

Dragged gears

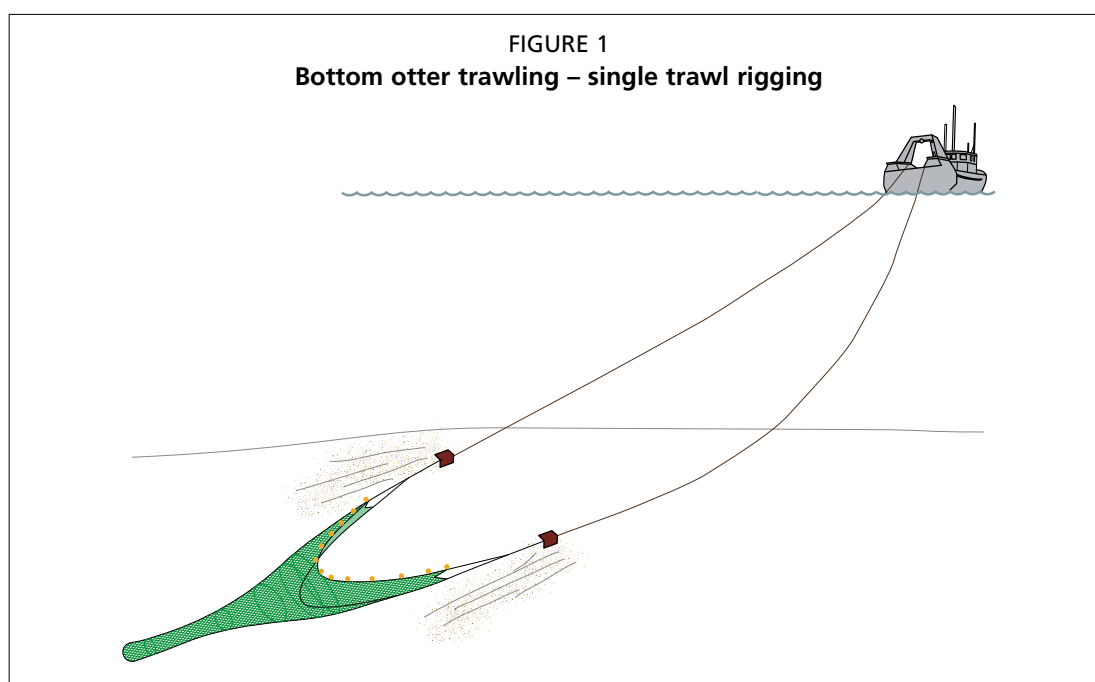
Dragged gear in the context of this document refers to bottom otter trawls, pair trawls and beam trawls.

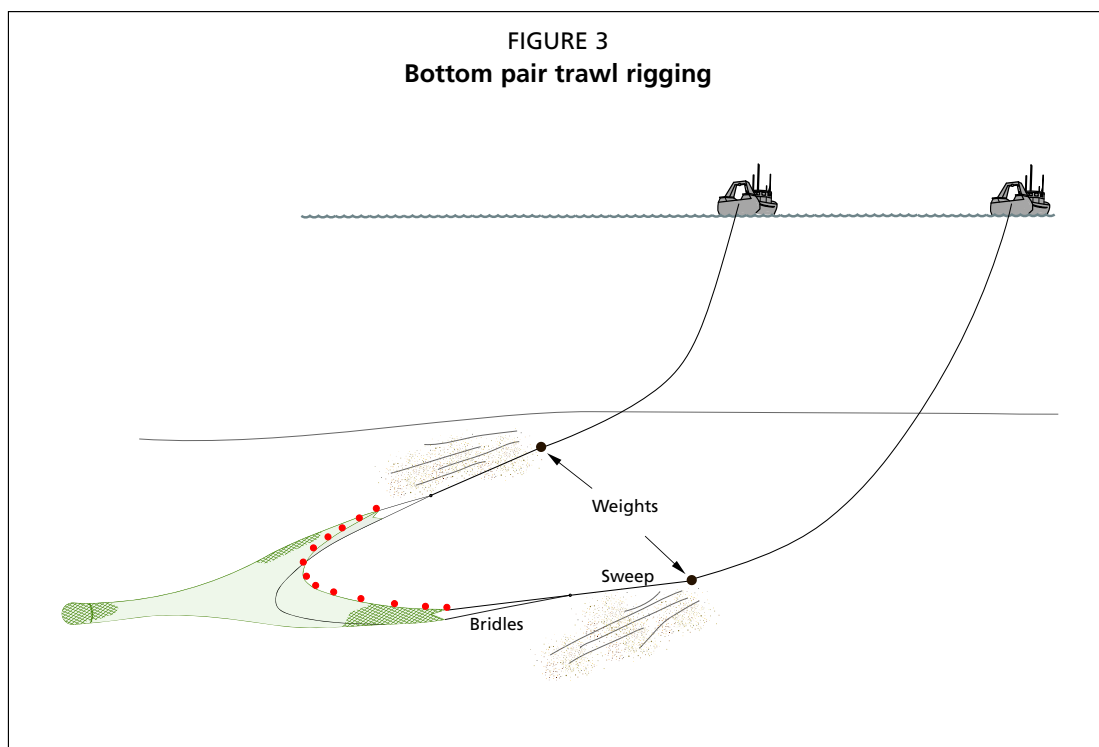
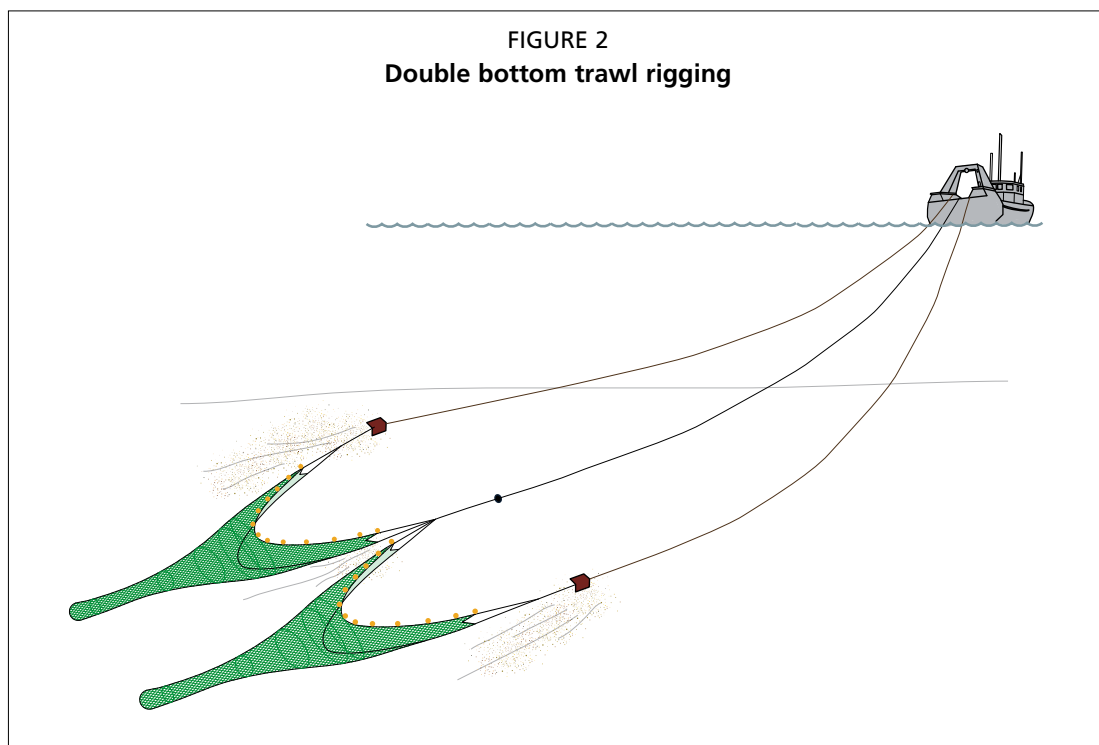
Bottom otter trawls encompass a large variety of designs, riggings and dimensions. Common components are a pair of otter boards (trawl doors), sweeps/bridles and one or more trawl nets (Figure 1). In a multirig configuration, weights are additional parts of the trawl system (Figure 2).

