Quality of Life and Management
of Living Resources

A strategy for the design, development and implementation of a new standard demersal survey trawl.

SURVEYTRAWL

Final Report

Proposal number : QLAM-2001-00593
Key action : 5.1.2
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Summary

The trawls used to sample demersal fish are normally slightly modified commercial fish or shrimp trawls. Such trawls are designed to capture commercial species, and do not lend themselves well to representative sampling, mainly due to the herding effect of trawl doors, sweeps and bridles. The impact of herding is different on different species and size groups of the same species, and both inter- and intra-specific effects can be quite large.

The **SURVEYTRAWL** project intends to provide the strategic basis and initial design for a new survey trawl, which will represent a good compromise in terms of being non-herding and non-selective, and with stable and consistent operation. The final objective is to produce a new trawl with the characteristics of a beam trawl (no herding effect, stability), but with no beam.

To avoid the herding effect, different rigging concepts are studied. The netting part of the different trawls are very similar for each concept, but the riggings is very different. The designs have been tested by means of numerical simulation, using Dynamit (commercial software), to verify whether the designs represent hydrodynamically viable options.
Particular attention is paid to:

- The gear simplicity.
- The net openings and geometry variations versus the towing speed and depth.

Partners involved :

IFREMER (co-ordinator)
IMR
NCMR

1 Objectives of the SURVEYTRAWL project

According to ICES, the amount of mature demersal fish in ICES waters were on average about 90 % greater in the 1970's than in the late 1990's. The situation has not shown improvement over the last couple of years, as demonstrated by the ongoing hake and cod crisis, as well as depleted whiting stocks. There are several reasons for this state of affairs, e. g. overfishing of quotas, unreliable catch reporting, unreliable survey data, all of which create difficulties in fisheries management.

Stock assessment of demersal fish in the ICES area generally relies on some variation of Virtual Population Analysis (VPA). The main datasets in this kind of analysis are derived from catch statistics and samples from commercial catches, as well as from scientific surveys. As mentioned above, catch statistics tend to be unreliable, partly due to "black landings" and partly due to unreported discarding. This situation indicates a need to get away from fisheries data to rely more on scientific data for stock assessment. This can only be achieved through a representative sampling.

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Herding appears differently in different species and size groups of the same species, and both inter- and intra-specific effects can be quite large. In an experiment with three small trawls towed in parallel behind one vessel with one set of doors, almost all the blue whiting were caught in the central trawl. 20 % of the cod and haddock were caught in each of the side trawls, with 60 % in the central trawl. The monkfish and the hake were caught equally in each of the three trawls. This illustrates that there exist substantial interspecific differences in herding.

In comparisons between different survey trawls there have been demonstrated significant intraspecific differences in the representation of age groups in catches from different trawls. It is also a well established feature of catch-at-age data for many demersal species in trawl surveys that the youngest year classes, despite being more than large enough to be withheld by the cod-end meshes, are underrepresented in the catches. The bulk of this discrepancy is ascribed to the limited herding (swimming) capacity of the smaller fish. Attempts have been made to try to compensate for intra-specific variation in herding when applying the survey data in stock assessment , but the results are uncertain at best.

This variable herding has also barred the development of calibration factors from survey trawl catches to natural fish density, meaning that survey trawl catches can only be applied in stock assessment as relative indices. A migration towards the use of trawl surveys as the only source of data for stock assessment of demersal species would necessitate a survey trawl that would sample representatively in terms of species as well as length group, and which could be calibrated in terms of catch per area unit swept, relative to the natural abundance of the stocks under survey.

The present project therefore aims at providing the strategy for designing a non-herding demersal survey trawl, primarily to provide representative samples, but ultimately to provide absolute density estimates.

2 Sampling trawl and avoidance behaviour review (WP 2 - IMR)

2.1 Introduction

To improve precision in survey indexes, standardisation plays a key role. Given a sampling gear that has the same and known attributes in all sampling, the corrections of fish behaviour patterns may become good enough for an absolute abundance estimate. Reducing variance in the efficiency of surveytrawls starts with monitoring and stabilizing gear performance; with rigorous standardisation of survey protocol as an essential component (Byrne *et al*. 1981, Stewart and Galbraith, 1987). The physics around the gear, the non-controllable parameters (temperature, light, current etc) are affecting the catchability coefficients for each species and size group. The largest contributions to uncertainty in the estimates are the unknown proportions of the target species that avoid the gear at all levels in the catching process and the interactions with all variables to this avoidance behaviour.

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Herding appears differently in different species and size groups of the same species, and both inter- and intra-specific effects can be quite large. Andrew *et al*. (1991) compared triple rigged prawn trawls to single trawls with and without sweeps of 40 and 140 m length. Sweeps were found to herd Australian red spot whiting and sand flathead but not prawns and shovelnose lobsters. Single trawls with long sweeps caught significantly larger red spot whiting and sand flathead than any other trawl configuration.

Engås and Godø (1989a) did comparative fishing experiments with long and short sweeps, and increased the catch of large cod and haddock substantially with increasing sweep length, more than could be explained by the increase in swept area.

In comparisons between different surveytrawls there have been demonstrated significant intraspecific differences in the representation of age groups in catches from different trawls. It is also a well-established feature of catch-at-age data for many demersal species in trawl surveys that the youngest year classes, despite being more than large enough to be withheld by the cod-end meshes, are underrepresented in the catches. The bulk of this discrepancy is ascribed to the limited herding (swimming) capacity of the smaller fish (Bridger, 1968). Attempts have been made to try to compensate for intra-specific variation in herding when applying the survey data in stock assessment , but the results are uncertain at best.

2.2 The Surveytrawl concepts

The relevant literature is discussed in light of the concepts for a new surveytrawl presented in the SURVEYTRAWL-project proposition. All the concepts aim to reduce herding in the trawling process.

Can aspects of these concepts give problems, reduced bottom contact, variance in swept area or larger variance in herding effectiveness? Monitoring the behaviour of a sampling trawl is essential for predicting the trawl catch efficiency and stability. We start this review with the monitoring phase.

2.3 Monitoring trawl gear performance

Extrapolation of data from surveys is based on assumptions of dimensions and characteristics of the trawl gear. Already deBoer (1959) presented instrumentation for measuring door spread, door tilt angle, door attack angle and vertical opening of the trawl net, from experiments they started in 1953. Boer tested a warp to depth ratio of 3.4 to 8.1 and observed lower angle of attack, larger spread and lower height of the trawl as the warp to depth ratio increased. Wathne (1977) measured headrope height, bottom contact and wingspread for the three standard sampling trawls used by NMFS Northwest and Alaska Fisheries Center (400 mesh eastern, 83/112 eastern and 61' shrimp sampling trawl), and found particularly more variable bottom contact than assumed.

The evolution to today's commercial products makes monitoring trawl geometry more an issue of how to use the information and to set the limits of gear geometry to assure survey data quality in the best possible way (e.g. Huse *et al*. 2002), and part of the job is to make rigorous standardization protocols for the surveys (e.g. McCallum and Walsh, 2002). To monitor the concepts put forward in the SURVEYTRAWL will eventually require different settings for the different concepts. However, a more detailed look for specifications of the survey vessels capabilities are needed.

Many survey protocols lack any strategy for current, or measuring trawl speed through water. Bottom contact may therefore be highly variable in different towing directions and stations, as shown by e.g. Somerton and Weinberg (2001). The Norwegian trawlsampling manual specifies the towing speed to 1.5 ms^{-1} of water flow through the trawl (Engås, 2003), but normally speed over ground is used in surveys.
The monitoring of survey trawl is very useful both for removing hauls of bad quality, as well as checking the human factor of rigging and handling gears, that may give different gear functionality over time (Walsh, 1995) or between hauls. Engås and Ona (1993) showed that the doorspread of the IBTS 36/47 GOV trawl increased from 80 to 110 m when fishing depth increased from 70 to 300 m. The doorspread of the Campelen 1800 increased from 47 to 64 m when fishing depth increased from 50 to 350 m (Engås and Ona, 1993). When introducing new surveytrawls the monitoring can be vital for knowing why and how to covert the indexes, and to see different riggings in results (Cardador and Azevedo, 1995; Stansbury, 1996; Walsh and McCallum, 1997,1998). An early work using high-frequency sonars as trawl sonde to detect trawl performance was reported by Ona and Eger (1986).

2.4 Review of the different relevant trawl gear components and their consequences on fish behaviour/catchability

2.4.1 Noise and warps

Margetts (1952) discuss the possibility of the increased catch in the Vigneron-Dahl modification (including bridles in the arrangement) of the otter trawl could be due to the fish being lead to the path of the net due to the vibrations set up by the gear that might be detected or heard by the fish. Bagenal (1968) discuss out of video observations of fish reacting to the bridles if the bridles can be seen by the fish at 30-40 m, or if it is the low frequency vibrations that triggers the reaction. He also notes that even if it has been shown that fish actually perceive a wide range of frequencies, they do not continue to move away from a stationary sound source. Noise stimuli from an acoustic "banger" did not increase the herding effect of any of the basic herding devices in the experiments done by Blaxter and Parrish (1966). Olsen *et al*.(1983) suggest an avoidance reaction from the noise stimuli of a vessel by increasing swimming speed and swimming away from the approaching vessel with a downward component. Olsen *et al*. (1983) showed that polar cod (*Boreogadus saida*, Gadidae) avoided the vessel 150 m in front of it.

By passing a stationary echo sounder by a trawling vessel, Engås and Ona (1993) reported horizontal dispersion and downward swimming by cod as early as 200 m in front of the vessel propeller, and at speeds of nearly 17 m/min, and at depths from 50-170 m. Ona and Chruickshank (1986) showed avoidance from pelagic haddock when trawling a pelagic trawl. Without trawl, no strong reactions in the pre-vessel zone, except for the disappearance of the uppermost fish traces, but at the moment of propeller passage and later, a slight density reduction was seen. When trawling, a comparable slight reaction in the pre-vessel zone, but a sudden and vigorous diving reaction is found just after the propeller passage. Shoaling herring in fjords do not seem to react at a distance (Olsen, 1979, 1990; Ona and Toresen, 1988). Takao and Furusava (1996) used dual-beam echo integration to investigate avoidance from survey vessel in Pollock (*Theagra Chalcogramma* (Pallas)) in the Bering Sea, and found avoidance reactions of Pollock to decline when the fish was deeper distributed. Aglen (1996) used acoustic estimates and found maximum correlation between catch and observed backscattered area for fish up to 10 m over the dead zone at day and 30 m at night. Yousif and Aglen (1999) finds the same tendency, but cannot rule out that the extra fish caught may emerge from the "dead zone" rather than the pelagic zone. However, Olsen *et al*. (1983) and Ona and Godø (1990) found weak, if any, reactions 50 meter in front of the survey vessel when studying cod and haddock, but strong diving response (50-100 m dive) after the passage of the vessel.

Of course, a downward reaction towards the bottom (and trawl) does not prove that the fish actually analyse the direction of the sound stimuli, merely dives as a natural respond to the threat. In some instances, cod is found to migrate upwards in the zone between vessel and trawl (Michalsen *et al*. 1999). It can be hard to see that fish can separate the complex sound picture from a rattling and bouncing trawlgear (Wardle, 1986). Handegaard (in prep.) has found profound reactions from pelagic cod on the warps, the fish showing a clear dive respond. Also, the constrain technique can be affecting behaviour of fish (Rose and Nunnallee, 1998).

Vertical herding from sound or warp stimuli in the three concepts for SURVEYTRWAL must be considered. For example, Concept 1b, with increased sweepangle and the use of double warp (to the wingtip and the door) can increase the possibilities of vertical herding from the warps. If the double warps do not have the same height over bottom, a fish may be herded twice, and a possible bias evolve. Therefore, in Concept 1b, both warps must be monitored properly.

2.4.2 Light

Underwater lights, of constant intensity or flashing, were found to be an efficient herding device, giving higher reaction distances than other devices (groundropes, netting etc.) by Blaxter and Parrish (1966). They also found very low reactions in low light (less than 0.1 mc) and suggest that herding is insignificant at night or at deep, turbid water. Bioluminescence might produce sufficient light under the influence of disturbance of trawl doors, bridles and a net of a trawl gear to produce strong visual stimuli capable of herding the fish even at night. This was pointed out already by Parrish (1968), but has not been systematically investigated. Trawling during night, with deck lights on, may give severe underestimation of herring as observed by scanning sonar (Ona and Toresen, 1988).

Adams *et al*. (1995) used a ROV with four 400W sodium scandium lights at 200, 400 and 600 m depth and observed that 80 % of all fish taxa did not react to the ROV, and that the taxa with the strongest reaction (Pacific whiting) 69% was attracted to the ROV. Weingberg and Munro (1999) reports that the use of a 50 W artificial light did not affect the escapement under the footrope of a trawl with a 36 cm rubber bobbin roller gear for 5 out of 6 species examined.

2.4.3 Trawl doors

Dickson (1993) shows how to calculate the efficient door spread and sweep efficiency to calculate the efficiency of the whole trawl system from the doors and backward. The position of the herding sand cloud may be shifted if the door spread shifts, giving openings between the sandcloud and the wings of the trawl, making a critical area for escapement of fish (Main and Sangster, 1981a; Kortokov, 1984). Also, the bottom contact of the groundgear may be reduced if overspreading the doors (Engås and West, 1987). Several attempts to minimize the problems have been suggested, for example increase of sweep length with depth (Wilemann, 1984; Palsson *et al*. 1989). This will give higher door spread for increasing depth (Hagstrøm, 1987), and may bias the length distributions, as higher catch of large cod and haddock with increasing sweep length has been shown (Engås and Godø, 1989a). Also warp-to-dept ration for different depths are commonly used (Anon. 1992). The equipment and procedures of Norwegian and International Bottom Trawl Survey (IBTS) in the North Sea give reduced door spread in shallow water and overextended door spread in deeper waters. Engås and Ona (1991 and 1993) described a constraint technique using a rope for minimizing the variability of trawl geometry with dept. Although the variance of swept area decrease, there were in some hauls observed a slow increase to normal doorspread, this might take 5 minutes, and not 30 seconds as normal.

2.4.4 Bridles, sweeps and sand clouds

Several authors have investigated maximum swimming speed of marine fishes in relation to body length. He (1993) has summed up and redrawn these in the figure below. There seems to be length dependence both between and within species.

