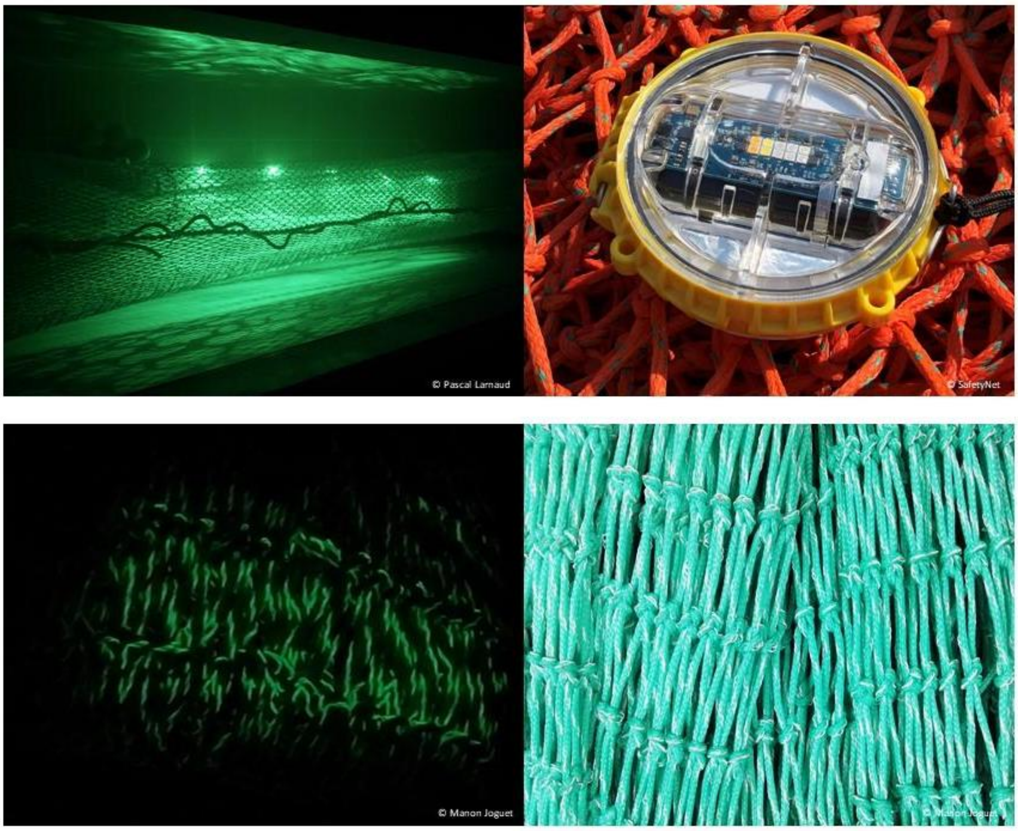
Report on the SELUX project

Improving the selectivity of the artisanal trawlers fishing in the English Channel and the southern North Sea through the use of lighting systems

January 2019 – December 2020



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Summary

The aim of the SELUX project (January 2019 - December 2020) was to test lighting systems which enable the selectivity of the 80 mm square mesh panel which is legally prescribed for use in the North Sea to be improved. The aim was to enable a reduction in catches of horse mackerel and whiting (species which have to be landed and which are largely discarded by this fishing fleet) while retaining species which are commercially valuable.

Two lighting systems were tested in real fishing conditions: PISCES, which are waterproof LEDs developed by the English start-up, SafetyNet, and Brezglow, a fluorescent wire developed by the Le Drezen company which is based in Brittany.

Brezglow was tested in just one configuration on 3 fishing trips between December 2019 and September 2020: Brezglow mesh on the belly part of the trawl underneath the square mesh panel

The Pisces devices were tested in two different configurations on 4 fishing trips between October 2019 and July 2020

- Configuration 1 on the fishing trip in October 2019: 4 non-flashing PISCES on the belly part of the trawl underneath the square mesh panel
- Configuration 2 on the 3 following fishing trips: 5 flashing PISCES on the belly part of the trawl underneath the square mesh panel.

The “alternate haul” method was used for these experiments. This method involves using a control trawl followed by a test trawl while ensuring that the factors which influence the abundance of fish and the efficiency of the gear are as similar as possible. Two observers were on board during each fishing trip in order to sample the catches.

This project enabled an improved understanding of the behaviour of different species in response to light to be obtained. These analyses show that whiting – like mackerel – tends to shun the light, and that by contrast small pelagic species (herring, sprats) seem to be attracted by it. Horse mackerel also seem to be attracted by the light but could be repelled by it when it is flashing.

The configurations of lights and square mesh panels that were tested enabled catches of whiting of all sizes to be reduced over two fishing trips (one fishing trip for each system), which means commercial losses for the ships that are fitted with these systems. These results are nevertheless encouraging. Adjustments could be made so as to prevent individuals larger than the MCRS (Minimum Conservation Reference Size) from escaping, e.g. the use of T90 netting which is more suitable for this species. The efficiency of the lights could also be improved by varying their brightness and adjusting their position on the trawl net (installing them further above the selective panel). The configurations that were tested were unable to improve selectivity in relation to horse mackerel. However, the results are promising in relation to species which have a high added value, and the amounts of such species that are landed do not seem to be affected by the presence of lights on the trawl net.

These results provide initial indications of how light can be used to improve the selectivity of this fishery. There are many different ways in which the light could be adjusted in relation to selective systems. It would be interesting to continue the trials using new configurations.

Introduction

Improving the selectivity of fishing gear is a major challenge for the artisanal trawlers fishing in the eastern English Channel and the southern North Sea. In order to comply with the landing obligation that has been in force since 2019 and to maintain the fleet's long-term economic viability, a substantial reduction of by-catches is essential. For these ships the by-catches which are managed by a Total Allowable Catch (TAC) system, and which are therefore affected by the landing obligation, account for up to 52.1% of their total catches (Gauduchon & Al., 2020).

Over several years numerous selectivity tests have been carried out by this fishing fleet (selective grids, cylinders with different mesh sizes etc.), although none of them seems to achieve an acceptable trade-off between reducing by-catches and preserving species which are very commercially valuable. It is not clear how selectivity can be improved for this fleet. These ships target about forty species whose Minimum Conservation Reference Sizes (MCRS's) may vary considerably (for example, in the eastern English Channel: mackerel 20 cm / whiting 27 cm / cod 35 cm). Simply increasing the mesh size may lead to significant losses of some species. Selectivity must therefore be interspecific so as to not merely facilitate the escape of certain species, but it must also be intraspecific so as to only preserve individuals which are above the MCRS. The combining of selective systems seems to be the most efficient solution for the time being.

This is the finding upon which the SELUX project has been developed. Over a period of two years (January 2019 – December 2020) the project has aimed to test the combining of known selective systems, such as the Square Mesh Panel (SMP), with lighting systems. Various studies (O'Neill et al., 2017; Marchesan & Al., 2004, Kurc et al, 1966, Breen & Lerner, 2013) examine the influence of light on the behaviour of fish. Depending on the position, colour and brightness that are used, the lighting systems seem to attract – or alternatively to repel – certain species. Light may also reinforce the relevance of the selective systems that are already in place on fishing gear by making it easier for certain species to escape. Although there are a number of studies on this subject around the world, none of them involves the artisanal trawlers which target demersal species in the eastern English Channel and the North Sea.

The SELUX project focuses on whiting and horse mackerel, the latter of which are one of the three species which are most commonly discarded by these ships (Gauduchon & Al., 2020). The aim is to reduce catches of horse mackerel of all sizes, and catches of whiting that are under 27 cm in length, while preserving species which are very commercially valuable, such as red mullet and squid. The system must enable a balance to be achieved between reducing discards and maintaining turnover.

Two lighting systems are tested in this project:

- The "PISCES" developed by the SafetyNet company is a system consisting of a transparent cylinder fitted with LEDs whose colour and brightness may vary.
- The "BREZGLOW", a system devised by the Le Drezen company, comprises a fluorescent wire which replaces the conventional meshwork of the trawl net.

The first part of the project involved analysing the behaviour of the species in response to light so as to specify the best configuration of SMP/lighting. Experimental fishing trips were then organised in order to evaluate the efficiency of these combinations of lighting systems and selective systems.

This report, after outlining the context and the methodology that was used, presents the results of these various experimental fishing trips.

1. Context

1.1. Regulatory context: Landing obligation (Regulation (EU) No 1380/2013, Art. 15)

Since 2015 the Common Fisheries Policy (CFP) has progressively brought into effect the Landing Obligation within the various European fisheries (Regulation (EU) No 1380/2013, Art. 15). The aim of this new regulation is to encourage improved selectivity so as to achieve both a healthy level of the various stocks and the Maximum Sustainable Yield (MSY). Since the 1st of January 2019 all European ships are subject to this Regulation. Professional fishermen are therefore no longer authorised to discard catches of species that are subject to a TAC, even if they are below the MCRS. These catches must be kept on board, unloaded and set off against the quotas, and they cannot be used for direct human consumption. Exceptions are made for species where improving selectivity is “very difficult” and/or for which the application of the Landing Obligation (LO) involves “disproportionate costs” for the fishery concerned. These exceptions are called “de minimis” exceptions. This is an annual maximum percentage of the catches of the species that is subject to the LO which it is possible to discard. There are also exceptions for species which have a “high survival rate” or which are subject to a fishing ban.

This new regulation has serious consequences for artisanal trawlers operating in the eastern English Channel and the southern North Sea. In fact, despite significant advances in selectivity that have been achieved over recent years there are still high discard rates for some species, such as horse mackerel, mackerel and whiting. The implementation of this regulation may lead to critical situations.

The main difficulty relates to the issue of “choke species”. Some species are subject to very low quotas. However, it is not always possible to avoid such species, either because they are caught at the same time as other target species (mixed fisheries), or because they constitute unwanted, accidental catches (stocks which are improving, or development of species within new zones). Since the ship is obliged to unload them, the quota for these species may therefore be reached very quickly. The ship would consequently be obliged to remain in port since if it was at sea it would run the risk of fishing species whose quota has been exhausted – even if the quotas have not been used up for all the species. This situation may force ships to cease their fishing operations.

Apart from this “choke species” issue, professional fishermen run the risk of using up their quotas too quickly and in an inefficient manner. Landings themselves may well not be regular throughout the year, and this will affect the market. Sailors will also waste time sorting the catches, and they will lose space on board in storing species that have no economic value. It is estimated that fishermen on a trawler of over 18 metres in length will spend an additional 15.4% of their time sorting these catches. This will therefore affect the rest periods that they have (Balazuc A, 2016). Improving selectivity consequently represents a major challenge for this fleet.

1.2. The fishery: artisanal trawlers fishing in the eastern English Channel and the southern North Sea

The project focuses on demersal trawlers over 18 metres in length which target demersal species and cephalopods in the eastern English Channel and the southern North Sea. These ships are particularly affected by the problems of discards that are subject to a TAC. Of the 15 main species that are caught, 8 are subject to a TAC and account for a sizeable proportion of the discards (Gauduchon & Al., 2020). This is a real problem in the context of the landing obligation. The results of these studies could however be of benefit to the fleet of ships under 18 metres in length which is also affected by this discards issue at certain times of year.

The members of the producers' organisation (OP FROM Nord) had 44 ships undertaking bottom trawling in 2019. These ships vary in length between 9.6 metres and 33 metres, with 29 of them being less than 18 metres long and 15 of them longer than 18 metres. Many of these trawlers, especially those under 18 metres long, are not single-use, and they are often used for 2 or 3 different purposes (dredging for scallops, midwater trawling, beam trawling, Danish seine fishing…). Of the 44 ships which are used for trawling, only 5 are used exclusively for this purpose (FROM Nord data).

Three types of trawl nets are used: bottom otter trawl (OTB), otter twin trawl (OTT), and bottom pair trawl (PTB). Each unit of towed fishing gear has its unique features (number of sides, vertical opening, etc.), but since the implementation of the cod plan (Regulation (EC) No 1098/2007) the ships covered by the regulation must be equipped with an SMP of 80 millimetre squares which is stretched over the back of their trawl (measuring 3 m by 1 m at the level of the lengthener, Fig. 23) in order to be authorised to fish in the North Sea. Some of them also retain it in area VIId.

Depending on the time of year, these ships undertake fishing trips lasting between one and five days. In winter they mainly undertake daily fishing trips in the VIId area, and they fish for squid and red mullet which are species that are very commercially valuable. During the rest of the year some ships go to areas IVc and IVb for a period of a week to fish for species such as whiting and mackerel (Figs. 1 and 2). The duration of hauls varies according to the targeted species, but on average it is 3 hours.

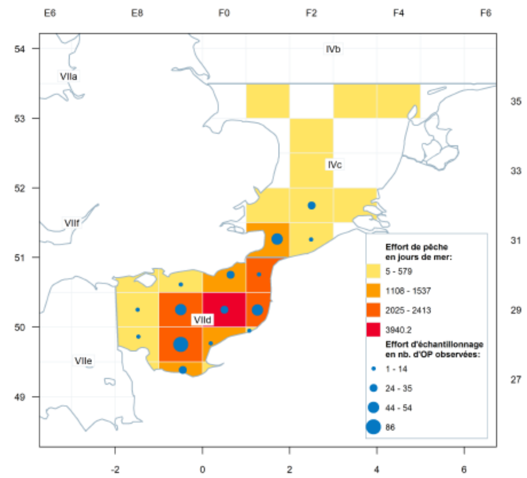


Figure 1: Geographic distribution of observed fishing operations (circles) and of the overall fishing effort (rectangles) expressed in number of days at sea (Gauduchon & Al., 2020).

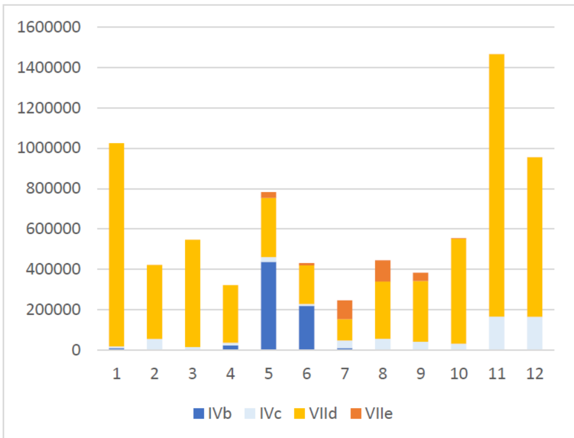


Figure 2: Areal distribution of catches by month for the FROM Nord artisanal trawlers in 2018 (FROM Nord 2018 data)

These artisanal trawlers have varying rates of discards. Nevertheless, whiting and horse mackerel are among the main species that are discarded on the basis of quotas. In fact, an average of 28% of catches of whiting are discarded, and the figure is 51.4% for horse mackerel. These two species account for 31.6% of total discards (Fig. 3).

La composition spécifique des captures en poids est présentée ci-dessous.

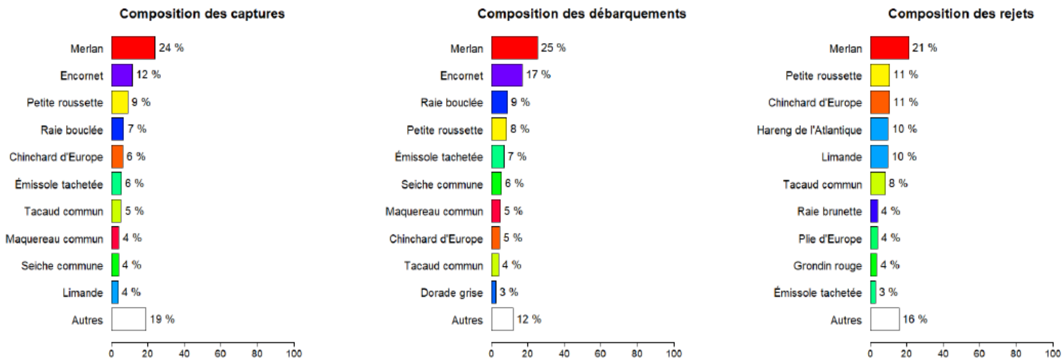


Figure 3: Species composition by weight of catches (left-hand side), of landings (centre), and of discards (right-hand side) from the 2018 observations for this sector (Gauduchon & Al., 2020).

Whiting is a very important species for the fleet which has been studied, but it is subject to a high discard rate. It is the species which makes up the largest share of landings (25% of total catches), but on average 28% of these catches are discarded. These discards are primarily linked to compliance with the minimum landing size, which is 27 cm. The majority (67.6%) of the whiting which are discarded are smaller than the MCRS.

The reason for discards is very different in the case of horse mackerel. This species suffers from the lack of a market, and particularly from a limited quota: only 9% of discards are smaller than the 15 cm MCRS (Gauduchon & Al., 2020). If the ships landed all the catches of horse mackerel the quota would be reached too early (probably in May) (simulation based on the figures provided by OP FROM Nord). It is therefore naturally these two species which will be mainly studied in the SELUX project.

1.3. Projects for improving the selectivity of trawls

Since the turn of the century various trawler fleets fishing in the eastern English Channel and the North Sea have been involved in – or have even initiated – programmes for testing the selectivity of fishing gear. Various adaptations can be made to fishing gear in order to improve its selectivity: modifying the size of the mesh, the number of the meshes, the diameter of the trawl thread, or the addition of selective features (grids, SMPs, floats, etc.). The aim is to adapt the equipment to the morphology and the behaviour of the targeted species. Taking this diversity into account is the issue that complicates the task because these ships fish numerous species which have differing MCRS's and differing morphologies. It is therefore essential to pay attention to these aspects.

This overview presents the various selective systems that have been tested by these fleets, and the results of these tests, by focusing on whiting and horse mackerel, the two target species for the project. A summary presentation of the various systems that were tested and of the results of these tests is provided in Annex A.

1.3.1. Sorting grids:

Three projects, SAUPLIMOR, SELECMER and SELECCAB, have concentrated on the development of sorting grids. These grids are developed in particular so as to provide different levels of selectivity according to the species.

The SAUPLIMOR (1999-2001) programme aimed to reduce catches of undersized cod and plaice. As part of this project a “sorting grid” was tested at various strategic points on the trawl lengthener: on the upper and lower sides, reinforced by a fine-mesh guide sheet on top, or alternatively linked with an elevating sheet. A total of 11 configurations were designed for testing the various responses of the juveniles of the target species. In the final report (Mortreux & Al., 2001), it is stated that the best results were obtained for whiting juveniles, with the proportion of them which escaped reaching 68% in spring based on the use of a grid with bars spaced at 25 mm intervals. Nevertheless, this system is observed to cause a direct loss of turnover. This economic loss is due, in particular, to the escape of 34% of whiting which are larger than the minimum size, as compared to an average of 6% if a "conventional" trawl net is used.

The main objective of the SELECMER (2008-2009) project which was funded by CRPMEM Nord Pas-de-Calais Picardie (now CRPMEM Hauts-de-France) was to reduce catches of undersized whiting (under 27 cm). Of the two selective systems tested in the project, the grid produced positive results in terms of the escape of whiting (16% reduction in undersized whiting). Nevertheless, this system still raises questions, particularly regarding its feasibility and economic viability in relation to other key species for the fleet (red mullet, squid, mackerel etc.).

Results were no more encouraging in the SELECCAB project (2009-2010) (Viera & Al., 2010) which was undertaken as a follow-up to the SAUPLIMOR and SELECMER projects. The combining of two sorting grids, one for whiting and one for cod, leads to a high proportion of whiting of commercially useful sizes escaping (landings are reduced by up to 43%).

Therefore, despite their efficiency in reducing by-catches, these grids currently cause too great an economic impact. What's more, some fishermen don't find them easy to use.

1.3.2. Square-meshed panel (SMP):

These projects also focused on the development of square mesh panels which are also called square-meshed windows. The square mesh facilitates the escape of many species, in particular species of codfish. The SMP of 80 mm meshwork on the back of the trawl has been mandatory for trawlers operating in the North Sea since 2007.

Various configurations have been tested over recent years as part of the SELECMER project, such as the square mesh panels in a 120 mm and an 80 mm meshwork configuration. The aim was to replace the panel of 80 mm square meshwork which is currently mandatory in the North Sea with a panel made of 120 mm meshwork. Two positions have been tested: a panel 6 m away from the codline, and a panel before the lengthener at a distance of 10.5 m from the codline. The SMP made of 120 mm mesh does indeed enable the discards of undersized whiting to be reduced. However, whiting of all sizes ranging from 22 cm to 35 cm escape via the system, causing commercial losses of between 26% and 28%. The escape of horse mackerel and mackerel is also facilitated by this system, but it too is accompanied by major commercial losses of mackerel. The results of this project show that the position of the panel on the lengthener does not seem to have any impact on the escape of whiting, but that the positioning of the window at the rear of the lengthener seems to facilitate the escape of mackerel (Leonardi & Al., 2009).

Another test was carried out as part of this project using an additional panel made of 80 mm meshwork in the batings. The results do not show any improvement in selectivity for whiting with this additional panel. The explanation could be due to the fact that the vertical opening in the trawl is still too large in this section of the trawl that was tested to enable the whiting to reach the SMP.

1.3.3. Square-mesh cylinders

The SELECFISH project (2013-2014) designed square-mesh cylinders (SMCs), made of two pieces of netting rotated through 45°. Placed in the lengthener of the trawl just behind the 80 mm SMP which is already mandatory in the North Sea, these square-mesh cylinders have been tested in sections that are 1 m and 2 m long, and with mesh sizes of 80 mm, 100 mm and 115 mm. These SMCs have been combined with the previously tested systems such as the sorting grids. The various SMCs that have been tested have enabled discards to be significantly reduced: by between 20% and 78%. They are, in particular, fairly efficient in relation to whiting, where discards have reduced by between 35% and 60%, and they have proved to be really useful in facilitating the escape of small pelagic species (herring, mackerel and horse mackerel). Nevertheless, as in the case of the previous projects, the square mesh raises the question of the commercial trade-off between the discards that are avoided and the reduced landings, and commercial losses may be up to 35% of turnover.

Once again, the multi-specificity of the fleet greatly complicates the improving of selectivity (Weiller & Al., 2014).

1.3.4. T90 mesh

Other projects have recently been carried out in order to test T90 mesh. This is a patch of the net in which all the lozenge-shaped meshes are rotated through 90°. The meshwork is therefore fitted in the opposite direction to normal. The traction forces no longer operate according to the natural direction of the mesh, and this enables this meshwork to be kept fully open (Fig. 4).

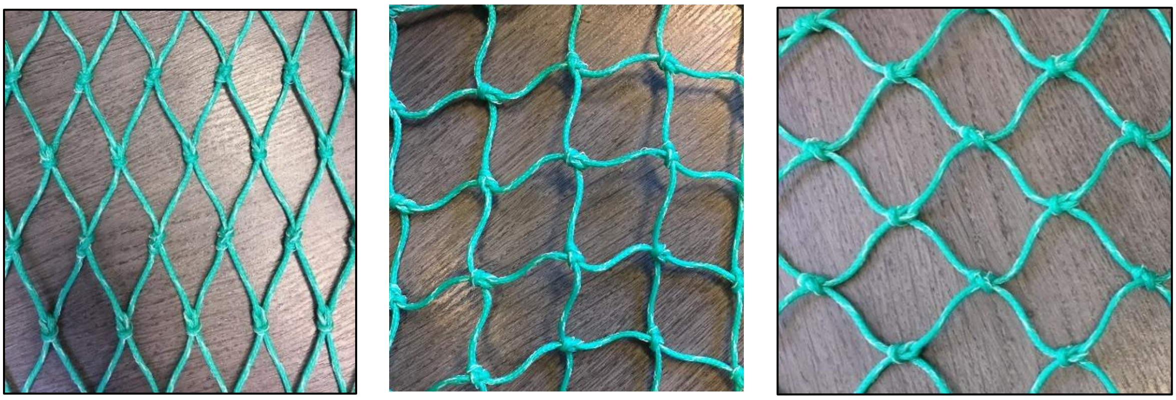


Figure 4: Lozenge-shaped meshwork (left-hand side), square meshwork (centre), and T90 meshwork (right-hand side)

The first of these projects, CELSELEC (2014-2016), which was jointly funded by the producers' organisation 'Les Pêcheurs de Bretagne' and IFREMER, tested T90 with a mesh size of 100 mm in the Celtic Sea, using it throughout the lengthener and the bottom of the codline of the trawl. It proved to be highly effective in achieving an overall reduction in the amount of discards (of the order of 40% to 50% depending on the ships), and in particular in relation to haddock and whiting. On the other hand, commercial losses of between 20% and 30% were noted in relation to whiting due to the 100 mm mesh size (Lamothe, 2017).

The second project, REJEMCELEC (2016-2018), was jointly funded by the Cobrenord producers' organisation together with OPN (Organisation de Producteurs de Normandie) and IFREMER, and it carried out tests in the western English Channel on 80 mm meshwork T90 panels in the throat (last conical part of the trawl) and in the lengthener (right-hand side). The 80 mm T90 mesh, which is more suitable for allowing whiting to escape than the square mesh, was shown to be very good at allowing small, undersized whiting to escape: catches were reduced by 73% for fish smaller than 27 cm and by 44% for whiting between 27 and 32 cm, while for fish between 33 cm and 35 cm there was an equivalent level of catch. Commercial losses are negligible within this fishery (Lavialle, 2018). In the eastern English Channel and the North Sea very few whiting bigger than 33 cm are caught. This may be linked to the geographic distribution of the species (more juveniles in 7d), and/or to the state of the stock. The latest reports from ICES show a picture of stocks that are still exploited beyond the F_{rmd} (Maximum Sustainable Yield for the Instantaneous Rate of Fishing Mortality), and a fertile biomass which barely reaches the B_{rmd} (Maximum Sustainable Yield for the Spawning Stock Biomass). Currently, a reduction in catches of individuals between 27 cm and 32 cm in size would therefore have a significant economic impact.

So numerous projects already provide solutions and ideas for reducing the share of unwanted catches. Nevertheless, achieving an economic balance is still a tricky undertaking. It has been proved that it is often more fruitful to combine selective systems. At present the combining of systems mainly relates to the grids and the square mesh. But there is no doubt that it is the combining of the systems which reinforces their respective efficiency (Sarda & Al., 2006). This is borne out in particular by the demersal fisheries in the Mediterranean, but also by the demersal fisheries in the North Sea (Graham & Al., 2004).

1.4. Light, one solution for improving selectivity?

The use of light in the world of fishing is not a new phenomenon. For thousands of years it has been used as a means of attracting and/or repelling fish – either in order to make target species easier to catch, or in order to reduce by-catches (Bryhn et al., 2014; Hannah, Lomeli, & Jones, 2015; Ortiz et al., 2016). In the past simple torches were used, then over the course of time various types of fishing gear were equipped with lights, such as the purse seine in Norway, fishing with lights in the Mediterranean, and cephalopod fishing in Asia (Breen & Lerner, 2013, Bryhn et al., 2014; Ortiz et al., 2016). These types of fishing gear have become increasingly sophisticated, and most of them are now equipped with (LED) lights which are long-lasting and provide good rendering of colour (An, 2013; Breen & Lerner, 2013; Bryhn et al., 2014; Kroger, 2013; Yamashita et al., 2012), but other systems, such as luminescent nets, are starting to appear (Nguyen, 2019).

Numerous scientific studies describe the changes that have been made over the last few decades. Reports on various types of fishing gear that have been tested have been published since the 1960s, but also a wealth of research into the phenomenon of phototropism in fish. The development of suitable fishing equipment does in fact require a deepening of the knowledge of the biology and physiology of fish, but also a deepening of knowledge in other fields such as physics and engineering (Marchesan & Al., 2004, Kurc et al, 1966, Breen & Lerner, 2013).

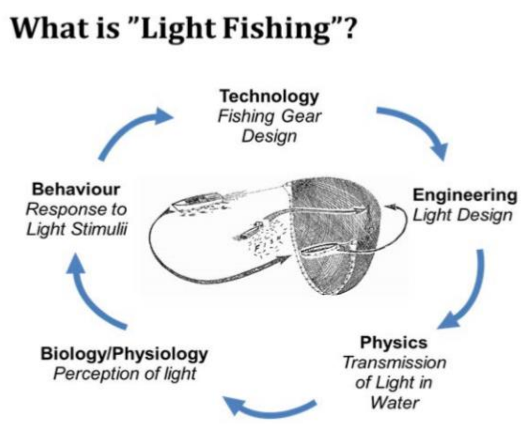


Figure 5: Breen, M., & Lerner, A. (2013)

1.4.1. Changes in the light spectrum in water

Wavelengths and visible light range from 0.4 mm (violet) to 0.7 mm (red) followed by infrared. When light enters water it undergoes a number of processes such as absorption, refraction and reflection as well as diffusion – processes which change its characteristics (speed, propagation direction, wavelength spectrum, and polarisation). Some of the light which reaches the surface of the water is reflected and refracted, and some of the light which enters the water may likewise be absorbed and diffused. These changes vary greatly depending on the optical properties of the bodies of water, which are mainly linked to the concentrations of dissolved and particulate matter (Matsushita et Awakawa, 2013).

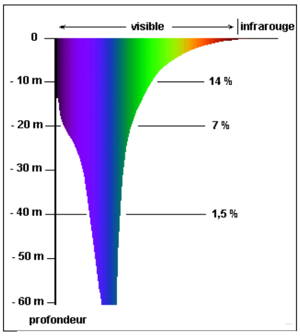


Figure 6: Spectra of light under water

The longest wavelengths, such as red, are absorbed more rapidly, and the shortest ones such as blue and green penetrate more deeply before being (6) attenuated. Violet, blue and green lights are therefore the most visible to fish living near the sea floor. As from a depth of 5 metres red is effectively no longer visible, and it appears to be grey or black (De Vevey and Rodriguez, 2016). White and yellow light disappears just as quickly and it therefore only attracts fish from a short distance (Kurc et al, 1966). Visibility also varies depending on the bodies of water in question. In general terms underwater visibility is limited to 50 metres in the clearest waters, and it is much less in coastal waters (Kroger, 2013).

1.4.2. The phenomenon of phototropism

Phototropism in fish corresponds to the attraction or repellent effect of light. There are various reasons for fish reacting to light. Some authors explain that fish ascend to sunlit waters in order to feed, while others such as Verheijen talk of a photic balancing reflex. Disorientation, or alternatively curiosity, are also explanations that are put forward by some authors (Kurc et al, 1966; Arimot, 2013).

Fish have a greater sensitivity to light than human beings (E. Jones et al., 2004). Light is principally detected by the eye. This unleashes a stream of biochemical reactions which end up by generating an electrical nerve impulse (Breen, M., & Lerner, A. 2013). The visual functions of fish – i.e. visual acuity, sensitivity, and adaptation to the intensity of light and to light spectra – are key to understanding the movements that are induced by light. It is possible to determine the sensitivity of a fish's eye to various intensities of light and colours by using an electroretinogram, and as shown by the graph below visual acuity differs between species (Fig. 7).

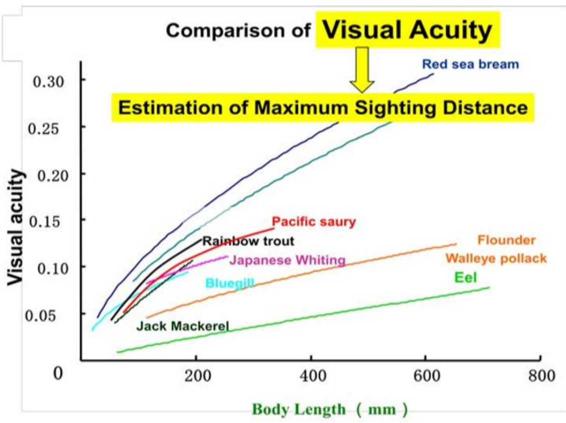


Figure 7: Takafumi Arimot, 2013

This acuity varies between species, but also depending on the maturity of the fish (Kurc et al, 1966). Therefore some species are attracted by light while others are not. European seabass (*Dicentrarchus labrax*), for example, does not seem to be either attracted or repelled by light, whereas the flathead grey mullet (*Mugil cephalus*) seems to gather close to a source of light and to stay there. Other species are attracted by light, but only at specific intensities. Squid, for example, tend to approach a light source while still staying a certain distance away from it (An, 2013). And finally, some species are sensitive to a broad spectrum of light, while others such as squid and cuttlefish are colour-blind. The snow crab, for example, avoids violet light and does not react to green or red light. It can therefore only be attracted by pots fitted with a blue or white light (Nguyen & Al., 2016).

1.4.3. Light and selectivity

Various projects around the world underline the efficiency of light in improving the selectivity of fishing gear (Annex B). Light may be installed directly on the fishing gear or else it can be linked with another selective device such as a grid in order to facilitate the escape of species or of fish smaller than the MCRS. Tests carried out in langoustine and shrimp fisheries have shown that a sizeable reduction in by-catches is achieved by fitting lights on the trawl (Hannah et al, 2015; Elliott et al, 2015). Experiments have also been undertaken in Peru and Mexico on gillnet fishing in order to reduce by-catches of turtles and seabirds. In Mexico the average catch rate for marine turtles has been reduced by 39.7% by using nets that are lit by UV lights, with no effect on the overall catch rate for target species of fish or on turnover.

So far there have been few detailed studies of artisanal trawlers targeting demersal species. Nevertheless, some projects provide interesting findings regarding the combining of equipment/systems and the impact of light on the species that are targeted by the SELUX project:

For instance, two projects have tested the effects of adding light to square mesh panels:

- One test was carried out on shrimp and langoustine trawlers in the North Sea. During this test a square mesh panel was fitted with 6 illuminated rings consisting of compact, green LEDs that were designed by the start-up SafetyNet (3 on each side of the SMP). Catches of fish smaller than 24 cm in length are generally reduced by 40% by using the experimental trawl net, including a 69% reduction in the number of whiting under 15 cm in length. However, the results are based on a small amount of data (a sample of 4 trawls) (Elliott et al, 2015).
- The second project relates to a scallop fishery on the Isle of Man. The square mesh panel was fitted with 6 white LEDs that were also designed by SafetyNet. In this case too the results are positive in terms of the reduction in by-catches. At average depths of 29-40 m by-catches of whiting were reduced by 77% (P = 0.01) by using the lights, and catches of haddock by 55% (P = 0.06) (Southworth, 2017).

See below a summary of the findings of scientific articles concerning the behaviour of the various species targeted by the project:

Whiting (*Merlangius merlangus*): This species undertakes vertical migrations at various times of day. At night it rises to the surface where it disperses, probably in order to hunt for its prey (Patterson 1985), and during the day it gathers together at depth. As a result, the catch rates may be higher during the daytime due to the shoaling behaviour near the seabed (Mergardt and Temming 1997). The Young's Seafood LTD (2016) project shows a 69% reduction in catches of juvenile whiting (fish less than 15 cm in length) when using 4-6 white LED lights on a square mesh panel (100 mm mesh). The project in the scallop fishery around the Isle of Man highlights a 77% reduction in catches of whiting when using 6 LEDs on the SMP (Southworth, 2017). The publication "Some recent trials with illuminated grids" by Barry O'Neill also highlights the tendency of whiting to be repelled by light (O'Neill 2018).

Horse mackerel (*Trachurus trachurus*): Horse mackerel swims in shoals. It uses the reflective patterns on its body to identify its neighbours. Its vision is probably a key sensory system, which would explain why it is attracted by light (Rowe and Denton 1997). A study in 2013 proved that horse mackerel is attracted by blue, white and green light (Chen et al 2013). A fairly old report relating to the Japanese species, *Trachurus japonicus,* highlights an aversion to light when it is given off intermittently. Horse mackerel therefore tend to avoid light that is flashing, but to be attracted by it if it is continuous (Koike et al 1987).

Squid (*Loligo vulgaris and loligo forbesii*): Most of the cephalopods (octopus, squid, cuttlefish) are colour-blind and have a maximum sensitivity to wavelengths of between 470 and 500 nm (Hanlon et Messenger 2018). European squid have chromatophores on their body and tentacles: these are cells which contain pigments and reflect light (Hanlon et al 2002). According to one study, catches of squid are said to be greater at sunset because recreational fishing baits are still visible and the squid are more active then (Cabanellas-Reboredo et al. 2012b). Another study has revealed that the pupils of squid dilate more in response to blue and green light as compared to red light (Matsui et al 2016). Finally, a report by the ICES-FAO Working Group explains that squid tend to keep to the edges of the zone of light – where the intensity of light is ideally suited to their visual capabilities (Report of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour, 2013).

Mackerel (*Scomber scombrus)*: According to one study, as the intensity of green LED light (1.8 x 10-6 µEs-1 m^{-2}) increases so does the mackerel's tendency to form a shoal around that light (Glass et al 1986).

Herring (Clupea harengus): Artificial light is used to catch herring, which is naturally attracted to it (Dragesund 1958). A study has revealed that herring have a spectral sensitivity of between 510 and 520 nm, which means a sensitivity to blue-green light and a reduced sensitivity to red light (Blaxter 1964).

There is no specific information in the literature concerning red mullet, pouting, gurnard and cuttlefish.

2. Methodology

2.1. Equipment/systems tested during the project

The aim of the SELUX project is to test the combination of lighting systems together with a square mesh panel which is obligatory in the North Sea. Two lighting systems have been tested: PISCES developed by the English start-up, SafetyNet, and Brezglow developed by the Le Drezen company which is based in Brittany.