The main difference between a bottom otter trawl and a pair trawl is the lack of otter boards (Figure 3). Instead, the foremost contact points of a bottom pair trawl are often weights attached to the joinings of the towing warp and the sweep. For a beam trawl the mouth of the net is held open by a solid metal beam. Solid metal plates (shoes) are welded to the ends of the beam so that it can slide over the seabed (Figure 4). Often two parallel beam trawls are towed from outriggers by a single vessel.

Bottom trawling encompasses a wide range of gear designs and methods of operations. Towing speed ranges from 2 knots ($1 \text{ m}\cdot\text{s}^{-1}$) to 6 knots ($3 \text{ m}\cdot\text{s}^{-1}$) and fishing might be conducted at depths from 10 to 2 500 metres. The vessels operating bottom trawls might have towing bollard pull ranging from 200 to 70 000 kg.

Reduced impact of bottom otter trawling on the seabed can basically be achieved by minimizing the impacted area and by reduction of the pressure of gear components on the bottom.

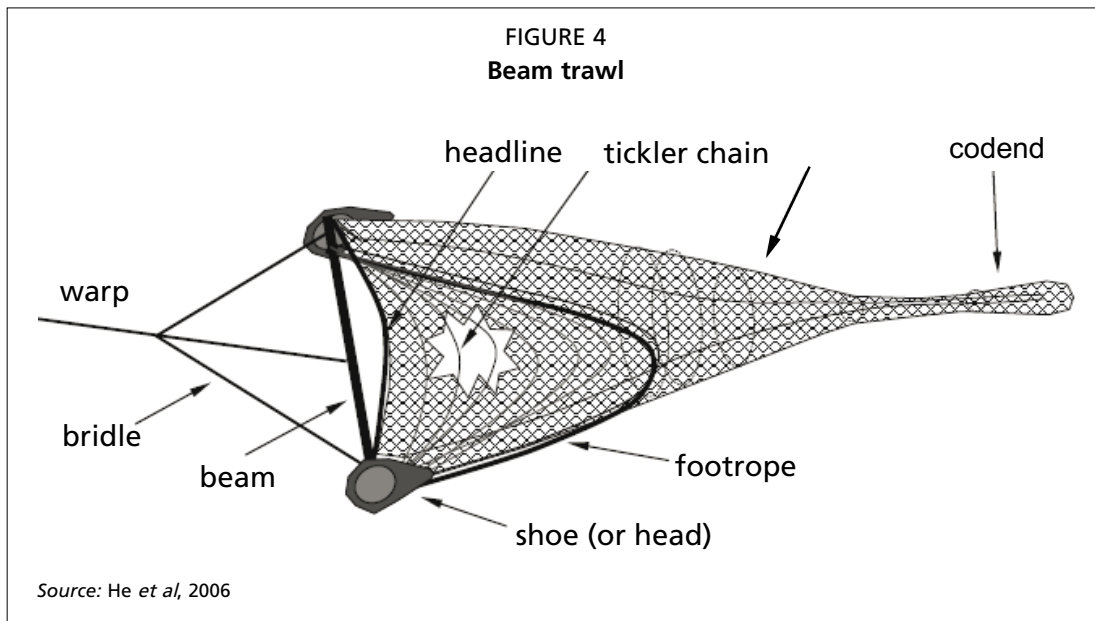




BOTTOM OTTER TRAWLING

Gear design and bottom impact

A bottom trawl design generally consists of netting divided into two wings, a belly and a codend (Figure 5). The front part of a trawl is framed with a headline equipped with floats along the top and a fishing line along the bottom equipped with various types of ground gears the purpose of which is to protect the netting

