A comparison of the coastal fishery from Thorupstrand to the conventional bottom trawl fishery with focus on environmental impact

by Iben Rathje, Ole Eigaard and Erik Hoffmann

Photo: Han Herred Havbåde

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1. Summary and conclusions

This study provides a description of the coastal fishery from Thorupstrand and a comparison between this local small scale fishery and the conventional Danish bottom trawl fishery with focus on environmental impact.

The work has included a description of the fishing methods, boats and gears, target species, total landings and discards from Thorupstrand. This description is largely based on direct information from the fishermen, which has been extended and contrasted with relevant information from the national and international scientific literature.

In the comparison of the two fisheries the following three main criteria for environmental impact have been used: *fuel consumption, discard* and *sea floor impact* plus two secondary criteria - *local knowledge* and *quality of catch*. The following conclusions concerning these criteria are based on an exposition of direct information from interviews with Thorupstrand Kystfiskerlaug and relevant national and international scientific literature.

Literature estimates of the *fuel consumption* (litres per kg of fish caught) for the species of concern are substantially lower for gillnetters (0.15-0.55) and Danish seiners (0.12-0.18) than for bottom trawlers (0.4-1.5). Presumably, this difference is even more pronounced for coastal fisheries, such as the Thorupstrand fishery, where the short distances to the fishing grounds diminishes fuel consumption.

In the conventional DK fishery for the most common target species in Skagerrak *discard values* of Danish seines (22%) and gillnets (3-9%) are lower than values for bottom trawlers (36%). The discard levels informed by the Thorupstrand fishers and those documented from two Danish seine trips with observers from DTU-Aqua in September 2011, are even lower than the average values from the scientific literature, and it is concluded that the Thorupstrand gillnets and Danish seiners have a substantially lower level of discard than conventional bottom trawlers.

Concerning *impact on the sea floor* it is concluded, based on available literature, that the gillnets and the relative small seines used by the Thorupstrand fishermen in Skagerrak, have much smaller impact on the environment compared to a situation where the same areas were trawled by bigger boats with larger engine power.When considering all three criteria: Fuel consumption, discard and impact on sea floor, as a whole, it is likely that it would have a larger impact on the environment all together, if the Thorupstrand quotas were sold to and fished by large bottom trawlers.

In addition to the three main criteria with focus on the environmental impact, notice has also been given to *local knowledge* and *quality of the catch*. Although a comparative evaluation of the Thorupstrand fishery and the conventional bottom trawl fishery in relation to these two sustainability criteria is mainly speculative, it seems appropriate to underline the importance of the local knowledge and the quality of the fish.

2. Introduction

This report - ordered by Thorupstrand Kystfiskerlaug - gives a description of the Danish coastal fishery from Thorupstrand and considers the environmental impact from the fishery in comparison with conventional Danish demersal (bottom) trawl fishery in Skagerrak.

Thorupstrand is situated on the west coast of Northern Jutland, bordering the North Sea. The small fishing community, consisting of 13 active fishing vessels and a number of land based buildings for working up of the fresh caught fish, is placed directly on the sandy beach and behind the sandy dunes. The boats are all capable of being hauled on the beach with a land based winch.

The fishery takes place in Skagerrak at distances less than 20-25 nautical miles from Thorupstrand, the catch is landed daily and no vessels are at sea for more than 24 hours. This type of fishery is the traditional way of fishing from the west coast of Jutland due to the lack of harbours back in history. Today only a few fishing villages of this type are still active, but for Thorupstrand the situation is different and the fishing activities have been increasing to survive falling prices during the last five years.

Figure 1. Fishing boats on the beach, Thorupstrand (photo Han Herred Havbåde)

The text in this report is based partly on oral information from interviews with Thorupstrand Kystfiskerlaug and partly on relevant national and international scientific literature. The scope and budget of the project have been limited and DTU Aqua has not made any effort to collect catch and effort data from the fishery from Thorupstrand to verify the oral information. An exception is a few fishing trips in September 2011 with observers from DTU Aqua onboard fishing boats from Thorupstrand, which are part of the national EU-financed discard monitoring program.

3. Purpose of the report

The purpose of this report is to compare the environmental impact of the fishing methods of the Thorupstrand fishermen to conventional bottom trawl fishery for the same target species in Skagerrak.

The report uses three main criteria for assessing the environmental impact from the fisheries: i) *fuel consumption* per kg fish caught, ii) *discard* per kg fish caught and iii) *physical disturbance* of the seafloor, plus two secondary criteria - *local knowledge* and *quality of catch*.

Following this, the report will evaluate the environmental consequences of a scenario where the quota of cod, plaice and sole today fished by Thorupstrand Kystfiskerlaug is sold to and fished by larger conventional bottom trawlers. This scenario was close to being effected when the Thorupstrand quotas were temporarily for sale a year ago to the large trawlers which are expanding their fishery in Skagerrak.

