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Report on assessing trawling impact in regional seas

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SUMMARY AND GENERAL CONCLUSIONS

Baltic Sea

Benthic ecosystem impacts from demersal fishery in the western Baltic is assumed to come mainly from Nephrops trawling in the central and southern Kattegat, mussel dredging in the Belt Sea, and mixed cod trawling in the western Baltic Sea.These fisheries both impact the seabed, as well as produce substantial amounts of discards. The western Baltic Sea offer a unique opportunity to analyse the benthic effects of fishingthanks to the closure of Øresund to towed gears since the 1920s, and the introduction of the Kattegat MPA in2009 (including cod closure) and the western Baltic Sea Natura-2000 areas. Furthermore an extensive benthic nationalmonitoring and data collection effort has taken place in the area over a number of years, which can be usedto investigate spatial and temporal differences in the development of benthic communities in (chronically) towed and non-towed areas.

To evaluate benthic impacts of towed gears in the Baltic Sea a number of gear technological innovations to reduce effort, benthic contact of fishing gears, and discarding are evaluated. There are conducted experimental fisheries in relation to evaluation and comparison of direct ecosystem and habitat impacts, catch efficiency (target/by-catch/discard/invertebrates), selectivity (discard), energy efficiency, and economic efficiency (vessel specific cost-efficiency/cost-benefit analyses) of different gear modifications compared to standard gears. Furthermore, the case study evaluates potential fishing closures directed towards sensitive benthic habitats and communities.

A review of known regional benthic impacts of fishery with demersal towed gears in the area is evaluated with focus on the mussel dredging, demersal cod trawl fishery and Nephrops trawl fishery, where latter is also compared to Nephrops creel fishery. Subtidal dredging and benthic trawling in the area has been reported to affect the benthic fauna and flora as well as to change the structure of the sea bed. The impact of towed gears may also reduce substrate complexity owing to by-catch and movement of shells and stones. Among other this has been demonstrated to locally reduce survival of juvenile blue mussels as well as the population structure of sessile epibenthic organisms. Benthic towing also potentially impact on water transparency either directly owing to resuspension of sediment or as a result of a reduction in the filtering biomasser. Resuspension is induced at the bottom and in the water column during towing and at the surface when by-catch of sediment is released when heaving/washing the catch. Besides reducing transparency, resuspension of sediment has been found to increase levels of ammonia and silicate in the water column and to reduce the oxygen content.

The innovations evaluated comprise: A) Lighter mussel dredges with less benthic impact; B) Smart mussel and cod fishery with previous acoustic or video monitoring or test fishery on the resources before fishery to optimize the catch and to reduce total effort as well as effort on more sensitive habitats resulting in reduced benthic impact; C) Semi-pelagic doors and alternative gear riggings to lift the doors off the seafloor in the western Baltic trawl mixed cod trawl fishery.For species like 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. D) Another focus is scenario evaluation of different effort (re-) allocation schemes with respect to benthic impacts and catch efficiency of W. Baltic mixed trawl fishery by reduction of overall effort or effort in more sensitive habitats through potential closures. The evaluation use the DISPLACE spatial explicit bio-ecomic model (Bastardie et al. 2013; 2014).E) Use short sweep lengths to reduce benthic impacts in the Nephrops trawl fishery (standard of 74 m compared to 5-10 m sweeps). Shorter sweeps are not expected to change the selectivity and catch of Nephrops, because Nephrops are not herded by the sweeps, while fish by-catch and discard is expected to be reduced because of less herding. Benthic impacts of demersal trawl fishing in an open fishing area, a short-term closed area, and a long term closed area in the Kattegat and the Sound is investigated. F) Evaluate benthic impacts of creels to be compared to benthic impacts of the Nephrops-fish mixed trawl fishery through overlapping fishery, creel fishery on soft bottom, and test attachment points of creels and inside creel shelters. The comparative analysis of all the above points of changed fishing methods with less benthic impact will involve comparative analyses of catchefficiency, benthic impacts, cost benefit (CBA), energy efficiency, and by-catch and discard.

Pilot investigations on use of a light mussel dredge indicate that: a) the weight of sediment retained and re-reduction in energy transfer to the sediment, c) catch efficiency tend to increase – reducing effort and area of impact and reducing fuel consumption - and accordingly increasing economic efficiency, and d) 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. Pilot investigations in relation to use of semi-pelagic trawl doors indicate similar catch rates between door settings, however, there are area and seasonal differences in the catch efficiency when using pelagic doors, possibly due to substrate or seasonal related behavior differences of cod in reaction to the gears. Pilot investigations with evaluation of mixed trawl fishery impact on W. Baltic and Kattegat sensitive habitats with respect to effort pressure is presented here and will be made finally reported under WP2 when the actual impact of the specific gear is known. Pilot investigations of bio-diversity and presence/absence of species from benthic sampling in open and short term closed trawl fishing areas in Kattegat is ongoing. Pilot investigations with creels in (Frandsen et al. 2013b) indicate that i) the creels sank very much down into the soft sediment (camera monitoring); ii) the creels were not directly lifted off the bottom but were dragged for several minutes making a footage (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 observed no visible deviations in the cod's behaviour when they swam to the bottom; v) the catch rates were about 180 g/creel per day; vi) CBA indicate a daily profit about 3800 DKK per day which is comparable to trawl fishery for trawlers < 12 m with profit about 3050 DKK per day, however, larger trawlers have higher profit.

North Sea

The North Sea, a marginal sea of the Atlantic on the European continental shelf, is intensively used as an important European shipping lane, for fishery, for recreation and tourism and as a rich source of energy resources including fossil fuels, wind, and early efforts in wave power. A wide mix of fishing methods is being used in the North Sea ranging from active gear like beam trawls, otter trawls, twinrigs, dredges and rope seines (flyshooting) and passive gear like set nets, pots and lines. In terms of swept area, otter trawls are the most significant gears accounting for some 2/3 of the total. Beam trawls only account for 13 % of the swept area although they are economically the most important group. The average discard rate over all gears is some 40 %, based on weight and the small meshed beam trawls show the highest discard rates. Each of the fisheries in the North Sea has its typical geographical distribution, with in general otter trawls operating rather north and beam trawls rather south.

In the North Sea, a total of 38 habitat types occur although a few mainly soft sediment habitats dominate. The surface area is dominated by sublittoral sand, coarse sediment and mud. Bottom trawling mainly occurs in the soft bottom habitats that dominate the North Sea.There is a clear difference in preference for particular habitat types across métiers, although each métier is not restricted to one or two specific habitat types. The deep hard sediments are 'relatively' being fished most intensely, followed by sublitoral mud. In contrast, sublitoral sand that has by far the highest surface and swept area in absolute numbers has the lowest preference score.Fishing intensity has an uneven distribution within each habitat. Some parts of the habitat are trawled intensively while other parts are trawled lightly or are not trawled at all. The proportion of habitat fished more than once a year is less than 15%.

For the Benthis North Sea case study, the beam trawl has been selected as a focus and is deployed as different types of beam trawls. These types are defined by their target species (mainly shrimp and sole) and by the type of stimulation in the netopening, which is determining for the benthic impact. As such, a bobbin rope can be the only stimulus and this is usually used to target shrimps ; tickler chains or a chain mat can be rigged into the netopening and flatfish are the target ; or an electric pulse field can be rigged for targeting sole or shrimps. A preliminary analysis suggests that compared to traditional beam trawls, the pulse trawlers differ in the choice of fishing grounds.

Western waters

Fishing activity spreads out over large areas of the European western waters and some trawling fisheries operate for more than one century on those continental shelves. They represent a large variety of metiers utilizing various types of fishing gears (dredges, beam trawl, otter trawl, Danish and Scottish seines). From the coast to the shelf break, they operate in various benthic habitats, generating impacts on benthic community as well as on habitats themselves. The severity of impacts is a function of fishing spreading out and level, covered habitats and operated fishing gears.

The Nephrops fishery in the Bay of Biscay (BoB) mainly operates twin-trawl gears adopted from 1985 onward. Nephrops reaches the third and second rank in terms of biomass and value respectively for the exclusive trawlers of the French Atlantic coast. Fishing activity for Nephrops concentrates on soft sediment habitats (muddy-sands) of the specific "Grande Vasière" area. Despite a fishing effort reduction's trend and adoption of various selectivity devices, BoB trawlers still generate a high rate of discards (50% of their catches), impose a significant level of physical disturbance to the bottom (trawl-induced fine particle remobilization = 10 to 30 percent of the storm-induced erosion) and generate additional mortality to associated benthic species.

The scallop dredge fishery started along the Irish coast in the 1970s as a small scale inshore fishery and expanded into offshore waters during the 1990s. Others towed gears, otter trawling and beam trawling, occur in the same area. When total effort of dredgers is increasing, bottom trawling is stable and beam trawl activity is declining. Dredgers utilize series of toothed spring loaded dredges suspended on a beam whose generic effects on benthic habitats are well known and unequivocal. The fishery operates on sedimentary sand, gravel habitats and cobble/kelp reef areas. Despite a number of Special Areas of Conservation (SACs), the scallop fishery encroaches onto these areas and the impact of the fishery may be inconsisten with the conservation objectives. Dredge design modifications and/or encouraging scallop fishery to concentrate fishing effort on the most productive/less sensitive areas will help to mitigate the effects of the fishery on benthic habitats.

From the Bay of Biscay to the Norway shelf, the list of vulnerable marine ecosystems (VME) includes as diverse habitats as cold water corals (CWC), sponges' grounds or pennatulaceans communities. As compared to others exploited habitats, fisheries interacting with VME's can generate immediate and long lasting impacts, even at relatively low effort level. In such complex and fragile habitats (*e.g.* CWC), generation of impacts comes not only from trawling activity but from metiers utilizing passive gears too (*e.g.* demersal longline, gill nets, pots). Only strong spatial regulations could help to protect those habitats from severe unwanted and uncontrolled fishing damages.

The western waters case studies proposed a mix of strategies that involve the development of less impacting gears (e.g. modified trawls or alternative metiers) and new management options including spatio-temporal rules. That combination will help to reach fisheries sustainability and good environmental status as considered in Habitats Directive and the Marine Strategy Framework Directive (MSFD).

Mediterranean

In the Mediterranean highly impacting bottom fishing (trawling, dredging, etc.) mainly affects shelf areas, where seabed surfaces are mainly muddy and sandy. Although these fishing grounds are very suitable to trawling fisheries, they represent an important part of the ecosystem since they are inhabited by a wide variety of benthic organisms.Scientific studies carried out in the Adriatic Sea showed that hydraulic dredging causes the destabilization and partial modification of sediment conditions, decreasing the habitat complexity and leading to fluctuations within benthic communities (Brambati and Fontolan 1990). In particular the macrobenthic community appears to be altered by intense hydraulic dredging activity (Morello *et al.*,2005).Rapido trawling has one of the most severe impacts onbenthos, both because it captures epifaunal and infaunal componentsand also because of the high direct and delayed mortalityassociated with contact with this gear (Giovanardi *et al.*,1998). Asingle Rapido tow may induce changes in the structure ofbenthic infauna that last up to 9 months before completerecovery takes place (Pranovi *et al.*, 2000).Owing to their different catching principles, otter trawls are likely to have a different physicalimpact on the seabed from those of the Rapido trawls anddredges (Lucchetti and Sala, 2012).The most evident physicaleffects of trawlingare produced by the otterboards, while other parts have not a significant impact (Lucchetti and Sala, 2012). Eastern Mediterranean studies on otter trawling impact (Smith *et al.*, 2000) showed that trawlingcaused functional change on the macrofaunal and megafaunal community structure,where sessile or discretely mobile filter-feeding organismswere replaced by mobile scavengers and opportunists, changes to physico-chemical properties and chemical fluxes (Smith *et al.,* 2003, 2005, 2007). Bottom trawl is also believed to have contributed to the disappearance of sea-grassbeds in the northern Adriatic Sea, where meadows that werepresent at the beginning of the 20th century have almostdisappeared (Zavodnik and Jaklin 1990). Therefore, for a substantial reduction of bottom impact, some additional measures related to type of gear are needed, as well as avoidance of certain sensitive habitats (e.g. Posidonia, maerl). A reduction of fishing effort by reducing dredge fleet or the number of Rapidos on board, or introducing pelagic otterboards may lead to a reduction of physical impact on the seabed and a better protection of benthic habitats.

Black Sea

Case studies of effects of beam trawl fisheries on the coastal benthic ecosystem by CFRI (Central Fisheries Research Institute) and OMU (Ondokuz Mayıs University) conducted a series of sampling study in order to reveal the impact of bottom and beam trawl gears on benthic and demersal macro fauna along in SSA (Samsun Shelf Area) in 2013 and 2014. The major targets of these field study for the Black Sea Turkish coasts can be outlined as; (1) to define and draw out the structural and technical properties of beam trawls (algarna) conventionally used for rapa whelk fisheries, (2) to estimate the catch per unit effort in beam trawl fishery in SSA, (3) to reveal the species composition of benthic and benthopelagic macro fauna (invertebrates and fishes) besides of the target species; rapa whelk. (4) The monthly variation of bycatch in beam trawl fishery. In experimental design, the samplings were made by a pair of algarna in the same vessel which is equipped with two kinds of gears (commercial gear with the mesh size of 72 mm and the blind gear with the mesh size of 12 mm) to find out the species composition of benthic and macrobenthic fauna and its monthly variation. (5) The seasonally discard in bottom trawl samplings were carried out within the depth range of 30 and 120 m by using meshes varying between 400 and 900 and 40 mm diamond mesh size in codend in traditional bottom trawl by commercial vessels. The monthly samplings were realized by two kind of vessels in size > 18 m (12-17 m) and <18 m (18-32 m) which are common for Black Sea trawl fishery fleet. In each sampling period, the catches were recorded on board from at least two commercial vessels representing the study area. Fieldwork included estimating the total catch and the relative fractions per haul and recording the faunal composition as standardized for per haul duration or per day. The sediment samplings were taken from totally 40 stations and particle size analysis were realized. The stations for sediment sampling were assigned as on a vertical line to land at certain distances from each other and at four different depths. The data derived from PSA (Particle Size Analysis) and also the information of coordinates applied to the ArcMap Sediment Classification Tool (ArcGIS ver 9.2) to derive the habitat map of the substrate in SSA.

The abundance of macro benthic fauna is greater in summer months than in winter, spring and fall. The fishing mortality is increasing in this period. 70.3% of total catch is composed of Rapa whelk and 29.7 % is the bycatch species. The reasons for the heavy pressure on red mullet and whiting populations were the low selectivity of meshes and the long operation durations. The high exploitation rate generally causes the catch of relatively small and immature individuals. Though the rate of discarded catch in weight is lower than the marketed catch, as it is considered in number of individual the discarded portion is larger than the market. The age composition of red mullet was composed of 0 and 1 age groups and of whiting are 0, 1 and 2 age groups. In the whiting fishery of the 2013 and 2014, the mean values of fishing effort are found to have no significant difference between seasons for the landing. The highest CPUE for the landing and discard is estimated in fall and the lowest in spring but the difference is not statistically significant. In red mullet fishery for the same years, the trend seems similar within the whiting fishery. The mean values of fishing effort in red mullet are also not significantly different between seasons for the landing. The highest CPUE for the landing and discard is determined in winter and the lowest in spring with no statistical difference. Though the rate of discard by weight seems less than of landings, the rate of discard by individual number is significantly high and cause great bio-economic losses. SSA can be accepted as a soft bottom habitat that is mostly composed of muddy sand and sandy mud. Stations having hard substratum is very limited. This soft bottom is highly available for all kind of drag-net fisheries and this makes this habitat highly sensitive because of heavy fishing pressure.

1 - INTRODUCTION

Fishing activities with towed bottom gears are an important anthropogenic pressure that affects marine ecosystems worldwide (Dayton et al., 1995; Jennings and Kaiser, 1998; Collie et al., 2000; Kaiser et al., 2006; He and Winger 2010). The adverse impacts of fisheries on the benthic ecosystem may negatively affect the fisheries yield and integrity of the sea bed (see overview below). Conservation of marine ecosystems may be achieved by reduction of fishery impact through limiting fishing pressure or banning fishing activities or by introducing gear types with reduced impact on the ecosystem. Ecosystem impacts of fisheries cover among other the impacts on the stocks from landings and discard, physical impacts on the seabed and on the benthic ecosystems (benthic community functioning) from fishing gears, and emissions of greenhouse gasses from fuel consumption in the fishery. The fishing activity and effort levels with the different hauled gears in different types of habitats including sensitive habitats is very much determining the overall marine benthic impacts of fishing with hauled gears.

In the present deliverable demersal hauled gear impact on the benthic habitats, communities and physical-chemical-biological processesis assessed in the regional seas with focus on trawl fisheries. This isbased on evaluation of fishing pressure, effort allocation, catch composition including discard, as well as distribution of fisheries according to distribution of habitat types and sensitive habitats in the regional seas. Furthermore, known specific impacts of trawl gears on the benthic ecosystem in general and in the regional sea areas is reported with focus on trawl fishery based on existing literature and information form the fishery catch sector through the regional stakeholder workshops conducted under each of the BENTHIS case studies. The overview is based on high resolution spatial data for fishing effort allocation based on satellite and VMS data on fishing operations (VMS, Sattellite Vessel Monitoring Systems) in the regional seas. For the spatial patterns of fishing activity the VMSTools library created as part of EU tender No MARE/2008/10 and further enhancement of this has been applied. This allows collating national VMS data intoregional maps of international fishing intensity of all relevant metiers at an appropriate spatio-temporalresolution.Maps of the fishing impacts is created for a number of different benthic ecosystems in the regionsstudied by combining information of the sea bed habitat types (BALANCE and/or EUNIS), with high resolution trawling frequency (VMS-based) maps for a selected number of fisheries.

Overview of main benthic impacts of trawling general for all regional sea areas

The benthic ecosystem provides important ecosystem goods and services (Anon, 2003). They providefisheries production and the food for bottom dwelling fish species which contribute about 50% of thelandings in the north-east Atlantic (FAO 2010). Benthic ecosystems also play a vital role in the functioningof marine ecosystems. Benthic organisms are key to the benthic-pelagic coupling in which pelagic primaryproduction is channeled into the benthic food web, and play an important role in the re-mineralization ofnutrients and the storage of organic matter in the sea bed (Thrush et al 2006). Fish species may lay their eggson the sea bed or fasten them to corals (e.g. sharks eggs have been observed on deep water corals), or seekshelter in biogenic structures such as corals, sponges, shells or geologic structures such as stony areas (e.g.Buhl-Mortensen et al. 2005). Soft sediments provide habitats to benthic organisms that may constructnetworks of burrows and habitat forming invertebrates build structures such as corals or colonies with a lifetime exceeding the life expectancy of individual organisms that are essential habitat for other organisms (e.g.Buhl-Mortensen et al. 2005, 2010; Duineveld et al 2007).

Fishing has a major impact on marine ecosystems in general and benthic ecosystems in particular (Halpern etal. 2008; Jackson et al. 2001). Commercial fisheries utilize a wide variety of fishing gears ranging from passive gears such as pots andtrammel nets, to bottom trawl that are towed over the sea bed. Passive gears may damage benthos, forinstance when a long line deployed on a reef may tear off branches of the reef or when long strings of creels are heaved, but it is generally assumedthat bottom trawls will have a much larger impact on benthic ecosystems than passive gear because a) theycause higher mortality rates of benthos and higher habitat modification rates and b) because the footprint oftowed gears will be many orders of magnitudes larger than those of passive gears (Jennings and Kaiser1998). The main fishing gears utilized on the continental shelves aretowed bottomgears such as otter and beam trawls. Because these gears are heavy when in contact with the seabed, theycause significant mortality among the animals that live on the seabed and this result in chronic alteration ofthe state and functioning of seabed ecosystems. Fishing activities with towed bottom gears are an important anthropogenic pressure that affects marine ecosystems worldwide (Dayton et al., 1995; Jennings and Kaiser, 1998; Collie et al., 2000; Kaiser et al., 2006; He and Winger 2010).

Bottom trawling has a long history that goes back for many decades and even centuries (Smith 1994; Engelhard 2008) and has affected large areas of the continental shelf seabed in Europe and elsewhere aroundthe world (Rijnsdorp et al., 1998; Pitcher et al 2000; Roberts 2007). Fishing gear affects seabed habitats and damages or kills benthos. The spatial extent of the impact of fisheries has increased over time due totechnological innovations (such as rock hopper gear and chain mats beam trawls) and the increase in size and power of fishing vessels and their gear. This combined with developments in GPS plotters and eco-soundershas allowed bottom trawl fisheries to extend their activities into previously un-trawlable grounds (Morato etal, 2006). The trawling impact is a function of direct physical impact of the hauled gears on the physical benthic impacts as well as associated biological impacts of the contact of the fishing gears with the habitats. This impact is a function of the degree of actual contact and level of intrusion into the sediment, i.e. their penetration depth as well as the speed and distance over which the gear is towed. Furthermore, it is a function of the size and weight of the gear components of the hauled gears, the setting/fishing/heaving methods, and the hauling speed. Several parts of bottom gears are in contact and impacting the seabed. These may include tow warps in front of the door, the trawl doors, the door to net warps, the ground rope or parts of the ground rope and the belly of the net. In an otter trawl, the sweeps only touch the surface of the sea bed, whereas the otter boards dig a furrow into the sediment. The warp contact is dependent on how much wire there is deployed and how the gear is rigged and of the seafloor if it has a high level of topography.The trawl doors and ground rope are in demersal towed gear fisheries most often in direct contact with and more impacting the seafloor. The trawl doors contribute to fishing in a number of ways; keeping the net open, cause optical and acoustic disturbance to the fish in order to herd them towards the centre of the tow line and the net opening (e.g. He and Winger 2010). In spreading the net and keeping the trawl down the design has been towards a high-contact device that drags along the seabed digging a furrow. The traditional basic design has remained unchanged for decades. Only in the last years local door manufactures have started to collaborate with scientists to develop new prototypes. New door technologies for low-weight, low drag, off-bottom designs that can still maintain the trawl opening at typical trawl speed. Many modern trawl doorsare the result of initial designs, improved through practical trials until they work well enough to be used commercially. Modern door designs are more advanced and sophisticated as a result of increasing fuel costs and the necessity to minimize impact on the environment. Meeting these challenges has led to significant improvements in the way new otterboards are designed and tested (Sala et al., 2009; Gemba 2011). In a beam trawl the tickler chains that are mounted between the shoes penetrate into the sediment and disturb the upper layer as well the benthic organisms that live in the sediment. The penetration depth depends on the number of tickler chains and depends on the sediment type (Ivanovic et al. 2011). A promising development is the numerical modelling of the physical impact of a fishing gear on the sea bed based on the characteristics of the gear. Ivanovic et al. (2010) has developed such a model for an otter trawl distinguishing between different components such as the otter door and the roller clump and validated the model in sea trials on two sediment types where the physical alteration to the seabed following the passage of a roller clump and a trawl door was measured and profiled. If extended to other gear components, and thoroughly validated, this approach offers great potential to predict the physical impact on the sea bed of a variety of gears in different benthichabitats without having to go to sea to carry out experiments.

Impacts on the ecosystem through fishing with hauled gears such as demersal trawls, beam trawls, mussel dredges, and seines is a complex issue and involve mostly negative impacts such as reduction in diversity and habitat damage. Direct impacts are mediated through removal of organisms, damage to or killiing organisms including benthic invertebrates, modifications to the environment (modifying the sedimentary habitats), and many complex secondary impacts through ecosystem functioning, e.g. changes to sedimentary processes, increasing or decreasing nutrient fluxes, loss of habitat heterogeneity, changes to predator/prey relationships, etc. Positive impacts may be in the addition of organic material to the benthic communities through discards, i.e. organic carbon/feed inputs to the seabed, or increased productivity through the re-direction of energy from discards to the seabad. These changes in turn may lead to changes in the functioning of the benthic ecosystem and theavailability of food for commercial fish species. The different pathways by which fishing may impact the benthic ecosystem is summarised in Table 1 distinguishing between the mechanism and the ecological effect.

There is evidence for a loss in biodiversity and shifts in thebenthic community from large long-lived species to small fast growing species (Frid and Hall, 1999). The direct mortality imposed to organisms that are hit by a fishing gear has been estimated in field experiments. Mortalities vary between species, fishing gears and sediment type and are generally around50% for a single passage of a trawl (Kaiser et al. 2006). Beam trawls and scallop dredges on average causehigher mortality rates than an otter trawl. Biogenic habitat building species were more vulnerable thaninfaunal invertebrates. However, for many benthic organisms and bottom trawl gears, no direct mortalityestimates are available and we are currently lacking the ability to make predictions for species that falloutside current studies and regions for which no research exists (Kaiser et al. 2006). There is a major concern about the detrimental effects of fishing on bioengineering species such as cold watercorals, sponge aggregates, mussel beds, and on the long lived and slow growing mega-fauna (e.g. burrowingcrustaceans: Duineveld et al. 2007).

The disturbance of the sediment may cause changes in the geo-chemical processes in the seafloor (Dupliseaet al. 2001).Little is known on how fishing indirectly affects bioturbation, nutrients fluxes and bentho-pelagic couplingthrough changes in benthic community composition. Trawling has been shown to reduce the abundance ofbioturbating species and this is likely to affect nutrient fluxes (Widdicombe et al. 2004). Trimmer et al(2005) found that biogeochemical processes in the upper layers of sediment, both oxic and suboxic, seemedunaffected by trawling in the long-term. In deeper anoxic sediment, however, mineralisation via sulphatereduction may be stimulated by the extra disturbance, at least in areas where tidal energy is slight. Studies onthe effect of trawling on benthic-pelagic coupling have so far not been conducted. A serious deficiency ofour understanding and predictive ability of the effect of trawls on ecosystem functioning therefore exists. Trawling and dredging may reduce transparency locally owing to re-suspension of sediment due to the fishing activity (He and Winger 2010). This reduces water transparency, and re-suspended sediment also increase levels of ammonia and silicate in the water column and reduced oxygen contents. Resuspension of organic material (Durrieu De Madron et al. 2005; Pilskaln et al. 1998) may affect the nutrient and carbon fluxes from the sediment, and consequently affect primary production andeutrophication. O'Neill & Summerbell (2011) have demonstrated that, for a given sediment type, there is arelationship between the hydrodynamic drag of the gear element and the mass of sediment entrained behind it. These changes not only affect the biodiversity but also affect the benthic ecosystem functioning and production with ramifications for the provisioning of ecosystem goods andservices.

The many years of bottom trawling is likely to have caused structural changes in benthic habitats by altering sediment structure or removing biogenic structures such as corals or biogenic reefs (Roberts 2007).Several long term studies have shown changes in the benthos, in particular the decrease of long-lived slow growing species and the increase in short-lived fast growing species (Pitcher et al 2000; Tillin et al 2006). Theinterpretation however is not unequivocal since some of the observed changes could also be caused by pollution or climate change (Borja et al 2000; Kroncke et al 2011). Mediterranean studies on otter trawling impact (Smith et al. 2000; Lucchetti et al., 2011) showed that trawling implied functional change on the mega-faunal community structure, where sessile or discretely mobile filter-feeding organisms are replaced by mobile scavengers and opportunists. The ecosystem effects related to the use of bottom gear may extend farbeyond the direct impacts discussed above. For example, eutrophic processes in closed basins and low depth (as in the northern Adriatic) may be enhanced by trawling, leading to hypoxia in sensitive soft bottom areasand an increase in the quantity of hydrogen sulphide released from sediments (Caddy, 2000; Lucchetti et al.,2011).

The modification of the seabed habitat, mortality of invertebrates and flow of discards to the seabed has resulted in long-term changes to the functioning of benthic ecosystems. Fishing will result in changes in the species and size composition of the benthic community due to differential mortality across species and size classes, and due to the food subsidies provided by the trawl track mortality and the discards and offal that sink to the sea bed. Community changes will influence the ecosystem functioning affecting geo-chemical fluxes as well as trophic interactions (Dayton et al. 1995; Kaiser et al. 2000; Tillin et al. 2006). Few studieshave been carried out to evaluate how the effects of large scale commercial fisheries results in geo-chemicaland community changes and how these translate into effects on measures of ecosystem functioning such asbioturbation, nutrient fluxes and bentho-pelagic coupling. Furthermore, we are currently lacking the abilityto evaluate the effect of large-scale chronic trawling on the food availability for benthivorous fish such asplaice, cod and haddock. Such reductions in food availability may reduce secondary production in fisheries(Hiddink et al. 2011).

Only a few studies have attempted to model the large-scale effects of chronic trawling impacts on the benthic ecosystem structure and functioning. Duplisea et al (2002) and Hiddink et al (2006) used a size-based model to show that current bottom trawl activities in the North Sea resulted in a 56% reduction in biomass and 21% reduction in production of benthic invertebrates in the southern North Sea. This model was applied to address the question how the reduction in beam trawling in the Plaice Box, an MPA established to reduce thebycatch of undersized plaice, could have affected the food for plaice that feed on small benthic invertebrates (Hiddink et al. 2008). It was shown that the overall biomass and production of the benthic ecosystem decreased with increasing trawling intensity, but that the production of suitable prey, small worms, was low without trawling and maximal in areas that are trawled once to twice a year, suggesting that the food for plaice may have been reduced within the Plaice Box following the reduction in beam trawling in the box. Allen and Clarke (2007) used a coupled physical-ecological model (the European Regional Seas EcosystemModel (ERSEM) with the General Ocean Turbulence Model (GOTM)) to investigate the impact of demersal trawling on the benthic and pelagic ecosystems of generic stratified and unstratified water columns in the central North Sea. The modelling suggests that the biogeochemical impact of demersal trawling is most significant in regions where the gear type, trawl frequency and bed type cause high levels of filter feeder mortality. This results in significant changes in its biogeochemistry (increased phosphorus absorption,increased nitrification of ammonia, reduced silicate cycling).Our ability to predict the ecosystem effects of fishing at a regional scale, requires sophisticated models, and is therefore currently hampered by insufficient knowledge on how fishing affects different ecosystemfunctions in different habitats. Furthermore, to allow meaningful management of these fisheries, we need toknow how large the effect of fishing is relative to the natural variations such as those caused by storms.

Many important commercial fishes, such as flatfish and gadoids, feed on these benthic invertebrates for partof or all their life-history. Bottom trawling thus not only reduces the population size of fish through directremoval, but also reduces the abundance of their prey (Auster and Langton 1999). Recent studies have shown that this may results in reduction of the growth of flatfish species (Shephard etal. 2010), and could therefore reduce the sustainability of fisheries. These results contrast with the hypothesis that bottom trawling may promote the typical small benthic organisms on which small-mouthed flatfish species like sole and plaice feed (Hiddink et al. 2008; Rijnsdorp and Van Beek 1991; Rijnsdorp and Van Leeuwen 1996). We are currently lacking the ability to assess to what extent such trawling induced changesin food availability are affecting fisheries over large scales and for most important fished species. A theoretical modelling study of the fish – benthos – bottom trawl interactions showed that the effect of bottom trawling on the food of benthivorous fish was dependent on whether the benthos was controlled by bottom-up processes (food competition) or top-down processes (predation). A positive effect of bottom trawling on the food of benthivorous fish was possible in a bottom-up controlled system where the preferred food of the benthivorous fish were insensitive for trawling (van Denderen et al., 2013).

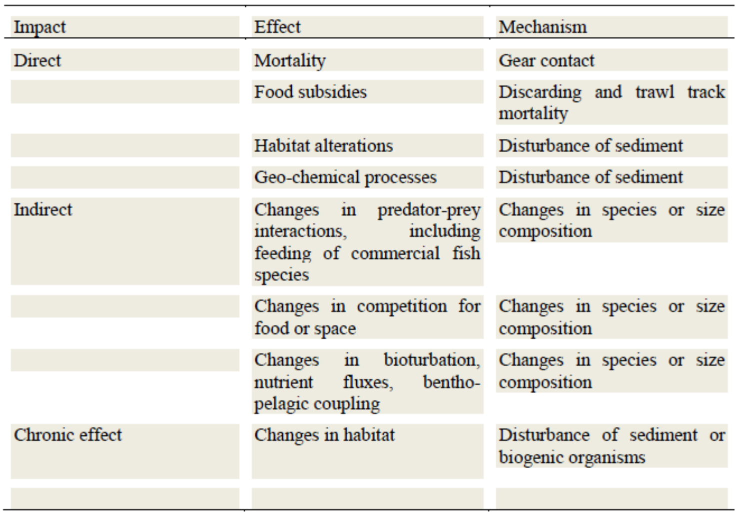
Fisheries generate carrion as a result of material discarded at sea from fishing boats. It is unclear whether theincreases in the population sizes in scavenging seabirds that have been partially attributed to discar-dingpractices might be mirrored in changes in the populations of benthic scavengers. As discarding has beenongoing for decades, benthic ecosystems that are reliant on discards as a food source may have developed (Kaiser and Hiddink 2007). As a discarding ban will reduce the flow of energy to the seabed, it is necessaryto understand what changes this may cause to benthic ecosystems, and to do this it is necessary to quantify to flow of energy from pelagic and demersal fisheries to the seabed, and to assess what effect this has on sea bed ecosystems. In relation to discard, the selectivity of hauled gears is also an important issue with respect to ecosystem impacts of fishery. Hauled gears such as trawls are in general not very selective gears and catch both targeted species and size groups as well as un-wanted by-catch of other species and size groups. A number of different selectivity studies have been undertaken and some measures have been implemented with corresponding legislation. The primary selectivity measures concern mesh size, orientation or pattern and use of special devices (sorting grid, TEDs, square panel, separators, etc.). Although selectivity measures have been introduced, there are local issues that make this more difficult; this mostly concerns the single type of bottom trawl used in mixed, multispecies-targeted bottom trawl fisheries. In some cases a selectivity measure may be beneficial for one species, but not for another within the same fishery. As such selectivity of the used hauled gears and the associated discard is relevant with respect to ecosystem impacts of hauled gears.

A further complication for the appropriate assessment of the impact of bottom trawling is the lack of suitable untrawled reference areas (Lokkeborg 2005). Few studies have been able to compare the benthos between untrawled reference areas and trawled areas (Blyth-Skyrme et al. 2004). For instance, Duineveld et al (2007) showed the higher abundance of habitat engineering species in the safety zone around oil platforms in the intensively trawled southern North Sea. In addition reference areas are often not representative because they are not selected at random. Recent comparative field studies, utilising fisheries data collected at the appropriate resolution, suggested that benthic biomass decreased with increasing trawling frequency (Hinz etal 2009; Jennings et al 2001). These studies, however, do not provide insight into the underlying mechanisms. In general, our poor level of mechanistic understanding of benthic ecosystem state and functioning has hampered the integration of bottom fauna into ecosystem based fisheries management. For instance, there is still debate about the effectiveness of the Plaice Box, an area in the coastal waters of the south-eastern North Sea that was closed to large beam trawlers to reduce the excessive discarding ofundersized plaice. After the establishment of the Plaice Box, discarding has not been reduced because the undersized plaice have moved to deeper waters outside the box. It is unresolved whether this is due to thelack of bottom trawling in the Plaice Box which has reduced the food availability for plaice, as fishers claim, or due to the increase in temperature (van Keeken et al 2007; Verweij et al., 2010; Beare et al., 2013).

Another problem in quantifying the impact of trawling on the benthos is the lack of data on the frequency offishing at appropriate spatial and temporal scales. Although data on the distribution of fishing effort isavailable for historic periods (Jennings et al 1999; Engelhard et al., 2011), the spatial resolution of the data (ICES rectangles of ~50 x 50 km) is too crude because fishing effort has been shown to be highly patchy at a scale of ~2x2 km (Rijnsdorp et al., 1998). It is only since the introduction of the Vessel Monitoring System that fishing effort is recorded at the appropriate spatial resolution (Deng et al., 2005; Murawski et al., 2005; Mills et al., 2007; Mullowney and Dawe, 2009; Bastardie et al. 2010b; Lee et al., 2010; Hintzen et al. 2010; Gerritsen and Lordan,2011). With the high resolution VMS data of the relevant fisheries, trawling frequencies can be estimated at appropriate spatio-temporal scales for different benthic communities to assess the impact on communities ofdifferent sensitivities.

In order to understand how fishing may impact benthic ecosystems, there is a need to develop a mechanisticunderstanding on the 'key' processes that determine the structure and functioning of the benthic ecosystemas well as having the knowledge of how fishing may impact these 'key' processes.

Table 1.1. The different pathways by which fishing may impact the benthic ecosystem by distinguishing between the mechanism and the ecological effect.



Impact	Effect	Mechanism
Direct	Mortality	Gear contact
	Food subsidies	Discarding and trawl track mortality
	Habitat alterations	Disturbance of sediment
	Geo-chemical processes	Disturbance of sediment
Indirect	Changes in predator-prey interactions, including feeding of commercial fish species	Changes in species or size composition
	Changes in competition for food or space	Changes in species or size composition
	Changes in bioturbation, nutrient fluxes, bentho-pelagic coupling	Changes in species or size composition
Chronic effect	Changes in habitat	Disturbance of sediment or biogenic organisms

2 - BALTIC SEA

2.1. Introduction

Baltic demersal fisheries are dominated by otter trawlers targeting roundfish or Norway lobster (*Nephrops norwegicus*) in soft sediment habitats. These fisheries both impact the seabed, as well as produce substantial amounts of discards. Gill net fisheries target a variety of demersal fish such as cod and the flatfish sole, plaice, flounder and turbot and are supposed to have minor impacts on the benthos. In coastal waters bivalves are exploited using shellfish dredges. The western Baltic Sea offer a unique opportunity to analyse the benthic effects of fishing thanks to the closure of Øresund to towed gears since the 1920s, and the introduction of the Kattegat MPA (marine protected area) in 2009 (including cod closure) and the western Baltic Sea Natura-2000 areas. Furthermore an extensive benthic national monitoring and data collection effort has taken place in the area over a number of years, which can be used to investigate spatial and temporal differences in the development of benthic communities in (chronically) trawled/dredged/seined and non-trawled / dredged / seined areas.

Benthic ecosystem impacts from demersal fishery in the western Baltic is assumed to come mainly from Nephrops trawling in the central and southern Kattegat, mussel dredging in the Belt Sea, and mixed cod trawling in the western Baltic Sea. The Baltic case study has focus on gear technological innovations to reduce effort, benthic contact of fishing gears, and discarding. Management measures according to ecosystem impacts of the western Baltic and Kattegat trawl (and seine) fisheries have so far focused on by-catch and discard reduction. This has involved implementation of a row of gear technical measures to increase selectivity of especially trawl gears, e.g. mesh sizes, mesh types, grids, and sorting panels. No measures are implemented at present for reduction of benthic impacts of fishing gears on the benthic habitats and communities by the Baltic trawl fisheries.

In relation to evaluation of benthic impacts of towed (demersal) gears in the Baltic Sea a number of innovations are evaluated under the BENTHIS project. There are conducted experimental fisheries in relation to evaluation and comparison of ecosystem and habitat impacts, catch efficiency (target/by-catch/discard/invertebrates), selectivity, energy efficiency, and economic efficiency (vessel specific cost-efficiency/cost-benefit analyses) of different gear modifications compared to standard gears. Furthermore, the case study evaluates potential fishing closures directed towards sensitive benthic habitats and communities. The case study explore in cooperation with the industry a number of possible innovations, gears and their modifications to reduce fuel consumption, maintain catch efficiency towards target and by-catch species, reduction of discard, and to reduce direct benthic impacts by the gears on the benthic habitats and communities in order to reduce ecosystem impacts compared to standard gears.

2.2. Fishing gears used with benthic impact and major bottom contact

Mussel dredging

Sub-tidal beds of blue mussels (*Mytilus edulis*) are fished with dredges in several countries including UK, Ireland, and Denmark (Dolmer and Frandsen, 2002; Smaal, 2002). Blue mussels form beds that support high densities of associated fauna and, compared with the surrounding sediment, the mussel beds can be regarded as islands of high biodiversity (Norling and Kautsky, 2008; Ysebaert et al., 2009). In Denmark, 30000–40000 tons of blue mussels are harvested annually by mussel dredging in coastal areas (Frandsen et al. 2014). The fishing grounds include NATURA 2000 sites designated for a number of marine habitat types including 1110 Sandbanks, 1160 Large shallow inlets and bays, 1170 Reefs, marine mammals, and a number of birds including mussel-eating birds. In 2013 a new Mussel Fishery Management plan was decided in Denmark in order to regulate the fishery in Natura 2000 areas. The mussel fishery was banned in habitats that are vulnerable to dredging, e.g. Zostera beds and geogenic reefs, while restricted fishing effort with low impact gear was permitted in the remaining NATURA 2000 area. The management plan allows for a cumulative impact by area of 15% on 'Large shallow inlets and Bays' and 'Sandbanks' in 2013, reducing to 13% in 2017. The management plan is an adaptation of the Irish management of aquaculture (Anonymous, 2013), and the Dutch management of the fishery for seed blue mussels used for bottom culturing (Nehls et al., 2009).

Subtidal dredging is reported to affect the benthic fauna (Eleftheriou and Robertson, 1992; Dolmer et al., 2001; Dolmer, 2002) and flora (Neckles et al., 2005) and to change the structure of the sea bed (Dolmer, 2002; Dolmer and Frandsen, 2002). Dredging may also reduce substrate complexity owing to by-catch of shells and stones and this has been demonstrated to locally reduce survival of juvenile blue mussels (Dolmer and Frandsen, 2002; Frandsen and Dolmer, 2002) as well as the population structure of sessile epibenthic organisms such as *Metridium senile* (Riis and Dolmer, 2003). Furthermore, dredging is reported to affect higher trophic levels such as birds through competition for resources (Atkinson et al., 2010). Apart from the potential impact on transparency as a result of a reduction in the filtering biomass (Møhlenberg, 1995; Dolmer, 2000), dredging may also reduce transparency locally owing to resuspension of sediment (He and Winger 2010). Resuspension is induced at the bottom during dredging and at the surface when by-catch of sediment is released when washing the catch (Riemann and Hoffmann, 1991; Dyekjær et al., 1995). Besides reducing transparency, resuspension of sediment has been found to increase levels of ammonia and silicate in the water column and to reduce the oxygen content (Riemann and Hoffmann, 1991).

Figure 2.1. Different types of mussel dredges – light at the left and standard heavy at the right hand side.

Pilot investigations presented in Frandsen et al. (2014) have focused 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 are 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 results of the pilot investigations of dredging blue mussels, *Mytilus edulis* are the following:

i. With respect to ecosystem impacts of mussel dredging: 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 (Figure 2.1);
iii. Tested against a standard dredge on commercial vessels using different experimental setups;
iv. Results from use of light dredge: 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 not be distinguished by use of a side-scan sonar and the tracks were still detectable two months after fishing.

Mixed fishery cod trawling in the Western Baltic Sea

The main fishery (main catches) of western Baltic cod is by trawlers, gillnetters and to a small degree by Danish Seines in the ICES subdivisions (SD) 22-24, i.e. in the Belt Sea and the western part of the western Baltic Sea (ICES 2013a). There is a trawling ban in place in subdivision 23 (the Sound). This implies that at present gillnetters are taking the major part of the commercial cod catches in the Sound. In SD 22 and 24 the main part of the catches are taken by trawlers. The cod trawl fishery in the western Baltic Sea is mainly conducted with demersal otter board trawlers. Catches are predominantly Danish, German and Swedish, with smaller amounts occasionally reported by other Baltic coastal states (ICES 2013a). In 2012, most of cod landings in SD22-24 were taken in SD24. The landings from SD24 has been rather stable while those from SD22 has decreased substantially in recent years Presently, around one third of the cod catches is taken in SD22, where fishery mainly takes place in the first quarter of a year.

Management measures according to ecosystem impacts of the Baltic cod fisheries have so far focused on by-catch and discard reduction. No measures exist at present for reduction of benthic impacts of the Western Baltic cod fisheries. In the Baltic cod fishery, different cod-end mesh sizes and panels have been implemented as technical management measures to increase targeting and avoid un-intended by-catch and discard. The Baltic Sea trawl fishery that targets cod has traditionally been with two different cod-end types. The first is a BACOMA cod-end with 105- or 110-mm mesh-size (depending on period) with diamond mesh netting in the normal T0 orientation, and with a 120-mm square mesh netting in the upper panel (Madsen et al., 2002); the second is a 120-mm T90 cod-end, in which the mesh orientation is turned by 908 (Wienbeck et al., 2011). The BACOMA cod-end was in 2010 increased from 110 mm to 120 mm to minimize the discard of cod in the western Baltic. The purpose of mounting different selection panels in the cod-end of the Baltic cod trawls has been to target certain species and size groups and accordingly to reduce discard.

Pilot investigations with initial trials with pelagic doors and alternative gear riggings to reduce bottom contact in the western Baltic trawl mixed cod trawl fishery have already been conducted. It is considered that the most 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 the 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 when 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, the 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 Technical Report 2007).

The initial results of the 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 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 values in the figure should be treated with caution. Further testing is needed.

Figure 2.2. Pelagic trawl doors compared to standard trawl doors in demersal cod trawl fishery.

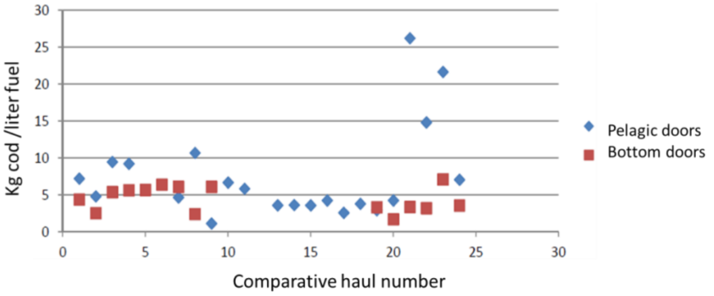


Figure 2.3. Cod catch weight (kg) per liter fuel consumption for the same trawl and sweep lengths fished with pelagic doors (blue diamonds) and bottom doors (red squares) from the same vessel, but on different trips (Gemba, 2011).

A major scientific approach has been to develop bio-economic and spatial and seasonal explicit fisheries management evaluation methods and models which take into account and integrate fisheries dynamics and behavior, maritime cross sector spatial planning, fish population dynamics, and marine ecosystem dynamics, as well as fisheries energy efficiency. These innovative methods and simulation tools cover different marine seas and areas, several fish stocks and international fisheries. They operate on a spatio-temporal highly explicit scale and on vessel or fleet (métier) specific basis enabling quantitative effect evaluation of fisheries management measures and broader marine management for different areas to reduce impacts on the marine environment, ecosystem, and habitats to optimize fisheries performance both with respect to ecological sustainability, economic sustainability and energy efficiency. The Baltic FLR model (Bastardie et al. 2010a; Kell et al., 2007), which is a multi-stock and multi-fleet bio-economic model that is seasonal and spatial explicit, has been developed to evaluate effort regulation and quota based regulation systems and management scenarios for the Baltic cod fishery on a fleet specific basis (Bastardie et al. 2010a; Bastardie et al. 2010d; Bastardie et al. 2009). The Baltic FLR model has furthermore been dynamically coupled with the multi-species model SMS to take into account biological interactions between cod, herring and sprat in the management evaluation (e.g. Bastardie et al. 2012; Nielsen et al. 2011). The DISPLACE model is an individual vessel based bio-economic multi-stock and multi-fleet model (Bastardie et al. 2010c; Bastardie et al. 2013; Bastardie et al. 2014; Bastardie et al. (submitted); Bastardie et al. (In advanced prep.)) which is highly spatial explicit using satellite track data of individual vessels and their fishing trip based catch information (coupling of Logbook-VMS data; e.g. Bastardie et al. 2010b) and using individual fishermen behavior information (e.g. Bastardie et al. 2013). This model has been developed to perform spatial fisheries management evaluation also in context of broader marine management and cross sector maritime spatial planning. A major facet of the model is to evaluate energy efficiency of the fishery in terms of individual vessel fuel consumption in relation to effort allocation (Bastardie et al. 2013; 2014), impacts of large marine constructions on stocks and fisheries (e.g. Miethe et al. 2014). In present context it has been used in a pilot study for evaluation of overall fishing pressure by type of vessel and gear in relation to assessment of fishery impacts on benthic sensitive habitats according to effort allocation in different habitat areas (Bastardie et al. (submitted)).

Another focus in this pilot study for the Baltic cod-fishery is scenario evaluation of different effort allocation schemes with respect to benthic impacts and catch efficiency of Western Baltic trawl fishery evaluated through effects of potential fishing closures. The western Baltic waters offer a unique opportunity to evaluate the benthic impacts of fishing closures (both acute and chronic impacts) from comparative studies of habitats and catches inside and outside potential closures. The DISPLACE model has also been developed to evaluate this aspect (Bastardie et al. 2013; 2014). In the pilot study certain fishing closures in the Western Baltic Sea has already been evaluated according to large marine constructions (fixed Fehmarn 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. (submitted)). In relation to the BENTHIS project (Baltic case study) initial investigations with evaluation of trawl fishery impacts on sensitive habitats with respect to effort pressure is performed in Bastardie et al. (In advanced prep). These simulation studies will be followed up upon when the actual impact of the specific gear is known which among other will be obtained from a desk study using comparable results from BENTHIS.

Mixed Nephrops trawl fishery in Kattegat

Both Denmark and Sweden have *Nephrops* fisheries in the FU4 (Kattegat). In 2012, Denmark accounted for about 77% of the total landings in FU4 on ca. 1900 tons, while Sweden took 23 %. Minor landings have been taken by Germany (1%), however, no landings were recorded in 2012 (ICES 2013b). The Danish landings exclusively originate from demersal trawl fishery directed for *Nephrops* but with by-catches of cod and flatfish. Also, the major part of the Swedish landings originates from demersal trawl fisheries, but by-catches and landings of other species are minor due to the use of sorting grid in this trawl fishery(Frandsen et al. 2013a). About 20% of the total Swedish landings of *Nephrops* were from creel fishery with minor by-catches (Jansson 2008; ICES 2013b).

Cod and sole are significant by-catch species in the mixed fisheries in Kattegat-Skagerrak, and even if data on catches, including discards, of the by-catch gradually become available, they have not yet been used in the management. The ICES WGNSSK (ICES 2013b) has for many years recommended the use of species selective grids in the fisheries targeting *Nephrops* as legislated for Swedish national waters. New technical measures (Swedish grid and SELTRA trawl) to reduce by-catch have recently been agreed upon for the *Nephrops* directed fishery and have been implemented since the 1st February 2013. The European Union and Norway have also agreed that a discard ban should be implemented in the Skagerrak (Division IIIa N) (ICES 2013b). The mixed *Nephrops*-fish fishery is characterized by a relatively high by-catch of juvenile fish species and high discard rates. In the Kattegat, the cod stock is at a critically low level (ICES 2013a), and measures have been taken to rebuild it, including designating seasonally, year round protected areas where only selective fishing gears are allowed, and a fully closed area (ICES 2013a; Madsen and Valentinsson 2010; Sköld et al. 2012; Vinther and Eero 2013). The use of a sorting grid is an option in the Norway lobster fishery under current legislation in Skagerrak and Kattegat (Valentinson and Ulmestrand 2008; Frandsen et al. 2009; Madsen and Valentinson 2010) and has also been tested recently in other Norway lobster fisheries (Loaec et al. 2006; Catchpole et al. 2006; Graham and Fryer 2006; Drewery et al. 2010). While sorting grids are very effective at allowing cod to escape and to reduce discard (Valentinson and Ulmestrand 2008; Frandsen et al. 2009; Madsen and Valentinson 2010), they are more difficult to handle onboard the small vessels that typically operate in this area, and fish and debris can block the grid. Furthermore, losses of Norway lobster, particularly the larger and more valuable individuals, have been observed (Frandsen et al. 2009). In general, Danish vessels in Kattegat and Skagerrak have not used the Norway lobster grids that have been permitted by the legislation since 2005, even though the use of these grids allows unlimited days at sea, whereas there have been severe restrictions on using less selective gear. The square-mesh escape window (henceforth window) is one of the most widely used selective devices in European fisheries. A 120 mm window was implemented in the Kattegat and Skagerrak fisheries beginning in 2005 (Krag et al. 2008), but it did not produce a marked improvement in selectivity for cod (Frandsen et al. 2009).

Conventional escape windows are not adequate to properly release cod and other by-catch species caught in the trawls. To address this issue Madsen et al. (2012) developed a novel sorting box concept consisting of a four-panel section with a window on the top in order to improve the escape of cod and other by-catch species through an escape window while retaining the target catch of Norway lobster. The concept was tested on a commercial trawler in Kattegat and Skagerrak. Two different window mesh sizes and two different sorting box heights were tested using a traditional codend cover and a dual cod-end cover. Here there were observed greatly reduced by-catches of both cod and other fish species compared to a standard cod-end.

On the contrary, the major part of the Swedish fishers have adapted to the use of sorting grid since it was introduced in national waters in 2004. The incremental use is likely due to the incentives by the management, i.e. access to *Nephrops*-fishing grounds along the coast, derogation from effort limitation (article 11) and dedicated quotas (Sköld et al. 2011). Currently the Swedish *Nephrops* quota is allocated to different gear categories (20% to creels, 50% to grid trawls, and the remaining 30% to other trawls, ICES 2013b).

In summary, management measures according to ecosystem impacts of the Kattegat Nephrops fisheries have so far focused mainly on by-catch and discard reduction. The exception is the trawl boundary along the Swedish coast. The trawl boundary was furthered out in 2004 with aim of avoiding trawling on reefs according to the habitats directive (Sköld et al. 2011). However, no measures exist aimed at reducing benthic impacts in the open Kattegat.

One focus in the Baltic case study for the mixed Nephrops trawl fishery is to evaluate impacts of existing fishing closures. In general, a complication for the appropriate assessment of the impact of bottom trawling is the lack of suitable untrawled reference areas. Only few studies have been able to compare the benthos between untrawled reference areas and trawled areas (Blyth-Skyrme et al. 2004; Løkkeborg 2005; Duineveld et al 2007). In addition, reference areas are often not representative because they are not selected at random. In the western Baltic Sea and Kattegat case study there is made evaluation of closures of certain fishing areas in relation to distribution of sensitive habitats and benthic communities. This includes comparative analyses of multiple data time series of catch rates and benthic sampling according to the different types of fishing areas, involving the long term closure of the Sound to towed gears since the 1920s and the short term closed area from the Kattegat MPAs introduced in 2008 which are compared to (nearby or surrounding) otherwise heavily exploited fishing regions in Kattegat (open fishing grounds) in relation to the potential effects of *Nephrops* trawl fishery but also in context of a broad variety of mixed demersal trawl (and seine) fisheries (Figure 2.4).

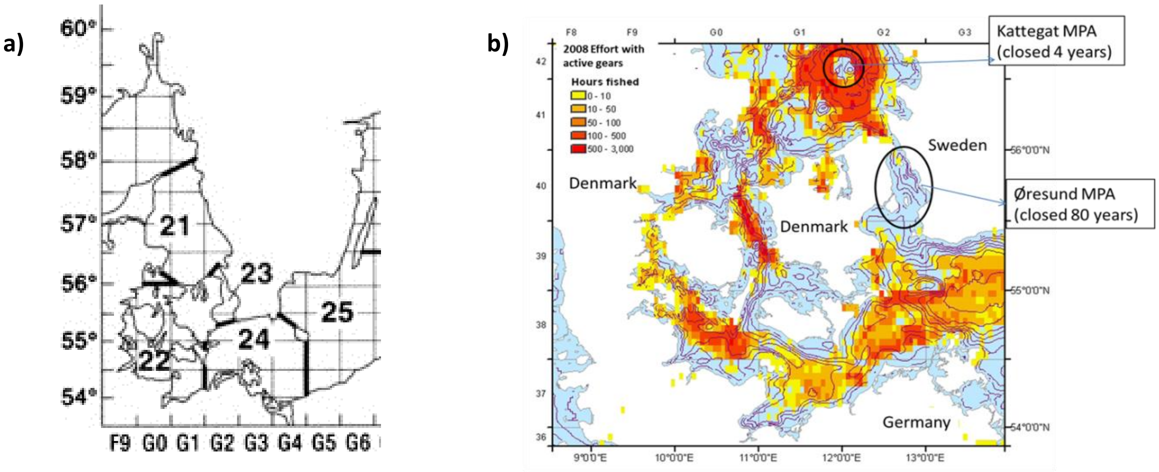


Figure 2.4. A) Fishing areas and B) fishing closures in Kattegat and the Sound.

Data have been gathered to evaluate the closure effects and contribution of closed areas to good environmental status in the Kattegat benthic communities in relation to Nephrops mixed trawl fishery including the short term closure from 2009. The permanent closure, i.e. the SE area (crossed in Fig. 2.5 below) in the Kattegat is an area that fully protects bottom habitats and the associated organism from abrasion by bottom trawling which is one of the pressures that affects the status of the seafloor. The intention of the study is firstly to evaluate the performance of the pressure indicator of bottom trawling, i.e. satellite positioning of fishing vessels (VMS) as an indicator of seabed status in the Kattegat utilising the improved state of the art modelling of trawling pressure developed in WP2 of the BENTHIS project. Secondarily, the aim is to evaluate the potential recovery of benthic community in the permanently closed area following the establishment of the closure in 2009. Benthic habitats are patchy on different scales and so are the use of the ecosystem e.g. fishery by bottom trawling. The topography and substrates of Kattegat overlaid by positions of active bottom trawlers is a good example of that as shown in Figure 2.5.

To evaluate the potential recovery of benthic organism from bottom trawling and trawling impact on the areas, a grid 1 X 1 km was constructed and the sum of trawling positions from fishing vessels satellite positioning (VMS) within each cell during the years 2004-2007 (Swedish vessels) and 2006-2007 (Danish vessels). A stratified sampling design was then applied to the trawled areas to allocate 16 benthic grab sample stations to be taken in each part of the closure. Eight samples within each area were allocated to either high trawling frequency (>30 positions) or low trawling frequency (0-10 positions). The samples of benthic infauna were taken in May 2009-2011 and in 2014 using a Smith-McIntyre grab (0,1 m^2). In 2014, sediment profile images are as well collected to complement the analysis. The putative effects on species are tested against the factors area and year and age, using multivariate approaches. Data distribution graphs will be used to visualize potential associations and proportional significance of each variable (species) to explain the association pattern.

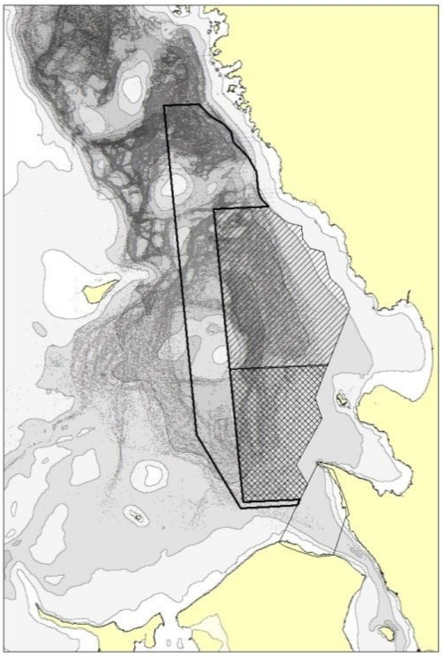


Figure 2.5. Depth contours and Swedish and Danish bottom trawlers positions as indicated by hourly VMS positions (black dots). The crossed area is completely closed to fishing activities since 2009. The other outlined areas are seasonal and partial closures for non-selective fishing gears.

Further investigations of differences in benthic impact of the Nephrops trawl fishery (and other trawl fishery) in the Kattegat area in relation to the open fishing area Northern Kattegat, the short term closed area Southern Kattegat, and the long term closed area in the Sound (ICES SD23) with respect to longer term biological benthic impacts of fisheries and short term differences in catch rates from the different areas will be carried out. The evaluations will involve comparative analyses of catch efficiency, cost benefit analyses (CBA), energy efficiency analyses, by-catch and discard analyses, etc.

A gear technological efficient option to reduce benthic impacts of the Kattegat Nephrops trawl fishery is shortening of the sweep lengths according to fishermen and gear manufacturers. Accordingly, traditional Nephrops twin-trawl with benthic doors and 2 different sweep lengths (standard, 74 m, compared with short sweeps around 10 m) will be evaluated according to fishery in the Aalbæk Bay, Northern Kattegat, which is a standard Nephrops trawl fishery area (open). The rationale 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) 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. 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 according to a fish catch (especially according to cod), or because of lack of individual quotas for fish species for the *Nephrops* fishermen because these quotas are very expensive. Accordingly, un-wanted by-catch and according discard will be reduced. The shorter sweep lengths will as such also meet a coming discard ban in the fishery. The rationale is furthermore that shorter sweeps are considered to have less benthic contact and cause less benthic and impact. Physical and biological benthic impacts of different sweep lengths will be evaluated with respect to different sweep lengths. This is planned to be tested in a BACI design using sediment profile imaging (SPI) and core samples (haps corer) for measures of sediment grain size composition, SPI index values, pigment profiles (HPLC), depth of H2S free zone, and species abundance, biomass and diversity and biological traits composition. Furthermore, side scan sonar & UW video recording may be used. If possibly, laser profiling will be carried out to evaluate the physical impact of different trawl elements. Furthermore, the evaluations will involve comparative analyses of catch efficiency, cost benefit analyses (CBA), energy efficiency analyses, and by-catch and discard analyses in relation to different sweep lengths.

Nephrops creel fishery as an alternative to Nephrops trawl fisheries in Kattegat

In the Skagerrak (ICES SD20 or Division IIIaN), approximately 25% of the Swedish Nephrops quota is taken by the creel fishery, while the creel fishery in the Kattegat (ICES SD21 or Division IIIaS) is limited. Most creel vessels are less than 12 meters and fish in coastal areas, where it is often combined with gillnetting, trawling or creeling for other species (e.g. crabs and black lobster). The Swedish creel fishery for Nephrops occurs primarily north of Varberg, largely due to the absence of the archipelago, which is why the use of trawls further south is favoured (ICES 2013a). It is also difficult to deploy creels in trawled areas and since the fishing grounds for Nephrops in the central and southern Kattegat are intensively trawled there is only limited space for the creel fishery to develop. Fishermen's understanding on the benthic impact of creeling is that there is very limited impact, whereby creels are directly lifted off the bottom. During a creel trail in autumn 2013 cameras were used to obtain a preliminary understanding around this issue. The footage 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 footage obtained and therefore needs to be measured. However, it should be noted that dragging of creels over the seabed during a relatively limited time interval of heaving is physically impacting a smaller area than a trawl haul with impact from doors, sweeps and footrope over long time span covering a larger area.

During commercial creel fishing, catches are sorted immediately, where Nephrops are retained and the rest thrown overboard. Previously, it was estimated that by-catch was thrown back in the water within 20 seconds (Jansson, 2008), which was also the case in the DTU Aqua trial in spring 2013. All catch immediately went to the bottom, and no predation from sea birds was observed. By-catch of round fish is considered most vulnerable to this type of fishing as their swim bladder inflates when they pulled up quickly through the water column. There were observed no visible deviations in the cod's behaviour when they swam to the bottom. However, previous studies have shown that cod can swim far down (> 10 m) with distended swim bladders until they become exhausted and float back to the surface where they become available to sea bird predation (pers. Comm. J. Karlsen, DTU Aqua, http://www.dtu.dk/Service/Telefonbog/Person?id=39844&tab=2&qt=dtupublicationquery).

Pilot investigations with creels on soft (muddy) bottom are reported in (Frandsen et al. 2013b). The main results were the following:

(i) Camera monitoring indicated that the creels sank very much down into the sediment;
(ii) The bait attracted Hagfish (*Myxine spp.*) which scared the Nephrops in the creels => some escapement;
(iii) Catch rates about 180 g/creel per day;
(iv) CBA: Daily profit about 3800 DKK per day;
(v) CBA: Comparable trawl fishery for trawlers < 12 m about 3050 DKK per day, i.e. comparable; Larger trawlers have higher profit;

Figure 2.6. Creel fishery as an alternative to trawl fishery as well as different options for the creel settings and parameters.

The overall aim of the evaluation is to provide information on benthic impacts of creels (Fig. 2.6) to be compared to benthic impacts of the Nephrops-fish mixed trawl fishery and at the same time compare the catch efficiency and the economic efficiency in these fisheries, as well as discard levels, given different fishing conditions. Aspects of this purpose are already covered in the pilot studies described above. Further, evaluation will be performed through:

(i) Overlapping fishery between Swedish commercial Nephrops trawl fishery with standard trawl and Swedish creel fishery in northern Kattegat;
(ii) Experimental fishery to follow up on pilot investigation results on fishery at soft bottom in standard Nephrops trawl areas compared to usual creel fishery at harder sediment types;
(iii) Attachment points of the creels (top instead of center point), shelters in the creels;

The evaluation will cover change in catch rates (Catch per Unit of Effort, CPUE), discard reduction, economic efficiency, cost-benefit analyses, and potentially estimation of reduced bottom impact (also when heaving 40 creels on one line).

2.3. Importance of fishing gear types used with benthic impact in regional seas

The different types of fishing gears used in the international Baltic fisheries are tabulated below as assessed and reported in EU STECF (2013).

Table 2.1. Regulated gear types, mesh sizes and special conditions as defined in Reg. (EC) No. 1098/2007.

Gear	Mesh Size	SPECON
OTTER	>=90mm	None
OTTER	>=90mm	BACOMA
Danish Seine	>=90mm	None
Danish Seine	>=90mm	BACOMA
Pelagic Trawl	>=90mm	None
Pelagic Trawl	>=90mm	BACOMA
Pelagic Seine	>=90mm	None
Pelagic Seine	>=90mm	BACOMA
Gill net	>=90mm	None
Trammel net	>=90mm	None
BEAM	>=90mm	None
Longlines		

Table 2.2. Unregulated gear types, mesh sizes and special conditions as defined in Reg. (EC) No. 1098/2007.

Gear	Mesh Size	SPECON
OTTER	<90mm	None
Danish Seine	<90mm	None
Pelagic Trawl	<90mm	None
Pelagic Seine	<90mm	None
Gill net	<90mm	None
Trammel net	<90mm	None
Beam Trawl	<90mm	None
DREDGE	All	None
POTS	All	None

The gear groupings used by EU STECF (2013) covers:

(a) Bottom trawls and seines (OTB, OTT, PTB, SDN, SSC, SPR) of mesh:

- TR1 equal to or larger than 100 mm,
- TR2 equal to or larger than 70 mm and less than 100 mm,
- TR3 equal to or larger than 16 mm and less than 32 mm;

(b) Beam trawls (TBB) of mesh:

- BT1 equal to or larger than 120 mm
- BT2 equal to or larger than 80 mm and less than 120 mm;

(c) Gill nets, entangling nets (GN);

(d) Trammel nets (GT);

(e) Longlines (LL).

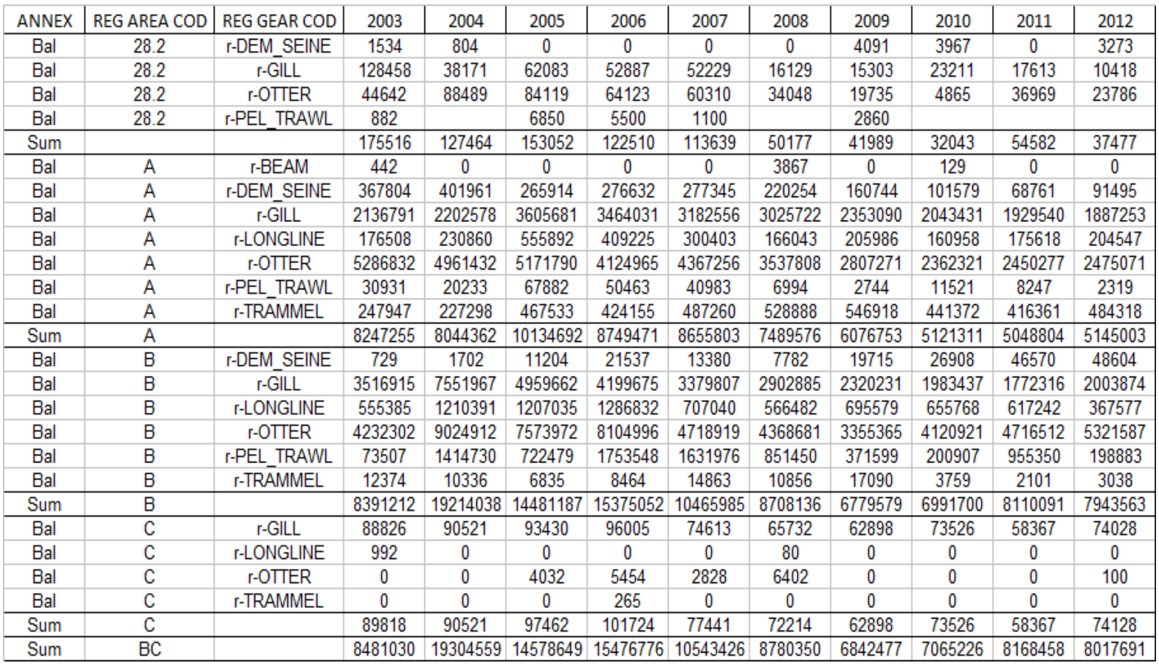
The deployed effort of regulated gears remains rather constant in ICES Subdivisions (SD) 22-24 (slight increase in regulated otter trawls). The effort-regulated otter trawls are the major cod gears, contributing 67% to the catch in SD 22-24. The second among the ranked cod gears are gill nets. Cod discards are generally low. With a lack of information from Estonia, small boats <8m LOA were found to constitute 7 and 12% to the overall effort deployed in the Baltic in 2011 and 2012, respectively. Small boats are primarily operating in the northern cod plan area (SD 29-32). (EU STECF, 2013). Fisheries in the Kattegat are almost exclusively conducted by Denmark and Sweden (88% and 11% of the total regulated effort in 2012, respectively) using predominantly trawls and primarily the gear class TR2. The TR2 gear constitutes 90% of the total regulated effort. Beam trawls are forbidden. The effort deployed by passive gears (GN1, GT and LL1) in Kattegat is relatively small, with a stable share of around 3% of the total regulated effort in 2012. The effort deployed by unregulated gear categories in Kattegat (including effort under the derogation CPart11) was 30% of the total effort in 2012. In 2012, the nominal effort (kW days at sea) deployed by small vessels (LOA<10m) in Kattegat constituted 12% of the total effort in the area. (EU STECF, 2013)

Table 2.3. Trend in nominal effort (kW*days at sea) by gear categories according to Council Regulation (EC) 1098/2007, 2004-2012 for the international Baltic Sea fisheries. An “r” in front of the gear type indicates regulated gears. Gear types without an “r” are non-regulated gears. Data from Sweden and Poland were only available from 2003 or 2004 respectively. Relative change from 2004 to 2012.

REG GEAR COD	SPECON	2004	2005	2006	2007	2008	2009	2010	2011	2012	rel. change
BEAM	none	0	132	1090	881	27566	16298	884	884	368	1,00
DEM_SEINE	none	50829	31212	20892	20597	12522	5337	5031	12266	882	-0,98
DREDGE	none	78384	72955	97700	110931	45088	48712	65364	56203	91968	0,17
GILL	none	2514485	2781351	2465917	2293892	2019216	1862392	1922682	1906426	775303	-0,69
none	none	75976	144961	174621	150574	118723	114766	84697	68246	77949	0,03
OTTER	none	2870433	2450721	1971668	1672218	1353484	1477623	1197194	1101870	973442	-0,66
PEL_SEINE	none	2499	0	0	0	3528	16467	13674	12645	27163	9,87
PEL_TRAWL	none	15552840	62133235	45906681	39463937	43240579	40031349	29616128	26579447	8216408	-0,47
POTS	none	1519123	1616616	1346062	1211896	1209985	883458	1035858	919071	379577	-0,75
r-BEAM	BACOMA	0	0	0	0	3867	0	0	0	0	0,00
	none	0	0	0	0	0	0	129	0	0	0,00
r-DEM_SEINE	BACOMA	0	0	35178	46741	46182	62042	36621	52390	29641	1,00
	none	404467	277118	262991	243984	181854	122508	95833	62941	113731	-0,72
r-GILL	none	9883237	8720856	7812598	6689205	6010468	4751522	4123605	3777836	3975573	-0,60
r-LONGLINE	none	1441251	1762927	1696057	1007443	732605	901565	816726	792860	572124	-0,60
r-OTTER	BACOMA	8077219	6708057	8744572	6593542	5519745	4073745	4223497	3584428	3535393	-0,56
	none	5997614	6125856	3554966	2555771	2427194	2099090	2103909	3342583	4089663	-0,32
	T90	0	0	0	0	0	9536	160701	276747	195488	1,00
r-PEL_TRAWL	BACOMA	1185898	577852	1689966	1636710	854557	349455	199507	936461	181573	-0,85
	none	249065	219359	119545	37349	3887	27748	12921	27136	19629	-0,92
r-TRAMMEL	none	237634	474368	432884	502123	539744	564008	445131	418462	487356	1,05
TRAMMEL	none	20495	31581	32540	31788	25870	11054	11927	10883	5265	-0,74
Grand total		50161449	94129157	76365928	64269582	64376664	57428675	46172019	43939785	23748496	-0,53

The trend in nominal effort (kW*days at sea) by gear categories for the international Baltic Sea fisheries for the period 2003-2013 is shown in Table 2.3 as assessed and reported in EU STECF (2013). The similar trend by area in nominal effort (kW*days at sea) by gear categories for the international Baltic Sea fisheries for the period 2003-2013 is shown in Table 2.4 as assessed and reported in EU STECF (2013). The Sub-Areas are defined according to Council Regulation (EC) 1098/2007. This means that Subdivision 22-24 is declared as fishing area “A”, Subdivision 25-28 as “B” and Subdivision 29-32 as “C” (EU STECF, 2013).

Table 2.4. Trend in nominal effort (kW*days at sea) by regulated gear categories and sub-area 2003-2012. An “r” in front of the gear type indicates regulated gears in accordance with Council Regulation (EC) 1098/2007. Data from Sweden and Poland were only available from 2003 and 2004, respectively.



ANNEX	REG AREA COD	REG GEAR COD	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bal	28.2	r-DEM_SEINE	1534	804	0	0	0	0	4091	3967	0	3273
Bal	28.2	r-GILL	128458	38171	62083	52887	52229	16129	15303	23211	17613	10418
Bal	28.2	r-OTTER	44642	88489	84119	64123	60310	34048	19735	4865	36969	23786
Bal	28.2	r-PEL_TRAWL	882		6850	5500	1100		2860			
Sum			175516	127464	153052	122510	113639	50177	41989	32043	54582	37477
Bal	A	r-BEAM	442	0	0	0	0	3867	0	129	0	0
Bal	A	r-DEM_SEINE	367804	401961	265914	276632	277345	220254	160744	101579	68761	91495
Bal	A	r-GILL	2136791	2202578	3605681	3464031	3182556	3025722	2353090	2043431	1929540	1887253
Bal	A	r-LONGLINE	176508	230860	555892	409225	300403	166043	205986	160958	175618	204547
Bal	A	r-OTTER	5286832	4961432	5171790	4124965	4367256	3537808	2807271	2362321	2450277	2475071
Bal	A	r-PEL_TRAWL	30931	20233	67882	50463	40983	6994	2744	11521	8247	2319
Bal	A	r-TRAMMEL	247947	227298	467533	424155	487260	528888	546918	441372	416361	484318
Sum	A		8247255	8044362	10134692	8749471	8655803	7489576	6076753	5121311	5048804	5145003
Bal	B	r-DEM_SEINE	729	1702	11204	21537	13380	7782	19715	26908	46570	48604
Bal	B	r-GILL	3516915	7551967	4959662	4199675	3379807	2902885	2320231	1983437	1772316	2003874
Bal	B	r-LONGLINE	555385	1210391	1207035	1286832	707040	566482	695579	655768	617242	367577
Bal	B	r-OTTER	4232302	9024912	7573972	8104996	4718919	4368681	3355365	4120921	4716512	5321587
Bal	B	r-PEL_TRAWL	73507	1414730	722479	1753548	1631976	851450	371599	200907	955350	198883
Bal	B	r-TRAMMEL	12374	10336	6835	8464	14863	10856	17090	3759	2101	3038
Sum	B		8391212	19214038	14481187	15375052	10465985	8708136	6779579	6991700	8110091	7943563
Bal	C	r-GILL	88826	90521	93430	96005	74613	65732	62898	73526	58367	74028
Bal	C	r-LONGLINE	992	0	0	0	0	80	0	0	0	0
Bal	C	r-OTTER	0	0	4032	5454	2828	6402	0	0	0	100
Bal	C	r-TRAMMEL	0	0	0	265	0	0	0	0	0	0
Sum	C		89818	90521	97462	101724	77441	72214	62898	73526	58367	74128
Sum	BC		8481030	19304559	14578649	15476776	10543426	8780350	6842477	7065226	8168458	8017691

Plots of trends in nominal effort by main sea area for the international Baltic Sea fisheries is shown in the below figures as assessed and reported by EU STECF (2013).

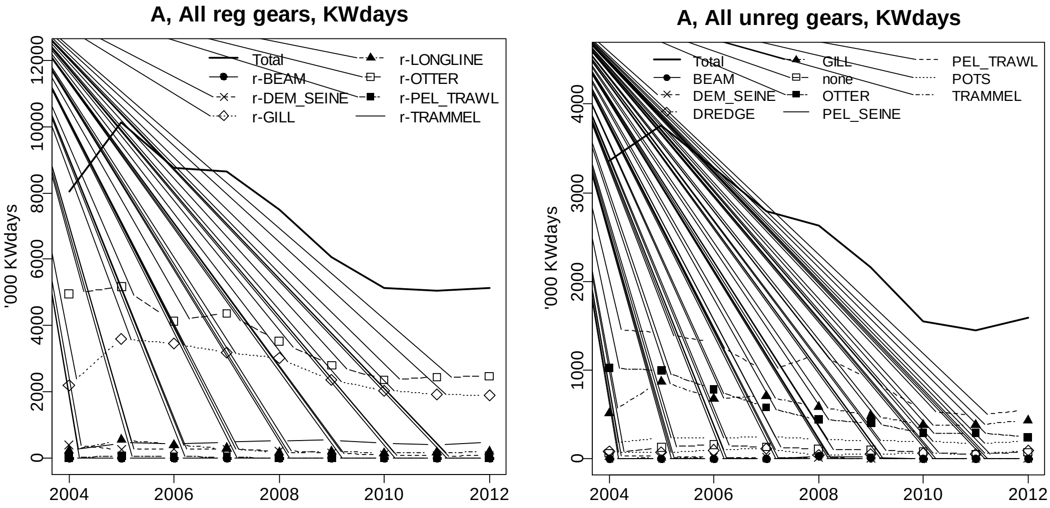


*Figure 2.7. Area A Baltic: Trend in nominal effort by gear types 2004-2012 (kW*days at sea). Left panel: Regulated gears. Right panel: Unregulated gears. Note that data from Poland, Latvia and Lithuania are only available from 2004 and from Estonian from 2005 onwards. Therefore, effort trends are shown from 2004 to 2012. No data from Finland.*

Table 2.5. Kattegat: Trend in nominal effort (kW*days at sea) by regulated gear group and country. 2003-2012. The gear category TR2 does not include effort carried out under the derogation CPart11 (from 2009 onwards) or IIA83b (2004-2008).