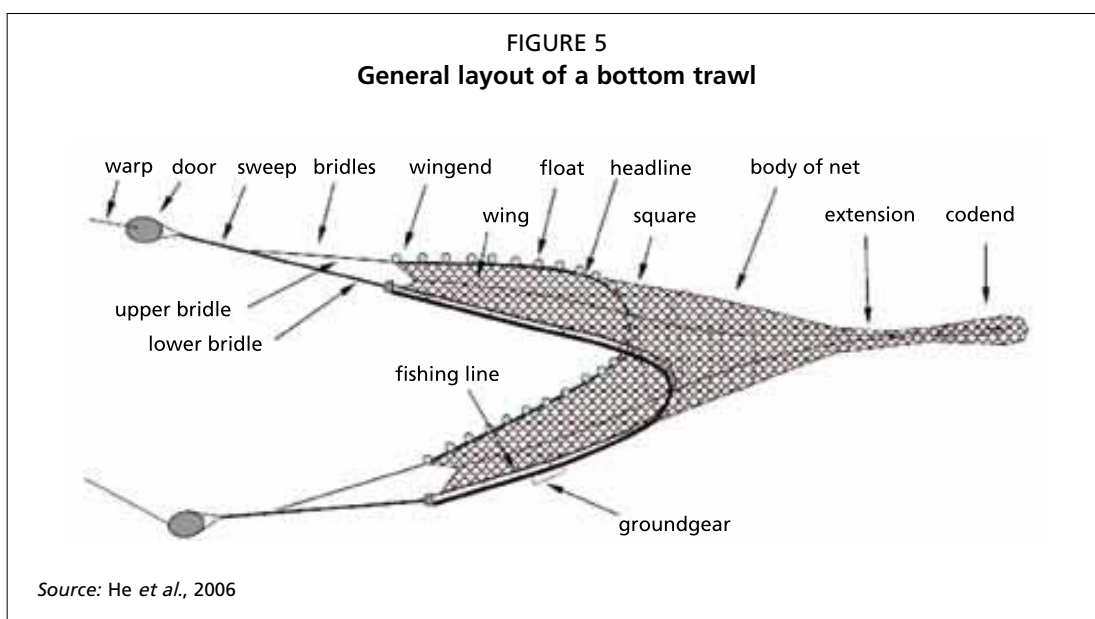


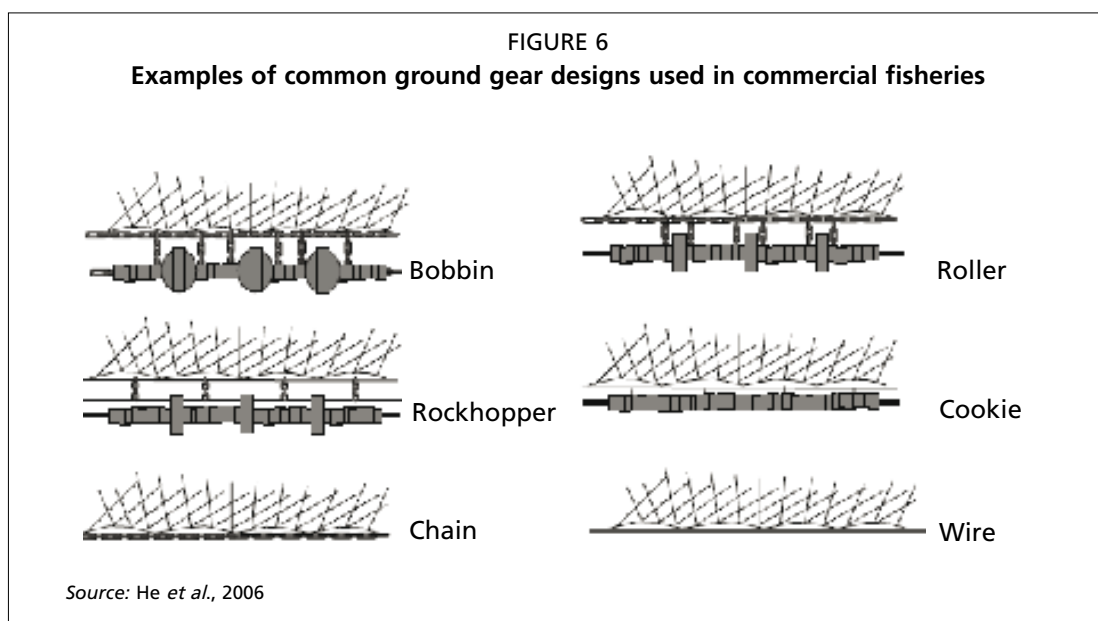
of the trawl from damage and to allow continuous towing without hook-ups. Typical ground gear designs in common use are illustrated in Figure 6.

In a bottom otter trawl rigging the trawl is held open horizontally with a pair of trawl doors which have three main functions:

- to open the trawl horizontally;
- to provide the front bottom contact points of the trawl gear; and
- to stimulate fish to swim towards the trawl path.

As for trawl nets, there is a wide range of designs and sizes/weights of trawl doors in common use. Traditional trawl doors were designed in such a way that they relied on the ground shear to spread the trawl (rectangular and V-doors). Such doors lost much of their spreading force when lifted off the bottom. Recent development has been towards more hydrodynamic efficient doors, maximizing





spread forces and minimizing resistance. Another recent trend is to increase the size and weight of trawl doors. Figure 7 shows some common trawl door designs. While towing, the shoe of a trawl door is often angled 25-40 degrees relative to the trawl track. When a door is 4 metres long, the width of the track is thus 2 metres with a door angle of 30 degrees. The track can be made narrower basically by reducing the angle of the shoe and by using doors with a higher height/length ratio (H/L). Both options are to some extent used in commercial trawl fisheries.

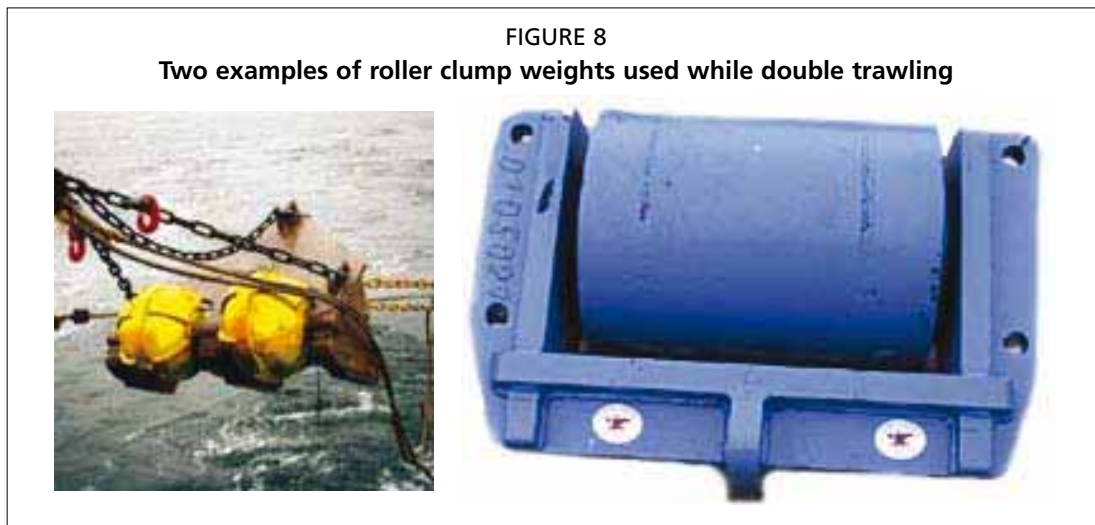
In a double trawl rigging a weight is used to achieve bottom contact of the front part of the inner sweeps/bridles located in the centre between the two trawl nets. This weight might be heavier than the weight of a trawl door (normally 30 percent heavier in double trawl riggings). The weights differ in shape and rigging, and their

effect on the bottom will vary. Two roller clump designs are shown in Figure 8. The doors and weights are connected to the trawl wings by sweeps or bridles (wire/chain/ropes). These connections vary in length from a few metres up to 300 metres. The lower bridle or sweep has normally bottom contact during towing. A selection of arrangements of bridle/sweeps is illustrated in Figure 9.



Mitigation of bottom impact

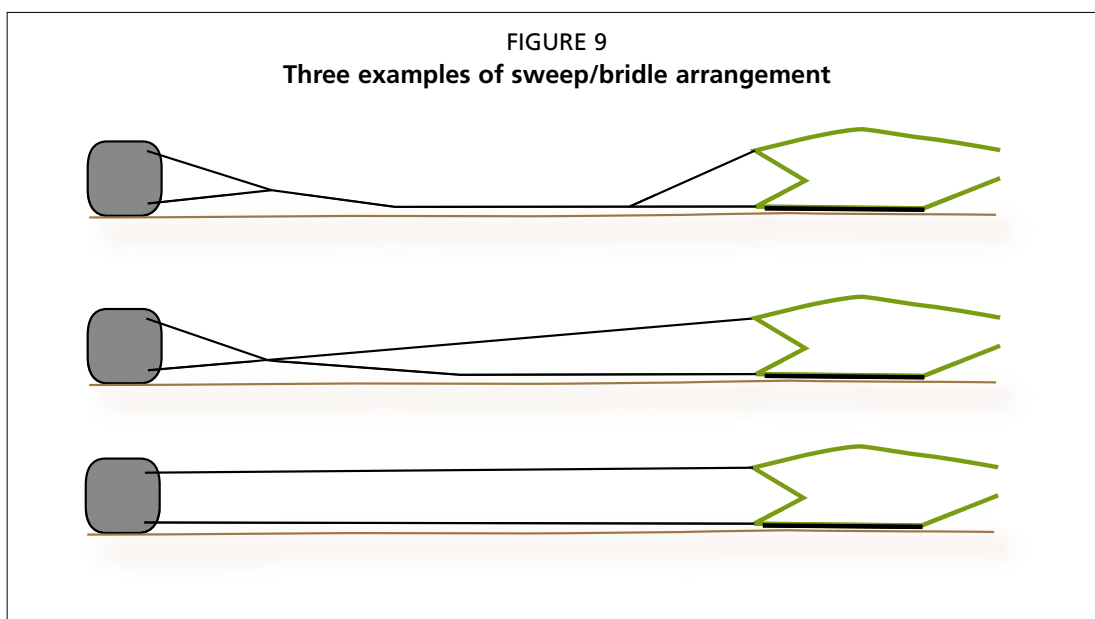
Trawl doors, weights, bridles/sweeps and the ground gear represent different components of otter trawl rigging, each with a specific impact on the bottom