2.1.1. Brezglow

Brezglow is a product that has been developed by the Le Drezen company. It's a technology which emits visible green light which can be seen in the dark. Luminescent filaments are inserted into a fishing net, and this system recharges itself both in artificial and natural light (Fig. 8).

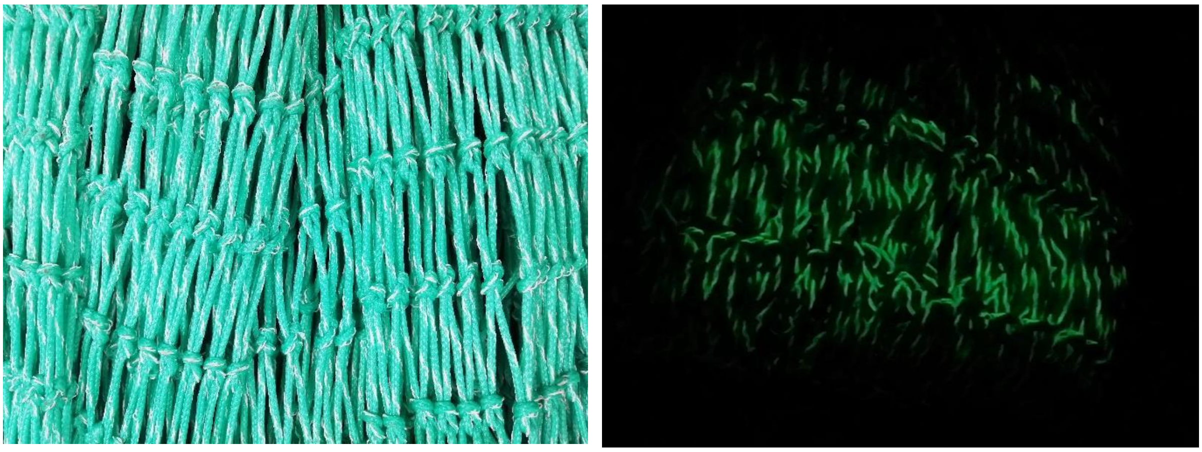


Figure 8: Brezglow with and without light

For recharging purposes the net must be exposed to light for just 1 second in order to be able to generate light for 2 hours, or for 10 minutes in order to be able to do so for 6 hours. The brightness of the light is important during the first minute, after which it reduces considerably until it levels off for the following hours (Fig. 9).

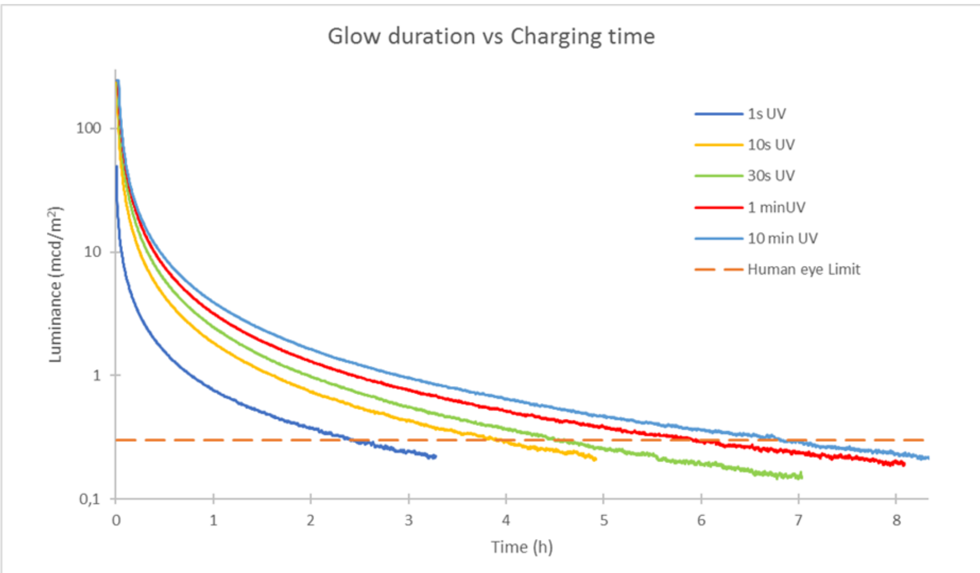


Figure 9: Brightness of Brezglow depending on the duration of exposure to light

The resistance to breaking of these filaments is equal to that of the high-density fishing twine which is normally produced by Le Drezen. The webbing is made using 3 mm high-density polyethylene (HDPE) braid which incorporates 2 luminescent strands.

2.1.2. PISCES

“PISCES” is a lighting system that has been developed by the English company, SafetyNet. The system comprises a transparent cylinder fitted with LEDs whose colours and light intensity can be adjusted by remote control (Figures 10, 11 and 12). PISCES can emit light for 60 hours continuously, a period which should be increased over the coming years. The system lights up when it enters the water and switches off when it is removed from the water, and it is recharged by induction on a dedicated charging unit.

Figure 10: PISCES

Figure 11: PISCES remote control

Figure 12: PISCES charger

The programmable nature of Pisces makes the system adaptable, particularly during fishing seasons.

2.1.3. The square-mesh panel

Projects carried out by other producers' organisations in the English Channel (Lavialle, 2018 and Lamothe, 2017) have shown the benefits of meshes that are rotated through 90° (T90) in terms of the escape of undersized codfish, and of whiting in particular. At the start of the project it had therefore been decided to test the combination of T90 and light. This combination was therefore used for the preliminary fishing trips. However, after discussion, the T90 was removed so as to leave just the SMP, which is the only selective system that is specified within European regulations. Since the implementation of the cod plan (Regulation (EC) No 1098/2007), artisanal trawlers are obliged to use an 80 mm mesh SMP on the back of their trawl (measuring 3 m by 1 m at the level of the lengthener) in order to be authorised to fish in the North Sea. Therefore it is this selective system which was used during the project's experimental fishing trips.

It is however interesting to study the effect of T90 on this fleet because this system is not used by the fishermen in this area. It could, in particular, provide a level of selection in relation to whiting in particular which is closer to the MCRS than the statutory Square Mesh Panel. A test was therefore carried out at the end of the project in order to compare the efficiency of these two systems. The results are set out at the end of this report.

2.2. Ships selected for the test fishing trips

Three trawlers that are members of FROM Nord were selected for testing the two systems. Only ships of over 18 metres in length were used in order to have enough space on board for the sampling and for the handling of the various systems and cameras as well as for the two members of staff on board other than the crew.

The two ships which carried out the preliminary fishing trips are the Sainte Marie de la Mer II using the PISCES system, and the Saint Jacques II using the Brezglow system.

As regards the experimental fishing trips, each system had to be tested by a different ship. All the fishing trips for testing PISCES were undertaken by the Saint Jacques II. As regards the Brezglow system, the Précurseur was only able to carry out one experimental fishing trip, so it was the Saint Jacques II which undertook the remaining 3 fishing trips using Brezglow.

			
	Sainte Marie de la Mer II	**Saint Jacques II**	**Précurseur**
Date of construction	2017	1998	1999
UMS (net tonnage)	231.31	153.71	153.71
KW	526	552	552
Length	24.95 metres	22.5 metres	22.5 metres
Fishing zone	72% of catches in zone 7d 21% in zone 7e 8% in zones 4b and 4c (French waters and British EEZ)	37% of catches in zone 4b 40% in zone 4c 24% in zone 7d (French and Belgium waters and British and Dutch EEZs)	50% of catches in zone 4b, 25% in zone 4c and 25% in zone 7d. (French and Belgium waters, British EEZ and Dutch offshore waters)
System	2- and 4-sided trawls 80 mm meshwork in the codend of the trawl and the lengthener.	2-sided trawl 4.2 metre vertical opening 80 mm meshwork in the codend of the trawl and the lengthener.	2-sided trawl 4.2 metre vertical opening 80 mm meshwork in the codend of the trawl and the lengthener.

2.3. Preliminary fishing trips: collection and analysis of data relating to the behaviour of the species

Tests were initially carried out in the testing tanks at Lorient and Brest in order to see how the systems behaved in the water and to test and optimise the techniques for taking underwater photographs without added lighting (Fig. 13). Then two preliminary fishing trips lasting 5 days were organised in the spring of 2019, mainly in order to observe the behaviour of whiting and horse mackerel in response to the lighting systems and to specify the ideal location on the trawl for the use of these lighting systems.

A fishing trip using the PISCES systems on the Sainte Marie de la Mer II was organised in the week from the 8th to the 12th of April 2019, and a fishing trip using the Brezglow system on the Saint Jacques II from the 6th to the 10th of May 2019. During these fishing trips a technician from LTBH (Laboratoire de Technologie et Biologie Halieutique – IFREMER Lorient) and a biologist from LRHBL (Laboratoire Ressources Halieutiques de Boulogne – IFREMER Boulogne) were present aboard the ship in order to operate the cameras and the systems and to undertake the sampling of the catches.

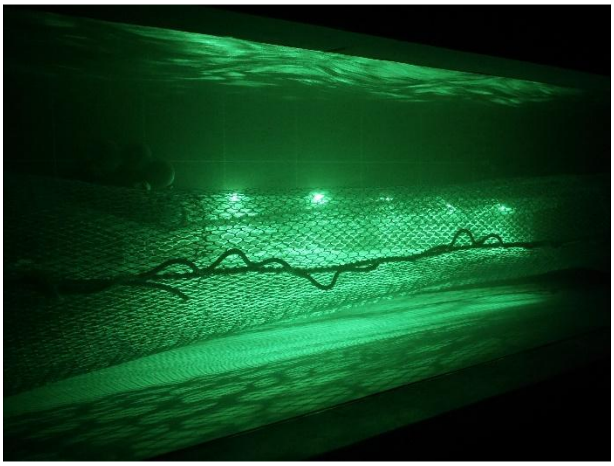


Figure 13: PISCES test in the IFREMER testing tank at Lorient

2.3.1 PISCES fishing trip: 8th to 12th April 2019

Configurations tested

Various configurations were tested during this fishing trip in order to observe how species reacted depending on the position of the PISCES lights on the trawl (Fig. 14). The PISCES were installed in the middle and on the top and bottom of the trawl, and also on half-panels on the top of the trawl, which enabled the levels of escapes to be compared.

During this fishing trip the tests were carried out using the trawls that were usually used by the Sainte Marie de la Mer II with PISCES installed on them.

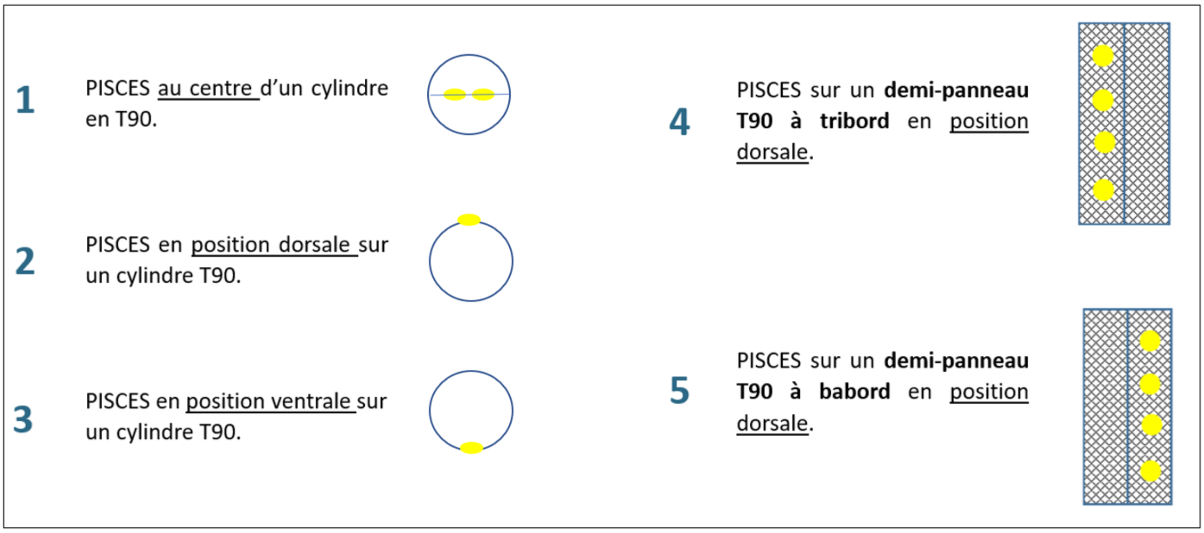


Figure 14: Configurations tested during the PISCES preliminary fishing trip

Test protocol

The main aim of this fishing trip was to make videos, but some of the catches were also sampled in order to determine which species were caught by the trawl. Two IFREMER scientists were aboard the ship in order to install the two types of cameras that are referred to below and to carry out the sampling of the catches (Fig. 15).

GoPro VECOC

Figure 15: Cameras used during the 1st preliminary fishing trip

Videos were made both in the daytime and at night using highly sensitive black & white cameras (without any additional lighting other than what was linked to the lighting system). Preliminary trials of camera settings for observing the systems by day and at night were carried out in the testing tank at Lorient.

Analysis of the Data

The videos made during this fishing trip were analysed by IFREMER at Lorient. The various species shown in the videos were identified and their behaviours were noted. Some of the analysis also consisted in comparing the differences in escapes between the lit side and the unlit side.

At the start of the project the intention was to try and count the escapes by automatic means. Unfortunately the conditions for taking photos were very poor with a very high level of muddiness within the fishing zone, coupled with clouds of sediments that were raised by the fishing gear. Despite numerous attempts at the Laboratoire de Technologie et de Biologie Halieutique in Lorient, it was not possible to reach a good compromise which was sufficiently sensitive to be able to detect the fish escaping from the trawl without being too sensitive so that it detected the plumes of "smoke". Figure 16 is a very good example of this, showing the muddiness detected by the system software. It was therefore decided to carry out manual counts for the sequences where this was possible. Double manual counting was carried out by two IFREMER scientists in relation to different sequences. Nevertheless, the analysis of the videos remains more qualitative than quantitative. The aim of these preliminary trials was to observe any behavioural trends in response to the positioning of the lights.

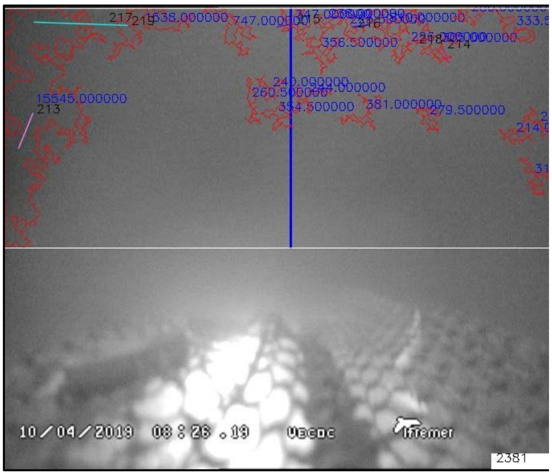


Figure 16: Testing of an automatic counting system


Figure 17: The ship and the crew during this fishing trip

Preliminary results

The hauls during this fishing trip were carried out in zone 7d and mainly within the British exclusive economic zone (EEZ). The PISCES were tested over 16 hauls, 12 daytime hauls and 4 night-time hauls (Fig. 18).

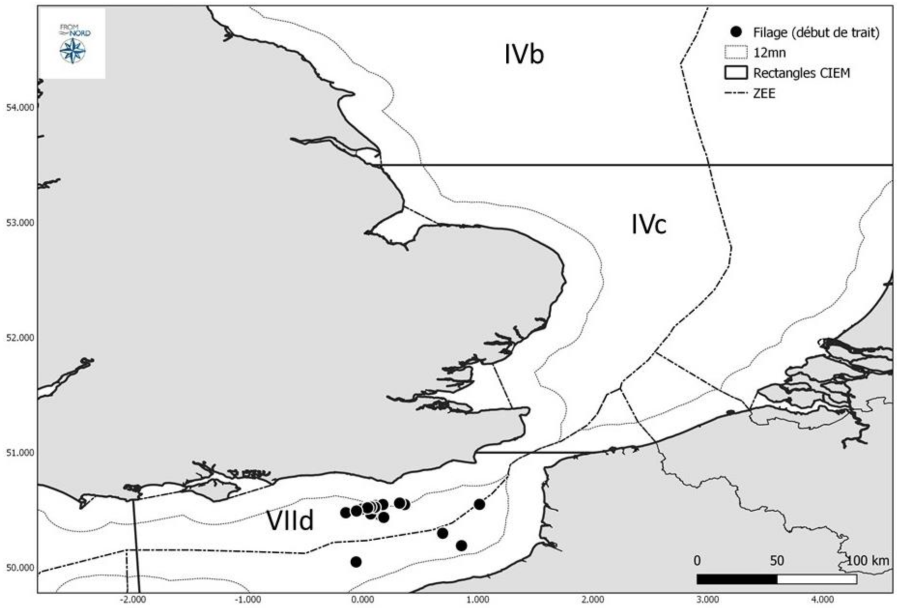


Figure 18: Map showing the hauls during the preliminary PISCES fishing trip

The main species that were observed on the videos are whiting, small pelagic species (herring, sprats, and mackerel, so the results of this trial mainly relate to these species.

As regards the qualitative observations, when the lights are placed in the various positions (configurations 1/2/3 - Figure 14), the behaviours of whiting and small pelagic species in response to light are completely different. In the various videos whiting seem to shun the light. They swim along the net when the light is in the middle of the trawl (Figure 19), and they tend to escape through the top of the trawl when the PISCES are installed at the bottom of the trawl. Mackerel also seem to have a tendency to behave in the same way. On the other hand, small pelagic species (herring, sprats) seem to be attracted by the light. Large numbers of fish can be seen escaping through the top of the trawl when the PISCES are installed there (Figure 20).

Figure 19: Whiting "hugging" the net while moving away from the lights in the centre

Figure 20: Herring escaping by being drawn upwards towards the light

The manual counting carried out by IFREMER confirms the purely qualitative video observations. It was carried out on the two T90 half-panels positioned on the back of the net (configurations 4 and 5 - Figure 14), with light on the port or starboard side (see Figures 21 and 22). Clearly the light on one side may have an influence on the darker side, but this enabled the trends to be observed. Sequences were selected based on the species that could be easily recognised, and they were correlated with the species that had been counted in the catches. Often there are at least two species in the sequences, with one of them being dominant, but it is not possible to quantify their respective percentages.

Figure 21: Example of the counting of whiting escaping from the dark side (PISCES lights on starboard side)

Figure 22: Counting using PISCES lights on port side

Table 1 summarises the various sequences for which the three “counters” were able to do visual counts with the aid of the simple “Stopwatch” recording software. The actual speed was slowed by a factor of 4 to enable the counting to be done. The raw counting data for the side fitted with the light and for the dark side are enclosed in Annex E. Table 1 shows for each sequence the species which were mainly observed in the trawl, the percentages of escapes that were observed by the three counters on the “lit side” (together with the corresponding average percentage), and the average total number of the associated escapes that were observed as well as the p-value from the two-tailed binomial test. These statistics were also measured by combining the sequences which share the same characteristics in terms of the combination of species, the light level, and the time of day/night (no. 2, 2b, 3, 4, 5 & 5b). The dominant escapes from the lit side are underlined in yellow, those from the unlit side in grey, and those where there is no significant difference in white.

1	T10_1_ SNet_Demipan_T90_Tri	mackerel, whiting	8 p.m.	38.35%	39.20%	37.06%	**38.21%**	206	0.00101			
2	T11_1_ SNet_Demipan_T90_Tri	herring, sprats?	Overcast daylight 1 p.m.	50.00%	55.60%	56.29%	**53.85%**	680	0.05041	53.61%	1573	0.004728
2b	T11_1_ SNet_Demipan_T90_Tri	herring, sprats?	Overcast daylight 1 p.m.	51.29%	53.21%	56.61%	**53.38%**	893	0.0446			
3	T14_2_ SNet_Demipan_T90_Bab	mackerel, whiting, other small pelagic species	Overcast daylight 10 a.m.	46.67%	46.03%	39.55%	**44.52%**	705	0.004173	42.64%	880	1.324e-05
4	T15_2_ SNet_Demipan_T90_Bab	mackerel, whiting, other small pelagic species	Overcast daylight 10 a.m.	42.29%	40.29%	39.23%	**40.77%**	175	0.01532			
5	T15_1_ SNet_Demipan_T90_Bab	small pelagics *	Daytime 1 p.m.	50.28%	49.93%	51.21%	**50.45%**	901	0.7899	48.52%	2165	0.169
5b	T15_1_ SNet_Demipan_T90_Bab	small pelagics*	Daytime 1 p.m.	46.76%	43.31%	50.04%	**46.60%**	1264	0.01678			

*Except herring

Table 1: Results of the manual counting carried out for the preliminary PISCES fishing trip.

All the results show significant differences (p-value < 5%), or very significant differences, between the sides with and without light, except for sequence 5. It should be noted that sequences 5 and 5b (fishing operation no.15) are particularly muddy and were carried out at 1 p.m. on a clear day, and there is the option of applying a weighting to them to offset the effect of the light. Moreover, according to the catches that were recorded, these sequences 5 and 5b did not contain any herring – unlike sequences 2 and 2b, for example, where this species was dominant.

The results of these counts appear to show that whiting and mackerel escape more from the dark side, i.e. that the (PISCES) light tends to have a repellent effect upon these species (sequences 1/3/4). The difference is slightly less noticeable, although still very significant, when small pelagic species that can't be identified are mixed together with whiting and mackerel (sequences 3 and 4). By contrast, sequences 2 and 2b – which show herring in particular – indicate that this species tends to be attracted by light, with more escapes on the side fitted with PISCES.

2.3.2 Brezglow fishing trip: 6^{th} - 10^{th} May 2019

Test protocol

The initial tests of the Brezglow wire quickly showed that if there was no adequate source of light for the video it was necessary to have another technical method for recording the escapes via the selective systems during the preliminary fishing trip.

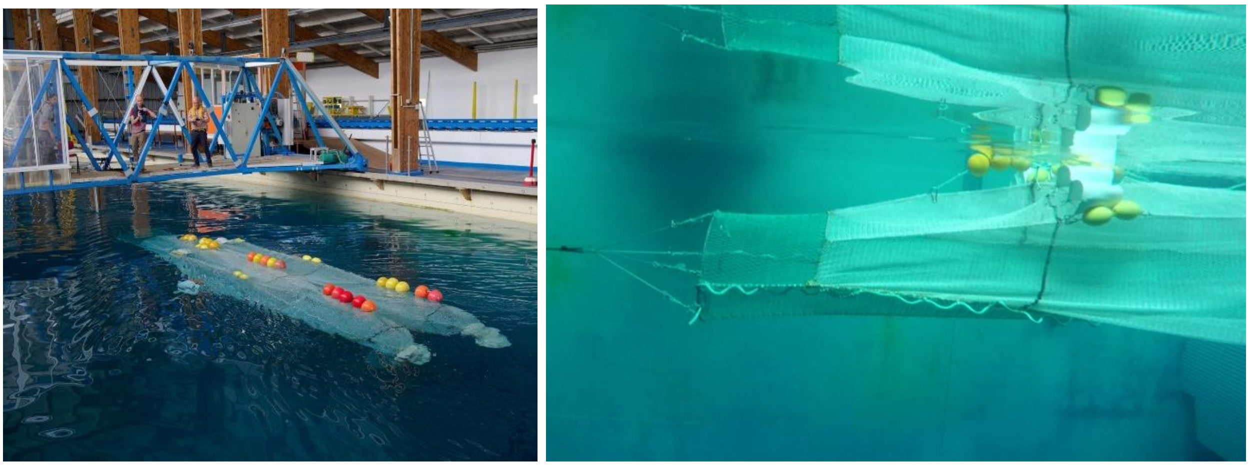
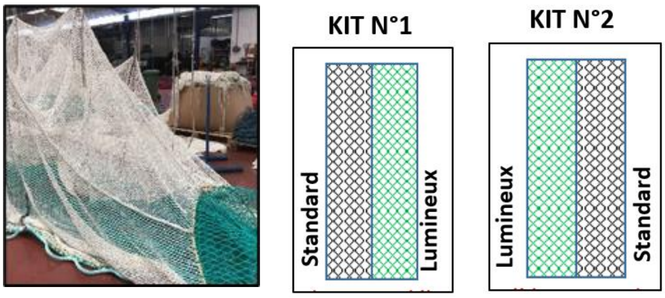


Figure 23 : Test of Brezglow fitted with bags in the IFREMER testing tank at Brest

The adding of light would distort the results, so it was decided to compare the escapes by using covering bags made of small-size mesh. This system of trapping bags that was inspired by systems that had been devised during other scientific programmes was therefore created for the second preliminary fishing trip. The Lorient testing tank was too small to test equipment of this size, so the final modifications were made at the testing tank in Brest. In the absence of any current, the rail-mounted gangway of the testing tank enabled the system to be towed at a speed of 1 m/s, or almost 2 knots. In order to implement this new system it was necessary to install a considerable number of floats and items of “aeroplane” lifting equipment and “kite” separation equipment. The tests in the testing tank enabled the positioning of the various items of equipment to be optimised so as to improve the efficiency of the system and approve its use (Fig. 23).

These bags were installed on the port and starboard side of the codend of the trawl in order to compare escapes from the side of the Brezglow net with escapes from the side of the standard net. Two kits were tested: one kit with a T90 half-panel made of standard thread on the starboard side and a T90 half-panel made of phosphorescent wire on the port side (on the back of the net in the lengthener), and one kit the other way round in order to check that the side which is used has no effect on the results (Fig. 24). The trawls used for these tests were the ones that are normally used by the Saint Jacques II – to which these two kits were added.



Covering bags Kit no. 1 Kit no. 2

Figure 24: Covering bags used for recording the escapes during the preliminary Brezglow fishing trip

Preliminary results

The hauls during this fishing trip were carried out in areas IVc and IVb. Brezglow was tested during 10 hauls, 6 daytime hauls and 4 night-time hauls (Fig. 25).

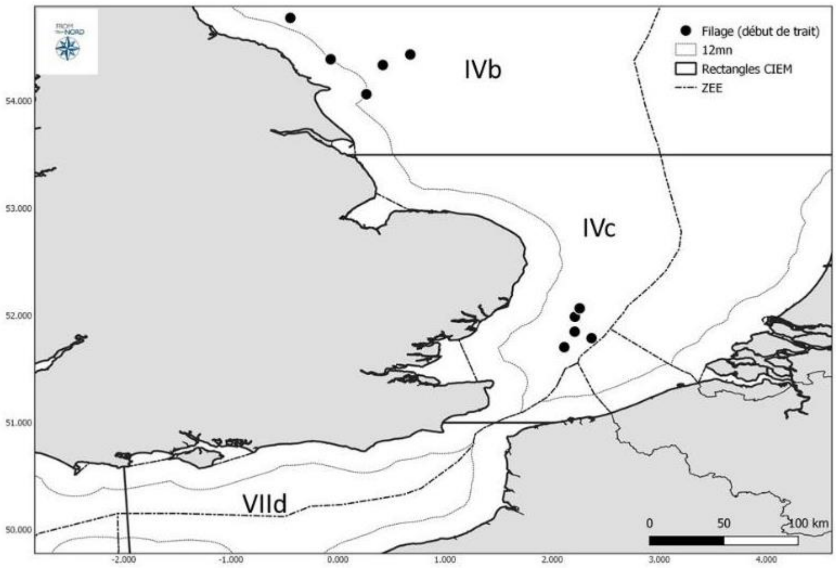
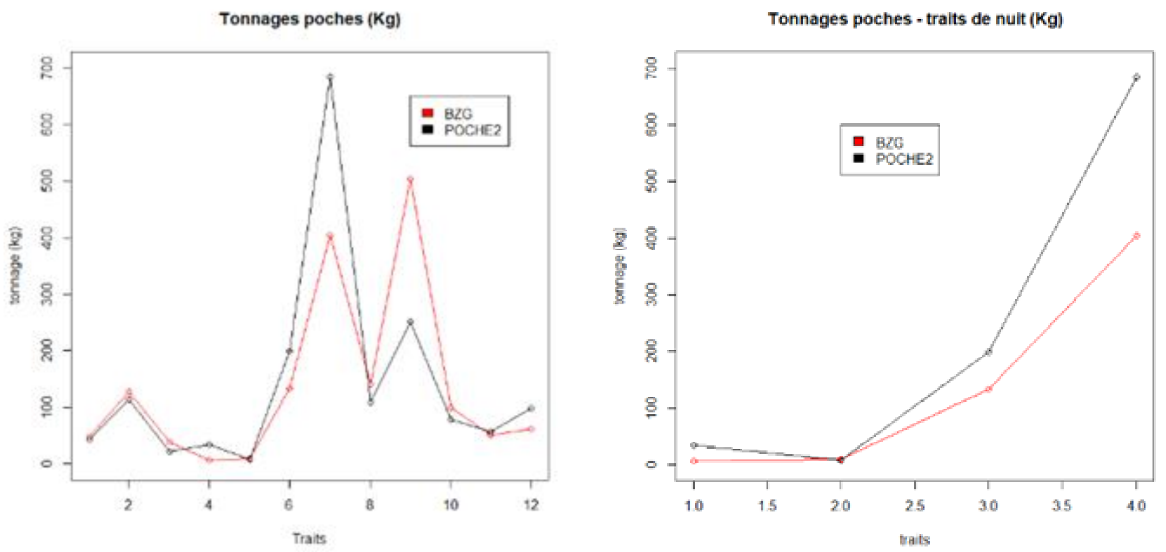


Figure 25: Map showing the hauls during the preliminary Brezglow fishing trip

The main species that was seen during this fishing trip was whiting, and the results of this trial therefore chiefly relate to this species.



12 hauls (daytime and night-time): Brezglow had no visible effect on escapes

4 hauls (night-time): Larger escape amounts in the bag on the side opposite Brezglow

Figure 26: Biomass amounts per haul in the Brezglow (BZG) covering bag and in the bag covering a standard net (bag 2)

No trend can be discerned from all the hauls, daytime and night-time combined, that were carried out during this fishing trip. However, when one selects the 4 night-time hauls Brezglow seems to have an impact on whiting, which seems to move away from the system and therefore from the light (Fig. 26). The trend seems to be similar for the other priority species, but the lack of sufficient data does not permit a firm conclusion to be drawn in this regard.

The results from this fishing trip are therefore similar to those from the PISCES fishing trip.

2.3.3 Configuration used for the experimental fishing trips

The results of these preliminary fishing trips highlight the fact that whiting shun the light. In order to encourage small whiting to escape, the light must therefore be installed on the side opposite the square mesh panel. The videos and the analysis of the bags does not provide any information about the behaviour of horse mackerel in response to light. The configuration used for the experimental fishing trips was therefore chosen based on the behaviour of the whiting, with the systems being installed as follows (Fig. 27):

- For the fishing trips using PISCES: the PISCES systems will be on the belly of the trawl lighting the square mesh panel which is situated on the back of the trawl
- For the fishing trips using Brezglow: Brezglow will be on the belly of the trawl underneath the SMP.

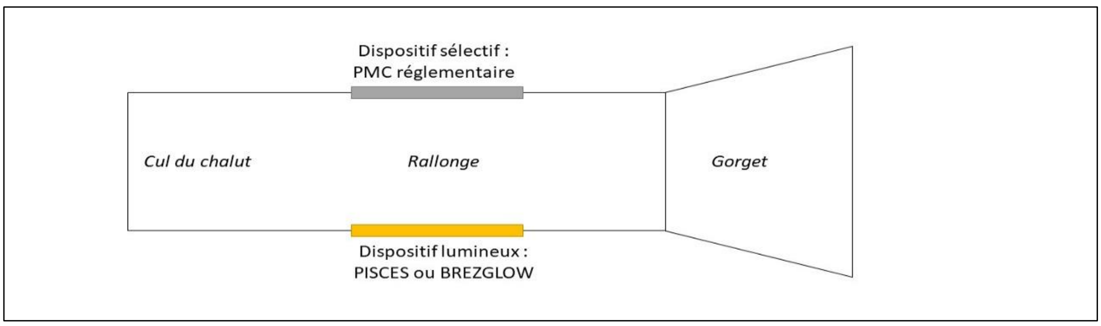


Figure 27: Configuration used for the lighting systems on the trawl

As regards the PISCES systems which provide the option of choosing the colour, the decision was made to use green because it is the colour which is most visible to these deep-sea species according to the scientific literature (De Vevey and Rodriguez, 2016).

2.4. Experimental fishing trips

In order to evaluate the efficiency of these selective systems, 3 fishing trips using Brezglow and 4 fishing trips using PISCES were carried out between October 2019 and September 2020. A fishing trip was also organised in August 2020 for comparing the efficiency of T90 mesh and the SMP.

Fishing trip no.	Departure date	Duration of the fishing trip	System	Ship	Configuration
1	21/10/2019	5 days	PISCES	St Jacques II	Without flash
2	02/12/2019	4½ days	BREZGLOW	Précurseur	-
3	16/03/2020	4½ days	PISCES	St Jacques II	With flash
4	22/06/2020	5 days	PISCES	St Jacques II	With flash
5	20/07/2020	4½ days	PISCES	St Jacques II	With flash
6	10/08/2020	4½ days	BREZGLOW	St Jacques II	-
7	17/08/2020	5 days	SMP/T90	St Jacques II	-
8	07/09/2020	5 days	BREZGLOW	St Jacques II	-

Table 2: Timetable of the SELUX fishing trips

2.4.1 Configurations tested

PISCES

Two configurations were tested during these 4 experimental fishing trips (Figures 28 and 29). During the first fishing trip carried out using the PISCES system, the following configuration was used:

- 4 PISCES;
- Under the SMP, on the belly side of the trawl;
- All separated by a distance of 6 meshes;
- Emitting a constant green light.

The results of the first fishing trip highlighted the fact that relatively few whiting were escaping. It was therefore decided to increase the number of the PISCES devices to 5 and to install one of them above the SMP in order to encourage the fish to ascend towards the SMP more quickly. It was also decided to use the PISCES devices in flashing mode because according to the scientific literature (Koike et al 1987) horse mackerel tend to be attracted by constant light but tend to be repelled by flashing light. The configuration used for fishing trips 2, 3 and 4 is therefore as follows:

- 5 PISCES;
- Under the SMP (including one above it), on the belly side of the trawl;
- Spaced 8 meshes apart;
- Emitting a flashing green light.

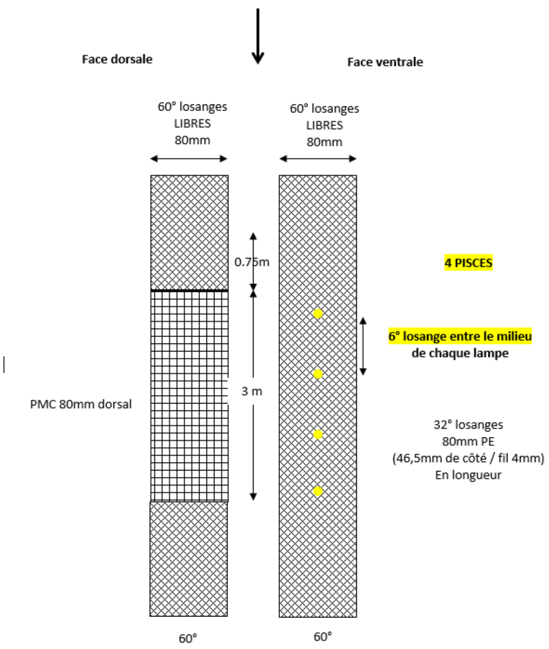


Figure 28: Configuration for experimental fishing trip no. 1 – constant light

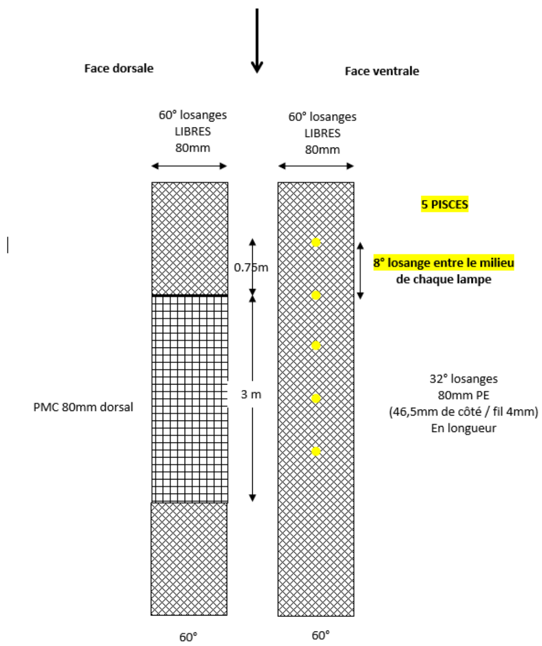


Figure 29: Configuration for experimental fishing trips no. 2, no. 3 and no. 4 – flashing light

The PISCES devices have a battery life of 60 hours in the water, so there was no need to recharge them during the fishing trip. However, it was decided to use 5 PISCES during one section of the fishing trip and 5 for the other section in order to ensure that they remained lit for the experiments.

Figure 30: Installation of the PISCES on the trawl (fishing trip no. 2, March 2020)

Brezglow

Brezglow in its square mesh pattern was installed on the belly of the trawl below the SMP (Fig. 31).