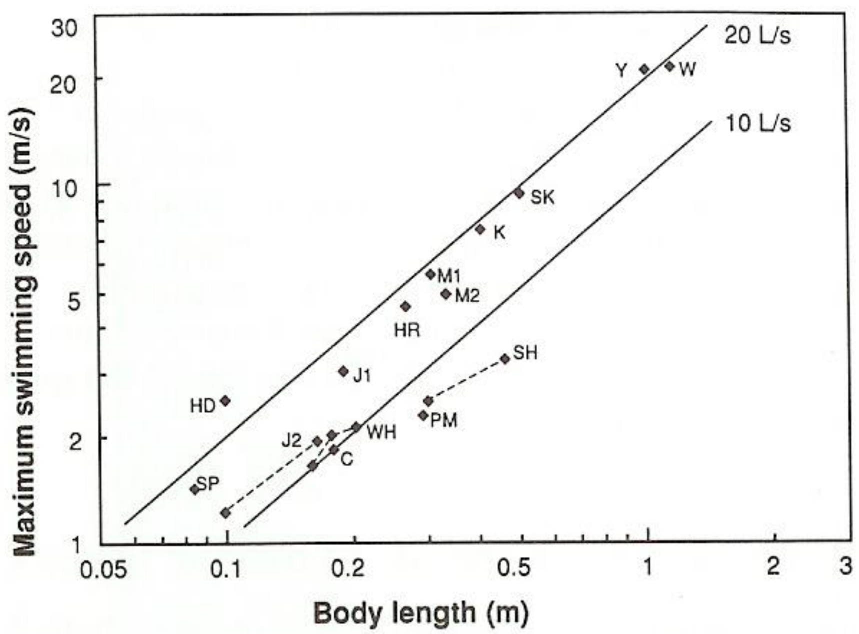


Figure 1. (from He, (1993)) Maximum swimming speeds of marine fish in relation to body length. Dashed lines link different lengths of the same species. In the paper, also references for each observation is mentioned. Here we only identify the species: C- cod, HD – haddock, HR – herring, J1 and J2 Jack mackerel, K – kawakawa, M1 and M2 – Atlantic mackerel, PM – Pacific mackerel, SH – saithe, SK – skipjack tuna, SP – sprat, W – wahoo, WH – whiting, Y – Yellowfin tuna.

The angel of the bridles is important for the sweeping effect of the trawl. The sweeping effect is demonstrated to be species dependent by many studies. For flatfish specially, the effective length of the bridles is the length where the bridles sweep across the bottom, sometimes the herding does not trig until the bridles touches the fish (Main and Sangster, 1981b). In a comparison between a twin rigged trawl (average bridle angle 6.6 º) and a single trawl (average bridle angle 13.3 º) Sangster and Breen showed that the catch per area (between doors) was higher for the twin rigged gear for both Nephros, haddock, flatfish (plaice and lemon sole) and monks, but not significant for whiting and cod.

Andrew *et al*. (1991) demonstrated sweeping effect for long sweeps for heardable fish as Australian red spot whiting (*Sillago bassensis*) and sand flathead (*Platycephalus* *caeruleopunctatus*), even at night, but find no sweeping effect of prawns and shovelnose lobster. Low sweeping effect is also suggested for Norwegian lobster (*Nephros norvegicus*), as Newland and Chapman (1989) have demonstrated that almost 50% of the individuals did not react to the gear until they were touched by it. For many flatfish, the swim and settle strategy when herded (Main and Sangster, 1981b) are typical, Winger *et al*. (1999) finds that the American plaice use several different strategies, and they conclude that the herding in the Campelen 1800 with 40 m sweeps may be highly dependent on temperature and length of the species. But for cod, Winger *et al*. (2000) could not find any effect of temperature or length of the swimming endurance of cod; they only found swimming speed to be significant. Breen *et al* (this meeting) has found prolonged sustained swimming speed in haddock to be length dependent.

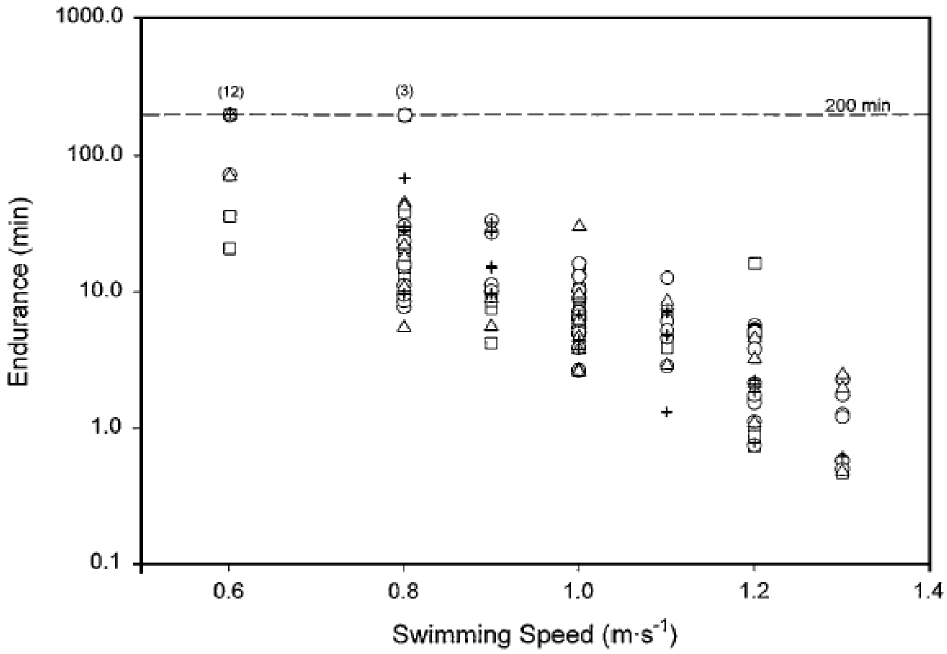


Figure 2. Logarithm of endurance plotted against swimming speed for different size ranges of Atlantic cod: <50 cm (u), 50–59 cm (s), 60–69 cm (n), and >69 cm (+). Swimming trials exceeding 200 min were terminated and the values in parentheses represent the number of occurrences (>1) observed. (from Winger et al. 2000)

Rose and Nunnallee (1998) found no change in size distribution when comparing trawl catches with and without constraint line for controlling doorspread.

The effective length of the sweeps when trawling for flatfish is also of importance. Somerton (2003) measured the effective sweeping length of the Poly Nor'eastern trawl where the bridles are normally hidden in the sand cloud (as opposed to the normal situation of the bridles of the 83-112 Eastern trawl (Somerton and Munro, 2001)). The Eastern trawl may be less herding efficient than the Poly Nor'eastern for roundfish if the sandcluds does not meet the wingtips (Main and Sangster, 1981a, Korotkov, 1984).

If current or rigging causes the sand cloud not to cover the bridles, the efficiency of the sweeping will be dramatically reduced. Korotkov (1984) estimates the coefficient of fish in the catching zone escaping between the wingtip and the sand cloud made from the turbulence to be 8,3-18,8 % when the distance between the sand cloud and wingtip is 4-5 meters. In IBTS two different sweep lengths (60 m and 110 m) are used depending on depth (Anon. 1999). The Icelandic surveys use 18.2 m longer bridles when the depth is larger than 182 m (Einarsson *et al*. 2003).

Bridger (1968) compared a Granton and SARO trawl and made assumptions of herding in the trawls variable with different bridle lengths and sweeping angles. He expects the different sweeping angels to affect the length composition of the catches, and longer bridles with constant doorspread to give higher catches of small fish. His results for small fish are inconclusive, but it must be added that the codend meshsizes were rather big in some of the surveys. He concludes that sweeping angels above 17 º seemed to reduce shepherding efficiency. Engås and Godø (1989a) found that small cod and haddock were relatively underestimated when using long sweeps. Andrew *et al.* (1991) also finds an underestimation of small Australian red spot whiting when compared a single trawl with long (120 m) sweeps compared to a triple trawl or single trawl with 7 m bridles or 40 m bridles. Engås and West (1987) found excessively high door spread and wing spread, and low vertical openings between different survey vessels.

When comparing the efficiency of the MEDITS trawl to the commercial trawl most often used in the Adriatic, Fiorentini *et al*. (1999) measured catch per swept area for ten fish species, one crustacean and four molluscs. They found the MEDITS trawl to be less efficient for hake (*Merluccius merluccius*), Common sole (*Solea vulgaris*) and Norway lobster (*Nephros norvegicus*) and the number (not weight) of Atlantic horse mackerel (*Trachurus trachurus*). The commercial trawl was most efficient for the weight of common Pandora (*Pagellus erythrinus*). Sweeping angels in the commercial trawl varied from 10.6º to 18.9º between the trips, whereas the MEDITS trawl had angels of 14.3º to 22.3 º. The commercial trawl had a vertical opening of approximately 1 m, and the MEDITS trawl from 2.4 m to 2.9 m. The commercial trawl had close bottom contact, not only the footrope, but also the whole lower panel is towed in close contact with the seabed.

Several of the manuals for bottom trawl surveys (Table 2) points out the need for changing sweeps with increasing depths. In all concepts presented in SURVEYTRAWL, this will not be needed, due to the stabile for of the gear independent of depth.

2.4.5 Groundgear

Early works on the reaction of several species; herring (*Clupea harengus* L.), haddock (*Melanogrammus aeglefinus* L., cod (*Gadus morhua* L.) whiting (*Merlangius merlangus* L.) and flatfish species (specially plaice, *Pleutrnectes platessa*) to various moving objects (various types of groundropes, with and without attachments (chains, lights, floats, etc) panels of netting of different mesh sizes and bubble curtain) in both daylight and darkness, were done by Scottish workers (Blaxter et al.,1964; Blaxter and Parrish, 1966) in large tanks. They found no panic reactions, and they found the herding efficiency to be directly related to the objects conspicuousness. They found herding to decrease considerably at towing speeds more than 1 ms^{-1}. At low light intensities (below 0.5 lux) they found the herding to decrease markedly. On the basis of these observations and photographs taken at trawls in the sea, Blaxter *et al*. (1964)

concluded that reactions observed in daylight were in response of visual stimuli and postulated that they are mainly responsible for the herding by the warps and bridles of trawls. One review by Parrish (1968) based on both tank and observations at sea emphasise the overall importance of the visual stimuli in the herding process. Beamish (1968) observed that cod in groups (68%) was better oriented in the direction of the tow than single specimen (55%) when swimming in front of the gear. It is often observed that fish concentrate in front of the centre section of the ground gear, and that escapement under the footrope also occurs most here (Main and Sangster, 1981; Korotkov, 1984; Walsh, 1992).

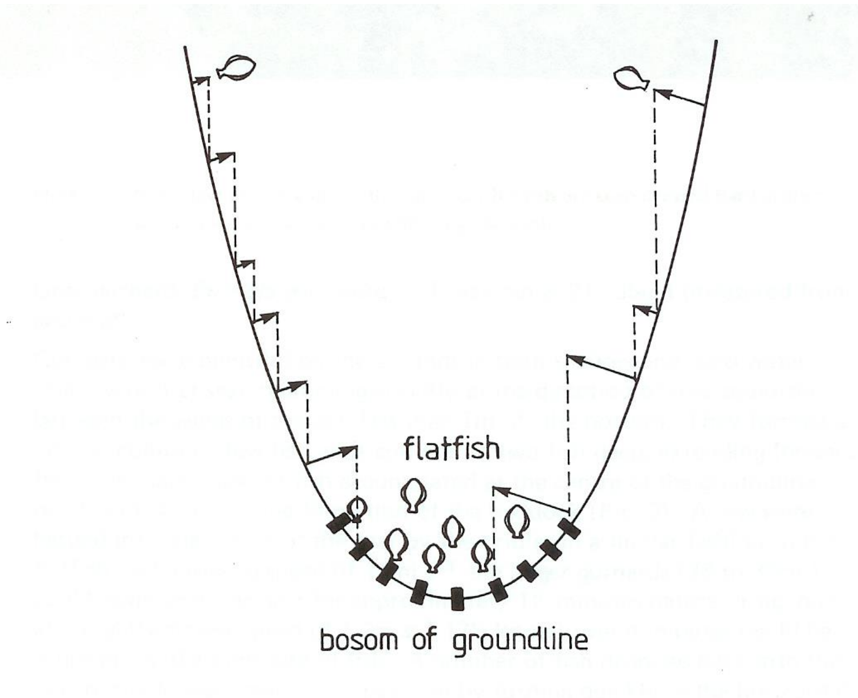


Figure 3. From Main and Sangster, 1981. Direction of swimming of flatfish to effective herding by the sweeps and bridles.

Albert *et al*. (in press) filmed Greenland halibut in front of the gear, and observed 63 to 70 % of the fish that entered the trawl, most of them at the midsection of the gear. They suggest that the largest Greenland halibut escapes the trawl before they enter the video-frame, more large fish at the beginning of the tow, catch by surprise (Godø *et al*., 1990). All the observations shows the fish swimming horizontally, with the blind side towards the bottom, most fish did not react until the ground gear was less than 1.5 m away. Walsh and Hickey (1993) found flatfish resting on the seabed and not reacting at the gear until it was 0.5-1 m away, whereas Bublitz (1996) found herding of flatfish to take place close to the gear (approx. 54 +- 13 cm away) and for short periods, 2-12.2 s, and identified two distinct behavioural patterns during entering of the trawl.

Engås *et al*. (1988) showed that catch ratios bobbins/rockhopper (B/R) for cod and haddock show a higher efficiency for rockhopper than for bobbins, especially for small fish. The catch ratio B/R for cod varied by time of day. Rockhopper was shown to be more efficient compared to bobbins during daytime. The same trend was not found for haddock. Their results contradict Ehrich (1991) in that in the Barents Sea, the haddock showed the same behaviour as cod, whereas Ehrich (1991) found no indications of haddock escaping under the groundrope in the North Sea.

Ehrich (1991) did comparative fishing by research trawlers for cod and haddock in the North Sea in a small area of 240 nm^2 with three ship-gear combinations. FRV “Walter Hervig” with the GOV (36/47 m) and rubber disc ground rope, FRV “Anton Dohrn” with the GOV (36/47 m) and FRV “Anton Dohrn” with a 180-foot herring trawl. The 180-herring trawl had significant higher catching efficiency for haddock, while the combined factor of vessel and groundgear was insignificant. The catch of small cod was strongly dependent on groundgear, and 85 % of the small cod escaped between the heavy bobbins under the fishing line. For cod > 32 cm, the GOV was 2.4 times as efficient as the 180-foot herring trawl.