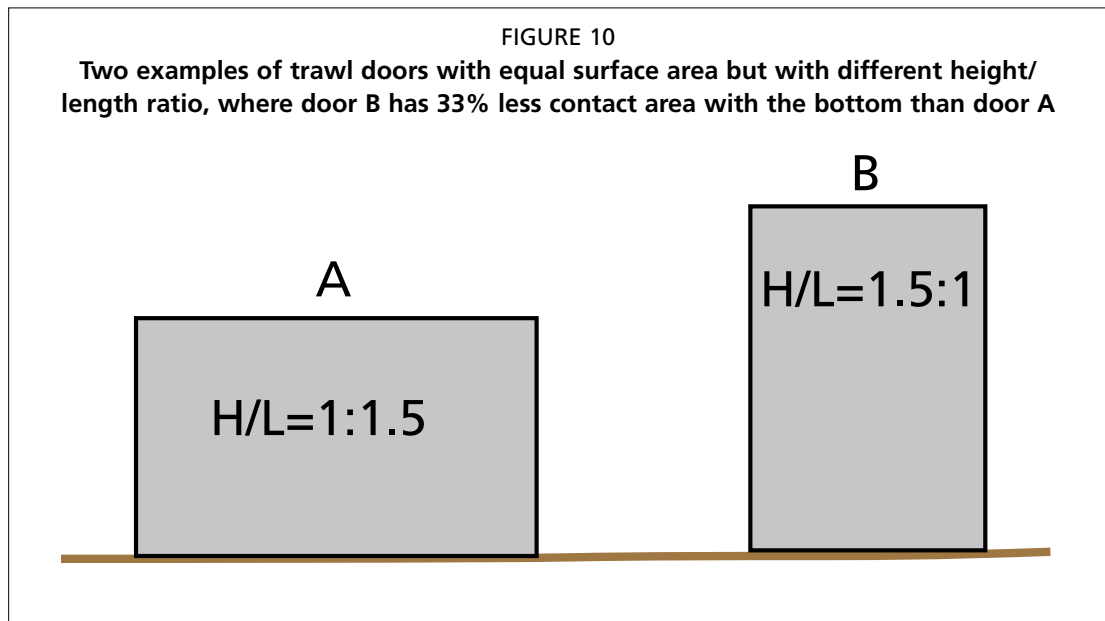


habitat. Types of impact and possible modifications to each gear component are therefore described separately below.

Trawl doors

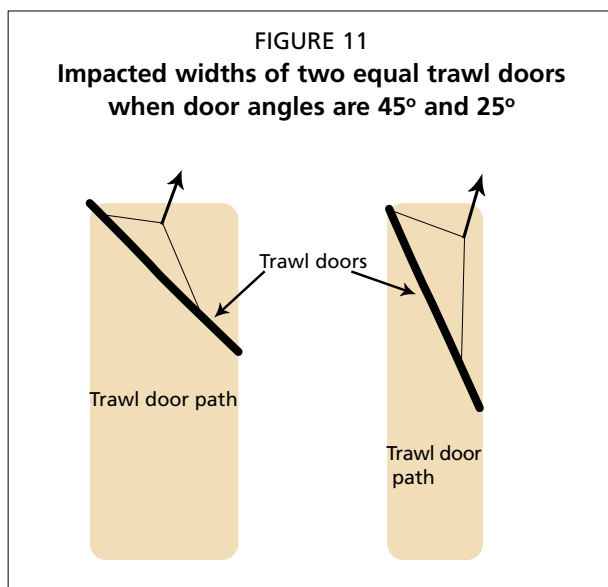
The trawl doors are often considered as the most significant source of bottom impact and the relatively deep and visible furrows they create in the bottom substrate are frequently easily seen on side scan sonar and video recordings of the seabed. Two trawl doors with four-metre long shoes towed at a 30 degree angle of attack will create two two-metre wide furrows on each side of the trawl path. Depending on whether the trawl doors are in a long sweep rigging with 150 metres door distance or in a short bridle rigging with only 30 metres door distance, the affected bottom areas of the trawl doors are then about 3 percent and 10 percent of the total area between the two doors, respectively.





