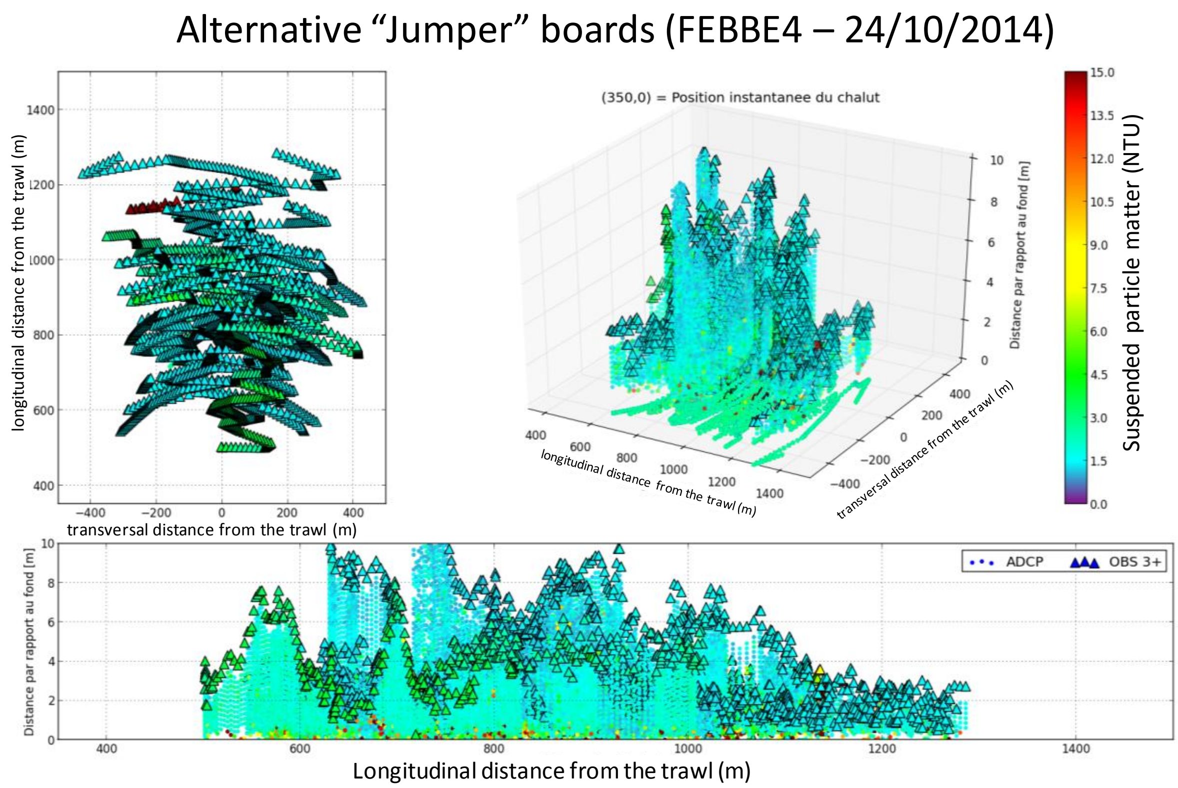


Figure 44. Summary of turbidity measures during FEBBE 4 survey (24/10/2014, Area A) as obtained from Rosette (ADCP and turbiditymeter) and "turbidity line" behind a twin Nephrops fishing trawl equipped with alternative "jumpers" doors. Results for the 6 experimental hauls are included in the graphics.

Sediment structures and trawls impact on the bottom

At the time of the present report, analyses of the data collected with the "Pagure" sledge during surveys FEBBE 3 & 4 were still in progress. Presented results are therefore very preliminary. Such data would give high resolution maps of the bottom (Figure 45). Bottom microtopography measurements will help us to measure sediment reworking by trawl gears (*e.g.* current fishing gears doors penetration depth Figure 45.C and Figure 46) as compared to that produced by natural, biological and physical, processes (*e.g.* burrows from benthic fauna, Figure 45.A & B). From those datasets, various indicators of bottom structure and disturbance both before and after a trawling events will be compared: differences in roughness at various spatial scales, density of biological structures (*e.g.* burrows), and identification of trawl footprints (doors or footrope).

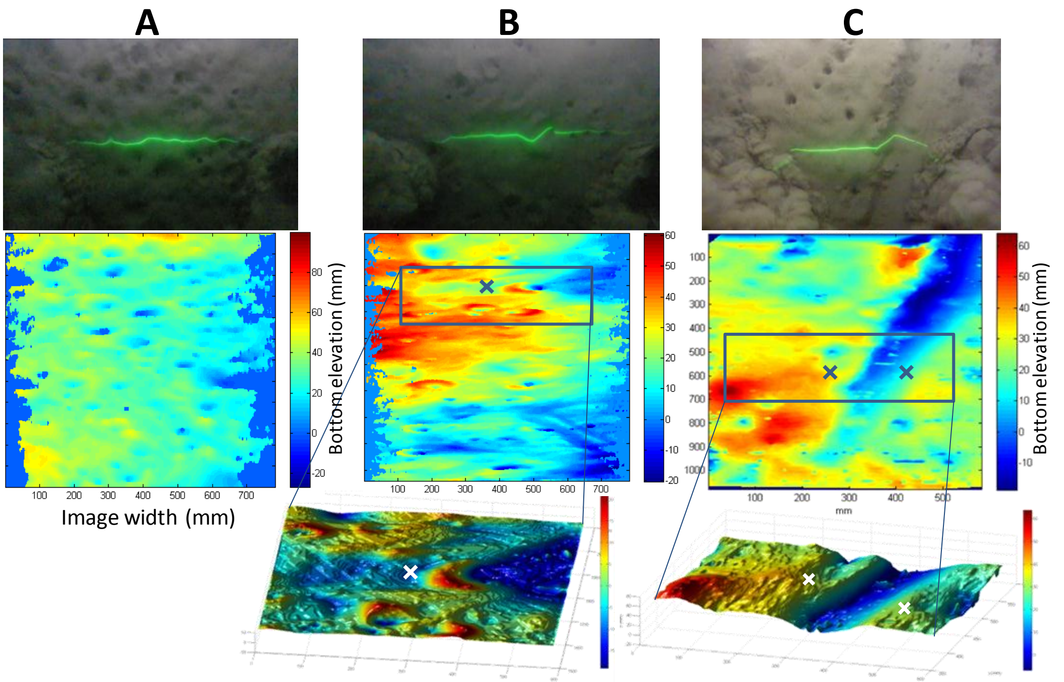


Figure 45. Microtopography records (bottom elevation colour scale in mm) as obtained from "Pague" sledge on muddy bottom A. biological & physical bottom structure with high rugosity at small scale(area A, FEBBE4), B. records with large biological structure like Nephrops burrow and zoom(area A, FEBBE4) and C. classical fishing board track obtained with "Thyboron" board type (area A, FEBBE3).

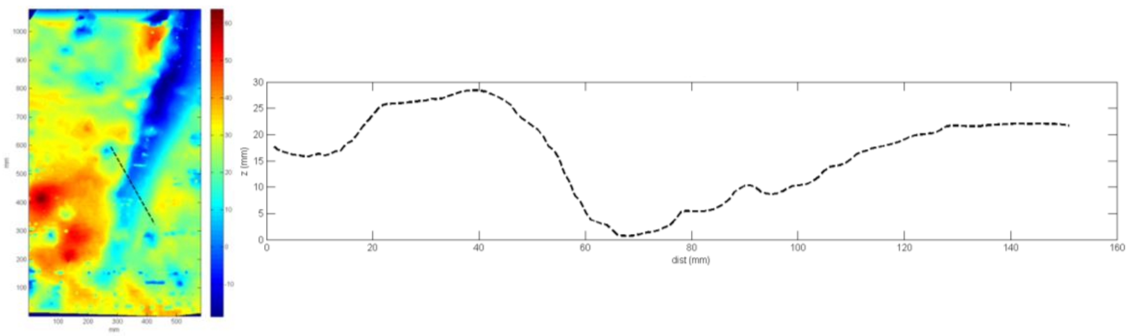


Figure 46. Transverse section across a trawling board track induced by current gear (Thyboron type) during FEBBE 3 survey.

Further work

The preliminary results and analysis will be completed and further work will focus especially on description of gear behaviour and fishing efficiency (*e.g.* auto-observation protocol of trawl catches). Already acquired datasets will be completed with the addition of new data obtained during the last surveys in spring-summer 2015 with professional fishing vessels. Those complementary tests with both gears (current and alternative) have been performed in operational fishing trip conditions. To complete the door behaviour analysis, current or alternative gears have been equipped during standard F/V trips (F/V Côte d'Ambre, SME09) with the same turbidity line system for the measurements of sediment re-suspension processes as well as with a video and gear behaviour measurements system (pressure probes and MARPOR system). Moreover, fishing efficiency and economic viability of the new gear will be analysed through new data acquired during those regular fishing trips utilizing alternatively current *vs* 'Jumper' trawling gear. Analysis of mid-term fuel consumption data and production efficiency (catches amount and characteristics) collected during the BENTHIS project will give us an insight into economic efficiency of the alternative gear.

Sub-Case study 2: Scallop dredge in the Celtic Sea (South-Eastern Irish coast): comparison of impacts and catch composition in scallop gears in mixed sedimentary habitats

General objectives and expected results

Impacts of scallop dredging on benthic habitats

Scallop dredging exerts surface and sub-surface disturbance pressure on benthic habitats. The generic effects of scallop dredging on benthic habitats are well known and unequivocal. They include homogenization of habitat with loss of structural feature (Thrush *et al*., 1998; 2001; Collie *et al*., 1996), increased dominance of smaller species and increased physical stress as shown by abundance biomass curves (Kaiser *et al*., 2000), short term increase in scavenging, sediment mounding and decline in epifauna (Sewell *et al*., 2007), loss of fine materials from sediments and reduction in burrowing megafauna (Langton and Robinson 1990).

Recovery from impact is slow but habitat dependent (Foden *et al.,* 2010). Impacts on fauna of soft sediments are less conclusive; infauna may be unaffected (Bullimore, 1985), infaunal communities change substantially following experimental dredging in closed areas (Bradshaw *et al*. 2000), infaunal bivalves and peracarid crustaceans may be unaffected but polychaetes and amphipods (peracarids) are reduced (Eleftheriou and Robertson, 2002).

Significant impacts to benthic environments can, therefore, be caused by scallop dredging. This impact will depend on the frequency of dredging relative to habitat sensitivity. In soft sediments the frequency of dredging is likely to be more important than intensity or quantity of dredging as the initial dredge tows are likely to cause most impact although in reef habitat damage may be incremental (Boulcott and Howell, 2011).

There has been very little modification or re-design of scallop dredges over the past 40 years. The standard dredge is the Newhaven) scallop dredge consists of a triangular frame which supports a rake or tooth bar and is attached to a steel net or belly which collects the scallops. The main variation here is in the action of the teeth and the tooth bar. The tooth bar can be either fixed in position or spring mounted. The spring mount is a modification to enable fishing in stony ground and allows the entire tooth bar to ‘spring backwards’ away from obstacles encountered during towing.

Some new dredge designs have been produced with the objective of reducing impacts of dredging on the seabed. These include the Hydrodredge which operates by passively generating turbulent vortices in front of the dredge to disturb scallop and which exerts sufficient force on the seabed to lift scallops into the water column so they can be captured by the trailing net/chain bag (Shepherd *et al*., 2009). Catch rates of commercial king scallop (*Pecten maximus*) however are lower than in standard dredges and this dredge is not in common use in the industry.

The N-Viro dredge claims both reduced impacts on seabed, catch rates that are similar or better than the NewHaven dredge, reduced damage to scallops in the catch, reduced by-catch, reductions in the number of stones in the dredge which reduces sorting time and reduced drag which reduces fuel consumption (http://n-virodredge.com/).

The objective of the trial was to investigate and compare the impacts of scallop dredging with standard spring loaded Newhaven Scallop dredges and N-Viro scallop dredges on sedimentary seabed habitats in a shallow inshore bay. Specifically, the field studies had the following objectives:

- Benthic characterisation:
  - To collect sediment core samples to characterise infaunal communities in areas that are subject to regular/periodic dredging activity and areas that have not been regularly or recently dredged
  - To conduct a number of characterisation SCUBA dives on undredged grounds to establish typical background faunal composition of the associated benthic communities
- Impacts of scallop dredging
  - To collect video and photographic evidence of seabed habitat impacts and invertebrate fauna injury and mortality as a result of scallop dredging over sedimentary seabeds
  - To collect video evidence of dredge operation in order to improve understanding of the function of both spring dredges and N-Viro dredges.

Study location

The study was undertaken in Clew Bay on the west coast of Ireland. The inner portion of Clew Bay is designated as a Special Area of Conservation (SAC) under the EU Habitats Directive. Qualifying interests are:

Qualifying Interests

***** indicates a priority habitat under the Habitats Directive*

001482 Clew Bay Complex SAC

QI	Description
1013	Geyer's whorl snail *Vertigo geyeri*
1140	Mudflats and sandflats not covered by seawater at low tide
1150	* Coastal lagoons
1160	Large shallow inlets and bays
1210	Annual vegetation of drift lines
1220	Perennial vegetation of stony banks
1330	Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)
1355	Otter *Lutra lutra*
1365	Common seal *Phoca vitulina*
2110	Embryonic shifting dunes
2120	Shifting dunes along the shoreline with *Ammophila arenaria* ("white dunes")

A number of discrete habitats types or marine community types occur within QI Large Shallow Inlets and Bays (Figure 47).

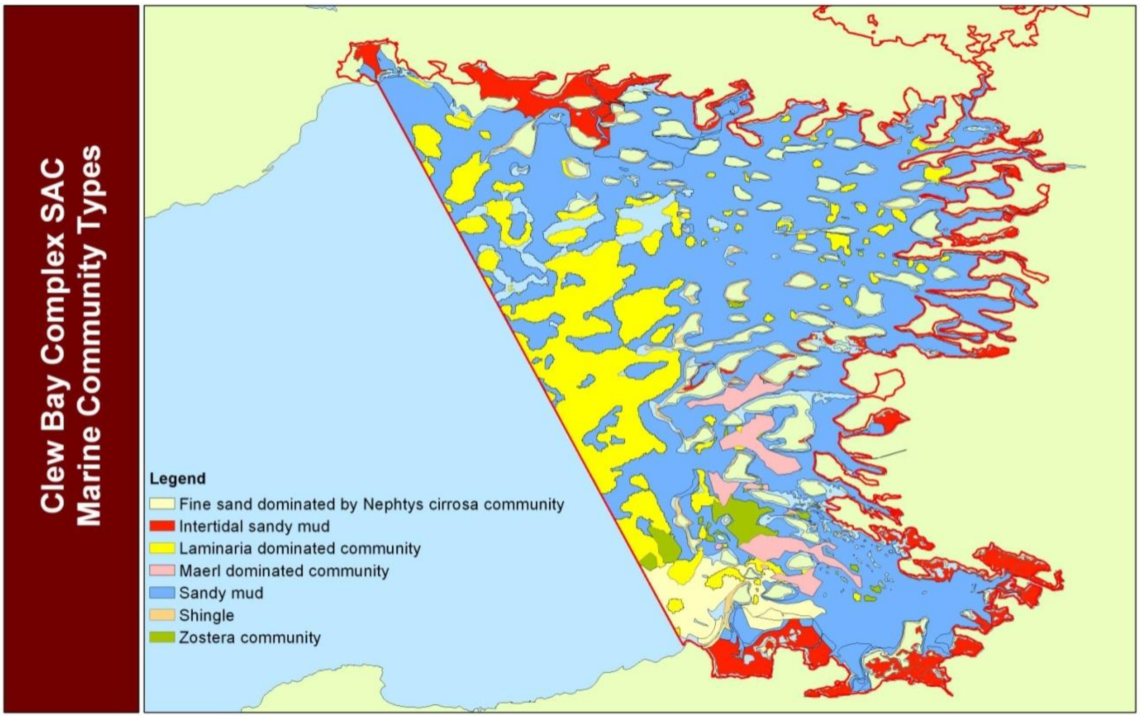


Figure 47. Clew Bay on the mid-west coast of Ireland showing the SAC boundary and marine community types within qualifying interest ‘Large Shallow inlet and Bay’ and Intertidal mud and sand flats. The scallop impact study was completed on Laminaria dominated community and sandy mud sediments.

Materials and methods

Vessel

The vessel used for the fishing trials was an 8 meter glass reinfoced plastic catamaran vessel MFV ‘NATALIE’ (Figure 48) with 40 kW nominal engine power (registration number WT275).

Figure 48. MFV Natalie showing arrangement of 3 dredges across the stern.

Dredge designs

1. A traditional (or Newhaven) scallop dredge consists of a triangular frame which supports a rake or tooth bar and is attached to a steel net or belly. The tooth bar digs the scallops from the seabed and deposits them into the net. Each dredge measures 76 cm wide and they are mounted onto a towing bar, the number of dredges depends on the size of the vessel used to tow them. In the present case 3 dredges were used.

2. The **N-Virodredge™** runs along the seabed on two skids which bear the full weight of the dredge. Mounted between the skids are a number of springs or tines. These tines move individually as opposed to a traditional dredge in which the teeth are mounted together and move as one. The tines are vertically adjustable so penetration below the level of the skids into the seabed can be altered. Three dredges were used in the present study.

The main anticipated operational difference between the dredges is the deeper depth of penetration of the tooth bar on the standard dredge compared to the tines on the N-Virodredge which are designed to disturb surface sediments (and scallop) only.

Data collection

<u>A. Seabed habitat and community characterisation dives.</u>

Four dives were carried out to characterise seabed habitat and the associated epi-faunal community in areas that were not (according to informed local knowledge) believed to have been subject to significant recent dredging activity. These areas were typical of grounds associated with local populations of scallops based on knowledge relating to seabed depth, exposure regime, seabed relief and sediment type.

Dives were carried out on July 7^{th} 2014, prior to any scallop dredging being carried under the present study. During these dives, typical species encountered were recorded and enumerated by a two-person team while swimming a 50 m transect across the seabed and following a pre-determined course, using a DAFOR scale (Dominant, Abundant, Frequent, Occasional, Rare). Observations on seabed features and fauna physical attributes were done in-situ using underwater slates. Dive entry/exit points were recorded using GPS. At the end point of each dive, three replicate sediment core samples were collected for each transect. A summary of data in relation to characterization dives is presented in Table 6.*a-d*.

In order to allow for description of infaunal communities, scuba techniques were used to collect three (3) replicate sediment core samples from four (4) separate locations in the Newport Bay area. Cores were 100mm in diameter and were inserted into the sediment to a depth of 25 cm to remove the sample from the seabed. Once brought to the surface, sediment samples were sieved to 1mm and the sieved remnant preserved using buffered formalin solution. Fauna was subsequently sorted, enumerated and identified to species.

<u>B. Evaluation of impacts of dredging</u>

The impact of dredging activity on seabed habitats and associated communities of epi-fauna in the Newport Bay area was also assessed by SCUBA. A total of 14 dives were completed on the 8^{th} and 9^{th} July 2014. Dives were conducted by swimming along a 100m transect of seabed that had previously been dredged over earlier that same day by the survey vessel using either standard spring dredges or N-Viro dredges.

During the dives, a two-person dive team recorded evidence of physical impacts on the seabed using video and/or stills photography, while evidence of impacts on biological communities was recorded in a similar manner and also by enumerating dead/injured organisms occurring along the line of the dredge path. Samples of dead/injured organisms were collected and returned to the surface where necessary in order to aid identification.

C. Evaluation of dredge action.

In order to improve knowledge and understanding of the nature and extent of interactions between scallop dredges and seabed habitats, a series of dives were carried out on dredges that were operating/fishing during which time observations were made and underwater video evidence was collected for the Newhaven type spring dredges and N-Viro type dredges. Dives were carried out on the 9th July 2014. Divers were deployed from and recovered to a dedicated dive boat.

D. Evaluation of catch and by-catch.

A total of 22 tows with 3 NewHaven dredges mounted on a single bar and 22 tows with 3 N-Viro dredges mounted on a single bar were completed on July 8th and 9th respectively. The tow tracks were recorded using Trimble Nomad® GPS survey units. This enabled parallel tows to be completed within 5m of each other to compare the performance of each dredge type and to remove or minimise the effects of spatial variability in distribution of scallop and by-catch in assessing dredge performance. Tow path length averaged 156 m.

Dredge track length and swept area was calculated for each tow and scallop catch per tow was converted to scallops per 100m^2 sea area. Catches were not corrected for dredge efficiency. The shell height of all scallops in the catch was measured. By-catch was identified and enumerated for each tow.

Catch rates of each dredge type under normal commercial working conditions was also compared after the survey by the skipper operating on the same vessel. N-Viro dredges were used from 24th July to 25th Aug and the NewHaven dredges were used 3rd Sept to 10th Nov. Scallop catch was reported for 108 tows of the N-Viro dredge and 115 tows of the NewHaven dredge.

Preliminary results: seabed characterization

Undisturbed habitat

Overall, the seabed habitats surveyed by diving in apparently undisturbed (or relatively undisturbed) areas comprise a range of mixed sediments including muds, sands and stones as well as cobbles and very occasional boulders. The clear dominant sediment type in this area is muddy sand mixed sediment. Depth ranged between 7 and 15 meters. A range of coarser sediments including gravel, cobbles and stones were recorded in some areas, where they formed a thin and patchy veneer overlying or partially mixed in with surface muddy sand sediments. Coarser sediments in turn provided seabed relief and a limited three-dimensional structure that formed a series of micro-habitats which supported additional species of fauna.

Occasional boulders present on the seabed had associated communities that were more typically associated with reef type habitats, however boulders were not recorded on all dives and the presence of boulders in this area appears to be limited. No evidence of prior dredging activity was apparent during any of the characterisation dives. It is likely that no dredging had taken place in recent times at these sites.

Habitats of the area where the characterisation dives were carried out appear to correspond with EUNIS level 4 biotope codes **A5.33** *Infralittoral sandy mud* and/or **A5.43** *Infralittoral mixed sediments*.

Based on the further evidence provided by infaunal analysis of benthic cores, associated sub-biotopes (EUNIS Level 5) considered likely to best describe the area include **A5.332** *Sagartiogeton undatus and Ascidiella aspersa in infralittoral sandy mud* and **A5.334** *Melinna palmata with Magelona spp. and Thyasira spp. in infralittoral sandy mud*.

Physical evidence of dredging impacts from dive surveys

Overall, the studies confirmed that there are significant physical and visually detectable impacts on seabed sediments and associated biological communities, connected to the use of both Newhaven and N-Viro type scallop dredges in Clew Bay.

Evidence of dredging related impacts recorded during the surveys include:

- moderate to severe visible physical alteration to surface sedimentary habitat structure along the path of dredge tracks;
- visible impacts to cobble and boulder habitats. Coarser sediments (cobble, stones and boulders) had apparently been lifted out of the sediment and turned over or pushed or dragged along the seabed surface, frequently being are left in an inverted condition which is likely to destroy attached fauna;
- visible dredging associated injury and direct mortality of both epi-fauna and in-fauna
- Smothering related impacts associated with re-suspension and settling out of the water column of sediments;
- visually detectable difference in the epi-fauna within dredge tracks and on adjacent areas of seabed. Overall reduction in abundance was apparent between recently dredged and undredged areas. This could not be confirmed through in-situ enumeration of all species of epifauna due resource limitation.

From the study, it is apparent that scallop dredging can have obvious and pronounced physical impacts on seabed habitats that can be detected using visual survey techniques. While the significance of such impacts is likely to be related to the frequency of dredging events, the inherent ability of the particular biotope to recover from such events as well as the overall natural level of background variability, it is likely that scallop dredging over soft and mixed infralittoral sediments will lead to long term damage and changes in habitat distribution, extent, structure and function.

There are clear risks to specific biota including biogenic reef forming communities, seagrass beds and maerl beds although no such communities were witnessed during these studies. However they are known to exist in many areas within Clew Bay complex SAC, as has previously been documented. There is ample evidence in the literature to support the prediction of serious potential impacts. The damage that can be caused by dredging for bivalve species over sensitive seabed types has been investigated by many previous studies carried out on similar habitats within the EU. Relatively little (if any) previous work of this nature has however been carried in Ireland, however there is a documented case in Northern Ireland whereby serious damage to a horse mussel (*Modiolus modiolus*) biogenic reef was attributed to localised scallop dredging activity.

The main physical impacts to seabed habitats appear to arise from contact with downward and forward pressure between the dredge skids and the seabed, penetration of the seabed sediments by dredge teeth or tines with resulting damage to burrowing in-fauna and associated burrow and tube structures in particular, as well as impacts of the rollers at either end of the beam from which dredges are towed which tend to cause a degree of compaction.

Additional damage may be caused through the pushing or dragging across the seabed of larger stones and/or boulders, which may lead to significant gouging and mortality of attached sessile fauna. A further source of impact is associated with the dragging behind the dredge of the chain bag within which the targeted scallops are gathered by the dredge. Over the medium to long term, repeated dredging is likely to lead to reduction in habitat structure through the removal of seabed relief, sorting of sediments and destruction of burrows and tubes associated with burrowing fauna.

In terms of impacts on biological communities, it is apparent that dredging activity has a detectable impact on biota associated with the seabed after a single pass of the dredge. Certain impacts are immediately apparent after dredging, typically these include destruction of sensitive sessile organisms attached to boulders, broken shell and stones (including hydroids such as *Nemertesia antennina*), the bringing a broad range of burrowing species including razor clams, burrowing anemones, polychaete worms and other organisms to the surface of seabed sediments, many of which are damaged in the process along with the removal of the target species. Little discernible (if any) difference between the level of impacts of Newhaven spring dredges and N-Viro dredges was apparent from the work carried out in the present study, which was based on a series of observations and did not collect data that would allow for more detailed evaluation or description of impacts.