REG AREA	REG GEAR	COUNTRY	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Rel. 2003	Rel. 2011
3a	GN1	DEU	13612	14289	26827	38486	39725	31562	23156	19526	21484	11860	0.87	0.55
3a	GN1	DNK	184739	111648	129061	103851	72616	65829	80031	64536	46211	19778	0.11	0.43
3a	GN1	SWE	20309	17690	9609	14748	14949	32697	33120	32270	27481	35082	1.73	1.28
3a	GT1	DNK	12963	14791	28220	24754	11927	11758	22410	13398	11408	5279	0.41	0.46
3a	GT1	SWE	25558	11254	12833	19178	34170	29266	17518	26612	25205	14941	0.58	0.59
3a	LL1	DNK	3240	3080		220					221	397	0.12	1.80
3a	LL1	SWE	5683	1376	10684	27478	37856	25234					0.00	
3a	TR1	DEU	894	2390	4985	5262	5526	1964				4309	4.82	
3a	TR1	DNK	201690	191743	203625	191632	184599	156198	100777	67525	48671	100989	0.50	2.07
3a	TR1	SWE	44370	15121	24870	5160	19799	57592	6985	13626	1006		0.00	0.00
3a	TR2	DEU	35966	31861	7505	10318	35338	38716	19918	30730	13670	2645	0.07	0.19
3a	TR2	DNK	3457175	3062610	2546820	2250888	2026560	2148333	2208298	2378545	2000136	2233489	0.65	1.12
3a	TR2	SWE	1369635	1043622	1046257	1062871	1041966	920320	436355	284594	271686	260287	0.19	0.96
3a	TR3	DEU												
3a	TR3	DNK	655409	483712	485616	359693	301698	146119	75792	27110	25572	70101	0.11	2.74
3a	TR3	SWE					1470		1148					
Total			6031243	5005187	4536912	4114539	3828199	3665588	3025508	2958472	2492751	2759157	0.46	1.11

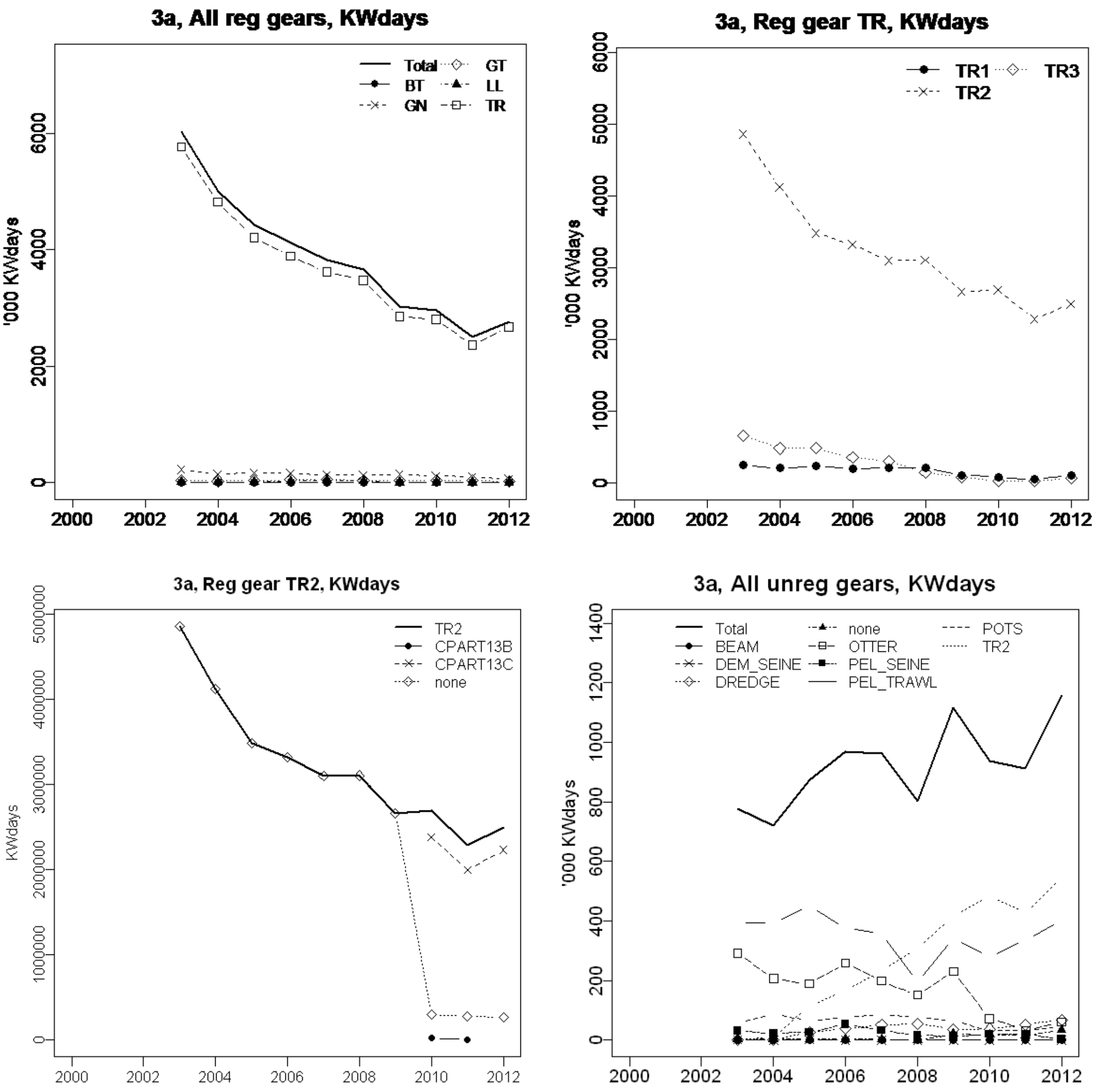
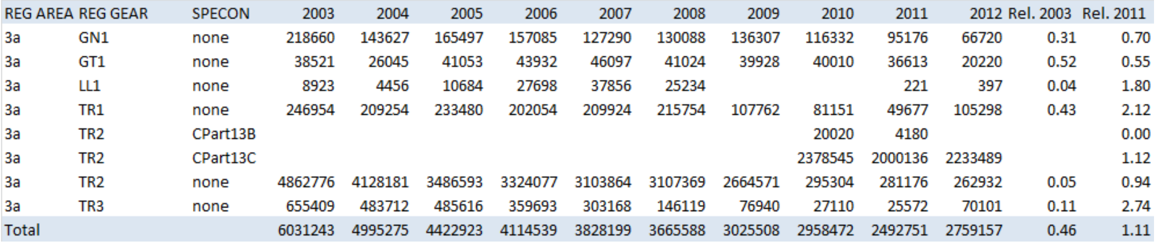


*Figure 2.8. Kattegat: Top left: Trend in nominal effort (Kw *days at sea) by regulated gear types,*

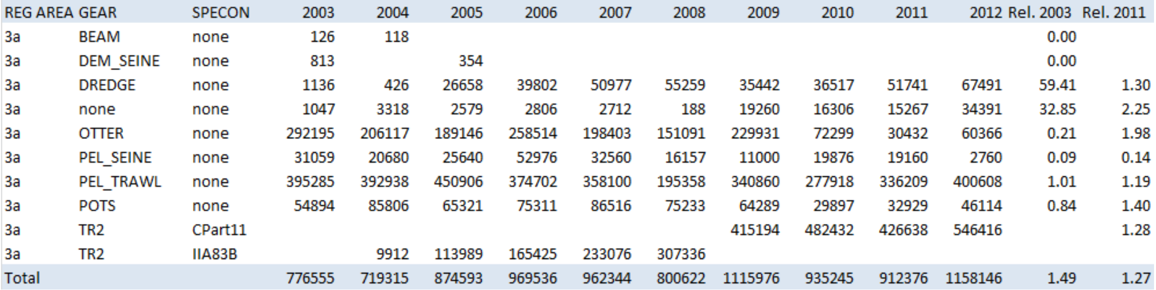
2003-2012. TR=Demersal trawl, BT=Beam trawl, GN=Gillnet, GT=Trammel net, LL=Longline. Note that the derogations CPart11 and IIA83b are not included in the TR gear category since they are considered unregulated. Top right: effort by gear types within gear group TR; TR1=mesh size ≥100mm; TR2=mesh size ≥70, ≤100mm; TR3 ≥16, ≤32 mm. The derogations CPart11 and IIA83b are not included in the TR2 category. Bottom left: Effort by derogation within gear type TR2. Note that the derogations CPart11 and IIA83b are not included in the TR2 category. Bottom right: effort by unregulated gear categories. The TR2 effort here is the effort carried out under the derogations IIA83B (2003-2008) and CPart11 (2009-2012). Cod landings and discards in the western Baltic Sea by year and gear type is given below as assessed and reported by EU STECF (2013).

Table 2.6. Kattegat: Trend in nominal effort (kW*days at sea) by regulated gear group and derogation 2003-2012. All the Danish TR2 effort is under the derogation CPart13C from 2010 onwards while the German TR2 effort is partly under the derogation CPart13B between 2010 and 2011.



REG AREA	REG GEAR	SPECON	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Rel. 2003	Rel. 2011
3a	GN1	none	218660	143627	165497	157085	127290	130088	136307	116332	95176	66720	0.31	0.70
3a	GT1	none	38521	26045	41053	43932	46097	41024	39928	40010	36613	20220	0.52	0.55
3a	LL1	none	8923	4456	10684	27698	37856	25234			221	397	0.04	1.80
3a	TR1	none	246954	209254	233480	202054	209924	215754	107762	81151	49677	105298	0.43	2.12
3a	TR2	CPart13B								20020	4180			0.00
3a	TR2	CPart13C								2378545	2000136	2233489		1.12
3a	TR2	none	4862776	4128181	3486593	3324077	3103864	3107369	2664571	295304	281176	262932	0.05	0.94
3a	TR3	none	655409	483712	485616	359693	303168	146119	76940	27110	25572	70101	0.11	2.74
Total			6031243	4995275	4422923	4114539	3828199	3665588	3025508	2958472	2492751	2759157	0.46	1.11

Table 2.7. Trend in nominal effort (kW*days at sea) of unregulated gears in Kattegat 2003-2012. Sweden is the only country using the derogation Cpart11/IIIA83B.



REG AREA	GEAR	SPECON	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Rel. 2003	Rel. 2011
3a	BEAM	none	126	118									0.00	
3a	DEM_SEINE	none	813		354								0.00	
3a	DREDGE	none	1136	426	26658	39802	50977	55259	35442	36517	51741	67491	59.41	1.30
3a	none	none	1047	3318	2579	2806	2712	188	19260	16306	15267	34391	32.85	2.25
3a	OTTER	none	292195	206117	189146	258514	198403	151091	229931	72299	30432	60366	0.21	1.98
3a	PEL_SEINE	none	31059	20680	25640	52976	32560	16157	11000	19876	19160	2760	0.09	0.14
3a	PEL_TRAWL	none	395285	392938	450906	374702	358100	195358	340860	277918	336209	400608	1.01	1.19
3a	POTS	none	54894	85806	65321	75311	86516	75233	64289	29897	32929	46114	0.84	1.40
3a	TR2	CPart11							415194	482432	426638	546416		1.28
3a	TR2	IIA83B		9912	113989	165425	233076	307336						
Total			776555	719315	874593	969536	962344	800622	1115976	935245	912376	1158146	1.49	1.27

Table 2.8. Fishing effort (kWdays at sea) of small boats (< 8 m by area), Member State and fisheries in 2003-2012.

ANNEX	REG AREA COD	REG GEAR COD	SPECON	COUNTRY	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bal	28.2	GILL	none	LVA							2460	1024		594
Bal	28.2	r-DEM_SEINE	none	LVA							46	36		
Bal	28.2	r-GILL	none	LVA							7387	5022	6518	3432
Bal	A	DEM_SEINE	none	DNK				34			32			
Bal	A	DEM_SEINE	none	POL		1925	1035							
Bal	A	DEM_SEINE	none	SWE			16							
Bal	A	GILL	none	DNK	664	356	4026	7693	4976	4158	3089	1542	3049	2575
Bal	A	GILL	none	POL		70644	49864	34033	43230	35850	21984	35190	40226	48359
Bal	A	GILL	none	SWE	2871	6271	383	885			1353	485	313	442
Bal	A	none	none	DNK	263032	248064	204447	207229	144252	154790	142535	168846	184330	200985
Bal	A	none	none	SWE	22	74	2813	4251	2659	5197	279	706		
Bal	A	OTTER	none	DNK		8		19		15				
Bal	A	OTTER	none	POL						21				
Bal	A	POTS	none	DNK			12524	13839	16716	11219	5304	5506	2272	2455
Bal	A	POTS	none	POL		26730	20268	14502	15888	25323	21954	20576	13086	8841
Bal	A	POTS	none	SWE	28974	23886	25365	28788	23451	12845	23090	29839	8425	14312
Bal	A	r-DEM_SEINE	none	DNK			8				32			32
Bal	A	r-GILL	none	DEU									192	
Bal	A	r-GILL	none	DNK	62	46	15677	15957	14579	21185	15050	12637	10723	11759
Bal	A	r-GILL	none	POL		26014	19941	15700	18809	17544	15584	9865		
Bal	A	r-GILL	none	SWE	24692	13884	15332	16650	15614	15720	7406	13074	15376	9473
Bal	A	r-LONGLINE	none	DNK	782	621	2766	4149	6128	2210	996	982	798	793
Bal	A	r-LONGLINE	none	POL		658			29	97	753	102	173	826
Bal	A	r-LONGLINE	none	SWE		2522	392							
Bal	A	r-OTTER	none	DNK		23	79	121	54	158	63	232		
Bal	A	r-TRAMMEL	none	DNK	419		7361	9765	7424	10027	7100	8239	9080	2845
Bal	A	r-TRAMMEL	none	SWE	3672	8118	10053	8683	7146	7657	7687	14540	9764	6458
Bal	A	TRAMMEL	none	DNK			86	197	40	240	135	4	24	212
Bal	A	TRAMMEL	none	POL		3058	2708	2357	5414	1367	971	112		
Bal	B	DEM_SEINE	none	POL		3111	959	31		59		82	1054	
Bal	B	DEM_SEINE	none	SWE						44				
Bal	B	GILL	none	DNK			56	19		23				
Bal	B	GILL	none	LTU							34504	30277	16793	48662
Bal	B	GILL	none	LVA							844	462	720	1013
Bal	B	GILL	none	POL		145108	109011	72210	71172	60146	51258	50365	397312	386491
Bal	B	GILL	none	SWE	11760	17940	17036	18779	21529	17550	27674	31454	28688	33454
Bal	B	none	none	DNK	34833	25493	22940	27175	22623	24599	29787	23237	25846	19750
Bal	B	none	none	SWE	249	9		1014	4495	1166	1175	998		1798
Bal	B	PEL_SEINE	none	POL									22	
Bal	B	PEL_TRAWL	none	POL			59							
Bal	B	POTS	none	DNK					8					
Bal	B	POTS	NONE	LTU									5018	4869
Bal	B	POTS	none	POL		124796	107603	69044	59160	46886	44134	69259	29144	36719
Bal	B	POTS	none	SWE	152174	138253	149638	180982	205254	137653	162669	129568	85842	85807
Bal	B	r-DEM_SEINE	none	LVA										0
Bal	B	r-GILL	none	DNK			1060	207	610	3465	3415	2783	45	79
Bal	B	r-GILL	none	LTU				30799	67068	16778				
Bal	B	r-GILL	none	LTU							28808	42127	42080	127316
Bal	B	r-GILL	none	LVA							1078	1979	3266	1694
Bal	B	r-GILL	none	POL		613889	572660	483645	447619	343626	398418	322538	22	40
Bal	B	r-GILL	none	SWE	118038	111340	86034	71269	79583	81410	68069	61424	42923	55460
Bal	B	r-LONGLINE	none	DNK			223		718	2210	2163	1041	117	18
Bal	B	r-LONGLINE	none	LTU				1966	10496	132				
Bal	B	r-LONGLINE	none	LTU							2170	3787	7999	2981
Bal	B	r-LONGLINE	none	POL		30606	27836	21358	19258	12028	14925	13281	8997	6490
Bal	B	r-LONGLINE	none	SWE	6965	12481	15858	8229	8089	6978	6209	5882	3589	4140
Bal	B	r-OTTER	none	DNK						54				
Bal	B	r-TRAMMEL	none	SWE	1423	3881	3238	3931	3740	3410	1530	11884	10915	9024
Bal	B	TRAMMEL	none	POL		119			37	31				
Bal	B	TRAMMEL	none	SWE	6098	6999	3406	11500	5455	4858	5238	5030	5433	
Bal	C	DEM_SEINE	none	SWE	1827	824			526					
Bal	C	GILL	none	FIN	1168557	1152304	1000201	1033994	957521	888768	1057622	1188962	1101469	1087866
Bal	C	GILL	none	POL									102	
Bal	C	GILL	none	SWE	165644	160268	173471	166700	168797	154373	185927	169655	139908	106857
Bal	C	none	none	SWE	3523	257	1269	4478	2030	2206	9670	331	6665	2469
Bal	C	OTTER	none	SWE	816			66						
Bal	C	POTS	none	FIN	532031	505759	510189	483518	472706	527856	609518	586124	599198	664637
Bal	C	POTS	none	SWE	255454	240193	275226	277286	251989	227243	247262	234842	191732	140684
Bal	C	r-GILL	none	SWE	47268	39858	49762	46841	40313	28534	38939	38007	25078	29051
Bal	C	r-LONGLINE	none	SWE				3077						
Bal	C	TRAMMEL	none	SWE	912	912								

Table 2.9. Landings (t) and discards (t) for cod in 2004-2012 by gear category, area and Member State. An "r" in front of the gear type indicates regulated gears in accordance with Council Regulation (EC) 1098/2007. Gear types without an "r" are non-regulated gears. Data from Estonia are only available from 2005 onwards.

REG_AREA	REG_GEAR	SPECON	COUNTRY	2004 L	2004 D	2005 L	2005 D	2006 L	2006 D	2007 L	2007 D	2008 L	2008 D	2009 L	2009 D	2010 L	2010 D	2011 L	2011 D	2012 L	2012 D
28.2	GILL	none	EST																	0	
28.2	GILL	none	LVA													0		0		0	
28.2	OTTER	none	LVA			0		0													
28.2	PEL_TRAWL	none	EST															0			
28.2	PEL_TRAWL	none	LVA	17		9		9		13		5				1		3		1	
28.2	POTS	none	EST																	0	
28.2	r-GILL	none	LVA	74		151	3	90	2	102	7	39	1	39	0	37	0	36	0	33	
28.2	r-OTTER	BACOMA	EST							1											
28.2	r-OTTER	BACOMA	LTU																	14	
28.2	r-OTTER	BACOMA	LVA	173	1	195		168	1	93		57		121		12		41		114	
28.2	r-PEL_TRAWL	BACOMA	LVA																		
A	BEAM	none	DEU													2		3			
A	DEM_SEINE	none	DNK	0	0	1		7		0											
A	DEM_SEINE	none	POL	0	0					0											
A	DREDGE	none	DNK																		
A	GILL	none	DEU	0	0	22	0	21		17		4		1	0	3	0	0	0	1	0
A	GILL	none	DNK	58	0	216	22	123		117		21		12	0	7	0	7	0	2	0
A	GILL	none	POL	9	0	1	0	1		5		3		1	0	0	0			0	0
A	GILL	none	SWE	0	0	1	0	0		1		0		1	0	1	0	2	0	1	0
A	none	none	DEU	3		18		34	1	9		3		3						0	
A	none	none	DNK	2829		446		849	16	110		59		27		46	0	47		63	
A	none	none	SWE	1		23		7	0	35		15		6		17	0				
A	OTTER	none	DEU	21		77		60		39		57		33	0	22	34	52		8	0
A	OTTER	none	DNK	77		124		125		51		23		24	0	8	15	9		7	0
A	OTTER	none	POL	3		3		1		1		0						7		0	0
A	OTTER	none	SWE	1		0		1		0				0	0					1	0
A	PEL_TRAWL	none	DEU	26	0	65		83		50		47		17	0	17	0	6	1	3	0
A	PEL_TRAWL	none	DNK	36	0	86		92		47		28		18	0	20	0	11	4	4	0
A	PEL_TRAWL	none	LVA							11				0	0						
A	PEL_TRAWL	none	POL	10	0	35		40		9		16		0	0	1	0	1	1	1	0
A	PEL_TRAWL	none	SWE	60	1	71		53		31		27		23	0	28	0	25	9	3	1
A	POTS	none	DEU	2		0		2		0		1		4		14	0	4	0	3	0
A	POTS	none	DNK			278		86		180		66		60		87	0	49	0	43	0
A	POTS	none	POL	0				1													
A	POTS	none	SWE	3		3		4		6		1		0		2	0	4	0	4	0
A	r-BEAM	BACOMA	DEU									9									
A	r-BEAM	none	DEU																		
A	r-DEM_SEINE	BACOMA	DEU					51		143		250		194		51		71		4	
A	r-DEM_SEINE	none	DEU	6	1	37															
A	r-DEM_SEINE	none	DNK	1369	171	1014		1392		1460		1268	10	601	47	481	85	388	41	438	9
A	r-GILL	none	DEU	624	13	1140	48	1744	0	1699	0	1534	0	874	87	1174	40	864	28	1030	15
A	r-GILL	none	DNK	1490	14	2935	138	2382	0	2177	0	1933	1	1447	78	1426	130	1516	0	1518	19
A	r-GILL	none	EST			60	3	102	0	52	0	132	0	194	8						
A	r-GILL	none	LVA	247	2	406	20	580	0	90	0	30	0	23	1	71	3	24	1	11	0
A	r-GILL	none	POL	316	7	449	18	436	0	884	0	641	0	266	36	168	8	225	4	403	8
A	r-GILL	none	SWE	1217	18	1151	46	1063	0	1153	0	1245	2	946	39	817	17	870	15	873	11
A	r-LONGLINE	none	DEU	24	0	59	3	32		20	0	20		13	0	32	0	27	0	14	0
A	r-LONGLINE	none	DNK	313	4	617	29	497		432	13	136		127	0	164	0	229	0	202	2
A	r-LONGLINE	none	LTU			8	0														
A	r-LONGLINE	none	POL	33	0	258	12	128		265	1	78		10	0	13	0	20	0	29	0
A	r-LONGLINE	none	SWE	113	3	204	7	100		54	0	58		157	0	107	0	167	2	231	4
A	r-OTTER	BACOMA	DEU					4944	332	4941	319	3155	231	2623	300	2556	567	3133	411	3028	170
A	r-OTTER	BACOMA	EST			1	0									0	0			3	0
A	r-OTTER	BACOMA	LVA			57	0	1	0	173	13					87	11				
A	r-OTTER	BACOMA	POL	129	13	309	0	177	13	1182	78	611	37	238	20	127	11	224	48		
A	r-OTTER	BACOMA	SWE	755	40	634	2	1217	61	1525	132	1256	51	879	91	429	45	1241	542	984	161
A	r-OTTER	none	DEU	3685	437	4670	1204	22	2	9	0	18	1	4	0	1	0	17	1	1	0
A	r-OTTER	none	DNK	7697	814	6866	1822	6675	634	7170	554	5708	486	5531	502	4543	963	5546	691	5876	292
A	r-OTTER	none	LTU			129	28	42	5												
A	r-OTTER	none	POL															7	0	386	31
A	r-OTTER	none	SWE													19	2				
A	r-OTTER	T90	SWE													45	4	149	65	173	39
A	r-PEL_TRAWL	BACOMA	DEU					76	0	187		5	0			13		13	3	5	
A	r-PEL_TRAWL	BACOMA	EST			1	0			10											
A	r-PEL_TRAWL	BACOMA	POL			27	0	2	0	3											
A	r-PEL_TRAWL	BACOMA	SWE	8	0	5	0	7	0			2	0					6	2		
A	r-PEL_TRAWL	none	DEU	11	2	35	6	0	0												
A	r-PEL_TRAWL	none	DNK	17	2	41	11	102	10	19	1	8	1	24	2	36	6	0		1	0
A	r-PEL_TRAWL	none	LTU			10	2														
A	r-TRAMMEL	none	DEU	2	0	16	0	29		88		96	0	61	8	42	4	77	0	103	3
A	r-TRAMMEL	none	DNK	251	2	482	55	496		473		471	0	297	14	359	35	395	0	557	8
A	r-TRAMMEL	none	SWE	24	0	65	5	80		36		47	0	47	1	89	1	71	1	56	1
A	TRAMMEL	none	DEU			3		2		3		1		0				0			
A	TRAMMEL	none	DNK	4		18		4		4		6		0		1		0		0	
A	TRAMMEL	none	POL	0																	
A	TRAMMEL	none	SWE																		

Table 2.10. Cod landings and discards taken by < 8 m vessels by area, gear type and Member State in 2003-2012 (t).

REG_ARE	REG_GEA	SPECON	COUNTRY	2004 L	2004 D	2005 L	2005 D	2006 L	2006 D	2007 L	2007 D	2008 L	2008 D	2009 L	2009 D	2010 L	2010 D	2011 L	2011 D	2012 L	2012 D
28,2	GILL	none	EST			0,139	0	0,03	0	0,12	0	0,182	0	0,242	0	0,166	0	0,282	0	0,262	0
28,2	POTS	none	EST			0,002	0					0,198	0	0,104	0	0,15	0	0,164	0	0,147	0
28,2	r-LONGLIN	none	EST									0,004	0					0,013	0		
28,2	GILL	none	LVA							0,137	0	0,12	0			0,011	0			0,05	0
28,2	r-DEM_SE	none	LVA									0,012	0			0,005	0				
28,2	r-GILL	none	LVA			8,417	0	39,05	0	50,342	0	35,52	0	8,461	0	5,85	0	3,65	0	4,422	0
A	GILL	none	DEU	318,361	0	426,537	0	371,402	0	375,492	0	274,343	0	193,613	0	307,331	0	257,194	0	578,837	0
A	none	none	DEU	0,019	0	2,784	0	0,291	0	0,289	0										
A	POTS	none	DEU	0,064	0			0,139	0	0,351	0	0,093	0	0,3	0	1,47	0	0,384	0	1,327	0
A	r-LONGLIN	none	DEU	2,881	0	3,798	0	3,461	0	2,289	0	1,157	0	0,198	0	0,032	0	0,049	0	2,472	0
A	GILL	none	DNK	1,564	0	9,493	0	9,268	0	11,896	0	16,02	0	5,865	0	0,698	0	2,492	0	1,069	0
A	none	none	DNK	717,511	0	594,038	0	478,029	0	345,446	0	329,186	0	227,118	0	290,896	0	337,404	0	352,824	0
A	OTTER	none	DNK					0,087	0			0,027	0								
A	POTS	none	DNK			20,174	0	9,164	0	9,549	0	1,06	0	1,486	0	6,091	0	2,334	0	5,118	0
A	r-DEM_SE	none	DNK											0,001	0						
A	r-GILL	none	DNK	0,013	0	115,976	4	71,612	0	68,508	0	76,073	0	47,48	0	29,898	3,152	26,826	0	33,287	0
A	r-LONGLIN	none	DNK	0,702	0	20,7	0	10,281	0	43,404	0	16,735	0	9,947	0	8,415	0	6,2	0	6,682	0
A	r-OTTER	none	DNK	0,736	0,057	0,019	0,021	0,193	0,017	0,05	0,004	0,57	0,044	0,022	0,004	0,022	0,086				
A	r-TRAMME	none	DNK			2,873	0	3,466	0	5,408	0	9,239	0	3,577	0	6,341	0,781	16,619	0	5,254	0
A	TRAMMEL	none	DNK			0,002	0	0,263	0			0,008	0	0,016	0						
A	GILL	none	POL	0,65	0	0,4	0	0,23	0	0,506	0	0,952	0	0,126	0			3,598	0		
A	POTS	none	POL	0,2	0					0,002	0										
A	r-GILL	none	POL	36,704	1	13,365	0	15,393	0	23,144	0	17,898	0	15,835	0	10,235	1				
A	r-LONGLIN	none	POL									0,37	0								
A	none	none	SWE	1,43	0	1,435	0	2,172	0	3,375	0	5,805	0	0,08	0	0,645	0				
A	POTS	none	SWE	9,587	0	13,549	0	6,745	0	13,212	0	4,28	0	2,671	0,017	1,932	0	2,736	0,062	2,861	0,059
A	r-GILL	none	SWE	38,975	0,582	41,163	1,868	30,316	0	39,144	0	62,261	0	23,732	0,081	26,38	0,522	28,962	0,512	14,813	0,219
A	r-LONGLIN	none	SWE	6,315	0,18	3,153	0,144														
A	r-TRAMME	none	SWE	1,397	0,018	3,143	0,248	0,124	0			0,018	0	0,361	0,001	0,551	0,009	2,967	0,046	1	0,016
B	GILL	none	DNK									0,178	0								
B	none	none	DNK	185,558	0	147,197	0	152,503	0	136,781	0	169,28	0	180,255	0	136,907	0	130,394	0	87,022	0
B	r-GILL	none	DNK			3,814	0			6,271	0	23,087	0	21,623	0	10,152	0	0,027	0	0,189	0
B	r-LONGLIN	none	DNK			0,337	0			4,602	0	13,7	0	17,455	1	9,046	1	0,503	0	0,039	0
B	r-OTTER	none	DNK									0,256	0,037								
B	GILL	none	EST			0,428	0	0,204	0	0,284	0	0,339	0	0,36	0	0,34	0	0,443	0	0,517	0
B	POTS	none	EST			0,42	0	0,11	0	0,147	0	0,552	0	0,314	0	0,382	0	0,285	0	0,317	0
B	r-LONGLIN	none	EST									0,004	0					0,013	0		
B	r-GILL	NONE	LTU			107,68	0	60,534	0	55,577	0	48,012	0	30,7	0	48,2	0	25,1	0	50,3	2
B	r-LONGLIN	NONE	LTU					1,043	0			2,095	0	7	0	11,6	0	23,2	0	5,1	0
B	GILL	none	LVA					0,12	0			0,01	0							0,05	0
B	r-GILL	none	LVA			6,885	0	62,759	4	68,333	0	30,885	0	7,076	0	10,703	0	9,696	0	15,246	0
B	GILL	none	POL	5,646	0	1,748	0	4,235	0	1,44	0	2,072	0	5,916	0	6,826	0	510,719	0	484,779	2
B	PEL_SEIN	NONE	POL															0,005	0		
B	POTS	none	POL	0,793	0	1,858	0	0,814	0	0,005	0	0,213	0	0,425	0	0,1	0	0,449	0	0,167	0
B	r-GILL	none	POL	285,318	3	420,445	4	382,058	38,989	194,836	0	329,041	0,286	794,467	20,459	467,33	12,868			0,2	0
B	r-LONGLIN	none	POL	32,274	0	52,882	0	102,677	0	66,001	0	43,576	0	82,984	6	67,851	6	50,686	1	34,35	1
B	GILL	none	SWE			0,14	0	0,001	0	0,001	0	0,09	0	0,055	0,002	0,044	0			0,02	0,001
B	none	none	SWE	0,211	0			5,423	0	1,791	0	2,946	0	1,422	0	1,403	0			0,016	0
B	POTS	none	SWE	13,459	0	12,079	0	12,951	0	11,378	0	13,754	0	7,051	0,491	6,025	0	3,822	0,262	2,456	0,096
B	r-GILL	none	SWE	117,981	1,689	59,795	1,781	74,419	11	96,492	0	99,658	0	86,209	4,777	63,722	1,771	54,547	3,303	58,127	1,963
B	r-LONGLIN	none	SWE	57,466	0,768	57,702	1,064	32,653	0	24,713	0	37,134	0	17,31	1,239	5,163	0,715	6	0,409	13,593	0,466
B	r-TRAMME	none	SWE	0,108	0,001	0,359	0,012	0,2	0	0,308	0	0,148	0	0,021	0,001	5,345	0,107	0,883	0,044	1,626	0,079
B	TRAMMEL	none	SWE	0,176	0,003	0,186	0,008	0,288	0			0,007	0	0,002	0	0,002	0				
C	GILL	none	EST			0,455	0	0,264	0	0,368	0	1,468	0	3,14	0	2,851	0	2,637	0	2,161	0
C	POTS	none	EST			0,012	0	0,005	0	0,036	0	0,037	0	0,114	0	0,12	0	0,116	0	0,107	0
C	r-GILL	none	EST					0,004	0												
C	r-LONGLIN	none	EST											0,002	0					0,003	0
C	GILL	none	FIN	0,062	0	0,064	0	0,125	0	0,044	0	0,268	0	0,644	0,01	1,057	0,021	0,835	0,005	0,461	0,011
C	POTS	none	FIN	0,01	0			0,002	0	0,005	0	0,004	0	0,086	0,001	0,125	0	0,012	0	0,058	0,004
C	GILL	none	SWE	0,2	0	0,004	0			0,002	0	0,246	0			0,004	0			0,008	0
C	POTS	none	SWE																		
C	r-GILL	NONE	SWE											0,117	0,008	0,004	0				

Table 2.11a. Weight (kg) and vallue (DKK) of landings for the Danish western Baltic (ICES SD 22-24) fishery for all quarters 2012 by species and DCF metier level 6.

	Cod		Nephrops		Plaice		Flounder		Other flatfish		Other		Sum	Sum
DCF_Metier_level_6	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**
DRB_MOL_>0_0_0											10983482	11046215	10983482	11046215
FPN_ANA_>0_0_0	217	1932			1	4	96	453	1	40	933	17642	1247	20070
FPN_CAT_>0_0_0	8178	89822			480	3638	2552	16278	149	5392	145148	13668674	156507	13783803
FPN_DEF_>0_0_0	28656	330728			1130	8624	10813	41632	230	10334	8551	84236	49380	475555
FPN_FWS_>0_0_0	165	1676					37	367	5	245	1276	18117	1483	20404
FPN_SPF_>0_0_0	2293	23362			155	879	4754	15903	123	5644	166038	1207914	173364	1253701
FPO_CAT_>0_0_0	2452	29378					22	77	2	186	7229	494692	9705	524333
FPO_DEF_>0_0_0	4300	51283			6	58	203	1290			1147	9048	5655	61678
GNS_CAT_>0_0_0	2389	32382			1105	11165	473	3390	37	1199	4076	318878	8080	367012
GNS_CRU_>0_0_0	113	2069	20	1406	455	5603	704	6719	43	2194	2259	307206	3594	325196
GNS_DEF_>=157_0_0	761011	13216079			241112	2185401	35264	199323	22921	1064708	43987	797243	1104294	17462754
GNS_DEF_110-156_0_0	1261354	16634372	3	248	315473	2840251	175087	931550	43661	2815568	82364	781024	1877942	24003013
GNS_DEF_90-109_0_0	1221	15374			213	2519	233	1606	1087	64629	478	5762	3231	89890
GNS_FWS_>0_0_0	2699	34545					186	1767	2	112	10060	115811	12948	152234
GNS_SPF_110-156_0_0	162	2054			30	763	6	35	44	4239	3394	101551	3636	108641
GNS_SPF_32-109_0_0	591	6374			5	50	205	855	3	263	10058	169576	10862	177117
LHP_FIF_0_0_0	3997	51686											3997	51686
LLD_ANA_0_0_0	0	0									59312	1938624	59312	1938624
LLS_DEF_0_0_0	197729	1711463			21	160	44	123			142	383	197936	1712129
No_logbook6	389453	4443930			106805	980821	116324	951233	14105	791763	425229	12409975	1051916	19577722
No_Matrix6	31109	314068			4193	33227	2712	13205	631	36012	182245	2829724	220890	3226237
OTB_CRU_>0_0_0			1815	118928	96	729	62	190	236	14328	26	178	2235	134353
OTB_DEF_>=105_1_120	5648981	56174280	1	67	950702	6791215	506265	2098559	31940	1517780	448437	2498120	7586326	69080021
OTB_DEF_90-104_0_0	5905	93129	28	1960	34705	295424	44130	279413	8703	675482	8339	60612	101810	1406020
OTM_DEF_<16_0_0	69	499									25810	38715	25879	39214
OTM_DEF_>=105_1_120	550	4724			1	5							551	4729
OTM_SPF_16-31_0_0											98720	163780	98720	163780
OTM_SPF_32-104_0_0	131	1012									790056	3208834	790186	3209846
OTM_SPF_32-89_0_0											23150	92600	23150	92600
PTB_DEF_<16_0_0											1043090	1978400	1043090	1978400
PTB_DEF_>=105_1_120	13668	137079			686	4248	3646	13567	277	7873	1017	4385	19293	167152
PTB_SPF_16-31_0_0	254	2341			37	69	24	44			514663	970595	514978	973049
PTB_SPF_32-104_0_0	23	402									560045	2264583	560068	2264985
PTM_DEF_<16_0_0	41	583									1045665	1996028	1045706	1996610
PTM_DEF_16-31_0_0	1799	17939			990	8951	157	471	35	1440	239	1515	3220	30316
PTM_SPF_16-31_0_0	1049	12696			6	10	4	6			4989425	9392620	4990484	9405333
PTM_SPF_32-104_0_0	71	760									1300537	5300444	1300608	5301204
PTM_SPF_32-89_0_0	12	28									457755	1791468	457767	1791496
SDN_DEF_>=105_1_120	421305	4823196			21612	148056	11842	43792	1377	53987	84514	598752	540650	5667783
SSC_DEF_>=105_1_120	1439	10493			1105	12129	3396	35668	30	1040	2891	28987	8861	88316
Sum	8793383	98271734	1866	122609	1681124	13333998	919241	4657513	125641	7074456	23531786	76712911	35053042	200173220

Table 2.11b. Weight (kg) and value (EUR) of landings for the Swedish western Baltic (ICES SD 22-24) fishery for all quarters 2012 by species and DCF metier level 6 .

	Cod		Plaice		Flounder		Other flatfish		Other		Sum	Sum
DCF-Metier_level_6	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**	**Weight**	**Value**
FPN_CAT_>0_0_0	227	18			241	2			19 358	23	19 826	43
FPO_DEF_>0_0_0	1 697	13							10	3	1 707	16
FYK_CAT_>0_0_0	5 023	51			35	3	4	1	56 238	39	61 300	94
FYK_SPF_>0_0_0									44	2	44	2
GNS_ANA_110-156_0_0									6	1	6	1
GNS_DEF_>=157_0_0	45 575	166	881	37	3 942	29	1 253	27	22 706	46	74 357	305
GNS_DEF_110-156_0_0	842 891	973	11 328	158	24 658	161	1 671	63	8 689	84	889 237	1 439
GNS_DEF_90-109_0_0	319	8					125	3	20	1	464	12
GNS_FWS_>0_0_0									20	2	20	2
GNS_SPF_32-109_0_0	1 289	55							685 637	87	686 926	142
GTR_DEF_>=157_0_0	5 872	65	3 857	48	4 378	20	351	29	1 172	9	15 630	171
GTR_DEF_110-156_0_0	51 460	173	6 010	107	5 883	21	1 510	70	340	19	65 203	390
LHP_FIF_0_0_0	13 568	27									13 568	27
LLD_ANA_0_0_0									21 878	17	21 878	17
LLS_DEF_0_0_0	215 985	167			48	6			467	9	216 500	182
OTB_DEF_>=105_1_120	711 077	259	7 406	86	2 167	16	670	22	30 187	52	751 507	435
OTB_DEF_>=120_0_0	172 840	138	1 084	37	830	9	143	8	3 259	19	178 156	211
OTB_SPF_32-104_0_0	1 348	19							86 215	16	87 563	35
OTT_DEF_>=105_1_120	273 335	109	4 142	43	3 404	14	286	15	11 238	22	292 405	203
PTM_SPF_16-31_0_0	205	1							131 138	7	131 343	8
PTM_SPF_32-104_0_0	2 526	13							2 771 181	56	2 773 707	69
Sum	2 345 237	2 255	34 708	516	45 586	281	6 013	238	3 849 803	514	6 281 347	3 804

Table 2.12. Kattegat landings (L), discards (D) and discard rate (R) of cod (COD), Nephrops (NEP), plaice (PLE), sole (SOL) and whiting (WGH) by regulated gear category and derogation 2008-2012. The derogations CPart11 and IIA83B are considered unregulated and are not included.

REG_AREA	REG_GEAF	SPECON	SPECIES	2008 L	2008 D	2008 R	2009 L	2009 D	2009 R	2010 L	2010 D	2010 R	2011 L	2011 D	2011 R	2012 L	2012 D	2012 R
3a	GN1	none	COD	46.621			13.617	95.25	0.875	10.047	4.119	0.291	2.865	33.352	0.921	0.545	0.11	0.168
3a	GT1	none	COD	3.106			1.208	1.04	0.463	0.73	0	0	0.016	0.276	0.945	0.03	0.012	0.286
3a	LL1	none	COD	13.507														
3a	TR1	none	COD	32.748	9.264	0.221	17.439	0.609	0.034	4.079	2.214	0.352	1.521	3.503	0.697	1.989	4.454	0.691
3a	TR2	CPart13B	COD							0.15			0.018					
3a	TR2	CPart13C	COD							85.105	177.224	0.676	81.14	153.991	0.655	49.001	104.15	0.68
3a	TR2	none	COD	305.275	135.996	0.308	123.781	55.226	0.309	27.336	10.198	0.272	38.127	21.595	0.362	24.263	18.241	0.429
3a	TR3	none	COD	0.284			0.076						0.053			0.74		
Sum of COD landings				401.541			156.121			127.447			123.74			76.568		
3a	GN1	none	HAD	2.24			0.16			0.002	0	0				0.002	0	0
3a	GT1	none	HAD	1.173			0.161			0.014	0	0	0.006					
3a	LL1	none	HAD	0.91														
3a	TR1	none	HAD	6.663	2.228	0.251	5.913	0.469	0.073	0.803	1.209	0.601	0.154	0.915	0.856	0.284	0.063	0.182
3a	TR2	CPart13B	HAD							0.067			0.002					
3a	TR2	CPart13C	HAD							17.511	56.8	0.764	11.067	113.817	0.911	3.93	4.345	0.525
3a	TR2	none	HAD	136.989	35.068	0.204	67.801	46.305	0.406	6.457	5.656	0.467	3.99	2.869	0.418	0.654	11.701	0.947
3a	TR3	none	HAD	0.034									0.003			1.729		
Sum of HAD landings				148.009			74.035			24.854			15.222			6.599		
3a	GN1	none	NEP	0.221			0			0.001	0	0	0.091	0	0			
3a	GT1	none	NEP	0.126			1.15	0.003	0.003	0.002			0.986					
3a	LL1	none	NEP													0.152		
3a	TR1	none	NEP	63.401	41.734	0.397	17.321	9.593	0.356	34.669	16.758	0.326	20.467	18.226	0.471	65.613	94.693	0.591
3a	TR2	CPart13B	NEP							16.387			5.258					
3a	TR2	CPart13C	NEP							1680.755	847.8	0.335	1086.195	1277.901	0.541	1350.869	1972.222	0.593
3a	TR2	none	NEP	1779.912	885.178	0.332	1628.266	1049.988	0.392	133.253	119.722	0.473	101.141	67.458	0.4	112.569	102.139	0.476
3a	TR3	none	NEP	1.096			0.807			0.003			1.097					
Sum of NEP landings				1844.756			1647.544			1865.07			1215.235			1529.203		
3a	GN1	none	PLE	61.125			26.98	9.243	0.255	21.522	3.948	0.155	10.502	18.553	0.639	11.291	4.427	0.282
3a	GT1	none	PLE	39.505			6.627	0.534	0.075	9.975	0.548	0.052	5.715	13.339	0.7	2.689	1.128	0.296
3a	LL1	none	PLE															
3a	TR1	none	PLE	281.737	224.82	0.444	187.133	72.92	0.28	55.411	42.645	0.435	60.669	34.866	0.365	21.831	52.34	0.706
3a	TR2	CPart13B	PLE							1.791			0.166					
3a	TR2	CPart13C	PLE							256.353	1030.817	0.801	202.832	1089.726	0.843	136.954	313.589	0.696
3a	TR2	none	PLE	481.068	293.976	0.379	295.97	604.518	0.671	34.688	94.082	0.731	14.202	58.113	0.804	12.264	16.884	0.579
3a	TR3	none	PLE	0.533			0.192			0.221			0.066			0.257		
Sum of PLE landings				863.968			516.902			379.961			294.152			185.286		
3a	GN1	none	SOL	57.436			72.476	1.7	0.023	58.239	0.966	0.016	60.754	0.177	0.003	26.422	0.036	0.001
3a	GT1	none	SOL	15.818			14.65	0.158	0.011	21.047	0.084	0.004	20.181	0.031	0.002	8.778	0.008	0.001
3a	LL1	none	SOL													0.003		
3a	TR1	none	SOL	6.881	0.745	0.098	2.253	0.227	0.092	1.639	0.648	0.283	0.976	0.135	0.122	4.082	0.013	0.003
3a	TR2	CPart13B	SOL							1.094			0.007					
3a	TR2	CPart13C	SOL							132.504	45.48	0.256	153.813	16.782	0.098	102.579	2.209	0.021
3a	TR2	none	SOL	214.77	12.855	0.056	170.131	15.703	0.085	6.146	0.357	0.055	4.048	0.321	0.073	0.689	2.345	0.773
3a	TR3	none	SOL	0.201			0.147			0.082			0.005					
Sum of SOL landings				295.106			259.657			220.751			239.784			142.553		
3a	GN1	none	WHG	0.356			0			0			0			0		
3a	GT1	none	WHG	0.175			0			0.012	0.027	0.692	0					
3a	LL1	none	WHG															
3a	TR1	none	WHG	1.506	8.982	0.856	0.359	1.095	0.753	0.116	0.862	0.881	0.006	0.1	0.943	0.009	0.389	0.977
3a	TR2	CPart13B	WHG							0.004			0.003					
3a	TR2	CPart13C	WHG							7.644	305.633	0.976	7.152	288.532	0.976	4.901	123.61	0.962
3a	TR2	none	WHG	40.719	254.395	0.862	22.495	170.224	0.883	6.758	37.698	0.848	5.108	34.63	0.871	1.838	11.653	0.864
3a	TR3	none	WHG	0.001			0.001									22.77		
Sum of WHG landings				42.757			22.855			14.534			12.269			29.518		

Table 2.13. Unregulated gears, landings (t) of cod in Kattegat 2003-2012. Discards for unregulated gears are not sampled for discards in Kattegat except for the Swedish sorting grid, derogation CPart11. The discards of cod for the derogation CPart11 in 2012 were 12,1 tonnes.

SPECIES	AREA	GEAR	SPECON	COUNTRY	2003 L	2004 L	2005 L	2006 L	2007 L	2008 L	2009 L	2010 L	2011 L	2012 L
COD	3a	DEM_SEINE	none	DNK	0.8	0	0	0	0	0	0	0	0	0
COD	3a	none	none	DNK	6.4	3.0	5.7	10.2	1.1	0.1	0.2	0	0.3	0.4
COD	3a	none	none	SWE	16.9	8.0	7.6	0	0	0	0	0	0.3	0
COD	3a	OTTER	none	DNK	2.0	3.8	5.0	13.9	0.6	0	0	0.2	0	0
COD	3a	OTTER	none	SWE	0	0	0	4.5	4.6	4.4	8.7	3.2	1.1	2.9
COD	3a	PEL_TRAWL	none	DNK	0	0	0	5.0	0.4	0.1	0.1	0.1	0.2	3.8
COD	3a	PEL_TRAWL	none	SWE	1.8	0.6	4.9	0	3.6	0	0	0	0	0
COD	3a	POTS	none	DNK	0	0	0	0	0	0	0	0	0	0
COD	3a	POTS	none	SWE	0	0	0	0	0	0	0	0	0	0
COD	3a	TR2	CPart11	SWE							0.1	0.2	0.4	0.1
COD	3a	TR2	IIA83B	SWE		0	0.3	0	0.3	0.2				
Total					27.9	15.3	23.5	33.6	10.5	4.8	9.1	3.7	2.3	7.3

Table 2.14. Unregulated gears, landings (t) of plaice in Kattegat 2003-2012. Discards for unregulated gears are not sampled for discards in Kattegat except for the Swedish sorting grid, derogation CPart11. The discards of plaice for the derogation CPart11 in 2012 were 19 tonnes.

SPECIES	REG_AREA	REG_GEAR	SPECON	COUNTRY	2003 L	2004 L	2005 L	2006 L	2007 L	2008 L	2009 L	2010 L	2011 L	2012 L
PLE	3a	DEM_SEINE	none	DNK	0.3	0	0.7	0	0	0	0	0	0	0
PLE	3a	none	none	DNK	24.0	11.1	1.3	3.9	7.2	1.8	0.6	0.7	0.3	1.6
PLE	3a	OTTER	none	DEU	0	0	0	0.1	0	0	0	0	0	0
PLE	3a	OTTER	none	DNK	0.9	0.2	0.6	4.4	1.6	0.6	0.4	0.3	0.1	0
PLE	3a	OTTER	none	SWE	0.1	0	0.1	0.8	0.7	1.1	3.2	1.9	0.1	0.2
PLE	3a	PEL_TRAWL	none	DNK	0.5	0.3	0.0	0.5	0.2	0.1	0.1	0.1	0.0	1.2
PLE	3a	POTS	none	DNK	0	0	0	0	0	0	0	0	0	0
PLE	3a	TR2	CPart11	SWE							3.2	2.8	1.2	1.0
PLE	3a	TR2	IIA83B	SWE			0.1	0.3	0.7	1.7				
					25.8	11.6	2.9	10.0	10.4	5.2	7.6	5.8	1.7	4.1

Table 2.15. Unregulated gears, landings of sole in Kattegat 2003-2012. Discards for unregulated gears are not sampled for discards in Kattegat except for the Swedish sorting grid, derogation CPart11. The discards of sole for the derogation CPart11 in 2012 were 4,6 tonnes.

SPECIES	AREA	GEAR	SPECON	COUNTRY	2003 L	2004 L	2005 L	2006 L	2007 L	2008 L	2009 L	2010 L	2011 L	2012 L
SOL	3a	DEM_SEINE	none	DNK	0	0	0	0	0	0	0	0	0	0
SOL	3a	none	none	DNK	2.2	1.3	2.4	2.2	2.7	1.3	0.2	0.1	0.2	1.8
SOL	3a	OTTER	none	DEU	0	0	0	0	0	0	0	0	0	0
SOL	3a	OTTER	none	DNK	0.3	0	0.3	1.5	0.3	0.1	0.2	0.1	0.1	0
SOL	3a	OTTER	none	SWE	0	0		0	0	0	0	0	0	0
SOL	3a	PEL_TRAWL	none	DNK	0	0.2	0	0	0	0	0	0.1		0
SOL	3a	POTS	none	DNK	0.4	0	0	0	0	0	0	0	0	0
SOL	3a	TR2	CPart11	SWE							0.8	1.7	1.5	0.4
SOL	3a	TR2	IIA83B	SWE			0.5	0.5	0.8	0.9				
Total					2.9	1.5	3.2	4.1	3.8	2.3	1.2	1.9	1.9	2.2

Table 2.16. Unregulated gears, landings of Nephrops in Kattegat 2003-2012. Discards for unregulated gears are not sampled for discards in Kattegat except for the Swedish sorting grid, derogation CPart11. The discards of Nephrops for the derogation CPart11 in 2012 were 227 tonnes.

SPECIES	REG_AREA	REG_GEAR	SPECON	COUNTRY	2003 L	2004 L	2005 L	2006 L	2007 L	2008 L	2009 L	2010 L	2011 L	2012 L
NEP	3a	none	none	DNK	2.0	2.1	1.9	6.2	4.5	2.0	1.9	0.7	0.9	6.0
NEP	3a	OTTER	none	DEU	0	0	0	0.3	0	0	0	0	0	0
NEP	3a	OTTER	none	DNK	2.2	0.7	1.2	1.3	0.3	0.7	1.6	1.9	0.7	0
NEP	3a	OTTER	none	SWE	0.1	0	0.1	0.4	0.2	0.4	1.4	0.3	0	0.1
NEP	3a	PEL_TRAWL	none	DNK	6.9	0.5	0.1	1.5	0	0.8	0.1	0.9	0	0.03
NEP	3a	POTS	none	DNK	0.3	0	0	0	0	0	0	0	0	0
NEP	3a	POTS	none	SWE	1.8	7.3	3.9	6.4	9.9	9.9	8.0	5.8	4.7	8.5
NEP	3a	TR2	CPart11	SWE							240.9	264.0	202.2	274.4
NEP	3a	TR2	IIA83B	SWE		2.9	46.2	51.3	95.5	129.3				
Total					13.2	13.4	53.5	67.4	110.3	143.2	253.8	273.6	208.5	288.9

Landings of cod, Nephrops, plaice and sole from vessels <10m LOA in Kattegat are presented below. The landings by small vessels show largely the same pattern as the total landings and the percentage portions have remained fairly stable through the time series.

Table 2.17. Landings (t) of cod, plaice, sole and Nephrops by vessels <10m LOA, 2003-2012.

SPECIES	REG_GEAR	2003 L	2004 L	2005 L	2006 L	2007 L	2008 L	2009 L	2010 L	2011 L	2012 L
COD	GN1	41.4	17.0	24.0	31.6	22.0	7.9	5.4	7.6	6.7	3.5
COD	GT1	0.1	0.2	0.9	1.8	1.1	1.7	3.7	3.3	1.9	1.0
COD	LL1	1.3	0.5	1.9	6.0	7.5	1.1	0.2	0	0	0
COD	none	203.6	129.8	103.1	117.6	44.1	26.4	20.2	10.7	8.1	6.7
COD	OTTER	0	0	0	0	0	0	0	0	0	0
COD	PEL_TRAWL	0	0	0.1	0	0	0	0	0	0	0
COD	POTS	0.3	0	0.2	0.1	0.1	0.1	0	0.1	0	0.1
COD	TR1	2.1	0	0.3	2.2	1.6	0.2	0.5	0.0	0	1.0
COD	TR2	0.8	1.9	0.8	3.6	2.4	1.4	0.5	0.9	1.2	1.2
COD	TR3	0	0	0	0	0	0	0	0	0	0
COD Total		249.5	149.4	131.3	163.0	78.9	38.8	30.7	22.6	18.0	13.5
NEP	GN1	0	0	0.1	0.2	0.1	0	0	0	0	0
NEP	GT1	0	0	0	0	0	0	0	0	0	0
NEP	none	9.9	11.1	7.8	3.6	5.3	5.8	9.0	8.5	25.7	33.9
NEP	OTTER	0	0	0	0	0	0	0	0	0	0
NEP	PEL_TRAWL	0	0	0	0	0	0	0	0	0	0
NEP	POTS	2.9	3.9	4.4	4.5	4.5	5.6	8.4	11.1	11.4	24.9
NEP	TR1	0	0	0	0	0.1	0	0.1	0.2	0.3	1.4
NEP	TR2	3.0	1.6	3.9	4.8	9.0	9.9	6.4	30.2	17.4	24.6
NEP	TR3	0	0	0	0	0	0	0	0	0	0
NEP Total		15.8	16.6	16.2	13.1	19.1	21.2	23.9	50.1	54.7	84.8
PLE	DREDGE	0	0	0	0	0	0	0.2	0	0	0
PLE	GN1	29.3	31.4	31.9	43.2	46.7	26.6	19.5	14.6	5.4	5.3
PLE	GT1	11.9	3.1	7.5	12.2	13.4	9.8	24.7	12.9	14.0	8.8
PLE	LL1	0	0	0	0	0	0	0	0	0	0
PLE	none	264.8	253.8	190.1	213.9	194.9	124.0	93.5	69.0	35.2	19.1
PLE	OTTER	0	0	0	0.1	0	0	0	0	0	0
PLE	PEL_TRAWL	0	0	0.1	0	0	0	0	0	0	0
PLE	POTS	0	0	0	0	0	0	0	0	0	0
PLE	TR1	0	0	1.6	1.2	11.4	0.0	0.1	0	7.0	2.7
PLE	TR2	11.7	15.1	1.9	11.2	16.8	10.9	14.5	15.4	10.6	2.9
PLE Total		317.7	303.4	233.1	281.8	283.2	171.3	152.4	112.0	72.1	38.7
SOL	DREDGE	0	0	0	0	0	0	0	0	0	0
SOL	GN1	2.7	4.3	25.1	23.7	15.4	19.4	17.3	24.1	21.5	13.6
SOL	GT1	0.5	0.1	6.6	10.3	10.4	9.7	11.7	9.7	8.1	3.5
SOL	LL1	0	0	0	0	0.1	0	0	0	0	0
SOL	none	50.7	73.4	176.6	153.5	106.8	92.6	90.6	79.6	53.8	30.7
SOL	OTTER	0	0	0	0	0	0	0	0	0	0
SOL	PEL_TRAWL	0	0	0.1	0	0	0	0	0	0	0
SOL	POTS	0	0	0.1	0.7	0.3	0.2	0.1	0	0	0
SOL	TR1	0	0	1.9	0.4	0.6	0.1	0	0	0	0
SOL	TR2	0	0.8	2.2	7.4	9.2	9.2	11.0	13.4	8.6	1.2
SOL	TR3	0	0	0	0	0	0	0	0	0	0
SOL Total		54.0	78.6	212.5	196.0	142.8	131.2	130.8	126.8	92.2	49.0

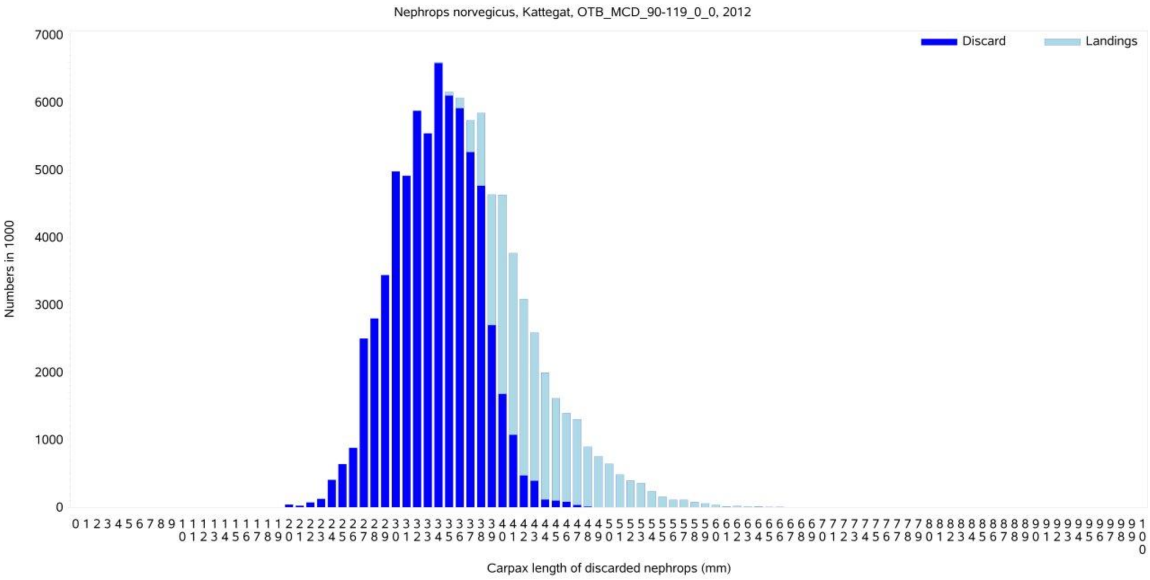
2.4. Size composition of catch for important gears (incl. selection and discard)

Fishery including bottom trawling reduces the population size of fish through removal of fish (fishing mortality) and directly impacts on the stock dynamics according to stock sustainability criteria (MSY) as assessed in e.g. ICES (International Council for Exploration of the Sea) stock assessments and stock projections (www.ices.dk). Furthermore, fishery also reduces the abundance of the fish prey, e.g. of forage fish species. We are currently lacking the ability to assess to what extent such trawling induced changes in food availability are affecting fisheries over large scales and for most important fished species. Other impacts may be in the addition of organic material to the benthic communities through discards, i.e.. organic carbon/feed inputs to the seabed, or changes in productivity which is not thoroughly investigated at least not for the Baltic Sea area. In relation to discard, the selectivity of towed (demersal) gears is an important issue with respect to ecosystem impacts of fishery. Ecosystem impacts of discarding have not been thoroughly evaluated besides the direct fishing mortality caused by the discarding. Fisheries generate carrion as a result of material discarded at sea from fishing boats. It is unclear whether the increases in the population sizes in scavenging seabirds that have been partially attributed to discarding practices might be mirrored in changes in the populations of benthic scavengers. As discarding has been ongoing for decades, benthic ecosystems that are reliant on discards as a food source may have developed (Kaiser and Hiddink 2007). As such the magnitude of discarding in different fisheries is important in context of benthic ecosystem impacts of fisheries. A discarding ban will reduce the flow of energy to the seabed and it is necessary to understand what changes this may cause to benthic ecosystems. To do this it is necessary to quantify to flow of energy from pelagic and demersal fisheries to the seabed, and to assess what effect this has on seabed ecosystems for different regions, ecosystems, and benthic seabed types and communities. For certain areas modeling results of energy flows indicate that landing the entire catch while fishing as usual will severely affect seabirds, marine mammals and seabed fauna, and will not benefit fish stocks. However, combining landing obligations with changes in fishing practices to reduce by-catches of fish can for certain systems result in trophic cascades that may benefit ecosystem components including the seabed fauna and the fish stocks (Heath et al. 2014).

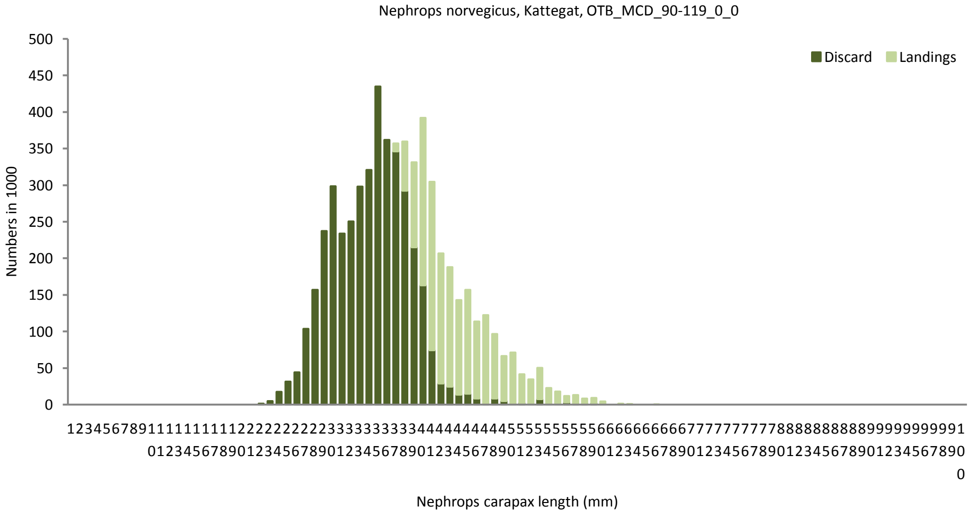
In relation to discard, the selectivity of towed (demersal) gears is an important issue with respect to ecosystem impacts of fishery. Towed (demersal) gears such as trawls are in general not very selective gears and catch both targeted species and size groups as well as un-wanted by-catch of other species and size groups. A number of different selectivity studies have been undertaken and some measures have been implemented with corresponding legislation. The primary selectivity measures implemented concern mesh size, orientation or pattern and use of special devices (sorting grids/TEDs, square panel, separators, etc.) as described above for major relevant Baltic fisheries. Although selectivity measures have been introduced, there are local issues that make this more difficult; this mostly concerns the single type of bottom trawl used in mixed, multispecies-targeted bottom trawl fisheries. In some cases a selectivity measure may be beneficial for one species, but not for another within the same fishery. As such selectivity of the used towed (demersal) gears and the associated discard is relevant with respect to ecosystem impacts of towed (demersal) gears.

The size compositions in catch divided by landings and discard for main Kattegat and western Baltic fishing gears for the recent period (2012) is presented below for the Danish and Swedish fishery.

a)


Nephrops norvegicus, Kattegat, OTB_MCD_90-119_0_0, 2012
Discard
Landings
Numbers in 1000
7000
6000
5000
4000
3000
2000
1000
0
Carpax length of discarded nephrops (mm)

b)


Nephrops norvegicus, Kattegat, OTB_MCD_90-119_0_0
Discard
Landings
Numbers in 1000
500
450
400
350
300
250
200
150
100
50
0
Nephrops carapax length (mm)

c)

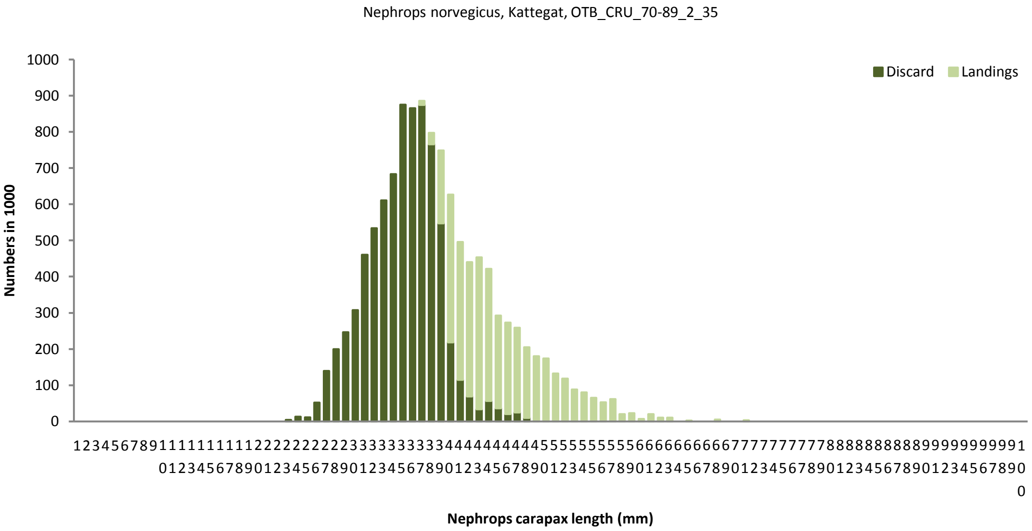
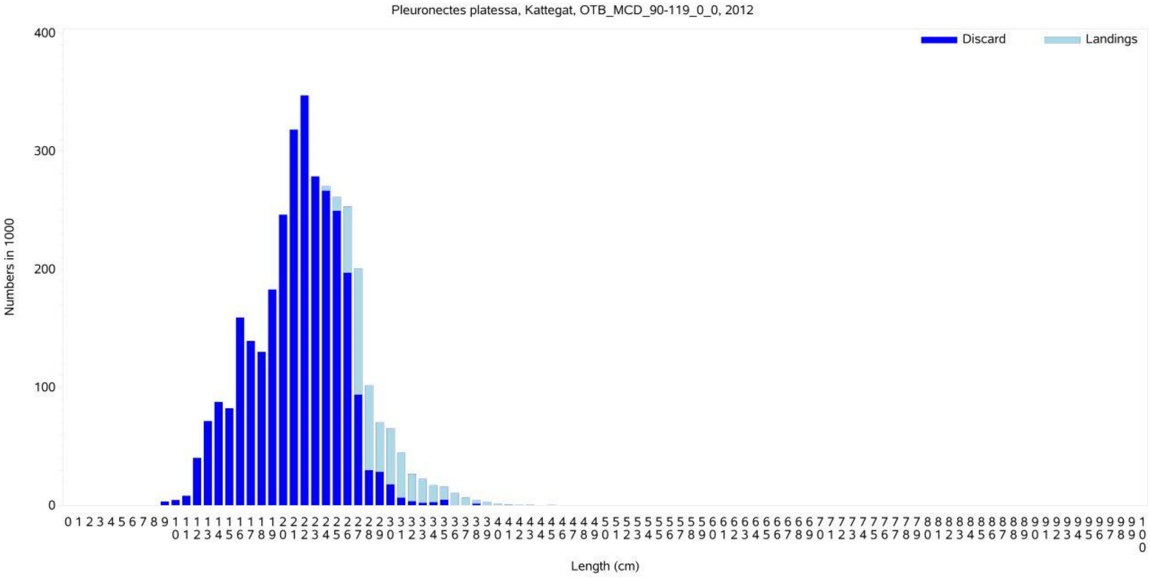
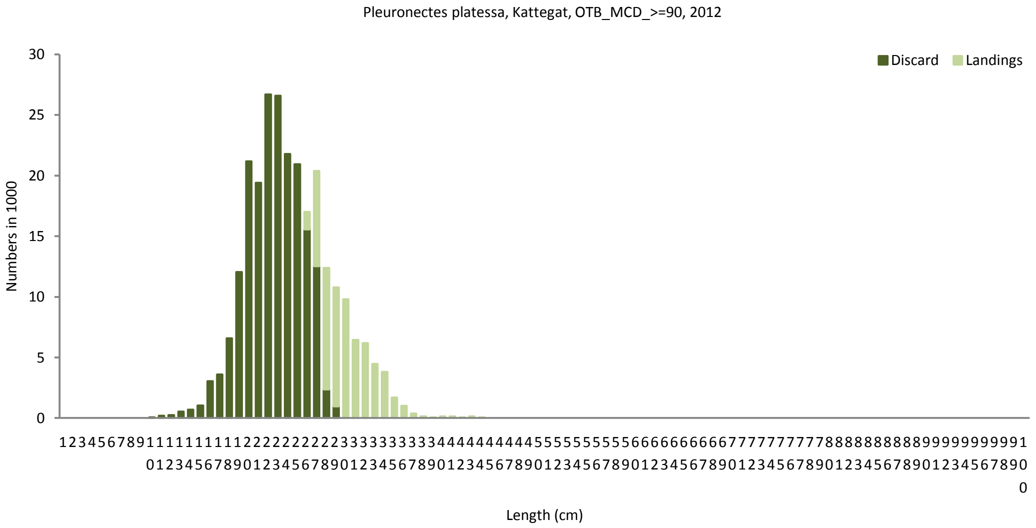


Figure 2.9. Size composition of Norway lobster (*Nephrops norwegicus*) catch by Danish (a, blue) and Swedish (b, green) demersal otter board trawl fishery in 2012 in Kattegat (ICES SD 21) divided into landings and discard. The lower green graph (c) show landings and discards in the Swedish Nephrops fishery using sorting grid (derogation CPart11).

a)



b)



c

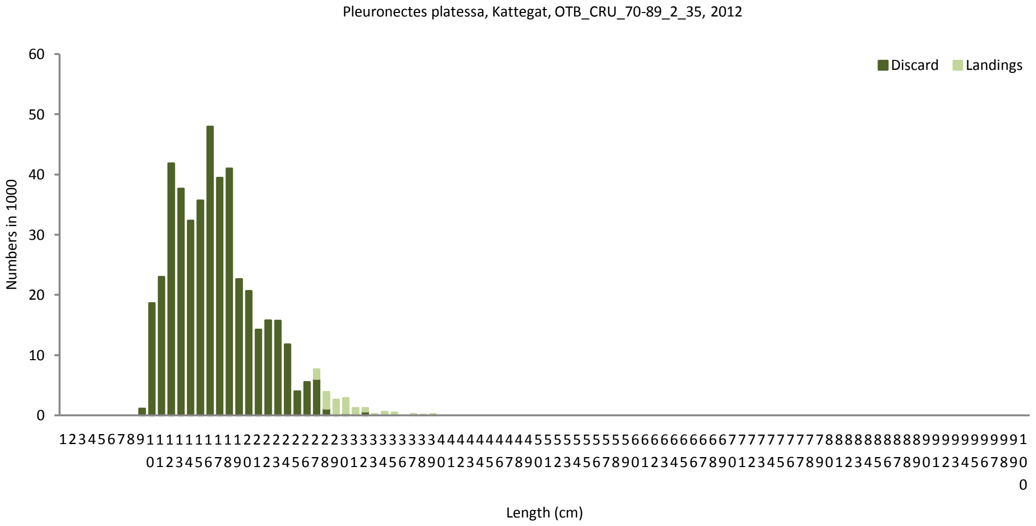
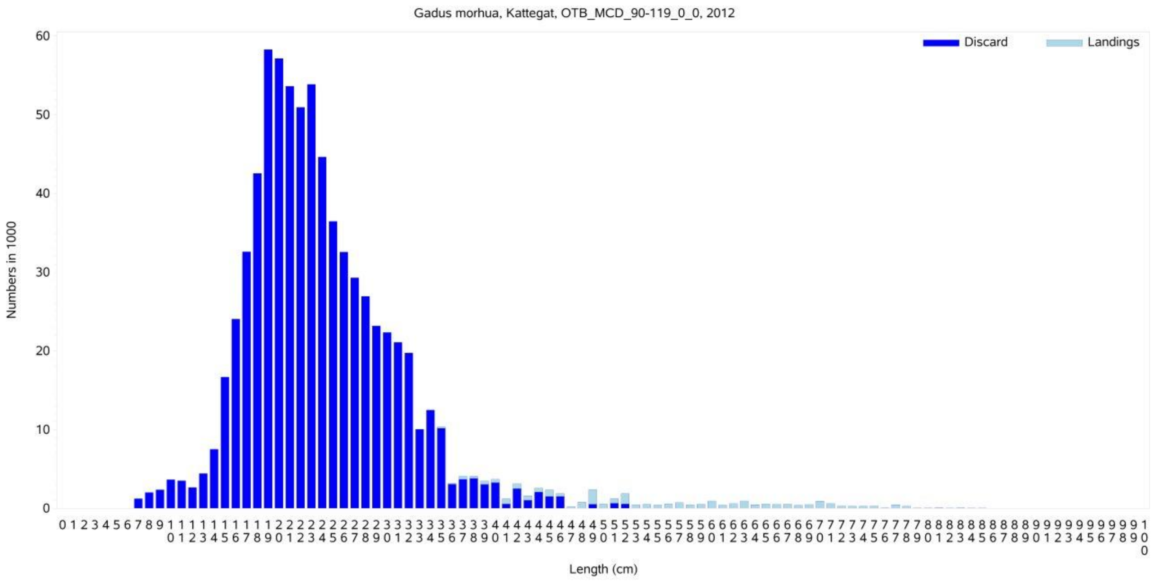
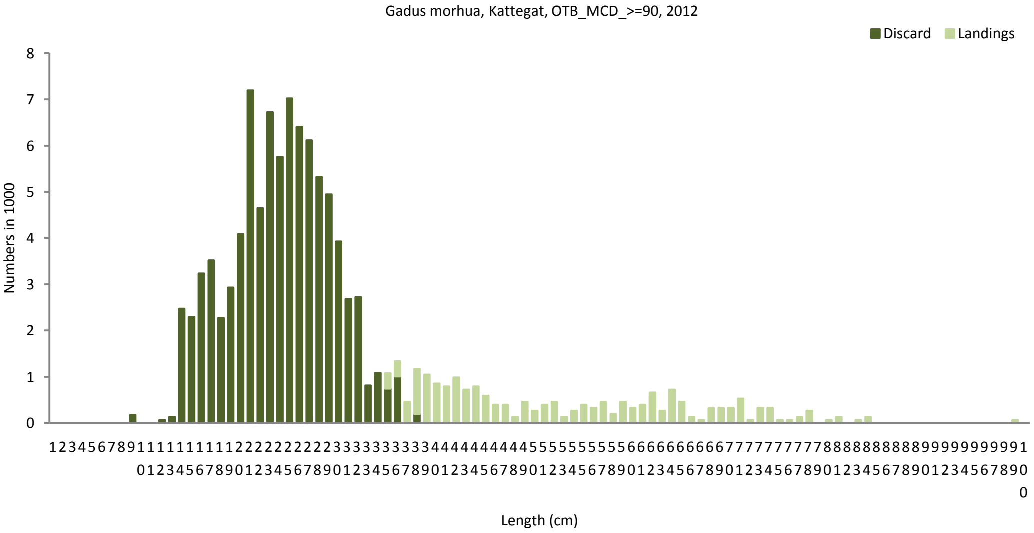


Figure 2.10. Size composition of plaice (*Pleuronectes platessa*) catch by Danish (a, blue) and Swedish (b, green) demersal otter board trawl fishery in 2012 in Kattegat (ICES SD 21) divided into landings and discard. The lower green graph (c) show landings and discards in the Swedish Nephrops fishery using sorting grid (derogation CPart11).

a)


Gadus morhua, Kattegat, OTB_MCD_90-119_0_0, 2012
Discard
Landings
Numbers in 1000
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 6 6 6 6 6 6 6 6 6 6 7 7 7 7 7 7 7 7 7 7 8 8 8 8 8 8 8 8 8 8 9 9 9 9 9 9 9 9 9 9 1
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
0
Length (cm)

b)


Gadus morhua, Kattegat, OTB_MCD_>=90, 2012
Discard
Landings
Numbers in 1000
8
7
6
5
4
3
2
1
0
123456789111111111122222222223333333333444444444455555555556666666666777777777788888888889999999999 1
0123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
0
Length (cm)

c)

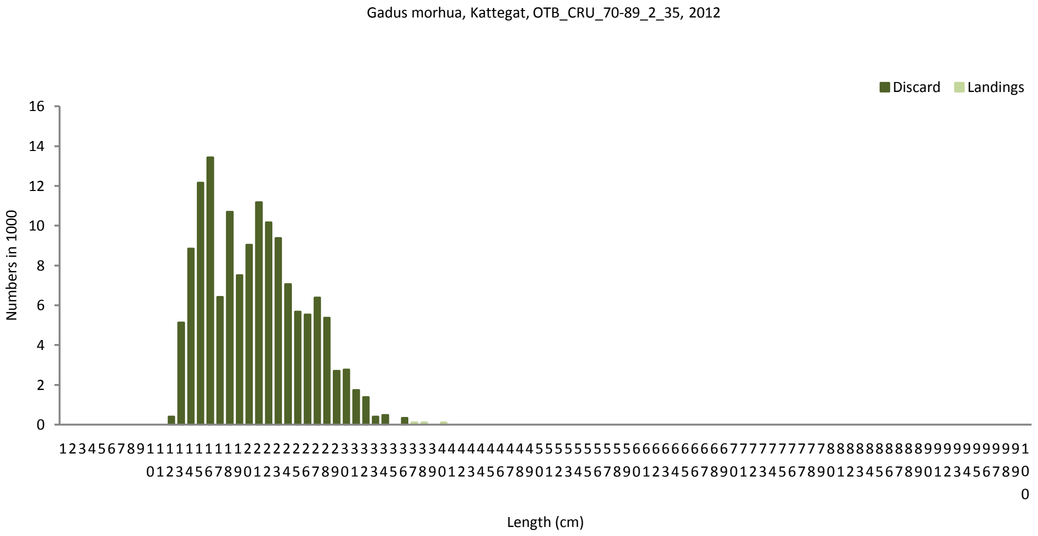
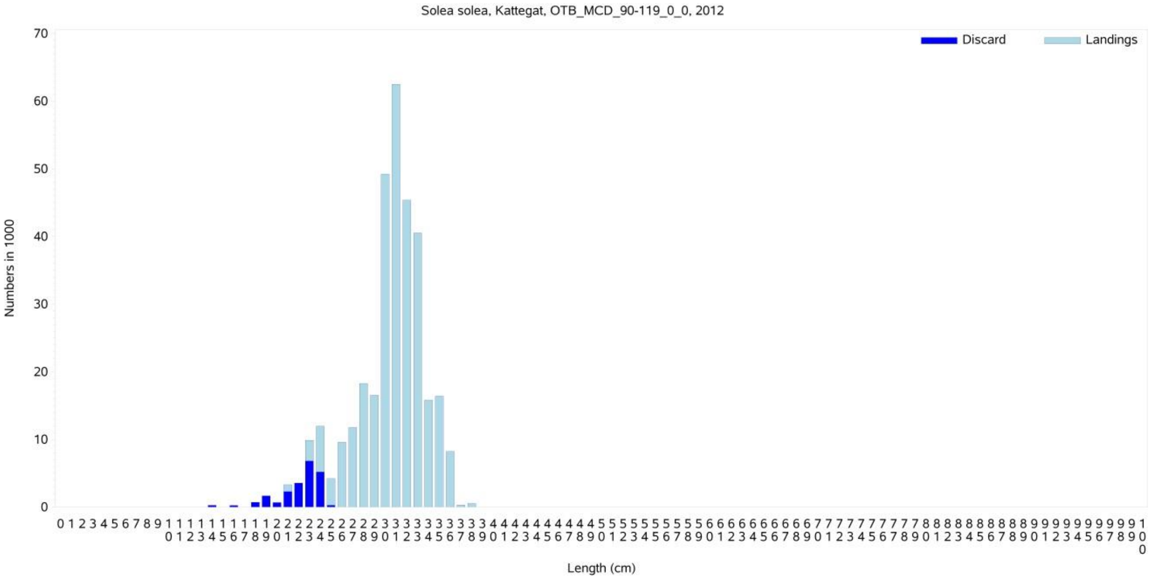
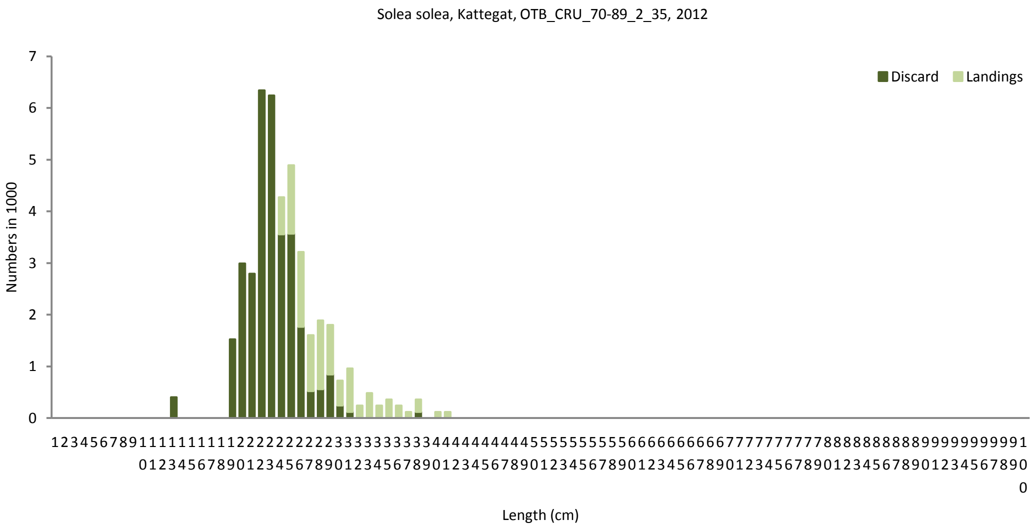


Figure 2.11. Size composition of cod (*Gadus morhua*) catch by Danish (a, blue) and Swedish (b, green) demersal otter board trawl fishery in 2012 in Kattegat (ICES SD 21) divided into landings and discard. The lower green graph (c) show landings and discards in the Swedish Nephrops fishery using sorting grid (derogation CPart11).

a)



b)



c)

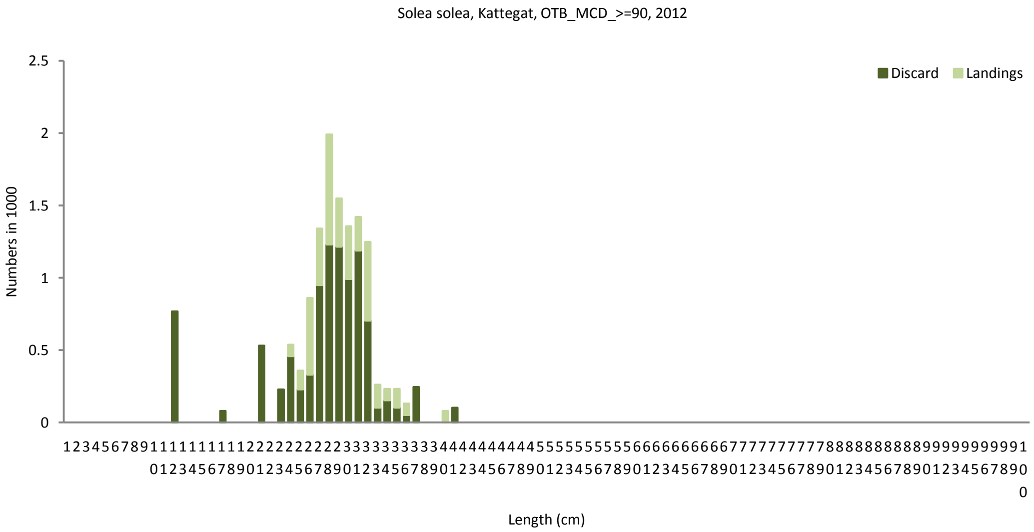


Figure 2.12. Size composition of sole (*Solea solea*) catch by Danish (a, blue) and Swedish (b, green) demersal otter board trawl fishery in 2012 in Kattegat (ICES SD 21) divided into landings and discard. The lower green graph (c) show landings and discards in the Swedish Nephrops fishery using sorting grid (derogation CPart11).