4. The coastal fishery from Thorupstrand

4.1. Target species

Plaice (*Pleuronectes platessa*) is the main target species from March to October and cod (*Gadus morhua*) from October to February. Depending on prices and the occurrence of migrating spawning Dover sole (*Solea solea*) there is also a small fishery for this species in March-May. Cod and sole are typically caught in gillnet whereas plaice is the main target species for the Danish seiners. Depending of the season some *bycatch* is taken and typical species are; Flounder (*Platichthys flesus*), dab (*Limanda limanda*) and more sporadic turbot (*Psetta maxima*) and brill (*Scophthalmus rhombus*) plus some codfish species such as hake (*Merluccius merluccius*), haddock

(*Melanogrammus aeglifinus*) and pollack (*Pollachius pollachius*). The European lobster (*Homarus gammarus*) and edible crab (*Cancer pagurus*) is taken sporadic in gillnets.

The total landings have been relative stable in the last 5-6 years. In 2010 the landings were 1628 tonnes at a value of 18 Mio. Dkr. In 2005 landings reached 1240 tonnes.

Bycatch of non-target species is a problem if the bycatch has to be discarded because of shortage in quota of the species in question. In Thorupstrand this potential problem is avoided by letting each fisherman lease a part of a common quota pool for the relevant species on an ad-hoc basis. The quota pool is owned and managed by the Thorupstrand Kystfiskerlaug. In harbour based sections of the Danish fishery other pool systems are established where private quota owners can lease their quota shares to other fishers if they want to earn the resource rent without catching the fish themselves.

Bycatch of *harbour porpoises* and also some bird species is a problem for some gillnet fisheries. No data on bycatch of harbour porpoise exists from Thorupstrand, but from the literature (Sveegaard *et al.*, 2011 and Teilmann *et al.* 2008), it is observed that the fishing area of Thorupstrand has a relatively low abundance of harbour porpoises. In areas where abundances of harbour porpoises are higher, gillnets can be mounted with acoustic alarms (*pingers*), which have been shown to reduce bycatches of this species (Larsen 1999).

4.2. Fishing method and gears

Only two fishing methods are used by the fishermen from Thorupstrand: *Bottom gillnet* and *Danish seine*. All fishery with these two gears is carried out on positions less than 20-25 nautical miles from the landing site; Danish Seine only on sandy bottom and gillnet in more heterogeneous and stony areas.

It is not the purpose here to go thoroughly into the Danish Seine technique, but a short description is beneficial for appreciating the differences in environmental impact between this gear and traditional bottom trawls. A Danish seine is somewhat similar to a demersal trawl but simpler in construction with no otterboards and very long ropes (warps). In the Thorupstrand fishery, each rope is up to 3 km long. The catch principle is that the boat, from a buoy/anchorpoint, sails out the long ropes and the seine net in roughly a circular path. Once back at the anchor, the boat starts hauling the gear and the two ropes will slowly come together trapping the fish inside the area encircled by the ropes as they were set out. At the same time the seine is dragged towards the boat, the gear in principle describing a gradually shrinking circle, and at some point in this process the fish enter the seine net (see figure 2).

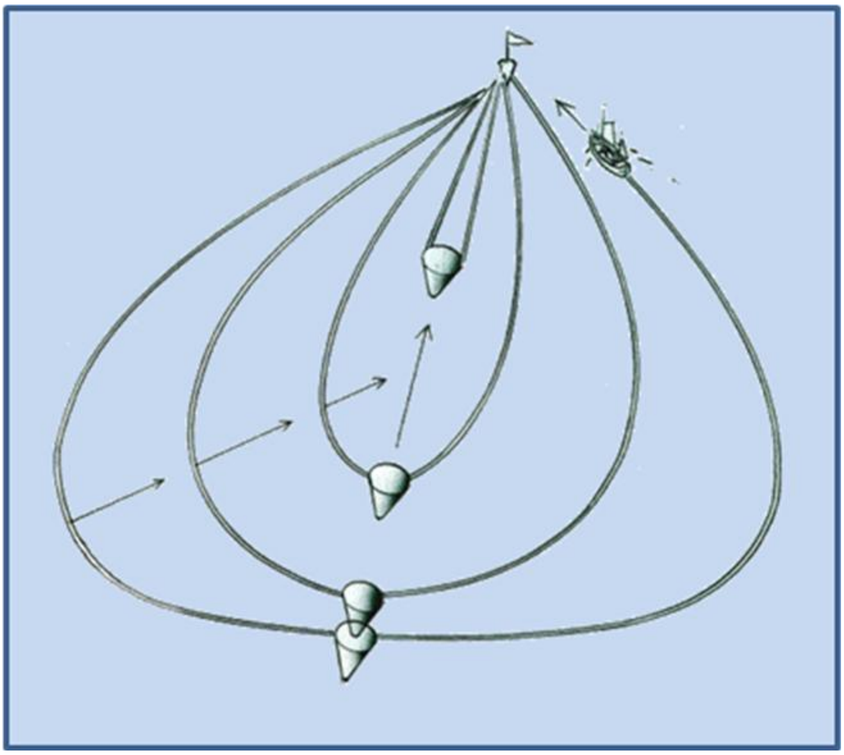

Figure 2. Danish seine - the fishing technique.