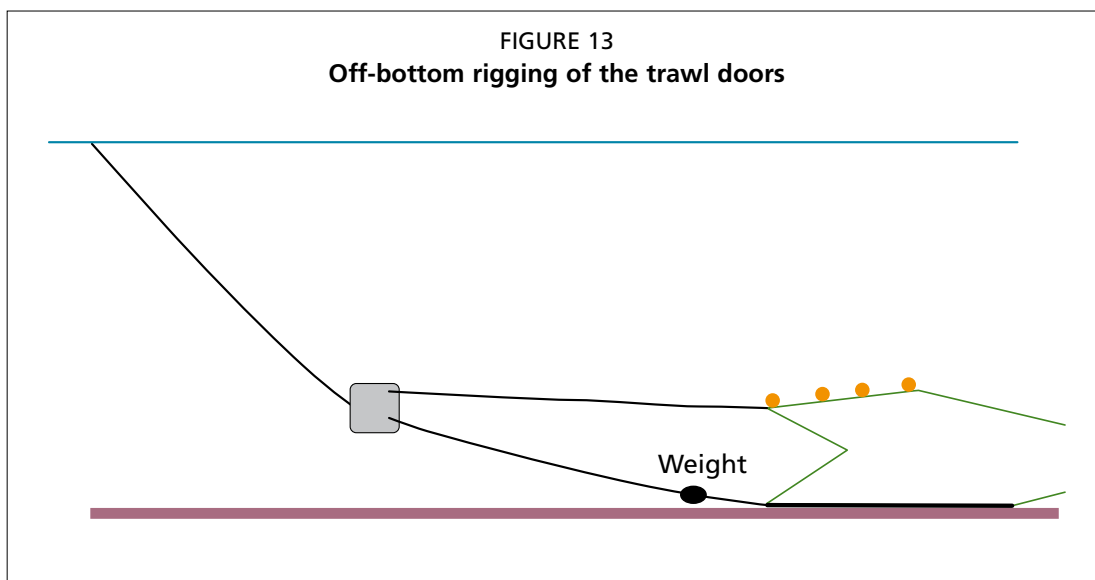
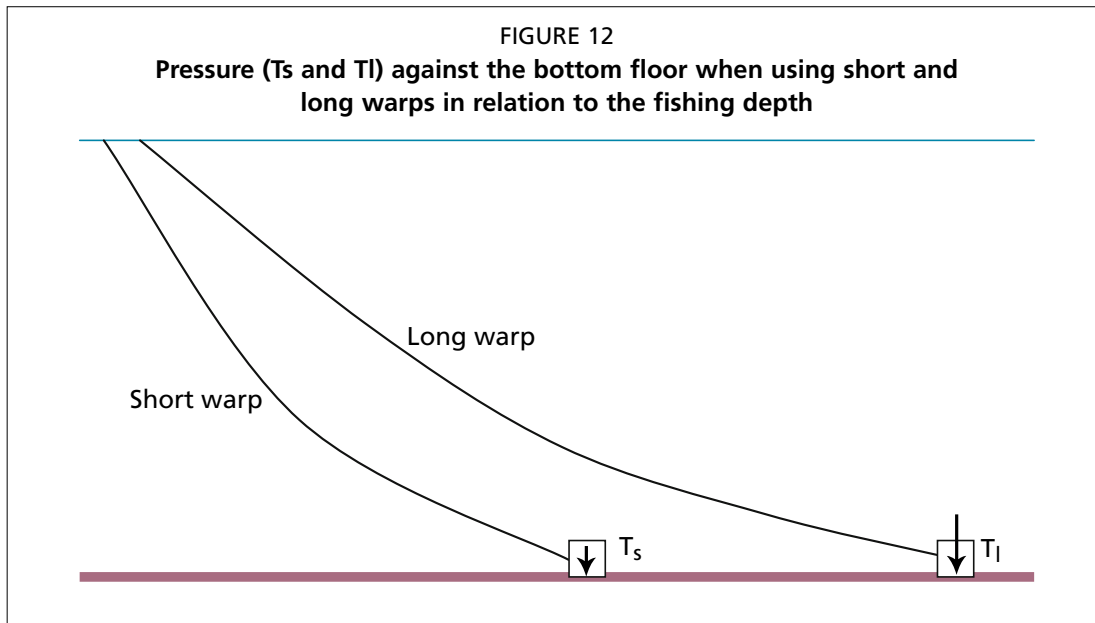
- There are basically four methods to reduce the bottom impact of trawl doors:
1. use of trawl doors with a higher aspect (height/length) ratio (Figure 10);
 2. use of trawl doors with a lower shoe angle relative to the towing direction (Figure 11);
 3. use of a shorter warp length relative to the fishing depth to achieve bottom contact (Figure 12); and
 4. off-bottom rigging of the trawl doors (Figure 13).

High-aspect doors are more hydrodynamically efficient than low-aspect ratio doors. Such doors are commonly used as pelagic trawl doors. The main reason for not using such trawl doors for bottom trawling is that they require more attention to keep them stable and vertical during towing. The recent development of gear instruments that monitor the vertical roll and pitch angles of trawl doors while towing may better facilitate the use of such trawl doors for bottom trawling.



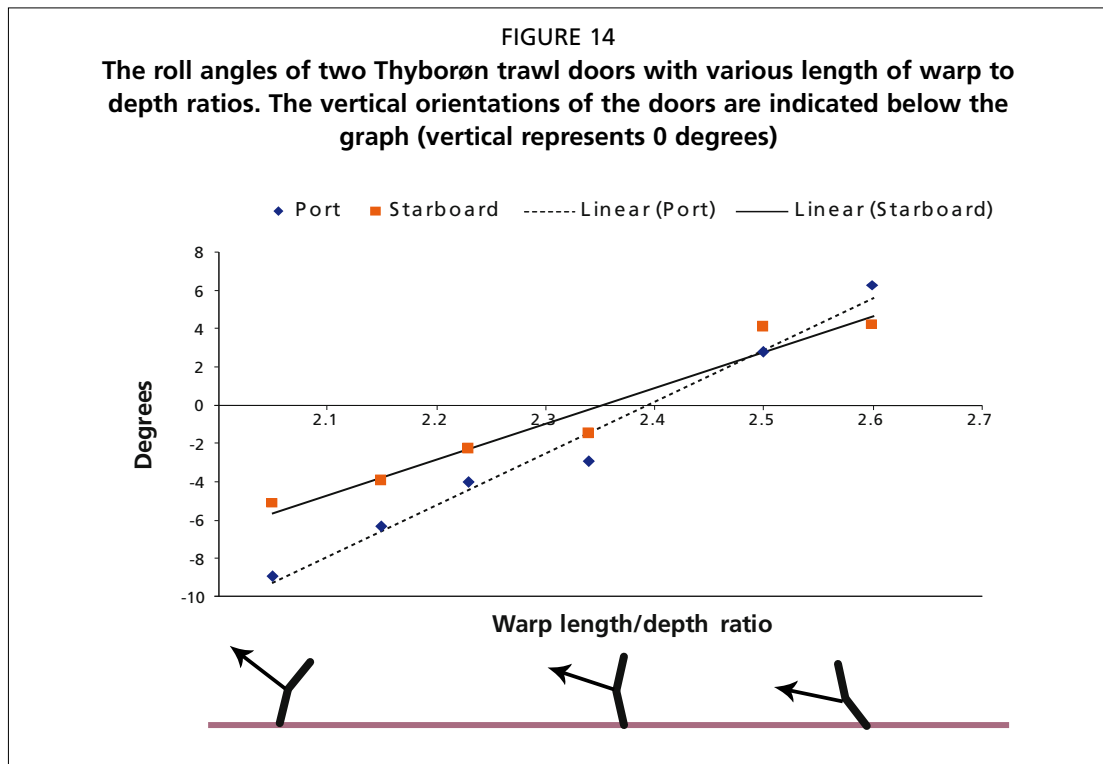
In conventional rectangular or V-door designs the shoe is parallel to the trawl door surface. In modern bottom trawl door design, however, the flat surface has been replaced with one or several curved surfaces. In these new curved designs the shoe angle is reduced, resulting in narrower furrows in the bottom.

Another practical solution to reduce the shoe angle relative to the towing direction is described by Sterling and Eayrs (2006). The shoe consists of a frame towed at zero angle of attack relative to the towing direction to which a light-weight polyethylene wing was attached.



Door performance is quite complex to describe but in simplified terms the pressure of a trawl door against the bottom substrate (BP) can be expressed as a function of the doors' weight (W), the warp tension (T) and the warp slope angle (α): $BP = W - T \cdot \sin(\alpha)$.

