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BELGIAN SEA FISHERIES – BACKGROUND INFORMATION ON THE SUSTAINABILITY PATHWAY IN THE LAST DECADE

ILVO
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INTRODUCTION

The Belgian fishing fleet mainly consists of beam trawlers targeting a mix of flatfish and other demersal species with sole and plaice as its main target species. It is defined as a small mesh (80 mm) mixed demersal fishery. Beam trawl fishing is not perceived as an environmentally friendly way of fishing, as it is characterized by high fuel consumption, possible seafloor disturbance and high by-catch rates of undersized fish and non-target species. To improve the sustainability of the Belgian fishing fleet, a formal cooperation has been established in 2009, in the form of a covenant, between the Flemish government, the Flemish fisheries administration, province West-Vlaanderen, the fishery PO Rederscentrale, the NGO Natuurpunt and the marine branch of the research institute ILVO. Its aim is to open the dialogue, to build trust and to be a long-term driver for concrete actions to improve the sustainability of the fishery.

This report presents a description of the Belgian fishing fleet, the gears being used and the policy and innovations that have been introduced during the last decade. The aim of this document is to serve as a source of background information in the assessment of the Belgian fishery in terms of sustainability. Figures on landings (Scherrens, 2022) and economic results (Scherrens, 2023) of the Belgian shipping companies are published by The Flemish government.

This report contains:

1) The current situation of the Belgian sea fishing fleet (Section 1)
2) The fishing gears used and the innovations (Section 2)
3) Seafloor impact according to the Benthis project (Section 3)
4) Seafloor impact according to the Belgian VALDUVIS approach (Section 4)
5) Energy use in the Belgian fishing fleet (Section 5)
6) The Fishery policy (Section 6)
7) Various initiatives in the Belgian fishery (Section 7)

1 BACKGROUND ON THE BELGIAN SEA FISHING FLEET

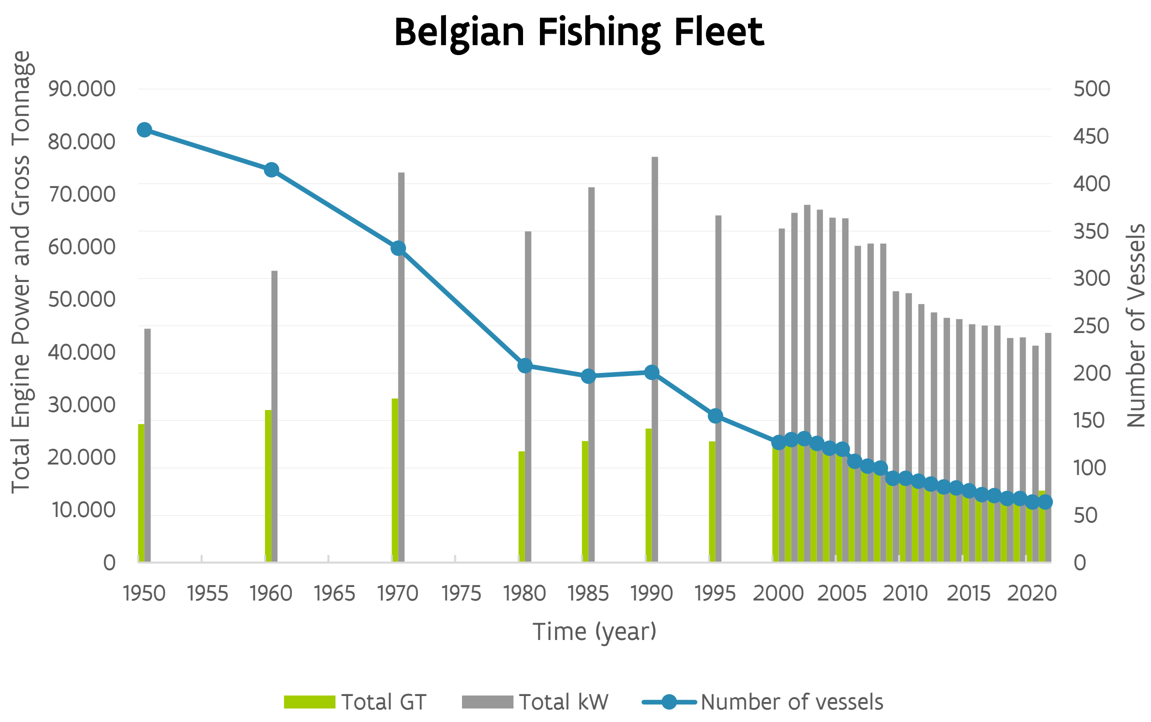
1.1 Fishery Fleet Evolution

After the over-exploitation of herring and sprat (until the end of the 1970s) and the period of Iceland fishing (1950 - 1980), bottom trawl fishing for sole, plaice and shrimp became increasingly important for the Belgian sea fishery (Omey, 1982). Today, Belgian sea fishing is still primarily focused on these benthic species. The dominant fishing technique within this demersal fishery is the beam trawl with tickler chains or chain matrices (Scherrens, 2023). The beam trawl fishery is an efficient fishing technique in terms of catch and especially value per unit of effort (CPUE). Scientific studies into the ecological effects of this technique, however, have led to this technique being increasingly questioned (Rijnsdorp et al., 2008; van Marlen et al., 2014; Polet et al., 2018). More information about the history of Belgian sea fishing can be found on the website "A century of sea fisheries in Belgium" of the Flanders Marine Institute (VLIZ) (Sandra et al, 2019).

The number of vessels has continuously decreased from 457 in 1950 to 59 active vessels in 2023. Since 1990 also total engine power and tonnage significantly decreased (Figure 1-1). Total engine power decreased from 77.102 kW in 1990 to 43.629 kW in 2021 while total tonnage decreased from 25.498 in 1990 to 13.689 in 2021. The average tonnage per vessel however increased from 127 in 1990 to 214 in 2021 and the average power increased from 384 kW in 1990 to 682 kW in 2021.

Total landings have continuously decreased since the 1960s and were at a minimum in 2009 (Figure 1-2). Since then, landings have gradually increased again till 2016, after which they decreased again. The most important species in terms of landed weight is plaice (Figure 1-3) but in value sole is clearly the main target species of the Belgian fleet (Figure 1-4). The price of both fish species has slightly increased since 2013 (Figure 1-5).

The Belgian fleet is quite small but has a wide range in terms of fishing grounds (Figure 1-6). The most important fishing grounds in terms of landings are located in the central North Sea and the Eastern English Channel. From the North Sea South and Southeast Ireland, the landings for 2020 were above 2000 tonnes. Around 1600 tonnes comes from the Bristol Channel and around 1000 tonnes from the Irish Sea and Western English Channel. The lowest, bust still significant landings are harvested in the Bay of Biscay (512 tonnes) and Southwest Ireland (290 tonnes). As such, the fishing effort of the Belgian fleet is widely spread.



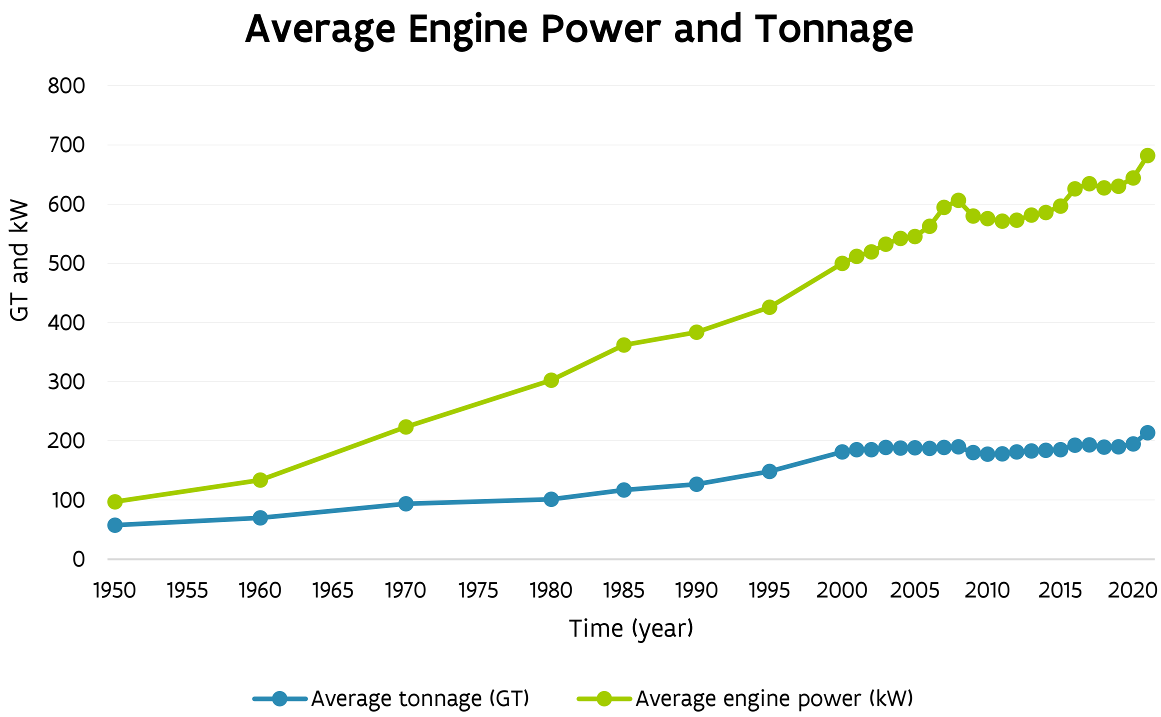


Figure 1-1: Evolution of the Belgian fishing fleet in no. of vessels, average and total tonnage (GT) and engine power (kW) (Scherrens, 2023).

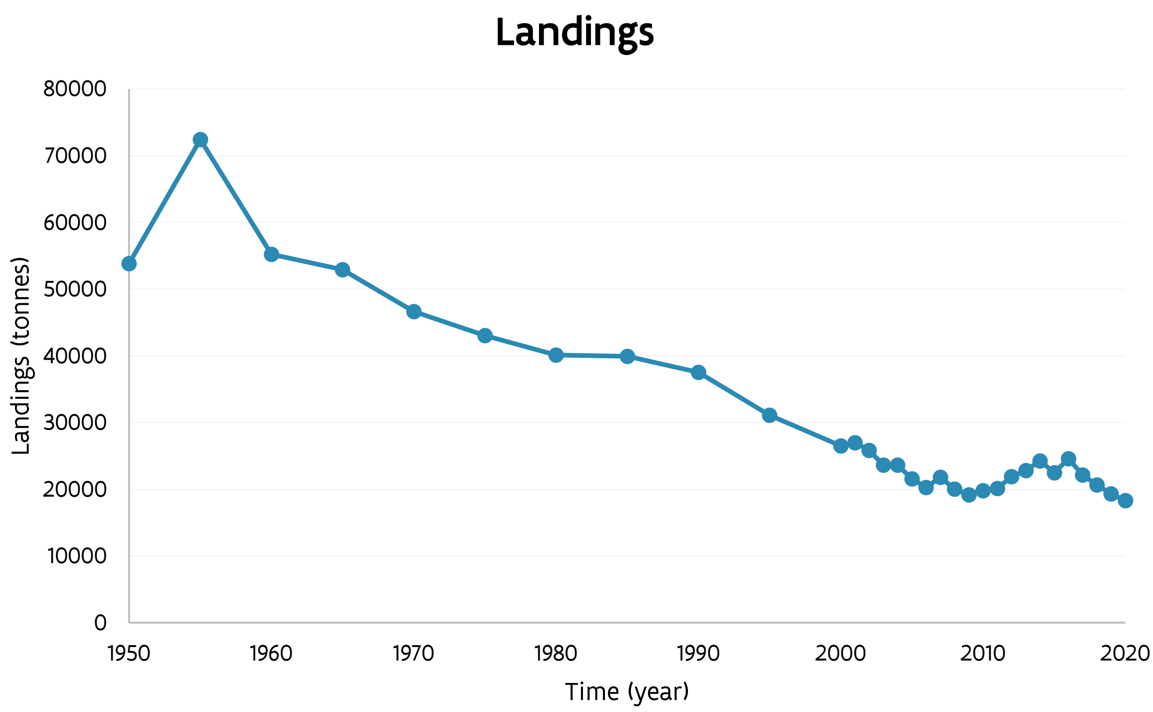


Figure 1-2: Evolution of total yearly landings (tonnes) by Belgian sea fishing vessels since 1950 (Scherrens, 2023).

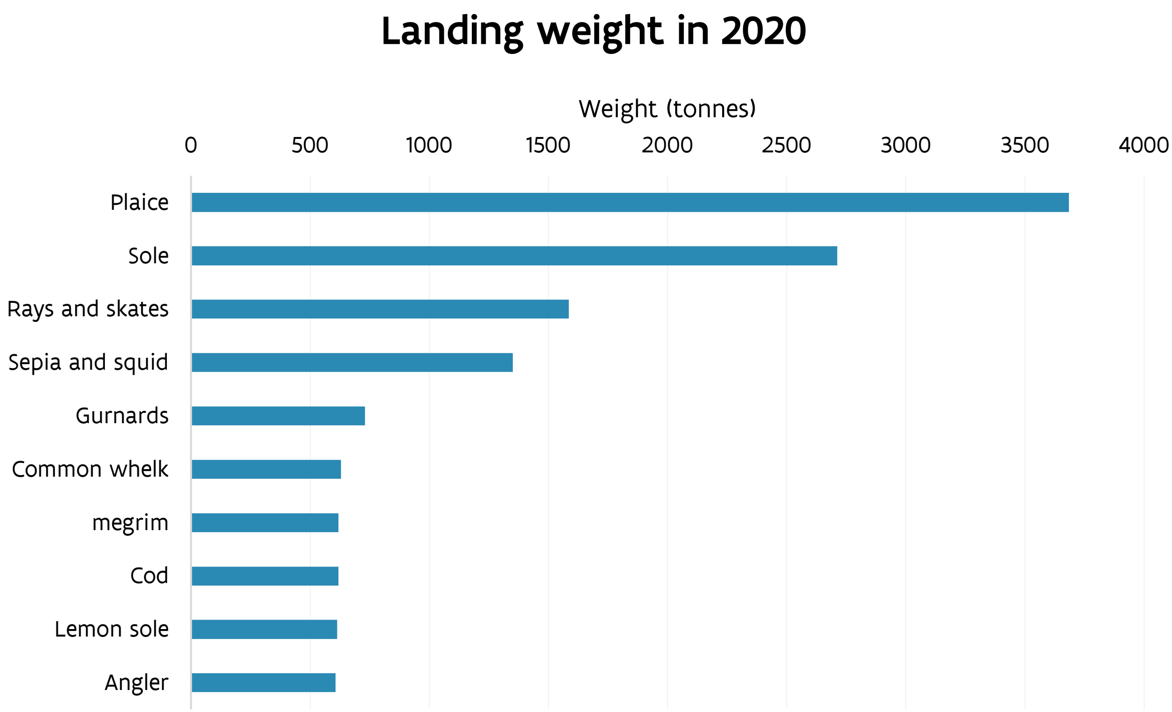


Figure 1-3: Top 10 landings in weight in 2020 (Scherrens, 2023).

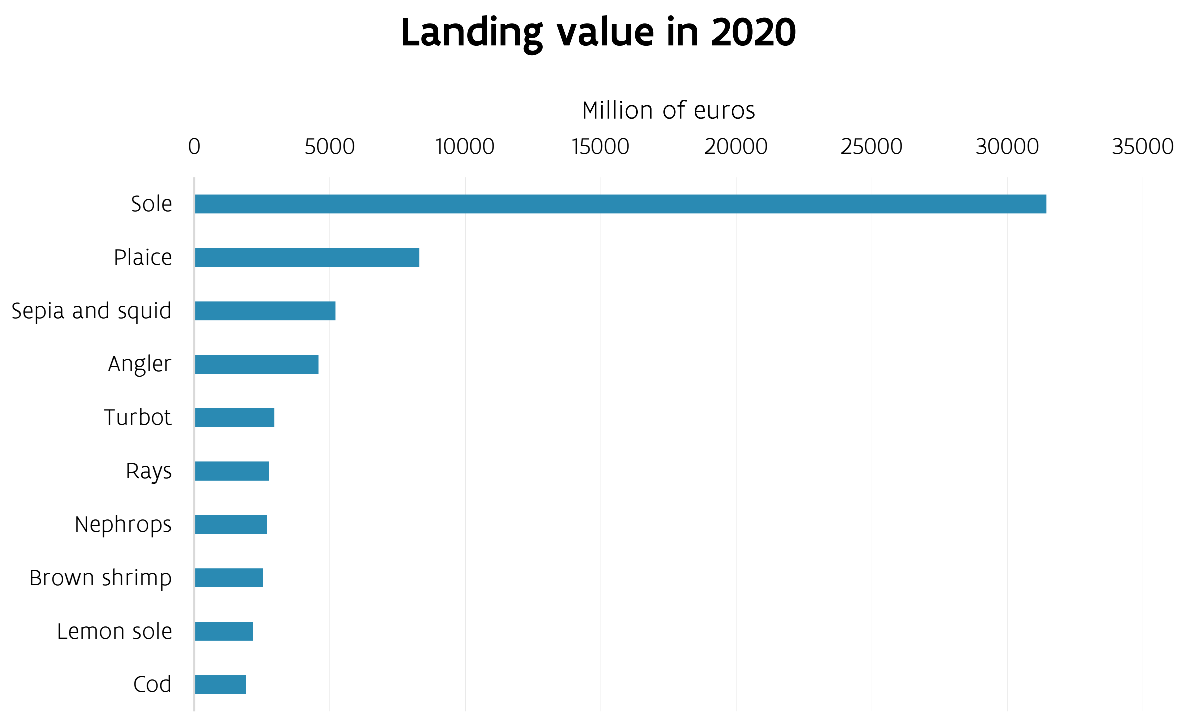


Figure 1-4: Top 10 landings in value in 2020 (Scherrens, 2023).

Figure 1-5: The evolution of the average price of plaice and sole in the fish auction (Scherrens, 2023).

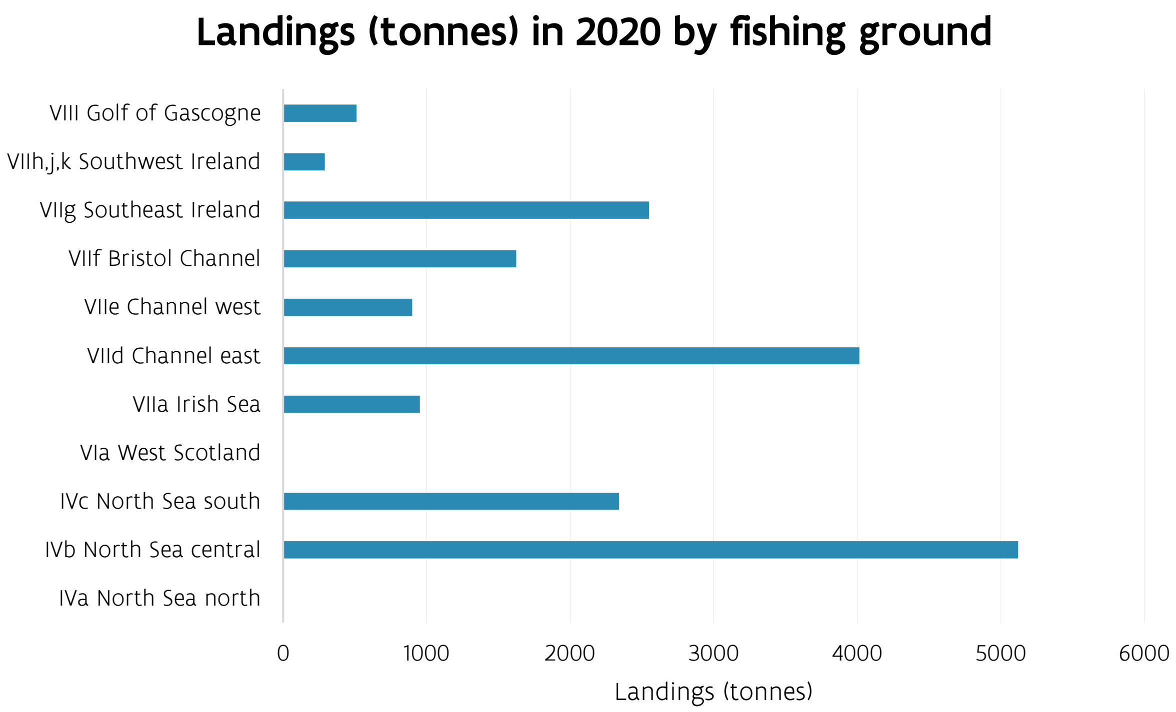


Figure 1-6: Yearly total landings in weight by fishing ground in 2020 (Scherrens, 2023).

1.2 Fishing Gears Overview

The vast majority of fishing gears used in the Belgian fishery are active gears with a long-term dominance of the beam trawl that started in the 1960s (Anon., 2017). During the last decade a slow but steady diversification has started (Figure 1-8). Passive fishing gears, like gill nets, are also being used but at a marginal scale. The division on fishing activity or métier[1] level is often complex as one and the same vessel can practice different métiers during the year (Figure 1-7).

The beam trawl is still the main fishing technique used in the Belgian fishery (Figure 1-7). The second most important fishing technique is the demersal or bottom otter trawl. The shrimp trawl is a lighter beam trawl with brown shrimp (*Crangon crangon*) as target species and the lobster trawl is a light otter trawl with 2 or 4 nets (twinrig or quadrig) with *Nephrops norvegicus* as target species. In addition, dredges, seines (mostly flyshoot or Scottish seine) and passive gears (mostly gill nets and entangling nets or trammel nets) are being used but remain a minority.

The Belgian fleet is traditionally split up into sub fleets according to engine power: the small fleet segment (KVS; < 221) and the large fleet segment (GVS; 221>) (Table 1-1) (Scherrens, 2022). The two segments are further subdivided according to the type of fishing gear. The small fleet segment

[1] a métier is a group of fishing operations targeting a specific assemblage of species, using a specific gear, during a precise period of the year and/or within the specific area. (Definition according to the European Data Collection Framework (EC, 2008).

consists of inshore vessels, Eurocutters and others while the large fleet segment consists of large beam trawlers and others (otter trawlers, flyshooters and gill netters).

Inshore or coastal fishing is practiced by the smaller vessels throughout the year usually within the 12-miles zone. Inshore fishing vessels usually make trips of one day, targeting brown shrimp, although sometimes ship owners switch in winter to demersal fish (sole and plaice). The beam trawl is the main fishing gear. Some inshore fishermen use (single) otter trawls. The Eurocutters mainly fish within the 12-miles zone and generally make multi-day fishing trips (4 days average). In winter the target species are demersal fish, in summer very often they switch to brown shrimp. Eurocutters can be equipped either with a beam trawl or an otter trawl. A minority of vessels in this fleet segment use other gears such as the dredge, targeting scallops.

The large fleet segment consists of larger vessels in terms of length, tonnage and engine power and generally fish with beam trawls throughout the year. These vessels make multi-day trips (around 7 days) and are active on the fishing grounds that are located further away from Belgian waters. It happens that these vessels switch to bottom otter trawl in summer. The other vessels in the large fleet segment use bottom otter trawls, gill nets or carry out the flyshoot fishery.

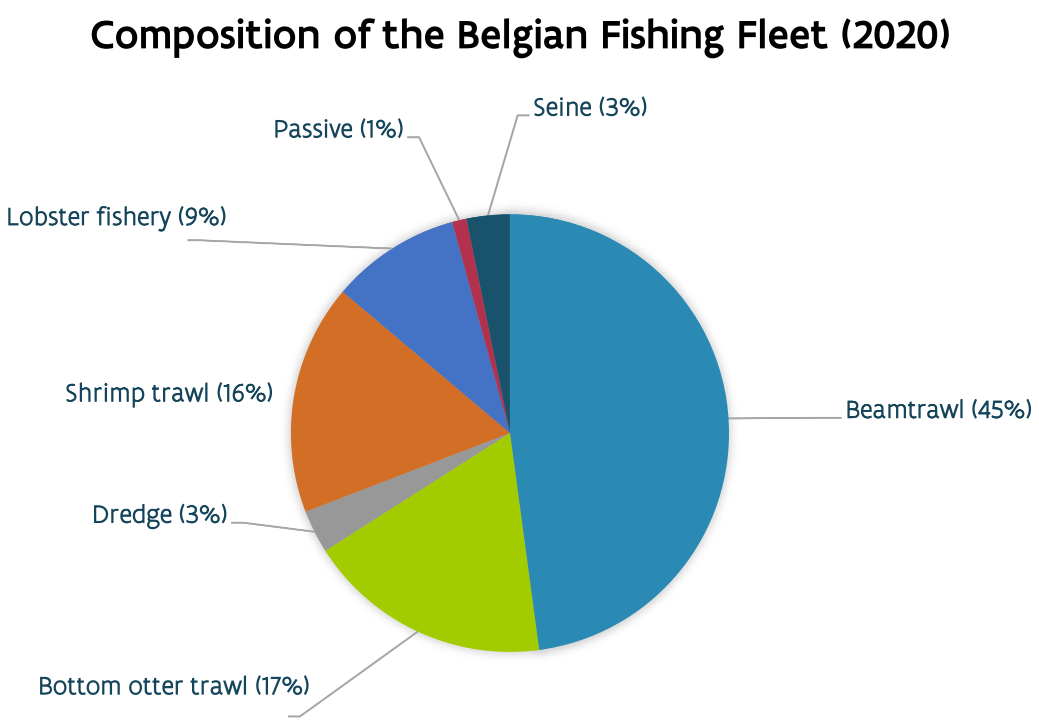


Figure 1-7: Share of the most important fishing techniques used in the Belgian fishery (Scherrens, 2022). A vessel can sometimes switch to a different fishing method depending on the season, this vessel is then added in multiple fisheries, so that the sum of the vessels practicing the different fishing methods is not equal to the total number of fishing vessels. Note: Lobster is *Nephrops norvegicus*.

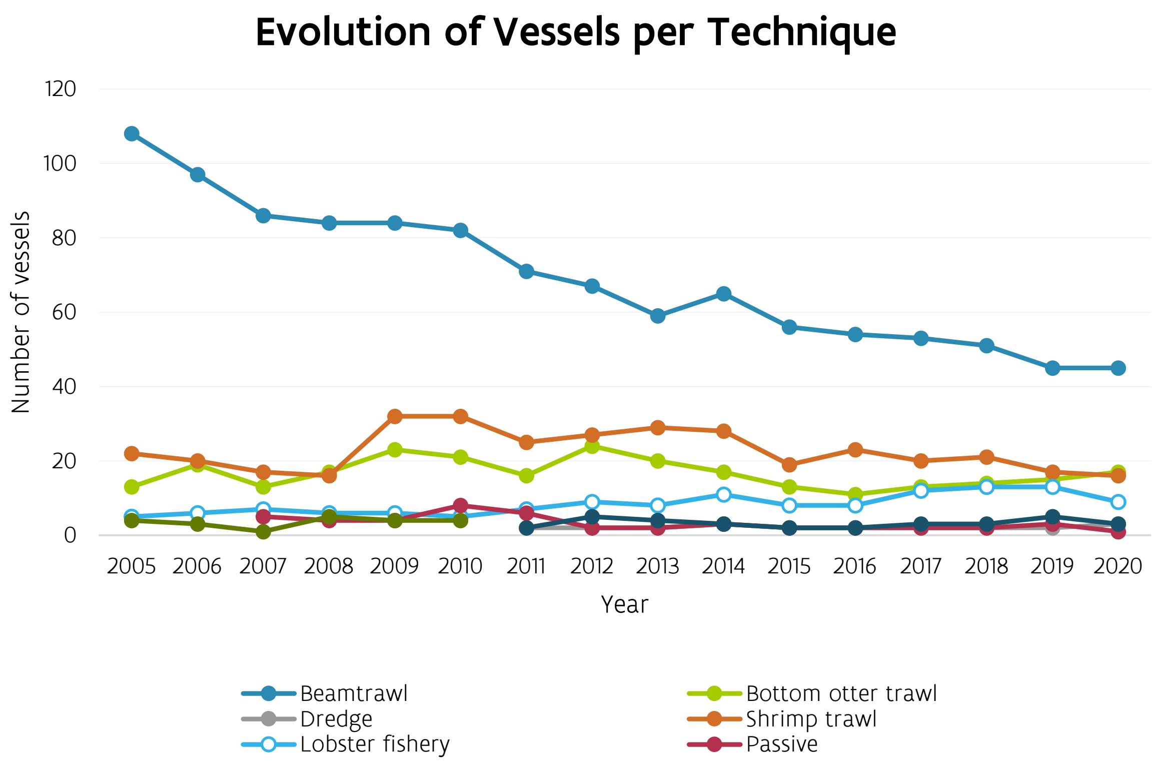


Figure 1-8: Number of fishing vessels per technique. A vessel can sometimes switch to a different fishing method depending on the season, this vessel is than added in multiple fisheries, so that the sum of the vessels practicing the different fishing methods is not equal to the total number of fishing vessels. (Departement Landbouw en Visserij, Aanvoer en besomming, 2006 – 2022).

Table 1-1: Classification of the Belgian fleet according to engine power for 2020 (Scherrens, 2022). Labels in blue are values per major categories.

Group	Engine Power	Number of Vessels	Share in the Belgian Fleet
Small Fleet Segment	**≤ 221 kW**	**34**	**52%**
KVS – Inshore vessels	≤ 221 kW	13	20%
KVS – Eurocutters	≤ 221 kW	13	20%
KVS – Others	≤ 221 kW	8	12%
Large Fleet Segment	**> 221 kW**	**32**	**48%**
GVS – Large beam trawlers	≥ 662 kW	27	41%
GVS – Others	> 221 kW	5	8%
TOTAL		66	100%

2 FISHING GEAR USED IN BELGIAN SEA FISHERIES

This chapter provides an overview of the fishing gears used in the Belgian fishery. The beam trawl and its adaptations, the bottom otter trawl, the flyshoot, dredges and set nets are discussed. A technical description as well as the current number of vessels that use this gear type are given. For the gear that is most used by Belgian fishermen, the beam trawl, information about the weight of the gear is given.

2.1 The Beam Trawl

Beam trawling is the main fishing method in the Belgian fishery (Figure 1-7). The design and operational characteristics differ among vessels and depend upon the skipper's preferences and experience. The design of the beam has slightly changed over time by adapting certain aspects of the beam (beam or shoes) (Table 2-1). These different types of beam trawls are discussed below. The main driver for those changes is the reduction of fuel consumption.

Table 2-1: Different types of beam trawls used in the Belgian fishery and their adaptations in relation to the traditional beam trawl (ILVO VV).

Type beam trawl	**Adaptations compared to the traditional beam trawl**
Sumwing	Wing profile instead of beam Runner instead of traditional shoes
Aqua planning gear	Wing profile instead of beam Adapted shoes
Ecoroll beam	Wing profile instead of beam Roller shoes
Beam trawl with roller shoes	Roller shoes instead of traditional shoes

2.1.1 The traditional flatfish beam trawl

The beam trawl is constructed of a funnel-shaped net, opened horizontally by a steel beam and vertically by the beam trawl shoes. The vertical net opening is generally quite small, typically <1m. The gear is used to target flatfish. The fish are not herded but are startled from the seabed by chains that can be rigged as tickler chains or as a chain matrix (Anon, 1992;. Nédélec & Prado, 1990). Figure 2-1 shows a standard net design of a 4m flatfish beam trawl. The net itself consists of a top panel, a bottom panel or belly, two small side panels and a cod-end in which the catch is collected. The front of the belly of the net is cut out and bounded by the groundrope. It must be sufficiently heavy to ensure good contact with the seabed and thus prevent the fish from escaping underneath the net (Polet and Fontaine, 1995). The bottom panel of the net is usually made of double braided polyethylene net material for the chain matrix beam trawl and polyamide for the tickler chain beam trawl, sometimes polyamide is used. The top panel consists of single braided polyethylene (chain matrix net) or polyamide (tickler chain net). The standard mesh size in the net is 120 or 150 mm. The standard cod-end has 100 meshes in the circumference and is 50 meshes long. The netting material for the cod-end is usually double-braided polyethylene or polyamide. The mesh size of the cod-end of a flatfish beam trawler is minimum 80mm (Polet and Fontaine, 1995; personal communication Eddy Buyvoets, ILVO).

Beam trawl vessels are equipped with powerful engines and outrigger booms to drag two nets, one on each side of the vessel (Figure 2-2). Within the 12-mile zone the beam of a single flatfish beam trawl is maximum 4.5 m. Outside the 12-mile zone the length of the combined beams can go up to maximum 24 meters. Traditional trawlers can be equipped with two types of nets: the so-called V-net with tickler chains and the so called R-net with a chain matrix. It also happens that an R-net is rigged with tickler chains.

The V-net (Figure 2-3) is mostly used on flat, sandy bottoms without obstacles such as stones and boulders. The tickler chains are a series of chains, which are rigged in the net opening between the beam and the groundrope or the shoes. The groundrope is cut in a V-shape in order to maximize the number of tickler chains. In order for the tickler chains to operate well, a certain speed must be developed by the vessel. Usually a V-net is towed at a towing speed of 5 knots for small vessels (<221 kW) and 6 knots for large vessels (>221 kW) (Rijnsdorp et at., 2021). These nets are exposed to high hydrodynamic drag forces (Rijnsdorp et at., 2021).

The R-net (Figure 2-4) is designed to withstand rough bottoms, with an uneven relief and with stones and boulders. The chain matrix is a grid of chains rigged in the net opening in order to prevent (large) stones from entering the net. The configuration of this chain matrix depends on the type of fishery. If larger fish are targeted (ray, turbot, brill), the matrix contains larger openings, e.g., 5 to 3 links. Observed towing speed of beam trawls with a chain matrix is similar to towing speed of V-nets (Rijnsdorp et at., 2021) although the new data collection tools (VISTools) demonstrates that the Belgian fishery often fishes at lower speed. Since R-nets can be used on rough grounds, the netting is made thick and with impregnated twines that are resistant to abrasion.

In the Bay of Biscay, V nets are used. On the other fishing grounds, both R-nets as V-nets are used. Vessels can alternate between a V-net and an R-net. See Table 2-3 for the number of Belgian vessels that fish with a traditional beam trawl with shoes.

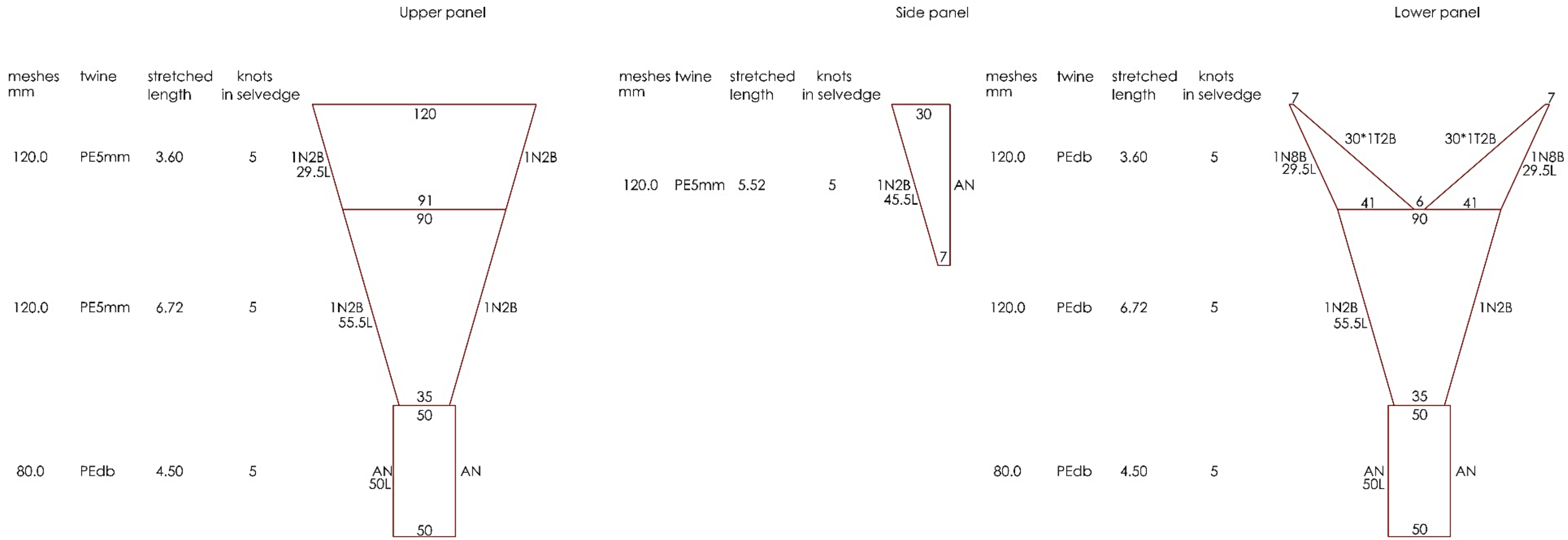


Figure 2-1: Flatfish 4m beam trawl net design (ILVO, Eddy Buyvoets).