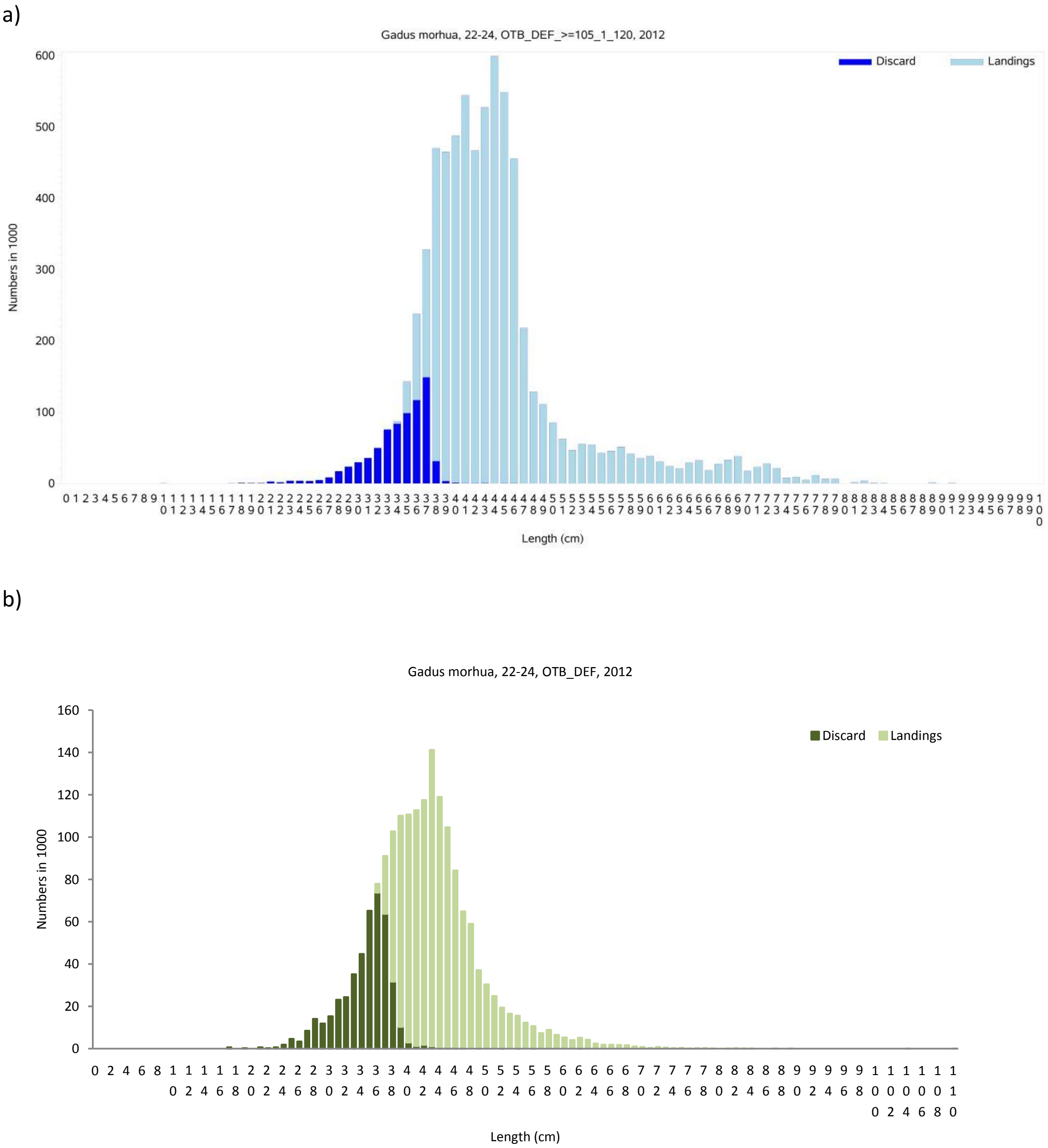
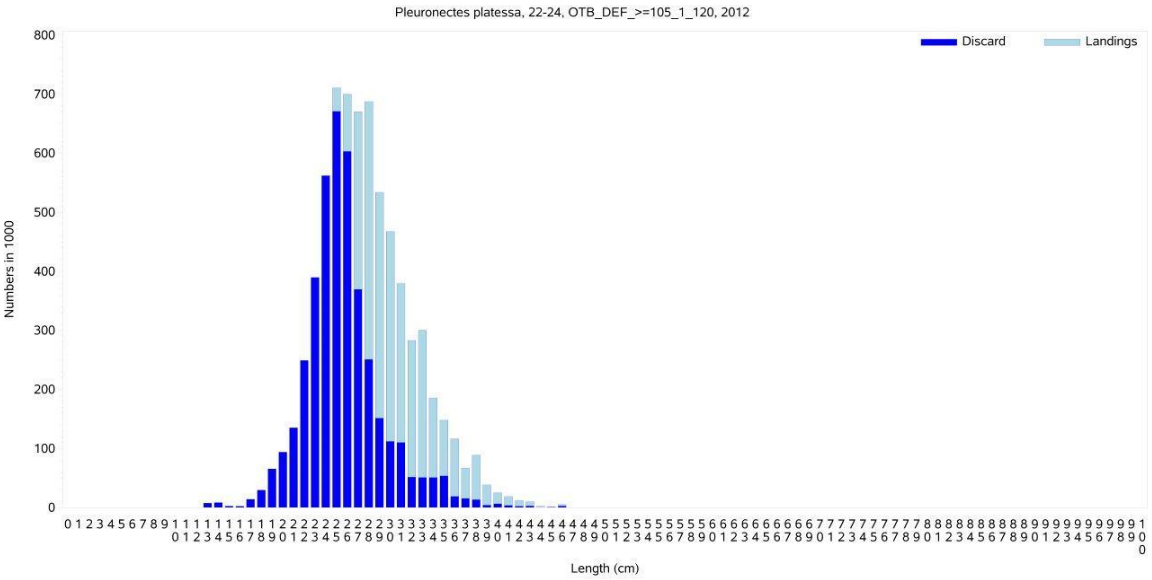


Figure 2.13. Size composition of cod (*Gadus morhua*) catch by Danish (a, blue) and Swedish (b, green)demersal otter board trawl fishery in 2012 in the western Baltic Sea (ICES SD 22-24) divided into landings and discard.

a)



b)

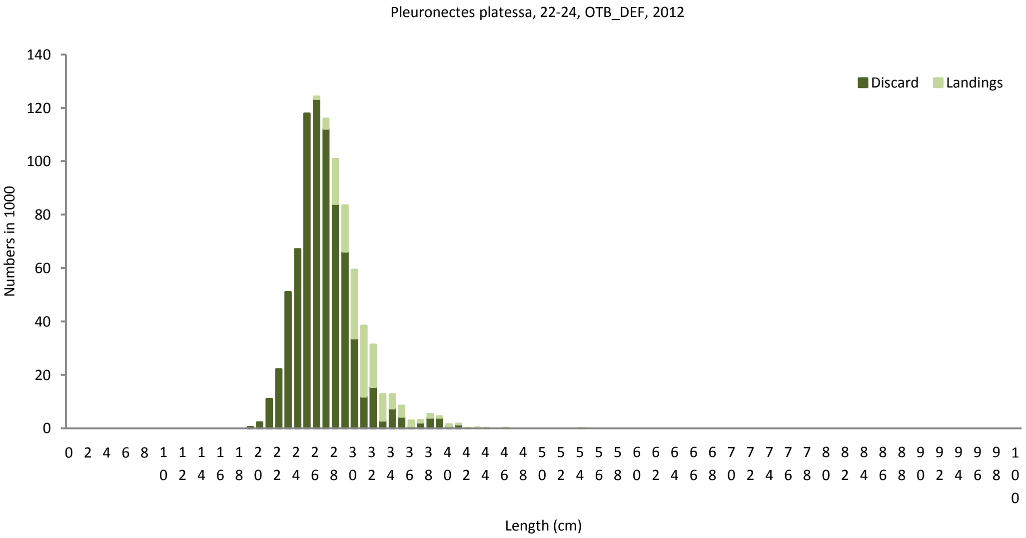


Figure 2.14. Size composition of plaice (*Pleuronectes platessa*) catch by Danish (a, blue) and Swedish (b, green)demersal otter board trawl fishery in 2012 in the western Baltic Sea (ICES SD 22-24) divided into landings and discard.

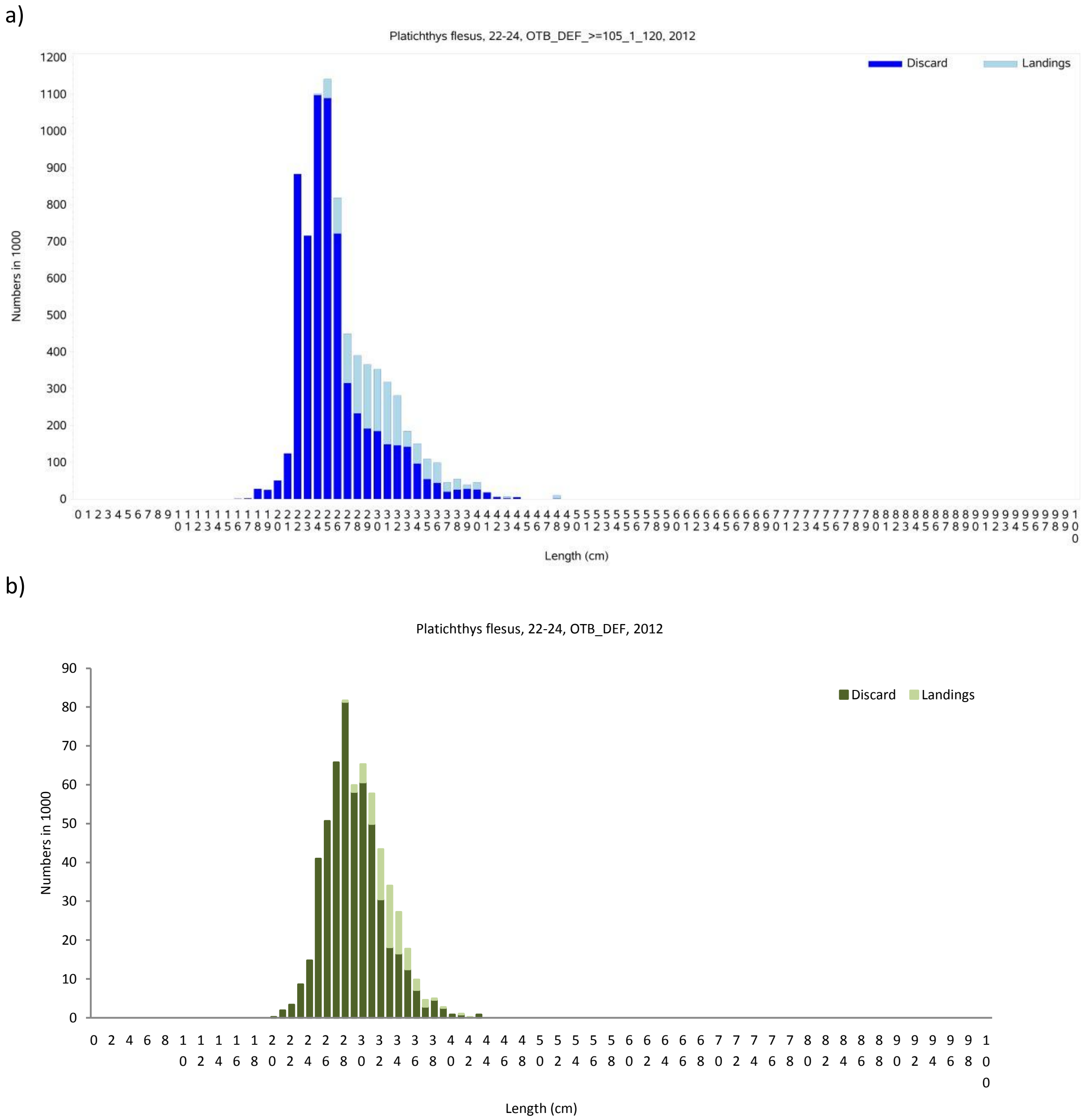


Figure 2.15. Size composition of flounder (*Platichthys flesus*) catch by Danish (a, blue) and Swedish (b, green)demersal otter board trawl fishery in 2012 in the western Baltic Sea (ICES SD 22-24) divided into landings and discard.

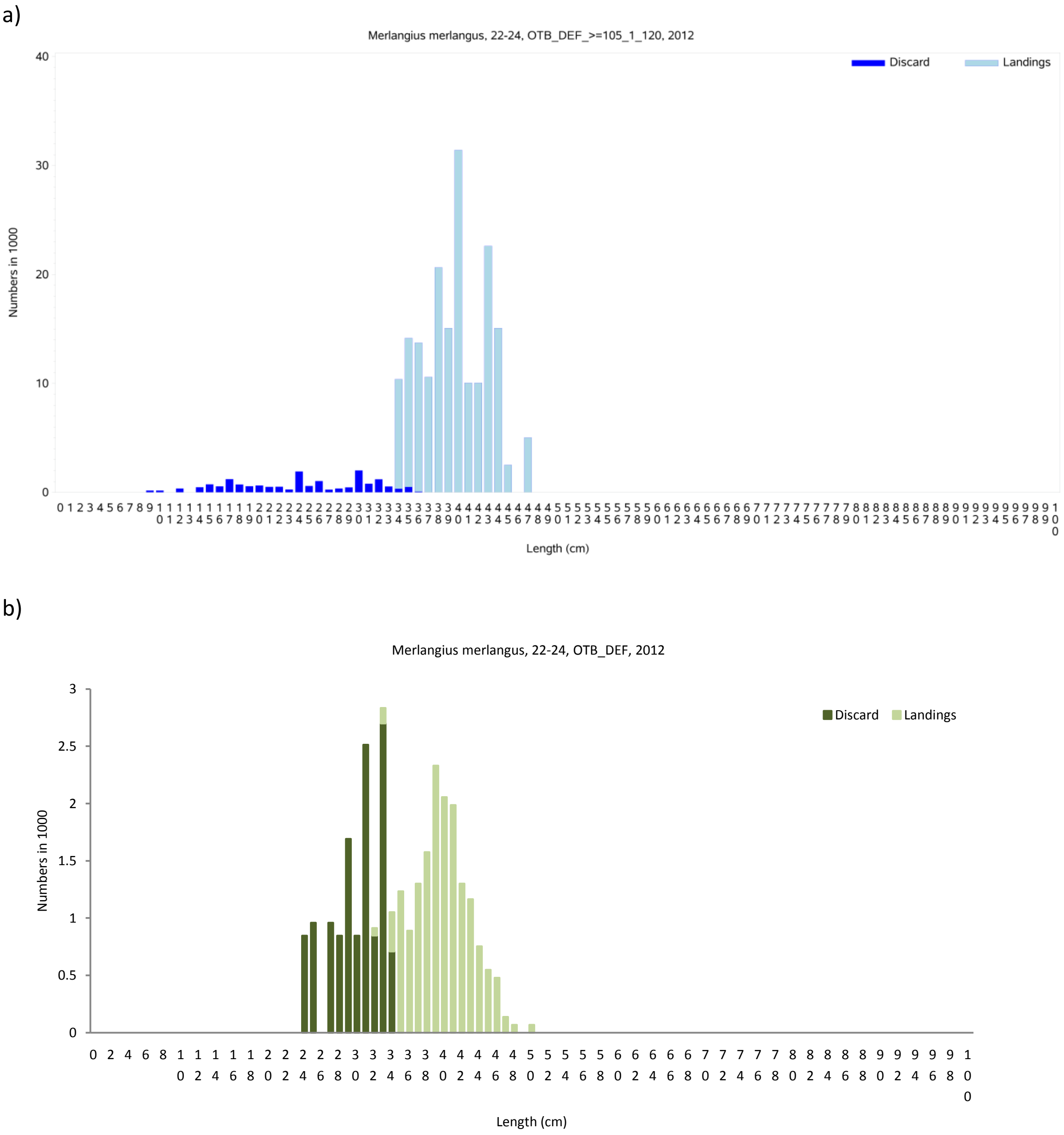


Figure 2.16. Size composition of whiting (*Merlangius merlangus*) catch by Danish (a, blue) and Swedish (b, green)demersal otter board trawl fishery in 2012 in the western Baltic Sea (ICES SD 22-24) divided into landings and discard.

As can be seen from the above length frequency plots significant parts of the catch is discarded in the western Baltic Sea area and Kattegat. The emerging EU landing obligation will likely reduce this discard significantly.

2.5. Distribution of fishing effort as indication of fishing pressure

Until now a problem in quantifying the impact of trawling on the benthos is the lack of data on the frequency of fishing at appropriate spatial and temporal scales. Although data on the distribution of fishing effort is available for historic periods, the spatial resolution of the data (ICES rectangles of ~50 x 50 km) is too crude because fishing effort has been shown to be highly patchy. It is only since the introduction of the Vessel Monitoring System that fishing effort is recorded at the appropriate spatial resolution (e.g. Bastardie et al. 2010b). With the high resolution VMS data of the relevant fisheries, trawling frequencies can be estimated at appropriate spatio-temporal scales for different benthic communities to assess the impact on communities of different sensitivities.

Fishing effort by towed (demersal) fishing gears in the western Baltic Sea and Kattegat is dominated by demersal otter board trawl fishery. Only very limited fishery is conducted with Danish Seine. Detailed fishing pressure maps with combined fishing effort of Danish, Swedish and German fishery by main métier in the period 2010-2012 in the western Baltic, the Kattegat and the Skagerrak areas have been produced. This has been done to investigate the distribution and concentration of the areas with intensive fishing pressure and effort allocation with gears assumed to have major benthic impact. The investigation covers high resolution spatial data for effort allocation of fishing operations for VMS equipped vessels > 12 m (based on satellite Vessel Monitoring Systems). For the spatial patterns of fishing activity the VMS Tools library created as part of EU tender No MARE/2008/10 and further enhancement of this has been applied. This allows collating national VMS data into regional maps of international fishing intensity of all relevant metiers at an appropriate high spatio-temporal resolution. The evaluation covers the metiers OT_DMF (Otter board Trawler Demersal Fishery), OT_MIX_DMF_PEL (Otter Board Trawler Mixed Demersal and Pelagic Fishery), OT_MIX_NEP (Otter Board Trawler Mixed Nephrops Fishery), OT_CRU (Otterboard Trawler Crustacea Fishery), OT_SPF (Otter Board Trawler Sprat Fishery), and SDN_DEM (Danish Seine Demersal Fishery). The BENTHIS metiers are listed in the table below and are further defined in Eigaard et al. (2014).

	BENTHIS-Metier	List of single species fisheries included in metier	List of primary target species in the various mixed fisheries (secondary target species in parentheses)
1	OT_CRU	NEP PRA TGS ARA DPS	
2	OT_SPF	SAN SPR CAP	
3	OT_DMF	COD PLE SOL LEM WHG POK PDS HAD HKE MON MUT	
4	OT_MIX_NEP		NEP PRA CSH
5	OT_MIX_DMF_BEN		PLE SOL LEM MON
6	OT_MIX_DMF_PEL		COD WHG POK PDS HAD HKE MUT PDS
7	OT_MIX_MED		ARA DPS TGS (CTC) (OCC)
8	OT_MIX		MIX* WHG (MUT) (TUR) (SHC) (BLU) (HMM)
9	TBB_CRU	CRG	
10	TBB_DMF	PLE SOL	SOL PLE TUR BLL
11	TBB_MOL	RPW	
12	SDN_DMF	PLE COD	PLE COD (PLE) (COD)
13	SSC_DMF	COD PLE HAD	PLE COD HAD (PLE) (COD) (HAD) (SAI)
14	DRB_MOL	SCE	

* no species information in questionnaire, only "MIX"

OT = otter trawl
TBB = beam trawl
SDN = anchored seine/Danish seine
SSC = flyshooting/Scottish seine
DRB = Dredges

Note that otter trawls (OT) include all towing modes, i.e. single trawl = twin trawl = pair trawl (OTB=OTT=PTB)

Species abbreviations: ARA=Blue and red shrimp; BLL=Brill; BLU=Bluefish; COD=Cod; CRG=Green crab; CSH=Common shrimp; CTC=Common cuttlefish; DPS=Deep-water rose shrimp; HAD=Haddock; HKE=Hake; HMM=Mediterranean horse mackerel; LEM=Lemon sole; MIX=No species information – only mixed species; MON=Angler/Monkfish; MUT=Red mullet; NEP=Nephrops/Norway lobster; OCC=Common octopus; PDS=Smallscale redfin; PLE=Plaice; POK=Pollock; PRA=Prawn; RPW=Rapa whelk; SAI=Saithe; SCE=Great Atlantic scallop; SHC=Pontic shad; SOL=Sole; TGS=Caramote prawn; TUR=Turbot; WHG=Whiting.

In Figure 2.17 the cumulative swept area (in km^2) by metier for Danish, Swedish and German fishery in the period 2010-2012 in the western Baltic Sea, Kattegat and Skagerrak area is shown. From this figure it is obvious that Otter Board trawler Crustacea fishery (OT_CRU), Otter Board Trawler Mixed Nephrops

Fishery (OT_MIX_NEP), Otter board Trawler Demersal Fishery (OT_DMF), and Otter Board Trawler Sprat Fishery (OT_SPF) are the most important Danish, Swedish and German fisheries in terms of swept area in the overall western Baltic and Kattegat area. Figures 2.18-2.23 can be interpreted in a similar way given the actual fishery as listed in the above table.

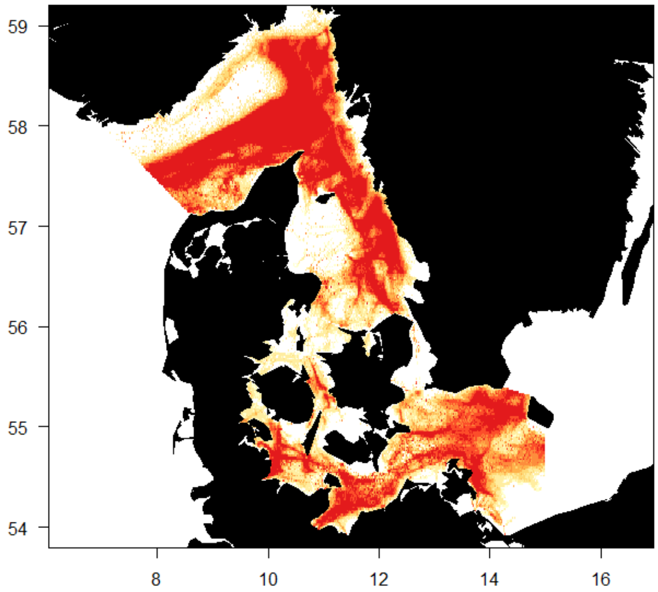


Figure 2.17. Distribution of fishing pressure and effort allocation of all Danish, Swedish and German fishery with VMS equipped fishing vessels (all metiers) in the period 2010-2012 in the western Baltic, Kattegat and Skagerrak area.

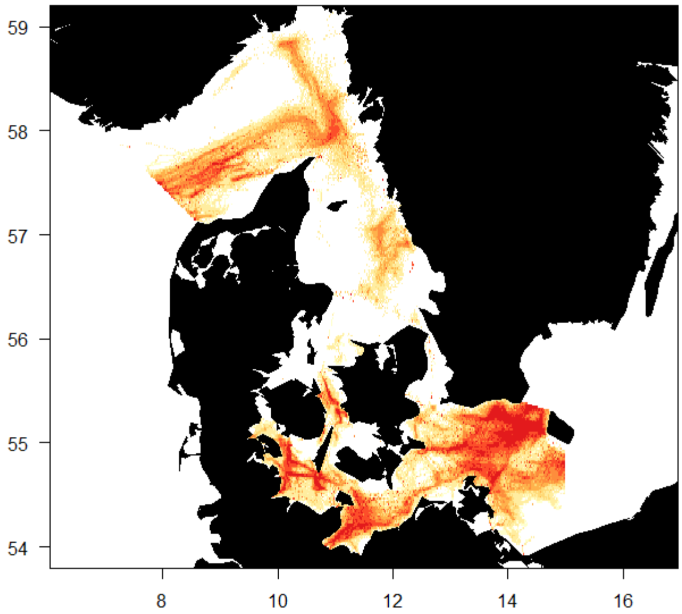


Figure 2.18. Distribution of fishing pressure and effort allocation of Danish, Swedish and German Otter board Trawler Demersal Fishery (OT_DMF) in the period 2010-2012 in the western Baltic, Kattegat and Skagerrak area.

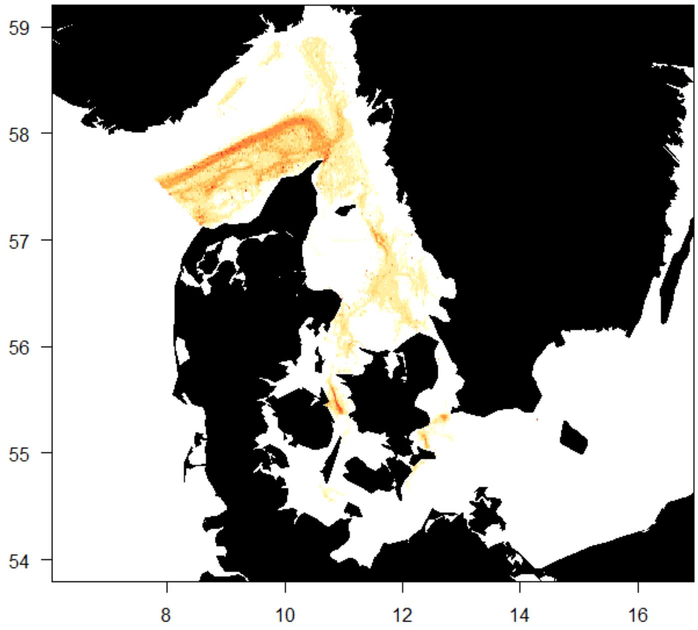


Figure 2.19. Distribution of fishing pressure and effort allocation of Danish, Swedish and German Otter Board Trawler Mixed Demersal and Pelagic Fishery (OT_MIX_DMF_PEL) in the period 2010-2012 in the western Baltic, Kattegat and Skagerrak area.

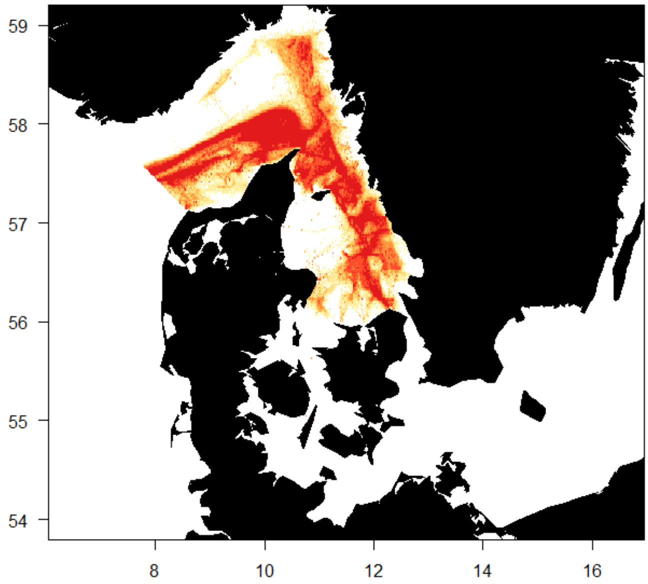


Figure 2.20. Distribution of fishing pressure and effort allocation of Danish, Swedish and German Otter Board Trawler Mixed Nephrops Fishery (OT_MIX_NEP) in the period 2010-2012 in the western Baltic, Kattegat and Skagerrak area.

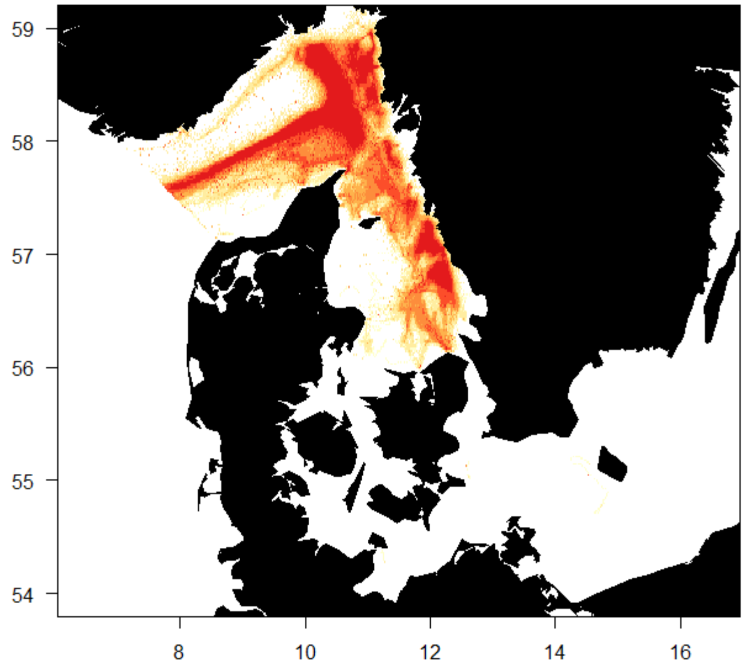


Figure 2.21. Distribution of fishing pressure and effort allocation of Danish, Swedish and German Otterboard Trawler Crustacea Fishery (OT_CRU) in the period 2010-2012 in the western Baltic, Kattegat and Skagerrak area.

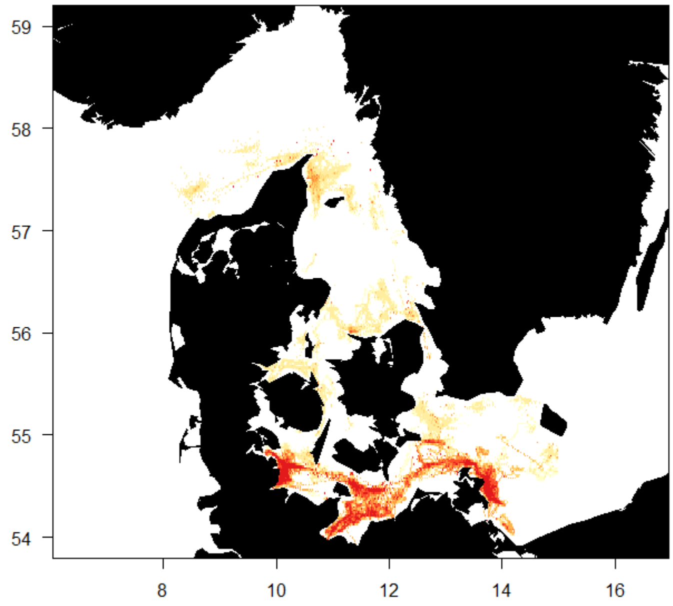


Figure 2.22. Distribution of fishing pressure and effort allocation of Danish, Swedish and German Otter Board Trawler Sprat Fishery (OT_SPF) in the period 2010-2012 in the western Baltic, Kattegat and Skagerrak area.

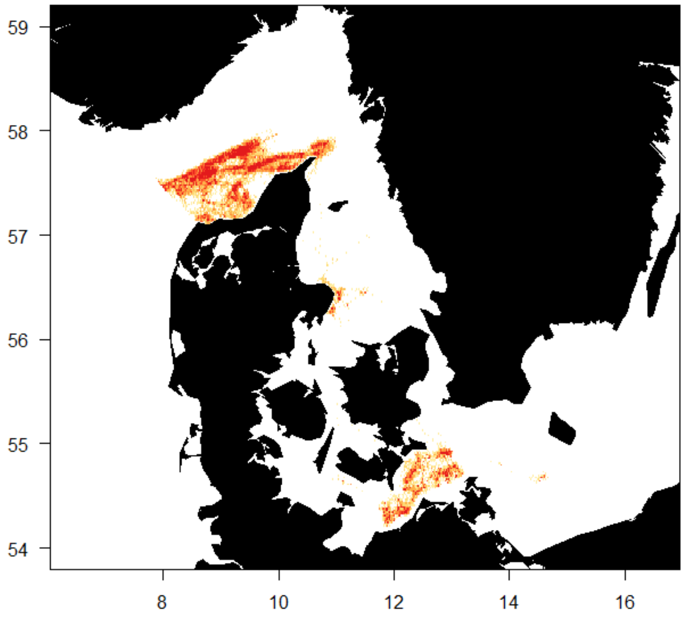


Figure 2.23. Distribution of fishing pressure and effort allocation of Danish, Swedish and German Danish Seine Demersal Fishery (SDN_DEM) in the period 2010-2012 in the western Baltic, Kattegat and Skagerrak area.

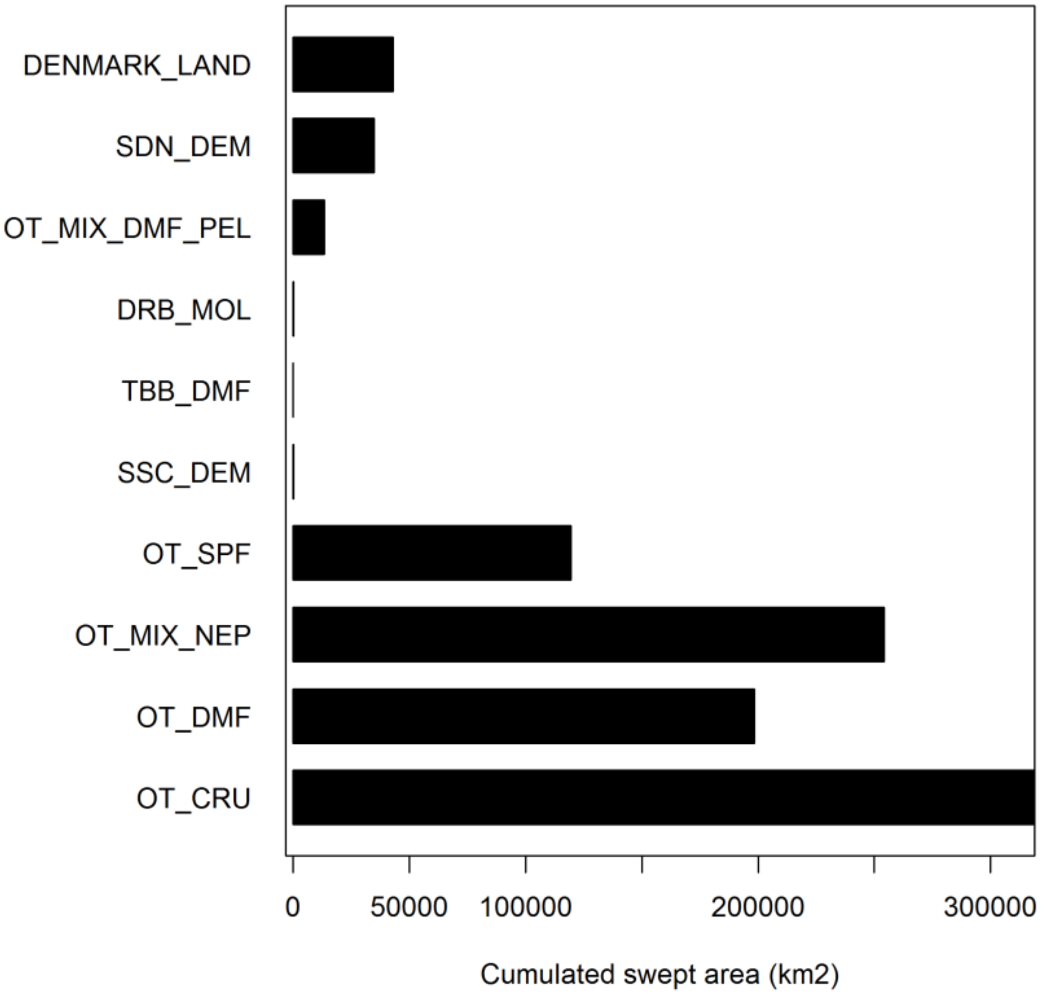


Figure 2.24. Cumulative swept area (in km^2) by metier for Danish, Swedish and German fishery in the period 2010-2012 in the western Baltic Sea, Kattegat and Skagerrak area. For comparison the size of Denmark (44 000 km^2) has been visualized.

2.6. Overview of distribution of benthic habitats (substrates)

The distributions of main habitats characterized by main substrate types are given below for the western Baltic, Kattegat and Skagerrak area in Figures 2.25, 2.26, 2.28 and 2.29. The maps originate from the BALANCE Project (www.balance.com).

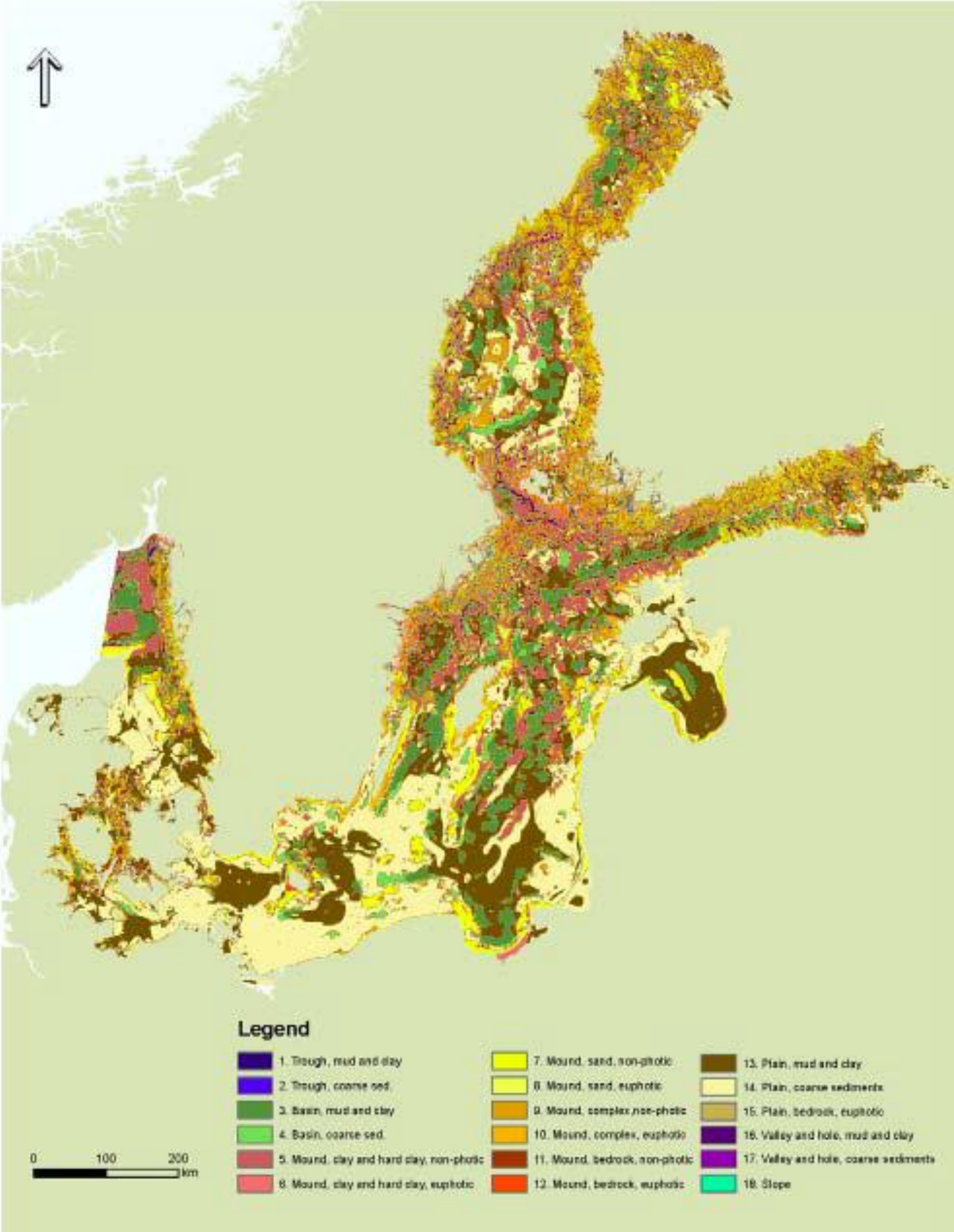


Figure 2.25. *Topographic and bedform features identified during the preparation of the benthic marine landscape map of the Baltic Sea.* From EU-BALANCE http://www.balance-eu.org/.

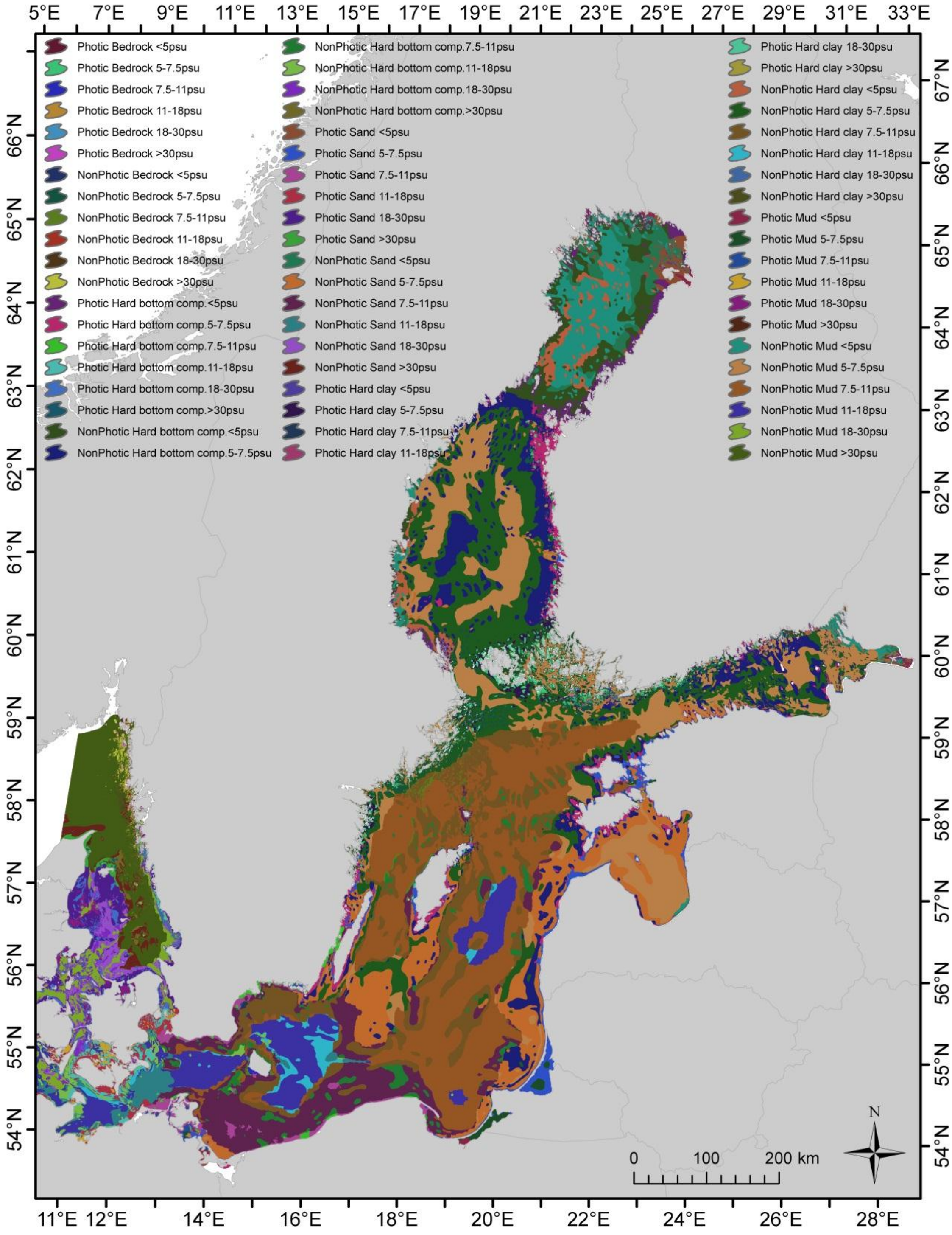
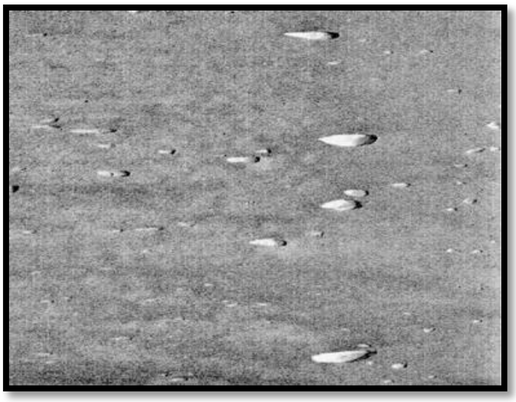


Figure 2.26. Benthic marine landscape map of the Baltic Sea using multi criteria evaluation (MCE) modeling from EU-BALANCE http://www.balance-eu.org/ (modified after Al'Hamdani et al. 2007).



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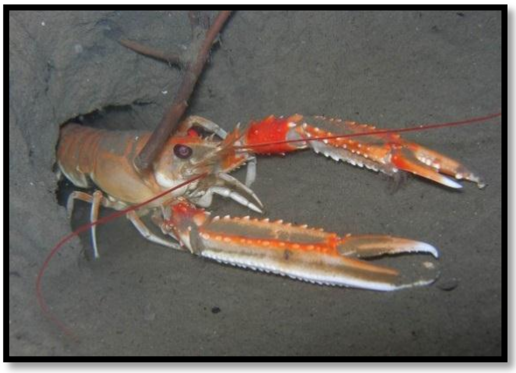

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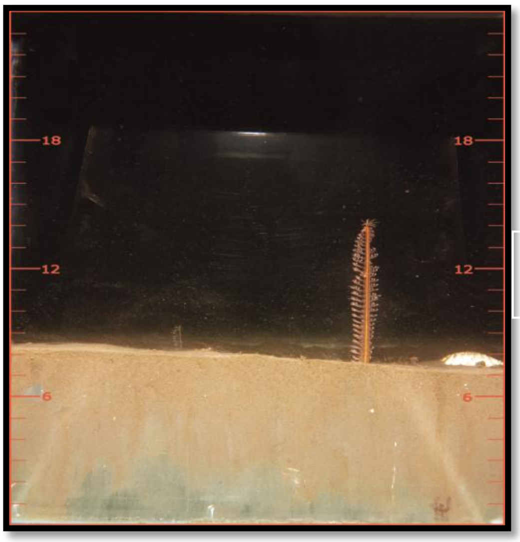
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Figure 2.27. Marine benthic habitats. Hard Bottom (1-2) (partly protected under the Natura 2000 network and the habitat type 'Reef – 1170'). Aphotic mud at salinity >30 with associated burrowing megafauna (3-4) and emergent megafauna (5-8) (partly protection recommended by the OSPAR Convention, Baltic Sea areas not yet designated). From the top left: 1) Side scan sonar image from a Batic Sea area showing scattered boulders on a flat, pre-dominantly gravely seabed. The largest boulders in the picture raise 3-4 m above the seabed. Approximate dimension of the sections: Height 150 m and width 50m. 2) Under water photographs from the same area showing a vertical rocky wall with a variety of species (Photo: Jan Nicolaisen) (From EU-BALANCE http://www.balance-eu.org/.). 3) Under water video image of the Norwegian lobster Nephrops norvegicus in it's burrow (Photo: Rikke Frandsen). 4) Nephrops norvegicus on the sea floor (Photo: Jordan P. Feekings). 5) The emergent sea anemone Bolocera tuediae attached in the mud (tentacle diameter up to 30 cm)(Photo: Jordan P. Feekings). 6) Bolocera tuediae with associated shrimps (Photo: Jordan P. Feekings). 7) Sediment profile image (SPI) of the emergent sea pen Virgularia mirabilis (Photo: Marina Magnusson). 8) Sediment profile image (SPI) of the emergent, tube-building amphipod Haploops spp. (Photo: Marina Magnusson).

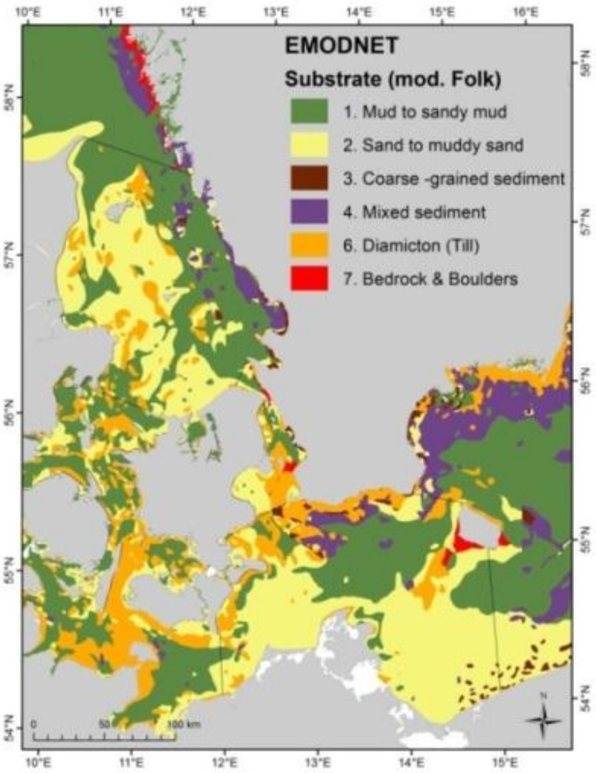


Figure 2.28. Sediment types in Kattegat and the western Baltic Sea as mapped under EMODNET (GEUS, unpublished).

Maps of the fishing impacts (see Fig. 2.30 below) has been made for a number of different benthic ecosystems in the regions studied by combining information of the distribution of the physical habitat types, i.e. sediment types, salinity gradients and near bottom photic conditions from the BALANCE habitats (http://www.balance-eu.org/) (Figs. 2.25-2.29) with high resolution data on spatial effort allocation of fishing operations of different métiers obtained from the present BENTHIS work and analyses under WP7 Baltic Case Study and WP2. The habitats used for this analysis originates from the marine landscapes established by Al'Hamdani et al. (2007) within BALANCE (Figs. 2.25-2.29). The landscapes were established based on a combination of 3 features with 5 substrate categories (bedrock, hard bottom, sand, hard clay, mud), 2 photic conditions (photic, aphotic) and 6 salinity intervals (<5, 5-7.5, 7.5-11, 11-18, 18-30, >30). The salinity intervals were based on salinity levels each know as distribution barriers to a considerable number of plant and animal species.

With respect to the benthic habitats in the area, Skagerrak forms a 100-600 m deep trench connecting the North Sea with the Baltic sea. From the habitat maps Figs. 2.25-2.29 it appears, that the north-western part of the Baltic Sea region comprise of Kattegat, with bottom salinity ranging between 30-34 in the deeper parts (> 30 m), which are all dominated by mud substrate. The marine landscape 'aphotic mud with a bottom salinity >30' is the natural habitat of the Norwegian lobster (*Nephrops norwegicus*) which is the target of a substantial fishery in the Kattegat and Skagerrak region. Several non-target species associated with this landscape are considered sensitive to bottom trawling, including sea pens (*Pennatula phosphorea*, *Virgularia mirabilis*, *Funiculina quadrangularis*) and tube-building amphipods (*Haploops* spp.).

At shallower depth (> 30 m), the substrate in Kattegat is heterogenic, comprising of patches of mud, sand, gravel, pebbles and boulder reefs. At shallow depths (<20 m) salinity levels may reach down to 15-20. Landscapes with bedrock are distributed through the region and comprise of all ranges of salinity and photic conditions. These landscapes harbours a number of species which are sensitive to trawling, thus this fishing activity is rare or non-existing in the area.

The majority of the Baltic Sea region is covered by Sea. Although the sea substrate is spatially heterogenic, the water masses are characterised by low salinity levels ranging between 0 and <20. The low salinity levels has resulted in a total species diversity of benthic fauna of ~300, which is much lower than the total diversity of ~3000 in the Kattegat and Skagerrak areas. In the shallow parts (<20 m) blue mussels (*Mytilus* spp.) and vegetation (eel grass, macro algae) forms patches of biogenic habitats. The deeper parts of the Baltic Sea suffer from nearly permanent hypoxia and anoxia, with only few or no permanent benthic fauna present.

Table 2.18. Habitat classes in the current EUNIS marine habitat classification in the Baltic Sea area.

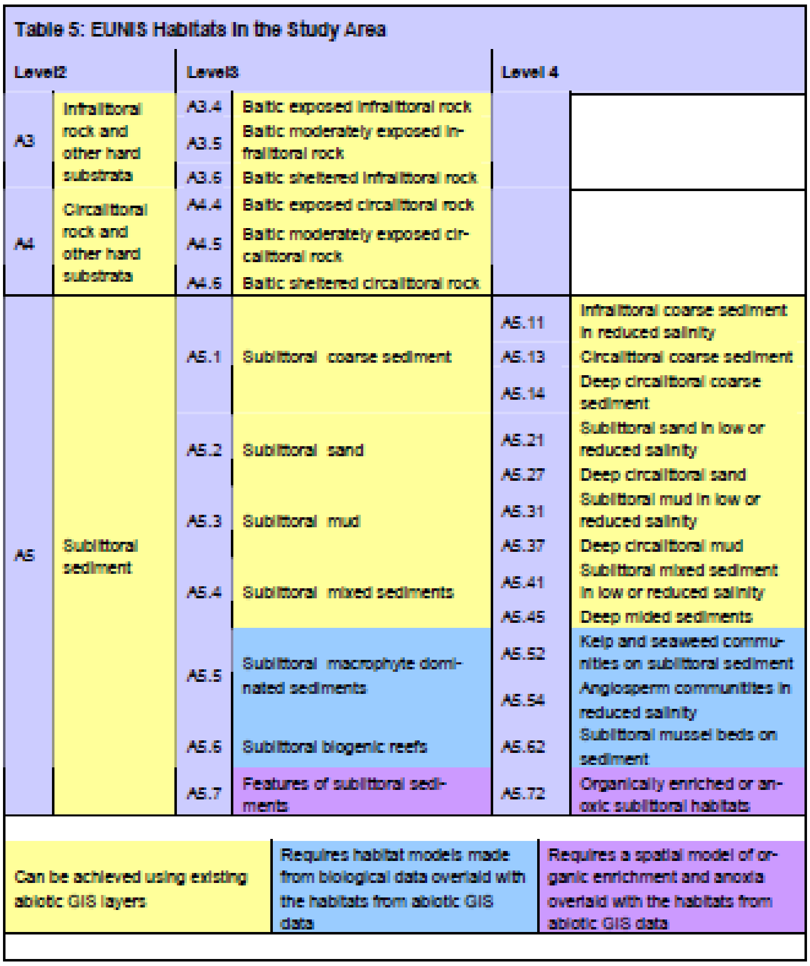


Table 5: EUNIS Habitats in the Study Area

Level2		Level3		Level 4	
A3	Infralittoral rock and other hard substrata	A3.4	Baltic exposed infralittoral rock		
		A3.5	Baltic moderately exposed infralittoral rock		
		A3.6	Baltic sheltered infralittoral rock		
A4	Circalittoral rock and other hard substrata	A4.4	Baltic exposed circalittoral rock		
		A4.5	Baltic moderately exposed circalittoral rock		
		A4.6	Baltic sheltered circalittoral rock		
A5	Sublittoral sediment	A5.1	Sublittoral coarse sediment	A5.11	Infralittoral coarse sediment in reduced salinity
				A5.13	Circalittoral coarse sediment
				A5.14	Deep circalittoral coarse sediment
		A5.2	Sublittoral sand	A5.21	Sublittoral sand in low or reduced salinity
				A5.27	Deep circalittoral sand
		A5.3	Sublittoral mud	A5.31	Sublittoral mud in low or reduced salinity
				A5.37	Deep circalittoral mud
		A5.4	Sublittoral mixed sediments	A5.41	Sublittoral mixed sediment in low or reduced salinity
				A5.45	Deep mixed sediments
		A5.5	Sublittoral macrophyte dominated sediments	A5.52	Kelp and seaweed communities on sublittoral sediment
				A5.54	Angiosperm communities in reduced salinity
		A5.6	Sublittoral biogenic reefs	A5.62	Sublittoral mussel beds on sediment
		A5.7	Features of sublittoral sediments	A5.72	Organically enriched or anoxic sublittoral habitats

Can be achieved using existing abiotic GIS layers	Requires habitat models made from biological data overlaid with the habitats from abiotic GIS data	Requires a spatial model of organic enrichment and anoxia overlaid with the habitats from abiotic GIS data

2.7 Overview of distribution of fishery according to environment

In Figure 2.30 below the fishing effort as cumulative swept area per habitat (in km^2) and relative habitat coverage (percentage) by métier is shown for Danish, Swedish and German fishery in the Kattegat, Skagerrak, and Western Baltic area during the period 2010-2012 for VMS equipped vessels. The 6 panels in the figure represent different metiers: Panel a: OT_CRU (Otterboard Trawler Crustacea Fishery); panel b: OT_DMF (Otter board Trawler Demersal Fishery); panel c: OT_MIX_NEP (Otter Board Trawler Mixed Nephrops Fishery); panel d: OT_SPF (Otter Board Trawler Sprat Fishery); pane e: OT_MIX_DMF_PEL (Otter Board Trawler Mixed Demersal and Pelagic Fishery); panel f: SDN_DEM (Danish Seine Demersal Fishery).

This analysis shows that the fisheries with highest swept area is b OT_DMF (Otter board Trawler Demersal Fishery), d OT_SPF (Otter Board Trawler Sprat Fishery), f SDN_DEM (Danish Seine Demersal Fishery) and e: OT_MIX_DMF_PEL (Otter Board Trawler Mixed Demersal and Pelagic Fishery).

The main habitat impact by fishery in terms of relative habitat coverage for all metiers is for the aphotic mud habitat with >30 psu in salinity where more than 20% of this habitat is covered by fishery in the full western Baltic and Kattegat area. Aphotic sand habitats with 7.5-11 psu and aphotic mud with 11-18 psu or 18-30 psu are the second most impacted habitats with around 10% of their full habitat area covered by fishery. All other habitats are not extensively impacted with less than 5% of the habitat impacted or covered by fishery including the sensitive hard bottom and bedrock habitats.
It should be noted that the background information on habitats and benthic substrates in many areas are uncertain, i.e. there is relatively low monitoring and sampling coverage of geological transects and bathymetry.

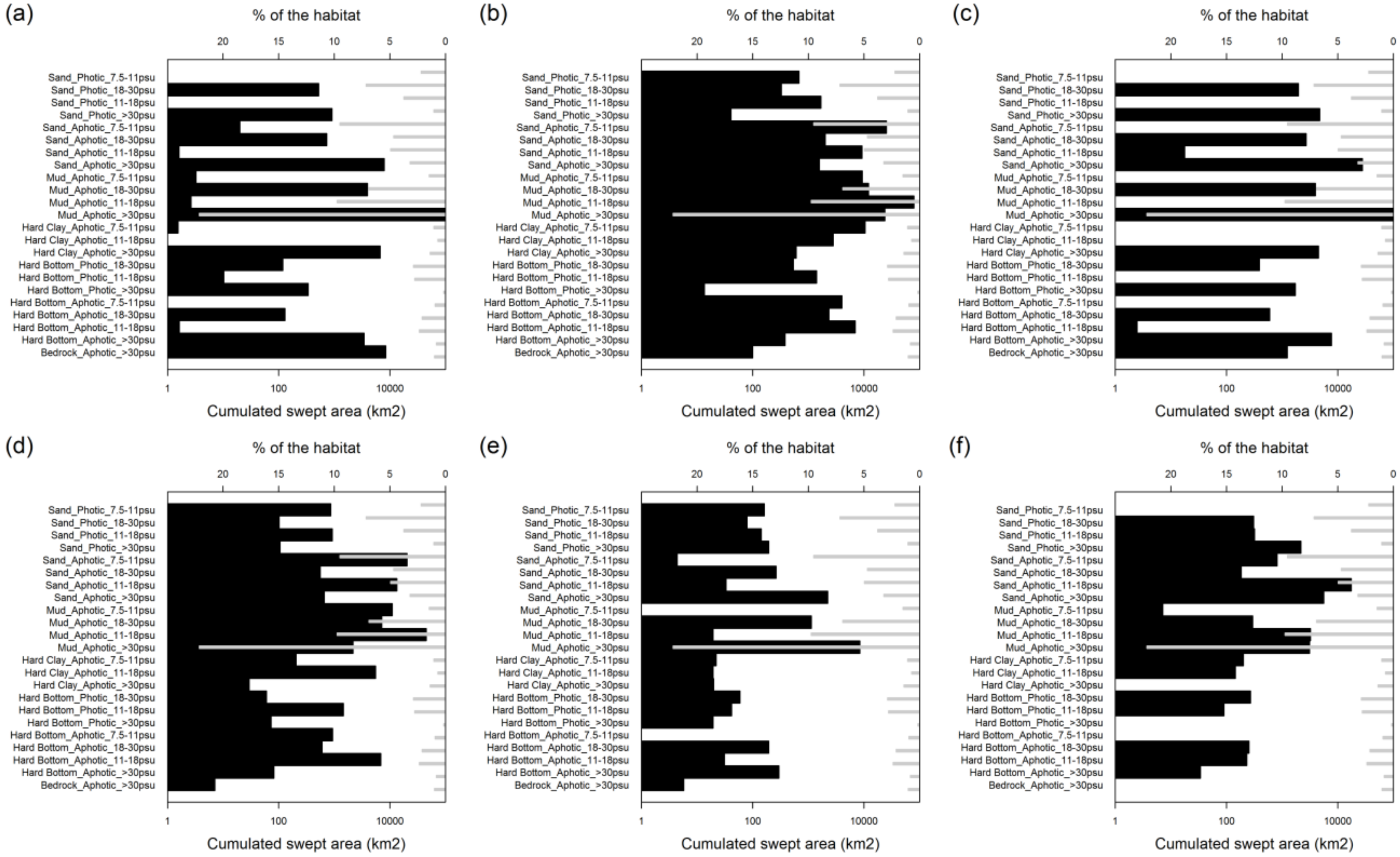


Figure 2.30. Cumulated fishing effort in swept area (km2) by habitat (black bars) and relative area coverage (percentage) by habitat (grey bars) for the western Baltic, Kattegat and Skagerrak area evaluated for the period 2010-2012 for Danish, Swedish and German fishery with VMS equipped vessels which apply on the underlying benthic marine habitats (landscapes) defined within the Baltic Sea (Al-Hamdani et al. 2007, BALANCE http://www.balance-eu.org/). The figure panels a-f is explained in the text.

3 - NORTH SEA

3.1. Introduction

The flatfish fishery in the North Sea is a fishery in transition. The persistent criticism of the environmental impact of fishing through seabed impacts, discards, by-catch of marine mammals and impacts on seabirds has been an important driver. Beam trawling has been the focus of much criticism because of its impact on the seabed but several fishing methods have had their share of attention. Seafloor impact is also evident for otter trawling, and while the intensity of seabed impacts is less than for beam trawling, otter trawls affect a much larger surface area. The fuel crisis provided the incentive to develop and adopt fuel saving techniques like the fuel consumption meter, the Sumwing, Dyneema netting and modernization of engine and propeller which have already resulted in a reduction in the fuel bill. Several vessels now tow different (lighter) gears like the pulse trawl as an alternative for the beam trawl. Others have joined the passive fishing fleet like the Dutch MSC-labeled set netters. The flyshoot has reappeared in a modern version.

The flatfish fishery in the North Sea is dominated, in terms of landings and fishing effort, by large vessels which deploy beam trawls. The 80mm mesh is "the" mesh size for the fishery targeting sole but is also the most important mesh size for plaice. Most of the gears in the North Sea operate in mixed species fisheries. The mesh size used is usually chosen to catch the main target species, e.g. for sole 80 mm or 90 mm and for plaice 100 mm or 120 mm. This implies that the selectivity is non-optimal for other species that enter the net, leading to by-catches and discarding of undersized fish and benthic invertebrates.

In general it can be concluded that trawling reduces biomass, production and species diversity, with a higher sensitivity for the softer sediments and hard substrates. Sandy sediments appear to be more resilient to trawling, especially in dynamic areas. In order to get a better insight into the relation between fishing effort, swept area, gear type and habitat, the data available through the BENTHIS project were combined.

3.2. Fishing gears used with benthic impact in regional seas

Three beam-trawl categories operate in the North Sea, i.e. the larger meshed flatfish beam trawl with plaice as the main target species, the smaller meshed flatfish beam trawl with sole as the main target species and the shrimp beam trawl. The distribution of activity by these gears is shown in Figure and Figure .

TBB-DMF (flatfish ; mesh size >120 mm)

The larger meshed flatfish beam-trawl gear is principally used in the plaice fishery of the Central and Eastern North Sea. Cod is also taken in this fishery. Denmark, Belgium and England mainly carry out this fishery.. These beam trawls can take on different designs such as tickler chain beam trawls and SumWing trawls(*Fig.* , *Fig.*).

TBB-DMF (flatfish ; mesh size between 80 mm and 120 mm)

The smaller meshed beam trawl gear (accounting for around 40% of all fishing effort in the North Sea) is mainly used in a fishery located in most Southerly parts of the North Sea and into the English Channel. This mixed flatfish fishery for sole, plaice and other flatfish, is operated principally by the Netherlands, Belgium, the UK and Germany. These beam trawls can take on different designs such as tickler chain beam trawls, chain matrix beam trawls, SumWing trawls and pulse trawls (*Fig.* , *Fig.* , *Fig.*).

TBB-CRU (brown shrimp ; mesh size > 16 mm)

The small meshed shrimp beam trawl is used in the coastal waters and estuaries of the eastern side of the North Sea and in some isolated areas of the UK side of the North Sea such as the Wash and the Humber estuary. This fishery is operated principally by the Netherlands and Germany with Denmark, the UK and Belgium as minor players. Two main designs are in use, i.e. the traditional shrimp beam trawl and the shrimp pulse trawl (*Fig.*).

The beam trawl, gear characteristics and environmental impact

The main difference between the shrimp and the flatfish beam trawl is the stimulation needed to startle and catch the target species. For shrimps the stimulation is limited to a light weight bobbin rope or low frequency electric pulses. For flatfish, chains in the net opening and a ground rope with intense seafloor contact is needed. The chains can be replaced by high frequency electric pulses.

The net of a beam trawl is kept open horizontally by means of a steel beam, which is supported at each end by a trawlhead. The length of the beam varies between 4 and 12 m. Flatsteel plates, the sole plates, are welded to the bottom of the trawl heads. When fishing, the sole plates are in directcontact with the seabed and generally slightly tilted. Beam trawls are normally provided with tickler chains to disturb the flatfish from the seabed. On rough groundsthe tickler chains are replaced by a chain matrix to prevent boulders from being caught by the net. Light beam trawls, without tickler chains or chain matrices,are used to catch brown shrimps, *Crangon crangon* in coastal waters. Double-rig beam trawlers tow two beam trawls,one from either side of the vessel, by means of two derrick booms. The weight (in air) of a complete beam trawl variesfrom several hundred kg for a shrimp trawl to up to 7 tons (and more) for the flatfish trawls equipped with tickler chains. Thetowing speed varies between 3 and 7 knots.

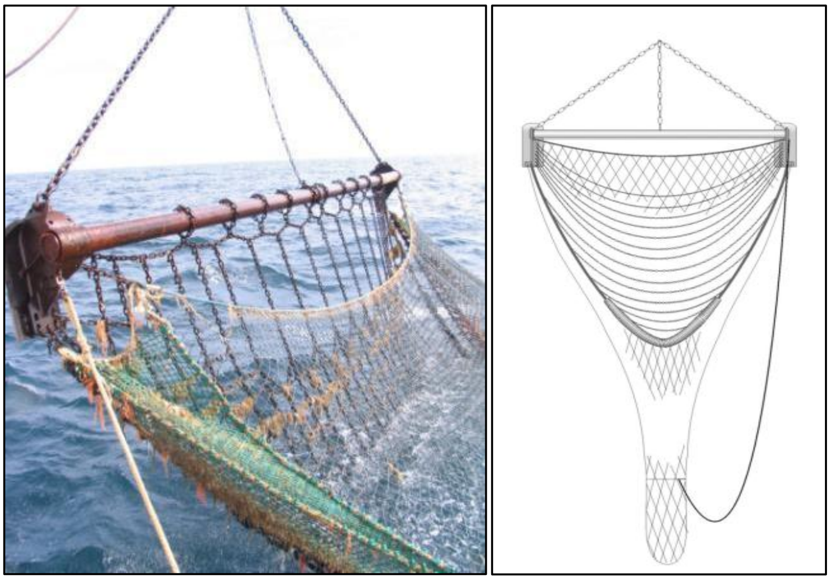


Fig. 3.1 - A beam trawl with chain matrix (left) and with tickler chains (right)

The pressure on the seabed exerted by beam trawls is strongly related to the towing speed (Fonteyne, R., 2000). For a beam trawl, the pressure exerted by the trawl heads varied from 0.2 to 1.1 N/cm^2. The actual pressure can be 2-3 times higher if the sole plate is tilted. Although larger vessels use heavier gears, this is compensated by the larger sole plate dimensions and the higher towing speeds. By adjusting the length of the warp, the towing speed and the weight of the gear, fishermen will strive to a certain intensity of seafloor contact, irrespective the size of the gear or vessel. In practice fishermen will tune the intensity of seafloor contact to the type of sediment. On soft grounds, where the risk of fastening is high, seafloor contact will be less intense compared to harder grounds.

The parts of the trawl gear in closest contact with the seabed are the trawl head, the tickler chains or chain matrix andthe groundrope. The pressure from the tickler chains or matrix chain elements is substantially lower than that exerted by the trawl heads, although the area covered is significantly greater.During the passage of a gear component the pressure in the sediment at a certain point will gradually increase up to amaximum and then gradually decrease. Model tests have shown that, irrespective of the weight of the gear, the reactionpressure is reduced to 10 % of the near-surface value at a depth of 10 cm and unchanged at depths greater than12.5 cm(Paschen et al., 1999).

When towing a tickler chain or a chain matrix over the seabed, sediments will be transported and pass through and/orover the links and resettle after passage. Smaller particles will go into suspension and may be transported away bycurrents or resettle in the track of the trawl. Local variations in morphology such as ripples will be flattened out. Theeffect of an array of chains running consecutively over the seabed is that the increase in penetration depth becomes lessand the additional effect is smaller with an increasing number of chains. The passage of the first chain compacts thesediment, diminishing the effect of elements passing later. After about seven passages the increase in penetration ishardly noticeable (Paschen et al., 1999).Fluctuations in the pressure exerted on the seabed indicate that beam trawls are not in a steady contact with the seabed(Fonteyne 2000). Measurements showed penetration depths between 1 and 8 cm (Paschen et al., 1999). The tickler chain beamtrawls, used on clean grounds, have a simple and rather light groundrope. The groundropes of chain matrix beam trawls, for use on rough grounds, are equipped with bobbins.

The SumWing

The Sumwing is a wing shaped hydrodynamic trawl beam assuring the horizontal opening of the net. It has been designed by the Dutch company HfK Engineering to reduce the hydrodynamic resistance of the beam trawl beam and increases its effectiveness with increasing fishing speed (and thus turbulence).

The wing is steered by the nose (Fig. 3.3). The equilibrium of the hydrodynamic and gravitational forces in the warp, wing or beam, and the net with tickler chains, tilt the wing downwards so that the gear is sent to the seafloor. Once the nose touches the seafloor, it causes the wing to tilt upwards until it is in a hydrodynamically neutral position. The nose is an essential part of the gear and allows the gear to closely follow the surface profile of the seafloor.

A Dutch (van Marlen et al, 2009) and a Belgian report (Huyghebaert et al, 2010) have reported first results of commercial trials. Fuel savings reported were 11% (van Marlen et al, 2009) to 13% (Huygghebaert et al, 2010), avg. 12%. Recently fuel savings up to 23% have been reported.

Fig. 3.2- The Sumwing with tickler chains.

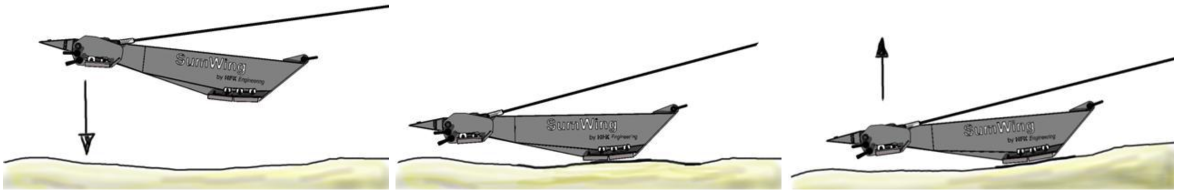


Fig. 3.3– The functioning of the nose of the Sumwing (towing direction is to the right)

The flatfish pulse trawl

The principle of the flatfish pulse trawl is that electric pulses are being used as an alternative stimulation for the mechanical stimulation of tickler chains. The electric field is generated by a pulse generator mounted on the beam of the trawl and the pulses are released to the seawater through electrodes rigged longitudinally in the net mouth. The system was invented by Piet Jan Verburg from Colijnsplaat (Netherlands) in 1992 and was purchased by the ministry for Food Quality in 1998. In 2005, the UK 153 was equipped with two pulse nets to test the system in the field. In

2006, the UK153 fished fulltime using the pulse net. At the end of 2006, the European Community gave permission for pulse-fishing for 5% of the fleet in the North Sea.

Two similar systems are being developed and are currently tried in commercial conditions in the Netherlands (Fig. 3.4) being the pulse trawl developed by Delmeco (Nl) and the PulseWing designed by HfK Engineering (Nl). For the pulse trawl, the SumWing as well as the traditional design can be used. The main difference is the replacement of ticklers by electrodes and the use of a square netopening allowing electrodes of equal lebgth all along the width of the gear. In principle this trawl remains a beam trawl since the net is held open horizontally with some sort of beam. The pulse trawl however lacks the heavy tickler chains which significantly reduces the seafloor and benthic impact. The towing speed has been reduced from some 7 kn to somewhat more than 5 kn which decreases the fished surface and thus benthic impact. The average penetration depth has also been reduced from over 2.5cm to less than 1cm. Fuel consumption is at least 45% less and anecdotal information points at a further reduction with the PulseWing. The fish caught are in principle not killed or paralyzed by the electricity, but are only startled. This is in contrast with traditional electro-fishing, which is forbidden without a license.

Fig. 3.4– The two main designs of the pulse trawl.

Rijnsdorp et al. (1998) state that it is likely that beam trawling will have a different effect according to the characteristics of the environment it is deployed in. According to Duineveld et al. (1991) the benthos in the southern North Sea can be divided into three different benthic clusters which were related to sediment characteristics. In shallow (<30 m) coastal waters and in the Southern Bight, the benthos is characterized by relatively small, highly productive organisms in shallow coarse sand or shallow fine sand, which are particularly resilient to physical disturbance. In these areas, physical disturbance is a natural feature due to strong tidal currents and the effect of storm surges. The deeper offshore waters (>30–40 m), coinciding with muddy sand, were characterized by a more sensitive cluster, including larger animals such as *Arctica islandica*. Since, despite the patchiness of the effort distribution, beam trawling occurs in areas with a different vulnerability to fishing, the impact may be comparable to natural phenomena in one area and may have serious consequences for the benthic ecosystem in another.

Fig. 3.5– The two main designs of the shrimp beam trawl. Left: the traditional shrimp trawl with round bobbin rope of 400 kg (and optional beam/groundgear connections). Right: the shrimp pulse trawl with straight bobbin rope of 155 kg and electrodes.

Rijnsdorp et al. (1998) also state that beam trawling may be micro-habitat specific. Hence, some specific habitats, and therefore specific benthic communities, can be exposed to intensive trawling much more than others. The areas of intensive beam trawling have already been trawled intensively for several years and still provide profitable fishing grounds. Without ample benthic food for plaice and sole, these fishing grounds would have lost their profitability for fishing. Beam trawling effort is directed to certain ecotopes and these withstand the impact.

Piet et al. (2000) concluded that fishing mortality based on environmental strata differed considerably from the fishing mortality based on ICES rectangles, at least for some species. He explains this by the fact that both the benthos densities and the beam-trawl effort distribution seem to follow the environmental strata. This suggests that the spatial distribution of the fish that are targeted by the fleet is determined by the same environmental variables that determine the spatial distribution of the benthic species selected. The observation that these species still occur in the southern North Sea, in spite of estimated annual fishing mortalities over 50%, suggests that their populations are sustainable at the present level of additional mortalitycaused by beam trawling. This, of course, is no guarantee that all benthic invertebrate species originally present have been able to withstand these levels of fishing mortality. Presumably the species selected possessed life-history characteristics (e.g. early reproduction, highreproductive rate, and low longevity) that enabled themto maintain a population in spite of the beam-trawlingactivities. Densities of species that do not possess such life-history characteristics might have decreased because of commercial trawling earlier this century (Lindeboomand de Groot, 1998) to such low levels that they could not be used in this study.