By shortening the warp length, the slope angle increases, resulting in an increased lift force $T \cdot \sin(\alpha)$. For a certain warp tension there is an angle when the lift force exceeds the weight of the door, resulting in a situation wherein the trawl door will lose bottom contact. In normal bottom trawling situations proper bottom contact of the door is regarded as important for efficient capture. Therefore, longer warp than required to keep bottom contact is often used in commercial fishing situations. This is done to be "on the safe side" and because methods to monitor "optimal" bottom contact requires special instrumentation. An indicator of bottom contact of the trawl doors is the roll angle of the door,



as most trawl doors heel inward when too long warp is used, while they heel outwards when the towing warp is too short. This effect on the door is illustrated on the graph in Figure 14 (Valdemarsen, unpublished). The optimal horizontal spread of a trawl door is normally achieved when it is vertical and therefore an optimal warp length often corresponds with optimal door efficiency.

Certainly the most effective method to reduce trawl door impact on the bottom habitat is to lift the doors off the bottom as illustrated in Figure 13. This measure, however, has a technical as well as a catchability disadvantage and will therefore not work in all fishing situations. Off-bottom trawl doors are mainly an option for target species that are not herded by doors and sweeps/bridles along the bottom, such as shrimp and nephrops. For such target species the mouth area of the trawl itself is the key parameter for the catching efficiency. The technical challenge with such rigging is to keep the trawl door distance above bottom nearly constant.

He *et al.* (2006) reported on the development and testing of such semi-pelagic rigging in the shrimp fishery in the Gulf of Maine (United States of America). In these experiments the door height was set above the seabed by adjusting the length of the warps when the distance of the doors to the bottom was monitored with acoustic instruments. Similar catch rates were obtained with this semi-pelagic trawl door rigging as with traditional trawl doors.

Monitoring the height of the trawl doors above the bottom requires appropriate instruments which can be used to adjust the door height by altering trawl warp length or, alternatively, the towing speed. An active control of the trawl door depth can also be achieved technically by adjusting the towing point and back-strops of the doors while towing.

Weights

The bottom impact of weights depends on the shape and design of the weight as well as the warp length/depth ratio. Reduced physical bottom impact of weights can thus be achieved by the use of:

- a shorter towing warp to reduce the downward pressure of the weight; and
- a narrower weight with rollers.

The clump used in double-rigged trawling matches the trawl doors with regard to bottom contact. The sweeps/bridles behind these front bottom contact points should have equal tension and bottom contact. An alteration of the warp length/depth ratio will therefore affect bottom contact of the clump as well as the pair of trawl doors. Active control of warp length requires proper monitoring of the bottom contact of the trawl door and the clump, which can be achieved by the use of sensors measuring the roll and tilt angle of the doors as already described.

The shape of a clump varies between producers as indicated in Figure 8. To reduce the width of the impacted area, designing a narrower clump is an alternative. The use of wheels under the weight might also reduce the pressure exerted on the bottom.

Sweeps/bridles

The sweeps/bridles in most bottom trawl situations have the largest contact area with the bottom. With 200-metre sweep lengths angled at 25 degrees relative to the towing direction, each sweep will be dragged across an 85-metre wide corridor totalling 170 metres in width for a single tow. The impact of sweeps/bridles dragged across the bottom is poorly understood but certainly affect protruding objects on the bottom. Possible mitigation measures are to:

- reduce the sweep/bridle length or angles of attack; and
- lift the sweeps/bridles off the bottom.

Short bridles are used in trawls when the wingspread is the important catch efficiency parameter, as in shrimp and nephrops trawls. In some trawl riggings the wings are therefore attached directly to the doors, e.g. for outrigger prawn trawlers. However, in situations when there is a need for vertical height to the trawl, two or more bridles connect the wings to the trawl doors. The lengths of such bridles vary, but are commonly 30–50 metres in deepwater shrimp trawling.

The impacted area of such short bridles can be made smaller by reducing the bridle angle. A possible solution to achieve this is to include spreading devices in the trawl itself in such a way that the wingspread is maintained while the door spread is reduced. This option has proven to work well with the self-spreading ground gear developed by Hansen and Valdemarsen (2006).

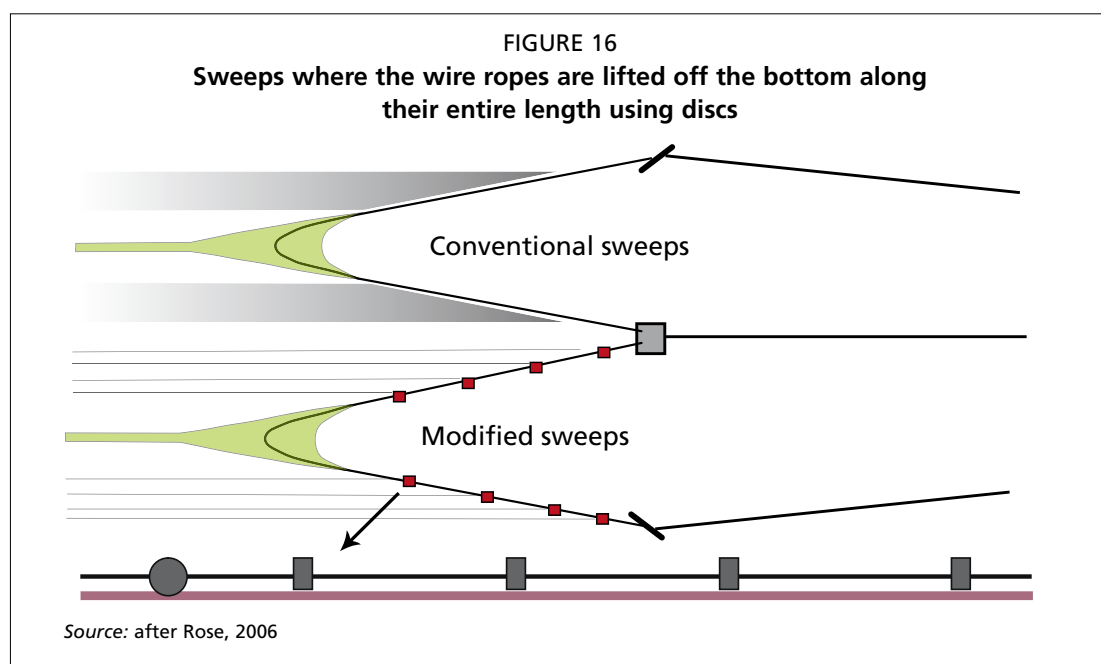
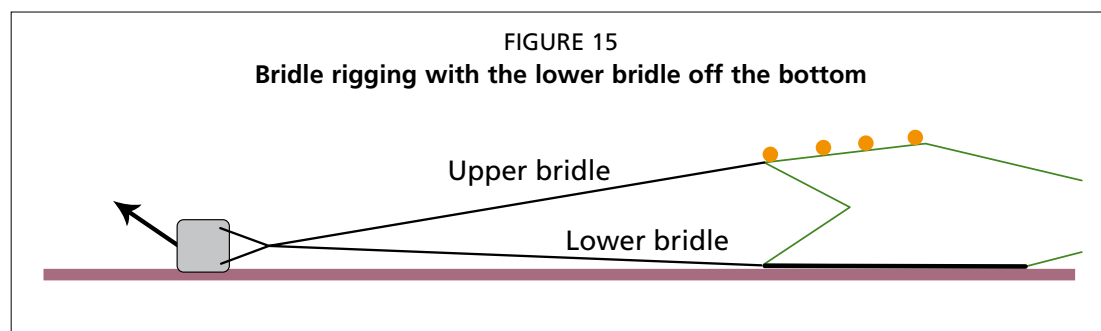
When trawling for species that are efficiently herded inward towards the central trawl path by the sweeps, the sweep length is probably the most important factor affecting capture efficiency. Shortening of the sweep length is therefore not an option in fisheries where long sweeps are part of the common rigging, as it will result in lower catch rates.