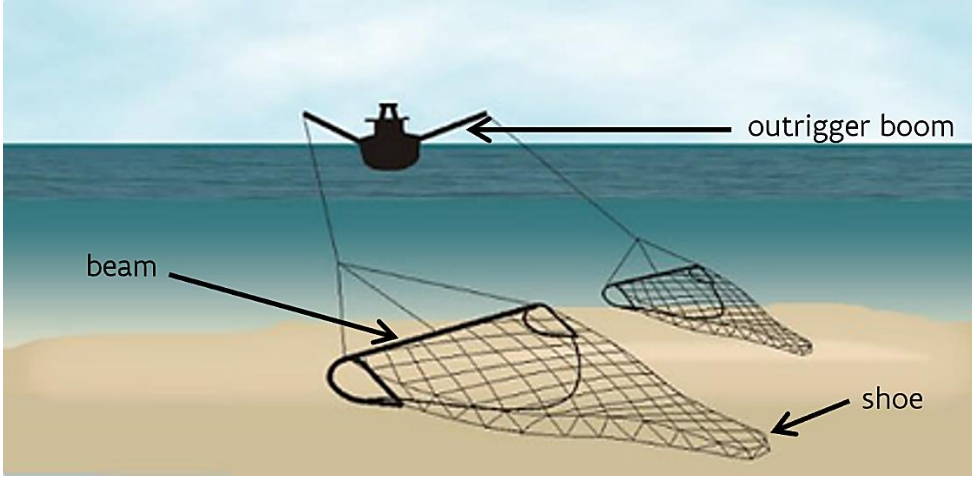


Figure 2-2: Illustration of a beam trawl (www.zeeinzicht.nl).

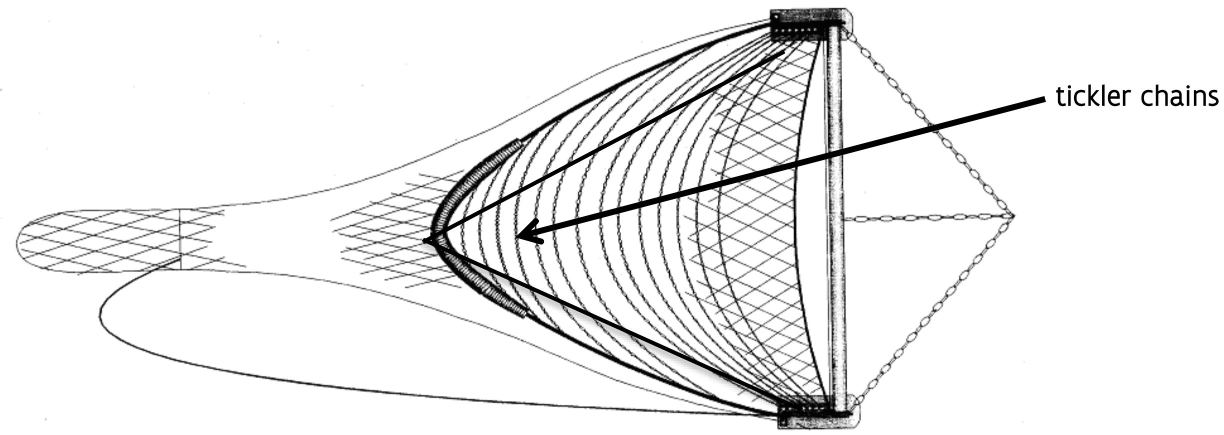


Figure 2-3: V-net with tickler chains (ILVO).

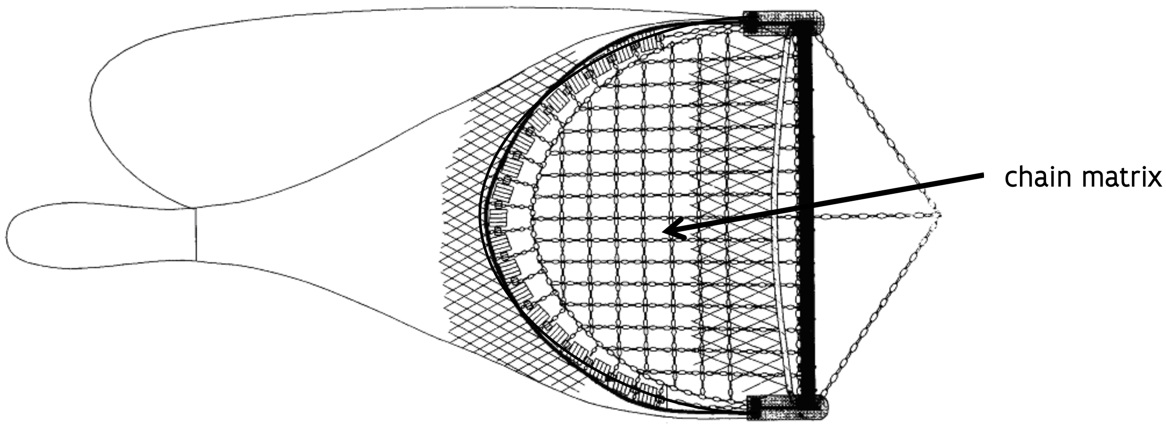


Figure 2-4: R-net with chain matrix (ILVO).

2.1.2 The shrimp trawl

In the North Sea brown shrimps (*Crangon crangon*) are caught in the coastal zone and estuaries by small beam trawlers with a maximum engine power of 221 kW (300 hp) (Polet, 2000). The coastal shrimp trawlers fish during the night and a fish trip takes less than 24 h. The so called Eurocutters often spend 4 to 5 days at sea before returning to the harbour.

A beam trawl for shrimp fishing has a similar construction to the flatfish beam trawl (2.1.1) but is much lighter. The force due to weight exerted by the shrimping gear on the sea bottom is only half as high (Vorberg 2000). The beam is generally 6 to 8 m long and the shoes are about 50 cm high (Polet and Fonteyne, 1995). Within the 12-mile zone the beam of a shrimp beam trawler is maximum 9.3 m. The front of the belly of the net is cut round and attached to a bobbin string with rubber bobbins. This bobbin string holds the bottom of the net against the bottom and helps the net over small obstacles (Polet and Fontaine, 1995). Bobbin ropes come in different designs from light weighed with wide space between the bobbins to more heavy and less open space between the bobbins.

The net is entirely made of polyamide and the (diamond) mesh size of the cod-end is small, 22 mm, to avoid the loss of commercial sized brown shrimp, at the expense of a large bycatch of small individuals (Santos et al., 2018; Polet and Fonteyne, 1995). In order to protect the cod-end against wear, a codend cover made of heavier network, but with larger meshes (80 mm), is installed (Polet and Fonteyne, 1995).

2.1.3 Adaptations of traditional beam trawl

2.1.3.1 SUMWING

The Sumwing (Figure 2-5 and Figure 2-6) was developed by a Dutch company, HfK Engineering, with the aim to decrease the hydrodynamic resistance of the trawl during fishing (Leijzer & Bult, 2008; van Marlen et al., 2009). The Sumwing is a hydrodynamic type of beam trawl and has the beam replaced by a wing shaped profile that provides the horizontal opening of the net. The wing is controlled by the runner in front of the wing. The tensile points on the wing and the runner provide a dynamic equilibrium that allow the wing to narrowly follow the relief of the seafloor with a minimum of downward force (http://www.sumwing.nl). The Sumwing has the advantage that it saves some 10 % of fuel and has some 10 % less seafloor contact (Marlen and Berghe 2013; Polet and Depestele 2010; Taal and Klok 2012).

The Sumwing functions best when it is rigged with a V-net and tickler chains. The Sumwing is not used in combination with a chain matrix due to stability issues that can cause damage to the gear. The Sumwing is not used in the shrimp fishery because of stability issues due to the low towing speed. The Sumwing has also been rigged with a pulse generator and electrodes to carry out pulse fishing with flatfish as target species. This variant of the Sumwing is called a Pulsewing. Pulse fishing is currently not practiced because it is not allowed by European legislation (2.1.3.5).

In the Belgian fishery the Sumwing is used by a rather small number of vessels the whole year round. In addition, a number of vessels fish with a Sumwing during the annual fishing campaign in the Bay of Biscay. See Table 2-3 for the number of vessels using the Sumwing.

Figure 2-5: Illustration of the Sumwing (www.ecomare.nl).

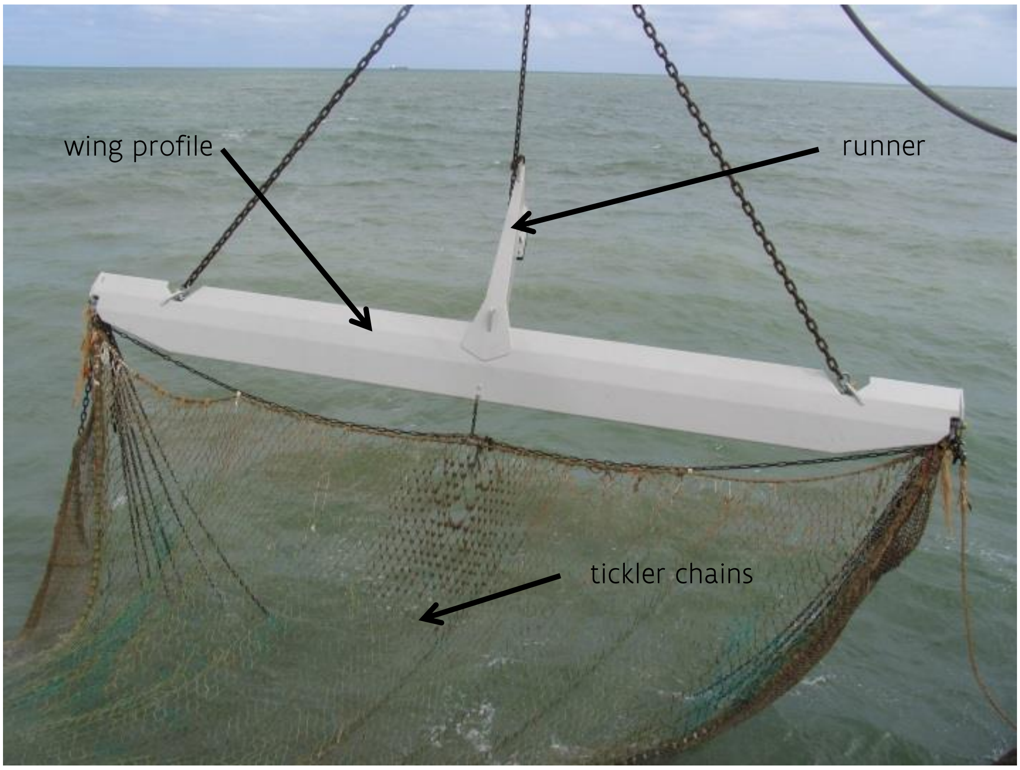


Figure 2-6: Illustration of the wing profile of the Sumwing (ILVO).

2.1.3.2 AQUA PLANING GEAR

The aqua planing gear (Figure 2-7) was invented by the owner of the fishing vessel Z.201 Job Schot, and realized in cooperation with 'Van Wijk Installations and Constructions'. In the aqua planing gear, the beam is replaced by a hydrodynamic wing profile but unlike the Sumwing, the beam trawl shoes are still present. A reduced drag is assumed due to the customized design of the shoes and the altered shape of the beam (Figure 2-8). The shoes have a groove in the middle so that during fishing a layer of water would be formed between the seabed and the shoe because of the speed. The hydrodynamic forces developed by that water layer are than supposed to cause the gear to be forced upwards with less drag on the seabed and fuel consumption as a result. This claim has not yet been backed up scientifically (Aqua Planning Gear, 2012). The aqua planing gear is rigged with tickler chains. It can also be rigged with a pulse generator.

Nevertheless, there is currently no scientific proof that aqua planing gear creates less seafloor disturbance compared to the traditional beam trawl. In the Belgian fisheries the use of Aqua Planning Gear is limited (Table 2-3).

Figure 2-7: The Z.201 uses aqua planning gear (ILVO).

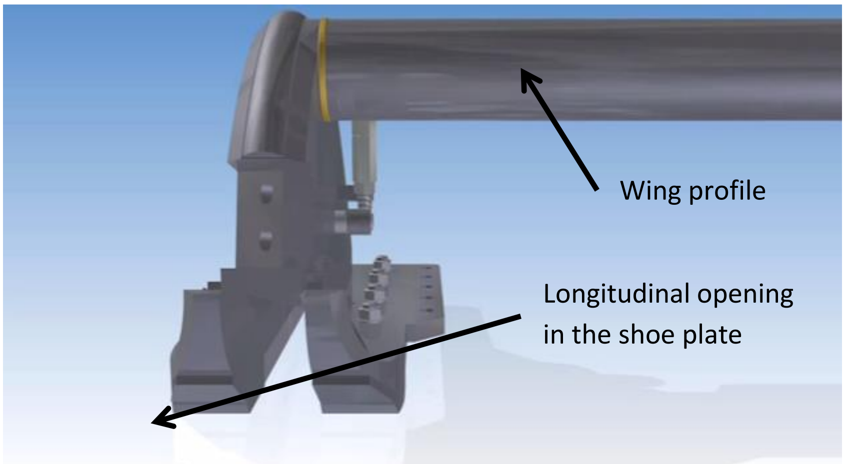


Figure 2-8: Illustration of the aqua planning gear (http://www.youtube.com/watch?v=hBkVobcTLxc).

2.1.3.3 ECOROLL BEAM

The Ecoroll Beam (Figure 2-9) is an alternative for the traditional beam trawl with the beam being replaced by a wing profile. The trawl shoes are replaced by wheels and the wing is rigged with a runner that, unlike the Sumwing, is provided with a wheel. The Ecoroll Beam was designed and built by the owner of the beam trawler Z 53, Steve Savels and Joël Snauwaert of Maritime Constructions in Zeebrugge. The Ecoroll Beam is an alternative to the traditional design of the beam trawl aiming at a reduction of the fuel consumption by reducing the hydrodynamic resistance through the water and reducing the friction on the seafloor (Depestele et al., 2007).

The advantage of the Ecoroll Beam over the Sumwing is that it can be rigged with an R-net with a chain matrix as well as with a V-net with tickler chains. In the Belgian fishery, ship owners experiment with different designs (probe length, tilt of the wing profile, size of wheels, etc.) of the Ecoroll Beam. See Table 2-3 for the number of Belgian vessels using Ecoroll beam.

Figure 2-9: Illustration of the Ecoroll Beam (ILVO).

2.1.3.4 ROLLER SHOES

The trawl shoes of a beam trawl can be fitted with or replaced by wheels. With this adaptation the sliding resistance of the shoes is replaced by a rolling resistance of the wheels (Figure 2-10). Different configurations (single large wheel, large wheel with one or two smaller wheels, two large wheels) of roller shoes have been tested on board of commercial vessels (Van Craeynest et al., 2013). The wheeled beam trawls appeared to be performing well on hard grounds, giving similar catches. Skippers reported only minor fuel savings in the range of a few percentages on hard grounds. Skippers taking part in the project complained about the poor performance of the roller shoes on soft grounds. The use of roller shoes can lead to fuel savings, mainly on hard grounds (Bult, 2007, Van Craeynest et al., 2013). Another advantage reported was that repair and maintenance costs for the wheels appear to be lower than for the trawl shoes. See Table 2-3 for the number of Belgian vessels currently using roller shoes.

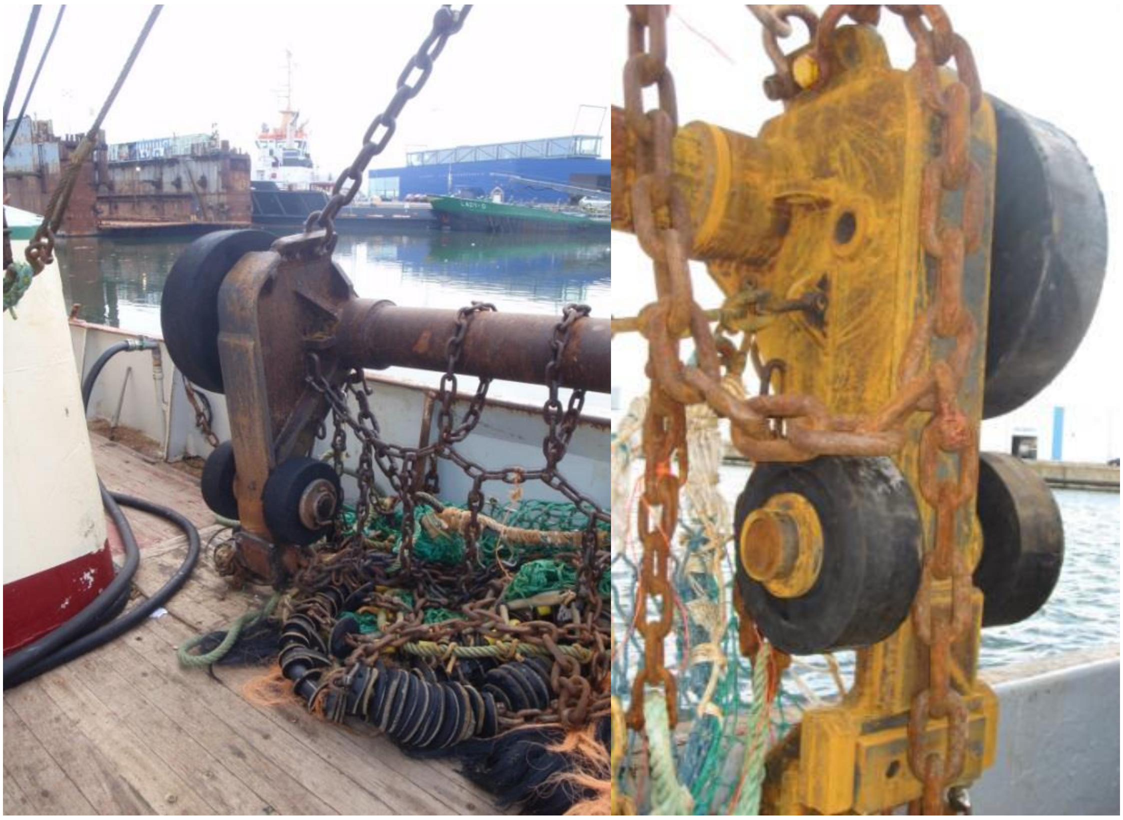


Figure 2-10: Illustration of the roller shoes (ILVO).

2.1.3.5 SHRIMP PULSE TRAWL

In pulse fisheries, the mechanical stimulation in the net opening by bobbin rope is replaced by electric pulse stimulation emitted by electrodes that startle animals out of the seabed (Figure 2-12 and Figure 2-13).

Electric pulses can be used to catch shrimp and sole. Research has shown that a pulse with a frequency of 5 Hz, a pulse width of 0.5 ms and an electric field strength of approximately 30 V/m is most effective to startle shrimp (Polet et al., 2005a; Polet et al., 2005b). Due to the short duration and low energy input of the pulses, the shrimp pulse is catalogued as a "startle pulse". In 2008, ILVO, in collaboration with Marelec NV and UGent, developed the first European shrimp pulse rig (HOVERCRAN) based on the startle pulse (Verschueren and Polet, 2009; Soetaert, 2015b). To minimize by-catch and seafloor disturbance, the groundrope was raised and the bobbin rope replaced by 11 electrode pairs (Figure 2-11) (Verschueren and Polet, 2009). In addition, other organisms than shrimps remain on the seafloor when exposed to the startle pulse, which means that mainly shrimp are caught.

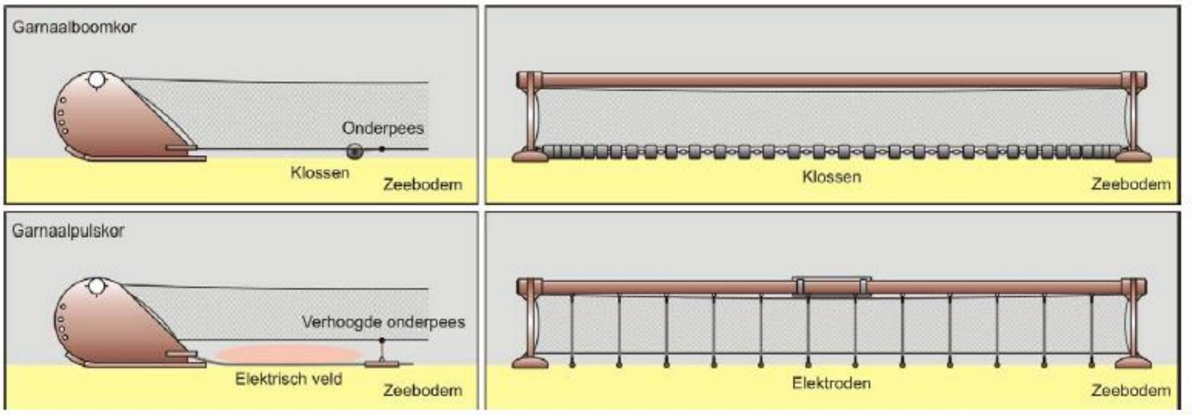


Figure 2-11: Hovercran with raised groundrope and 12 electrodes (ILVO).

The EU decided in 1998 to ban electric fishing (Verordening (EG) nr. 850/98 art.31; Quirijns et al., 2015; Soetaert et al., 2015c; Haasnoot et al., 2016; ICES WGELECTRA, 2018). As studies into pulse fisheries have shown promising results, all EU member states have been permitted - between 2006 and 2021- to fish in the southern part of the North Sea (ICES area 4c and southern half of 4b) with a temporary exemption for pulse fisheries (Annex III(4) EU Regulation 41/2006). The maximum number of exemptions that could be allocated on the basis of this regulation represented 5% of the beam trawling fleet of the member state (Kraan et al., 2015; Quirijns et al., 2014). These exemptions have been granted on the condition that the pulse technique was studied and developed further. Various North Sea countries made partial or full use of this exemption. In the Netherlands for instance 84 fishermen used the pulse technique by 2015. However, increasing criticism began to arise from various sections of the fishing industry. The main bottleneck for the majority of European member states was the limited controllability of the technology and the potential environmental impact that comes with it (Kraan et al., 2015). After lengthy negotiations the European commission voted for a complete ban on electric fishing from 1 July 2021 (European Parliament, https://www.pulsefishing.eu/).

Figure 2-12: Illustration of a pulse trawl net (ecomare.nl).

Figure 2-13: Illustration of a shrimp pulse trawl (ILVO).

2.1.4 Net adaptations to improve selectivity

The fishery sector is investigating modifications of the fishing gear to improve efficiency and selectivity and reduce seafloor disturbance. Adaptations have been tested and new technologies bring new possibilities (Depestele et al., 2008b; http://www.discardless.eu/selectivity_manual). Some adaptations have been incorporated into the legislation and are mandatory in certain areas or fisheries (Regulation (EU) 2019/1241). A technical description of these incorporated adaptations is given here.

2.1.4.1 LARGE MESH TOP PANEL

In order to reduce the by-catch of roundfish such as whiting and haddock, the Belgian fishing industry decided to implement a large mesh (360 mm) window in the front part of the top panel. The industry together with the Flemish government decided to make this compulsory for all Belgian beam trawlers and for all fishing grounds since 2013 (ministerial decree 2012-09-11/05). The legislation was based upon a large series of scientific experiments demonstrating the potential benefits of this type of large mesh top panel (Van Craeynest et al., 2013; Fonteyne et al., 1997).

2.1.4.2 LARGE MESH EXTENSION PIECE

In order to reduce the unwanted by-catch of undersized sole, the Belgian fishery took the initiative to test a large mesh extension piece, the so-called ‘Flemish panel’ (Figure 2-14). The 3-meter-long panel with meshes of minimum 120 mm is located in front of the cod end. The test led to positive results that are considered to benefit the sole stock if implemented (Bayse and Polet, 2015), although tested during just one sea trip. As such, the industry together with the Flemish government decided to make this compulsory for all Belgian beam trawlers and for all fishing grounds in order to enjoy a de minimis for sole (ministerieel besluit 2019-12-23/01). See Table 2-3 for the number of Belgian vessels currently using a Flemish panel.

Figure 2-14 - Illustration of the large mesh extension piece (ILVO).

2.1.4.3 BENTHOS RELEASE PANEL (BRP)

The Benthos release panel (BRP) is a square mesh panel installed at the bottom of the net, in front of the cod-end, that leads to a reduction of unwanted by-catches and benthic animals (Figure 2-15). Mesh size, dimensions, placement of the panel and towing speed also determine the efficiency of the adaptation (Fonteyne and Polet, 2002; Revill and Jennings, 2005; Van Craeynest et al., 2013; Soetaert et al., 2016). Since 2019 there is an obligation to have either a flip-up rope (2.1.4.4) or a benthos release panel in the beam trawl nets of the large fleet segment (ministerieel besluit 2019-12-23/01). See Table 2-3 for the number of Belgian vessels currently using a BRP.

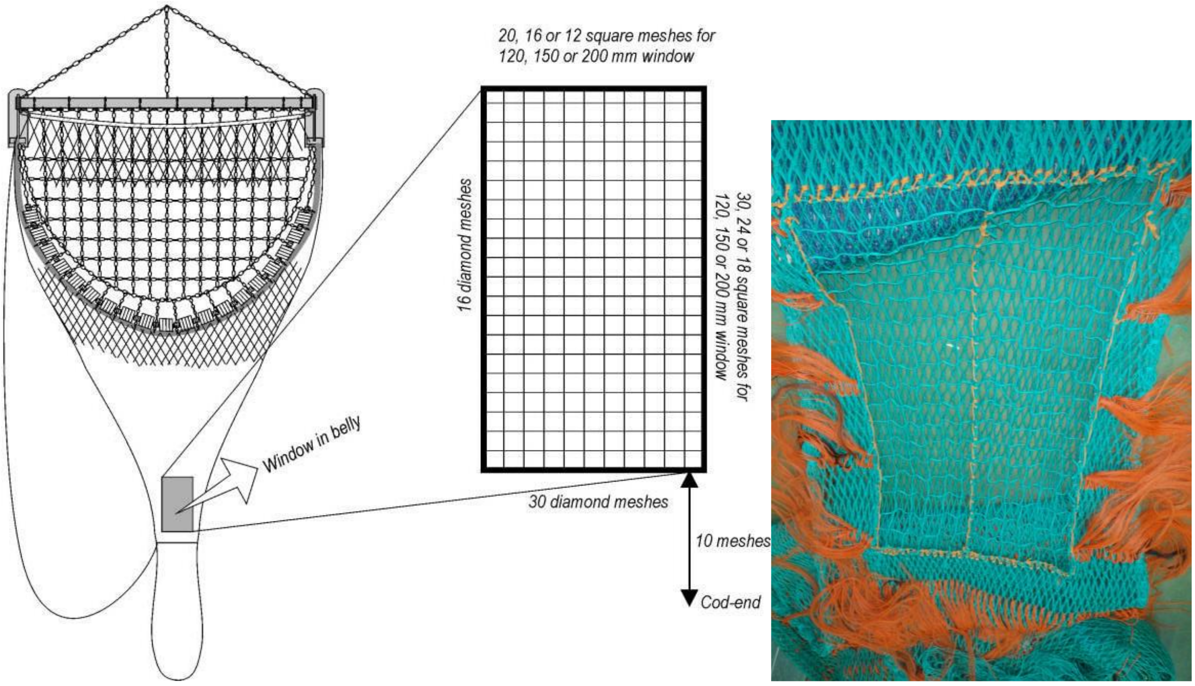


Figure 2-15: Benthos release panel (ILVO).

2.1.4.4 FLIP-UP ROPE

A beam trawl or otter trawl can be equipped with a "flip-up" rope, this is an extra construction that is rigged in the net opening on top of the bobbin rope to avoid stones and boulders in the catch on stony fishing grounds (Figure 2-16). Since 2019 it is mandatory, in the frame of the landing obligation, for beam trawlers of the large fleet segment to have either a flip-up rope or a benthos release panel (2.1.4.3) in the nets (ministerieel besluit 2019-12-23/01). See Table 2-3 for the number of Belgian vessels currently using a flip-up rope. The aim of the legislation is to avoid stones in the catch and reduce the bycatch of benthic animals in order to improve survival of discarded fish, although not scientifically proven.

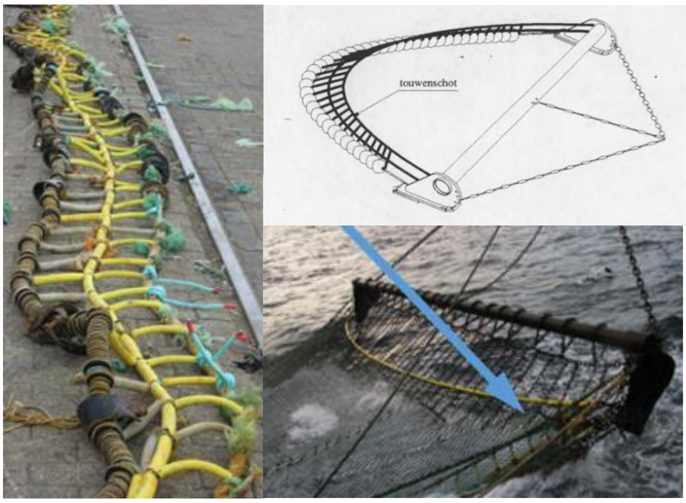


Figure 2-16: Flip-up rope (Polet and Fonteyne, 1995; ILVO).

2.1.4.5 THE SIEVE NET

In shrimp trawls a sieve net can be rigged to reduce discards (Polet et al. 2004, Revill & Holst 2004b, Verschueren et al., 2014). The sieve net is a funnel-shaped piece of netting with a mesh size of usually 60 mm (maximum 70 mm), attached all around the net circle in the front part of the net and leading to an outlet in the aft belly section (Figure 2-17). Shrimp passively flow through the meshes of the sieve net and end up in the codend. Anything too large to pass through the sieve net is diverted to the outlet and discharged. The efficiency of the sieve net was studied in the EU project DISCRAN (van Marlen et al. 2001). This study showed that the sieve net significantly reduces the bycatch of one year old and older fish. The use of the sieve net is mandatory for shrimp brown fishing in all EU waters (EC No. 850/98). Several countries provide an exemption for the use of the sieve net at times when algae and jellyfish occur in large quantities and clog the sieve net.

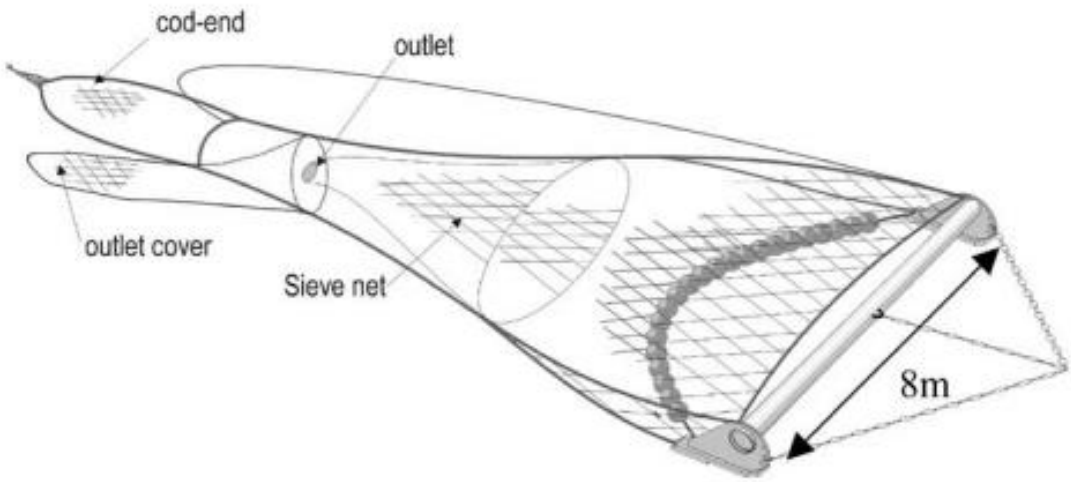


Figure 2-17: Shrimp trawl rigged with a sieve net (Polet et al., 2004; ILVO).

2.1.5 The weight of the beam trawl

A beam trawl is towed over the seafloor by a vessel designed for traction and is used to catch species living close to the seafloor. Beam trawling causes physical disruption of the seabed through contact of the gear components with the sediment (Depestele et al., 2016). An extensive series of scientific experiments have indicated that penetration into the seabed differs according to the type of trawl and the characteristics of the seabed. Any impact on the ecosystem strongly depends on the resilience of animals and depends on the dynamics of natural disturbance which shapes the composition of the animal communities (EC, 2014). Beam trawls are characterised by relatively deep penetration into the seabed but also by a relatively low fished surface. The penetration into the seabed is on average some 2 cm but can be up to 8 cm, depending on beam trawl weight, towing speed, and sediment type (Paschen et al., 2000; Depestele et al., 2016; Eigaard et al., 2016).

The larger the beam trawl, the higher the weight (Figure 2-18). However when the weight of the gear per kW is shown (Figure 2-19), the weight per kW of the vessels with higher power is similar to the vessels with lower power. The reason is that the penetration of the gear should be deep enough to startle the flatfish but not deeper because of increasing fuel consumption with depth. It is an equilibrium independent of vessel size and gear weight.

According to HFK Engineering BV (HFK Engineering BV, 2010), the weight (in air) of a Sumwing 12 m wing and nose amounts 3094 kg. However, the hydrodynamic shape of the sumwing ensures that the weight is not responsible for the gear sinking to the bottom (2.1.3.1). The weight of the different parts of the traditional beam trawlers is shown in Table 2-2.

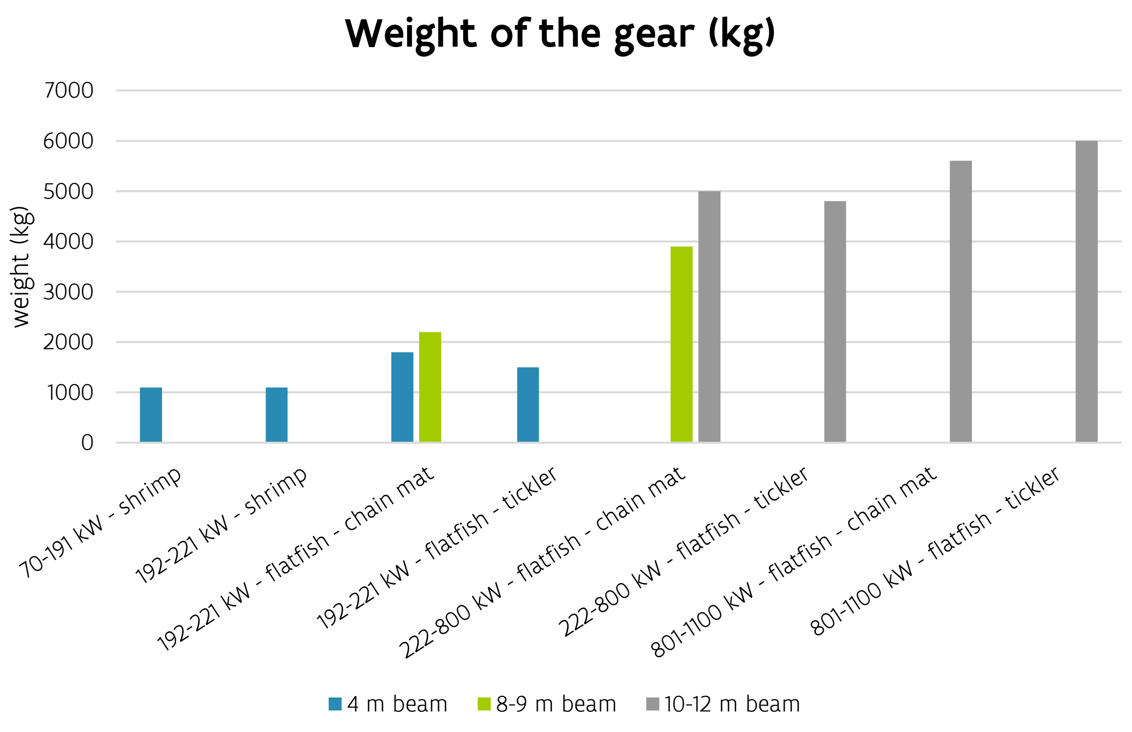


Figure 2-18: Weight of the gear (kg) (Lindeboom, 1998).