The Danish seiners from Thorupstrand fish - as mentioned above - mostly for plaice with some bycatch of other flat- and codfish. The mesh size in the codend is 120-130 mm and the ropes (warps) have a diameter between 24 and 26 mm and a length each of up to 3 km. The legal minimum mesh size in the cod end for Danish seine in Skagerrak is 90 mm. There is no statutory maximum rope diameter. Normally bigger seiners, however, use much thicker and heavier ropes than the Thorupstrand fishermen (see also later in chapter on discard).

The demersal gillnet fishery targets cod, plaice and to some extend sole and occasionally other flat- and codfish. The mesh sizes vary according to the target species: 160-190 mm in the cod fishery, 140-160 mm for plaice and 120 mm in the fishery for sole. The legal minimum mesh size for cod fishery in Skagerrak is 120 mm, for plaice 100 mm and for sole 90 mm. In the sole fishery the fishermen from Thorupstrand do not use the traditional Danish sole nets which have very thin threads but a more sturdy net with thicker threads – a net type that, according to the Thorupstrand fishermen, should give less bycatch of unwanted species – see also later in chapter on discard.

4.3. Boats and engines

Thorupstrand Kystfiskerlaug consists of 13 boats, 6 of these are pure gillnetters, whereas the remaining 7 also use Danish seines in approximately half of the year. The vessels used are all boats capable of being hauled on the beach with the land based winch. Most of them (9) are wooden boats made of oak; the remaining four are smaller fibre-glass boats. The draught in these boats is relatively low, meaning that the propeller is placed higher than on most other vessels, which diminishes the bollard pull of the boat. In addition, the boats have to be light, which excludes large engines and the use of engine power as a catch enhancing factor. The size of the engines in the boats varies between 80 and 200 HK (60 to 150 kW). With these characteristics the boats are not well suited for using bottom trawls.

4.4. Fuel Consumption

It has not been possible to obtain reliable estimates of the fuel consumption per kg fish caught from the Thorupstrand fishery, mostly because of lack of documentation backwards in time. Instead we have listed the existing estimates of fuel consumption by gear type from the literature, and compare the methods of Thorupstrand (gillnets and Danish seine) with bottom trawl fishery. In addition to fuel on board, the fishermen in Thorupstrand also use energy to run the land based electric hydraulics. The hydraulics used for hauling the ships on the coast uses 20-30.000 kilowatt hour/year. This energy converted to fuel is around 2500 litre fuel/year in total, which is a minor part of the total energy consumption in the fishing action of the 13 boats from Thorupstrand.

Some values on fuel consumption comparable to the methods used by the Thorupstrand fishing can be obtained from the literature. Thrane (2004) estimates the Danish gillnet fishery to have an average fuel consumption of 0.24 litre per kg cod caught, but between 0.32 and 0.55 when all species are included. Norwegian gillnetters are estimated to use on average 0.15 litre per kilo catch when all species are included (Winther et al., 2009). Thrane (2004) estimates the average fuel consumption to 0.18 for Danish seiners catching flatfish. Norwegian boats using Danish seine are estimated to have a fuel consumption of approximately 0.12 litre per kilo catch, all species included (Table 1).

Average values of bottom trawl fuel consumption estimates from a number of different authors are: 0.40 litre per kilo in the cod fishery, 0.98 for flatfish and 1.5 in mixed fisheries (Winther et al., 2009; Thrane, 2004; Schau et al., 2008; Ziegler et al., 2003) (Table 1)

Table 1: Average fuel consumption (litres of fuel per kg caught fish) by fishing method and country from a number of studies.

	Gillnet Denmark	Gillnet Norway	Danish seine Denmark	Danish seine Norway	Bottom trawl average
l/kg cod	0.24				0.40
l/kg flatfish			0.18		0.98
l/kg mixed	0.32-0.55	0.15		0.12	1.50

Even though there is great variability in the estimates from the literature, and also between the geographically different fisheries, it seems reasonable to conclude that both gillnetters and Danish seiners use less fuel per caught fish than bottom trawlers.