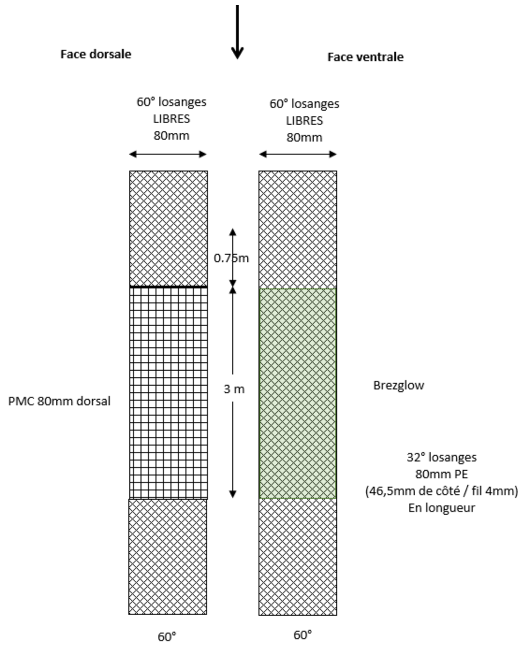


Figure 31: Configuration for experimental fishing trips nos. 1,2,3

Brezglow was exposed to sunlight during the daytime, and to the boat's spotlights at night, for a period of two minutes in order to recharge it before each casting of the net.

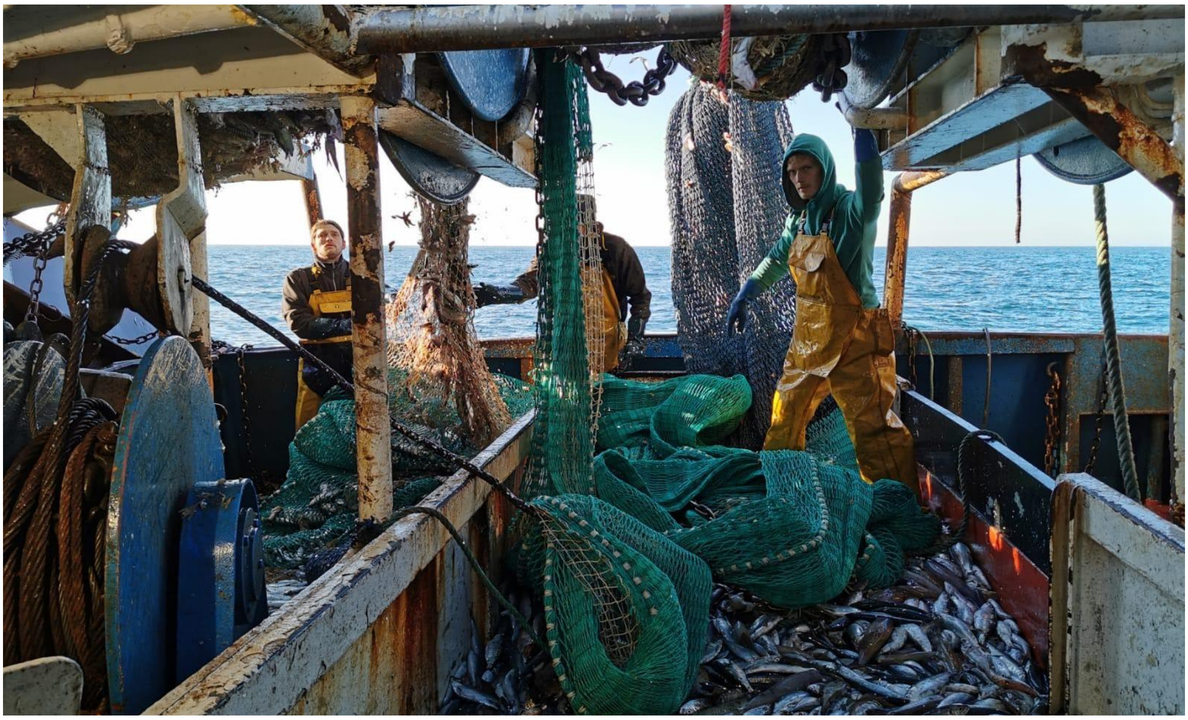


Figure 32: Brezglow fishing trip no. 1 on board the Précurseur – December 2019

2.4.2 Test protocol

Technique used

The techniques which are most commonly used for collecting data within a selectivity project are the alternate haul method and the parallel haul method (Wileman et al., 1996). Since there were not enough ships of the same category which were willing to carry out parallel hauls, the alternate haul technique was used for this project. This method involves using a control trawl followed by a test trawl while ensuring that the factors which influence the abundance of fish and the efficiency of the gear are as similar as possible. In order to do this, the following details had to be adhered to during each fishing trip:

- Two identical trawls;
- Keeping to a defined “procedural sequence” for lit hauls and for standard hauls (ensuring that the procedure did not always begin with a lit haul and alternating the sequence between daytime and night-time hauls);
- Carrying out clearly separate night-time and daytime hauls (to assess the effects of light during these two periods), making sure that the hauls within any one towing operation[1] were either daytime or night-time hauls (so that the hauls within any one towing operation are comparable);
- Carrying out hauls of equal duration: 2½ hrs.;
- Maintaining an identical towing speed;
- Taking the direction of the current into account so as to ensure that it was identical for the hauls within the same towing operation;
- Making sure that the depth and substrate were identical;
- Not carrying out both hauls within a single towing operation in the same zone, but instead in zones that are close to each other.

Despite these recommendations, the variability of the catches between two hauls within a pair may be significant when the technique of alternate hauls is used. The number of sampled pairs of catches must therefore be greater than 30 in order to cover a maximum number of possible situations and to ensure that the differences that are observed are indeed due to the system rather than merely being the result of chance. 3 to 4 fishing trips were scheduled for each system in order to carry out these 30 pairs of operations.

Timetable and trial zone

The composition of the catches made by this fleet varies according to the seasons. In order to check the efficiency of the systems for all these species and all the sizes that were caught, it was decided to carry out fishing trips at different times of year: October - December during the squid season, in March for the fishing of smaller whiting, and in summer for the targeting of larger whiting and of horse mackerel.

Depending on the season, the trawlers don't go to the same zones. So each period that is used relates to different fishing zones.

[1] *A towing operation = a pair = a haul carried out by the reference trawl (standard trawl) + a haul carried out using the test trawl (trawl fitted with lights) in comparable conditions.*

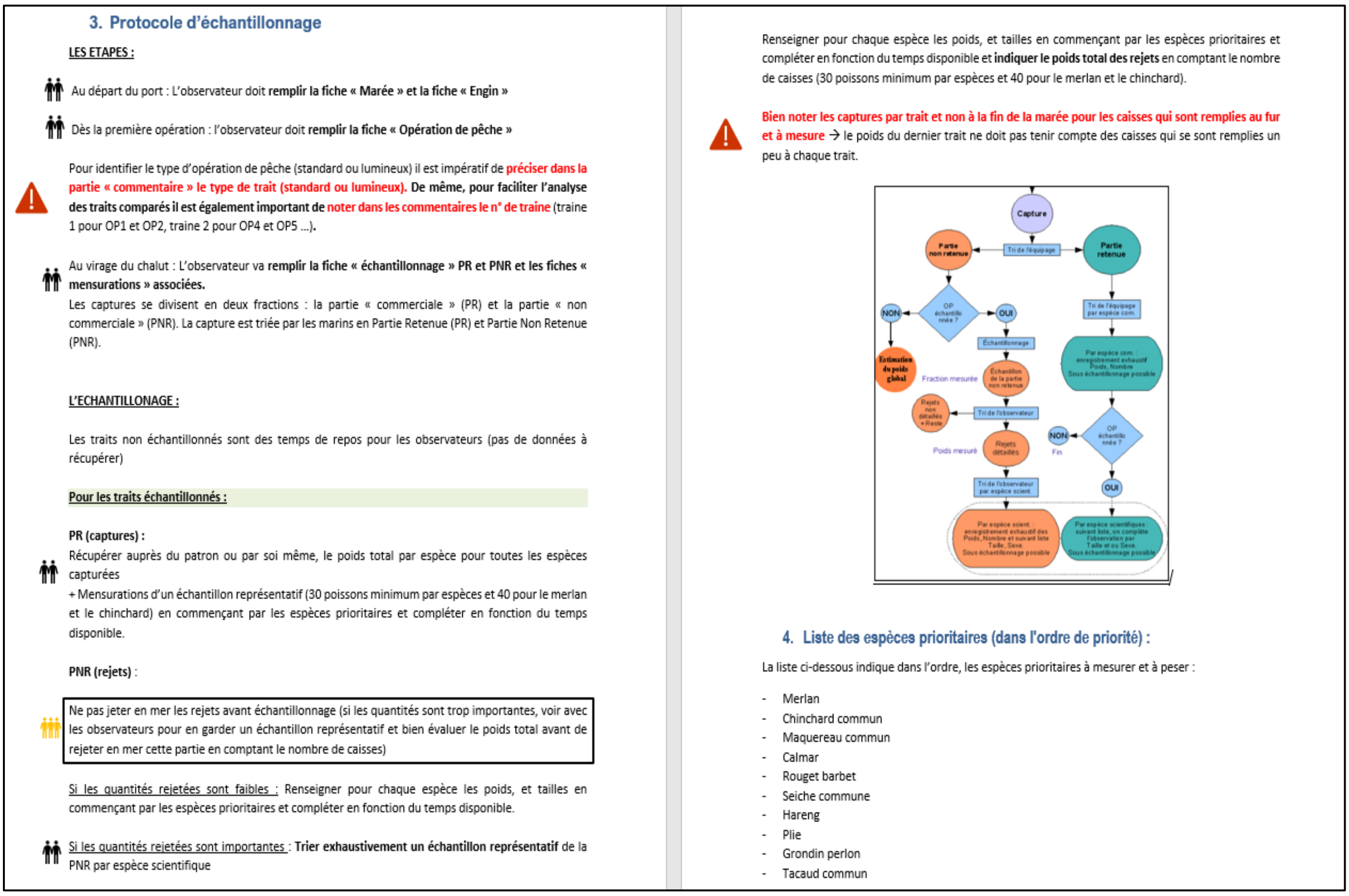
2.4.3 Collection of catch data

The sampling protocol is similar to the procedure for monitoring the catches on board fishing vessels which is undertaken by Ifremer (OBSMER). The sampling was carried out by two observers from the Océanic Développement consultancy, as well as an Ifremer technician during the first fishing trip.

Some changes were made to the OBSMER procedure:

- Additional variables were incorporated, such as the number of the towing operation and the type of system (selective or standard).
- In order to make the procedure easier and to sample as many hauls as possible, the observers identified and weighed all the species, but they only measured the 13 priority species.

The sampling of the catches took place as follows (Fig. 33) (see details of the protocol in Annex C):



3. Protocole d'échantillonnage

LES ETAPES :

Au départ du port : L'observateur doit **remplir la fiche « Marée » et la fiche « Engin »**

Dès la première opération : l'observateur doit **remplir la fiche « Opération de pêche »**

Pour identifier le type d'opération de pêche (standard ou lumineux) il est impératif de **préciser dans la partie « commentaire » le type de trait (standard ou lumineux). De même, pour faciliter l'analyse des traits comparés il est également important de noter dans les commentaires le n° de traine** (traine 1 pour OP1 et OP2, traine 2 pour OP4 et OP5 …).

Au virage du chalut : L'observateur va **remplir la fiche « échantillonnage » PR et PNR et les fiches « mensurations » associées.**

Les captures se divisent en deux fractions : la partie « commerciale » (PR) et la partie « non commerciale » (PNR). La capture est triée par les marins en Partie Retenue (PR) et Partie Non Retenue (PNR).

L'ECHANTILLONAGE :

Les traits non échantillonnés sont des temps de repos pour les observateurs (pas de données à récupérer)

Pour les traits échantillonnés :

PR (captures) :

Récupérer auprès du patron ou par soi même, le poids total par espèce pour toutes les espèces capturées

+ Mensurations d'un échantillon représentatif (30 poissons minimum par espèces et 40 pour le merlan et le chinchard) en commençant par les espèces prioritaires et compléter en fonction du temps disponible.

PNR (rejets) :

Ne pas jeter en mer les rejets avant échantillonnage (si les quantités sont trop importantes, voir avec les observateurs pour en garder un échantillon représentatif et bien évaluer le poids total avant de rejeter en mer cette partie en comptant le nombre de caisses)

Si les quantités rejetées sont faibles : Renseigner pour chaque espèce les poids, et tailles en commençant par les espèces prioritaires et compléter en fonction du temps disponible.

Si les quantités rejetées sont importantes : **Trier exhaustivement un échantillon représentatif** de la PNR par espèce scientifique

Renseigner pour chaque espèce les poids, et tailles en commençant par les espèces prioritaires et compléter en fonction du temps disponible et **indiquer le poids total des rejets** en comptant le nombre de caisses (30 poissons minimum par espèces et 40 pour le merlan et le chinchard).

Bien noter les captures par trait et non à la fin de la marée pour les caisses qui sont remplies au fur et à mesure → le poids du dernier trait ne doit pas tenir compte des caisses qui se sont remplies un peu à chaque trait.

4. Liste des espèces prioritaires (dans l'ordre de priorité) :

La liste ci-dessous indique dans l'ordre, les espèces prioritaires à mesurer et à peser :

- Merlan
- Chinchard commun
- Maquereau commun
- Calmar
- Rouget barbet
- Seiche commune
- Hareng
- Plie
- Grondin perlon
- Tacaud commun

Figure 33: Sampling procedure allocated to the observers and the ship

During each fishing trip the observers were able to sample all the species in the list.


Figure 34: PISCES fishing trip March 2020 – Saint Jacques II


Figure 35: PISCES fishing trip April 2019 - Sainte Marie de la Mer II

The data from the SELUX fishing trips were then entered using the Allegro application and made available in the Harmonie database that is part of the Système d'informations halieutiques [Fisheries research information system] (SIH - https://sih.ifremer.fr/).

2.4.4 Processing of the data

The aim of the analysis is to evaluate whether the system that was tested enables unwanted catches to be reduced without causing excessive commercial losses compared to the standard system. In order to do this, the catches from the test trawl are compared to those from the standard trawl. Amounts of biomass, but also the size of fish that are caught, are analysed for each species in order to obtain a clear picture of the selectivity of the test system.

Three types of data were collected during the experimental fishing trips:

- Environmental data (depth, sea state, day/night, direction and strength of the current)
- Technical data (duration of the haul, period between hauls, distance between hauls)
- Catch data (catches, discards, landings (overall and by species) + sizes)

The environmental and technical data are indispensable for validating the catch data.

Selection and validation of the catch data

The catch data were obtained using the alternate hauls method. Since the two hauls within a single towing operation were not carried out simultaneously, a strict protocol was followed in order to obtain hauls which were as comparable as possible in terms of the available resources and the fishing conditions (see protocol in Annex C). It is in fact important to ensure that the differences in catches that are observed between the standard trawl and the test trawl are indeed linked to the selectivity of the systems rather than to other factors.

Only the data that were obtained in normal fishing conditions and in accordance with the protocol were used for the analysis.

- Outliers, such as an abnormal catch of a species, were also removed from the analysis.
- For the analysis by species, only the species that were present in at least 15 pairs of hauls were used.
- The duration of the hauls may vary, which is why a standardisation of the data relating to catches has been carried out in order to obtain comparable data: the amounts of biomass and the numbers of fish were divided by the duration of the respective haul and were then multiplied by the average duration of the hauls.

$$\boxed{\frac{Y_{ei}}{D_{ei}} * D}$$

Y_{ei}: Quantity (biomass numbers) associated with the haul system (selective or standard)

D_{ei}: Duration of the respective haul

D: Mean duration of hauls

- Correlation tests were carried out on the depth data, and on data relating to the duration of the towing operation and sea state, in order to check the similarity of the fishing conditions for hauls within the same towing operation. For each test a p-value is used to validate (or not validate) the correlation, and a correlation coefficient (Spearman's Rank) shows the strength of the relationship, while a black bisecting line provides an indication of the strict equality of the conditions between the two systems (see Figure 35).

Analysis of the environmental conditions

Over all the fishing trips various variables could influence the selectivity of the test system: the depth, the season, the zone, the lack of light during night-time hauls (diurnal variable), and the ship. In order to evaluate whether the analysis should be undertaken differently based on these variables, a graphical analysis and a GLM (Generalized Linear Model) were used in relation to the priority species for the project.

Comparison of levels of biomass caught

In order to compare the levels of biomass that were caught, unloaded and discarded during both the standard trawl and the test trawl, <u>a mean comparison test was used</u> in order to test whether the difference within each towing operation is zero on average.

In order to specify the test that was to be used – Student's parametric test or Mann Whitney's non-parametric test for matched hauls – the normality of the difference within each pair was first tested by using a Shapiro-Wilk test (Shapiro and Wilk, 1965). If the Gaussian hypothesis has not been rejected, the parametric test will be used, otherwise the non-parametric will be used. For this, the statistical test provides a p-value (probability of rejecting the null hypothesis). If it is < 0.05 the null hypothesis (H0) is rejected, and so it is possible to conclude that there is a difference between the means of the two populations from which the samples were taken. On the other hand if the p-value is > 0.05, the null hypothesis (H0) is not rejected, and the conclusion will be that there is no difference between the two populations.

These various analyses were also carried out for each species for which sufficient data were available. Not all of the species which are designated as priority species within the sampling protocol were able to be analysed owing to a lack of adequate data.

Then <u>rates of change in total biomass (T1) and mean biomass (T) levels that were discarded or unloaded were calculated</u>. They show the losses or gains produced by the system that was tested as compared to the standard system.

$$T1 = \left(\frac{Ztest}{Zstd}\right) * 100$$

$$\boldsymbol{T} = \left(\frac{\sum_{i=1}^{I} \boldsymbol{Ztest_i}}{\sum_{i=1}^{I} \boldsymbol{Zstd_i}} - \mathbf{1}\right) * \mathbf{100}$$

$Ztestj$ and $Zstdj$ are the biomass amounts for towing operation i in the test and standard trawls respectively.

Comparison of sizes caught

The efficiency of the test system in terms of the size of the individuals was then studied. This analysis enables the sizes to be specified for which the test trawl is more selective than the standard trawl. In order to do this, Generalized Linear Mixed Models (GLMM) were the method that was used (Holts R., Revill A., 2009) (Fig. 36). The mixed model is used in this type of analysis in order to take into account the changes in fishing conditions between different towing operations.

The measurements were carried out both on the discarded portion and on the used portion, so this model does not take account of this means of categorisation. The sizes of individuals therefore relate to all the catches for the species. The modelling may be sensitive to the extremes of the size spectrum because numbers of fish are often lower there. The size ranges comprising less than 5 individuals (pairs) were therefore removed from the analysis. Size T was tested up to order 4 in the form of standardised orthogonal polynomials in order to facilitate the adjustment. The best model (i.e. the polynomial degree) was defined by using the Akaike information criterion.

C:\Users\I\Desktop\SELUX\SCRIPT_SELUX_TAILLE.R - Editeur R

```
# ---- #---- #---- #---- #---- #---- #---- #---- #---- #---- #---- #---- #---- #
#                              CATCH COMPARISON
# ---- #---- #---- #---- #---- #---- #---- #---- #---- #---- #---- #---- #---- #

library(lme4)

# normalize la variable Taille pour le GLMM -->
DATA$TAILLEsc <- scale(DATA$TAILLE) # (TAILLE-mean(TAILLE))/SD(TAILLE)

#--------
# GLMM    --> ## peut-on utiliser glmer car SEL et STD ne sont pas des entiers --> lmer ?
#--------

GLMM0 <- glmer(SEL/(SEL+STD)~ 1 + (1 | TRAINE),weights = Total, data = DATA, family = binomial)
summary(GLMM0)
GLMM1 <- glmer(SEL/(SEL+STD)~ TAILLEsc  + (1 | TRAINE),weights = Total, data = DATA, family = binomial)
summary(GLMM1)
GLMM2 <- glmer(SEL/(SEL+STD)~ TAILLEsc + I(TAILLEsc^2) + (1 | TRAINE), weights = Total, data = DATA, family = binomial(logit))
summary(GLMM2)
GLMM3 <- glmer(SEL/(SEL+STD)~ TAILLEsc + I(TAILLEsc^2) + I(TAILLEsc^3) + (1 | TRAINE),weights = Total, data = DATA, family = binomial)
summary(GLMM3)
GLMM4 <- glmer(SEL/(SEL+STD)~ TAILLEsc + I(TAILLEsc^2) + I(TAILLEsc^3) + I(TAILLEsc^ 4) + (1 | TRAINE),weights = Total, data = DATA, family = binomial)
summary(GLMM4)
```

Figure 36: Script used for the analysis of selectivity by relative size

The modelling enables a selectivity curve to be obtained for each species that is studied (Fig. 37). This curve shows the probability of being caught by the test system according to the size of the individual. The value 0.5 is the size for which the probability of an individual being retained by the test trawl is the same as for the standard trawl. If the curve is below 0.5, this means that the probability of retention by the test trawl is less than for the standard trawl, and vice versa if the curve is above 0.5. The grey zone around this curve and the stippled zone around Lr0.5 represent the 95% confidence intervals. This means that there is a 95% probability of the true value lying within this interval.

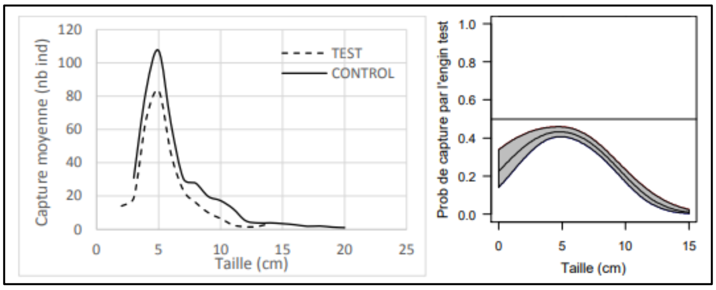


Figure 37: Example of biomass distribution curves per size of catches for the test and the control trawls, and of the relative selectivity curve derived from the modelling processes (Holst and Revill, 2009)

If the confidence interval of the selectivity curve is around 0.5, this does not permit the drawing of any conclusion regarding the efficiency of the test trawl (Vogel, 2016).

3. Results

3.1. PISCES

3.1.1 Description of the sample

Four experimental fishing trips were organised in order to test the PISCES systems. During these four experimental fishing trips 62 hauls were sampled, 31 lit hauls and 31 standard hauls, or 31 pairs. Of these 31 pairs, 1 pair was removed from the analysis due to the malfunctioning of the lighting system.

Fishing trip no.	Departure date	Duration of the fishing trip	No. of sampled hauls	No. of sampled pairs	No. of pairs used
1	21/10/2019	5 days	16	8	7
2	16/03/2020	4½ days	16	8	8
3	22/06/2020	4½ days	16	8	8
4	20/07/2020	4½ days	14	7	7

Table 3: Description of the sample

The hauls during these experimental fishing trips were carried out in VIId and IVc in the zones normally frequented by this ship and the OP FROM Nord artisanal trawlers (Fig. 38).

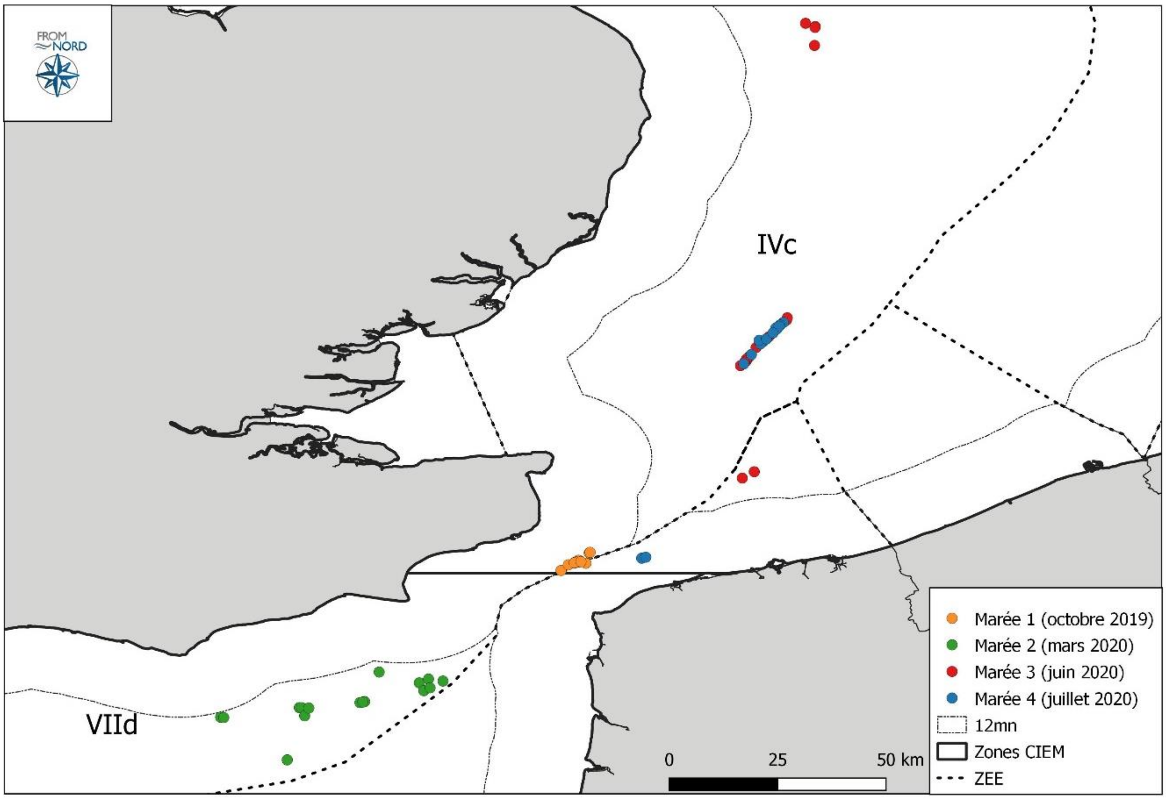


Figure 38: Map showing zones where nets were cast

3.1.2 Validation of the data

Pairs were carried out separately, either at night (15 pairs) or during the day (15 pairs), in comparable fishing conditions (similar towing speed, same direction of current, zones close to each other, similar substrate depth, and comparable duration of towing operation and sea state).

Correlation tests were carried out in order to validate the similarity of the fishing conditions. Since there was not a Gaussian distribution, a non-parametric Spearman test was carried out. The black bisecting line marks the strict equality of the conditions between the two systems (Fig. 39).

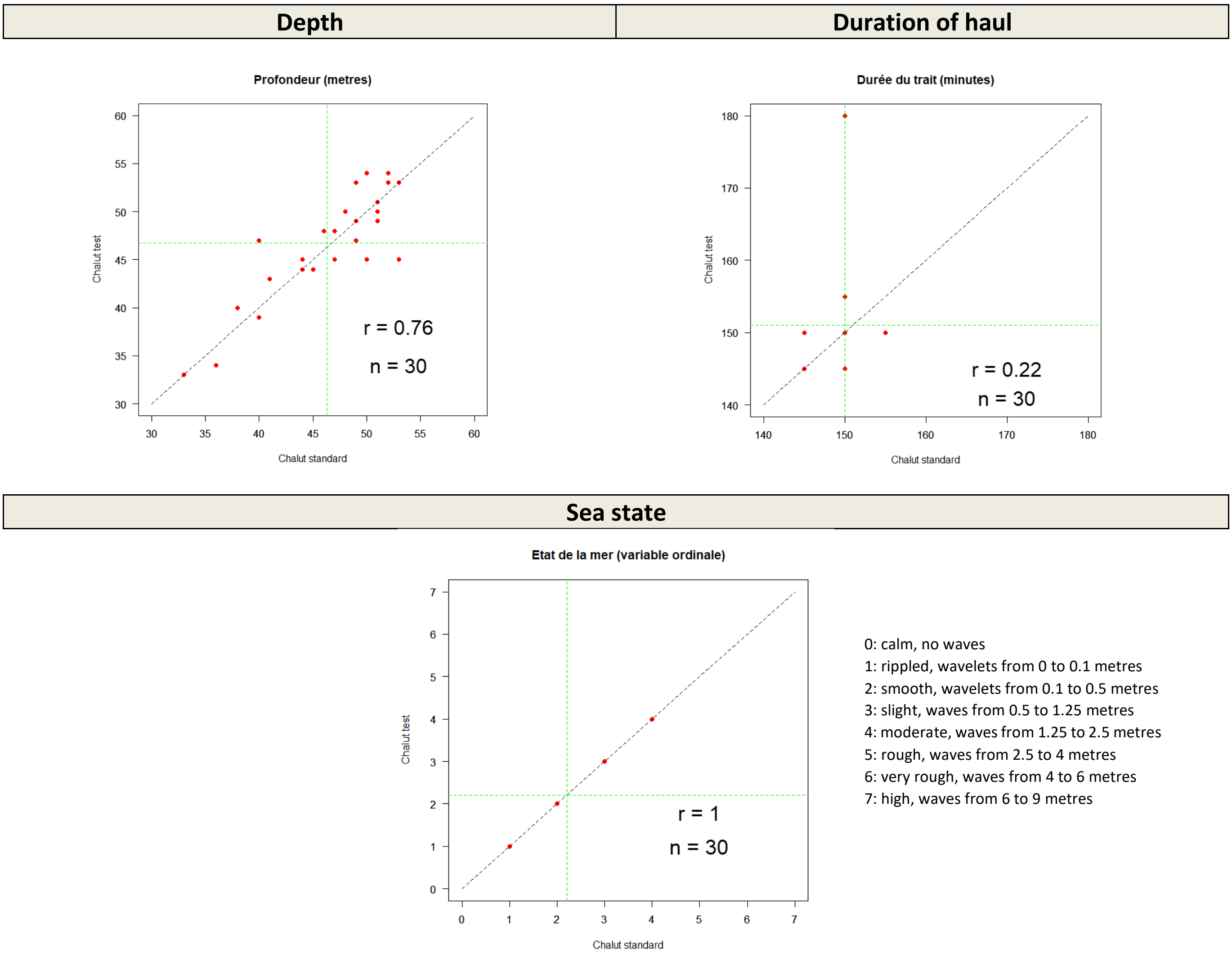


Figure 39: Comparison of fishing conditions (correlation test)

The results of these tests show that the depth of the sea and the sea state are similar within each pair. As regards the duration of haul, the standardisation of the data will enable differences to be adjusted. The measured quantities were divided by the duration of the associated haul, and the result was multiplied by the average duration of a haul (for details see the methodological section of the report).

The pairs were carried out under very similar conditions with regard to these 3 variables, and it is therefore possible to use a methodology that is suitable for the matched samples.

3.1.3 Study of the factors which may exert an influence on the selectivity of the test system

Two variables may have an impact on the selectivity of the test system: the “diurnal” variable and the “seasonal” variable. In order to evaluate the need to split the analysis according to these variables, a graphical analysis and a Generalized Linear Model (GLM) were used for the project's 7 priority species (details in Annex G). The variable to be explained is an escape metric. This metric is the proportion of the number of individuals of a given species that are caught in the test trawl in relation to the total catches of that species that are made in both trawls: $P=Ntest/Ntest+Nref$ where N = the number of individuals within a size category that are caught in a particular trawl.

For horse mackerel, the “diurnal” variable seems to be an explanatory factor for the proportion of individuals caught in the test trawl as compared to the standard trawl, and the p-value is < 0.05 (Fig. 40). The analysis of the horse mackerel data will therefore be undertaken separately for the night-time and daytime pairs.

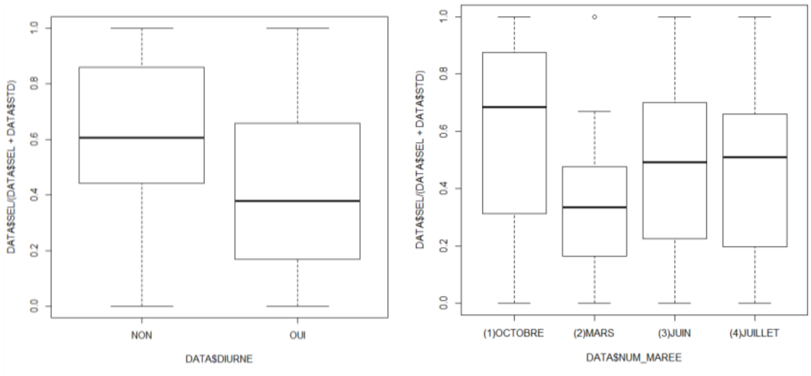


Figure 40: Boxplot proportions of horse mackerel caught per trawl depending on the two variables ("diurnal" and "seasonal")

For whiting, the “seasonal” variable seems to be an explanatory factor for the proportion of individuals caught in the test trawl as compared to the standard trawl, and the p-value is < 0.05 (Fig. 41). The analysis of the data for whiting will therefore be undertaken separately for the different seasons.

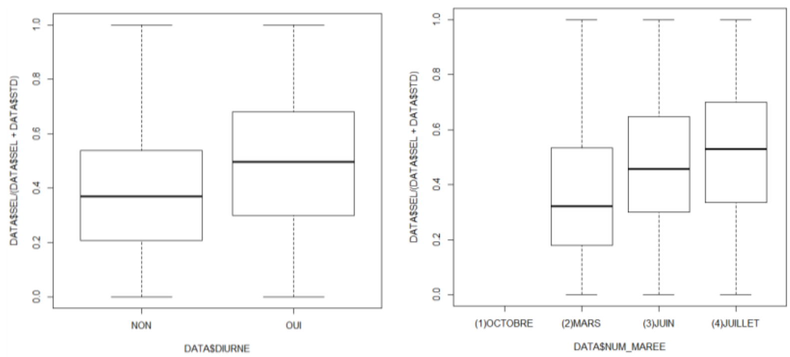


Figure 41: Boxplot proportions of whiting caught per trawl depending on the two variables ("diurnal" and "seasonal")

For the other species, the seasonal and diurnal variables are not explanatory factors for the proportion of individuals caught in the test trawl.

3.1.4 Overall analysis of the catches

The quantities caught over all the systems and fishing trips taken together vary from 114.6 kg to 1,206.50 kg per haul, and discard rates vary from 13% to 83%.

The quantities caught per trawl that was fitted with PISCES lights are greater on average than those caught using the reference trawl (+38.4kg/trawl). There are virtually no commercial losses (- 1.1kg/haul on average), but there are larger amounts of discards (+39.5 kg/haul on average) (Table 4). However, these results hide a high level of variability between pairs (Fig. 43).

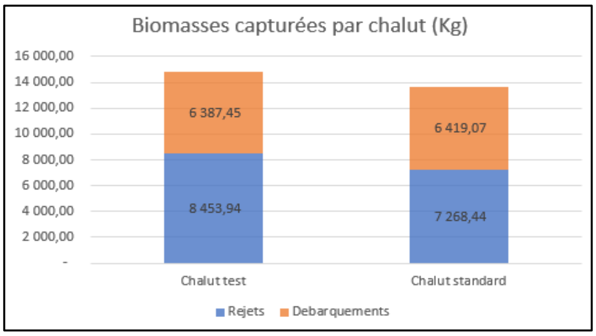


Figure 42: Amounts of biomass caught per standard trawl and test trawl (kg)

System	Average catches	Average landings	Average discards	Average discard rate
Standard (STD)	456.3	214	242.3	50.6%
Test (SEL)	494.7	212.9	281.8	54.8%

Table 4: Average catch, landing and discards data per haul

The results of the tests comparing median values that are shown below reveal p-values > 0.05, which indicates that **the differences in amounts caught between the two systems are not statistically significant.**

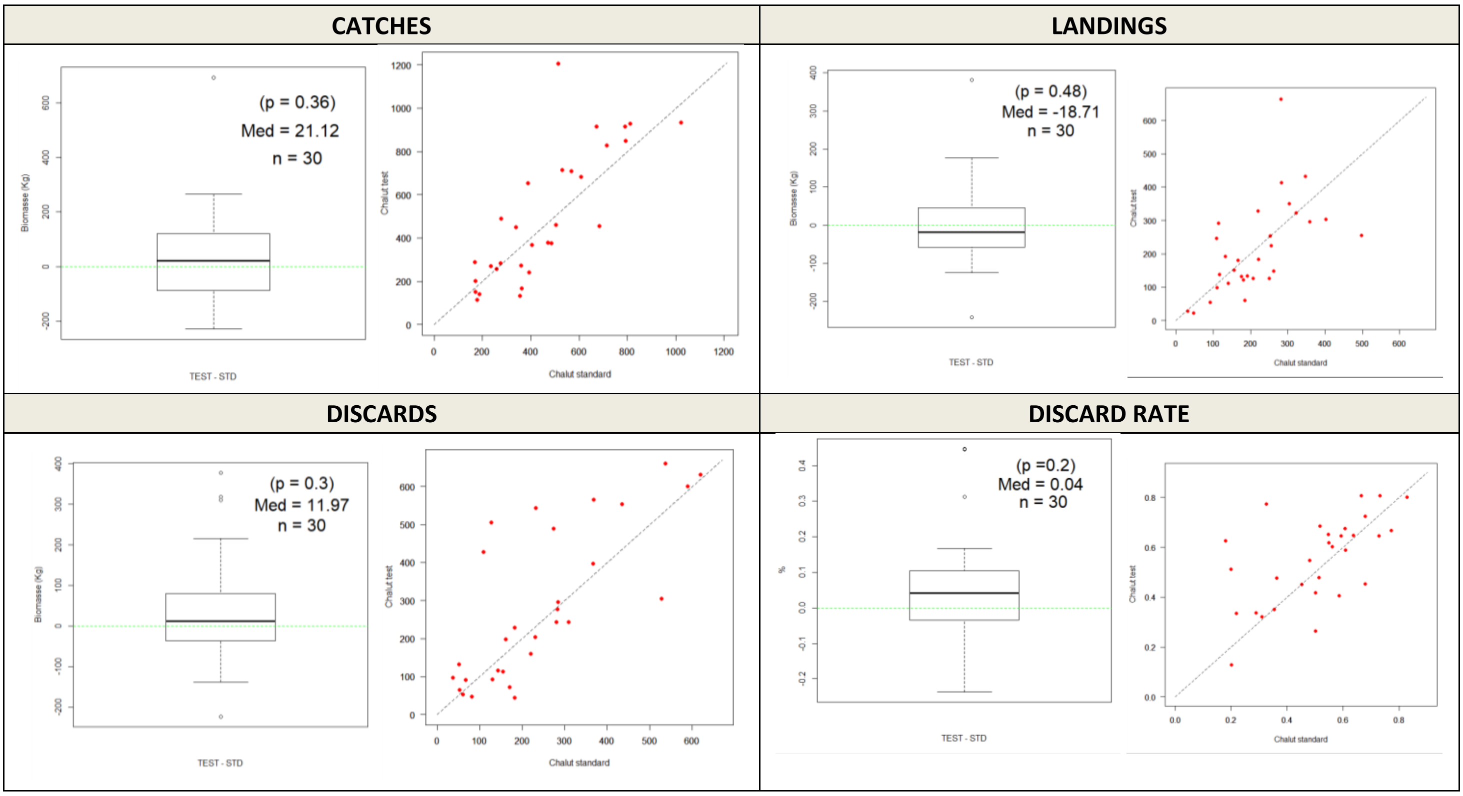


Figure 43: Right-hand side: Biomass amounts per pair and black bisecting line showing the precise equality of the biomass amounts caught using the two systems – test trawl on y-axis and standard trawl on x-axis. Left-hand side: Result of the non-parametric Mann

Whitney test relating to matched hauls (p-value), and differences in catches within each pair (TEST biomass amounts – STD biomass amounts).