Box core sampling data from 80 stations in the Dutch part of the North Sea, sampled annualy over a period of 6 years, were analysed by a structural equation model in relation with bottom trawl intensity, sediment grain size, water depth, proimary productivity (van Denderen et al., 2014). It was shown that trawl disturbance relates to benthic species richness. The relationship is mediated by total benthic biomass, primary productivity, water depth, and median sediment grain size. Our results show a negative relationship between trawling intensity and species richness. Richness is also negatively related to sediment grain size and primary productivity, and positively related to biomass. Further analysis showed that the negative effects of trawling on richness are limited to relatively species-rich, deep areas with fine sediments. We find no effect of bottom trawling on species richness in shallow areas with coarse bottoms. These results corroborate the results of Diessing et al (2013), who showed the importance to include natural disturbance in assessing the impact of trawling.

It has been suggested by different authors that the increased growth rate of plaice and sole in the 1960' and 70', which coincided with the introduction of the beam trawl, was causally linked with beam trawling (Rijnsdorp and Vingerhoed, 2001). De Veen (1976) postulated that beam trawling contributed to the increase in growth rate by enhancing the availability of food through damaging benthic organisms in the trawl path. Several studies have shown scavenging behaviour in dab, whiting, cod, dragonet and dogfish. Benthic predators may also have benefited if repeated beam trawling results in a change in the species and size composition of the epi- and infauna towards highly productive small and short-lived species at the expense of the low-productive larger and long-lived organisms (ICES, 1988). The observed increase in growth rate of both sole and plaice species, which prey mainly upon the smaller opportunistic benthic species, may be a result ofthe increased productivity of suitable benthic food in the heavily trawled areas (de Veen, 1976; Rijnsdorp and van Beek, 1991; Rijnsdorp and van Leeuwen, 1996, Rijnsdorp et al., 1998). However, a re-analysis of a longer time series did not confirm the earlier conclusion (Beare et al., 2013). In a theoretical model study it was shown that the effect of bottom trawling on the food of benthivorous fish like flatfish was dependent on the mechanism that controlled the benthic ecosystem. If the benthos was controlled by bottom-up processes (competition for food) and flatfish prefer benthos that is insensitive for trawling, bottom trawling may promote the food for flatfish (van Denderen et al., 2013). The question now is whether the benthic ecosystem in the different North Sea habitats is controlled by bottom-up or top-down processes.

3.3. Importance of gear types with benthic impact in regional seas

a) Effort

No North Sea wide data on fishing effort have been compiled in time to include in this report, but the swept area estimates for the BENTHIS métiers give a good proxy for the fishing effort. In Table 3.1. the BENTHIS métiers were grouped into 6 fleet segments. Otter trawls targeting a mix of demersal fish have the largest area swept (set at 100 %), followed by otter trawls targeting Nephrops (62%) and Danish and Scottish seiners (43%). The swept area of beam trawlers targeting flatfish or shrimps and dredgers targeting molluscs is much lower with 21%, 9% and 9% of the swept area of OT-DMF, respectively.

Swept area of OT-CRU will be an overestimate of fishing effort because of the wider horizontal net opening of the twin trawls used in this fishery, while the swept area of beam trawlers will an underestimate of fishing time because of the smaller horizontal net opening. For beam trawlers targeting flatfish, however, the small net opening will be compensated by the higher towing speed.

Table 3.1: Mean annual area swept (km^2) by each fleet segment . Fleet segments combined BENTHIS métiers: OT-CRU = OT_CRU + OT_MIX_NEP; OT-DMF= OT_MIX + OT_DMF +OT_MIX_DMF_BEN + OT_MIX_DMF_PEL; SSC = SDN_DMF + SDN_DEM + SSC_DMF + SSC_DEM; TBB_DMF= TBB_DMF + TBB_MOL

Fleet segment	Surface area swept (km^2)	Relative surface area swept
DRB	33166	9%
OT-DMF	356207	100%
OT-CRU	219389	62%
SSC	153374	43%
TBB-DMF	75737	21%
TBB-CRU	31141	9%

b) Landings/discards

On average 40% of the catch in weight was discarded in the North Sea between 2010 and 2012 and 78% of the discards consisted of plaice and dab. Average discard ratios were highly variable between species ranging from zero (e.g., megrim, blue ling) to over ninety percent (dab) (Table 3.2)).

The highest average catch between 2010 and 2012 was estimated for plaice with a discard ratio of 43%. Dab had the second highest average catch and by far the highest discard ratios (91% on average). The high abundance of dab and the low market value contributed to this result. Discard ratios above ninety percent mean that small changes in discard ratios lead to very high changes in absolute discard estimates in tonnes. Therefore, absolute discard estimates in tons have to be taken with great care for dab. In contrast to the two mentioned flatfish species, discard ratios for sole were much lower (13% on average) demonstrating the high market value and the ability of fishermen to avoid unwanted by-catch of sole.

The flatfish fisheries with beam trawls (BT2) produced high discard ratios especially for plaice, dab and whiting. Currently, discard ratios for cod are low in this fishery (11%). Lower discard ratios were reported for fisheries with large meshed beam trawls (BT1).

Table3.2: North Sea demersal fisheries: landings and discards (tons) per gear, species and year; table sorted in descending order on average catch 2010-2012, top 10 species per gear (Pastoors, 2014).

REG_GEAR	SPECIES	SPEC_NAME	2010 Landings	2010 Discards	2010 %DR	2011 Landings	2011 Discards	2011 %DR	2012 Landings	2012 Discards	2012 %DR	Avg 2010-2012 Landings	Avg 2010-2012 Discards	Avg 2010-2012 Catch	Avg 2010-2012 %DR
TR1	POK	Saithe	33,726	2,044	6%	33,040	2,530	7%	32,943	5,500	14%	33,236	3,358	36,594	9%
	HAD	Haddock	23,676	3,661	13%	22,447	3,962	15%	26,864	1,555	5%	24,329	3,059	27,389	11%
	COD	Cod	19,387	3,586	16%	17,118	1,682	9%	17,642	2,742	13%	18,049	2,670	20,719	13%
	PLE	Plaice	13,755	491	3%	17,249	745	4%	19,798	4,083	17%	16,934	1,773	18,707	9%
	WHG	Whiting	5,967	2,820	32%	6,768	1,026	13%	7,805	714	8%	6,847	1,520	8,367	18%
	HKE	Hake	3,827	1,226	24%	4,430	2,212	33%	5,316	2,607	33%	4,524	2,015	6,539	31%
BT2	PLE	Plaice	34,628	26,658	43%	35,468	21,149	37%	34,138	31,070	48%	34,745	26,293	61,037	43%
	DAB	Dab	4,130	35,527	90%	3,920	48,552	93%	3,166	23,577	88%	3,739	35,885	39,624	91%
	SOL	Sole	10,953	1,479	12%	9,047	1,222	12%	9,619	1,915	17%	9,873	1,539	11,412	13%
	WHG	Whiting	416	2,705	87%	415	917	69%	280	1,657	86%	370	1,760	2,130	83%
	TUR	Turbot	1,393	3	0%	1,621	53	3%	1,740	106	6%	1,585	54	1,639	3%
	COD	Cod	1,790	265	13%	1,304	98	7%	1,012	138	12%	1,369	167	1,535	11%
TR2	DAB	Dab	897	12,686	93%	806	56,273	99%	667	10,521	94%	790	26,493	27,283	97%
	PLE	Plaice	4,950	1,133	19%	5,288	45,937	90%	4,963	2,749	36%	5,067	16,606	21,673	77%
	NEP	Norway lobster	18,615	163	1%	14,514	857	6%	11,315	1,709	13%	14,814	910	15,724	6%
	WHG	Whiting	4,225	6,774	62%	11,422	8,737	43%	3,474	4,456	56%	6,374	6,655	13,029	51%
	HAD	Haddock	2,785	5,014	64%	3,706	5,040	58%	2,021	2,011	50%	2,838	4,022	6,859	59%
	COD	Cod	1,259	1,249	50%	1,093	1,436	57%	653	1,119	63%	1,002	1,268	2,270	56%
GN1	COD	Cod	2,605	14	1%	2,209	113	5%	1,764	59	3%	2,193	62	2,255	3%
	ANF	Anglerfish	1,341		0%	1,519	0	0%	1,614	0	0%	1,491	0	1,491	0%
	PLE	Plaice	1,607	0	0%	1,493	3	0%	929	3	0%	1,343	2	1,345	0%
	SOL	Sole	720		0%	609	0	0%	776	0	0%	702	0	702	0%
	HKE	Hake	407		0%	380	0	0%	424	0	0%	404	0	404	0%
	TUR	Turbot	252	0	0%	323	3	1%	256	11	4%	277	5	282	2%
BT1	PLE	Plaice	2,988		0%	3,945		0%	7,875		0%	4,936	0	4,936	0%
	COD	Cod	308		0%	404		0%	688		0%	466	0	466	0%
	LEM	Lemon sole	207		0%	276	10	4%	354		0%	279	3	283	1%
	DAB	Dab	102		0%	103	196	65%	232		0%	146	65	211	31%
	ANF	Anglerfish	87		0%	112	0	0%	148		0%	116	0	116	0%
	TUR	Turbot	71		0%	71	0	0%	133		0%	92	0	92	0%
Grand Total			197,075	107,499	35%	201,103	202,751	50%	198,610	98,302	33%	198,929	136,184	335,113	41%

c) Revenue

Information on the economic performance of the different gear types active in the North Sea was taken from the EU Annual Economic Report (2013).

Table 7.11 EU North Sea and Eastern Arctic fleet economic performance by gear type in 2011

North Sea	N vessels		FTE		Days at Sea (thousand days)		Volume landed (1000 tonnes)		Income (million €)		Gross Value Added (million €)		Gross profit (million €)		Net profit 2011			GVA per FTE (thousand €)	
	2011	%Δ 2010	2011	%Δ 2010	2011	%Δ 2010	2011	%Δ 2010	2011	%Δ 2010	2011	Development Trend	2011	Development Trend	Profit margin	Profitability	Development Trend	2011	Development Trend
DFN	874	3%	1260	5%	64.0	3%	12.0	-1%	64.1	6%	36.7	Improved	10.5	Improved	8%	Medium	Improved	29.2	Improved
DRB	285	5%	664	9%	32.5	11%	64.9	32%	89.1	28%	53.5	Improved	28.1	Improved	10%	High	Stable	80.6	Improved
DTS	1,067	-1%	3884	-6%	150.8	-2%	827.6	-11%	767.9	3%	412.7	Improved	230.0	Improved	17%	High	Improved	106.2	Improved
FPO	1,099	11%	1870	10%	97.6	10%	22.1	6%	56.9	19%	26.3	Improved	7.7	Improved	8%	Medium	Improved	14.1	Stable
HOK	136	-18%	202	-24%	7.9	-20%	2.0	-27%	7.3	-17%	3.5	Improved	0.5	Deteriorated	6%	Medium	Improved	17.3	Improved
MGP	48	7%	96	-4%	8.1	35%	5.2	6%	16.2	7%	8.3	n/a	2.4	n/a	6%	Medium	n/a	86.4	n/a
PG	205	-4%	31	534%	3.8	-17%	0.7	-69%	4.8	5186%	4.4	Improved	4.3	Improved	88%	High	Improved	140.8	Improved
PGP	623	1%	391	31%	28.1	0%	9.6	-17%	28.4	1%	16.7	Improved	3.7	Improved	0%	Weak	Improved	42.5	Deteriorated
PMP	68	7%	162	11%	11.4	18%	9.7	12%	26.0	15%	14.4	Improved	5.3	Improved	3%	Medium	Improved	88.5	Improved
PS	12	24%	157	17%	0.8	20%	124.8	24%	141.8	92%	88.8	Improved	61.1	Improved	40%	High	Improved	564.2	Improved
TBB	611	-7%	1572	-24%	70.6	-20%	110.0	-5%	281.3	-14%	112.7	Deteriorated	39.3	Deteriorated	4%	Medium	Deteriorated	71.7	Improved
TM	12	-8%	181	-8%	2.2	-17%	101.2	-13%	30.2	-43%	1.7	Deteriorated	-10.1	Deteriorated	-70%	Weak	Deteriorated	9.2	Deteriorated

3.4. Size composition (selection) of important gears

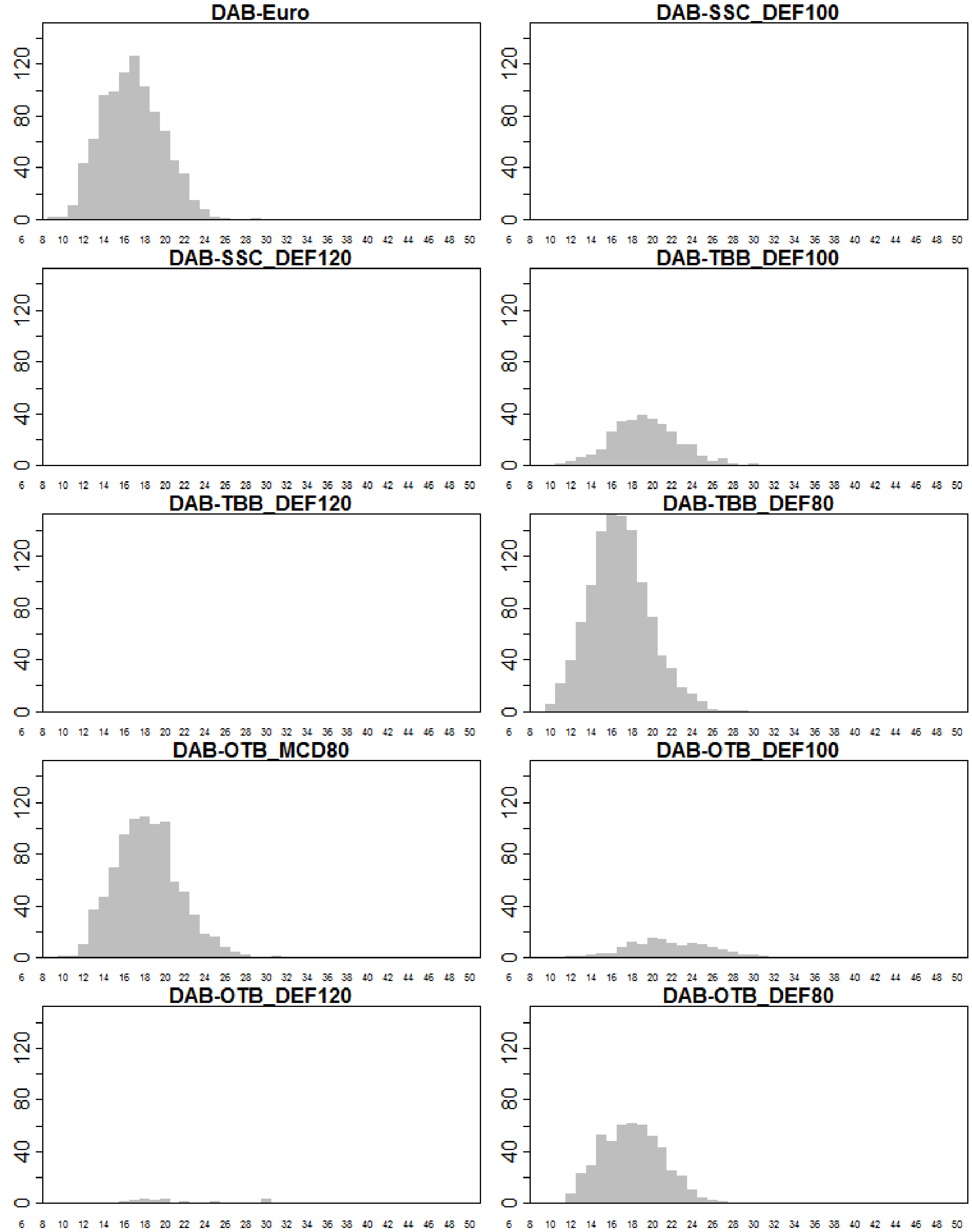


Fig. 3.6–. Length frequency distribution of the average number per hour of discarded dab (minimumlanding size=none) for each of the relevant métiers in 2012.

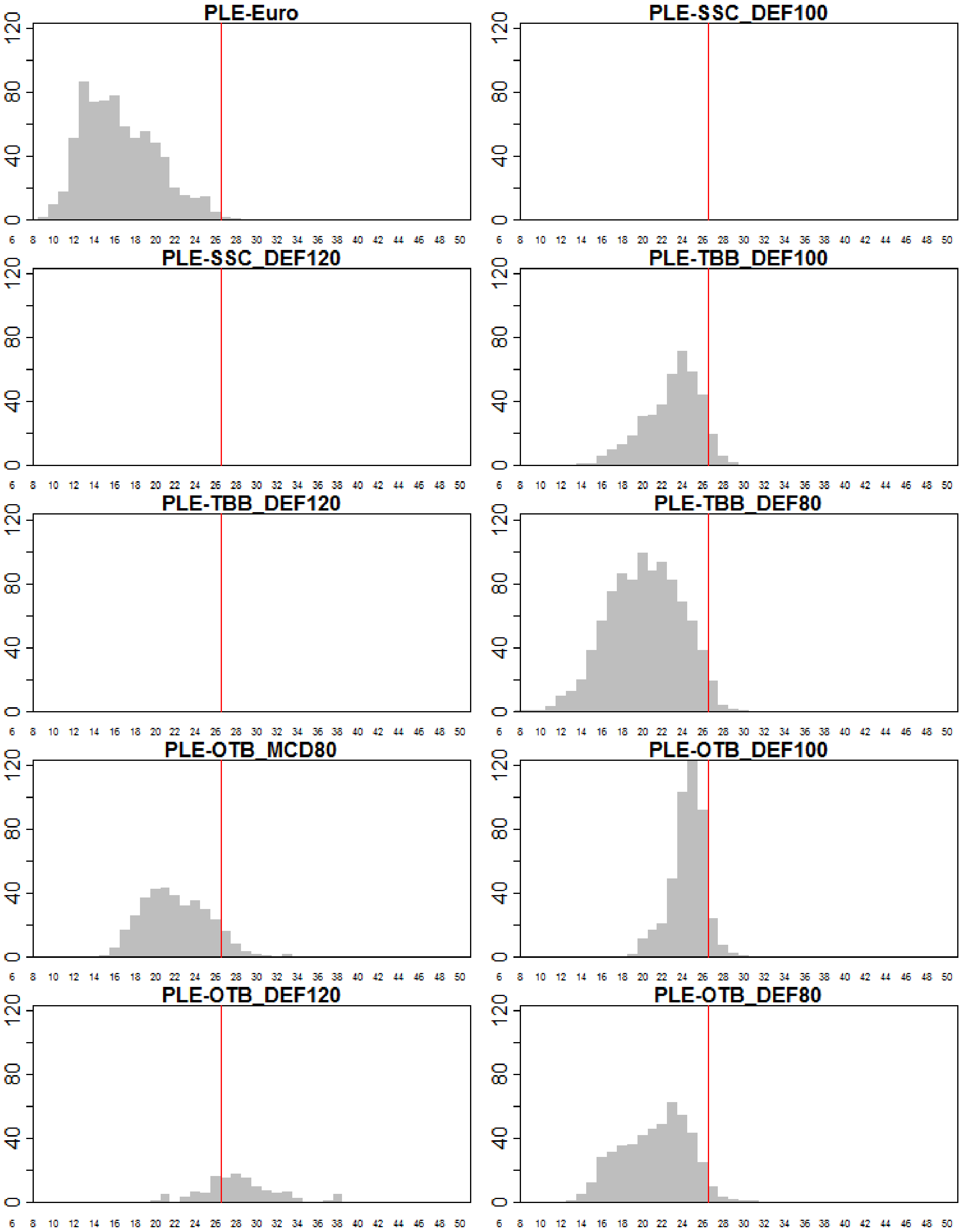


Fig. ctd - Length frequency distribution of the average number per hour of discarded plaice (red lineindicates minimum landing size=27cm; ICES code= "PLE") for each of the relevant métiers in 2012.

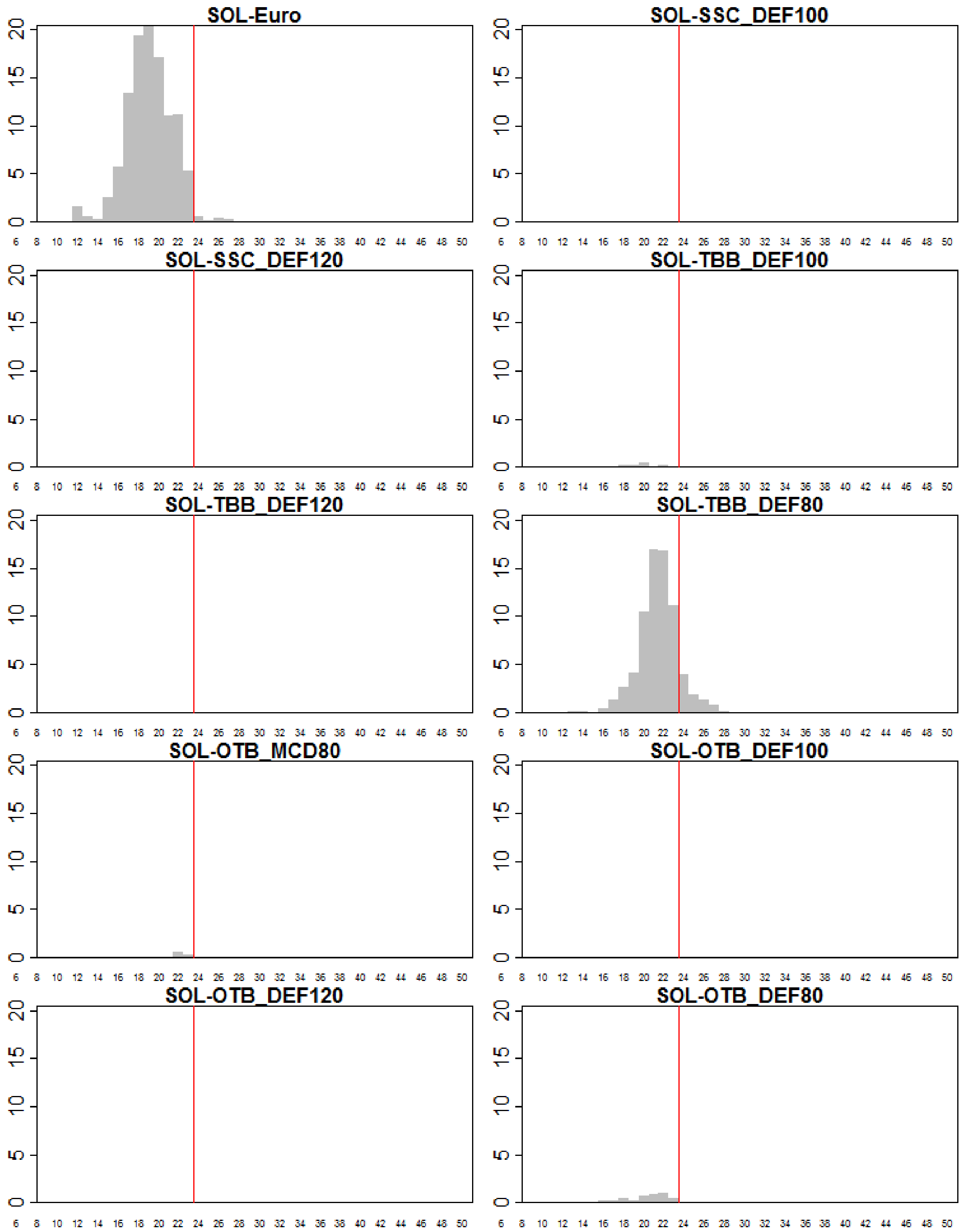


Fig. ctd - Length frequency distribution of the average number per hour of discarded sole (red lineindicates minimum landing size= 24cm; ICES code= “SOL”) for each of the relevant métiers in 2012.

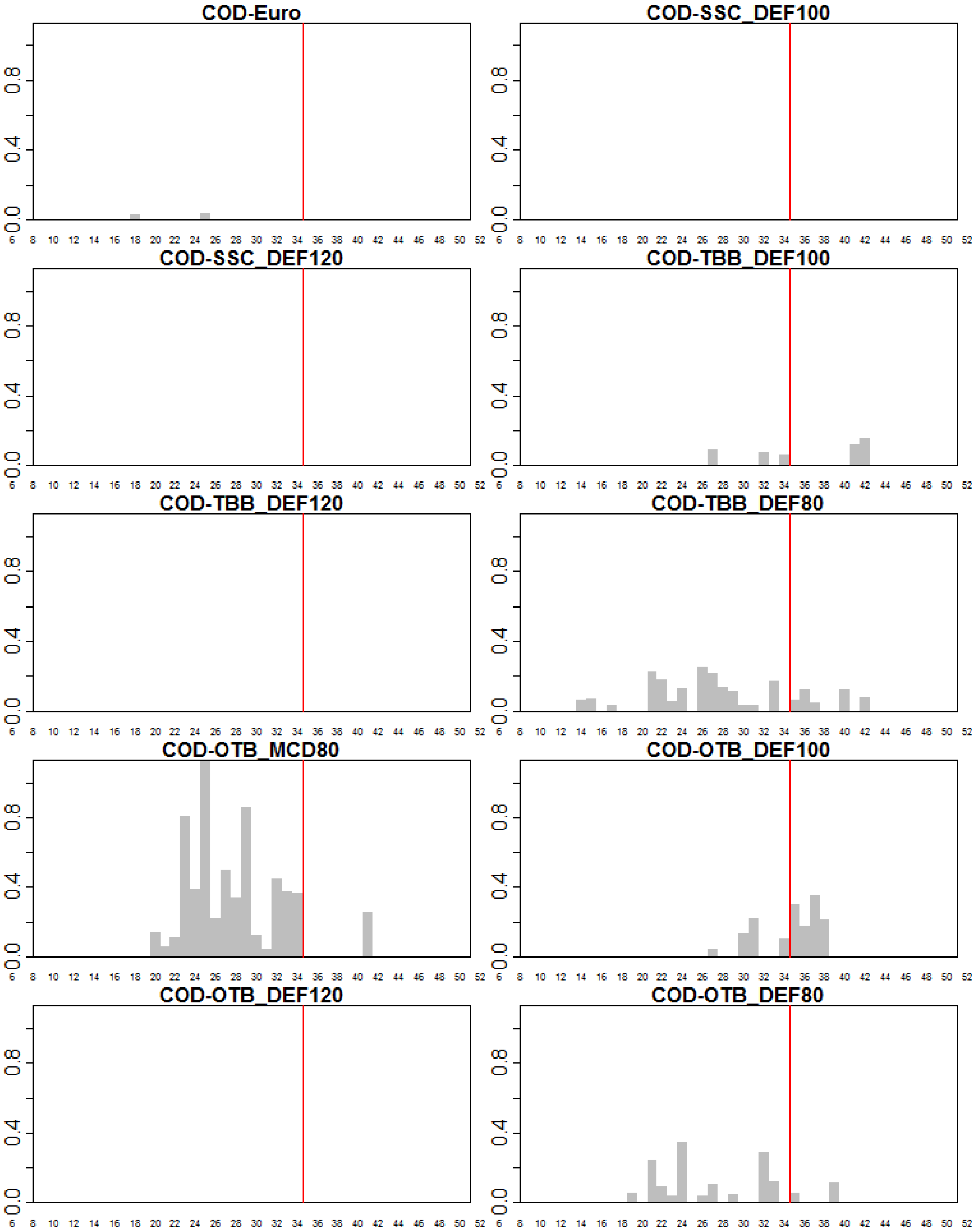


Fig. ctd - Length frequency distribution of the average number per hour of discarded cod (red lineindicates minimum landing size=35 cm; ICES code= "COD") for each of the relevant métiers in 2012.

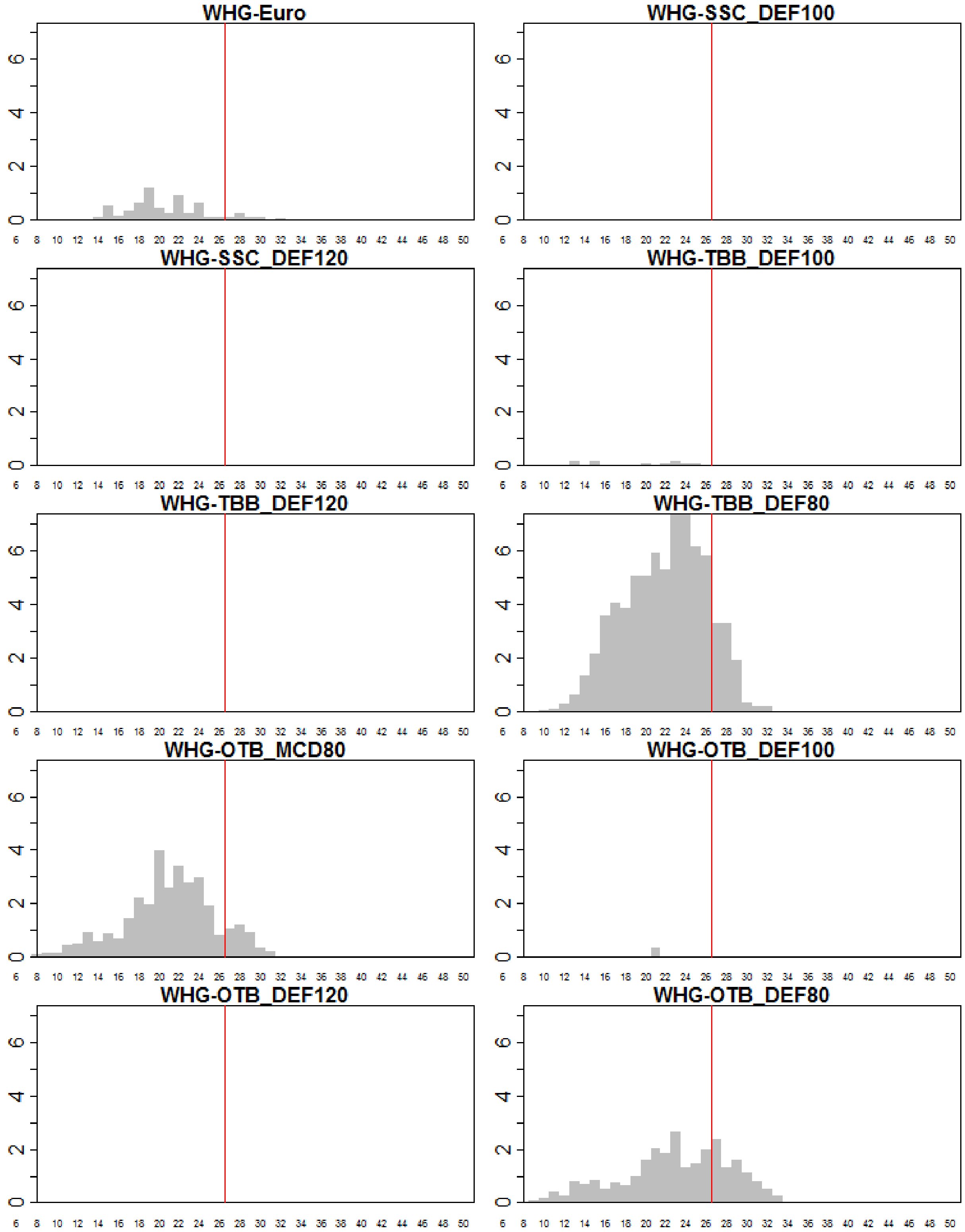


Fig. ctd - Length frequency distribution of the average number per hour of discarded whiting (red lineindicates minimum landing size=27 cm; ICES code= "WHG") for each of the relevant métiers in 2012.

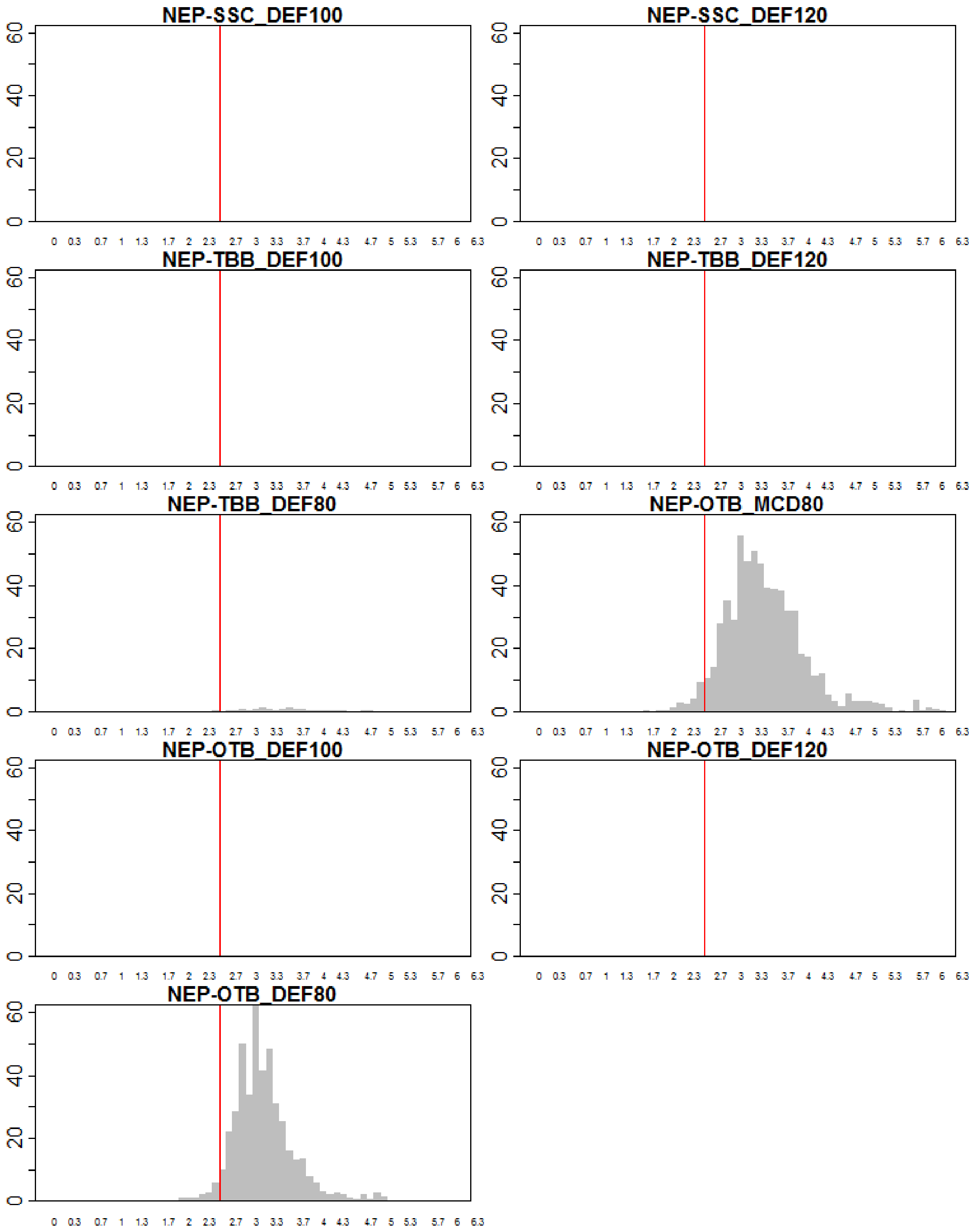
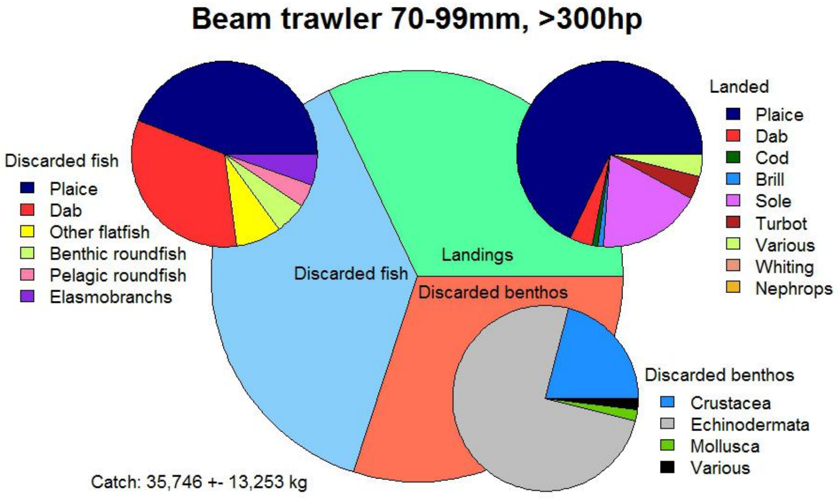
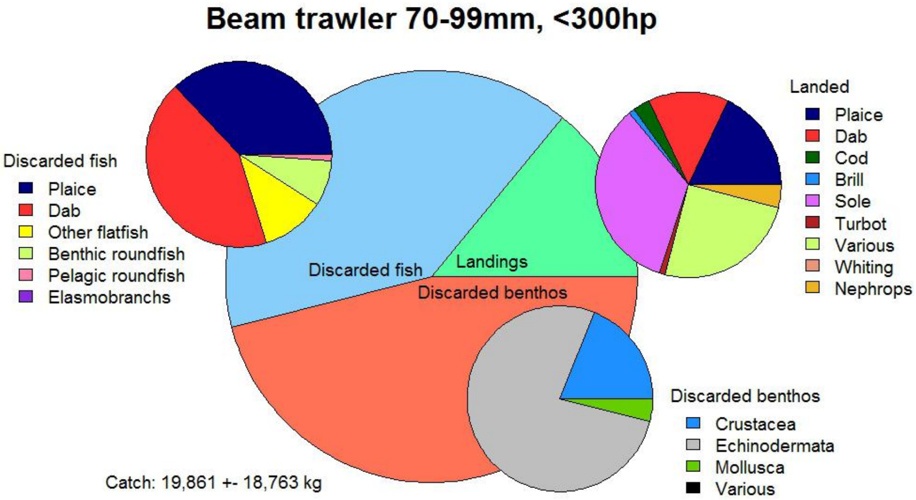


Fig. ctd - Carapax length frequency distribution of the average number per hour of discarded Norwaylobster (red line indicates minimum landing size=2.5 cm; ICES code: “NEP”) for each of the relevantmétiers in 2012.

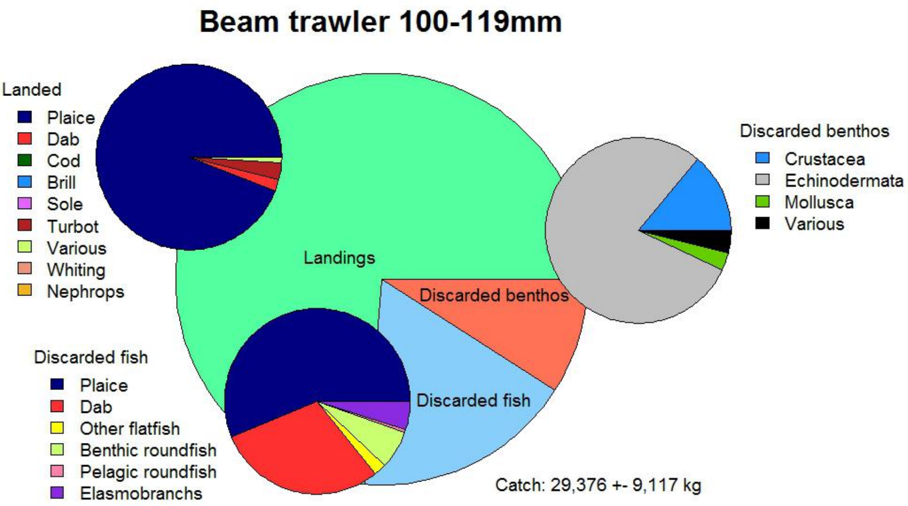
A.


Beam trawler 70-99mm, >300hp
Discarded fish
Plaice
Dab
Other flatfish
Benthic roundfish
Pelagic roundfish
Elasmobranchs
Discarded fish
Landings
Discarded benthos
Landed
Plaice
Dab
Cod
Brill
Sole
Turbot
Various
Whiting
Nephrops
Discarded benthos
Crustacea
Echinodermata
Mollusca
Various
Catch: 35,746 +- 13,253 kg

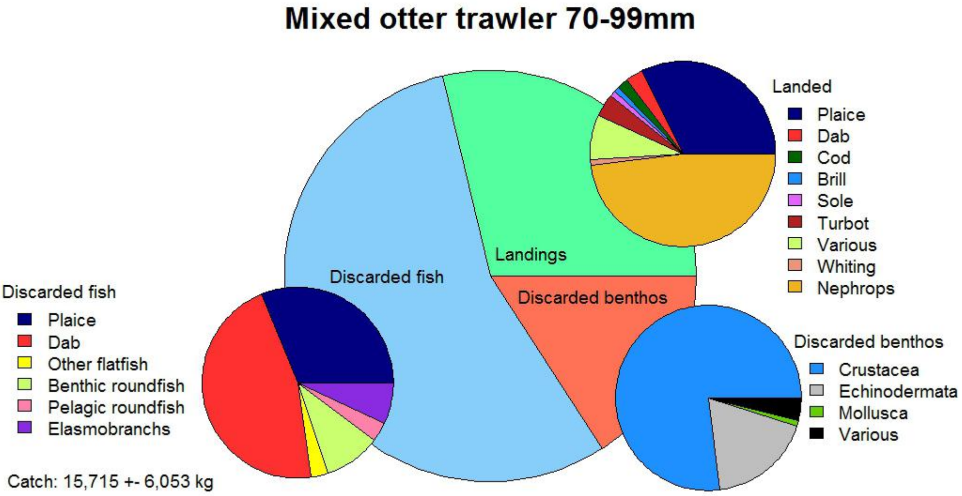
B.


Beam trawler 70-99mm, <300hp
Discarded fish
Plaice
Dab
Other flatfish
Benthic roundfish
Pelagic roundfish
Elasmobranchs
Discarded fish
Landings
Discarded benthos
Landed
Plaice
Dab
Cod
Brill
Sole
Turbot
Various
Whiting
Nephrops
Discarded benthos
Crustacea
Echinodermata
Mollusca
Various
Catch: 19,861 +- 18,763 kg

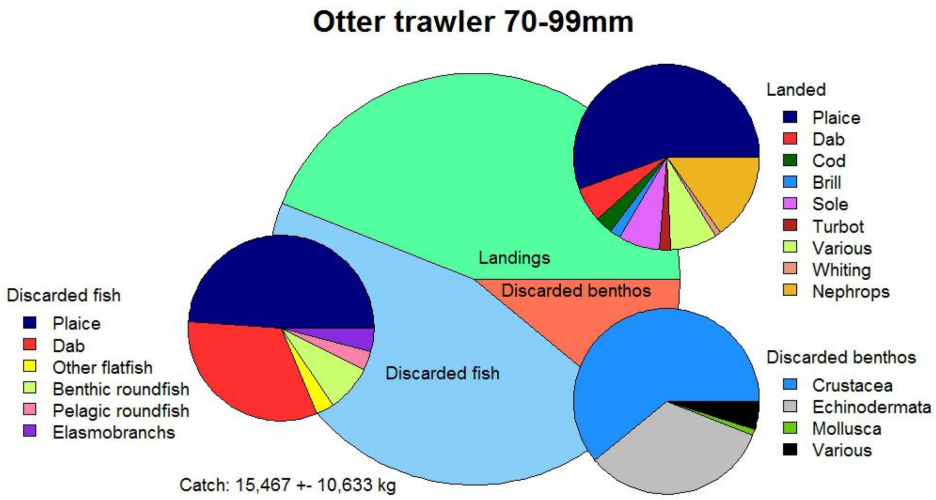
C.


Beam trawler 100-119mm
Landed
Plaice
Dab
Cod
Brill
Sole
Turbot
Various
Whiting
Nephrops
Landings
Discarded benthos
Crustacea
Echinodermata
Mollusca
Various
Discarded benthos
Discarded fish
Plaice
Dab
Other flatfish
Benthic roundfish
Pelagic roundfish
Elasmobranchs
Discarded fish
Catch: 29,376 +- 9,117 kg

D.


Mixed otter trawler 70-99mm
Landed
Plaice
Dab
Cod
Brill
Sole
Turbot
Various
Whiting
Nephrops
Landings
Discarded fish
Discarded benthos
Discarded fish
Plaice
Dab
Other flatfish
Benthic roundfish
Pelagic roundfish
Elasmobranchs
Discarded benthos
Crustacea
Echinodermata
Mollusca
Various
Catch: 15,715 +- 6,053 kg

E.



F.

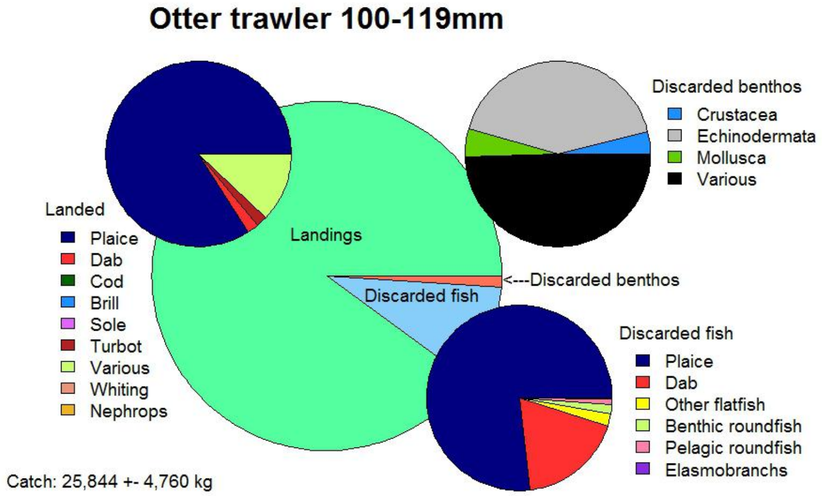
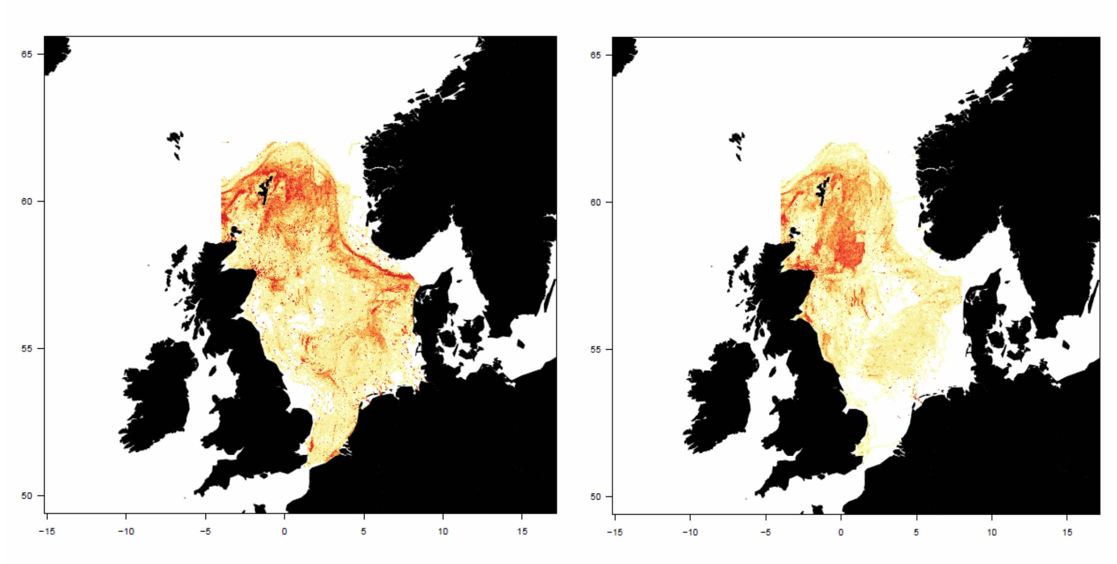


Fig. 3.7– Pie charts of the proportional distribution of quantities of landings, discarded fish and benthic,invertebrate species for A) beam trawlers (70-99 mm mesh size, <300 horse power – 'Eurokotters'); B)beam trawlers (70-99 mm, ≥ 300 hp); C) beam trawlers (100-119 mm mesh size); D) otter trawlers forNephrops (70-99 mm); E) otter trawlers targeting demersal fish (70-99 mm); and F) otter trawlers fordemersal fish with larger mesh sizes (100-119 mm). It should be noted that in the current monitoringprotocol, debris is not accounted for (weighed) separately and so, the parts of the main pies here whichspecify benthos should be read as 'benthos and debris together'. This results in an overpresentation ofbenthos discards in these figures, which thus should only be regarded as generally indicative of catchcompositions. The further separation of composition of benthos discards by species classes is based onobserved ratios of numbers (counts) of individuals; i.e. differences in size/weight are not accounted for.

3.5. Distribution of fishing effort as indication of fishing pressure

The distribution of the mean annual trawling intensity (swept area by surface area of the grid cell) in the period 2010-2012 for a selection of the métiers is given in Figure 3.8 and 3.9.

OT-DMF OT-MIX



SSC-DMF TBB-DMF

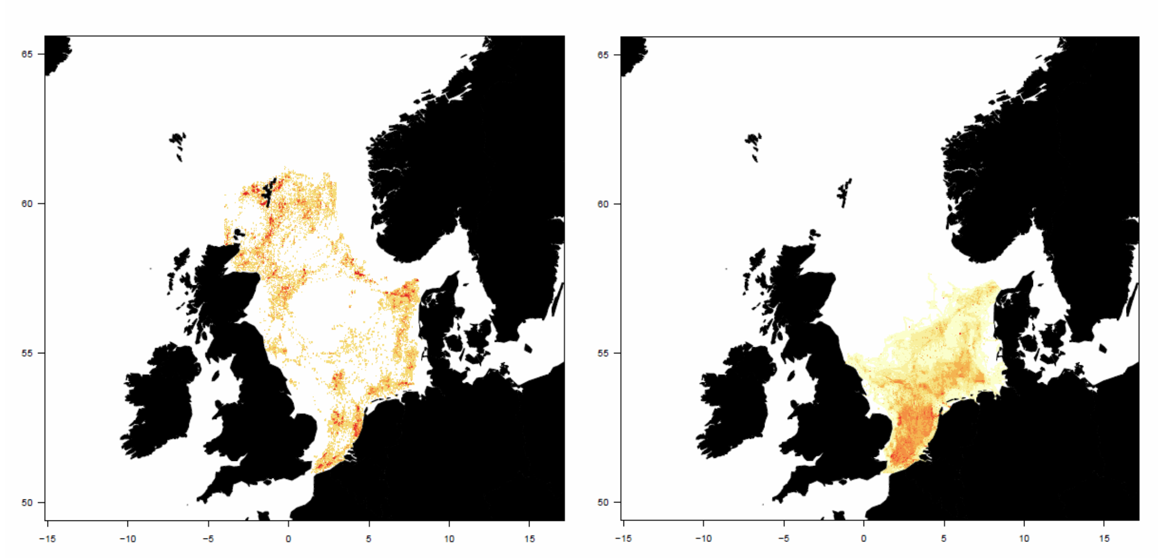
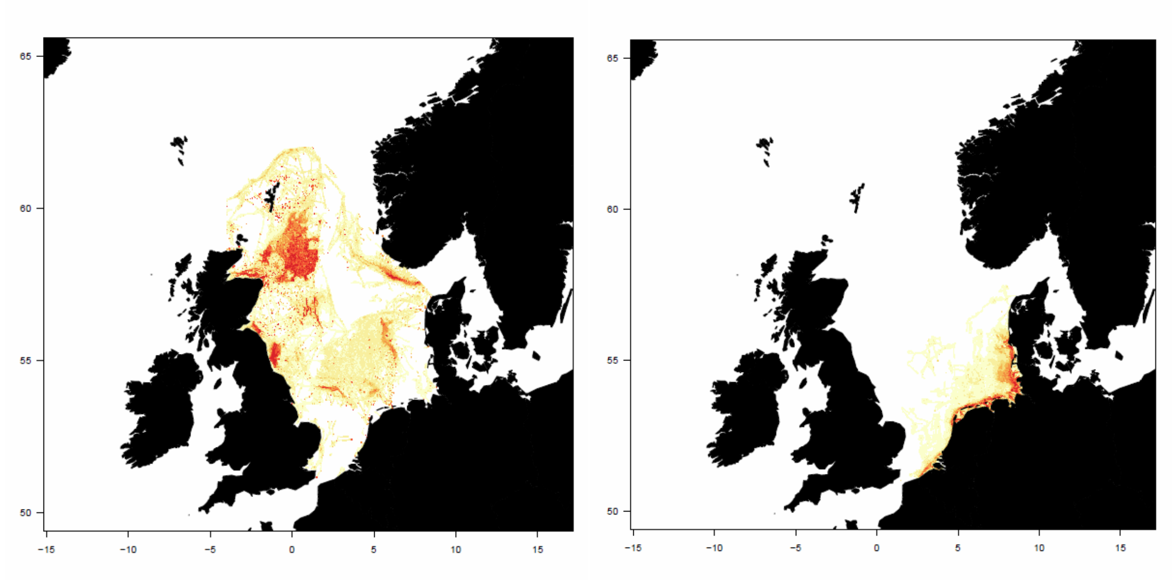


Figure 3.8- Distribution of the mean annual trawling intensity (swept area by surface area of the grid cell) in the period 2010-2012 for a selection of the metiers. OT-DMF = demersal otter trawlers targeting roundfish; OT-MIX = demersal otter trawlers targeting a mix of demersal fish; SSC – DMF = Danish seine targeting a mix of demersal fish; TBB-DMF = beam trawlers targeting flatfish.

OT-CRU TBB-CRU



OT-MIX-NEP DRB

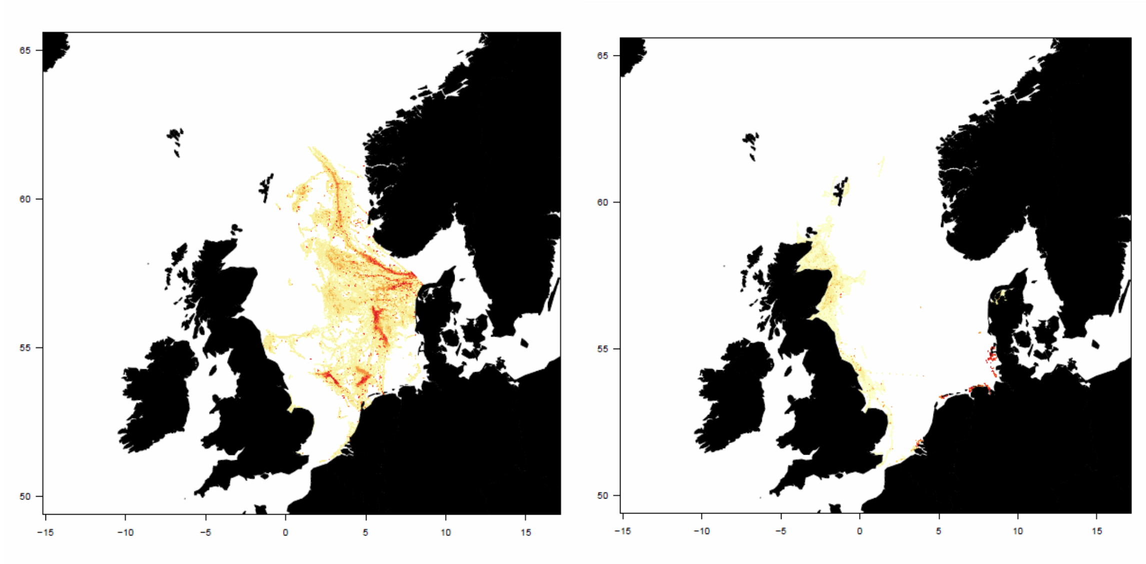


Figure 3.9 - Distribution of the mean annual trawling intensity (swept area by surface area of the grid cell) in the period 2010-2012 for a selection of the metiers. TBB-CRU = beam trawlers targeting brown shrimps; OT-MIX-NEP = otter trawls targeting mixed demersal fish and Nephrops; DRB = dredgers targeting molluscs.

3.6. Distribution of benthic habitats or substrates in regional seas

Habitat types, classified according to EUNIS3 (Figure 3.10) , were used to study the association of the trawling and habitat. In the North Sea a total of 38 habitat types occur although a few mainly soft sediment habitats dominate (Figure 3.10). The surface area is dominated by sublittoral sand (A5.2), coarse sediment (A5.1) and mud (A5.3). Deep sea habitats comprise of a relatively small surface area and is dominated by deep-sea mud (A6.5). Hard bottoms are rare. Rocky bottoms and artificial hard substrate represent 2.3% and mixed hard bottoms represents 2.1% of the surface area of the North Sea.

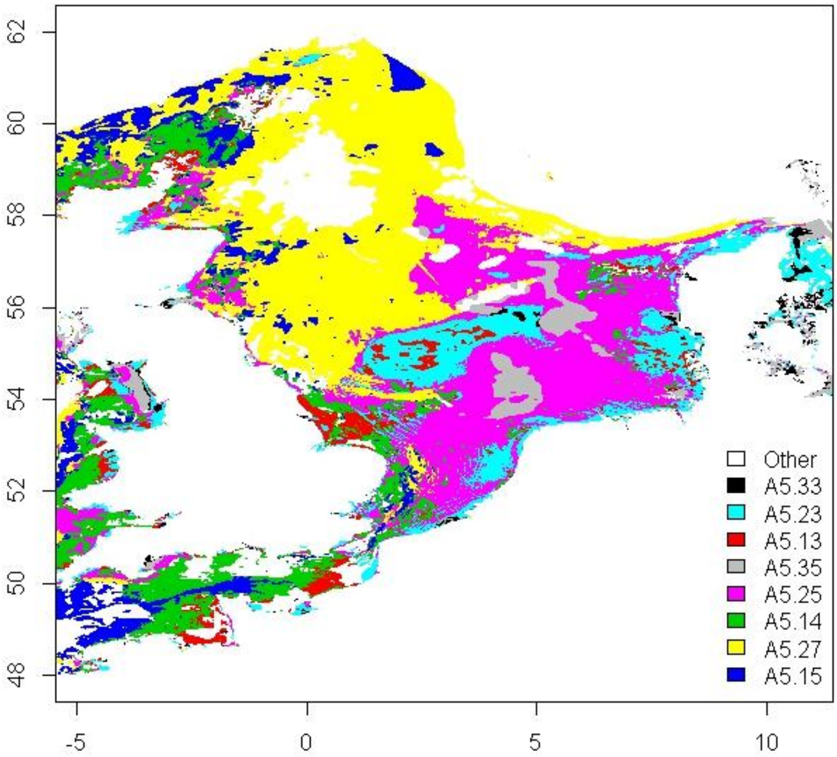


Figure 3.10 - A map of the EUNIS3 habitats of the North Sea and English Channel.

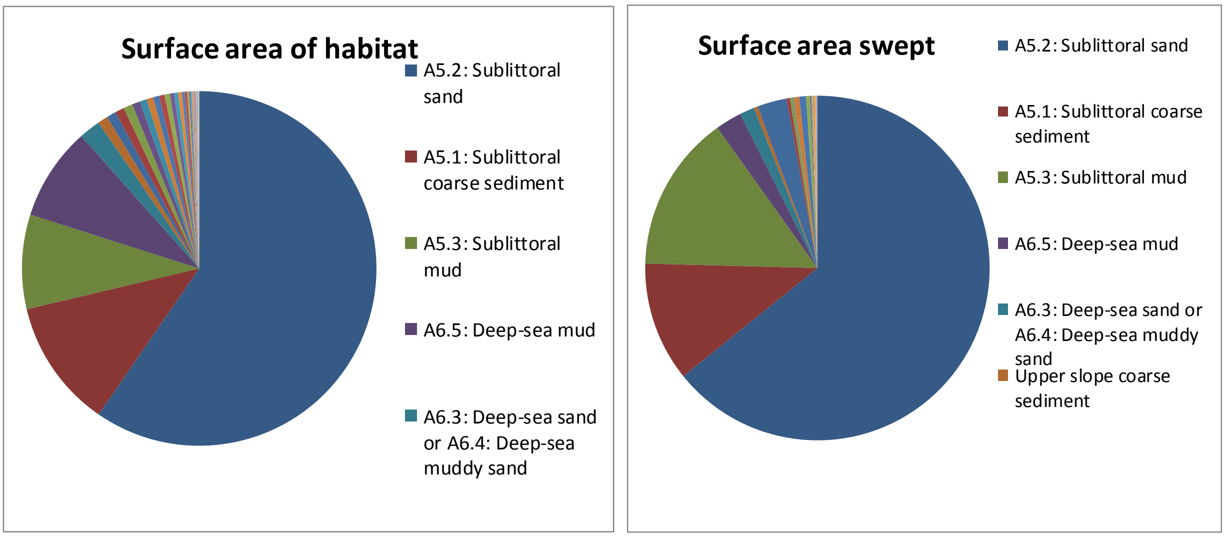


Figure 3.11 – The area swept by sediment type in the North Sea

3.7. Overview of distribution of fishery according to environment

Figure and Figure show the trawling intensity maps of a selection of métiers. Bottom trawling mainly occurs in the soft bottom habitats that dominate the North Sea. The habitat types dominating the North sea are also the habitat types where most of the bottom trawling occurs (Figure 3.11Figure 3.11). A preference score was calculated to study whether a métier was disproportionally using a particular habitat type. The preference score was calculated as $p = \frac{S_i}{A_i} / \frac{\sum S_i}{\sum A_i}$ where Si is the surface area swept of habitat I, Ai is the surface area of habitat i.

The text table below shows the habitats that were preferred by bottom trawlers and were disproportionally used. Deep circalittoral mixed hard sediments, sublittoral mud and low energy circalittoral mixed hard sediments had a preference score >1.5. High energy circalittoral rock and Moderate energy circalittoral mixed hard sediments had a preference score >1. Other habitats had a preference score <1. It is noteworthy that the habitat type that dominates the North Sea (sublittoral sand) had a preference score of 0.75.

Habitat	Surface	Swept area	Preference score
Deep circalittoral mixed hard sediments	5228	23977	3.20
A5.3: Sublittoral mud	51771	127122	1.71
Low energy circalittoral mixed hard sediments	750	1634	1.52
A4.1:High energy circalittoral rock	384	671	1.22
Moderate energy circalittoral mixed hard sediments	3314	5462	1.15
A5.1: Sublittoral coarse sediment	70409	96812	0.96
High energy infralittoral seabed	3714	4519	0.85
Moderate energy infralittoral mixed hard sediments	476	534	0.78
A5.2: Sublittoral sand	358887	554529	0.75

The preference scores for the métiers shows a clear difference in preference for particular habitat types across métiers, although each métier is not restricted to one or two specific habitat types. The deep hard sediments are relatively being fished most intensely, followed by sublitoral mud. In contrast, sublitoral sand that has by far the highest surface and swept area in absolute numbers has the lowest preference score.

The distribution of trawling intensity within each habitat was studied by calculating the surface area trawled at a certain trawling intensity. Figure 3.12Figure 3.12 illustrates the results for the habitat types trawled most intensively. The results again illustrate that the infralittoral soft sediment habitats A5.1 – A5.3 are used by almost all of the major fleet segments, while the deep-sea habitats (A6.3 and A6.5) are mainly used by otter trawls targeting either Nephrops or mixed roundfish.

Fishing intensity has an uneven distribution within each habitat. Some parts of the habitat are trawled intensively while other parts are trawled lightly or are not trawled at all. The proportion of habitat fished more than once a year is less than 15%. Highest fishing intensities are observed for crustacean otter trawlers and demersal otter trawlers, in particular in sublittoral mud habitat (A5.3). Fishing intensity in coarser sediments are somewhat lower.

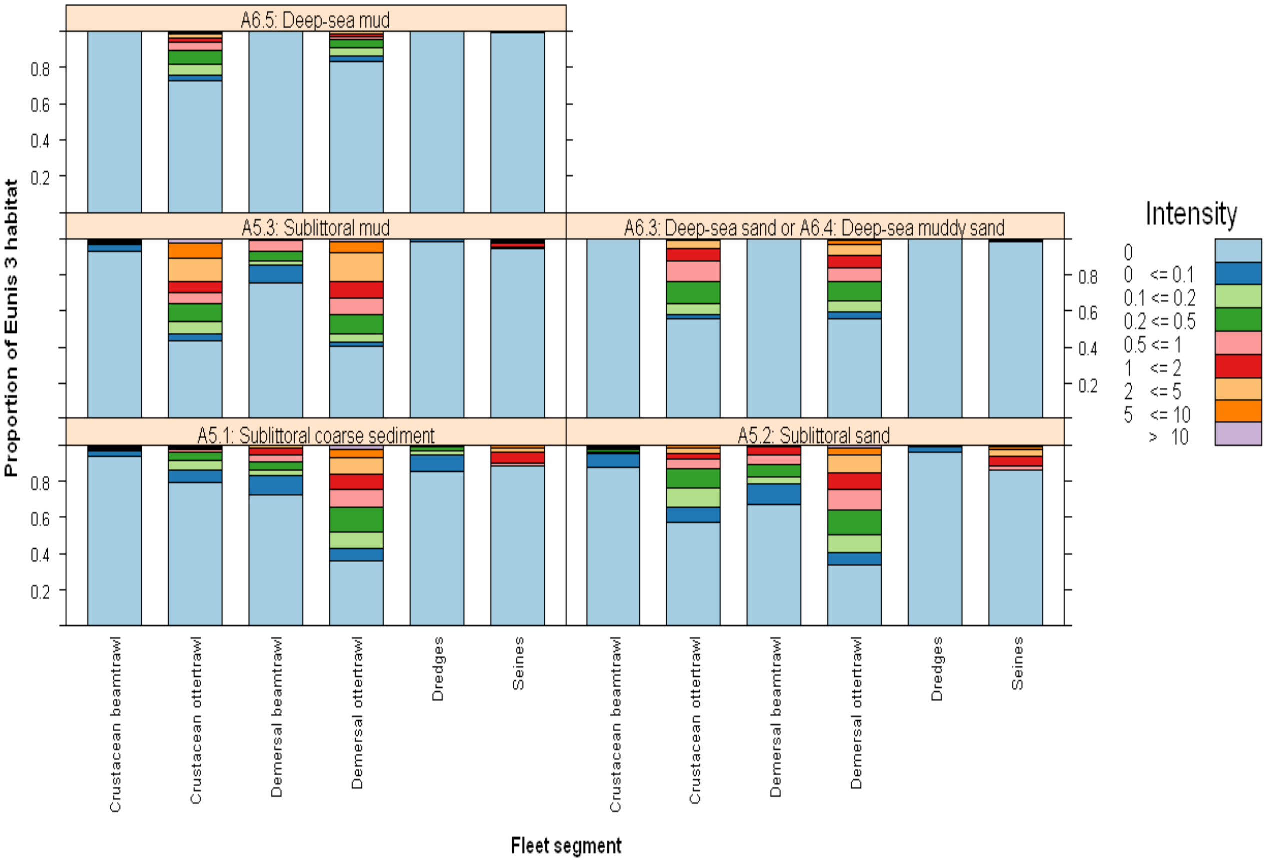


Figure 3.12 - Proportion of the surface area fished at a certain intensity (number of times the surface area of a grid cell is swept/yr) for six fleet segments and five habitats in the North Sea. Data 2010-2012.

Table 3.3: Total swept area of the beam trawl, pulse trawl and chain mat gear used in the Dutch fisheries in 2012 and the distribution over EUNIS3 habitats.

	Beam trawl	Pulse trawl	Chain mat
Total effort (km2 swept area by year)	24647	44693	6994
A5.13: Infralittoral coarse sediment	2.1%	1.7%	2.7%
A5.14: Circalittoral coarse sediment	3.4%	7.4%	29.7%
A5.15: Deep circalittoral coarse sediment	0.6%	2.7%	15.9%
A5.23 – A5.24: Infralittoral fine sand or muddy sand	21.3%	18.3%	13.0%
A5.25 – A5.26: Circalittoral fine sand or muddy sand	64.0%	58.8%	30.9%
A5.27: Deep circalittoral sand	2.3%	6.5%	5.8%
A5.33 – A5.34: Infralittoral sandy mud or fine mud	0.6%	0.5%	0.5%
A5.35 – A5.36: Circalittoral sandy mud or fine mud	5.6%	2.7%	0.9%

Since 2009, the beam trawl fleet of the Netherlands started to replace the traditional tickler chain beam trawl gear, or chain-mat gear with electrical pulse gear. In the previous results, these vessels have been included in the TBB-DMF métier. A preliminary analysis suggests that the pulse trawlers differ in their choice of fishing grounds, with pulse trawlers fishing slightly more in coarser habitats.

Table 3.4: Swept area (km2) by fleet of all EUNIS3 habitat types distinguished in the North Sea. Data 2010-2012.

Habitat	Surface	Total Swept	%unfished	%fished	DRB MOL	TBB DMF	TBB CRU	SSC DEM	OT DMF	OT NEP	OT CRU	SSC DMF
A3.1: High energy infralittoral rock	375	165	59	41	2	0	0	0	120	0	12	31
A3.2: Moderate energy infralittoral rock	880	193	68	32	7	2	0	0	120	29	28	26
A3.3: Low energy infralittoral rock	46	5	72	28	0	0	0	0	1	0	1	10
A4.1:High energy circalittoral rock	384	671	25	75	6	9	0	0	513	0	86	56
A4.2: Moderate energy circalittoral rock	5033	2624	55	45	77	88	3	0	1482	9	779	190
A4.3: Low energy circalittoral rock	4942	2318	73	27	17	2	0	0	1253	18	875	154
A5.1: Sublittoral coarse sediment	70409	96812	30	70	9581	10950	3086	1377	52287	2269	5682	11579
A5.2: Sublittoral sand	358887	554529	28	72	20598	59531	23333	53924	239418	54434	50205	53086
A5.3: Sublittoral mud	51771	127122	39	61	474	4450	1898	7389	33957	20754	56436	1764
A5.4: Sublittoral mixed sediments	2850	2954	58	42	22	178	97	0	1927	11	255	464
A6.1: Deep-sea rock/artificial hard sub	756	19	96	4	0	0	0	0	1	1	18	0
A6.2: Deep-sea mixed substrata	2358	796	63	37	0	0	0	0	749	0	47	0
A6.3/6.4: Deep-sea sand & muddy sand	11810	11953	56	44	1	0	0	1009	6959	4983	661	2
A6.5: Deep-sea mud	51228	21376	78	22	0	0	0	2113	4506	7024	10075	0
Abyssal seabed	0	0	0	0	0	0	0	0	0	0	0	0
Deep circalittoral mixed hard sediments	5228	23977	23	77	0	0	0	16326	6649	876	174	244
Deep circalittoral seabed	4428	284	97	3	0	5	186	0	21	57	14	0
High energy circalittoral mixed hard sed.	85	32	39	61	0	1	5	2	20	10	0	3
High energy circalittoral seabed	2220	601	95	5	4	46	257	0	155	50	31	60
High energy infralittoral mixed hard sed.	233	212	36	64	0	12	1	81	61	38	0	31
High energy infralittoral seabed	3714	4519	76	24	2377	70	1468	0	302	244	49	9
Low energy circalittoral mixed hard sed.	750	1634	16	84	0	0	0	460	669	605	11	94
Low energy circalittoral seabed	693	3	99	1	0	0	0	0	0	2	2	0
Low energy infralittoral mixed hard sed.	0	0	0	0	0	0	0	0	0	0	0	0
Low energy infralittoral seabed	122	27	96	4	0	0	0	0	27	0	0	0
Lower bathyal coarse sediment	0	0	0	0	0	0	0	0	0	0	0	0
Lower bathyal seabed	0	0	0	0	0	0	0	0	0	0	0	0
Mid bathyal coarse sediment	162	0	100	0	0	0	0	0	0	0	0	0
Mid bathyal seabed	1438	0	100	0	0	0	0	0	0	0	0	0
Moderate energy circalittoral mixed hard sediments	3314	5462	32	68	0	223	1	2131	1606	1752	78	255
Moderate energy circalittoral seabed	2090	722	95	5	0	73	510	0	53	76	5	7
Moderate energy infralittoral mixed hard sediments	476	534	22	78	0	76	0	236	104	73	4	66
Moderate energy infralittoral seabed	755	427	86	14	0	22	295	0	72	22	14	3
Upper bathyal coarse sediment	1510	9	99	1	0	0	0	0	9	0	0	0
Upper bathyal seabed	714	22	99	1	0	0	0	0	22	0	0	0
Upper slope coarse sediment	5578	3198	57	43	1	0	0	0	2982	28	203	3
Upper slope mixed hard sediments	3884	490	95	5	0	0	0	188	156	201	12	0
Upper slope seabed	2938	44	99	1	0	0	0	0	4	64	0	0

Table 3.5: Preference score for benthic habitats of the various fleet segments

	DRB MOL	TBB DMF	TBB CRU	SSC DEM	OT DMF	OT MIX_NEP	OT CRU	SS DMF	All metiers
A3.1: Atlantic and Mediterranean high energy infralittoral rock	0.1	0.0	0.0	0.0	0.5	0.0	0.1	0.7	0.3
A3.2: Atlantic and Mediterranean moderate energy infralittoral rock	0.2	0.0	0.0	0.0	0.2	0.2	0.2	0.3	0.2
A3.3: Atlantic and Mediterranean low energy infralittoral rock	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.9	0.2
A4.1: Atlantic and Mediterranean high energy circalittoral rock	0.3	0.2	0.0	0.0	2.3	0.0	1.1	1.3	1.2
A4.2: Atlantic and Mediterranean moderate energy circalittoral rock	0.3	0.1	0.0	0.0	0.5	0.0	0.7	0.3	0.4
A4.3: Atlantic and Mediterranean low energy circalittoral rock	0.1	0.0	0.0	0.0	0.4	0.0	0.8	0.3	0.3
A5.1: Sublittoral coarse sediment	2.5	1.2	0.8	0.1	1.3	0.2	0.4	1.5	1.0
A5.2: Sublittoral sand	1.0	1.3	1.3	1.1	1.1	1.0	0.7	1.3	1.1
A5.3: Sublittoral mud	0.2	0.7	0.7	1.0	1.1	2.6	5.2	0.3	1.7
A5.4: Sublittoral mixed sediments	0.1	0.5	0.7	0.0	1.1	0.0	0.4	1.4	0.7
A6.1: Deep-sea rock and artificial hard substrata	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
A6.2: Deep-sea mixed substrata	0.0	0.0	0.0	0.0	0.5	0.0	0.1	0.0	0.2
A6.3: Deep-sea sand or A6.4: Deep-sea muddy sand	0.0	0.0	0.0	0.6	1.0	2.7	0.3	0.0	0.8
A6.5: Deep-sea mud	0.0	0.0	0.0	0.3	0.1	0.9	0.9	0.0	0.3
Deep circalittoral mixed hard sediments	0.0	0.0	0.0	22.1	2.1	1.1	0.2	0.4	3.2
Deep circalittoral seabed	0.0	0.0	0.8	0.0	0.0	0.1	0.0	0.0	0.0
High energy circalittoral mixed hard sediments	0.0	0.1	1.2	0.1	0.4	0.8	0.0	0.3	0.3
High energy circalittoral seabed	0.0	0.2	2.2	0.0	0.1	0.1	0.1	0.2	0.2
High energy infralittoral mixed hard sediments	0.0	0.4	0.1	2.5	0.4	1.0	0.0	1.2	0.7
High energy infralittoral seabed	11.6	0.1	7.6	0.0	0.1	0.4	0.1	0.0	0.8
Low energy circalittoral mixed hard sediments	0.0	0.0	0.0	4.3	1.5	5.2	0.1	1.1	1.7
Low energy circalittoral seabed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low energy infralittoral seabed	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.2
Mid bathyal coarse sediment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mid bathyal seabed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Moderate energy circalittoral mixed hard sediments	0.0	0.5	0.0	4.5	0.8	3.4	0.1	0.7	1.3
Moderate energy circalittoral seabed	0.0	0.3	4.7	0.0	0.0	0.2	0.0	0.0	0.2
Moderate energy infralittoral mixed hard sediments	0.0	1.3	0.0	3.5	0.4	1.0	0.0	1.2	0.8
Moderate energy infralittoral seabed	0.0	0.2	7.6	0.0	0.2	0.2	0.1	0.0	0.4
Upper bathyal coarse sediment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper bathyal seabed	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Upper slope coarse sediment	0.0	0.0	0.0	0.0	0.9	0.0	0.2	0.0	0.4
Upper slope mixed hard sediments	0.0	0.0	0.0	0.3	0.1	0.3	0.0	0.0	0.1
Upper slope seabed	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0

4 - WESTERN WATERS

4.1. Sub-case study 1: Hake-Nephrops mixed fisheries in the Bay of Biscay

4.1.1. Introduction

Bottom trawling induces chronic and widespread disturbances on benthic communities and habitats. Bottom trawling in coastal environments is well known to modify the upper sedimentary characteristics and to generate significant local re-suspension. Impacts intensity depends on the nature of the substratum (more significant for fine sediment such as mud), the weight of the gear components, the trawl towing velocity, and the local hydrodynamic conditions (Jones, 1992). Some gears components such as doors or footropes can penetrate deep in the surficial sediment (from few centimeters to few tens of centimeters; Linnane et al, 2000) and can generate significant local re-suspension. Only a few percent of the reworked sediment are really injected into the water column as suspended sediments (Palanques et al., 2001; Durrieu de Madron et al., 2005). This sediment re-suspension is mainly due to doors impact (about 70-80 percent of the total mass re-suspended; O'Neill and Summerbell, 2011). It results in the formation of a turbid plume in the trawl wake. Turbid plumes have generally a vertical height that corresponds to 2 or 3 times the vertical opening of the net (Main and Sangster, 1981; Durrieu de Madron et al., 2005) and are characterized by maximum values of suspended sediment concentration near the bottom that can reach several hundreds of milligrams per litre (e.g. Schubel et al., 1978; Schoellhamer, 1996;Durrieu de Madron et al., 2005; Dellapenna et al., 2006; Martin et al., 2013). Palanques et al. (2001,2014) showed that the suspended sediment concentration in a trawled area is about three times higher than in a protected area. Furthermore, the trawling-induced resuspension also induces important releases of nutrients into the water column (e.g. Pilskaln et al., 1998; Durrieu de Madron et al., 2005; Dellapenna et al., 2006; Palanques et al., 2014). Concerning bottom impacts, the surficial sediment reworking due to bottom trawling leads to the modification of the sediment properties in terms of grain size, silt content and organic content, which all increase upwards in the upper part (20 cm) of the surficial sediment layer (Dellapenna et al., 2006; Palanques et al., 2014). Besides, trawl marks can persist from several months for up to one year for a fine sediment substratum (Palanques et al., 2001, 2014; Linnane et al., 2000).

The « Grande-Vasière » area (GV) is a mud belt localized in the Bay of Biscay (French Atlantic area). GV area covers about 8000 km² (250 km long and 30 km wide) in the 80 to 120m depth area of the continental shelf. This area is subjected to deposition and remobilization cycles controlled by river discharges, tidal currents, storms and anthropogenic factors in particular bottom trawling. The balance between these deposition and erosion factors controls its temporal evolution. Bourillet et al. (2006) have proposed a first estimation for the contribution of each factor to the GV evolution. They suggested that the trawl-induced fine particle remobilization represents about 10 to 30 percent of the storm-induced erosion. However, this estimation was based on several hypotheses required in order to make up for the lack of quantitative in situ measurements.

The GV benthic community diversity and size structure of benthic invertebrates follow the classical patterns of trawling impacts described in similar systems: reduction of species richness, reduction of sensitive species, increase of small opportunistic species, modifications of size structure of demersal fish population (Blanchard, 2001, Blanchard et al., 2004; Vergnon & Blanchard, 2006; Serrano et al., 2011). In the GV area, the megafauna is dominated by large opportunistic and carnivores species, mainly crustaceans such *Liocarcinus depurator*, *Munida rugosa* and *Nephrops norvegicus*. Impacted sensitive species in the GV area are: e.g. *Alcyonium digitatum*, *Brissopsis lyrifera*, *Phaxas pellucidus*, *Pennatula phosphorea*, *Pteria hirundo*, *Virgularia mirabilis*. 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). Dominant macrofauna species changed to mostly selective deposivores (e.g. *Aponuphis bilineata*, *Terrebelides stroemi* and *Nothria britannica*) and predators (e.g. *Glycera rouxii*, *Nephtys caeca* and *Lumbrinereis impatiens*). Those changes could be due to an increase of the fishing pressure during this period but this pressure still has not been adequately quantified.