4.5. Discard

4.5.1. General remarks

In the course of trying to catch fish from the sea, fish are also caught which either are not in demand on the markets or cannot be landed because of legislation such as minimum legal landing sizes or quota restrictions. Much of this fish is *discarded* at sea.

The weighted discard rate worldwide is estimated at 8 percent (proportion of the catch discarded). Based on this discard rate, in the 1992-2001 periods, yearly average discards are estimated to be 7.3 million tons. **(**Kelleher, K. 2005). Bottom trawl fisheries for shrimp and finfish account for over 50 percent of total estimated discards while representing approximately 22 percent of total landings recorded. Bottom (demersal) finfish trawls account for 36 percent of the estimated global discards. Most gillnet, purse-seine including Danish seine, hand line, jig, trap and pot fisheries have low discard rates. Small-scale fisheries generally have lower discard rates than high sea fisheries. The small-scale fisheries have a weighted discard rate of 3.7 percent **(**Kelleher, K. 2005).

Discard is a controversial subject in fishery politics due to several aspects**.** Very few species will survive to be discarded if they have been in contact with the gear for a longer period of time and handled onboard before being re-introduced to the sea. Therefore the existence of discard in a fishery is a reflection of the resource being harvested in a sub-optimal way. This is especially true if the resource is limited.

Discard can have a large impact on the results and reliability of stock assessments in terms of an unallocated mortality, indicating that the fishery is withdrawing a much larger part of the stock than is reported to the official landing statistics. Furthermore, discards will result in changes in the species and size composition of the benthic community in terms of food subsidies and offal that sink to the sea floor. Community changes will influence the ecosystem functioning affecting geo-chemical fluxes as well as trophic interactions (Kaiser et al. 2000; Tillin et al. 2006).

Efforts are being – and have been - made to reduce unwanted bycatch and discards at sea, through a number of technical changes to fishing gears and operations such as exit windows, sorting grids and real time closures.

In general, discards are defined as all fish, shellfish and mollusks thrown overboard after a fishing activity. The main reasons for discarding in the Danish commercial fishery can be divided in five categories as follows:

- The catch is below the minimum landing size
- The quota for a given species is already used (*bycatch - see below*)
- To optimize total catch value the smaller specimens are discarded (*high-grading*)
- The catch does not fulfil the regulation of preservation (e.g. closed season)
- The species is not marketable or it is not possible for the fisherman to sell the species to a price that will cover the cost of handling and landing the species (as could be the case for flounder in the East Baltic)

4.5.2. Discards in Thorupstrand

The information of discard from the fishery in Thorupstrand in this report comes from two sources: i) undocumented estimates of general discard rates from the Thorupstrand fishermen and ii) two fishing trips in September 2011 with participation of an observer from DTU Aqua who documented the catch and discard.

In table 2 below the internal Thorupstrand estimates of discard rates are compared with documented discard rates for Skagerrak and a mean value for all Danish waters (Dalskov et al. 2006).

Table 2.Discards from Thorupstrand and Skagerrak given in percentage of weight discarded/total landed.

(Data from Dalskov et al 2006 and Thorupstrand Fishermen)

	Thorupstrand	Skagerrak	DK average
Danish seine	10	22	19
Cod-gillnet	<1	3	3
Plaice gillnet	<1	9	9
Sole-gillnet	2-3	46*	46
Demersal trawl		36	28

* North Sea

It can be observed that the estimated Thorupstrand discard values for Danish seine and gillnets are lower than values from other parts of Denmark for the same gears. Again it has to be underlined that the Thorupstrand data in Table 2 are undocumented estimates given by the fishermen. However, DTU Aqua made two trips in late September 2011 onboard a Danish seiner from Thorupstrand, which give support to the low internal estimates. The target species was plaice and the catch and discards are given in table 3.

Table 3. Catch and discard from Danish seiner from Thorupstrand. DTU-Aqua, September 2011.

	Total catch (kg)	Total landing (kg)	Plaice landed (kg)	Total discards(kg)	Total discards (%)	Discard plaice* (%)	Bycatch** landed (kg)
Trip 1	857	806	800	51	6,0	5,4	6
Trip 2	3760	3620	3600	140	3,7	2,0	20

* The discard % of plaice is calculated against total catch

** The bycatch was dab, flounder, turbot and red gurnard

The data given above are derived from only two trips, which do not give an overall picture of the total discard during the year. The discard percentages are however lover than the estimated yearly discards given by the fishermen from Thorupstrand – see table 2.

The most striking difference in discard values between Thorupstrand (2-3%) and mean DK (46%) is observed for the sole fishery. This difference might be explained by other net types and mesh sizes being used by the Thorupstrand fishermen. They do not use traditional sole nets, which have very thin treads, but a more sturdy net with thicker treads. The mesh size of 120 mm used by the Thorupstrand fishermen is also substantially larger than the minimum legal mesh size of 90 mm.