3.1.5 Analysis by species

In these 4 experimental fishing trips 38 species were caught (Table 5) (details in Annex H). Among these species, 10 are priority species within the project, either because they are economically significant, or because they have a high discard rate. These 10 species are horse mackerel, whiting, squid, mackerel, pouting, red mullet, cuttlefish, yellow gurnard, plaice and herring. They make up 81% of catches, 90% of landings, and 72% of discards in the standard trawl over the total of the 4 experimental fishing trips (Annex H).

Espèces	Tonnages (Kg)	% cumulé
Merlan	6 096,51	44,54%
Chinchard d'Europe	2 164,60	60,36%
Limande	1 625,75	72,23%
Plie d'Europe	657,03	77,03%
Maquereau commun	598,61	81,41%
Encornet	570,70	85,58%
Petite roussette	519,51	89,37%
Tacaud commun	518,23	93,16%
Rouget de roche	207,73	94,68%
Seiche commune	115,18	95,52%
Limande sole	109,54	96,32%
Grondin perlon	98,17	97,03%
Grondin rouge	75,84	97,59%
petit tacaud	69,54	98,10%
Hareng de l'Atlantique	43,16	98,41%
Morue de l'Atlantique	41,64	98,72%
Dorade grise	31,91	98,95%
Bar européen	28,22	99,16%
Grondin gris	19,85	99,30%
Émissoles nca	16,28	99,42%
Saint Pierre	12,33	99,51%
Raie lisse	10,11	99,58%
Flet d'Europe	8,57	99,65%
Daurade Royale	7,07	99,70%
Sprat	6,84	99,75%
Callionymus	6,03	99,79%
Sole commune	5,99	99,83%
Barbue	3,81	99,86%
Raie bouclée	3,46	99,89%
Grande vive	3,36	99,91%
Turbot	3,11	99,94%
Baudroies, etc. nca	2,81	99,96%
Aiglefin	2,78	99,98%
Congre d'Europe	1,94	99,99%
Callionymus lyra	0,73	100,00%
Sole-pole	0,30	100,00%
Sardine	0,25	100,00%
souris de mer	0,02	100,00%

Table 5: Total biomass amounts caught by species over the 4 experimental fishing trips in the standard trawl (STD)

Of these 10 species, 7 are the subject of an in-depth analysis because they are present in sufficient quantities within the catches (more than 2 kg in at least 15 pairs). These species are whiting, horse mackerel, plaice, mackerel, squid, pouting, and red mullet (Fig. 44).

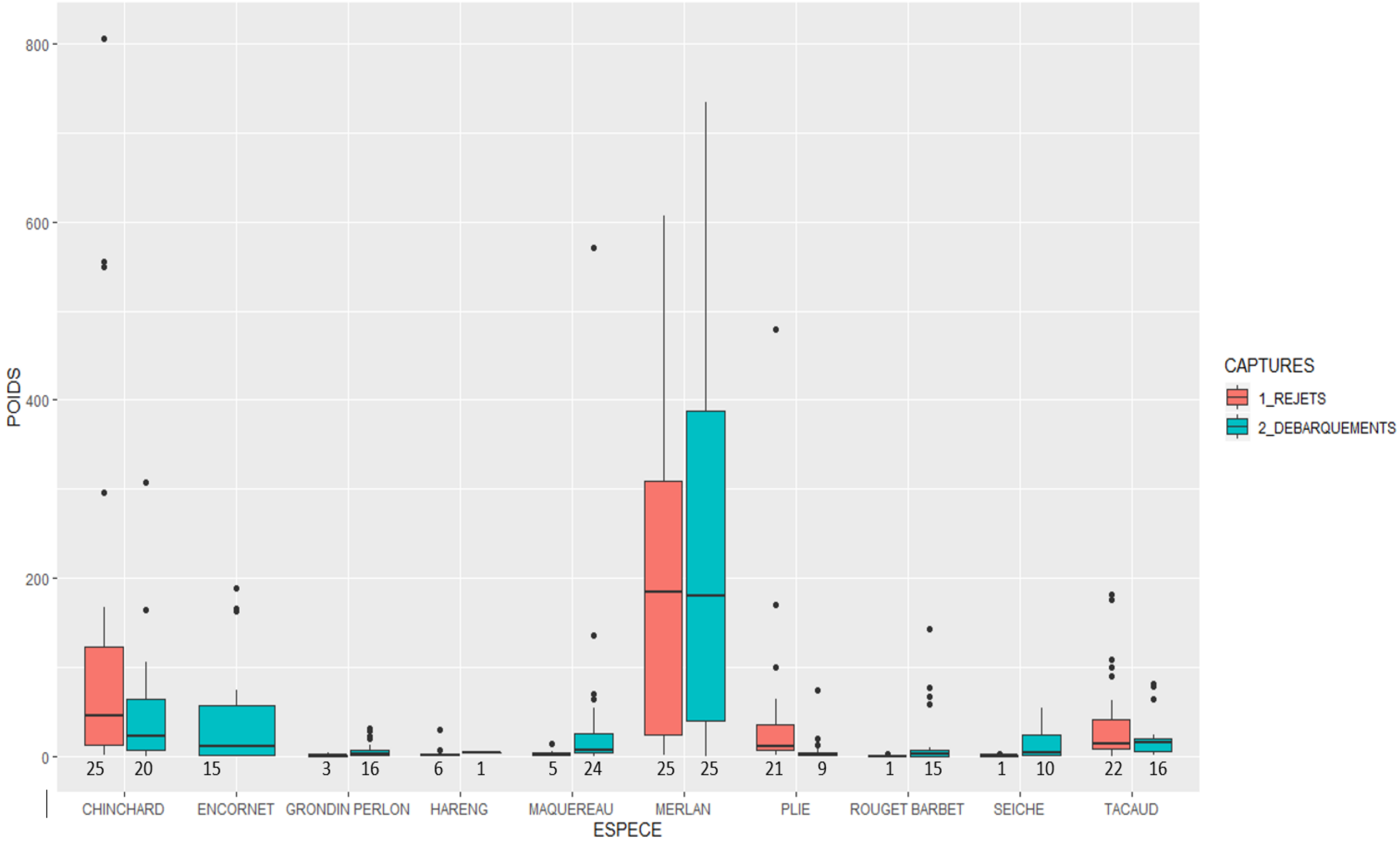


Figure 44: Landings and discards by species and by pair (number of pairs with a tonnage of > 2 kg in the boxplot)

According to the graphs below, the results for mackerel, plaice and red mullet are positive with equivalent amounts landed, and there are also positive results for whiting with a reduction in the discards. By contrast, smaller amounts of squid and whiting are landed, and discards of horse mackerel are increased (Fig. 45).

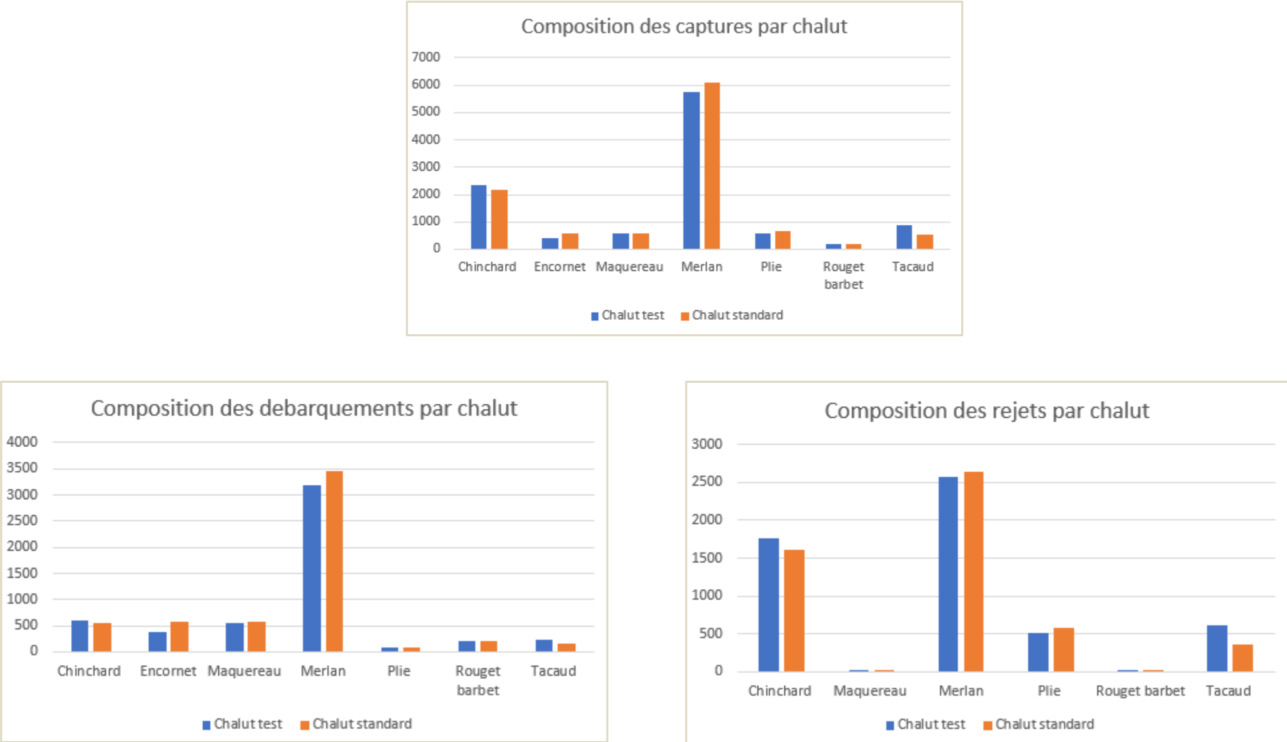


Figure 45: Composition of catches, landings and discards per trawl

The averages should be viewed with caution because they hide considerable variability between pairs (Table 6).

Species	Var. landings rate (mean)	Var. landings rate (total weight)	No. of pairs	Var. discards rate (mean)	Var. discards rate (total weight)	No. of pairs
Horse mackerel	**+ 101%**	**+9%**	21	**+ 84%**	**+9%**	29
Squid	**-6%**	**-31%**	21			
Mackerel	**+ 70%**	**-3%**	27			
Whiting	**-14%**	**-7%**	28	**-8%**	**-3%**	27
Plaice	**+ 122%**	**-1%**	23	**+108%**	**-13%**	23
Red mullet	**-13%**	**No difference**	22			
Pouting	**+136%**	**+44%**	20			

Table 6: Tonnages landed and discarded in the test trawl compared to the standard trawl (pair where Std > 0 kg)

In order to check these observations, a comparison of the amounts of biomass that were landed and discarded was carried out by using a non-parametric Mann Whitney median comparison test for matched hauls as well as an analysis of sizes using a GLMM.

***WHITING:** The aim is to <u>maintain the quantities that are landed and to reduce the quantities that are discarded</u>*

The data for whiting were analysed separately for the month of March because this fishing trip shows a different trend to the other fishing trips (cf. section 3.1.3 of the PISCES results).

October 2019 & June and July 2020 fishing trips:

For the fishing trips in October, June and July, the results of the median comparison tests do not show any statistically significant difference between the amounts of biomasses in the test trawl and in the standard trawl (Fig. 46).

Landings (kg)	Discards (kg)

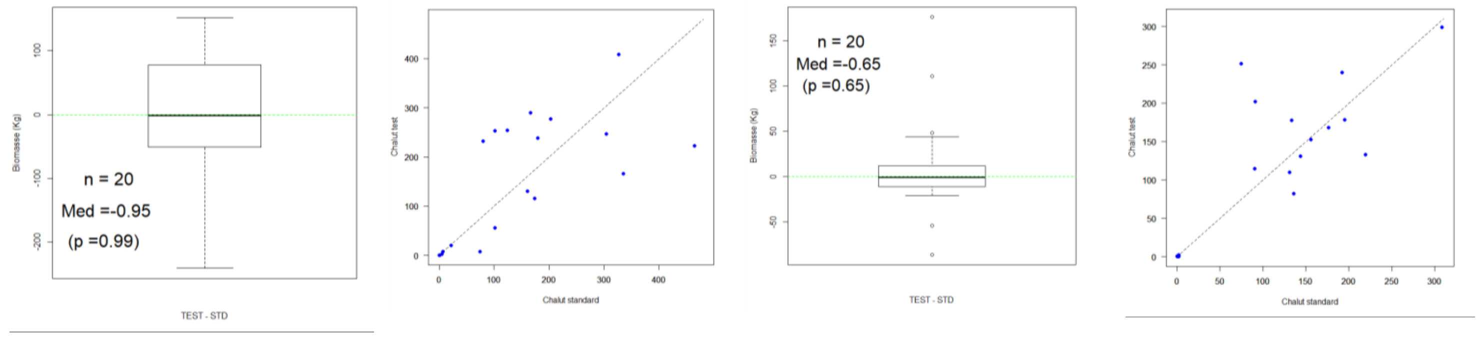


Figure 46: Right-hand side: Biomass amounts per pair and black bisecting line showing the precise equality of biomass amounts caught between the two systems – test trawl on y-axis and standard trawl on x-axis. Left-hand side: Result of the non-parametric test

As regards the size distribution, there is also no observable difference for these fishing trips (Fig. 47).

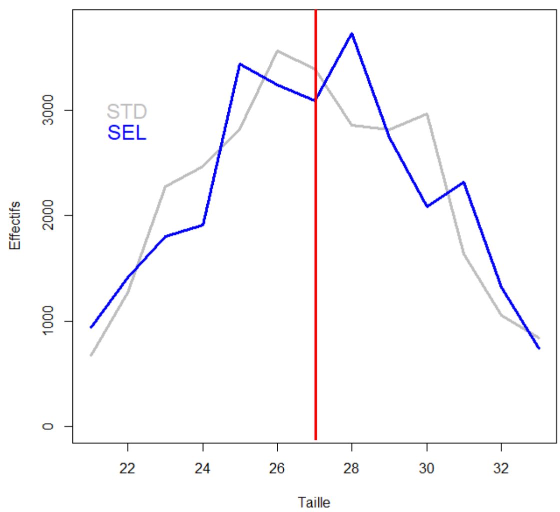


Figure 47: Distribution of sizes of whiting caught in the test trawl and the standard trawl for the fishing trips in October, June and July

March 2020 experimental fishing trip:

For the experimental fishing trip carried out in March (8 pairs sampled), smaller quantities were landed and discarded in the test trawl than in the standard trawl (p-value < 0.05) (Fig. 48). <u>For this fishing trip the test trawl is therefore more selective</u>.

Landings (kg)	Discards (kg)

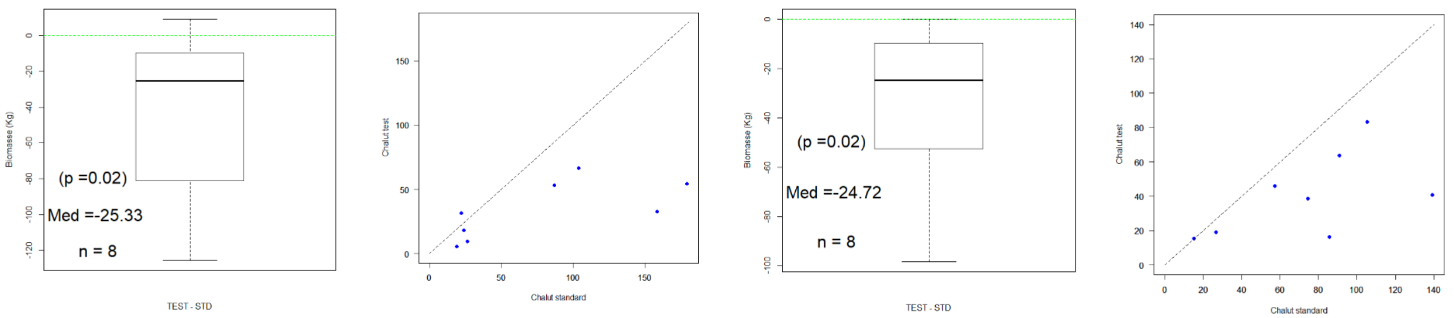


Figure 48: Right-hand side: Biomass amounts per pair and black bisecting line showing the precise equality of biomass amounts caught between the two systems – test trawl on y-axis and standard trawl on x-axis. Left-hand side: Result of the non-parametric test

In this fishing trip the test trawl enables discards to be reduced by 37% on average, but it also reduces the commercially usable share by 42%.

In terms of the distribution of sizes during this fishing trip, <u>the test system is more selective than the standard system across all the sizes (Fig. 50)</u>.

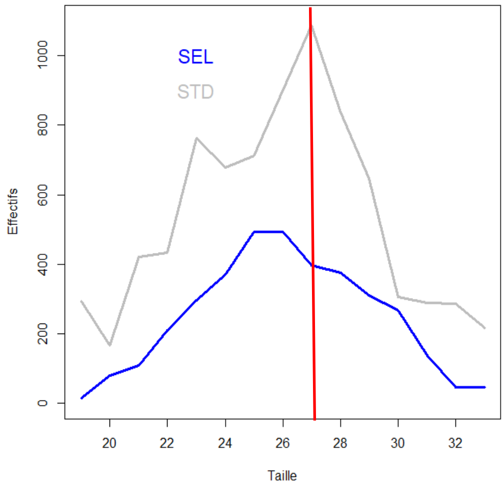


Figure 49: Size distribution of catches of whiting in the test trawl and the standard trawl for experimental fishing trip no. 2

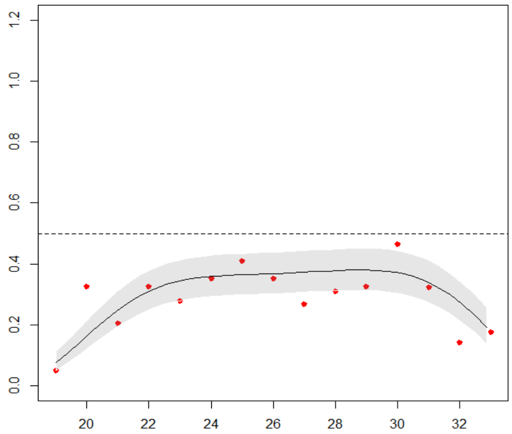


Figure 50: Probability of retention in the selective trawl according to size for fishing trip no. 2; the straight horizontal line shows the probability of catching 50% of the individuals

The difference between this fishing trip and the others could be explained by the difference in brightness between spring and the summer as well as the muddiness of the water. Another explanatory cause could be the fact that March is at the end of the period when whiting reproduce. However, depth cannot explain this difference because it is more or less the same during all the fishing trips.

HORSE MACKEREL: The aim is to <u>reduce the quantities that are landed and caught</u>

The data for horse mackerel were analysed separately for the night-time and daytime hauls because the trend differs according to this variable (cf. section 3.1.3 of the PISCES results).

For daytime hauls, there is no statistically significant difference between the amounts of biomass in the test trawl and the standard trawl. When one looks at the size distribution for the different systems, there are fewer individuals measuring between 19 cm and 26 cm in the test trawl, but this masks a high level of variability. The GLMM confidence interval does not allow any conclusion to be drawn regarding the significance of escapes (Fig. 51).

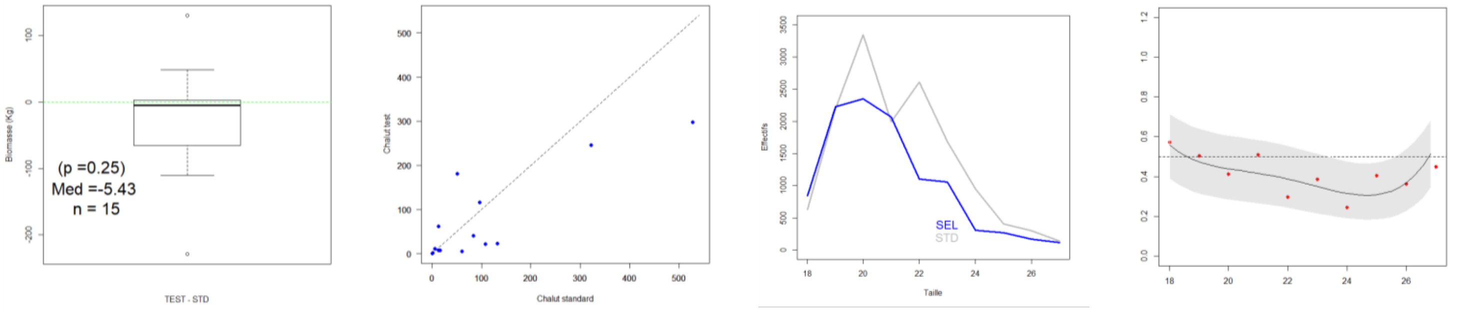


Figure 51: Comparison of biomass amounts (left-hand side) and sizes (right-hand side) in daytime catches

For night-time hauls, there are seen to be greater quantities caught in the test trawl than in the standard trawl (p-value < 0.05). The number of individuals is greater in the test trawl across all size bands. However, the GLMM confidence interval does not allow any conclusion to be drawn regarding the significance of the difference in escape levels (Fig. 52).

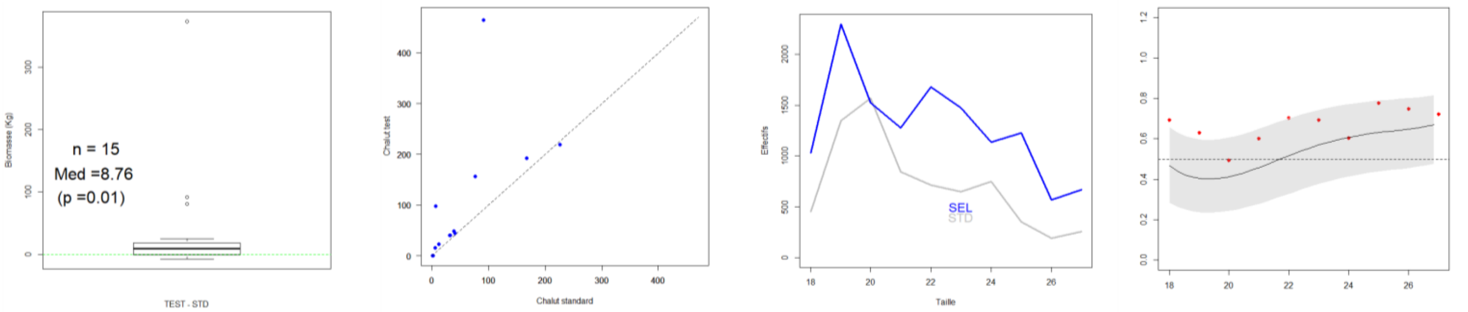


Figure 52: Comparison of biomass amounts (left-hand side) and sizes (right-hand side) for night-time catches

If one selects only **the night-time catches using <u>the flashing light</u>** (excluding the October trial, i.e. 11 pairs), the results of the tests do not show any statistically significant difference between the amounts of biomass in the test trawl and in the standard trawl. This means that the constant light must have been responsible for the larger catches in the test trawl (Fig. 52).

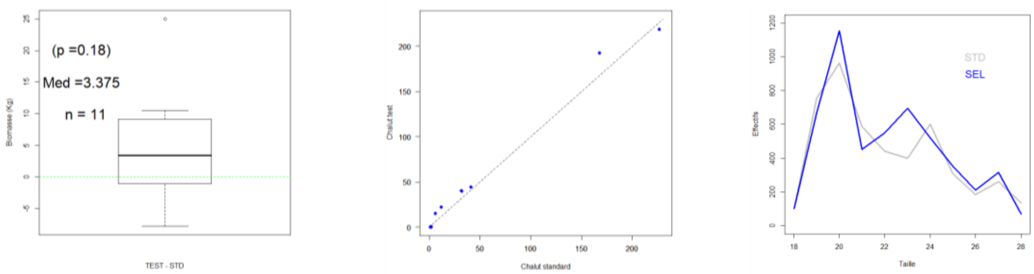


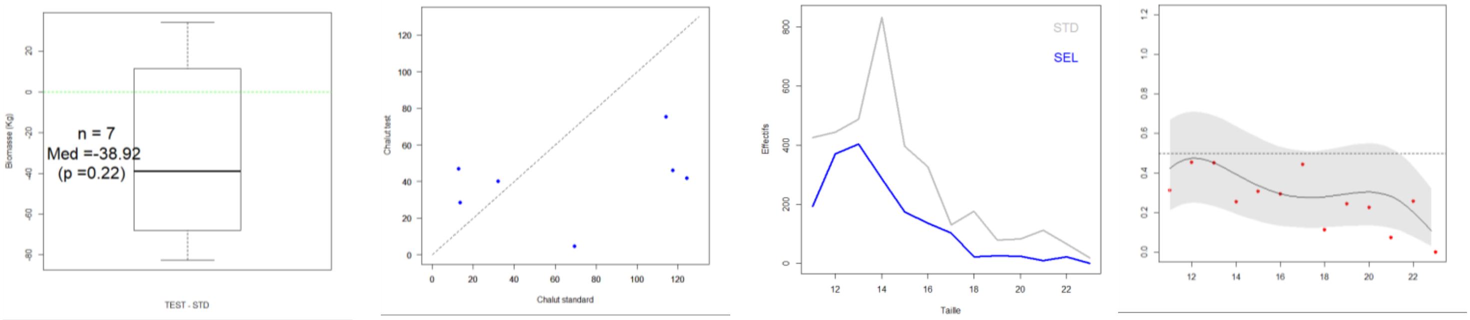
Figure 53: Comparison of biomass amounts (left-hand side) and sizes (right-hand side) for night-time catches using the flashing PISCES

Mackerel, squid, red mullet and pouting, *the aim is to* <u>*maintain the quantities that are landed.*</u> *For* ***plaice,*** *the aim is to* <u>*maintain the quantities that are landed and to reduce the quantities that are discarded.*</u>

SQUID:

For squid only the October fishing trip provides enough catch data for analysis. The results of the tests do not show any statistically significant difference between the amounts of biomass in the test trawl and in the standard trawl. When one looks at the size distribution for the systems, there are fewer individuals in the test trawl; however, the GLMM confidence interval does not allow any conclusion to be drawn regarding the significance of escape levels (high variability of the data).

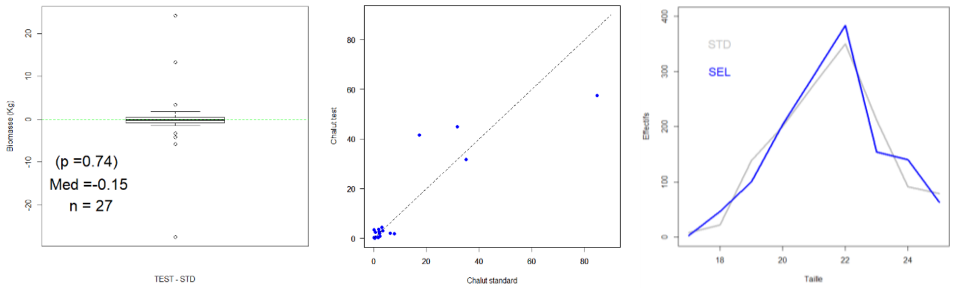
SQUID (landings - kg)



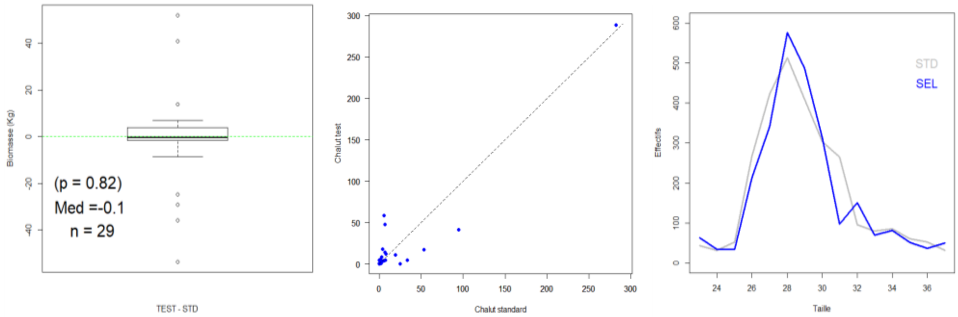
MACKEREL AND RED MULLET:

For red mullet and mackerel the results of the tests do not show any statistically significant difference between the amounts of biomass in the test trawl and the standard trawl. When one looks at the number of individuals of each size according to the system used, there is no significant difference between the two trawls.

RED MULLET (landings - kg)

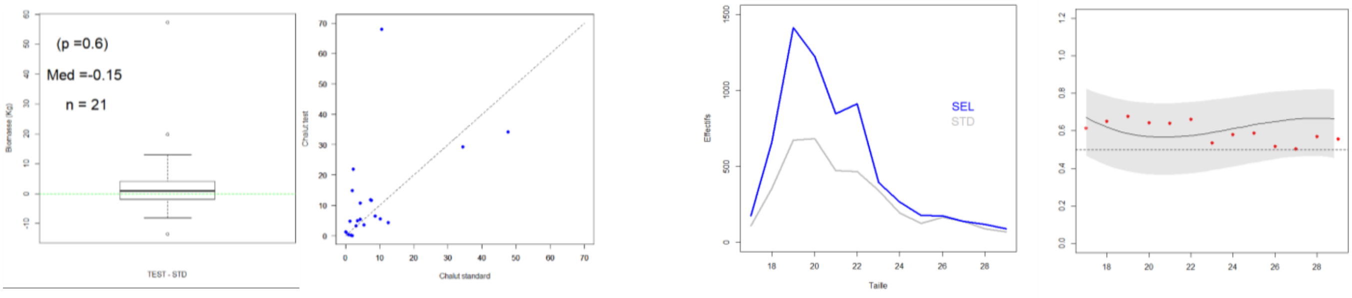


MACKEREL (landings kg)



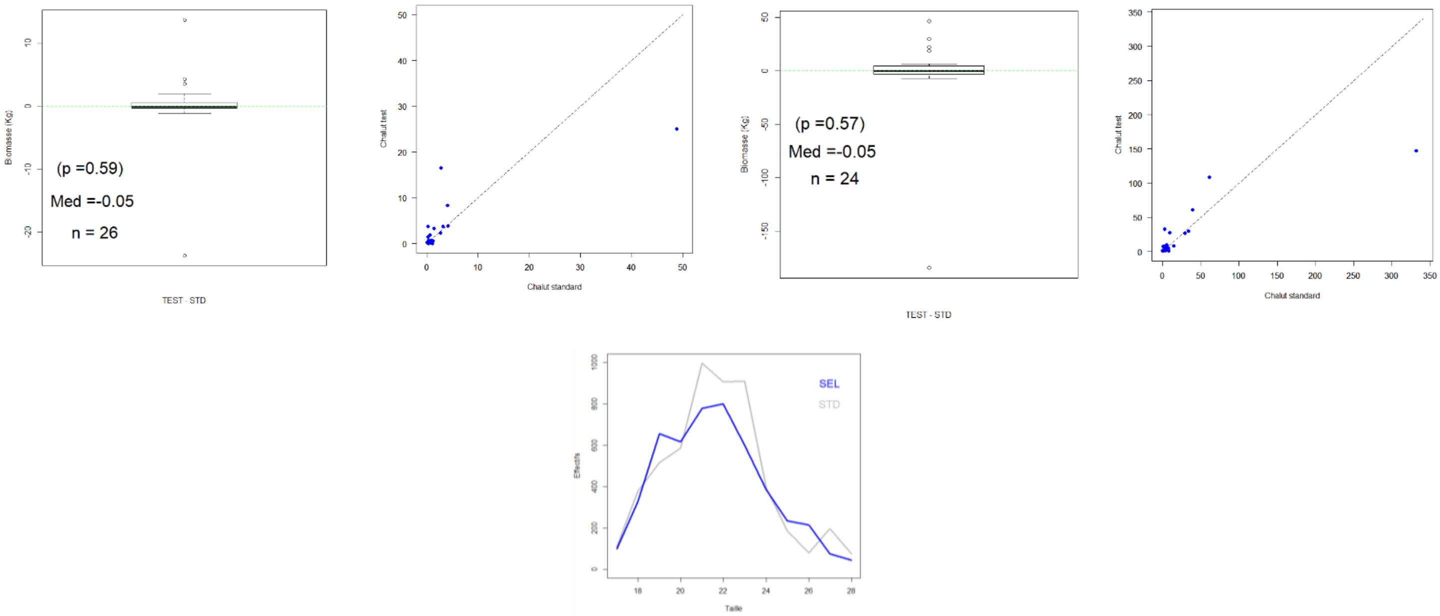
For pouting, there is no statistically significant difference between the amounts of biomass in the test trawl and the standard trawl. When one looks at the size distribution for the systems, there are more individuals in the test trawl; however, the GLMM confidence interval does not allow any conclusion to be drawn regarding the significance of this difference (high variability of the data).

POUTING (landings kg)



For plaice, there is no statistically significant difference between the amounts of biomass landed and discarded in the test trawl and in the standard trawl. When one looks at the size distribution for the systems, there are more individuals in the standard trawl; however, no GLMM model converges and so it is not possible to draw any conclusions regarding the significance of this difference (high variability of the data).

PLAICE (landings kg)	PLAICE (discards kg)



3.2. Brezglow

3.2.1 Description of the sample

Three experimental fishing trips were organised in order to test the Brezglow system. During these three fishing trips, 44 trawls were sampled comprising 22 lit hauls and 22 standard hauls, or 22 pairs. Of these 22 pairs, 19 pairs were used for the analysis. 3 pairs had to be withdrawn from the analysis:

- One haul within a pair included particularly large catches of mackerel.
- One haul within a pair was slightly damaged with a resultant loss of fish
- The two hauls within a pair were carried out 4 hours apart instead of an average of 20 minutes apart due to damage having occurred.

Fishing trip no.	Departure date	Duration of the fishing trip	No. of sampled hauls	No. of sampled pairs	No. of pairs used
1	02/12/2019	4 days	12	6	4
2	10/08/2020	4½ days	16	8	8
3	07/09/2020	4½ days	16	8	7

Table 7: Description of the sample

The hauls during these fishing trips were carried out in VIId and IVc in the zones normally frequented by these ships and the OP FROM Nord artisanal trawlers.