More than 1600 fishing vessels actively operated on the French Atlantic coast in 2011 (Leblond et al. 2013). Bottom trawling activity represented 32% of that French Atlantic fishing fleet in 2011 (364 exclusive bottom trawlers and 150 none exclusive bottom trawlers in Leblond et al. 2013). The hake-Nephrops mixed fishery has a major economic importance both at the regional and national scale. Trawls for fish and for Nephrops are among the top five main metiers with respectively 26% and 14% of all the fishing vessels (all vessels and gears included) operating at least one month a year that metier. Nephrops trawlers spend 200 days at sea by year on average (Macher 2008). Depending on locations of trawlers harbour origin, each fishing trip can last from half a day to 3 days.

In 2011, 3809 tonnes of *Nephrops* were landed, generating gross revenue of 37.7 million euros. Nephrops contribute on average 40% of the total gross revenue of the fleet. This proportion declines however from the Northern to the Southern location of the fleet in the Bay of Biscay (51 and 25% respectively). 64% of the direct employment and 68% of the fleet are localised in South Brittany (A. Biseau unpubl. data). The Bay of Biscay hosts one of the two major nurseries areas of the Northern stock of hake (Drouineau et al. 2010). In recent assessments, estimated fishing mortality was just above the fishing mortality level corresponding to the precautionary approach (Fpa) and the spawning stock biomass (SSB) which declined during the 1980s, is stabilized at a low level since the early 1990s (Drouineau 2008), raising serious doubts about the fishery's sustainability. A recovery plan was enforced in April 2004 (Anonymous 2001, EC 2001, 2002, 2004). In the Northern Bay of Biscay, hake constitutes an important by-catch in the Nephrops fishery. In this area, the biomass of Nephrops is considered to be at a low level (Drouineau et al. 2006), and a decrease in catch per unit of effort is observed. The state of these two stocks makes it urgent to find new regulation measures in order to achieve sustainability. The two stocks are presently regulated through TAC, with minimum landing sizes, mesh size legislation and selectivity devices. From 1970 to 1973, a marine protected area was introduced in the Bay of Biscay to protect hake juveniles but it was inefficient because of an inappropriate location (A. Forest unpubl. data). In 1996-1997, MPAs in the Northern Bay of Biscay were proposed again by the European Commission to preserve hake juveniles, but no MPA was implemented (A. Forest unpubl. data). In 2001, hake “boxes” were set (Anonymous 2001) in the Bay of Biscay and in the south west of Ireland to protect juveniles. Increased minimum mesh size had been enforced in these “boxes”.

4.1.2. Fishing gears used with benthic impact in regional seas

French trawls fisheries in the "Grande Vasière" area mainly operate single and twin otter trawls. Traps are one among the others gears utilized in the BoB Nephrops fishery but they are almost negligible at present time (less than 5 vessels recorded in 2008) and generates spatial conflicts with others metiers. Twin trawls have been developed in the 70's for North American shrimps fisheries. They have been introduced in the European countries in the 80's. In the Bay of Biscay twin trawls have been adopted by *Nephrops* fisheries from 1985 (Nedelec & Brabant 1988). Depending on their size, those trawls present a horizontal opening from 25 to 60m and a vertical one generally less than 1m for twin trawls, up to 7m for the four-sided trawls and 10m for trawls operated by pair-trawlers. For a same vessel size, twin trawls generate a 20 to 25% larger foot print as compared to comparably sized single trawls (Nedelec & Brabant 1988). For both type of gears (single or twin), the doors generate the main benthic impact. With a weight from 150 up to 600 kg, they penetrate into the first centimeters of the sediment. They produce "reworking" of impacted sediment layers, they induces re-suspension of particles into the water column and induce direct mortality of benthic epifauna and some sub-surface infauna. Regarding twin trawls, a weight localized at the middle of the trawls, composed by chains (not in permanent contact with the sea floor) or by a clumb (with metallic spheres rolling on the sea floor) and accounting for 50 to 60% of one door weight (Nedelec & Brabant 1988), generates impacts too but at a lower level as compared to those of the doors.

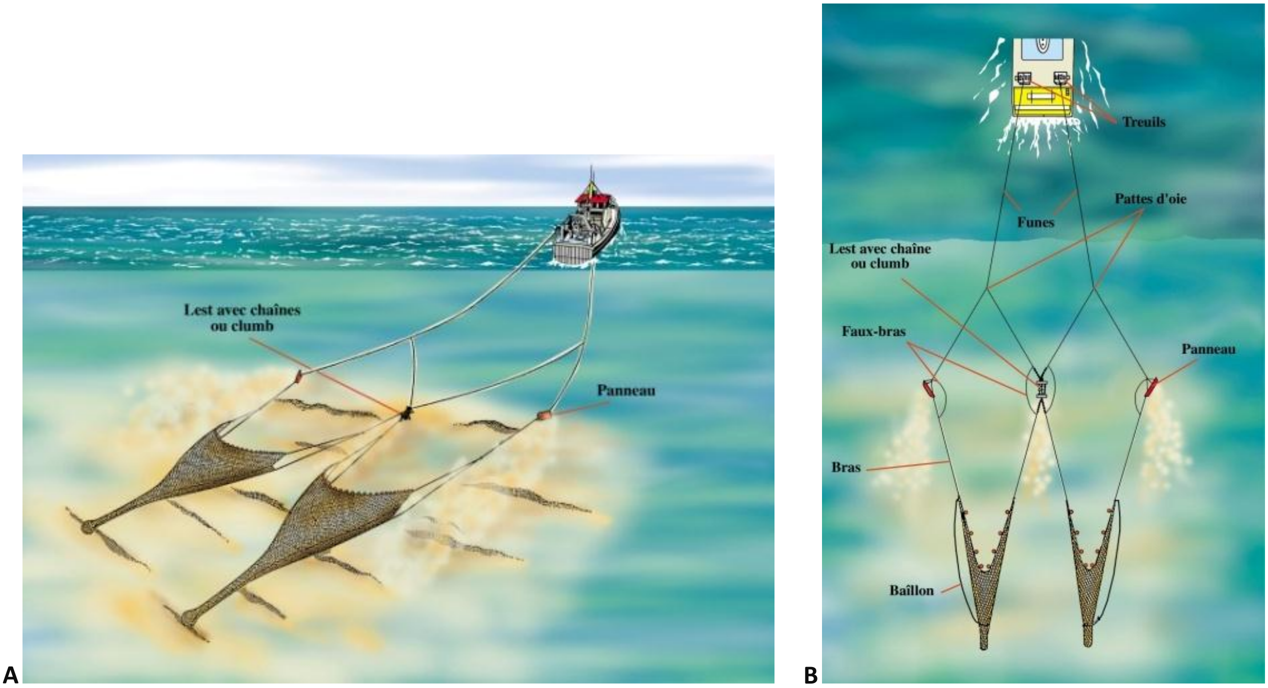
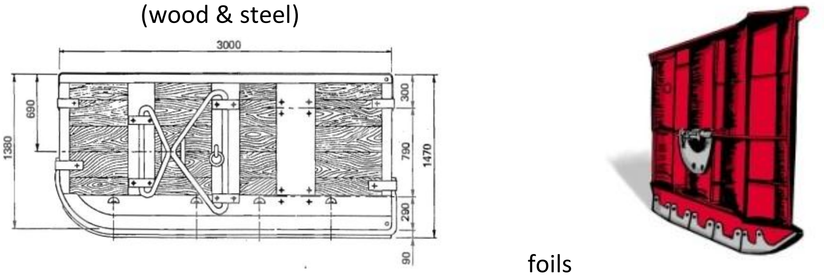
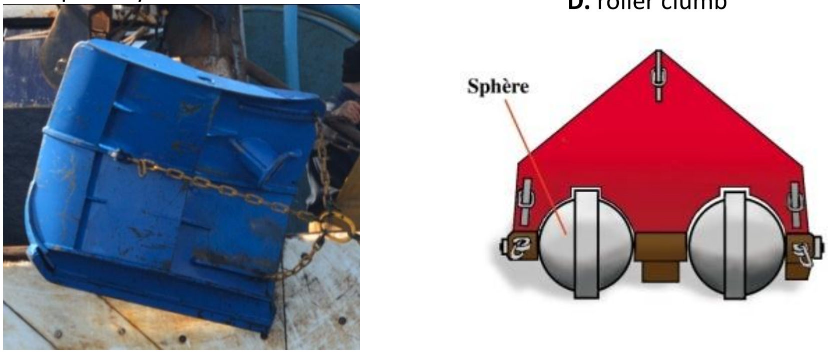


Figure 4.1 - Schematic representation of a classical twin trawl, (A) lateral view and (B) top view utilized for the mixed fish-Nephrops fishery of the "Grande Vasière" area in the bay of Biscay (© Ifremer,Deschamps).



A. Square plan-shaped doors (wood & steel)

B. Steel made plan-shaped door with foils



C. V-shaped Thyboron doors with foils

D. roller clumb

Figure 4.1 - Examples different types of doors utilized in the GV area: A & B and traditional plan-shaped wooden and/or steel made doors (A & B), C. doors with foils, example of thyboron from one of trawler partner of Benthis and D. example of sometimes utilized roller clumb (instead of more generalized weight made of chains).

Depending on the sediment types, fishermen operate two kind of groundgear: simple footrope ("bourrelet franc" in French) for softer bottoms and footrope with bobins ("diabolos" in French) for harder fishing grounds. Some others devices can be added to the trawl gear depending on the habitat types: "tickler chains" in harder grounds, grid against rocks ("grilles à cailloux" in French) or "Rock-hopper " to operate fishing activity in rocky areas. Devices like tickler chains enhance damages to habitat and benthic organisms from epibenthic horizon to some centimeters under the sediment surface. Rock-hopper and "rocks grids" open access to trawlers of a larger range of habitats (irregular or rocky and hard bottoms). Those gears with heavy footrope generate more impacts on sediment (e.g. greater masses of re-suspended sediment) than gears with lighter footropes (Durrieu de Madron et al. 2005). However, no statistics about their utilization are available for the Bay of Biscay fisheries.

In order to reduce unwanted fishing mortalities generated from by-catches and discards (especially for hake's juveniles and smallest *Nephrops*), a set of technical rules and selectivity devices has been progressively developed. At present, landing size for Nephrops French National Fisheries committee imposed a minimal cephalo-thorax length of 28 mm (total length of 9 cm, European rules being set at 8.5 cm). European rules imposed a mesh size of 70 mm. Moreover, French fishermen operating in the BoB Nephrops fishery have to select at least 1 selectivity devices among the proposed set: square mesh panel, flexible grid and increased codend mesh size to 80 mm (CNPMEM 2008, JORF 2011 in Raveau et al. 2012). A square mesh panel of 100 mm has been made compulsory for fishing vessels operating Nephrops Metier (more than 50kg of Nephrops per day) in the GV area and/or in the "hake Box" (EC 2006 in Raveau et al. 2012) and, from 2008 onwards, 90% of trawlers adopted the codend mesh size of 80 mm . During recent years and despite the adoption of those rules, discards stayed at high rates for the hake-Nephrops mixed fisheries of the GV. Bearing out the level of discards estimated by Talidec et al. (2005) and Guérineau et al. (2010), Raveau et al. (2012) stressed that 58% of the number of Nephrops caught in 2009 have been discarded (38% in weight) and that trawlers targeting Nephrops discarded 46% of the total caught weight of hakes (*in* ICES 2010, 2011). More recent dataset confirmed that trawlers, and especially Metiers targeting Nephrops, generate a level of discards corresponding to 50% of their catches.

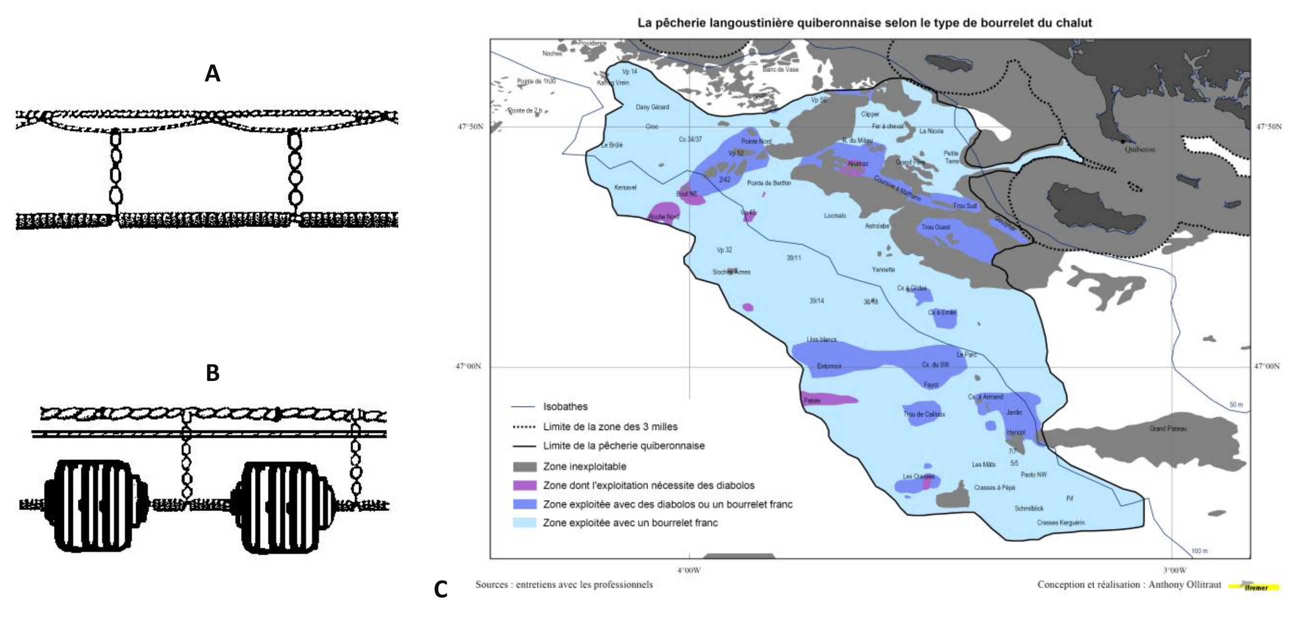
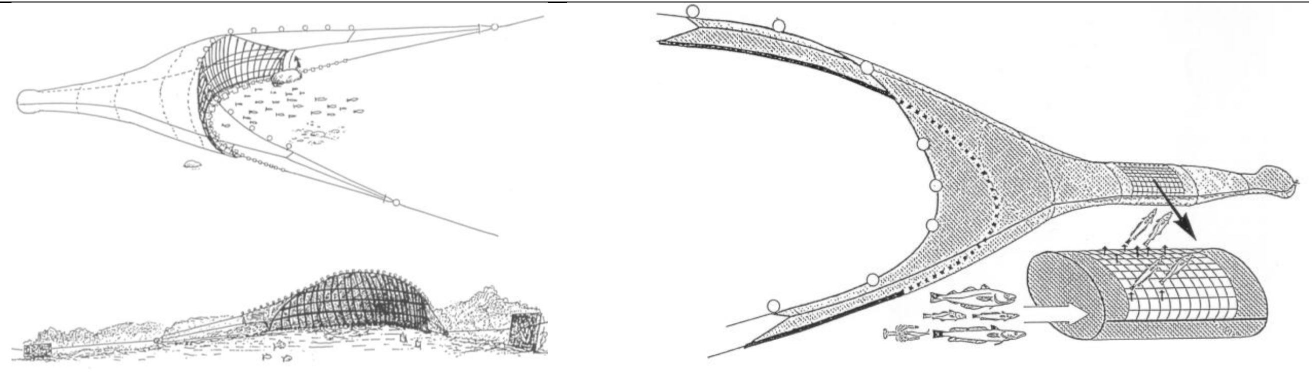


Figure 4.2 - Variations in footrope utilization by the French Nephrops fishery depending in the sediment type: A) simple footrope utilized on soft bottom (figure from G.Deschamps), B) - footrope with bobbins (or "*diabolos*" in French, from F.Morandeau) utilized on harder bottoms (two schemas from Nedelec & Brabant 1988), C) example of the utilization of those two types of footrope in the northern part of the "Grande Vasière" area of the Bay of Biscay (from Ollitraut 2005).



A. Grid against rocks **B**. Selectivity device: square mesh panel

Figure 4.3 - Examples of additional (A) or selective (B) devices optionally utilized by trawlers in the bay of Biscay depending on fishing area and Metiers (illustration from G.Deschamps)

Table 4.1 - Technical specifications of the main gear traditionally utilized by the French vessels in the GV area operating Fish and Nephrops trawling activity on muddy grounds (data collected from "BENTHIS interviews" of gear manufacturer and fishermen partners).

Trawl type and name (production year)		**Twin trawl for Nephrops (Chaluts jumeaux à langoustine)**	**Single trawl for various fish (Chalut simple à divers poissons)**				**4 sided trawl (Chalut 4 faces)**	**Pair trawl (Chalut traîné en bœuf)**
Trawling mode		Single	single		single	single	single	pair
Rigging		Twin	single		single	single	single	single
Codend: mesh opening, inside knots (mm)		70mm gauge if combine with a square mesh panel if not 80mm gauge	70		70	70	70	70 or 100
Targeted species		1) Nephrops 2) Monkfish 3) Flat fish	1) Sole, flat fis 2) Monkfish, cuttlefish, squid		1) Sole, flat fis 2) Monkfish, cuttlefish, squid	1) Sole, flat fis 2) Monkfish, cuttlefish, squid	Makerel, sea bream, other demersal & pelagic fish	1) Squid 2) other
Vessel specificities	**Trawling speed (knots)**	3 to 3.5	2.5 to 3		3 to 3.5	3 to 3.5	3 to 3.5 sometimes more	3 to 3.5
	engine power (kW)	350-450 CV	200 CV max		200 - 450	max 600	max 600	550-800max
	overall length (m)	15 to 18m	10 to 12		12 to15m	15 to 18m	12 to 18m	18-24m
Codend - Trawl circumference (number of meshes)		120	120		120	120	120	120 if 70mm codend and 110 if 100mm codend mesh size
Trawl	**trawl height (m)**	1.20m max	1.5 to 2m		2-3m	2-4m	minimum = 3m maximum = 7m, generally 5m	10m max
	wing spread (m)	10-12m for one trawl	< 12m		10.20m	20-30m	12-15m	35-40m
Doors	**Type**	Bottom	bottom		bottom	bottom	bottom	-
	number	2	2		2	2	2	-
	producer, and model	Traditional wooden or iron rectangle doors	Doors with "Foils" (usually from Morgères or thyboron)	Thyboron Type 2, 50 inch	Thyboron Type 2, 60-66 inch	Thyboron Type 11, without foil	Thyboron Type 2 (or type 11 for the larger vessels)	Same weight as the chains
	length (m)	1.50 to 1.70m	1.2m	1.3	1.6 to 1.75	1.6	1.6 to 1.75	-
	height (m)	0.90 to 1.10m	1m	0.85	1 - 1.1m	1.3	1 - 1.1m	-
	weight (kg)	250 to 300kg	250 to 300kg	150kg	300 - 450KG	450-600kg	300 - 450KG	Weigts instead of doors : 500kg each side of the trawl
	spread (m)	45 to 50m	60m	20 to 25m	25 to 50m	65m max	25 to 50m	Distance between trawlers depends on the trawl size and the warp length (usually, distance between trawlers = horizontal opening + 0.6 x (warp + sweeps))
sweep length (m)		40m ("bras") *(+ 60m "fourche" in case of Nephrops Twin trawl)*	no sweep		from 25 to 60m, tend to be short if hard bottom, and long if plane bottom	60 to 85m	no sweep	100 minimum and 300 m max
Bridles (number)	**number**	2 per wing, 4 per trawl, 8 in total for twin trawl	2 per wing, 4 per trawl		2 per wing, 4 per trawl	2 per wing, 4 per trawl	2 per wing, 4 per trawl	2 per wing, 4 per trawl
	Length (m)	10m each	10 to 15m		10 to 15m	10 to15m	50m	30m
Tickler chains or lines	**number**	max 2 per trawl	max 2 per trawl		max 2 per trawl	max 2 per trawl	No	No general use of tickler chain
	total weight of each chain or line (kg)	Depending on the length of the chain	Depending on length of the chain, but usually heavier than for Nephrops trawl		Depending on length of the chain	Depending on length of the chain	-	?
Groundgear	**Length (m)**	13 to 22m	15m		20 to 28m	max 40m	26m min	70m
	type	Simple footrope ("*bourrelet franc*", Footrope bosom with chain or footrop bosom with bobin or rockhopper (max 6m) if rocky grounds	Simple footrope ("*bourrelet franc*"), with footrope bosom with chain and/or small bobin ("*rondelles moulées*")		Simple footrope ("*bourrelet franc*"), with footrope bosom with chain and/or small bobin ("*rondelles moulées*")	Simple footrope ("*bourrelet franc*"), with footrope bosom with chain and/or small bobin	Rockhopper for larger vessels only	Simple footrope ("bourrelet franc"), with footrope bosom with chain and/or small bobin ("*rondelles moulées*")
	Diameter (mm)	Rock-hopper = 250mm diameter, bobin = 200mm diameter in the footrope bosom, and 80mm diameter bobin ("*rondelles moulées*") in the wings	80mm diameter bobin ("rondelles moulées")		80mm diameter bobin ("rondelles moulées")	80mm diameter bobin ("rondelles moulées")		80mm diameter bobin
	Weight (kg)	Simple footrope ("*Bourrelet franc*") : 5kg/m	5kg/m		5kg/m	5kg/m		5kg/m
Clump	**Type**	Chain are generally used in the case of "fourche" rigging, roller are much less used	-		-	-	-	
	Weight (kg)	Weight of chain is usually similar to the doors weight	-		-	-	-	

Table 4.2 - Estimation based on expert knowledge of the impact of different gear parts for various types of bottom habitats for the Benthis sub-case study sub-CS1 & sub-CS4.

Gear Type	Gear parts	GV habitats		VME's		
		Sands dominated	Mud dominated	Various VME's (e.g. sponges grounds)	CWC garden like	CWC reefs like
All trawls (twin or single trawls)	Doors	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪
	Simple groundrope	🟨🟨🟧🟥⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪
	groundrope with bobbins	🟨🟨🟧⬜⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪
	bridles	🟨⬜⬜⬜⬜	🟨⬜⬜⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪
	Tickler chains	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪
	Rockhopper	🟨🟨🟧⬜⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪
	"Grid for rocks"	🟨🟨🟧⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧⬜⬜
	Trawl net	🟨🟨⬜⬜⬜	🟨🟨⬜⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪
	Trawl net - Selectivity devices *	🟨⬜⬜⬜⬜	🟨⬜⬜⬜⬜	🟨⬜⬜⬜⬜	🟨⬜⬜⬜⬜	🟨⬜⬜⬜⬜
Twin trawls	Chains weight	🟨🟨⬜⬜⬜	🟨🟨⬜⬜⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪
	Roller clumb	🟨🟨🟧🟥⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪
Set gillnets	Net	🟨⬜⬜⬜⬜	🟨🟨⬜⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧🟥⬜
	Settled part **	🟨🟨🟧⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪
Set longlines	Lines	🟨⬜⬜⬜⬜	🟨⬜⬜⬜⬜	🟨🟨⬜⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧🟥⬜
	Settled part **	🟨🟨🟧⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪
Pots	Nephrops pots	🟨🟨🟧⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪
	Settled part **	🟨🟨🟧⬜⬜	🟨🟨🟧⬜⬜	🟨🟨🟧🟥⬜	🟨🟨🟧🟥🟪	🟨🟨🟧🟥🟪

none or very low 🟨⬜⬜⬜⬜ **low** 🟨🟨⬜⬜⬜ **medium** 🟨🟨🟧⬜⬜ **high** 🟨🟨🟧🟥⬜ **very high** 🟨🟨🟧🟥🟪

* selectivity devices imposed to Bay of Biscay trawlers in the GV area: square mesh, greater mesh size, T90 mesh ; ** (anchors, sinkers or stakes)

Table 4.3 - List of the métiers to be considered into the analysis for the French fleet occurring on the Bay of Biscay continental shelf in 2013. Métiers have been defined from landing values in Euros as recorded into logbook dataset. For each métier, only species representing at least 10% of the catch are represented.

Gear category	Gear type	Main species *	Metier code
PASSIVE gears	Set gillnet and trammel net (GNS & GTR)	HKE	G-LE_EURO_HKE
		MNZ	G-LE_EURO_MNZ
		MUR	G-LE_EURO_MUR
		POL	G-LE_EURO_POL
		SOL	G-LE_EURO_SOL
	Settled longlines (LLS)	BSS	LLS-LE_EURO_BSS
		WHG, POL	LLS-LE_EURO_WHG_POL
		COE	LLS-LE_EURO_COE
		HKE	LLS-LE_EURO_HKE
	Pots and traps (FPO)	LBE, SCR, CRE	FPO-LE_EURO_LBE_SCR_CRE
		CRE	FPO-LE_EURO_CRE
		CPR	FPO-LE_EURO-CPR
ACTIVE gears	Bottom single otter trawl (OTB)	CTC, SQZ	OTB-LE_EURO_CTC_ SQZ
		MNZ, SQZ, BSS, HKE, JOD	OTB-LE_EURO-MNZ_SQZ _BSS_HKE_JOD
		NEP	OTB-LE_EURO_NEP
		SOL	OTB-LE_EURO_SOL
		CSH	OTB-LE_EURO_CSH
	Bottom twin otter trawl (OTT)	SOL, CTC, SQZ, HKE, MUR, SCR	OTT-LE_EURO-SOL_CTC _SQZ_HKE_MUR_SCR
		MNZ, MEG	OTT-LE_EURO-MNZ_MEG
		NEP, SOL	OTT-LE_EURO-NEP_SOL
		NEP	OTT-LE_EURO-NEP

* Species codification: Seabass = *Dicentrarchus labrax* (BSS), Conger = Conger conger (COE), common prawn = *Palaemon serratus* (CPR), edible crab = *Cancer pagurus* (CRE), brown shrimp = *Crangon spp.* (CSH), Cuttlefish= *Sepia spp.* (CTC), Hake = *Merluccius merluccius* (HKE), john dory = *Zeus faber* (JOD), European lobster = *Homarus gammarus* (LBE), meagre = *Argyrosomus regius* (MGR), anglerfishes = *Lophius spp*. (MNZ), red mullet = *Mullus surmuletus* (MUR), Norway lobster = *Nephrops norvegicus* (NEP), pollack = *Pollachius pollachius* (POL), cuckoo ray = *Leucoraja naevus* (RJN), spider crab = *Maja squinado* (SCR),sole = *Solea solea* (SOL) , Squids = *Loligo spp.* (SQZ) , turbot = *Scophthalmus maximus* (TUR), Whiting = *Merlangius merlangus* (WHG).

Table 4.4 - Fishing effort (hours of fishing), landings in value (kilo Euros) and weight (tons) by metiers and seasons for the French fishing vessels operating active gears in the Bay of Biscay during 2013. Source: IFREMER Fisheries Information System (SIH-IFREMER), *http://sih.ifremer.fr/Description-des-donnees/Les-donnees-estimees/SACROIS*.

Gear	**Métiers**	**Fishing effort ($h.10^3$)**				**Landing Value (k€)**				**Landing weight (tons)**			
		1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
OTB	OTB-LE_EURO_CTC_ SQZ	5.2	5.7	16.9	11.4	1310.2	1164.1	3074.4	3082.9	372.0	306.7	667.7	765.9
	OTB-LE_EURO-MNZ_SQZ_BSS_HKE_JOD	31.3	29.2	29.6	34.1	7002.1	4992.6	5934.5	8065.0	1891.0	1392.4	1974.7	2190.8
	OTB-LE_EURO_NEP	2.6	9.3	5.9	2.7	3726.7	1907.0	952.9	397.1	51.1	308.9	156.1	61.4
	OTB-LE_EURO_SOL	7.6	10.5	11.9	3.5	1747.3	1339.6	1508.5	628.2	368.7	228.4	240.2	126.1
	OTB-LE_EURO_CSH	1.9	3.4	4.6	0.6	103.5	306.5	524.6	46.7	7.8	29.9	51.7	5.2
OTT	OTT-LE_EURO-SOL_CTC_SQZ_HKE_MUR_SCR	11.8	2.3	3.6	8.4	2798.8	447.0	728.3	2235.6	757.7	104.9	172.9	572.3
	OTT-LE_EURO-MNZ_MEG	23.8	18.8	19.5	22.8	4070.5	3169.3	3315.3	4505.4	1296.1	966.7	964.7	1089.1
	OTT-LE_EURO-NEP_SOL	10.4	37.5	23.8	21.5	1606.3	8205.1	4616.2	4468.6	285.1	1602.8	918.9	797.5
	OTT-LE_EURO-NEP	11.3	29.1	19.8	6.5	1759.4	6311.4	4016.8	1170.2	202.0	898.7	514.4	152.2

* "seasons" are defined by trimester for each one of the considered year from January to December

Table 4.5 - Estimates of discards by the fishing métiers in the bay of Biscay - Data from the national onboard observer program in 2012 (Source: Cornou, A.-S., J. Diméet, A. Tétard, O. Gaudou, B. Dubé, L. Fauconnet, and M. J. Rochet. 2013. Observations à bord des navires de pêche professionnelle. Bilan de l'échantillonnage 2012. http://dx.doi.org/10.13155/27787. Ifremer, Nantes).

Métier	**Fleet size**	**% trips obs.**	**Total catch (t) [95% confidence interval]**	**Total discards (t) [95% confidence interval]**	**No species in the catch**	**Top discarded species**
Bottom trawlers	386	0.3	20,104 [14,822 – 25,386]	5,727 [3,451 – 8,892]	116	Mackerel, horse mackerel, bib
Gilnetters < 15 m	366	0.5	7,314 [6,816 – 7,811]	1,160 [898 – 1,460]	98	Whiting, bib, mackerel
Gilnetters > 15 m	73	0.3	15,957 [14,051 – 17,862]	1,777 [1,100 – 3,205]	75	Hake, bib, mackerel
***Nephrops* trawlers**	227	0.1	10,522 [8,180 – 12,865]	5,159 [3,627 – 6,898]	87	Hake, *Nephrops*, bib
Longliners	225	0.2	4,854 [4,598 – 5,110]	438 [277 – 665]	43	Hake, undulate ray, blackmouth catshark
Danish seiners	9	2	2,005 [1,654 – 2,534]	622 [384 – 937]	65	Horse mackerel, whiting, mackerel
Small pelagic trawlers	74	1	9,780 [9,064 – 10,496]	450 [244 – 751]	29	Anchovy, hake, mackerel

Hake is one of the most important species landed in value in France (Direction des Pêches maritimes / OFIMER 2010). When considering the entire fishing fleet, Hake represents the first species caught in weight (21.10^3 kg, 17% of the total catches) and *Nephrops* the 5th one (4.10^3 kg, 3% of the total catches). *Nephrops* reaches the third place in value with 10% of the total landed value and 5% for the hake. When considering bottom trawlers only, 46% of the exclusive bottom trawlers operated at least one time a year the metiers "twin-trawl for *Nephrops*". *Nephrops* reaches the third and second rank in terms of biomass and value respectively for the exclusive trawlers of the French Atlantic coast (6% of total species catches and 17% of value in Leblond et al. 2013).

Table 4.6 - Vessels and production proportions by the French Atlantic bottom trawling fleet (adapted from Leblond et al. 2013) . Only metiers for Nephrops, hake, sole & Monkfish operating simple and twin bottom trawl are considered.

Metier		Exclusive bottom trawlers (n=364)			Non-exclusive bottom trawlers (n=150)		
		% Vessel number**	Species catches and value		% Vessel number**	Species catches and value	
Gear	Species		% weight (total = 63.10^3 tons)	% value (total = 220.10^6 €)		% weight (total = 3.10^3 tons)	% value (total = 14.10^6 €)
OTT	Nephrops	46	6	17	-	-	-
OTB		13			11	3	7
OTT	Monkfish	27	15	20	-	-	-
OTB	Sole	23	≤2	5	36	6	15
OTT		12			-	-	-
OTT	Various fish	13	-	-	-	-	-
OTB		13	-	-	22	-	-
Various	Hake	-	7	5	-	-	-

** % of vessel operating the metier at least one month a year

Depending on gears types or métiers, fishing effort displays a high seasonality in the Bay of Biscay and the GV areas. The main period for *Nephrops* associated métiers occurs from April to august with a significant peak of activity in May and June. It corresponds with the main utilization of OTT, and to a lesser extent of OTB, in the GV area. Depending on years and months, fishing effort of OTB gears in the GV represents 6.6% up to 18.5% of the whole OTB fishing effort in the Bay of Biscay. Regarding OTT, GV represents from 22.5% up to 60.2% of that of the whole Bay of Biscay. It emphasizes the specific utilization of OTT gear in the GV and especially the modification of spatial distribution of that activity with a concentration during specific periods in the GV.

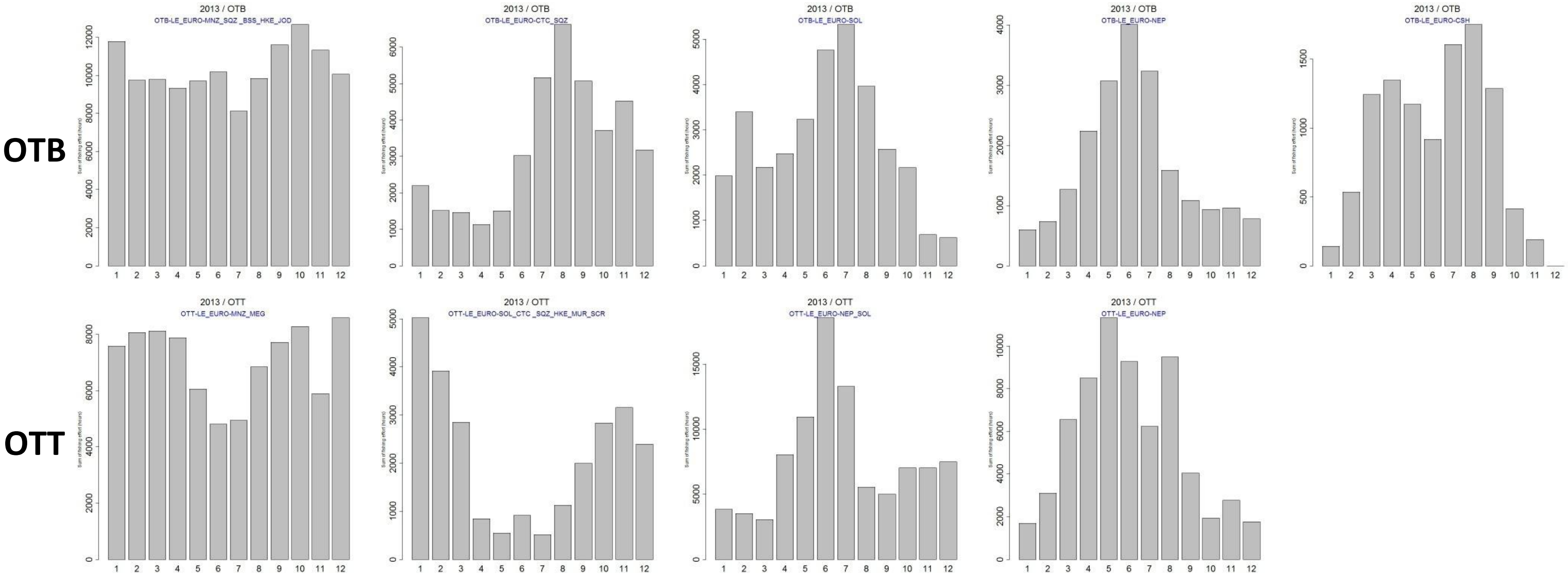


Figure 4.4 - Monthly distribution (from January:1 to December:12) of fishing effort (sum of fishing hours) for the main Métiers of the French fishing fleet utilizing active bottom gears (OTB or OTT) in 2013 on the Bay of Biscay continental shelf as derived from Logbook/SACROIS dataset (IFREMER Fisheries Information System, SIH-IFREMER, http://sih.ifremer.fr/Description-des-donnees/Les-donnees-estimees/SACROIS).

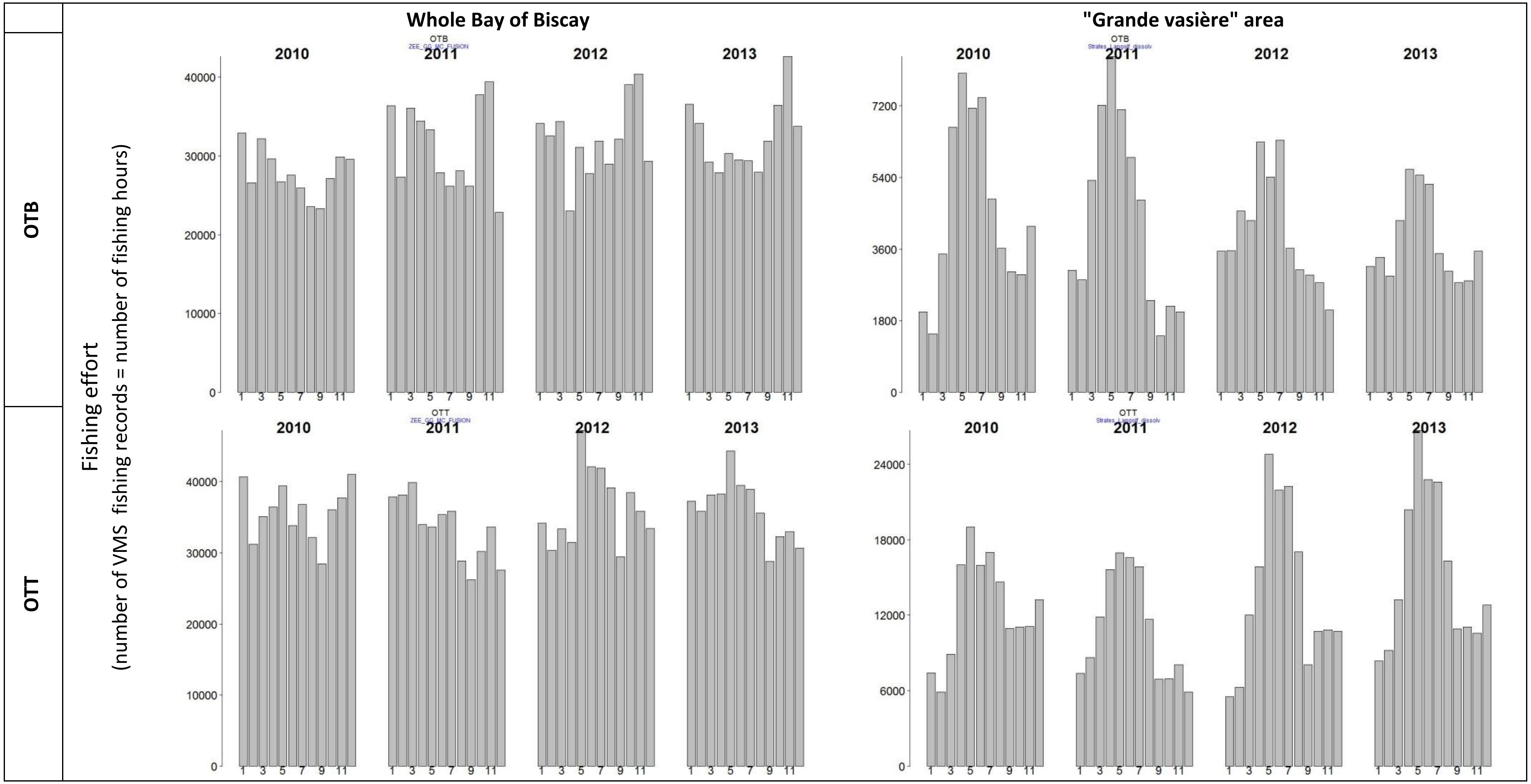


Figure 4.5 - OTB and OTT total fishing effort (number of VMS recorded fishing points equivalent of hours of fishing) in the Bay of Biscay and GV areas by month (1 to 12) from 2010 to 2013 (as derived from VMS dataset, source DPMA/SIH-IFREMER).

4.1.3. Distribution of fishing effort as indication of fishing pressure in regional seas

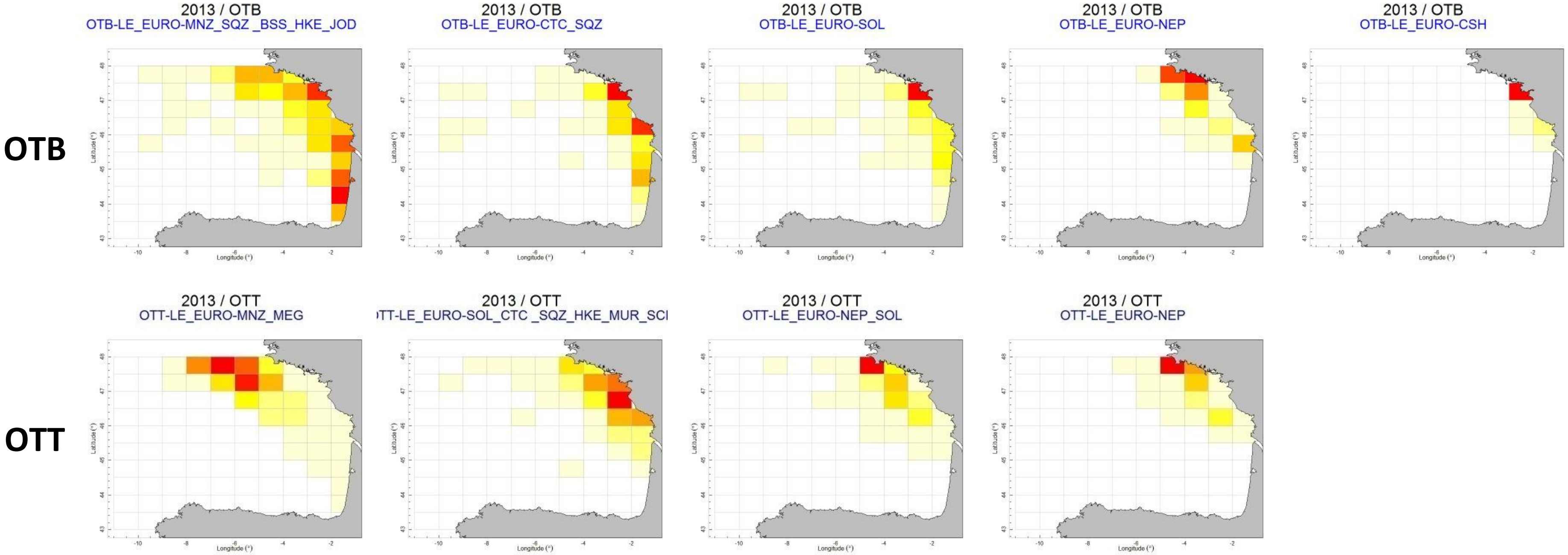


Figure 4.6 - Distribution of fishing effort (sum of fishing hours) at ICES squares scales and by month (january:1 to december:12) for the main Métiers of the French fishing fleet utilizing active bottom gears (OTB or OTT) in 2013 on the Bay of Biscay continental shelf.

Métiers operating trawls and linked to Nephrops are quite exclusively localized in the "Grande Vasière" area of the Bay of Biscay. On the shallowest/eastern and deepest/western edges of that habitat, metiers focus on a mixed of fish and cephalopods targets.

[Since there was no authorization from French fisheries agency to publish maps at the time of the deliverable, we were not able to display any high resolution map from VMS dataset.]

4.1.4. Distribution of benthic habitats or substrates in regional seas

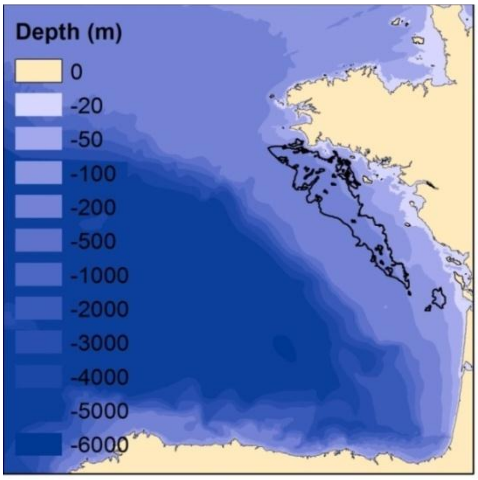
The Bay of Biscay is characterized by a continental shelf extending from the coast to about 180 m deep. Continental shelf enlarged along French part of the BoB (from south-east to north-east), as large as about 200 km in its northern part and about 5 km only in the southern part near Spanish border. Shelf shows globally a gently slope (less than 0.5%). Coastal morphology is more diverse in its northern part where rocky and sandy shore as well as cape, bay and islands alternate. Regarding area located south to Gironde river, coast is characterized by a monotonous linear sandy coast about 250km long followed by the Basque country cliffs. Continental break shows a slope varying from 10 to 12% and is mostly constituted by muds and crossed by deeper canyons. Infra-littoral BoB habitats are characterized by the large mudflat "Grande Vasière" (GV), occupying the north-central part of the shelf between 70 and 110 m deep. Between that mud flat and the coast we can distinguish 3 main parts: (1) Brittany region where, behind an island belt, sedimentations processes accumulate fine particles coming from many estuaries and « from pre-littoral mudflats »; (2) Loire-Gironde region which is characterized , a part from littoral mudflats leaned against islands, by large gravel plains and (3) Aquitaine region where, from the coast to the offshore area, alternate fine sand dune, coarse sands, gravels and fine "grey sands" near from the fine sands of the GV.

Main hydrological processes acting upon sediment disposals are:

- the residual north-south coastal current that makes littoral mudflats and fine particules from estuaries accumulating in the northern part of the BoB.
- permanent action of waves at depth above 20m and only few days a year at deeper locations on the whole continental shelf.

The GV area is characterized by mudflats that can be summarized into 3 main types of fine sands depending on mud proportions: <25% , >25% and >75% mud.

No Eunis map already exists for the whole circalittoral part of the BoB continental shelf. Existing maps made from historical dataset are mostly restricted to the northern part of the BoB. They give the distribution of the main habitats into a Eunis-like habitat types recently adapted from the original communities description. 83.7% of the GV surface is covered by Eunis-like habitat map. It could be summarized into 3 main EUNIS community types representing at least 74% of the area.



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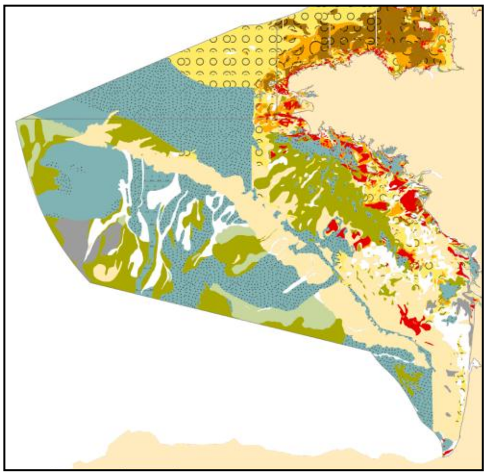

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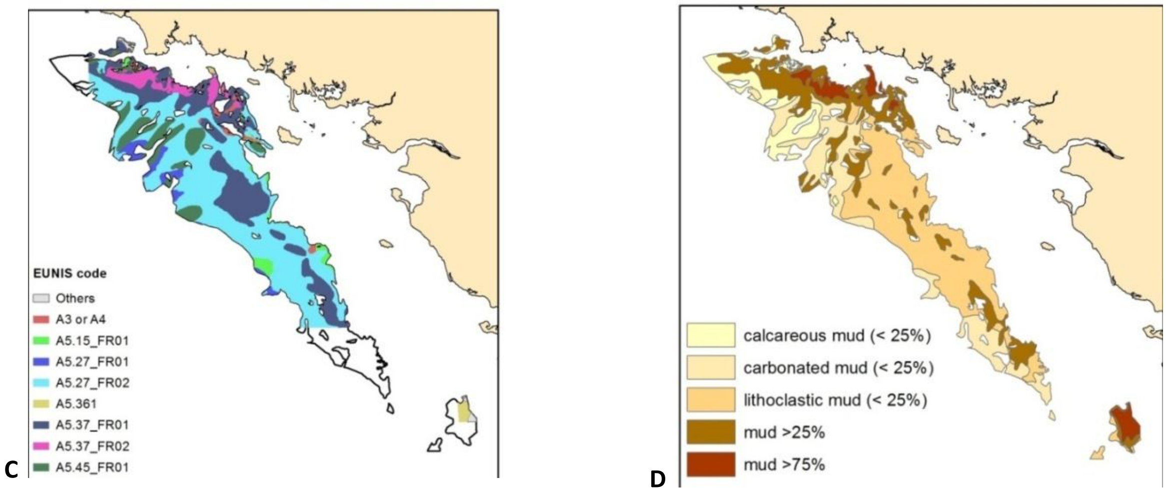


Figure 4.7 - Habitats maps for the bay of Biscay with a special focus on the "Grande Vasière" mud belt (GV): bathymetric (A) and sediment (B) maps for the whole Bay of Biscay, Eunis habitat (C) and sediment (D) maps for the GV area.

Table 4.7 - Main EUNIS-like habitats types in the "Grande Vasière" area (GV, 83.7% of the surface covered) as derived from C.Hily maps (2009, EUNIS_VERSION_2007-11).

EUNIS code	Original habitat name	Proposed EUNIS habitat type	% of GV covered
NONE	NONE	NONE	14
A5.27_FR02	Sables fins envasés du large à Amphiura chiajei, Onuphis lepta et Auchenoplax crinita	*Amphiura chiajei* in deep circalittoral muddy sand	43.7
A5.37_FR01	Vases sableuses du large à *Nucula sulcata* et *Brissopsis lyrifera*	*Nucula sulcata* and *Brissopsis lyrifera* in deep circalittoral sandy mud	22.6
A5.45_FR01	Sables envasés hétérogènes du large	*Nucula nucleus*, *Pitar rudis* and *Amphiura chiajei* in deep circalittoral muddy mixed sediment	8.1
A5.37_FR02	Vases du large à *Ninoe armoricana* et *Sternaspis scutata*	*Ninoe armoricana* in deep circalittoral mud	4
A5.27_FR01	Sables fins du large à *Ditrupa arietina* et *Dentalium entalis*	*Ditrupa arietina* and *Entalis entalis* in deep circalittoral mobile clean sand	2.7
A3 or A4	Roches tertiaires du large		1.5
A5.15_FR01	Graviers propres du large à *Astarte sulcata* et *Venus casina*	[*Astarte sulcata*] and [*Venus casina*] in deep circalittoral gravel	1.9
A5.361	Vases côtières à *Virgularia tuberculata* et *Sternaspis scutata*	NONE	0.8
Various others	Various others	Various others	0.6

Table 4.8 - GV classification from sediment map (adapted from Bouysse 1985), proportion of surface covered (total GV considered surface = 11671.6 km^2) and distribution of Nephrops trawling fleet fishing effort in % (mean fishing effort from 2003 to 2005 as given into ICES WGHMM report 2013).

Mud proportion	Mud type	GV surface proportion in %	Fishing effort (%)
<25%	Calcareous	10	9.1
<25%	Carbonated	21.6	4.9
<25%	Lithoclastic	39.7	19.8
>25%	-	23.2	54.1
>75%	-	5.4	12.1

Analyzed period (6 years from 2005 to 2010) shows significant reduction of total fishing effort for trawlers (2010 effort representing only 55% of 2005 effort level). When examining depth distribution of effort (Figure 4.9 -4.10), diminution mainly occurs in areas deeper than 200m, shallowest areas being rather stable. Those results contrast with longlines effort evolution that seems rather stable despite a specific increase in 2010 representing the most important fishing effort value of the time series. In 2010, LLS fishing effort shows specific increase in the 200 to 600 m deep areas (Figure 4.9 – 10). Those LLS effort variations does probably not reflect an overall increase of longlines fishing effort but much probably changes of fishing distribution at North Eastern Atlantic scale (P.Lorance com.pers.). Fisheries impose to deepest parts of the bay a relatively high fishing pressure by units of space. The density of fishing operations (expressed in hours/km2 by bathymetric range) appears more important in the deepest areas for trawls (OTB) as compared to shallowest areas. It appears even truer for longlines whose activity is closely related to 200-800m area. Those highest effort values in deepest areas reflect concentration of fishing in rather small depth-related habitats.

Discards maps are being generated for Benthis project but were not available for the present report.

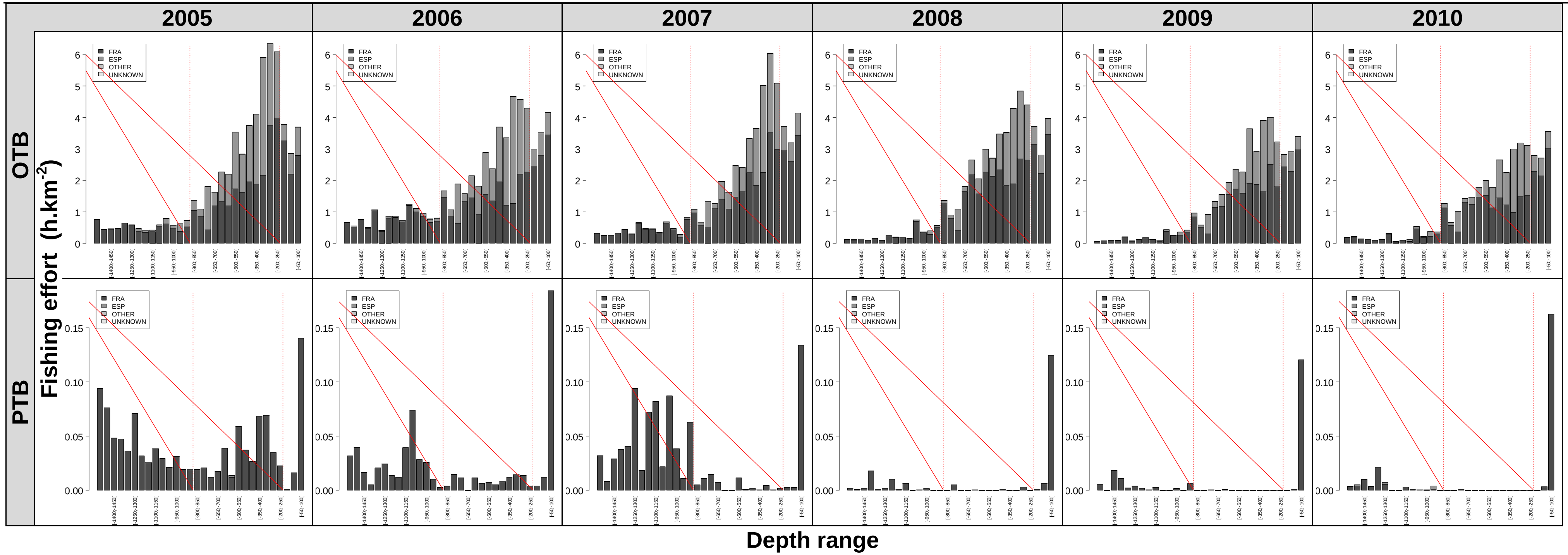


Figure 4.8 - Bathymetric distribution of fishing activity in the bay of Biscay as derived from VMS data (expressed as yearly total duration of fishing operations in hours by km^2) for main active demersal gears (OTB, PTB and TBB) operating in the Bay of Biscay French exclusive economic zone from 2005 to 2010 as derived from VMS data. Fishing effort is aggregated depending on depth ranges (each 50 m depth band, from 50 m, right side of barplot, to 1500 m deep at the left side of barplot). Main countries operating in the area are also indicated (France, Spain and others). Dotted lines show bathymetric limits of main theoretical CWC distribution in the BoB (see sub-CS4).

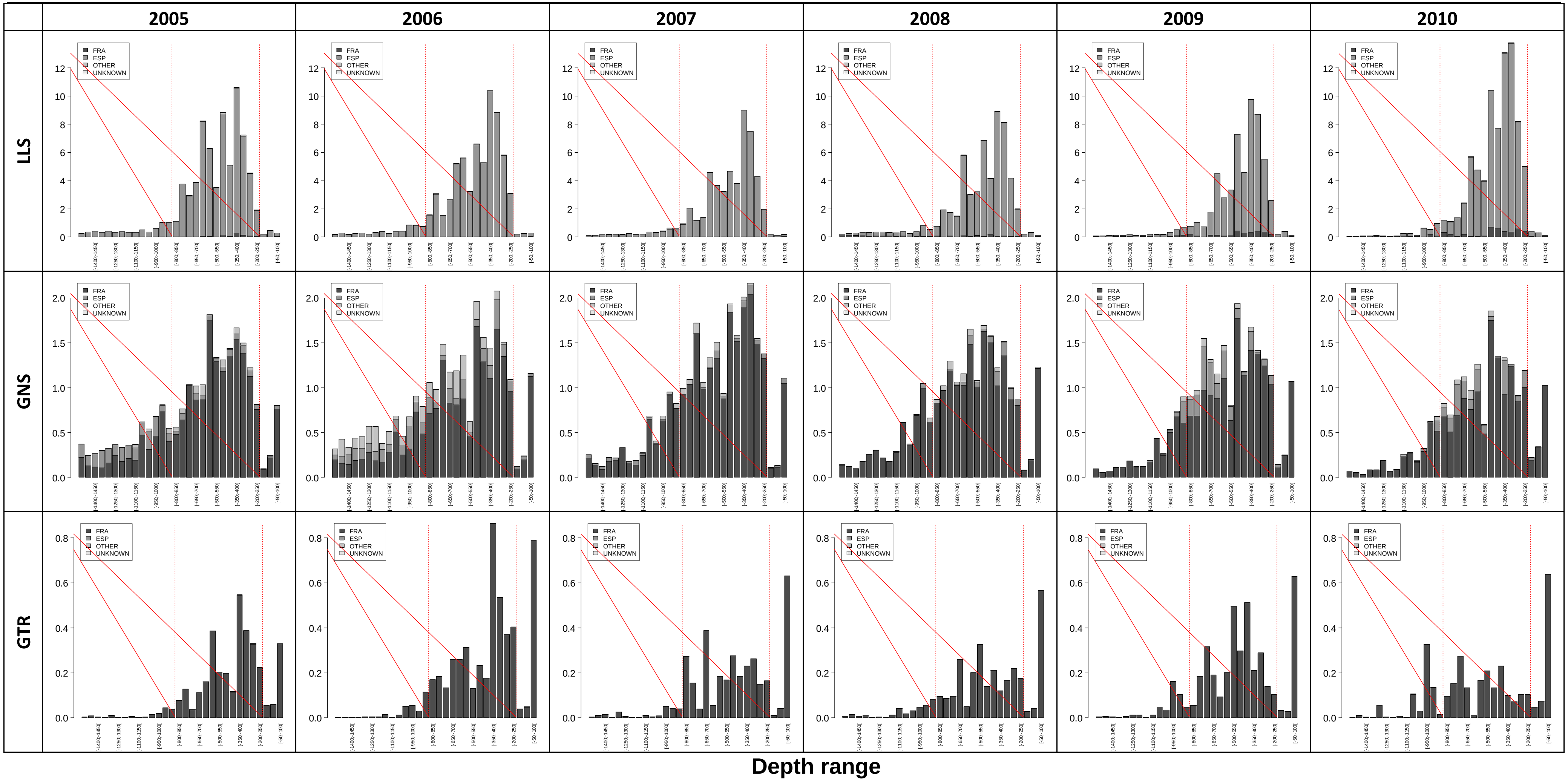


Figure 4.9 - Bathymetric distribution of fishing activity (yearly total duration of fishing operations expressed as in hours by km2) in the bay of Biscay for main passive demersal gears (LLS, GNS, GTR, FPO and GND) operating in the Bay of Biscay French exclusive economic zone from 2005 to 2010 as derived from VMS data. Fishing effort is aggregated depending on depth ranges (each 50 m depth band, from 50 m, right side of barplot, to 1500 m deep at the left side of barplot). Main countries operating in the area are also indicated (France, Spain and others). Dotted lines show bathymetric limits of main theoretical CWC distribution in the BoB (see sub-CS4).

4.2. Sub-case study 2: Scallop dredging in the north east Celtic Sea

4.2.1. Introduction

Sub-case study 2 refers to Scallop fishing in the north east Celtic Sea and also scallop fishing in inshore coastal waters on the Irish south and west coasts. The target species for this fishery is Pecten maximus. The fishery uses series of toothed spring loaded dredges suspended on a beam to catch scallop. In the case study area the fishing effort is dominated by the Irish fleet fishing from ports off the south east coast or Ireland. The capacity and fishing effort potential of this fleet is lower since 2006 when a number of vessels were decommissioned. Post 2006 the tonnage in the fleet has been disaggregated and the fleet now consists of moderate size vessels towing 20-24 dredges compared to up to 36 dredges per vessel prior to 2006. Total landings and effort is increasing annually however. Some of this is driven by 'effort creep' as new seabed visualisation technology is being used on board some vessels. In the north east Celtic Sea, where the Irish fleet fishes, most of the fishing ground is outside the national 12nm fishing limits and is open to fishing effort from other EU member states. Nevertheless, the vast majority of fishing effort in this area is from Irish vessels.

The species inhabits sedimentary sand and gravel habitats and also occurs on cobble/kelp reef areas or on the edges of these reefs. The species is effectively sedentary in adult life. Population structure and distribution is defined by the availability of suitable substrate and by the larval dispersal dynamics. There are significant scallop beds in the Irish Sea, Celtic Sea and English Channel. The beds in the southern Irish Sea and north east Celtic Sea and Bristol Channel are connected through larval source sink dynamics. In coastal waters off the south coast of Ireland there are a number of Special Areas of Conservation (SACs) which are designated under the Habitats Directive for the protection of sedimentary and reef habitats. The scallop fishery encroaches onto these areas and the impact of the fishery may be inconsistend with the conservation objectives for these habitats.

Scallop dredges are known to have significant impacts on epibenthic and inbenthic fauna. Mitigating the effects of the fishery on benthic habitats is an important objective and is driven by the requirements of the Habitats Directive and the Marine Strategy Framework Directive (MSFD). The case study will examine whether dredge design can be modified to reduce inbenthic disturbance and whether high resolution information on seabed structure can be used to focus fishing effort on areas where scallop occur at high density thereby reducing dreding effort per unit of catch.

4.2.2. Benthic impacting fishing gears used in the case study area

4.2.2.1. Typology

A number of benthic impacting gears are used in the north east Celtic Sea including bottom otter trawls (OTB), beam trawls (TBB), dredges (DRB) and pots (FPO).

Scallop dredgers in the Celtic Sea target king scallop (*Pecten maximus*) on sand and gravel substrates. The fishery occurs throughout the year but effort is higher in summer. Multiple dredges are towed on beams on port and starboard side of the vessel. The number of dredges used varies with vessel length (Figure 4.1). Dredges are toothed and spring loaded. The spring loading allows the tooth bar and teeth to move and not become snagged when rocks or large stones are encountered. The dredges can therefore be used both on sedimentary and reef habitats. The teeth are 80-100mm in length and penetrate the sediment to this depth. Distance between teeth is 65mm. The bag of the dredge is a mesh of interconnected metal rings 75mm in diameter. The ring diameter and the spacing between the teeth on the tooth bar determine the selectivity of the dredge.

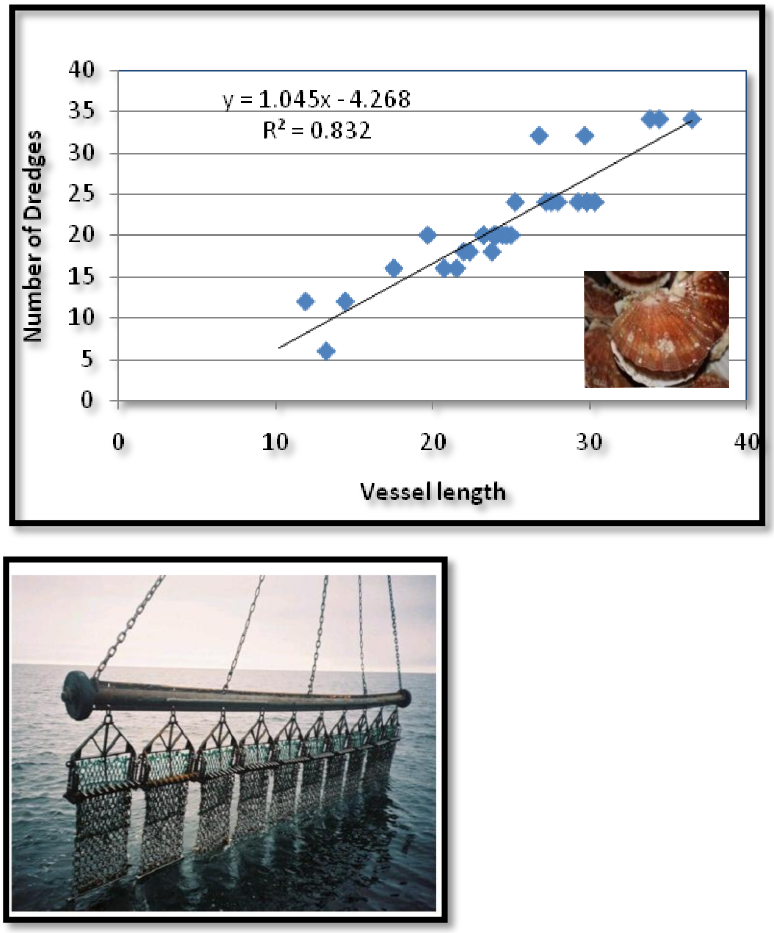


Figure 4.11. Relationship between vessel length and number of dredges towed. Dredges (n=10) configured for fishing are shown.

4.2.2.2. Expected impacts

The fishery 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).

4.2.3. Importance of gears

The fishery for scallops in this area developed in the 1970s as a small scale inshore (artisanal) fishery and expanded into offshore waters during the 1990s. The stock is fished only by Irish vessels although 90% of the stock is distributed outside the 12nm fishery limit. Other fisheries occur in the same area. With respect to benthic impacting towed gears these include otter trawling and beam trawling. Total effort

(VMS hrs, all nationalities) of dredgers is increasing, bottom trawling is stable and beam trawl activity is declining (Table 4.9, Figures 4.12-4.14).

Table 4.9. Irish scallop fleet capacity 2002-2012.

Year	N	GTs	kws	Average GT
2002	22.00	2596.70	9932.00	118.03
2006	5.00	646.00	1790.00	129.20
2007	11.00	1160.55	3048.00	105.50
2008	16.00	1025.48	3047.66	64.09
2009	19.00	952.35	2916.01	50.12
2010	22.00	1098.55	3172.84	49.93
2011	19.00	900.96	2894.84	47.42
2012	15.00	962.52	2734.89	64.17

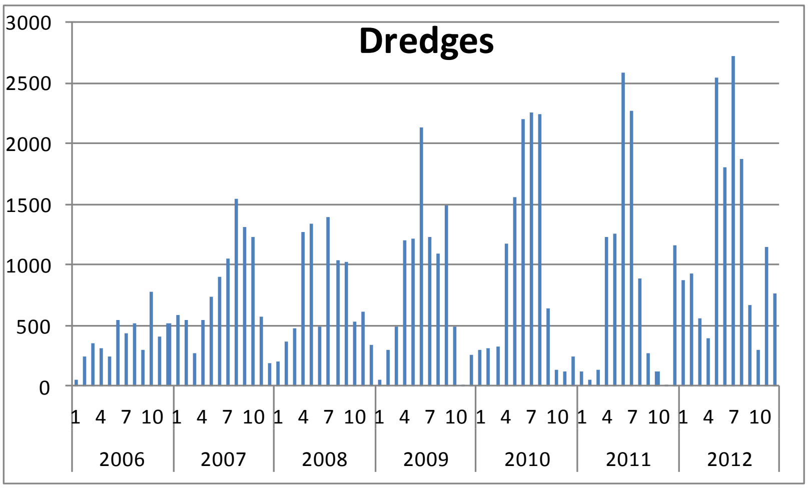


Figure 4.12. VMS hrs of activity by vessels >15m using dredges in the north east Celtic Sea by month during the period 2006-2012

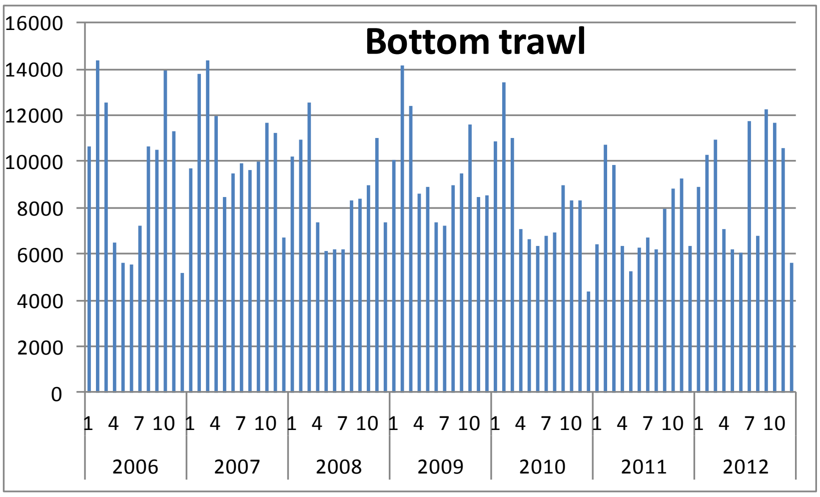


Figure 4.13. VMS hrs of activity by vessels >15m using bottom trawls in the north east Celtic Sea by month during the period 2006-2012

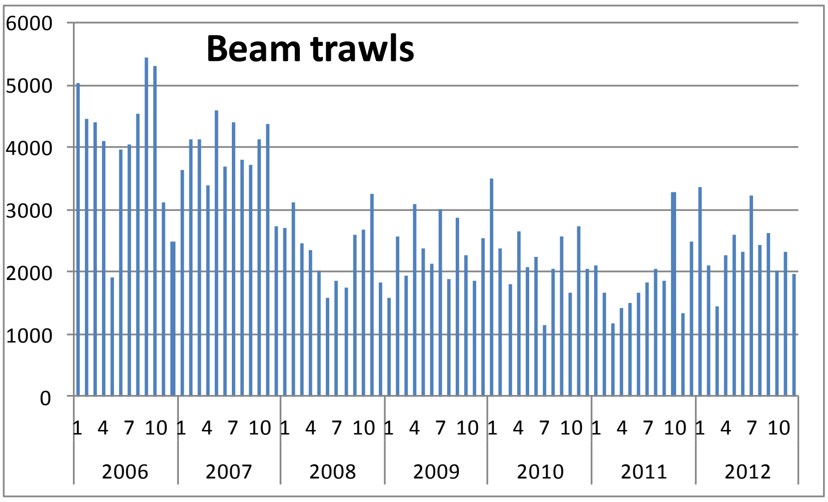


Figure 4.14. VMS hrs of activity by vessels >15m using beam trawls in the north east Celtic Sea by month during the period 2006-2012

4.2.4. Gear selectivity

Scallop dredge selectivity changes as the gear ages; the steel is eroded and the effective diameter of the rings increases. The teeth and the bag of the dredge are replaced frequently due to this 'wear and tear' and also because teeth may break from the tooth bar on rough ground especially. Full selectivity (100%) occurs at 96mm shell height and that 90% of scallops at the legal landing size (equivalent to 89mm shell height) are selected (Hervas 2008).

Efficiency of the gear is thought to be low. Depletion experiments on different ground types have shown efficiency to vary from 4-25%. The efficiency is lower on harder grounds and higher on sedimentary habitats. On rough ground the gear is not in contact with the seabed 100% of the time. Tidal current strength and wind speed (and sea state) also affects efficiency. Catch rates are lower in higher wind speeds and in stronger currents.

4.2.5. Distribution of fishing effort

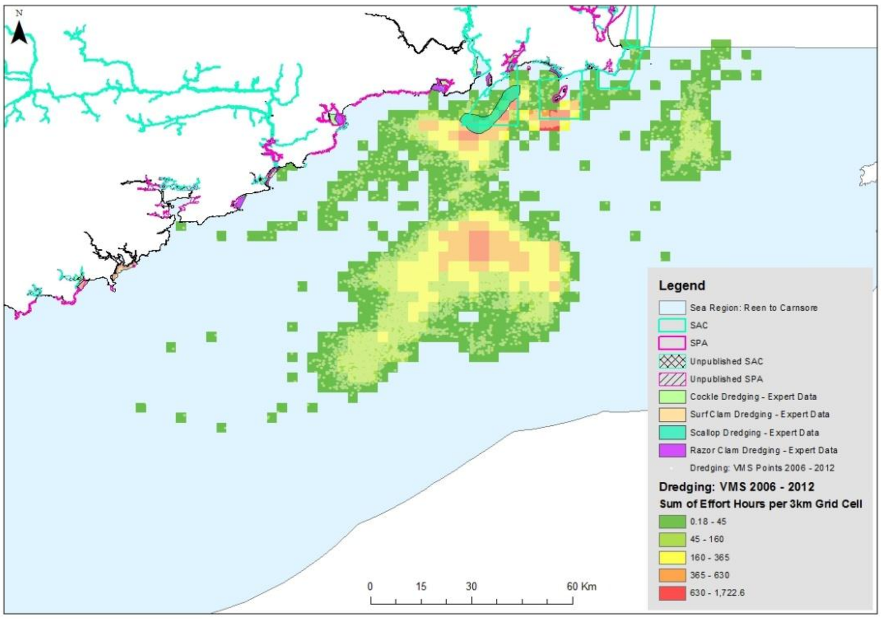


Figure 4.15. Distribution dredge fishing (DRB) in the north east Celtic sea. The VMS data for the scallop fleet is shown in grid and point format. Other small scale dredge fisheries occur inshore. European Marine Sites (SACs, SPAs, are shown).

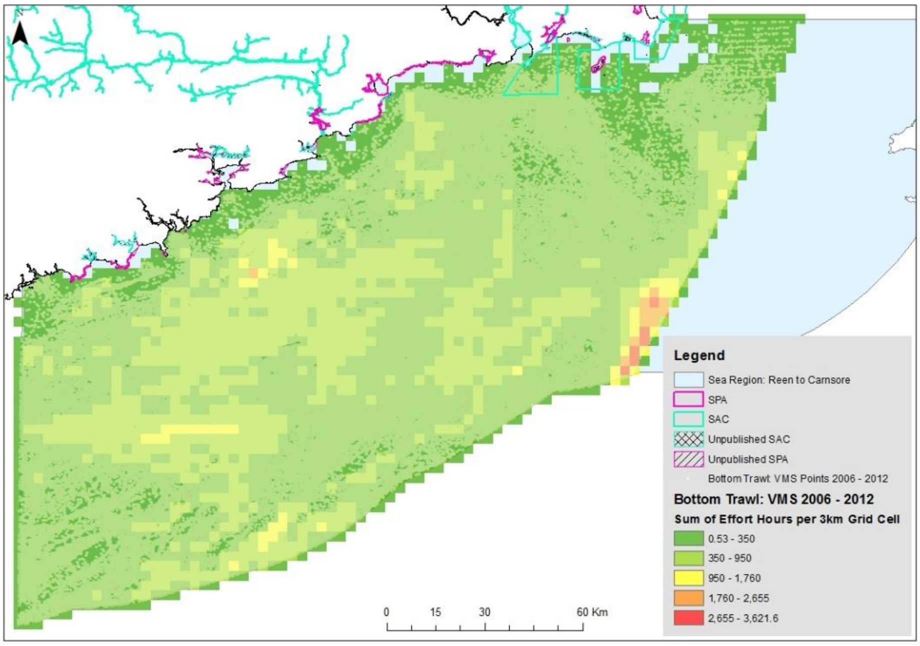


Figure 4.16. Distribution of bottom trawling (OTB) in the north east Celtic sea. The VMS data for the scallop fleet is shown in grid and point format. Other small scale dredge fisheries occur inshore. European Marine Sites (SACs, SPAs, are shown).

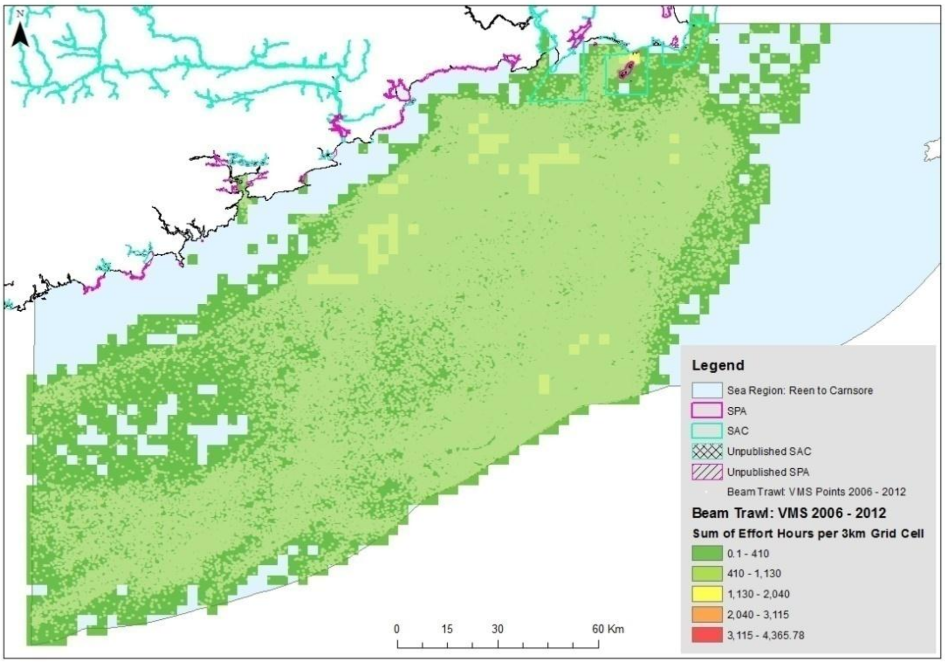


Figure 4.17. Distribution of beam trawl (TBB) in the north east Celtic sea. The VMS data for the scallop fleet is shown in grid and point format. Other small scale dredge fisheries occur inshore. European Marine Sites (SACs, SPAs, are shown).

4.2.6. Distribution of benthic habitats

Habitats in the north east Celtic sea are mainly a mix of sands and gravels with rocky reefs and current swept reefs occurring in shallow water. A significant proportion of the area has been acoustically mapped using multibeam technology. High resolution bathymetry and backscatter data provides an index of sediment composition in the area (Figure 4.18).

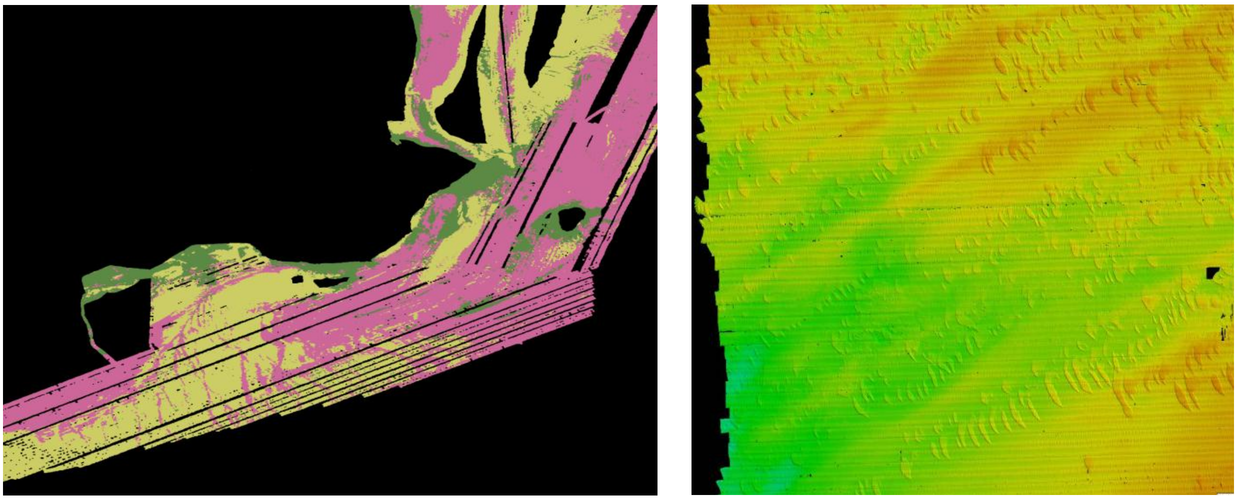


Figure 4.18. Examples of classified acoustic backscatter data (left) showing sands, (yellow, gravels (pink) and reef (green) and illuminated bathymetry (right) for an area in the Celtic Sea showing sand wave formations.

Benthic community assemblages have not been mapped for the entire area. Marine Communities have been mapped in coastal EMS (Figure 4.19).