Evaluation and comparison of action of each dredge type

Dive teams descended on dredges prior to the tow being commenced and once mobile, observations and video recordings were made in relation to dredge movement, bottom contact, depth of penetration of sediments and interaction with biota. A total of 5 dives were completed for this purpose, 2 on tows with regular Newhaven type spring dredges and 3 dives on N-Viro dredges. Some edited footage of both types of dredge in action during the dive studies can be viewed here.

Results showed that both types of dredge maintain close contact with the seabed during fishing operation, with the tooth bar of the Newhaven type dredge penetrating the surface sediments to varying depths. Observations also seemed to indicate that the spring dredge tended to jump or jerk its way along the seabed, momentarily slowing down or stopping as the teeth of the dredge encountered obstructions. Dredges would slow down or stop until such time that continued forward movement of the vessel would cause the spring tension in the dredge to rise and thereby force the dredge to either dislodge the obstruction or to 'jump' over it.
There appear to be three main areas of contact between dredges and the seabed:

- rollers at either end of the beam to which the dredges are attached;
- the tooth bar on the Newhaven dredge, or tines in the case of the N-Viro dredge the shoes at either side of each dredge.

The chain bag that is attached to the rear of the dredge, in which scallops, stones and other organisms entering the dredge are collected, may make further contact with the seabed once the forward end of the dredge has passed. The degree of contact in terms of compression between the bag and the seabed is likely to be related to the weight of the bag itself but also to the overall mass it contains, which is a function of overall catch (including stones and debris). The chain bag tends to sit on the seabed at all times, even when empty (it being made of steel chain links). This is considered very likely to cause further sediment sorting and flattening of seabed relief after the dredge tooth bar/tines have passed over. Dive studies confirmed that dredge track marks that can be seen on the seabed after a dredge has passed, are most likely created by the dredge shoes which skid along the seabed. These marks persist long after the dredge has passed over, as was apparent in a number of locations where marks from earlier dredging activity during 2014 was still visible.

Direct evidence of penetration of dredge teeth (or tines in the case of the N-Viro dredge) was more difficult to find. While video evidence clearly shows significant penetration of teeth and tines of moving dredges into the sediment, the narrow spacing between teeth and tines likely makes individual tine or teeth tracks less discernible. However, video evidence clearly shows dredge teeth/tines penetrating the sediments for the full length – circa 4 inches (100 mm) on Newhaven dredges, while tines on N-Virodedges can be seen to penetrate sediments deeper than this and perhaps up to 150 mm into the sediment.

The dives proved useful also in that it clearly demonstrated that some organisms can pass beneath the dredge (such as some crabs) however most organisms falling within the path of the dredge were either captured or were knocked out of the path of the dredge, others became trapped in front of the dredge and were pushed forward for extended periods. Organisms encountering the dredge in any of these ways were very likely to suffer injury and /or mortality.

There were clear instances where burrowing organisms were seen to be brought to the sediment surface by the dredge action, while some bivalve specimens including cockles and smaller scallops were also disturbed by the dredge, which led to visual damage to shells. Few organisms were seen to be capable of moving out of the path of a moving dredge and most organisms that were within the path of the dredge were either captured or suffered significant damage as the dredge was seen to pass over them.

Evidence of how dredges may uproot partially buried stones and boulders was also collected. From video evidence it can be seen how dredging is inclined to reduce the three-dimensional structure of the seabed by removing stones, rocks and boulders and by flattening the sediment surface. Well-dredged areas were characteristically flattened, sediments were well sorted and the surface was devoid of sessile epi-fauna, as well as scallops. The tendency for both dredge types to have this kind of impact was apparently confirmed however it was not possible to make a more informed analysis of the real level of impact associated with each dredge type due to the nature of the data that was collected (visual assessment only).

The studies did not reveal a discernible difference in levels of impact between the two types of dredges. However, based on observations and video recordings, it is apparent that the tines of N-Viro dredge may penetrate seabed sediments to a greater depth than do normal toothed dredges, depending on the length of the tine when first fitted. Tines tend to wear down relatively quickly compared to normal dredge teeth, however when they are first fitted, tines may be up to 150 mm in length and the great majority of this length will (and was seen to) penetrate surface sediments.
In contrast with Newhaven dredges which typically have teeth in the range of 80-100 mm in length, the greater gap between tines compared to the gap between teeth on Newhaven dredges means that there are more opportunities for organisms to escape or simply be passed over.

Table 6. Dredge track dive data and description of impacts.

Dive No.	Date	Latitude	Longitude	Ave depth	Bottom type/dredge type	EUNIS habitat	Observations
5	8/7/14	53° 52.503N	009° 41.165W	10m, 50m transect	Sandy mud mixed sediment. Newhaven spring dredge	A5.33 Infralittoral sandy mud	Deep gouges in sediment up to 100mm deep. No indicator species typical of the area present including M. *infundibulum*, *C. lloydii*. Re-suspended sediments, reduced/low visibility. Extensive and prominent physical impacts on the seabed. Stills recorded.
6	8/7/14	53° 52.551N	009° 41.468W	12m, 50m transect	Fine sand and mud mixed sediment. NViro dredge	A5.33 Infralittoral sandy mud	Very obvious dredge marks recorded and heavy re-suspension of sediment, very low visibility. Complete absence of attached hydroids, low scallop abundance. No anemones or burrowing fauna noted. Apparently a stable habitat and some dredge marks appeared to be older. No stone or seabed relief, very flat. Video recorded along with stills imagery.
7	8/7/14	53° 52.638N	009° 41.570W	10m, 50m transect	Sand/ muddy mixed sediment with occasional cobble. NViro dredge	A5.33 Infralittoral sandy mud	Large numbers of scavenging fauna present – *L depurator*, *C pagurus*, *P. bernhardus*. A flat plain of sandy mud apparently well dredged with no relief noted. No hydroids or anemones in tow path but some species apparent off dredge track. The dive was carried out c. 2 hrs post dredging activity. Dredge tracks prominent. Stills imagery taken.
8	8/7/14	53° 52.299N	009° 43.97W	12m, 50m transect	Sandy mud mixed sediment with occasional boulders and cobble. NViro dredge	A5.33 Infralittoral sandy mud, possibly A5.43 Infralittoral mixed sediments	Dredged approximately 1hr prior to diving. Sandy mud. With coarser sediments on top. Relatively abundant epifauna. Physical evidence of dredge impacts on sediment surface again in places. Estimated 50mm deep. Overturned stones and cobbles.
9	8/7/14	53° 52.201N	009° 42.960W	9-11m, 50m transect	Mixed coarse and fine sediments with some larger stones and occasional boulder. NViro dredge	A5.43 Infralittoral mixed sediments dominant A5.33 Infralittoral sandy mud	A diverse and species rich seabed. Very pronounced differences visually apparent between dredge path and adjacent ‘undredged’ areas. Some scallops sitting ‘proud’ of seabed, apparently disturbance related. Large burrowing bivalves including cockles *Cerastodermedule* lying on seabed, likely taken to surface sediment by dredge action. Evidence of boulders and stones overturned,

Dive No.	Date	Latitude	Longitude	Ave depth	Bottom type/dredge type	EUNIS habitat	Observations
							hydroid communities inverted on underside of overturned stones. Clear dredge induced depressions in sediment surface, broken living *Ensis*sp. Shells and associated scavenging activity. Video and stills imagery.
10	8/7/14	53° 52.201N	009° 42.920W	17m, 50m transect	Muddy sand, NViro dredge	A5.33 Infralittoral sandy mud	Few scallops in dredge path/track. A rich hydroid community attached to shell and stones. Overturned stones and shells. Deep dredge marks in sediment noted. Cockles removed from sediment and lying on sediment surface. Video and stills imagery
11	8/7/14	53° 52.201N	009° 42.916W	13m, 50m transect	Muddy sand, NViro dredge	A5.33 Infralittoral sandy mud, with A5.43 Infralittoral mixed sediments	Physical damage apparent and the dredge track is very visible in sediments. Overturned stones, seemingly well dredged area, no relief, no scallops and low species diversity.
12	8/7/14	53° 52.461N	009° 43.160W	10m, 50m transect	Sand, coarse sediments and cobbles and shell. NViro dredge	A5.33 Infralittoral sandy mud with A5.43 Infralittoral mixed sediments	No scallops recorded. Evidence of physical impacts – deep gouges c. 60-100mm in places. Track mark of dredge clearly visible on seabed in places, not so visible in others. Abundant scavenging organisms (crabs) present. Some damaged infauna including *Ensis* sp. and parchment worm *Chaetopterus variopedatus.*
13	8/7/14	53° 52.757N	009° 43.531W	14m, 50m transect	Sandy mud mixed sediment. NViro dredge	A5.33 Infralittoral sandy mud	Largely flat seabed with stones overturned, very low visibility – most likely caused by dredging related re-suspension of sediments. Track of dredge clearly identifiable on sediment surface and through presence of scavengers on sediments surface. Stills imagery taken.
14	8/7/14	53° 52.678N	009° 42.801W	13m, 50m transect	Muddy sand mixed sediment. NViro dredge	A5.33 Infralittoral sandy mud	Fine muddy sand with some very big stones and occasional cobble. Abundant scallops, dredge track clearly visible through changes in sediment surface and dredge line marked by rollers.
15	9/7/14	53° 52.048N	009° 42.619W	13m, 50m transect	Fine muddy sand, stones and gravel mixed sediment. Newhaven spring dredge.	A5.33 Infralittoral sandy mud with A5.43 Infralittoral mixed sediments	Very few scallops, very pronounced dredge 'line' with occasional deep gouges in sediment surface. Abundant scavengers. NViro dredge track from the preceding day could clearly be seen on an adjacent line, c 5m away. Little if any difference visually apparent between the two tracks. Entire area looks to have been dredged previously. Stills and video recorded.
16	9/7/14	53° 52.166N	009° 42.60W	14m, 50m transect	Sandy mud mixed sediment with a lot	A5.33 Infralittoral sandy mud with	Injured *Myxicola infundibulum* present on sediment surface, no scallops in dredge path whereas moderate numbers of scallops

Dive No.	Date	Latitude	Longitude	Ave depth	Bottom type/dredge type	EUNIS habitat	Observations
					of gravel on the surface with broken shell and stones occasionally also. Newhaven spring dredge	A5.43 Infralittoral mixed sediments	present off the dredge path. Abundant scavengers.
17	9/7/14	53° 52.445N	009° 42.989W	12m, 50m transect	Fine sand/muddy mixed sediment with shell. Spring dredge.	A5.33 Infralittoral sandy mud	No scallops recorded in track of dredge. Outer edge of dredge track very visible, abundant scavengers present. Dredge teeth marks obvious in sediment.
18	9/7/14	53° 52.321N	009° 43.075W	12m, 50m transect	Mud with shell, spring dredge.	A5.33 Infralittoral sandy mud	Outer edge of dredge track very visible, abundant scallops outside of dredge path but none within the dredge path. Various marks on sediment surface apparent, including deeper gouges in places. Stills and video imagery recorded.

Comparison of catch and by-catch

Survey data

Scallop catch, by-catch and the catch of stones were similar in each dredge type (Table 7). The size frequency distribution of scallops in catches was also similar across dredge type. By-catch species included starfish (Asterias spp), crab (Cancer, Maja, Liocarcinus), whelk (*Buccinum undatum*) and juvenile Ray (Raja spp). Starfish were common in the by-catch but other species were occasional only. The average number of starfish per tow was 5.6 and 7.3 in N-Viro and NewHaven dredges respectively.

Table 7. Average (Standard deviation) number of scallop, by-catch and stones per 100 m^2 swept area in N-Viro and Spring loaded dredges in 22 paired tows during survey on July 8th and 9th.

	N-Viro		Spring Load	
	Average	S.d.	Average	S.d.
Scallop	7.97	3.92	6.77	5.87
By-catch	2.04	1.66	2.50	2.65
Stones	4.72	8.31	3.14	5.14

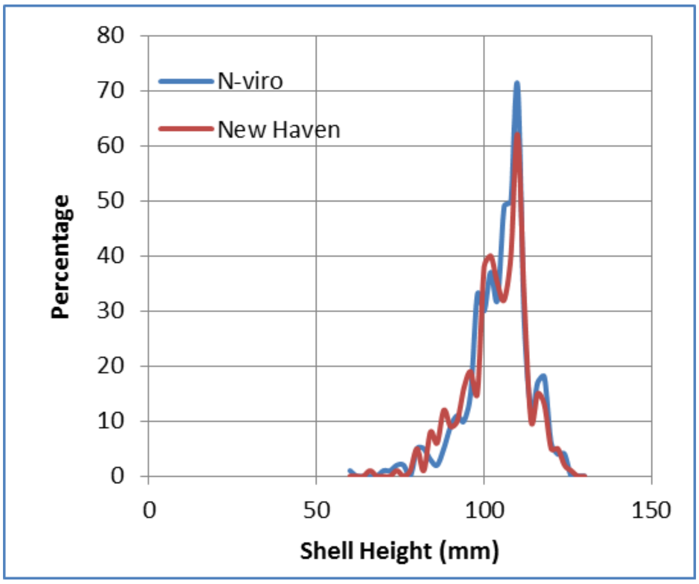


Figure 49. Size frequency distribution of scallops captured in the N-Viro and NewHaven dredges.

Commercial data

Scallop catch rates on commercial fishing operations were similar for each dredge type. Average landing per minute of fishing averaged 6.9 and 6.1 in N-Viro and NewHaven dredges respectively. This translated to 205 and 168 scallops landed per tow in N-Viro and NewHaven dredges respectively. Although not statistically significant (because of high variability between tows) the N-Viro dredge tended to catch more legal sized scallops. However, this may reflect the locations fished using each dredge; the skipper fished 'new' and more stony grounds with the N-Viro as a test of how it performed in such habitats.

Table 8. Commercial landings and discards of scallop per minute fishing time in N-Viro and New Haven dredges.

		Landings		Discards	
	N	Mean	S.d.	Mean	S.d.
N-Viro dredge	108	6.92	2.86	1.80	1.22
New Haven	115	6.17	2.06	1.34	0.93

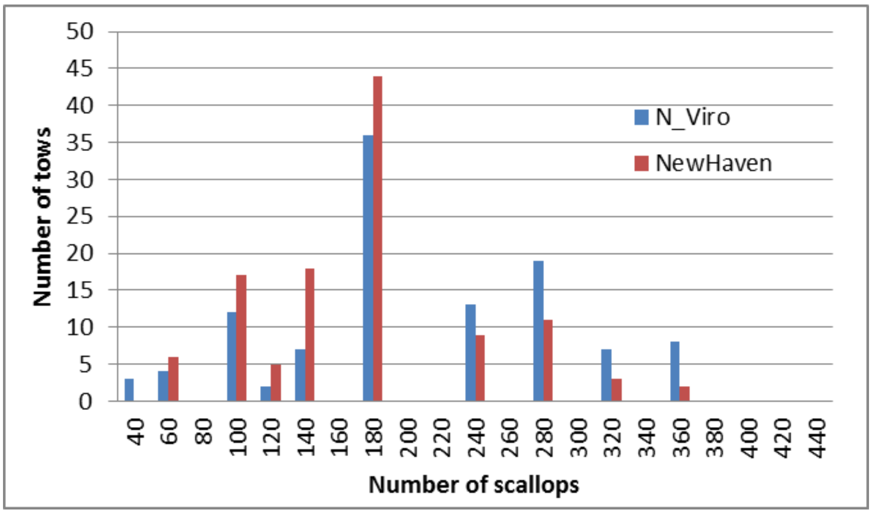


Figure 50. Distribution of legal sized scallop per tow in N-Viro and NewHaven dredges under commercial fishing conditions.

Conclusions

In situ comparison of the physical impact of N-Viro and NewHaven spring loaded scallop dredges failed to find significant differences in the level of impact caused to seabed habitats in mixed sedimentary environments. Both dredges cause significant impact to epifauna and infauna, reduces small scale relief on the seabed and homogenises and increases the sorting of sediments. The catch and by-catch composition, scallop catch rate and selectivity of the dredges is similar.

MEDITERRANEAN SEA

One of the aims of the Task 7.4 is to shift from traditional demersal otterboards to novel and semi-pelagic otterboards. Several sea trials have been organized, which focused on the development of novel otterboards, and to some technical modification of a bottom trawl net design. In order to assess the physical impact reduction of novel otterboards, two traditional and two experimental otterboards, from Grilli (SME13) and Mori (SME14), have been tested. Traditional models are bottom otterboards while the experimental models have been designed as floating, semi pelagic otterboards (Mellibovsky et al., 2014). The performances of the otterboards have tested in terms of geometrical and mechanical parameters as well as from the physical bottom impact through side scan sonar monitoring (Lucchetti and Sala, 2012).

With respect to the trawl net design, the development of novel trawl design focused on the test of a particular device implemented in a traditional bottom otter trawl. Such modification in the design is expected to increase the selective attitude of juveniles (Sala et al., 2015; Brčić et al., 2015; O'Neill et al., 2016). A set of sea trials has been carried out through a comparative approach, on-board a twin trawl bottom commercial trawler.

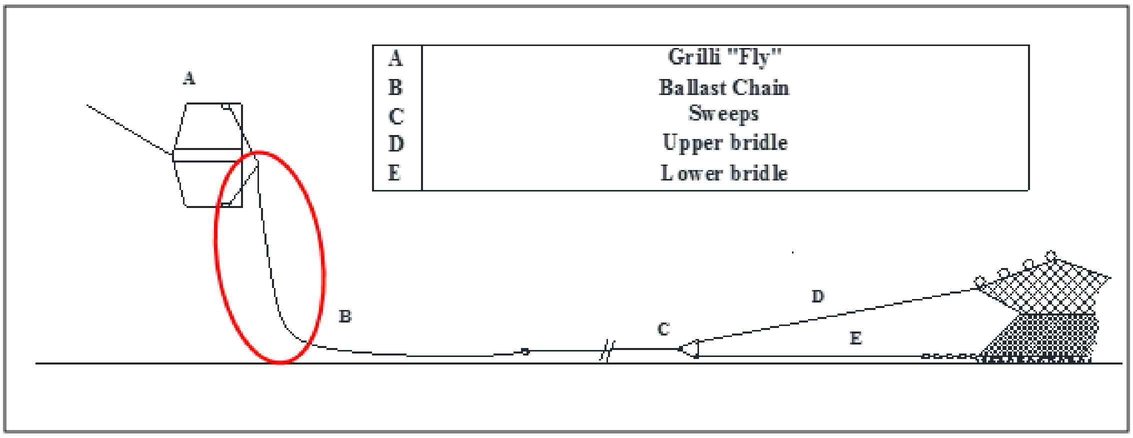
Tests of novel otterboards

In February 2014 a first set of sea trials has been carried out on board the research vessel "G. Dallaporta" in Ancona (Italy). The aim of the sea trials was to verify the stability and operability of the experimental otterboards and a preliminary performances comparison with respect to the respective traditional otterboards. All the otterboards have been tested with different door configuration and at different depth and fishing ground. The experimental door from SME13 (Figure 51) is a pelagic door with a hyper-lift device on the forward part of the vertical line of the door. The experimental door from SME14 (Figure 52) is designed as a "near-bottom" floating door. The idea of the manufacturer is to increase the energy efficiency of the door by reducing bottom contact, while, remaining near the bottom, no sensors are needed. In Figure 53 it is reported a representation of the different rigging of the doors.

In order to evaluate the effective applicability of experimental doors on a commercial fishing gear, in June 2014 another set of sea trials have been carried out on board a commercial vessel (Figure 54). During this second set of sea trials, more attention have been paid to the fishing gear behaviour with respect to the catchability. Furthermore, the point of view of the fisherman was essential to collect information from a technical and practical point of view (Prat et al., 2008; Sala et al., 2009).

Figure 51. Grilli Fly. On the left, the model tested in wind tunnel and flume tank; on the right the full-scale otterboard used during the sea trials.

Figure 52. Mori Biplan. On the left, the model tested in wind tunnel and flume tank; on the right the full-scale otterboard used during the sea trials.



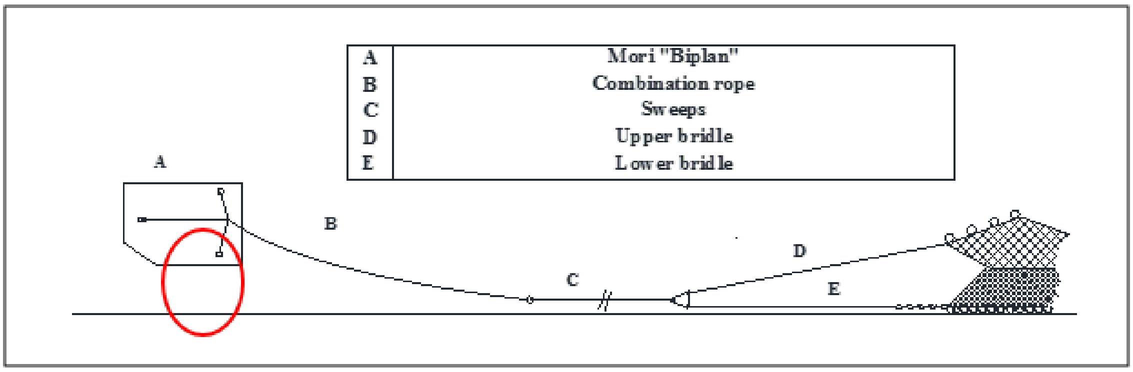


Figure 53. Different configuration and working properties of the two experimental doors. The Grilly "Fly" operates as a proper pelagic door, floating in the water column. The Mori "Biplan" is conceived as a "near-bottom" floating door.

Figure 54. Sea trials on board the commercial fishing vessel. On the left, the Grilli Fly, on the right the Mori Biplan.

Preliminary results

Table 9 and Table 10 show a preliminary report of the results. Each of the experimental doors (i.e. Grilli Fly and Mori Biplan) have been compared with a traditional type. The experimental otterboards improved geo-mechanical performances with respect to their traditional reference doors, with respect to the trawling power demand (TP) which affects directly the fuel consumption (Sala et al., 2011). On the other hand the using the experimental doors reduced net openings have been noticed.
After the first set of tests, SMEs further developed the doors and an updated version has been tested onboard a fishing vessel. Table 10 reports results of such second set of tests. The evolution applied to the doors was able to increase the opening properties of the net, which were comparable among traditional and experimental doors (Notti et al., 2013). In particular, the trawling power was reduced in both cases.

Table 9. Sea trials onboard R/V «G. Dallaporta» – February 2014 (HDS[m] horizontal door spread; HNO[m] horizontal net opening; VNO[m] vertical net opening; TS[kn] trawling speed; TTF[kg] total towing force; G-Ar-Poly and G-Fly: traditional and experimental doors from SME13; M-Z and M-Biplan: traditional and experimental doors from SME14).

Benthis 14.1 - R/V "G. Dallaporta"

	HDS [m]	HNO [m]	VNO [m]	TS [kn]	TTF [kg]	TP [kW]	HDS/TTF [m/kg]	HNO/TTF [m/kg]	VNO/TTF [m/kg]
G-Ar-Poly	57.11	16.03	1.05	3.59	3108	56.25	1.84	0.52	0.03
G-Fly	53.44	13.59	1.36	3.36	2843	48.18	1.88	0.48	0.05
M-Z	61.75	17.42	1.15	3.46	3302	57.60	1.87	0.53	0.03
M-Biplan	48.60	13.35	1.33	3.36	2690	45.55	1.81	0.50	0.05

Table 10. Sea trials onboard fishing vessel – July, 2014. (HDS[m] horizontal door spread; HNO[m] horizontal net opening; VNO[m] vertical net opening; TS[kn] trawling speed; TTF[kg] total towing force; G-Ar-Poly and G-Fly: traditional and experimental doors from SME13; M-Z and M-Biplan: traditional and experimental doors from SME14).

Benthis 14.2 F/V "Orizzonte"

	HDS [m]	HNO [m]	VNO [m]	TS [kn]	TTF [kg]	TP [kW]	HDS/TTF [m/kg]	HNO/TTF [m/kg]	VNO/TTF [m/kg]
G-Ar-Poly	44.06	16.48	0.78	3.71	3566	66.73	1.24	0.46	0.02
G-Fly	59.00	18.59	0.68	3.41	3316	57.04	1.78	0.56	0.02
M-Z	50.90	19.19	0.64	3.57	3455	62.22	1.47	0.56	0.02
M-Biplan	51.01	18.21	0.73	3.58	3415	61.67	1.49	0.53	0.02

Tests of new trawl net design

Novel designs for a bottom trawl net have been selected on the basis of information collected in Task 7.4.1. In particular, an evolution of a selector already tested in Spain by the Spanish company "Tecnopesca" (www.tecnopesca.com/) has been applied on a bottom twin trawl, through an innovative implementation procedure. SME12 provided the implementation of the novel design.
The experiment focused on two different tasks. One task was related to a possible modification in the net design, and the other is related to the net material. A selector device has been implemented on one net of a twin trawl gear, while the other net has represented the reference in terms of geometrical and catch performances.

Furthermore, two sets of selectors have been prepared, with same design: one realized in standard material, the other using Dyneema, in order to evaluate possible influence of the material in selectivity and drag resistance of the net. The same set of trawl nets has been tested with experimental doors from SME13 and SME14.