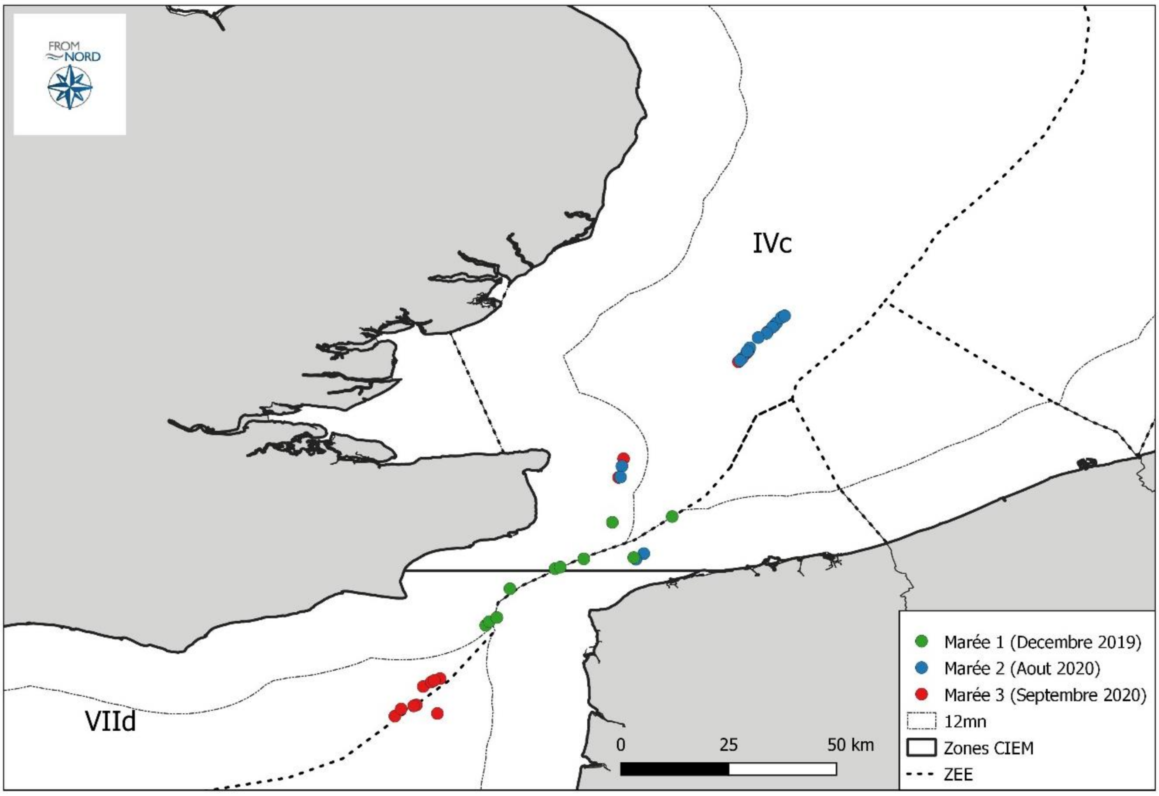


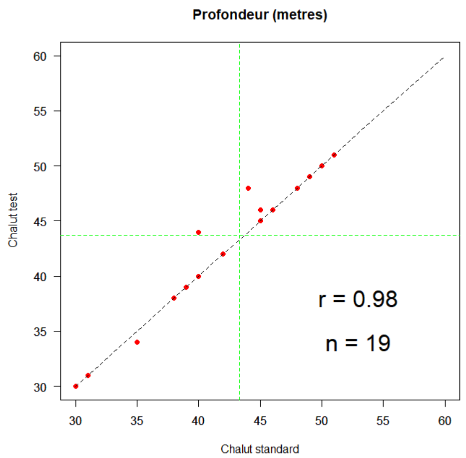
Figure 54: Map showing zones where nets were cast

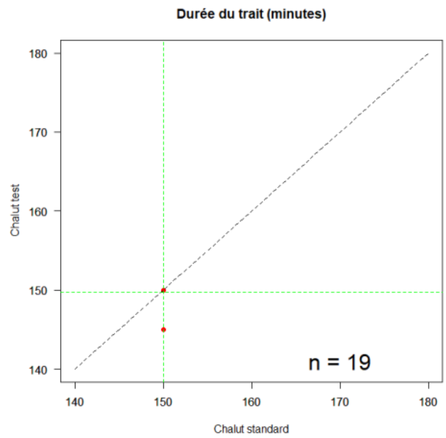
3.2.2 Validation of the data

Pairs were carried out separately, either at night (9 pairs) or during the day (10 pairs), in comparable fishing conditions (similar towing speed, same direction of current, zones close to each other, similar substrate depth, and comparable duration of towing operation and sea state).

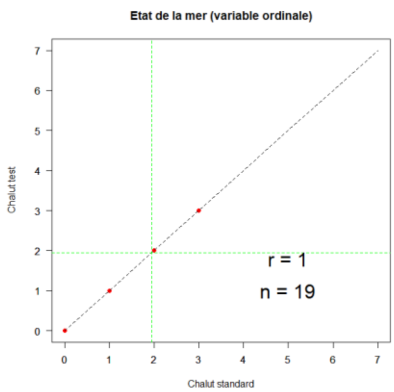
Correlation tests were carried out in order to validate the similarity of the fishing conditions. Since there was not a Gaussian distribution, a non-parametric Spearman test was carried out. The black bisecting line marks the strict equality of the conditions between the two systems.

Depth	Duration of haul





Sea state



0: calm, no waves
1: rippled, wavelets from 0 to 0.1 metres
2: smooth, wavelets from 0.1 to 0.5 metres
3: slight, waves from 0.5 to 1.25 metres
4: moderate, waves from 1.25 to 2.5 metres
5: rough, waves from 2.5 to 4 metres
6: very rough, waves from 4 to 6 metres
7: high, waves from 6 to 9 metres

Figure 55: Comparison of fishing conditions (correlation test)

The results of these tests show that the depth of the sea and the sea state are similar within each pair.

As regards the duration of haul, the standardisation of the data will enable differences to be adjusted. The measured quantities were divided by the duration of the associated haul, and the result was multiplied by the mean haul duration.

The pairs were carried out under very similar conditions with regard to these 3 variables, and it is therefore possible to use a methodology that is suitable for the matched samples.

3.2.3 Study of the factors which may exert an influence on the catches

Two variables may have an impact on the selectivity of the test system: the “diurnal” variable and the “seasonal” variable. In order to evaluate the need to split the analysis according to these variables, a graphical analysis and a Generalized Linear Model (GLM) were used for the project's 7 priority species (details in Annex G). The variable to be explained is an escape metric. This metric is the proportion of the number of individuals of a given species that are caught in the test trawl in relation to the total catches of that species that are made in both trawls: P=Ntest/Ntest+Nref where N = the number of individuals within a size category that are caught in a particular trawl.

HORSE MACKEREL: The “seasonal” variable seems to be an explanatory factor for the proportion of horse mackerel caught in the test trawl as compared to the standard trawl, and the p-value is < 0.05. The analysis of the data for horse mackerel will therefore be undertaken separately for the different seasons.

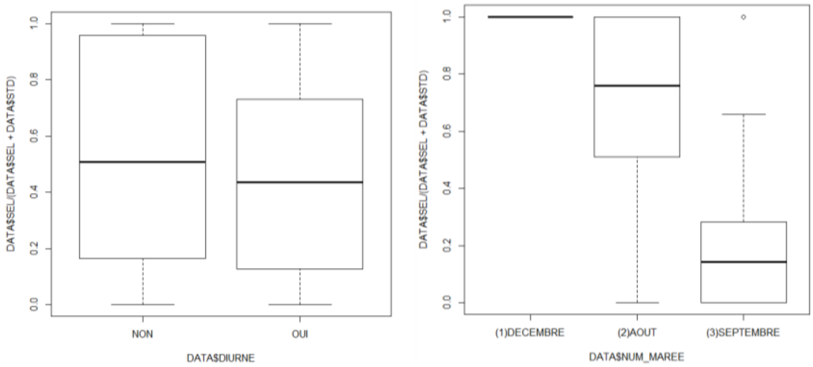


Figure 56: Boxplot proportions of horse mackerel caught per trawl depending on the two variables ("diurnal" and "seasonal")

WHITING: The “seasonal” variable seems to be an explanatory factor for the proportion of whiting caught in the test trawl as compared to the standard trawl, and the p-value is < 0.05. The analysis of the data for whiting will therefore be undertaken separately for the different seasons.

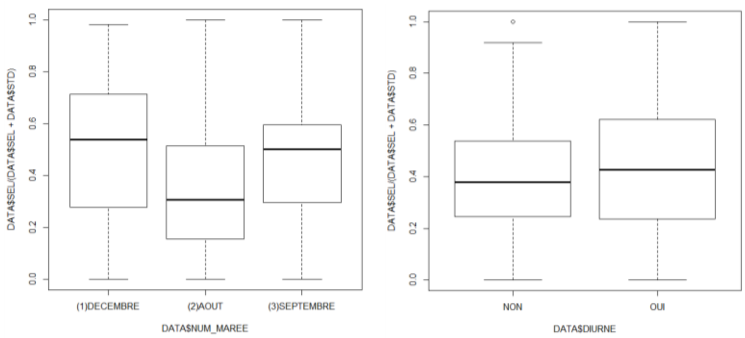


Figure 57: Boxplot proportions of whiting caught per trawl depending on the two variables ("diurnal" and "seasonal")

For the other species, the seasonal and diurnal variables are not explanatory factors for the proportion of individuals caught in the test trawl.

3.2.4 Overall analysis of the catches

The quantities caught over all the fishing trips and systems as a whole vary from 110.3 kg to 1,524 kg per haul, and discard rates vary from 5% to 90%.

The quantities caught per trawl that was fitted with Brezglow phosphorescent wire are greater on average than those caught using the reference trawl (+11.54kg/trawl). On average, the landings are greater (+46.77kg/haul), and the discards are reduced (-35.23kg/haul) (Table 8). These results do not represent major differences in tonnages, and in any event they mask a high level of variability between pairs (Fig. 59).

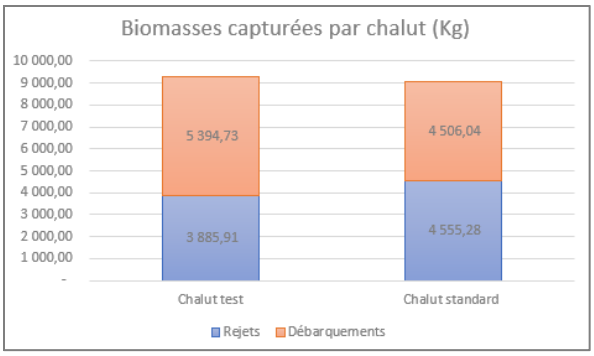


Figure 58: Amounts of biomass caught per standard trawl and test trawl (kg)

System	Average catches	Average landings	Average discards	Average discard rate
Standard (STD)	476.91	237.16	239.75	53.1%
Test (SEL)	488.45	283.93	204.52	51.1%

Table 8: Average catch, landing and discards data per haul

The results of the tests comparing median values that are shown below reveal p-values > 0.05, which indicates that the differences between the two systems are not statistically significant.

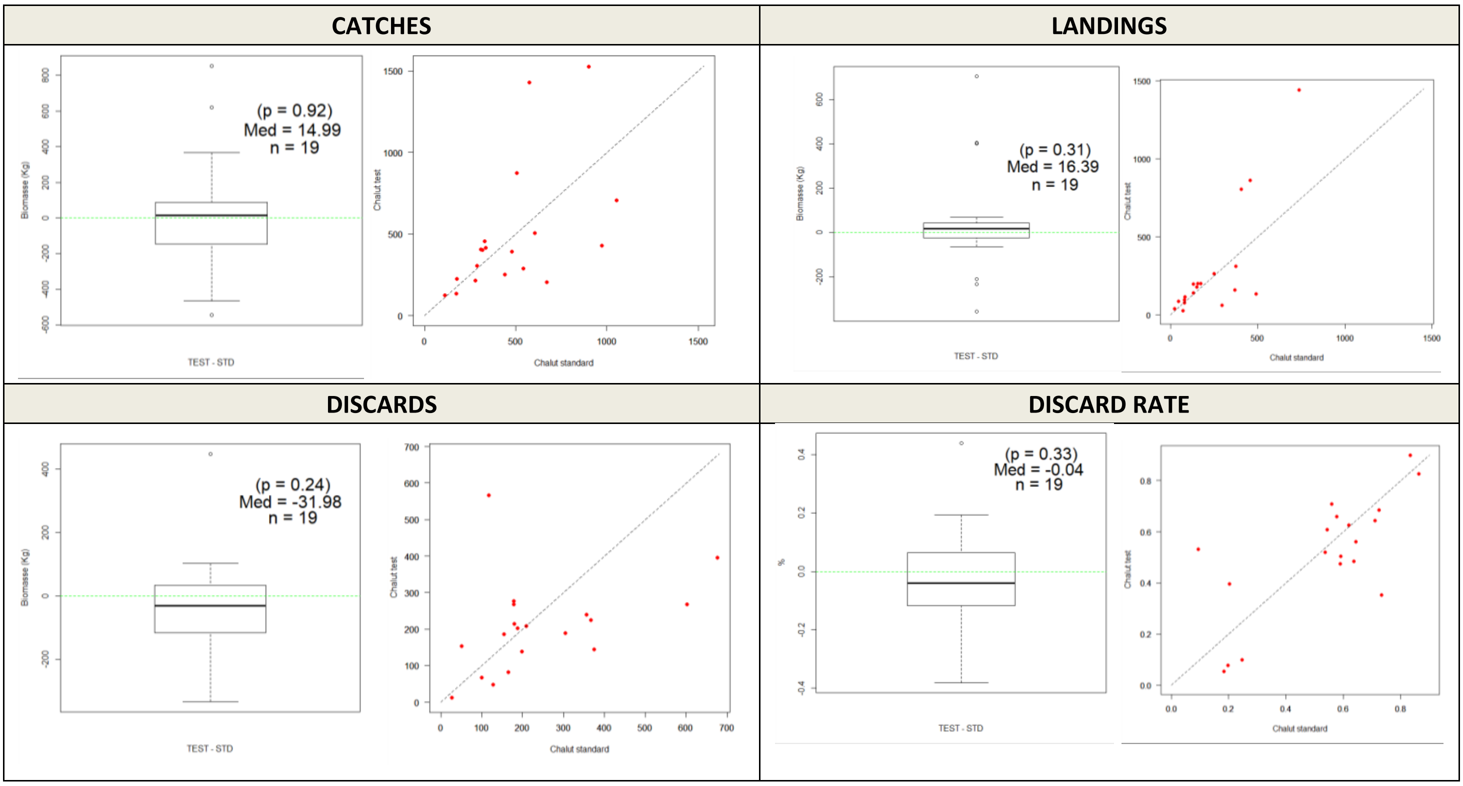


Figure 59: Biomass amounts per pair and black bisecting line showing the precise equality of biomass amounts caught between the two systems (graph on right-hand side), test trawl on y-axis and standard trawl on x-axis. Result of the non-parametric Mann Whitney test relating to matched hauls (p-value) and differences in amounts caught within each pair (TEST biomass amounts – STD biomass amounts) (graph on right-hand side).

3.2.5 Analysis by species

In these 3 experimental fishing trips 27 species were caught in the standard trawl (Table 9). The project's 10 priority species make up 84% of catches, 86% of landings, and 82% of discards in the standard trawl over the total of the 3 fishing trips (Annex H).

Espèces	Tonnages (Kg)	% cumulé
Merlan	4 517,47	49,85%
Encornet	1 266,40	63,83%
Chinchard d'Europe	557,50	69,98%
Limande	519,89	75,72%
Maquereau commun	293,88	78,96%
Tacaud commun	279,86	82,05%
Plie d'Europe	261,46	84,94%
Petite roussette	245,64	87,65%
Bar européen	220,01	90,08%
Rouget de roche	150,03	91,73%
Limande sole	136,13	93,23%
Raie bouclée	124,23	94,61%
Seiche commune	100,98	95,72%
Grondin perlon	92,69	96,74%
hareng	88,63	97,72%
Émissole tachetée	61,07	98,39%
Grondin rouge	56,67	99,02%
petit tacaud	32,43	99,38%
Raie lisse	17,59	99,57%
Morue de l'Atlantique	16,42	99,75%
Sole commune	12,44	99,89%
grondin gris	5,00	99,95%
Grande vive	2,20	99,97%
Dorade grise	1,40	99,99%
Saint Pierre	0,65	99,99%
Raie brunette	0,47	100,00%
sardine	0,20	100,00%

Table 9: Total biomass amounts caught by species over the 3 experimental fishing trips in the standard trawl (STD)

Of these 10 species, 7 species are present in over 15 pairs with a total weight of over 2 kg, and they can therefore be the subject of in-depth analysis: horse mackerel, whiting, yellow gurnard, mackerel, plaice, red mullet, pouting (Fig. 60). A sizeable quantity of squid is present, but only above 2 kg in weight in 6 pairs.

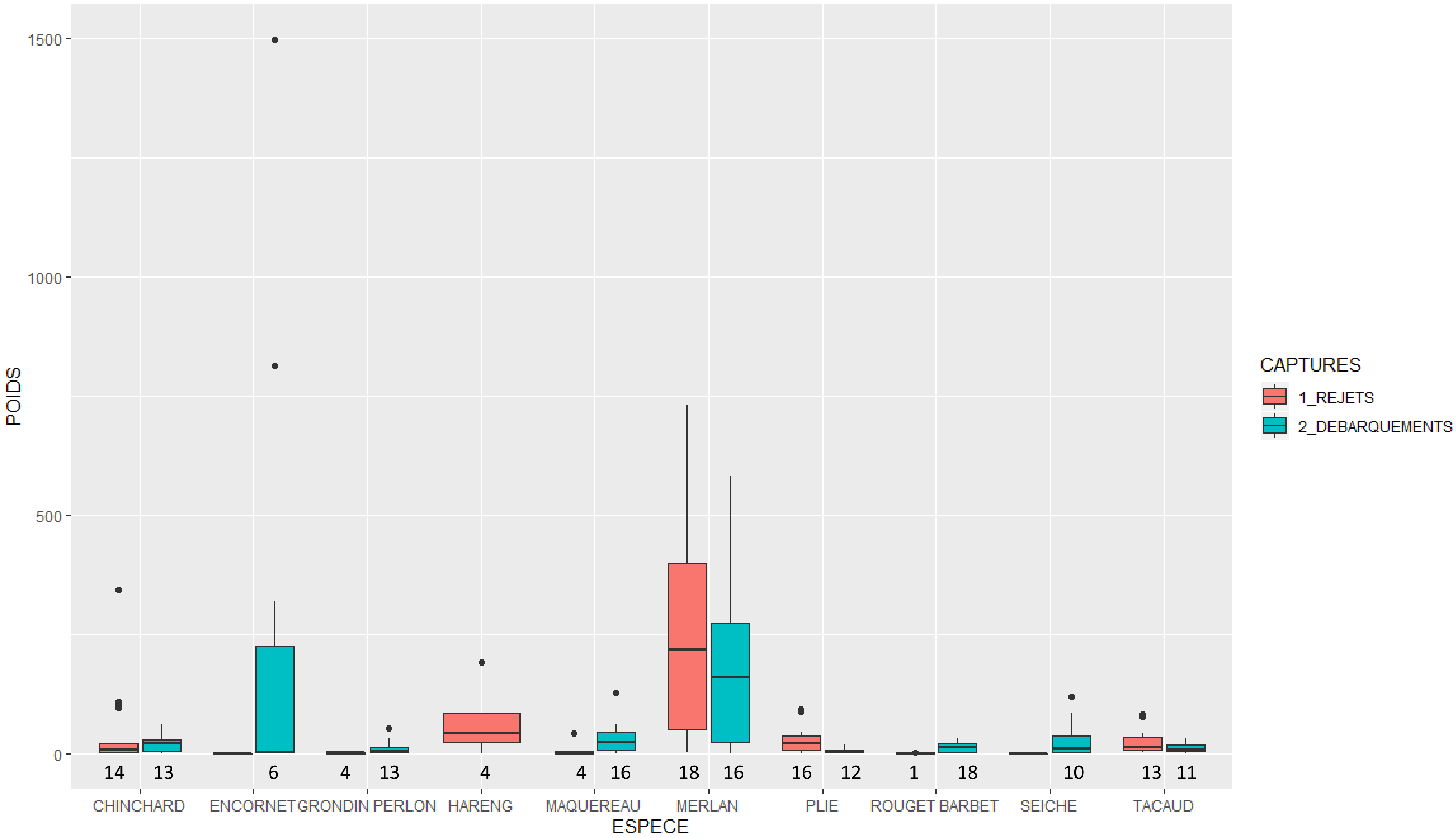


Figure 60: Biomass (landings and discards) per haul for each priority species

Over all the fishing trips there are commercial losses of mackerel, whiting and red mullet, but a reduction in discards of horse mackerel and whiting. (Fig. 61 and Table 10).

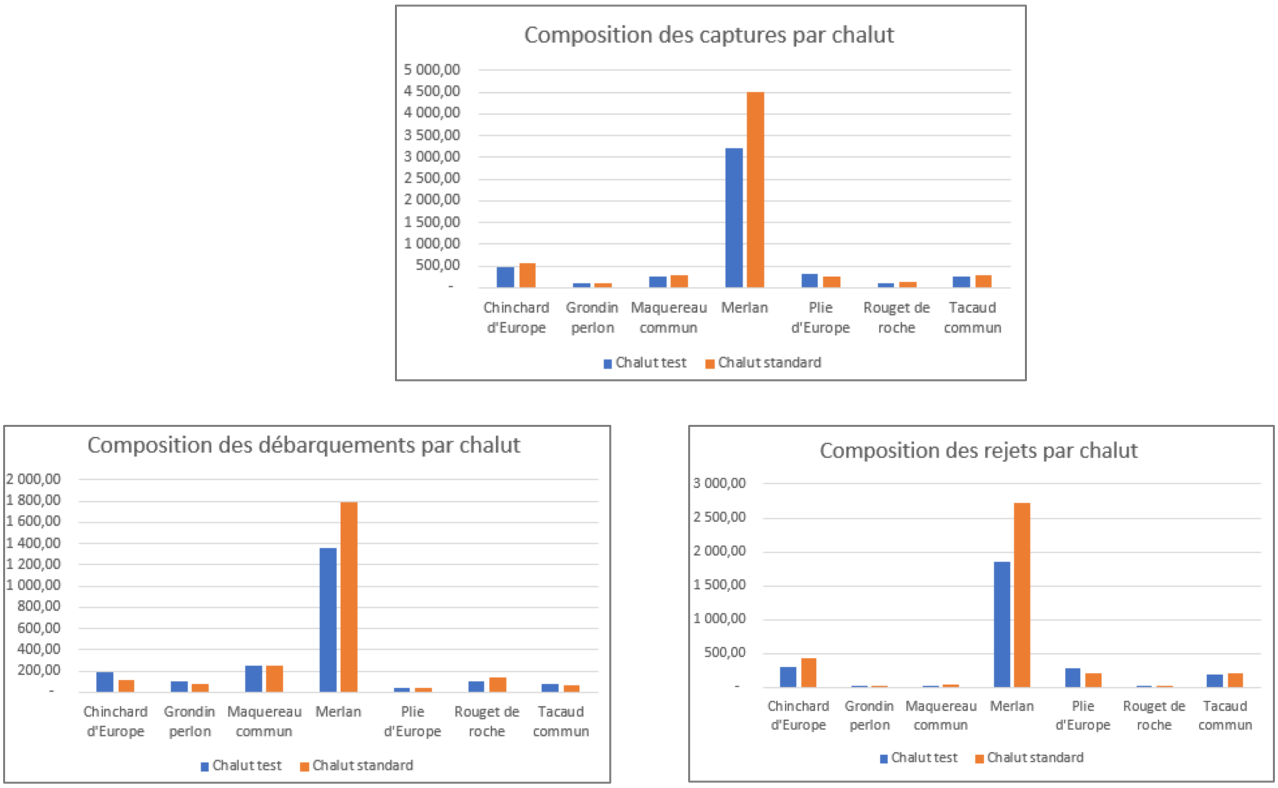


Figure 61: Composition of catches, landings and discards per trawl

The averages should be viewed with caution because they hide considerable variability between pairs (Table 10).

Species	Var. landings rate (mean)	Var. landings rate (total weight)	No. of pairs	Var. discards rate (mean)	Var. discards rate (total weight)	No. of pairs
Horse mackerel	+ 125%	+ 58%	14	+ 2%	-33%	17
Yellow gurnard	+ 57%	+ 25%	18			
Mackerel	+ 82%	-2%	17			
Whiting	+ 2%	-24%	18	-12%	-32%	18
Plaice	+ 127%	+ 10%	17	+ 209%	+ 26%	18
Red mullet	+ 49%	-25%	19			
Pouting	+ 84%	+22%	13			

Table 10: Tonnages landed and discarded in the test trawl compared to the standard trawl (pair where Std > 0 kg)

In order to check these observations, a comparison of the amounts of biomass that were landed and discarded was carried out by using a non-parametric Mann Whitney median comparison test for matched hauls as well as an analysis of sizes using a GLMM.

Whiting: *The aim is to <u>maintain the quantities that are landed and to reduce the quantities that are discarded</u>*

The data for whiting were analysed separately for the month of August because this fishing trip shows a different trend to the other fishing trips (cf. section 3.2.3 of the BREZGLOW results).

For the December and September fishing trips the results of the tests do not show any statistically significant difference between the amounts of biomass in the test trawl and the standard trawl.

Landings (kg)	Discards (kg)

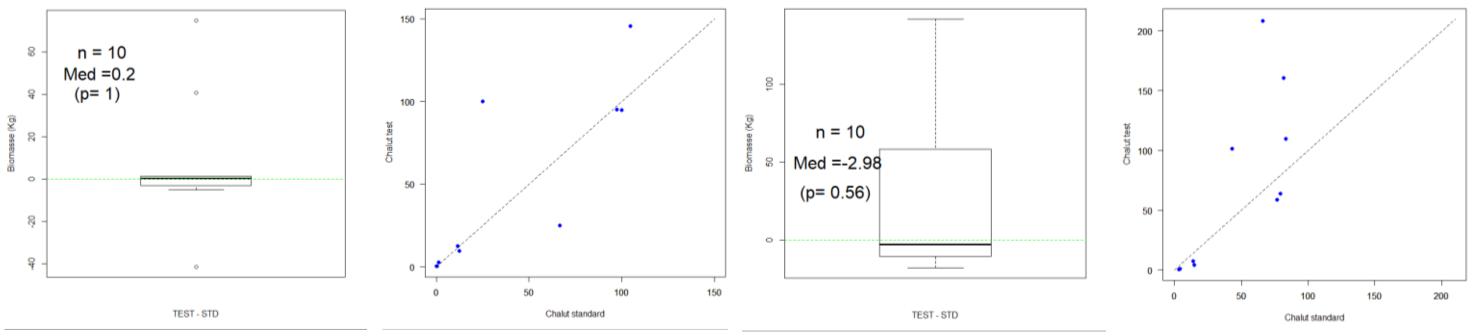


Figure 62: Right-hand side: Biomass amounts per pair and black bisecting line showing the precise equality of biomass amounts caught between the two systems – test trawl on y-axis and standard trawl on x-axis. Left-hand side: Result of the non-parametric test

When one looks at the size distribution for the systems, there are more individuals in the test trawl; however, the GLMM confidence interval does not allow any conclusion to be drawn regarding the significance of this difference (high variability of the data) (Fig. 63).

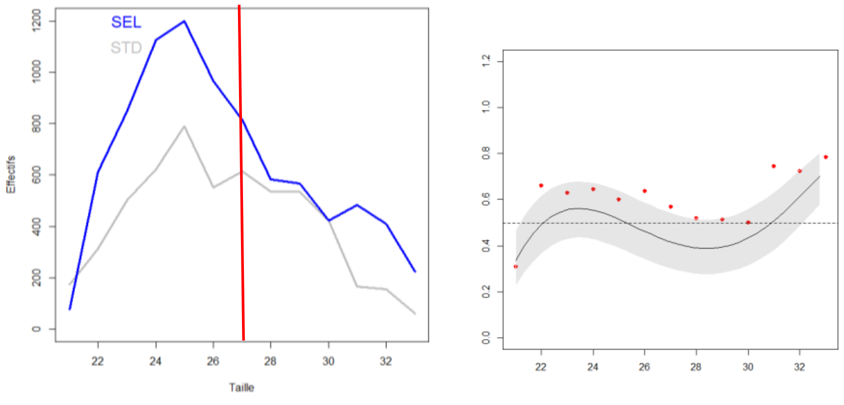


Figure 63: Distribution of sizes of whiting caught in the test trawl and the standard trawl for the fishing trips in October, June and July

For the fishing trip carried out in August (8 pairs sampled), smaller quantities were discarded in the test trawl than in the standard trawl (p-value < 0.05).

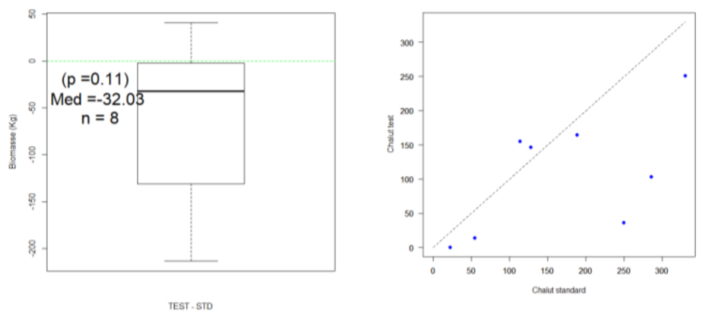
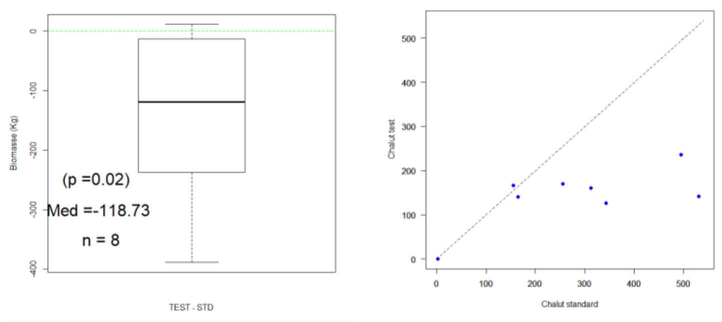
Landings (kg)	Discards (kg)
	

Figure 64: Right-hand side: Biomass amounts per pair and black bisecting line showing the precise equality of biomass amounts caught between the two systems – test trawl on y-axis and standard trawl on x-axis. Left-hand side: Result of the non-parametric test

When one looks at the size distribution for the different systems, there are more individuals of all sizes in the standard trawl. This difference in selectivity is validated by the GLMM for sizes from 25 cm to 29 cm, although there is a high level of variability within the data. For the other sizes, the GLMM confidence interval does not allow any conclusion to be drawn regarding the significance of this difference (high level of data variability). For this fishing trip the test trawl would therefore results in more fish escaping than the standard trawl for horse mackerel between 25 cm and 29 cm in size.

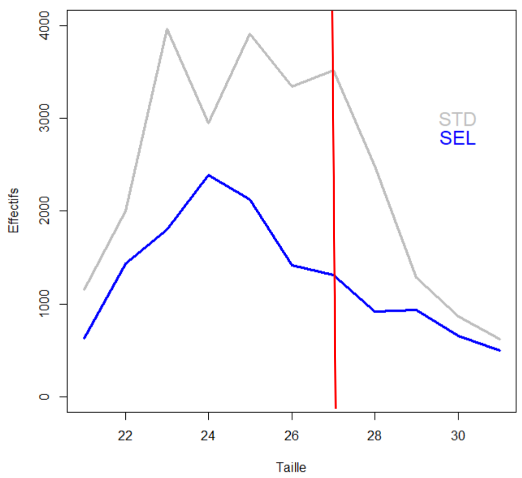


Figure 65: Size distribution of catches of whiting in the test trawl and the standard trawl

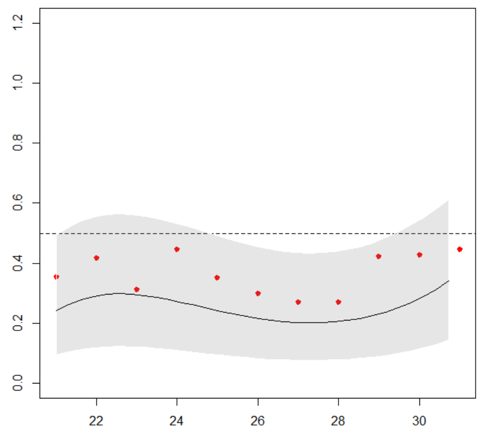


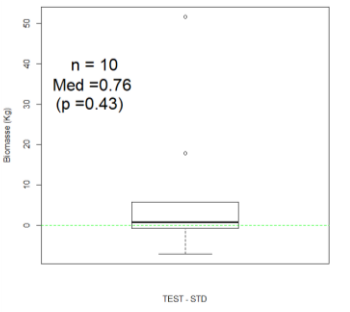
Figure 66: Probability of retention in the selective trawl according to size; the straight horizontal line shows the probability of catching 50% of the individuals

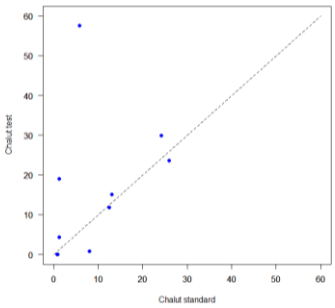
Horse mackerel: *the aim is to reduce the quantities that are landed and caught*

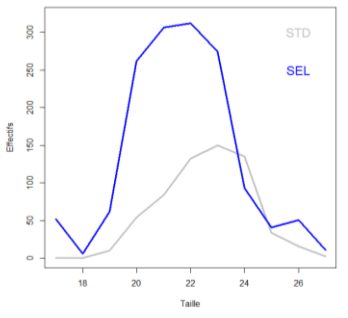
The data for horse mackerel were analysed separately for the month of September because this fishing trip shows a different trend to the other fishing trips (cf. section 3.2.3 of the BREZGLOW results).

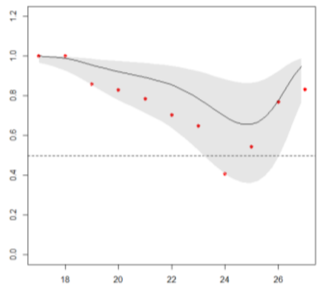
For the December and August fishing trips the results of the tests do not show any statistically significant difference between the amounts of biomass in the test trawl and the standard trawl. When one looks at the size distribution for each system, there are more individuals of up to size 24 in the test trawl. There is significant variability from size 24 upwards, with data that is insufficient for drawing conclusions.

Analysis of biomass amounts (catches kg)	Analyse of sizes



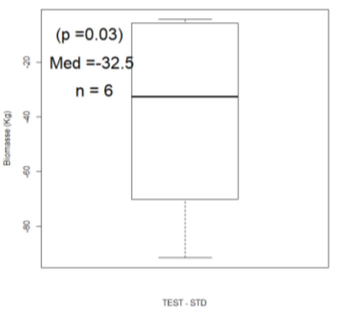


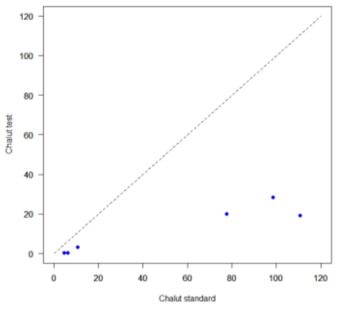


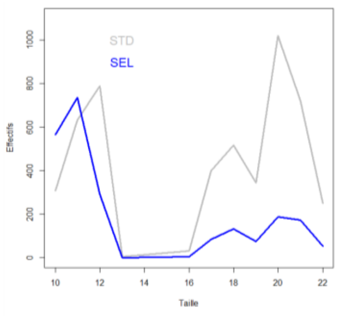


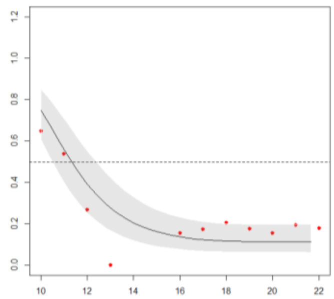
For the trial carried out in September (6 pairs sampled), smaller quantities were caught in the test trawl than in the standard trawl (p-value < 0.05). The same applies to the size distribution of the catches for each type of trawl. The test trawl would let more individuals escape than the standard trawl for sizes above 16 cm. However, this only relates to 6 pairs, 3 of which are under 20 kilos.

Analysis of biomass amounts (catches kg)	Analyse of sizes





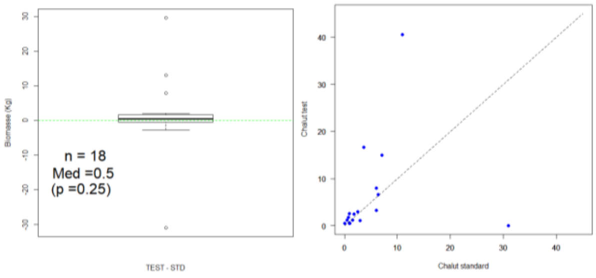




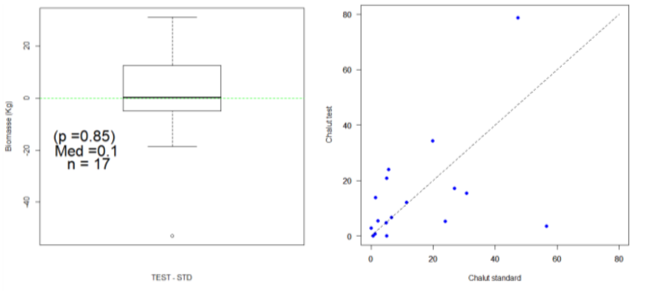
Yellow gurnard, mackerel, red mullet and pouting, *the aim is to* *maintain the quantities that are landed, and for plaice the aim is to maintain the quantities that are landed and to reduce the quantities that are discarded.*

For yellow gurnard and mackerel, the results of the tests do not show any statistically significant difference between the amounts of biomass in the test trawl and the standard trawl.