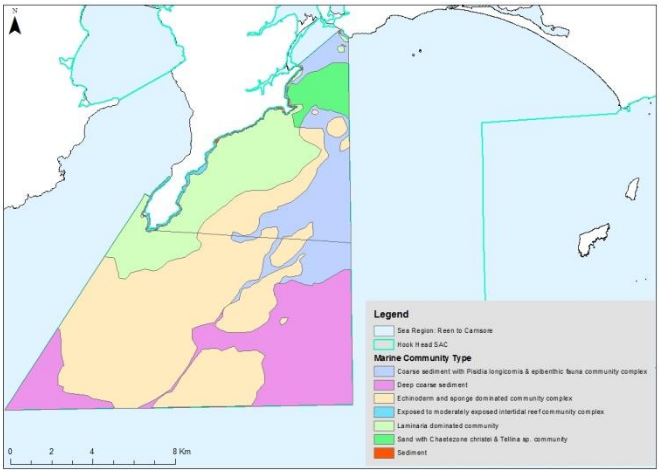


Figure 4.19. Marine habitat map for the Hook Head EMS showing distribution of sedimentary and reef communities.

4.3. Sub-case study 3: fisheries interacting with VME's

4.3.1. General Introduction

Sub-CS4 focus on fisheries interacting with Vulnerable Marine Ecosystems (VME) in European waters and especially in the Bay of Biscay and Norwegian sea. In the Bay of Biscay, Benthis will mainly focus on cold water coral habitats as defined from previously recorded locations.

Table 4.10 - List of VME's present in studied regions and taken into account for Benthis.

Sensitive habitats (modified from OSPAR' list of threatened and/or declining habitats)	**Bay of Biscay**		**Norwegian waters**	
	Presence	Taken into account for Benthis	Presence	Taken into account for Benthis
Soft and hard bottom coral gardens	YES	YES	YES	YES
Seapen and burrowing megafauna	YES	YES	YES	YES
Umbellula stands	?	NO	YES	YES
Glass sponge community	YES	NO	YES	YES

4.3.2. Introduction: Fisheries interacting with Cold Water corals habitats (CWC)

Parts of the introduction text below are based on the report on fisheries impact over CWC habitats realized for the EU-FP7 CoralFish project (Laffargue et al. 2011).

The cold-water coral (CWC) habitats represent biodiversity “hot-spots” on the bottoms of the bathyal and abyssal depths, providing ecological niches for a large number of species (Freiwald & Roberts 2005). CWC habitats include stony coral reefs and octocoral/antipatharian gardens, and are typified by corals that live in cold waters, inhabit hard substrates and feed on zooplankton or particulate organic matter. They harbor a diversity of associated species (Freiwald et al. 2004). Thanks to advances in deep-sea exploration, CWC habitats have been located during extensive seafloor mapping in a number of regions. These include the Northern and Eastern Atlantic continental margins and recent dedicated oceanographic expeditions in the Mediterranean sea (Reveillaud et al. 2008, Freiwald et al. 2009, Corselli 2010). CWC habitat in the present report principally refers to *Lophelia pertusa* and *Madrepora oculata* recognized as the main reef-building species in NE Atlantic and Mediterranean (Freiwald et al. 2004, Freiwald & Roberts 2005, Freiwald et al. 2009). These species (i.e. azooxanthellate Scleractinia) can occur on the seafloor as individual corals, isolated colonies, and reefs or three dimensional structures ranging in size and shape from small scale low relief (several metres high and tens of metres across) to prominent morphologies (hundreds of metres tall and a few kilometres across) known as giant carbonate mounds. The main environmental features associated with CWC habitats such as reefs and carbonate mounds, include: some hard substrata for the initial settlement of coral larvae; nutrient enriched water masses supplying food for coral growth; and strong bottom currents, often topographically driven, which keep the polyps from sediment burial. The local hydrography and sedimentary dynamics have a strong influence on the growth of CWC and therefore on the resultant morphologies at the seafloor.

One of the main threats to cold-water coral (CWC) habitats is the physical damage caused by fishing gears, mainly by bottom trawlers (Fosså et al. 2002, Hall-Spencer et al. 2002) but by longlines too (Freiwald et al. 2004). Trawling activity took place early in the 20th century for European seas. The northern North Sea has been trawled for demersal fish since the early 1900s (Jennings & Kaiser 1998). In that context, interactions of trawlers with Cold Water Corals are an old story for European waters. As soon as 1922 corals are presented as threats for trawlers in the bay of Biscay and celtic Sea areas (Joubin 1922 : "*Deep sea harmful corals for trawlers*"). The author gives the following description of encounters between corals and trawlers: «*… trawls are tear up and can stay hooked on it; at least they fill in with broken branches that prevent them from functioning. Once "Tanche" trawler brought 5 to 6 tonnes into one haul* » (translated from original text in french). Sánchez et al. (2008) explained that interactions of Spanish fishermen with corals occurred in the early twentieth century with large specimen of *Lophelia pertusa* from "El Cachucho" bank caught in 1918 (Santander Maritime Museum collections). After small sized and geographically restricted fisheries, deep fishing activity grows up after mid 20's century that deeply increase potential impact of fisheries over CWC grounds all over the world. The commercial deep-sea fisheries in northwest Atlantic began in mid 1960's (Atkinson 1995) and late 1960's in southwest Pacific around New-Zealand (Clark & King 1989). Year 1973 was the birth of French deep water fishery in the northeast Atlantic with the exploitation of blue ling : *Molva dypterygia* (in Allain & Lorance 2000). In 1980's, exploitation of species was restricted to area from 200 to 500m depth with a maximal total landings amount around 2400kT. They principally fished for *Lophius* spp., *Lepidorhombus w.*, *Molva* spp., *Pagellus bogaraveo*, *Helicolenus dactylopterus*, *Phycis blennoides*. In the mid-1980's, deep-water fisheries showed a heavy increase in Northern Atlantic region characterized by the exploitation of deeper species (*e.g. Alepocephalus bairdii, Coryphaenoides rupestris, Hoplostethus atlanticus*). From 1990s, the exploitation was extended to deeper area (>500m) and related species. Landed species were principally *Coryphaenoides rupestris, Hoplostethus atlanticus, Aphanopus carbo, deep water sharks or «Siki» (Centrophorus squamosus, Centroscymnus coelolepis*), with a maximal total landed amount around 330kT. Therefore, over the past few decades, the development of deep-water fishing worldwide has caused an extension of fishing grounds over previously unexploited areas and unimpacted benthic communities (Koslow et al. 2000, Koslow et al. 2001, Fosså et al. 2002, Hall-Spencer et al. 2002, Clarke 2005, Morato et al. 2006). More fishing effort is actually expanded on the shelf break (200-400m) and upper slope (400-750m) by several types of fisheries targeting primarily hake (*Merluccius merluccius*), anglerfish (*Lophius spp.*) and megrims (*Lepidorhombus spp.*) with bycath of ling (*Molva molva*) greater forkbeard (*Phycis blennoides*), Blackbelly rosefish (*Helicolenus dactylopterus*), conger (*Conger conger*) and other species. These shelf break and upper slope fisheries did not undergo such strong regulation as fisheries for deep-water stocks and might have been mostly stable for the past two decades. Nowadays, the presence of corals is well known to the fishermen who often experience gear damage and losses, but they often fish close to these areas (e.g. D'Onghia et al. 2010). Fishing methods depend on different local socio-economical factors, resources and regulations, but primarily consist of long-lining, gillnets and trawling from large and small vessels depending on the geographic area (Holley & Marchal 2004). From recent scientific surveys, side scan sonar and underwater video images often show the characteristic seabed scars of otter boards through the coral banks and some investigations have found coral samples with entangled longlines and pieces of coral branches on the bottoms or fishing gears remains (e.g. Morgan et al. 2005, Taviani et al. 2005).

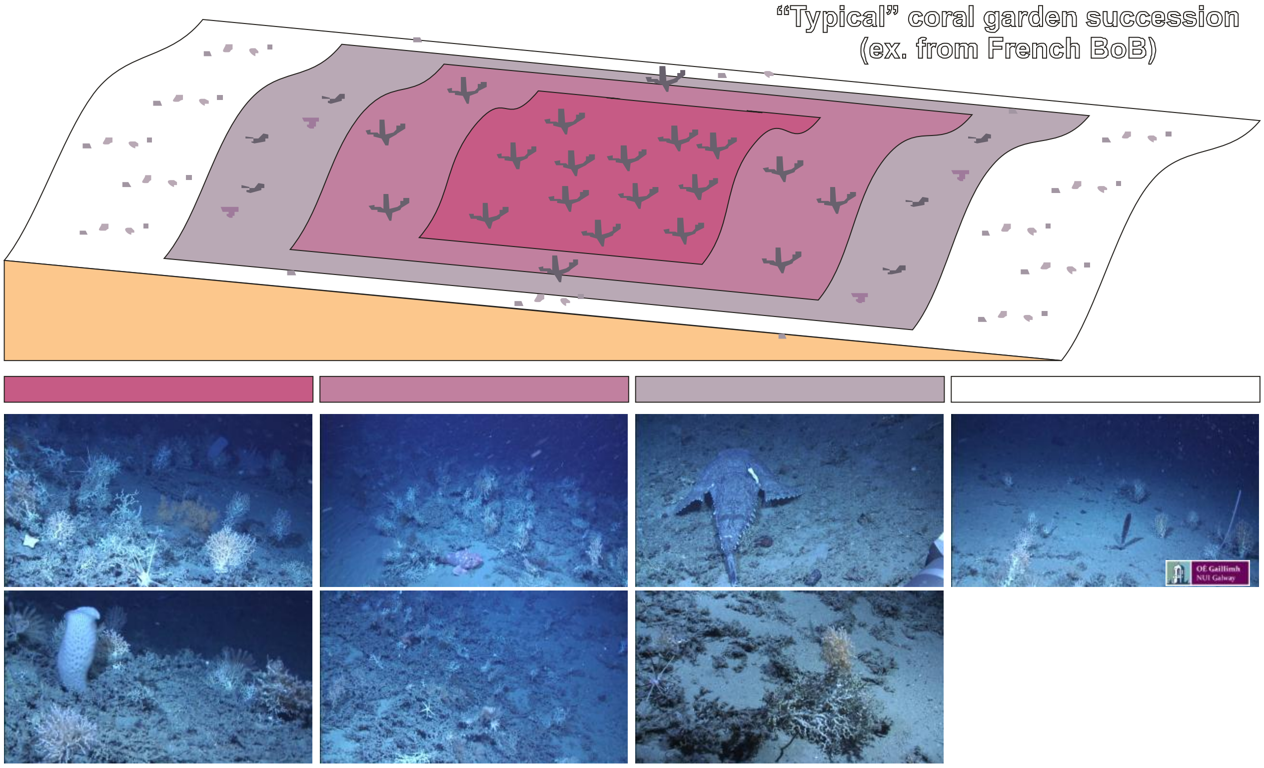


Figure 4.20 - Illustration of the habitats succession in and around a CWC garden on the shelf break of the Bay of Biscay (images from Celtic Explorer survey CE0907, NUI Galway / Ifremer).

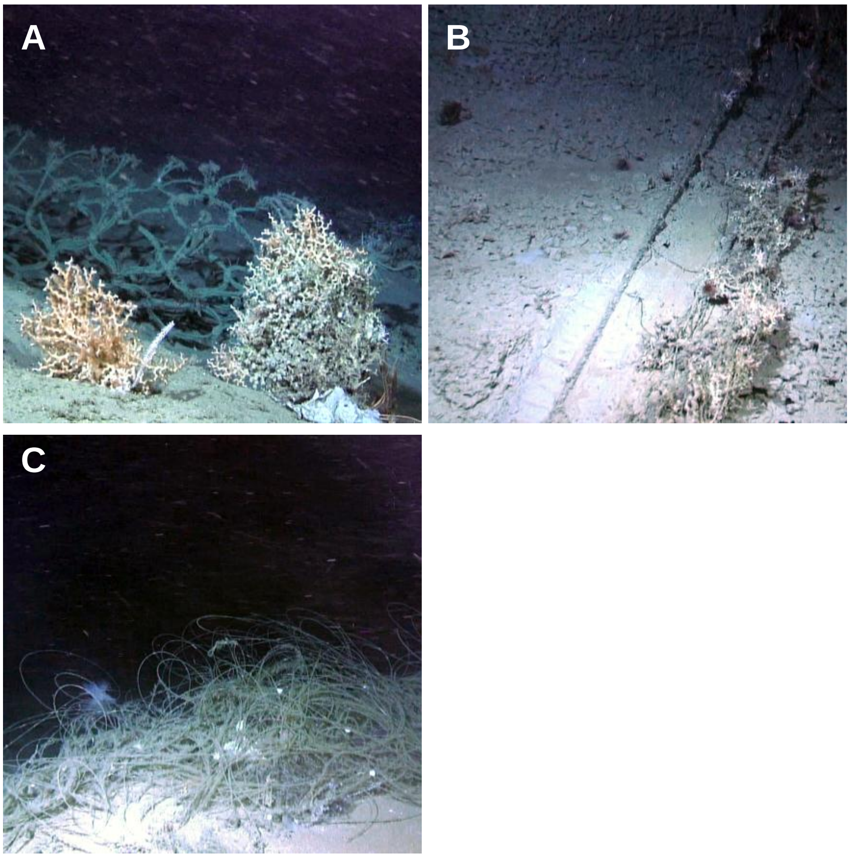


Figure 4.21 - Examples of fisheries activity remains in the vicinity of CWC habitats. A, B and C on the continental slope in north of the Bay of Biscay, trawls and longlines (depth 1150, 790 and 680m for A, B and C respectively).

Although some fisheries are still spreading over new grounds, the rate of expansion of impact on CWC is not known with accuracy. Some quantitative estimates of the proportion of impacted CWC communities have been conducted off the Norwegian coast (Fosså et al. 2002). Many coral-areas have been destroyed by fishing in Icelandic waters (Steingrimsson et al. 2006). Evidence of trawling impacts from recent ROV surveys and fishermen testimonies state that Western Irish continental shelf and Bay of Biscay slope have been submitted to heavy fishing impact during the 20th century. In the Mediterranean, there are CWC areas impacted by deep-water trawl fishing targeting red shrimps (*Aristeus antennatus* and *Aristaeomorpha foliacea*) and longline fishing directed to hake, greater forkbeard (*Phycis blennoides*), gurnard (*Chelidonichthys lucerna*), Blackbelly rosefish, conger (D'Onghia et al. 2010, Indennidate et al. 2010). Thus, fishing had greatly affected CWC habitats and may still affect those fragile ecosystems.

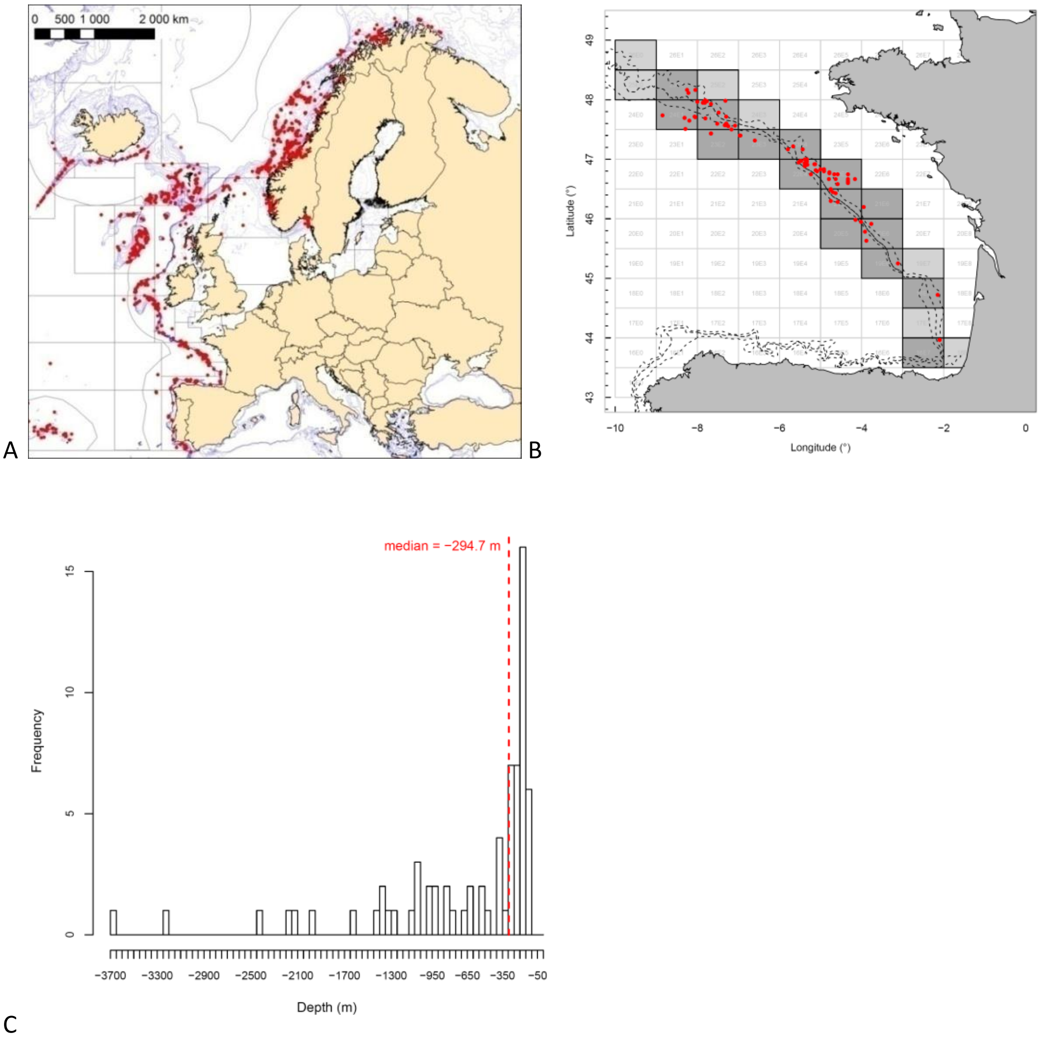


Figure 4.22 - Distribution of CWC locations (*Lophelia* and/or *Madrepora* habitats) accross European seas, B) Zoom into the bay of Biscay (BoB) region, continuous red isobath lines indicates the main bathymetric ranges of CWC habitat in the BoB (200 to 800m), B) logbook statistical ICES squares grid. Grey ICES squares are those selected in the bathymetric range of CWC habitats, darkgrey squares are those with CWC records. CWC records are also shown and C) bathymetric distribution (in m) of recorded CWC. CWC locations area derived from OSPAR GIS database (in http://www.searchnbn.net/), Reveillaud et al. (2008) and the most recent CWC observations from ROV surveys (CE0907-N/0 Celtic Explorer & BoBEco-N/O Pourquoi Pas? surveys, personal communication B.Guillaumont, Ifremer).

4.3.3. SUB-CS3 / Norwegian waters

4.3.3.1 Introduction

This is a description of the types of fishing gear currently used by Norwegian and foreign vessels in Norwegian fisheries. It is mainly bottom trawling for fish and shrimp that is relevant in terms of having an impact on sediments and benthic fauna, and which areas of the Norwegian sector are exposed to these gear types, as well as the degree of exposure. The final section describes ongoing and future technological developments that will help to reduce the impact of trawling on sediments.

4.3.3.2 Description of the fishing gears used in Norwegian fisheries that contact the seabed

There follows a general description of the most widely used fishing gears in Norwegian fisheries that contact the seabed. A detailed description of the design, capture method and operation of the various fisheries is given by von Brandt (1984) and Karlsen et al. (2001).

Bottom trawls: Bottom trawls are essentially conical nets that are dragged along the sea floor. The trawl net is held open using trawl floats, ground gear and trawl doors. The trawl doors that are used by the biggest vessels can each weigh up to 5-6 tonnes. The trawl is dragged along the bottom at a speed of between two knots (shrimp trawling) and five knots (fish trawling). The trawl doors are connected to the net by sweeps made of steel wire or chain. These can be 30-150 m long. Under the net there is the ground gear, which is designed to protect the net against wear, and to help it across rough terrain. There are various designs of ground gears, as shown in Figure 4.25. In traditional bottom trawling, the trawl doors, sweeps and ground gear all come into contact with the ground during trawling. Depending on the length of the sweeps, the width of seabed affected by a single bottom trawl can vary between 40 and 200 m. Assuming a speed of four knots, and a width of 100 m at the trawl doors, this equates to 740,800 m2 of affected seabed for each hour of trawling. In modern bottom trawling, multi-rig trawling is also used, which involves two or three trawls being tied together so that they can be dragged side by side. Twin rig trawling involves the use of two trawl doors, two trawls and a weight located between the middle warp (towing cable) and the sweeps going to each of the trawls. The weight is approximately 30 per cent heavier than the trawl doors. Twin rigs are mostly used for shrimp trawling, and to some extent for cod trawling. Triple rigs, which consist of three trawls, two trawl doors and two weights, are also used for shrimp trawling. A third type of bottom trawling is pair trawling, where two vessels drag a single trawl. In that case there are no trawl doors, but there may be weights at the transition between the warps and sweeps.

Danish and Scottish seines: A Danish seine consists of a conical net with wings, rather like a trawl. What is special about a Danish seine is that the net is laid out in a triangle on the seabed using very long ropes that are hauled in by an anchored vessel. A variation on the Danish seine is the Scottish seine, which involves a vessel using its own power to maintain a virtually constant position while towing in the ropes. The technique is illustrated in Figure 4.28. The rope length on each side can vary between 1,000 and 2,500 m. As the two ropes are hauled in the net gradually closes, and towards the end of the haul it moves forwards in the same way as a trawl.

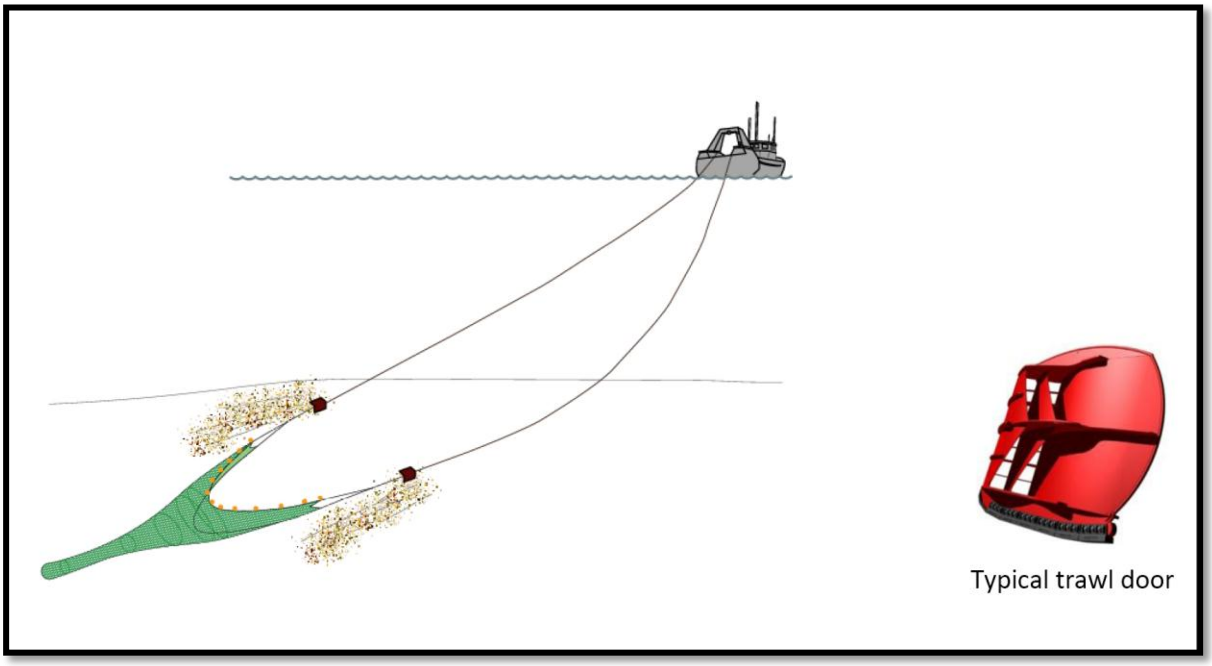


Figure 4.24 - Illustration of bottom trawling using a single trawl.

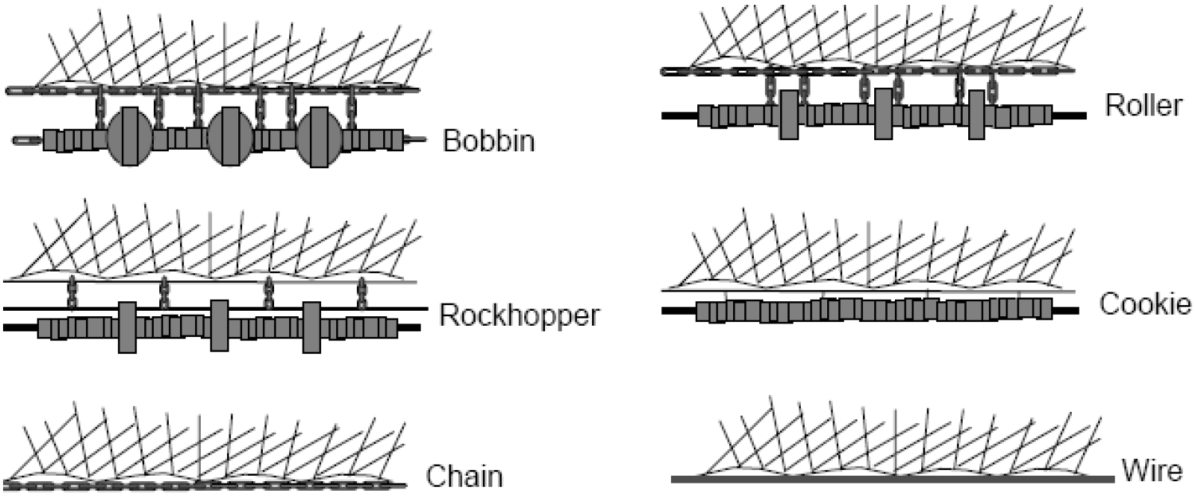


Figure 4.25 - Examples of ground gear designs for bottom trawling.

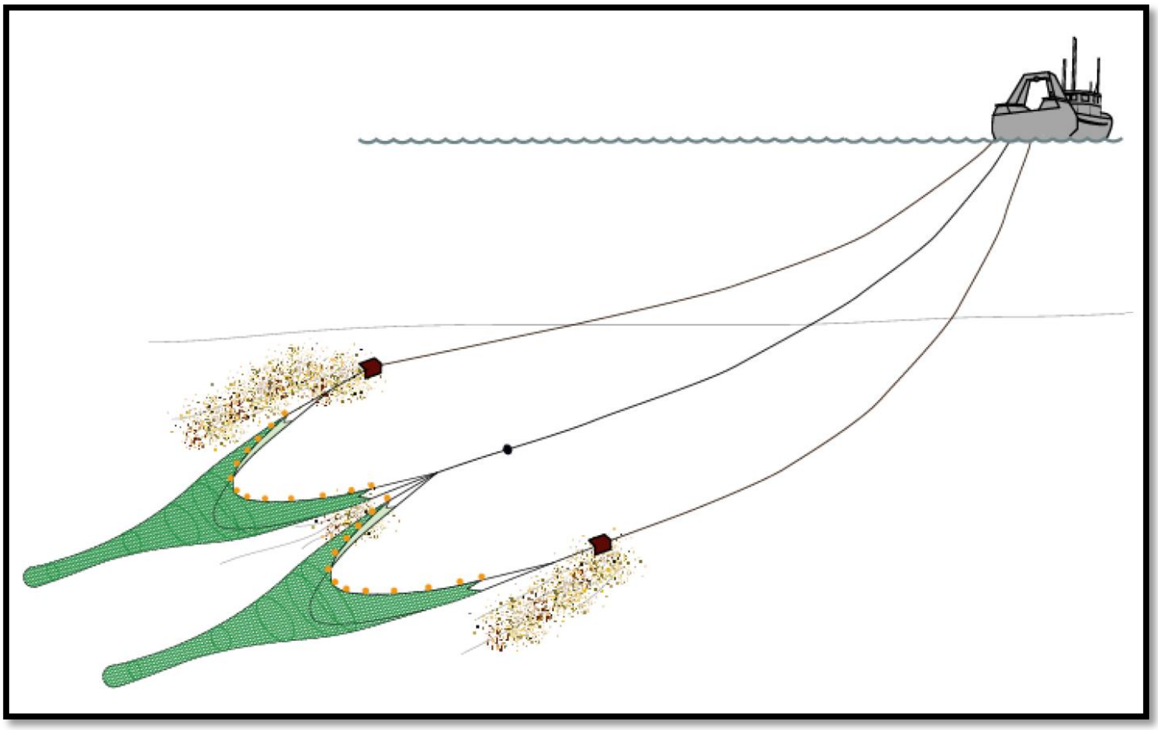


Figure 4.26 - Bottom trawling using two trawls (twin rig trawling).

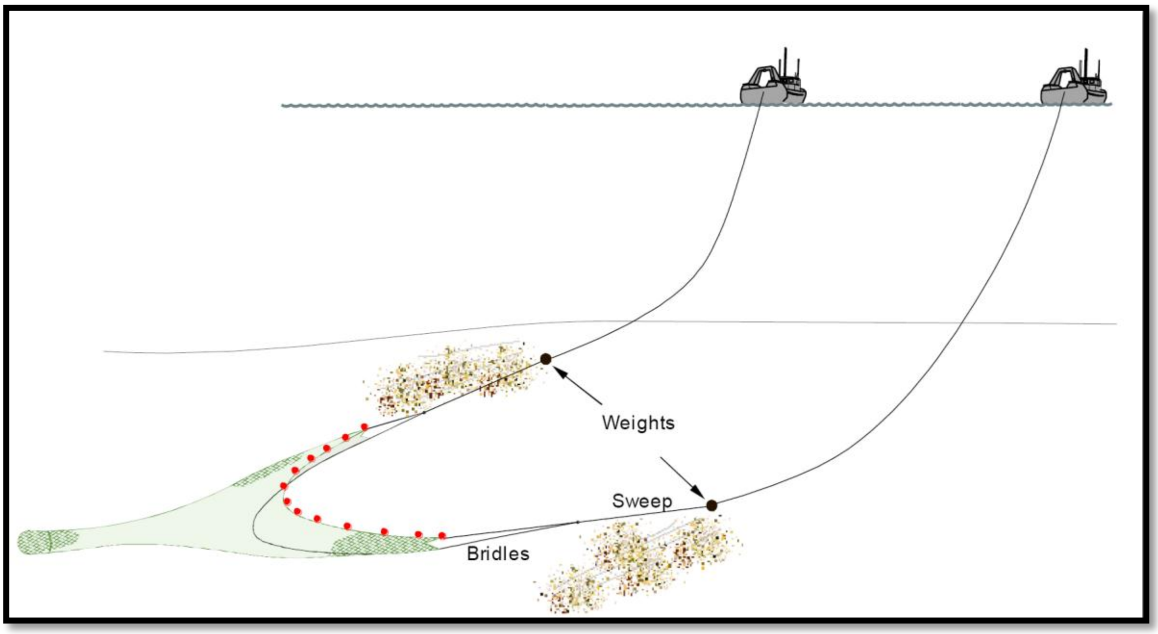


Figure 4.27 - Pair trawling with a bottom trawl.

Danish and Scottish seines have lighter ground gear than trawls. They involve “shooting” the net at schools of fish. The area of seabed affected mainly depends on the length of the ropes used and the sea depth, and is therefore much smaller than the area affected by trawling. The biggest impact is from the ropes, when they are pulled together in the first phase of the operation. Since this kind of fishing is dependent on the ropes not getting caught on obstacles during the herding phase, there are clear limitations on the sediment types where it can be used. No studies have been done to document the physical impact of Danish and Scottish seining on seabed habitats. The potential effects are probably much smaller than for bottom trawling, since there are no trawl doors, the ground gear is lighter and the seine is not dragged long distances. However, the ropes may have a physical impact similar to that of the sweeps of a trawl.

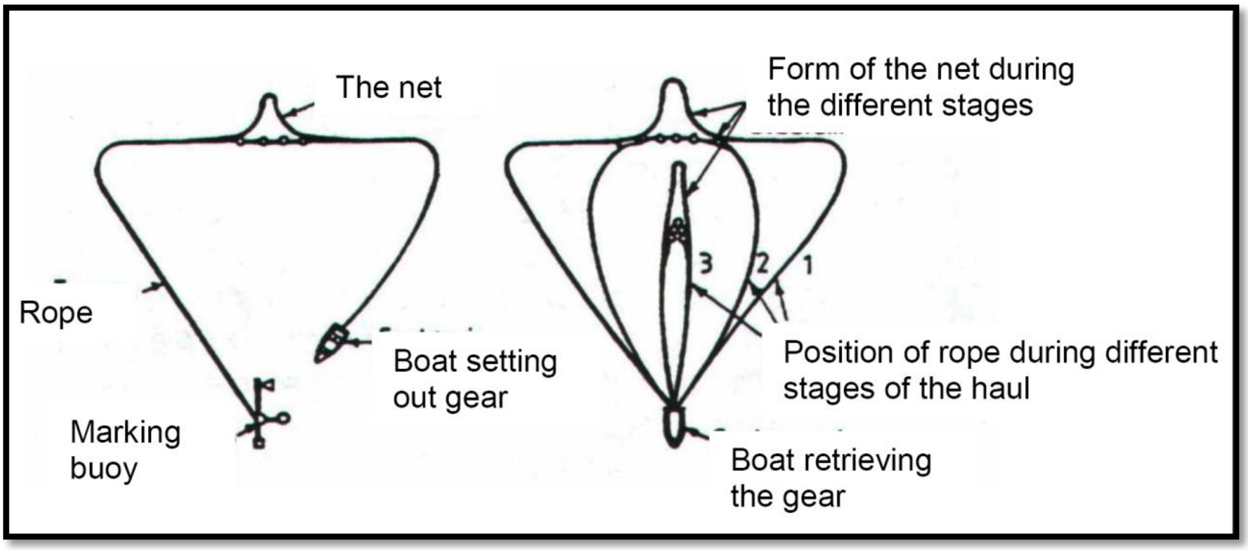


Figure 4.28 - Sketch showing the principles of Scottish seining.

Pelagic trawl: This fishing gear is mainly used when targeting pelagic species (e.g herring, mackerel, capelin, blue whiting). The trawl is towed through the pelagic zone, and does not come into contact with the seabed. Under current regulations, pelagic (midwater) trawling is defined as trawling where no parts of the fishing gear contact the seabed. However, pelagic trawling is also increasingly being used to catch codfishes during the periods when they swim up from the sea floor. Pelagic trawling has been particularly successful in the saithe fishery, where it is often used in such a way that parts of the trawl come into contact with the seabed.

Demersal longline: Demersal longlines are set on the sea floor, and have a grapnel at either end. The grapnel, the line itself and the hooks lie on the ground during fishing. With the exception of the grapnel, which is heavy, this gear won't affect the seabed, as the line, hooks and bait are of low density. However, the hooks may catch on benthic species, so sponges and corals are sometimes torn loose when the line is hauled in. The line can only affect a narrow strip of the seabed, so it has a small footprint. Longlines are often set parallel to one another at a distance of around half a nautical mile.

Semi-pelagic longline: This method is a hybrid between a pelagic and a demersal longline. The line is raised off the seabed using floats, and the hooks do not come into contact with benthic organisms. Semi-pelagic longlines have a grapnel at each end, and are anchored to the sea floor using stones roughly every 100 metres. This type of longline therefore only potentially affects the seabed in small, scattered locations.

Gill nets: Gill nets are set along the sea bed. At the top they have a float line to keep the top of the net up, and at the bottom they have a lead line or iron rings to keep the bottom of the net on the ground. Like longlines, gill nets only come into contact with a narrow strip of the seabed. In strong currents, the bottom of the net itself may also be pushed onto the ground. When they are hauled in, the nets can tear loose benthic organisms that have become entangled in the net. Another problem, which is a serious issue in some areas, is "ghost fishing". This happens when nets that are lost for one reason or another remain on the seabed and continue to catch fish, and in some cases also damage the sea floor. The Norwegian Directorate of Fisheries puts a significant amount of resources into clearing up lost nets, which is important both in terms of protecting habitats and fish stocks.

Pots: Pots are cages used to trap fish and crustaceans that are lured into them by bait. In Norwegian fisheries, pots are mainly used to target crustaceans (brown crab, king crab, lobster) and to a lesser extent when targeting codfishes (tusk, ling, cod). The normal size of a cod pot is 1.0 x 1.5 m, which is also the size of the seabed area that the gear comes into contact with. Raised pots have also been developed, which are held up by floats, in order to avoid taking a king crab bycatch. Cod pots are set 30-50 m apart.

4.3.3.3 Importance of gear types with benthic impact in regional seas

Fleet structure, landed catches and catch value

Table 15 shows the approximate distribution of vessels by fishing gear type in 2011, based on the Electronic Reporting System (ERS). It should be noted that many vessels use several fishing gears, and the type of gear/code can therefore change from report to report, depending on which gear has been used. The summary shows reported shrimp catches under shrimp trawlers, even if those vessels have also landed fish. Beam trawls are only used to a very limited extent in the North Sea/Skagerrak, so they have been included in the bottom trawl category. It would be possible to use this data to categorise the catches more precisely, but it would require a more detailed analysis.

Table 4.11 - Distribution of vessels by fishing gear type in Norway in 2011, based on data from the Electronic Reporting System (ERS) provided by the Directorate of Fisheries.

Fishing gear type	Fishing gear code (Directorate of Fisheries)	Number of vessels
Purse seine	10 & 11	195
Pelagic trawl	53 & 54	56
Hooks and lines, pelagic	31, 33 & 34	27
Gill nets	20 & 22	109
Hooks and lines, demersal	30 & 32	91
Pots	42	9
Bottom trawling, fish	51	70
Bottom trawling, shrimp/langoustine	55	87
Danish and Scottish seines	61	175
TOTAL		**819**

The shrimp/lobster trawl category almost entirely relates to trawling for the shrimp species Pandalus borealis, but other species in the Pandalus genus and the Norway lobster or langoustine (Nephrops) are also included in this group. Langoustine trawling is only done on a very small scale, and only in parts of the North Sea/Skagerrak, but all shrimp and langoustine species have been included in the same category here, due to some incorrect classifications in the catch logs.

The total volume of the catch landed in the Norwegian economic zone increased each year over the period 2005-2010, but then fell slightly in 2011. In spite of the lower volume, the value of the catch was highest in 2011.

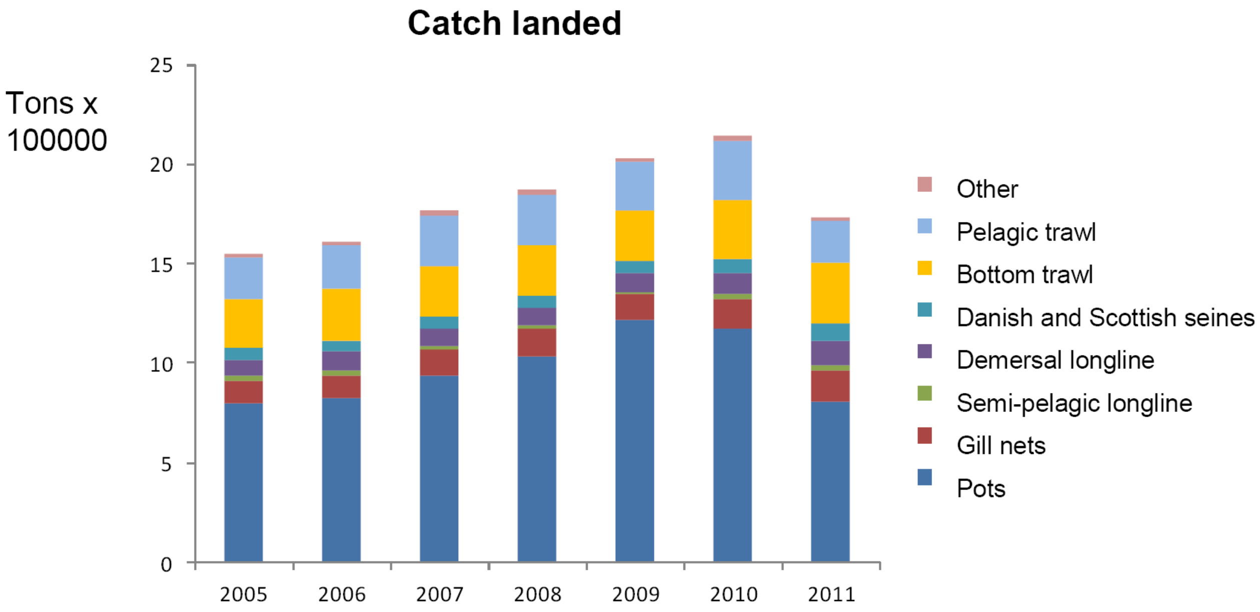


Figure 4.29 - Total landed catch (in 100,000 tonnes round weight) by fishing gear type in the Norwegian economic zone over the period 2005-2011; data from the Directorate of Fisheries (2012).

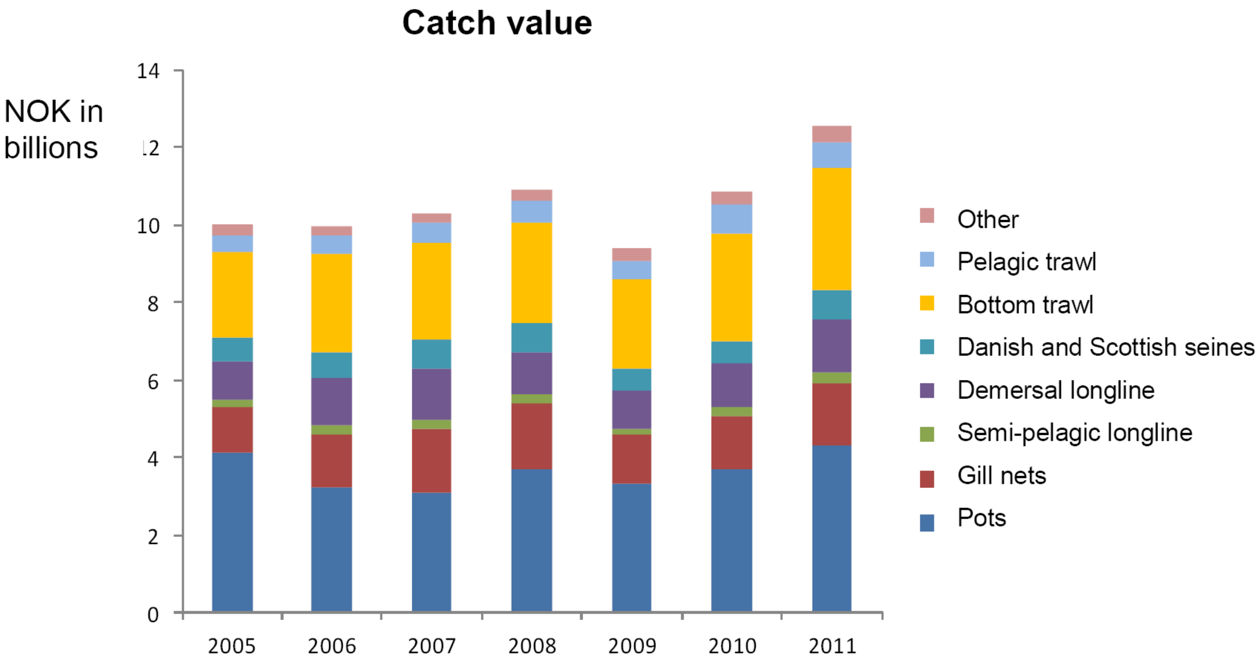


Figure 4.30 - Total catch value (in NOK billion) by fishing gear type in the Norwegian economic zone over the period 2005-2011; data from the Directorate of Fisheries (2012).

4.3.3.4. Distribution of fishing effort as indication of fishing pressure in regional seas

The estimates of trawling intensity and maps have been calculated using ERS data for 2011. The data includes all Norwegian and foreign vessels above 15 m that used bottom trawls in the Norwegian economic zone (NOR) or fisheries protection zone (XSV). In the ERS regulations, the duration of the capture operation is defined as the period from when the trawl is shot until the gear is back on deck, and is therefore a slight overestimate of the time that the gear is in physical contact with the seabed. In order to map where trawling took place, including which areas were exposed, and the trawling intensity in those areas, the GPS coordinates for shooting and hauling in the ERS data were analysed and plotted in a Geographic Information System (GIS).

Each data point was allocated to the relevant geographic cell (5 x 5 km). The towing distances were calculated as straight lines between the recorded initial (shoot) and final (haul) positions. The trawl intensity was calculated for each cell as the distance per area (km/km2). Figure 4.31 shows the geographic distribution of bottom trawling carried out by Norwegian and foreign vessels in Norwegian waters in 2011.

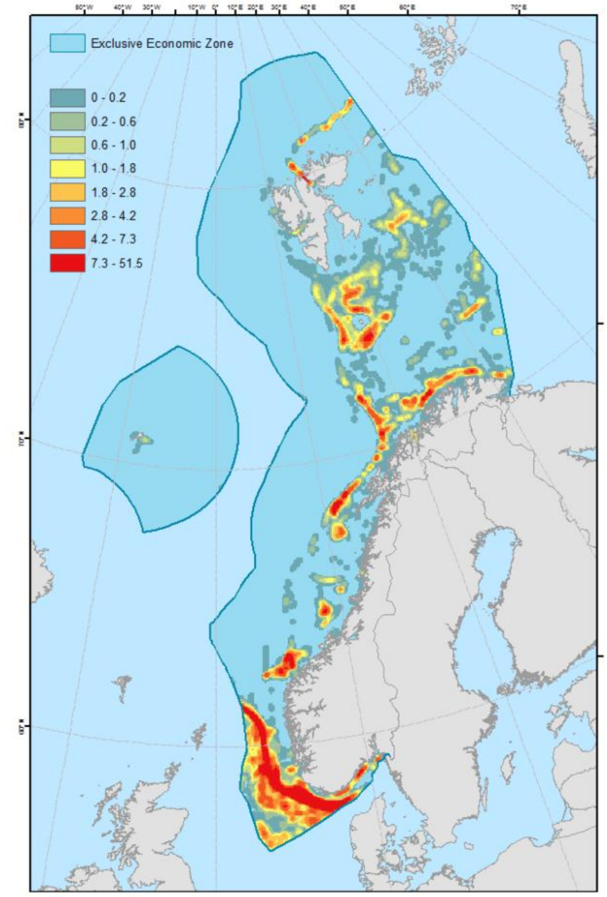


Figure 4.31 - Trawling intensity in Norwegian waters (Norwegian and foreign vessels) in 2011, plotted on 5x5 km cells. The scale indicates the trawling intensity in towing distance by area (km/km2), split into 8 intensity categories (quantiles). The total area trawled is 607,683 km2, with an average trawling intensity of 0.17 km2/km2 in the affected cells. Blue represents areas not exposed to trawling.

Bottom trawls are mainly used to target cod, haddock and saithe, whereas shrimp trawls almost exclusively target the shrimp species Pandalus borealis. Overall, there is a lot of trawling in large parts of the North Sea, from the Dogger Bank and the German Bight in the south to Tampen in the north. Large areas of medium to high trawling intensity can be found in Skagerrak and the northern part of the North Sea. The highest intensity area stretches from Skagerrak along the Norwegian Trench to north of Shetland. There are some other areas exposed to high trawling intensity: off Møre, Haltenbanken, Sklinnabanken and the banks and outer continental shelf off Nordland. However, large parts of the waters closest to the coast of western Norway are unaffected by trawling. Medium to high intensity areas stretch north from Vesterålsbankene up to the banks off Troms and Tromsøflaket. There is also a belt of relatively high trawling intensity in the banks off Finnmark. The map shows that there is medium to high trawling intensity in the area around Bear Island and in the northern parts of the Barents Sea. There is also trawling by Svalbard and in the area around Jan Mayen, including some high intensity areas. However, large parts of the central and eastern Barents Sea are not exposed to trawling.

The total seabed area exposed to bottom trawling is estimated to be 607,683 km2, or 25.1% of the Norwegian exclusive economic zone (2,419,182 km2 in total). The average trawling intensity within this area was 1.7 km/km2, which assuming an average door spread of 100 m equates to an average affected area of 0.17 km2/km2 within the relevant cells. The true area may be somewhat higher, however, due to changes of course while trawling, e.g. trawling in an arc, in which case the towing distance is longer than the distance between the initial and final positions. This is partly compensated by the fact that the gear will not have been in contact with the seabed throughout the period recorded by the ERS.

4.3.3.5. Distribution of benthic habitats or substrates in regional seas

Distribution of vulnerable habitats has been modelled using conditional inference model for large parts of the area mapped by Mareano.. Mariano also provides predicted maps of biotopes based on ordination analysis of megafauna composition. Substrates have been mapped for the whole Mareano mapping area. The substrate map is based on interpretation of backscatter and topography calibrated with ground truthing data from video observations and bottom samples.

4.3.3.6. Overview of distribution of fishery according to environment in regional seas

By comparing the distribution of vulnerable habitats with the distribution of trawling activities it is possible to identify potential areas of conflict. Moreover, it is possible to use information about the distribution of large benthic species to study the chronic effects of trawling, by comparing those data with past trawling activity. Much of the trawling activity is taking place at the margin of the continental shelf and coincides with the occurrence of VMEs e.g. sponge and coral communities.

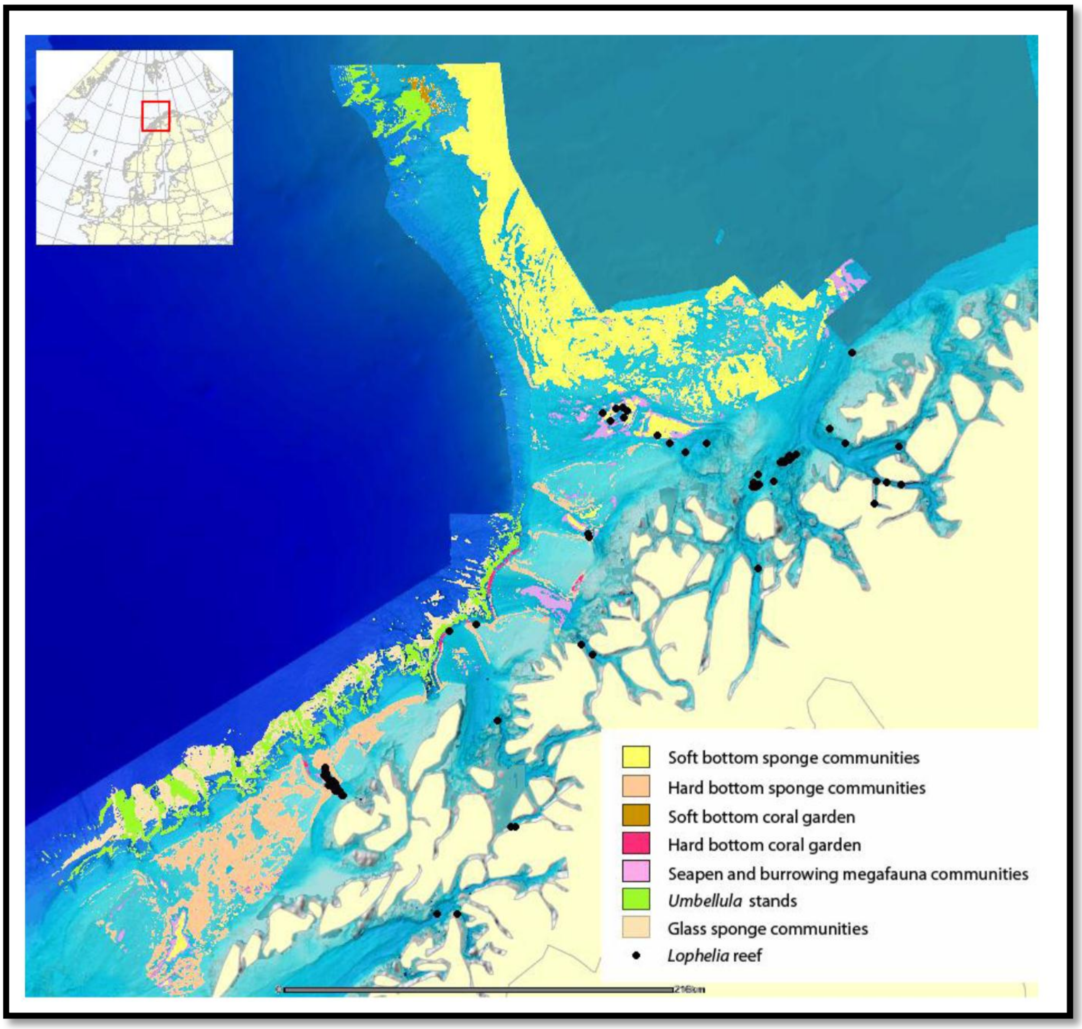


Figure 4.32 - The distribution of vulnerable benthic habitats based on information from MAREANO.

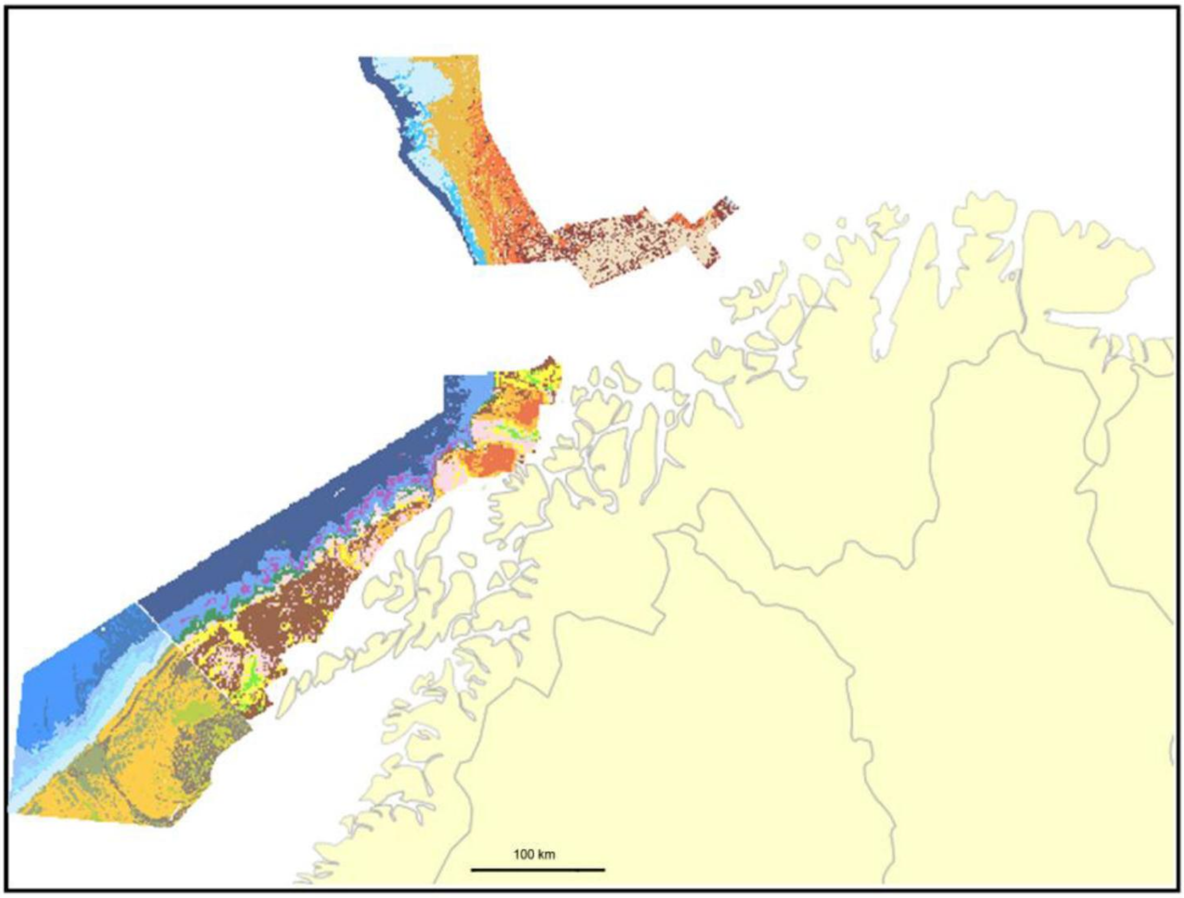


Figure 4.33 - Map of predicted (Maxent) biotopes within three subareas of the Mareano mapping area. The modelling is based on ordination analyses of megafauna data from video. Note that the areas of biotopes indicated with different colours are not comparable between the three areas analysed separately. Further work is needed to provide standardized and comparable biotopes..

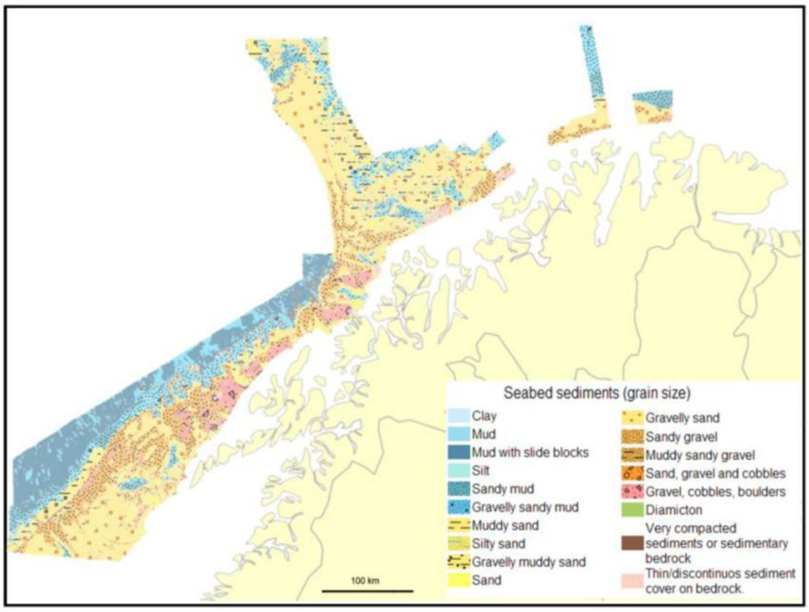


Figure 4.34 - The distribution of sediments based on information from MAREANO.

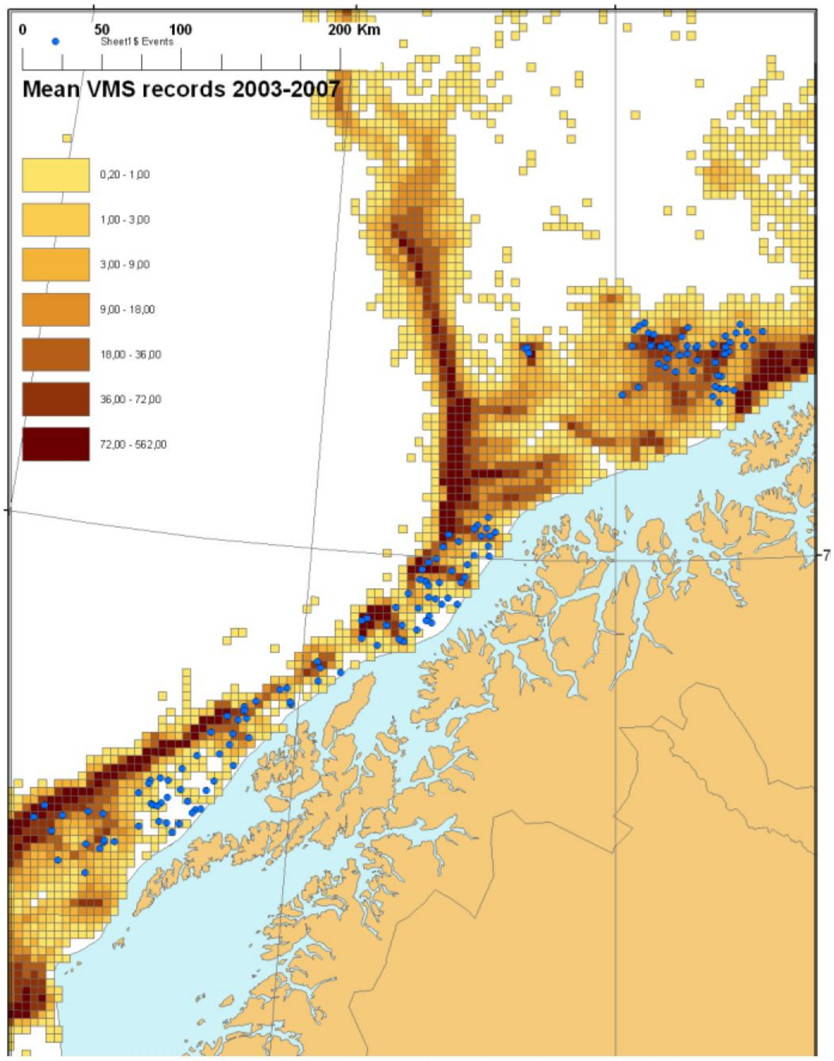


Figure 4.35 - Average annual trawling activity (otter trawl) based on satellite tracking (VMS data) for a five-year period (2003-2007). The colour codes represent activity level categories: 0.2-1, 1-3, 3-9, 9-18, 18-36, 36-72 and > 72 trawlers recorded per year within 5x5 km grid squares. The blue spots represent places where MAREANO video observations have been used to analyse the impacts of trawling.

5 - MEDITERRANEAN SEA

5.1. Introduction

The Mediterranean is considered as one of the most important marine regions in the world for its peculiarities and biodiversity levels. This semi-enclosed marine sea area is generally characterised by narrow continental shelves, deep waters, warm temperatures, high evaporation and low primary production (Papaconstantinou and Farrugio, 2000). The total area of Mediterranean Sea is 2,528,398 km^2 with a shelf area of 326,665 km^2 and an inshore fishing area of 520,837 km^2. The Mediterranean region is characterised by a very high level of anthropogenic pressure with fishing vessels from more than 20 countries sharing the same pool of fisheries resources. In terms of fisheries, its two fundamental characteristics are the large variety of species harvested and the absence of large single-species stocks (with some exceptions such as bluefin tuna) compared to those inhabiting the coastal borders of open oceans and the subject of extensive fisheries (Lleonart, 2004). Fishing activities in the Mediterranean employ several hundreds of thousand persons and largely have artisanal characteristics. The fishing gears used are highly diversified and the fleets are generally composed of large numbers of vessels, mostly of low tonnage, based in a multitude of ports. Bottom trawling is one of the most important fishing sectors in terms of fleet dimension, fishing power and income although relatively low in percentage vessel composition. The bottom trawler fleet is characterised by the peculiar multi-gear and multi-species Mediterranean fisheries characteristics. Mono-specific fisheries are very rare and are largely limited to deep shrimp fisheries on muddy slope bottoms. Demersal fish (also called groundfish) stocks have traditionally provided the most important catches in economic terms, and several species have a very high commercial importance at the local level. The high marketability of small fish in many countries encourages the targeting of the juvenile fraction of some species, often in violation of laws regarding minimum sizes. Mediterranean fisheries management is therefore a complicated task. There are no quotas in the trawl fishery and generally speaking management is based on number of vessels (by limiting the number of licenses or permits issued), size of engine, spatio-temporal closures, and minimum landing sizes (Lucchetti *et al*., 2014).

The negative effects of fishing on marine ecosystems and benthic communities have been known for a long time and represent a world-wide concern. In the Mediterranean, they vary from local effects on the seabed caused by trawling gears to large-scale impacts on food web structures. This variety (which makes the Mediterranean a unique global model for the implementation of the Ecosystem Approach to Fisheries) is due to four main interrelated factors: the huge diversity of fishing gears and practices, the very high intensity of fishing, a high diversity of habitats distributed from shallow-waters to the deep-sea and the oceanic domain, and an important biological diversity. The latter is demonstrated in the Mediterranean presence by a vast array of vulnerable species, many of them listed in international protection agreements that include emblematic sharks, turtles, whales and seals. Evidence shows that the effects of fishing in the Mediterranean go far beyond the isolated impacts on overfished target species, vulnerable non-commercial groups or sensitive habitats. The ecosystem effects of fishing in the Mediterranean are also conspicuous at the systemic level, as highlighted by the massive ecological footprint of fishing or the marked effects on the foodweb structure. A holistic approach should therefore be adopted if the overall changes to the structure and the functioning of marine ecosystems caused by fishing are to be remedied.

5.2. Fishing Gears & Bottom Contact

There are a wide variety of fishing gears used in the Mediterranean, partially reflected by the widely differing cultures and levels of economic development form North to South and East to West. It is difficult to separate all gears because of limited reporting, but gross categorisation of gear use contributing to reported catches is given in Table 1 based on the average contribution to catches from the *Sea Around Us* project database (based on FAO data and available at www.seaaroundus.org), for the Mediterranean, averaged over the last few years of available data (2001-2006). The tables shows that the most impacting gears, Bottom trawls comprise on average 12.2% of the recorded Mediterranean landings with dredges comprising another 3%. Generally speaking there are some issues with Mediterranean level reported catch data due to differences in accuracies, categorisations and underreporting, but the representation by the gears is felt to be accurate.

Table 5.1. Gross category gears used in the Mediterranean and how their average percentage composition of total Mediterranean landings in the period 2000-2006 (abstracted from *Sea Around Us* database, www.seaaroundus.org). Bottom trawls highlighted in grey.

Gear	Percent
Gillnets	15.62
Purse seines	19.45
Mid-water trawls	19.30
Bottom trawls	12.21
Lampara-like nets	4.13
Seine nets	3.73
Hooks or gorges	3.19
Shrimp trawl	3.53
Traps	2.56
Dredges	3.00
Boat seines	2.87
Other gears	10.42

At the country level for Italy and Greece, two EU Member States, the data are at a more accurate level and the 2014 fleet registry for these countries is given in Table 2 and 3 (data from EC fleet register for 2014, http://ec.europa.eu/fisheries/fleet/index.cfm). These tables show some of the differences at the country level where, for example Greece, has a very large fishing fleet, 25% larger than Italy although landings in Greece are approximately 30% of the Italian landings. This is because Greece has a very high number of small artisanal fishery boats, mostly netters or long liners. With both countries reporting, there are still difficulties in having an absolutely correct picture as the gears recorded are the primary licences and vessels may have other licences for other gears and switch depending on catch area or season. Of the 12,689 Italian registered fishing vessels, 2790 or 22% are bottom trawlers and 717, 5.6% are dredges. In Greece 292 or 1.8% of the vessels are registered for bottom trawling as their primary fishing gear and 44 or 0.3% as dredges. In very shallow coastal waters beach seines actively move along the bottom from a fixed point, but the gear is generally much lighter than standard otter trawling gear and the activity has a small fishing footprint close inshore. Purse seines could scrape across the bottom, but are restricted to depths where they may not reach the bottom, although there is perhaps some illegal fishing in waters where they do contact the seabed.

Table 5.2. Standard category fishing gears registration for Italian fishing vessels in 2014 (abstracted from EC fleet register for 2014, http://ec.europa.eu/fisheries/fleet/index.cfm). Bottom trawls highlighted in grey.

Code	Category	Vessels	%
DRB	Boat Dredges	717	5.65
GND	Drift Nets	146	1.15
GNS	Set Gillnets	2255	17.77
LHP	Handlines (mechanical)	10	0.08
LLS	Set Longlines	4845	38.18
OTB	Otter Trawl	2790	21.99
PS	Purse Seine	1919	15.12
PTM	Midwater Pair Trawl	2	0.02
TBB	Beam Trawls	5	0.04
	Total	12689	

Table 5.3. Standard category fishing gears registration for Greek fishing vessels in 2014 (abstracted from EC fleet register for 2014, http://ec.europa.eu/fisheries/fleet/index.cfm). Bottom trawls highlighted in grey.

Code	Category	Vessels	%
DRB	Boat Dredges	44	0.28
DRH	Hand dredges	5	0.03
FPO	Pots/Traps	373	2.36
GNC	Encircling Gillnets	13	0.08
GNS	Set Gillnets	2442	15.43
GTN	Combined Gill/Trammel	686	4.33
GTR	Trammel Nets	6974	44.06
LHM	Handlines (mechanical)	9	0.06
LHP	Handlines (manual)	232	1.47
LLD	Drifting Longlines	157	0.99
LLS	Set Longlines	4058	25.64
LTL	Trolling Lines	30	0.19
OTB	Otter Trawl	292	1.84
PS	Purse Seine	251	1.59
SB	Beach Seine	261	1.65
	Total	15827	

Bottom nets and traps will have some contact and scrape along the seabed when they are hauled, but impacts are probably quite low. Hook lines and hook long lines may also contact the seabed (either hooks or line weights) but with less impact than nets and traps. The gears that have the most bottom contact are bottom trawls, beam trawls and dredges (Lucchetti and Sala, 2010). The latter two gears are not widely used in the Mediterranean and therefore the most impacting gear is the bottom trawl.

5.3. Importance of Gear Types

There are a number of landings databases for Mediterranean countries, all of them with slightly different reported data. The General Fisheries Council of the Mediterranean reports for all Mediterranean countries with a time lag for publication of several years. The Sea Around Us project uses this and FAO data to 'clean' and categorise on a higher level, but has a current 8-year lag. The EU has the shortest lag (2 years) and some of the most comprehensive statistics but only reports for the EU countries (8 out of 21 Mediterranean countries) and sometimes groups its data by Mediterranean and Black Sea Member States rather than those two sea areas individually (e.g. STECF, 2013). In terms of overall landings Table 4 shows the recent recorded Mediterranean landings. Applying the 2000-2006 constant value of 12.2%, the catch attributed to trawling only is shown next to the total Mediterranean landings.

Table 5.4. Mediterranean landings from 2006 until the most recent available year from GFCM records. Landings are total and for trawl catch by applying a 12.2% composition of trawlcatches.

Year	Total	Trawl
2006	1030451	125941
2007	876664	107146
2008	912146	111482
2009	929802	113640
2010	861280	105265
2011	841442	102841

Data for different metiers at higher level are not available at the Mediterranean level. At the EU level reporting is more detailed and shows the 2012 Italian fisheries metier data, including segment, number of vessels, full-time employment, effort in days at sea, landings and landings value (Data from STECF, 2013).

Typically while the majority of the vessels are the small sized coastal artisanal fishing vessels (mostly netters, PGP) that have the highest number of fishermen, the largest part of the landings are from trawlers (DTS). In terms of overall value, the highest value is from the trawl fishery, although netters and hookers have a slightly higher catch value per ton. The lowest value is from the pelagic trawlers (TM) and purse seiners (PS) targeting small and medium pelagic fisheries. Further data and calculations are available in the STECF (2013) report.

Recent similar data is not available for the Greek fishing industry due to lack of Greek reporting to the EU. Table 5.6 shows the Greek fleet data for 2007, abstracted and converted to similar categories as the Italian data above from STECF (2010).

Table 5.5. Italian fishing metiers information for vessels effort, Full-time employment (FTE), days at sea landings and value by individual metier and grouped segments. Metiers are DTS Demersal Trawl/Seine, HOK Vessels fishing with Hooks, TM Pelagic Trawler, DRB Dredge, PGP Polyvalent Passive Gears, PMP Combined Mobile & Passive Gears, PS Purse Seiner, TBB Beam Trawl, VL Vessel. Segment numbers length range i.e. 1218 = 12-18 m length.

Segment	Vessels	FTE(N)	DaysAtSea	Landings (kT)	Landing Value (kE)
DTSVL1218	1424	2671	200143	29998	205116
DTSVL1824	731	2210	111000	26144	183368
DTSVL2440	233	1335	38440	11468	105769
DTSVL0612	178	125	17961	1607	10700
Total	2566	6341	367544	69217	504953
HOKVL1218	142	324	15661	2614	22640
HOKVL1824	48	194	7819	2653	16454
Total	190	518	23480	5267	39094
TMVL1218	26	17	3075	5675	5104
TMVL1824	44	95	5152	8574	8323
TMVL2440	77	216	10565	21280	29200
Total	147	328	18792	35529	42627
DRBVL1218	708	306	59870	21790	62618
Total	708	306	59870	21790	62618
PGPVL1218	448	988	66030	7552	58553
PGPVL0612	6012	6043	817321	28139	226808
PGPVL0006	2821	2129	355710	8344	68453
Total	9281	9160	1239061	44035	353814
PMPVL1218	37	61	4555	495	4084
PMPVL0612	42	16	4902	233	1974
Total	79	77	9457	728	6058
PSVL1218	132	272	12800	9064	22563
PSVL1824	47	130	3649	8623	15297
PSVL2440	64	243	5363	11415	19624
PSVL40XX	17	16	261	920	6239
Total	260	661	22073	30022	63723
TBBVL1218	12	16	927	251	1155
TBBVL1824	27	22	3463	788	6012
TBBVL2440	32	112	3794	2696	10273
Total	71	150	8184	3735	17440
All Vessels	13302	17541	1748461	210323	1090327

Table 5.6. Greek fishing metiers information for vessels effort, Full-time employment (FTE), days at sea, landings and value by individual metier and grouped segments. Metiers are DTS Demersal Trawl/Seine, HOK Vessels fishing with Hooks, PGP Polyvalent Passive Gears, PMP Combined Mobile & Passive Gears, PS Purse Seiner, VL Vessel. Segment numbers length range i.e. 1218 = 12-18 m length.

Segment	Vessels	FTE (N)	DaysAtSea	Landings (kT)	Landing Value (KE)
DTS0012	1				
DTS1224	97	558		8.8	30800
DTS2440	126	839		14.6	64700
Total	224	1397		23.4	95500
HOKVL0012	699	1614		15.6	61300
HOKVL1226	176	787		6.0	24800
Total	875	2401		21.6	86100
PGPVL0012	10708	18149		36.1	316900
PGPVL1224	129	306		1.2	6500
Total	10837	18455		37.3	323400
PMPVL0012	197	561		2.3	8100
PMPVL1224	30	106		0.6	1400
Total	227	667		2.9	9500
PSVL0012	6				
PSVL1224	169	1553		29.7	51300
PSVL2440	19	272		9.5	16200
Total	194	1825		39.2	67500
All Vessels	12357	24745	2634600	124.4	582000

As noted above, small artisanal fishing boats (PGP and HOK) dominate the Greek fleet in number, employment, landings and landings value. Hook landings (HOK, long line) are similar to trawler landings, although they have a higher value per ton. Trawlers (DTS) are one of the smallest segments but have very high landings and landing value per vessel.

5.4. Known Gear Impacts

In The following section the impacts of trawling in the Mediterranean are described, from removal of species from the ecosystem to impacts on different ecosystem components and characteristics. A large part of this has been abstracted and updated from Smith (2007).

5.4.1 Removal by Trawling

In Mediterranean there are no quotas in the trawl fishery and management is based on number of vessels, size of engine spatio-temporal closures, and minimum landing sizes. The demersal trawl fishery is not very selective and is comprised of many individual target species within any particular trawl area. There are over 100 recognised commercial fish species from all fisheries (Vassilopoulou *et al.*, 2005). Cod-end mesh size has in the last decade been regulated for larger mesh size (26 mm diamond stretch mesh at the end of the last century) and is now either 40 mm square mesh or 50 mm diamond. There is a high mixed catch comprised of legal commercial sized species and a by-catch comprised of undersized commercial species, unmarketable species (that could be marketed at some times) and unwanted species (fish and benthos). Consequently there is a high level of discarding. Discarding practices have a degree of variability according to seasons, area and depth and may comprise 45% of the total annual catch (Machias et al. 2001; Tsagarakis et al., 2012). It is thought there is little or no survival of fish through the discarding process, but that a small percentage of benthos may survive. Resulting discards are a return of carbon to the system, a portion of which may be removed at the surface (seabirds), in the water column (fish, mammals or zooplankton) or at the seabed (fish and benthic scavengers) with little survival.

5.4.2 Impacts to Seabed Habitats

The vast majority of Mediterranean seabed surfaces lack large vegetal cover and are muddy, sandy or, in some places, rocky. These apparently modest habitats, far from being lifeless, are inhabited by complex biological communities, often part of fragile ecosystems. The mechanical impact of demersal fishing activities reduces the coverage of habitat-forming species and the diversity and abundance of associated invertebrates and fish whilst sediment re-suspension causes habitat degradation. Highly impacting bottom fishing (trawling, dredging, etc.) primarily affects shelf areas, where soft and hard bottom habitats are exploited differently.

5.4.2.1 Soft bottoms

Recent studies have highlighted the impact of towed gears on the marine benthos of shelf seas including clam dredging (Morello *et al*., 2005), bottom trawling (Smith *et al*., 2007; Sala *et al*., 2009, 2011), and Rapido trawling (Giovanardi *et al.,* 1998). As synthesised by Pranovi *et al.* (2000), "*trawls and dredges scrape or plough the seabed, resuspend sediment, change grain size and sediment texture, destroy bedforms, and remove or scatter non-target species*". An innovative approach with side-scan sonar technology during towing operations has directly observed the behaviour and impact on the sea bottom of the hydraulic dredge, Rapido trawl, and two types of Mediterranean bottom trawls ("Americana net" and "Volantina net") in the Adriatic area (Lucchetti and Sala, 2012). The sonograms demonstrated *in real time* that gear type and rigging, together with environmental conditions, are the main factors affecting the disturbance caused by fishing. Hydraulic dredges scrape the surface of the substratum and dig into it by resuspending large amounts of sediment (Figure 5.1). Notably, because the hydraulic dredges operate in restricted coastal areas (i.e., from 3 to 10 m deep), the density of the dredge tracks is very high, with less than 2 m between tracks. Dredge marks identified were long stripes 3 m wide, equivalent to the dredge width. Rapido trawls used in muddy areas targetting common sole (*Solea solea*) dig deeper into the sediment, making furrows up to 10–13 cm deep (Figure 5.1). The impact of Rapido trawlers on the seafloor is basically similar to the hydraulic dredge, where both gears flatten and plough through seabed features. Rapido trawling exerts the widest impact on the seabed, each vessel ploughing a surface of about 237 000 $m^2 \cdot h^{-1}$ (4 gear x 4 m width, at a speed of 14.8 $km \cdot h^{-1}$). In otter trawl fisheries the most evident physical effects of trawling were the furrows produced by the otterboards up to 20–30 cm high and 30–40 cm wide (Figure 5.2). The effects of the groundrope, chains, bobbins, sweeps, doors, or other parts of the net mainly result in scraping, ploughing, or sediment resuspension.

In the Mediterranean basin deep trawling fisheries targeting Norway lobster or red shrimps also affects slope muddy bottoms. In general, muddy sediments, which form in high depositional areas with low external disturbance, are much more sensitive to trawling disturbance than more dynamic coarser sediments; trawl doors penetrate them more deeply than other sediments, with potentially greater effects on infaunal species (Ball *et al.*, 2000).

In all sedimentary habitats bottom trawling is responsible for large scale flattening and reduction in spatial heterogeneity. In siltier sediments, however, trawl door marks may persist and a gross rippling might be seen to increase heterogeneity. Trawling removes small structures, whether they are sedimentary (natural rippling, mixed sediment or other substrates), biological (bioturbation mounds and openings, feeding pits and other traces, biogenic structures or structural species), or anthropogenic (litter, wrecks, lost items). Side scan sonar images from the Southern Aegean of 200 x 200 m sections of seabed from commercial trawl areas are shown in Figure 5.3 (from Smith *et al.*, 2007). The silty seabed is heavily marked with ploughed trawl door tracks. In coarser sediments the marks are much more diffuse because the trawl doors have lesser penetration and the sweeping action of the gear is more important. The use of Sediment profile imagery in the same areas has also evidenced the loss of visible structures in trawled areas in both coarse and fine sediments at the centimetre scale (from Smith *et al.,* 2003). Loss of spatial heterogeneity leads to a smaller range of microhabitats and in general, to a decrease in biodiversity.