Compared to bottom trawl both gillnet and Danish seine has much lower discard rates. Data from table 2 show discard rates for bottom trawl of 36% in Skagerrak and a mean value for Danish waters of 28 % (Dalskov *et al.*, 2006).

Another important factor when considering discard, is the survival of the fish discarded. As mentioned earlier only few species will survive to be discarded if they have been in contact with the gear and handled onboard before being re-introduced to the sea. Danish seine has the highest survival rate compared to other gears (Humborstad *et al.*, 2009). Coastal fisheries with Danish seine are generally carried out in relatively shallow water (max 15-20 m) which also has a positive effect on the survival rate for the fish because the pressure difference from bottom to the surface is low compared to trawling carried out at depth down to 50-70 m. and even more. The relative leniency of the Danish seine is reflected in the use of this fishing method to catch fish for recruitment to aquaculture (Humborstad *et al.*, 2009). The higher survival rate of discard from Danish seines reduces the problems with discard from using this gear. If the discard is alive, the impact on the stock and the benthic community is much less than if it is dead when it goes back to sea.

As mentioned above the discard rates for the Thorupstrand fishery seem to be lower than the discard rates in other areas in DK. However, the differences between the national estimates and the estimates from Thorupstrand Kystfiskerlaug are encumbered with some uncertainty even though the two trips monitored by DTU Aqua supports the estimates from the fishermen. On the other hand it is obvious that if the estimates on discards from the fishermen are precise, then the large mesh sizes used by the Thorupstrand fishermen mentioned earlier on 120 mm in Danish seine, 160 mm in net fishery for cod, and 140 for plaice can explain the differences in bycatch. The legal mesh size is 120 for cod and 100 for plaice i Skagerrak (see table 3)

Table 3. Legal mesh sizes in mm in the Danish fishery (DK) compared to the mesh sizes used by the Thorupstrand fishermen.

	Danish seine*	**Danish seine***	**Gillnet**	**Gillnet**	**Trawl***
	Thorup Strand	Skagerrak-DK	Thorup St.	Skagerrak-DK	Skagerrak **DK**
All species	**120**	**90**			**90**
Cod			**160-190**	**120**	
Plaice			**140-160**	**100**	
Sole			**120**	**90**	

* only species for human consumption (cod, plaice etc)

5. Impact on the sea floor

5.1. General remarks

The environmental impact of marine fishing is subject to growing public and political awareness. The effects of bottom trawling have long been known – effects like the physical disturbance and flattening of the sea floor, the resuspension of sediments and the destruction of non-target benthic animals, especially non-mobile forms like corals and sponges (see reviews by Jones, 1992; Dayton et al., 1995; Jennings and Kaiser, 1998; Clark and Koslow, 2007).

There are, however, big differences in the sea floor impact between fishing methods. In the following an overview is provided of the differences in benthic impacts from bottom trawling, gillnet fishing and Danish seine.

5.2. Bottom trawling

Bottom trawling is controversial because of its environmental impacts. It involves towing heavy fishing gear over the sea floor, which can cause large scale destruction, including damage to habitats and removal of seaweed. Along with the increase in the intensity of trawl fishing in the 20th century, there has been an expanding scientific literature with growing evidence of the type of impacts, and what these can mean to the habitat and longer term sustainability of the environment (e.g. de Groot, 1984; Hutchings, 1990; Auster et al., 1996; Collie et al., 1997; Auster and Langton, 1999; Rumohr & Kujawski, 2000; Frid et al., 2000; Collie J. et al., 2000; Kaiser et al., 2000; Koslow et al., 2001; Kaiser et al., 2002). These studies and reviews indicate a number of changes in faunal communities and habitats exposed to trawling. Commonly with trawled ecosystems there is a reduction in species number, biomass, diversity and alteration in the composition of benthic assemblages and also a reduction in the age composition and size structure of species (Daan et al.2005). The dominant species can change as a result of the trawling impact, from large sessile suspension-feeding taxa (e.g. corals, sponges) to small opportunistic species and scavengers (Jennings et al. 2005).

The primary sources of impact are the otter boards (doors), which can weigh several tons and the ground rope. The depth and area of the furrows created when the otterboards are dragged along the bottom are very much depending on the design of the trawl and the weight of the otter boards (see figure 1).

There is no doubt that the otter boards contact with the seafloor has consequences for the species at sea floor (Gilkinson *et al.*, 1998; Moran & Stephenson, 2000 and Collie *et al.*, 2000). While the trawl (the ground rope) itself primarily removes the epifauna, the otterboards also damage the infauna i.e. animals and algae living within the sea bottom. (Gislason, 1995).