YELLOW GURNARD (landings kg)

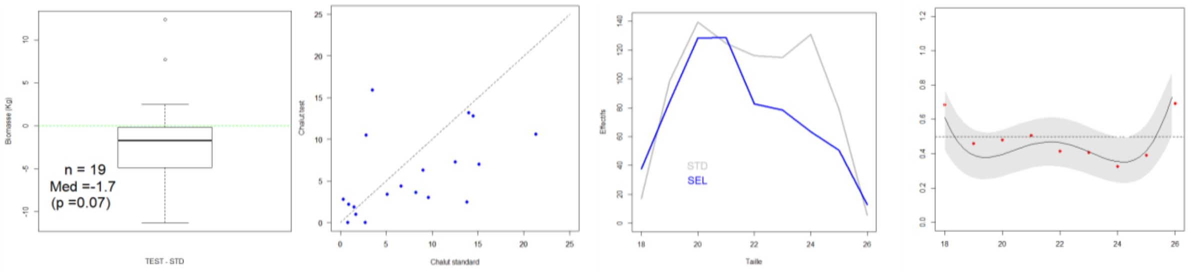


MACKEREL (landings kg)



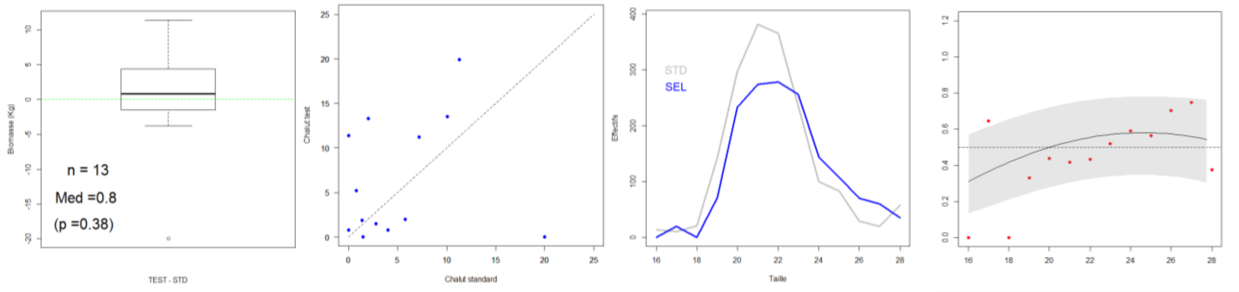
For red mullet there is a significant difference between the test trawl and the standard trawl, with lower amounts of landings in the test trawl. When one looks at the size distribution for the systems, there are more individuals that are longer than 21 cm in the standard trawl, but the GLMM confidence interval does not allow any conclusion to be drawn regarding the significance of this difference (high variability of the data).

RED MULLET (landings - kg)



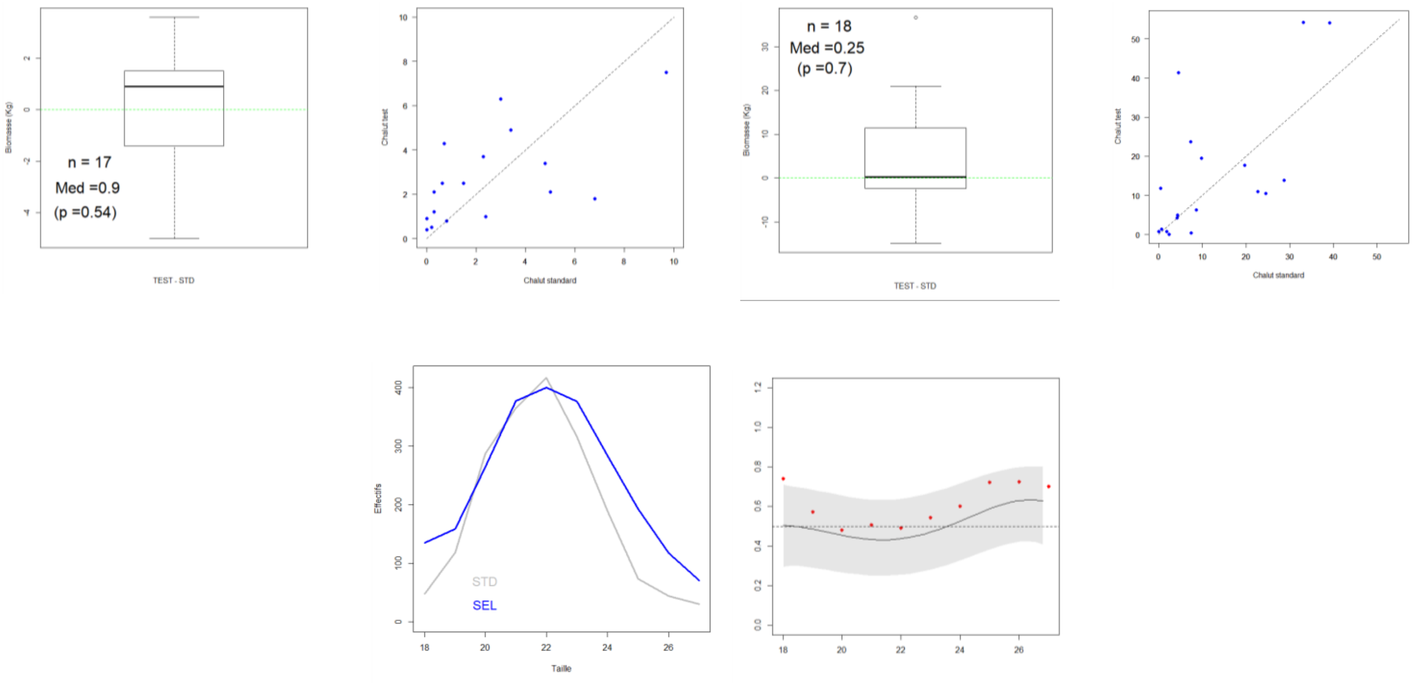
For pouting, the test result does not show any statistically significant difference between the amounts of biomass in the test trawl and the standard trawl. When one looks at the size distribution for the systems, there are more individuals of sizes 18 cm to 24 cm in the standard trawl, but the GLMM confidence interval does not allow any conclusion to be drawn regarding the significance of this difference (high variability of the data).

POUTING (landings kg)



For plaice, the test results do not show any statistically significant difference between the amounts of biomass in the test trawl and the standard trawl. When one looks at the size distribution for the systems, there are more individuals longer than 23 cm in the test trawl, but the GLMM confidence interval does not allow any conclusion to be drawn regarding the significance of this difference (high variability of the data).

PLAICE (landings kg)	PLAICE (discards kg)

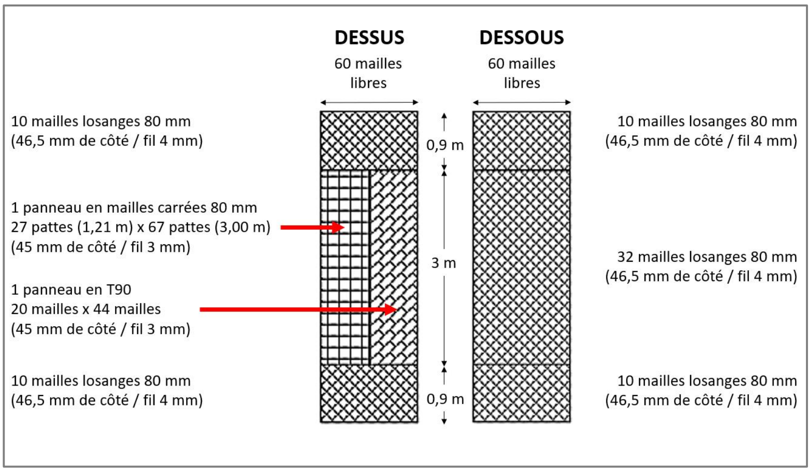


3.3. SMP/T90 TRIAL

3.3.1 Test protocol

Projects carried out over recent years in the English Channel and around western Brittany (Lavialle, 2018 and Lamothe, 2017) have shown the benefit of meshes that are rotated through 90° (T90) in relation to the escape of undersized codfish, and in particular whiting. This system has not been used in this project owing to regulatory issues (cf. section 1.3 of the methodology); however, it has been decided to make use of the equipment developed for the project (covering bags separated into two sections) in order to compare its efficiency with that of the SMP so that the best possible combination of so-called “selective” systems (SMP or T90) and lighting systems can be found. An experimental fishing trip with the aim of comparing these systems was therefore organised in August 2020.

The system used for gathering the data is virtually identical to the one used for the preliminary fishing trip in May 2019. The only change made relates to the phosphorescent T90 which has been replaced by an SMP (Fig. 67). The system therefore comprised a 3 metre panel cut in half on the back of the trawl, with one section fitted with T90 netting and one section fitted with square mesh. Each section is covered by a fine-mesh bag which enables escaped fish to be caught so that they can be sampled.



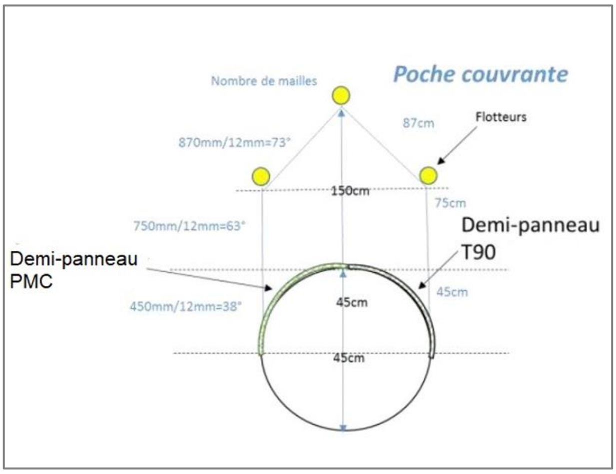


Figure 67: Diagram of covering bags on a codend fitted with an SMP and a T90 panel

The sampling protocol is similar to the procedure for monitoring the catches on board fishing vessels which is undertaken by Ifremer (OBSMER). For each haul the “catches” in the bags were sampled, and full sampling was carried out on 3 hauls which also included the discards and the landings that were taken from the codend. There was too much work (large tonnages) involved in sampling each bag to enable the sampling of the codend for every haul. It was therefore decided to maximise the number of hauls, but to sample the codend only once every 24 hours.

3.3.2 Results

Description of the sample

The experimental fishing trip was organised from the 17th to the 21st of August 2020 in order to compare the efficiency of an SMP and T90. During this fishing trip, 14 hauls were sampled, and 3 of these were fully sampled (codend + bags). Of these 14 hauls, one haul was withdrawn from the analysis due to an abnormally low tonnage in one of the bags (bag fitted with T90).

The hauls during this fishing trip were carried out in IVc in the zones normally frequented by this ship and by the OP FROM Nord artisanal trawlers (Fig. 68).

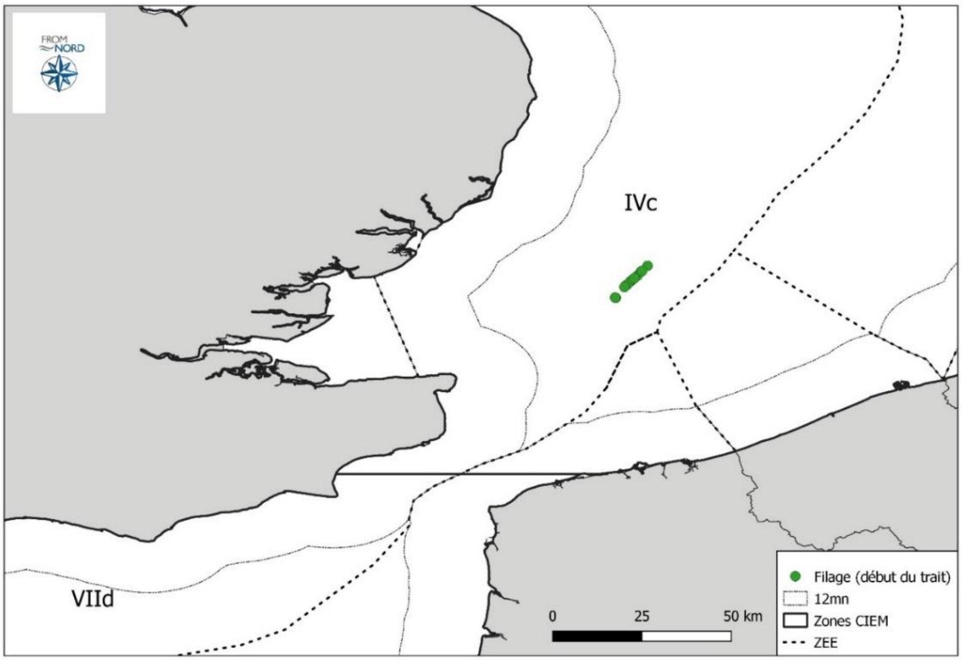
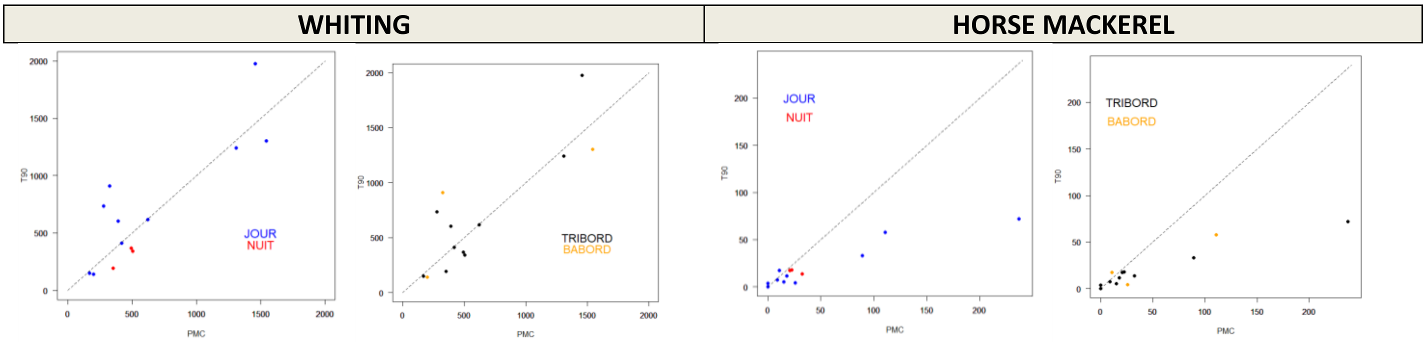


Figure 68: Map showing zones where nets were cast

Two variables may have had an impact on the selectivity of the systems: the "diurnal" variable and the "side" variable. A graphical analysis was carried out in order to check whether these variables affected the efficiency of these systems for whiting and horse mackerel.



The graphs above do not show <u>any difference in tonnage according to these variables</u>. A differentiated analysis according to these variables has not therefore been necessary.

Overall analysis of the catches

The tonnages in the codend for the three trawls that were fully sampled vary from 143 kg to 223.1 kg for the landings, and from 136.64 kg to 237.28 kg for the discards.

The tonnages in the bags vary from 232 kg to 1,669.8 kg for the SMP and from 146.7 kg to 1,975.7 kg for T90, with an average of 669.6 kg in the bag fitted with the SMP and 716.4 kg in the bag fitted with T90.

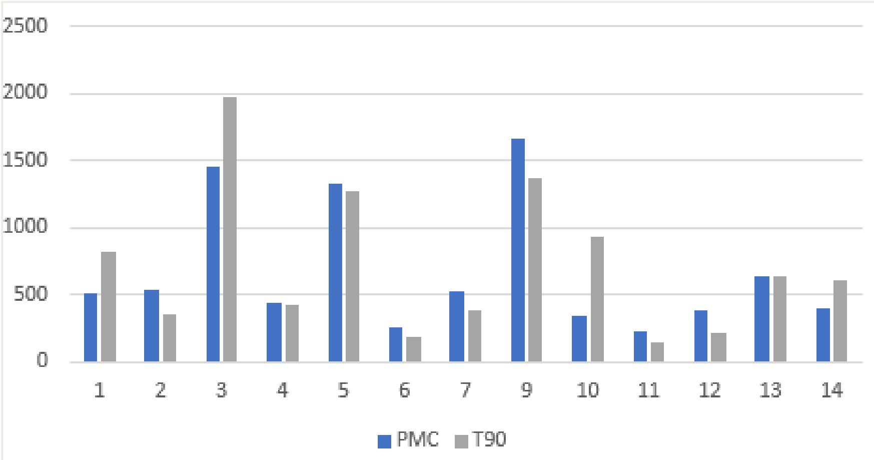


Figure 69: Tonnages per haul – bag fitted with a T90 shown in grey, and bag fitted with an SMP shown in blue

The result of the test below for comparing the medians produces a p-value > 0.05, which indicates that there is no statistically significant difference between the amounts of biomass in the two systems for all the species as a whole (Fig. 70).

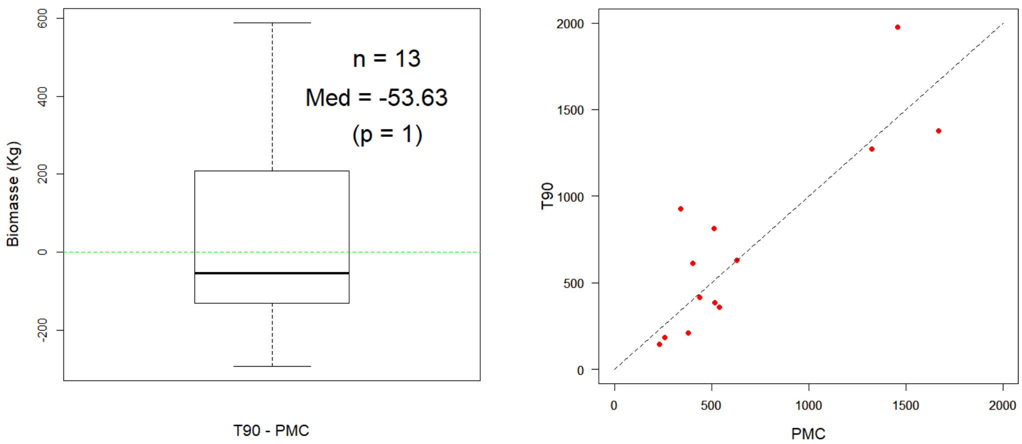


Figure 70: Biomass amounts per haul in the bags and bisecting line showing the precise equality of biomass amounts in the two bags (graph on right-hand side), T90 on y-axis and SMP on x-axis. Result of the Mann Whitney non-parametric test

Analysis by species

Among the total "escapes" that were found in the two bags, 14 species were identified (Fig. 71). Whiting and horse mackerel are the only species which are present in the bags in sizeable quantities which permit an in-depth analysis.

Espèces	Tonnages (Kg)
Merlan	17 059,20
Chinchard d'Europe	854,30
Petite roussette	32,81
Limande	31,03
Rouget barbet	14,20
Maquereau commun	5,85
Petit tacaud	4,51
Grondin rouge	4,25
Hareng de l'Atlantique	3,47
Tacaud commun	3,47
Limande sole	3,45
Plie d'Europe	1,21
Grondin perlon	0,73
Sardine	0,58

Figure 71: Tonnages per species in the SMP +T90 bags

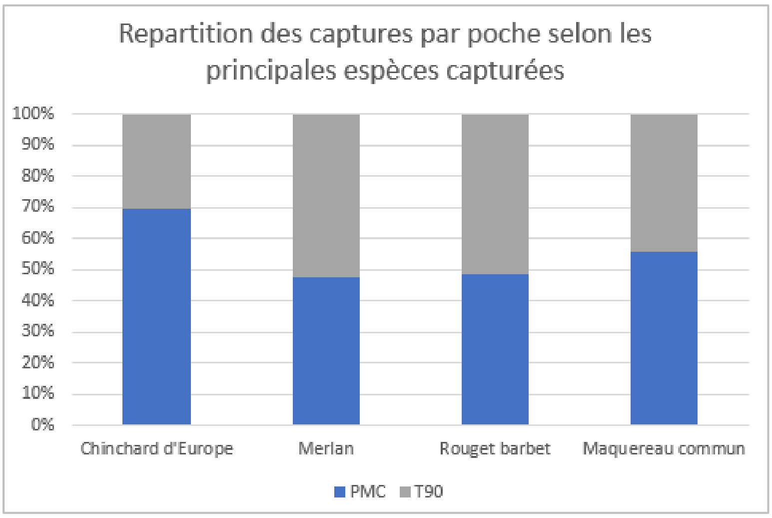


Figure 72: Distribution of catches in the bags (SMP +T90) per bag and per species

Catches of horse mackerel are greater in the bag fitted with the SMP, in contrast to whiting (Fig. 72).

A. Whiting

For whiting the result of the test comparing median values that is shown below reveals a p-value > 0.05, which indicates that the difference in tonnages between the two systems is not statistically significant.

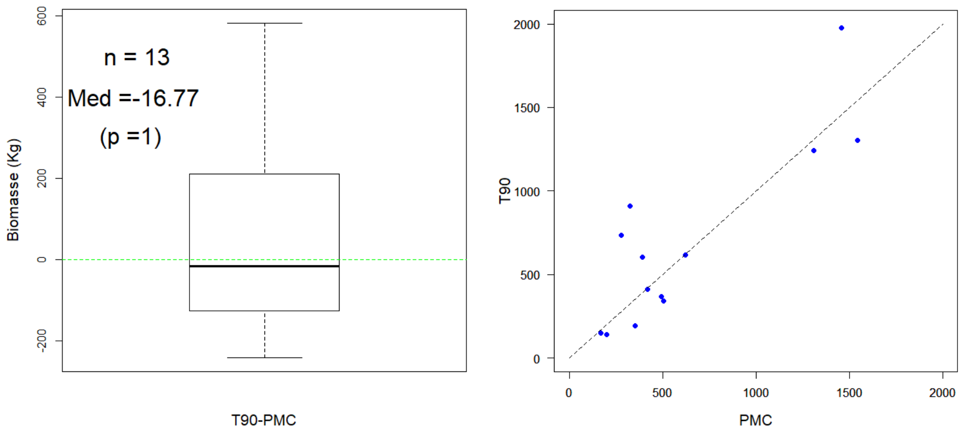
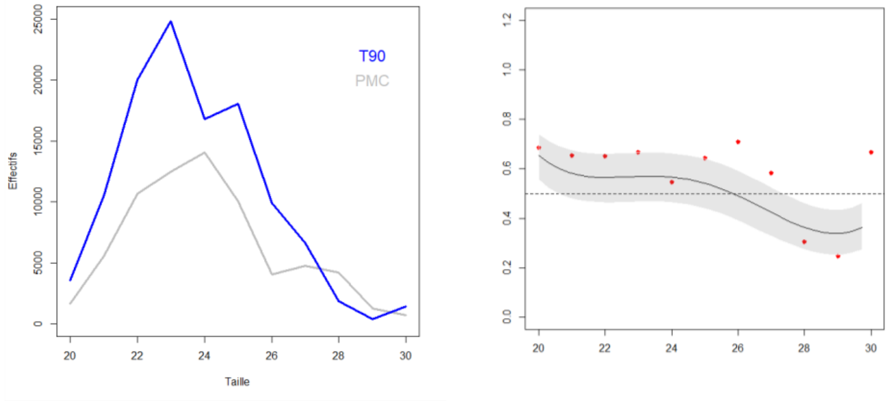


Figure 73: Biomass amounts per haul in the bags and bisecting line showing the precise equality of biomass amounts in the two bags (graph on right-hand side), T90 on y-axis and SMP on x-axis. Result of the Mann Whitney non-parametric test

However, the graph below showing the size distribution of whiting in the bags highlights the fact that T90 provides greater selectivity for sizes ranging from 18 cm to 27 cm, i.e. the sizes that are below the MCRS.



B. Horse mackerel

For horse mackerel, the result of the test comparing median values that is shown below reveals a p-value < 0.05, which indicates that <u>the difference in tonnages between the two systems is statistically significant (Fig. 74).</u>

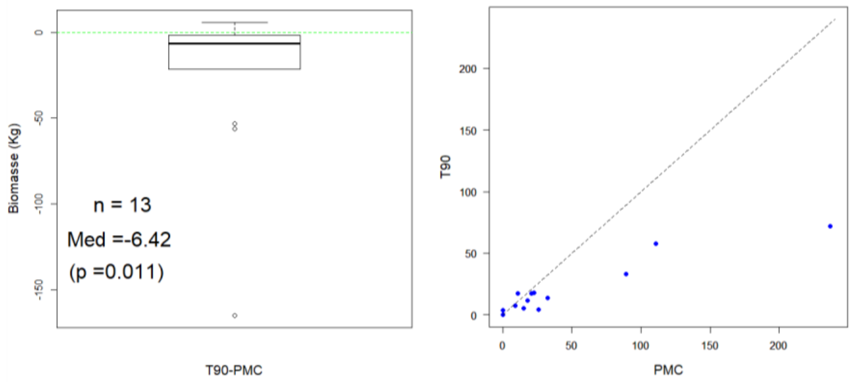
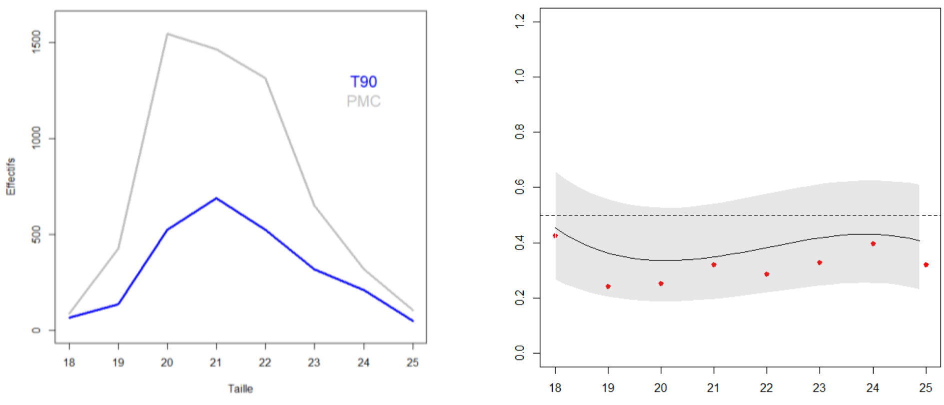


Figure 74: Biomass amounts per haul in the bags and bisecting line showing the precise equality of biomass amounts in the two bags (graph on right-hand side), T90 on y-axis and SMP on x-axis. Result of the Mann Whitney non-parametric test

The graph below showing the size distribution for horse mackerel highlights the fact that the SMP provides greater selectivity for sizes ranging from 18 cm to 25 cm.



4. Discussion

The SELUX project enabled 2 lighting systems to be tested: Brezglow (one configuration) and PISCES (2 configurations). The table below provides a summary of the results that have so far been presented.

<table>
<tr><th>System</th><th>Configuration</th><th>Impact on whiting and horse mackerel</th><th>Impact on species which have a high added value</th></tr>
<tr><td rowspan="2">PISCES</td><td>- 4 PISCES
- Under the SMP, on the belly side of the trawl
- All separated by a distance of 6 meshes
- Emitting a constant green light</td><td>Whiting: No adequate data
Horse mackerel: Increase in the amounts caught</td><td rowspan="2">Landings of red mullet and mackerel are not affected by the presence of light</td></tr>
<tr><td>- 5 PISCES
- Under the SMP, on the belly side of the trawl
- All separated by a distance of 8 meshes
- Emitting a flashing green light</td><td>Whiting: Reduction of catches of all sizes in the March experimental fishing trip.
Horse mackerel: No significant change</td></tr>
<tr><td>BREZGLOW</td><td>- 3 mm luminescent filaments
- area measuring 300 mm/80 mm
- square mesh
- Under the SMP, on the belly side of the trawl</td><td>Whiting: Reduction of catches of all sizes in the August experimental fishing trip (high variability of the data).
Horse mackerel: No significant change</td><td>Landings of yellow gurnard, red mullet and mackerel are not affected by the presence of the light</td></tr>
</table>

The aim of these tests was to evaluate whether the configuration that was used enabled catches of all sizes of horse mackerel as well as catches of whiting smaller than the MCRS to be reduced while retaining species which are commercially valuable.

Regarding the PISCES, the analysis of the data was only carried out for 7 out of the 10 species involved in the project. The catches of cuttlefish, herring and yellow gurnard were too small and too variable in these experimental fishing trips to allow the impact of this system on the amounts that were landed to be evaluated.

The addition of PISCES <u>enabled the selectivity of the SMP to be improved for whiting only in the fishing trip in March</u>. In fact, the fishing trip in October produced very few catches of this species, whereas the fishing trips in June and July did not produce any significant differences in the amounts caught. For the hauls in March, the amounts of biomass landed and discarded are lower when PISCES are used. In fact, the test trawl shows a 42% reduction in landings and a 37% reduction in the discards of whiting. Light improves the selectivity of the SMP across all sizes, but this causes a <u>significant commercial loss</u>. Several factors could explain this difference. The season and the geographical zone were different for each of these 3 fishing trips, which potentially led to variations in ambient light levels, depths and muddiness of the water. We assume that these three elements may strongly influence the efficiency of the lighting systems. It would therefore be interesting to gather more data in the spring in order to check these results.

As for horse mackerel, the configurations that were tested do not manage to produce any reduction in catches. No difference can be seen either in the night-time or the daytime catches during the fishing trips in which PISCES was used in “flashing” mode. On the other hand, for the fishing trip in October (PISCES in “non-flashing” mode), an increase in catches of horse mackerel was noted during night-time hauls – when the efficiency of the PISCES devices is probably augmented. The PISCES should not therefore be used in constant mode in this configuration. If one wishes to obtain the same effect of light on horse mackerel and whiting in order to facilitate escapes, it will be necessary to give preference to the flashing mode.

As regards squid, only the October fishing trip produced significant catches (greater than 2 kg), i.e. just 7 pairs. For this fishing trip the addition of PISCES does not lead to any reduction in the amounts that are landed. However, it appears to be important to carry out other tests in relation to this species because squid is highly responsive to light according to the scientific literature. What's more, it's also a very important species for this fleet. It should be ensured that the presence of light does not have any impact on landings of this species.

Finally, there is no significant observable difference between biomass amounts for red mullet, mackerel, pouting and plaice between the two trawls. The presence of PISCES does not therefore have any impact on landings of these species.

As regards Brezglow, the analysis of the data was only carried out for 7 out of the 10 species involved in the project. The catches of cuttlefish, herring and squid were too small and too variable in these experimental fishing trips to enable the impact of BREZGLOW on the amounts of them that were landed to be evaluated.

For whiting the addition of BREZGLOW to the trawl only managed to produce an improvement in selectivity during the August fishing trip. The discards during this fishing trip were significantly lower when Brezglow was used ($p\text{-value} < 0.05$) for all sizes in the standard trawl. However, this difference in selectivity is only validated by the GLMM for sizes between 25 cm and 29 cm. It would be interesting to gather more data relating to this season in order to check these results because the size analysis using GLMM highlights considerable variability of the data. Light intensity could be improved by increasing the number of the phosphorescent strands in the webbing that the net is made of.

For horse mackerel, two diametrically opposed trends are apparent. For the trials in December and August larger quantities of individuals under 24 cm in length are found in the trawl which is fitted with Brezglow. The lit trawl is therefore less selective than the standard trawl for these sizes. There is significant variability from size 24 upwards, with data that is insufficient for drawing conclusions. For the trial in September the opposite trend can be seen. The lit trawl is more selective than the standard trawl from size 13 upwards. However, this relates to only 6 pairs, so it is difficult to draw conclusions based on such scant data. It would be interesting to gather more data for this species because it is currently difficult to draw any conclusions since the results differ so much between the various fishing trips.

Finally, for yellow gurnard, mackerel, red mullet, pouting and plaice there is no significant difference between the two trawls. The presence of Brezglow does not therefore have any impact on landings of these species.

The aim of the trial carried out using T90 and the SMP was to compare the efficiency of these two selective systems in order to specify which is the more appropriate for reducing the by-catches in this fishery. This fishing trip only enabled data on horse mackerel and whiting to be collected. Therefore it was only possible to compare the efficiency of these systems in relation to these species.

For whiting the difference in the amounts of biomass in the two bags is not statistically significant. However, it can be seen that there are more individuals of under 27 cm in length in the bag that is fitted with T90, but fewer individuals of over 27 cm in length. The variability of the data does not allow any conclusions to be reached regarding sizes 18 cm to 27 cm, but <u>for sizes greater than 27 cm the GLMM clearly shows that there are more escapes of whiting when the SMP is used</u>. These findings are in keeping with the results of other projects relating to T90, such as the Rejemcelec project. It would be interesting to carry out further tests in zones where larger amounts of whiting larger than 27 cm are present in order to back up these results. For horse mackerel the opposite can be seen. The amounts of biomass are greater in the bag that is fitted with the SMP. <u>The SMP seems to be more selective than T90 for all sizes of horse mackerel</u>. However, the GLMM confidence interval does not allow any conclusion to be drawn regarding the significance of this difference (high level of data variability). The catches made during this fishing trip were principally made up of whiting, therefore it would be interesting to continue the tests in a zone where there are more horse mackerel.

These initial tests of combining light with a square mesh panel are very encouraging. It would be interesting to continue these experiments in order to pin down the effects of environmental factors. In fact the results vary greatly depending on the zone/season and light levels (day/night). Factors such as muddiness, depth, ambient light levels (seasons and day/night) probably have an influence on the efficiency of the lighting systems. In the next experiments the parameters of “ambient light level” and “muddiness” should be added to the data that are collected and the focus should be on specific zones/seasons which present the most problems in terms of discards of whiting and horse mackerel. That would enable us to have more consistent data and to support the results of this project.

Various adjustments could also be made in order to reinforce certain trends that have been observed during these fishing trips:

In relation to whiting, the addition of lighting systems enabled discards to be reduced in two experimental fishing trips. However, landings were also impacted. The effect of the SMP therefore seems to be made too efficient in conjunction with the use of light. It would therefore be interesting to test the combination of T90 with light, which could be more appropriate for this species. Indeed, various studies underline the efficiency of T90 for selectivity in relation to whiting, and it is considered to be more appropriate for selection in line with the MCRS, as is confirmed by the results of the SMP/T90 comparison carried out within this project. For the time being fishermen cannot replace the 80 mm meshwork SMP that is used in the North Sea by T90. However, more and more projects confirm the efficiency of T90 for improving selectivity in relation to these species. These results may therefore allow this system to be incorporated into the regulations.

As regards the position of the systems on the trawl, adjustments can also be made. The position of the square mesh panel on the trawl is presumably conducive to the escape of whiting because according to previous studies codfish are more inclined to escape via the upper part of the trawl. The position of the lights on the belly of the trawl should also favour escapes via the SMP for this species because it tends to shun light. In order to reinforce this movement it may be useful to install lighting systems higher up the SMP in order to encourage these species to climb up towards the panel earlier, thereby maximising their chances of escaping.

Light intensity is also adjustable and it could reinforce the efficiency of the systems. For the PISCES systems the light intensity is already strong, but it could easily be increased simply by adjusting the remote control setting. For Brezglow, light intensity could be improved by increasing the number of the phosphorescent strands in the meshwork of the net. The surface covered by the light (number of PISCES and size of the Brezglow patch) could also be a factor for adjusting the light intensity.

There are numerous possible adjustments. For instance, different configurations could be considered which are adapted to the seasons, target zones, and species.

Finally, the practicality of the systems was also a subject of discussion throughout the project. According to the fishermen, certain aspects of the systems could be improved. In relation to PISCES, there has been a great deal of communication between the SafetyNet start-up and the fishermen about improving the robustness and practicality of the systems. Following these discussions SafetyNet is currently devising a pouch for facilitating the installation of the systems on the trawl as well as a more compact charger. There are fewer opportunities for adjusting Brezglow, but the system consequently seems to be less onerous for professionals to use because all that has to be done is to insert the Brezglow patch into the trawl that is normally used. SafetyNet and Le Drezen have been able to concentrate fully on the project by forming a partnership. All the technical resources, discussions and experimental fishing trips will also enable them to refine their systems so as to make them even more operationally effective and even more appropriate to the needs of professional fishermen.

Conclusions and outlook

The SELUX project was devised with the aim of testing the combining of known selective systems (Square Mesh Panel and T90 mesh) with innovative lighting systems that can improve the selectivity of trawlers in the eastern English Channel and the North Sea. The aim is to reduce catches of horse mackerel of all sizes, and catches of whiting that are under 27 cm in length, while retaining species which are commercially valuable, such as red mullet and squid.

Two lighting systems were able to be tested in the course of the project: Brezglow which was developed by the Le Drezen company, and PISCES which was developed by the start-up, SafetyNet. Two preliminary fishing trips (one fishing trip per system) enabled various configurations to be tested. T90 was initially used due to its effectiveness in facilitating the escape of undersized codfish, and due to its shape being well suited to the morphology of whiting in particular. However, for the experimental fishing trips it was decided to use the SMP with 80 mm meshwork which is mandatory for use in the North Sea in order to work with a configuration which complies with the current regulations. Cameras that were deployed with PISCES and covering bags that were used with Brezglow enabled the behaviour of the species in response to light to be observed, and the best configuration for testing in real fishing conditions to be specified. The configurations used are as follows: Brezglow was tested in just one configuration (Brezglow mesh on the belly of the trawl underneath the SMP) on 3 fishing trips. The Pisces systems were tested in two configurations over 4 fishing trips (configuration 1 during 1 fishing trip: 4 non-flashing PISCES on the belly part of the trawl underneath the SMP / configuration 2 during 3 fishing trips: 5 flashing PISCES on the belly part of the trawl underneath the square mesh panel).

All these fishing trips enabled valuable knowledge to be obtained concerning the behaviour of certain species in response to light. The behaviour of whiting, mackerel and small pelagic species was able to be observed during two preliminary fishing trips thanks to the use of cameras and covering bags. The results show that whiting and mackerel tend to behave in a light-averse manner. By contrast, small pelagic species (herring, sprats) are attracted by the light. In fact in the videos of the fishing trip that was organised for using PISCES, the images show larger escapes of these species from the side where lights are fitted. Horse mackerel is also attracted by constant light, however this behaviour seems to be reversed when the light is flashing. These observations are crucial for enabling the lighting systems to be used in an appropriate and efficient way within professional fishing operations.