A representation of the design is reported in Figure 55. One of the twin trawls (A) represents the reference in terms of catches and geometrical and mechanical characteristics such as net openings and drag resistance. The other twin trawl will be used for the implementation of the selector device (B). The selector device consists of two separator panels, which carry the fish near the side panels of trawl net. The side panels along the separator panels will be provided of an escapement window (C) proper mesh size and configuration to guarantee the escapement of juveniles and other unwanted catches. At the end of the separator panels, through two passages (D) fishes will proceed along the net until the codend.

Both the geometrical and mechanical parameters of the fishing gear have been monitored during the sea trials (Figure 56, Figure 57), in particular data of the horizontal door spread, the horizontal and vertical net opening of both the nets, the total towing force of the fishing gear, the fuel consumption and the GPS data. Meanwhile, catches of the two covers have been analysed (Figure 58).

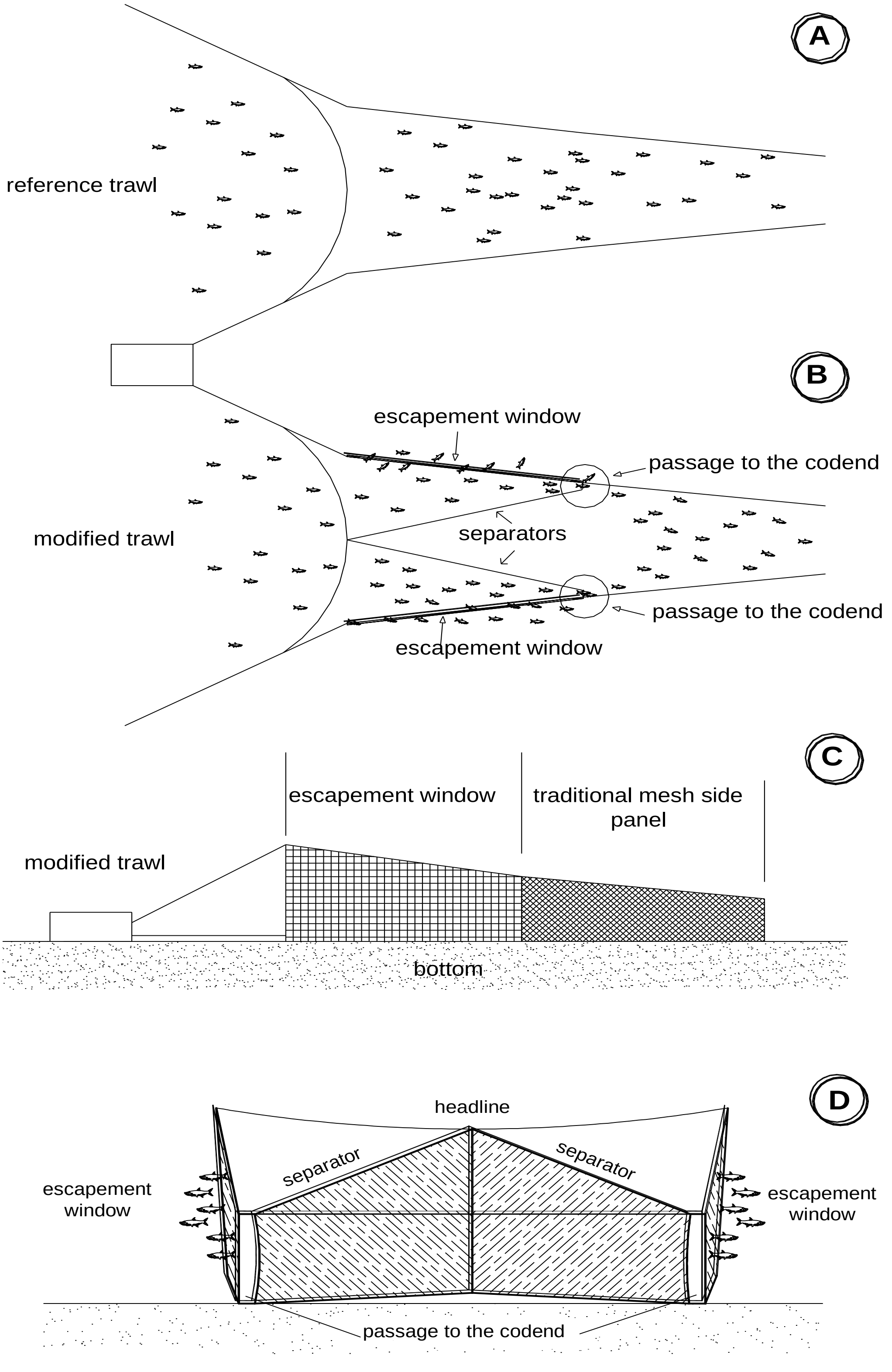


Figure 55. Schema of the test. One of the twin trawls (A) represents the reference in terms of catches and geometrical and mechanical characteristics such as net openings and drag resistance. The other twin trawl will be used for the implementation of the selector device (B). The selector device consists of two separator panels, which carry the fish near the side panels of trawl net. The side panels along the separator panels will be provided of an escapement window (C) proper mesh size and configuration to guarantee the escapement of juveniles and other unwanted catches. At the end of the separator panels, through two passages (D) fishes will proceed along the net until the codend.

Figure 56. Fishing vessel hauling the twin nets.

Figure 57. Gear monitoring system from Simrad. The screen shows the horizontal net opening of the two nets and the vertical net opening of the net with selector.

Figure 58. Catch analysis for both the covers.

Preliminary results

Table 11 reports preliminary results obtained. The comparison between the different material showed, as assumed, a better energy performance of the net made y Dyneema. The overall fuel consumption and the total towing force are as average less for Dyneema net. With respect to the geometrical specifications, no relevant effects could be related to the selector.

Comparing catches and discards (i.e. discard is the fraction of the total catch which was considered as non-commercial), the selector decreased the fraction of discard, in both the net configuration (standard material and Dyneema). While the catch is almost the same, it seemed that the lateral panels evacuated most of the potential discard.

Table 11. Results of the sea trials with the twin trawls. Data are disaggregated by net material, while are pooled by doors. Minimum, maximum, average, standard deviation and median of the most relevant parameter are reported (TS[kn] trawling speed; D[m] depth; FC[l/h] fuel consumption; TTF[kg] total towing force; MI1_TOT[kg] gear drag at the end of the bridles for the net with selector; MI2_TOT[kg] gear drag at the end of the bridles for the net without selector; HNO[m] horizontal net opening; VNO[m] vertical net opening; Catch1 total commercial fraction of the catch of the net with selector; discard1 the amount of discards from the net with the selector.

TRX/TRA

	TS	D	FC	TTF	MI1_TOT	MI2_TOT	HNO1	HNO2	VNO1	Catch1	Discard1	Catch2	Discard2
	[kn]	[m]	[l/h]	[kgf]	[kgf]	[kgf]	[m]	[m]	[m]	[kg]	[kg]	[kg]	[kg]
min	3.45	19.00	66.80	4015	1610	1827	14.41	14.75	0.60	11.59	5.00	11.87	3.40
max	3.77	34.96	75.91	4394	2197	2486	18.85	16.55	0.70	24.21	55.00	69.48	59.00
avg	3.57	22.83	70.53	4249	1940	2172	16.16	15.41	0.65	17.16	18.39	34.26	29.32
st.dv	0.09	4.92	3.06	134	247	239	1.64	0.58	0.04	4.55	15.81	16.82	17.82
Median	3.57	21.30	69.51	4318	1978	2196	16.53	15.33	0.65	15.86	13.50	34.48	26.00

DYN/DYX

	TS	D	FC	TTF	MI1_TOT	MI2_TOT	HNO1	HNO2	VNO1	Catch1	Discard1	Catch2	Discard2
	[kn]	[m]	[l/h]	[kgf]	[kgf]	[kgf]	[m]	[m]	[m]	[kg]	[kg]	[kg]	[kg]
min	3.37	15.70	58.30	3500	1878	1763	15.78	16.38	0.60	11.49	11.50	8.56	4.50
max	3.87	47.60	70.43	4154	1962	2132	18.70	17.40	0.87	24.11	68.00	24.43	111.50
avg	3.65	29.30	67.08	3960	1914	1918	17.28	16.92	0.70	16.03	29.45	16.37	30.30
st.dv	0.15	11.68	3.49	186	31	152	0.94	0.51	0.08	4.48	15.89	4.80	29.93
Median	3.66	28.03	67.82	3977	1906	1943	17.30	16.95	0.70	14.96	28.00	16.93	24.75

Greece: Development of viable alternative fishing methods

The Sea Trials in Greek waters were based around the development for alternative fishing gears that are less damaging to the standard Greek trawl gear in the demersal mixed fishery. This would allow for future possibilities to a) maintain fishing in areas where trawling may be closed with less damaging gears or b) allow fishing in areas not currently fished by trawling because of rough grounds. Two gears were to be investigated:

- The "Norwegian Floated Pot", developed for gadoid fishes, had been seen as an alternative to less selective and/or less environmental friendly methods (nets and trawls). Trials will be carried out in Aegean Sea mixed Coastal Fishery on a muddy ground, 200 m depth, typical hake/shrimp ground and a coarser sediment, 70-90 m depth, typical bream and red mullet ground.
- For crustacean fisheries, information will be collated on existing commercial systems, and trap trials/comparisons will be carried out in the Aegean Sea (mixed shrimp/fish fishery).

For the pot/traps experimental fishing was planned for two periods using replicate long-line trap deployments and video observations. Trials were planned for summer 2014 and spring/summer 2015. To date, for this report the two sets of trials have been completed and an additional trial is planned for early 2016.

Sea Trials

Trials were carried out during two periods, August 2014 and May 2015, in 2 areas in Heraklion Bay, Southern Aegean Sea, representing two different trawl fisheries (Figure 59 and Figure 60).

1. Gournes: the site was approximately 70-90 m depth, characterised by coarse sediments (muddy sand and maerl – 70% sand, 30% mud). Mean annual bottom temperature 16.4 degrees. Fishery characterised by red fish (red mullet, picarel and sparids).
2. Dia Island: approximately 190-220 m depth on a soft silty bottom (70 % sand, 30 % mud). Mean annual bottom temperature 15.4 degrees. Fishery characterised by white fish and shrimp.

Due to poor catches during the first period, sampling was carried out in the second sampling period at additional shallower depths closer to shore in the Gournes area at 30-50 m depth (Figure 60) characterised by coarser sediments.

Fishing Gear

The cod trap was originally developed by the Norwegian institute for oceanic research and later further developed by Carapax (Sweden). The trap is marketed to catch cod, pollock, ling, all kinds of flatfish, but also for catching lobster, prawn (Nephrops) and catfish. The pot is a collapsing design of aluminium frame and nylon netting. The main characteristics are:

- Dimensions 150x100x120 cm (LxWxH)
- Unfloated weight 11 kg
- 2 Chamber (feeding and parlour) collapsible
- Collapsible
- 12 mm aluminium top and middle frame, 14mm hot dip galvanized bottom steel frame
- Twisted twine black nylon netting, approximately 40 mm.
- Detachable nylon mesh bait bag
- Soft monofilament clear mesh entrances, oblong, approximately 30 cm high by 40 cm wide.

The pots were in two configurations (Figure 61); floated to sit on the bottom with two entrances, one at either end or floating just above the bottom on a bridle with one entrance on the downstream side. Main entrances were on the bottom feeding chamber with an entrance into the upper parlour chamber from the roof of the lower chamber. Zips in the sides of both chambers allowed emptying of catch and putting the bait bag in. Salted mackerel was used as bait in the bait bag in the middle of the feeding chamber.

Greek crustacean traps and fish traps (kurtos) were also used in the Spring 2015 trials. The crustacean traps were locally manufactured with a 8 mm rebar metal frame (45x45x25 cm, LxWxH) with hard/fixed plastic square mesh (17 mm diagonal) and two opposite side funnel entrances. These traps are used in Pagasitikos Bay, Northern Greece to target *Nephrops norvegicus* using the same design but 28 mm diagonal mesh. The kurtos are locally commercially available, flat collapsible rounded traps, approximately 50 cm diameter and 40 cm height, with stainless galvanised supports and variable diamond galvanised mesh with a top cone entry (Figure 62).

Operations

Pot long lines were made up of approximately 500 m sinking nylon rope (10 mm) with 10 kg concrete end weights, floating nylon riser and radar reflector top floats. Every 50 m along the bottom line, a loop in the line allowed the pots to be shackled on. Each trap had a chain and shackle (weight) connection to its short bridle. Each line had a total of 10 pots, alternate floating and bottom sitting. During the summer 2014 trials 2 pot long lines were used.

In the Spring 2015 trials one pot long line was used as described above with an additional two smaller trap lines. These two lines had alternate crustacean trap and kurtos traps, 10 of each on each line (20 traps in total on each line) using a 2 m sideline with swivelled long line clips on either end. The clips were attached at one end to the trap and at the other to a loop in the ground rope with 20 m spacing. The bottom line was approximately 300 m in length along the traps with an additional 100 at each end to facilitate shooting.

A power line hauler was used to haul the long lines. Long lines were shot in the morning and allowed to soak for 24 hours, being hauled, catch recorded, re-baited and re-shot the following morning. Prior to first operations the new pots/traps were soaked for a 24 hour period over the side of the fishing vessel in harbour to reduce the ‘new’ smell on the pots. The pots were first dropped in shallow waters to set up the floatation (multiple 0.5 litre low profile ring floats) required for a) the bottom pots to float open, but remain on the bottom and b) the floating pots to float open, but to raise off the bottom in a level manner allowing the main opening to float downstream of the attachment point and bait (Figure 61). A small remotely operated vehicles was also used to observe the pots at 70 m depth again to investigate underwater attitude and was able to see that the traps needed further floatation adjustment (Figure 63). On recovery of the pots, catch was recorded in terms of species, number, length (fish length, cephalopod mantle length, crustacean carapace width of cephalothorax length) and weight.

Camera Observations

Two identical camera systems were deployed on one each of the floating and bottom pot. The systems consisted of a GoPro high definition camera in a deep water housing fixed to a base plate on one side net wall of the trap to view across the feeding chamber, bait and entrance (Figure 64).

The cameras ran with a time-lapse function allowing for 10 minutes recording, 40 minutes off, repeated until the camera batteries finished (4 hours). The cameras had a 15 minute delay function to start recording after deployment to the seabed.

Comparative Fishing

Around the pot and trap deployment areas, trawls were completed in each area, each of approximately 45 minute duration. A slightly smaller version of the standard Greek otter trawl for mixed bottom fisheries was used. Door spread was 17 m and cod end mesh size 40 mm diamond stretch mesh.

Results

During the Summer 2014 trials a total of 20 pots were fished per day, with 4 x 24 hour periods fished in Dia Island and 5x24 hour periods fished in Gournes, with a total of 180 individual pots fished. A total of 10 comparative trawls were also fished.

During the Spring 2015 trials a total of 80 pots, 160 crustacean traps and 160 kurtos were fished with 7 comparative trawls – half the traps and pots fished in the deeper (Dia) and half fished in the shallower areas (Gournes 1, 2 and 3) Most of the trawls were fished in the shallower Gournes sites as bad weather affected the working days in the Dia area and only one trawl could be completed there. Cameras were deployed to make video recordings on 2 pots/traps for each daily deployment in each of the areas.

Some of the operations are shown in Figure 65.

The species caught from the two different areas during the summer 2014 sampling are shown in Table 12 with presence marked either in the floating (F) or bottom (B) pots. In the deeper Dia Island area, 16 species were caught, 9 fish and cephalopods and 7 other invertebrates. Of these the main commercial species were the fish *Phycis phycis*, and *Dentex macrophthamus* and the octopus *Octopus vulgaris*, other species had a minor commercial interest, whilst the small eel-like *Echelus mirus* has no value. Of the invertebrates, only *Parapenaeus longirostris* had a commercial importance. In Gournes only 9 species were caught with 5 fish and cephalopods and 4 other invertebrates. Only the fish *Phycis phycis* and the cuttlefish *Sepia officinalis* had main commercial importance, *Conger conger* and *Muraena helena* have minor local commercial importance whilst all other species would be discarded. In both areas, more species were caught in the bottom pots than in the floating pots. Surprisingly, a few bottom invertebrates were found in the floating pots, but this most probably was during retrieval. All species were retrieved live and in good condition. Most individuals were caught in the bottom feeding chamber with very few in the upper parlour chamber.

The species caught from the different areas during the Spring 2015 sampling are shown in Table 13 with presence marked either in the floating (FP) bottom (BP) pots kurtos (Kr) or shrimp trap (Sh). In terms of area, the lowest numbers of species were caught in the deeper Dia Island area, with higher numbers of species in shallower waters. Of the main commercial species, the sparids *Spondyliosoma cantharus* and *Pagrus pagrus* were caught in the shallower grounds and *Dentex macrophthamus* in the deeper ground. Additionally *Phycis phycis* was recorded only in the deeper ground, but the octopus *Octopus vulgaris* in both shallow and deep areas. *Parapenaeus longirostris* was not caught in the deeper ground with any kind of pot/trap. In both areas, more species were caught in the bottom pots than in the floating pots. Most species were also caught in the bottom fishing Kurtos and shrimp trap with the maximum numbers in the latter.

Overall the catches in the pots and traps were very poor and would seldom exceed the cost of the bait alone. Bait seemed to be consumed very quickly in the shallower areas with the remains of the bait infested with amphipods. In the shallowest 30 and 40 m depth deployed traps the polychaete fireworm *Hermodice carunculata* was also found in high numbers on the bait. This worm is problematic because it has fine needle-like spines containing an irritant and can only be handled with gloves.

In general catch numbers in the pots were generally very low in both areas and for both the floating and bottom pots. Just a few individuals of any species were caught with the exception of some of the invertebrate scavengers which were in higher numbers (hermit crabs *Dardanus arrosor* and *Pagurus* spp. and the echnoid *Cidaris cidaris*). Of the fish, the highest number in Dia Island by far, were 8 individual *Phycis phycis* out a total of 80 pots fished, the next highest was *Conger conger* with 4 individuals. In Gournes the highest number was 6 individual *Sepia officialis* in 100 pots, followed by 3 individual *Muraena helena*.

During the second sampling period, no fish or octopus were caught in the floating pots and only 2 *Muraena helena* in the bottom pot in Gournes, whilst in Dia Island, 2 *Conger conger* were caught in the floating pots and 4 Phycis *blennoides* in the bottom pots. In Gournes the highest total catch in 4 days was 4 *Spicara flexuosa* in the square traps. In Dia Island the total of the 4 day catches of the Kurtos traps were 2 *Dentex macrophthalmus* and one *Conger conger*. There was zero catch in the shrimp traps. Overall catches were extremely poor.

Video Observations

In Dia island observations were to be made for timelapse periods for up to 4 hours after deployment (available battery time), but lighting was very poor at close to 200 m depth limiting observations. Some movement could be detected at times from small individuals that were most likely fish and possibly gobiids within the trap. No large commercial-sized individuals were seen. Video observations were very clear at 70 m depth clear in the Gournes site over the timelapse period after deployment. Two species of small fish were observed, a low number of *Coris julis*, the Mediterranean rainbow wrasse were observed around the bottom close to but not in the trap. Many individuals of the *Spicara* sp., picarel were also observed (Figure 66). Individuals were generally of small size (approximately 10-15 cm length) swam into the pots through the entrance but also through the side wall mesh and occasionally fed on the bait. No individuals were recovered in the pots, although a few *Spicara* were recovered in the traps.

Comparative Trawl Fishing

During the summer 2014 sampling, a total of 5 short trawls were completed in each area in the vicinity of the pot long line deployments. The fish/cephalopod species in the 2 areas are shown in Table 14 with main commercial species highlighted in grey. A total of 64 species were caught with 40 in each of the areas, of which 23 were of high commercial importance (although many other of the non-highlighted by-catch species may also be marketed).

The target fisheries were confirmed by the make up of the trawl catches. Dia Island was characterised by more whitefish whilst Gournes was characterised by red mullets and sparids. A little less than half the species in each area were considered to have high commercial importance although others may maintain a local importance (e.g. *Conger conger* or some of the triglids). Many of the commercial species caught were undersize individuals and would not have been landed. Additionally there was a large catch of commercial invertebrate the rose shrimp, *Parapeaneus longirostris*.

During the spring 2015 sampling, a total of 7 trawls were completed in the 4 areas in the vicinity of the pot long line deployments, 2 in each of the Gournes sub-areas and one trawl in Dia. The fish/cephalopod species in the 2 areas are shown in Table 15 with main commercial species highlighted in grey. A total of 76 species were caught with 40 in each of the areas, of which 22 were of high commercial importance. The totals for the different areas were 43 species in the Gournes 1 (30 m depth), 35 species in Gournes 2 (50 m depth), 25 species in Gournes 3 (90 m depth) and 26 species in Dia Island (220 m depth) – species number generally decreasing with depth. Additionally in Dia Island there was a large catch of commercial rose shrimp, *Parapeaneus longirostris*.

Discussion

The pots used in both seasons and the traps used only in Spring had very low catches both in terms of species and particularly in abundance. This may be due to:

- the traps were not correctly fished
- the traps were not attractive to the local fish community

Correct Fishing

It is believed that the pots and the traps were fished correctly. The pots were new to Greece having been imported from Scandinavia and after trials were finally rigged to perform in the water as designed. Cameras and direct observation were used to check the pots' underwater geometry with adjustments made to ensure that they were properly open and the floating traps were correctly off the bottom with their opening down-stream of the bait. The shrimp traps have been successfully used commercially and experimentally in a number of places in Greece for different species. The square rigid frame with the plastic hard or metal mesh has been a design developed by Greek fishermen. The round kurtos is also a design that is traditionally being used by artisanal fishermen and its use has been explored in a number of other projects for various purposes (unrelated to BENTHIS).

Local Suitability

Whether the pots are suitable in the area is difficult to assess, this may be technically or biologically mediated. Technical unattractiveness may be through, for example, the new traps having a machine smell or processed smell. The traps were soaked for 24 hours prior to first deployment and over the following 10 day use there was no visible increasing trend in catches that may have signalled a change in attractiveness from loss of smell. Biological attractiveness refers to the fish behaviour allowing the fish to enter the trap.

The pots had been designed for northern gadoids and are known to be effective for commercial fishing in northern waters. There was some attraction of some fish to the bait in our trials (observed on video and from catches) – so bait is not the main issue. Salted mackerel is often used in the shrimp/*Nephrops* trapping fishery in other areas, so is not thought to be a major problem. However, the fish attracted were generally small sized fish that could swim in and out of the meshes.

Some larger predatory/scavenging fish were caught in the traps, but in very low, non-commercially viable numbers. It is accepted that not all species will be attracted to, or enter, the pot and not all the species present in pot/trap catches will be caught in the trawl, but in the summer trials in Dia Island only 9 species fish/cephalopods were caught in comparison to the trawl catches of 40 species.

In Gournes this was much less with 5 species of fish/cephalopods in comparison to 40 species from the trawl catches. It had been expected that more sparids besides *Dentex macrophthalmus* would be caught, with another 4 sparid species recorded in the trawl catches. Locally the pots do not seem to be very attractive to the fish and would not seem to perform at a commercial level.

Final trials will be conducted in very different areas to further assess regional suitability. This will include a semi-enclosed shallow (90 m depth) area in central Greece where there is a historic trawling ban and only netting and small scale trapping is undertaken and in a deep water area (400 m) where trawling does not take place.

Ease of Use

The large fish pots were reasonably easy to handle on deck. They required at least two persons for handling when deploying and bringing on board. On board, they took up a relatively low footprint in relation to their deployed size and could be stacked upright or on one side, still needing their complete length and width but having the height reduced from 120 cm to approximately 15 cm. Baiting and catch removal was easy through the zippered side entrances.

The design was quite rugged, and they suffered no hang-ups/damage on the slightly rougher shallower ground in Gournes. Two fish species caught by the traps were the eel like *C. conger* and *M. Helena*, both of which have a degree of danger associated during removal from the pots with them as they are known to inflict bad bites. The more local shrimp trap and kurtos were smaller and much easier to handle on deck in terms of size and baiting. They could be spaced closer on the long line due to their size and ease in shooting and recovery. Line shooting could be handled by one person, but recovery of the traps required two persons.

Continuing Sea Trials.

Final deployments are planned with the fish pots and traps in early 2016, targeting deeper waters (400+ m) in northern Greece and a 90 m shallow area where trawling is currently banned but netting and limited trapping is used for *Nephrops* in central Greece.

Dissemination

The first set of trials were reported in the BENTHIS newsletter and on the BENTHIS Facebook account. In the second trials additional personnel from the coordinating partner allowed extensive documentation for the trials (photo and video) for on-line publication in multimedia: https://www.facebook.com/media/set/?set=a.795609437202300.1073741841.405411256222122&type=3

Three presentations have been made based on data collected during the 2014 trials at the Panhellenic Symposium on Oceanography and Fisheries, in Mytilini, Greece, May 2015:

1. Papadopoulou K.-N., Smith C.J. , Apostolidis, Ch., Karachle, V. 2015. Fish pot trials in the Aegean Sea: first experimental results. 11th Panhellenic Symposium on Oceanography and Fisheries, “Aquatic Horizons: Challenges & Perspectives” Mytilene, Greece. Proceedings Volume: 157-160.
2. Papadopoulou, K-N., Smith, C.J., Apostolidis Ch., Karachle P.K. 2015. Trawled up marine litter, first observations from Heraklion Bay. 11th Panhellenic Symposium on Oceanography and Fisheries, “Aquatic Horizons: Challenges & Perspectives” Mytilene, Greece. Proceedings Volume: 373-376
3. Kapiris, K., Karachle, P.K., Papadopoulou, K.-N. and Smith, C. 2015. *Maja goltziana*: an under-reported species from the Hellenic Seas. 11th Panhellenic Symposium on Oceanography and Fisheries, “Aquatic Horizons: Challenges & Perspectives” Mytilene, Greece. Proceedings Volume: 597-600.