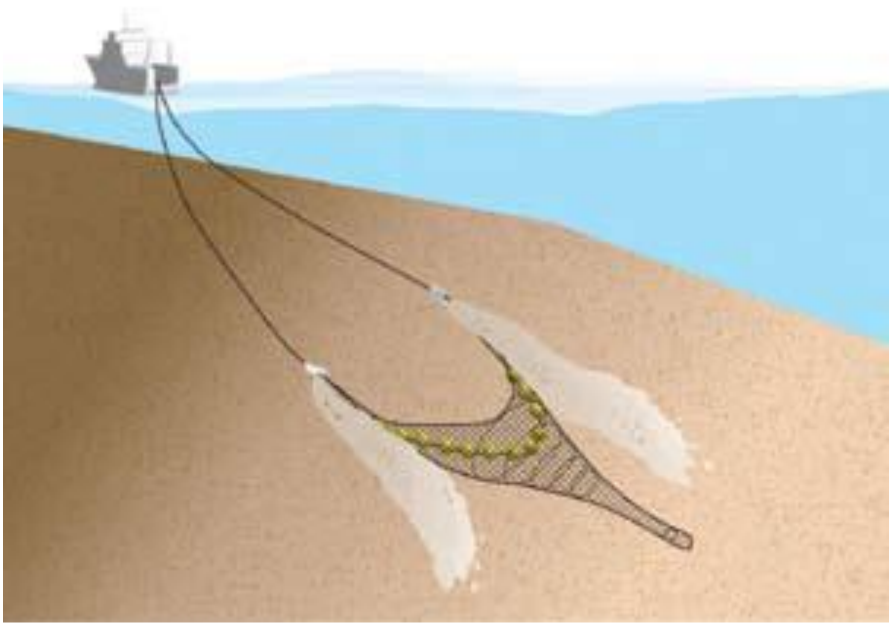

Figure 1: Bottom trawl (from: Clarke M.R. in *Oceanography*, Volume 23, Number 1, 2010)

Trawl fishing will also result in changes in the species and size composition of the benthic community due to: i) differential mortality across species and size classes, ii) the food subsidies provided by the trawl track mortality and iii) the discards and offal that sink to the sea floor. 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).

The ground rope which usually remains in contact with the sea floor across the entire lower edge of the net can be equipped with rubber discs, bobbins, spacers and, when used on very rough sea floor, special rock hopper gears. Depending on the configuration, the ground rope may turn over large rocks or boulders, possibly dragging them along with the net, disturb or damage sessile organisms or rework and re-suspend bottom sediments. These impacts result in decreases in species diversity and ecological changes towards more opportunistic organisms.

With increased engine power (Marchal *et al.* 2002) and the introduction of heavy and sophisticated ground gear, trawlers are expanding their range of activity and to include more hard bottoms (Collie, 2000 & Auster *et al.* 1996). At the hard bottom, the fauna is more exposed to the fishing activity and thereby the influence from trawl is much higher.

The regeneration of an area is often depending on recolonisation from nearby areas, and this is only possible if some areas are not disturbed, or the trawl frequency is low. Some species only exist in areas not trawled (Jennings *et al.*, 2005 and Duplisea, 2002). The efficiency in trawl fishery is often related to the engine power (O'Neill *et al.*, 2003), because the engine power determines the size of the trawl and the use of heavy gear as rockhoppers (Eigaard & Munch Petersen 2010, Eigaard et al. 2011). A big trawl enlarges the trawled area, and the otter boards have to be bigger and heavier. Rockhoppers makes it possible to trawl new areas with hard bottom, which makes the impact on the sea floor higher (Collie, 2000; Jennings *et al.*, 2005 & Auster *et al.*, 1996).

In Øresund, the sound between Denmark and Sweden a ban on towed gear has existed since 1932. Analyses of both bottom habitats (Angantyr et al. 2007) and fish populations show that the stock of cod and other fish are in a good state in this area compared to the neighbouring area, Kattegat, where trawling has been intensive (Svedäng, 2010). Also the size and age-distribution of cod is different between Øresund and Kattegat, where the fish are smaller and younger, and the abundance of other non-commercial species is much higher in Øresund than in Kattegat. The benthic habitats in Øresund are also more variable (Angantyr et al. 2007).

5.3. Bottom gillnet

The influence on the sea floor from gillnet fishing is rather minimal (Jennings and Kaiser, 1998). A net is not towed over the sea floor, but placed static and with a minimal contact with the bottom (see figure 4). If the fishermen set on reefs, however, there is a possibility of breaking some of the structures, sponges or chorals, when hauling the net. There is also a risk of loosing or tearing the gear when gillnet fishing in reef areas, suggesting that fishing in such areas mostly takes place by mistake.