As regards the efficiency of these configurations in reducing unwanted catches of whiting and horse mackerel, the results are mixed. The lighting systems enabled catches of whiting to be reduced in the case of each system, but only on one fishing trip. What's more, this applies to all the sizes – which leads to economic losses. As for horse mackerel, the configurations that were tested do not enable catches to be reduced. The results are however encouraging for the species caught by these ships which have a high added value. Landings of them are not affected by the presence of light on the trawl.

The results of the SELUX project are encouraging. The knowledge that has been acquired over the course of these two years will be able to be put to good use in future projects. There are many different ways in which the light could be adjusted in relation to selective systems. Other configurations could therefore be tested following this project.

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List of acronyms

ICES: International Council for the Exploration of the Sea

SMC: square-mesh cylinder

CRPMEM: Comité Régional des Pêches Maritimes et des Elevages Marins [Regional Committee for Maritime Fisheries and Aquaculture]

FAO: Food and Agriculture Organization

LO: Landing Obligation

OP: Organisation de producteurs [Producers' Organisation]

GLMM: Generalized Linear Mixed Model

CFP: Common Fisheries Policy

SMP: Square Mesh Panel

MSY: Maximum Sustainable Yield

SIH: Système d'informations halieutiques [Fisheries research information system]

TAC: Total Allowable Catch

MCRS: Minimum Conservation Reference Size

EEZ: Exclusive Economic Zone

Annexes

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A. Selectivity projects

Sorting grids

Description	Project	Zone	Selectivity results	Impacts on turnover	Details
Grid for whiting and plaice Bars at 25 mm intervals	SAUPLIMOR (Mortreux et *al.*, 2001)	Strait of Dover	Whiting: Significant escapes of juveniles (-53%) Plaice: : Significant escapes of juveniles (49%)	Commercial loss of whiting (38% by weight)	
Grid 1 Bars spaced at 20 mm intervals, angle 45°-50° + mandatory SMP in IVc (3x1 m, 80 mm meshwork) Grid 2 Bars spaced at 23 mm intervals, angle 30°-35° + mandatory SMP in IVc (3x1 m, 80 mm meshwork)	SELECMER (Leonardi et *al.*, 2009)	English Channel & North Sea	Bar spacing 23 mm: - **Whiting:** Good level of escapes (-52% under 27 cm in size) - **Horse mackerel:** Good level of escapes Two grids: 16% - 30% reduction in discards of whiting < 22 cm	Bar spacing 23 mm: Commercial losses of whiting (-38% by weight) and mackerel (-55% by weight). Two grids: No immediate commercial losses (differing info. in REJEMSELEC)	Sealing the grid + selectivity to be improved for 23-26 cm whiting
Grid divided into 2: lower part selective for cod, and upper part selective for whiting + SMP	SELECCAB (Viera et *al.*, 2010)	English Channel North Sea	High level of escapes of whiting of commercially useful sizes	Significant commercial losses	The addition of a square mesh window in front of the grid for whiting prevents the grid being blocked by 27-30 cm whiting, something which was seen during the SELECMER study
2 grids: 1 in the lengthener for large cod + 1 grid used in the SELECMER study + SMP for escapes of small whiting					

SMP (square-mesh panel)

Description	Project	Zone	Selectivity results	Impacts on turnover	Details
2 versions: SMP on the back of the lengthener (120 mm meshwork, length 3 m) at 6 m and 10.50 m from the codline	SELECMER (Leonardi et al., 2009)	Eastern English Channel & North Sea	- **Mackerel:** Significant escapes facilitated by the window's position on the rear of the lengthener - **Whiting:** SMP of 120 mm meshwork useful for reducing discards of undersized whiting. However, there is a significant level of escapes which varies between 13% and 40%, and whiting of all sizes from 22 cm to 35 cm escape via the system.	Commercial losses of whiting between 26% and 28% as well as commercial losses of mackerel	
2 versions: SMP on the back of the throat (80 mm meshwork, 2 m x 3 m) either 18.30 m or 21.30 m (front of the throat) from the codline + mandatory SMP in IVc	SELECMER (Leonardi et *al*., 2009)	English Channel & North Sea	**Whiting:** Not able to reduce catches of undersized fish (the authors presume that the vertical opening in the trawl may be too large to allow the fish to reach the window)		
SMP (33 m²) 90 mm meshwork in the throat (4-sided trawl)	REJEMSELEC (Lavialle et *al*., 2018)	Demersal trawl made of 80 mm meshwork Western English Channel 7.e & 7.h	- **Whiting:** Significant increase in selectivity up to 32 cm, and on average up to 34 cm - **Red mullet:** No significant difference in catches irrespective of the size (15-40 cm) - **Mackerel:** Moderate reduction	Negligible commercial impact (if any) Possible reduction of size 40 whiting, but low average price and insignificant quantities for this size	Very few undersized whiting (< 27 cm) were caught in the two trawls
SMP of 80 mm meshwork in throat/lengthener (4-sided trawl)	REJEMSELEC (Lavialle et *al*., 2018)	Demersal trawl made of 100 mm meshwork Western English Channel 7.e & 7.h	Selective system is too efficient - **Whiting:** Reduction T40 (-71%), T30 (-39%) - **Red mullet:** Reduction in landings (-45%) - **Mackerel:** Reduction in discards (-78%)	Significant commercial impact, 6% of the industry's annual turnover (mainly due to whiting, haddock and red mullet)	Too few undersized whiting caught to be able to measure the differences in catches due to the selective system
SMP of 80 mm meshwork SMP over rear upper half of the throat	REJEMSELEC (Lavialle et *al*., 2018)	Demersal trawl made of 80 mm meshwork Western English Channel 7.e & 7.h	- **Whiting:** Reduction in undersized whiting (-35%), reduction up to 30 cm on average, but significant only up to 23 cm - **Red mullet**: no selectivity - **Horse mackerel:** significant reduction in catches of small horse mackerel up to 16 cm	No data available	

SMC (square-mesh cylinder)

Description	Project	Zone	Selectivity results	Impacts on turnover	Details
SMC 80 mm meshwork 2 m long In the lengthener Ship + 18 m	SELECFISH (Weiller et *al*., 2014)	Eastern English Channel & North Sea	(Eastern English Channel) - **Mackerel**: 11% reduction in catches - **Whiting:** 34% reduction in discards (North Sea) - **Mackerel:** Significant escapes up to size 32 cm - **Whiting**: no reduction in discards except for sizes < 22 cm	(Eastern English Channel) Overall commercial losses limited to - 8% of T/O (North Sea) Overall commercial losses of 20% of T/O	
SMC 80 mm meshwork - 2 m long - In the lengthener Ship - 18 m	SELECFISH (Weiller et *al*., 2014)	Eastern English Channel & North Sea	Well suited for **- 18 m**: average 39% reduction in the quantity that is discarded	Slight impact on the quantity of commercially useful catches.	
SMC 80 mm meshwork 1 m long	SELECFISH (Weiller et *al*., 2014)	North Sea	Similar results as for the version which is 2 m long - average 25% reduction in the quantity that is discarded	12% reduction in the quantity which is sold	Conditions with sizeable catches of whiting
SMC 115 mm meshwork 2 m long In the lengthener Ship + 18 m	SELECFISH (Weiller et *al*., 2014)	Eastern English Channel & North Sea	Average 37% reduction in the quantity of discards - **Mackerel:** Not advised (54%) - **Flatfish:** Potentially useful effect - **Whiting:** Appropriate system because it increases catches of commercial sizes and provides 35% reduction in quantity discarded	22% reduction in the quantity which is sold, i.e. a 33% reduction in T/O Commercial losses of whiting and mackerel (47% and 49% by weight)	Low number of trawls sampled
SMC 100 mm meshwork 2 m long + mandatory SMP in IVc (3x1 m, 80 mm meshwork)	SELECFISH (Weiller et *al*., 2014)	Eastern English Channel & North Sea	Average 36% reduction in the quantity of discards - Not recommended for fishing which targets whiting and mackerel	40% reduction in the quantity which is sold, i.e. a 33% reduction in T/O	

SMC 80 mm meshwork 2 m long + Selecmer grid	SELECFISH (Weiller et *al*., 2014)	Eastern English Channel	Average 8% reduction in the quantity of discards Positive effect on mackerel (-55% discards) and on whiting (-34% discards) (but no greater than an 80 mm mesh SMC used by itself)	**+ 18 m:** Reduces quantities that are discarded without reducing the marketable proportion, but relatively slight increase in selectivity + inserting the grid is complicated Too selective for ships under 18 m long	
SMC 100 mm meshwork 3 m long In the lengthener, 12.5 m from the codline + SMP of 100 mm and 120 mm meshwork	CELSELEC (Lamothe et *al*., 2017)	Celtic Sea	Positive effect on the rates of escapes when the meshwork is increased from 100 to 120 mm: -20% discards with a selective trawl SMC (100 mm) + SMP (100 mm), and -50% SMC (100 mm) + SMP (120 mm)	No commercial losses of whiting on this boat Commercial losses of langoustines	Small number of individuals below the Minimum Conservation Reference Size. Difficult to reliably quantify this effect in relation to small individuals
SMC composed of 2 pieces of square mesh netting, 86 mm and 89 mm meshwork, fitted along the headline	EODE (Balazuc et *al*.,2016)	Eastern English Channel & North Sea	- **Red mullet:** Escapes are through the codend rather than through the square meshwork of the cylinder - **Whiting and horse mackerel**: main unwanted catches are within quotas. The system's efficiency is reduced in relation to horse mackerel when the ship is sailing against the current. When sailing against the current, the cylinder apparently isn't taut and small individuals no longer escape	With the exception of red mullet, commercial losses are limited. Overall a generally positive finding because losses of red mullet are due to over-large size of meshwork	Qualitative feedback

T90 mesh

Description	Project	Zone	Selectivity results	Impacts on turnover	Details
Bottom made of 88 mm T90 meshwork	EODE (Balazuc et *al.*,2016)	Eastern English Channel & North Sea	**Whiting:** few catches of 27 cm to 30 cm fish (the main sizes which are usually caught)		Mixed results which don't allow any certain conclusions to be drawn
Lengthener and codline made of 100 mm T90 meshwork	CELSELEC (Lamothe et *al.*, 2017)	Celtic Sea (western Brittany)	Roughly 40% to 50% reduction of discards depending on the ships, and in particular for haddock and whiting	Commercial losses potentially serious for squid, crustaceans, red mullet and ling Commercial losses of 20% to 30% for whiting due to the 100 mm meshwork size	No conclusion could be drawn regarding the discards of whiting and cod given the low levels of these species in the fishing zones – results need to be validated based on greater numbers of fish (shoal of small pelagic species)
Lengthener and codline made of 100 mm T90 meshwork + 100 mm and 120 mm SMP meshwork	CELSELEC (Lamothe et *al.*, 2017)	Celtic Sea	**Whiting:** Discards were almost completely eliminated Efficient in reducing catches of small pelagic species that are not landed (mackerel or horse mackerel)	Commercial losses of roughly 20% to 30% – mainly of fish whose size is close to the Minimum Conservation Reference Size Commercial losses of whiting and small-spotted catshark	
T90 SMP on the upper side of the throat and of the lengthener (2.3 metres on the end of the throat + 3.2 metres on the start of the lengthener) (80 mm meshwork)	REJEMSELEC (Lavialle et *al.*, 2018)	Demersal trawl made of 80 mm meshwork - western English Channel 7.e & 7.h	- **Whiting:** Reduction in undersized fish (-73%), T40 (-44%), sizes 30 and 20 (slight reduction) - **Mackerel:** Reduction in discards (-85%) - **Horse mackerel:** Reduction in discards (-48%), selective for all sizes up to 18 cm	No significant reduction in landings of squid, cuttlefish, gurnard, pouting, monkfish and hake Slight commercial losses	The 4 sides facilitate the opening of the mesh

Other systems

Description	Project	Zone	Selectivity results	Impacts on turnover
EODE selective trawl with two codends	EODE (Balazuc et *al.*,2016)	Eastern English Channel North Sea	The results are not conclusive	
Conventional demersal trawl of 90 mm C10 meshwork	EODE (Balazuc et *al.*,2016)	Eastern English Channel North Sea	Meshwork not appropriate for the squid and mackerel season (all the catches are likely to pass through the 90 mm meshwork) System is appropriate for the fishing season during which whiting is targeted in the North Sea. Gains in selectivity not very great.	Commercial catches of whiting between 27 cm and 30 cm in size are reduced.
400 mm throughout the square / 200 mm in the rear of the batings (coastal vessels)	(Smith and Catchpole, 2013)	ICES area 7.e (28E3 and 28E4) Twin trawls	Significant reduction in catches of whiting and dabs.	

B. Fishing with light projects

Source	Fishery	System	Results
(Hannah et al, 2015)	Pink shrimp fishery (*Pandalus jordani*) (Oregon)	1) 1 to 4 lights (green or blue) around a sorting grid. 2) 10 LEDs on the headline of a trawl	1) For 12 hauls the addition of light on the grid did not have the expected effect; it increased catches of sole (*Lyopsetta exilis)* by 104% (total weight, P = 0.0005) and by-catches of candlefish (*Thaleichthys pacificus)* by 77% (P = 0.0082) without having any effect on catches of ocean shrimp or by-catches of other fish (P> 0.05). 2) Over 42 hauls, the addition of the lights greatly reduced by-catches of a wide variety of fish without impacting catches of shrimp (P> 0.05).
(Elliott et al, 2015)	Shrimp and langoustine trawlers (North Sea)	1) Sets of green lights (Marine Scotland) 2) 6 illuminated rings fitted with compact green LEDs (3 on each side of the SMP) (SafetyNet)	Only the tests carried out using the illuminated rings provided enough data for statistical analysis (4 hauls). Catches of fish smaller than 24 cm in length are generally reduced by 40% by using the experimental trawl net, including a 69% reduction in the number of whiting under 15 cm in length.
(Wang et al, 2013)	Gillnet fishing – By-catches of green turtles (Mexico)	Gillnets equipped with ultraviolet (UV) LEDs	The average catch rate for marine turtles has been reduced by 39.7% by using nets that are lit by UV lights, with no impact either on the overall catch rate for targeted fish or on their market value.
(Southworth, 2017)	Scallop fishery (Isle of Man)	6 LEDs (white light) (SafetyNet) on an SMP	Average depths of 29-40 m: by-catches of whiting reduced by 77% (P = 0.01) by using the lights, and by-catches of haddock by 55% (P = 0.06). Depths of 45-95 m: by-catches of starry smooth-hound reduced by 48% (P = 0.04), of flatfish by 26% (P = 0.002), and of haddock by 55% (P = 0.001). Depth seems to have a significant influence on the efficiency of the systems in reducing by-catches of haddock (P = 0.004).

(Maynard and Gaston, 2010)	Shrimp fishery (Australia)	8 LEDs installed at equal intervals on the headline of the trawl and pointing downwards	The test was stopped after 5 hauls due to excessive commercial losses and an increase in the numbers of by-catches (increased catches of Leiognathidae)
(Bryhn et al., 2014)	Cod fishery (Floating pots)	A green light in the middle of each pot (www.artisanalfish.com).	80% increase by weight in catches of cod thanks to the use of a green light.
(Bielli et al, 2019)	Gillnet fishing (Peru)	Green LEDs placed at 10 m intervals along the floatline of the net.	By-catches of marine turtles were reduced by up to 74.4%, and catches of small cetaceans by up to 70.8%, in each series of tests compared to unlit gillnets. For seabirds, the nominal BPUEs (bycatch-per-unit effort) reduced by 84.0% when LEDs were used. The CPUE (catch-per-unit-effort) of targeted species was not negatively affected by the presence of LEDs.
(Nguyen et al, 2016)	Snow crab fishery (Newfoundland and Labrador)	LEDs of different colours for laboratory tests and	In the laboratory: snow crabs move towards the blue and white lights, stay away from violet lights, and don't seem to perceive green and red lights. In the field: the addition of white and violet LEDs in the baited pots significantly improves the CPUE – by 77% and 47% respectively. Unbaited traps which are equipped only with LED lights could also attract similar quantities of snow crab to traditional traps with baits.
(Nguyen et al, 2019)	Snow crab fishery	Luminescent nets	This study investigates how luminescent nets could improve the level of catches of snow crab. The effect of luminescent nets on the CPUE (measured in the number of crabs per pot) depended on the immersion period. The CPUE is significantly higher (+ 55%) in luminescent traps which have been immersed for a relatively short period (~ 1 day), but the CPUE isn't significantly different if the immersion period is longer (~ 8 days).
(Ortiz et al, 2016)	Gillnet fishing (Sechura Bay - Peru)	Green LEDs placed at 10 m intervals along the floatline of the net.	The CPUE (catch-per-unit-effort) of targeted species was not negatively affected by the presence of LEDs. The average CPUE for green turtles (*Chelonia mydas*) was reduced by 63.9% in the illuminated nets. A total of 125 turtles were caught in the control nets, whereas 62 were caught in the illuminated nets. The cost of equipment is a major expense for the fishermen.
(Yamashita et al, 2012)	Squid fishery (2 species) (Japan)	50 low-power blue LEDs on each test boat and a variable number of metal halide (MH) lamps as required for the tests.	The catches of the two species tended to increase in line with the number of MH lamps. The largest catches of the P. edulis species were made when 24 MH LEDs were used. The results are not as clear for the species T. pacificus because the largest catches were obtained by using 36 MH LEDS, which is the maximum number of MH LEDs that was used.

C. Test and sampling protocol

Protocol for the SELUX experimental fishing trips

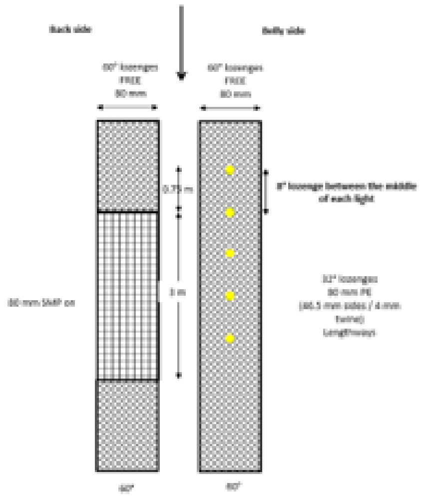
THE AIM: **To compare the efficiency* of a trawl fitted with a lighting system to that of a standard trawl.** *(*Efficiency = Achieving an acceptable trade-off between reducing by-catches and retaining species which are very commercially valuable)*

An operation (OP): 1 haul (with or without a lighting system)
One towing operation: 2 hauls (in the context of the SELUX fishing trips one towing operation consists of 1 haul using a trawl fitted with the lighting system + 1 haul using a standard trawl)
The compared operations (OPs): Two hauls within a single towing operation: 1 standard haul and 1 haul using a lighting system.

1. Configurations of the lighting systems:

Conventional trawl of 80 mm meshwork with **SMP** – lighting system **on the belly of the trawl.**

- PISCES: 5 PISCES installed at 8-mesh intervals on the belly of the trawl, <u>below the SMP</u>, which <u>shine upwards</u>, including one PISCES above the SMP (cf. diagram)
  The PISCES must be flashing (at the slowest speed) and the ON-OFF mode is used to illuminate them before casting the trawl and when raising it.



- Brezglow: 32 lozenge-shaped Brezglow meshes of 4 mm in length installed <u>beneath the SMP</u>.

2. Test protocol

- A single ship for each fishing trip: **alternate hauls method**. With this method the variability of the catches between two hauls within the same towing operation may be significant. Therefore each system must be tested over the course of **at least 30 pairs** (60 hauls sampled) on all the fishing trips, i.e. **10 pairs (20 hauls) sampled per fishing trip** (if there are 3 fishing trips) in order to ensure that the differences observed between the catches in the two hauls (standard and lit) are actually due to the systems used rather than due to other conditions.

- In order to eliminate the effect of the "procedural sequence", the OPs must be organised as follows:
L-S (day) / L-S (night) / S-L (day) / S-L (night) / L-S (day / L-S (night) / S-L (day)...
(L = lit haul, S = standard haul)

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
OUTWARD TRIP (departure 05:00)	00:00	01:00	02:30	05:00
	02:30	03:30	05:00	08:00
	RAISING CASTING	RAISING CASTING	RAISING CASTING	RAISING CASTING
	03:00	04:00	05:10	08:30
	06:00	06:30	08:10	11:00
	RAISING CASTING	RAISING CASTING	RAISING CASTING	RAISING CASTING
	06:30	07:00	09:00	11:30
	9:30	10:00	11:30	14:00
08:00	RAISING CASTING	RAISING CASTING	RAISING CASTING	RETURN TRIP (arrival approx. 17:00)
11:00	10:00	10:30	12:00	
RAISING CASTING	12:10	13:00	14:30	
11:30	RAISING CASTING	RAISING CASTING	RAISING CASTING	
14:00	13:00	13:30	15:00	
RAISING CASTING	15:10	16:00	19:00	
14:30	RAISING CASTING	RAISING CASTING	RAISING CASTING	
17:00	16:00	16:30	19:30	
RAISING CASTING	19:00	19:30	22:30	
17:30	TRAVEL	RAISING CASTING	RAISING CASTING	
20:30		20:00	23:00	
RAISING CASTING		23:00	01:10	
21:00		RAISING CASTING	RAISING CASTING	
21:50		23:30	02:00	
RAISING CASTING		02:00	04:30	
	sampled haul: duration 2 hours 30 mins.			
	non-sampled haul: duration 3 hours			

Between each towing operation, if possible:

One or more 3-hour non-sampled hauls

2 daytime hauls & 2 night-time hauls sampled every 24 hrs.

- Clearly separated daytime and night-time hauls (to assess the effects of light over the two periods), and the hauls within a single towing operation must be either daytime or night-time hauls (so that the hauls within a single towing operation are comparable);
- **Duration of hauls**: 2 hrs. 30 mins.
- The two hauls within a single towing operation must be able to be compared (compared operations):

  - Zones close to each other
  - Same towing speed
  - Same direction of current
  - Same depth
  - Same substrate
  - Identical ambient light conditions in either the daytime or the night-time pair (but not a daytime and night-time towing operation)

3. Sampling protocol

THE STAGES:

When the ship leaves port: the observer must **fill in the "Fishing trip" form and the "System" form**

Once the first operation begins: the observer must **fill in the "Fishing operation" form**

To identify the type of fishing operation (standard or lit) it is essential to specify the type of haul (standard or lit) in the "comments" section. **Similarly, in order to facilitate the analysis of the compared hauls, it is also important to** note the haul no. in the comments (haul 1 for OP1 and OP2, haul 2 for OP4 and OP5…).

When each trawl is raised: the observer will **fill in the "Sampling" form (UP and NUP) and the associated "measurements" forms.**
The catches are divided into two portions: the "commercial" portion (UP) and the "non-commercial" portion (NUP). The catch is sorted by the sailors into the Used Portion (UP) and the Non-Used Portion (NUP).

THE SAMPLING:

The non-sampled hauls constitute rest periods for the observers (no data to be recorded).

For the sampled hauls:

UP (catches):

Record (with or without the skipper's help) the total weight per species for all the species that have been caught.
+ Take measurements of a representative sample (a minimum of 30 fish per species, or 40 in the case of whiting and horse mackerel), beginning with the priority species, and complete according to the amount of time that is available.

NUP (discards):

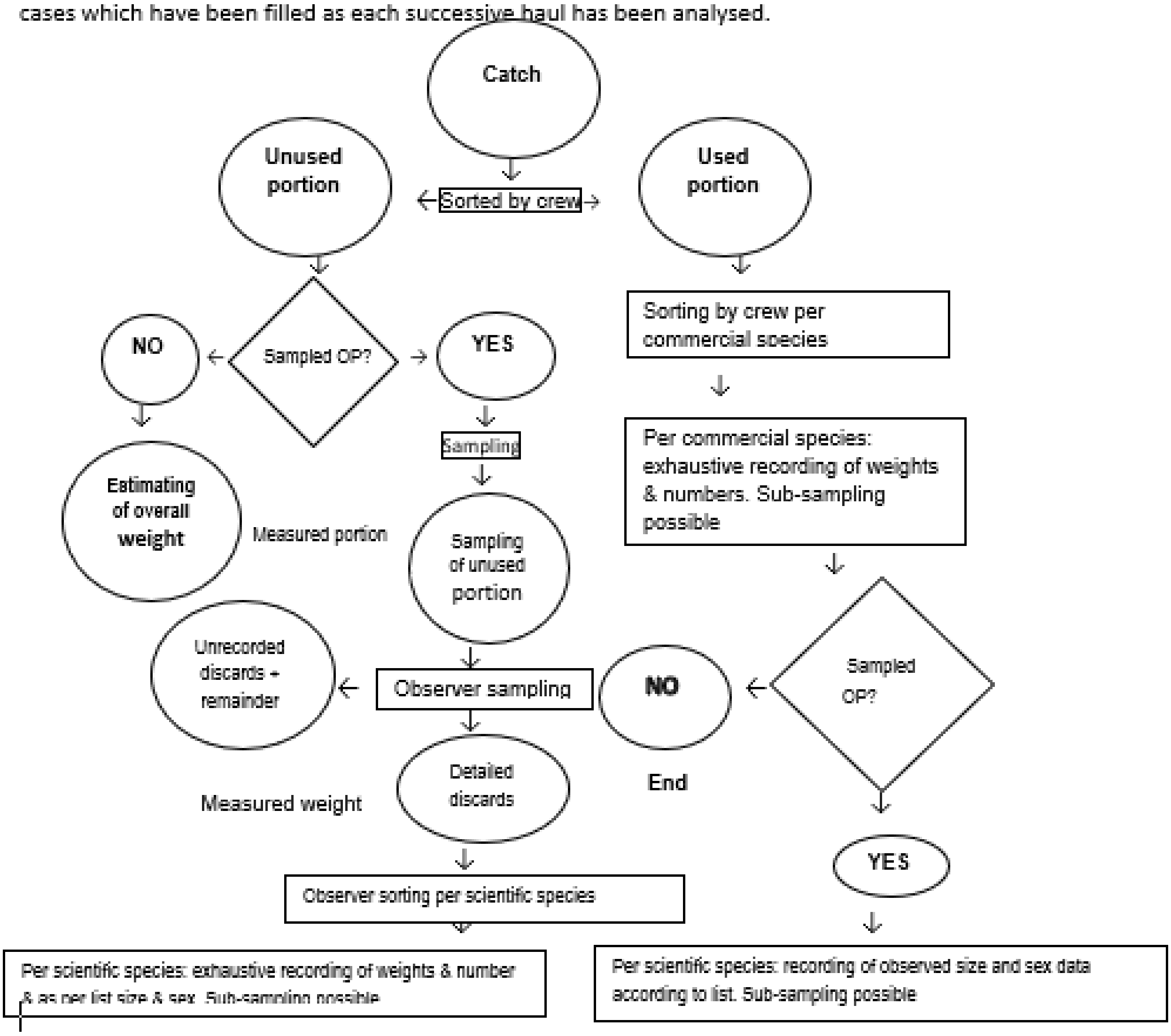
Don't throw the discards into the sea before sampling is done (if there are excessive quantities, agree with the observers to retain a representative sample, and carefully note the total weight by counting the number of crates before throwing this portion back into the sea)

If there are small amounts of discards: Record the weights and sizes for each species, starting with the priority species, and complete according to the amount of time that is available.

If there are large amounts of discards: **Fully sort a representative** NUP **sample** for each scientifically categorised species.

Record the weights and sizes for each species, starting with the priority species, and complete according to the amount of time that is available; **state the total weight of discards** by counting the number of cases (a minimum of 30 fish per species and 40 in the case of whiting and horse mackerel).

Make sure that you record the catches per haul, and not at the end of the fishing trip, for the cases that are filled up as and when necessary → the weight of the last haul must not take account of the cases which have been filled as each successive haul has been analysed.



4. List of priority species (in order of priority)

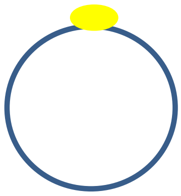
The list below shows in order of priority the priority species to be measured and weighed:

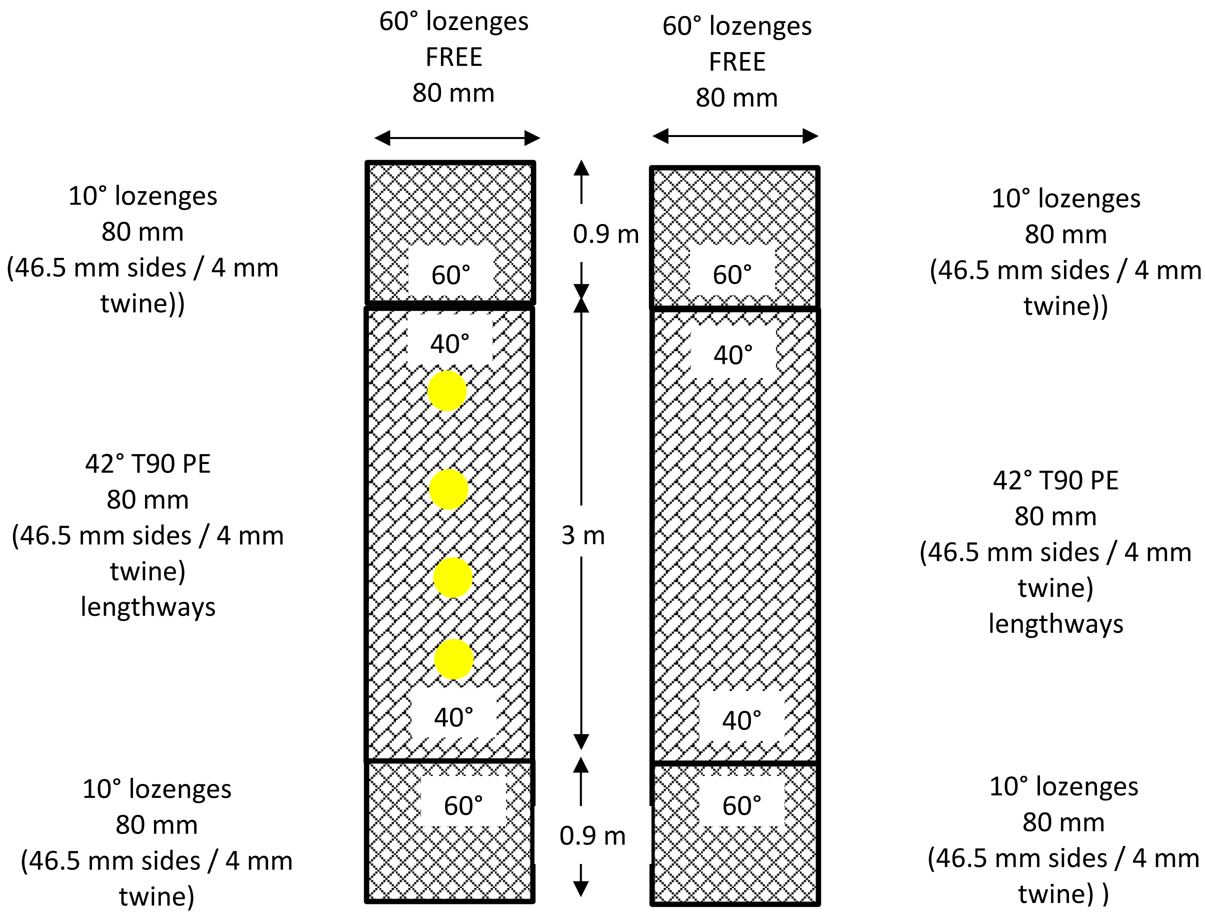
- Whiting
- Horse mackerel
- Mackerel
- Squid
- Red mullet
- Cuttlefish
- Herring
- Plaice
- Yellow gurnard
- Pouting

D. Plans of systems for preliminary fishing trips

1) PISCES light on the back section

- **5 lights, then 4**
- **Continuous green setting**
- **Lighting directed downwards**

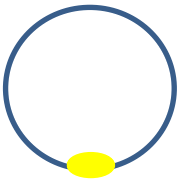


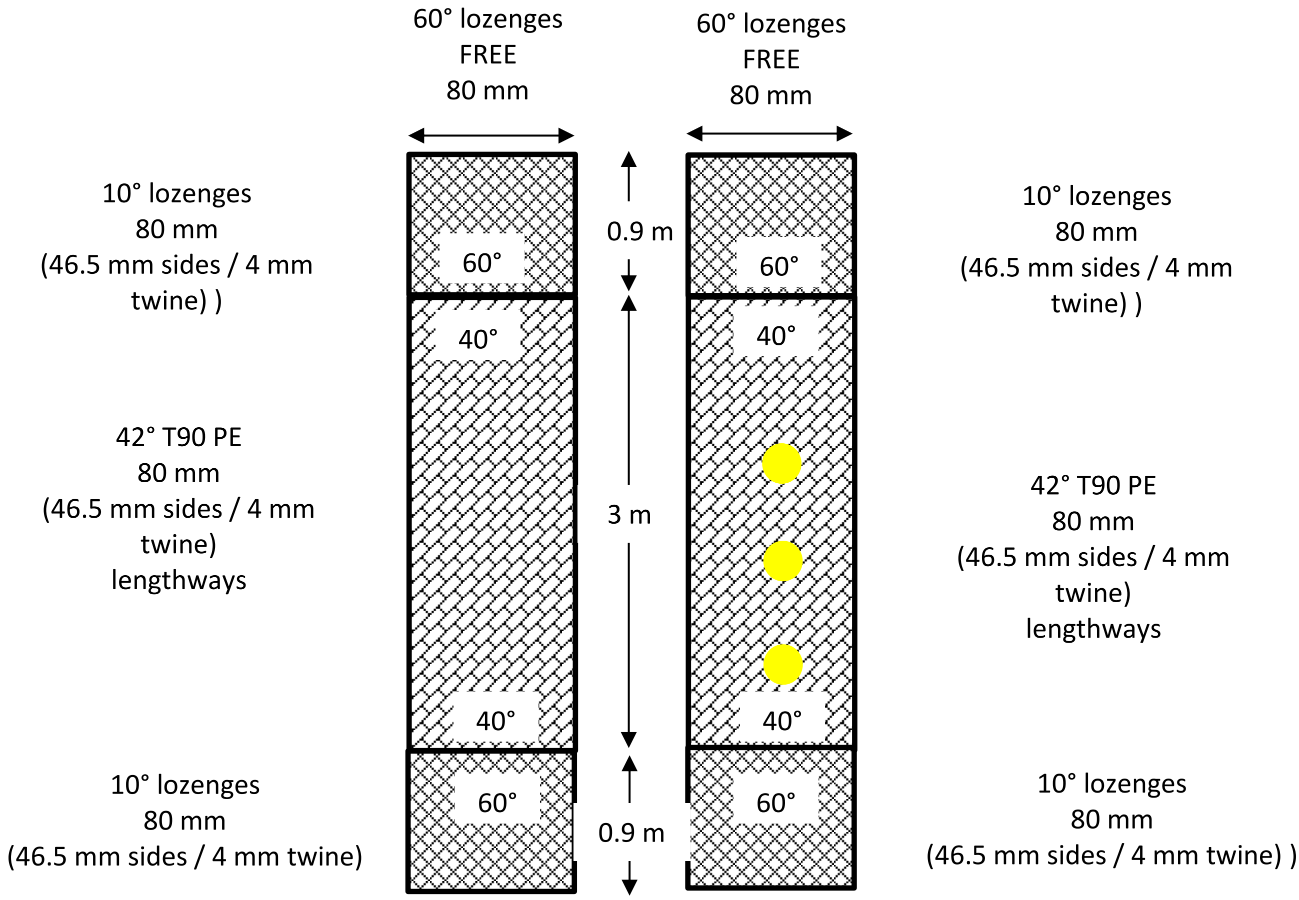


Calculation for T90 PE 4 mm lengthways: 3000/(46.5*2)*13/10 =42°
Corresponding width for 80 mm 60° free lozenges =60*2/3=40° T90 80 mm

2) PISCES light on the belly section

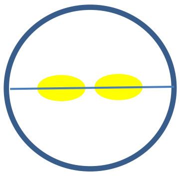
- **3 lights**
- **Continuous green setting**
- **Lighting directed upwards**



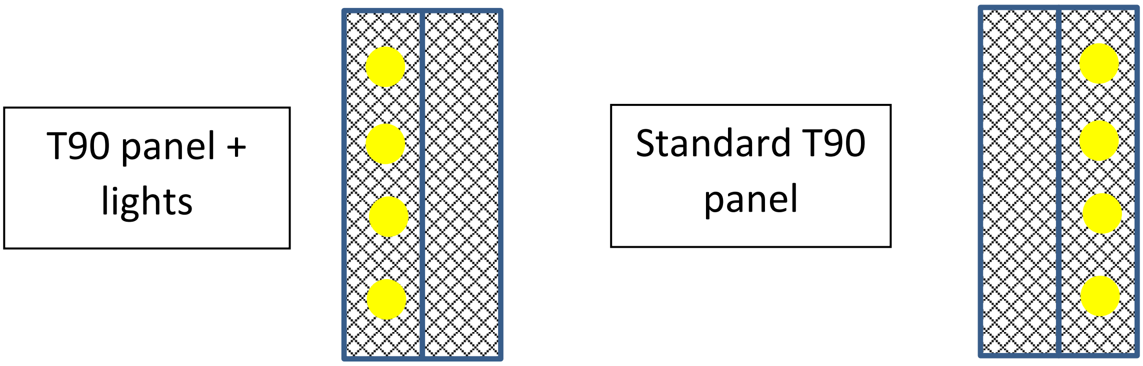


Calculation for T90 PE 4 mm lengthways: 3000/(46.5*2)*13/10 =42°
Corresponding width for 80 mm 60° free lozenges =60*2/3=40° T90 80 mm