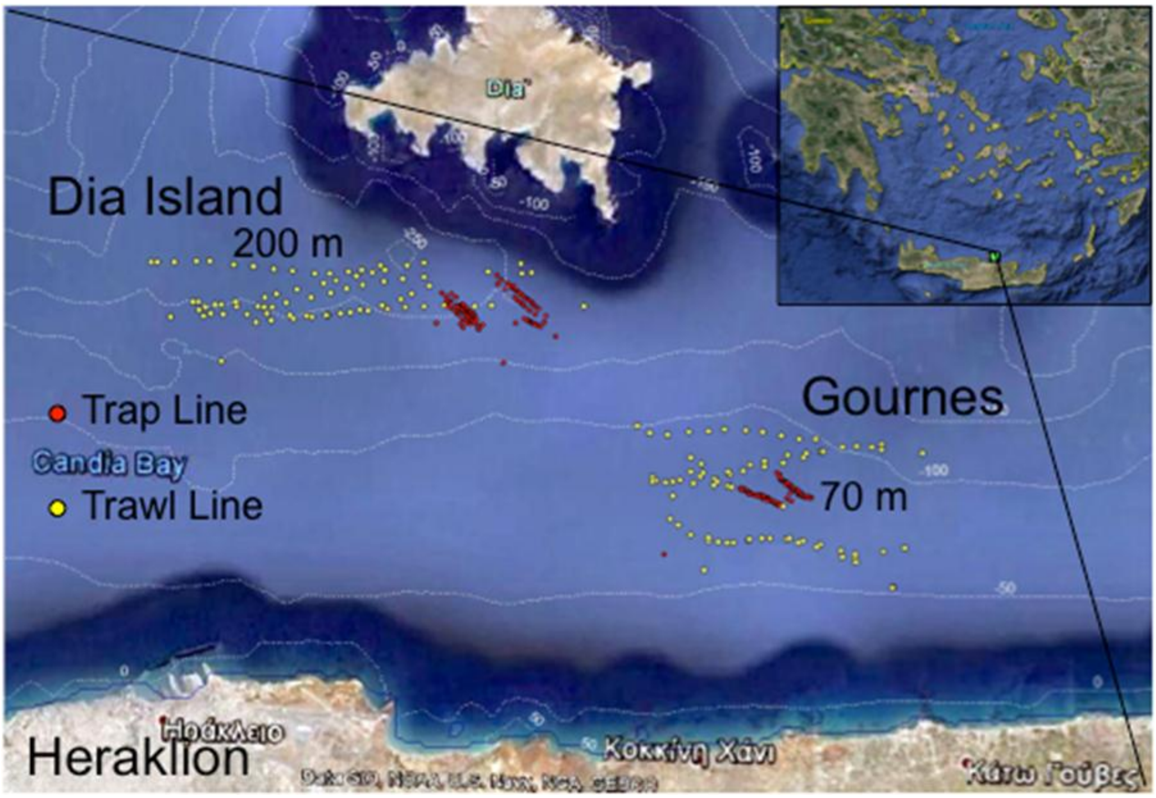


Figure 59. Sampling sites in Heraklion Bay – Gournes and Dia Island, showing positions of fish pot long lines and trawl tracks during the summer 2014 sampling.

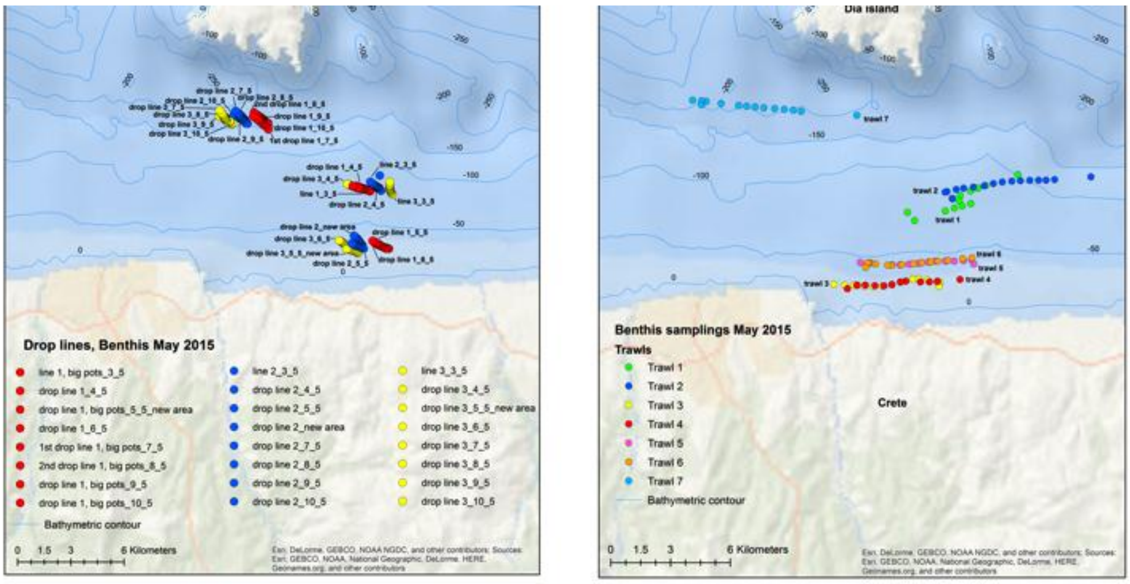


Figure 60. Sampling sites in Heraklion Bay – Gournes and Dia Island, showing positions of fish pot and trap long lines and trawl tracks during the spring 2015 sampling.

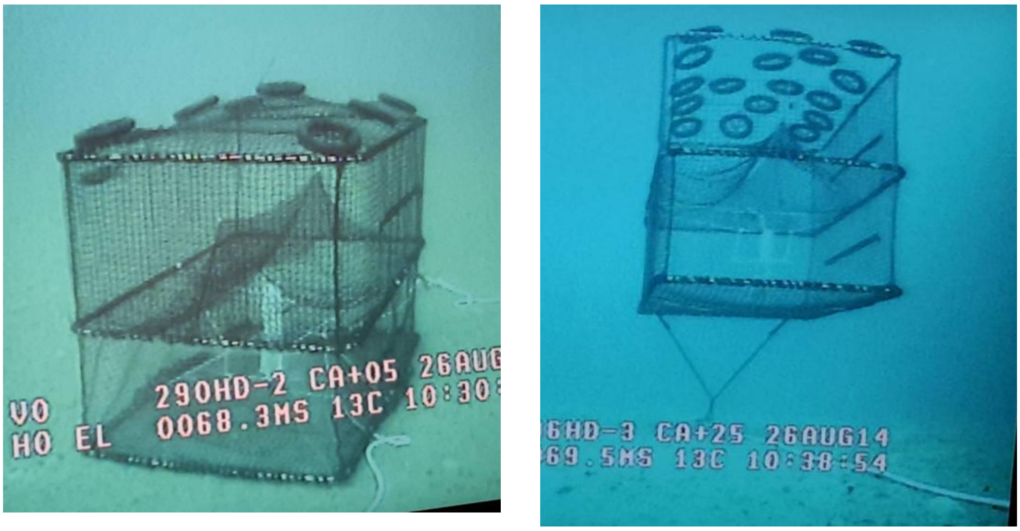


Figure 61. Norwegian cod pot fished in the Aegean in two configurations, on and off the seabed.

Figure 62. Shrimp trap (square trap with plastic mesh) and kurtos (round metal trap) used in the 2015 spring trials.

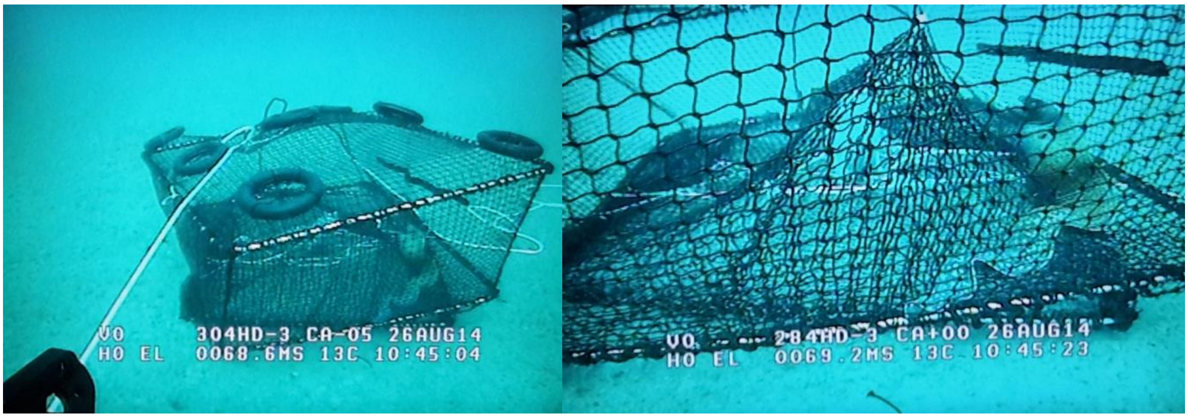


Figure 63. Pots needed observation and adjustment for correct opening – feeding chamber is not open.

Figure 64. Housed GoPro camera on base plate and side wall of a pot.

Figure 65. Images showing operating the fish pots and their catches in Heraklion Bay.

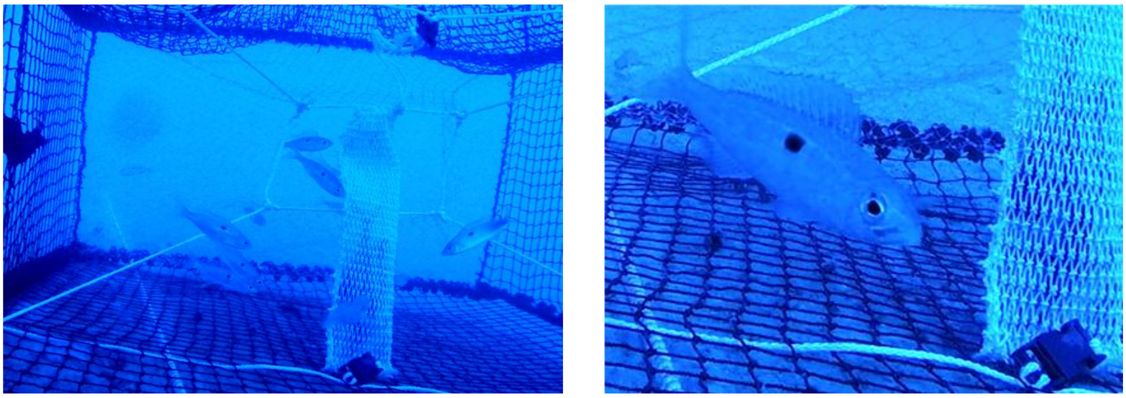


Figure 66. Individual picarel moving in and out of the pots and feeding on the bait.

Table 12. Presence of different species in the floating (F) or bottom (B) pots in the Dia Island and Gournes sampling areas. Commercial species highlighted in grey.

Species list	Taxa	Dia	Gournes
Conger conger	Fish	B/F	B
Murena helena	Fish	B	B
Echelus mirus	Fish	B	
Phycis phycis	Fish	B/F	B
Helicolenus dactylopterus	Fish	B	
Dentex macrophthalmus	Fish	B	
Citharus linguatula	Fish		B
Squalus acanthias	Fish	F	
Raja circularis	Fish	B	
Octopus vulgaris	Mollusca	B	
Sepia officinalis	Mollusca		B/F
Bolinus brandaris	Mollusca		F
Plesionika ensis	Crustacea	B/F	
Parapenaeus longirostris	Crustacea	B	
Homola barbata	Crustacea	F	
Maja crispata	Crustacea	B	
Dardanus arrosor	Crustacea	B	
Pagurus prideaux	Crustacea	B	
Pagurus sp.	Crustacea		B/F
Cidaris cidaris	Echinodermata		B/F
Sphaerechinus granularis	Echinodermata		B
Ophiura texturata	Echinodermata	F	

Table 13. Presence of different species (fish/cephalopods and other invertebrates in the different areas and pots/traps (FP: floating pot, BP: bottom pot, Kr: Kurtos, Sh: shrimp trap). Commercial species highlighted in grey.

	Gournes 90 m				Gournes 30-40 m				Dia Island			
	FP	BP	Kr	Sh	FP	BP	Kr	Sh	FP	BP	Kr	Sh
Muraena helena		X				X						
Conger conger									X	X	X	
Spicara flexuosa			X	X				X				
Spondyliosoma cantharus			X									
Pagrus pagrus				X								
Dentex macrophthalmus										X	X	
Bothus podas								X				
Phycis blennoides									X	X		
Raja asterias										X		
Octopus vulgaris						X		X				X
Dardanus arrosor	X		X	X							X	X
Pagurus sp.		X						X				
Inachus sp.								X				
Macropodia sp.								X				
Bolinus brandaris			X	X			X	X				
Murex trunculus					X	X	X	X				
Apporhais sp.			X									
Cidaris cidaris			X	X			X					
Sphaerodiscus placenta		X		X								
Chaetaster sp				X								
Ophiothrix fragilis				X								
Hermodice carunculata						X	X	X				

Table 14. Trawl caught species in Dia Island (220) and Gournes (90 m) around the trapping areas. Commercial species highlighted in grey.

Species	Dia	Gournes	Species	Dia	Gournes
Fish			*Serranus hepatus*		X
Argentina sphyraena	X		*Solea solea*		X
Arnoglossus laterna	X	X	*Spicara flexuosa*		X
Arnoglossus rueppelii	X		*Spicara smaris*		X
Arnoglossus thori		X	*Synodus saurus*		X
Aspitrigla cuculus	X		*Trachinus araneus*		X
Blennius ocellaris		X	*Trachinus draco*		X
Boops boops	X	X	*Trachurus mediterraneus*	X	X
Bothus podas		X	*Trigla lucerna*		X
Callanthias ruber	X		*Trigloporus lastoviza*		X
Capros aper	X		*Uranoscopus scaber*		X
Centracanthus cirrus	X		*Zeus faber*	X	X
Cepola macrophthalma		X			
Citharus linguatula	X		**Elasmobranchs**		
Conger conger	X		*Oxynotus centrina*	X	
Dentex macrophthalmus	X		*Raja circularis*	X	
Dentex maroccanus	X	X	*Raja clavata*	X	
Diplodus annularis		X	*Raja miraletus*		X
Gobiidae	X	X	*Raja polystigma*	X	
Helicolenus dactylopterus	X		*Rodentiola* sp.	X	
Lepidotrigla cavillone	X	X	*Scyliorhinus canicula*	X	
Lepidotrigla dieuzeidei	X		*Squalus acanthias*	X	
Lesueurigobius suerii	X		*Torpedo marmorata*	X	
Lophius budegassa	X	X			
Macroramphosus scolopax	X		**Cephalopoda**		
Merluccius merluccius	X	X	*Alloteuthis media*	X	X
Microchirus ocellatus		X	*Eledone moschata*	X	X
Mullus barbatus		X	*Illex coindetii*	X	X
Mullus surmuletus	X	X	*Illex* sp.	X	X
Myliobatis aquila		X	*Loligo vulgaris*	X	
Pagellus acarne		X	*Octopus vulgaris*	X	X
Pagellus erythrinus		X	*Sepia elegans*	X	X
Phycis blennoides	X		*Sepia officinalis*		X
Scorpaena loppei	X		*Sepiola* sp.		X
Serranus cabrilla		X			

Table 15. Trawl caught species in Dia Island (Di=220 m depth) and extended Gournes areas (G1-30 m, G2=50 m, G3=90 m depth) around the trapping area. Commercial species highlighted in grey.

Species	Di	G1	G2	G3	Species	Di	G1	G2	G3
Argentina sphyraena	X				*Sardina pilchardus*				X
Arnoglossus laterna		X	X	X	*Sardinella aurita*			X	
Arnoglossus rueppelli	X				*Sepia officinalis*		X	X	
Arnoglossus thori		X	X	X	*Serranus cabrilla*		X	X	X
Aspitrigla cuculus	X				*Serranus hepatus*		X	X	X
Blennius ocellaris			X	X	*Siganus rivulatus*		X		
Boops boops		X	X		*Sphyraena rivulatus*	X			
Bothus podas		X	X		*Spicara flexuosa*		X	X	X
Capros aper	X				*Spicara maena*	X			
Centracanthus cirrus	X				*Spicara smaris*		X	X	X
Cepola macrophthalma				X	*Spondyliosoma cantharus*		X		
Chlorophthalmus agassizi	X				*Stephanolepis diaspros*		X	X	
Chromis chromis		X			*Symphodus cinereus*		X		
Citharus linguatula	X		X	X	*Symphurus nigrescens*		X		
Conger conger		X	X		*Syngnathus acus*		X		
Dactylopterus volitans		X			*Synodus saurus*		X	X	
Diplodus annularis		X	X		*Trachinus draco*			X	X
Epinephelus aeneus		X	X		*Trachurus trachurus*	X			
Gobius niger		X	X		*Trigla lucerna*		X	X	
Helicolenus dactylopterus	X				*Trigloporus lastoviza*		X	X	X
Hippocampus guttulatus		X	X	X	*Uranoscopus scaber*		X	X	X
Hippocampus hippocampus		X		X	*Zeus faber*		X	X	
Labridae		X							
Lepidorhombus whiffiagonis	X				**Elasmobranchs**				
Lepidotrigla cavillone	X	X	X	X	*Dasyatis pastinaca*		X		
Lepidotrigla deuzeudei	X				*Raja clavata*	X	X		
Lesueurigobius suerii	X				*Raja miraletus*				X
Lithognathus mormyrus		X			*Myliobatis aquila*			X	
Lophius budegassa				X	*Torpedo nobiliana*	X			
Macroramphosus scolopax	X				*Oxynotus centrina*	X			
Merluccius merluccius	X		X						
Microchirus ocellatus		X			**Cephalopoda**				
Microchirus variegatus				X	*Eledone moschata*	X			X
Monochirus hispidus		X	X		*Octopus vulgaris*	X	X	X	X
Mullus barbatus		X	X	X	*Sepia elegans*	X	X		
Mullus surmuletus		X	X	X	*Sepia officinalis*		X	X	
Pagellus acarne		X	X		*Sepia orbignyana*				X
Pagellus erythrinus		X	X	X	*Sepiola sp.*	X			
Pagrus pagrus		X			*Loligo vulgaris*			X	
Phycis blennoides	X				*Illex coindetii*	X			

BLACK SEA

Introduction

The impact of bottom dragging nets (algarna and bottom trawls) which were widely used along the southern Black sea littoral, on the benthic ecosystem have been investigated during marine surveys held in 2013. In 2014, sea trials were undertaken in order to test different options for mitigation of impacts. Three different trial studies were planned for three fishing gears (pots, algarna and bottom trawl).

The problems identified and solutions suggested for the mitigation of the impact on benthic ecosystem discussed in RSE1 (Trabzon 30.04.13 - WP8) were the major directives in planning the sea trials. The options for mitigation of benthic ecosystem impacts included:

- Trials of passive gear designs (pots) in sea snail fishery,
- Modification of the algarna;
  - use of sledges instead of traditional shoes to decrease drag
  - removal of steel wires between the shoes
  - measurements for fuel savings
- Selectivity studies to reduce the discard rate by modification of the fishing net in terms of mesh size and design in the bottom trawl fishery (targeting red mullet and whiting).

Trials of pot/trap for sea snail fishery

The sea snail fishery along the near-shore waters of the Black Sea has two kinds of negative impact on the benthic ecosystem; (1) physical disturbance on the sea bottom affecting benthic infauna, (2) discarding of non-target species including bivalves and juvenile fish (D7.6). The trails objective was to firstly test a passive fishing method using pots instead of the algarna and secondly, to make some modifications in the design of the algarna such as the inclusion of sledges instead of conventional shoes and the removal of steel wires between shoes in order to reduce drag.

Materials and Methods

It was decided to test a pot design conventionally used in South Korea. Using fresh bait the pot is known to reduce by-catch by 80 %. Typically a South Korean fisherman may operate with 200 pots on-board. After deploying the pots for three days, typical catches are 3-5 kg per pot baiting with live mussels. The pot has an opening near the bottom edge allowing the sea snails to creep into the pot. The pots are collapsible providing great easiness in carrying and storage. The 28 trail pots were produced by a fisherman in Yakakent financed by SME16- Sadıklar Fishery (Figure 67).

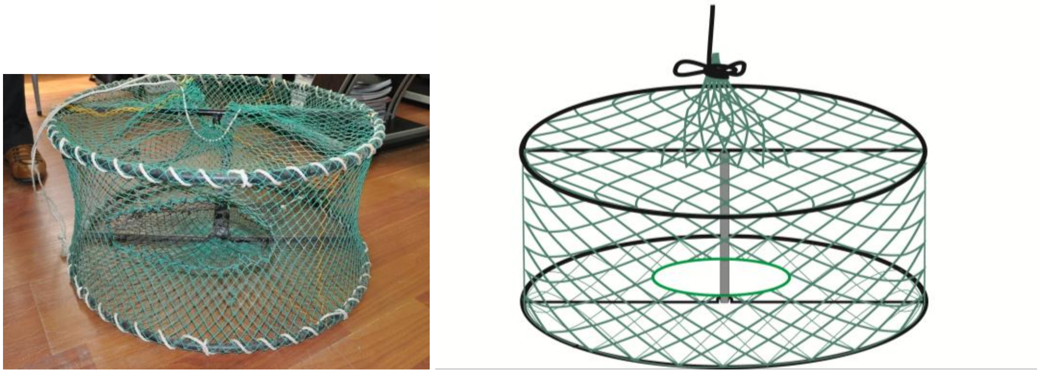


Figure 67. The pots used in sea snail fishery in southern Korea (provided by SMS Mustafa Sadıklar from Korea as a sample).

Summer surveys (July, 2014)

The first trials were undertaken at two different stations where the intense fishery is located. The first station (Dereköy) has a sandy substrate and the second station (Costal) has a sandy-mud substrate representing the general substrate type of the Samsun Shelf Area (SSA) (Figure 68).

In Dereköy, 15 pots were fished and 13 in Costal. Each pot was joined to the bottom line (150 m length) with 1 m thinner ropes with 10 m intervals between pots. *Mytilus galloprovincialis* were collected from the same locality by diving 5-6 large individuals packed into a transparent nylon sock to hang on the inside upper part of each pot. Additionally, a few individuals were left free on the bottom of pots to observe the response of sea snail to the live bait (Figure 69).

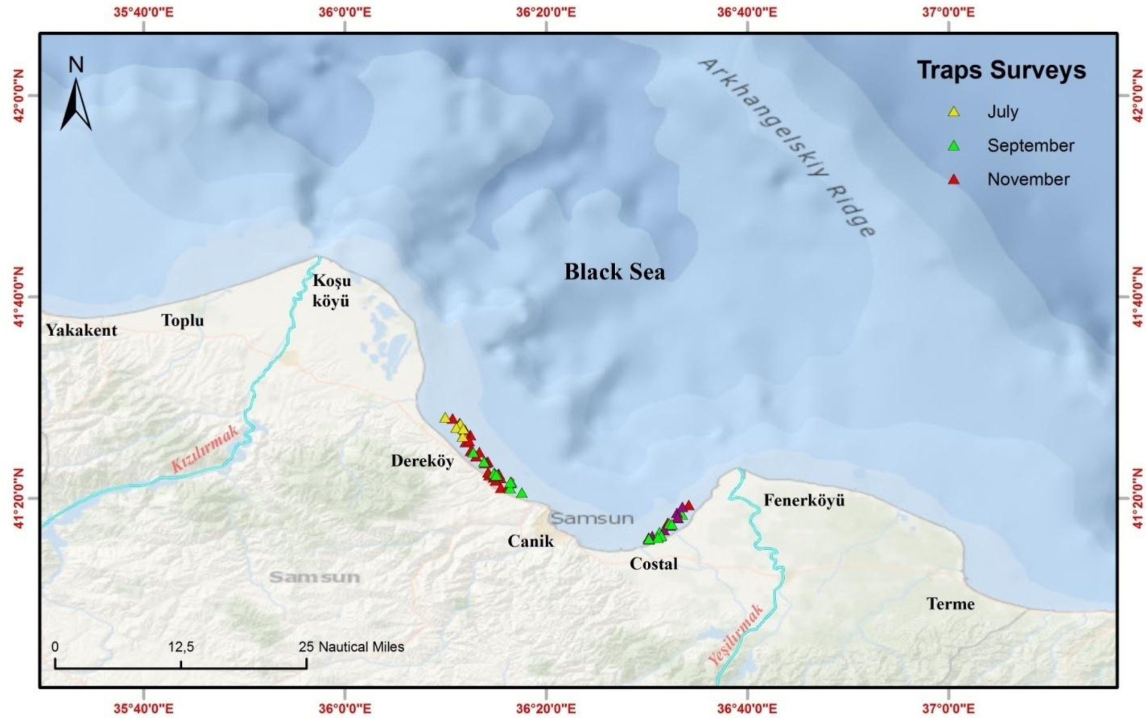


Figure 68. Station locations for sea snail pots trials in the Dereköy and Costal localities in the SSA in the summer (July, 2014) and autumn (September and November, 2014) sampling periods.