The risk of unintentional gillnet fishing on reefs is highly dependent on the skipper skills and experience with the area fished. Local knowledge of the fishing areas are here of great importance. For most coastal fisheries such knowledge is normally very high. For the Thorupstrand fishermen this knowledge is presented in appendix 1. On this scanned map from the fishing area - drawn on the basis of knowledge collected by the fishermen - all different structures on the sea floor are shown: Stones, reefs, sandy bottom etc. All are named and have a history and give the fishermen a unique possibility to fish on the exact right spot depending on season and target species. In this way the fishermen can optimize their catch, avoid damages of their gear, diminish discard and use as little fuel as possible.

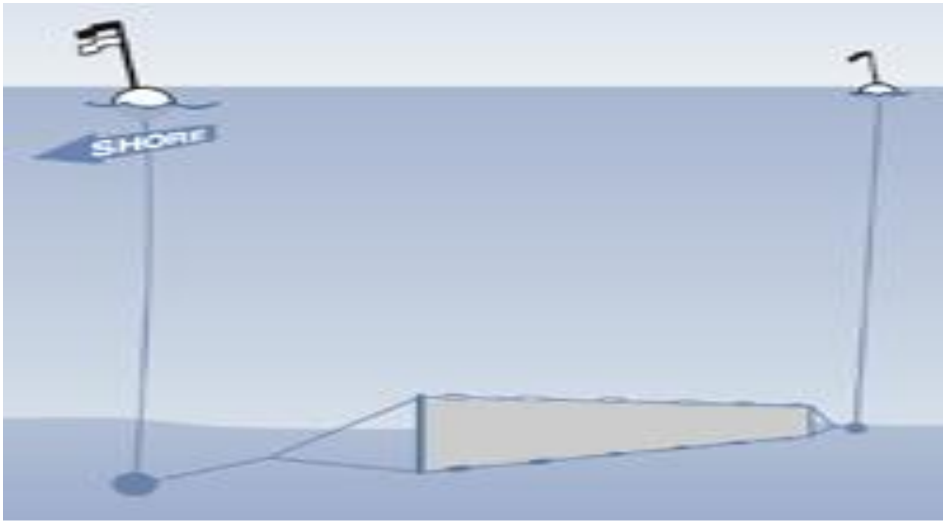

Figure 4. Bottom gillnet

In the Thorupstrand area some “bubbling reefs” created by exudation of gas have been discovered in the area called “Store Rev” north of Thorupstrand. These structures normally have a unique flora and fauna which is sensitive to fishing activities – mainly trawling but also to some extent gillnet fishing. The nets can be entangled in the reef structures and when they are hauled structures can be broken. The distance to Store Rev from Thorupstrand is, however, about 30-35 nautical miles meaning that the reefs will never be a fishing area for Thorupstrand fishers.

5.4. Danish seine

The literature on the effect of the Danish seine on the sea floor is very scarce. The following remarks are based on general considerations and oral information from the fishermen

As mentioned earlier the Danish seine is a trawl without otter boards. The effect from the gear is therefore restricted to the ropes and the ground rope in the trawl. The effect of the trawl itself is likely to be the same for a Danish seine as for an ottertrawl. However there are differences also when it comes to the comparison between the trawl and the seine. The hauling of the seine is done with much lower power and speed, 1 knot instead of 3 knots compared to bottom trawl. This factor diminishes the possible fishing grounds (and the type of sea floor impacted by the gear) to only sandbanks for the seiners. The trawl has to move faster, because it catches the fish from one side instead of encircling them. One more difference between the two gears is that the trawlers can go on much more uneven and stony bottom, because of the flexible and strong gear and engines.

One disadvantage of the Danish seine seen from an environmental perspective is that the area fished on average is three times bigger per hour for a Danish seiner than for a trawl, even if the trawl has much bigger engine power (Flintegård, 1986). This is a disadvantage especially in a situation with epifauna and macroalgaes. However, it has to be remembered first of all, that it is only the ropes that sweep the bottom in order to herd the fish to the trawl and second since the Danish seine can only fish on sand, this disadvantage might be overruled by the fact that the bottom trawl can go on more uneven bottom with a much more diverse flora and fauna.

6. Conclusions

6.1. General remarks

The overall purpose of this report was to enable a comparison of the coastal fisheries from Thorupstrand to the conventional bottom trawl fishery with focus on environmental impact.

The work has included a description of the fishing methods, boats and gears, target species, total landings and discards from Thorupstrand. This description is largely based on direct information from the fishermen, which has been extended and contrasted with relevant information from the national and international scientific literature.