Lifting bridles and sweeps off the bottom is probably a more feasible option to reduce their bottom impact. For relatively short bridles (20-40 m), a possible technical option is to avoid bottom contact between the trawl door and the wing as illustrated in Figure 15. This option might require some heavy weights on the wing tip to ascertain proper bottom contact at this point.

With longer sweeps/bridles, inserting discs or bobbins at certain intervals along the sweep is a possible option to raise the sweep cable off the bottom as illustrated in Figure 16. The diameter of the rollers and their spacing determines the clearance below the sweeps as well as their weight in water. This solution has successfully been developed and tested in the Bering Sea (Rose, 2006).

Ground gear

As illustrated in Figure 5, a wide range of ground gear designs are used on bottom trawls. The length of ground gears range from approximately 10 metres in small inshore trawls to nearly 100 metres in some large deepwater shrimp trawls. As the ground gear frames the bottom mouth of the trawl, it is of vital importance for both trawl protection and to get fish into and not under the trawl.



Fish herded inward by the sweeps/bridles often continue to swim in the trawl mouth in front of the ground gear until they are fatigued and are overtaken by the gear. The capture success then depends on how many fish are overtaken by the trawl and end up in the codend, and how many are able to escape over or under the trawl. The under-trawl escapement for many species is significant (e.g. Ingolfsson and Jørgensen, 2006) and therefore the challenge for efficient capture is often related to the ground gear design.

A ground gear design that balances proper trawl protection, minimum bottom contact and minimal under-trawl escapement of targets is obviously the ideal ground gear. As these somewhat contradictory objectives doubtfully can be incorporated fully in any ground gear designs, compromises must be found in practical situations.

Three basic methods to reduce the bottom impact of a ground gear are to:

1. reduce the length and thus the width of the ground gear;
2. reduce the physical pressure from gear components on the bottom; and
3. reduce the number of bottom contact points along the ground gear.

In situations where the target species are herded by sweeps/bridles into the trawl mouth, the length of the fishing line equipped with a ground rope can be relatively short and thus have a relatively narrow ground gear spread. The behaviour of the various target species might be different so that the optimal length of the ground gear will be species specific. Optimal gear lengths in various trawl fisheries have to be evaluated but many trawl gears will probably maintain capture efficiency with shorter ground gears than what is commonly used in that particular fishery.

Reduction of the ground gear weight in water or the creation of an upward lift on the ground gear might technically solve the second option. An optimal gear weight is one that balances the lifting forces in such a way that the ground rope is touching, but not digging into the bottom sediment. In many trawls, however, extra weight is added to the ground gear to insure bottom contact. Use of sensors that monitor bottom contact while towing may be a solution to reduce the risk of losing bottom contact with light-weight ground gear.

A possible solution to create an upward lift is the use of the self-spreading plate gear developed by Hansen and Valdemarsen (2006). As these plates can be rigged to have either a lifting or depressor function, rigging with lifting function along the wings is considered a feasible option. Fish seem to be herded inward towards the trawl mouth centre by the off-bottom ground gear similar to a ground gear with bottom contact. However, the escape behaviour of fish aggregating in front of the centre ground gear is often sideways where they seek openings under the fishing line. Therefore, the ground gear in the aft wing section close to the quarter section should have proper bottom contact to avoid escapement under the trawl.

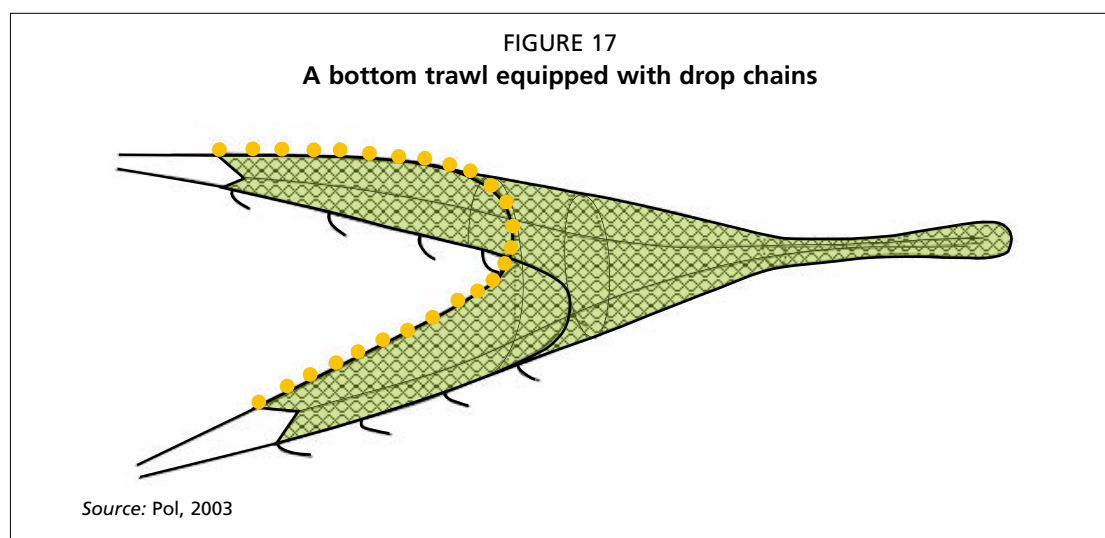
The third option is one which has already been introduced with some success in various trawl fisheries. It is basically to use fewer rollers or rock hopper discs with bottom contact than normal ground gear. In a large offshore shrimp trawl gear, He and Foster (2000) replaced 31 bobbins with a diameter of 24" and 21"

with 9 bobbins, resulting in a reduction in gear weight in water from 2 984 kg to 1 306 kg and a 70 percent reduction in affected bottom area. Although this ground gear did not decrease the shrimp catch, the reduced number of bobbins was more likely to incur gear damage, especially when fishing on grounds with rough seas and bottom conditions.

In the Gulf of Maine in the United States of America, a trawl with a raised footrope was developed for the small mesh whiting fisheries. This trawl is locally called a sweepless trawl because in the northeastern United States a ground gear is called a sweep. Drop chains scattered along the fishing line are used to keep bottom contact, as illustrated in Figure 17 and on cover page. The bottom contact with this arrangement is limited to a number of points (bottom of the drop chain), instead of a continuous ground line. Because of its advantages, fishers in the Gulf of Maine area have adopted this ground gear concept voluntarily, although concerns have been raised about loss of target species.