Pots were deployed at depths of 5.5-8.3 m, parallel to the coast line in an east-west direction for durations of 24, 48 and 72 hours (Figure 70). The positions of pots and their contact with the bottom were observed by a diver to note any problems (Figure 71). The pots on the sea bottom were checked and recorded with a underwater camera (Figure 72). At the end of operation deployments all pots were retrieved and the amount of catch were recorded (Figure 73).

At the Dereköy station, trials were undertaken by placing a total of 20 rapa, 10 of small size (5-6 cm in length) and 10 of larger size (8-10 cm) in each pot at release. The aim was to observe the behaviour of the rapa. The objective was to observe if the individuals inside the pots move outwards or repel other individuals from entering. At the end of operation, 5 individuals were still in the pots and the others had moved out. Furthermore, egg capsules were observed over the iron frame and net at the top of pots (Figure 74). The rapa are therefore capable of moving over the net material.

Autumn surveys (September-November, 2014)

After fixing some deficiencies in pot designs (openings of the pots were tied to the central axis to prevent them turning inside-out as happened during the summer trials), a second set of trials was held in September and November 2014 after the spawning period. Trials included three day (72 hours) pot deployments in one station (Dereköy).

The pots were deployed a half mile north of port at the depth of 7 m. Although not a very productive period, the rapa fishery is still active in the area at this time. Baiting was the same as the summer. By the end of the trials it was noted that catches were again very low and the fishery by pots had not been very satisfactory (Figure 75 and Figure 76). The modifications to the trap openings ahd been successful (kept to the side), but this did not allow for an increase in catch.

Results

Summer surveys

The pot trials in July 2014 did not produce satisfying amounts of catch. The probable causes of the failure in functionality of the pots were discussed by researchers and experienced fishermen and included the following issues.

- It is argued that the main reason may be the design of pots especially the position of the openings. It is observed in the first trials that all openings or at least one of them among 10 of 15 pots turned inside-out in water (Figure 74).
- The pot model that had been brought from South Korea had three openings and the tip of these openings was tightly tied to the central axis of the pot. The pots produced in SSA were somewhat different from this model. The material used in construction of the net at the openings was thick and bright in colour. Furthermore, the openings was not tied to the central axis and turned inside-out in the water. These may be the major handicaps causing low catches.
- The pots used in a sea trial at Yakakent in June 2014 had a different mesh size and mesh number when compared to the prototype.
- In some pots, some mussels were left free on the bottom instead of the bait bag tied at to the central axis. At the end of operations it was observed that all mussels had been preyed upon and the empty shells remained. However, no rapa individuals were observed inside the pots. This means the rapa were able to escape the pot after consuming the mussels.

- All these issues indicated that it is necessary to repeat the sea trials after modifying the pots.
- In further trials, it would be useful to attach an underwater camera to the pots to observe individual rapa behaviour to observe how rapa use the openings of pots and feed on the prey.
- The major reason for the failure in the catch of rapa by pots may be related to the low period of feeding of this organism. The maximum rapa catch is obtained in July in the SSA and this period coincides with the reproduction period of rapa. At this time rapa individuals move to nearshore waters and remain on the sea bottom (not buried in the sand). Although the high mobility of rapa individuals related to reproduction in this period, it is expected that they enter the pots with high frequencies. However, they also reduce food intake or totally stop feeding while they are spawning. It is thought that the prey is not attractive for rapa individuals in this spawning period.
- By August, spawning activity slows down and generally finishes. The individuals begin to feed intensely again to compensate for their low physical condition. It may therefore be expected that individuals are attracted to the prey in pots. The fishermen also suggested using the pots during the post spawning period. These suggestions should be tested with additional sea trials.
- When compared to the pot fishery in South Korea, it is known that the rapa fishery is not active during the summer period in that region. They generally start fishing in the second half of August. The spawning period is the same as in the Black Sea region and rapa individuals are possibly reluctant to feed in this period. There is no management ban on rapa fisheries in order to protect the stock in this spawning period.

Autumn surveys

The CPUE values from the pot fishery trials in the summer and autumn surveys are presented in Table 16. A total catch of 1525.2 g (26 individuals) was recorded during ten days of operation in the summer trials. In one of the stations (Dereköy, 48 hours deployment) no catch was was observed from any of the 15 pots. The average catch per day (24 h) and per pot for summer trials was estimated at 21.5 g. In autumn trials, catches were lower and at the end of 6 days only 294.9 g (3 individuals) was caught. CPUE was estimated at 4.9 g/pot/day for this period. However, the by-catch was composed of 18 different species including 6 species of bony fishes, 8 species of crustaceans, 3 molluscan species and one tunicate (Table 16).

The reasoning behind the to repeat pot trials in autumn (September and November) was the thought that rapa spawns in summer and were not attracted to the prey in the pots. It was expected that rapa would show more interest in the bait when spawning was over and the food requirements increased. However, there was no change in the amount of catch in autumn, and this would make the gear less likely to be accepted by fishermen as an alternative fishing gear.

Different factors may have been behind the low pot catches including the burial behaviour of rapa in sand. It is known that there are bottom currents bringing colder water to the SSA at the depths where rapa lives. Rapa generally live buried in sand except during spawning and feeding. Pots may be more effective in use in very shallow and semi-enclosed bays that are not affected by bottom currents.

Conclusion

In conclusion, no success was obtained in the trials for the use of pots in sea snail (rapa) fishery as an alternative gear in order to mitigate the fishery impact on benthic habitat. The efficiency of fishing and the catch amount was not satisfactory for the commercial fishing activity. To take the pots further, additional studies should cover (a) feeding-spawning and migration behaviours and their seasonal variations, (b) bio-ecological features of the sea snail should be taken into account in design of pots and arrangements for fishing operations.

Figure 69. Sea trials for sea snail fishery at Dereköy Portin 16 June, 2014. (1) The pots for sea snail fishery (a set of 15) (2) The live bait, Mediterranean mussel were collected from moles in the port (3-4) Mussels were placed in nylon socks and tied inside the top of the pots.

Table 16. Sampling details for rapa fishery pot trials, completed at SSA stations in summer and autumn 2014.

Survey No	Starting day	Finishing date	Operation time (hour)	Location	Average Depth (m)	Substrate type	Flow direction	Number of pot	Catch (number-weight, g)	
									target Rapa	By-catch species
1	16.7.14	17.7.14	24	Dereköy	7.8	Sandy	Mid level: to west	15	1-121.7	*-L. depratur (36-457.1)* *-C. aestuarii(7-872.41)* *-B. sexdentatus (16-21.1)* *-A. cornea (1-17.7)* *-P. elegans (1-2.4)*
2	17.7.14	20.7.14	48	Dereköy	8.2	Sandy	Mid level: to west	15	-	*-S. porcus (8-390.4)* *-P. tentacularis (1-7.1)* *-L. depuratur (19-241.9)* *-E. verrucosa (4-536.1)* *-N. reticulates (3-5.84)* *-A. cornea (1-10.0)*
3	20.7.14	24.7.14	72	Dereköy	5.5	Sandy	Mid level: to west	15	16-922.8	*-P. tentacularis (2-7.4)* *-L. depratur (12-140.4)* *-C. aestuarii(2-173.6)* *-B. sexdentatus (2-2.2)* *-A. cornea (1-2.3)* *-P. elegans (9-19.9)* *-C.crangon (7-20.3)* *-P. hirtellus (2-8.8)*
4	18.7.14	19.7.14	24	Costal	8.3	Sandy-muddy	Mid level: to west	13	7-306.6	*-H. Hippocampus (9-15.0)* *-L. depratur (20-287.1)* *-C. aestuarii(4-433.1)* *-B. sexdentatus (5-5.2)* *-C. gallina (6-14.3)* *-N. reticulates (2-5.6)* *-D. pugilator (18-4.9)*
5	19.7.14	23.7.14	72	Costal	8.0	Sandy-muddy	Mid level: to west	13	2-174.1	*-S. smaris (1-67.7)* *-H. Hippocampus (7-10.6)* *-L. depratur (21-263.9)* *-C. aestuarii(7-632.4)* *-B. sexdentatus (5-6.0)* *-C. gallina (10-31.0)* *-N. reticulates (4-10.4)* *-D. pugilator (18-7.2)*
6	17.9.14	20.9.14	72	Dereköy	7.8	Sandy	High level: to east	10	1-139.0	*-S. porcus (1-70.0)* *-C. aestuarii (34-3719.2)* *-C. gallina (2-5.3)* *-Ascidia (1-7.5)*
7	11.11.14	14.11.14	72	Dereköy	7,8	Sandy	High level: to east	10	2-155.9	*- M. batrachocephalus (1-85.3)* *-G. niger (2-28.2)*

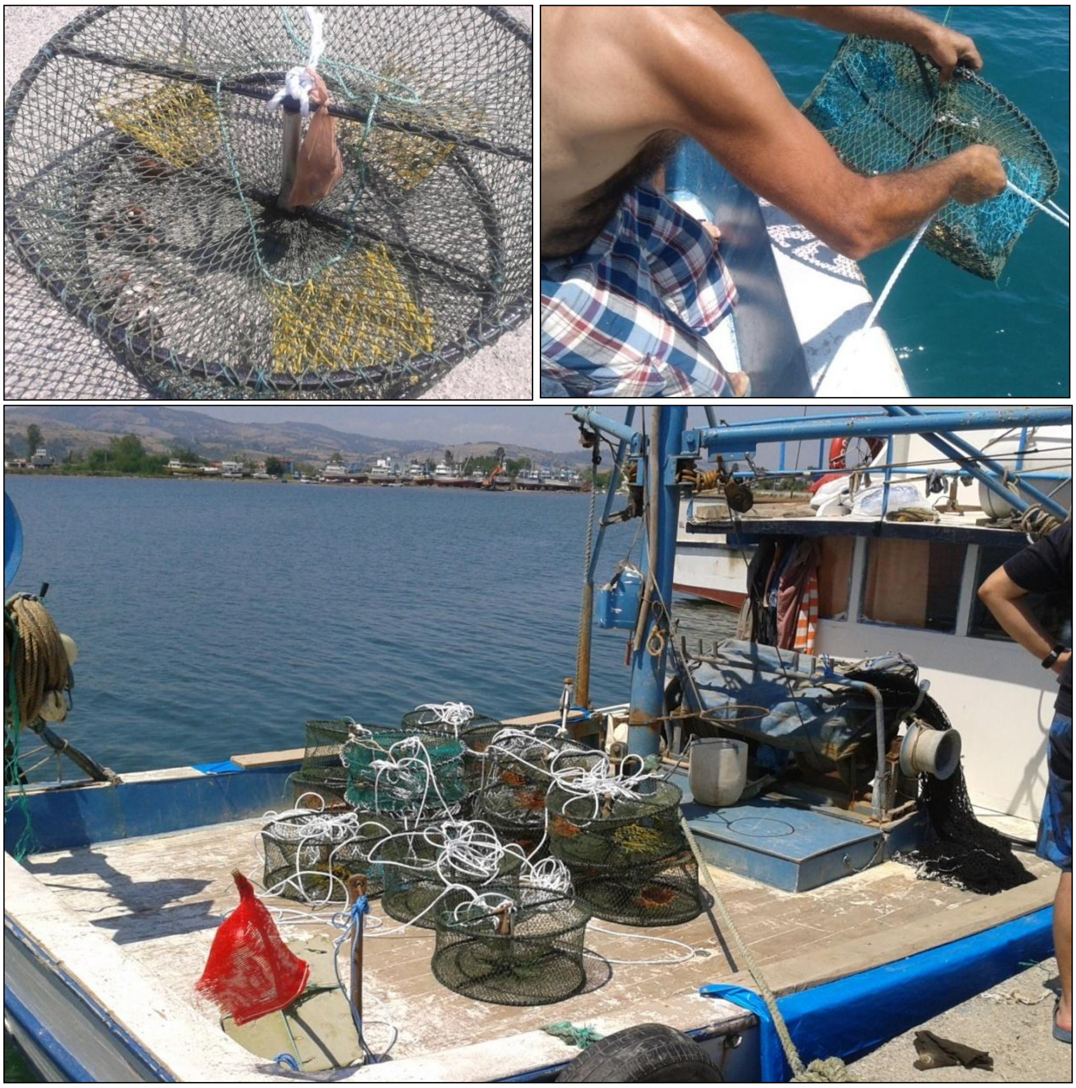


Figure 70. A pot with the live bait; pots on board ready for deployment; and pot deployment to the sea bottom around depths of 7-8 m.

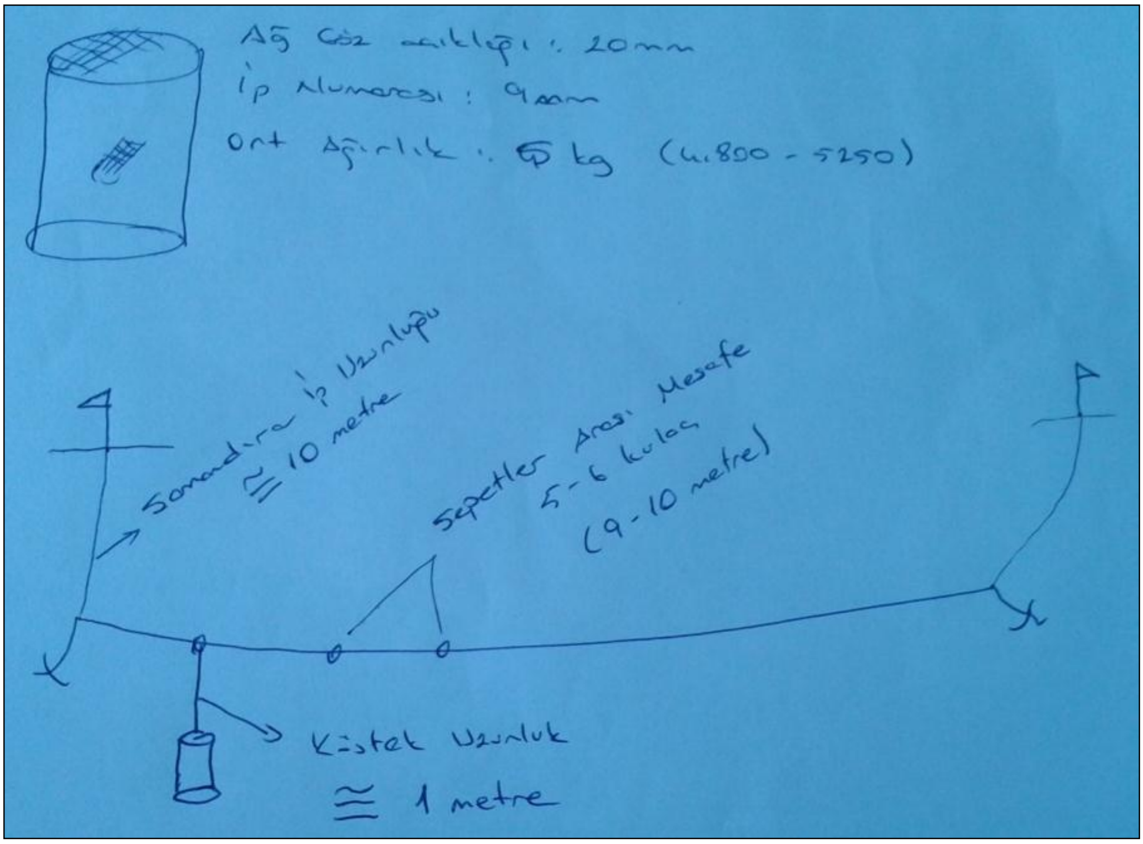
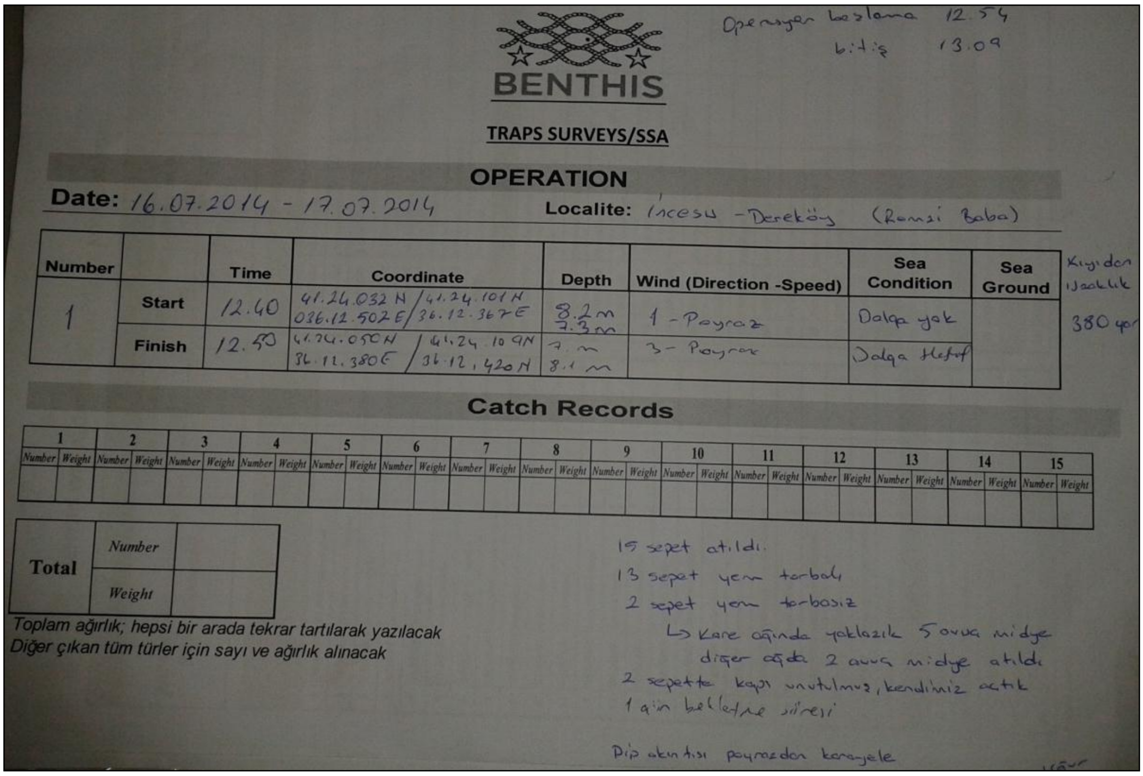


Figure 71. The schematic diagram for pot long-lines.

Figure 72. The pots at the sea bottom (16.06.14, Dereköy Port; east side).



Operasyon başlama 12.54
bitiş 13.09

BENTHIS

TRAPS SURVEYS/SSA

OPERATION

Date: 16.07.2014 - 17.07.2014 Localite: İncesu - Dereköy (Remzi Baba)

Number		Time	Coordinate	Depth	Wind (Direction -Speed)	Sea Condition	Sea Ground
1	Start	12.40	41.24.032 N / 41.24.101 N 036.12.502 E / 36.12.367 E	8.2 m 7.3 m	1 - Poyraz	Dalga yok	
	Finish	12.50	41.24.050 N / 41.24.109 N 36.11.380 E / 36.12.420 N	7 m 8.1 m	3 - Poyraz	Dalga Hafif	

Kıyıdan uzaklık 380 m

Catch Records

1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	
Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight

Total	Number	
	Weight	

Toplam ağırlık; hepsi bir arada tekrar tartılarak yazılacak
Diğer çıkan tüm türler için sayı ve ağırlık alınacak

15 sepet atıldı.
13 sepet yem torbalı
2 sepet yem torbasız
↳ Kare ağında yaklaşık 5 avuç midye
diğer ağda 2 avuç midye atıldı
2 sepette kapı unutulmuş, kendimiz açtık
1 gün bekletme süresi
Dip akıntısı poyrazdan karayele

Figure 73. The recording forms used in pot trials.

Figure 74. The pots on board after operation. The openings turned inside-out and the egg capsules laid on the net material (19 July, 2014, Costal).

Figure 75. Mediterranean mussels collected in port by diving to be used as live-bait in the pots. 2: The live-baits were tied in small net bags and hung at the top of pots inside. 3-4:Pots ready on board to leave at sea bottom.

Figure 76. The pots taken on board in the Dereköy station. Left: Mesogobius *batrachocephalus* by-catch in one of the pots. Right: A rapa whelk attached to the bag of bait and feeding on mussels inside the pot.

Gear Modifications in Algarna (Beam Trawl)

A two-stage study was carried out using the 'traditional beam trawl', a fishing gear used and developed since the 1980's by local fishermen in SSA and the other sea snail fishing areas in the Black Sea. The stages of the study were; (1) the potential reduction in physical and biological impact on the benthic habitat, (2) the extent of fuel savings that could be reached by the fishermen.

Towards these aims, data collected from traditional and modified gears were compared in terms of the amount and composition of by-catch species, the size frequency distributions and CPUE values of the target species, and from measurements of fuel consumption.

Materials and methods

In this context, structural changes were made to the traditional beam trawl. Firstly, a 'sledge system' was designed to replace the regular shoes to reduce the physical impact on the substrate. Secondly, a structural and an operational change was undertaken to the "steel wire" stretching between the shoes at the mouth of the gear which scrapes the seabed while the gear is working.

The structural modification was to attach the steel wire to the claw of the shoes at a height of 0.5 cm, to reduce the penetration depth in the seabed. The steel wire stretched between shoes of the beam trawl is functional, in taking out the rapa whelk individuals from the sand where they are buried. The steel wire in the traditional beam trawl has a penetration depth of 5.0 cm along the whole mouth of the gear and cause an important physical disturbance. The operational change to the modified gear with sledges was to remove the steel wire completely from the gear.

The fishermen have the steel wire in traditional gear fixed with a penetration depth of 5.5 in Costal, Fenerköy and Terme (eastern stations) localities that have a sandy-muddy substrate type. However, the fishermen operating in Dereköy, Bafra and Toplu (western stations) fix the steel wire with 1.5 cm distance to the claws of shoes.

Experimental surveys regarding the traditional and the modified beam trawls were carried out in two different localities having different type of substrates. Dereköy station has a sandy substrate and Coastal station has a sandy-muddy bottom type (Figure 77). Surveys in Dereköy Port were conducted with a sea snail fishing boat ('Remzi Baba', 11.3 m in length and 135 HP engine power, owned by İsmail Özdemir). In Costal, another sea snail fishing boat was used ('Two brothers-2', 11.6 m in length, 185 HP engine power, owned by Cemal İş).

The structural design of the modified gear and the dimensions of the sledge part is shown in Figure 78. The width and height of the mouth (the frame length) are 297 cm and 15 cm, respectively. The thickness of the steel wire 8 mm, height of the beam 120 cm, radius of the beam conduits 32-42 mm, width of the sledges 15 cm and mesh size of the net 72 mm. The total weight of a beam trawl is about 45-50 kg including ropes, pallettes and drawchains, steel rope, dry net material and the cover bag.

The gear trials were made at depths around 7-8 m in the same area as the the pot trials. The operations were standardized to 30 min tow durations. The catches on board were classified into target and by-catch species and the total weights were recorded on survey forms. In total 53 hauls were undertaken with the details of the operations presented in Table 17.

The comparisons between the modified and traditional gear in two localities were based on two operational designs; 1) Sledges with steel rope (modified) versus traditional gear and 2) Sledges without steel rope (modified) versus traditional gear (Table 17, Figure 77). The modified and traditional gear was used at the same operations hauling in parallel.

- Trials of Sledges with steel wire: In total 28 operations were realized in both stations (Table 17). In this modified gear design, the steel wire attached to the claws of shoes was at a distance of 0.5 cm (Figure 78 and Figure 79). This modified gear was compared to the traditional gear where this steel wire joined the claws at a distance of 5.5 cm. This type of gear (clawed shoes) is preferred by fishermen for use in sandy localities (Figure 80).
- Trials of Sledges without steel wire: In total 25 operations were realized in both Dereköy and Costal stations (Table 17). In this trial, the steel wire stretching along the mouth of the gear and scraping the seabed was removed. This modified gear was also tested against the traditional gear where the steel wire joined the claws at a distance of 5.5 cm (Figure 81).

Fuel consumption

A series of experimental studies were conducted for the comparison of fuel consumption when using modified and traditional gears, during the same period and in the same localities. During the study period a fuel meter was not available so measurements of fuel consumption were attempted in a rough practical way, using multiple 10 L fuel containers weighed before and after operations.

The speed of the boat was kept constant at 2.2 knot for all operations. Fuel consumption was tested on 4 different operational designs. In two of the operations sledges were tested by hauling with and against the current direction. In the other two operations the traditional beam trawl was tested with and against the current direction. Fuel consumption was recorded during each operation. At the end of the operations, for a more precise weighing, the fuel containers were weighed on land.

The operation duration was kept constant at 20 min. for all operations. While testing the fuel consumption for both the modified and traditional beam trawl, the variables of depth, hauling direction, speed, duration were kept constant and coordinates noted. All operations were all undertaken using the same boat. A total of 16 operations were undertaken and the catch obtained in operations were recorded.