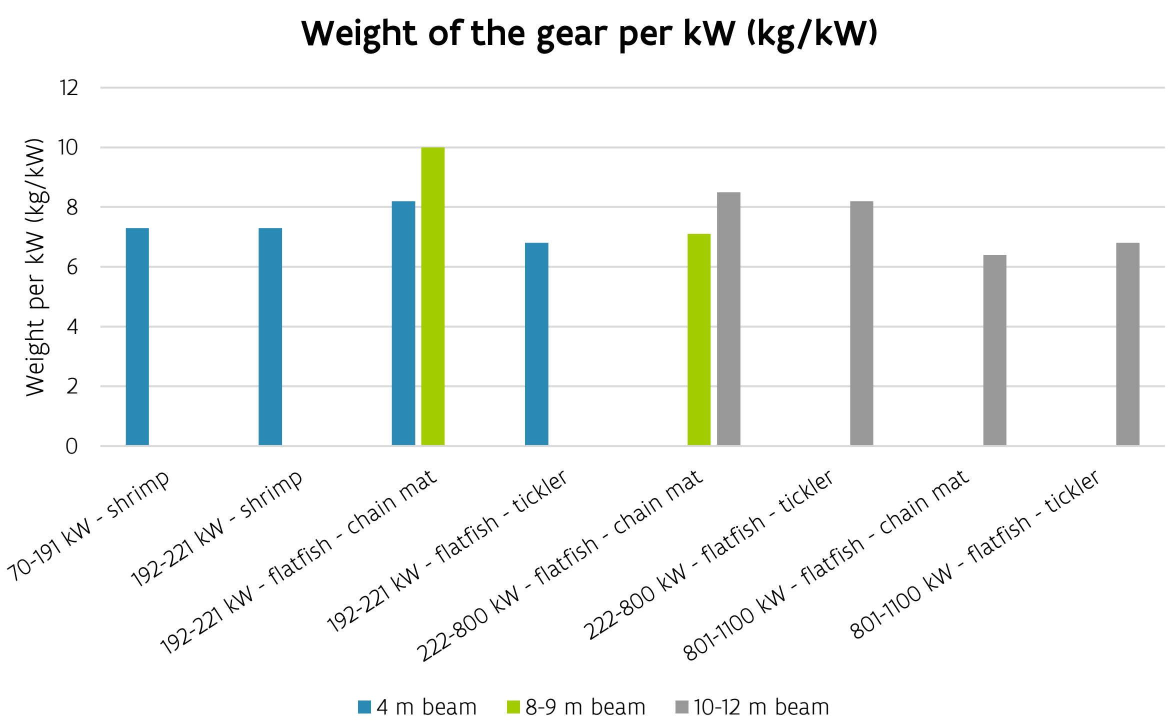


Figure 2-19: Weight of the gear per kW (kg/kW) (Lindeboom, 1998).

Table 2-2: Beam trawl gear information (Lindeboom, 1998).

	70-191 kW	192-221 kW			222-800 kW		801-1100 kW	
	Shrimp Beam Trawling	**Shrimp Beam Trawling**	**Flatfish Beam Trawling**		**Flatfish Beam Trawling**		**Flatfish Beam Trawling**	
			Chain Mat Gear ***	Tickler Chain Gear ***	Chain Mat Gear	Tickler Chain Gear	Chain Mat Gear	Tickler Chain Gear
Beam length (m)	4 (35%) – 8 (65%)	4 (35%) – 8 (65%)	5.1 (4 – 8)*	4.4 (4 – 6)*	9.6 (7.5 – 11.8)	11	10.6 (9.4 – 11.5)	11.4 (10.5 – 12)
Weight beam (kg)	260	260	300 (4m beam) 390 (8m beam)	350	810 (9m beam) 930 (10.5 beam)	1600	1100 (11m beam)	1850
Weight 1 shoe (kg)	200	200	250 (4m beam) 300 (8m beam)	255	245 (9m beam) 400 (10.5 beam)	635	450 (11m beam)	800
Weight bobbins (kg)	300	300	170 (4m beam) 175 (8m beam)	200	350 (9m beam) 360 (10.5 beam)	500	430 (11m beam)	600
Weight of the chain mat (kg)	N/A.	N/A.	550 (4m beam) 570 (8m beam)	N/A.	1450 (9m beam) 2210 (10.5 beam)	N/A.	2000 (11m beam)	N/A.
Weight of the tickler chains (kg)	N/A.	N/A.	N/A.	370	N/A.	1000	N/A.	1150
Weight gear (kg)	1100	1100	1800 (4m beam) 2200 (8m beam)	1500	3900 (9m beam) 5000 (10.5 beam)	4800	5600 (11m beam)	6000
Weight gear (kg/kW)	7.3	7.3	8.2 (4m beam) 10.0 (8m beam)	6.8	7.1 (9m beam) 8.5 (10.5 beam)	8.2	6.4 (11m beam)	6.8
Surface of the sole plate (cm^2)	270	270	300.0	260.0	360	530	475	635
Vertical netopening (c.l. beam) (m)	0.65	0.65	0.55 (0.42 – 0.70)*	0.53 (0.42 – 0.70)	0.58	0.53	0.61	0.43
Length groundrope (m)	8.6 (7m beam) 10 (8m beam)	8.6 (7m beam) 10 (8m beam)	9.2 (4m beam) 12.5 (8m beam)	10.5 or 17	16	28	18.5	32

Diameter groundrope (mm)	Ø bobbins: 210 Ø axes: 20	Ø bobbins: 210 Ø axes: 20	Ø bobbins: 250 Ø steel wire: 24 - 32	Ø chain: 18 Ø roller: 200 to 300	Ø bobbins: 250 Ø steel wire: 28 - 32	Ø chain: 22 Ø roller: 230 to 300	Ø bobbins: 250 Ø steel wire: 30 - 34	Ø chain: 22 Ø roller: 320 to 400
Material groundrope	Steel axes + rubber bobbins	Steel axes + rubber bobbins	Steel wire + rubber bobbins	Chain + central rubber roller	Steel wire + rubber bobbins	Chain + central rubber roller	Steel wire + rubber bobbins	Chain + central rubber roller
Flip-up rope	none	none	15%	10%	70%	none	90%	20%
Vessels with tickler chain gear	none	none	65%	100%	35%	100%	20%	100%
Diameter of the shackles (mm)			N/A.	Ticklers: 16 net ticklers: 10 to 14	N/A.	Ticklers: 18 net ticklers: 11 to 22	N/A.	Ticklers: 18 net ticklers: 11 to 22
Vessels with chainmat gear	none	none	100%	0%	100%	0%	100%	0%
Diameter of the shackles (mm)	N/A.	N/A.	14 or 18	N/A.	18	N/A.	18	N/A.
Dimension of the quadrants (mm)	N/A.	N/A.	25 long on 25 wide or 35 long on 35 wide	N/A.	35 long on 25 wide	N/A.	35 long on 25 wide	N/A.
Mesh size net (mm)	32 to 24**	32 to 24**	120	120	120 – few 150	120	120 – few 150	120
Netting material net	PA-sngl	PA-sngl	Top panel: PE-sngl; belly: PE-sngl or dbl	PE-sngl (67%), PA-sngl (33%)	Top panel: PE-sngl; belly: PE-dbl few sngl	Top panel: PA-sngl; belly: PA-dbl	Top panel: PE-sngl; belly: PE-dbl few sngl	Top panel: PA-sngl; belly: PA-sngl or dbl
Mesh size cod-end (mm)	22	22	80 or 100	80 or 100	80 or 100	80 or 100	80 or 100	80 or 100
Netting material cod-end	PA-sngl	PA-sngl	PE-dbl	PE-dbl	PE-dbl	PA-dbl	PE-dbl	PE-dbl
Cod-end cover	Yes (100%)	Yes (100%)	25%	10%	45%	30%	45%	20%

*:Average (minimum – maximum)
**: from trawl mouth to trawl end
***:vessels which operate a chain matrix beam trawl or a tickler chain beam trawl as the main gear.

2.2 Bottom otter trawl

The otter trawl (Figure 2-20) is a fishing gear of which the net is opened horizontally by the hydrodynamic forces of the water on the otter boards that are rigged to the front part of the gear. Together with the ground rope, the otter boards usually do not leave the seabed while fishing (Anon, 1992; Nédélec & Prado, 1990). Depending on the type of substrate, there are different types of ground rope, which are intended to protect the lower part of the trawl for damage by bottom contact, and to enable the net to drag over the seafloor. There are different types of otter boards on the market that differ in weight, size and design. The desired horizontal opening of the net, the type of seafloor and the target species determine the type of board that is used. The sweeps and bridles are cables connecting the boards to the net.

The bottom otter trawl is the second most important fishing technique for Belgian fishermen. However, this technique only accounts for 11% (in 2020) of the total fishing activity in days at sea. Within the otter trawl category there are a lot of possibilities for the configuration of the nets: single otter trawl, twinrig, triple rig, or quadrig.

In the Belgian fishing industry, there are vessels that fish with otter boards throughout the year and there are vessels that alternate between the beam trawl and otter trawl. The Belgian otter trawlers generally do not use tickler chains nor chain matrices. See Table 2-3 for the number of Belgian vessels fishing with otter trawls.

2.2.1 Single otter trawl

In a single otter trawl a single net is attached to the two boards (Figure 2-20). The single otter trawl is used in the Belgian fishery by inshore fishermen in the small fleet segment with demersal fish as target species. Two vessels in the large fleet segment and one Eurocutter fish with a single otter trawl (Table 2-3).

2.2.2 Twinrig

The twinrig (Figure 2-21) consists of two nets attached to each other at the clump where the two central bridles come together. The outside of each of the two nets is attached to an otter board. The twinrig as used in the Belgian fishery, can have a horizontal net opening of more than 200 m. See Table 2-3 for the Belgian fishing vessels using twinrig. This fishery targets sole, plaice and skate.

2.2.3 Multirig

A multirig (Figure 2-22) is designed in a similar way as the twinrig but the gear consists of three, four or more nets. The quadrig consists of four nets and the horizontal gear opening is on average 110 meters. The quadrig gear is used in a seasonal fishery (May to November) by Eurocutters with

Nephrops as the main target species. The rest of the year these fishing vessels use beam trawls or other types of otter trawls to fish for demersal fish or shrimp (Table 2-3).

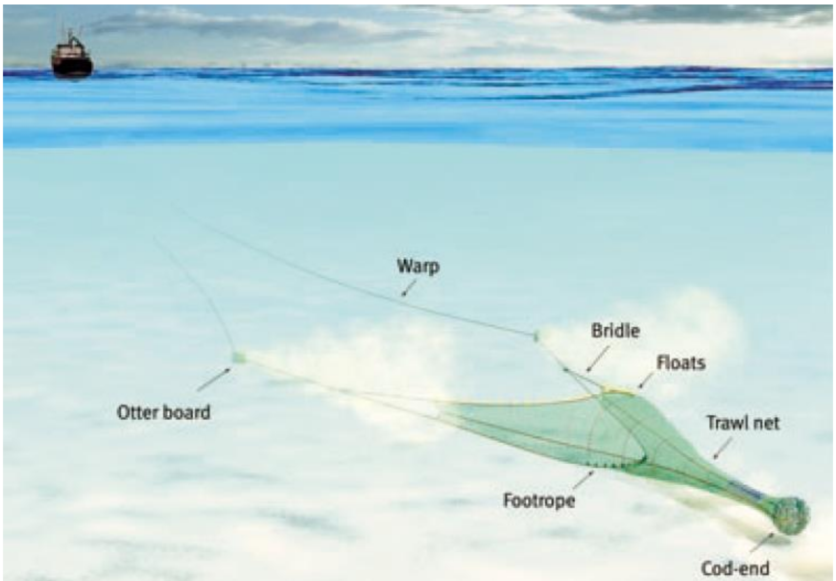


Figure 2-20: Illustration of an otter trawl (Galbraith et al., 2004).

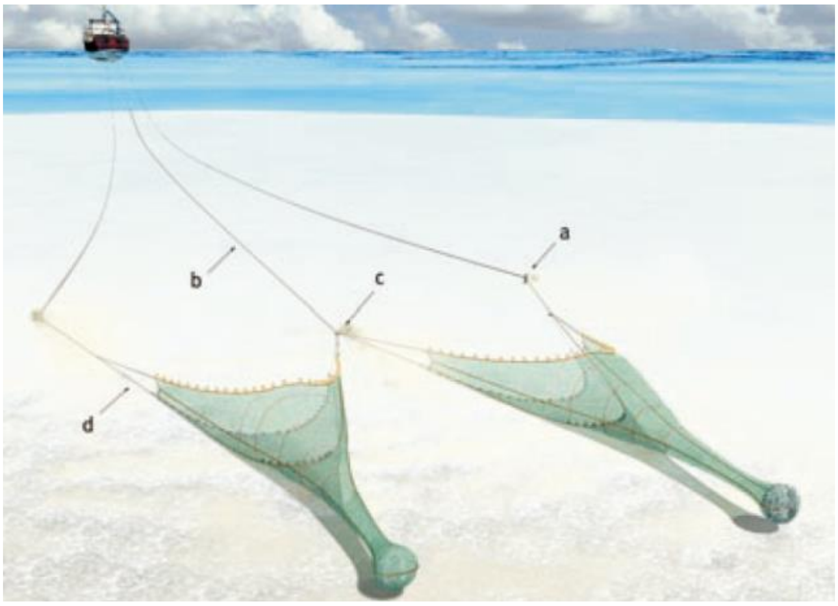


Figure 2-21: Illustration of a twinrig a: otter board, b: warp, c: clumb weight, d: bridles (Galbraith et al., 2004).

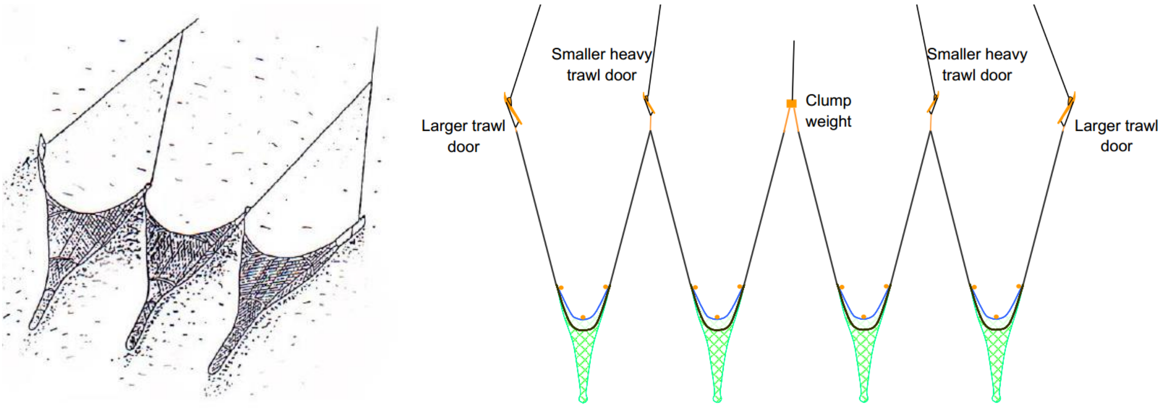


Figure 2-22: Illustration of a triple rig and a quadrig (Seafish, 2005; Seafish, 2010).

2.2.4 Outrigger

A beam trawler is usually not designed to tow otter trawls (unless a net drum is present on the aft deck) but with an adapted technique and a skilled skipper and crew, it is possible to tow two otter trawls, one at each side of the vessel. The method has been developed in the tropical shrimp fishery where the nets are towed from two outrigger booms. As such, the fishing gear is called the outrigger net (Figure 2-23 and Figure 2-24). The horizontal net opening as used in Belgium is between 15 and 17 m (Vanderperren, 2007). Because of the lower weight of the gear compared to the beam trawl and the lower towing speed, there is a significant fuel saving. The target species are plaice, Norway lobster, sole and skate (Vanderperren, 2007). The outriggers are allowed within the 12 miles zone.

A few beam trawlers of the Belgian fishery have been equipped as outriggers in summertime-. In wintertime, these vessels change back to the beam trawl. Because of safety issues, this technique is limited to the season with prevalence of calm weather.

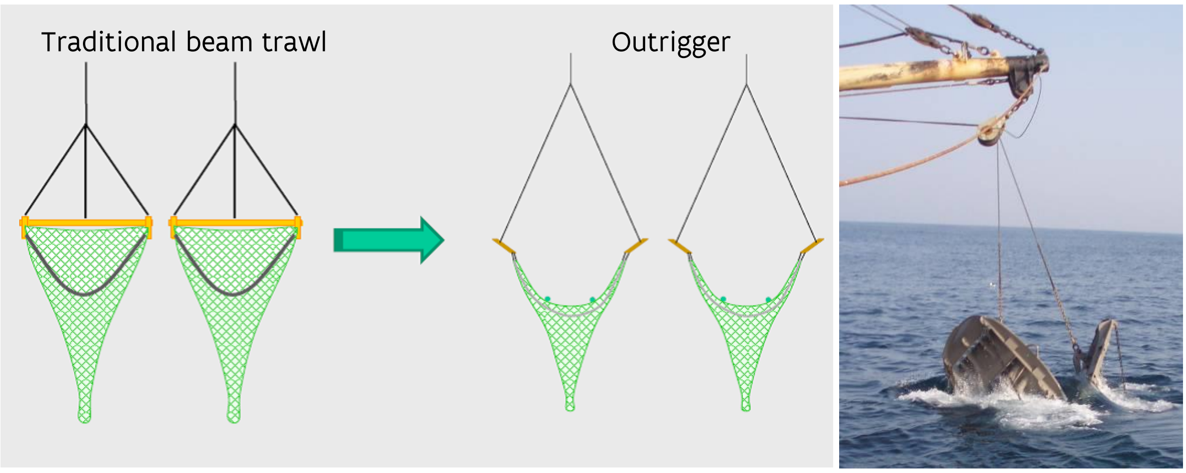


Figure 2-23: Illustration of an outrigger (SDVO).

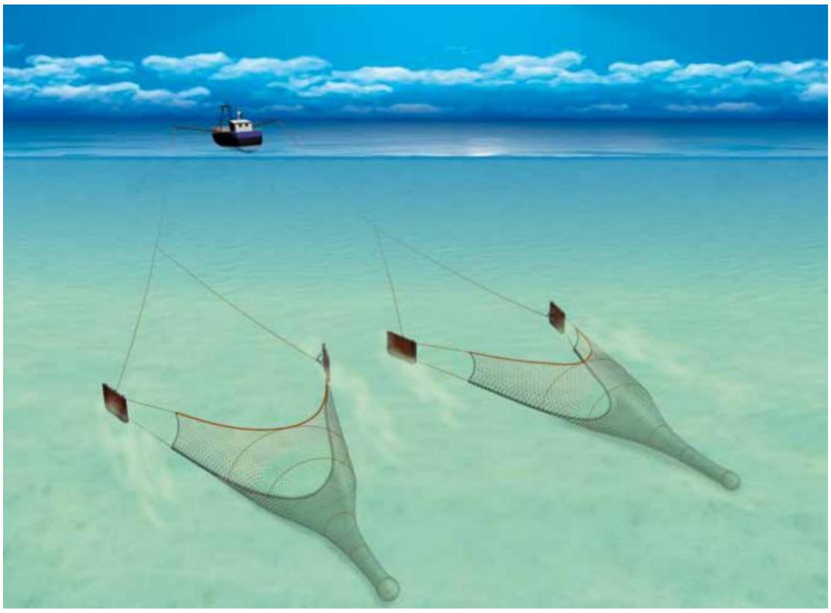
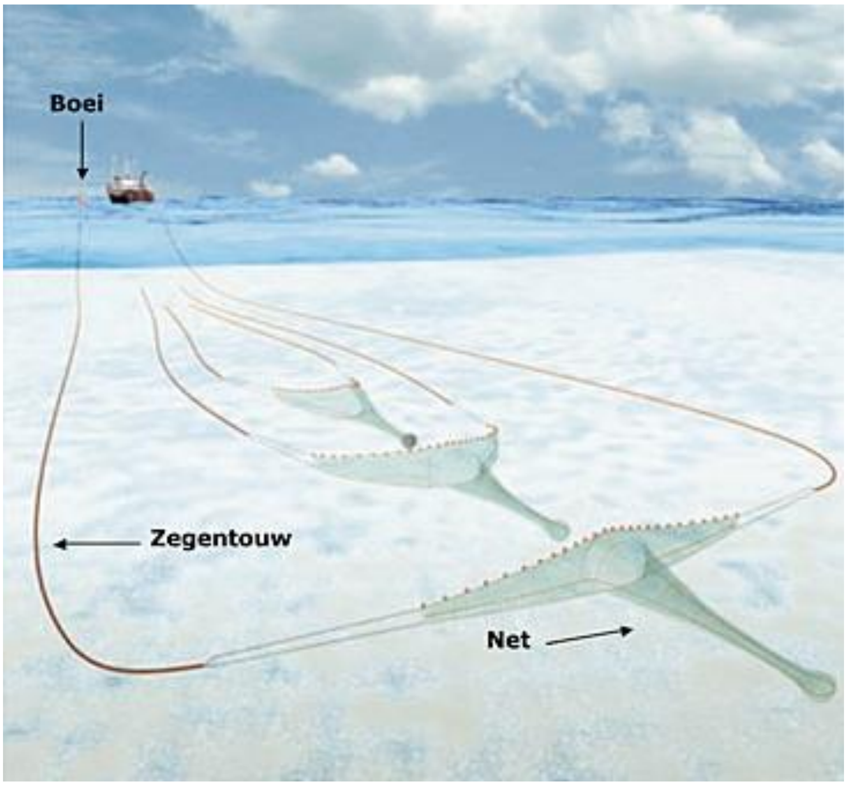


Figure 2-24: Outrigger (Montgomerie, 2015)

2.3 Flyshoot fishery

The flyshoot fishery, as used today in the southern North Sea and the English Channel, is based on the Scottish and Danish seine fishery (O'Neill & Noack, 2021). The principle is explained in Figure 2-25. First a buoy is thrown overboard with the flyshoot rope attached to it. When the ship sailed half a round, the net is shot. The ship completes the circular or rectangular target area and ends up at the buoy again. Here the crew picks up the end with the buoy and hauls in the seine ropes and net. The seine ropes roll over the seabed and cause vibrations and dust clouds that startle the fish. The fish are herded into the opening of the net when the seine ropes close up together and the net approaches the ship. That is why this fishery is only carried out during the day because at night the dust clouds and the flyshoot rope are not visible to the fish. Also, during winter months flyshoot is not used because the days are short and the light intensity is low. Flyshoot fishing can only be practiced in areas without obstacles such as rocks and wrecks, because the fishing line would get stuck on them. The bottom must be flat and sandy. Flyshooting is therefore both area-specific and seasonal. However, this disadvantage is offset by a higher selling price, lower fuel consumption and the possibility of fishing for non-quota fish species (Geeraert, 2008; Den Heijer and Keus, 2001). See Table 2-3 for the Belgian fishing vessels using the flyshoot during summertime.

A scientific update of the fishing method is needed because the present day flyshoot method is by no means comparable to the original Danish and Scottish seine fishery. The fishing gear and flyshoot ropes have become heavier, the engine power and fuel consumption have risen significantly and there is no clear view on discarding and seafloor disturbance in the region (pers. comm. Hans Polet).



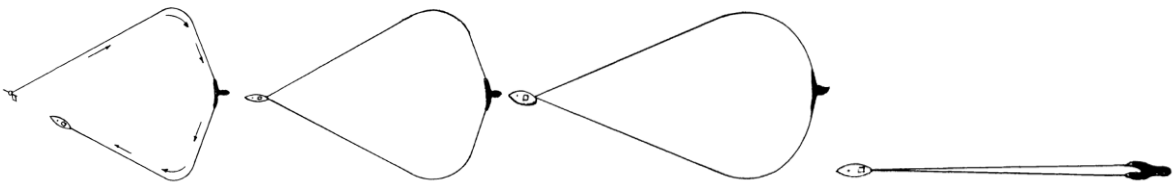


Figure 2-25: The principle of the flyshoot fishery (www.flyshootvis.nl).

2.4 Mechanical Dredge

A dredge (Figure 2-26) is a fishing gear usually designed to target shellfish like scallops. Mechanical dredges are dragged across the sea floor, scraping or penetrating the bottom to catch shellfish. To catch shellfish that live in or on the seabed, it takes some force to detach these organisms. The vessel shoots the dredge to the sea bottom and drags it over the seabed. A dredge consists of a metal framework with at the lower part a scraping plate rigged (Pitel et al., 2001). This plate, with or without teeth, digs into the sediment in order to extract and to collect organisms. A heavy network or metal rings form a bag in which the catch is retained. The bag allows the water, sand and mud to wash out. Each dredge is designed specifically for the fishery and target species (Pitel et al., 2001).

Usually more than one dredge is used. Larger vessels generally tow two sets of dredges. Beam trawlers do this by securing the dredges on a beam with wheels. These beams are dragged from the outrigger booms. The number of dredges that can be used varies with the strength of the vessel, the possibilities for manipulation of the fishing vessel and the area (Seafish, 2005; Montgomerie, 2015).

In the Belgian fishery there were two vessels equipped with dredges (Table 2-3) but they switched to other methods so there is no more dredging in Belgium in 2023. It can be used year-round or switched to (shrimp) trawling in summertime.

Figure 2-26: Illustration of a dredge (Galbraith et al., 2004).

2.5 Set nets

Set nets (Figure 2-27) are passive fishing gears and are used in the Belgian fishery as vertical net panels held on to the seafloor by anchors and weights and kept vertically by buoys or floats. Fish swim into the nets and become entangled in the fine netting. There are two types of set nets used in the Belgian fishery: gillnets and trammel nets (Depestele et al 2006). The naming of the different types of set nets varies from country to country. In Belgium, the single layer net is a gillnet and a triple layer net is a trammel net. They can be rigged to fish on the seabed or at any position between the seabed and surface, depending on the target species. In case of gillnets, the netting is very thin, almost invisible to the fish, and the fish swim into it and get caught in the meshes by their gills (Montgomerie, 2015). Trammel nets are made up of three layers of netting, two outer layers of large mesh with a sheet of fine small mesh sandwiched between them. As with the gill net, the netting in the trammel net is almost invisible to the fish. They will swim through the meshes of the first layer of large mesh netting, into the layer of slack small mesh, forcing the slack small mesh netting through the meshes of the second layer of large mesh and entrapping the fish in a pocket of the inner small mesh netting (Montgomerie, 2015). The mesh size and height of the net varies depending on target species (FANTARED 2, 2003).

Table 2-3 shows the vessels in the Belgian fishery that currently practice the set net fishery. The number of Belgian vessels practicing this métier varies over the years. These vessels target mainly sole and occasionally cod.

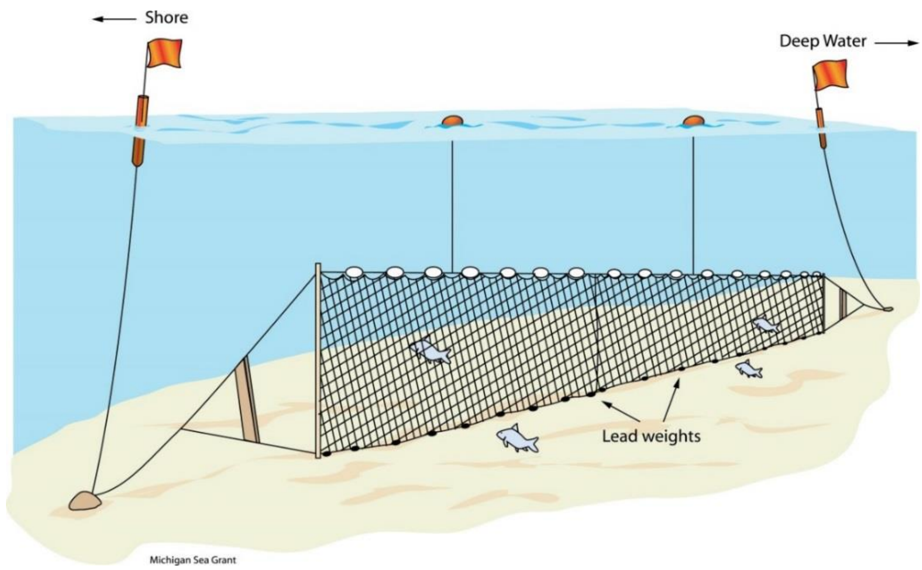


Figure 2-27: Illustration of a gillnet (http://safinacenter.org, Michigan Sea Grant).

Table 2-3: Overview of the Belgian fishing fleet according to fishing technique (2022) (Source: Dienst Zeevisserij, FOD mobiliteit, ILVO). Each line represents a different ship however for privacy reasons ship names are not shown. Instead, the segment group and the fishing technique(s) used per ship are shown. Vessel numbers indicated with * represent ships for which data are missing or for which it is not known whether they are still fishing.

Vessel	Fleet Segment Group	Extra		Beam trawl					Otter trawl					Fly shoot	Passive gear		Extra			
		Shrimp trawl	Sieve net	Traditional beam trawl with shoes	Traditional beamtrawl with roller shoes	Ecoroll beam	Sum wing	Aqua planing gear	Single	Twin rig	Trip let	Quad rig	Out rigger		Set nets	Pots	BRP	Flip-up rope	Panelen in de rug	Vlaams Paneel
1	Eurokotter			x				x												x
2	Eurokotter	x	x	x	x			x												x
3	Eurokotter											x					x	NVT	x	NVT
4*	Eurokotter																			
5	Eurokotter	x	x	x	x															x
6*	Eurokotter																			
7*	Eurokotter																			
8*	Eurokotter																			
9*	Eurokotter																			
10	Eurokotter			x	x							x								x
11	Eurokotter			x					x										x	
12	Eurokotter							x				x								x
13	Eurokotter							x											x	x
14	Eurokotter				x													x		x
15	Eurokotter			x								x						x		x
16	Eurokotter	x			x	x		x												x
17	Eurokotter			x								x					x		x	x
18	Eurokotter			x																x
19	Eurokotter			x	x							x						x		x
20*	Eurokotter																			
21	GVS								x									NVT	x	NVT
22	GVS					x	x										x		x	x
23	GVS								x									NVT	x	NVT
24	GVS				x													x		
25	GVS				x															x
26	GVS			x	x					x								x	x	x
27	GVS				x													x		x
28*	GVS																			

29	GVS				x							x							x	x
30	GVS			x	x													x	x	x
31	GVS				x													x	x	x
32*	GVS																			
33	GVS													x					x	
34	GVS				x					x								x	x	
35	GVS									x				x			x		x	NVT
36	GVS				x													x	x	x
37	GVS				x		x											x		x
38	GVS				x													x		x
39	GVS				x		x													x
40	GVS				x													x		x
41	GVS				x													x	x	x
42	GVS			x	x													x	x	x
43	GVS			x	x													x	x	x
44	GVS				x															
45	GVS				x		x											x	x	x
46	GVS				x													x		x
47*	GVS																			
48	GVS			x	x		x													
49	GVS				x													x		x
50	GVS				x													x		x
51	GVS																	x		x
52	GVS			x	x													x		x
53	GVS			x	x															
54	GVS			x	x													x	x	x
55*	rest KVS																			
56	rest KVS	x	x		x														x	x
57	rest KVS	x	x	x																
58	rest KVS														x	x				
59	rest KVS	x	x (year round)																	
60	rest KVS	x	x (year round)																	

61	rest KVS	x	x		x														x	x
62	rest KVS	x																		
63*	rest KVS																			
64*	rest KVS																			
65*	rest KVS																			
66	rest KVS	x	x (year round)																	
67	rest KVS																			
68*	rest KVS																			
69	rest KVS	x	x (year round)														NVT	NVT	NVT	NVT
70*	rest KVS																			

3 SEAFLOOR AND ECOSYSTEM IMPACT

3.1 Introduction

The seafloor, and particularly coastal and continental shelf sediments, are increasingly impacted by human disturbances (van de Velde et al., 2018). Bottom-contacting mobile fishing gears are found to be the most extensive cause of physical abrasion of the seabed, with a geographical footprint covering much larger areas than aggregate extraction (Eigaard et al., 2017; Kenny et al., 2017). Bottom-contacting mobile fishing gears include demersal otter trawls, beam trawls and scallop dredges and support demersal fisheries that account for about one quarter of the world capture fisheries production (FAO 2009). These gears typically use heavy ground ropes and chains to startle the fish away from the seabed into the nets; physical disturbance from such fisheries causes significant changes in the demersal ecosystem.

The earliest concerns on ecosystem impacts are nearly as old as the existence of demersal bottom trawling itself and focused primarily on the taking of large quantities of small and immature fish (Jones, 2018) by the medieval beam trawl or 'wondyrchoun' ('*wonderkuil* in Dutch). De Groot (1984) also refers to the concern that 'the wondyrchoun presses so hard on the ground that it destroys the living slime and the plants growing on the bottom under water' and that Dutch fishers expressed their concern in 1583 to the Prince William of Orange about 'the state of the seabed after passage of the trawl; it would become rough and likely less fish would be caught in future at these localities'. Despite concerns on seabed impact, the main focus of trawl fisheries was, however, directed to increasing catch efficiency. Catches first increased by expanding fishing grounds from the southern North Sea in the early 1800s to the entire North Sea by the end of the 19th century. This was the era of the industrial revolution, but it took until ~1880 when steam engines replaced sailing trawlers. Steam trawlers could tow faster and encouraged the switch to otter trawls with a higher catch efficiency than beam trawl for many species (Engelhard, 2008). Steam trawlers were replaced by motor trawlers with diesel engines for both propulsion and auxiliary systems in the early 20th (Lindeboom and De Groot, 1998) and led to the re-introduction of double-rigged beam trawls as an efficient way to catch buried flatfish (Rijnsdorp et al., 2008) in the 1950's. Improving catch efficiencies was the main focus of developments for centuries, until the early 1990s when wider ecosystem impacts and notably seabed impact came into focus (Pitcher, 2001; Kennelly & Broadhurst, 2002).

A vast number of impact studies identified the effects of the bottom trawling on the structure of benthic organisms and their habitats (e.g., de Groot and Lindeboom, 1994, Jennings and Kaiser 1998, Lindeboom and de Groot 1998). These studies were summarized in meta-analytic review studies that quantified the mortality of benthic invertebrates in relation to fishing gear, depth, and sediment type (Collie et al., 2000; Kaiser et al., 2006; Hiddink et al., 2017; Sciberras et al., 2018; Pitcher et al., 2022). Bottom trawling reduces benthic biomass, diversity and body size, and changes in the functional trait composition of the community. The magnitude of these effects varies between gears and habitats. More recently, efforts are being undertaken to improve our understanding of the bottom trawling impacts on benthic ecosystem functioning (Ramalho et al., 2020; Hinz et al., 2021; Tiano et al., 2022).