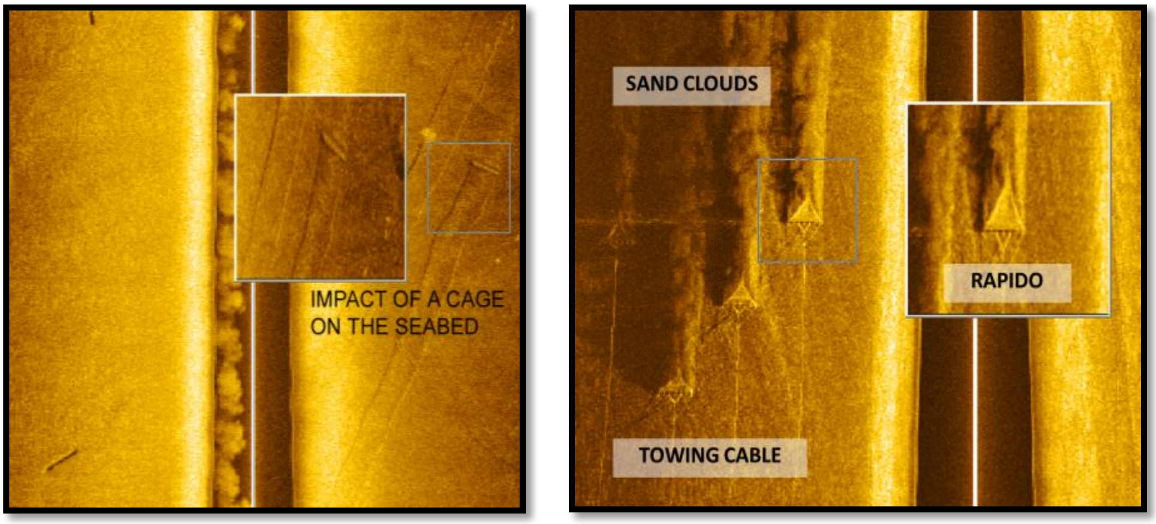


Figure 5.1. Side-scan sonar of the hydraulic dredging (on the left), showing evidence of considerable physical disturbance, with tracks crisscrossing the surveyed area. The dredge marks appear as long stripes of 3 m wide equivalent to the dredge width. Resuspension of sediments caused by Rapido trawling (on the right).

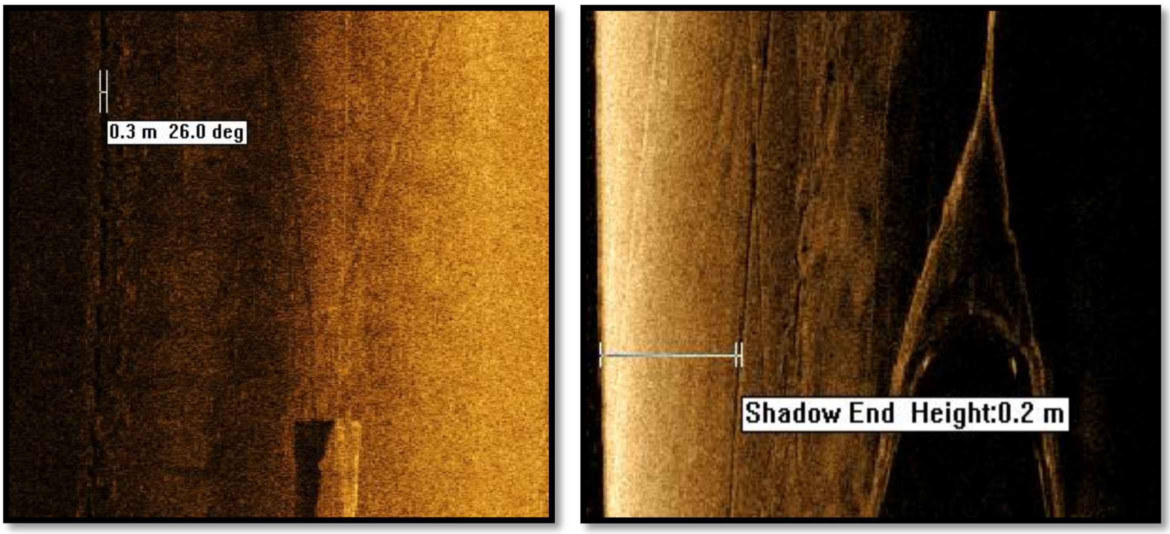


Figure 5.2. Width of the furrow left by otter trawl (on the left). Height of the furrow left by otter trawl (on the right).

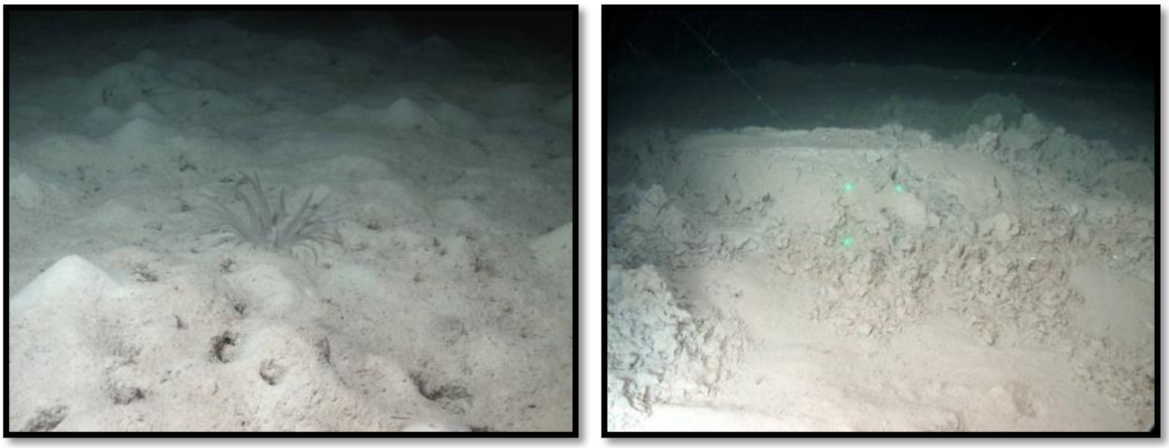


Figure 5.3. Photographic images of the seabed at 200 m depth in the Aegean Sea, regular seabed small scale structures (bioturbation and large filter feeder) and trawl door disturbed sediment (raised spoil heap, broken turned over sediment).

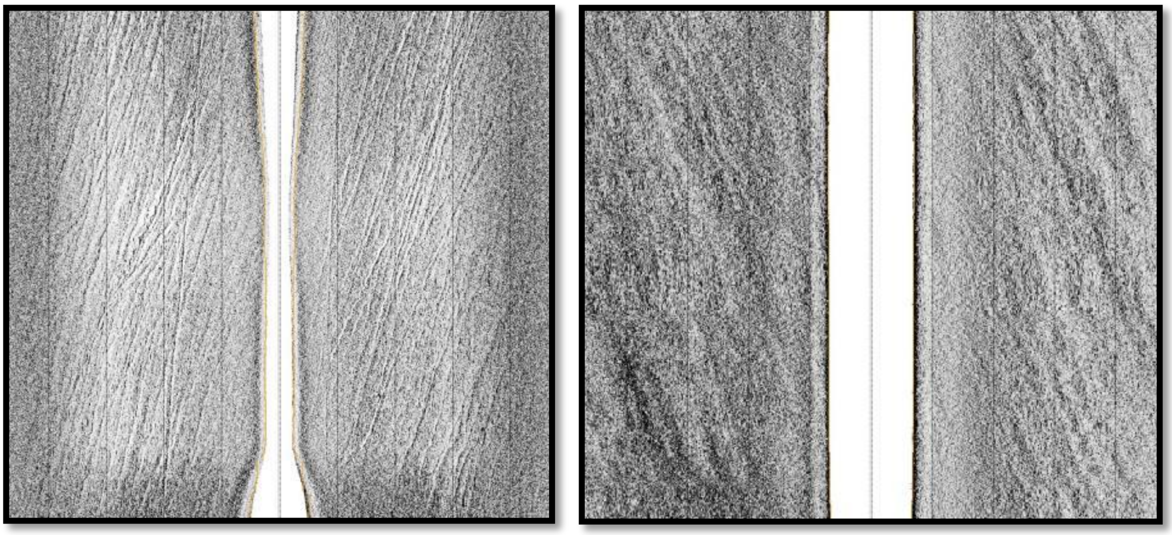


Figure 5.4. Side scan sonar image of the seabed (200 x 200 m) showing trawl door marks on a) soft sedimentary seabed, and b) coarse sedimentary seabed.

5.4.2.2 Hard Bottoms

There is little information on the impact of anthropogenic disturbance on Mediterranean sub-littoral hard bottoms. These systems are characterised by high habitat complexity and, consequently, high biodiversity. In the past, highly destructive gear has been used in date mussel fisheries (*Lithophaga lithophaga*) and in the harvesting of red coral (*Corallum rubrum).* Standard otter trawling is also known to harm rocky bottoms thanks to special rolling devices that prevent the gear from being damaged. This happens off northwestern Spain in rocky fishing grounds rich in sparid fish, in spite of being legally banned.

5.4.2.3 Special Habitats

In the Mediterranean, seagrasses are exceptional seabed habitats and trawling has largely been banned from *Posidonia* meadows (< 50 m deep or 3 miles from the coast or latterly where *Posidonia* meadows are known to occur. In the past, they have been dramatically affected by trawling. *Posidonia* (seagrass) beds in shallow waters range from a few metres depth to approximately 40 m depending on water clarity. They are extremely important ecosystems concerning high biodiversity, oxygen production, CO_2 sequestration, nursery grounds, substrate, refuge and feeding areas. These areas are now for the most part protected by the 50 m depth or 3 mile regulation or as protected areas where they are known to occur.

Figure 5.5. Photographic images of shallow water *Posidonia* meadows: regular meadow and trawl-damaged meadow. (Photographs courtesy of Y. Issaris, HCMR).

Maerl (coralligenous algae) is comprised of very slow growing algae species, ranging from coarse gravel-like sands to small reef structures. Leaf/like maerl species are very delicate and can be broken up/removed in one trawl pass. Maerl beds can occur from a few metres depth to approximately 100 m depth again depending on water clarity. They act in the same way as seagrass beds with lesser production potential. In the past, trawlers avoided maerl areas, but with the introduction of northern European trawling adaptations (rock-hoppers and wheels on the ground rope, which allow passage over rougher ground), these grounds are more accessible and have suffered in the last two decades. They are now coming under the same legislative gaze as *Posidonia* habitats.

Fishing activities are also responsible for the addition of litter items and lost fishing gears into the environment. It should be noted that these items whilst seen from a negative point of view do also add to heterogeneity on the seabed and can act in the long term as artificial substrates for colonisation.

5.4.3 Impacts to Benthos

Some studies have been carried out in NW Adriatic Sea concerning the impact of Rapido trawling on the benthic organisms (Giovannardi *et al.*, 1998; Pranovi *et al.*, 2000).The Rapido is a towed gear used only in the Adriatic Sea for fishing scallops in sandy offshore areas and flatfish in muddy inshore areas.The impact of this gear showed negative effects on macrobenthic community structure although with a very short-term increase in abundance and biomass of particular taxa due to the increase in the trophic availability benefiting a few opportunistic scavenger species. Commercial exploitation appears to result in cumulative disturbance as evidenced by the higher biomass of scavenger Crustacea and Echinodermata at the expense of Porifera, Mollusca and Annelida. Commercial fishing may therefore be selecting epibenthic species most able to cope with physical disturbance by gear and endure the discarding process. Experimental studies seem to conclude that Rapido trawling causes greater short-term disturbance on macrobenthos in muddy areas than in sandy bottoms, although short-lived fauna associated with the former recovers quite rapidly (within two weeks) (Pranovi *et al.*, 1998). Whilst some of the benthos is removed by the trawl net (to be kept as catch or dumped as discard), there are also direct impacts of collision with benthic organisms leading to damage and death. Damage leads to loss of energy as some must go back into maintenance (e.g. regenerating body parts or rebuilding tubes or burrows) or could also lead to secondary mortality from higher liability to predation. Bottom fishing has deeply affected some Mediterranean invertebrate species such as the endemic sponge *Axinella cannabina* or the bryozoan *Hornera lichenoides* (De Ambrosio, 1998). Otter trawling fisheries on muddy bottoms targeting shrimp *Parapenaeus longirostris* in Algeria has heavily impacted the benthic community associated with the seapen *Funiculina quadrangularis*. Animals may also be buried and die from smothering after sediment turnover, or be exposed and more liable to predation.

Studies may not be able to elucidate the exact mechanisms although the overall impact on community structure can be seen. Studies on a soft sedimentary commercial trawling lane at 200 m depth in the southern Aegean (Smith *et al.*, 2000) have shown that macrofaunal species number, abundance and biomass were all significantly lower in the trawled area. From a functional point of view impacts on the less mobile fauna were more pronounced and there were reduction of 98% of suspension feeders and 55% of deposit feeders (by biomass). For the megafauna indications are that trawling decreased numbers in general but increased the dominance of motile predator/scavengers (Smith *et al.*, 2000; Coggan *et al.*, 2001).

Although there is no information on the effects of deep sea trawling on muddy bottoms in the Mediterranean, it seems that recovery rates are much slower and the impacts of trawling may be very long lasting in deep water (mulitple years or even decades), where the fauna is less adaptable to changes in sediment regimes and external disturbances. Otter trawling in deep red shrimp grounds is injurious to the octocorallian *Isidella elongata* facies of the bathyal mud biocenosis.

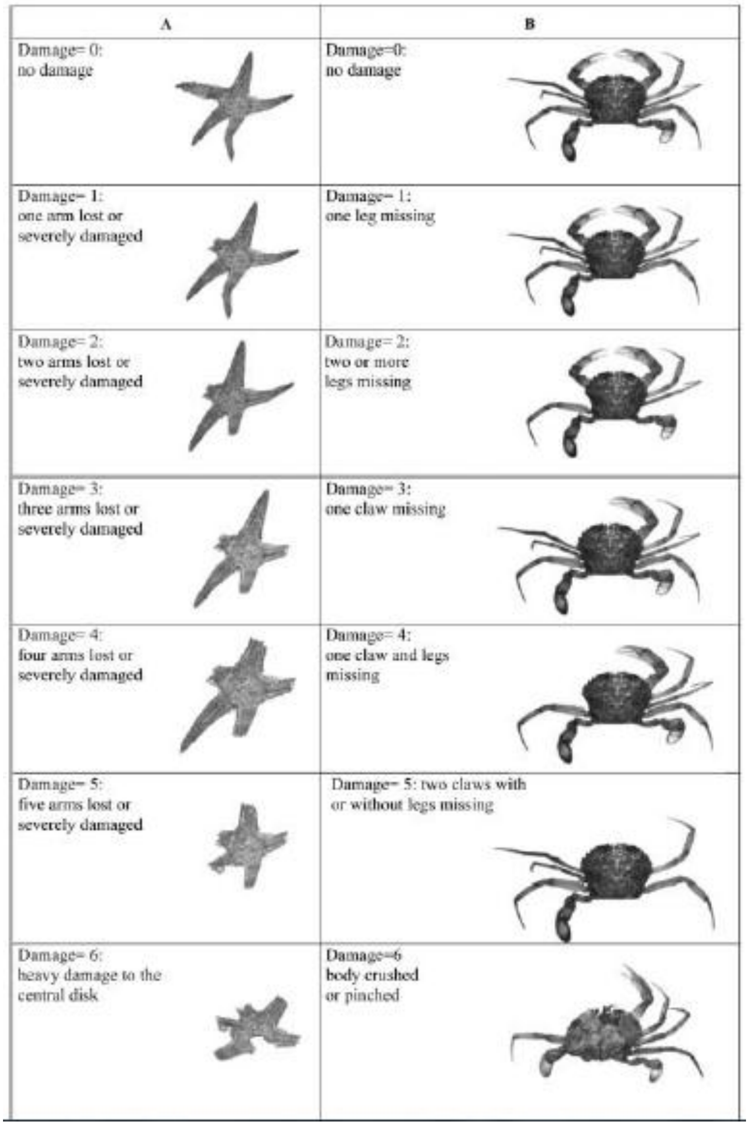


Figure 5.6. Examples of “level” damage scale applied to starfish (a) and crabs (b) in Rapido trawl fisheries (source: Pranovi *et al.*, 2001).

5.4.4 Impacts to Sediment Physical Properties

The passage of the trawl can affect the actual composition of the sediment through mixing and resuspension. Smith and Papadopoulou (2005) in a southern Aegean trawl site found an overall reduced median grain size, with more homogeneous sediments. Karageorgis *et al.* (2005) found heavily mixed surface layers in the Thermaikos Gulf that may have been attributable to trawling, although this was confounded by other local natural events (river flow and storms). In terms of compaction, Smith *et al.* (2003) did not find any overall effects from trawling whilst in Thermaikos Gulf Pusceddu *et al.* (2005a) did not find any change in sediment water content with the onset of the trawling season.

5.4.5 Resuspension and Sedimentation

Smith *et al.* (2000) from simple echosounders and video observations have reported the presence of turbidity clouds after the passage of trawl and as noted above in Figure 5.1, Lucchetti and Sala (2012) have imaged the clouds with side scan sonar. In the Western Mediterranean de Madron *et al.* (2005) have noted that trawls significant trawl resuspension, with sediment clouds several hundreds of metres behind trawls, 3-6 m high and 70-200 m wide with measured suspended sediment concentrations reaching 50 mg/l and with flux rates ranging 190-800 g/m2/s depending on sediment (coarse – silty). In Thermaikos Gulf, Price *et al.* (2005) identified a 2-3 fold increase in resuspension between at the start of the annual trawling season and in the same study Pusceddu *et al.* (2005b) noted a significant increase in suspended particulate organic matter with a change to a more refractory nature.

5.4.6 Heavy Metals and Pollutants

In Thermaikos Gulf, Cotou *et al.* (2005) noted that resuspension events appeared influence the chemical forms of micro-pollutants; potentially affecting their bioavailability and toxicity. Trawling activities in newly opened areas have been associated with the release of accumulated compounds and elements from marine sediments in concentrations much higher than when they were gradually deposited primarily. Existing trawling areas will be in a greater state of equilibrium unless there is some major change in technique (such as deeper digging gears).

5.4.7 Impacts to Sediment Chemistry

Sediment chemistry and chemical processes are dependent on sediment type and fabric, fauna dwelling in the sediment and diffusive processes over the sediment. Organic carbon and phytopigments are a very basic measure of richness/food availability in the sediment for the fauna. In the southern Aegean, Smith *et al.* (2000) and Smith and Papadopoulou (2005) were not able to detect trawl-related differences in organic carbon. However, in Thermaikos Gulf, Pusceddu *et al.* (2005a) found that sedimentary organic carbon concentrations significantly increased immediately after the beginning of the trawling season, possibly related to release of deeper buried. Changes in quality and bioavailability of organic carbon were also noted.

In the southern Aegean Smith *et al.* (2000) reported a change in sediment phytopigment concentrations just after the start of the trawling season. Later, Smith and Papadopoulou (2005) found similar results, and also much more variability in deep sediment profiles indicating deeper disturbance. In Thermaikos Gulf, Pusceddu *et al.* (2005a) did not find any significant changes in phytopigment sedimentary content related to trawling events

5.4.8 Impacts on Chemical Fluxes

In an experimental study on coarse sediments Smith and Papadopoulou (1999) had measured some immediate increases in bottom water silicate immediately after the passage of a trawl. Whilst in a chronic flux study Smith and Papadopoulou (2005) noted a lesser oxygen uptake but more nitrite uptake in a commercial trawl lane in winter (trawling season) and more ammonia being absorbed in the trawling lane in the summer (closed season) They concluded that there was strong interaction of trawling with the denitrification and reduction process, but this was complicated by both seasonality and the open/closed season for trawling.

The ecosystem effects related to the use of bottom gears may extend far beyond the direct, straightforward impacts discussed above. Eutrophic processes may be enhanced leading to hypoxia in sensitive soft bottom areas (as in the northern Adriatic) and the quantity of hydrogen sulphide released from sediments may increase (Caddy, 2000). Trawling and dredging can also play a role affecting the intensity and duration of naturally occurring seasonal hypoxic crises in some places. These fishing practices, carried out in hypoxic conditions in the Adriatic, can exacerbate the summer killings of young shellfish.

5.5. Size Composition of Important Gears

A general overview of size composition of important gears in the Mediterranean is available in the final report of the project the project "MyGears" (http://mareaproject.net/contracts/8/overview/)

Summary of technical specifications of Mediterranean trawl gears

- The length overall (LOA) of the investigated vessels ranged between 9.01 and 37.20 m, with a mean value of 22.20 m.
- The headline length (HL) varied from 12.30 m to 128 m, with a mean value of 53.68 m, while the footrope was from 16 m to 162.41 m with a mean value of 69.38 m.
- The smaller trawl is a TBB, specifically the Italian Rapido trawls with a trawl length of 4.90 m, while in the other trawl typologies trawls had a length of around 227 m.
- The square width varied from 12.44 m to 188.10 m with a mean value of 42.45 m.
- The fishing circumference (FCC) varied from 16.20 m to 409.60 m with a mean value of 75.38 m.
- The codend length varied from 1.5 m for the bottom trawl (OTB2) to 27.97 m for the pelagic pair trawl (PTM4), with a mean value of 5.02 m.
- The twine surface (TwS) ranged from 19.05 m^2 to 637.29 m^2 with a mean value of 201.08 m^2.
- The trawl weight (TrW) ranged 7.94-778.70 kg with a mean value of 278.06 kg.
- The mean drag resistance of the rigged trawls was around 4600 kgf.
- Otterboards length (OBL) ranged between 920-3371 mm with a mean value of 1885 mm, while the height (OBH) from 500 to 1900 mm and a mean value of 1242 mm. Notably in the Mediterranean, the otterboard projected areas (OBA) span from 0.57 to 5 m2 with mean weight (OBW) of around 450 kg.

5.6. Distribution of Fishing Effort

Mediterranean Fishing Effort

The spatial extent of trawling is primarily constrained by:

- Depth: the Mediterranean is characterised by deep waters with multiple basins in excess of 1000 m depth. Shelf areas are restricted in many areas although are more extensive to the northern areas. Operational constraints limit the maximum depth of trawling which for most vessels is less than 500 m depth. Deeper water trawling does takes place to target some deeper water species of shrimp and fish, particularly off the Spanish coast and the Western Ionian. EU regulations have recently given a deeper limit of 700 m for trawling in the Mediterranean to protect deep water stocks which tend to be more sensitive to disturbance.

- At the shallower end, the limitation of trawling is primarily governed by a 3-mile or 50 m depth limit for the protection of *Posidonia* meadows. Trawling shallower than 50 m depth is only possible where there are no known *Posidonia* beds or the depth is out with the 3-mile limit (with some local derogations).

- Suitable seabed. The seabed needs to be relatively flat and unobstructed. Trawling takes place on sedimentary seabeds ranging from soft muds to coarse sands. Where the seabed is very steep or rocky there are possibilities of damage to gear and typically a trawler needs an unobstructed tow line of more than 5 miles, although this does not have to be in a straight line.

- Territorial waters: Countries in the Western Mediterranean have typical 12-mile territorial water limits. Greece and Turkey have 6-mile territorial limits. In border areas trawling is constrained these limits.

- The legal framework of the fishing industry regulates temporal and spatial aspects of bottom trawling. Certain Gulf areas are permanently closed to protect nursery grounds. There are also some Marine Protected Areas (national parks) with no-take areas. Some areas may be closed on a temporal basis, either for stock recovery over some years, or for example, the Greek annual closed season from the end of May to end of September to protect breeding stocks.
- Production also plays a role in defining trawling spatial effort. More northerly eutrophic areas support higher fisheries and therefore more effort than more oligotrophic southern and eastern waters.

At the Mediterranean Sea level, fishing has been mapped through two different cumulative impact studies from Coll *et al.* (2011) and Micheli *et al.* (2013). Figures 7 shows the Coll *et al.* (2011) data for Mediterranean trawling/dredging and Figure 5.8 shows all Mediterranean fishing activities from Micheli *et al.* (2013). The data gridding for the both studies is extremely coarse, but it shows the mapping of activity to coastal and shallower waters with concentration in northern areas, particularly the shallower Adriatic and northern Aegean but also a large trawled shallower area between Tunisia and Sicily.

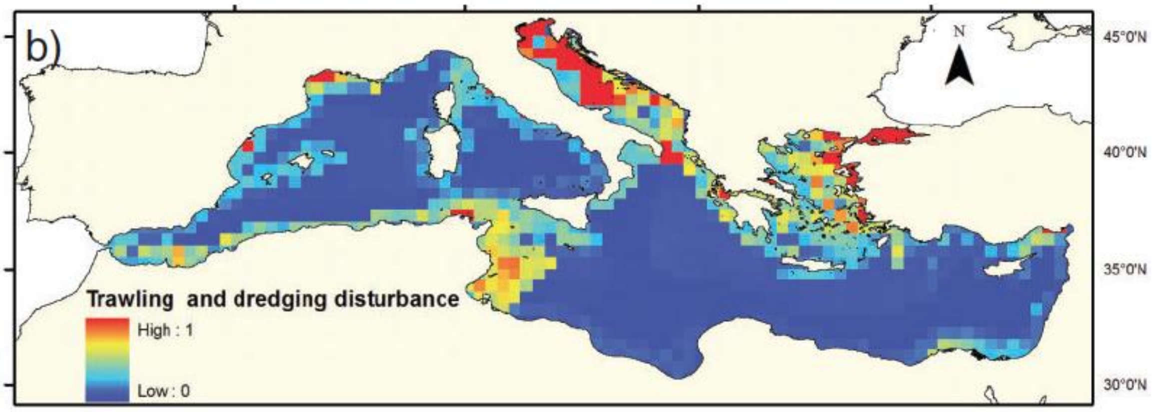


Figure 5.7. Trawling disturbance at the Mediterranean level (Coll *et al.,* 2012).

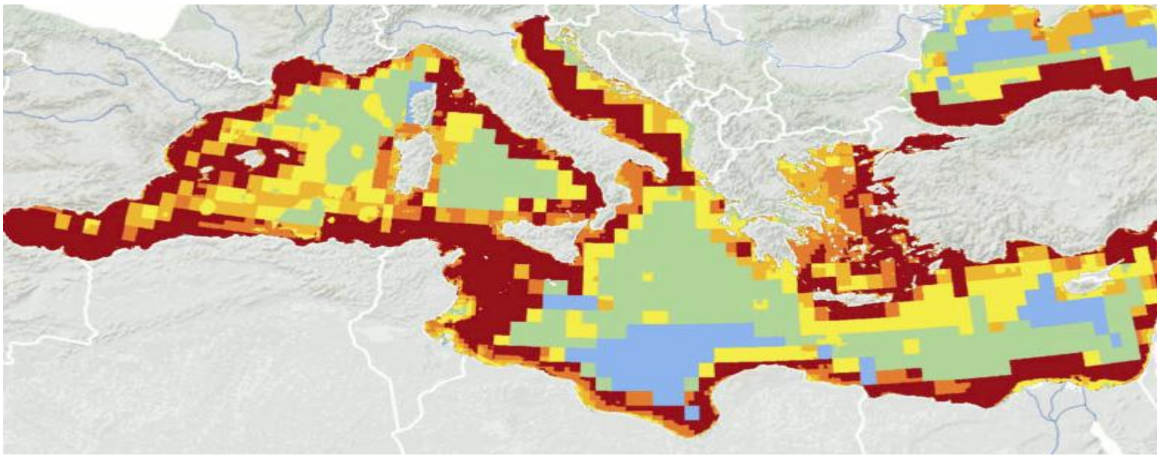


Figure 5.8. Disturbance from all fishing types at the Mediterranean level (Micheli *et al.,* 2013). Hotter colours indicate more intense activity.

Italian and Greek Fishing Effort

Fishing effort in the Mediterranean has been estimated Italian and Greek waters and subdivided by FAO Mediterranean Geographical Sub-Areas (GSA). The GSA areas are shown in Figure 5.9, with Italian waters in dark grey and Greek waters in light grey highlight. Commercial fishing vessels with total length greater than 15 meters are obligated to be equipped with VMS, which provides data to the fisheries authorities of fishing vessel's location, direction and speed at a two-hour interval (EC No2244/2003). VMS data, for the period 2010-2012, were analyzed according to the r-package VMStools by the Italian partners and

VMSbase by the Greek partners with estimation of swept area is based on methodology that was developed under the BENTHIS project (WP2).

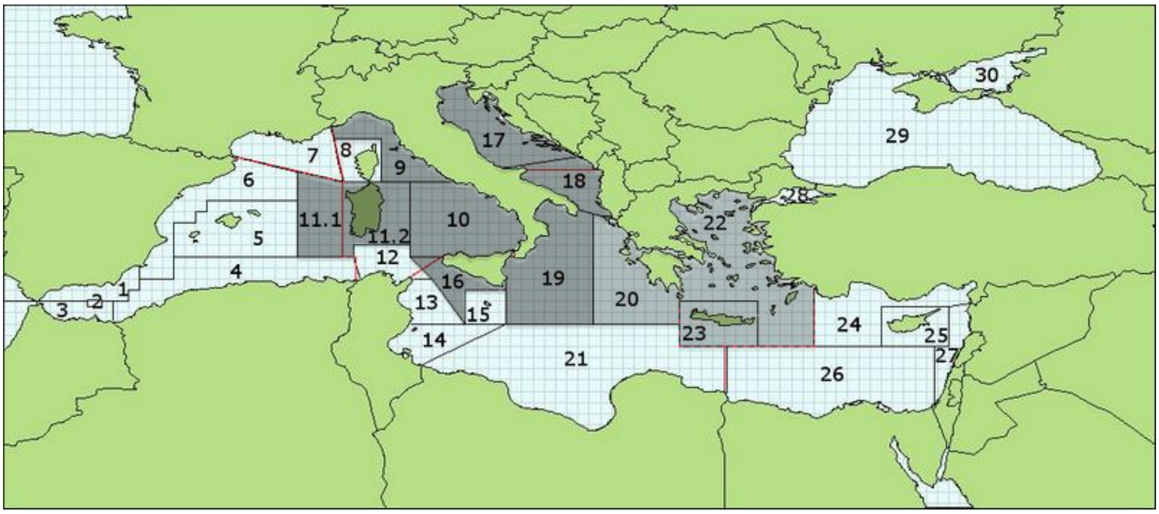


Figure 5.9. Distribution of different GSAs areas where trawling effort has been estimated in the Mediterranean. Italian GSAs highlighted in darker gray covered by:GSA 9 Ligurian and northern Tyrrhenian Sea, 10 south and central Tyrrhenian Sea, 11.1-11.2 Sardinia west and east, 16 south of Sicily, 17 northern Adriatic, 18 southern Adriatic, 19 western Ionian Sea. Greek GSAshighlighted inlight gray covered by:GSA 20 eastern Ionian Sea, 22 Aegean Sea, 23 Crete Island.

Italian Fishing Effort

Fishing effort by hauled fishing gears in the Italian fleet is dominated by demersal otter board trawl fishery. Only in very limited areas in the Northern central Adriatic sea and Strait of Sicily, is a fishery conducted with midwater pelagic trawl. Detailed fishing pressure maps with Italian fishing effort by main métier in the period 2010-2012 in Italian Mediterranean waters have been produced to investigate the distribution and concentration of the areas with intensive fishing pressure and effort allocation with gears assumed to have major benthic impact. The investigation covers high resolution spatial data for effort allocation of fishing operations for Vessel Monitoring Systems (VMS) equipped vessels > 12 m (based on satellite VMS). For the spatial patterns of fishing activity the VMSbase library created by Russo et al. (2014) has been applied. The evaluation covers the metiers OT_MIX_DPS (otter trawling for mixed demersal species) and OT_SPF (otter trawling for small pelagic fish). For OT_MIX_DPS case the métier OTB_DWS_>=40_0_0, OTB_DES_>=40_0_0, OTB_MDD_>=40_0_0, TBB_DES_0_0_0 have been aggregated. For OT_SPF only PTM_SPF_>=20_0_0 has been used.

In Figure 5.10 the cumulative swept area (in km^2) by métier for the Italian trawl fishery is shown for the period 2010-2012 in Mediterranean Sea. It can be seen that for the majority of trawled areas the swept area is <2km-^{2}. Only some coastal areas have higher trawling on the seabed particularly in central Italy, and less so in the north and around Sicily. The swept are maps for the two individual trawl metiers is shown in Figure 5.11. These maps along with the Figure 5.10 the cumulative swept area for all Italian waters show that it is obvious that OT_MIX_DPS is the most important Italian fishery in term of swept area, covering almost 2.5 million square kilometres. Whilst the OT_MIX_DPS fishery is distributed along the Italian coast, OT_SPF seems to be restricted to limited areas.

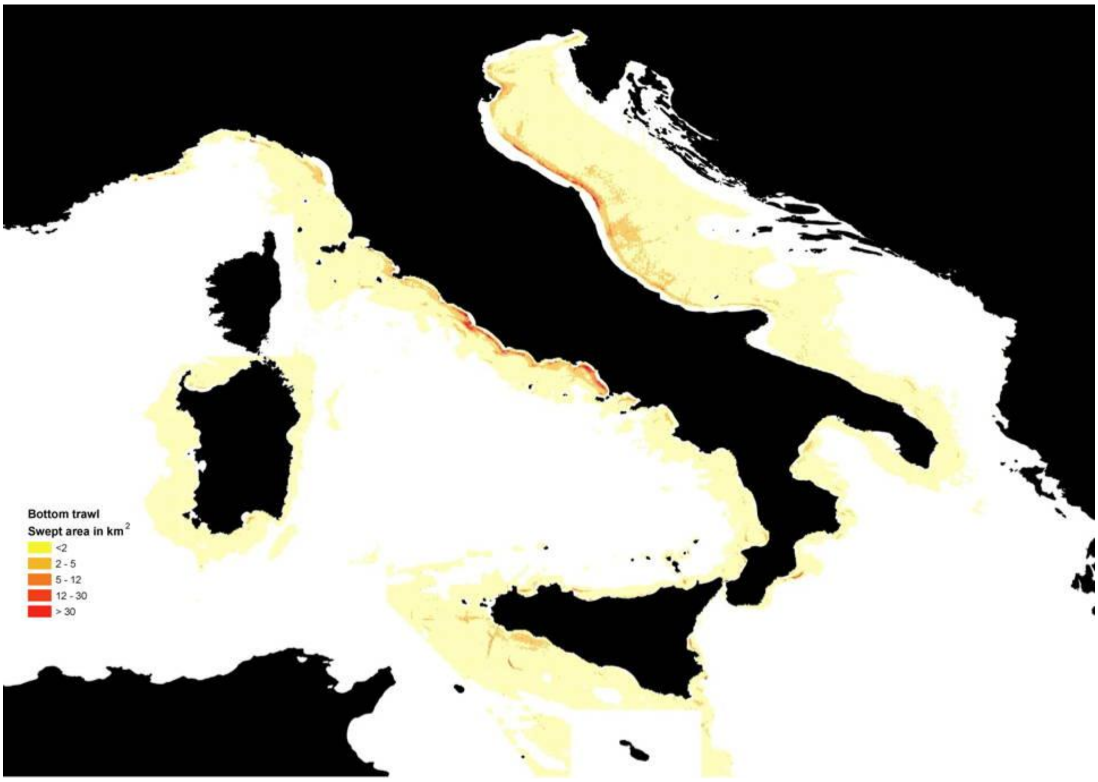


Figure 5.10. Distribution of fishing pressure and effort allocation of Italian towed gear (OT_MIX_DPS and OT_SPF) in the period 2010-2012 in Mediterranean area

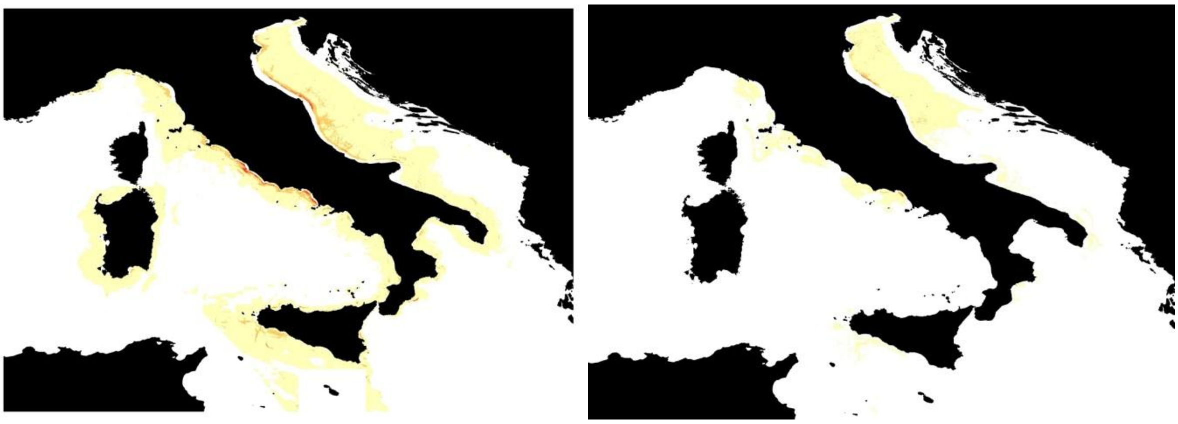


Figure 5.11. Distribution of fishing impact for OT_MIX_DPS (left) and OT_SPF (right)

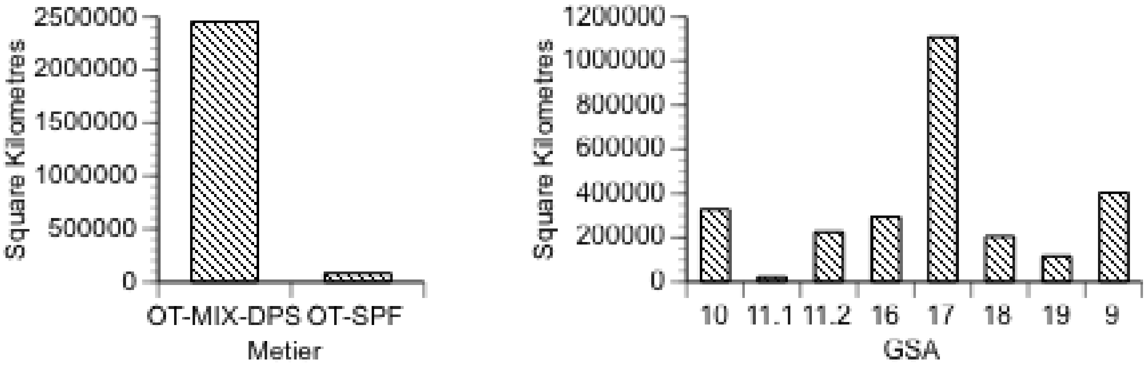


Figure 5.12. Cumulative swept area (in km^2) by metier for Italian fishery in the period 2010-2012 in total for the two metiers OT_MIX_DPS and OT_SPF (left hand graph) and in combined total for the different Italian GSAs (right hand graph).

Figure 5.12 shows the cumulative swept area (in km^2) for each Italian GSA. It is evident that the Northern Central Adriatic sea (GSA 17) is the area most affected by trawling impact with a 4 times higher coverage than any other individual area.

Greek Fishing Effort

Fishing effort by hauled fishing gears in the Greek fleet is dominated by the classification OT_MIX (classification Otter trawling for mixed demersal species). A detailed fishing pressure mapfor Greek fishing effort in the period 2010-2012 in Mediterranean waters is shown in Figure 5.13. It can be seen that for the majority of heavily trawled areas are coastal, and concentrated in gulfs particularly in the north in Thermaikos, mid Greece in Evoikos and Saronikos Gulfs in the Aegean and in Patraikos Gulf area in the west cost (Ionian). There is also widespread trawling on in the central Aegean across the island plateaus. Trawling is restricted by deeper water basins (areas in the northern Aegean and most of the southern Aegean and Ionian and from non-Greek territorial waters in the western Aegean.

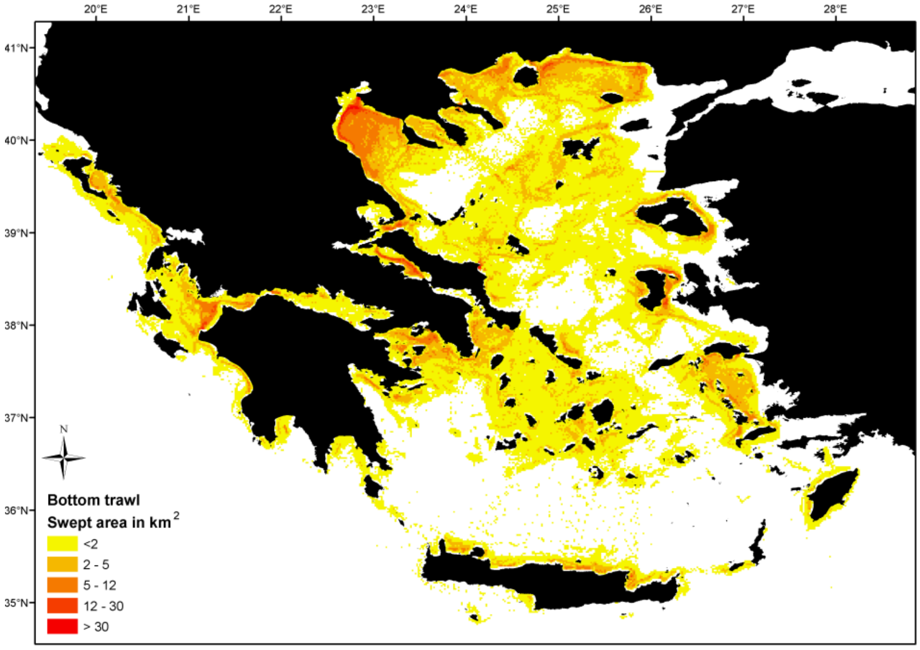


Figure 5.13. Cumulative swept area (km^2) for métier OT_MIX for Greek fishery in the period 2010-2012

The cumulative swept area for total Greek trawling is shown in Figure 5.14 both in total and by individual GSA. In total the swept are is approximately 1 million square kilometres less than half the swept are of trawling in Italy. When divided by GSA, area 22 the Aegean Sea, is the dominant trawling area. Trawling in the Ionian Sea is much less with trawling in Crete the least partially explained by the narrow shelf in that area.

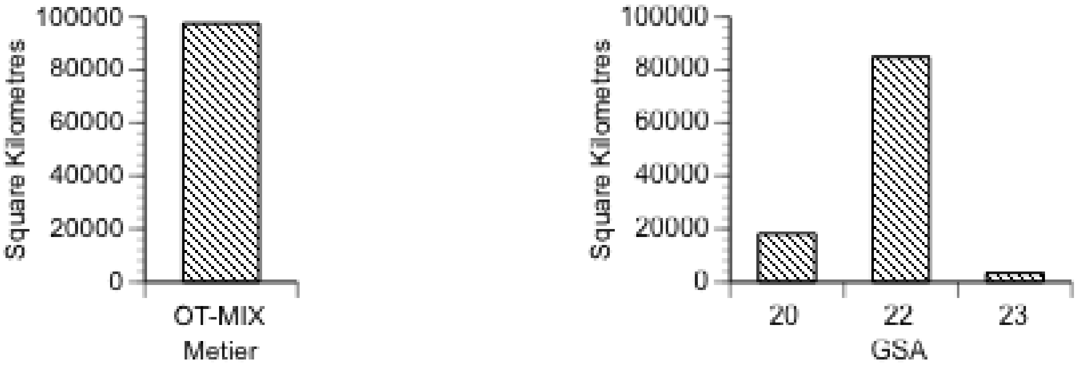


Figure 5.14. Cumulative swept area (in km^2) for métier TBB DMF and for the separate Greek GSAs for Hellenic fishery in the period 2010-2011

5.7. Overview of Distribution of Benthic Habitats (Substrates) and Distribution of Fishery According to Habitat

Mediterranean

In the Mediterranean there is no overall habitat mapping as is available for the North Sea effort. At a very gross level, depth could be used as there is a typical graduation from coarse to fine sediments with depth that could be filtered for the presence of rocky seabed by slope. A concerted effort has been undertaken using depth bands and slope as proxies and gross seabed habitats distribution across the world's oceans, recently available throughwww.bluehabitats.org, undertaken by Harris *et al.*(2014). Data has been abstracted for the Mediterranean concerning the basic layer, shelf, slope, abyss and the classification layer concerning the shelf habitat. The Mediterranean part of the data from *Blue Habitats* (www.bluehabitats.org) is shown in Figure 5.15.

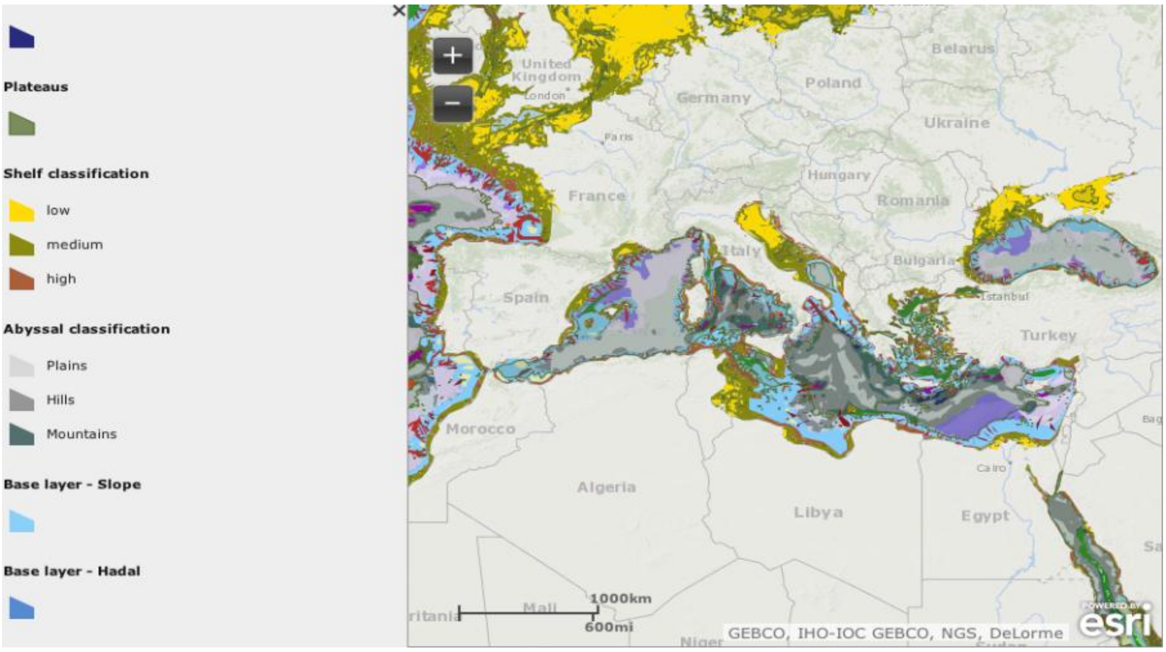


Figure 15. Gross habitat level classification for the Mediterranean (www.bluehabitats.org)

Italy

Figure 5.16 shows the processed data for the central Mediterranean and the Italian GSA areas. The shelf and slope have been defined in separate bands with a dividing line of 200 m and the deeper limit of the slope at 800 m depth (trawling is forbidden beyond 700m). The shelf and slope habitats are relatively large around Italy with only restricted extend areas around western Sardinia, north and western Sicily and off the toe of Italy as well as a deeper pit in the southern Adriatic.

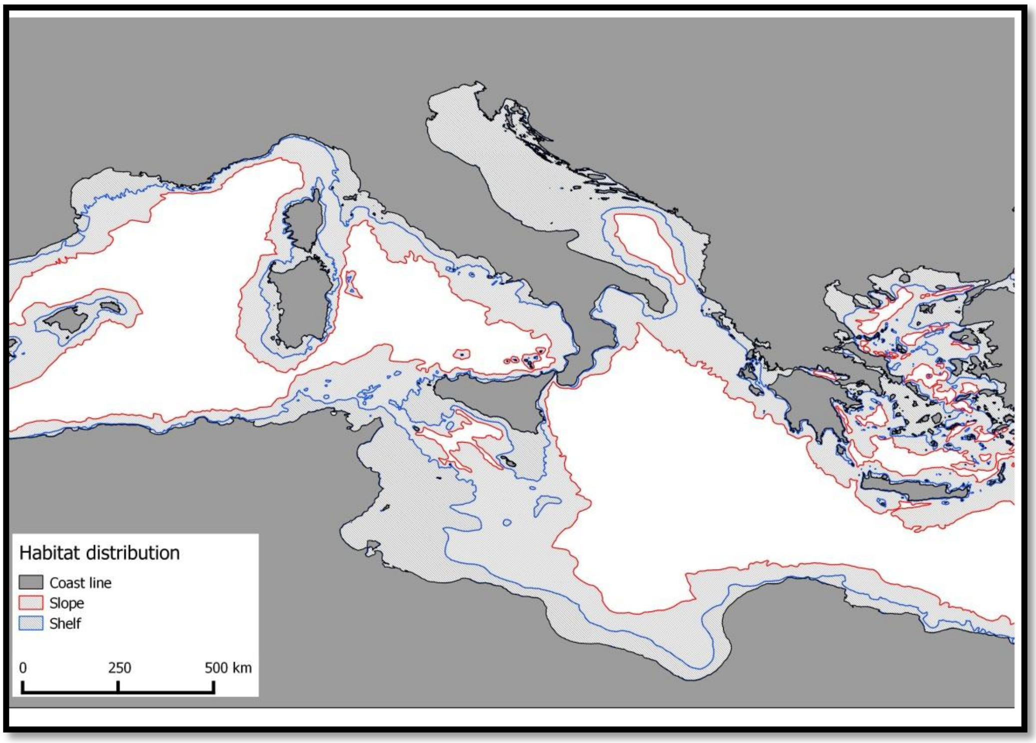


Figure 5.16. Distribution of physical habitat (shelf, slope) in Italian GSA areas

The extent of slope and shelf habitats in Italian sea varies in different GSAs as shown in Figure 5.17. The Adriatic, GSA 17,with the largest shelf/slope habitat is totally dominated by the shelf while the GSA 10 and 11.1, Sardinia and the Tyrrhenian Sea is dominated totally by the slope.

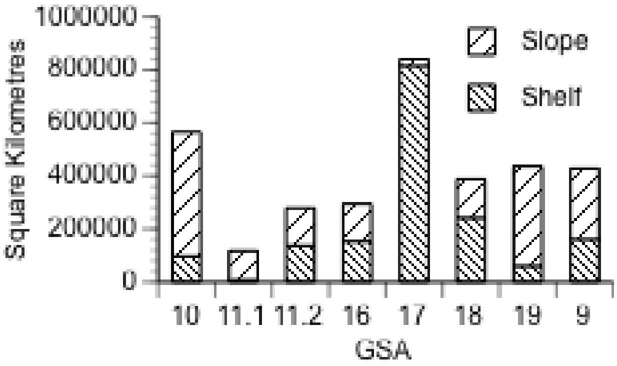


Figure 5.17. Distribution in km^2 of shelf and slope habitat in different Italian GSA

For the Western Mediterranean the distribution of main habitats characterized by main substrate types are available through the EUSeamap portal and JNCC (http://jncc.defra.gov.uk). For Western Italian waters these are shown in Figure 5.18. The area is mostly dominated by deep water muddy habitats.

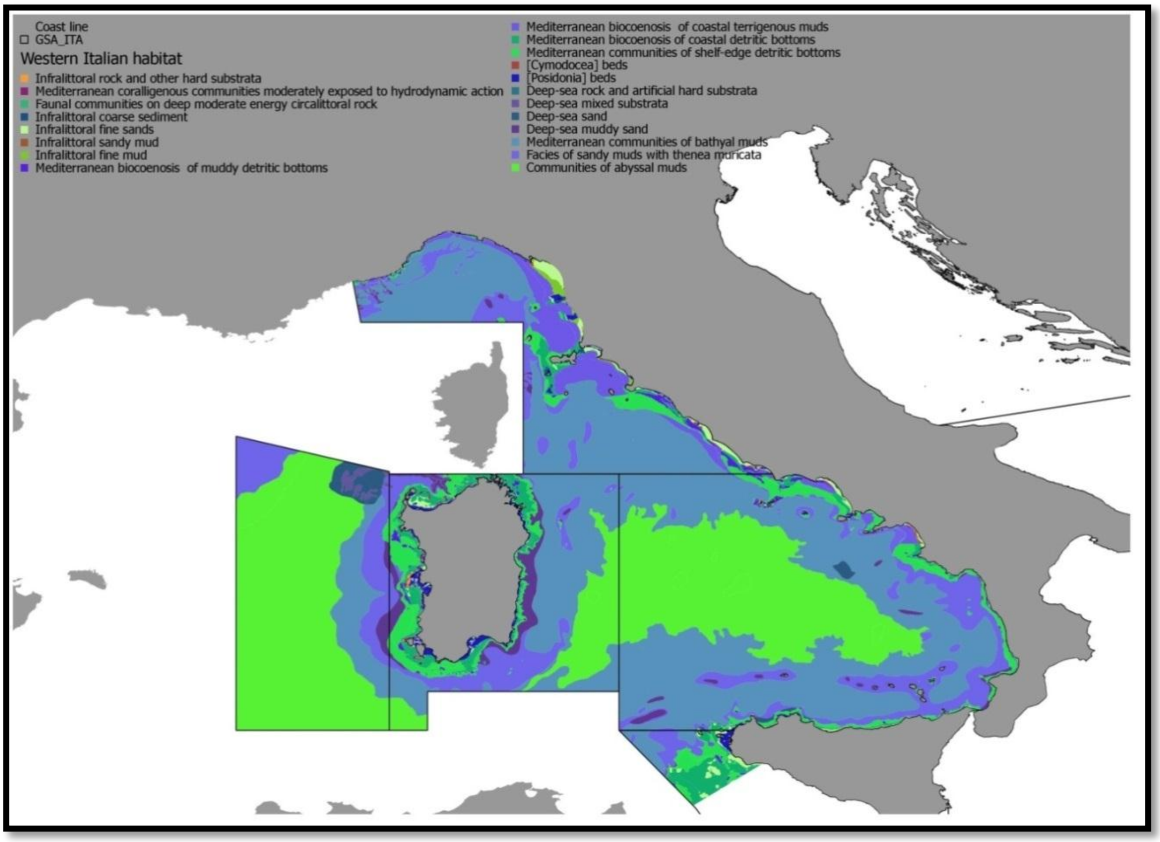


Figure 5.18. Overview of distribution of benthic habitats from Western Italian waters

Greece

The shelf and slope habitats for Greek GSA areas are shown in Figure 5.19. The Aegean Sea is punctuated by deeper basins, especially the southern Aegean and the Ionian Sea is also characterised by deep waters beyond normal trawling depths. The shelf habitat dominates in the northern and parts of the Central Aegean, whilst the slope dominates the south. This pattern is reflected in Figure 5.20 showing the extent of the different habitats in the GSAs reflecting the generally deeper waters of the Greek GSAs compared to the Italian GSAs and the preponderance for slope habitats over shelf habitats.

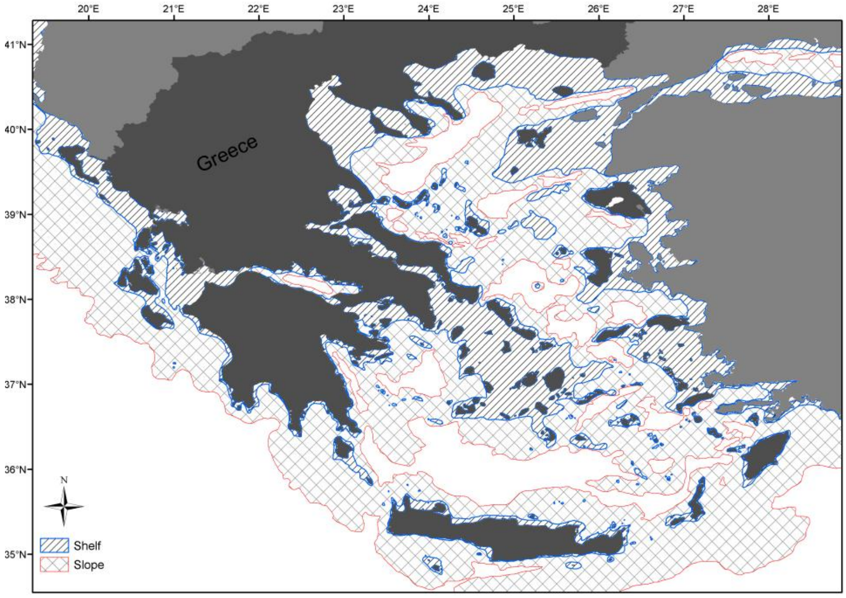


Figure 5.19. Distribution of physical habitat (shelf, slope) in Greek GSA areas

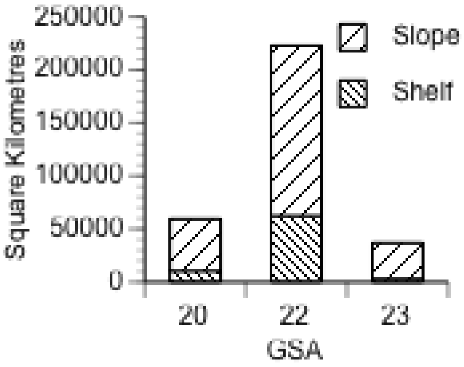


Figure 20. Distribution in km^2 of habitats by Greek GSAs

5.8. Overview of Distribution of Fishery according to Environment

Italy

Figure 5.21 below shows the Italian fishing effort as cumulative swept area overlaid over the Mediterranean shelf and slope areas during the period 2010-2012 for VMS equipped vessels. In Figure 5.22 the fishing effort by métier is shown as cumulative swept area per habitat (in km^2) for the different Italian Mediterranean GSAs during the period 2010-2012. The analysis shows that the fisheries with highest swept area is OT_MIX_DPS, particularly in GSA 17 (northern Adriatic) and particularly on the shelf habitat. The OT-SPF extent is much less but its extent is again mostly concentrated on the GSA 17 shelf habitat.

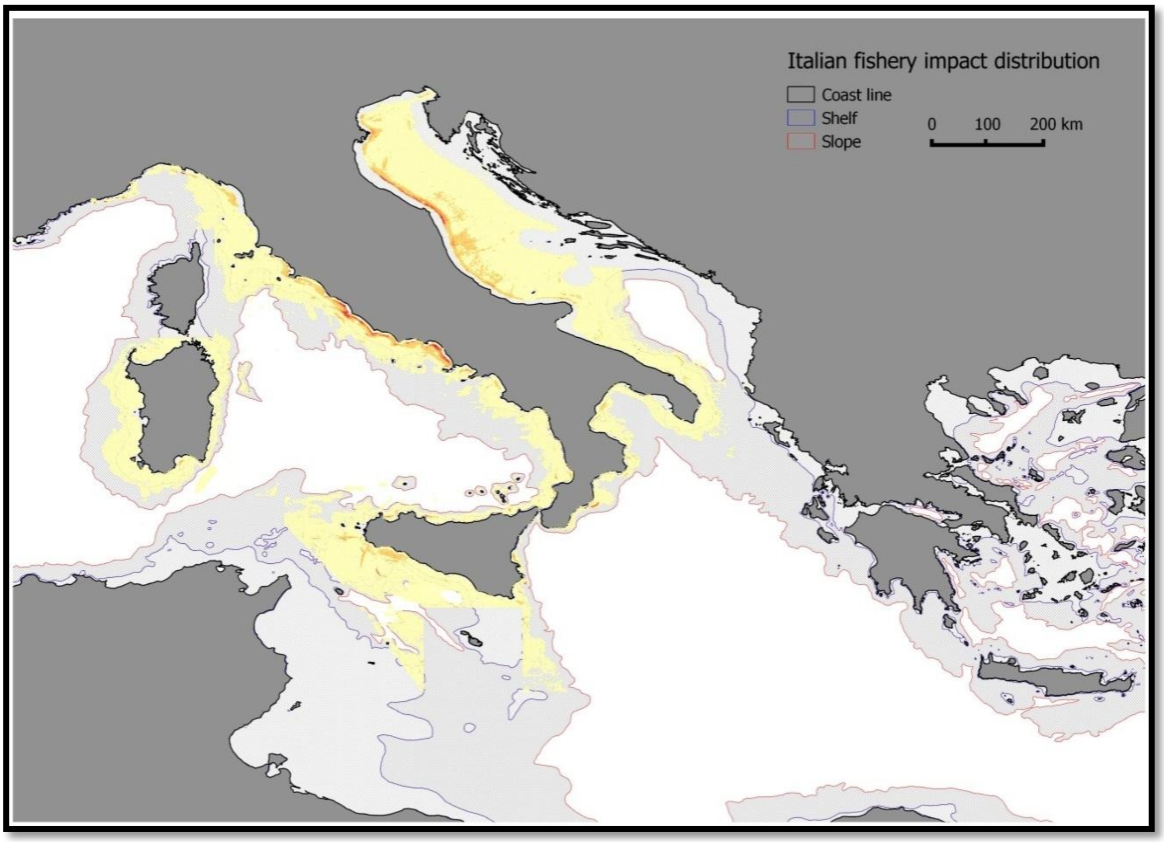


Figure 5.21. Distribution of fishing impacts as cumulative swept area overlain with distribution of the shelf and slope habitat

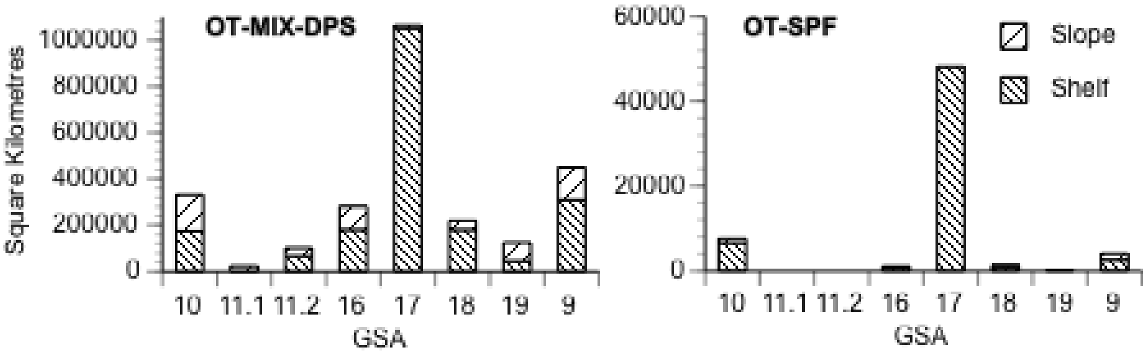


Figure 5.22. Cumulative swept area for OT_MIX_DPS and OT-SPF in each GSA

The swept are is compared to the habitats in each of the Italian GSAs in Figure 5.23. A coverage of 100% means that the habitat has been completely covered 1 time during the 2010-12 fishing period. The main habitat impact by fishery in terms of relative habitat coverage for all metiers is the shelf. From fig 23 it is obvious that OT_MIX_DPS is the major source of impact, particularly on the shelf. The cumulative swept area exceeds the total area of the shelf habitat in 4 GSAs, almost twice in the GSA 9 (Ligurian and northern Tyrrhenian Sea) shelf habitat. The coverage of OT_SPF is far less never exceeding 8% coverage of the shelf habitat or 1% of the slope habitat.

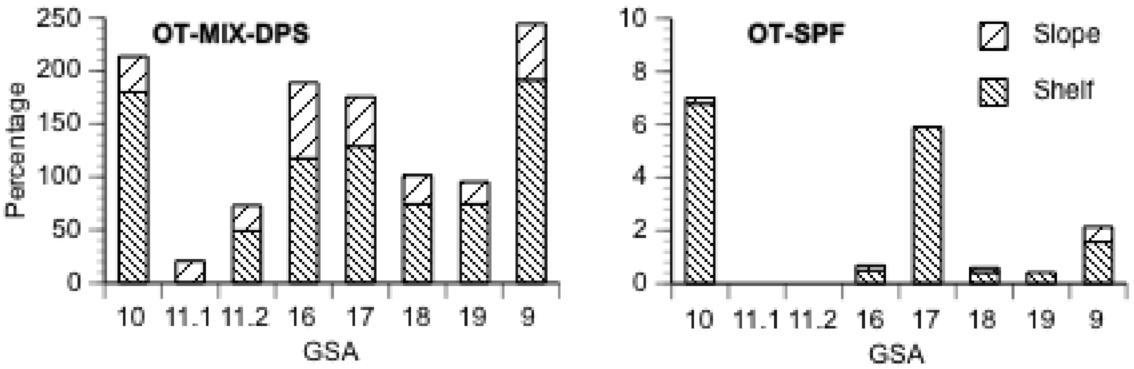


Figure 5.23. Percentage relative habitat coverage for OT_MIX_DPS and OT-SPF in each GSA

For higher resolution of habitat coverage for the Western Mediterranean Italian waters, Figure 5.24 shows the show the distribution of fishing impact as cumulative swept area in km^2 overlaid with seabed habitat from EUSeamaps layers (http://jncc.defra.gov.uk). The major unimpacted habitatsare the deep water ones, beyond trawling depth.

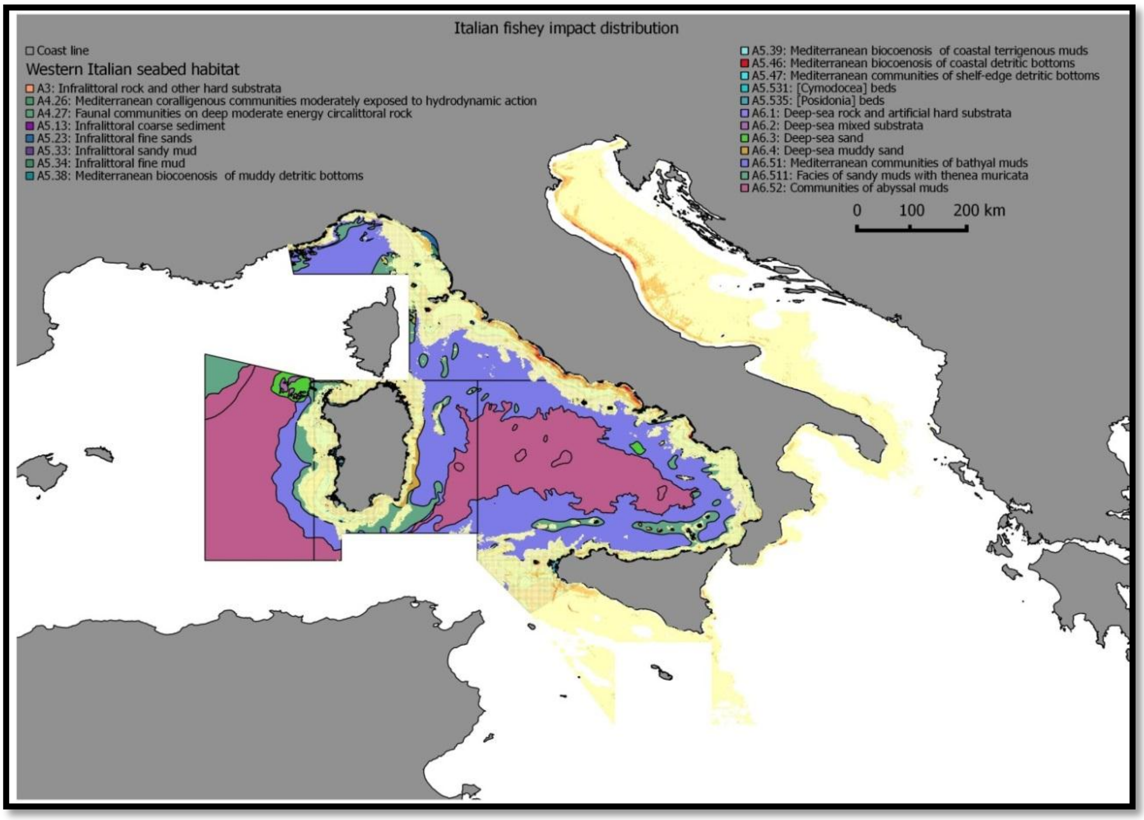


Figure 5.24. Distribution of fishing impact as cumulative swept area with respect to seabed habitat in western Mediterranean Italian waters.

Figures 5.25 and 5.26 show the fishing effort as cumulative swept area per habitat (in km^2) and relative habitat coverage (percentage respect to the total amount of habitat) for the Western Italian area during the period 2010-2012 for VMS equipped vessels for the two different metiers for individual habitat types. For OT_MIX_DPS, trawling is concentrated on two areas of seabed habitat one with a range of Mediterranean coastal shelf muddy habitats (A5.x) and the other for deeper muddy habitats (A6.x). For OT-SPF similar habitats are seen, but with more activity in the coastal/shelf habitats (terrigenous and detritic).

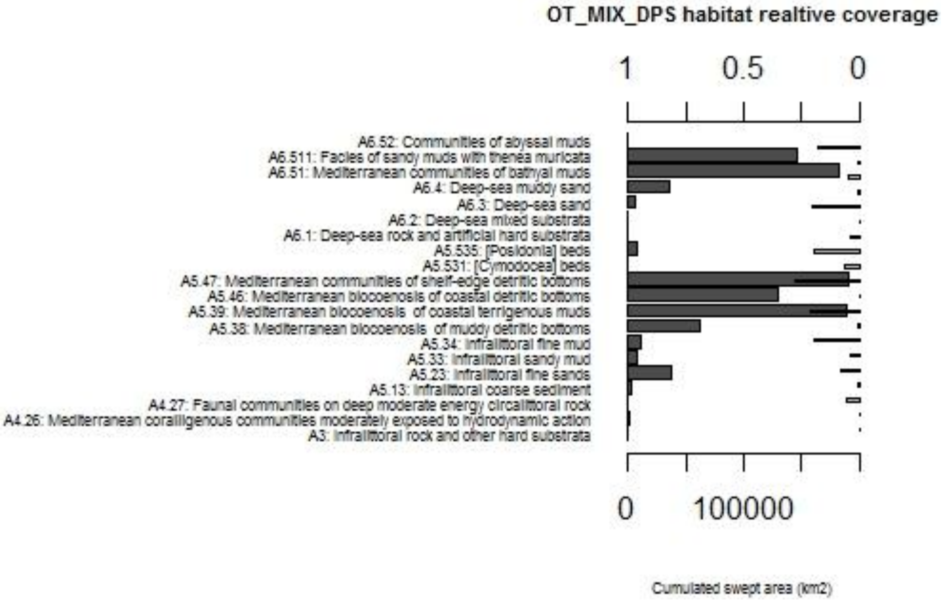


Figure 5.25. Cumulative swept area in km^{2}for OT_MIX_DPS in each habitat (lower x axis) and relative habitat coverage (percentage respect to the total amount of habitat) in Western Italian waters.

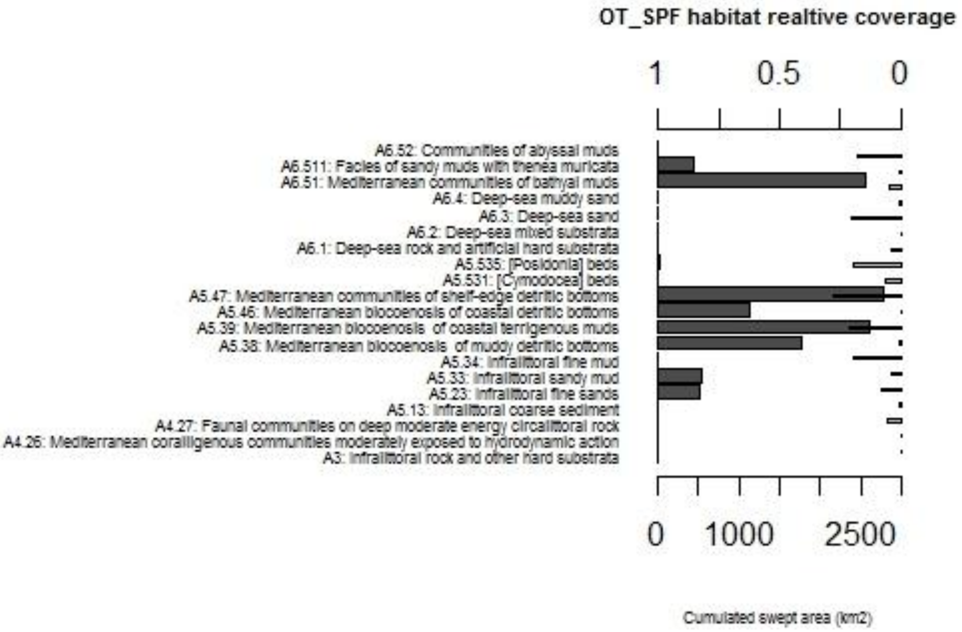


Figure 5.26. Cumulative swept area in km^2 for OT_SPF in each habitat (lower x axis) and relative habitat coverage (percentage respect to the total amount of habitat) in Western Italian waters.

Greece

Figure 5.27 shows the fishing effort for the Greek trawl fishery OT_MIX as cumulative swept area per habitat (in km^2) for the different Greek GSAs during the period 2010-2012. The highest coverage is in GSA 22, the Aegean, with most of the effort concentrated on the shelf habitat, covering approximately 60,000 km^2 with another 20,000 km^2 of the slope covered. The area coverage in GSA 20 (eastern Ionian Sea) was overall less than 20,000 km^2 with the majority on the shelf. Area coverage around GSA23 was very low. In terms of percentage coverage (Figure 5.28) GSA 20 had the highest, i.e. a low shelf area but a high level of trawling, giving a shelf coverage of 150% (1.5 times coverage). GSA 22, the Aegean had over 100% coverage, whilst GSA 23 around Crete was still high at almost 75% with again the majority on the shelf.

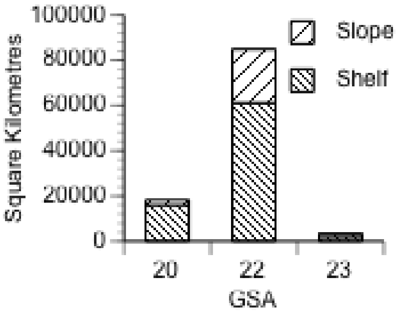


Figure 5.27. Cumulative swept area for OT_MIX in each GSA

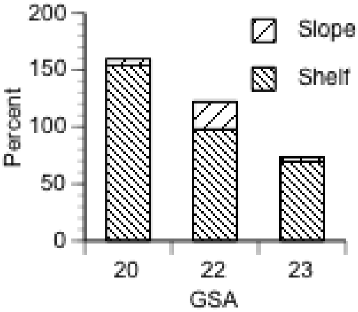


Figure 5.28. Percentage relative habitat coverage of OT_MIX in Greece.

6 - BLACK SEA

6.1. Introduction

The Black Sea Case study is being conducted in Samsun Shelf Area (SSA) to outline the impact of drag-nets (beam and bottom trawl) on the benthic habitat operating for a long period along the southern Black Sea. Samsun Shelf Area being discharged by two major river of Anatolia (Yeşilirmak and Kizilirmak) is a special ecosystem. The biodiversity of benthic and benthopelagic species is limited due to anoxic zone in Black Sea over depths of 150 m. The bottom topography is largely flat and composed of fine sand-silt sediment (mud) that makes the region available for trawl fishery (Figure 6.1).

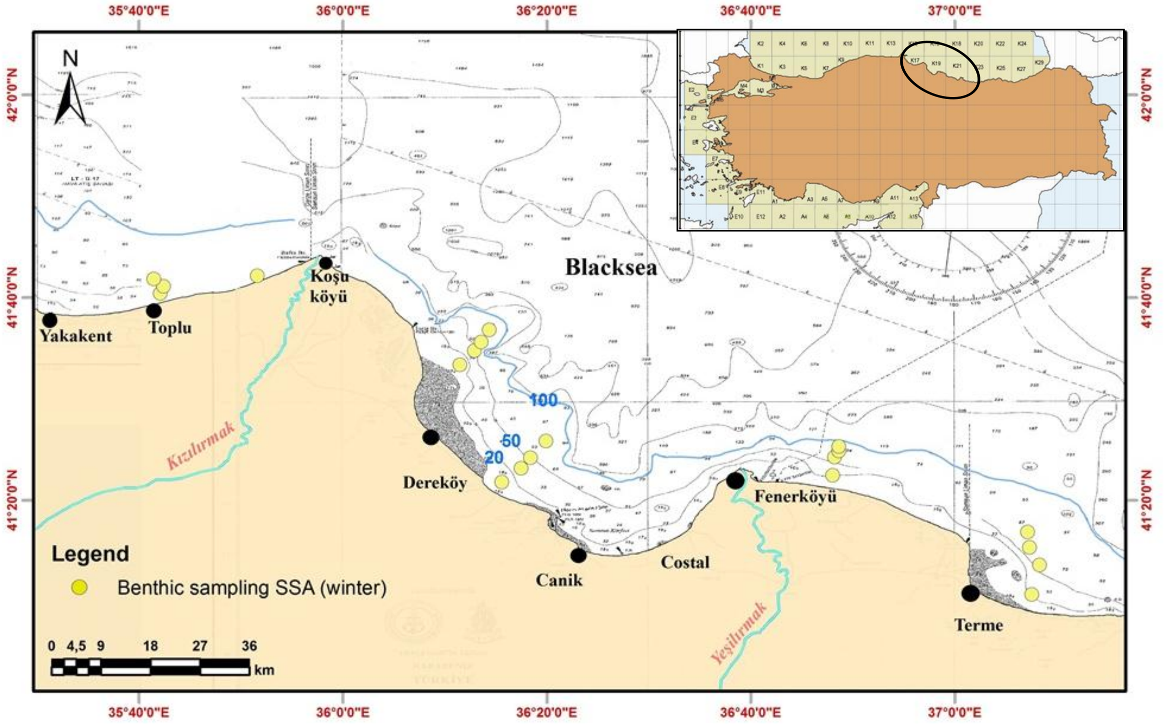


Figure 6.1. Map of Samsun Shelf showing case study area in the Turkish Black Sea Coast

SSA is one of the most important fishing areas along the Turkish Black Sea coasts. The bottom trawl fisheries began to flourish in the Black Sea coast of Turkey by the end of the 1950s. In addition, the rapa whelk invaded the Black Sea ecosystem in 1940 and has spread rapidly throughout whole Turkish Black Sea coast. The fishery on rapa whelk became economical by 1980s and reached an industrial scale still being supported by an intense fishery in the same marine area. For this reason, SSA is under high pressure of drag-nets since 1980s. The rapa whelk generally inhabit the near shore benthic waters and reproduce in summer months peaking between June and July. The commercial fishermen prefer to operate mostly on this period because of high catch per unit effort. In fact, these areas are forbidden by government for beam trawl fisheries on summer months as most of the demersal fish species spawn along this area and in this period. The time and area restrictions were generally violated by rapa whelk fishermen in SSA. The main catch of rapa (82%) mostly came from beam trawls. Nearly 400-450 vessels are operating in SSA, dragging the substratum and creating a serious impact on epi- and infaunal organisms.

In bottom trawl fishery, the growing fleet and effort by 1980s raised a collapse in demersal fish stocks affecting all ecosystem components. In monitoring studies on trawl fishery (2000-2013), high discard rates were estimated for two target species; as nearly 25.8% for red mullet and 42% for whiting. Commercial and beam trawl fishery in SSA was monitored monthly in 2013 relevant to tasks in WP7. The gear metiers and catch data (landing, discard and by catch) obtained from bottom trawl vessels larger and smaller than 18m were recorded. The beam trawl activities were also monitored between June 2013 and May 2014 and still in progress. Beam trawls are generally 6-15m in size and their engine power ranges between 35-350 HP.

6.2. Fishing gears used with benthic impact in regional seas

There are two fishing gears that have benthic impact used in SSA. The gear specifications are presented in Table 6.1. The beam trawls are being actively used in near shore waters nearly 5-30 m and bottom trawl are operating in sub littoral zone nearly 40-80 m. In Black Sea Case study the primary task was to define the technical and functional characteristics of the fishing gears in SSA. Relevantly, the tasks that has been completed; (1) structural and technical characteristics of gears (beam and bottom trawl) (Figure 6.2, 6.3), (2)Fishing effort (catch per unit effort for target species, the amount of by catch species, discard and landing) (subheading 3), (3) Quantity and quality of active fishing fleet (size range, fishing capacity, etc.) (subheading 3).

As it is presented in Table 6.1, the drag nets (ground gear and doors in bottom trawl and shoes in beam trawl) have larger scrapping impact especially on soft substratum types. This continuous and heavy pressure prevents some types of living forms such as sessile organisms. There is nearly no benthic organism living attached to substratum except a few species distributed on small areas of hard substratum which is unavailable for trawling.

The collaboration was realized with external partners to get advice about the modifications to be made both on bottom and beam trawl in order to mitigate the impact on benthic habitat. The technical specifications were defined in four different ground gears that are currently being used in traditional bottom trawls. Furthermore, any other alternative model for the ground gear was discussed (Figure 6.4).