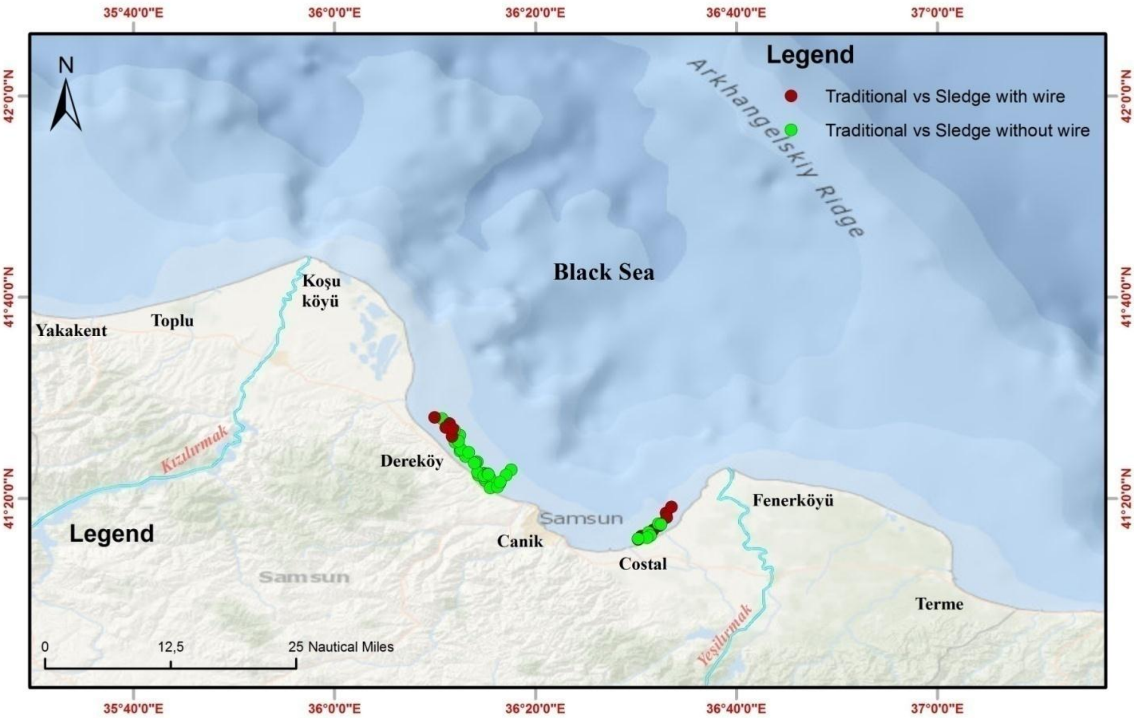


Figure 77. Study area. Dereköy and Costal localities in Samsun Shelf Area with the stations for experimental surveys for the trials of the modified beam trawls on summer (July) 2014 period.

Figure 78. The modified beam trawl produced in Dereköy industrial plants. The modification; the shoes replaced by a sledge of 15 cm width and the steel wire attached to the claw at 0.5 cm distance.

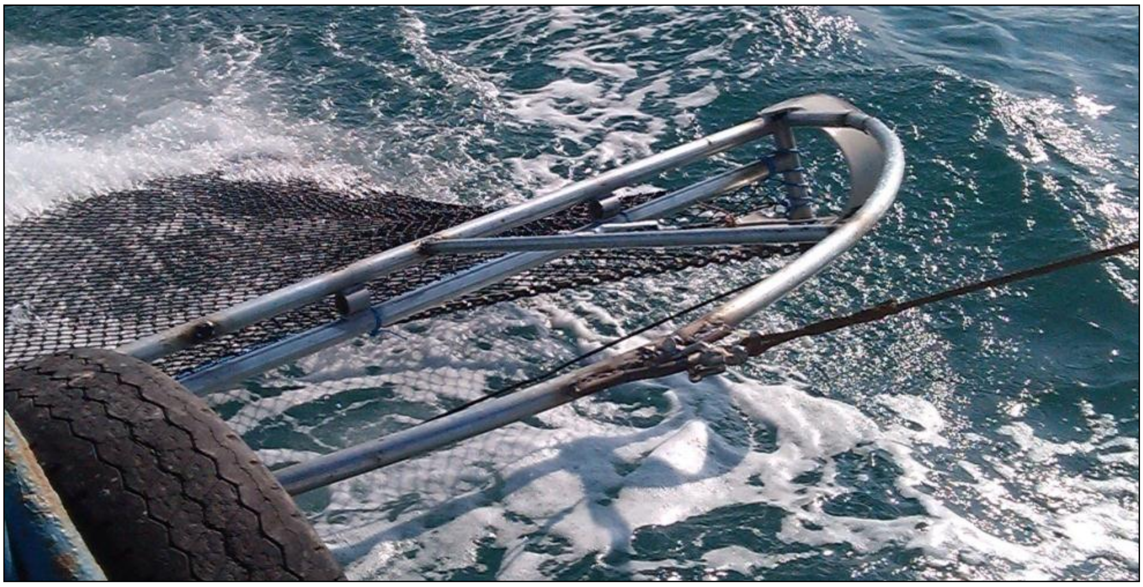


Figure 79. The trials of the modified gear at sea. 16 July, 2014, Dereköy Port.

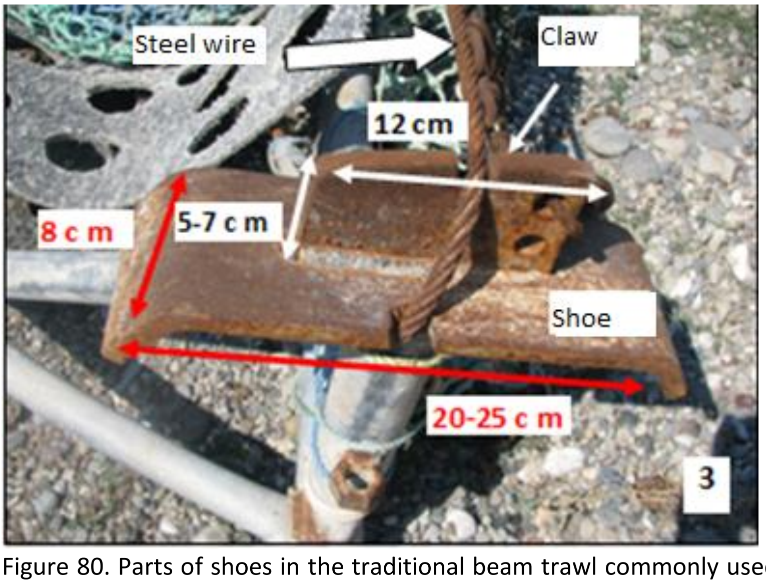


Figure 80. Parts of shoes in the traditional beam trawl commonly used in the SSA. 1: The distance where the steel wire attached the claws is about 5.0-5.5 cm. 2:The dimensions of a shoe, which is the digging part of a beam trawl causing physical disturbance to the substrate.

Figure 81. The sledge model commonly used in the sandy-muddy and muddy substrates along the Costal Yeşilırmak-Terme localities (top); the traditional beam trawl used in the Costal locality (middle); the modified gear without steel wire (bottom).

Table 17. The experimental surveys for the trials of the modified and traditional beam trawls in SSA in July and August 2014

Kind of survey	No of Survey	Date	Sampling period	Survey area	Name of vessel	Length-Engine power	Beam number	Mesh size (mm)	Number of operations	Substrat structure
I- Traditional /Modified (sledges with wire)	1	17.07.2014	Daylight	Dereköy	Remzi Baba	11,30 m- 135 HP	Twin	72	5	Sandy
	2	19.07.2014	Night	Dereköy	Remzi Baba	11,30 m- 135 HP	Twin	72	6	Sandy
	3	20.07.2014	Daylight	Costal	İki Kardeşler-2	11,75 m- 185 HP	Twin	76	7	Muddy-sandy
	4	21.07.2014	Daylight	Dereköy	Remzi Baba	11,30 m- 135 HP	Twin	72	5	Sandy
	5	22.07.2014	Daylight	Dereköy	Remzi Baba	11,30 m- 135 HP	Twin	72	5	Sandy
II- Traditional/Modified(sledges without steel wire)	6	20.07.2014	Daylight	Costal	İki Kardeşler-2	11,75 m- 185 HP	Twin	76	6	Muddy-sandy
	7	20.07.2014	Day-Night	Dereköy	Remzi Baba	11,30 m- 135 HP	Twin	72	9	Sandy
	8	22.07.2014	Night	Dereköy	Remzi Baba	11,30 m- 135 HP	Twin	72	10	Sandy
III-Fuel consumption (Traditional/sledges with and without steel wire)	9	22.07.2014	Daylight	Dereköy	Remzi Baba	11,30 m- 135 HP	Single	72	8	Sandy
	10	22.07.2014	Daylight	Dereköy	Remzi Baba	11,30 m- 135 HP	Single	72	8	Sandy
	11	23.08.2014	Daylight	Dereköy	Remzi Baba	11,30 m- 135 HP	Single	72	18	Sandy

Results

Physical and biological impact on benthic habitat

The number of individuals and species variety in by-catch composition obtained in parallel hauls of the traditional and modified gear (sledges with steel wire) and traditional and modified gear (sledges without steel wire) were examined. It was determined that both the modified beam trawls had nearly 50 % lower by-catch rates than the traditional gear (especially the sledges without steel wire). This significant effect became more visible when the by-catch composition is evaluated within organism groups as fishes, crustaceans, molluscs and tunicates (Figure 82). The difference in the number of individuals within each group obtained by traditional and modified gears were tested for significance with a nonparametric statistical test (chi square) and the results presented in Table 18. It was concluded that the modified gears (sledges with- and without steel wire) had a significant role in by-catch species reduction in the rapa whelk fishery. This result is extremely important with regards to juvenile fishes especially flat fish species which use this near-shore coastal area as nursery grounds.

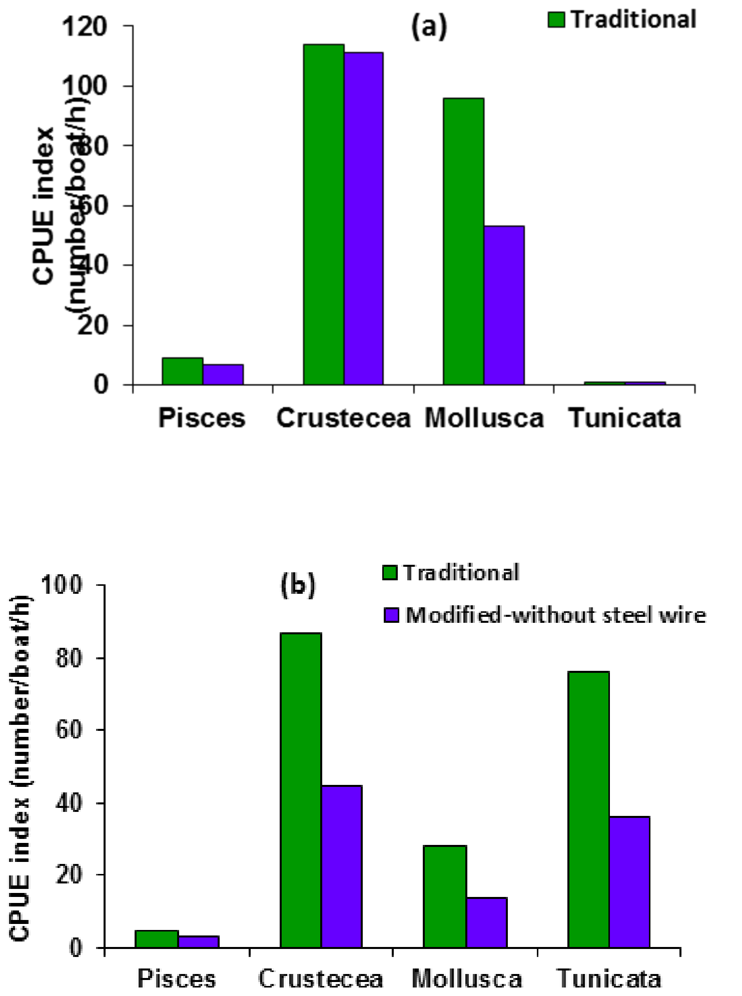


Figure 82. The CPUE index in number estimated for different organism groups of by-catch in; a) modified gear (sledges with steel wire) vs traditional gear and b) modified gear (sledges without steel wire) vs traditional gear in beam trawl fishery.

Table 18. Comparison of by-catch composition in parallel hauls of traditional and modified gears. Significant values are in bold.

Organism group	Traditional gear vs Modified (sledges with steel wire) gear		Traditional gear vs Modified (sledges without steel wire) gear	
	X^2 test value	Sig.	X^2 test value	Sig.
Fish	5.194	**0.023**	6.333	**0.012**
Crustacean	0.692	0.405	93.545	**0.000**
Mollusc	223.536	**0.000**	31.680	**0.000**
Tunicate	0.027	0.869	99.492	**0.000**

In order to examine the by-catch qualitatively, the species in each organism group were identified. The species list and their presence in terms of localities and the beam trawl type is shown in Table 19. At the Dereköy station, a total of 21 different species were caught in the parallel hauls of traditional gear and modified beam trawl (sledges with steel wire).

The number of species was 17 and 18 respectively, in the other trial undertaken by traditional gear versus modified gear (sledge without steel wire). There was no apparent difference in species variety within the by-catch composition of the tested gears. However, a significant difference in species diversity was found between the two localities; Dereköy and Costal. The Costal station having a muddy substratum seems to have less species variety (Table 20). The number of species in the by-catch decreased to 13:18 for traditional:modified gear (with steel wire) and to 12:10 for traditional:modified gear (without steel wire). It is concluded that the modified gears decrease the by-catch only quantitatively rather than qualitatively.

The traditional and modified beam trawls were also tested for the difference in catch of the target species; rapa whelk. The fishing performance of the modified gears is highly important and decisive in the potential adoption by fishermen in future. For this reason, the catch per unit effort for rapa whelk was estimated in parallel hauls of traditional and modified gears. The sea trials of the beam trawls were specifically designed as parallel hauls to keep environmental factors similar, because, wind and waves, type of substratum and the direction of the sea bottom current could are important factors in rapa whelk activity.

It is known that rapa whelk individuals can immediately bury themselves in the sand on windy and choppy days or at certain times of the day (pers. comm. with divers working in the rapa whelk fishery). As the weather can rapidly change within a day in SSA, the gears were tested in parallel hauls instead of subsequent operations in order to avoid any variation in catch caused by sea and weather conditions.

The rapa whelk size frequency distributions and the catch per unit effort (CPUE) values were used to compare the fishing performance of the traditional and modified beam trawls. The size frequency distributions from the different gears were tested for significant differences by Kolmogorov-Smirnov (2 sample) test (Table 21).

Table 19. The presence of species in by-catch within parallel tows of the traditional and modified gears at the Dereköy station.

	Traditional (T) vs Modified (Sledges with steel wire) (M1)																											
	20.07.2014								17.07.2014										19.07.2014									
	1		2		3		4		1		2		3		4		5		1		2		3		4		5	
	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1
Pegusa nasuta	o						o		o							o							o					
Diplogogaster sp.													o	o														
Uranoscopus scaber					o			o		o	o				o	o		o			o	o			o	o		o
Parablennius tentacularis						o					o			o														o
Hippocampus hippocampus	o		o	o	o		o	o				o	o	o	o		o		o	o	o	o		o			o	o
Psetta maxima															o													
Arnoglossus kessleri														o			o							o	o			
Platichthyis flesus									o																			
Syngnathus sp.							o																					
Scorpeana porcus																								o				
Callionymus sp.																												
Dasyatis pastinaca																		o										
Diogenes pugilator			o		o	o		o					o	o	o	o	o		o	o	o	o	o	o	o	o		
Liocarcinus depurator	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Carcinus aestuarii	o	o			o		o	o			o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o
Brachynotus sexdentatus	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o			o	o		o	o	o				o
Plimnus hirtellus																												
Palaemon elegans																												
Nerocilla sp.	o																						o					
Eriphia verrucosa										o			o	o	o	o			o				o	o	o			
Papillicardium papillosum														o														
Cyclope nerita																						o						
Nassarius reticulatus																						o			o			
Anadara cornea	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o		o	o	o	o	

	Traditional (T) vs Modified (Sledges without steel wire) (M2)															
	19.07.2014												22.07.2014			
	1		2		3		4		5		9		1		2	
	T	M_2	T	M_2	T	M_2	T	M_2	T	M_2	T	M_2	T	M_2	T	M_2
Pegusa nasuta												o				
Diplogogaster sp.	o					o										
Uranoscopus scaber				o	o	o			o	o	o	o		o	o	
Parablennius tentacularis		o														
Hippocampus hippocampus	o		o	o			o	o	o	o	o	o	o	o	o	o
Psetta maxima									o	o						
Arnoglossus kessleri		o						o	o	o						
Platichthyis flesus						o			o	o				o		
Syngnathus sp.																
Scorpeana porcus	o															
Callionymus sp.								o							o	
Dasyatis pastinaca																
Diogenes pugilator				o			o	o	o	o			o			
Liocarcinus depurator	o	o	o	o	o	o			o	o	o	o	o	o	o	o
Carcinus aestuarii	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o
Brachynotus sexdentatus					o	o	o	o	o	o		o	o	o	o	o
Plimnus hirtellus																
Palaemon elegans																
Nerocilla sp.																
Eriphia verrucosa	o	o			o	o	o								o	o
Papillicardium papillosum																
Cyclope nerita																
Nassarius reticulatus								o	o							
Anadara cornea	o		o	o	o		o	o			o	o	o		o	o

	Traditional (T) vs Modified (Sledges with steel wire) (M1)																																						Traditional (T) vs Modified (Sledges without steel wire) (M2)																			
	20.07.2014								17.07.2014										19.07.2014										19.07.2014												22.07.2014			
	1		2		3		4		1		2		3		4		5		1		2		3		4		5		1		2		3		4		5		9		1		2	
	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_1	T	M_2	T	M_2	T	M_2	T	M_2	T	M_2	T	M_2	T	M_2	T	M_2
Mytilus galloprovincialis					o	o	o	o						o							o			o																				
Chamelea gallina				o	o	o	o	o	o		o		o	o	o		o		o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o		o	o		o	o
Ascidia sp.							o	o				o	o	o									o	o									o	o	o	o			o	o				

Table 20. The presence of species in by-catch composition within parallel haulings of the traditional and modified gears at the Costal station.

	Traditional (T) vs Modified (Sledges with steel wire) (M1)								Traditional (T) vs Modified (Sledges without steel wire) (M2)					
	20.07.2014								20.07.2014					
	1		2		3		4		1		2		3	
	T	M_1	T	M_1	T	M_1	T	M_1	T	M_2	T	M_2	T	M_2
Pegusa nasuta	o	o						o						
Diplogogaster sp.		o												
Uranoscopus scaber	o		o			o	o	o			o		o	o
Parablennius tentacularis	o	o			o									
Hippocampus hippocampus	o		o	o	o	o			o				o	o
Psetta maxima													o	o
Arnoglossus kessleri									o					
Platichthyis flesus											o			
Syngnathus sp.														
Scorpeana porcus														
Callionymus sp.														
Dasyatis pastinaca														
Diogenes pugilator	o	o	o	o	o	o	o	o	o		o	o	o	o
Liocarcinus depurator	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Carcinus aestuarii	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Brachynotus sexdentatus	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Plimnus hirtellus	o					o	o	o				o		
Palaemon elegans				o							o			
Nerocilla sp.														
Eriphia verrucosa								o						
Papillicardium papillosum														
Cyclope nerita														
Nassarius reticulatus							o	o						
Anadara cornea	o	o	o	o	o	o	o	o		o	o	o	o	
Mytilus galloprovincialis	o	o	o	o				o						
Chamelea gallina	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Ascidia sp.						o								

There were difference was significant for some of the species and comparisons. No clear trend could be seen in size differences between gears. The size frequency distributions of rapa whelk (pooled for all operations) obtained from modified and traditional gears are presented in Figure 83. CPUE (kg/h) values were estimated for all sets of trials. A 2-sample t-test was performed for any significant difference between the fishing performance of the traditional and modified gears.

The mean CPUE was 70.11 kg/h for the traditional beam trawl and 63.23 kg/h for the modified (sledges with steel wire). The difference between CPUE values of the two gears was not significant (t=0.399, P=0.399). In the comparison of the traditional and the modified gear (sledges without steel wire), the mean CPUE values were estimated as 77.37 kg/h and 51.92 kg/h, respectively with a significant difference between the gears.

Fuel consumption

The results obtained from fuel consumption experiments were summarized as follows. The test design for fuel consumption, type of gear, substrate variables and the regarding outputs are shown in Table 22.

- In the trials carried out in sandy substrates, a fuel saving of 12% was obtained with the modified beam trawl against the traditional gear. This rate decreased to 9.5% for trials conducted in the muddy substrate.
- In the muddy substrates, there was no difference in fuel consumption rate between the modified (sledges with steel wire) and traditional beam trawls. There was only a slight decrease of fuel consumption with the other modified gear (sledges without steel wire).
- This result (removal of the steel wire) will be crucial in terms of both the decrease in fuel costs and the reduction of physical disturbance on the benthic habitat.
- Engine speed (rpm) is known to be related to the resistance between the gear and the substrate. The recorded engine speed using the traditional and the two modified beam trawls in trials were different: 763 rpm for the traditional gear, 734 rpm for the modified gear (sledges with steel wire) and 718 rpm for the other modified gear (sledges without steel wire).
- The direction of the current (against or parallel to the operation direction) is a determinative factor in fuel consumption. In operations where the hauls were undertaken parallel to current direction, fuel consumption was reduced.

Discussion

All experimental studies carried out to test the modified beam trawls pointed out that it is possible to reduce fishing impacts on the benthic ecosystem by using sledges and removing the steel wire stretched on the mouth of the gear. Additionally, a fuel saving can also be achieved by using this modified type of beam trawl. Therefore, a double benefit can be provided in terms of economy and ecology.

In the Black Sea, the rapa whelk beam trawl fishery is banned during the summer period. Even though it is illegal, fishermen continue to fish and obtain the highest catches from the year in this period. If modified gears are used, the impact on the benthic habitat would be reduced during this period which coincides with the reproductive and recruitment period of some fish species. We found that the modified gear of sledges without steel wire has a significant reduction in by-catch quantity. The modified gears did not reveal a significant effect in by-catch composition in terms of of species variety.

The rapa whelk, the target species in the beam trawl fishery in this region is an invasive species and one of the top predators of benthic fauna. It is reported that rapa whelk length at first maturity is 40 mm for the southern Black Sea coasts (Sağlam and Düzgüneş, 2007, Sağlam et al., 2009). The fishery management on rapa whelk is crucial and fishing pressure is important to control the population. If the rapa whelk fishery is not allowed in summer, it would not be possible to control the high spawning and recruitment as this species can only be effectively fished in summer months. Therefore, a mutual solution would be to allow the rapa whelk fishery in summer using the modified gears. This would at least reduce the negative ecological effects.

At this point, it should also be noted that the modified gears have no significant effect on the individual size of the catch but a significantly lower CPUE. This will make the fishermen unwilling to use the modified gear and will introduce isuues between stakeholders (scientists, fishermen and government). The most important result in the gear trials, which would provide a negotiating advantage with the fishermen for the adoption of the modified gears is the savings in fuel. Fuel savings were determined to be approximately 10 % using the manual method. Preliminary results of the repeated measurements carried out with a fuel meter showed that it is limited to approximately 4-5%. However, this is still an encouraging result to help convince the fishermen to use the modified gears as this will provide a reasonable economic benefit for fishermen operating over 5 or 6 months in the rapa whelk fishery. The future fishery management scenarios on rapa whelk will be based on the economic benefit of fuel saving, positive ecological effects and the reduction of by-catch due to the use of modified gears.

Table 21. The mean length of the rapa whelk catches from traditional and modified gears in 11 operations and the comparison of size frequency distributions (α=0.05).