A lack of recurrent coordinated and publicly available benthic monitoring data at regional scales has instigated static regional assessments of benthic impacts of bottom trawling using a risk-based approach. Risk is composed of two aspects, the recoverability of the benthic habitats on the one hand and acute trawling impacts on the other hand. Acute trawling impacts are quantified as depletion rates, i.e., the benthic mortality expressed as a proportion of its pre-trawling state. Depletion rates were originally estimated for a generic gears and including four gear types: a generic beam trawl, otter trawl, mechanic and hydraulic dredge (Hiddink et al. 2017). Depletion rates were further detailed by gear type using their swept area ratio (Eigaard et al. 2016) and particularly discriminated between a range of otter trawl types depending on their target assemblage (Rijnsdorp et al, 2020b). Beam trawls were separated into the flatfish and shrimp directed beam trawls (Rijnsdorp et al 2020b). Flatfish-directed beam trawling was further split up into beam trawls and pulse trawls. Replacing tickler chains by electrodes substantially reduced seabed impacts, though the use of the gear was banned by the European Parliament in 2019 (Rijnsdorp et al 2020a). Some beam trawlers are no longer using trawl shoes to keep the beam above the seabed, but have, instead, a wing-shaped foil that hovers above the seabed. No formal comparison between SumWing and traditional beam trawls, although the removal of the trawl shoes is expected to reduced seabed impacts slightly (Depestele et al., 2022; Szostek et al., 2023).

3.2 Fishing intensity, area swept and sediment displaced

Bottom trawling is widely distributed over the continental shelves of Europe in 2010-2012 (Figure 3-1), but note that between 15 and 72% of the most intensively fished region (0–200 m) was untrawled during study period (Eigaard et al., 2017). This chapter is focused on the NW European shelf seas: the Greater North Sea, and the Celtic Seas.

The North Sea has a regional swept area ratio of 1.2 $km^2/km^2/y$, whereby ~40% of the area accounts for 90% of the trawling activity (Amoroso et al. 2018). The North Sea can be largely split into different areas with different fishing intensities and gear types (Figure 3-3). The northern North Sea (ICES area 4.a) is the deeper part (>75m) of the North Sea and is mostly trawled by otter trawls, with a high concentration along the Norwegian deep trench and the Fladen grounds. Beam trawl fisheries dominate the shallow parts of the southern North Sea and notably the southern Bight. Fishing intensities are less in the shallow Wash area (NW part of the southern North Sea). The Central North Sea can be split in the western part which is only lightly trawled (less than once every two years), and the eastern part which is fished by all bottom trawls (otter trawls, beam trawls and bottom seines) in a patchily manner. The Eastern English Channel is one of the most heavily trawled areas of the European continental shelves (> once per year). Several areas in 2010-2012 were trawled at least 5 times per year by beam trawls, seines and otter trawls (although the French fishing effort is not shown in Figure 3-3).

Fishing in the Celtic Sea, the Bristol Channel and the Irish Sea are characterised by *Nephrops* fishing grounds which are heavily trawled (>10 times per year) (Figure 3-2). The Irish Sea fisheries is dominated by *Nephrops* trawlers, which are highly concentrated. Approximately 15% of the area accounts for 90% of the trawling activity in the Irish Sea in 2010-2012 (Amoroso et al. 2018). Beam trawling is second most trawling activity and mainly takes place in the eastern parts of the Irish Sea, although the areas are generally trawled less than one per year. Beam trawl and finfish otter trawl fisheries complement the *Nephrops* fisheries in the Celtic Sea and the Bristol Channel. Most areas are trawled at least once per year, except for the ridges of the southern Celtic Sea where intensive fishing is altered with low fishing patterns along the orientation of the ridges (Mateo et al. 2016) (Figure 3-2).

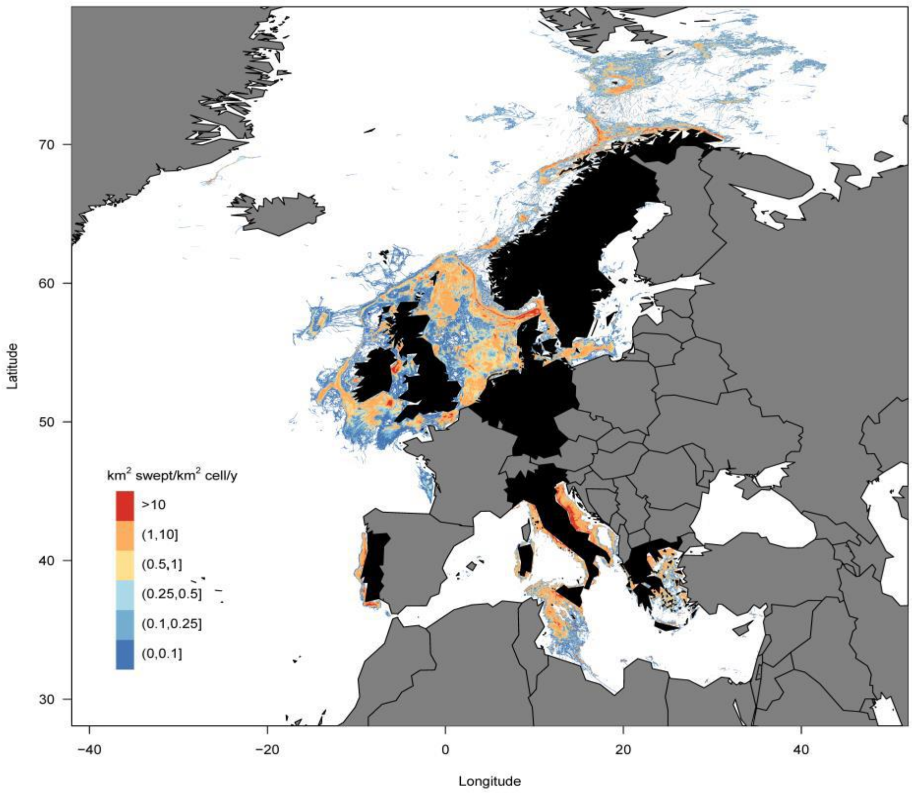


Figure 3-1: Mean annual trawling intensity in the period 2010-2012 at the surface layer (total swept area) estimated from VMS and logbook data of bottom trawl fleets. Countries marked black provided data.

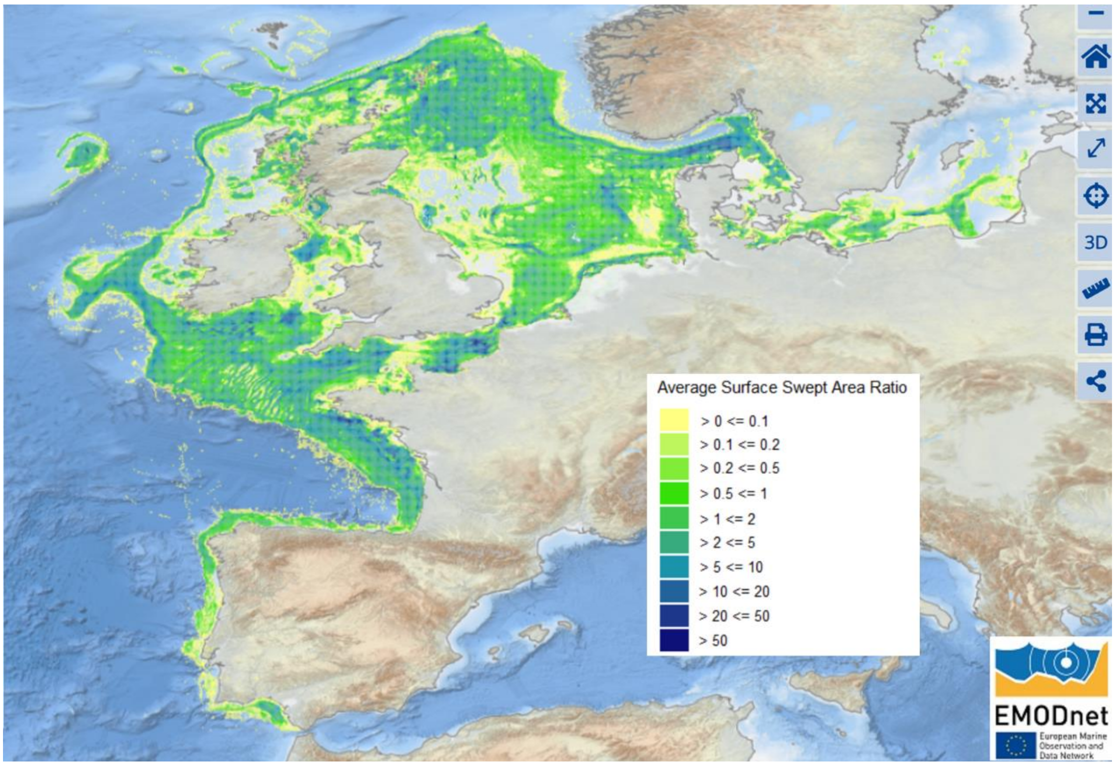


Figure 3-2: Mean annual trawling intensity in the period 2015-2018 at the surface layer (map downloaded from EMODnet on 28 February 2023, https://emodnet.ec.europa.eu/geoviewer/).

Bottom trawling intensities are much lower at the sub-surface level (deeper than 2cm), because the percentage of the total gear footprint that has sub-surface impact is low for otter trawls (<30%) (Figure 3-4). The sub-surface footprint is mainly driven by beam trawling and dredges, and is hence highest in the southern North Sea, the Irish Sea, the Celtic Sea and the Adriatic Sea. Otter trawl fisheries significantly contribute to subsurface impacts when fishing intensities are very high, such as in the Northern North Sea and Skagerrak.

The deeper penetration depths of beam trawls and dredges are compensated for by the limited width of the gears. The gear width is legally bounded to 24 m (two trawls of max 12 m beam width), whereas the max width of otter trawl métiers varies between 100 and 300 m (Eigaard et al., 2016). Beam trawls and dredge penetrate deeper in the seabed (Hiddink et al., 2017; Pitcher et al., 2022), but their area swept in one hour fishing is a twofold or threefold smaller than for other bottom trawls (Figure 3-4).

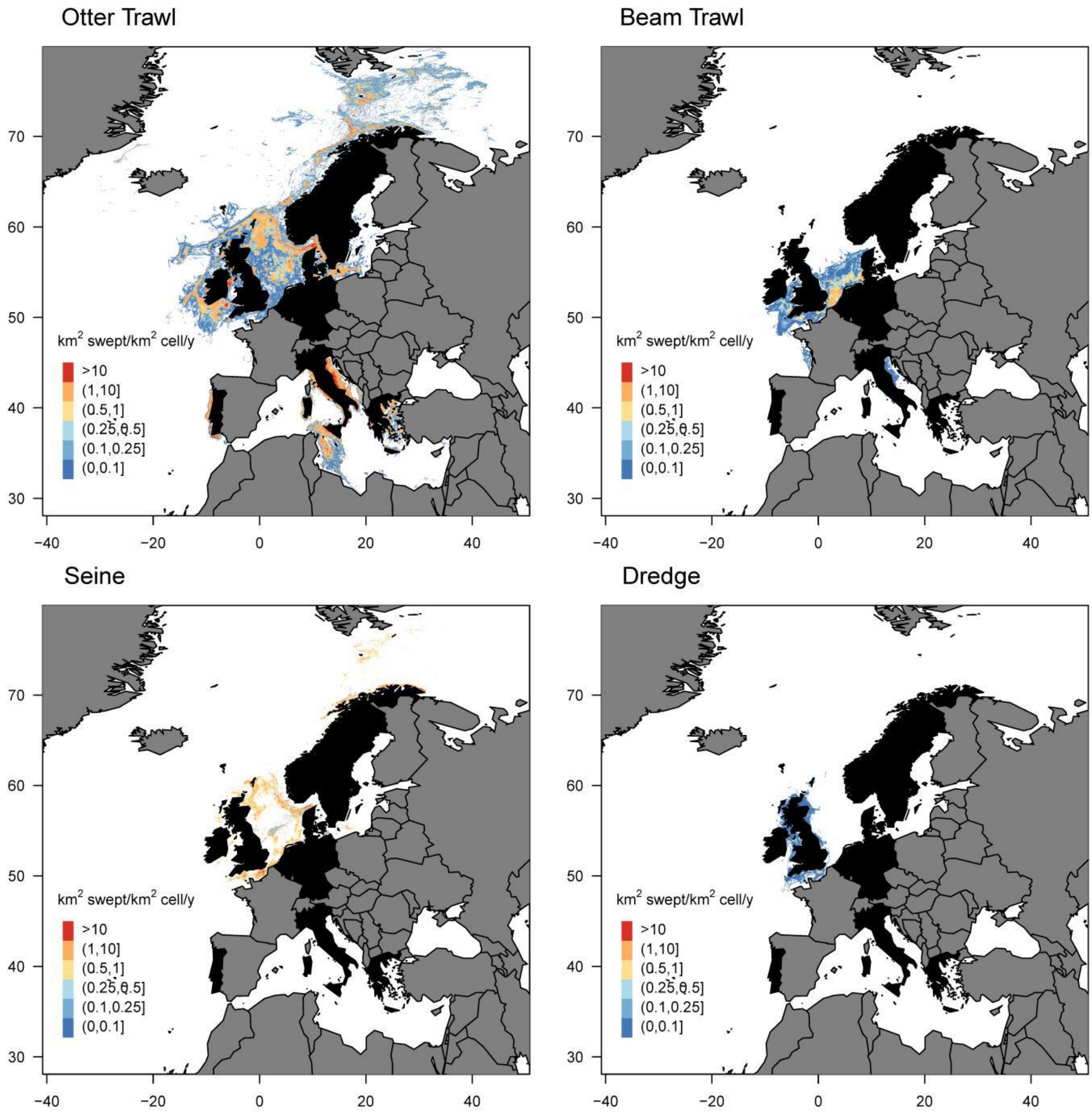


Figure 3-3: Fishing intensity (total swept area) by main gear groups (demersal otter trawls, beam trawls, demersal seines and dredges) for the areas analysed.

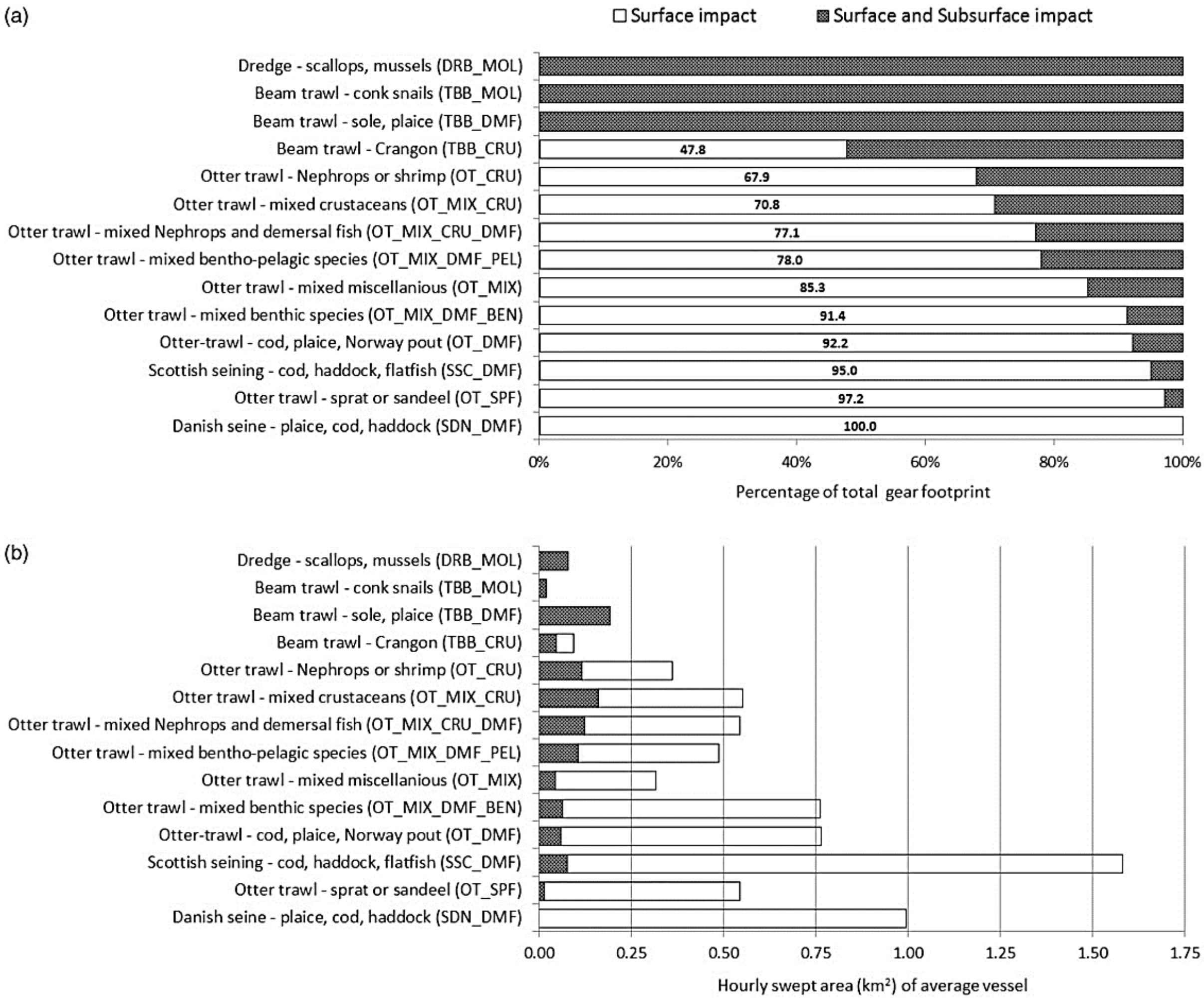


Figure 3-4: Proportion of total gear footprint (a) and the area of seabed swept in 1 h of fishing with an average-sized vessel (b) with impact at the surface level and at both the surface and the subsurface level for the 14 BENTHIS métiers.

3.3 Impact of bottom trawling and natural disturbance

Van Denderen et al. (2015) have studied the consequences of bottom trawling and natural disturbance on the benthic habitats and communities. They started from the hypothesis that natural and trawl disturbance affect benthic communities in a similar way. They examined the effects of trawl and natural (tidal-bed shear stress) disturbance on benthic communities over gradients of commercial bottom trawling effort in 8 areas in the North and Irish Seas. Using a trait-based approach, that classified species by life-history strategies or by characteristics that provide a proxy for their role in community function, they found support for the hypothesis that trawl and natural disturbance affect benthic communities in similar ways. Both sources of disturbance caused declines in long-living, hard-bodied (exoskeleton) and suspension-feeding organisms. Given these similar impacts, there was no detectable trawling effect on communities exposed to high natural disturbance. Conversely, in 3 out of 5 areas with low bed shear stress, responses to trawling were detected and resulted in community compositions comparable with those in areas subject to high natural disturbance, with communities being composed of either small-sized, deposit-feeding animals or mobile scavengers and predators. The findings highlight that knowledge of the interacting effects of trawl and natural disturbance will help to identify areas that are more or less resilient to trawling and support the development of management plans that account for the environmental effects of fishing. In addition, Rijnsdorp et al. (2016) and van Denderen et al. (2014) demonstrated that consequences of bottom trawling for the benthic ecosystem strongly depend on the type of sediment.

Rijnsdorp et al. (2018) demonstrated that the total benthic biomass of North Sea fauna could be predicted using these environmental parameters (sediment and bottom shear stress) in combination with trawling intensity and the longevity composition of the benthic community. The use of the biological trait 'longevity' was confirmed as a proxy for the recovery rate of the benthic community in Hiddink et al. (2018) who demonstrated that long-lived species have a slower recovery rate. Rijnsdorp et al. (2018) tested this approach and calculated how much trawling intensity could be sustained by long-lived (>10 year) North Sea benthic communities before they are reduced to 50% biomass of their untrawled reference (Figure 3-5). The most sensitive habitats are located in the north-eastern North Sea, whereas the southern and western part of the North Sea can accommodate trawling intensity up to 2-5 times per year. The threshold of 50% of the long-lived benthic community was selected for demonstration purposes.

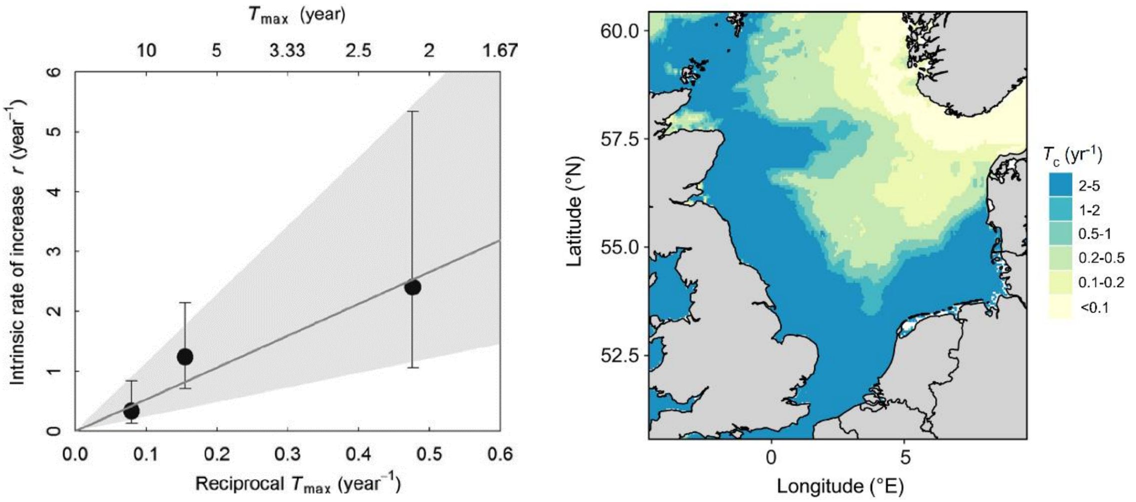


Figure 3-5: (Left) the recovery rate of benthic communities is inversely related to the longevity of the community. In other words, long-lived species take longer to recover from trawling disturbance (taken from Hiddink et al., 2018). (Right) critical trawling intensity (Tc) at which the biomass proportion of long-lived taxa (longevity ≥ 10 yr) is reduced to 50% of the untrawled reference (taken from Rijnsdorp et al., 2018).

These are interesting developments in the eye of the fisherman because it changes the perception of the beam trawl as an utterly unacceptable fishing gear. The similarities between natural and fishing disturbance suggest that beam trawling can be sustainably applied on certain fishing grounds, particularly as their swept area is relatively low in comparison to one hour of otter trawling. As such, it is clear that benthic effects of beam trawling require an assessment that takes account of its location and associated bottom shear stress and sediment type.

3.4 Indicator assessment for fishery benthic impact

The impact of fishery on the seafloor is described in the previous chapter and an assessment of it is needed for the Marine Strategy Framework Directive (MSFD), descriptor 6 "Seafloor integrity". Within this descriptor physical disturbance on the seabed habitats (D6C3: Adverse effects of physical disturbance on habitat) and the condition of habitats (D6C5) need to be evaluated (Figure 3-6). In the current scientific developments to evaluate those criteria, two type of benthic indicators are developed. One type are the "risk" indicators, which try to estimate the effect of physical disturbance on the benthic habitat community by means of a modelling approach. In other words, they estimate the potential (risk) effect (impact) of a certain physical disturbance level on the benthic community state. Examples of those risk-based indicators is the ICES-FBIT approach (relative benthic state), OSPAR BH3 and the HELCOM Cumuli. The other type of indicators is identified as "state" indicators, as they have the purpose to judge on the actual state of the benthic community, based on benthic variables (diversity, abundance, biomass, species composition, species traits, …) derived from specific derived benthic monitoring data. Examples of those indicators are the WFD benthic indicators (m-AMBI, IQI, BQI, BEQI, …) and the OSPAR indicators BH1 (SoS) and BH2 (Margalef diversity), among a lot of others (e.g., trawl disturbance indicators [TDI based indicators]). Risk indicators are more suited for large scale assessment and more easily extrapolatable than state indicators. Whereas state indicators are a more local assessment based on real monitoring data within the assessment period.

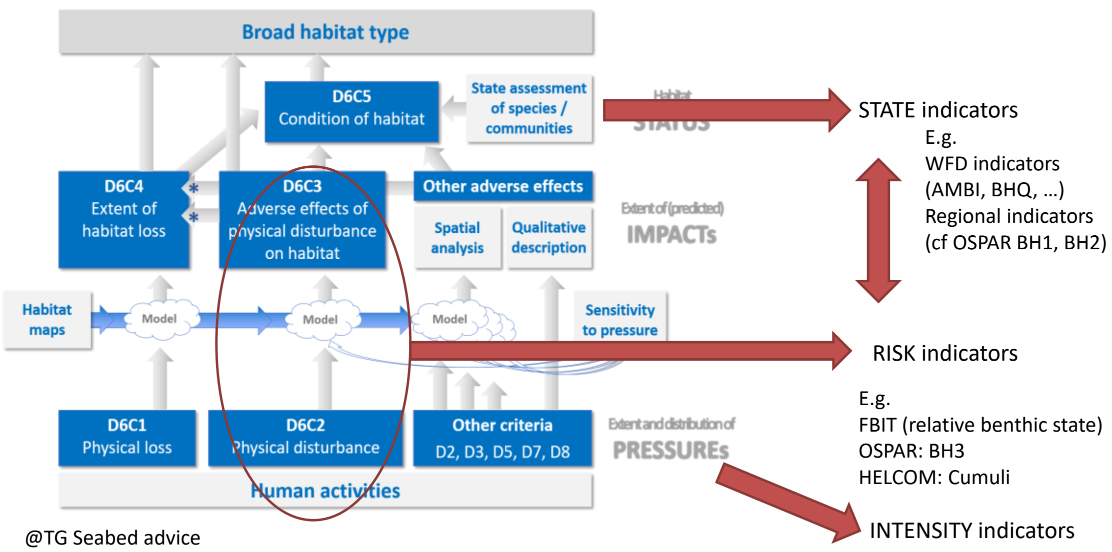


Figure 3-6: MSFD Descriptor 6 'Seafloor integrity' framework and the place of state and risk indicators to assess the benthic seafloor ecosystem for criteria D6C3 and D6C5. Those indicators translate the extent and magnitude of a pressure (intensity indicators) into a risk or state assessment of the benthic seafloor ecosystem.

So, there are various approaches/indicators to evaluate benthic impact, and none of the approaches are wrong, all have their advantages or disadvantages. The aim of an indicator is to detect and report on an unacceptable change in the ecosystem, and in this way it is a kind of warning. An indicator approach consists of one or a set of parameters (e.g. diversity measure, abundance, biomass, sensitivity/tolerance of species), combined in an algorithm (e.g. formula, model) and with a defined measuring scale (e.g. bad, moderate or good state thresholds). Therefore, the indicator(s) to use is depending on the needs of the policy (managing specific human pressures) or nature of the area (specific environmental conditions, e.g., shallow or deep sea areas; Baltic versus Mediterranean). There can be the need to rely on generic and specific indicators to accomplish an assessment. Whereas generic indicators are in play for detecting overall responses to raise an overall alarm bell but are hard in detecting what cause the response or what human activity needs adjusting. Therefore, specific indicators are also required to follow up the responsiveness to a specific human activity or measurement measure (e.g., Has the measure the desired effect on improved status?).

3.4.1 Indicator approaches

As outlined in the intro, the MSFD 'seafloor integrity' assessment should rely on a set of indicators, evaluating different aspects of the benthic ecosystem or different pressures. In this part, we focus on two major indicator approaches (OSPAR BH3 and Relative Benthic state [FBIT approach]) for a general assessment of fishery impact. At ILVO, we work with those two approaches to advise the Belgian sector on fishery benthic impact. Therefore, those two risk-based approaches are described in a bit more detail in this chapter. The comparability between the different indicator approaches (wider than those two put forward here), is described in the next chapter. Those indicator developments and applications will guide the EU and member states the coming years in managing seafloor disturbance and fishery.

3.4.1.1 OSPAR BH3

The OSPAR BH3 indicator is named as, extent of Physical Disturbance to Benthic Habitats (BH3a): Fisheries with mobile bottom-contacting gears. The OSPAR BH3 fisheries assessment aims to evaluate the potential risk of physical seabed disturbance caused by surface and subsurface abrasion, associated with mobile bottom-contacting fishing gears.

The BH3 method comprises four main components: the creation of a composite habitat map; assessments of habitat sensitivity; the creation of pressure layers and the calculation of potential physical disturbance. Inputs are combined using a stepwise approach to calculate the total area of potential disturbance within assessment units:

1. A composite habitat map showing the extent and distribution of habitats at different scales, is based on the EUNIS habitat classification (EMODNET Seabed habitat, Euseamap 2022).

2. Species and habitat sensitivity, derived from resistance (ability to withstand a given pressure) and resilience (ability of a habitat to recover) (Tyler-Walters, et al., 2018).

3. Distribution and intensity of pressures from human activities causing physical disturbance (surface abrasion, subsurface abrasion, extraction) to the seabed.

4. Calculation of potential disturbance of benthic habitats, per habitat type and per assessment unit. Calculation of potential disturbance is based on the intensity of pressures and degree of habitat sensitivity per pressure type.

The species and habitat sensitivity map are used in the ILVO visserij verduurzaamt bodem impact indicator (see section XX). Therefore, we outlined here how this sensitivity is determined. The next step (step 3), mapping the distribution and intensity of fishery, is harvested from ICES and follows the methodology as outlined in section 3.3. This fishery footprint layer is very similar to what ICES use (only difference in resolution) for their FBIT approach, so this is a common step for both indicator approaches. The final step (step 4) is the calculation of the impact, by combining the pressure layer (footprint) with the sensitivity layer. The BH3 impact assessment is published in the OSPAR Quality Status report 2023 (available autumn 2023).

Sensitivity classification BH3

Sensitivity information used in the assessment included Marine Evidence based Sensitivity Assessments (MarESA) (Tyler-Walters et al., 2018), part of the Marine Life Information Network (MarLIN). MarESA is a scientific approach (Figure 3-7) to assessing sensitivity of habitats (including habitat characterising species) within the North-East Atlantic to a range of pressures, for BH3 to surface and subsurface abrasion pressures (Table 3-1). The sensitivity assessment is based on resistance (tolerance against a pressure) (Table 3-2) and resilience (recovery potential) (Table 3-3) of the habitat and species for those pressures and put in a classification (Table 3-4). Habitat sensitivity assessment assumes that the sensitivity of a habitat is dependent on the physical nature of the habitat, and the sensitivity of the species that make up the community present. In practice, communities can be composed of many tens or hundreds of species. Therefore, the species identified as important for the structure and functioning of the community or characteristic of the habitat are used as focus for the sensitivity assessment.

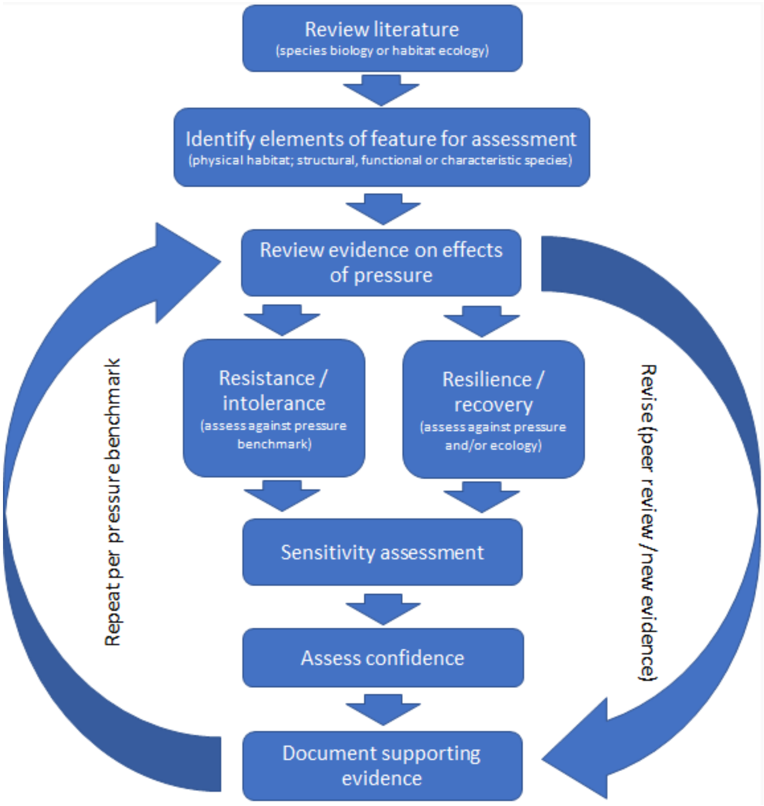


Figure 3-7: Overview of the Marine Evidence based Sensitivity Assessments (MarESA) framework

Table 3-1: Explanation of the pressures, wherefore sensitivity of habitats and species is determined within BH3 indicator (https://www.marlin.ac.uk/sensitivity/SNCB-benchmarks).

ICG-C Pressure	Benchmark	Pressure description
Abrasion/disturbance at the surface of the substratum	Benthic species or habitats damage to surface features (e.g. species and physical structures within the habitat)	Physical disturbance or abrasion at the surface of the substratum in sedimentary or rocky habitats. The effects are relevant to epiflora and epifauna living on the surface of the substratum. In intertidal and sublittoral fringe habitats, surface abrasion is likely to result from recreational access and trampling (inc. climbing) by human or livestock, vehicular access, moorings (ropes, chains), activities that increase scour and grounding of vessels (deliberate or accidental). In the sublittoral, surface abrasion is likely to result from pots or creels, cables and chains associated with fixed gears and moorings, anchoring of recreational vessels, objects placed on the seabed such as the legs of jack-up barges, and harvesting of seaweeds (e.g. kelps) or other intertidal species (trampling) or of epifaunal species (e.g. oysters). In sublittoral habitats, passing bottom gear (e.g., rock hopper gear) may also cause surface abrasion to epifaunal and epifloral communities, including epifaunal biogenic reef communities. Activities associated with surface abrasion can cover relatively large spatial areas e.g., bottom trawls or bio-prospecting or be relatively localized activities e.g. seaweed harvesting, recreation, potting, and aquaculture.

Penetration and/or disturbance of the substratum below the surface	Benthic species /habitats damage to sub-surface features (e.g., species and physical structures within the habitat)	Physical disturbance of sediments where there is limited or no loss of substratum from the system. This pressure is associated with activities such as anchoring, taking of sediment/geological cores, cone penetration tests, cable burial (ploughing or jetting), propeller wash from vessels, certain fishing activities, e.g., scallop dredging, beam trawling. Agitation dredging, where sediments are deliberately disturbed by and by gravity & hydraulic dredging where sediments are deliberately disturbed and moved by currents could also be associated with this pressure type. Compression of sediments, e.g., from the legs of a jack-up barge could also fit into this pressure type. Abrasion relates to the damage of the seabed surface layers (typically up to 50 cm depth). Activities associated with abrasion can cover relatively large spatial areas and include fishing with towed demersal trawls (fish & shellfish); bioprospecting such as harvesting of biogenic features such as maerl beds where, after extraction, conditions for recolonization remain suitable or relatively localised activities including seaweed harvesting, recreation, potting, aquaculture. Change from gravel to silt substrata would adversely affect herring spawning grounds. Loss, removal or modification of the substratum is not included within this pressure (see the physical loss pressure theme). Penetration and damage to the soft rock substrata are considered, however, penetration into hard bedrock is deemed unlikely.

Table 3-2:. Definitions of the resistance classes.

Resistance	Description
None	Key functional, structural, characterizing species severely decline and/or physicochemical parameters are also affected e.g., removal of habitats causing a change in habitats type. A severe decline/reduction relates to the loss of 75% of the extent, density or abundance of the selected species or habitat component e.g., loss of 75% substratum (where this can be sensibly applied).
Low	Significant mortality of key and characterizing species with some effects on the physicochemical character of habitat. A significant decline/reduction relates to the loss of 25-75% of the extent, density, or abundance of the selected species or habitat component e.g., loss of 25-75% of the substratum.
Medium	Some mortality of species (can be significant where these are not keystone structural/functional and characterizing species) without change to habitats relates to the loss <25% of the species or habitat component.
High	No significant effects on the physicochemical character of habitat and no effect on population viability of key/characterizing species but may affect feeding, respiration and reproduction rates.