In the discussion of environmental impact of a fishery several factors have to be considered. In the following three main criteria (fuel consumption, discard and seafloor impact) and two secondary criteria (local knowledge and quality of catch) will be discussed separately with special reference to the coastal fishery from Thorupstrand

6.2. Fuel consumption

Consistent data on fuel consumption per kg of fish caught in the Thorupstrand fishery have proven very difficult to procure and the discussed estimates for the Thorupstrand gillnetters and Danish seiners are purely based on literature values.

Data from literature on fuel consumption of gillnetters give values between 0,2 - 0,5 litres per kg caught fish depending on species compared to bottom trawlers with consumption values from 0,4 to 1,5 litre per kg caught fish. For Danish seiners the values vary between 0,12 l/kg/fish to 0,18 l/kg/fish depending on the target species. These values are again lower than the fuel consumption in the bottom trawl fishery.

Even though there is great variability in the estimates from the literature, and also between the geographically different fisheries, it seems reasonable to conclude that both gillnetters and Danish seiners especially from Thorupstrand with short distance from harbour to fishing grounds use less fuel per caught fish than the bottom trawlers.

The distance to the fishing grounds are of importance in relation to fuel consumption in all types of motorized fisheries. The situation in Thorupstrand, and in other coastal fisheries with short distances to the fishing ground, is therefore an advantage in relation to minimizing the impact on the environment through low levels of fuel consumption.

6.3. Discards

Oral information on discard rates were given by the fishermen from Thorupstrand, and discard rates from two Danish seine trips were thoroughly documented by DTU-Aqua observers.

It is observed from the data in table 2 and 3 that the discard values of Danish seines and gillnets from Thorupstrand are lower than values for the same gears from other parts of Denmark. This difference might well be related to the larger mesh sizes used in Thorupstrand in both Danish seine and the gillnets, but of course the species and size structure of the fish population of a given fishing ground influences the discard rates and makes comparisons between areas difficult.

In a comparison between gears, it seems safe to conclude, on the basis of Table 2 and Table 3, that the Thorupstrand gillnets and Danish seiners have a substantially lower level of discard than bottom trawlers.

The high survival rate in Danish seine further reduces the problem with discards from fishing with this type of gear, which is a positive factor in relation to the environmental friendliness of the Thorupstrand fisheries and other fisheries using relatively small seines and boats.

6.4. Impact on sea floor

The environmental impact of fishing is subject to increasing public and political awareness. Especially the effects of bottom trawling have been studied and the impact assessment in most of these studies pertain to the physical disturbance and flattening of the sea floor, the re-suspension of sediments and the destruction of non-target benthic animals, especially non-mobile forms. The general conclusion is that in this aspect the environmental impact from bottom trawling is much higher than that of both gillnet fishing and fishing with Danish seine.

The use of gillnet and the relative small seines used by the Thorupstrand fishermen, and other coastal fisheries as well, has a much smaller impact on the fishing grounds compared to a situation where the same areas were trawled by big sized boats with strong engines.

6.5 Other criteria

In addition to the three main criteria discussed above, notice should also be given to:

a) *Local knowledge*. This gives the fishermen a unique possibility to fish on the exact right spot depending on season and target species. In this way the fishermen can optimize their catch, avoid damages of their gear and of sea floor structures, diminish discard and use as little fuel as possible. This local knowledge is for the Thorupstrand fishermen presented in handwritten maps based on years experience showing all bottom structures presented in the local fishing area (see appendix 1).

b*) Quality of catch.* The one day trips and short distance to the fishing grounds that characterizes most coastal fisheries and the Thorupstrand as well is not only beneficial in a fuel saving context, but also has the advantage that the landed catch is of very high quality. In an economic context this is of course of great value, but also in terms of resource utilization it makes sense to optimize the quality of the catch. The landings from Thorupstrand is categorized as E-fish, which in some years gave a higher price and thereby contributed more positive to the economy compared to conventional bottom trawl catches where the gear is rough on the fish and catches are often many days old when landed. However, the E-fish in 2009-2010 surprisingly was sold for essentially the same price as the A-fish (Ministry of Food, Agriculture and Fisheries, 2011), so if the high quality of fish should effect the economic sustainability again, it is necessary to work on the logistics in the trading an transport of the E-fish. A higher price on coastal caught fish increases the possibility for the coastal fisheries to survive in the long run and in this way also diminish the environmental impact.

Although a comparative evaluation of the Thorupstrand fishery and the conventional bottom trawl fishery in relation to the two above described sustainability criteria is mainly speculative, it seems appropriate to underline the importance of the local knowledge and quality of the fish.

7. References

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8. Appendix 1. Map dawned by the Thorupstrand fishermen showing bottom structures in the fishing area North of Thorupstrand. The map is based on year's experience. The map below is a chart for the same area.