Engås and Godø (1989b) describes experiments with small bags to collect fish that escape under the sampling trawl where several different species were obtained in the small bags. Comparison between trawl and bag catches reveals a length-dependent escape of cod and haddock under the trawl; i.e., small fish are severely under-represented in the trawl catches. The escape of fish under the ground gear also has a considerable effect on the species composition.

Dremière *et al*. (1999) observed better bottom contact in a commercial Italian trawl than the MEDITS trawl.

2.4.6 The netting body

Margetts (1952) observed fish escaping from the open meshes in the forward part of the net as well as in the codend. Blaxter and Parrish (1966) found netting (including 120 cm mesh size) to be the most effective herding device in their tank experiments. Dremière *et al*. (1999) found escapement from the first two belly panels of the MEDITS trawl through 120 and 140 mm meshes, and found the escapement to the near bottom bags from Norway lobster (*Nephros norvegicus*) and greater forkbeard (*Phycis blennoides*) to be the dominant species in these bags, while in the mid-height of the sidepanels showed high escape rate only for blue whiting (*Micromestistius poutassou*). The only species escaping from the roof panels in the trawl was sardine (*Sardina pilchardus*), but not in any significant degree, and all escapement through the bottom panel was low. The MEDITS trawl was less efficient than the commercial trawl for the large size-classes of some species, which probably was due to larger mesh size in the MEDITS trawl.

In an experiment using twin trawl, one with 45 mm mesh, the other as commercial trawl (Cortesi nr 3, 140 mm and decreasing backwards in the trawl), Ingolfsson (pers. med) found 10-20% of the 0 and 1 group of haddock in the commercial trawl compared to the experimental trawl.

2.4.7 Density dependence and turnover rate

Blaxter and Parrish (1966) found a reaction distance of herring (*Clupea harengus*) as far as 7 m when a large group of herring was herded in front of a rope, the leader fish presumably reacting to the fish behind. Godø *et al*. (1999) studied video observations from Norwegian and Canadian waters, for the species cod, haddock and American plaice (*Hippoglossoides platessoides*) in the mouth of the bottom surveytrawls. They found, despite several limitations in data and methods, that higher concentrations of fish in the trawl mouth gave a higher turnover rate and higher catchability. See also the longer sustainable swimming ability of haddock when haddock swim in groups (Breen, this meeting). Godø (1994) showed that bottom-trawl indices of the Barents Sea cod tended to be biased downward compared to VPA indices when the stock was low, and biased upward at higher abundances. Albert *et al*. (in press) found no aggregation or schooling of Greenland halibut in front of the ground gear.

2.5 Modelling

To model the herding effect has been tried by several authors, individual based (e.g. Foster *et al*. 1981), or traditional (e.g. Ramm and Xiao, 1995), but parameter estimates needs data to such a degree that it often limits the application of the models. Can it be easier to avoid herding at all?

2.6 Overview over some sampling trawls

Many sampling programs have evolved over the years, giving rise to conversion of indexes and recalculation of estimates. For example, the most important revisions since 1981 to the trawl gear used in Norwegian waters are:

- 1986 All vessels started using the same doors (Waco 6m2, 1500 kg). Larger Wacos were earlier used by G.O. Sars and Eldjarn.
- 1987 towing time reduced from 60 min. to 30 min. in the Barents Sea.
- 1989 same sweeplength (40 m) introduced both in the Barents Sea and the Svalbard area (earlier: 80 m)
- 1989 rockhopper replaced the bobbins gear.
- 1989 towing time in the Svalbard region was reduced to 30 min
- 1994 22 mm mesh liner replaced the 40 mm mesh liner in the last part of the codend
- 1994 the constraining rope was introduced at every third haul

Based on parallel trawling experiments, conversion factors for comparing catches from the bobbins gear compared to the rockhopper gear has been calculated (Godø *et al*. 1989), to make the time series of indices from 1981 to 1988 consistent with those from 1989 onwards (Godø and Sunnanå, 1992; Aglen and Nakken, 1997).

The MEDITS programme, covering 9 nations around the Mediterranean, have adopted the GOC 73 trawl, designed for scientific purposes, a compromise between many constrains (Bertrand *et al*. 2002). It has a higher opening than the commercial trawls used in the area, and are being used without tickler chain.

The Icelandic trawl has not been changed, and is far from the commercial gears used today. The survey is conducted at predestined stations (not stratified random), with towing direction directions predestined to one out of two alternatives. The Norwegian surveymanual specifies trawling speed according to water speed (1.5 ms^{-1}) through the trawl. Is it the only manual specifying this?

The sampling trawls found in this study is listed in Table 1 and 2.

Table 1. Sampling gear used by IBTS (Anon, 2002)

Country/Institute **Sampling Material**	Ireland MIFRC	UK/ Scotland MLA	UK/North Ireland DARD	UK/ England CEFAS	France IFREMER	Spain IEO	Spain /Porcupine IEO	Portugal IPIMAR
Research vessel	*Celtic Voyager*	*Scotia*	*Lough Foyle*	*Cirolana*	*Thalassa*	*Cornide de Saavedra*	*Vizconde de Eza*	*Noruega*
Type	Stern Trawler							
GRT	340	N/A	547	1731	3022	1133	1400	496
KW	N/A	N/A	880	N/A	2200	1650	1800	1100
Overall length (m)	32	68.6	43.5	74	72.7	67	53	47.5
6.1.1.1 Gear Type	GOV 28.9/37.1	GOV 36/47	Rock Hopper	PHHT	GOV 36/47	BACA 44/60	BACA 60/72	NCT
Depth range (m)	15-200	20-200	20-120	40-600	30-400	30-700	150-800	30-750
Trawling speed (knots)	3.5	4	3	4	4	3	3.5	3.5
Doors weight (kg)	500	1100	N/A	1440	1350	650	800	650
Doors surface (m^2)	3.99	4.5	N/A	4.5	4.5	3.58	4.5	3.75
Sweep length (m)	60	60	12.5	18.28	50 100	200	250	No
Diameter of Lower Bridle (mm)	20	20	18	20	22	No	18	16
Diameter of Upper Bridle (mm)	12	14	20	16	12	No	18	14
Diameter of Middle Bridle (mm)	12	14	No	No	12	No	No	14
Exocet Kite	Yes	Yes	No	No	No	No	No	No
Floats in Headline	18	20	No	20	18	25	12	80
Floats in Winglines	32	20 + 20	No	32 + 32	24 +24	15 + 15	32	80
Mean vertical opening (m)	6	4.6	3	4.4	4 4.1	2.0	3.5	4.8
Mean doors spread (m)	48	82	37	81.7	76.9 112.7	107.1	120.4	44.3
Mean horizontal opening (m)	N/A	19.6	N/A	N/A	18.7 20.5	18.9	20	15.6
Groundrope	Rubber disks	Bobbins	Rubber disks	Rubber bobbins + Rubber disks + Chain	Rubber disks and Chains Rubber and metal disks	Synthetic wrappled wire core	Synthetic wrappled wire core double coat	Bobbins

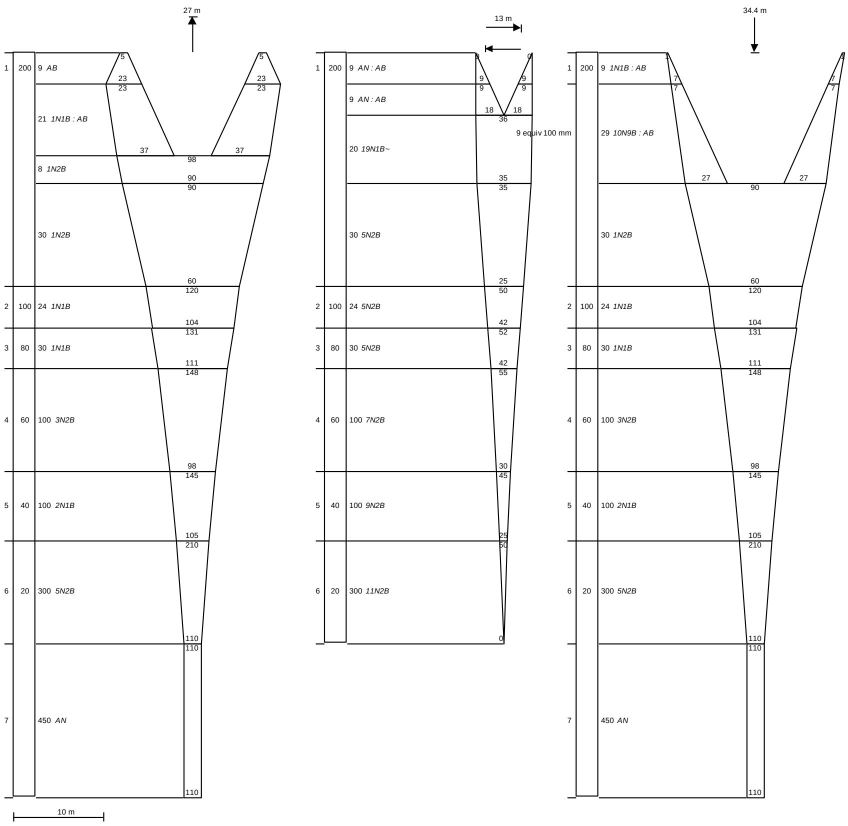
Table 2. Other bottom survey gears.

Area	Trawl	Doors/gear	Reference	Comments
Iceland	Mars botnvarpa	Poly-Ice nr 7, 1750 (1900) kg Bobbins 21" and 24"	Einarsson *et al*. 2003	At depths more than 100 ft the sweeps (chains) are elongated 10 ft
Alaska Aleutian Islands U.S. West Coast	Nor'east hard bottom trawl	4,86 m^2 V-doors 36.6 cm bobbins	Rose and Nunnallee 1998	
U.S. West Coast		V-doors, 567 kg	Weinberg *et al*. 2002	Used by NMFS-RACE-AFSC
Australia	56 m Engel balloon trawl	180 m sweeps, 45 m bridles, 2.4 m Vee doors	Graham and Liggins, 1995	Typical sweep angle :15º
Newfoundland	Engel 145 High Lift Otter Trawl	Different doors and rigging as a result of evolution	Walsh, 1995	Used until fall 1995 (?)
Newfoundland	Campelen 1800	4.3 m Morgere povalent, 40 m bridles, 6.1 m sweeps, rockhopper	McCallum and Walsh, 2002	From fall 1995
Faroe Island	Boxtrawl	Steinhamn nr 8, 6.4 m, 1800 kg. 60 or 120 m sweeps	Zachariassen, pers med.	Sweep length change with depth, approx 150 m limit, depending on bottom type
Portugal	Norwegian Campel	ground rope 18.2 m,16 inch bobbins	Cardador and Azevedo, 1995	
Portugal	Shrimp trawl	ground rope 70.0 m, chain	Cardador and Azevedo, 1995	
Portugal	Horse mackerel trawl	groundrope 54.6 m, chain	Cardador and Azevedo, 1995	
Italy (partly)	GRUND programme, commercial model	150 m sweeps. 75 kg chain directly to footrope, Morgere WS8 doors	Fiorentini *et al*. 1999	
North Sea, Skagerrak/Kattegat	GOV 36/47	60 m sweeps (depth < 70m) 110 m sweeps else. In 2-4 quarter: only 60 m sweeps	Anon. 1999 / Anon. 1992	9 m constraint rope tested 150 m in front of doors (Engås and Ona, 1993)
MEDITS	GOC 73	!00 or 150 m sweeps, depending on depth Morgere WS8 doors	Fiorentini *et al*. 1999	
Norway	Campelen 1800	Waco 6 m, 40 m sweeps, rockhopper gear	Engås, 2003	9 m constraint rope tested 150 m in front of doors (Engås and Ona, 1993)
NMFS area, from Cape Hatteras to Scootian Shelf	36 Yankee ("60-80" trawl)	24.4 m wire footrope, 0.5 m rubber rollers	Azarovitz *et al*. 1997	
NMFS area, from Cape Hatteras to Scootian Shelf, winter	newer Yankee, "New Bedford flounder trawl"	chain and cookie disk sweeps,	Azarovitz *et al*. 1997	

3 Review of the SURVEYTRAWL concepts (WP4 - IFREMER)

All the concepts presented and discussed in this section are based on the same 4-panels Mediterranean trawl design. This initial trawl design has been chosen for its very gradual shape convergence and its rational design (very few slack meshes, quantity of netting used and low drag …).

However almost any trawl design could have been used to calculate and test the SURVEYTRAWL concepts. Indeed, each concept is characterised by its rigging.



Netting section	Surface (m^2)	Weight (kg)
dos	25.62	24.33
côté 1	6.96	6.92
ventre	29.36	28.39
coté 2	6.96	6.92
Total	68.90	66.56

Description	Material	Runnage (m/kg)	Mesh side (mm)	Diameter (mm)
1	PA	400	200	2.3
2	PA	760	100	1.5
3	PA	760	80	1.5
4	PA	1060	60	1
5	PA	1060	40	1
6	PA	1550	20	0.8
7	PA	760	20	1.5
9 equiv 100 mm	PE	200	200	4.6

This trawl design has been used to simulate the SURVEYTRAWL concepts in the following section.

An **additional trawl design is described at the end of this chapter** and should be better adapted to SURVEYTRAWL concepts.

The analysis of variation in the trawl gear geometry as a function of depth or towing speed have been carried out for the concepts 1b and 3a, 3b, which seems to be the most promising designs regarding the non-herding performance and geometry stability.

Before we discuss the simulation results for the different concepts, we present a short review of the parts of the gear that have an essential role in the herding and fishing processes. These gears are classified by function : opening the trawl (doors and sweeps) and insuring the trawl to be in contact with the seabed.

We try hereafter to list the available gears that could potentially be used in the SURVEYTRAWL concepts.

3.1.1 Opening the trawl

- Different methods and techniques are available to open horizontally a bottom trawl : classical bottom doors, taking advantage or not from the ground effect that can bring a significant amount of the spreading force,
- kites,
- pelagic doors, with buoyancy tank if needed (LeBeon, France for instance)
- supple floating doors (IFREMER Lorient),
- or even pair trawling.

Additional techniques can be used to make it easier to open the trawl :

- self spreading netting,
- adapted ground gear with plates instead of rubber disks can reduce the tendency a trawl has to collapsebecause of its drag in the water or on the substrate,
- trials with square netting instead of diamond netting could also be tested since diamond meshes have a tendency to stretch and close when under tension, whereas square meshes do not.

Even a rigid system, such as a beam, commonly used by beam trawls, can be used to maintain the horizontal opening of a trawl.