Table 3-3: Definition of the resilience classes.

Resilience	Description
Very Low	Negligible or prolonged recovery possible; at least 25 years to recover structure and function
Low	Full recovery within 10-25 years
Medium	Full recovery within 2-10 years
High	Full recovery within 2 years

Table 3-4: Sensitivity assessment class, based on resilience and resistance of the species/habitats, as defined within the MarESA framework.

Resilience	Resistance			
	None	Low	Medium	High
Very **Low**	High	High	Medium	Low
Low	High	High	Medium	Low
Medium	Medium	Medium	Medium	Low
High	Medium	Low	Low	Not sensitive

The OSPAR BH3 sensitivity assessment map, based on the composite habitat map and the sensitivity classification, is incorporated in the 'Visserij verduurzaamt' bodem indicator (Figure 4-1).

3.4.1.2 RELATIVE BENTHIC STATE (FBIT APPROACH)

ICES-FBIT working group has developed a guidance document for this indicator (ICES, 2022). The document presents an overview of the ICES seafloor impact assessment framework to promote understanding and dissemination of this assessment method that can be applied at the regional scale and across European Seas. In this section, a short summary of the assessment concept is outlined.

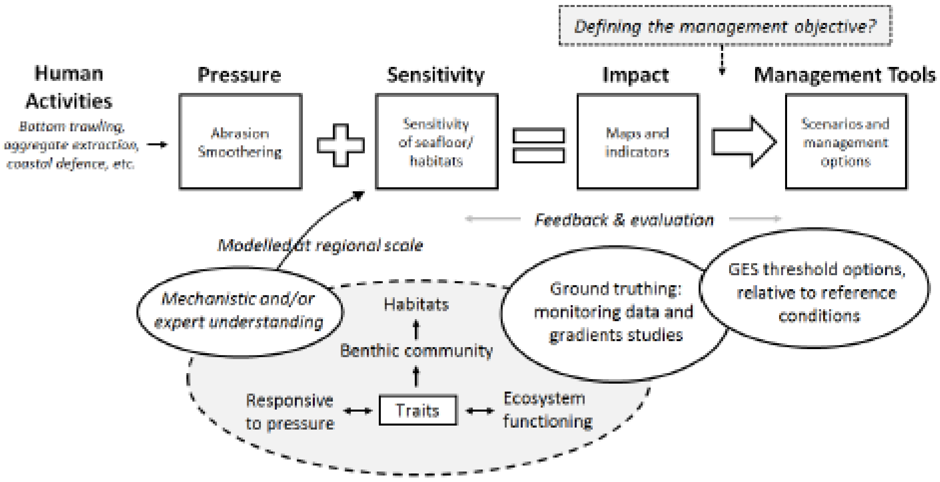


Figure 3-8: Conceptual diagram of the steps taken in developing management tools for assessing pressure and impact on the seafloor from human activity

The assessment approach can be used to derive a set of indicators for assessing physical disturbance pressures from bottom-contacting fishing gears and their environmental impacts on seabed habitats (Figure 3-8). The framework allows for the evaluation of trade-offs between catch/value of landings per unit area and the environmental impact and recovery potential of the seafloor. WGFBIT uses the so called "PD method" to assign sensitivity and derive impact. PD stands for ‘Population Dynamics model’. This approach is designed within the EU-benthis project and taken forward within the ICES FBIT working group.

The PD method is a quantitative method for assessing the risks to benthic habitats by towed bottom-fishing gears (Figure 3-9). The method is based on a simple equation for relative benthic status (RBS, defined as the biomass B relative to the carrying capacity K), derived by solving the logistic population growth equation for the equilibrium state (Pitcher et al., 2017).

$$RBS = B/K = 1- F\ d/r$$

Here, trawling effort (F = SAR) is defined as the total area swept by trawl gear within a given area of seabed in one year divided by that area of seabed (units y-1, see 2.1). Depletion d is the fraction mortality per trawl pass estimated from experimental trawling studies, and r is the intrinsic rate of population increase.

The impact of trawling on benthic biota depends on both d and r, and sensitivity to trawling depends on the ratio of d over r, and is therefore proportional to the reciprocal of the recovery rate r. This approach has a similar philosophy as the categorical approach (OSPAR B3), but in a quantitative way. ‘Resistance’ as used in OSPAR BH3 is equivalent to (1-d), while ‘resilience’ is equivalent to r, and ‘Sensitivity’ is generally defined as the ‘product’ of resistance (i.e. (1-d) * r) and often categorised in limited number of categories. The RBS equation above shows that sensitivity in our approach is equivalent to d/r, and that d and r are quantified based on empirical estimates rather than categorised based on expert opinion.

Estimating RBS therefore requires only maps of fishing intensity and habitat type – and parameters for impact and recovery rates, which have been taken from meta-analyses of all available studies of towed-gear impacts. The assessment produces a relative benthic state estimate (RBS) for each grid cell (C-square) in the assessed region, based on just two parameter values (depletion d and the intrinsic rate of population increase r, a metric of recovery rate) and the fishing intensity.

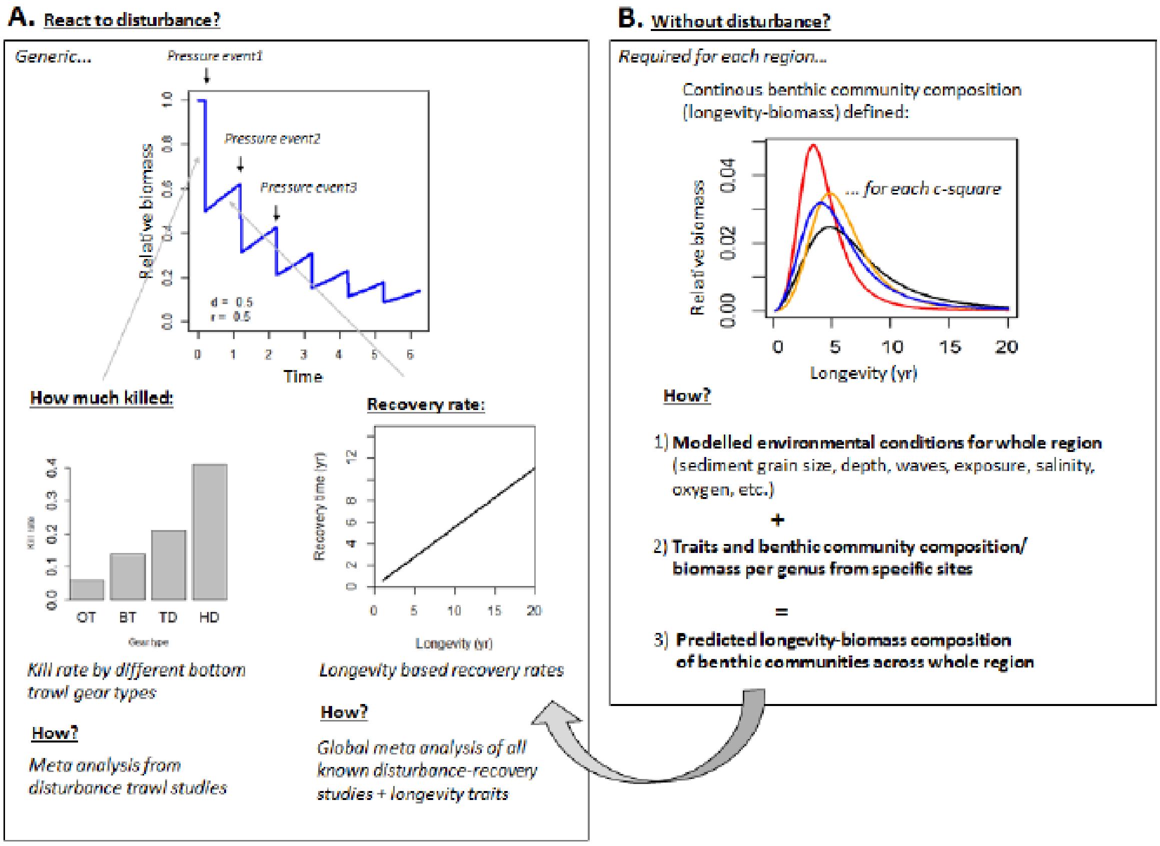


Figure 3-9: Flow diagram of how data layers and relationships derived from synthesis and analysis of the literature are combined to determine RBS (Relative Benthic Status) in the FBIT framework.

Two essential steps are the determination of the pressure (fishery footprint) and the sensitivity to determine the fishery benthic impact. The fishery footprint step is outlined in section 3.3 and is more or less the same layer as in the OSPAR BH3 approach. The step of determining the depletion and recovery (=sensitivity) is different and is in more detail outlined here.

Depletion (d) (How much killed?)

Here is explained how we estimated values for 'How much killed' in Figure 3-9. Bottom trawls [here defined as any towed bottom-fishing gear, including otter trawls (OTs), beam trawls (BTs), towed (scallop) dredges (TDs), and hydraulic dredges (HDs)] are used to catch fish, crustaceans, and bivalves living in, on, or close to the seabed. The meta-analysis in Hiddink et al. (2017) provided estimations of the depletion d for the biomass of the whole community of benthic invertebrates. Recent work by Rijnsdorp et al. (2020) estimated d for 10 different metier types based on the relationship between d and P (Table 3-5). These 10 metiers follow the groupings available in the ICES VMS database and are currently used to estimate metier-specific depletion. The d estimates presented here are for whole benthic communities, and do not differentiate between sediment type.

Table 3-5: Gear types, target species and depletion rates for the 10 different metier types (Rijnsdorp *et al.* 2020).

Metier	Main gear type	Target species assemblage group	Main target species	Depletion rate
DRB_MOL	Dredge	Molluscs	Scallops	0.200
OT_CRU[1]	Otter trawl	Crustaceans	Nephrops, Pandalus, mixed fish	0.100
OT_DMF	Otter trawl	Demersal fish	Cod or plaice	0.026
OT_MIX[2]	Otter trawl	Mixed fish	Mixed fish	0.074
OT_SPF	Otter trawl	Small pelagic fish	Sprat or sandeel	0.009
SDN_DMF	Danish seine	Demersal fish	Plaice, cod	0.009
SSC_DMF	Flyshooter (seine)	Demersal fish	Cod, haddock, flatfish	0.016
TBB_CRU	Beam trawl	Crustaceans	Brown shrimp	0.060
TBB_DMF	Beam trawl	Demersal fish	Flatfish	0.140
TBB_MOL	Beam trawl	Molluscs	Whelk, snails and scallops	0.060

[1] including OT_MIX_CRU and OT_MIX_CRU_DMF
[2] including OT_MIX_DMF_BEN, OT_MIX_DMF_PEL

Habitat sensitivity ICES FBIT-approach (r: recovery rate variable)

The PD method assumes that the sensitivity to trawling is proportional to the reciprocal of the longevity of species and communities. This approach therefore requires estimates of the longevity of all species in a community. The effect of any given rate of trawl mortality on a population will depend on its life-history, whereby populations with low r, low natural mortality rates (M) and greater longevity (Tmax) have an increased sensitivity to trawling disturbance (Duplisea et al., 2002). For example, Tillin et al. (2006) demonstrated that benthic epifauna with Tmax >10yr decreased in abundance with trawling, but that no such reduction occurred for fauna in the same areas with Tmax <2yr. Hiddink et al. (2018) showed that the effect of bottom trawling in comparative studies increased with longevity, with a 2–3× larger effect on biota living >10yr than on biota living 1–3yr. We attribute this difference to the slower recovery rates of the longer-lived biota. This work showed that r closely relates to the inverse of longevity of benthic fauna, and that this matches theoretical expectations (Figure 3-5 illustrates this).

The distribution of longevities can then be used to estimate the sensitivity to trawling of a habitat. A benthic community with many long-lived species will have a lower mean r than a community with many short-lived species. Because the effect of trawling is proportional to the ratio of d/r, a lower r will result in a higher impact at the same intensity of trawling. Figure 62 illustrates this, using two hypothetical habitats. A habitat will be sensitive to trawling if a large fraction of the biomass of the community, in an untrawled community, is made up of long-lived species with a low r (Figure 3-10a). A habitat will be less sensitive to trawling if a large fraction of the biomass of the community, in an untrawled community, is made up of short-lived species with a high r (Figure 3-10b). This results in sensitivity of habitats to bottom trawling being higher in habitats with higher proportions of long-lived organisms. Because the biomass of the high r, short-lived, species will respond less to trawling that the biomass of the low r, long-lived, species, total community biomass will respond differently depending on the longevity composition of the community at no trawling.

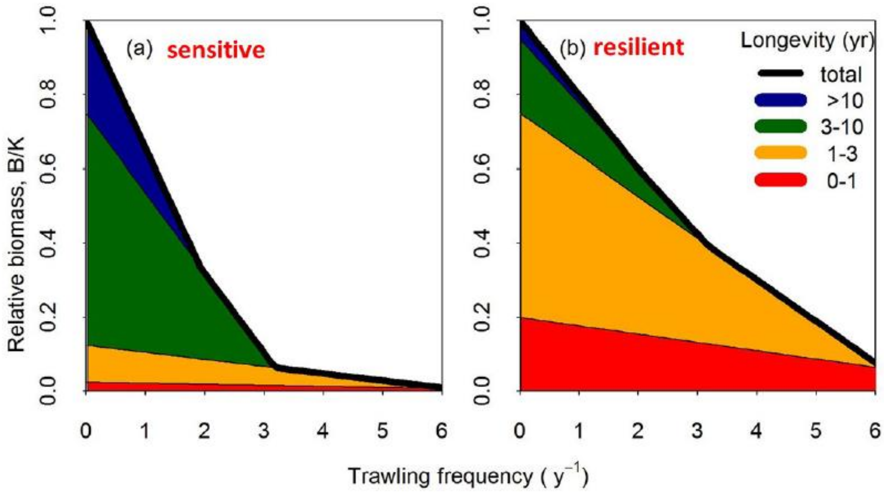


Figure 3-10: An example of how the longevity distribution of a benthic community at no trawling affects the response of total community biomass to bottom trawling.

Differences in longevity distribution of benthic communities are likely to be related to the environment they live in. Habitats with high levels of other disturbance, for example by waves, or hypoxia, are likely to have a low fraction of long-lived species as these disturbances will have already led to the loss of such species and are instead dominated by short-lived fauna. As a result, communities in high natural-disturbance environments with shorter-lived fauna will be less sensitive to anthropogenic disturbance, as shown in several previous studies (Hiddink et al., 2006; van Denderen et al., 2015; Rijnsdorp et al., 2018).

So, to apply the PD approach, the biomass-longevity distribution of untrawled communities will need to be estimated in relation to environmental variables (i.e., the reference state). This will require samples of benthic communities over the main environmental gradients. To estimate a reference state, Bolam et al. (2017) showed that it is possible to use both samples from untrawled (i.e., a zero fishing pressure estimate) locations and locations with low trawling intensity. They found that for the more sensitive shelf habitats locations with trawling intensities up to 0.1 per year could be used for estimating the reference state, whereas locations with even higher fishing intensities could be included in areas less sensitive.

WGFBIT currently uses the method described in Rijnsdorp et al. (2018) to estimate a reference state that represents the biomass-longevity distribution of untrawled communities. This is done based on the below four steps:

1. Estimate the fraction of benthic community biomass per Tmax category for each sampling location.
2. Convert the Tmax longevity categories into a continuous scale by assuming that in each sample the biomass proportion with longevity smaller than or equal to the upper range

of Tmax (e.g. Tmax 1–3 = 3, 3–10 = 10) is a sigmoidal (logistic) function of longevity, which starts at 0 and approaches 1 when longevity becomes large (Figure 3-11).

3. Fit a statistical model to estimate a biomass-longevity distribution. The model used is a logistic mixed effect model with the cumulative biomass proportions (Cb) as the response variable and longevity (l) and environmental conditions (H) as the predictor variables.
4. Predict the longevity distribution for each c-square in the region using the best candidate model and the prevailing environmental conditions.

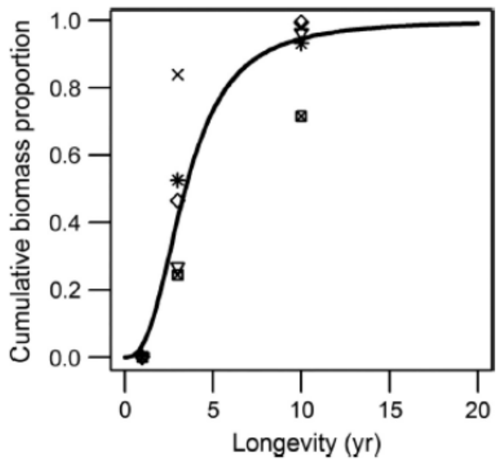


Figure 3-11: An example of the cumulative biomass–longevity relationship estimated from the observed cumulative biomass by longevity class (1, 1–3, 3–10 yr) in five sampling stations. Different symbols indicate the five different locations. Figure taken from Rijnsdorp et al. (2018).

This result in a habitat sensitivity map, based on the modelled longevity distribution in undisturbed conditions. An example is given in Figure 3-12.

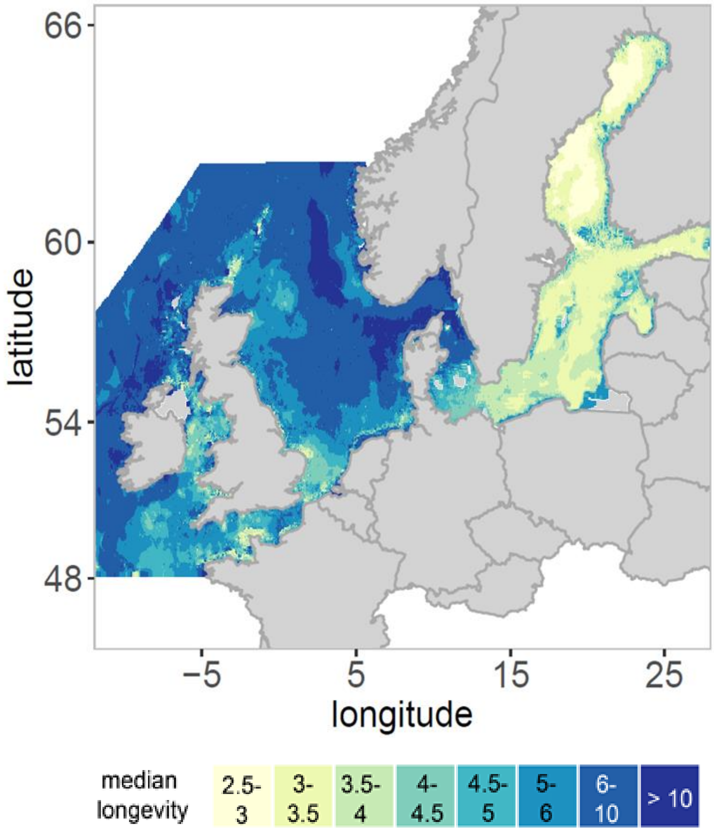


Figure 3-12: Habitat sensitivity map, based on longevity modelling, following the FBIT approach. Version from ICES FBIT report 2022 (ICES, 2022).

To conclude, this means that where the longevity of a species or the longevity distribution of a community is known or can be inferred, our estimates of depletion and intrinsic rate of increase can be combined with high-resolution maps of trawling intensity to assess trawling impacts at the scale of the fishery or other defined unit of assessment.

3.4.2 Indicator comparability

Assessing benthic habitat status is crucial for understanding the health of marine ecosystems. To evaluate the condition of benthic habitats, scientists and environmental managers often use indicators. These indicators provide quantitative or qualitative measurements that help monitor and assess the health and ecological integrity of these benthic habitats. However, to comprehensively assess benthic habitat conditions, multiple indicators are required as no single indicator can capture all ecosystem responses. Additionally, which indicators are selected could influence the outcome of the analyses and could thus lead to different management strategies being set in place. In other words, on one side we want to avoid that the selected indicators are focusing only on one aspect of the ecosystem (avoiding redundancy in the assessments) and on the other side you need a diversity of indicator approaches, which are all capable of detecting a change along a pressure gradient. Therefore, appropriate indicator comparability research is needed. The most recent progress is made during the WKBENTH 2 & 3 workshops of 2022. At WKBENTH3 hybrid meeting, the complementarity of different indices is determined by using cluster analyses and by comparing the risk-based indices outcomes on datasets from different regions. This risk-based index comparison was done to facilitate the understanding of relevant risk-based benthic indicator methods and their capacity for assessing seabed physical abrasion pressure. Cluster analysis was conducted to emphasize the interrelatedness among the selected indicators. This statistical method offers valuable insights into the similarities shared by these indicators and could thus help to avoid redundancy in outcome during indicator selection.

In this exercise, several benthic indicators were examined to assess the condition of benthic habitats and physical disturbance (MSFD descriptors D6C5 and D6C3). These indicators included risk-based and sample-based methods, each focusing on different aspects of seabed integrity and the impact on benthic ecosystems. Risk-based indicators were designed to evaluate seabed integrity using data on benthic sensitivity to bottom trawling or seabed abrasion, along with predictions of benthic impact. These indicators considered environmental conditions, habitat types, and species-specific traits, such as size and longevity, which play crucial roles in supporting important ecosystem functions. In addition, the analysis included several commonly used diversity indices which were easily calculated from the data such as Biomass, Abundance and Species richness. In total, the evaluation compared 19 benthic indicators using the gradient datasets compiled by WKBENTH2. These gradient datasets consisted of 17 benthic invertebrate datasets which were drawn from a range of pressure gradients which included 14 fishing (commercial bottom trawling intensity gradient), 2 eutrophication and 1 pollution pressures gradient study.

To determine the **complementarity** (avoiding redundancy) of the **different indicators**, a cluster analysis was performed by calculating the Spearman correlation coefficients for each indicator across all gradients, ordering indicators with Ward's hierarchical clustering (Figure 3-13). This analysis allowed them to compare the responses and similarities between indicators and identify potential cluster groups. The analyses revealed three major groups of indicators that exhibited higher correlations within the groups, indicating that indicators with similar parameters tend to correlate better than those with different parameters. One cluster included indicators with diversity components (e.g., M-AMBI, Shannon, Inverse Simpson), another consisted of TDI-based indicators which are trait-based indicators, and a third cluster comprised indicators focused on the most sensitive species or long-living species. An additional fourth group could also be distinguished and consisted of the highly correlated AMBI and BENTIX indicators which also exhibited a good correlation with the diversity-and TDI-based indicators. In contrast, the correlation between this fourth group and the indicators focusing on the most sensitive species was less pronounced. These results emphasized the importance of using multiple indicators from different clusters to get a comprehensive understanding of benthic habitat conditions.

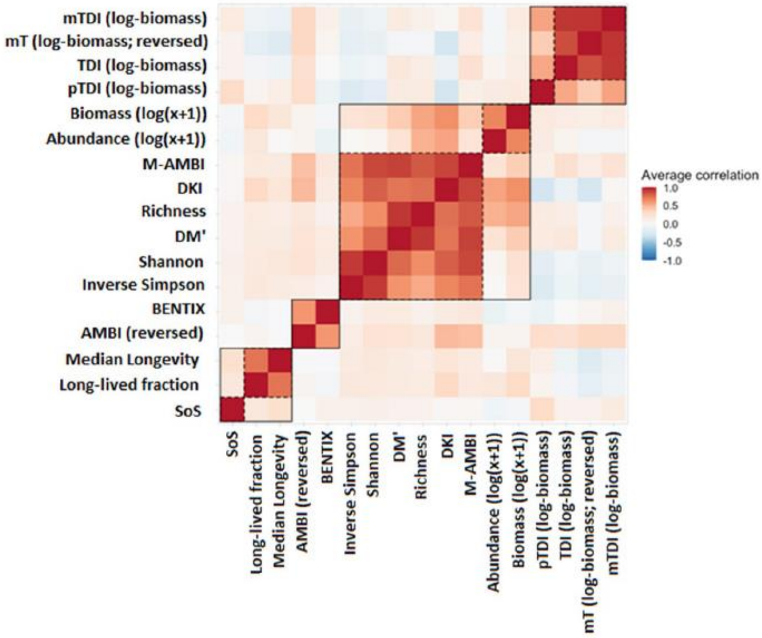


Figure 3-13: Hierarchical clustering of the different indicators based on the average Pearson correlation across datasets. For each pair of indicators, all gradients with sufficient data were included in the analysis. Thus, not all pairs of indicators are compared using the same datasets due to missing data.

The output of **different risk-based indicators** was compared across regions located in the Northeast Atlantic and Baltic Sea (I.e., North Iberian Atlantic, Northern/Central North Sea, Southern North Sea, Kattegat, Channel and Baltic Sea). However, this summary will focus on the regions relevant to the Belgian fleet which is the Northern/Central North Sea, Southern North Sea and the Channel. The comparison was done by evaluating the ranked sensitivity/impact scores per broad habitat type (BHT) and spatial subdivision. Habitat-specific scores were compared and ranked per subdivision, with the aim of highlighting consistencies and differences between indicator outputs when identifying habitats considered most sensitive, and therefore, at risk to adverse effects from physical pressure. The ranked scores show if the different risk-based approaches currently available in EU waters find the same type of seabed habitats most sensitive to bottom fishing and/or most at risk of adverse effects.

In each of the three regions (Northern/Central North Sea, Southern North Sea and the Channel), five indicators were compared using the method described above. These indicators include PD, L1, L2, BH3 and DM'. The population dynamic indicator (PD) is a risk-based mechanistic model used to estimate the total reduction in community biomass (B) relative to carrying capacity in response to fishing intensity. L1 estimates the proportion of the benthic community's biomass that is potentially impacted by trawling. It considers benthic taxa with longevity greater than the average interval between two successive trawling events to be potentially affected by bottom trawling. The L2 indicator calculates the decrease in median longevity, referring to the longevity where 50% of the community biomass is above or below, as a response to trawling. BH3 measures the extent of physical disturbance to sensitivity of benthic habitats by using a spatial analysis by subdividing sea areas into a grid. It then extrapolates data and knowledge from existing monitoring and local studies to larger areas. This indicator combines information about the distribution and sensitivity of habitats (resilience and resistance) with data on the distribution and intensity of human activities and pressures that cause physical damage, such as mobile bottom gear fisheries, sediment extraction, and offshore constructions. DM' or relative Margalef Diversity, is a biodiversity index which calculates the Species Richness of a sample divided by the logarithm of the total abundance within the same sample. By comparing these indicators across the three regions, the evaluation sought to understand their similarities and differences, considering their applicability and relevance in assessing benthic habitat conditions and physical disturbance impacts.

Comparing the outputs of risk-based indicators across all three regions showed both similarities and variations. Different indicators may highlight the same or different sensitive habitats and impacts, an example (Northern/Central North Sea) of this can be found in Table 3-6. The differences were attributed to variations in methodology and data inputs. Fishery impact evaluation on the seabed in the Belgian fishing areas focuses on the use of three of the five calculated indicators, namely BH3, PD2 and DM'. BH3 and DM' are used by OSPAR and PD2 forms the basis of the Relative Benthic State or RBS indicator used by the ICES FBIT. In this analysis, these indicators assessed different BHTs as most and least sensitive in almost all of the areas, stressing the need for cautious interpretation of indicator outputs when comparing them across different regions and datasets. Although sensitivities varied between indicators, impact (sensitivity combined with fishery pressure) outputs were broadly aligned.

Table 3-6: Indicator sensitivity information from the Northern/Central North Sea; ranked where 1 is the most and 5 being the least sensitive (WKBENTH3 report)

BHT	Fraction of total area	PD2	L1	L2	BH3
Offshore circalittoral sand	0.63	1	1	4	3
Offshore circalittoral coarse sediment	0.1	2	2	2	5
Circalittoral sand	0.01	3	3	3	2
Offshore circalittoral mud	0.24	4	4	5	1
Offshore circalittoral mixed sediment	0.01	5	5	1	4

In general, we can conclude that there is no one-size-fits-all approach, and the selection of appropriate indicators should depend on the specific context and objectives of the assessment area. Multiple indicators should be used in a complementary manner to accurately assess benthic habitat conditions and detect changes in ecosystems. A combination of generic and specific indicators, ideally picked from different cluster groups (or indicator families), is recommended to cover overall responses and responses to specific human activities or management measures. Based on the comparability analyses, it is recommended that benthic habitat indicators ideally encompass a combination of diversity, species sensitivity and abundance (density and/or biomass) components. These indicator components can be combined in one algorithm or as different indicators depending on the assessment objectives and the characteristics of the study region.

3.4.3 Threshold settings

The determination of the threshold settings for the MSFD criteria (and indicators) will be of vital importance in the managing of the maritime activities, especially fishery. It will give guidance on what level of fishery impact is acceptable and to which extent fishery activities can be executed and fishery closure actions will be undertaken by the EU member states. Therefore, this chapter outlined the current state on defining those thresholds and the future plans.

Each indicator approach needs a threshold setting to determine the measuring rule (e.g. bad, moderate, good status classes; or GES versus non-GES). There are many different approaches, each with their own strengths and weaknesses to identify those thresholds (not outlined here, but more info can be found in ICES WKBENTH2 report (ICES, 2002a; Hiddink et al., 2023).

The evaluation of the criteria of MSFD descriptor 5, seafloor integrity requires a quality and extent threshold. Threshold values for criterion D6C5 shall be defined for adverse effects on the condition of each habitat type (= quality threshold) and for the maximum allowable extent of adverse effects as a proportion of the total natural extent of the habitat type (= extent threshold). These thresholds will be established through cooperation at EU level, through the technical working group seabed of the EU (TG Seabed), taking into account regional or subregional specificities (Commission Decision (EU) 2017/848). At the moment of publication of this report, the following status of threshold definitions is achieved. First, there is a dual extent threshold for D6C5, which is defined as a combination of a maximum allowable area adversely affected with a minimum area with 'no sea-based and spatially manageable pressure'. Second, there is a concept on defining a quality threshold, defining the state when a system is adversely affected.

1) **Extent threshold on proportion of habitat that is allowed to be adversely affected** (accepted threshold)

   Currently there is a lack of targeted scientific advice on an acceptable extent of adverse effects on broad habitat types to be in good environmental status. Nevertheless, an adoption of an extent threshold value for D6C5 is critically needed in order to progress with the definition of good environmental status for seafloor integrity, the effective implementation of the MSFD, the management of human activities currently causing unsustainable damage to seabed habitats and, overall, the protection and possible restoration of broad habitat types and marine ecosystems in EU waters. Therefore, TG Seabed has recommended the following extent threshold, based on their expert judgment and building on the implementation of the Habitats Directive.

   The maximum proportion of a benthic broad habitat type in an assessment area that can be adversely affected is 25 % of its natural extent (≤ 25 %). This includes the proportion of the benthic broad habitat type that has been lost (D6C5).

2) **Extent threshold on proportion of habitat that should be free from all sea-based and spatially manageable pressures** (threshold under discussion)

In order to ensure that biological diversity is maintained and the structure and functions of the ecosystem are safeguarded, at least 10 % of the extent of a benthic broad habitat type in an assessment area need to be in 'reference state'. The 'reference state' (which is a realistic reference taking into account nowadays' environmental constitution and species pools) implies at least the permanent exclusion of all sea-based and spatially manageable pressures affecting the seabed, notably physical disturbance.

Some guidance that is described by TGSeabed on this threshold is outlined here. It is recommended to establish undisturbed reference areas in ecologically valuable and diverse biotopes of a broad habitat type and to ensure connectivity between reference areas. As stated, 'reference areas' are actually areas where a realistic reference state is or will be achieved in the near future, after sea-based and spatially manageable pressures affecting the seabed are gone and sufficient time has allowed a recovery of the benthic communities. Considering that nowadays environmental conditions, habitat constitutions, species pools, climate change effects and possible (minor) impacts from diffusely distributed nutrients and pollutants might lead to alternative benthic communities differing from historical states, these can nevertheless reflect good quality condition in the current situation. The assessment area is understood as an area in the marine waters of a Member State in an MSFD region. The respective Member State defines how large or small scale an assessment area per threshold value is. The 10 % per habitat type refer to each broad habitat type in a Member State's waters/seabed. Only in exceptional and duly justified cases, minor lower deviations from the 10 % per broad habitat type may be accepted. E.g., if the total area in reference state across all broad habitat types is greater than 10% in total, a Member State could protect a larger percentage of an ecologically more important broad habitat type or a smaller percentage of a habitat type that is considered less valuable in the Member State waters. However, neighbouring Member States may cooperate in achieving this value by adding the reference area of a specific broad habitat type together by forming a Member State group in a MSFD (sub-)region. The overall area in reference state per Member State group still needs to amount to at least 10 %.

3) **A quality threshold definition** (concept definition accepted, practical threshold in concept phase)

Determining the principles for adverse effects on seabed habitats and proposing a threshold value for the assessment of adverse effects on seabed quality under the D6C5 criterion has been worked out in TG Seabed. A qualitative description of the characteristics of seabed habitats in good state and bad state is being established and approved:

A benthic broad habitat type is adversely affected in an assessment area if it shows an unacceptable deviation from the reference state in its biotic and abiotic structure and functions (e.g. typical species composition, relative abundance and size structure, sensitive species or species providing key functions, recoverability and functioning of habitats and ecosystem processes) (D6C5) (Figure 3-14).

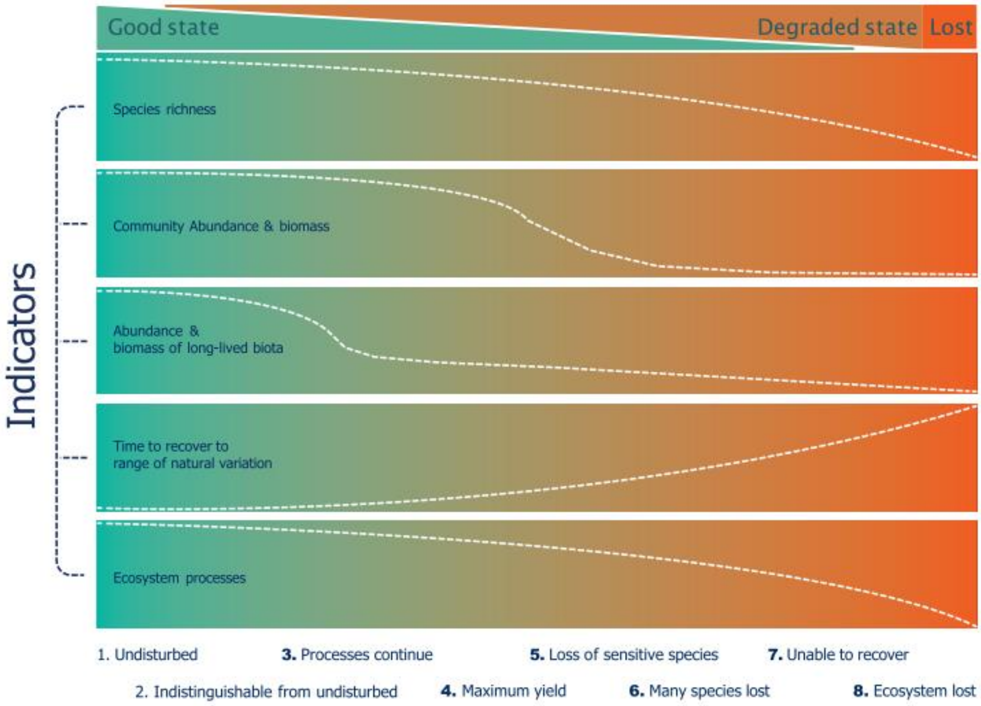


Figure 1. An undisturbed ecosystem is expected to have many species present, with each species having a natural distribution of abundance and biomass over the different age and size classes, with ecosystem processes at high rates (stage 1). Initially, when pressure from human activity is introduced, the ecosystem is indistinguishable from undisturbed in biodiversity, structure (age, size, species) and function because any changes fall within the range of natural variation (2). When the pressure increases further, it is expected that the largest and oldest individuals in the community will be lost, but all species will be present and ecosystem processes are likely to continue at rates that are near natural (3). Sustainable human exploitation that maximises the yield of targeted species can involve intense activities and is likely to result in widespread changes in size, age, and species composition, with values generally outside the range of natural variation (4). Progressing pressure may result in the loss of the largest and most-long-lived species, resulting in large drops in the total biomass of the community, and large drops in the rates at which ecosystem processes occur (5). With further pressure, more species will be lost, and therefore overall species richness continues to drop, and all parameters are likely to be much lower than in undisturbed systems (6). At some level of pressure, the ecosystem would not be able to recover to its undisturbed state on human time-scales, even if the pressure was totally removed (7), and at the highest levels of pressure, the ecosystem can be considered lost and transformed into another ecosystem altogether (8) (Levin *et al.*, 2016).