In SSA, there are some technical differences between the design of the beam trawls gears used in different sublocations such as western (Kızılırmak shelf area: Dereköy-Koşuköyü-Toplu-Yakakent) and eastern (Yeşilırmak shelf area: Canik-Costal-Fenerköy-Terme-Ünye) stations. In western locations fishermen attached a thick rubber plate under the net to prevent the deformation of mesh due to relatively hard substratum mostly covered by dead bivalve shelves and to minimize the force of friction.

Table 6.1. The gear specifications of two drag nets in Black Sea (SSA) that has impact on benthic ecosystem

Specifications	**Characteristics**	**Bottom trawl**	**Beam trawl**
Habitat type	Active fishing area and average depth (m)	-Littoral zone: shallow, smooth, silt -40-80 m	-Coastal zone: shallow, smooth, silt -5-30 m
	Bottom type	Sand, silt	sand, silty-sandy-silt, gravelly sediment
	Characteristic invertebrates	*Mytilus galloprovincialis, Modiolus sp, Crangon crangon,*	*Rapana venosa, Mytilus galloprovincialis, Chemelea gallina, Crangon crangon, Upogebia pusilla, Liocarcinus depratur*
Primary target species	Mixed-species fisheries	whiting, red mullet, turbot	-
	Single-species fisheries	-	sea snail
Vessel	Engine power (kW)	422	107
	Trawling speed (knots)	2.5-3	1.5-2.5
	Overall length (m)	21.5	9.9
	GRT	71.2	7.1
	One or two vessels (single or pair trawling)	single	single
	Number of trawls per vessel	1	2
Gear	Type	two panel, Italian modified model	traditional
	Codend: stretched mesh size (mm)	40	72-88
	Trawl circumference (stretched mesh size in mm)	500-975	-
	Trawl height (m)	0.5-2.5	-
	Beam height (cm)	-	20-22
Trawl doors	Model	bottom-rectangular	-
	Length (m)	1.2-2	-
	Height (m)	0.8-1	-
	Weight (kg)	50-150	-
	Spread (m)	22-28.5	-
Groundgear	Length (m)	20-37	2.5-3.5
	Weight (kg)	25-375	3-5.5
Beam	Width (m)	-	2-3
	Complete beam weight in air (kg)+nets (kg)	-	24-58
	Beam shoes (number)	-	2
	Beam shoes (width in mm)	-	70-100
	Beam shoes (length in mm)	-	200-350
	Shoes claw (depth in mm)	-	50-70

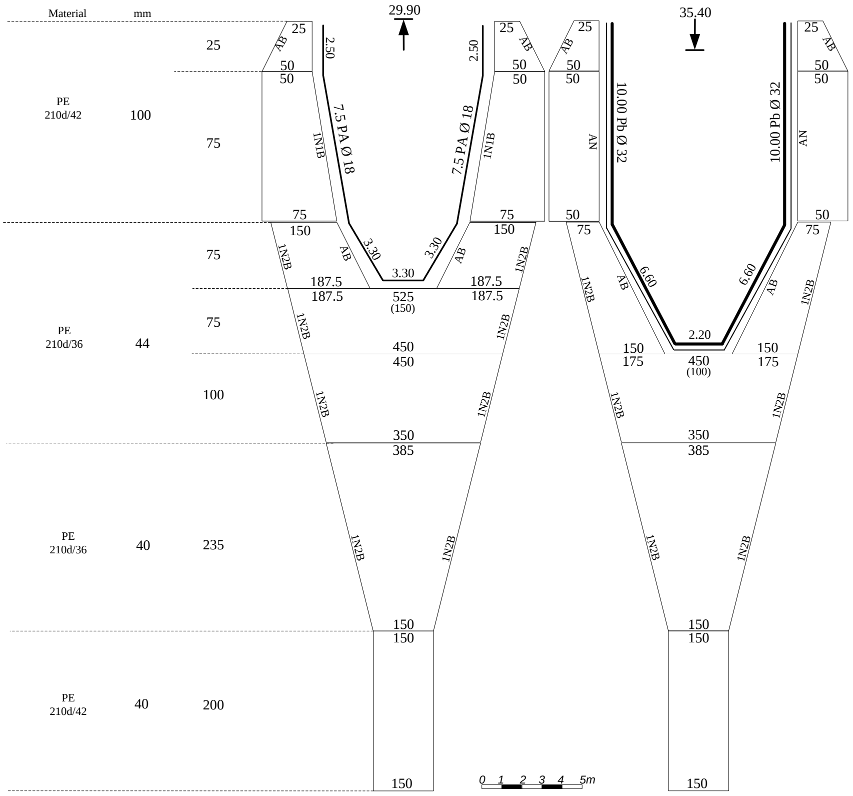


Figure 6.2. The model of a commonly used bottom trawl net having two panels and 900 mesh in codendt (Kaykaç,, Tosunoğlu ve Zengin, October, 2013, Copenhagen, BENTHIS Workshop).

Figure 6.3. A typical rectangular bottom trawl door is using in the SSA

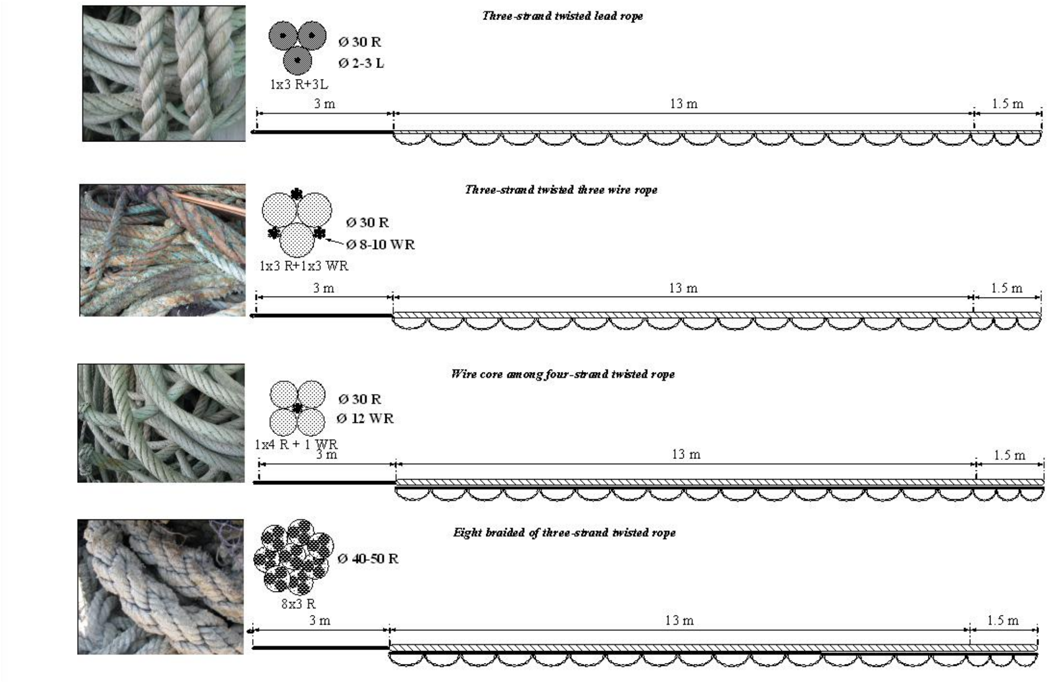


Figure 6.4. Using of four different groundgears for bottom trawl in the SSA

This rubber plate is not being used in eastern stations as the substratum is relatively soft composed of sand and mud in varying proportions. In relatively hard bottoms, to ease the hauling and to protect the net from damage, pallets were attached to beam ground gear with chain ropes. The total weight of an algarna (beam trawl) with all kind of attachments (ropes, palletes and chains, leadline, mesh codend and sheath). The mean weight of palletes is 15-16 kg and the dimensions were measured as 90x300 cm (Figure 6.5, 6.6).

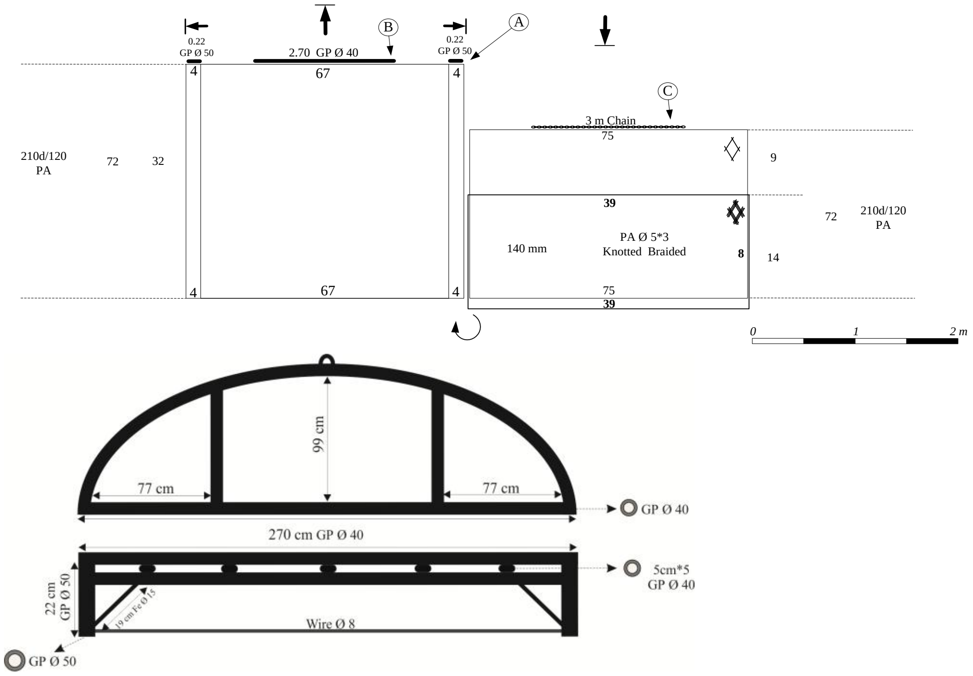


Figure 6.5. The diagram of the beam trawl (Kaykaç, H., August, 2013).

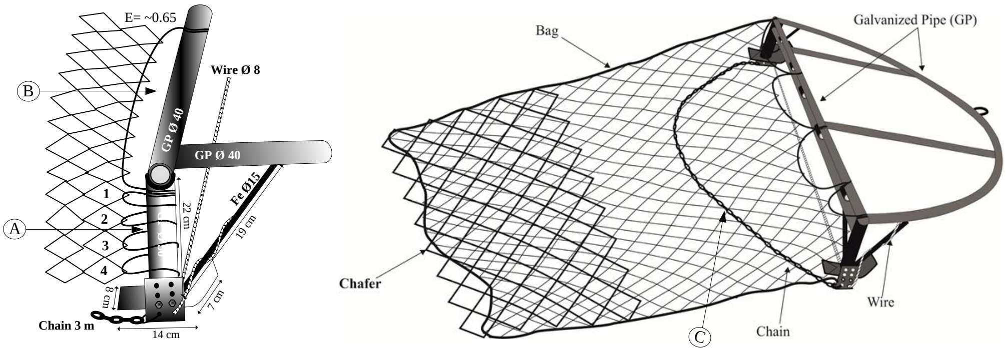
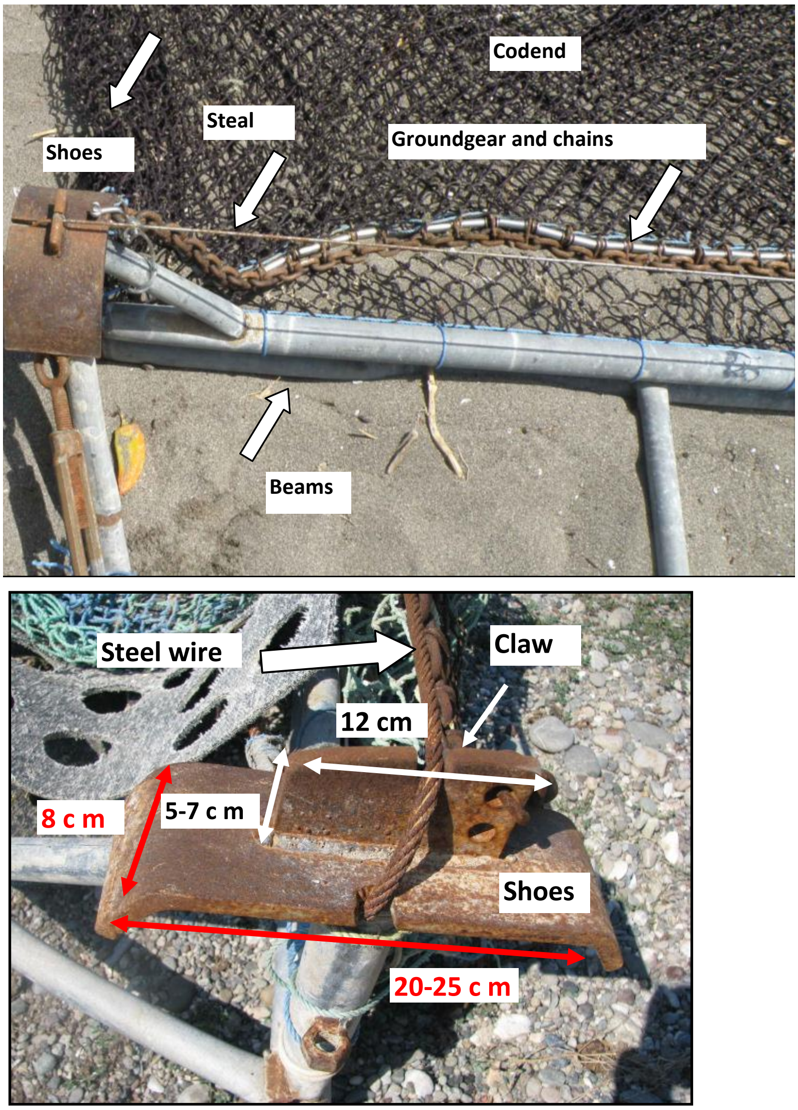


Figure 6.6. Illustration of the beam trawl (Kaykaç, H., August, 2013).

The general structure of traditional beam trawl/algarna used in SSA can be outlined as (Figure 6.7, 6.8):



Figur 6.7.<u>Leadline:</u> It is functional to dig out the rapa whelk buried or half buried in the sediment and to direct them to the net behind the ground gear. It weighs nearly 0.5 kg and has a length of 3 m and 8 mm thick.

<u>Chain rope</u>: It is 3.5 m long and made of small bean-shaped rings. Each ring is nearly 30-35 g in weight and there are nearly 120 rings in each side of rope.

Shoes: There are two shoes in each side of the beam opening. There is an iron-made protrusion (5-7cm thick) over the shoes called 'claw' contacting the bottom. The leadline is attached to the small notch on this claw. In the course of operation this part penetrates the substratum and forms a rift of its thickness.
Front-shoes: This equipment is only used in western stations in SSA. The front shoes is attached to the point connecting the mesh and the ground gear. It is 20 cm thick, made of iron and functional in floating of the net opening without sinking to the bottom. This apparatus is being used in western stations for the last three years. The front shoes also prevent the direct contact of leadline with bottom.

Figure 6.8. There is a perforated plastic/rubber palette attached to the chain on the opening of the gear, in order to mitigate the friction beneath the gear and to provide an easier slipping and also to minimize the gear deformation. Furthermore, to protect the upper panel of the gear, a covering (mantle) was added to the gear produced with a larger mesh size than of the bag and with a coarser thread material.

6.3. Assessing the fishing effort and landings

6.3.1. Fishing effort

Some quantitative and qualitative data about the fishing fleet operating with drag nets was collected in 2013. The data sources in this task were: (a) direct field observations (logbooks of trawl vessels, and landings for market), (b) the records of two SMEs (BENTHIS partners; Malkoçlar and Sadıklar) such as the number of algarna fishermen, the total amount of rapa whelk catch that has been brought to factory for processing, active fishing day, etc., (c) official records (Turkish Statistical Institute -TUIK, Fisheries Information System-BSUGM/SUBIS) about the general specifications of the registered fishing fleet, algarna and bottom trawl fishermen). In Table 2, some qualitative and quantitative properties of actively operating fishing fleet for both algarna and bottom trawl gears along Black Sea coasts were summarized.

It is determined that there are totally 43 fishing port or shelter between Samsun and Iğneada and 486 fishing vessels are active in 31 of them in 2013/2014 fishing season. 154 (31.7%) vessels in this fleet is belonging to SSA and 332 63.8%) to the western Black Sea (Sinop-İğneada). Another 55 vessels are coming from the southern Marmara Sea (Bandırma: Çakılköy-Karşıyaka) and temporarily operates in the western Black Sea waters between Ereğli and İğneada during the fishing season as the trawl fishery completely banned in Marmara. The active fishing day of these fishermen was estimated averagely as 120 per year.

In SSA, the algarna/rapa whelk fishery is more intense when compared to other locations throughout the whole Black Sea coast though the fleet is active in all area. There are 169 fishing vessels in SSA, 182 in western Black Sea (between Sinop-İğneada) and 105 in eastern Black Sea (between Ünye-Rize) currently operating as registered or unregistered. There is significant diffrence in the number of day-at-sea between SSA and the two other regions. The reason may be the more available bottom type of SSA for rapa fishery and the higher CPUE. The number of active fishing day per year is 115 in SSA and averagely 45 days per year for eastern and western Black Sea.

Table 6.2.The general profile of fishing fleet using drag nets along Black Sea coasts of Turkey in 2013.

Geographic locality	Number of bottom trawl vessel	Number of beam trawl vessel	Sources
EBS (Eastern Part of Turkish Black Sea	-	105	1-KARTİP, 2013 National Trawl Project 2- Turkish Ministry of Food, Agriculture and Livestock, BSÜGM 3-BENTHIS Black Sea Case Study, 2013 4-From Mustafa SADIKLAR, SME-13 Company of Sea Snail Plant: '*Sadıklar Balıkçılık*'
SSA (Samsun Shelf Area)	154	169	
WBS (Western Part of Turkish Black Sea)	332	182	
Total	**486**	**456**	
EBS- active fishing day/ for one vessel in a fishing season	Banning of bottom trawl fisheries	45 day/vessel	
SSA- active fishing day/for one vessel in a fishing season	120 day/vessel	115 day/vessel	
WBS- active fishing day/ for one vessel in a fishing season	120 day/vessel	45 day/vessel	
Total fishing day-all of the Black Sea fleet / for in a fishing season	**58320 days**	**169*115=19435 287*45=12915 Total=32350 days**	

6.3.2 Assessing the catch per unit effort

Marine field work was made by commercial vessels and the catch per unit effort was estimated according to 'swept area method'. Furthermore, parameters such as geographical coordinates, depth, fishery sub locations, haul speed, duration at sea, gear and vessel specifications, the amount of catch on board, untargeted species (by catch), discard and the amount of catch for market were recorded.

6.3.2.1. Bottom trawl fishery

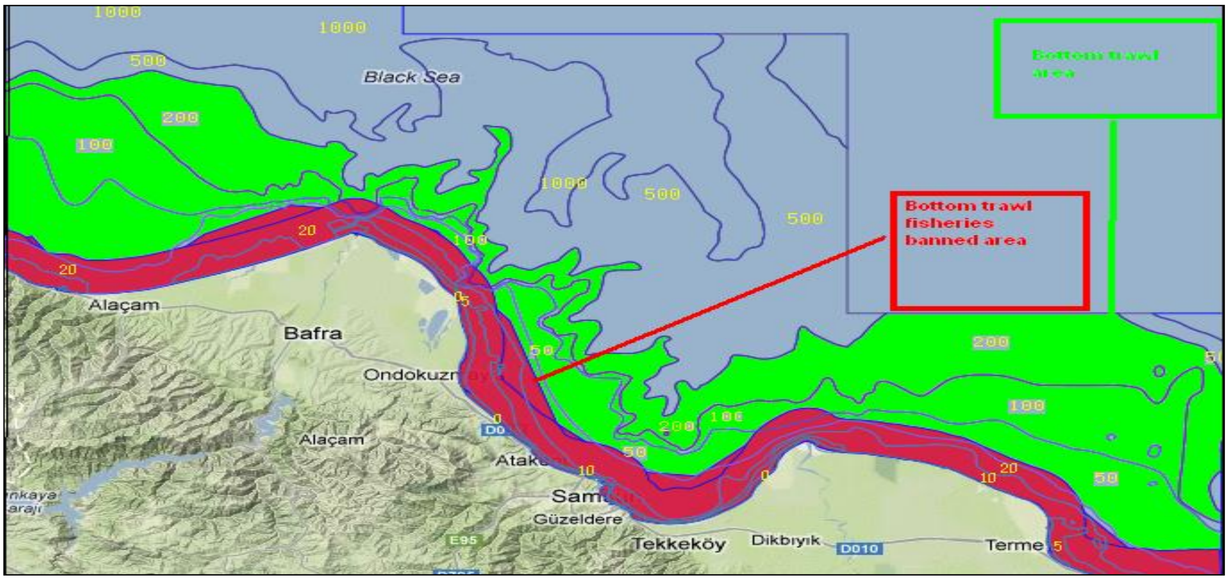


Figure 6.9. In SSA bottom trawl operations are carried out around the depths of 45 and 90 m. The three miles zone from land is closed to this kind of fishery

The bottom trawl fishery is banned in Turkish Black Sea between the mid of September to the mid of April. The study area (SSA) includes the near shore water of three miles where the fishermen operate illegally (Figure 6.9). Seasonal samplings were carried out around the depthsranging between 30 and 120 m and by using 400 and 900 meshes and modified 40 mm diamond meshsize in codend of traditional bottom trawl. The monthly samplings are realized with two size of vessel; smaller than 18 m (12-17 m) and larger than 18 m(18-32 m) which is typical for Black Sea trawl fishery fleet. In each sampling period, at least two commercial vessels, representing the study area were monitored and catches were recorded on board. In the fieldwork, the total catch and the faunal composition is recorded for each of haul that is standardized for duration.

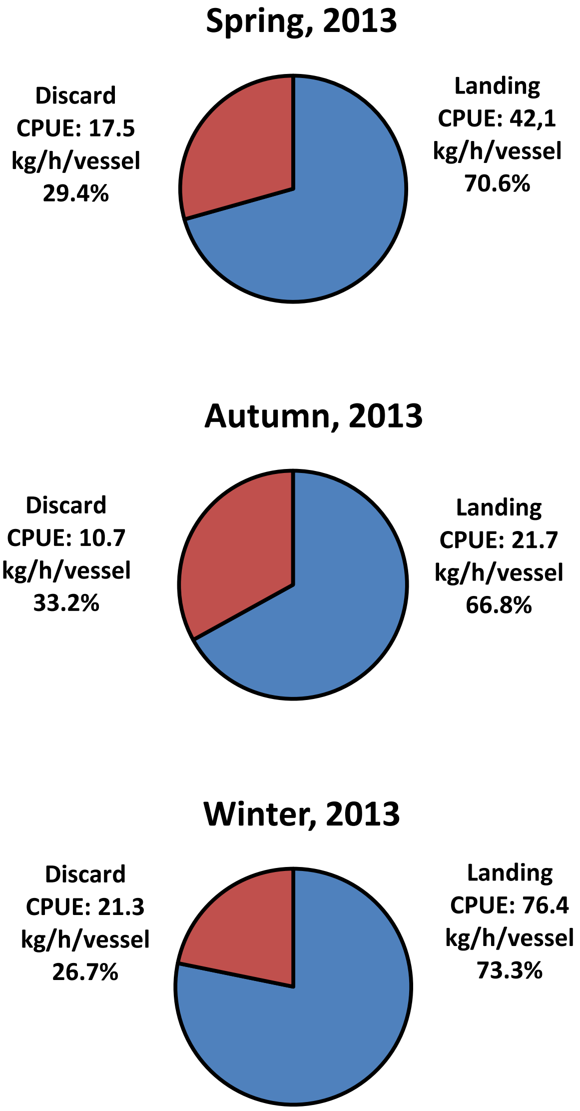


Figure 6.10. The seasonal variation in the CPUE of landing and discard in whiting (M. merlangius euxinus) caught by bottom trawls in SSA in 2013.

The catch per unit effort (CPUE) for whiting population is estimated as 59.6, 32.4 and 97.7 kg/h/vessel for spring, fall and winter (2013) respectively. The CPUE for red mullet population is also determined as 32.5, 18.6 and 7.9 kg/h/vessel for the same seasons respectively. For both species, the rate of discarded and marketed landing, the length and weight frequency distributions were presented in Figures 6.10, 6.11, 6.12, 6.13.

The length frequency distribution of Black Sea turbot which has relatively low fishery production when compared to red mullet and whiting but higher market price is presented in Figure 6.14. The CPUE of turbot is estimated as 0.7 kg/h/vessel for the bottom trawl fishery along Turkish Black Sea coasts. This result implies a steady decline in turbot stock in Black Sea shelf area. The CPUE values of turbot estimated for the same region were as 1.6, 1.3 and 1.8 kg/h/vessel respectively for 2010, 2011 and 2012.

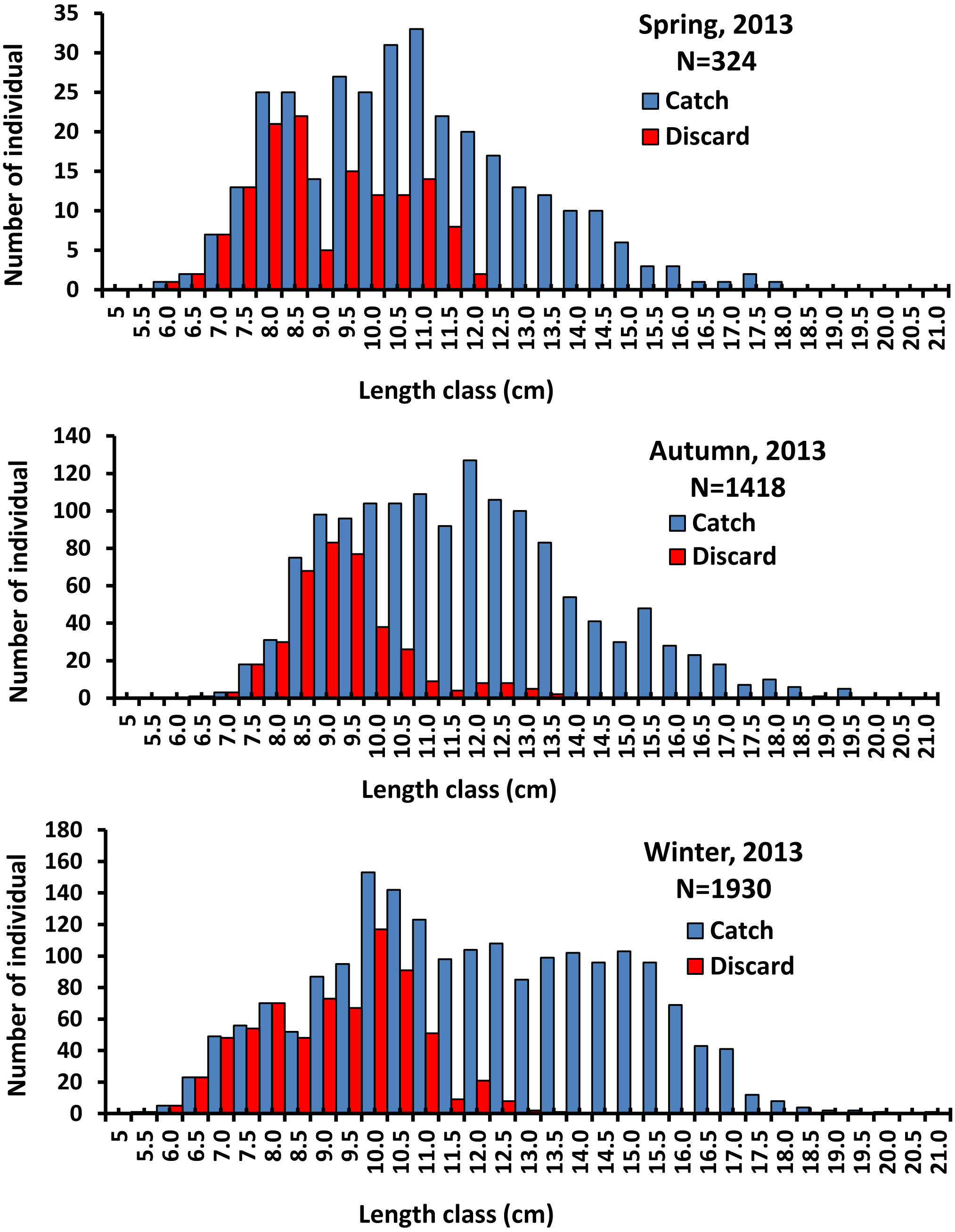


Figure 6.11. The seasonal variation in the CPUE of landing and discard in whiting (M. merlangius euxinus) caught by bottom trawls in SSA in 2013.

L_{50} at-maturity is reported as 14 cm for whiting population in southern Black Sea coasts. However, because the population is mostly composed of young individuals usually 12 cm tall individuals are sent to the market. The ones smaller than this size are being discarded. The seasonal variation of whiting discard in number is 41.4%, 26.8% and 35.9% respectively for spring, autumn and winter. Whiting discards the seasonal aspect ratios (number) respectively.

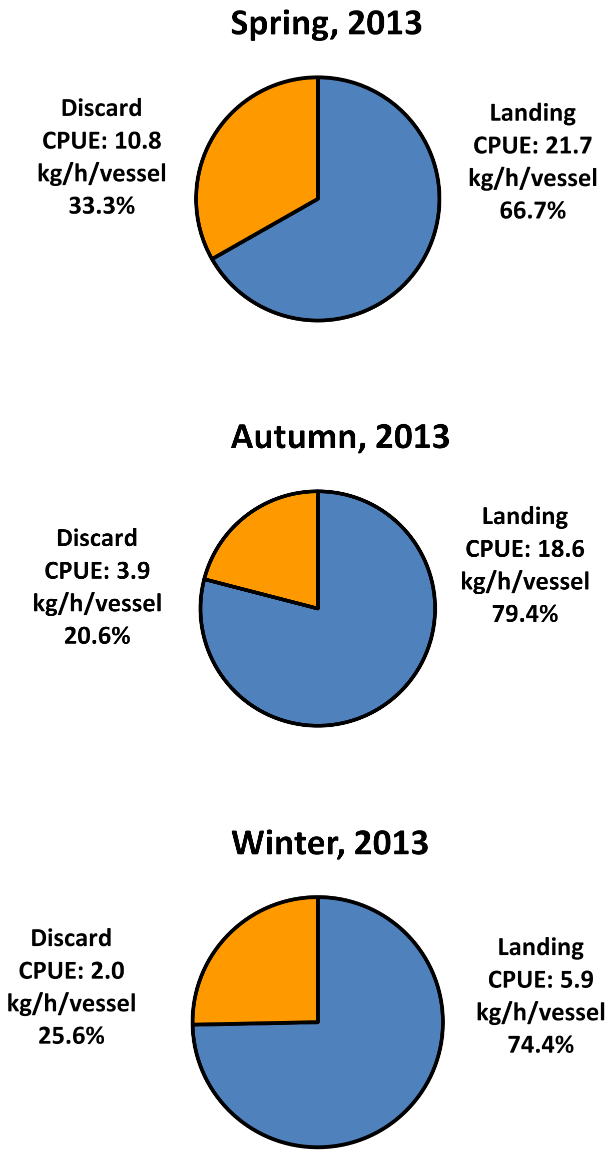
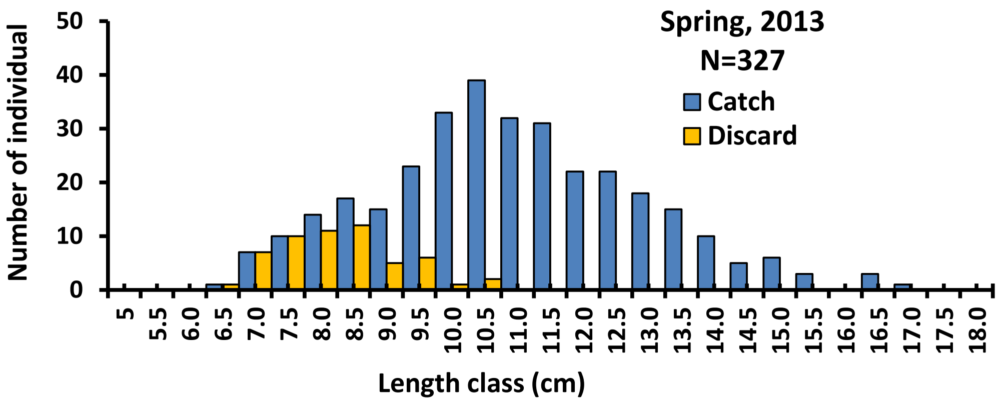
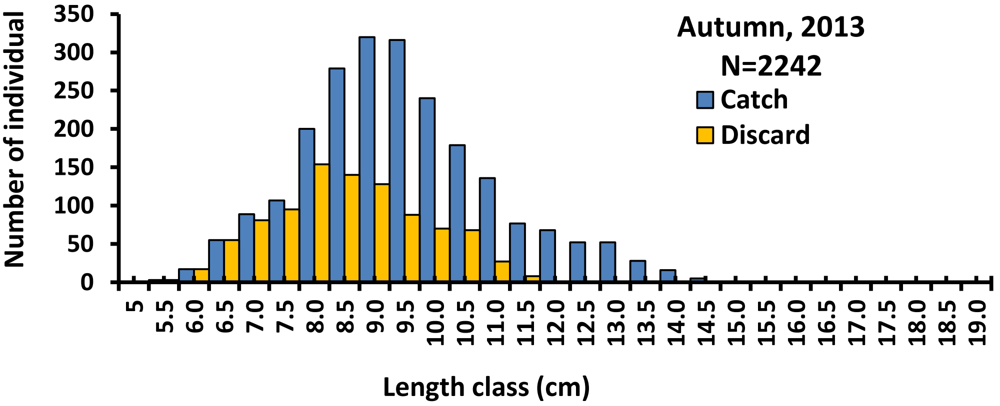


Figure 6.12. The seasonal variation in the CPUE of landing and discard in red mullet (Mullus barbatus) caught by bottom trawls in SSA in 2013.





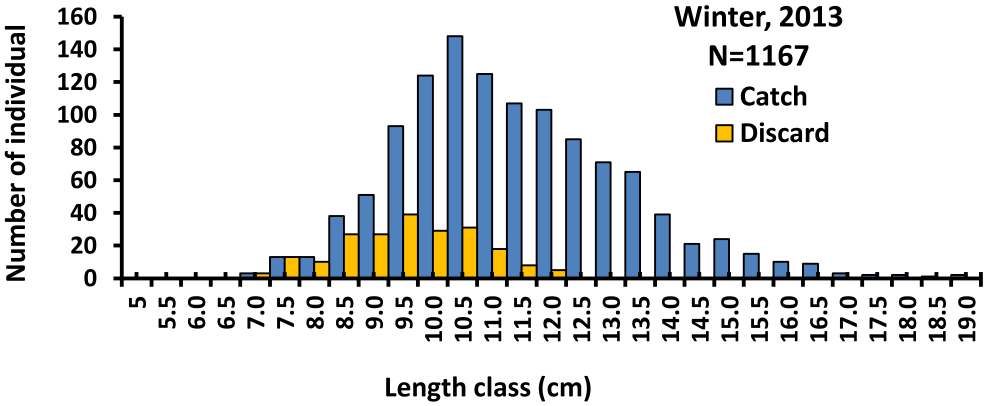


Figure 6.13. The seasonal variation in the length frequency distribution of landing and discard of red mullet (Mullus barbatus) caught by bottom trawls (40 mm mesh size) in SSA in 2013.

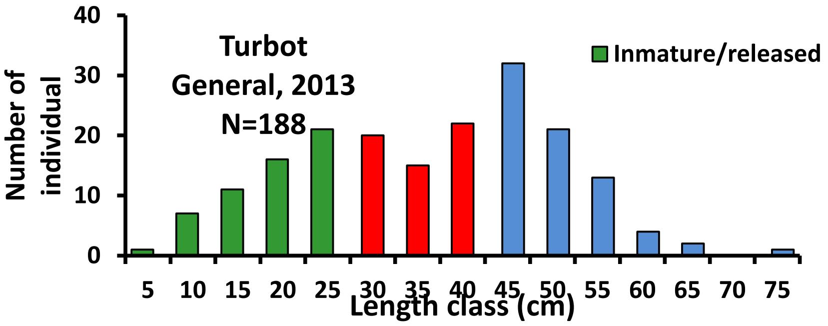


Figure 6.14. The length-frequency distribution of turbot obtained from sampling surveys conducted with commercial bottom trawls throughout Turkish Black Sea coast in fishing period of 2013.

L_{50} at-maturity is reported as 12 cm for red mullet population for southern coasts of Black Sea. However, because the population is mostly composed of young individuals and the market price is high, generally the individuals that could not reach sexual maturity at 8 cm also have been sent to market. The ones smaller than this size are being discarded. The seasonal variation of whiting discard in number is 16.8%, 41.7% and 18% respectively for spring, autumn and winter.

The Black Sea turbot is the most important target species of bottom trawl fishery but the amount of landings is very low compared to the other two species. Therefore the sample size seems insufficient to represent the length frequency of population and its seasonal variation in SSA. Even though the turbot is the most precious species in Black Sea fishery, the stock is heavily exploited. The individuals over 45 cm in size are being landed and all of the immature ones are sent back to the sea by fishermen. Therefore the amount of discard in turbot is very low when compared to other target species of bottom trawl. Accordingly, the discard rate is quite low in bottom trawl fishery. However, newly maturing individuals within the length range of 30-40 cm are also being marketed. The illegal catch reaches nearly 30% of the total catch.

The maps of CPUE distribution for whiting, red mullet and turbot in SSA and 2013 is presented in Figures 6.15, 6.16, 6.17.

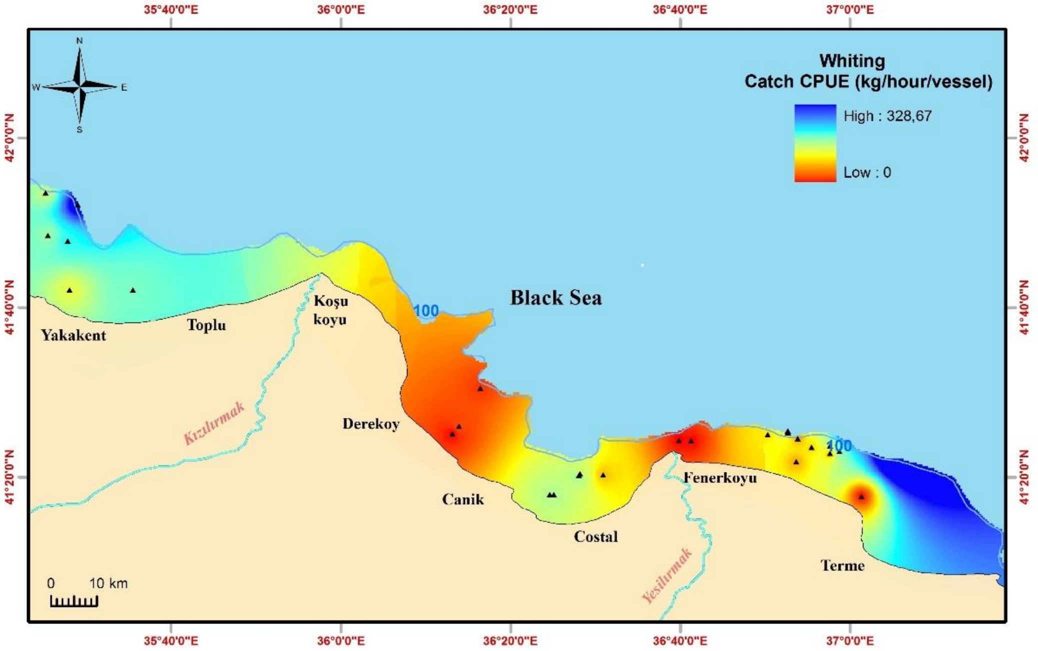


Figure 6.15. Mapping of CPUE for yearly variation whiting in SSA

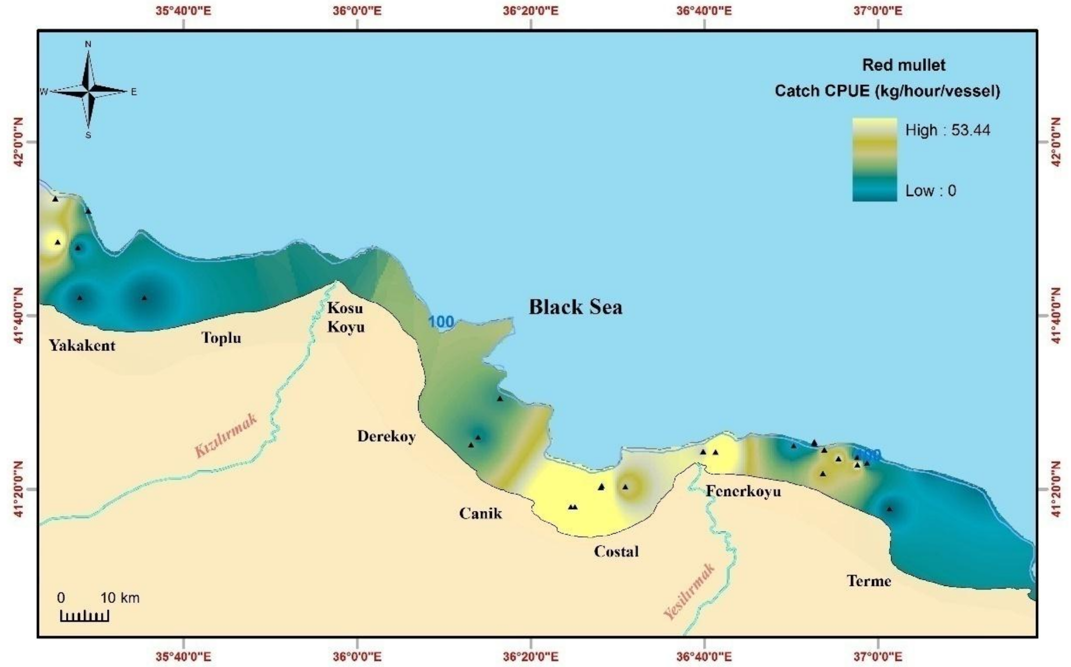


Figure 6.16. Mapping of CPUE for yearly variation red mullet in SSA

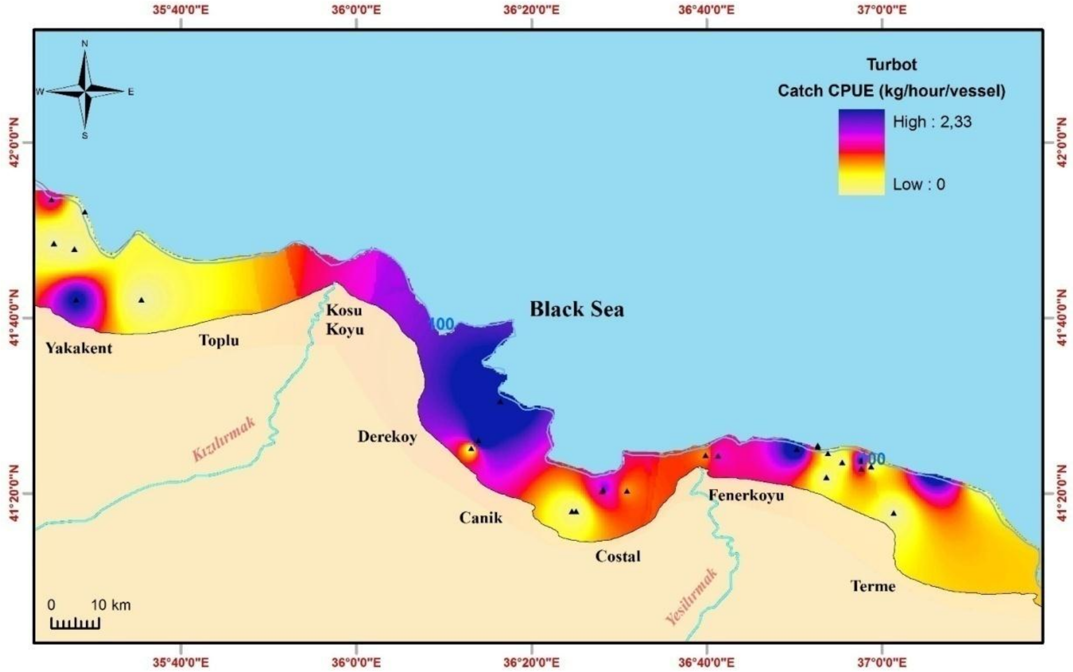


Figure 6.17. Mapping of CPUE for yearly variation turbot in SSA

6.3.2.2. Beam trawl fishery

As there are no long-term studies which monitored the beam trawl fishery on rapa whelk along the Turkish Black Sea coast to present and also the ones realized previously could not fully satisfy the BENTHIS requirements, a survey was started to obtain the parameters that we need for the tasks within WP7.

There is still some problems in management of rapa whelk fishery continued on SSA between depths of 5 and 30 m and becoming intense in summer months (Figure 6.1 and 6.9). The fishermen always tend to break the fishing rules in terms of location, timing and type of gear or its application. So, all kind of information about the impact of beam trawl fishery on benthic habitat in SSA will make a valuable contribution to BENTHIS outputs.

Six different local stations characterizing the rapa whelk fishery in SSA defined as Terme, Fenerköy, Costal, Dereköy, Koşuköyü and Toplu (Figure 6.1). The two of them; Yeşilırmak/Fenerköy and Kızılırmak/Koşuköyü is especially preferred to check out whether these estuarine zones make any significant difference for this fishery related to the type of substratum. In sampling operations, the commercial beam trawl vessels and tne nets with 70-90 mm mesh size were used. The size of vessels ranged between 6-12 m and the engine power between 35-350 HP. The samplings were made in all locations by at least two vessels in day or night time. In winter months, as the catch is extremely low, it was hard to find any operating vessel and therefore the samplings limited to three stations. Except the experimental blind gear trials, all operations were carried out according to fishermen initiatives.

The tasks to monitor the beam trawl fishery in the last one year (June, 2013-May, 2014) can be seen in the following substances. (a) the monthly variation of fishing effort (CPUE) in SSA (b) the species composition of benthic and benthopelagic macrofauna ((invertebrates and fish) and their seasonal distribution as well as the target species (c) the comparison of the selectivity of gears equipped with net bags of 72 and 88 mm mesh size (commercial type) and 12 mm mesh size (blind gear) and the impact on bycatch diversity.

a) Distribution of fishing effort (CPUE): The amount of catch reach its maximum in summer period. The seasonal variation in CPUEs is presented in Figure 6.18 and 6.19 and the length-frequency distribution of rapa whelk catch and its seasonal trend is indicated in Figure 6.20.
The summer period is also the banned season (May 1- August 30) for beam trawl fishery targeting rapa whelk. The diversity and the abundance of by catch species seems to be higher in summer months when compared to fall and spring (Figures 6.21 and 6.22). The data about species diversity and abundance is an important matter in terms of a rational fishery management.

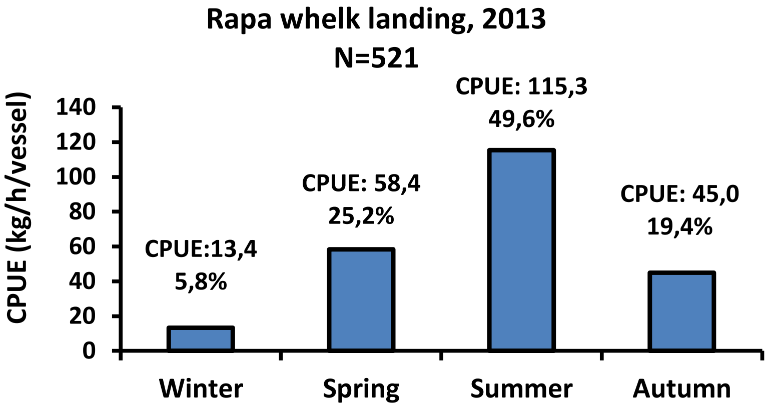
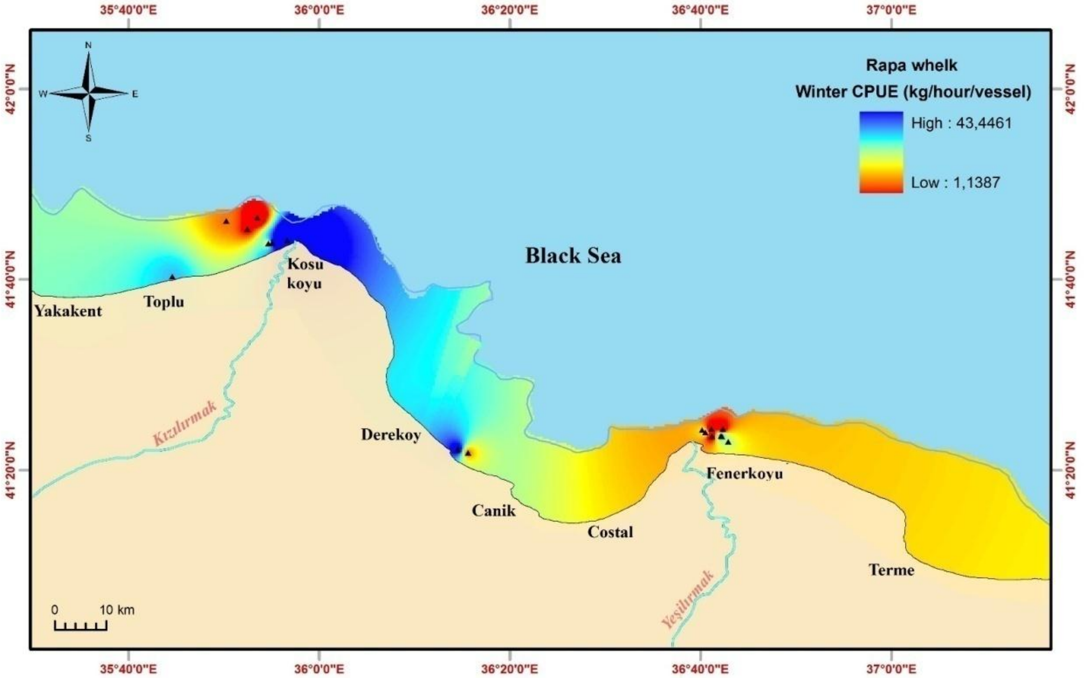
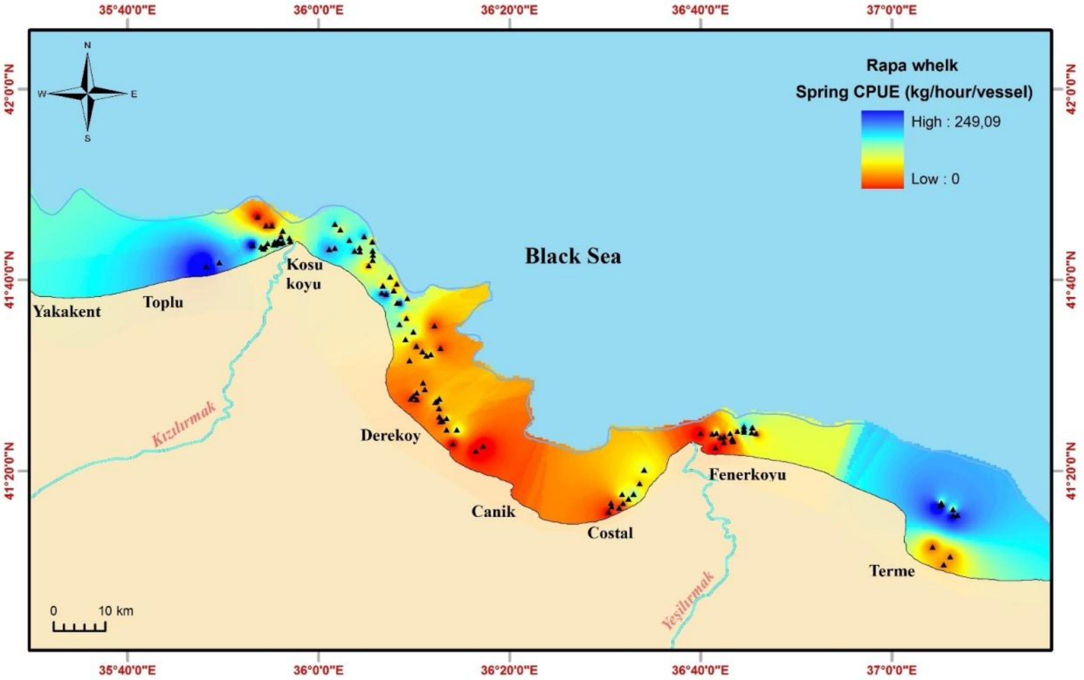


Figure 6.18. The seasonal variation of CPUE values of rapa whelk fishery in SSA and at fishing period of 2013.


Rapa whelk
Winter CPUE (kg/hour/vessel)
High : 43,4461
Low : 1,1387
Black Sea
Yakakent
Toplu
Kosu koyu
Kızılırmak
Derekoy
Canik
Costal
Fenerkoyu
Terme
Yeşilırmak
0 10 km
N
S
W
E
35°40'0"E
36°0'0"E
36°20'0"E
36°40'0"E
37°0'0"E
42°0'0"N
41°40'0"N
41°20'0"N


Rapa whelk
Spring CPUE (kg/hour/vessel)
High : 249,09
Low : 0
Black Sea
Yakakent
Toplu
Kosu koyu
Kızılırmak
Derekoy
Canik
Costal
Fenerkoyu
Terme
Yeşilırmak
0 10 km
N
S
W
E
35°40'0"E
36°0'0"E
36°20'0"E
36°40'0"E
37°0'0"E
42°0'0"N
41°40'0"N
41°20'0"N

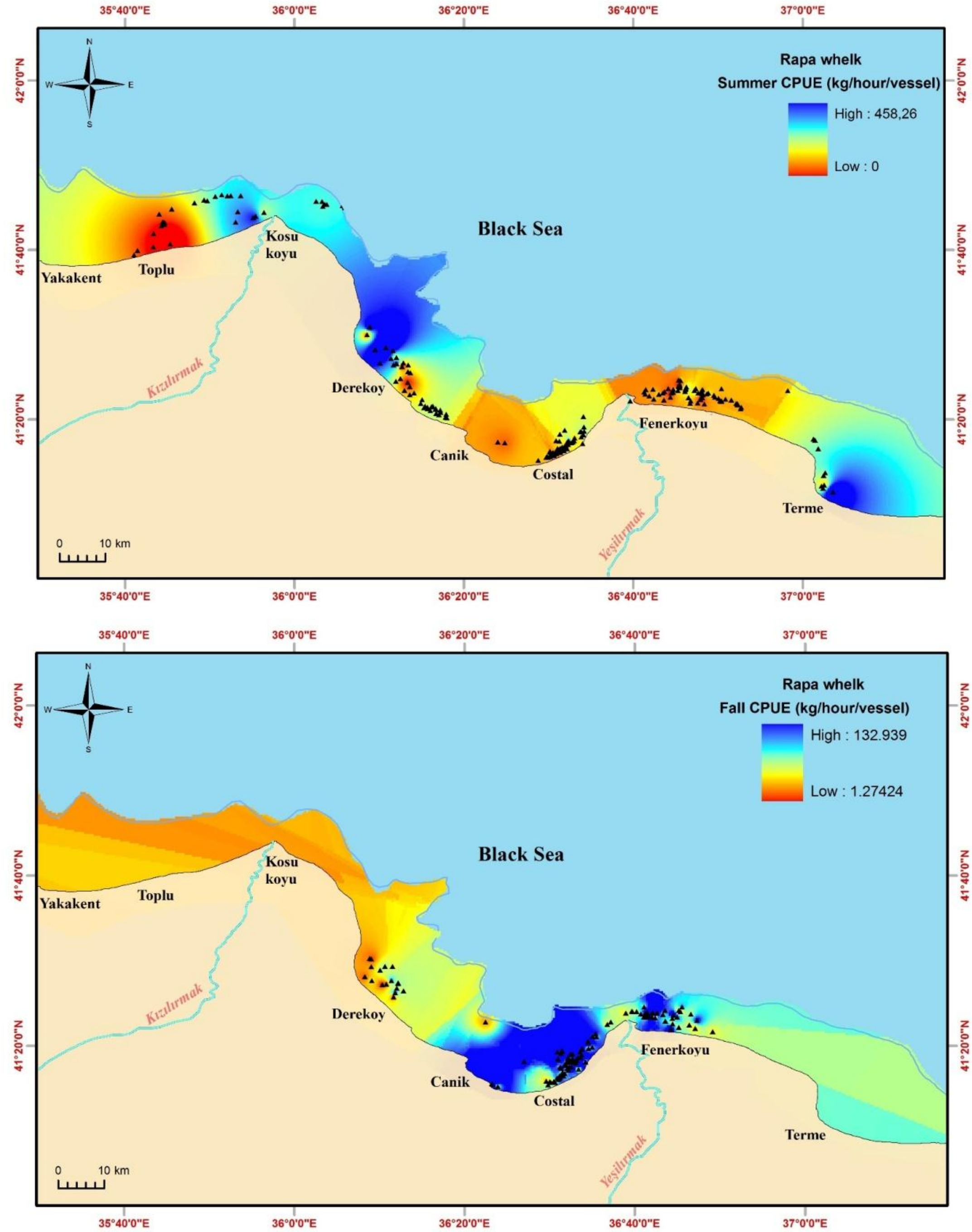


Figure 6.19. The seasonal catch per unit effort variation distribution of rapa whelk catch caught by traditional beam trawls (algarna) with mesh sizes ranging between 72 and 88 mm.

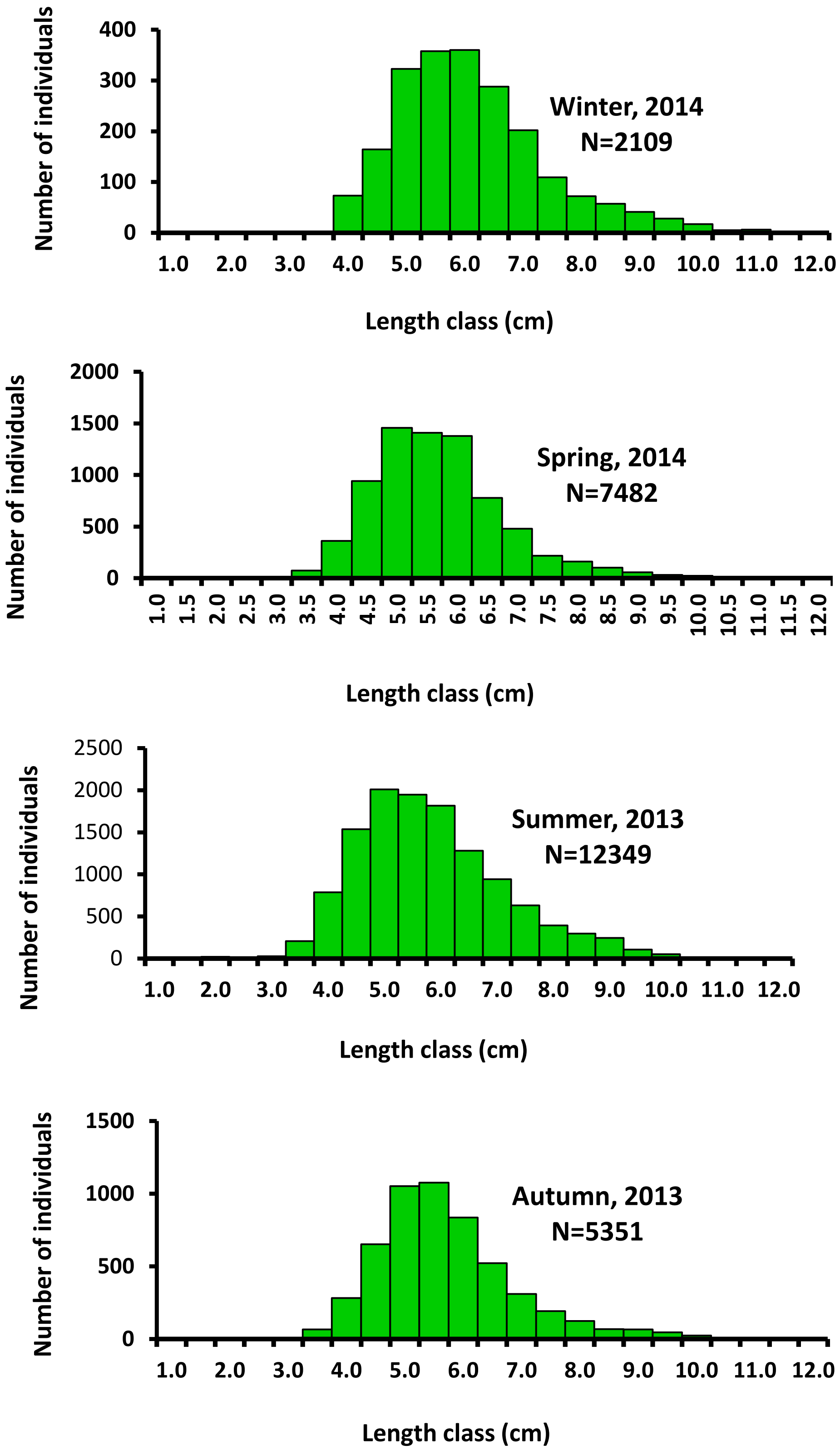


Figure 6.20. The seasonal length-frequency distribution of rapa whelk catch caught by traditional beam trawls (algarna) with mesh sizes ranging between 72 and 88 mm. Nearly the the total catch of rapa including the small individuals is transferred to the processing plants and there is no catch than can be defined as discard.

b-The composition of by catch (untargeted species): The fishing mortality caused intense algarna fishery is relatively high in summer months. This fishing effort has a significant effect on juvenile fish populations which used the nearshore benthic as nursery areas. The total catch of algarna fishery is composed of target species; rapa whelk (70.3%) and other by catch species (29.7%) in summer period. In this period totally 33 species identified belonging to four different taxonomic group. Their abundance is estimated as 25.7% Mollusca, 3.5% Crustaceans, 0.2% fishes (mostly juveniles) and 0.3% Tunicates. The species number in these groups is as 9, 7, 16 and 1, respectively (Figure 6.21).

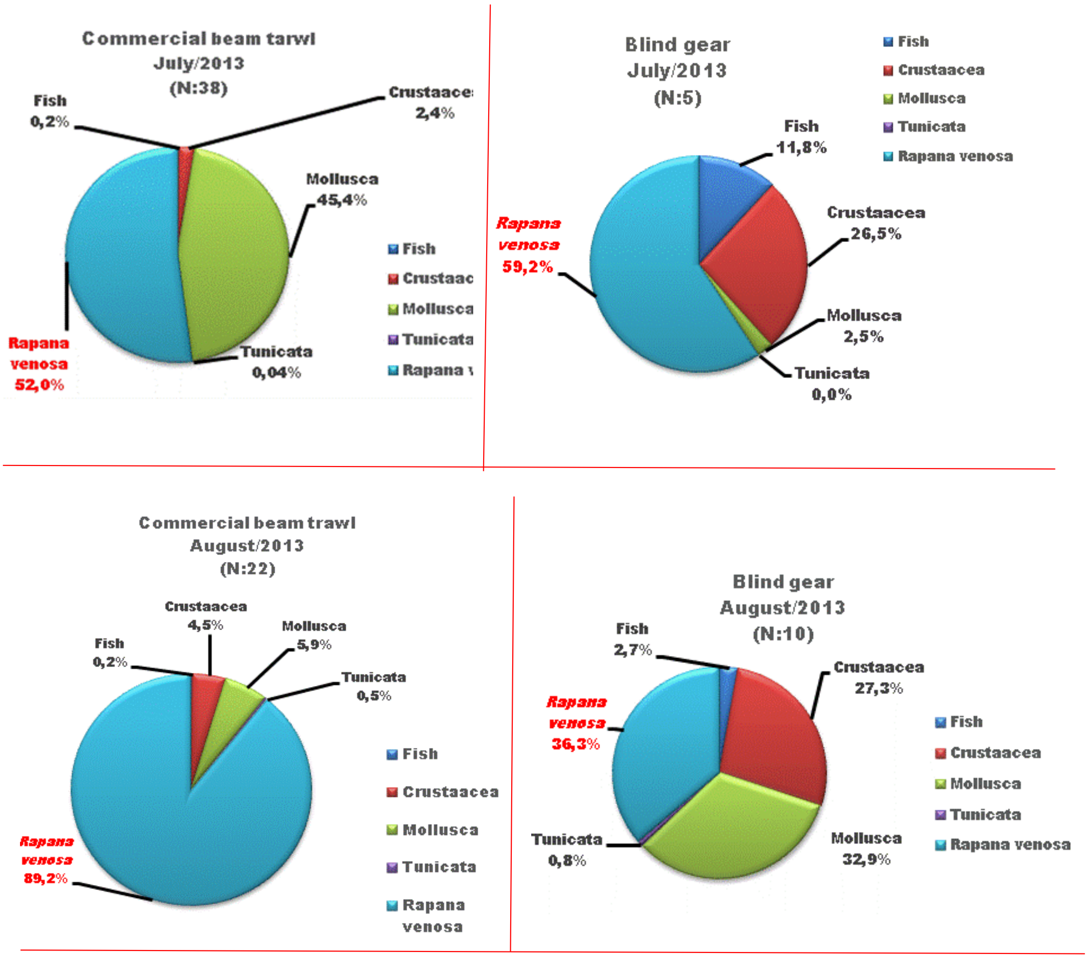


Figure 6.21. The relative distribution of benthic organisms in algarna (beamtrawl) catch in summer period (July-August) in SSA.


Bothryllus schlosseri, a colonial tunicate on inside of an empty *Anadara cornea* shell. The species firstly identified in this area by this study.

Figure 6.22.The by catch species from different taxa caught in beam trawl fishery beside the target species, rapa whelk in SSA.

c-The characteristic of landing: As the TUİK data processing system based on yearly data and the monthly variation of rapa whelk catch is obtained from the annual catch records (Black Sea coasts and 2013) of Sadıklar which is a company leading the rapa processing and export (Figure 6.23). This company buys nearly 45-50 % of total catch coming from from different fishery locations throughout the whole Black Sea coast. The distribution of total catch in terms of regions and months is derived from this data and presented in Figures 6.24 and 6.25.

We could be able to gather the data about rapa whelk fishery only in SSA relevant to the tasks in WP7, BENTHIS. Actually, 42.1% of the total catch is obtained from SSA and the rest percent is coming from other fishery locations (Figure 6.25). For example, 39.2 of the total catch is provided by the fishery conducted along coasts between Ünye and Rize (eastern Black Sea coast). Beam trawl is commonly used in legally open fishery season but in western locations (Sinop and its west) fishery by diving is more common.

Data gathered about the beam trawl fishing fleet and all other fishery parameters also contributes to the work in WP2 that aims to outline the level of fishing pressure and its impact on benthic ecosystems in regional seas.

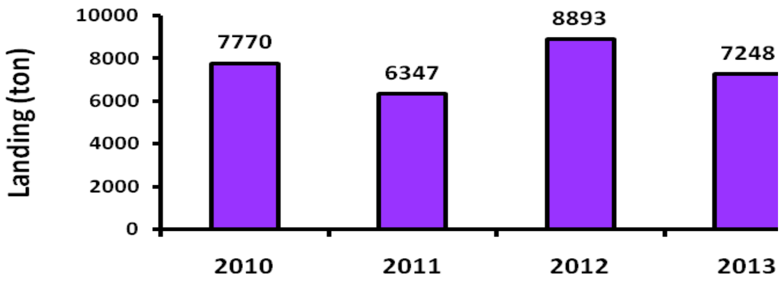


Figure 6.23. The annual variation of rapa landing in the last four years in Black Sea (data of 2010-2012 from TÜİK and 2013 from SADIKLAR rapa whelk Processing Plant)

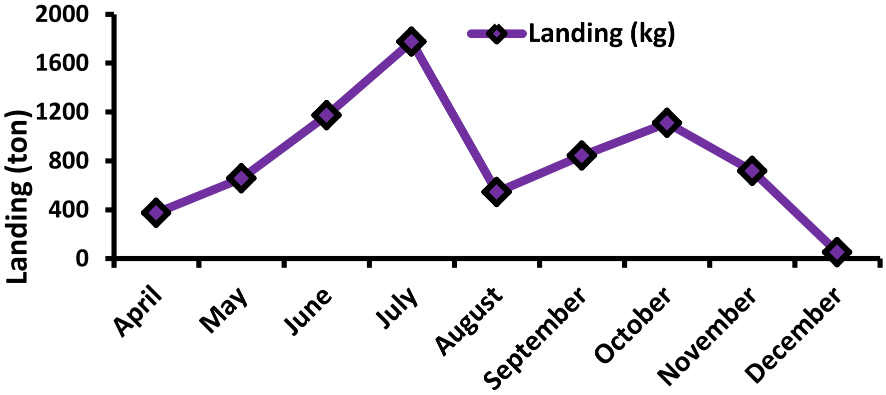


Figure 6.24. The monthly distribution of rapa whelk landing in the Black Sea coast (data obtained from SADIKLAR rapa whelk Processing Plant)

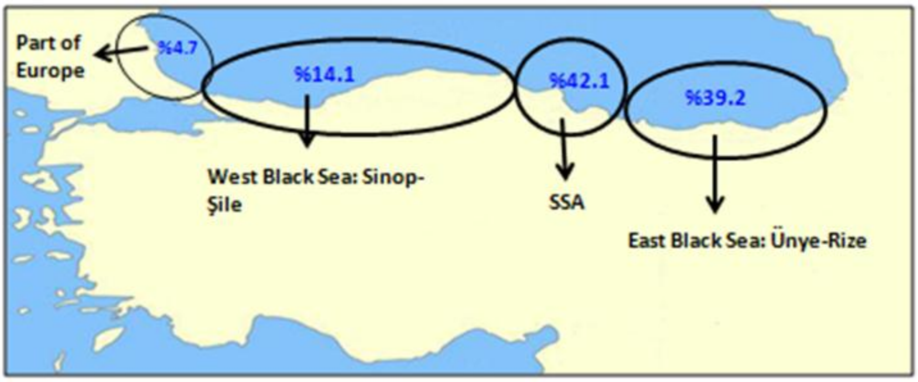


Figure 6.25. The distribution of total catch of rapa whelk among four sub-locations of fishery along the Black Sea coasts. These locations have some different in ecological and fishing properties. Though the area available for rapa whelk fishery is smaller than the other three, the most efficientfishery is being realized in this location. All fishermen use algarna in rapa whelk fishery. The nearshore benthic (depth of 5-30 m) is under high pressure of this algarna fishery.

3.3. The cost-benefit analysis of vessels

As there is no previous data about the economic profile of the fishing fleet in SSA, a query study is conducted on January 2013 relevant to WP5 work. Firstly, the type (beam or bottom trawl) and number of vessels and size categories were determined.

The sub-sampling is taken from the main fleet that have drag-nets and actively operating during 2011/12 and 2012/13 fishing seasons in SSA. Three size categories in vessels is defined according to fishing method and target species. There is 131 vessel in the first category ((7-11.9 m), 38 in the second (12-17.9 m) and 112 in the third category. The total number of vessels is 281 (Figure 6.26).One of the random stratified sampling tests; 'Neyman method' is used to determine the number of vessels required for sub-sampling. The sub-sampling was assigned as 42 within 99% confidence level.

Neyman method is also used to classify the sub-sampled vessels into size categories as 19-6-17 for categories 1-3 respectively. In this first field survey, we met totally 20 fishermen. The other interviews will be completed in summer 2014 field surveys. According to the preliminary data, the cost-benefit analysis of the fishing vessles in SSA for 2013 is summarized in Table 6. 3.

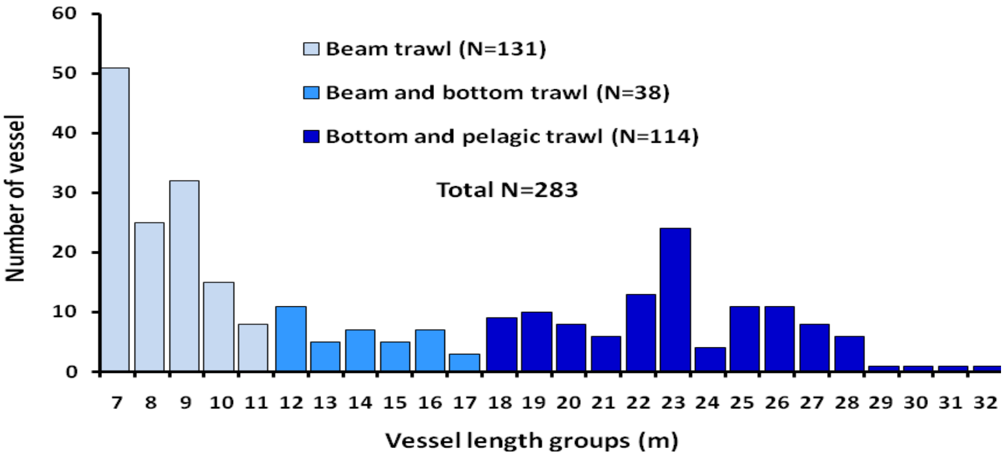


Figure 6.26. The size-frequency distribution of trawl fishing fleet in SSA for 2012/13 fishing season.

Table 6.3. The annual cost-benefit (€/vessel/year) analysis of beam and bottom trawl vessels in SSA for 2012/13 fishing season (*preliminary data*) .

Vessel type	Gross profit	Expense	Income
Beam trawl	51308,8	32899,9	18408,9
Bottom trawl	45307,7	36428,7	8879,0

6.4. Habitat map of the substrate types in Black Sea Case Study Area; SSA

We gather information to produce the habitat map of SSA from a previously conducted study (EKOBENT project, CFRI) and two surveys (winter and spring 2014) carried out by OMU and CFRI within the tasks of WP3 in BENTHIS. These benthic surveys will be continued in the next two seasons; summer and fall 2014. The sediment samplings were taken from totally 40 stations and particle size analysis were realized. The stations for sediment sampling were assigned as on a vertical line to land at certain distances from each other and at four different depths (Figure 6.27). The data derived from PSA and also the information of coordinates applied to the ArcMap Sediment Classification Tool (ArcGIS ver 9.2) to derive the habitat map of the substrate in SSA (Figure 6.28). This module makes sediment classification according to Shepard (1954) as modified by Schlee (1973) sediment classification. SSA can be accepted as a soft bottom habitat that is mostly composed of muddy sand and sandy mud. Stations having hard substratum is very limited. This soft bottom is highly available for all kind of drag-net fisheries and this makes this habitat highly sensitive because of heavy fishing pressure.

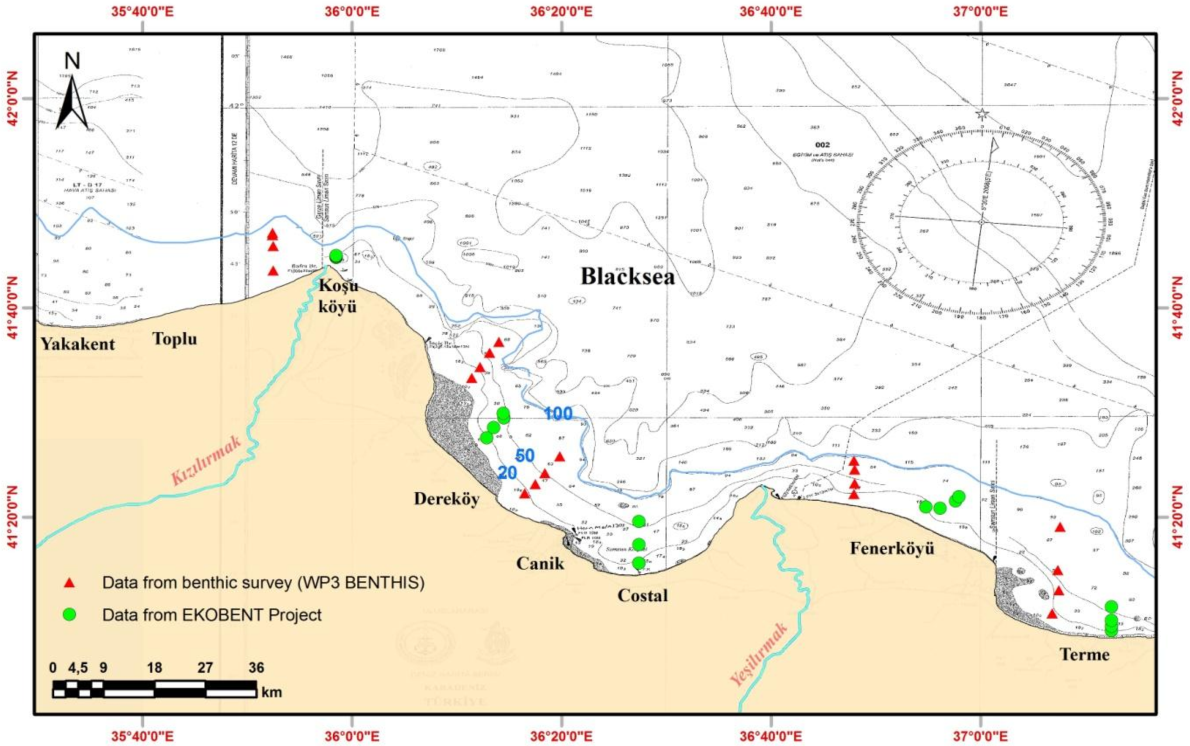


Figure 6.27.The stations of sediment sampling in SSA both from EKOBENT and WP3 task in BENTHIS.

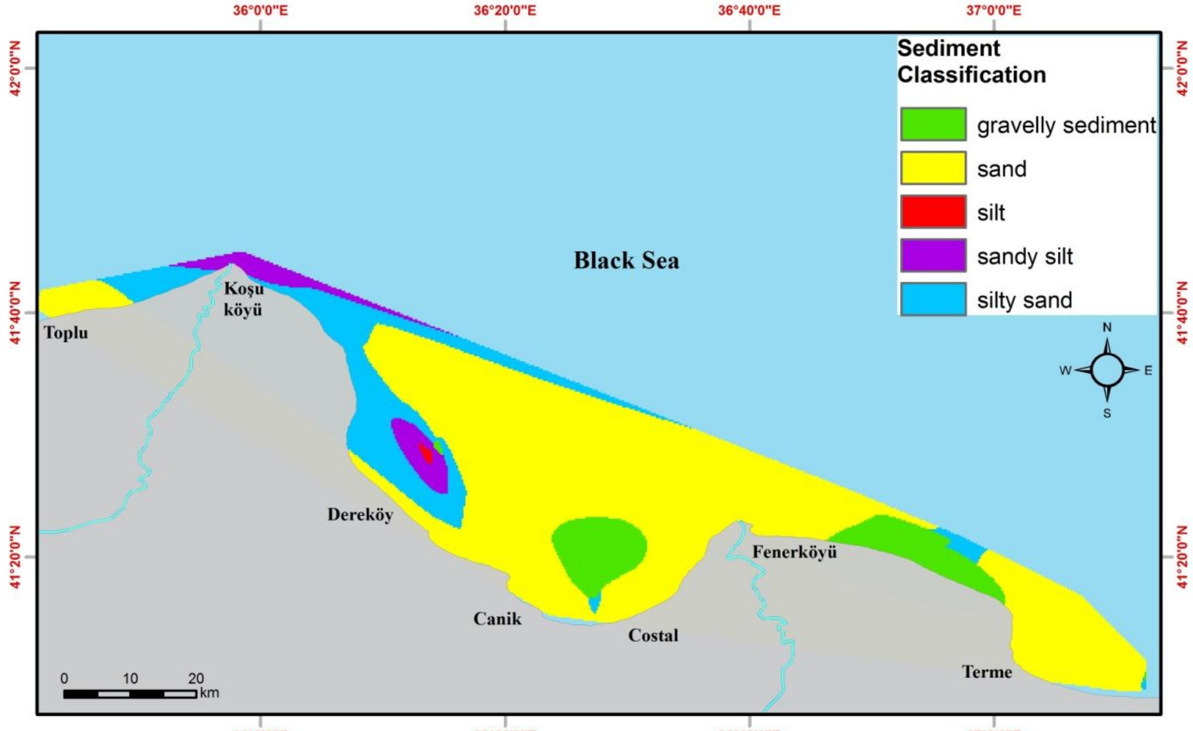


Figure 6.28. Habitat map of SSA showing that the region have soft bottom characteristic.

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