3.1.2 Sweeps

The sweeps lengths of a trawl are often inspired by professional fishing gear characteristics. The variation of length with depth generally aims at keeping constant the sweepingangle. They also have a function in the shooting and hauling operations.

The review of fish avoidance behaviour shown that sweeps must be as short as possible. However, the main limitation in the sweep length reduction, for a classical bottom doors + sweeps, is due to handling, especially on big ships.

Floating sweeps could be used to avoid some benthic and demersal species to be herded.

3.1.3 Ground gear

The ground gear has a triple function :

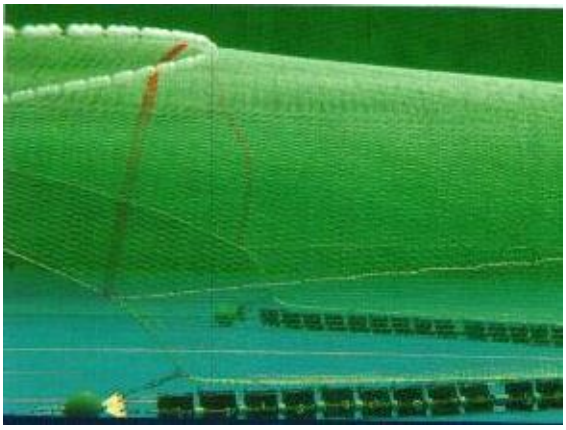
- to keep the trawl in contact with the seabed,
- to avoid damages from rough seabed,
- to minimise fish escapement between the netting (fishing line) and the substrate.

This essential part of the gear has not been particularly studied within the SURVEYTRAWL project. It was not a part of the purpose of the project.

However some recent innovative designs, such as the **plates ground gear** or a **double ground gear** could be applied in a new sampling gear.

We can forecast that a new **standard** "non-herding" sampling trawl could be equipped either with a ground gear adapted to soft bottom or a ground gear adapted to rough bottom, as the case may be.

A double ground gear can prevent the escapement of fishes under the fishing line.



A ground gear made with plates instead of disks can prevent the gear stretching.

3.2 Numerical simulation of the SURVEYTRAWL concepts (WP4)

In the following section we present the simulation results for the different SURVEYTRAWL concepts. Before each simulation, we summarise the approach used to **avoid** herding in concepts 1, 2 and 3.

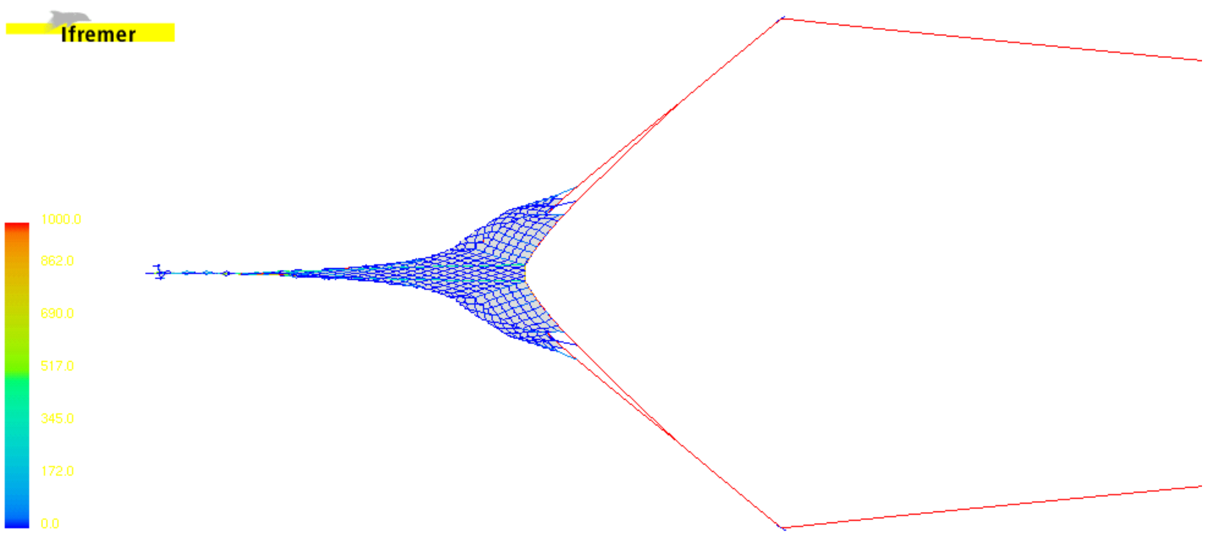
The 4th and 5th concept are based on a different approach where we do not try to avoid herding but to **impose** and **control** herding.

3.2.1 Concept 1 : increasing the angle of the bridles/sweeps

Concept 1 consists in bringing the doors out so far to the sides of the trawl, and increasing the angle of the bridles/sweeps so much that fish encountering the doors / sand-clouds / bridles / sweeps will be overtaken by the bridles and not be caught by the trawl.

3.2.1.1 Concept 1a : getting a high sweep angle using strong spread force

Solution : using big doors (12 m²)
Results :
Trawler speed / Heading : 3.50 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Number of bars / nodes : 3342 / 2488
Minimum / maximum tension : -59383.7 KgF / 59535.8 KgF
Vertical opening: 3.5 m
Horizontal opening: 26.8 m
Otter boards opening: 96.4 m
Warp tension / total towing traction Z (kgF) : 4564.0 4563.0 / 8571.4
Projected swept surface (m²) : 84.6 Swept water volume per second (m3/s) : 143.8

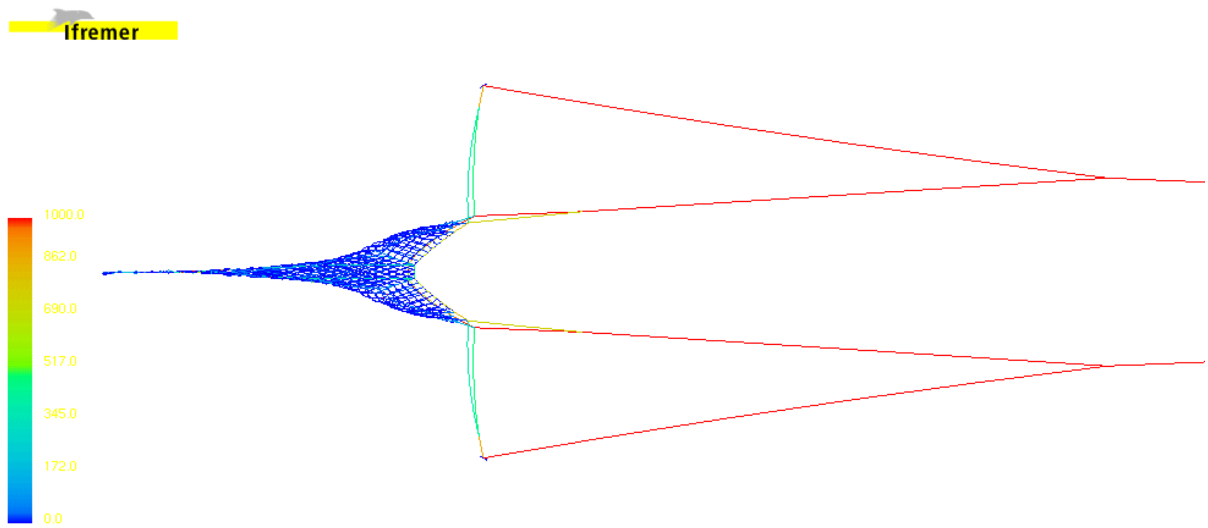


Advantages : simple, usual
Drawbacks : Big doors, low efficiency regarding herding ?

3.2.1.2 Concept 1b : increase the sweeps angle by reducing the tension in the sweeps

Solution : using an additional wire to support the net traction. 6 m² doors.
Results :
Trawler speed / Heading : 3.50 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Vertical opening: 5.1 m
Horizontal opening: 21.4 m
Otter boards opening: 85.2 m
Warp tension / total towing traction Z (kgF) : 4526.9 4527.7 / 8637.3
Projected swept surface (m²) : 103.1 Swept water volume per second (m3/s) : 185.9

Trawler speed / Heading : 5.00 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Vertical opening: 4.8 m
Horizontal opening: 22.9 m
Otter boards opening: 87.4 m
Warp tension / total towing traction Z (kgF) : 7051.2 7052.1 / 13612.4
Projected swept surface (m²) : 107.9 Swept water volume per second (m3/s) : 278.4



Advantages objective fully reached
Drawbacks : relative rigging complexity, door stability

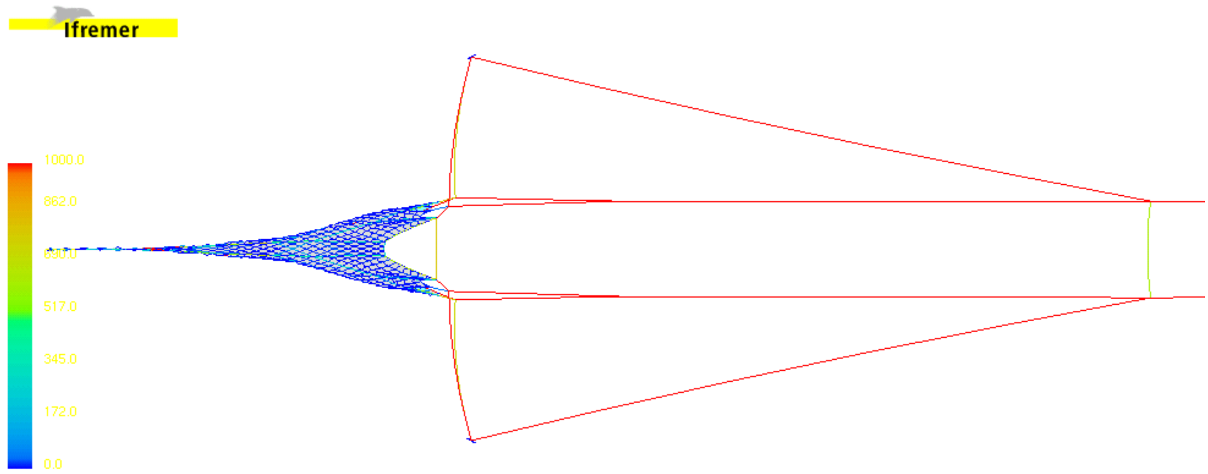
3.2.1.3 Reducing the variation of geometry with speed

Solution : Two restriction ropes are added : one between the warps to maintain them parallel, one in the upper wings to maintain constant the horizontal opening regardless doors efficiency (for different speeds).

Results :

Trawler speed / Heading : 3.00 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Number of bars / nodes : 3382 / 2522
Minimum / maximum tension : -59455.3 KgF / 59163.6 KgF
Vertical opening: 5.1 m
Horizontal opening: 16.3 m
Otter boards opening: 78.1 m
distance upper wings: 12.9 m
Warp tension / total towing traction Z (kgF) : 4132.0 4128.9 / 7813.6
Projected swept surface (m^2) : 70.4 Swept water volume per second (m3/s) : 106.6

Trawler speed / Heading : 5.00 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Number of bars / nodes : 3382 / 2522
Minimum / maximum tension : -59306.8 KgF / 59365.6 KgF
Vertical opening: 3.7 m
Horizontal opening: 18.3 m
Otter boards opening: 81.0 m
distance upper wings: 13.0 m
Warp tension / total towing traction Z (kgF) : 7207.7 7196.6 / 13873.2
Projected swept surface (m^2) : 57.0 Swept water volume per second (m3/s) : 146.0



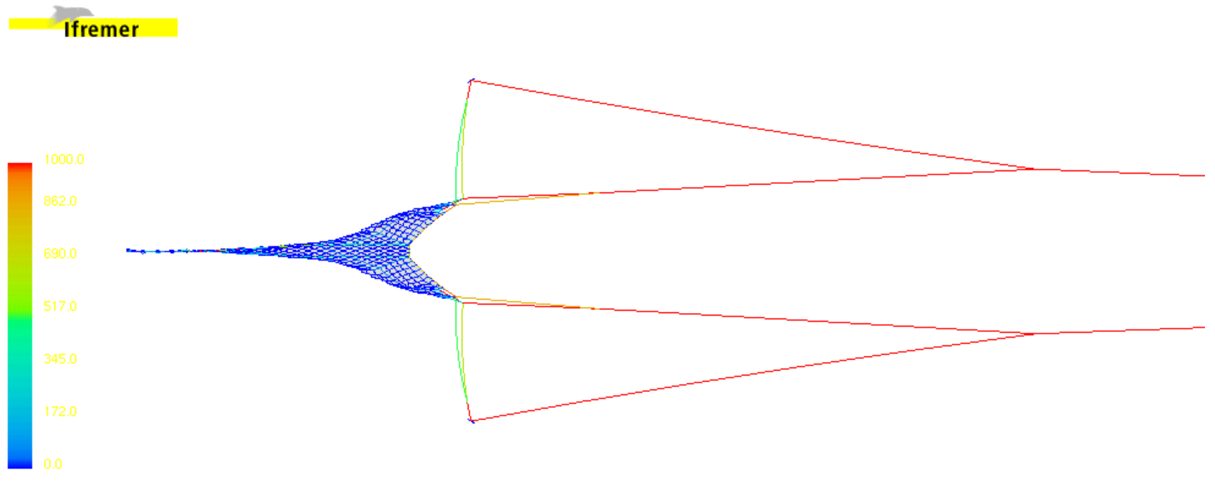
Advantages :
Drawbacks : opening not stable

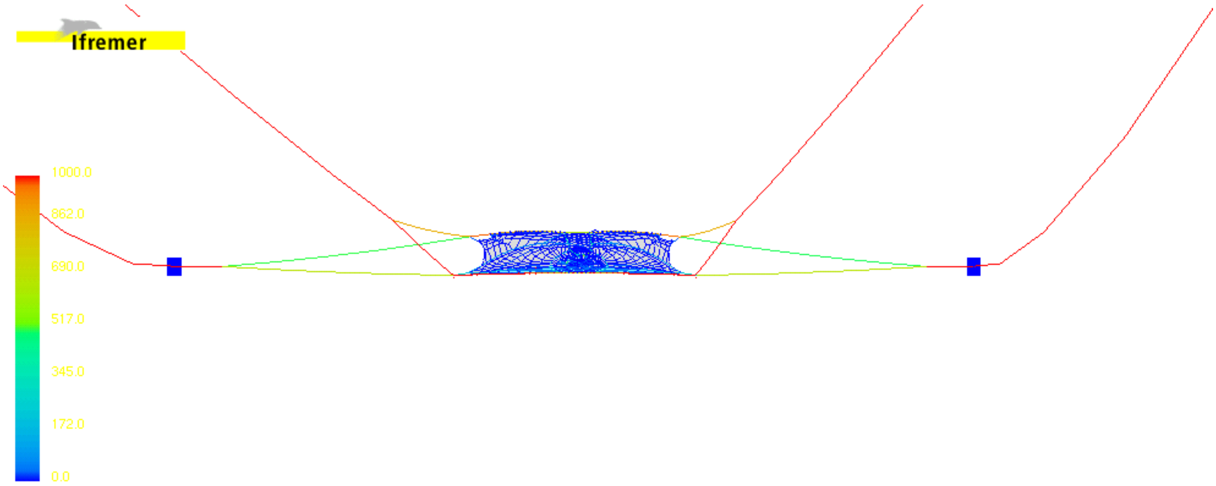
3.2.1.4 Reducing the geometry variation with speed