Figure 3-14: Conceptual scheme of the qualitative description of the quality threshold (Levin et al., 2016; Hiddink et al., 2023).

Assessment of habitat quality is typically undertaken using indicators (see previous chapters), based on observational data or on models. There are currently several indicators under development, each adapted for application to a particular range of broad habitat types and pressures and to the different assessment areas/regions in which they are applied and describing different aspects of structure and functions of habitats. Specific threshold values for each indicator will need to be calculated, considering the qualitative description mentioned above. By referring to this overall EU-wide description when determining the thresholds of individual regional/subregional indicators, the same level of protection should be afforded to all benthic broad habitat types across EU waters even if different indicators are used. ICES has developed a framework and methodology for the assessment of existing indicators and thresholds values (ICES 2022a, WKBENTH2 Report), along with a comparison of the performance of a range of indicators and risk-based assessment methods (ICES 2022b, WKBENTH3 report), as outlined in previous chapter. Within TGSeabed a workplan towards 2026 is set-up to work further on this ICES advice and to come to specific threshold value recommendations.

3.5 Benthis Nationaal project summary

The general research on fishery benthic impact and development of indicator assessments for it is outlined above, but the EFMZVA project benthis nationaal make it possible to put it in the context of the Flemish fishery. A summary of this project is given in this chapter.

The Flemish fisheries policy aims to make its fisheries more sustainable, which includes further addressing the issue of seabed disturbance. In concrete terms, this means that the results of the European Benthis project (https://www.benthis.eu) will be applied and further explored for the Flemish fishery. That approach - under the name Benthis National - aimed on the one hand at a more correct assessment of the bottom impact by the Flemish fishery métiers in an international framework, and on the other hand, this project gave the Flemish fishery and researchers the opportunity to follow more closely the scientific developments concerning the assessment of bottom impact at European level and in this way also leave its mark on European policy. In Depestele & Van Hoey et al. (2022) an overview of current knowledge and developments in sea-bottom impact assessment and what fisheries policy can do to reduce this impact is outlined and summarized here. Determining bottom impact from fishing is done from two components: 1) the footprint of a fishing gear, i.e. the pressure the gear exerts on the bottom, is determined by the penetration depth of the gear in the sediment combined with the spatial distribution of fishing activity with that type of gear; 2) the bottom sensitivity, i.e. the extent to which the bottom fauna is resistant and resilient to disturbance. These two components form the basis of the bottom impact assessment for each region.

3.5.1 Footprint

The footprint of Flemish fisheries was mapped based on data from the Vessel Monitoring System (VMS) and logbooks (gear type). The VMS data thereby provided info on the distribution of the fishery, and the gear specifications - which determine the penetration depth - give an idea of the impact on the bottom. At European level, the estimation of penetration depths was worked out by default to the level of generic métiers such as the flatfish beam trawl, otter trawl and seine fishery (since 2021 in 10 métiers). But for Flemish fisheries, further distinction between beam trawl with chain mat versus with ticklers is needed, and it is useful to know whether a SumWing (beam trawl with hydrodynamic wing instead of a beam) is used or not, as this still gives nuances in the degree of bottom impact. Currently, this SumWing analysis is based on data obtained through consultation with fishermen (via Visserij Verduurzaamt). A more systematic recording of gear characteristics in the logbook is therefore needed and would allow much more accurate analyses on the degree of bottom impact.

The distinction between types of flatfish beam trawl is also important to quantify the difference between sediment resuspension - agitation of bottom particles causing water turbidity - of a beam trawl with chain mat versus with ticklers. Indeed, resuspension plays a role in releasing carbon and nutrients normally stored in the soil. Based on modelling work, it was found that the chain-mat beam trawl usually causes less resuspension, well depending on the towing speed. However, those models can only give an indication of orders of magnitude. An estimation of resuspension based on more specific logbook data on the fishing gear would therefore allow the method to be refined and thus more precisely estimate the effect of beam trawling on the mineralization process in the seabed.

3.5.2 Seafloor sensitivity

Seafloor sensitivity can be determined in several ways, but this study relied on (1) a qualitative determination based on categories (MarLIN, OSPAR BH3 indicator) and (2) a quantitative determination based on the longevity of benthic fauna (RBS [Relative Benthic State]). In the MarLIN approach, the sensitivity of selected habitats to 'abrasion' or bottom damage was determined as low, moderate and high based on scientific literature. This allows for a relatively simple way to create a sensitivity classification for habitats, and factor this into a sensitivity assessment for fishing grounds. This classification is also being used within the 'Fishing sustainably' track for the development of the bottom indicator.

In addition, more quantitative methods for determining bottom sensitivity are also being developed to get more detail and nuance in the classification, and to enable economic pass-through for fisheries. In this study, we use the FBIT method that reflects a 'Relative Benthic Status'. This reflects bottom sensitivity and is formatted according to the longevity of the bottom fauna. The occurrence of more long-lived species in a habitat is thereby seen as a proxy for higher soil sensitivity. This method has been accepted and included in ICES advice, but further research is needed on validation for different habitats and EU regions.

This study estimated the sensitivity of some general habitat types where Flemish fisheries are active. In doing so, we distinguished sandy, muddy, coarse and mixed bottoms at different depths. Fishermen appear to be mainly active in coarse, dynamic bottoms (44%), which is classified as a habitat with low sensitivity. In addition, the Flemish fishery (26%) fishes in sandy bottom, which does receive a moderate sensitivity rating and is therefore considered more vulnerable. The sensitivity of the muddy bottoms is clearly different with depth, with lower sensitivity in the shallow mud, but higher sensitivity in deeper zones. A substantial proportion (4.5%) of the deeper muddy bottoms are also fished by Flemish fisheries. The mixed bottoms (3-4% fishing activity) are low to moderately sensitive depending on depth. Currently, this assessment is still too coarse: the occurrence of threatened bottom species and habitats (e.g., gravel beds, biogenic reefs) still needs to be integrated. The protection of these habitats is also part of the design of marine protected areas and finding a balance between nature protection and food extraction (fisheries) for the pursuit of a healthier marine ecosystem. This will further guide future fisheries research and policy.

3.5.3 Indicators and impact assessment

There is a whole set of indicators for evaluating the status of the seabed. These indicators each have their own history, specifications and objectives. As a function of evaluating the impact of fishing on the seabed in the Flemish fishing areas, there are currently 2 indicators (OSPAR BH3 and the RBS indicator) that are widely applied. Both indicators use the same principles, namely the impact is determined according to the footprint of the fishing method and the sensitivity of the seabed. In the method of calculation and determination of sensitivity, they differ in their approach: there is a qualitative classification (OSPAR BH3 indicator based on the MarLIN sensitivity assessment) and a quantitative classification (RBS indicator based on lifetime). Both methods are valid and certainly found to be good enough, but the relationship between the two remains to be determined. For certain areas, we see different impact assessments with both methods. Since these assessments are the basis for managing human activities at sea, it is important to further invest in follow-up and research in the assessment methodologies.

In this report, we present a comprehensive analysis of bottom impacts - determined by the 'Relative Benthic Status' (RBS) indicator - for different types of fisheries in the North Sea. Moreover, to specifically map the impact of Flemish fisheries and their annual variation, the RBS indicator was adapted and we refer to it as the Relative Benthic Impact or RBI indicator. This adapted indicator allows the bottom impact assessment to also take into account the fishing disturbance of other fleets, in addition to the gear-specific mortality rate and the sensitivity of the bottom. These three parameters (disturbance of other fleets, gear-specific mortality rate and bottom sensitivity) are crucial to quantitatively evaluate the annual bottom impact per vessel or sea trip and allows calculating the possible reduction in bottom impact after gear modifications or if other fishing grounds are fished.

The Relative Benthic Impact of Flemish fisheries was mapped for the period 2012-2018. This fishing impact broadly follows fishing intensity. More recently, however, we see that fishing impact is slightly decreasing while intensity is slightly higher. This is because the share of beam trawling decreases between 2016 and 2018 while the share of otter trawling increases. The highest bottom impact of Belgian fishing is caused by beam trawls and otter trawls. Seine nets also have a high fishing intensity but a lower gear-specific mortality rate while shrimp trawls and dredges have a low fishing intensity.

The location where fishing is concentrated varies for the different métiers. Beam trawlers fish over a wide area so the impact is scattered with the greatest impact in the more sensitive areas north-east of England, in the English Channel and west of Denmark. Otter trawl fishermen fish mainly in the central North Sea. Shrimp fishermen mainly cause moderate impacts off the Belgian coast. Seine nets show a high distribution and lower impact while dredges cause an impact mainly along the north-east coast of England and in the English Channel.

3.5.4 Opportunities to reduce seafloor impacts

There are three principles that help reduce seafloor impacts:

1) Reduce acute bottom disturbance, through technical modifications to fishing gear that reduce penetration depth.
2) Fish where the bottom recovers quickly from acute bottom disturbance, so this requires primarily spatial work (choice of fishing grounds) by reducing disturbance in areas with slow recovery capacity or dominated by long-lived fauna.
3) Fish where there has already been a lot of fishing (choice of fishing ground), because in many cases a first fishing disturbance has a higher mortality (impact on bottom life) than a second and third disturbance. But this depends very much on the recovery capacity of the fauna.

Policy efforts should therefore be made to implement technical adaptations in the fleet and a well-considered choice of fishing grounds (e.g., spatial planning of fisheries).

In terms of technical adaptations, simulations show that adaptations to the beam trawl (SumWing) have the potential to reduce bottom impact by up to a quarter if widely implemented. This simulation assumes that fishing is not affected by the use of those gear modifications, an assumption that requires verification and requires the systematic recording of gear characteristics in the logbook. The reality is that the use of the SumWing is limited to a few large vessels fishing with alarm clocks. For those vessels, a reduction in bottom impact is expected - based on the simulations - if their fishing remains largely the same. The theoretical beam trawl that penetrates half as deep into the bottom can reduce bottom impact by up to 75% if the fishery is applied unchanged. The pulse trawl is an example of a beam trawl where the penetration depth halves, but its application in practice shows that its bottom impact was also influenced by the location of the fishing grounds fished.

Reducing soil impact through the choice of fishing grounds is not an obvious solution, but it has a significant effect. Based on different scenarios, where both historical fishing and the recovery capacity of the bottom are taken into account, the bottom impact could be reduced by up to a quarter or even half. It is noteworthy that completely avoiding fishing grounds does not necessarily lead to a greater reduction in soil impact, but that this effect depends on increased soil impact in other areas. When choosing fishing grounds, it is even more obvious than for gear modifications that catches will change. The simulations do not take this into account but only look at the potential for bottom reduction by changing fishing grounds. In a policy aimed at changing fishing grounds, it is important to identify the 'core fishing grounds'. An example was made where, for the Flemish beam trawl fleet, the areas where the 80% highest fishing intensity of the beam trawl is located were designated as core fishing grounds. These are some distinct areas in the English Channel, the coast of England, the German Bight and the Danish North Coast. A large area in the North Sea is not fished by the Belgian beam trawl or is fished at very low intensity (peripheral fishing grounds). Further research in function of choice of fishing grounds now requires to better map the spatial variation in core and peripheral fishing grounds, sensitive habitats, catch (see below) and the relationship with marine protected areas.

3.5.5 Economic implications

The link with socio-economic implications in pursuing reduced soil impacts was examined internationally in a series of international ICES workshops. There it was argued that the balance between soil impact and total savings can be drawn up, but then variable costs are not taken into account. An approach that can do this is through determining the contribution margin, but this requires spatially explicit economic data at the individual level per métier, which is not available. This is why international work also uses a comparison of bottom impact against the sum or biomass of fish landed. This does not take into account the composition of the landings.

Benthis national analyses therefore still show that catch composition is of great importance in the context of spatial opportunities to reduce bottom impact. This component deserves due consideration when considering the potential of spatial management for reducing soil impacts. The catch composition of Belgian fisheries in the North Sea and English Channel can be clustered into 10 major groups. For example, bottom impact per kg of fish landed is significantly higher in the cluster where cod and lemon sole are the main target species (on the Danish coast). Reducing bottom impact by fishing less in this sensitive area therefore means compromising fishing opportunities for cod and lemon sole. It is therefore crucial to factor the composition of landings into this socio-economic story.

3.5.6 Conclusion

Within the Benthis National project, the European procedure for evaluating bottom impact from fishing was further developed and applied to Flemish fishing gear and fishing grounds. This was done by taking gear specifications and habitat sensitivity into account, and by developing a new indicator. This mapped the evolution of the bottom impact of Flemish fisheries. Also, the tailor-made refinement for Flemish fisheries allows the evaluation of scenarios that can mitigate bottom impact, while taking into account the effect on catch and income. Both gear modifications and shifts in choice of fishing grounds can reduce bottom impact, but their effect on catch composition is different. To know the already realized reduction of bottom impact by Flemish fisheries, additional information on gear configuration per sea trip through logbooks is still needed. To further reduce bottom impact, a more in-depth analysis is needed to map the core fishing grounds and know how catches and sums will change when moving to other fishing grounds.

4 SEAFLOOR DISTURBANCE – THE VALDUVIS APPROACH

'VALDUVIS 2.0' (www.valduvis.be) is a tool that resulted from a collaborative effort between various Belgian stakeholders to assess the sustainability of the Belgian fishery. It is based on 10 indicators that describe ecological, economic and social parameters. The tool is currently used to assess the sustainability of the fisheries, to set targets to improve the sustainability and to formulate actions to achieve these targets. Since 2018, fishers who meet certain thresholds in their indicator results are eligible to receive a market recognition depicted on the auction clock called 'Visserij Verduurzaamt'. This recognition states that these fishers are working on improving their sustainability.

One of the ecological indicators describes the seafloor disturbance. It essentially considers the physical pressure of a fishing gear on the abiotic, non-living, environment of the seabed. Physical disturbance is a proxy for the impact of fishing activities on the functioning of the ecosystem. Hence, the pressure on the abiotic components (the sediment, the seabed) are measured in order to draw conclusions on the impact on the biotic component of ecosystems (flora and fauna).

The revised indicator for 'Seafloor disturbance' will combine information on the distribution and **sensitivity** of habitats (resilience and resistance) and the distribution and intensity of the fishing activities. For the latter, the **swept area** and the **depletion rate** of a fishing gear were combined.

A detailed description of the methodology will be available in a separate document/publication.

4.1 Pressure

The Swept Area (SA) or fished area estimates how large the area is where fishing occurred on the seafloor. It considers the width of the fishing gear, fishing time and towed speed. It may be possible that the penetration depth of the seafloor surface is small but that the fished surface is very large (e.g., Seine fishery). The fished area combined with the penetration depth is a measure for the amount of **sediment displacement.**

The **depletion rate** is the fraction of the benthic fauna killed or removed in the trawl path by a single trawl pass. It is based on the subsurface proportion of the footprint as a proxy of the relative penetration of the gear (Rijnsdorp et al., 2020, Hiddink et al., 2017, Pitcher et al., 2022). An overview of the used depletion rate is given in Table 4-1.

By combining the fished area and the depletion rate, we estimate the trawling pressure or bottom disturbance for each fishing vessel.

Table 4-1: Overview of the depletion rate per gear group (compiled from Rijnsdorp et al 2020, Hiddink et al 2017, Pitcher et al., 2022 and results of Benthis-nationaal)

Gear Type	Gear Code	Penetration (cm)	Depletion rate
Mechanical dredge (molluscs)	DRB_MOL	5.47	0.2
Otter trawl shrimp	OTB_CRU	3.091587	0.1
Danish seine	SDN_DEF	1.804391	0.009
Scottish seine (or flyshoot)	SSC_DEF	1.880698	0.016
Shrimp trawl (lighter beam trawl)	TBB_CRU	1.694282	0.06
Beam trawl	TBB_DEF	2.72	0.14
Bottom otter trawl (Norway lobster)	OTB_MCD	3.091587	0.1
Bottom otter trawl	OTB_DEF	2.650785	0.074
Sumwing	TBW_DEF	2.653334	0.1358063
Passive fishing gear	Different codes	NA	NA

Numerous variations of the beam trawl have been developed, however in a lot of cases it is not clear whether they actually result in less bottom impact. In the Benthis project, no distinctions were made between the traditional beam trawl and its alternatives, e.g., the Sumwing. With the Sumwing, the shoes have been replaced by a runner which touches the seabed. The rest of the gear (chains and groundgear) are the same as for the beam trawl. The depletion rate of the sumwing was calculated in Benthis-nationaal and is slightly lower than the depletion rate of a traditional beam trawl (Table 4-1).

Table 4-2 provides an overview of the different beam trawling fishing techniques and the way their bottom impact is assessed and scored within VALDUVIS2.0. With the exception of the sumwing, the penetration depth and the depletion rate for the variations to the traditional beam trawlers, ie. roller shoes, ecoroll beam and aquaplaning gear, were considered to be the same as for the traditional beam trawler.

Table 4-2: Overview of beam trawl variations and impact on fuel reduction an on bottom disturbance

Technique	Fuel reduction?	Less bottom impact?	Scored as
Ecoroll beam	yes	Not scientifically checked	Traditional beamtrawl
Beam trawl with roller shoes	yes	no	Traditional beamtrawl
Hydrorig	yes	Less bycatch of benthos, variable results (LOT 3, 2010)	NA
Sumwing	yes	Minor reduction (Depestele et al., 2022)	Sumwing
Aquaplaning gear	yes	No, not scientifically checked	Traditional beam trawl
Pulse gear	yes	Yes, less bycatch and less bottom impact (Depestele et al 2019; Rijnsdorp et al, 2020, ICES WGELECTRA 2020). However, there is an EU-wide ban on pulse trawling from 2021.	NA

* A traditional beam trawl is considered to have a beam, shoes, tickler chains or a chain matrix and a ground rope (...).

4.2 Sensitivity

For the **sensitivity** of the habitat, the OSPAR sensitivity classification was used (REF BH3 CEMP guidelines). The sensitivity matrix () is calculated using a precautionary approach and is a combination of the resistance and the resilience of both the habitat and species sensitivities. The sensitivity values range from 1 to 5 with 1= very low sensitive and 5 = highly sensitive. The sensitivity to both surface abrasion and subsurface abrasion was provided by OSPAR but only the sensitivity to surface abrasion was used in the Valduvis indicator.

Resistance \ Resilience	very low (>25 yr.)	low (>10-25 yr.)	medium (>2-10 yr.)	high (1-2 yr.)	very high (<1 yr.)
none	5	4	4	3	2
low	4	4	3	3	2
medium	4	3	3	2	1
high	3	3	2	2	1

Figure 4-1: Seabed sensitivity classification using resilience and resistance.

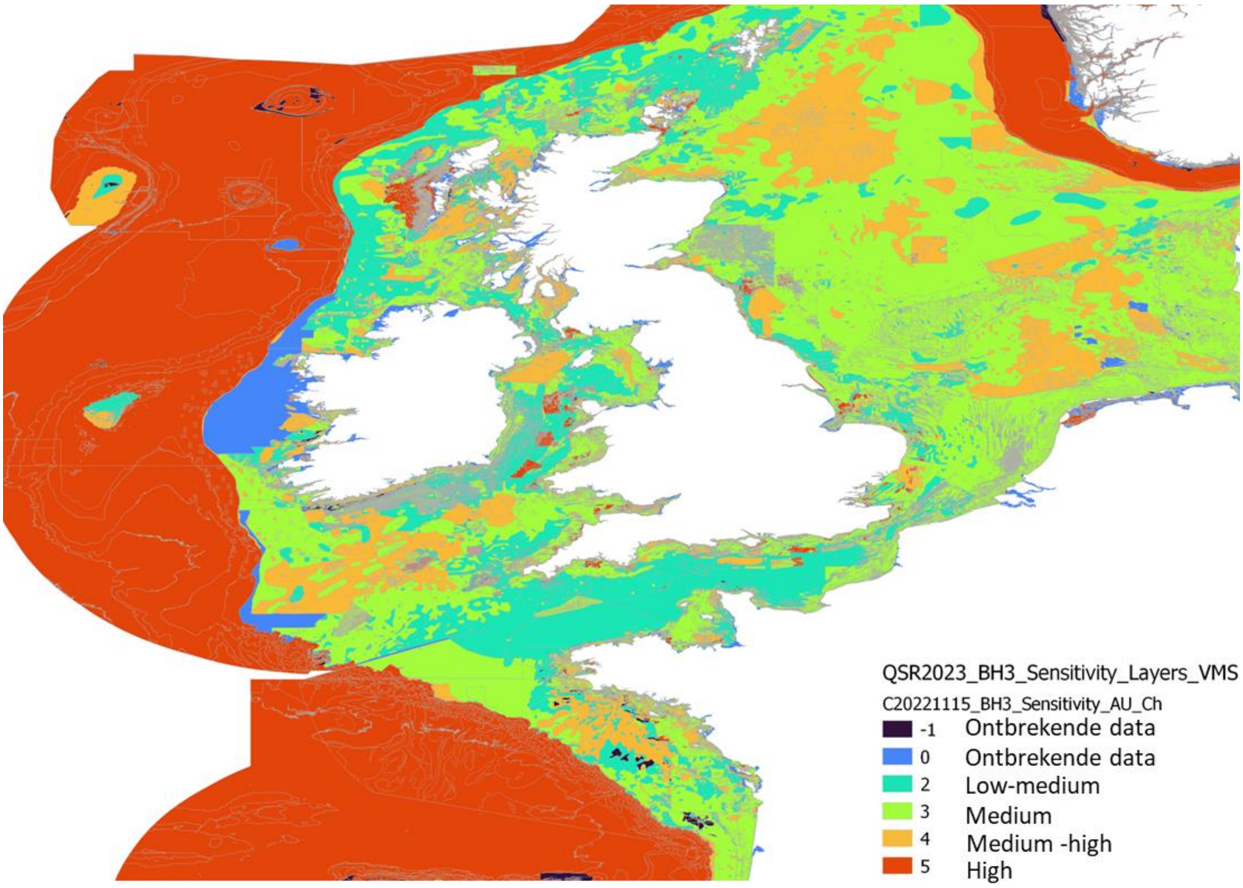


Figure 4-2 Extraction of the map with the habitat sensitivity to surface abrasion made by OSPAR.

4.3 VALDUVIS indicators for bottom disturbance

4.3.1 Monitoring indicator

This indicator is useful to follow the evolution of the fishing pressure in the different sensitivity areas. If there is more fishing then the pressure will increase. This allows us to follow the evolution of the total fishing pressure of the Belgian fleet and in which sensitivity classes changes can be observed.

For the VALDUVIS2.0 monitoring indicator 'Seafloor disturbance' is calculated as the **pressure** in each of the **sensitivity classes** for the entire fleet:

$$\sum SA_{\text{fishing gear}} \text{ x depletion rate}_{\text{per gear group}} \text{ per sensitivity class}$$

With:

- SA fishing gear: Swept area= total width of the fishing gear * towing speed * number of fishing hours Calculated per vessel per sensitivity per gear group.
- Depletion rate: differs according to the gear group (Table 4-1) (per gear group)
- Sensitivity classes (-1 & 0 = missing data, 1= low, 2= low-medium, 3= medium, 4= medium-high, 5=high)

4.3.2 Management indicator

The purpose of this tool is to motivate the vessel owners to avoid highly sensitive areas and marine protected areas. That is why we give a weight to the different sensitivity classes. The pressure in highly sensitive areas weighs more heavily than the pressure in less sensitive areas. In addition, a factor is added when fishing occurs in Natura2000 areas. Finally, we also take into account the alternative options of each vessel group. We assume that the potential fishing grounds depend on the type of fishing gear, the target species and the vessel group.

For this management indicator for seafloor disturbance, we developed the following formula:

$$\sum \text{SA x depletion rate x Sensitivity weight x \%alternative fishing grounds x factor if in Natura2000}$$

With:

- SA fishing gear: Swept area = total width of the fishing gear * towing speed * number of fishing hours
- Calculated per vessel per sensitivity per gear group.
- Depletion rate: differs according to the gear group (Table 4-1)

- Sensitivity classes (-1 & 0 = missing data, 1= low, 2= low-medium, 3= medium, 4= medium-high, 5=high)
- Sensitivity weights (missing data = 0.01, low=0.01, low-medium=0.05, medium=1, medium-high=4, high=40)
- %alternative fishing grounds: Potential fishing grounds outside high and medium-high sensitive areas and outside Natura2000 areas. Depends on gear group and vessel group.
- Factor if in Natura2000

4.4 Impact of the Belgian Fishery

Figure 4-2 gives an overview of the occurrences of the different sensitivity classes according to OSPAR BH3 in the waters vastly covering the activity of the Belgian fisheries. At a first glance, the areas with a high sensitivity are limited, while medium-high is more prominent. The VMS pings for the entire Belgian fleet in 2021 are shown in Figure 4-3.

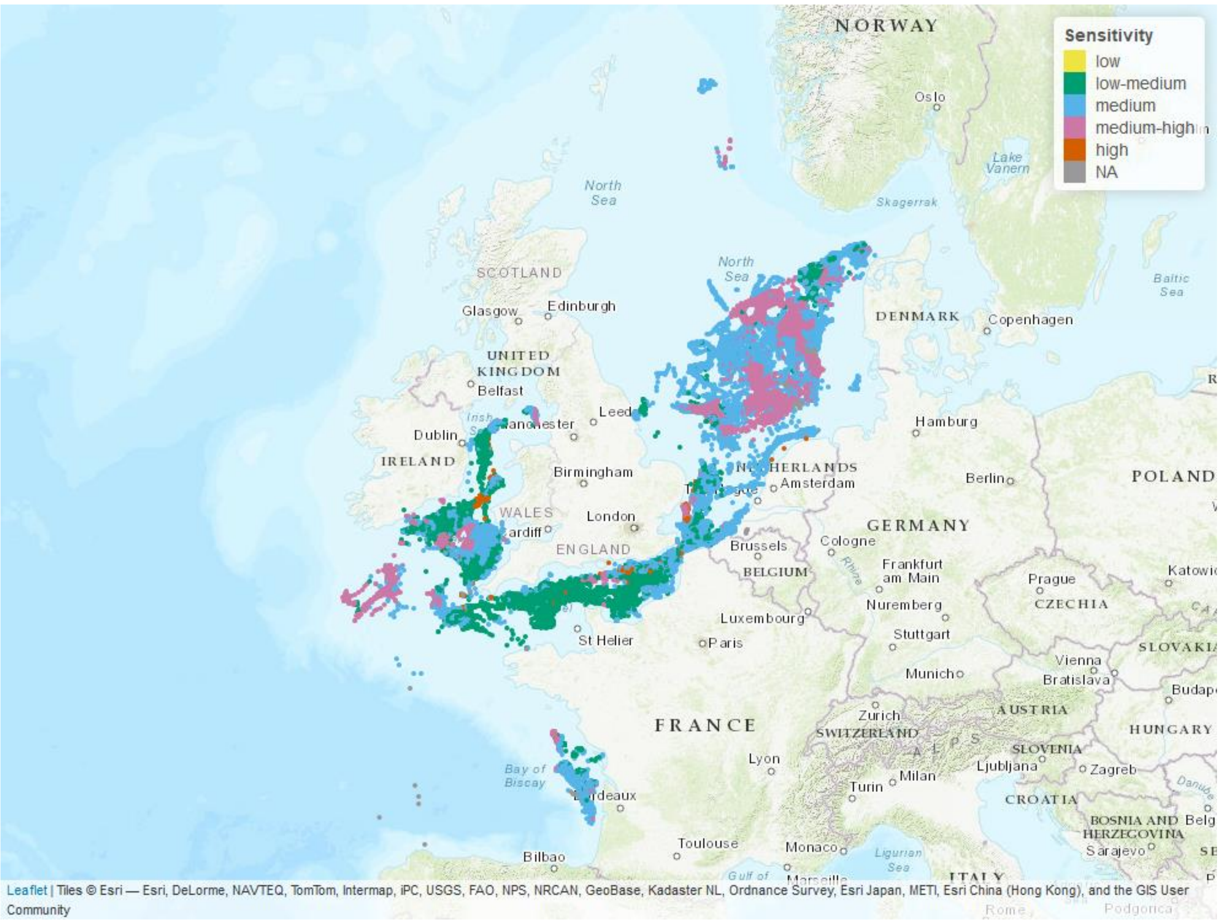


Figure 4-3: VMS pings of the Belgian fleet considered as fishing in 2021 per sensitivity category according to OSPAR BH3.

In 2021, most activity in terms of **fishing hours** occurred on areas with a medium sensitivity (48%) followed by areas with a low-medium sensitivity (34%). Medium-high and high represented about 15% and 2.7% respectively (Figure 4-4).

The outcome of the monitoring indicator described in the previous section is termed "bottom disturbance" in what follows. In terms of **bottom disturbance**, low-medium represented 48% and medium 41% of the total bottom disturbance (Figure 4-4). 2.6% of the total bottom disturbance by the Belgian fleet occurred in areas with a high sensitivity. The GVS (33 vessels) accounted for 98% of this figure, Eurocutters (18 vessels) for almost 2% and the remaining KVS group (13 vessels) for less than 2‰ (Figure 4-5 and Table 4-3). Medium-high represented about 9% of the total bottom disturbance. The GVS accounted for 59% of this figure while Eurocutters accounted for almost 40%.

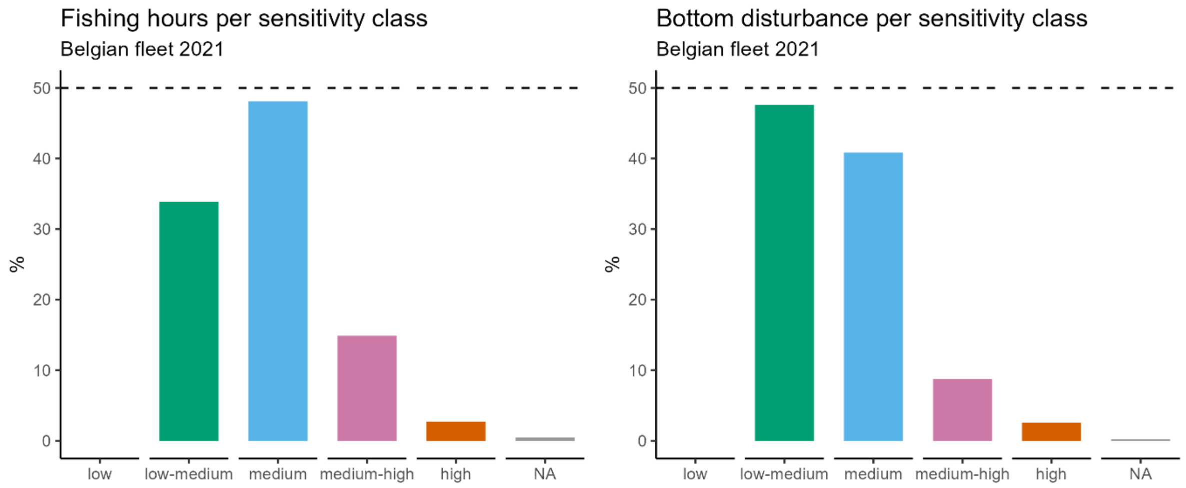


Figure 4-4: Share of the total fishing hours and total bottom disturbance (in %) for the different sensitivity categories. NA represents missing sensitivity.

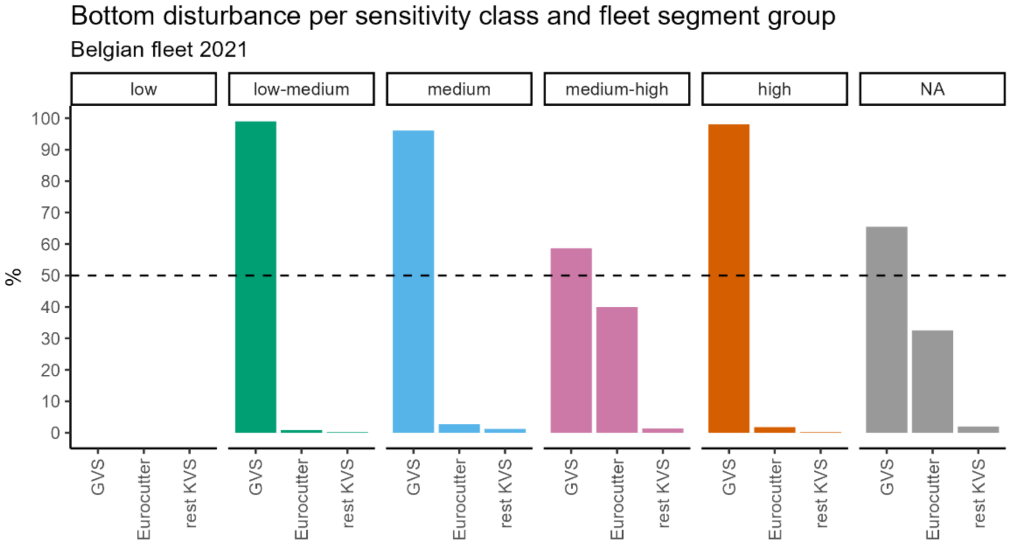


Figure 4-5: Share of the total bottom disturbance (in %) contributed by each fleet segment group for the different sensitivity classes. NA represents missing sensitivity.

Table 4-3: Total Share of the total bottom disturbance (in %) for each fleet segment group in the different sensitivity classes.

	GVS	Eurocutter	Rest KVS
missing sensitivity	65.46	32.53	2.01
low	0	0	0
low-medium	99.01	0.83	0.16
medium	96.06	2.74	1.20
medium-high	58.65	39.98	1.36
high	98.07	1.78	0.15

The most common métier was beam trawling for flatfish (TBB_DEF) and the majority of the Belgian fleet uses this métier at least seasonally (~50 vessels). The depletion rate of a Sumwing was estimated to be lower (0.1358) compared to a more traditional beam trawl (0.14), leading to slightly less bottom disturbances for a same swept area. In the figures that follow, the term TBB_DEF includes bottom disturbances of the Sumwing. In 2021, 44 % and 45 % of the bottom disturbance by the GVS using TBB_DEF was respectively done in low-medium and medium, while 3 % and 7.6% occurred in high and medium-high (Figure 4-6). For Eurocutters using TBB_DEF, 33% occurred in low-medium, 62% in medium, 1% in medium-high and 4.63% in high. For the remaining KVS using TBB_DEF, most of the bottom disturbance occurred in medium (84%) and low-medium (13%).

Most of the bottom disturbance made by the shrimp fishery (TBB_CRU, both rest KVS and Eurocutters) occurred in an area with low-medium (4.7%) and medium (95%) sensitivity (Figure 4-6 and Figure 4-7). TBB_CRU has a smaller depletion rate (0.06) than TBB_DEF.