Date, Station	Substratum	Gear type: Traditional beam trawl N	Traditional beam trawl Mean TL± s.e of the mean	Modified (sledges with steel wire) N	Modified (sledges with steel wire) Mean TL, s.e of the mean	Size frequency distribution (K-S test sig.)
17 July, 2014, Dereköy	Sandy	330	51.15± 0.605	403	52.97±0.558	0.097
19 July, 2014, Dereköy	Sandy	191	56.91±1.112	233	52.88±0.899	0.026
19 July, 2014, Dereköy	Sandy	322	57.02±0.747	330	55.80±0.677	0.652
19 July, 2014, Dereköy	Sandy	317	56.05±0.700	267	58.93±0.871	0.034
19 July, 2014, Dereköy	Sandy	225	55.56±0,951	130	64.50±1.307	0.000
19 July, 2014, Dereköy	Sandy	209	62.85±1.083	278	60.27±0.954	0.037
21 July 2014, Dereköy	Sandy	234	66.03 ± 0957	160	70.81, ±0.822	0.001
		Traditional beam trawl		Modified (sledges without steel wire)		
20 July 2014, Costal	Muddy-sandy	227	52.8±0.698	246	58.27±0.629	0.000
20 July 2014, Dereköy	Sandy	314	61.02±0.609	403	58.49±0.471	0.030
20 July 2014, Dereköy	Sandy	295	58.41±0.865	204	57.99±1.035	0.939
22 July 2014, Dereköy	sandy	281	54.04±0.774	250	51.52±0.725	0.053

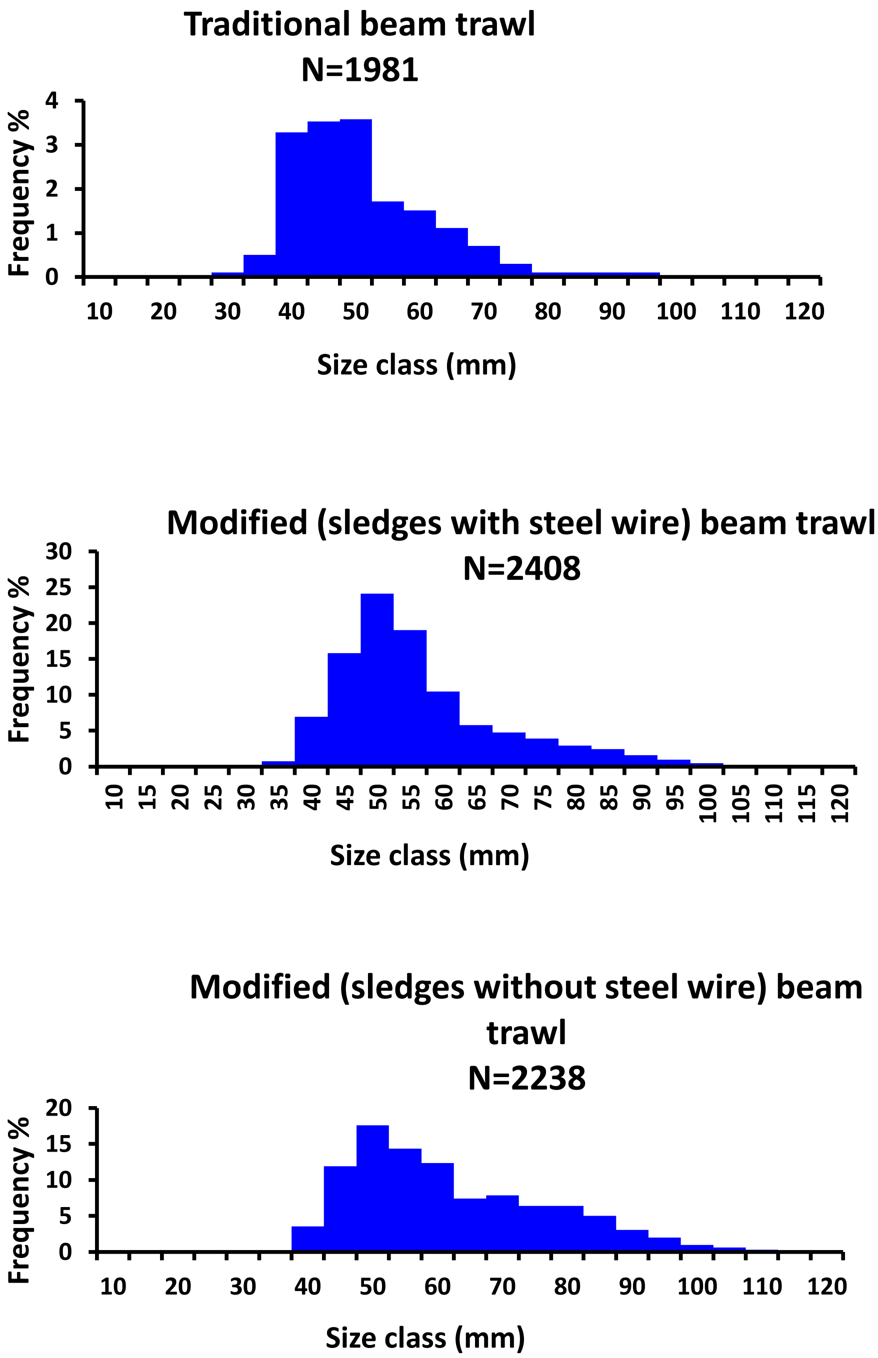


Figure 83. Size frequency distributions of rapa whelk catch (pooled by all operations) caught by traditional and the two modified beam trawls. The mean length at first maturity in rapa whelk is 40 mm.

Table 22. Comparison of the performance of traditional and modified (sledges with steel wire and sledges without steel wire) beam trawls in two different type of substrates in the rapa whelk fishery in SSA.

	Sandy Sediment	Muddy Sediment			
	Modified – Sledges with steel wire (n=8)	**Traditional (n=8)**	**Modified - Sledges with steel wire (n=6)**	**Modified - Sledges without steel wire (n=6)**	**Traditional (n=6)**
CPUE (kg/h)	38,7	40,2	192	66	150
Engine speed (round per minute)	-	-	734	718	763
Fuel Consumption	14,8	16,8	12,8	11,6	12,8
% Fuel save	12	9,4	9,5		
	Mean depth of operation: 7,7m Rope length: 82m	Mean depth of operation: 14,3m Rope length: 92m			

Selectivity studies on the bottom trawl codend

Introduction

The Samsun Shelf Area (SSA) with two major Anatolian rivers (Yeşilırmak and Kızılırmak) is the most important fishing area along the Turkish Black Sea coast. In the bottom trawl fishery, growing fleet size and effort since the 1980s led to a collapse in demersal fish stocks affecting all ecosystem components. Red mullet (*Mullus barbatus*) and whiting (*Merlangus merlangus euxinus*) stocks have been affected by this situation. In monitoring studies on the bottom trawl fishery (2009-2013), the discard rate was determined to be high for both these species in the SSA (Zengin et al., 2013). Seasonal discard rates in the fishing period of 2013 for whiting were as 26.7-33.2%, and for red mullet 17.3-25.6 % . The range of age groups for whiting discard was 0-2 yr and 0-1 yr for red mullet (Zengin et al, 2014). This causes a great economic loss and has impacts the food web as well as benthic ecosystem indirectly. The high discard rate indicates that there is a heavy fishing pressure populations of both species in the Southern Black Sea. Another reason for the high discard rate may be the long operation durations and the low selectivity of trawl codend. Mesh size of trawl codends used in the Black Sea cannot be smaller than 40 mm. Increasing the selectivity of the fishing gear used in SSA is one of the main objectives of the BENTHIS project (WP7).

Material and Method

Selectivity trials were carried out on-board the commercial trawler “Malkoç Bey” (31 m LOA, 1300 HP main engine) from 20 to 27 August 2014. Towing duration varied between 60-90 min, and trawling was undertaken at depths of 15-55 m. Trawling was carried out between 15 and 30 m for Red mullet and below the seasonal thermocline layer at 45-50 m for whiting . Fishing was conducted using a conventional bottom trawl with 900 meshes around (Figure 84). All hauls were made during daytime.

Trawling was carried out by using four different codends with a total of 21 valid hauls for red mullet and 20 valid hauls for whiting. The codends were (Figure 85):

40D: commercially used nominal 40 mm PE codend with 300 meshes on its circumference (three seams of 100 meshes panels).

40T90: nominal 40 mm PE material and turned 90º T-90 with 300 meshes on its circumference (three seams of 100 meshes panels).

36S: constructed with 150 bars on its circumference,, full square mesh codend with nominal 36 mm PE netting.

40S: constructed with 50 bars on its circumference full square mesh codend with nominal 40 mm PE netting .

All the codends were approximately 4-4.5 m in stretched lengths. They were attached to the end of the funnel which was 300 meshes in circumference and made of 40 mm mesh size PE netting.

The hooped-covered codend method was used to collect selectivity data (Wileman et al., 1996). An 8.2 m long, and 24 mm mesh size knotless PA (polyamide) netting cover was used to collect the individuals that escaped. The cover was supported by two hoops (PVC Ø 1.6 m) to avoid a masking effect and to provide water flow between the codend and the cover. These hoops were mounted on the cover at distances of 2.2 and 5.2 meters from the attachment point at the end of the funnel (Figure 86).

The mesh opening of the codend netting was measured using a caliper device. A 4 kg weight was tied vertically to the stationary jaw of the rule. A total of 60 meshes (3 lines of 20 meshes in the towing direction) near to the aft of each codend were measured (Figure 87). At the end of each haul the cover catch was first removed and sub-sampled when catches were large, target species were separately sorted from the rest of the catch and weighed. After sub-sampling, red mullet and whiting codend catches were weighed and length measurements taken (nearest cm). The main catch was then sorted by species and full or sub-samples of the target species were taken and weighted separately (Figure 88).

Selection curves of the individual hauls were obtained by fitting a logistic function:

$$r(l) = \exp(v_1 + v_2 l) / [1 + \exp(v_1 + v_2 l)]$$

where r(l) is the retained proportion of length class l, given that it entered the codend (Wileman et al., 1996), and v=(v1, v2)T is the vector of the selectivity parameters. The values of L50 were estimated from the expressions:

$$L_{50} = \frac{-v_1}{v_2}$$

These parameters were calculated by maximum likelihood using the software CC 2000 (ConStat, 1995). For red mullet and whiting, mean selectivity curves using the EC Model software (ConStat, 1995) were estimated by taking into account the between-haul variation of the selectivity parameters according to Fryer (1991).

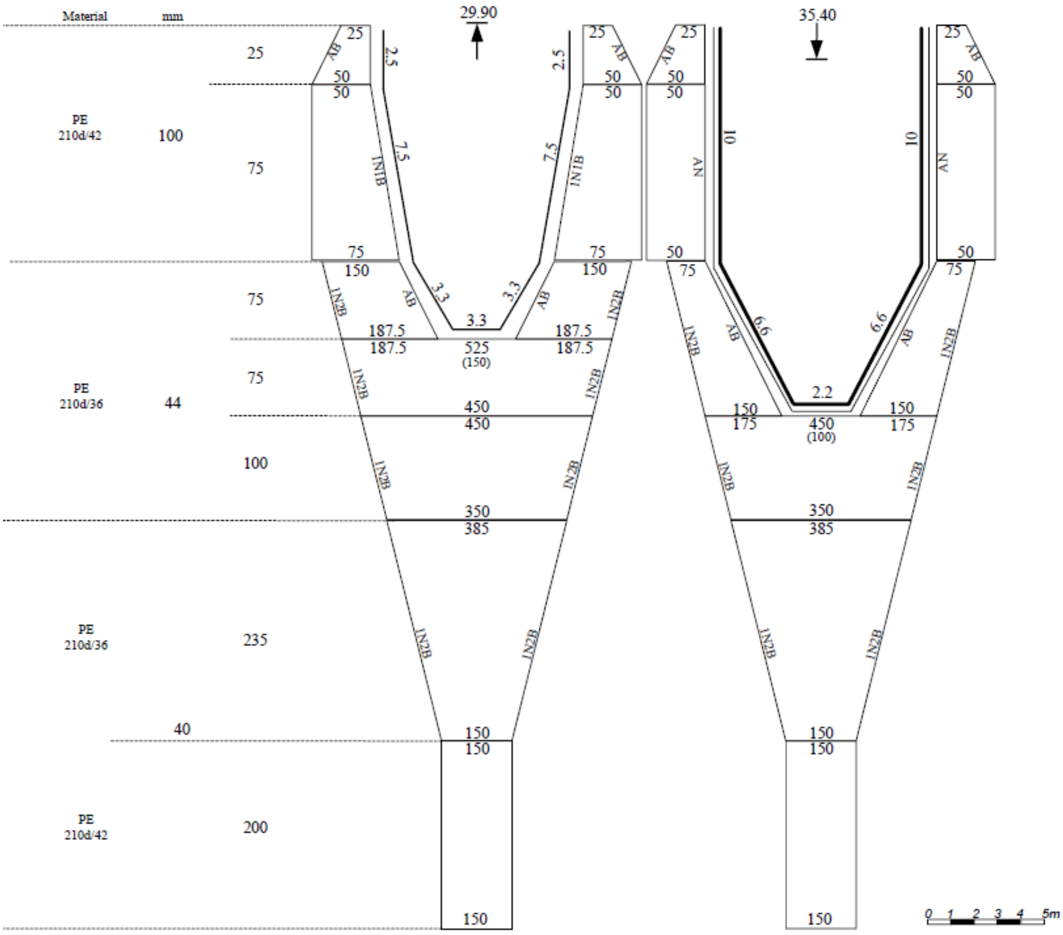


Figure 84. Commercial bottom trawl net used in the experiments.

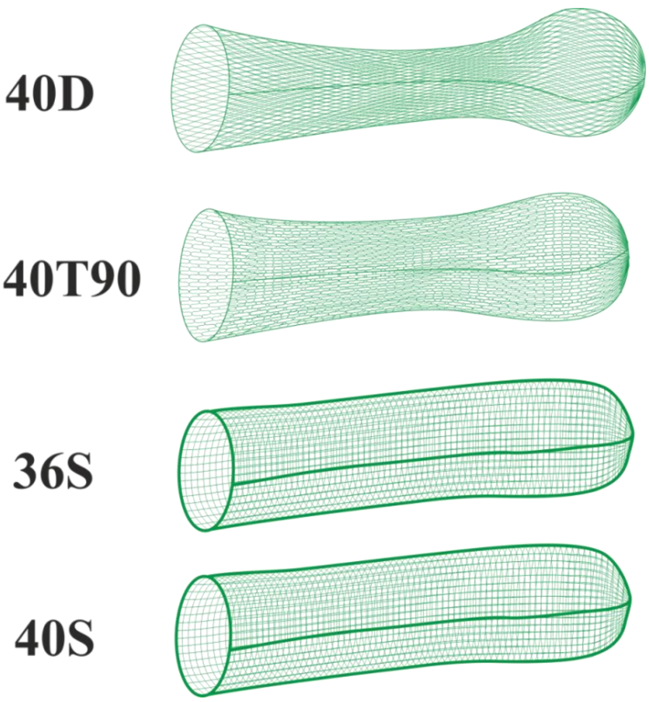


Figure 85. Illustration of the codend tested.

Figure 86. Illustration of the hooped cover used to collect selectivity data.

Table 23. Mean size measurements from the different wet codends.

	40S	40T90	36S	40D
Mean	39,85	39,47	35,95	44,29
SE	0,08	0,09	0,12	0,39
n	60	60	60	60
Min.-Max.	39-42	38-41	34-38	39-52

Figure 87. Measurement of mesh openings by caliper rule

Figure 88. Sub-sampling procedure and length measurements.

Results

During the sea trails, 21 valid hauls for red mullet and 20 valid hauls for whiting were carried out the depths of 15 and 55 m for all codends in SSA (Table 24). Depth was noted only at starting and ending points for each tow. Towing duration (min 60 and max 90 minute) was the time during which the trawl net was on the seabed.

Red mullet and whiting were rarely caught in the same hauls. *Raja clavata, Dasyatis pastinaca* and *Psetta maxima* are the important flatfish species in the by-catch of the Black Sea littoral. There are two common jellyfish in the SSA; *Rhizostoma pulmo* and *Aurelia aurita*.

Red mullet

L_{50} and SR values were estimated for all codends (Table 25). The highest rate of discard (18.1 %) was determined in the conventional gear net (40 mm-diamond mesh 40D) still used by fishermen. The best selectivity results were obtained in the 40S codend. L_{50} values of 40D codend used by the fisherman were determined to be the lowest and below the MLS value for the 40D. Mean selectivity curves for all codends are shown in Figure 89. MLS and L_{M50} values for red mullet is 11 cm.

Whiting

L50 and SR values were estimated for all codends (Table 26). The highest rate of discard (29.5 %) was determined in the conventional gear net (40 mm-diamond mesh) still used by fishermen. The best selectivity results were obtained in the 40S codend. L50 values of the 40D codend used by the fisherman were determined to be the lowest and below the MLS value for the 40D. Mean selectivity curves for all codends are shown in Figure 90. MLS and LM50 values for whiting are 14 cm.

Conclusion

In this study, selectivity experiments were conducted for the trawl codend (40D) used by the commercial trawl fisherman with three alternative different mesh shape and size (40S, 36S and 40T90) for two target species.

Results of the selectivity analysis show that the currently used commercial 40 mm nominal mesh size PE codend was rather unselective particularly for juvenile target species. The mean selectivity value (L50) of the 40D codend was well below MLS and LM50 values of the target species. Hanging ratios of the traditional codend meshes are quite low and the shape of mesh openings does not supply an effective escape area for most of the undersized fish species. Many researchers emphasize that the commercial trawl codend used in Turkey is rather unselective for these species (Zengin et al, 1997; Zengin and Düzgüneş, 1999; Tokaç et al., 1998, 2004; Özbilgin and Tosunoğlu, 2003; Tosunoğlu et al., 2003; Özbilgin et al., 2005; Özdemir et al, 2012). Results of the experimental codends in the present study show higher mean L50 values than that of the commercial codend for red mullet and whiting.

The square mesh trawl codend had a positive effect on size selectivity of red mullet and whiting. The full square mesh codend in general improved the selectivity for round fish such as whiting and red mullet. The best result of selectivity values were obtained with the 40S codend. However, trawl fisherman are not in favor of using this codend (40S) because of the high selectivity. At the same time, the use of a square mesh codend as a technical measure strongly supports size selectivity with small loss in marketable catch.

Mesh shape is the most important factor for understanding the consequences of changes in mesh selectivity, because there are many varieties of fish shapes in the landings. Tokaç et al. (2014) reported that the T90 trawl codend (41 mm mesh size) significantly improved size selectivity of red mullet when compared to conventional diamond mesh codend. In our study, the 40T90 codend was positive for red mullet size selectivity.

Selectivity studies carried out in the Black Sea have been very limited (Zengin et al, 1997; Aydın et al, 1998; Zengin and Düzgüneş, 1999; Özdemir et al, 2012). According to the results obtained in this study, square or T90 mesh shape codend would contribute to sustainable fishing of the two target species. However, there is also a need to be study the selectivity of other species. As stressed by many authors (Ordines et al., 2006; Sala et al., 2008; Düzbastılar et al., 2010a,b), knowledge of survival rates of the escapees is also very important when examining selectivity study results. We would therefore encourage further efforts on selectivity, behavioral underwater observation and survival studies realted to the use of bottom trawl nets in the Black Sea.

Table 24. Date and haul number of the codend used in the experiment. CMNC-circumferences number of mesh codends.

Date	*Codend Type*	*CNMC*	*Haul no*	*Target species*
20.08.2014	**40T90**	300	1	Red mullet
			2	Red mullet-Whiting
			3	Red mullet-Whiting
			4	Red mullet
			5	Red mullet-Whiting
21.08.2014		300	6	Red mullet
			7	Whiting
			8	Red mullet
			9	Whiting
21.08.2014	**36S**	150	1	Red mullet
			2	Red mullet
			3	Red mullet
22.08.2014		150	4	Red mullet
			5	Whiting
			6	Whiting
			7	Whiting
			8	Red mullet
			9	Whiting
24.08.2014		150	10	Red mullet
			11	Whiting
24.08.2014	**40S**	150	1	Whiting
			2	Red mullet
			3	Red mullet
			4	Red mullet
			5	Red mullet
25.08.2014		150	6	Whiting
			7	Whiting
			8	Whiting
			9	Whiting
			10	Whiting

Date	***Codend Type***	***CNMC***	***Haul no***	***Target species***
25.08.2014	**40D**	300	1	Whiting
			2	Red mullet
26.08.2014		300	3	Whiting
			4	Whiting
			5	Whiting
			6	Whiting
			7	Red mullet
			8	Red mullet
			9	Red mullet

Table 25. Selectivity parameters for Red mullet. Selectivity parameter estimates [L50 (cm), length at 50% retention; SR (cm), selection range; SE, standard error; v1 and v2, maximum likelihood estimators of selectivity parameters; R11, R12, and R22, variance matrix measuring within-haul variation; d.f., degrees of freedom].

	Haul no	L_{50}	(SE)	SR	(SE)	v_1	v_2	R_{11}	R_{12}	R_{22}	Deviance	d.f.	p-value
36S	1	**10,19**	(0,07)	**1,08**	(0,09)	-20,771	2,038	3,2137	-0,2993	0,0280	31,78	19	0,03
	2	**10,37**	(0,10)	**1,21**	(0,09)	-18,852	1,818	2,2626	-0,1983	0,0175	75,39	21	0,00
	3	**10,29**	(0,08)	**1,49**	(0,12)	-15,191	1,476	1,7357	-0,1575	0,0144	47,42	18	0,00
	4	**11,57**	(0,05)	**0,97**	(0,07)	-26,189	2,264	3,3018	-0,2893	0,0254	34,38	15	0,00
	8	**10,17**	(0,04)	**1,00**	(0,06)	-22,348	2,197	1,7820	-0,1656	0,0154	41,34	21	0,01
	10	**10,79**	(0,08)	**1,02**	(0,12)	-23,257	2,155	7,8489	-0,7009	0,0628	80,81	16	0,00
	Mean (Fryer)	**10,59**	(0,09)	**1,11**	(0,03)	-20,893	1,972	2,6232	-0,2017	0,0167			
40T90	1	**8,92**	(0,16)	**1,62**	(0,12)	-12,143	1,361	0,9575	-0,0930	0,0094	46,21	20	0,00
	2	**8,68**	(0,73)	**4,14**	(1,10)	-4,605	0,531	2,5418	-0,2243	0,0199	22,55	11	0,02
	3	**11,07**	(0,07)	**1,83**	(0,11)	-13,275	1,199	0,6884	-0,0592	0,0051	9,63	12	0,65
	4	**10,07**	(0,53)	**3,96**	(0,93)	-5,582	0,555	2,2082	-0,1903	0,0169	727,35	23	0,00
	5	**10,45**	(0,13)	**1,88**	(0,17)	-12,250	1,172	1,5294	-0,1334	0,0117	4,53	12	0,97
	6	**10,61**	(0,09)	**1,28**	(0,10)	-18,163	1,712	2,3775	-0,2106	0,0188	56,39	24	0,00
	8	**11,56**	(0,15)	**2,58**	(0,27)	-9,864	0,853	1,0606	-0,0920	0,0081	109,42	20	0,00
	Mean (Fryer)	**10,29**	(0,12)	**1,92**	(0,08)	-10,851	1,055	2,9099	-0,2624	0,0250			
40D	2	**10,76**	(0,21)	**2,26**	(0,37)	-10,471	0,974	3,1706	-0,2856	0,0261	1265,32	22	0,00
	7	**10,83**	(0,10)	**1,84**	(0,16)	-12,938	1,194	1,3556	-0,1230	0,0113	232,99	22	0,00
	8	**9,01**	(0,20)	**2,14**	(0,32)	-9,243	1,026	2,2336	-0,2256	0,0231	460,26	20	0,00
	9	**7,97**	(0,23)	**2,75**	(0,25)	-6,370	0,799	0,4811	-0,0483	0,0051	1026,71	21	0,00
	Mean (Fryer)	**9,79**	(0,35)	**2,20**	(0,11)	-9,714	0,992	2,4339	-0,1478	0,0094			
40S	2	**12,36**	(0,12)	**1,81**	(0,19)	-14,998	1,213	2,1864	-0,1848	0,0157	174,47	18	0,00
	3	**11,93**	(0,03)	**0,35**	(0,03)	-74,935	6,284	38,8766	-3,2506	0,2720	46,63	18	0,00
	4	**11,60**	(0,06)	**1,65**	(0,10)	-15,471	1,335	0,9127	-0,0788	0,0068	119,69	20	0,00
	5	**11,67**	(0,10)	**1,33**	(0,11)	-19,279	1,652	2,1752	-0,1968	0,0179	480,1	16	0,00
	Mean (Fryer)	**11,89**	(0,08)	**1,26**	(0,17)	-30,625	2,575	204,6551	-17,1415	1,4361			

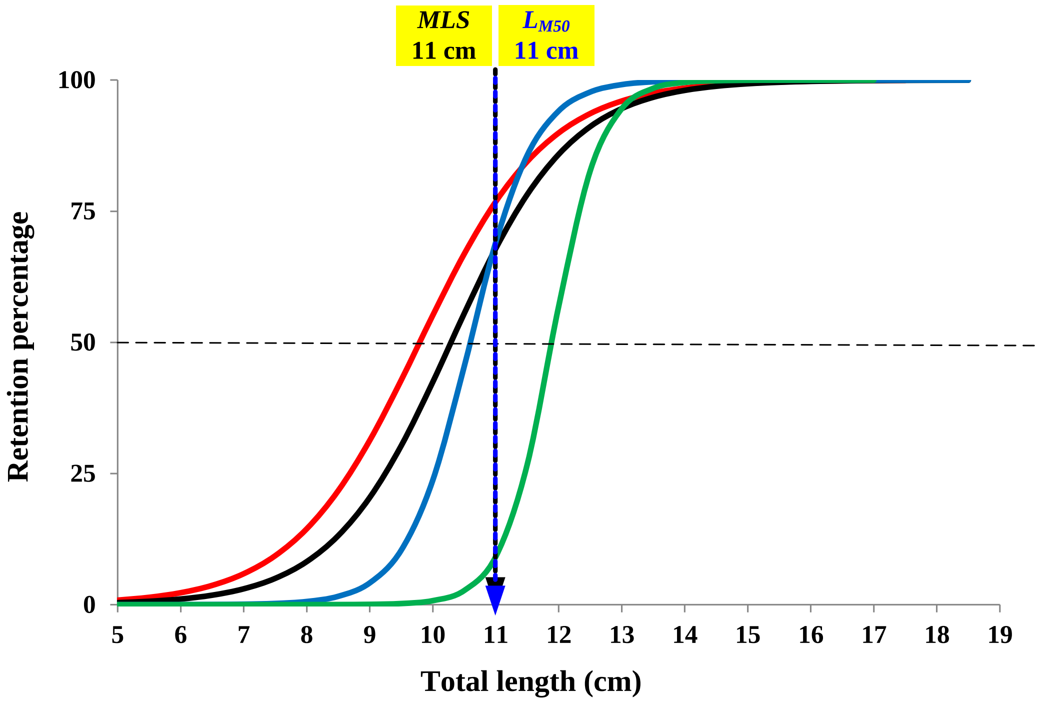


Figure 89. Mean selection curves in the all codends for red mullet (red line-40D, black line-40T90, blue line-36S and green line-40S).