Solution : increase the bridle length
Results :
Trawler speed / Heading : 3.00 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Vertical opening: 5.6 m
Horizontal opening: 20.4 m
Otter boards opening: 83.7 m
Warp tension / total towing traction Z (kgF) : 4269.5 4266.1 / 8111.3
Projected swept surface (m²) : 106.8 Swept water volume per second (m3/s) : 165.8

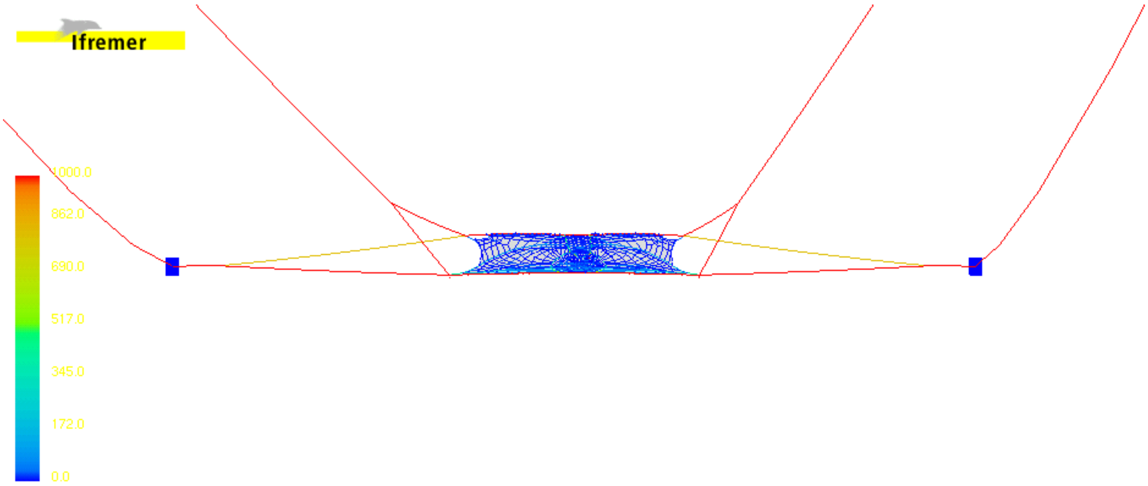
Trawler speed / Heading : 4.00 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Vertical opening: 4.8 m
Horizontal opening: 22.1 m
Otter boards opening: 86.1 m
Warp tension / total towing traction Z (kgF) : 5593.1 5590.4 / 10724.2
Projected swept surface (m²) : 103.0 Swept water volume per second (m3/s) : 210.7

Trawler speed / Heading : 5.00 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Vertical opening: 4.5 m
Horizontal opening: 22.8 m
Otter boards opening: 87.2 m
Warp tension / total towing traction Z (kgF) : 7434.2 7426.4 / 14343.5
Projected swept surface (m²) : 103.0 Swept water volume per second (m3/s) : 265.6





Front view at 4 knots



Front view at 5 knots

Advantages : can be improved with the use of a restriction rope in the warps
Drawbacks : still some geometry variation, however, the speed variation does not go from 3 to 5 knots in real use unless the towing direction is straight into of out of the tidal current.

3.2.1.5 Conclusions for concept 1

The use of reasonably big doors does not allow very high sweep angles. The use of an additional wire, to tow the netting and not the doors, can reduce the sweeps tension and relieve them. Consequently, the sweeps are only used to spread the trawl net and can have an angle around 90 °. Swept surface (by the trawl mouth) remains almost constant for the different speeds (concept 1 b).

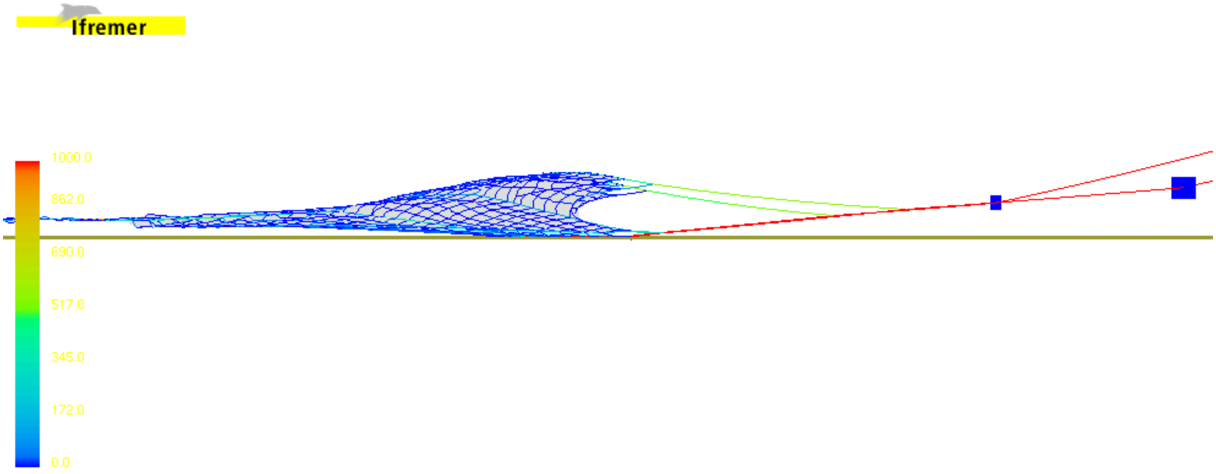
Drawback : the use of doors in this “high sweep angle configuration” is not common. Doors stability could suffer form a lack of “line up” backstrops traction (bad pitch stability). Doors backstrops will have to be attached inside the doors (instead of outside for a classical use). The use of a crowfoot (warps) could increase door stability.

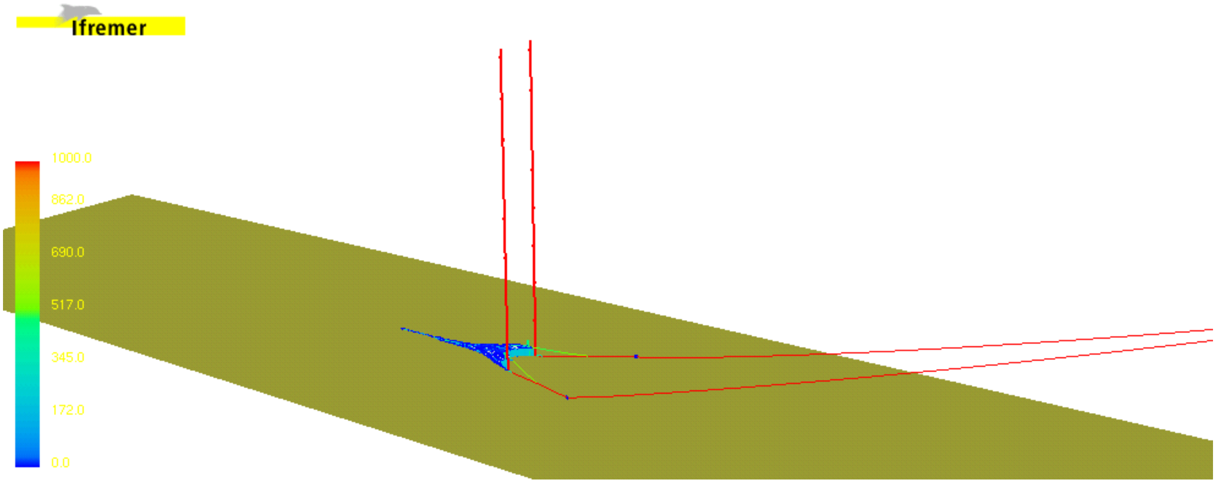
3.2.2 Concept 2 : lifting the doors off the bottom

Concept 2 consists in lifting the doors off the bottom to avoid the formation of a sand cloud, and to bring the larger part of the sweeps / bridles up from the bottom to avoid herding. Bottom contact is achieved through e.g. a heavy ground gear.

3.2.2.1 Getting a configuration where doors are off the bottom.

Solution : reduce the doors weight, consequently increase the ground gear weight (1000 kg at each gear ends)
Results :
Trawler speed / Heading : 3.50 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Vertical opening: 6.9 m
Horizontal opening: 22.4 m
Otter boards opening: 61.2 m
Warp tension / total towing traction Z (kgF) : 3542.3 3540.0 / 6683.1
Projected swept surface (m²) : 135.6 Swept water volume per second (m3/s) : 244.3





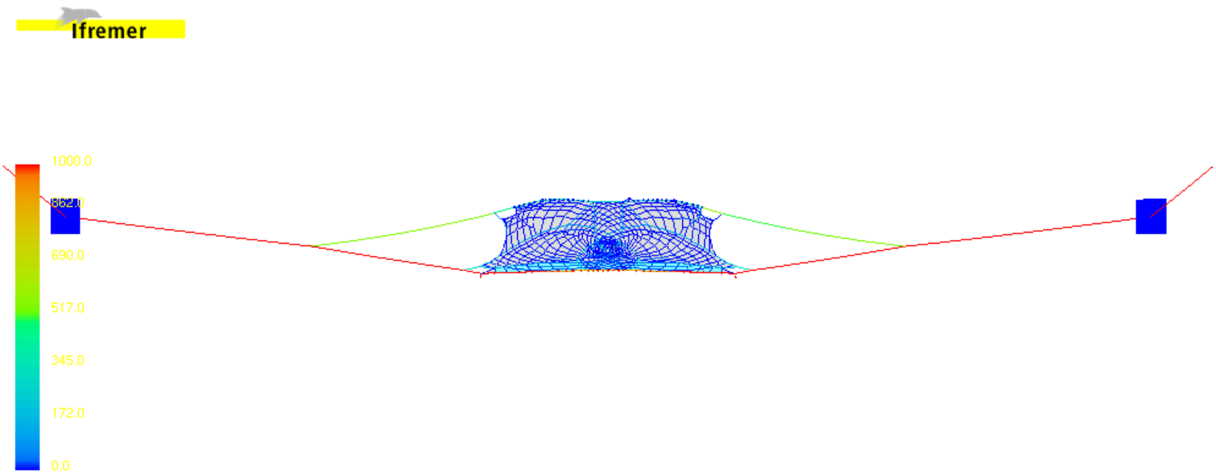
Ground reaction at the lower wing tips, no door reaction.

Advantages : simple.
Drawbacks : efficiency regarding herding is variable. Monitoring and regulating warp length could be difficult for long warp length (significanttime interval for stabilisation especially for large depths). Additional flexibility of the whole structure due to the possibility for doors to change their distance to ground.

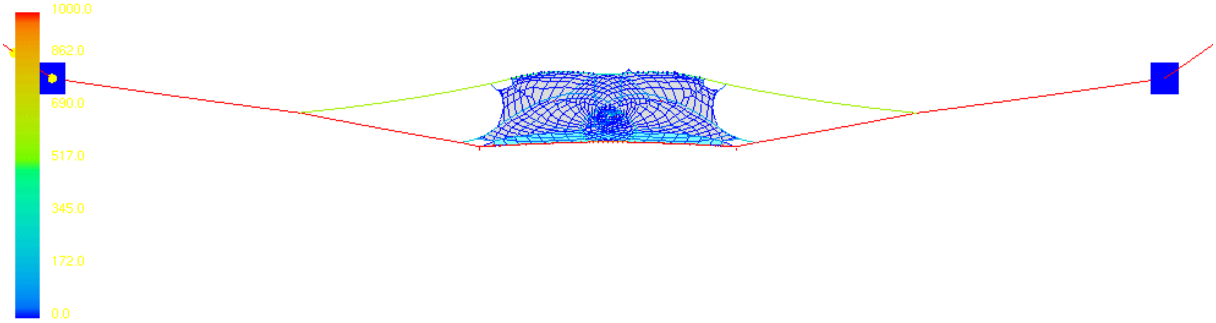
3.2.2.2 Verifying the vertical opening can be controlled by the warp length for different depths.

A crucial point for this concept is the geometry control and monitoring. We try to maintain a “constant” geometry (vertical and horizontal net openings) by adjusting the warp length, for two different trawling depths.

Solution : adjust the warp length till vertical openings are almost equal during the simulation.
Results :
Trawler speed / Heading : 3.50 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Vertical opening: 6.9 m
Horizontal opening: 22.4 m
Otter boards opening: 61.2 m
Warp tension / total towing traction Z (kgF) : 3542.3 3540.0 / 6683.1
Projected swept surface (m²) : 135.6 Swept water volume per second (m3/s) : 244.3



Front view for 100 m depth, warp length 330 m



Front view for 500 m depth, warp length 1330 m

Trawler speed / Heading : 3.50 knots / 0 °
Bottom depth / Friction coefficient : -500.0 m / 0.60
Vertical opening: 7.2 m
Horizontal opening: 23.7 m
Otter boards opening: 69.1 m
Warp tension / total towing traction Z (kgF) : 4247.7 4244.1 / 7711.2
Projected swept surface (m²) : 153.1 Swept water volume per second (m3/s) : 281.0

Advantages : feasibility
Drawbacks : variations of doors height introduce additional flexibility. The time needed to reach a stable configuration (door height) can be very long.

The possibility to connect the upper bridle directly to the door does not bring any significant advantage.

3.2.2.3 Conclusion for concept 2

It is possible to avoid herding due to sweeps on the seabed just by lifting off the doors. However the wire from the doors to the wings can herd fishes horizontally and/or vertically.
Moreover, the stability of the gear becomes very time consuming because of the high flexibility of the whole system. This will add extra variation to the herding effect.