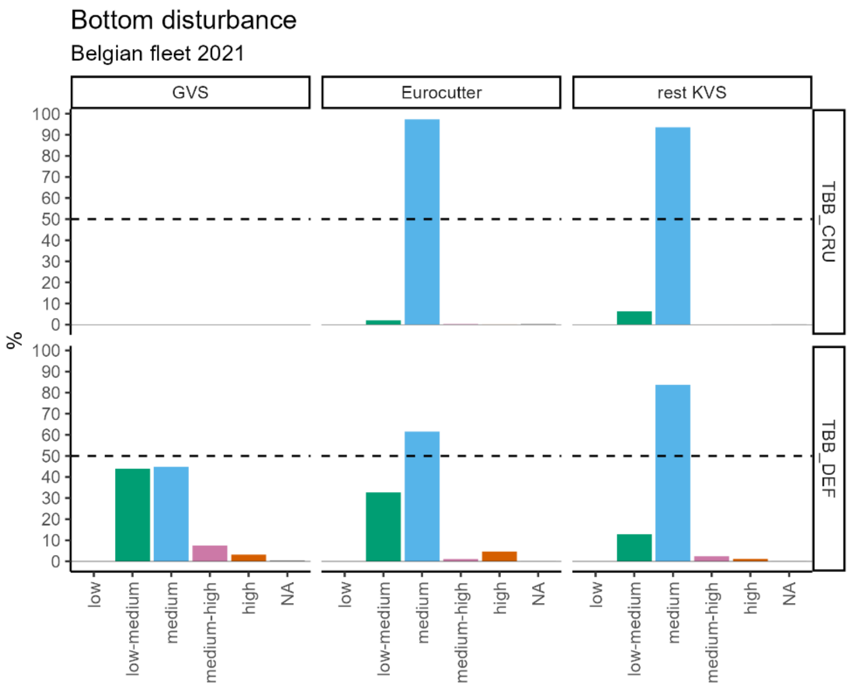


Figure 4-6: Share of the bottom disturbance (in %) for beam trawlers (TBB_CRU and TBB_DEF) per sensitivity classes for the different fleet segment groups. NA represents missing sensitivity.

The remaining métiers include otter trawling targeting demersal fish (OTB_DEF) and Norway lobster (OTB_MCD), flyshoot/demersal seining (SSC_DEF) and dredging (DRB_MOL). Bottom disturbance was not considered for vessels using passive gear. In 2021, 10 vessels used OTB_DEF, 15 vessels OTB_MCD, 3 vessels SSC_DEF and 1 vessel DRB_MOL. Despite having lower depletion rates than demersal beam trawlers, swept areas of otter trawlers and demersal seiners were considerably larger leading to relative higher bottom disturbances. In 2021, bottom disturbance was 51% and 41% on medium and medium-high for OTB_DEF and 15% and 80% on medium and medium-high for OTB_MCD (Figure 4-7).

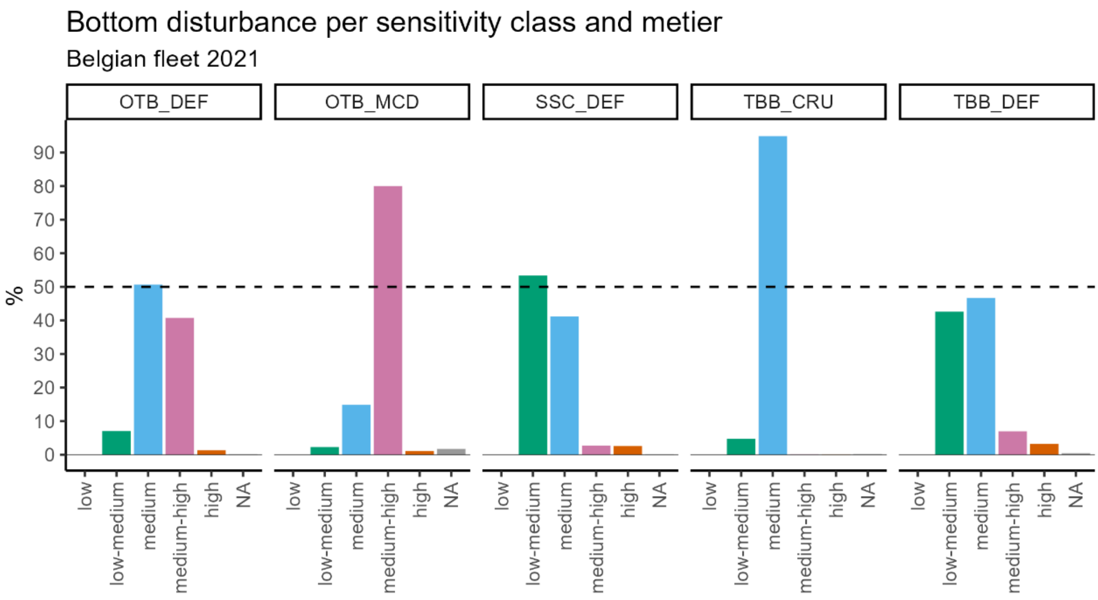


Figure 4-7: Share of the total bottom disturbance (in %) per sensitivity classes for the different métiers. DRB_MOL was omitted. NA represents missing sensitivity.

5 ENERGY USE IN THE BELGIAN FISHING FLEET

5.1 The fuel consumption of the fishing fleet

Fishing practices and gears vary in their environmental impacts as well as in fuel efficiency. Generally, passive fishing gears are considered to have less severe impacts and require smaller amounts of fuel per kg of landings compared to towed gears. More specifically, studies analyzing fuel consumption patterns by gear types reveal that passive fishing gears, such as pots, traps, long-lines and gillnets, generally require lower amounts of fuel (approximately 0.1 – 0.4 L of fuel per kg landings) compared to active fishing gears, like bottom trawls (approximately 0.5 – 1.5 L of fuel per kg landings). Bottom seines rank between passive gears and bottom trawls in terms of fuel consumption (ICES, 2010; Suuronen et al., 2012; Thrane, 2004; Winther et al., 2007). However, fuel consumption can significantly vary among seine net vessels due to differences in fishing effort and steaming times to the fishing grounds (Rúnarsson, 2008).

On the other hand, active pelagic gears, such as midwater trawls and purse seines, target fish that form dense schools, enabling the catch of hundreds of tonnes of fish with one short tow or haul. Fuel consumption for these methods is generally low when expressed per quantity of catch. In particular, purse seining stands out as one of the most fuel-efficient techniques for catching fish (approximately 0.1 L of fuel per kg catch). Nonetheless, vessels using this gear often spend significantly more time and, consequently, more fuel searching for schools than actually catching fish (ICES 2010; Schau et al., 2009; Thrane, 2004).

Research of Bastardie, Feary, Kell et al. (2022) states that beam trawlers have the highest fuel use intensity (liter of fuel per kg of fish landed) of all gear types examined in the study (Figure 5-1). Section 5.2 elaborates more on this issue.

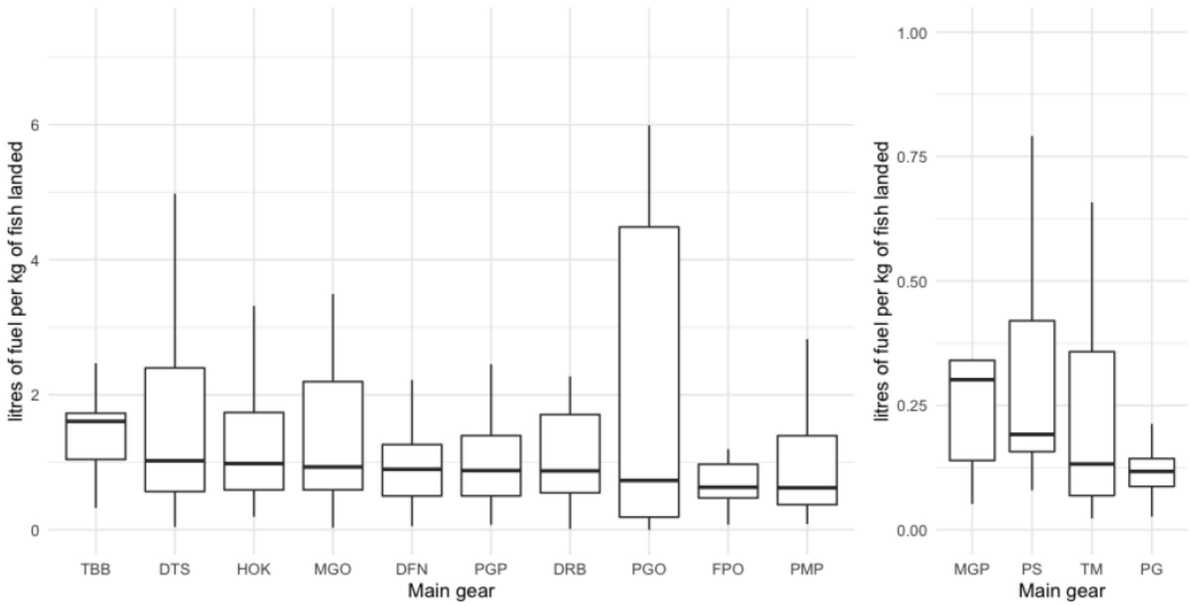


Figure 5-1: Fuel use intensity ranges in the EU fleet between 2016 and 2018 (Bastardie, Feary, Kell et al., 2022), with DFN: Drift and/or fixed netters, DRB: Dredges, DTS: Demersal Trawls and Seines, FPO: pots and traps, HOK: Hooks, MGO: Other active gear, MGP: Polyvalent active gear only and PG: Passive gear.

Not only fuel consumption during fishing mode is important, but also the fuel used for steaming, searching for fish and sailing back to the port. All of these aspects should be accounted for when searching for measures to reduce fuel consumption. According to Bastardie, Feary, Brunel et al., (2022), the highest fuel consumption in active fisheries occurs during the fishing mode. Thus, the most cost-efficient measures to reduce fuel consumption in such fisheries are those that target fuel usage during the fishing operation. In contrast, purse seiners and pole and liners targeting migratory pelagic species consume the majority of their fuel during the steaming stage, as stated above. Consequently, measures such as route optimization and slow steaming are best suited for reducing fuel consumption in this type of fishery.

In general, vessels often need to search longer and/or fish in deeper offshore waters because many fish stocks have declined due to excessive fishing. This has led to a significant increase in the fishing power of these vessels (World Bank et al., 2009) as well as more gear being set over a larger area and depth range (Suuronen et al., 2012).

5.2 The evolution of the fuel consumption of the demersal trawl fleet

Between 2008 and 2020, crew costs and fuel costs represented the most important operational costs in the Belgian fleet (STECF, 2022). Since trawl fisheries are characterized by a high fuel use intensity (Figure 5-1) high fuel costs are typical for this type of fishery (Poos et al., 2013). The energy costs for the Belgian fishery in the period 2008-2020 were on average 26,6% of the landing value. Since the fuel crisis (2008) experiments have been done to reduce the high share of fuel costs in the gross revenues. Suuronen et al. (2012) gives an overview of the different adjustments that can lead to a reduced fuel consumption in his review paper 'low impact and fuel-efficient fishing - Looking beyond the horizon" (Table 5-1). Reducing fuel consumption does not only lead to a beneficial financial component, but the ecosystem will benefit as well. These fossil fuels are a major source of greenhouse gas emissions. Through technological improvements and behavioral changes, the fishing sector can substantially decrease the damage to aquatic ecosystems, reduce emissions and lower its fuel costs. Changes in fishing practices can result in more economical and sustainable fisheries (Suuronen et al., 2012).

Table 5-1: Examples of potential energy saving techniques and operational adaptations to reduce fuel consumption and environmental impacts of demersal trawling (Suuronen et al, 2012).

Technique/measure	Effect	Constraints–barriers
Use of thinner and stronger twines, super fibres, knotless netting, square mesh netting, T90 net, less netting, larger mesh size	Reduces the amount, weight and surface area of netting and increases water flow through the net, thereby reducing the overall drag	High price and availability of materials; use of larger meshes can reduce the catch of marketable species and sizes; cost benefit analyses not carried out for most fisheries
Use of smaller and/or multiple nets for species that exhibit poor avoidance behavior to the presence of the fishing gear (e.g. shrimp, flatfish)	Reduces the overall netting surface area and thereby the weight and the drag without reduction in catch	Policy, complexity of rigging, resistance to change
Use of effective bycatch and benthos reduction devices (BRDs)	Allows the escape of unwanted species or sizes of fish and other unwanted objects thereby reducing the weight and overall drag	Variability in performance, lack of technical support to test and optimize BRDs, loss of revenues of target species and sizes, perceptions
Using four-panel design (instead of typical two-panel) in the belly, extension piece and codend, using square mesh netting in the belly	Ensures easier installation of BRDs and better geometry and stability for the back end of the trawl	Cost benefit analyses not carried out for most fisheries
Use of hydrodynamic trawl doors and use of optimal warp length (that corresponds to optimal door efficiency)	Less drag (traditional trawl doors contribute up to 25-35% of the overall gear drag), less weight, better fuel efficiency	Price, performance monitoring, control in different sea conditions and depths
Use of raised or flying trawl doors where the weight element of the door is separated from the spreading element (doors can be flown above the seabed to open the trawl)	Better spread, less drag and less pressure on the bottom (less seabed disturbances)	Price, performance monitoring, control in different sea conditions, depths, not suitable for all species
Better rigging of the gear, lighter ground-gear, shorter ground-gear, less discs and better rotation capacity, self-spreading ground gear, composite ropes, lengthened bridles, off-bottom bridles, lightweight warps, and proper matching of trawl net and trawl doors	Lighter and reduced contact points to seabed, less seabed pressure, smaller impact area, less drag	Performance monitoring
Use of hydrodynamic shape of floats, kites, beams, pulse trawls, SumWing-design	Reduced drag, reduced seabed contact	Performance monitoring, speed dependence
Converting from single boat trawling to pair trawling	Reduces fuel consumption, less seabed damages	Policy, human behavior
Improving real-time monitoring and control of gear with acoustic gear surveillance technology	Maintenance of optimal gear performance, reduces energy consumption and bycatch	Price, training
Installing real-time camera observation system for informing skipper of fish behavior and composition in the trawl	Helps to maintain optimal gear performance, reduces bycatch and collateral impacts. The next step may be an active mechanism to release unwanted catch	Price, training
Improving navigation and fish finding, and improving knowledge on fishing grounds (GPS, electronic charts, sea-bed mapping)	Maximizes catches and minimizes time, energy and collateral impacts	Price, training
Use of speed controls, reduction of towing speed	Reducing speed directly reduces the fuel consumption	Human behavior
Vessel and propulsion system optimization, preventive maintenance of vessel and engine, change in trip planning practices	Reduces fuel consumption	Price, human behavior

The Belgian fishery introduced many initiatives aiming for a reduction in fuel consumption in the demersal fleet. These range from small modifications of the vessel such as a shorter beam, a sealed beam, lighter chains to larger adjustments like the use of roller shoes and large meshes in the back of the net or applying thin twine like Dyneema network to replacing the engine and building new vessels. The Sumwing was developed as a hydrodynamic alternative to the beam in a beam trawl vessel and causes fuel savings around 10% (See Section 2.1.3.1; Polet & Depestele, 2010). In addition, beam trawlers can switch to alternative fishing methods that can be used with the same vessel. The most widely used technique is the so-called outrigger trawl (two otter trawls replacing the beam trawls) which causes a strong fuel reduction. This fishing method is seasonally applied.

Installing a fuel consumption meter is a tool that confronts the crew directly with the fuel consumption and allows the owner to follow this consumption. The econometer was installed on a number of trawling vessels in Belgium. It was developed by MARELEC NV, a company in Nieuwpoort (Be) which has been active since 1983 in the fisheries sector. The econometer measures the flow in the supply and return line with two electromechanical flowmeters. The difference between these two values is the fuel consumption. Fuel consumption is shown in the bridge or engine room (Marelec, n.d.). The use of an econometer rapidly led to fuel savings. Individual owners confirm that the use of an econometer combined with cruise control allows the skipper to reduce fuel consumption (ILVO, unpublished data). During the period 2008-2012 many vessels of the large fleet segment installed a new engine, usually in combination with a new propeller and kort nozzle. The fuel savings as a result of these innovations could be monitored from the econometer data from five vessels. The average savings for these vessels were between 8% and 19% (ILVO, unpublished data). The 2008 fuel crisis had an immediate effect on the Belgian fleet by a reduction in liters fuel used per day at sea from 2008 to 2011 (Figure 5-3). The large beam trawlers particularly reduced their fuel use after 2010 (Figure 5-2) (Bastardie, Feary, Brunel et al. 2022). The mean fuel use intensity of the Belgian fleet in 2010 was 2.2 L/kg fish caught while this was reduced to 1.6 L/kg in 2015 (Figure 5-3). The total fuel consumption (Figure 5-4) also decreased from 48 million L in 2010 to 39 million L in 2015, but did not follow the same continuously decreasing pattern as the fuel use intensity depicted in Figure 5-3. This illustrates that the fuel reduction is achieved by the many initiatives by the Belgian fishery (Bastardie, Feary, Brunel et al. 2022), but also highly depends on the amount of landings. The total amount of landings of the fleet increased from 2009 until 2014, decreased in 2015 and rose again in 2016 (STECF, 2022). This trend is visible in the fuel use intensity (L/kg fish) on Figure 5-3. Furthermore, the size of the Belgian fleet shrank during this period (Figure 1-1), explaining another part of the decreasing total fuel consumption.

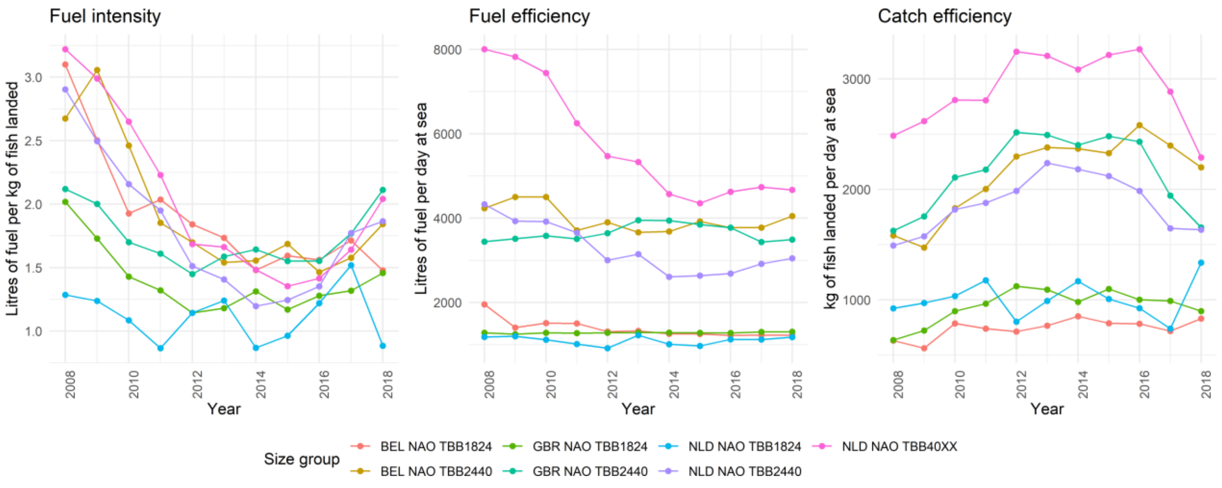


Figure 5-2: Re-construction of fuel intensity (fuel use to catch one kg of fish), fuel efficiency (liters fuel used per unit of effort) and catch efficiency (Bastardie, Feary, Brunel et al. 2022).

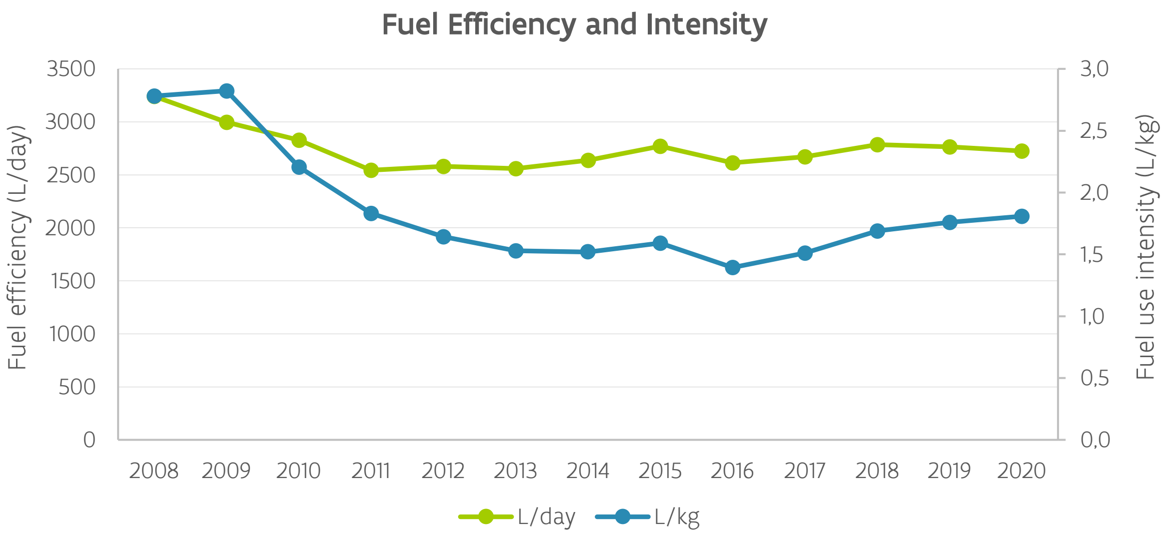


Figure 5-3: Fuel efficiency and fuel use intensity of the Belgian fisheries (STECF, 2022).

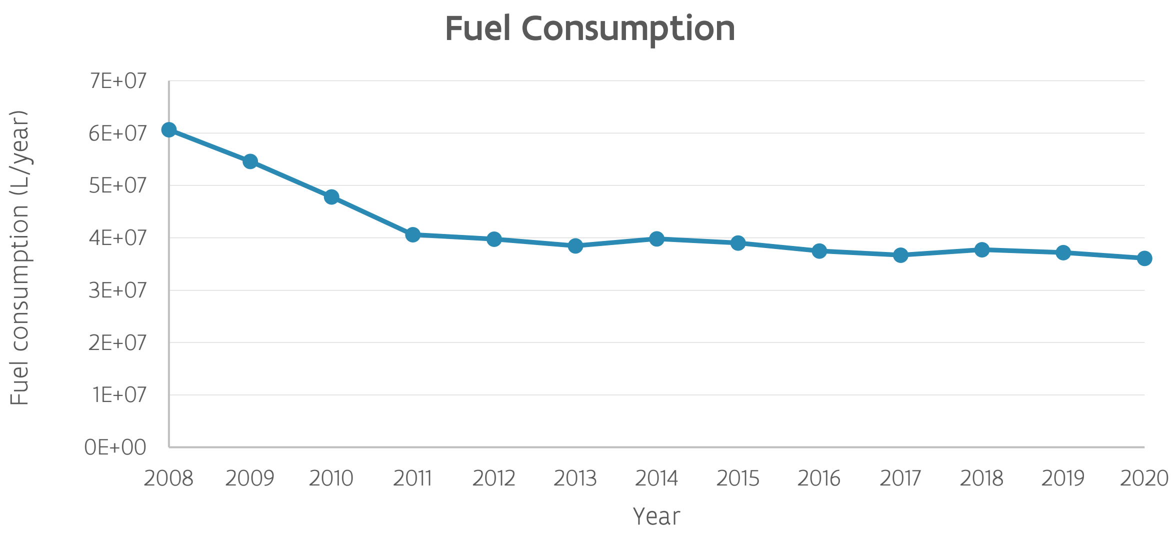


Figure 5-4: Fuel consumption of the Belgian fisheries (STECF, 2022).

5.3 Drivers and Barriers for the implementation of less fuel-intensive technologies

The main driver to search for new technologies to lower the fuel consumption is the high fuel price (Bastardie, Feary, Kell et al., 2022). Fuel prices were particularly high in 2008 and 2012 (Figure 5-5), were on the rise again during 2021 and continued to rise in 2022. A conflict that started in February 2022 between Russia and Ukraine only exacerbated the rise in fuel prices (STECF, 2022). The fuel consumption per day at sea of the Belgian fishery fell sharply between 2008 and 2011, stagnated until 2013, rose again slightly in 2014 and 2015, decreased in 2016 and stagnated until 2019 (Figure 5-3). Energy consumption per kg fish landed has followed a downward trend since 2008 (-40%), with the lowest estimated value in 2016 of 1.4 liters per kg landed. One of the reasons behind this still relatively high fuel consumption is the use of bottom trawling gear, as the focus remains on catching demersal species. Another explanation is that the fishing grounds are scattered and sometimes far away from the Belgian coast. Despite this, the fleet appears to be making efforts to reduce their fuel consumption and improve their overall efficiency (STECF, 2019).

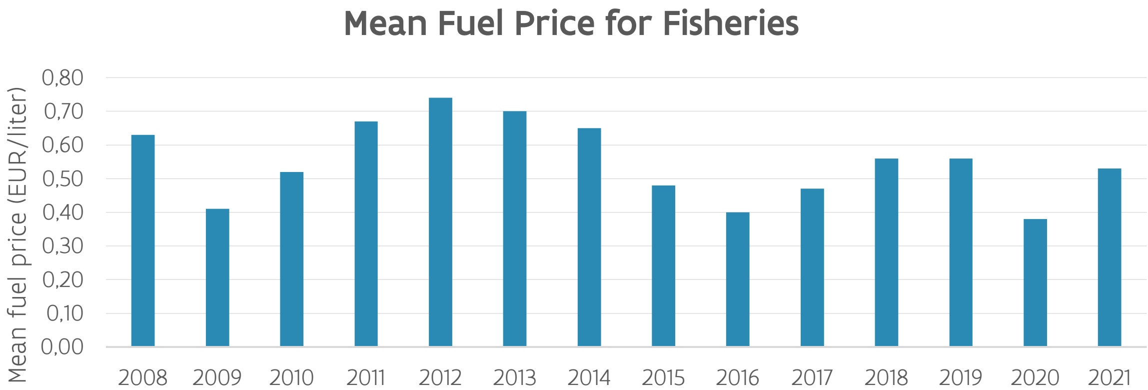


Figure 5-5: Mean fuel price for fisheries (euro/liter) (Departement Landbouw en Visserij – Visserijcijfers: www.vlaanderen.be/visserijcijfers).

Currently, various energy-efficient technologies already exist (see the ones described in section 5.2 among others) but are not yet widely used (Bastardie, Feary, Brunel et al., 2022; Bastardie, Feary, Kell et al., 2022). The various potential reasons why the adoption of these techniques is not easily occurring are listed below (Bastardie, Feary, Brunel et al., 2022; Bastardie, Feary, Kell et al., 2022; Suuronen et al., 2012):

- Not all proposed solutions in the scientific literature are applicable.
- There can be incompatibility of vessels with the alternative gear (Jennings & Revill, 2007).
- The alternative gear can involve a risk of losing marketable catch (Jennings & Revill, 2007).
- Technological innovations are commonly based on species-specific characteristics to improve catch and fuel efficiency of gears. Therefore, these innovations are not easily applied to fisheries targeting other species.
- Fishing methods are deeply rooted in traditional practices. People are often resistant to changing these traditions, which creates a reluctance to adopt new approaches. Therefore, it is better to make changes to operational techniques and gear design without drastic changes in behaviour instead of transitioning to a completely new gear type or fishing practice.
- Often, limited information on technologies and their applicability is available, which restrains fishers from acquiring accurate technological knowledge. Training courses and ocean literacy could partially fix this constraint.
- Inflexible fisheries management systems may inhibit changes in, for example, gear types (Gascoigne & Willsteed ,2009).
- There is a lack of collaborative work with and among end users, both in transferring technology and developing new technologies and strategies (Jafarzadeh & Utne,2014).
- Skippers may show less interest in enhancing fuel efficiency compared to vessel owners. The fisher may be more focused on fishing instead of trying new technologies whenever the current ones function well.
- The fishing industry falls outside the scope of global shipping emissions assessments, such as the IMO's Greenhouse Gas Studies (Coello, 2015). For example, certain fisheries operating

in Norway enjoy exemptions from environmental taxes (CO2 and NOx), which reduces the incentive to enhance energy efficiency.

- Investment costs can be too high and public funding might be lacking. Providing financial support through public funding to implement new technologies was deemed ineligible under the Operational Plan for Fisheries and Sea (2014-2020 and beyond), as well as other funding avenues like the European Fisheries Fund (EFF) and EMFF. Interestingly, the subsidization of innovative gears, outlined in *Action 4.1.20 for Energy efficiency and mitigation of climate change, investments on vessels, control systems of energy efficiency, alternative propulsion systems, and hull design*, hasn't received approval, even though such measures would reduce fuel use and possible reduce the negative impacts of trawling.
- Sometimes, national regulations can limit the opportunities for improvements supported by the EU.

Having subsidies available would help overcome a significant amount of the above-listed barriers, as well as having measures proven by scientific testing and proofs of increased catch efficiency. Furthermore, fuel consumption depends on a range of factors at the individual vessel level. Therefore, the best way to determine and optimize fuel consumption would be via monitoring system within vessels (Bastardie, Feary, Kell et al., 2022).

A new monitoring technology for data collection on board of fishing vessels, called VISTools, has been developed and deployed in the Belgian fishery in cooperation with ILVO. This technology, operational on 5 vessels since October 2022, allows to collect data from any instrument on board including fuel consumption meters. It allows a quasi real-time detailed view on fuel consumption. Starting in the summer of 2023, the whole Belgian fleet gets the opportunity to install the technology, with the aim to collect fuel consumption data from the main engine and the auxiliary engines and to stimulate fishermen to reduce fuel consumption.

6 FISHERY POLICY

6.1 EU fisheries management: The Common Fisheries Policy

The Common Fisheries Policy (CFP) is a set of rules for managing European fishing fleets and for conserving fish stocks (Verordening 1380/2013). Designed to manage a common resource, it gives all European fishing fleets equal access to EU waters and fishing grounds and allows fishermen to compete fairly.

Stocks may be renewable, but they are finite. Some of these fish stocks, however, are being overfished. As a result, EU countries have taken action to ensure the European fishing industry is sustainable and does not threaten the fish population size and productivity over the long term. The CFP was first introduced in the 1970s and went through successive updates, the most recent of which took effect on 1 January 2014 (EU 1380/2013).

The CFP aims to ensure that fishing and aquaculture are environmentally, economically and socially sustainable and that they provide a source of healthy food for EU citizens. Its goal is to foster a dynamic fishing industry and ensure a fair standard of living for fishing communities. Although it is often considered important to maximize catches, there must be limits. We need to make sure that fishing practices do not harm the ability of fish populations to reproduce. The current policy stipulates that catch limits should be set that are sustainable and maintain fish stocks in the long term.

To this day, the impact of fishing on the marine environment is not fully understood. For this reason, the CFP adopts a cautious approach which recognizes the impact of human activity on all components of the ecosystem. It seeks to make fishing fleets more selective in what they catch, and to phase out the practice of discarding unwanted fish.

The reform also changes the way in which the CFP is managed, giving EU countries greater control at national and regional level (Fisheries - European Commission, 2019).

6.2 The Landing Obligation

Discarding is the practice of returning unwanted catches to the sea, either dead or alive, because they are undersized, due to market demand, due to quota limits or because catch composition rules impose this. The radical change in fisheries management that came with the landing obligation aims to improve fishing behavior through improvements in selectivity and temporal/spatial measures.

The CFP phased in the implementation of the landing obligation from 2015 through to 2019 for all commercial fisheries (species under TACs) in European waters and for European vessels fishing in the high seas. Since 2020 the landing obligation is fully implemented. However, despite all efforts, the Commission's audits and the initiatives of the European Fisheries Control Agency (EFCA) indicate a general cross-border lack of compliance with the landing obligation. The underlying problems with the policy have been pointed out on several occasions by different stakeholders (e.g., the public hearing on "**Implementation of the landing obligation and allocation of quotas** ", organised by the Committee on Fisheries, **24 April 2017**, in the European Parliament). The most fundamental comments on the implementation of the landing obligation were, however, not reflected in the subsequent policy/management. Possible solutions today are sought in innovative control tools, such as closed-circuit television (a Remote Electronic Monitoring tool). This tool is included in the Commission's proposal for a revised fisheries control system (Fisheries - European Commission, 2019).

The landing obligation requires all catches of regulated commercial species on-board to be landed and counted against quota. These are species under TAC (Total Allowance Catch, and so-called quotas) or, in the Mediterranean, species which have an MLS (minimum landing size such as mackerel which is regulated by quotas; and gilt-head sea-bream regulated by size). Undersized fish cannot be marketed for direct human consumption purposes whilst prohibited species (e.g., basking shark) cannot be retained on board and must be returned to the sea. The discarding of prohibited species should be recorded in the logbook and forms an important part of the science base for the monitoring of these species.

If the quota of a target or by-catch species have been declared exhausted, fishing activities must be compulsorily closed. In this context, the so-called choke species can seriously disrupt fishing practices.

The regulations (joint recommendations) are transformed into temporary discard plans by means of delegated act. The regulations provide exceptions to this landing obligation. It does not apply to fish species with a high survival after returning them to the sea. There is also a limited deviation from the landing obligation if a fisherman can prove that it is impossible to carry out the selectivity measure or only after having to incur heavy costs. The term 'de minimis' is used in this context. This is the percentage of catches of certain species that can be legally released due to the above restrictions. The plans have a maximum duration of 3 years and the provisions of the landing obligation will eventually become incorporated into Multi Annual Plans (Fisheries - European Commission, 2019).

More information on managing fisheries can be found on the website of the European Commission and the Flemish government (https://ec.europa.eu/fisheries/cfp en; https://lv.vlaanderen.be/nl/visserij/visserijbeleid).

6.3 The Flemish Policy

Flanders translates the European fisheries policy into its own local situation, organizes the fisheries control and formal data collection. Flanders implemented the Covenant for Sustainable Fisheries and associated Fishing Trajectory ('Vistraject'). More information can be found in section 7.1 and on the website of Departement Landbouw en Visserij https://lv.vlaanderen.be/nl/visserij/visserijbeleid/convenant.

Technical measures

Fisheries technical measures are rules that determine the conditions under which fishermen may fish, so as to limit unwanted catches and the impact of fishing on marine ecosystems.

The framework is principally structured around two types of measures:

The common technical measures apply to all EU sea basins and have a permanent nature. They include provisions on prohibited gear and practices, protection of sensitive species and habitats, restrictions on the use of towed gears and static nets (including existing restrictions on the use of driftnets), measurement of a marine organism's size and the use of catches below the minimum size, and reduction of discarding.

The regional technical measures, applicable to a specific area, are set out in the annexes to the proposal. They define the minimum conservation reference sizes (i.e., the size of a marine organism below which its capture through fishing should be avoided), the mesh sizes, the areas closed or restricted to fishing, the mitigation measures for sensitive species, and the use of electric pulse trawls. These measures are supplemented by general principles for regionalisation, delegating to the Commission the power to establish regional measures, in particular under multiannual plans and temporary discard plans, based on joint recommendations submitted by regional groups of Member States (EPRS, 2018; Verordening (EU) 2019/1241).

6.4 Brexit

During the referendum of 23 June 2016, 52% of the participating British people opted for the United Kingdom's exit from the European Union. According to various studies, the Brexit will have negative consequences for the European fishing sector (Bartelings et al, 2018). The United Kingdom (UK) cut its ties with the European Union on January 1, 2021. This affects agriculture and fisheries. The UK develops its own agricultural policy, departing from the Common Agricultural Policy (CAP). Trade in agri-food products will also be less smooth, as the UK will then no longer be part of the internal European market. As far as sea fishing is concerned, the situation remains very unclear. In any case, since January 2021 third country legislation is applied to our trading relationships with the United Kingdom.

In addition to the trade and cooperation agreement between the EU and the UK, a transition period of 5.5 years has been foreseen for the fisheries sector, to ensure access to the 12-miles zone and 200-miles zone in exchange for a quota transfer that will be phased in until 2026. This is followed by annual negotiations on the access of European vessels to British waters. The agreement also provides for a level playing field: a Party may only apply measures to vessels of another Party in its waters if it also applies the same measures to its own vessels. The agreement goes into quite some detail about the procedure to be followed for the annual determination of the TACs, and also provides for a dispute settlement if both parties do not agree.