A solution using a combination of roller wheels, rock hopper discs and plates is under development within the European Commission-funded project “Development of Fishing Gears with Reduced Effects on the Environment” (DEGREE) (http://ec.europa.eu/research/fp6/ssp/degree_en.htm). The new ground gear design is illustrated in Figure 18. The basic requirements include a gear that has fewer contact points with the bottom, similar protection of the trawl as the rock hopper ground gear and no increase in loss of fish under the trawl. The contact points are roller wheels scattered along the ground gear, which is divided into a centre section of modified rock hoppers and two wing sections of plates. A chain runs through the centre axis of the rollers and through the lower part of the rock hopper discs and plates. This will lift the discs and plates off the ground because the rollers have a diameter large enough to reach below the discs and plates.

Initial testing of this gear set up during research cruise in 2006 clearly demonstrated that it performed satisfactorily with regard to reduced bottom contact for parts of the ground gear it had no extra escapement of fish under the



trawl and the protection of the trawl was comparable to rock hopper ground gear (Valdemarsen, unpublished). The off-bottom discs between rollers did hit obstacles on the bottom, but it was obvious that on sandy flat bottom the rollers were the main bottom contact points, as seen by the sand clouds behind the rollers.

The plates along the wings create some turbulence which might disturb small particles and thus create a sand or mud cloud. The direct physical pressure of the plates are controlled by tilting the plates inwards to get an upward lift and by using rollers in between the plates and in between the centre discs.

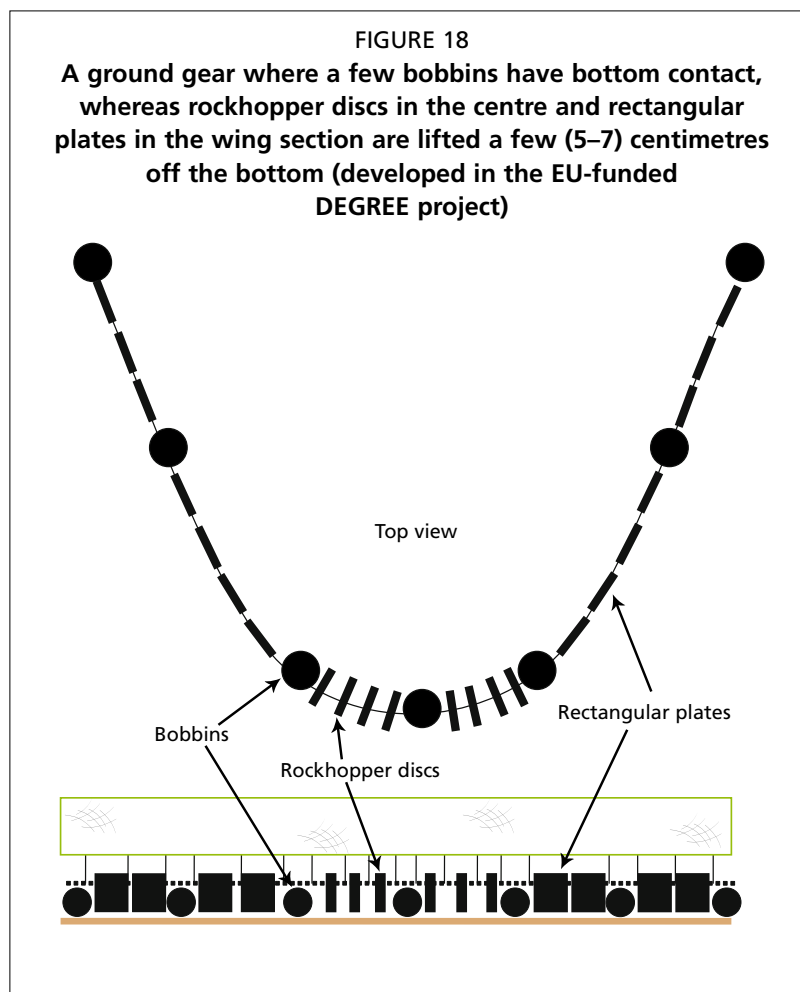
Also important for minimizing bottom contact of plates along the wings is to use a danleno bobbin in front of the gear that has a diameter large enough for the plates behind it to be lifted off the bottom.

These three examples of lighter ground gear are certainly options to be considered when a more bottom-friendly trawl technique is developed. All three have the potential to reduce the physical pressure on the bottom and thus reduce the impacted area. Organisms targeted with a bottom trawl, however, often stay very close to the bottom. Therefore, for such species an opening under the fishing line of the trawl might result in reduced capture efficiency.

BOTTOM PAIR TRAWLING

Bottom impact

A major difference between bottom pair trawling and bottom otter trawling is that trawl doors are not used. Instead, weights are normally used in the connection between the towing warp and the sweeps. In some pair trawl riggings the weights are removed, as in pair-seining which was developed in the North Sea to use the benefit of rope herding and at the same time cover a larger fishing area than a single-seine net operation.



Mitigation of impacts

Mitigation of bottom impact by pair trawls is similar to that for bottom otter trawling with regard to the sweeps/bridles and the ground gear. One possible difference might be when very long sweeps are used for herding purposes. Such techniques are normally associated with smooth and flat bottom and lifting of the sweeps a few centimetres off bottom might be feasible by the use of rubber discs and rollers scattered along the sweeps.

The impact of weights can partly be controlled by the length of warp in relation to the fishing depth as well as by using weight designs that minimize the impacted bottom area.

BEAM TRAWLING

Bottom impact

Beam trawling, or the concept of opening a trawl with a boom or spar, has existed since the 1400s. It became more important as a fishing method in the 1960s as a replacement for otter trawls where chains had been added between the two otter boards to enhance flatfish catches. Since then the beam trawls have increased in weight, number of chains used and size of the beam. Since 1988, beam width has been restricted to 12 metres in European Union waters.

The penetration depth of a beam trawl depends on the weight of the gear and the towing speed, as well as on the type of substrate, and ranges from 1 to 8 cm (Paschen, Richter and Köpnick, 2000).

Beam trawls cause direct mortality to non-target organisms in two ways. Firstly, the shoes, tickler chains or chain mat impact on animals on the seabed (Bergman and van Santbrink, 2000) and secondly, animals are caught in the net and die from sustained injuries during hauling or when the bycatch is processed and discarded (Lindeboom and de Groot, 1998).

Mitigation of effects

Although several mitigation measures have been examined over the last 30 years to reduce impact of beam trawling on the benthic environment, only electric fishing and benthos release panels are considered to have a positive potential.

Research into the potential for electrical beam trawling began in shrimp fisheries when the typical jumping behaviour of the animals to electrical stimulation was noted. Similar potential was later identified for catching flatfish, especially for sole, and significant effort was dedicated to develop this technique in Belgium, Germany, the Netherlands, and the United Kingdom of Great Britain and Northern Ireland in the 1970s and 1990s. In 1992 a private company in the Netherlands developed an electrical stimulation system which has been tested in commercial fishing with encouraging results with regard to reduced bycatch of benthos (Marlen *et al.*, 2006)

Benthic release panels (also known as drop-out panels) have the potential to reduce the environmental impact of beam trawling too. Some successful designs have reduced benthic invertebrate bycatch by 75–80 percent without loss of commercial target species.