3.2.3 Concept 3 : designing a trawl without classical doors/sweeps

Concept 3 consists in designing a trawl without the classical doors/sweeps system, or with small pelagic doors high up from the bottom, which alternatively is spread by means of kites or foils on the sides of the trawl, and where bottom contact is achieved through e.g. a heavy ground gear.

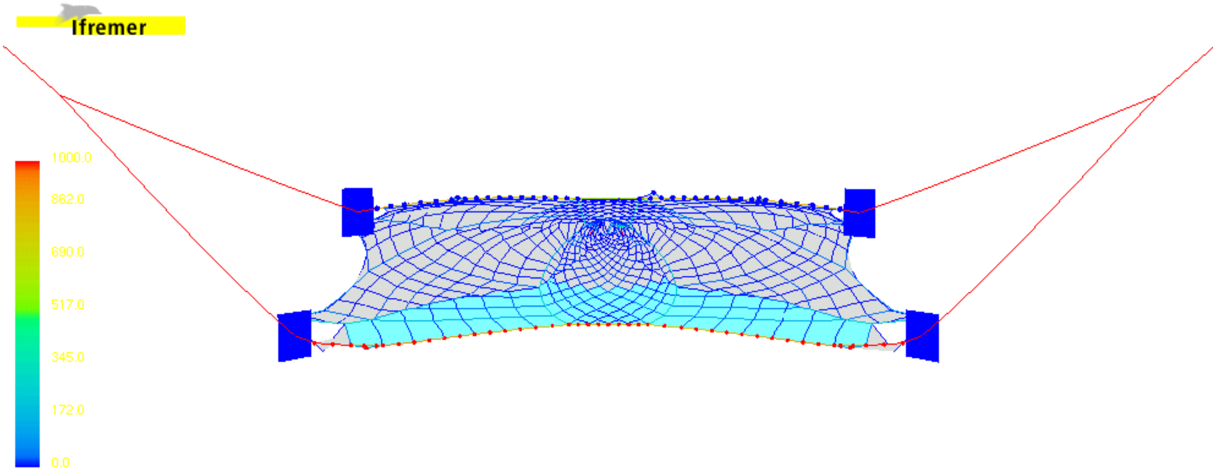
In this case we avoid the use of the classical system doors + sweeps, it is possible to get a trawl where warps are almost parallel, particularly next to the trawl, taking advantage of the low angle between the warps and the towing direction (blocks distance aboard a typical research vessel is around 8 to 10 meters and the horizontal opening of the trawl is around 20 meters).

One interesting point for this concept is the absence of wire sweeping the seabed.

3.2.3.1 Concept 3a : removing sweeps using 4 doors

Four doors are used in the following concept:. Two classical heavy bottom doors at the lower wings and two light pelagic doors at the upper wings.

Solution : Sweep length is reduced to 0 in the simulation. In order to ensure horizontal upper wings opening, smaller doors are added close to upper wings.
Results :
Trawler speed / Heading : 3.50 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Vertical opening: 6.4 m
Horizontal opening: 23.8 m
Otter boards opening: 26.4 m
Warp tension / total towing traction Z (kgF) : 4043.9 4043.7 / 7641.4
Projected swept surface (m²) : 146.3 Swept water volume per second (m3/s) : 282.2



Advantages : low flexibility, possibility to control geometry at different depth with the warp length.
Drawbacks : shooting and hauling with 4 doors close to the wings could be difficult.

3.2.3.2 Concept 3b : using 2 light doors

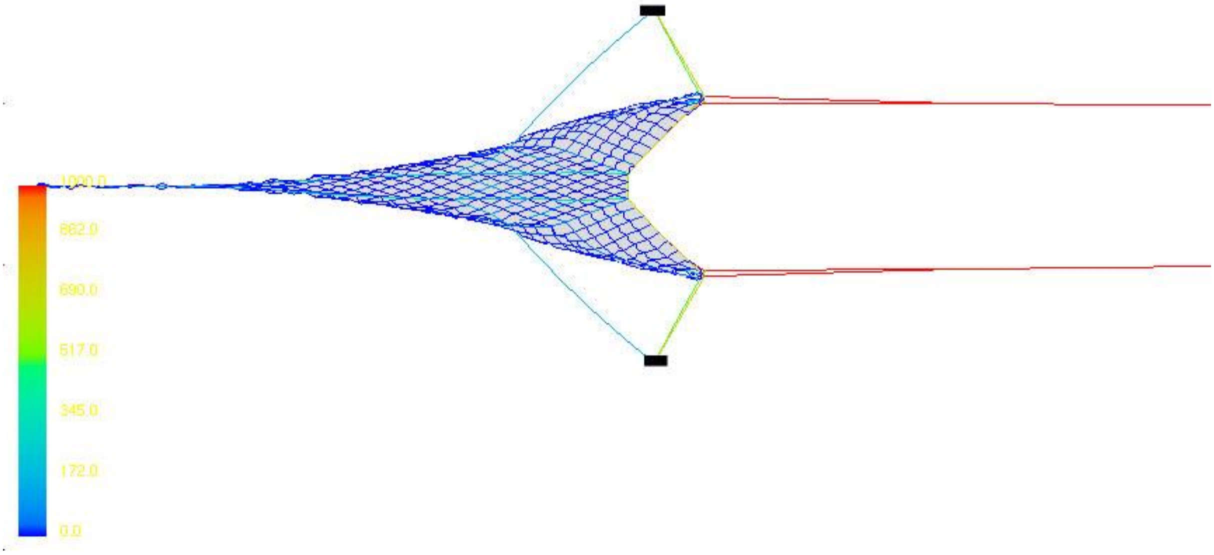
Light doors could be used, possibly supple doors made of a strong reinforced canvas that have been developed by IFREMER in the year 1995. These light doors could also be made of mould composite material to enable an efficient hydrodynamic profile. For this concept it is essential to use pelagic doors and to avoid their contact with the seabed.

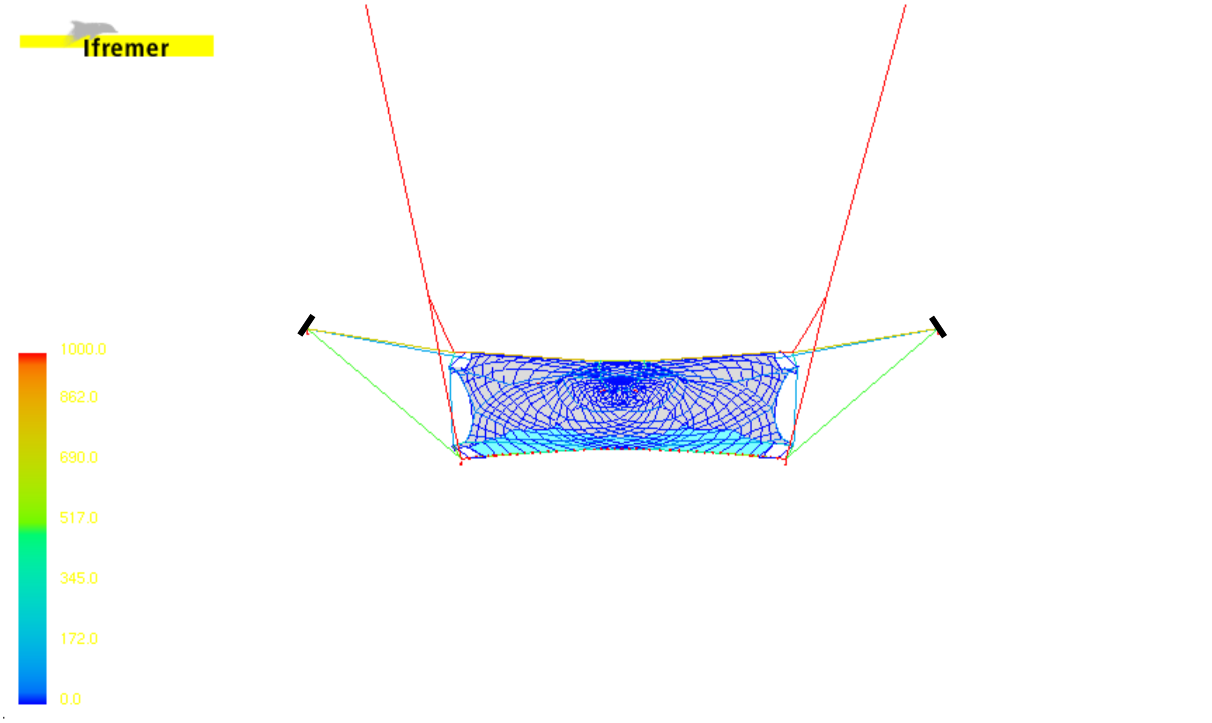
In order to compensate the lack of weight due to light doors, we need to add weight at the beginning of the lower wings (it can be included either in the footgear or with a heavy chain in front of the footgear), to ensure the trawl sinks fast enough and has good contact with the seabed.

In order to maintain an important vertical opening easily, light doors can be positioned at the upper wings height. In this case floats are not needed. This will improve the stability with speed variations.

In the concept 3b, the vertical flexibility of the netting has been reduced by the use of a rope maintaining a maximum distance between lower and upper wings.

Results :
Trawler speed / Heading : 3.50 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Vertical opening: 6.2 m
Otter boards opening: 42.0 m
Horizontal opening: 19.7 m
Warp tension / total towing traction Z (kgF) : 3564.8 3568.0 / 6733.2
Projected swept surface (m²) : 130.4 Swept water volume per second (m3/s) : 235.0


1000.0
862.0
690.0
517.0
345.0
172.0
0.0


1000.0
862.0
690.0
517.0
345.0
172.0
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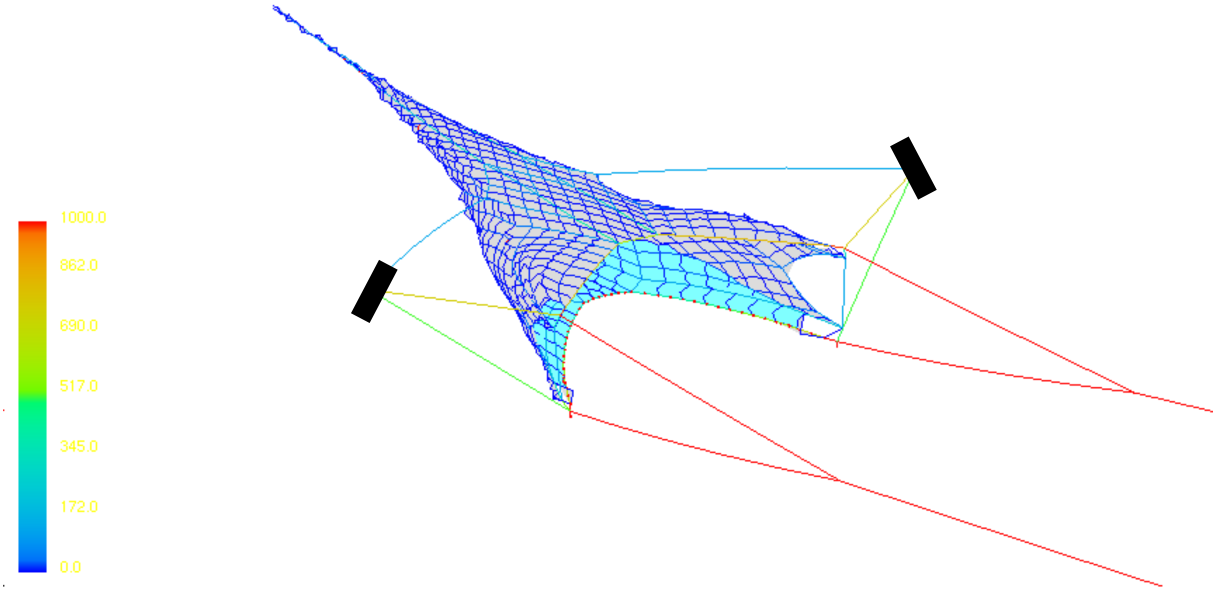


The ropes set between the upper and lower wing tips and the absence of floats on the headrope ensure the stability of the vertical opening.

3.2.3.3 Geometry stability of the concept 3b

Among all concepts presented in this chapter, only concept 1b, 2 and particularly concepts 3a and 3b gave a satisfactory geometry stability. Each time the doors laid down on the seabed, the upper bridle tension (depending on speed) modified the vertical trawl opening when the towing speed changed.

In this paragraph we compare the vertical and horizontal openings and the filtered surface (surface of the trawl mouth) for concept 3b (light doors) for different depths and towing speeds. Equivalent results are obtained with concept 3a.

Depth (m)	Towing speed (knots)	Vertical opening	Horizontal opening	Variation % of horizontal opening (1)	Filtered surface (m^2)	Variation % of filtered surface (1)
50	3.5	6.0	18.6	**-4.1**	122.1	**-6.3**
	4.5	5.9	18.2	**-6.1**	121.6	**-6.7**
100	3.5	6.2	19.7	**1.5**	130.4	**0**
	4.5	6.1	19.4	**0**	130.4	**0**
500	3.5	6.1	19.3	**0.5**	128.1	**-1.7**
	4.5	6.1	19.3	**0.5**	131.6	**0.9**

(1) the case 100 m deep / 4.5 knots is chosen as a reference

The table shows the very good stability of the concept 3b geometry for a wide range of depth and for significant towing speeds variations. The horizontal opening decreases for the shallow water (depth of 50 m) because of the short warp length. This effect could be minimised using additional small light doors higher on the warps that would be quite easy to handle.

3.2.3.4 Conclusion for concepts 3

Concepts 3 have very good geometry stability and are probably good “non herding” trawls. Concept 3b can avoid the use of floats that will increase the geometrically stability.

The main drawbacks of concepts 3 are the probable difficulties to handle the trawl during shooting and hauling operations. The absence of backstrops and the use of heavy (lower) doors in concept 3a is probably reason good enough to remove it from the list of candidate non-herding trawls.

The handling problems for concept 3b could be solved by a low door weigh.

3.2.4 Concept 4 : trying to control the herding effects with a set of chains

Concept 4 consists in adding a heavy chains set starting from the warps, in front of the doors and linked to the lower wings. The sand cloud produced by the chain will herd fish into the trawl path (concept 4a).
Notice: rigging of concept 4 is not far from concept 1b.