After the transition, we will have to negotiate annually with the British about quotas and access. For the aspect of access, the Privilege Charter remains a relevant legal document. On fishing quotas, the negotiating teams have reached an agreement whereby 25% of the value that European fishing boats fish today in British waters will be returned to the British. Fish species that are strongly present in British waters such as sole, rays, anglerfish and plaice are very important to Flemish fishermen. This therefore has serious consequences for Flemish fishermen.

The most radical changes for the Belgian fishing sector are related to the applicable regulations, access to British waters for European vessels, the establishment of (temporarily) closed zones in British waters and the uncertainties about landing in British ports.

Since 01/01/2021 fishermen need a specific fishing authorization to fish in the exclusive economic zone of British waters. The Brexit agreement stipulates that "qualified vessels" will be issued with a fishing authorization for the 6- to 12-mile zone (British territorial waters). Qualified vessels are those vessels (or their immediate successor) that can demonstrate a historical presence in the 12-mile zone for 4 years between 2012-2016. It was announced that the United Kingdom would grant 17 licenses to Belgian fishing vessels that can therefore fish in British territorial waters (12-mile zone).

At present there are no additional technical measures in force in British territorial waters. Under retained EU law, the landing obligation will continue to apply in UK waters. However, it is important to note that the exemptions from the landing obligation currently in place in EU waters do not automatically apply in waters of the United Kingdom. Currently, most of the discard exemptions from the discard plans for the North Sea and North Western waters will continue to be retained as EU legislation. The United Kingdom will designate ports where fish can be unloaded for transit and sale in Belgium. Landings of catches in the United Kingdom must be reported electronically on the NEAFC server by means of an electronic PSC notification (Departement Landbouw en Visserij https://lv.vlaanderen.be).

7 VARIOUS INITIATIVES IN THE BELGIAN FISHERY

7.1 Vistraject – an improvement trajectory for the Belgian fishery

Flemish Minister for Fisheries Hilde Crevits, the Rederscentrale, Natuurpunt, ILVO, the Department of Agriculture and Fisheries and the province of West Flanders signed the new Flemish covenant for sustainable fisheries 2021-2025 "On course to sustainability" in Ostend on 22 June 2021. The six partners are committed to working on sustainable, high-quality and fresh local fish and thus contribute to the objectives of the European Green Deal. The ambitions of the new covenant are situated on three different levels: to protect the natural and social environment, to produce and process ashore fisheries at sea, and to communicate with consumers.

The fishermen guarantee quality fish from board to plate. Together with their partners they claim to attach great importance to sustainability. Sustainability in terms of fishing, but also in terms of good conditions and safety for the crew and correct information towards the consumer. With this third covenant, the partners will continue on this path in the coming years. Fishermen and conservationists enter into a dialogue to increase knowledge about marine ecosystems. Fishermen collect data at sea for scientific research, after which scientists can process it into clear recommendations for fishermen. In this way, the Flemish fishery can continue to evolve sustainably and guarantee the consumer fresh fish that scores high in terms of quality with respect for the biological environment at sea.

The seven roads to sustainable Flemish fisheries according to the covenant:

1. The Flemish fishery contributes to ensuring that all commercial fish stocks are within safe limits.

   Sustainable management of fish stocks will allow for stable fish catches in the long term that fishermen can reel in with less effort, reducing fuel expenditure and reducing carbon emissions. In addition, a better catch composition with larger specimens could contribute to higher market prices.

2. The fishing fleet has a minimal impact on the ecosystem.

   The search for sustainable fishing techniques that have a minimal impact on the environment and increase the selectivity of catches will continue. The indirect negative impact on water quality and air quality is also taken into account.

3. Nature at sea is protected.

   Fishermen and conservationists work together to protect nature areas in the sea. Fishermen in training learn about the functioning of the ecosystem, Natura 2000 and protected animal species, so that there is a greater understanding of the necessary protection measures.

4. Shipping companies are economically viable.

   Economically profitable shipping companies form a solid basis for investing in ecological and social goals. The use of alternative techniques on board and on the fishing gear increases profitability. Information campaigns and certificates show consumers the way to sustainable fish.

5. Small-scale and coastal fisheries.

   The local small-scale and coastal fisheries have a separate problem that needs a specific approach because their reach away from their home port is much more limited and their possible fishing grounds usually have to be shared with other activities at sea and/or nature conservation.

6. A socially responsible fishery.

   The fishermen are satisfied with their job, their wages and work in safe working conditions.

7. The new fishermen.

   A job as a fisherman is once again popular with young people. The new generation of fishermen is trained within a broad maritime education to become 'guardians of the sea' and skilled entrepreneurs, so that they are well prepared to start their future as fishermen.

The heart of cooperation is The Task Force with different working groups consisting of all stakeholders in the sector that come together to discuss the needs of the stakeholders in relation to the covenant. During the annual meeting of the consultative group, the progress is measured, whenever possible by quantitative indicators. The covenant also demands a regular personal contact between vessel owners and scientists.

7.2 GeoFish: selection of fisheries data interactively displayed on geographical maps

The online tool GEOFISH, developed by ILVO, provides spatial visualisation of fisheries-related data and marine spatial planning (Van Hoey et al., 2020). Among other things, the tool quickly visualizes the status of a fish stock, as prepared by ICES. In terms of spatial planning, a clear picture is formed of activities or possible restrictions (marine nature reserves, wind farms, Brexit) that affect the economic importance (expressed in fishing hours, landings) for the Belgian fishing sector.

The tool is a useful tool for the fishing sector, which has been under pressure for several decades: high fuel prices, catch restrictions but also available fishing grounds are increasingly regulated by numerous (European) laws and directives. Also, with more intensive use of space in marine areas, there is increased competition between fisheries and other maritime sectors for fishing grounds (e.g. offshore energy) and nature restoration (Natura 2000 sites) (Figure 7-1). This can lead to conflicts and also makes fishing more and more regulated in space and time. For fishermen but also for policymakers, it is difficult to keep an up-to-date overview of all the (rapidly changing) information applicable to the sector, and to decide how best to deal with it.

The GEOFISH tool provide following information in an interactive way:

1) Data on spatial planning in Belgian fishing areas, displaying spatial and/or temporal implications (cf. section restrictions) for the Belgian fishing sector.
2) Economic data in and around fishing grounds where the Belgian fishing sector is active. There are layers visualizing the activity (fishing hours) or effort of the total catch or for 13 species specific (in kg and euro's). This layer is only available for fishery scientist, policy and the sector. This ensures, on the one hand, that the sector is in a stronger position in the discussions around possible new closures and on the other hand, these data can reveal new opportunities.
3) Bringing together information around the biology and occurrence of sole, with a focus on their spawning grounds (Pecceu et al., 2020). Furthermore, it was also examined what measures are already currently in place in these areas to protect the sole population (cf. VISTRAJECT objective).
4) A representation of the fish stock status (37 species) within the different ICES areas.
5) A quota and exploitation info for 37 species, available as an info sheet (static reporting, no visualization)
6) An extensive digital map archive, which can be searched interactively.

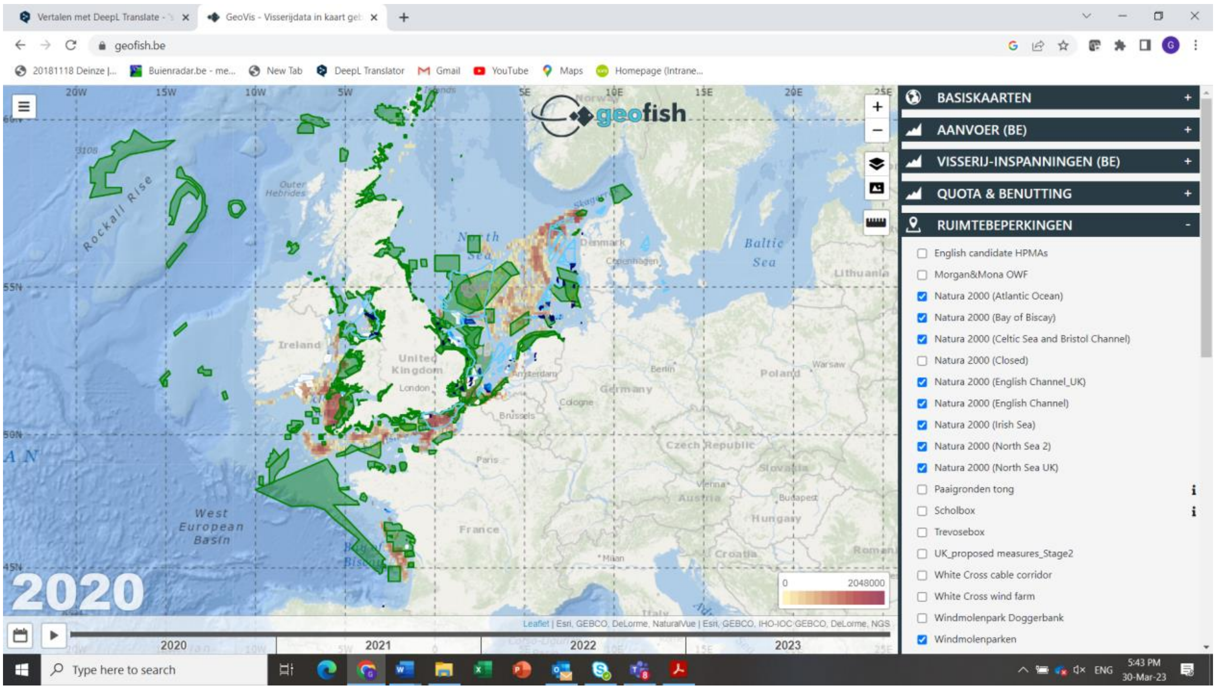


Figure 7-1: Print screen of the Geofish tool with indication of the Natura 2000 sites and offshore wind farms (situation in 2020).

The GEOFISH tool offers a solution through interactive visualization: the user selects the data of interest to him and the tool projects it onto geographical maps. This facilitates interpretation of the data and immediately shows variations between areas and between years or seasons. Fishermen and policy are also informed by the tool of possible restrictions on fishing grounds now and in the future. In turn, policymakers can use the interactive tool during negotiations around land use and possible compensations. Finally, the tool can also be used for wider communication to the public, such as on the annual review of the status of fish stocks (Figure 7-2).

On August 2023, 110 users have asked for access to the GEOFISH portal, whereof 75 are accepted according to the security rules. The majority of the users are scientists or policy makers. 10 users are fishers, which is rather low, but can be enhanced by adding near real time quota & exploitation info to the portal. An option that will be explored for a GEOFISH2.0 project. An update of the GEOFISH tool is required, as the Marine spatial planning in European seas (update of Natura 2000, wind farm layers) is further accelerating and the fishery activity data need to be available for sector and administration in much. Also, the technical set-up of the platform needs to be re-organized, so that it is more user-friendly (e.g. species info on landing, quota, exploitation & stock status grouped; security regulation; automatization of layer development, linkage with Polaris database, WMS/WFS services, ...). And the GEOFISH platform has also incorporated other fishery related project info, specific additional restriction layers, which need to be better structured and more to come (e.g., VISTools).

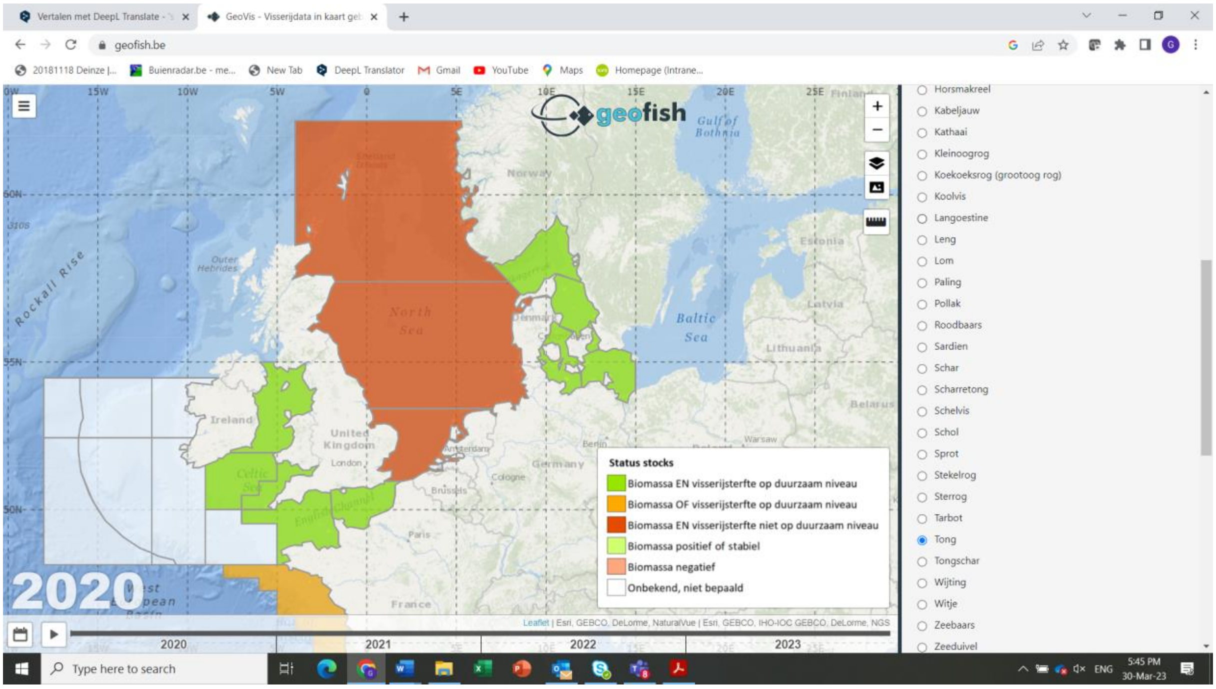


Figure 7-2: Printscreen of the Geofish tool with indication of the stock status of sole in 2020.

7.3 Belgian marine spatial planning initiative

A Belgian Marine Spatial Plan has been under implementation since 2014 in order to achieve Belgian ecological, economic and social objectives. This plan lays out principles, goals, objectives, and long-term vision, and spatial policy choices for the management of the Belgian territorial sea and EEZ (Figure 7-3). Management actions, indicators and targets addressing marine protected areas and the management of human uses including commercial fishing, offshore aquaculture, offshore renewable energy, shipping, dredging, sand and gravel extraction, pipelines and cables, military activities, tourism and recreation, and scientific research are included. The plan will be reviewed every six years and is legally binding. The MSP of the second cycle (2020-2026) entered into force on 20 March 2020. In 2023, the MSP process for the third cycle is started, with the aim to have an updated MRP in 2024. This update will be valid for 8 years, running from 2026 to 2034.

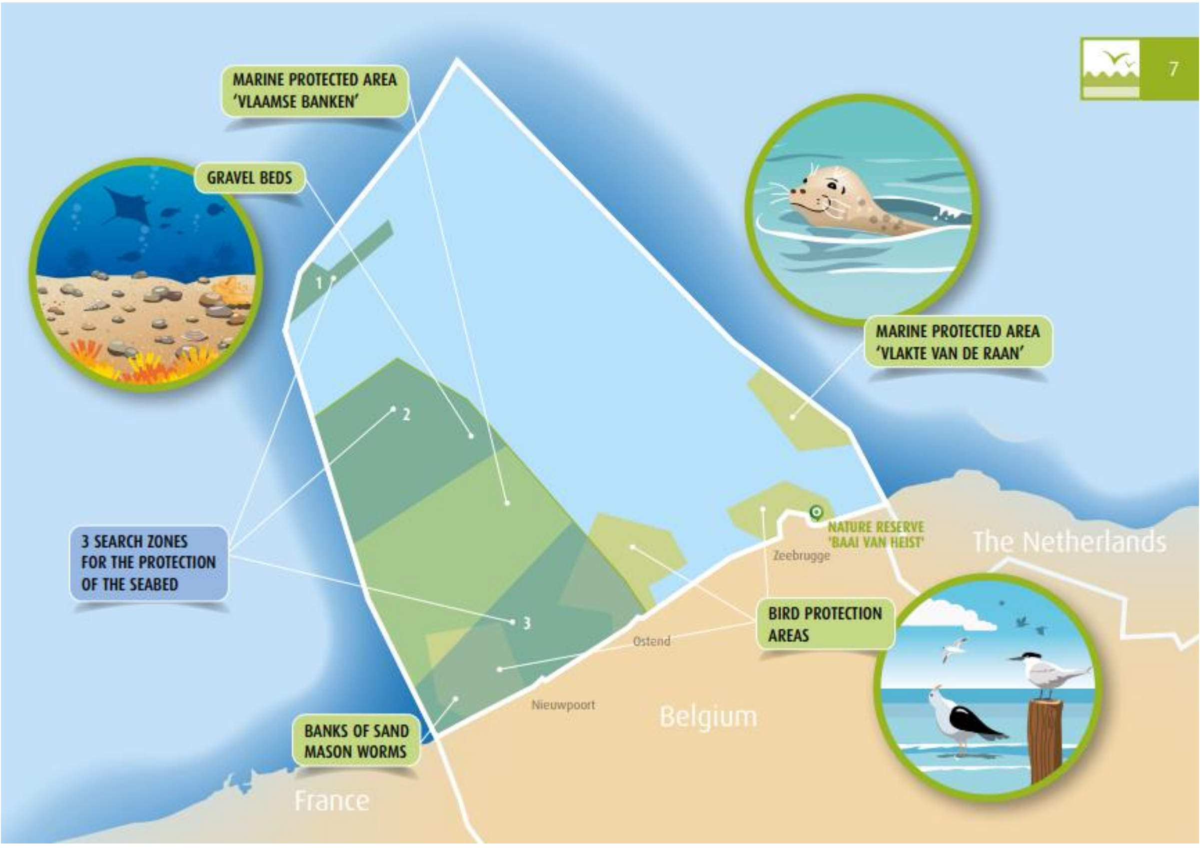


Figure 7-3: Brochure something is moving at sea (2020-2026)

In this plan, 3 search areas have been designated, two of which are within the 'Vlaamse Banken'. Within these zones, restrictions can be imposed on activities that affect the seabed in order to ensure nature restoration and conservation. Belgium is currently in the process of implementing management measure (fisheries restrictions) in these areas. For this process, ILVO and KBIN has made a detailed study (Pecceu & Paoletti et al., 2021) for a good determination of the fishery restriction areas, taking into account the nature conservation goals and socio-economic value of the areas for the fishery sectors. This resulted in a proposal of 3 areas within the search zones, made by the FOD Leefmilieu, wherefore a national and international consultation process is ongoing (2023-2024) to come to an EU delegate act. As part of this process, ILVO will publish a report in autumn 2023, with an updated evaluation of the socio-economic consequences for the fishery sector on this Natura 2000 management action.

7.4 Technical innovations in beam trawling to reduce bycatch and improve survival

The introduction of the landing obligation poses a major challenge for the Belgian fishing sector, since it mainly practices mixed beam trawling. In order to assist the sector in dealing with the landing obligation, ILVO and Rederscentrale intend to reduce the catch of choke species and other bycatch in beam trawling and improve survival development and refinement of technical innovations.

During the Combituig project (2018 – 2020) different innovations were tested to reduce choke species and other bycatch species in the net. Intense communication with and strong participation of the sector was important. Several innovations were tested in lab conditions and/or during sea trials on commercial and research vessels. Next to more common innovation types like benthic release panels (BRPs) and larger cod-end mesh-sizes, also more experimental innovations such as LED-lights, laserbeams and whirl spoilers (Figure 7-4) - a design by fisherman Job Schot aiming to lift the chain mat and create extra turbulence in the water - were tested. Evaluation on commercial vessels was done by means of self-sampling by the crew, followed by an extensive catch analysis by ILVO.

Figure 7-4: Picture of fisherman Job schot and his 'whirl spoilers'

The most successful story was the use of LED light. Various experiments were carried out which showed that a LED rope (a series of LEDs in a tube that was also inserted into the net) in the BRP could lead to a significant reduction of the by-catch of undersized plaice, without loss of commercial sole (Figure 7-5).

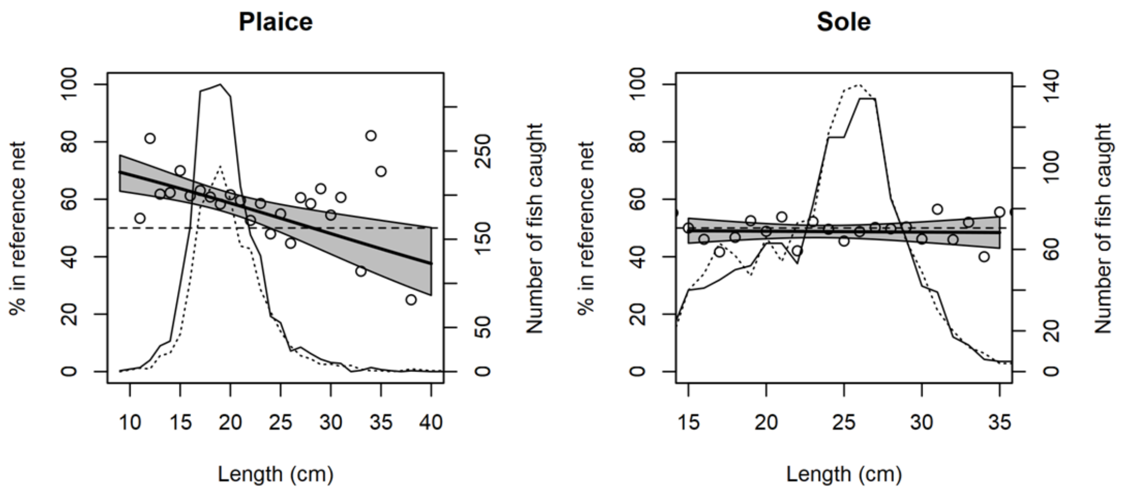


Figure 7-5: Proportion and length frequency distributions of plaice (left) and sole (right) that were caught on RV Belgica trials where we compared a net with LED-BRP (dotted line) to a net with a reference BRP (solid line). The left Y-axis indicates the proportion of fish retained in the experimental net (LED-BRP / (LED-BRP + BRP)) per length class and the right Y-axis gives the total number of fish caught. The horizontal dashed line represents the 0.5 proportion with the solid curve showing the modelled mean proportion of fish per length and the grey band indicating the 95% confidence interval.

The survival experiments of plaice showed that the longer a tow lasted, the smaller the chance of survival became. Dedicated sea trials on board of RV Belgica showed that after a 1-hour tow, 75% of the fish survived the following three days of monitoring, while after a 2-hours tow less than 25% survived the following three days. Injuries caused by the net, exposure to air and catch composition also had a negative influence on survival, while the effect of plaice length was positive (the larger, the higher the chance of survival). (referentie eindrapport combituig)

In a follow-up project called 'LED there be Light' (2021-2023) ILVO and Rederscentrale intend to further develop and optimize innovations in different fishery types from the Belgian fleet in order to reduce bycatch and/or optimize commercial catches. The project aims to evaluate the possibility to incorporate luminescent net material, LEDs (Figure 7-6), and other light sources into different net designs in different fishing techniques practiced within the Belgian sector. We evaluate whether different light wavelengths (colors) and frequencies (flickering speeds) can obtain equivalent or better results. The effect of environmental factors such as turbidity, temperature, depth and light levels, which all influence the effectiveness of the LED on the catches, is studied in more detail.

Figure 7-6: Picture of an illuminated BRP.

7.5 VISTools

A skipper of a fishing vessel has access to various sources of information that help him manage his work. Navigation instruments and sensors track the location (e.g., GPS/VMS), monitor any fishing activity (e.g., towing force, depth), fuel consumption and register landed catch (i.e., via an electronic weighing scale). These sensors gather valuable data, but none of that are of any use, if data are not integrated, stored or processed.

By automating data collection from conventional on-board equipment, adding additional sensors (CTD, TBD, weather station) and coupling this information with economic parameters (e.g. fish prices and fuel prices), the VISTools-project achieved;

1. The hardware development of a central hub for the automatic data gathering on board of a fishing vessel (concentrator). This includes data from conventional on-board equipment (towing force, fuel consumption, catches, GPS and depth) and additional sensors fixed to the fishing nets (CTD) or other parts of the vessels (for instance, fish hold temperature)
2. The development of a business intelligence tool for fishers presenting the processed data in a simple and accessible way on graphs and maps, ready for in fisheries evaluation and planning
3. The groundworks for private and protected information exchange for research purposes.

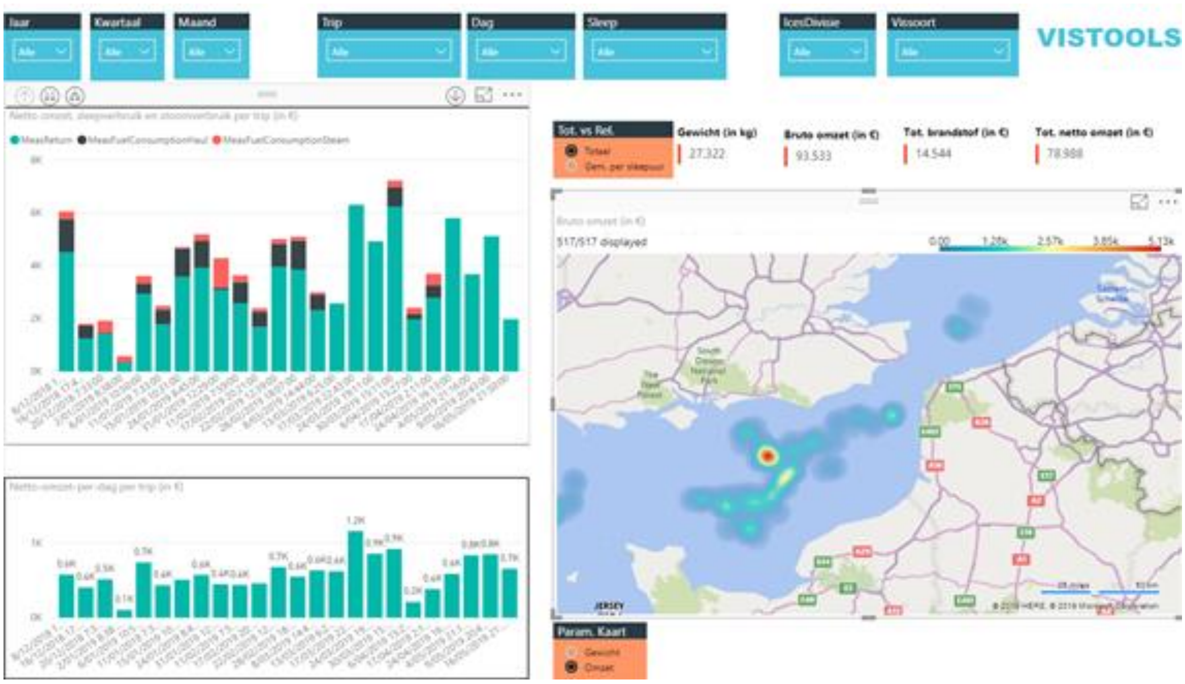


Figure 7-7: A screenshot of the VISTools PowerBI interface showing the different information related to the fishing activity of the vessel.

With this approach, fishers gain new insight in the economic performance of their fishery, while exchanging valuable high-resolution data with research institutes. This is a fully automatic process that does not entail unnecessary burdens on the fishers themselves.

The current system is operational on 5 vessels, with a planned upscaling to a total of 40 Belgian vessels by the end of 2023. The fleet-wide coverage of the data offers new avenues for research including catch prediction and fuel-efficiency models. To develop this case, ILVO is participating as a pilot in the development of the Digital Twin of the Ocean, where the fuel data from VISTools will be enriched with oceanographic and meteorological data to better understand the fuel consumption of fishing vessels within the marine environment. With these models, decision support tools can be developed that balance the trade-offs between the profitability of a vessel and reducing fuel consumption and the impact on the environment.

7.6 Fuel analysis

A detailed fuel analysis is being conducted to examine the fuel use of the Belgian fishing fleet. This consists of two main components. In the first part, which is currently carried out, the evolution of fuel consumption per vessel over the years is examined using government data. In the second part, the potential impact of vessel renewal on reducing fuel consumption will be assessed. For this purpose, VISTools data from the vessel Z-483 (Shipping company Nathalie) before and after the ship's renewal will be utilized.

The government data consists of information about the vessel, trips, landings, catch, sales and financial situation of a certain year. Note that the information about fuel use is on a yearly basis, limiting the possibilities to assess fuel consumption on a trip basis.

A selection of useful data for the analysis was made, after which it was cleaned. A correlation plot of the remaining variables is depicted in Figure 7-8. The figure indicates that less fuel is consumed in the more recent years compared to before and that the biggest correlation exists with the hours spend at sea and fishing as well as with the amount of catch. Other important factors that determine fuel consumption and cost are the technical characteristics of the vessel. Remarkably, the metier correlates poorly with the fuel consumption and cost. This is due to the fact that 74,4 % of the data points of this graph are the same metier, i.e., TBB_DEF-70-99.

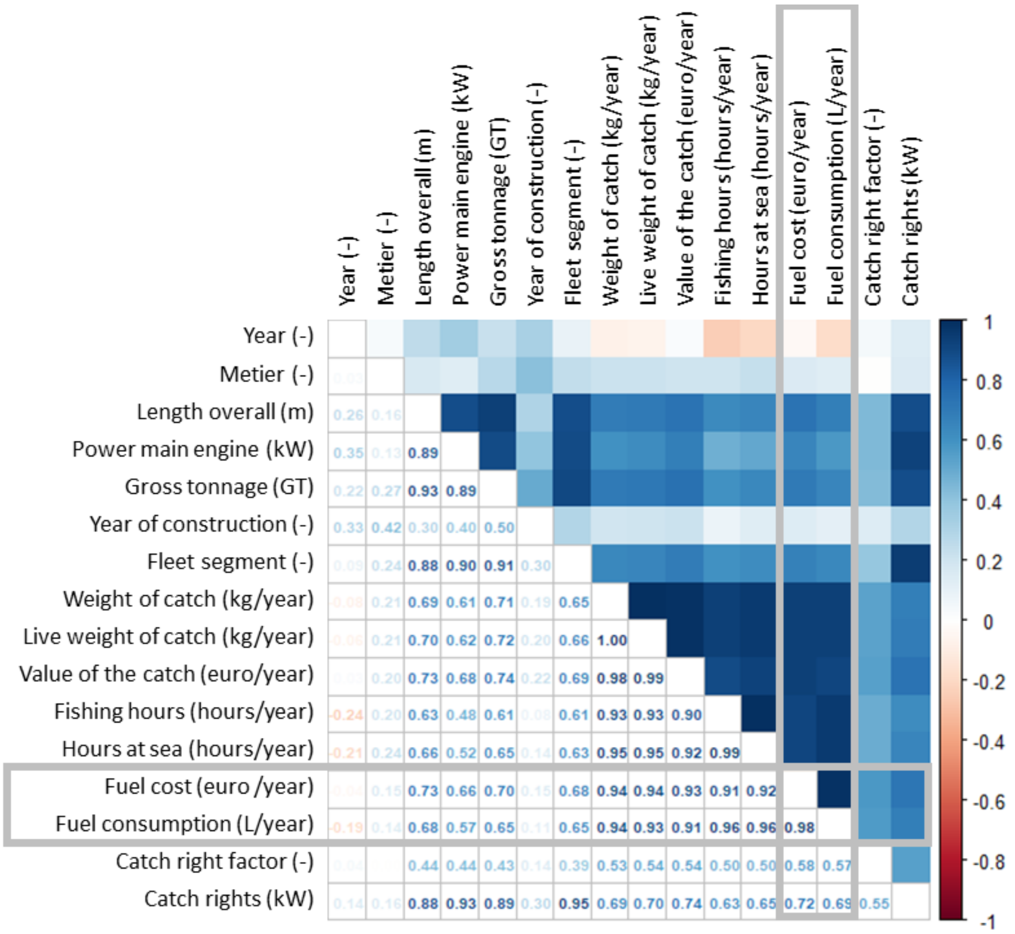


Figure 7-8: Correlation plot of the variables used for the fuel analysis. This graph only contains data for which the variables do not change within the year.

The trends of the fuel consumption per vessel over the years will be expressed in the following manners:

- Liters of fuel used per kg catch (= fuel use efficiency)
- Liters of fuel used per kW of the main engine
- Liters of fuel used per total kW (sum of real and fictitious power)

- Liters of fuel used per day at sea (= catch efficiency)
- Liters of fuel per day at sea per kW of the main engine
- Liters of fuel per fishing day per kW of the main engine

For each calculation, a distinction will be made based on metier and/or fleet segment. A practical report containing the findings of the fuel analysis will be completed by the end of 2023.

CONCLUSIONS

Despite the relative tiny Belgian coastline, the fishing fleet has always played an important role for the Belgian coastal community, with some 700 fishing vessels in the early 20th century, now reduced to less than 60. Despite this small number of vessels today, the Belgian fleet covers a very wide area of fishing grounds in the North Sea, the English Channel, The Celtic and Irish seas and the Bay of Biscaje. The main fishing gear since the 1960s has been the beam trawl with flatfish species like sole and plaice as target species. Besides the beam trawl, otter trawls, flyshoot gear, dredges and set nets have been and are being used but can be classified as marginal. The fleet consists of a subfleet of larger vessels with length over 30m and engine power around 1.000 kW, a subfleet of so called Eurocutters with length above 20m and engine power of 221 kW and a small subfleet of smaller coastal vessels. The larger vessels conduct sea trips of 5 to 10 days, the Eurocutter 5 days and the coastal vessels usually 24 hours.

The Belgian fleet performs quite well economically and is profitable, also during the Corona and fuel crises the last few years during which the fleet kept on fishing. The high value of the target species and the efforts of the fishermen to reduce fuel consumption have been the main factors in their profitability. The main challenges of the Belgian fishing fleet are discarding and seafloor disturbance. Due to the small mesh size needed to catch sole (80mm) and the highly mixed catches of fish and invertebrates, it is very hard to keep discarding at low levels. The fleet has introduced a number of discards reducing technical measures such as large meshes in the front top panel, large meshes in the extension in front of the cod-end, a benthos release panel in the belly and a flip-up rope which improves the situation. Despite these efforts, discarding remains at a relatively high level. The beam trawl has a bad reputation regarding seafloor disturbance. And it has indeed been scientifically proven that the beam trawl is an intensive and deep penetrating fishing gear. The impact, however, is highly dependent on the type of habitat. Recent research has indicated that the Belgian fishing fleet targets only a few percentages of its effort to highly sensitive habitats. Most of the effort is directed towards low to medium sensitive fishing grounds. Together with the observation that beam trawlers cover a relatively low area because of the small width of the fishing gears, the general perception of the impact of Belgian beam trawling is much higher than in reality. Despite this, the Belgian fleet has reduction of seafloor disturbance as one of its main targets for the next years. In a first step, the highly sensitive fishing grounds should be avoided.

Reduction of discarding and seafloor disturbance is stimulated by the fisheries improvement program "Visserij Verduurzaamt" and is strongly supported by the marine research institute ILVO and is based on building trust between stakeholders, good communication and flow of information and intense cooperation. One of the most important initiatives, however, is the VISTools-project where fishing vessels are being converted to data collection platforms. Since 2022, 5 fishing vessels have been fully operational and deliver real-time and detailed data to ILVO on catches, fuel consumption, position, speed, towing force, gear sensor for environmental parameters etc. During 2023 the initiative is expanded to the majority of the fleet. By the end of 2023, most of the fishing vessels will be delivering these data and as such, the Belgian fishing fleet is unique in the world. ILVO is also developing camera systems to analyse the catches and has the permission of a number of vessels to collect this detailed information for scientific purposes.

The Belgian fishing fleet still has a number of challenges but the so-called Covenant between sector, government, NGO and science developed a plan to improve sustainability for the longer term based on real change in a realistic way. As such, ILVO is developing a catch prediction model, based on the new detailed and high-quality data coming from VISTools, in order to help fishermen to target the wanted fish and avoid small fish and unwanted and protected fish. There also is a continuous effort to cooperate and find technical solutions to reduce discarding and seafloor disturbance. As such, the Belgian fleet has a long-term vision and strategy for a viable and sustainable fishery.

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