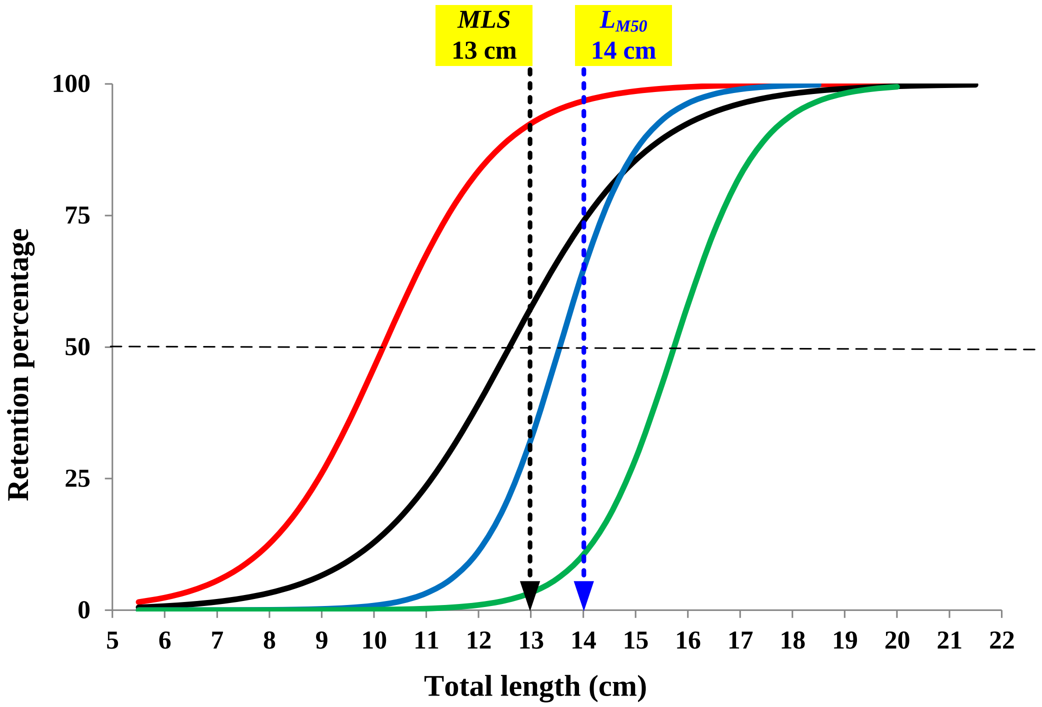


Figure 90. Mean selection curves in the all codends for whiting (red line-40D, black line-40T90, blue line-36S and green line-40S)

Table 26. Selectivity parameters for whiting. Selectivity parameter estimates [L50 (cm), length at 50% retention; SR (cm), selection range; SE, standard error; v1 and v2, maximum likelihood estimators of selectivity parameters; R11, R12, and R22, variance matrix measuring within-haul variation; d.f., degrees of freedom].

	Haul no	L_{50} (SE)	**SR** (SE)	v_1	v_2	R_{11}	R_{12}	R_{22}	Deviance	d.f.	p-value
36S	5	**13,86** (0,12)	**1,81** (0,12)	-16,863	1,217	1,0190	-0,0807	0,0064	223,49	18	0,00
	6	**14,26** (0,23)	**1,76** (0,20)	-17,823	1,250	3,2546	-0,2547	0,0201	235,18	18	0,00
	7	**13,69** (0,10)	**1,27** (0,13)	-23,641	1,727	5,4488	-0,4069	0,0305	305,93	21	0,00
	9	**12,93** (0,12)	**1,78** (0,16)	-15,944	1,233	2,0620	-0,1622	0,0129	110,43	21	0,00
	11	**13,05** (0,11)	**1,55** (0,12)	-18,540	1,421	1,7709	-0,1416	0,0114	111,42	22	0,00
	Mean (Fryer)	**13,55** (0,11)	**1,61** (0,04)	-18,069	1,334	1,0508	-0,0729	0,0056			
40T90	2	**12,40** (0,21)	**2,23** (0,32)	-12,228	0,986	3,5341	-0,2641	0,0199	11,67	17	0,82
	3	**12,62** (0,26)	**4,09** (0,66)	-6,779	0,537	1,4140	-0,1033	0,0076	43,36	18	0,00
	5	**12,40** (0,38)	**1,50** (0,44)	-18,138	1,463	30,6534	-2,3574	0,1829	2,84	16	1,00
	9	**13,97** (0,42)	**5,39** (0,74)	-5,699	0,408	0,4798	-0,0381	0,0032	230,5	22	0,00
	Mean (Fryer)	**12,59** (0,18)	**3,08** (0,40)	-9,286	0,737	3,3297	-0,2914	0,0256			
40D	1	**9,92** (0,12)	**2,09** (0,19)	-10,412	1,050	1,0027	-0,0952	0,0092	333,17	21	0,00
	3	**10,04** (0,17)	**3,01** (0,27)	-7,321	0,729	0,5021	-0,0450	0,0041	1294,51	21	0,00
	4	**10,43** (0,13)	**3,72** (0,29)	-6,166	0,591	0,2522	-0,0225	0,0021	852,03	23	0,00
	5	**10,06** (0,10)	**1,62** (0,17)	-13,621	1,353	1,9849	-0,2003	0,0204	1960,99	24	0,00
	6	**10,53** (0,11)	**2,78** (0,20)	-8,338	0,792	0,3637	-0,0337	0,0032	473,44	21	0,00
	Mean (Fryer)	**10,18** (0,05)	**2,59** (0,16)	-9,047	0,889	1,5366	-0,1577	0,0162			
40S	1	**14,21** (0,21)	**1,58** (0,15)	-19,755	1,390	2,5960	-0,2053	0,0165	225,59	23	0,00
	6	**15,88** (0,16)	**2,01** (0,16)	-17,335	1,092	1,5965	-0,1088	0,0075	211,23	25	0,00
	7	**16,14** (0,21)	**1,64** (0,21)	-21,644	1,341	6,3561	-0,4239	0,0284	970,37	24	0,00
	8	**15,85** (0,21)	**2,70** (0,29)	-12,901	0,814	1,6592	-0,1127	0,0077	259,68	19	0,00
	9	**16,11** (0,10)	**1,20** (0,10)	-29,417	1,826	5,2799	-0,3427	0,0223	309,16	23	0,00
	10	**15,83** (0,08)	**1,94** (0,09)	-17,945	1,134	0,6669	-0,0449	0,0030	247,35	24	0,00
	Mean (Fryer)	**15,74** (0,29)	**1,81** (0,08)	-19,388	1,232	4,8587	-0,2938	0,0181			

REFERENCES

Baltic Sea

1. Bastardie, F., Nielsen J.R, and Miethe, T. 2014. DISPLACE: a Dynamic, individual-based model for spatial fishing planning and effort displacement – integrating underlying fish population models. Can. J. Fish. Aquat. Sci. 71: 1-21. dx.doi.org/10.1139/cjfas-2013-0126
2. Bastardie, F., Nielsen, J.R., Andersen, B.S., and Eigaard, O. 2013. Integrating individual trip planning in energy efficiency – Building decision tree models for Danish fisheries. Fish. Res. 143: 119-130. dx.doi.org/10.1016/j.fishres.2013.01.018.
3. Bastardie, F., Nielsen, J.R., Eero, M., Eigaard O., Jonnson, P., Neuenfeldt, S. andVinther, M. (In advanced prep). Sustainability, fuel use and profitability: interlinked consequences of stock dynamics and individual spatial effort allocation choices within the Western Baltic (Danish) fisheries. (In Advanced Prep).
4. Bastardie, F., Nielsen, J.R., Eigaard O., Fock O.H., Jonsson, P., and Bartolino V. 2015. Competition for marine space: modelling the Baltic Sea fisheries and effort displacement under spatial restrictions. ICES J. Mar. Sci. doi:10.1093./icesjms/fsu215, 17 pp.
5. Eigaard, O.R., Rihan, D., Graham, N., Sala, A., and Zachariassen, K. 2011. Improving fishing capacity descriptors: modelling engine power and gear-size relations of five European trawl fleets. Fisheries Research, 110: 39-46.
6. Eigaard,O.R., Barstardie, F., Breen, M., Dinesen, G., Hintzen, N., Laffargue, P., Mortensen, L.O., Nielsen, J.R., Nilsson, H.C., O'Neill, F.G., Polet, H., Reid, D., Sala, A., Sköld, M., Smith, C., Sørensen, T.K., Tully, O., Zengin, M. and Rijnsdorp, A. 2015. Estimating seabed pressure from demersal trawls, seines and dredges based on gear design and dimensions. ICES J. Mar. Sci. doi.:10.1093/icesjms/fsv099.
7. FAO (2007). Options to mitigate bottom habitat impact of dragged gears FAO Fisheries Technical Paper. No. 506
8. Frandsen R.P., Eigaard O.R., Poulsen L.K., Tørring D, Stage B., Lisbjerg D., and Dolmer P. 2014. Reducing the impact of blue mussel (Mytilus edulis) dredging on the ecosystem in shallow water soft bottom areas. Aquatic Conservation: Marine and Freshwater Ecosystems 25(2): 162-173. 10.1002/aqc.2455
9. Frandsen, R, Feekings, JP & Madsen, N 2013. Forsøgsfiskeri med jomfruhummertejner i det permanent lukkede område i Kattegat. Charlottenlund. DTU Aqua-rapport, no. 268-2013
10. Frandsen, R., Jensen, F., andFeekings, J.P. 2015. Vurdering af økonomien i dansktejnefiskeriefterjomfruhummer. Report EU InterReg OBJ Fish Project (EU InterRegIVa, The Sound, Kattegat and Skagerrak) and the EU-FP7-BENTHIS Project. Report DTU Aqua.
11. Gemba Consulting. 2011. Projekt: "Demonstrationsfartøj i Østersøfiskeriet med fokuspåbedstkendteteknologierindenforenergieffektivitet i fangstredskaber under hensyntilselektivitetogdokumentation". Project report in Danish, 34 pp.
12. Hansen, J.L., Dinesen, G.E., Bastardie, F., and Eigaard, O.R. 2015. Notat om effecter affiskeri med bundslæbenderedskaberpåbundfaunaen I de indredanskefarvande (memorandum on evaluation of fisheries effects on the benthic fauna in the inner Danish waters). Memorandum Contracted by the Nature Directorate, Ministry of Environment, Denmark, 5th January 2015. (In Danish).
13. He, P., Hamilton, R., Littlefield, G. &Syphers, R.H. 2006. Design and test of a semi-pelagic shrimp trawl to reduce seabed impact. Final report submitted to the Northeast Consortium. University of New Hampshire, Durham, NH. UNHFISH-REP-2006-029. 24 pp.
14. Hornborg, S., Ulmestrand, M., Sköld, M., Jonsson, P., Eigaard, O.R., Feekings, J.P., Nielsen, J.R., Bastardie, F., and Lövgren, J. 2015. New policies may call for new approaches: the case of Swedish

Norway lobster (Nephropsnorvegicus) fisheries in the Kattegat and Skagerrak. Poster. ICES ASC 2015/B:29

15. Miethe, T., Bastardie, F., von Dorrien, C., and Nielsen, J.R. 2014. Supplementing impact assessment of closure to fisheries with high resolution spatial analysis of effort and landings in the Western Baltic Sea Fish. Res. 157: 170-179. Doi10.1016/j.fishres.2014.04.004.
16. Pommer, C.P., Hansen, J.L., and Olesen, M. (submitted). Impact and distribution of bottom trawl fishing on mud-bottom communities in Kattegat. (MS Submitted peer reviewed journal May 2015).
17. Thoya, P. 2015. Detecting ecological-economic effects of marine spatial plans from displacing the bottom fishing pressure. M.Sc. Thesis, EU ERASMUS Mundus Programme & EU-FP7-BENTHIS Project. MSc Report 61 pp. (available from DTU Aqua).
18. Thoya, P., Bastardie, F., Dinesen, G., Hansen, J.L.S., andNielsen, J.R. 2015. Detecting ecological-economic effects of marine spatial plans from displacing the bottom fishing pressure. Presentation and Extended Abstract ICES ASC CM 2015/O:05.

Black Sea

1. Aydın, M., Zengin, M., Düzgüneş, E., Mutlu, C. 1998. Determination of Selectivity Parameters of Gill Nets and Trawl Nets for Whiting (Merlangius merlangus euxinus) in the Eastern Black Sea. The Proceeding of the First International Symposium on Fisheries and Ecology, 2-4 September 1998, Trabzon, Turkey (Editors; Çelikkale, M.S., Düzgüneş, E., Okumuş, İ., Mutlu, C.), 121-129.
2. ConStat, 1995. CC selectivity. Granspaettevej 10, DK-9800 Hjjlarring, Denmark.
3. Düzbastılar, F.O, Özbilgin, H., Aydın, C., Metin, G., Ulaş, A., Lök, A., Metin, C., 2010b. Mortalities of fish escaping from square and diamond mesh codends in the Aegean Sea. Fisheries Research, 106, 386-392.
4. Düzbastılar, F.O., Aydın, C., Metin, G., Lök, A., Ulaş, A., Özgül, A., Gül, B., Metin, C., Özbilgin, H., Şensurat, T., Tokaç, A., 2010a. Survival of fish after escape from a 40 mm streched diamond mesh trawl codend in the Aegean Sea. Scienta Marina 74 (4), 755-761.
5. Fryer, R.J.,1991. A model of between-haul variation in selectivity. ICES J. Mar. Sci., 48: 281-290.
6. Ordines, F., Massutì, E., Guijarro, B., Mas, R., 2006. Diamond vs. square mesh codend in a multi-species trawl fishery of the western Mediterranean: effectson catch composition, yield, size selectivity and discards. Aquat. Living Resour.19, 329–338.
7. Özbilgin, H., Tosunoğlu, Z., 2003. Comparison of the selectivity's of double and single codends. Fish. Res. 63, 143–147.
8. Özbilgin, H., Tosunoğlu, Z., Aydın, C., Kaykaç, H., Tokaç, A.,2005. Selectivity of standard, narrow and square mesh panel trawl codends for hake (Merluccius merluccius) and poor cod(Trisopterus minutus capelanus). Turk. J. Vet. Anim. Sci. 29,967–973.
9. Özdemir, S., Erdem, Y., Erdem, E., 2012. The Determination of Size Selection of Whiting (Merlangius merlangus euxinus) by Square Mesh Panel and Diamond Mesh Codends of Demersal Trawl in the Southern Part of Black Sea. Turkish Journal of Fisheries and Aquatic Sciences 12: 407-410 (2012.
10. Sağlam, H., Düzgüneş, E., 2007, Deposition of egg capsule and larval development of Rapana venosa(Gastropoda: Muricidae) from the south-eastern Black Sea. Journal of the Marine Biological Association of the United Kingdom (2007), doi: 10.1017/S0025315407056330, J. Mar. Biol. Ass. U.K. (2007), 87, 953–
11. Sağlam, H., Düzgüneş, E., and Öğüt, H. 2009. Reproductive ecology of the invasive whelk Rapana venosa Valenciennes, 1846, in the southeastern Black Sea (Gastropoda: Muricidae). – ICES Journal of Marine Science, 66: 1865–1867.
12. Sala, A., Lucchetti, A., Piccinetti, C., Ferretti, M., 2008. Size selection by diamond- andsquare-mesh codends in multi-species Mediterranean demersal trawl fisheries. Fish. Res. 93, 8–21.

13. Tokaç, A., Herrmann, B., Aydın, C., Kaykaç, H., Ünlüler, A., Gökçe, G., 2014. Predictive models and comparison of the selectivity of standard (T0) and turned mesh (T90) codends for three species in the Eastern Mediterranean. Fisheries Research, 150: 76-88.

14. Tokaç, A., Lök, A., Tosunoğlu, Z., Metin, C., Ferro, R.S.T., 1998. Codend selectivities of a modified bottom trawl for three fishs pecies in the Aegean Sea. Fish. Res. 39, 17–31.

15. Tokaç, A., Özbilgin, H., Tosunoğlu, Z., 2004. Effect of PA and PE material on codend selectivity in Turkish bottom trawls. Fish. Res. 67, 317–327.

16. Tosunoğlu, Z., Özbilgin, Y.D., Özbilgin, H., 2003. Body shape and trawl codend selectivity for nine commercial fish species. J. Mar. Bio. Assoc. UK 83, 1309–1313.

17. Wileman, D.A., Ferro, R.S.T., Fonteyne, R. and Millar, R.B. (eds.), 1996. Manual of Methods of Measuring the Selectivity of Towed Fishing Gears. Copenhagen, ICES Cooperative Research Report No. 215, 126 pp.

18. Zengin, M., Düzgüneş, E., 1999. Karadeniz'de Mezgit (Merlangius merlangus euxinus Nord. 1840) Avcılığında Kullanılan Dip Trol Ağlarının Seçiciliğinin Belirlenmesi, İstanbul Ün. Su Ürünleri Fak., Su Ürünleri Dergisi Özel Sayı, 535-547 (in Turkish).

19. Zengin, M., Genç, Y. and Tabak, İ. 1997. Determination of the selectivity of bottom trawl. Republic of Turkey, Minister of Agriculture and Rural Affairs, (Project No: TAGEM/IY/96/12/1/004) Report of project, Trabzon, 51 pp. [In Turkish.]

20. Zengin, M., Gümüş, A., Süer, S., Dağtekin, M., Özcan, A. İ., Dalgıç, G., Van, A., Zengin, M., Zengin, B., 2013. Karadeniz'deki Trol Balıkçılığını İzleme Projesi (KARTRİP), Final Report, Proje No: TAGEM/HAYSÜD/2010/09/01/04.TAGEM 2012, Program Değerlendirme Toplantısı, 04-08 Mart, 2013, Antalya.

21. Zengin, M., Gümüş, A., Süer, S., Van, A., Özcan Akpınar İ., Dağtekin, M., 2014. Discard trends of bottom trawl fishery along the Samsun Shelf Area of the Turkish Black Sea coast. ICES Symposium, Effects of fishing on benthic fauna, habitat and ecosystem function, June 16-19, 2014, Tromso, Norway. Abstracts Books, 69 p.

Mediterranean Sea

1. Brčić J, Herrmann B, De Carlo F, Sala A, 2015. Selective characteristics of a shark-excluding grid device in a Mediterranean trawl. Fisheries Research, 172: 352-360.

2. Lucchetti A, Sala A, 2012. Impact and performance of Mediterranean fishing gear by side-scan sonar technology. Canadian journal of fisheries and aquatic sciences, 69: 1806-1816.

3. Mellibovsky F, Prat J, Notti E, Sala A, 2015. Testing otter board hydrodynamic performances in wind tunnel facilities. Ocean Engineering, 104: 52-62.

4. Notti E, De Carlo F, Brčić J, Sala A, 2013. Technical specifications of Mediterranean trawl gears. In Paschen (eds) Contributions on the Theory of Fishing Gears and Related Marine Systems Vol. 8. Proceedings of the 11th International Workshop on methods for the development and evaluation of maritime technologies (Rostock, 9-12 October 2013), ISBN 978-3-8440-2251-3, ISSN 0945-0874, doi: 10.13140/2.1.3147.1687: 163-169.

5. O'Neill FG, Kynoch RJ, Blackadder L, Fryer RJ, Eryaşar AR, Notti E, Sala A, 2016. The influence of twine tenacity, thickness and bending stiffness on codend selectivity. Fisheries Research, 176: 94-99.

6. Prat J, Antonijuan J, Folch A, Sala A, Lucchetti A, Sardà F, Manuel A, 2008. A simplified model of the interaction of the trawl warps, the otterboards and netting drag. Fisheries Research, 94: 109-117.

7. Sala A, Prat J, Antonijuan J, Lucchetti A, 2009. Performance and impact on the seabed of an existing- and an experimental-otterboard: Comparison between model testing and full-scale sea trials. Fisheries Research, 100: 156-166.

8. Sala A, De Carlo F, Buglioni G, Lucchetti A, 2011. Energy performance evaluation of fishing vessels by fuel mass flow measuring system. Ocean Engineering, 38: 804-809.

9. Sala A, Lucchetti A, Perdichizzi A, Herrmann B, Rinelli P, 2015. Is square-mesh better selective than larger mesh? A perspective on the management for Mediterranean trawl fisheries. Fisheries Research, 161: 182-190.

North Sea

1. Degrendele, K., and Roche, M. 2013. EM2040 RV Simon Stevin Sea Acceptance Test 29–30/05/2013. Internal report SPF Economy—VLIZ, Oostende. 12 pp.

2. Depestele, J.; Ivanovic, A.; Degrendele, K.; Esmaeili, M.; Polet, H.; Roche, M.; Summerbell, K.; Teal, L.R.; Vanelslander, B.; O'Neill, F.C. (2015). Measuring and assessing the physical impact of beam trawling. ICES J. Mar. Sci./J. Cons. int. Explor. Mer Online first. hdl.handle.net/10.1093/icesjms/fsv056

3. Desmet, C., 2015. Which benthivorous fishes feed greedily after bottom trawling? Master of Science in Marine Biodiversity and Conservation. University of Ghent.

4. Glorius, S., Craeymeersch, J., van der Hammen, T., Rippen, A., Cuperus, J., van der Weide, B., Steenbergen, J. and Tulp, I., 2015. Effecten van garnalenvisserij in Natura 2000 gebieden. Imares rapport C013/15.

5. Rhoads, D. C. and Cande, S., 1971 Sediment profile camera for in situ study of organism-sediment relations. Limnol. Oceanogr., 16, 110–114.

6. Teal, L. R., Parker, E. R, Fones, G., and Solan, M., 2009. Simultaneous determination of vertical transitions of colour, porewater metals and visualization of infaunal activity in marine sediments. Limnol. Oceanogr., 54, 1801–1810.

7. Teal, L. R., Parker, E. R., and Solan, M., 2010. The sediment mixed layer as a proxy for measuring benthic ecosystem process and function. Mar. Ecol. Prog. Ser., 414, 27–40.

8. Teal, L., Depestele, J., Vanelslander, B., (2016). Measuring and assessing the physical impact of beam trawling – sea trials 2014. To be submitted

9. Teal, L., Depestele, J., Vanelslander, B., (2016). Measuring and assessing the biological impact of beam trawling. To be submitted

10. Teal, L.R., Depestele, J., F. O'Neill, Craeymaersch, J., van Denderen, D., Parker, R., Perdon, J., Polet, H., Rasenberg, M., Vanelslander B., Rijnsdorp, A.D., 2014. Effects of beam and pulse trawling on the benthic ecosystem. IMARES Report c098/14.

11. Tulp, I., Craeymeersch, J., Glorius, S. and Rippen, A., (2015). Short-term effects of shrimp trawling on the composition of benthic communities in coastal zone and Wadden Sea. To be submitted

12. Uhlmann, S., Theunynck, R., Desender, M., Soataert, M. and Depestele, J., (2015). Reflex impairment of beam trawled flatfish. To be submitted

Western Waters

1. Boulcott, P. and Howell, T.R.W. (2011). The impact of scallop dredging on rocky reef substrata. Fisheries Research 110, 415-420.

2. Bouysse P (1985) Carte des sédimentssuperficiels du plateau continental du Golfe de Gascogne - Partieseptentrionale au 1/500.000. co-éditée par BRGM & IFREMER.

3. Bradshaw, C., Veale, L.O., Hill, A.S. and Brand, A. (2000). The effects of scallop dredging on gravelly seabed communities. In: The effects of fishing on non-target species and habitats: Biological Conservation and Socio-economic issues. (eds. Kaiser, M.J. and deGroot, S.J., pp 83-104.

4. Bullimore, B. 1985. An investigation into the effects of scallop dredging within the Skomer Marine reserve. Skomer Marine Reserve Subtidal monitoring project. A report to the NCC.

5. Caddy, J.F. (1973). Underwater observations on tracks of dredges and trawls and some effects of dredging on a scallop ground. Journal of the Fisheries Research Board of Canada, 30, 173-180.

6. Collie, J.S., Escanero, G.A. and Hunke, L. (1996). Scallop dredging on Georges Bank: photographic evaluation of effects on benthic fauna. ICES CM 1996/Mini:9

7. Eleftheriou, A. and Robertson, M.R. (2002).The effects of experimental scallop dredging on the fauna and physical environment of a shallow sand community.Netherlands j. Sea Research, 30, 289-299.

8. Foden, J., Rogers, S.I. and Jones, A.P. (2010). Recovery of UK seabed habitats from benthic fishing and aggregate extraction – towards a cumulative impact assessment. Marine Ecology Progress Series, 411, 259-270.

9. Kaiser, M.J., Ramsay, K., Richardson, C.A., Spence, F.E. and Brand, A.E. (2000).Chronic fishing disturbance has changed shelf sea benthic community structure. Journal of Animal Ecology, 69, 494-503.

10. Langton, R.W. and Robinson, W.E. (1990).Faunal associations on scallop grounds in the western Gulf of Maine. Journal of Experimental Biology and Ecology, 144, 157-171.

11. O'Neill, F.G., Summerbell,K. (2011) The mobilisation of sediment by demersal otter trawls. Mar Pollut Bull 62:1088-1097

12. Sewell, J., Harris, R., Hinz, H., Votier, S., Hiscock, K. (2007). An assessment of the impact of selected fishing activities on European marine sites and a review of mitigation measures. The MBA and University of Plymouth, report SR591, ISBN 0903941694

13. Thrush, S.F. et al (1998). Disturbance of the marine benthic habitat by commercial fishing: impacts at the scale of the fishery. Ecological Applications 8, 866-879.

14. Thrush, S.F. et al (2001). Fishing disturbance and marine biodiversity: role of sediment structure in simple soft bottom sediments. Marine Ecology Progress Series, 221, 255-264.