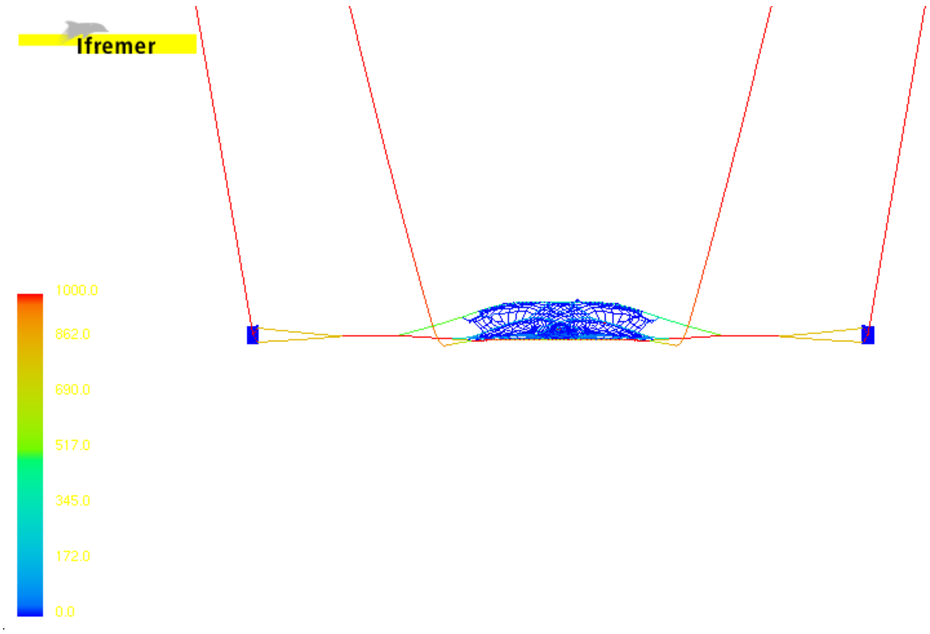
3.2.4.1 Concept 4a

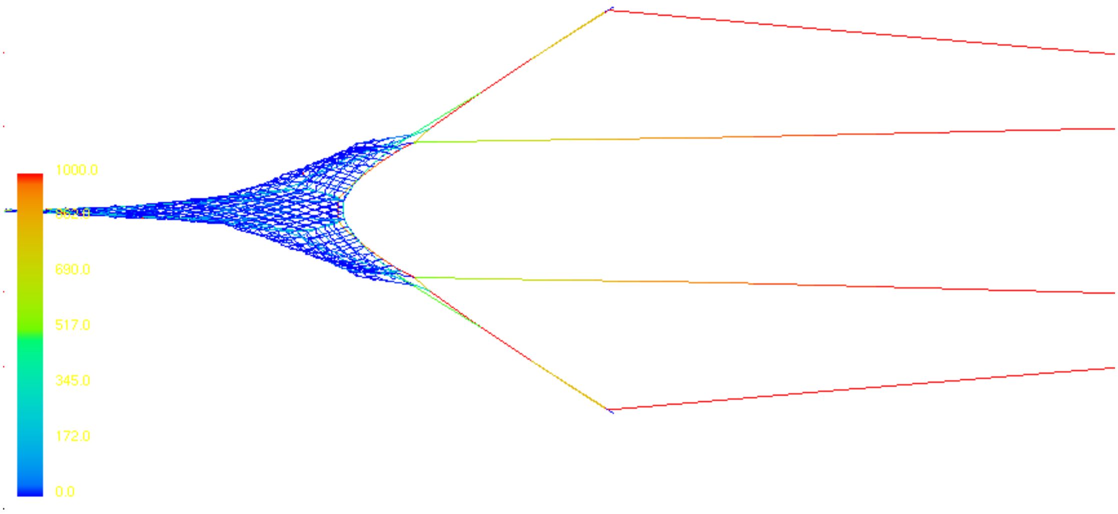
A set of chains can be added between the ground gear and the warps. The chains should be almost parallel. The chains will generate a sand cloud that should drive fishes into the trawl path. If the trawl wings shape (trawl mouth) is properly designed, we don't have to mind about the fishes outside the chain track that will not be fished.

The main question regarding this concept is about the intensity, and thus the efficiency, of the sand cloud produced by the chains. It cannot be compared to the sand cloud produced by a door, where the main "engine" is one or two big vortexes and a low pressure area that literally suck up the substrate from the seabed and mix it with the sea water to generate a "huge" sand cloud.

Results :

Trawler speed / Heading : 3.50 knots / 0 °
Bottom depth / Friction coefficient : -100.0 m / 0.60
Vertical opening: 4.8 m
Horizontal opening: 21.0 m
Otter boards opening: 64.8 m
Warp tension / total towing traction Z (kgF) : 4410.9 4404.8 / 8195.8





3.2.4.2 Concept 4b

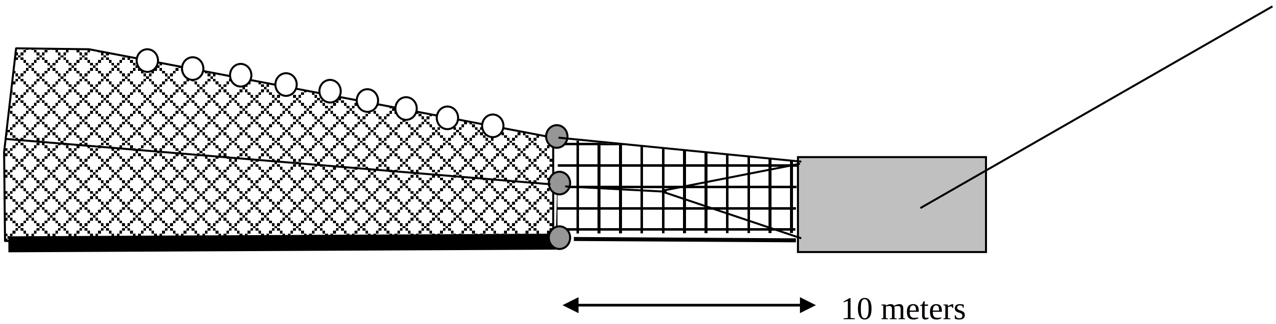
Alternatively, in the case of an insufficient sand cloud generated by the chains, a series of floating ropes regularly starting from the chains can be used to intensify herding. This would illustrate two walls that would perfectly define the trawl track (concept 4b).

3.2.5 Concept 5 : trying to control the herding effect with long wings

Concept 5 consists of filling the space between the doors and the trawl between the backstrops with a netting section comparable to a long wing. Consequently, fishes are herded toward the trawl path, defined by the door spread.

This concept can be seen as a usual trawl gear where a netting section is added to the backstrops.

This design is known as "long wing scraper" and used by Scottish fishermen. The only originality of our concept is the connection location, in the middle of the wing.



Three G hooks could be used to connect the “netting backstrops” to the net.

Finally, this concept is the concept 3 where backstrops are replaced by the beginning of the trawl wing. The only difference is that the connection is not made at the door (which is the main drawback of concept 3) but in the middle of the wing.

This concept has at least 2 drawbacks :

- As it cannot be very heavy (handling), a heavy ground gear cannot be used, thus it seems clear that the “net-backstrop” will either suffer from ground contact (stones ….) or will let escape fishes if ground contact is avoided.

- This concept can be criticized because a long wing trawl will be more easily damaged than a short wing trawl.

3.2.6 Conclusion relative to concepts numerical simulation

All the concept detailed above are hydrodynamically viable, except the concept 1b which could suffer of a lack of door stability, due to the way backstrops are attached to the doors.

Some of these concepts seem to be promising regarding herding, except concept 1a and 2.

The rigging should not be too heavy : weight in the sweeps/bridle/warp introduced flexibility when towing speed changed.

The geometry stability has been tested with different depth and speed for concepts 3 ad 1b. This could be one good criterion to select the best configuration. The speeds of 3.5 and 4.5 knots have been used to test the stability. This variation of 1 knot representing the maximum “uncontrollable” speed variation (undercurrents, vessel motion, swell …).

To test for the variation in trawl geometry by depth, a range from 50 m to 500 m has been tested and showed good results for concepts 3 / 3b.

Other concepts could be defined and tested. The key point for a new concept is to find an alternative solution to the classical “bottom doors + sweeps” to tow and spread the trawl.

All the calculation results are available in the **CDROM** delivered for the WP4. This **CDROM** contains the demo version 2.1 of the trawl simulator DynamiT and the files corresponding to the 5 concepts described in the project.

The DynamiT Demo version can open all SIM files provided but cannot calculate a new simulation. Thus, it is possible to observe the trawl shape from any point of view and to display any force and distance in the rigging or in the net.

3.3 Some physical trials

3.3.1 Sea trials

Although it was not defined in the project, we got the possibility to test the concept of parallel chains from the warps to the wing ends during a cruise in November 2003. A series of sea trials were undertaken aboard the IMR Johan Hjort research vessel to test the concept 4a. The main findings was that the sand cloud produced by the chains was not intense enough and there could be a handling problem (chain length is a critical point).

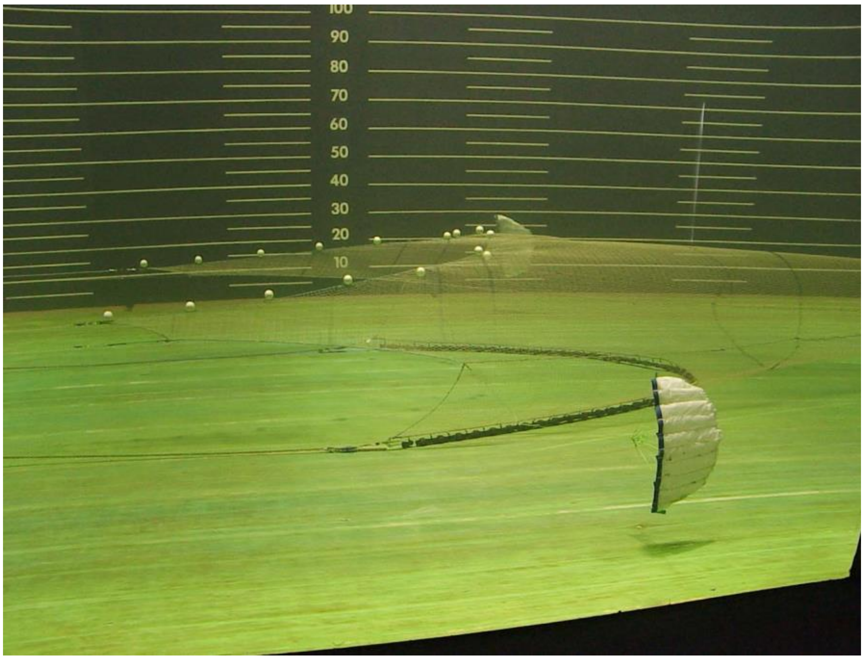
3.3.2 Flume tank trial

Flume tank trials were not planed in the project, but there was a crucial need to evaluate the stability of the doors in the concept 1b. Qualitative trials were carried out to observe the behaviour of a classical bottom door with modified attachments of the backstrops.

The trials showed very pour stability when using a classical door. This was due to the lack of backward traction (no classical backstrops) and the door weight which is important for a bottom door.

A classical bottom door has been tried out with a special rigging corresponding to the concept 1b.

We have also tried out a concept of light supple doors developed by IFREMER (Lorient) in the years 1995 to spread a trawl. This technique could be applied to the concept 3b.



This flume tank trial illustrate a possible use of light supple doors to spread a trawl (concept 3b)

3.4 Trawl design adapted to SURVEYTRAWL concepts

The objective in the initial proposition was to design a trawl that would avoid herding using one of the first three concepts. The modelling and tests of the three concepts and the additional ideas (concept 4 and 5) have leaded us to these conclusions:

- A 4 panels trawls enable a better control of the shape and stress share,
- Side panels don't need to be too wide,
- The geometry should be about 20m wide x 5 m high,
- The overlap (headrope / fishing line) should be about 5 m
- Wings should be short to reduce flexibility,
- High tenacity fibres could be used in the upper panel, this should help to maintain the lower panel off the seafloor,
- Mesh size from wings and backwards in the panels could be a compromise between GOV 36,47 and Campelen 1800.

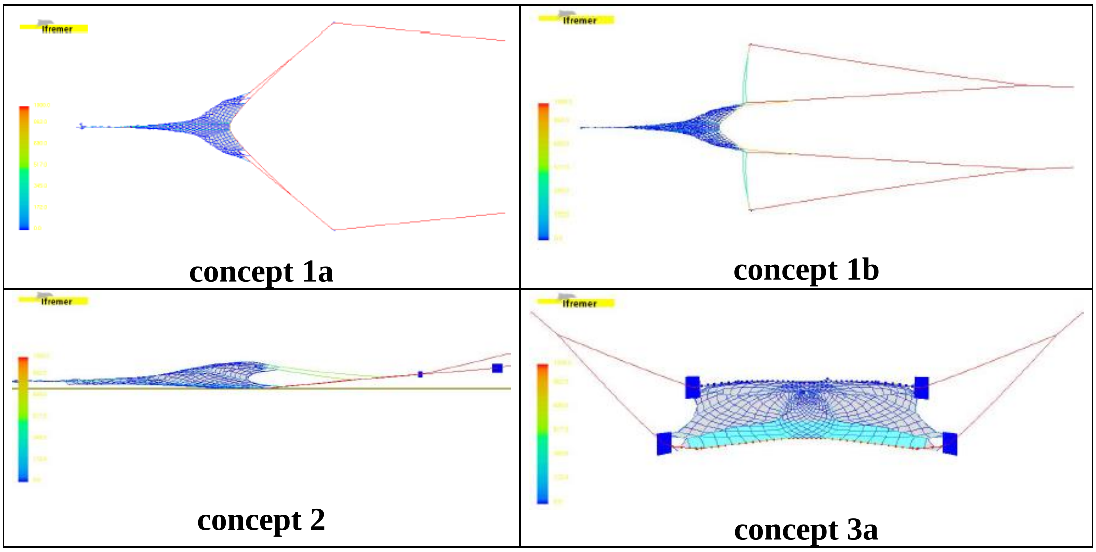
4 Project strategy (WP 3,5,6 - NCMR)

4.1 FTFB members feedback (stakeholder communication , dissemination)

A summary of the findings of the extended literature that has been presented to FTFB members by Dr Irene Huse during the FTFB meeting in Bergen in the 27th of June 2003, follows. Finally, FTFB members' initial feedback following project's presentation is given.

An extended review has been presented to FTFB members by Dr Irene Huse during the FTFB meeting in Bergen in the 27th of June 2003. We have tried to draw links between this review and the application to our different concepts. An important conclusion from this review is that almost all fishes in the length groups that has been experimentally tested, can swim over 1.96 m/s, which is the herding speed of 45° sweeps at 5 knots. Thus, concept 1a cannot be efficient to avoid herding in these fishes. Concept 2(sweeps off the bottom) cannot also be efficient for round fishes. Flat fishes are sensitive to herding mainly if they are touched by the sweep. Sweeps should not be in contact with the seabed, they can be made off light material, except in front of the ground gear where we need important weight. Strapping: in the case of using a strapping, particular care must be taken to reduce the contrast and the vibration. A vertical herding effect can occur. For the concept 3, the presence of doors just in front of the net brings both a visual and an acoustic stimulation. For the concept 2b, if the two cables are not at the same height, a lateral herding effect can occur.

Following up the project's presentation and recent advances made by Dr Benoit Vincent (presentation of **concepts 1a, 1b,2 and 3a**), a discussion with FTFB members took place.



concept 1a **concept 1b**

concept 2 **concept 3a**

The advantages and drawbacks of the different concepts were presented with the following table :

The 3 SURVEYTRAWL concepts	**Concept 1** (high sweep angle)	**Concept 2** (doors lift off the bottom)	**Concept 3** (parallel warps, no sweep)
Advantages	good geometry stability, can be improved. Parallel sweeps = symetrical herding No sweep change	Simple configuration No sweep change	Low flexibility, good geometry stability vs. depth. No sweeps. Parallel warps = symetrical herding No sweep change
Drawbacks	Doors pitch stability ? (can be improved)	Efficiency regarding herding ? Regulating long warp length could be difficult (important time interval for stabilisation especially for high depths). Additional flexibility of the whole structure due to the doors off the bottom.	Complex handling (in the case of a 4 doors-rigging). Replace 4 doors by long side kites ?

In general, feedback was supportive. A number of questions and positive remarks were made showing their interest in the project. Their **main remarks** are listed hereafter :

• What about the use of a beam trawl, or several beam trawls, modified in order to increase the vertical opening. However in the case of beam trawling, we have to face the herding due to the towing cables.

• In the case of the concept 2 (doors off the bottom), it could be difficult to ensure a efficient contact between the ground gear and the seabed.

• The geometry of a trawl gear that becomes complex (case 1b especially) could be difficult to control.

• The concept 1b is “appreciated” by some FTFB members.

• It is remarked that it must be impossible to design a non selective trawl. Thus it must be designed for some commercial species.

• No negative reaction about the possibility of using kites (concept 3).

• No particular remarks about the ground gear though it is an essential point.

• The SGSTG should take into account SURVEYTRAWL project.

• It is not a good idea to increase the sweeps length of an existing survey trawl.

Everybody agree on the fact sweeps must be as short as possible.

4.2 Stakeholder communication (WP3)

4.2.1 Introduction

In the framework of the EU Regulation 1543/2000 of the National Data Collection Programme, a meeting of fisheries stakeholders was held. The meeting took place in the National Center for Marine Research (NCMR) in Athens between 24-25th of September 2003. The Heads of the Fisheries Institutes in Greece, senior fisheries biologists and commercial trawl skippers were invited in this meeting. The morning session of the 25th of September 2003 was devoted to the presentation of the SURVEYTRAWL project to selected participants. Selection of fisheries scientists was based on their wide experience on research surveys using both research and commercial charter vessels. Selection of skippers was based on their experience of both research and commercial trawl surveys. Two of them were also representatives of National Fisheries Associations. A list of participants is given in the end of this report.

The main objective of this project's presentation was to obtain from stakeholders their support for the development and particularly the deployment of the new standard survey trawl. A historical overview of the development of SURVEYTRAWL programme was presented to them. The main aim of the project, i.e. to reduce herding in the trawling process, and a brief summary of the relevant literature was also discussed.

The three SURVEYTRAWL concepts were presented alongside their main advantages and possible drawbacks. The participants were then asked to provide their comments as well as to fill the specific questionnaire that has been prepared for the purpose of the project. Although they were asked to comment on the 3 initial project concepts, an alternative fourth concept was also briefly presented and their reactions were recorded. However, the current report includes only meetings' outcome for the 3 concepts initially included in the proposal.

In general, there was a positive reaction from the group both for the underlying idea of the project as well as the undertaken approach. Concept 1 and 3 were regarded as the more likely to work. Although the use of 4 doors was considered difficult to be adopted, the use of kites received some positive remarks. The group was skeptical on the effectiveness of Concept 2, thus it received the lowest marks on the questionnaire. Overall concept 3 received higher marks than concept 1 and 2.

Concepts 4 and 5 were further developed towards the end of the project months 11 and 12. This is why these concepts were not included in stakeholders' communication.

4.2.2 List of participants:

1. Dr. A. Kallianiotis (Director, Institute Fisheries Research, Kavala, IFR)
2. Dr. A. Machias (Head, Fisheries Dpt, Institute Marine Biology Crete, IMBC)
3. Mr. G. Petrakis (Fisheries Biologist, NCMR)
4. Dr. S. Vassilopoulou (Fisheries Biologist, NCMR)
5. Dr. G. Tserpes (Fisheries Biologist, IMBC)
6. Dr. M. Labropoulou (Fisheries Biologist, NCMR)
7. Dr. C-Y. Politou (Fisheries Biologist, NCMR)
8. Dr. C. Mitilineou (Fisheries Biologist, NCMR)
9. Dr. C. Papaconstantinou (Director, Institute Marine Biological Resources, NCMR)
10. Dr. C. Maravelias (Fisheries Biologist, NCMR)

Mr A. Doukas (skipper 1)
Mr D. Papaparisis (skipper 2)
Mr G. Moschos (skipper 3)

4.2.3 Questionnaire

Based on the proposed concepts' description give your mark for the following criteria on a 1 to 5 scale with 1 being poor and 5 excellent. (1: poor, 2: average, 3: good, 4: very good, 5: excellent).

4.2.4 Criteria

1.Stability of the proposed concept: (1-5)
2. Easiness to handle on deck:
3. Easiness to handle on shooting:
4. Easiness to repair (maintenance):
5. Safety aspects of the proposed gear:
6. Easiness to add additional equipment (e.g. sensors):
7. Efficiency of the materials used:
8. Easiness to obtain requisite vertical/horizontal opening
9. Behaviour of the gear in contact with the seabed substrate
10. Estimation of catch losses

4.2.5 Concept 1

Name / Criteria	1	2	3	4	5	6	7	8	9	10	Medium	Skipper 1	Skipper 2	Skipper 3	Medium
1	2	1	3	3	1	1	2	2	1	2	1,8	2	3	2	3
2	3	3	4	3	3	3	4	3	3	4	3,3	3	2	3	2,7
3	1	1	2	3	2	1	2	3	2	2	1,9	2	2	2	2
4	3	3	4	3	5	3	2	3	3	3	3,2	3	4	2	3
5	2	3	2	2	4	2	3	2	2	3	2,5	2	3	3	2,7
6	4	3	3	2	2	3	4	2	3	2	2,8	3	2	3	2,7
7	3	4	4	5	3	3	3	3	4	3	3,5	3	2	2	2,3
8	1	2	2	3	2	2	4	2	2	3	2,3	1	1	3	1,7
9	2	2	2	2	3	2	3	2	3	2	2,3	1	2	2	1,7
10	3	2	4	2	2	3	2	2	2	3	2,5	1	2	2	1,7

4.2.6 Concept 2

Name / Criteria	1	2	3	4	5	6	7	8	9	10	Medium	Skipper 1	Skipper 2	Skipper 3	Medium
1	1	2	2	2	1	1	1	2	2	1	1,5	1	1	1	1
2	2	1	2	1	2	3	1	2	1	2	1,7	1	2	2	1,7
3	2	2	1	2	2	2	1	3	2	2	1,9	1	1	2	1,3
4	3	2	2	3	2	1	3	2	2	3	2,3	2	2	1	1,7
5	2	2	1	2	3	2	1	1	2	2	1,8	2	2	2	2
6	3	4	2	2	3	2	1	3	2	2	2,4	4	2	2	2,7
7	1	4	3	4	2	2	1	1	3	2	2,3	1	3	2	1,7
8	1	1	2	1	2	1	2	2	1	2	1,5	1	3	1	1,7
9	2	3	1	2	2	3	1	2	1	1	1,8	2	1	1	1,7
10	2	4	2	2	3	2	2	4	2	3	2,6	1	1	2	1,3

4.2.7 Concept 3

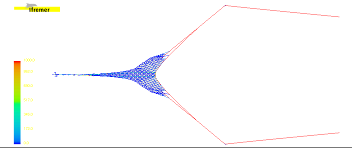
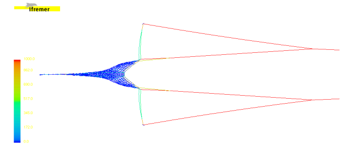
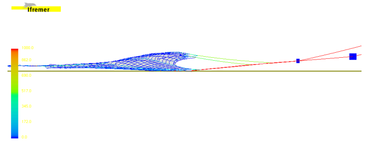
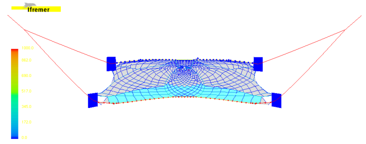
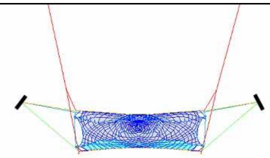
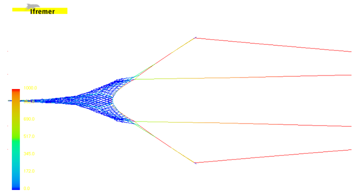
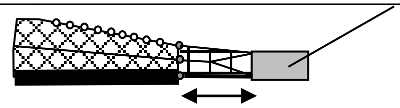
Criteria \ Name	1	2	3	4	5	6	7	8	9	10	Medium	Skipper 1	Skipper 2	Skipper 3	Medium
1	3	4	4	4	5	3	2	5	3	4	3,7	3	3	5	3,7
2	4	2	3	3	3	4	3	2	3	2	2,9	2	4	3	3
3	2	2	4	3	3	3	2	4	4	2	2,9	3	4	4	3,7
4	3	3	4	3	5	3	4	3	5	4	3,7	3	5	4	4
5	2	3	3	2	2	3	2	3	2	2	2,4	2	3	4	3
6	4	4	4	5	4	3	5	4	5	5	4,3	4	3	4	3,7
7	3	3	2	4	3	2	3	2	2	3	2,7	2	2	3	2,3
8	4	4	3	2	4	3	4	3	4	4	3,5	3	2	2	2,3
9	3	3	3	3	4	2	3	3	3	3	3	2	2	3	2,3
10	3	5	5	4	4	3	4	4	4	5	4,1	3	3	3	3

4.3 Concept evaluation

The following table presents, for all concepts, the main advantages and main drawbacks. Potential solutions are proposed.

Concept 1a and concept 2 are logically removed because no realistic solution can be found at the moment to solve their main drawbacks.

In order to be able to select the best concept, or at least to classify them, sea trials are needed, particularly to verify the feasibility of shooting / hauling the trawl in suitable working condition for the crew members.

	Advantage	Drawback	Potential solution	
Concept 1a	Simple	The sweep angle remains too low : bad efficiency regarding herding		
Concept 1b	Potentially low herding trawl	Doors stability	Modification of the door design	
Concept 2	Simple. Potentially low herding on benthic species	Bad trawl gear stability due to the doors off the seafloor, especially for deep trawling		
Concept 3a	Potentially very low herding trawl and very good geometry stability	Difficult to handle due to the absence of sweeps	This concept is used by fishermen with very short sweeps.	
Concept 3b	Simple. Potentially very low herding trawl and very good geometry stability	Use of unusual light (supple or composite ?) doors	Has to be assessed at sea	
Concept 4	Potentially low herding trawl	Insufficient sand cloud at least for simple chains	Use a heavier / hydrodynamic gear to produce a stronger sand cloud or additional devices.	
Concept 5	Potentially low herding trawl	Fragility of the net part between doors and wings (no footgear)	Has to be assessed at sea	

4.4 Dissemination (WP 6)

In accordance with initial proposal's plan, the project adopted a comprehensive dissemination strategy aiming at targeting all the potential end-users, EU and the public.

A first dissemination effort was undertaken with documents and animations being prepared and presented during the first meeting of the ICES SGSTG (STUDY GROUP ON SURVEY TRAWL GEAR FOR THE IBTS WESTERN AND SOUTHERN AREAS) Vigo, Spain, 12–14 February 2003. The objective was to make people aware of the advantage of waiting the results and recommendation of the SURVEYTRAWL project before they do any modification on their existing trawls.

A second communication of project activities and results, through working paper and presentation, was held during the ICES FTFB (Fisheries Technology and Fish Behaviour) meeting, in June 2003, Bergen, Norway. working papers

A presentation has also been planned for the ICES SGSTG meeting, in February 2004.

A wider communication of main advances of the project is under way through scientific publications in international peer-reviewed fisheries journals.

Distribution of a DVD that will contain a demo version of the computer trawl modelling software employed during the development, the SURVEYTRAWL trawl. It is believed that this will further contribute to an increased awareness amongst the end users of the development of new survey gear.

Diffusion of project results through EC reports.

5 Conclusions - Recommendations

It seems clear for most of the scientific stakeholders that the sweeps must be as short as possible. In fact, the potential success of a non herding sampling trawl is entirely depending on the horizontal spreading system : the solution will be find between :

- the classical “bottom doors & sweeps” system that must be avoided if possible because of important herding effects and pour stability, that represent the actual used configurations
- and a system with no bottom door and no sweep that represent the ideal configuration regarding both herding and geometry stability.

The geometry variability of the trawl is a crucial point that is very often a drawback of actual standard survey trawls. The variability is directly linked to the general trawl gear flexibility, which increase with the wings length (vertical variability), the sweeps and bridles length (vertical and horizontal variability). Thus, in order to reduce the trawl geometry variability, it is essential to reduce as much as possible of the flexibility. For example, the concept 3b is based on a trawl without sweeps, without bridles, with rather short wings and with a constraint rope that maintain a constant vertical distance between upper and lower wings.

All concept presented in this study have been studied from a theoretical point of view. The hydrodynamic viability has been assessed but the practical aspects have not been yet studied, except for the concept 4a (sea trials) and for the stability of doors in the concept 1b (flume tank trials). **Thus we recommend to undertake engineering sea trials to evaluate the feasibility of the most promising concepts**. The next step will be to validate the efficiency of the selected concept regarding herding, using underwater observation means, and finally intercalibration surveys to compare a selected new survey trawl, resulting from further studies, and actual sampling gears.

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