3) **PISCES light in the centre**
   - **Lights then 2 as from the 2nd haul**
   - **Continuous green setting**
   - **Bag with taught ropes**
   - **1 light pointing upwards / 1 downwards**

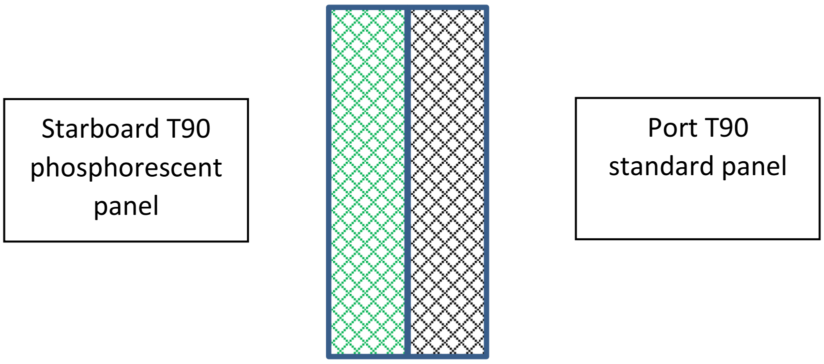


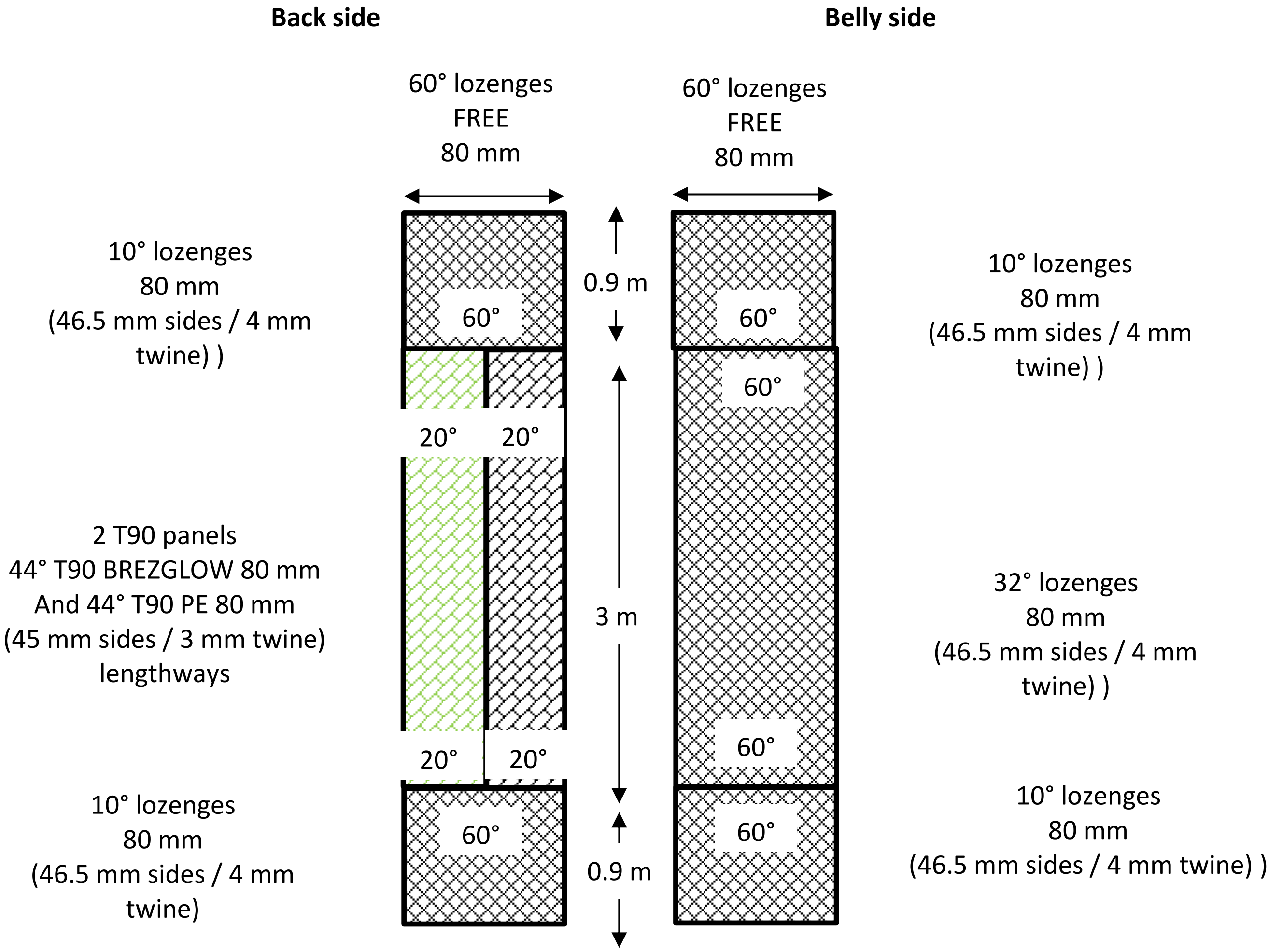
4) **Upper T90 half-panels**
   - **4 lights**
   - **2 positions port / starboard**

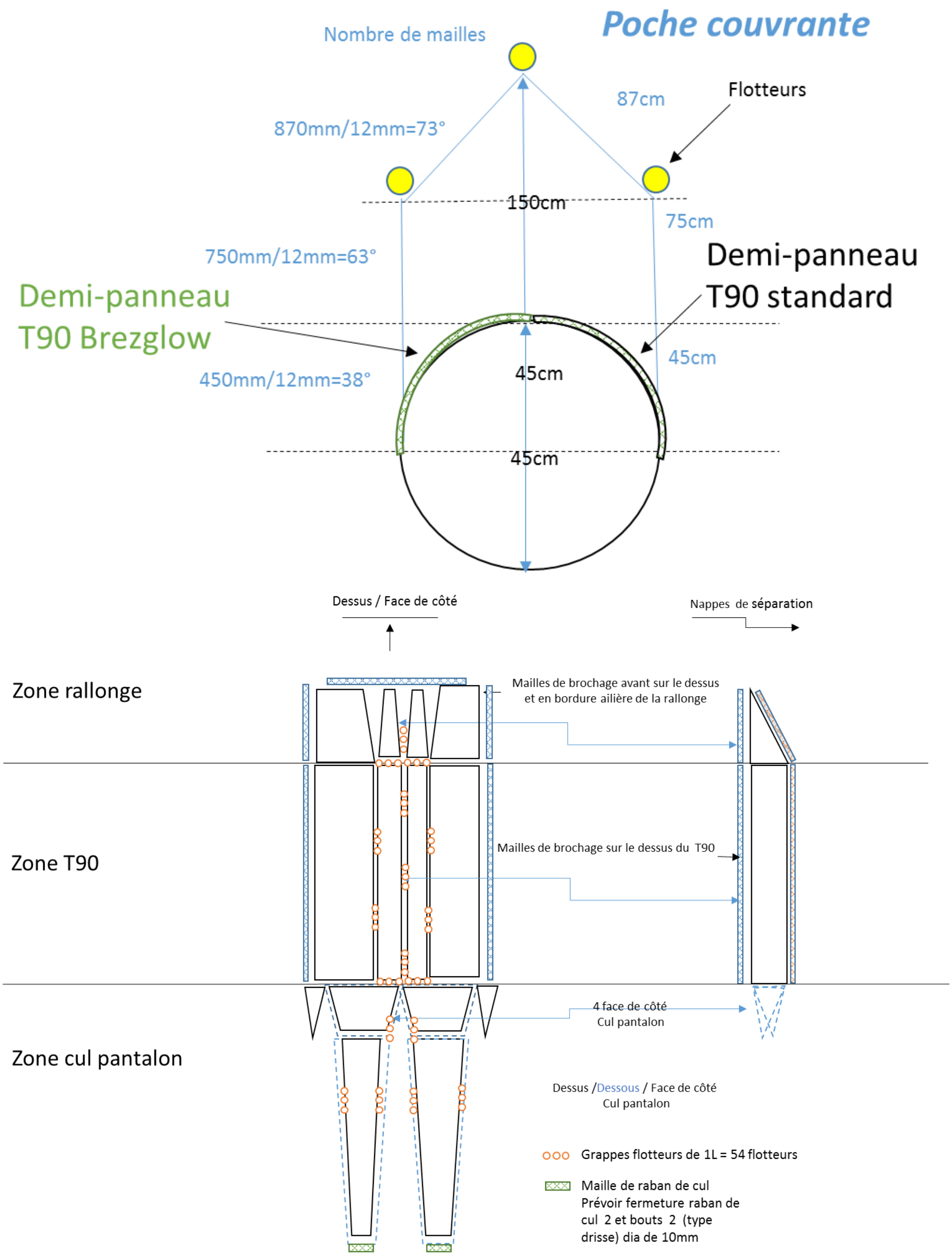


5) **Brezglow phosphorescent and standard upper half-panels**

- **2 positions port / starboard**







Schematic diagram of the two small-mesh half-bags (23 mm sides)

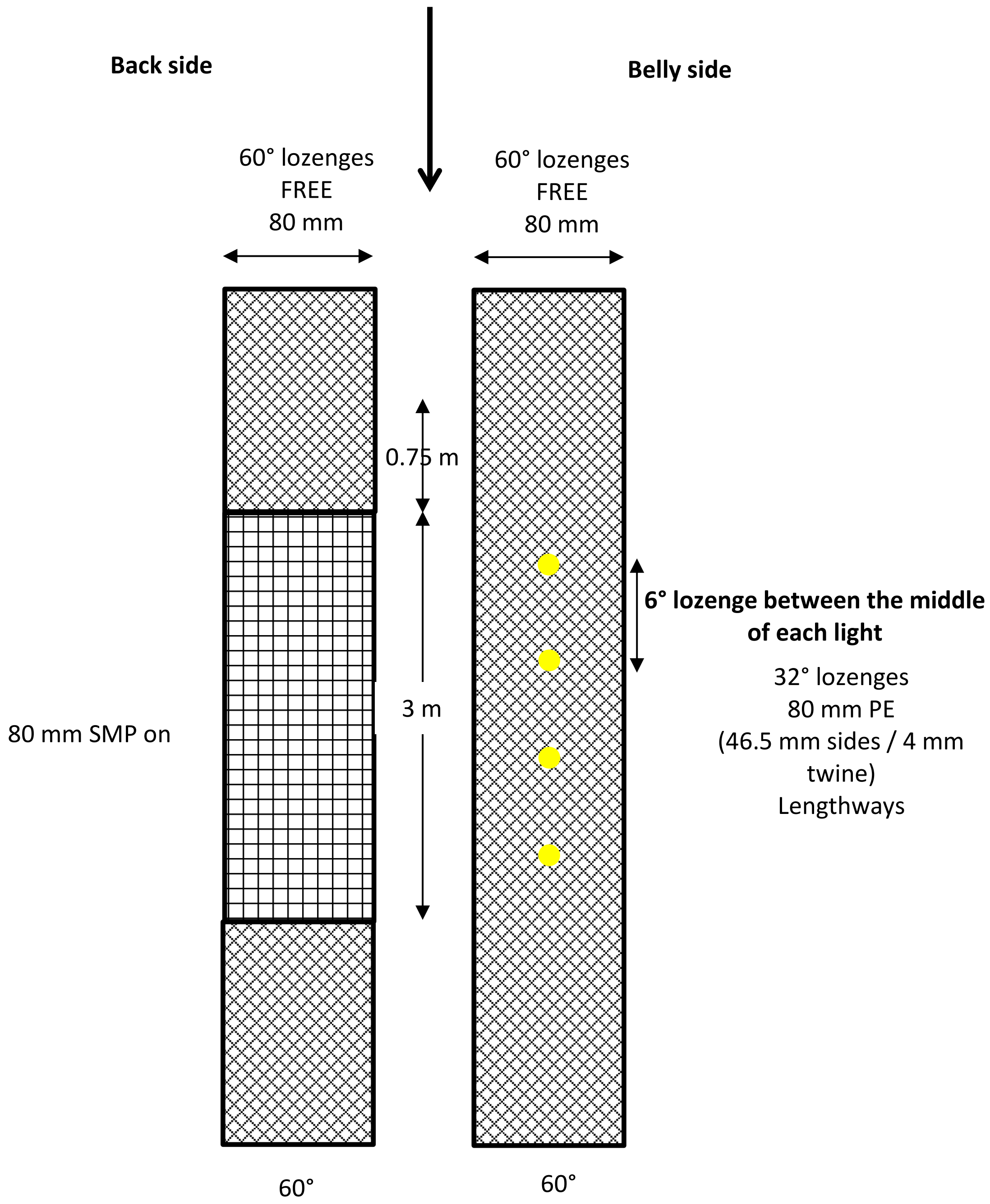
E. PISCES Preliminary fishing trip Results Table

				Nombre côté lumière					Nombre côté sombre				
N°	**Séquence**	**Espèces**	**Luminosité et heure**	**Compt. 1**	**Compt. 2**	**Compt. 3**	**Moyenne**	**%**	**Compt. 1**	**Compt. 2**	**Compt. 3**	**Moyenne**	**%**
1	T10_1_ SNet_Demipan_T90_Tri	maquereau, merlan	Nuit 08h	79	78	73	**77**	**38,21%**	127	121	124	**124**	**61,79%**
2	T11_1_ SNet_Demipan_T90_Tri	sprat, hareng	Jour sombre 13h	340	377	331	**349**	**53,85%**	340	301	257	**299**	**46,15%**
2bis	T11_1_ SNet_Demipan_T90_Tri	sprat, hareng	Jour sombre 13h	458	464	351	**424**	**53,38%**	435	408	269	**371**	**46,62%**
3	T14_2_ SNet_Demipan_T90_Bab	maquereau, autres petits pélagiques, merlans	Jour sombre 10h	329	284	195	**269**	**44,52%**	376	333	298	**336**	**55,48%**
4	T15_2_ SNet_Demipan_T90_Bab	maquereau, autres petits pélagiques, merlans	Jour sombre 10h	74	56	51	**60**	**40,77%**	101	83	79	**88**	**59,23%**
5	T15_1_ SNet_Demipan_T90_Bab	petits pélagiques	Jour 13h	453	371	359	**394**	**50,45%**	448	372	342	**387**	**49,55%**
5bis	T15_1_ SNet_Demipan_T90_Bab	petits pélagiques	Jour 13h	591	534	561	**562**	**46,60%**	673	699	560	**644**	**53,40%**

F. Plans of systems for experimental fishing trips

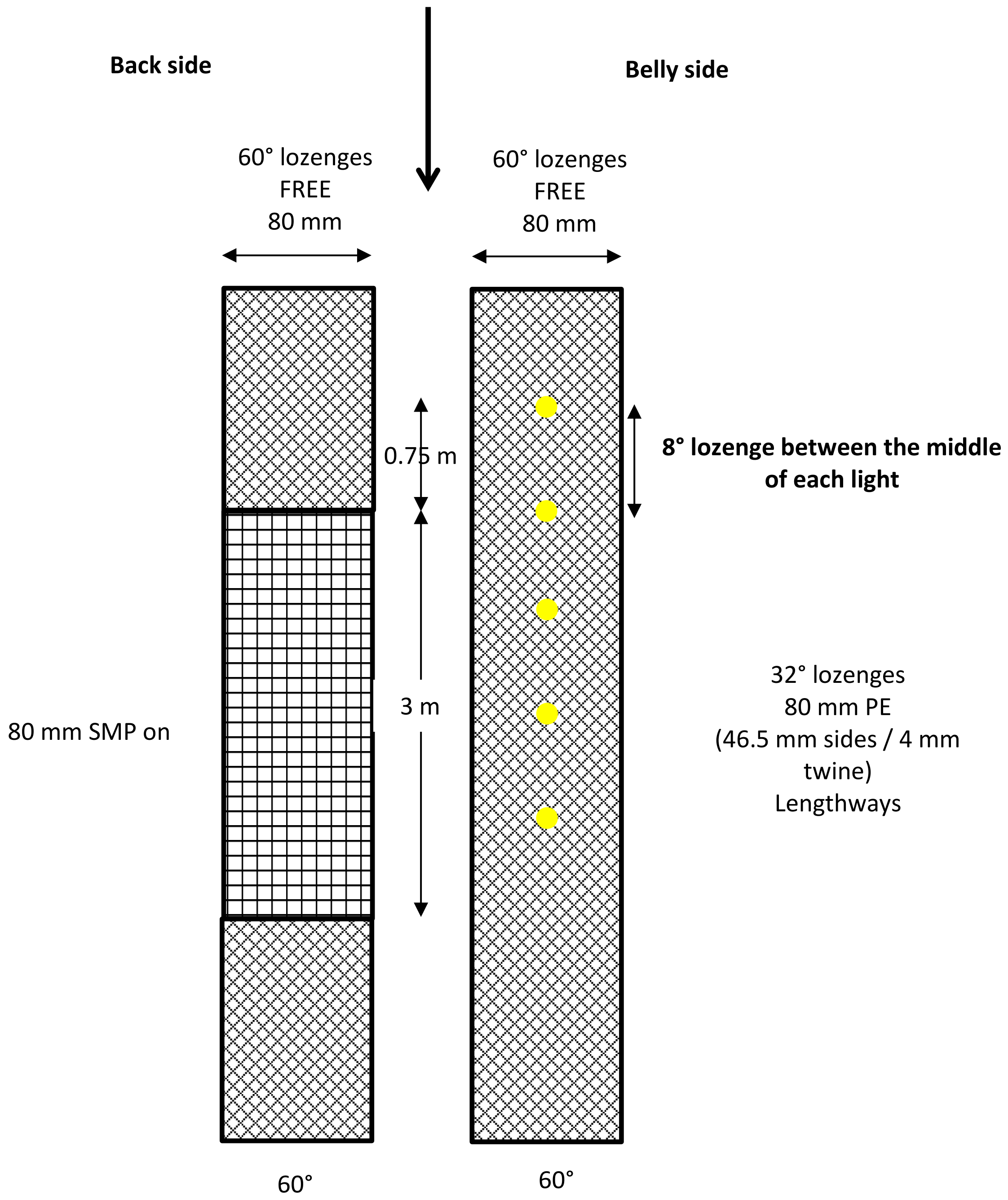
1) PISCES lights positioned on belly (light directed upwards)

EXPERIMENTAL FISHING TRIP 1 (4 lights)

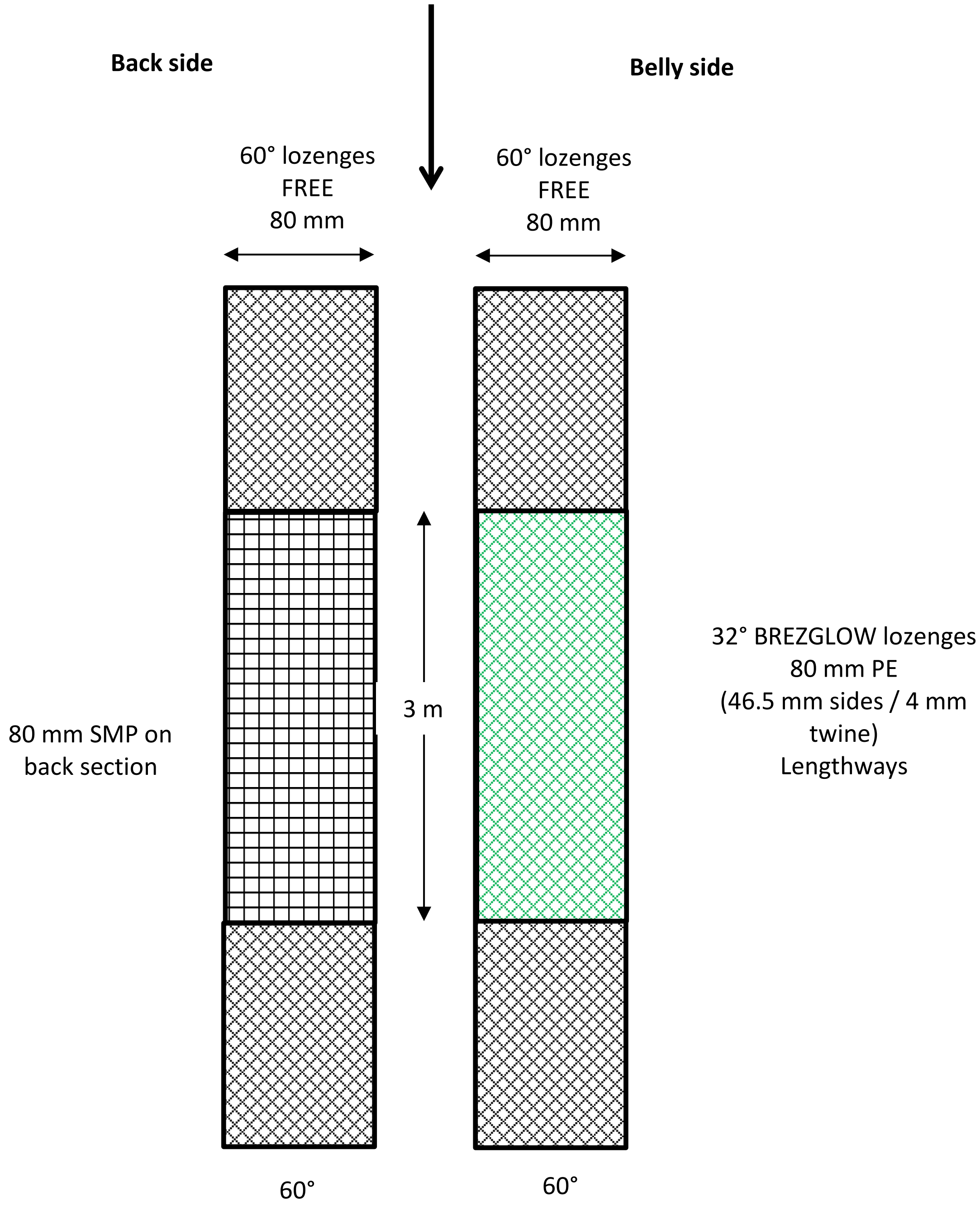


2) PISCES lights on the belly section

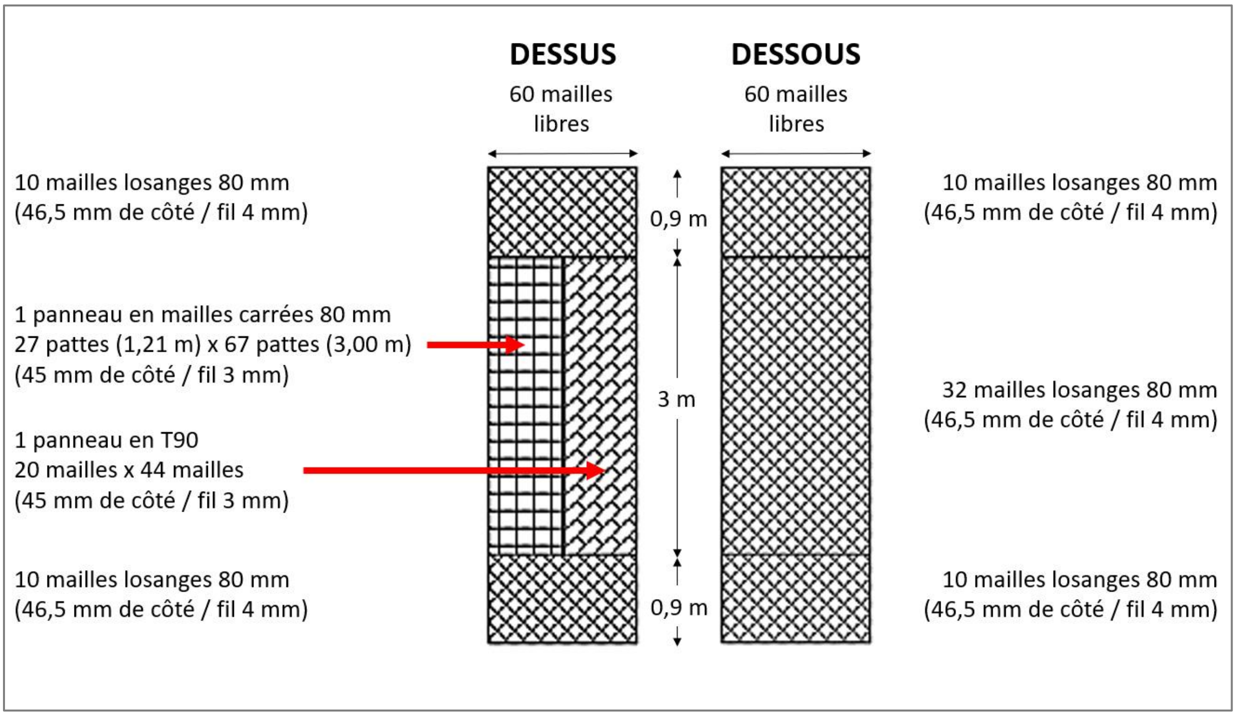
TRIALS 2 / 3 / 4 (5 lights)

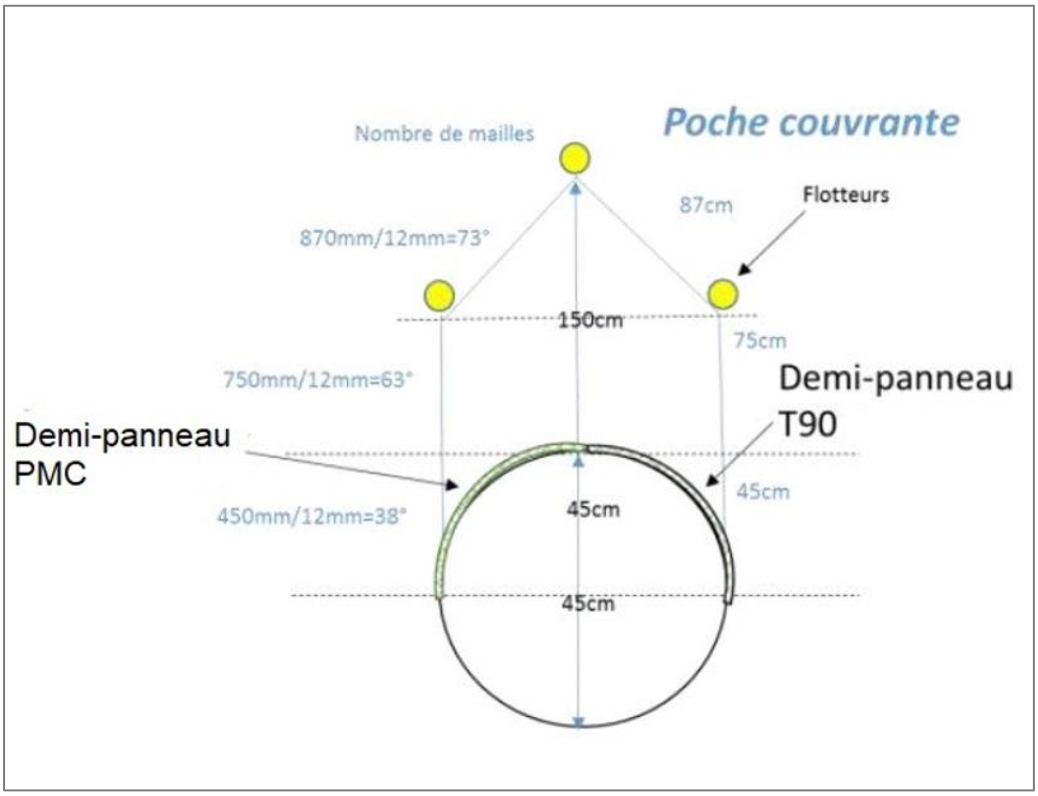


3) Brezglow positioned on belly



4) T90 and 80 mm meshwork SMP half-panels with covering bags

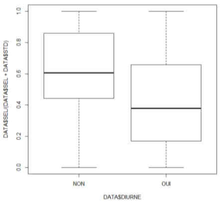


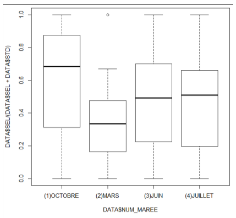


G. Details of the analysis of environment data

PISCES

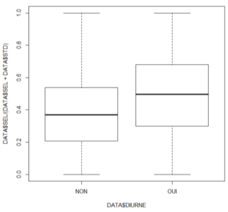
HORSE MACKEREL: the “diurnal” variable seems to be an explanatory factor for the proportion of individuals caught in the test trawl as compared to the standard trawl, and the p-value is < 0.05.

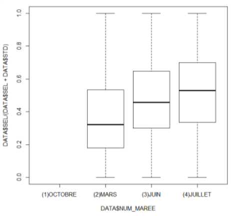





```
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.46386  -0.45815   0.01515   0.49166   1.52255

Coefficients:
                   Estimate Std. Error z value Pr(>|z|)
(Intercept)         0.22428    0.29413   0.763   0.4458
NUM_MAREE(1)OCTOBRE 0.42783    0.35116   1.218   0.2231
NUM_MAREE(2)MARS   -0.35900    0.51466  -0.698   0.4855
NUM_MAREE(3)JUIN    0.04929    0.33485   0.147   0.8830
DIURNEOUI          -0.64780    0.25856  -2.505   0.0122 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 131.95  on 258  degrees of freedom
Residual deviance: 120.52  on 254  degrees of freedom
AIC: 341.52

Number of Fisher Scoring iterations: 3
```

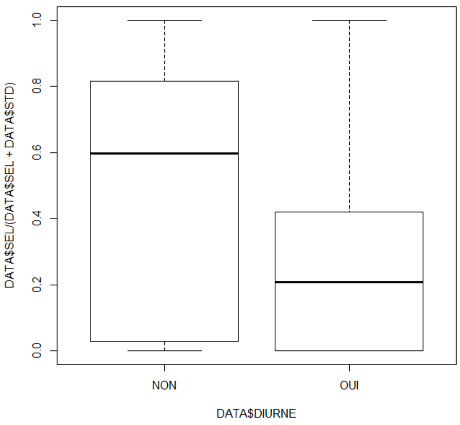
WHITING: the “seasonal” variable seems to be an explanatory factor for the proportion of individuals caught in the test trawl as compared to the standard trawl, and the p-value is < 0.05.





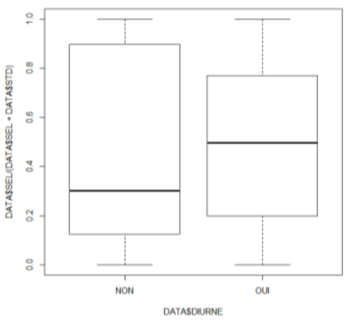

```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(4)JUILLET")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.22529  -0.38495  -0.02268   0.33879   1.45562

Coefficients:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)       -0.1569     0.2466  -0.636   0.5246
NUM_MAREE(2)MARS  -0.4768     0.2734  -1.744   0.0811 .
NUM_MAREE(3)JUIN  -0.1280     0.2742  -0.467   0.6406
DIURNEOUI          0.2688     0.2243   1.198   0.2308
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 144.87  on 338  degrees of freedom
Residual deviance: 139.50  on 335  degrees of freedom
AIC: 451.4

Number of Fisher Scoring iterations: 3
```

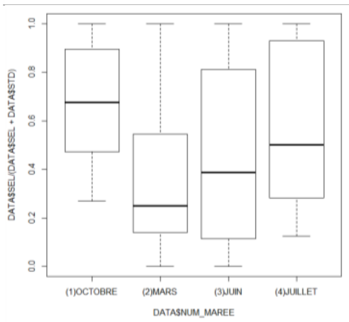
SQUID: According to these results, the diurnal variable is not an explanatory factor for the proportion of squid caught in the test trawl.




```
> boxplot(formula=DATA$SEL/(DATA$SEL+DATA$STD)~DATA$DIURNE)
> glm1<-glm(formula = (SEL/(SEL+STD))~  DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.10126  -0.82980   0.00417   0.51693   1.57067

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -0.1818     0.3136  -0.580    0.562
DIURNEOUI    -0.7074     0.4908  -1.442    0.149

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 51.005  on 74  degrees of freedom
Residual deviance: 48.876  on 73  degrees of freedom
AIC: 94.388

Number of Fisher Scoring iterations: 3
```

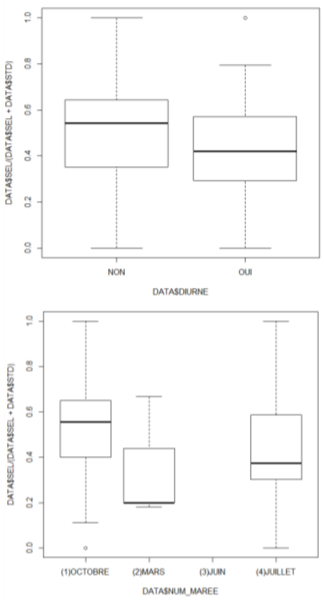
MACKEREL: According to these results, the seasonal and diurnal variables are not explanatory factors for the proportion of mackerel caught in the test trawl.





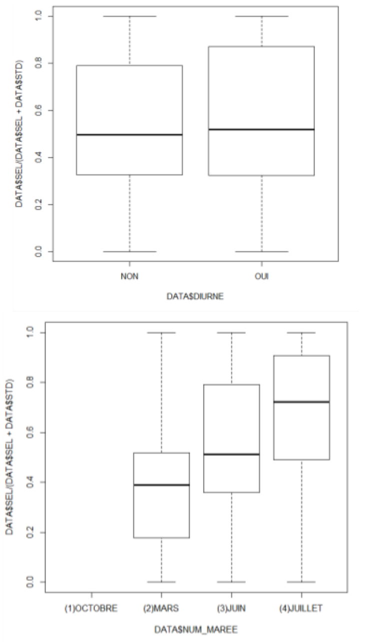

```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(4)JUILLET")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.1616  -0.5702  -0.1987   0.5797   1.4573

Coefficients:
                   Estimate Std. Error z value Pr(>|z|)
(Intercept)          0.2195     0.5726   0.383    0.701
NUM_MAREE(1)OCTOBRE  0.3463     0.7361   0.470    0.638
NUM_MAREE(2)MARS    -0.8571     0.6506  -1.317    0.188
NUM_MAREE(3)JUIN    -0.3888     0.5928  -0.656    0.512
DIURNEOUI            0.1319     0.4448   0.296    0.767

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 70.336  on 118  degrees of freedom
Residual deviance: 65.351  on 114  degrees of freedom
AIC: 170.65

Number of Fisher Scoring iterations: 3
```

RED MULLET: According to these results, the seasonal and diurnal variables are not explanatory factors for the proportion of red mullet caught in the test trawl.



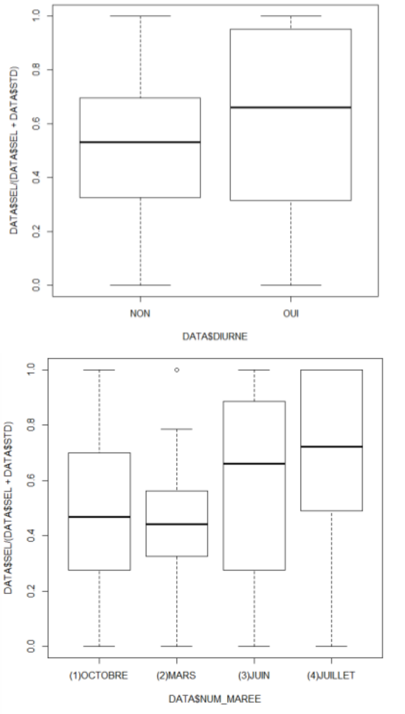

```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(4)JUILLET")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.24608  -0.30415   0.00699   0.25720   1.32149

Coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)          -0.2285     0.4864  -0.470    0.638
NUM_MAREE(1)OCTOBRE   0.3886     0.5590   0.695    0.487
NUM_MAREE(2)MARS     -0.3417     1.1357  -0.301    0.764
DIURNEOUI            -0.1040     0.5758  -0.181    0.857

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 15.775  on 64  degrees of freedom
Residual deviance: 14.754  on 61  degrees of freedom
AIC: 95.569

Number of Fisher Scoring iterations: 3
```

PLAICE: According to these results, the seasonal variable could be an explanatory factor for the proportion of plaice caught in the test trawl. However, little data has been collected and the differences vary greatly from one pair to another.




```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(4)JUILLET")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.5168  -0.4051  -0.0393   0.5097   1.3640

Coefficients:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)       0.67906    0.36513   1.860   0.0629 .
NUM_MAREE(2)MARS -1.10776    0.45468  -2.436   0.0148 *
NUM_MAREE(3)JUIN -0.49609    0.40975  -1.211   0.2260
DIURNEOUI         0.09068    0.32371   0.280   0.7794
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 84.164  on 163  degrees of freedom
Residual deviance: 77.740  on 160  degrees of freedom
AIC: 224.14

Number of Fisher Scoring iterations: 3
```

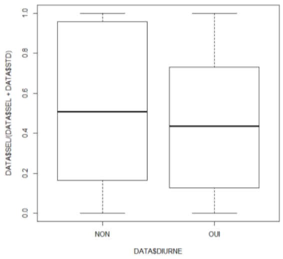
POUTING: According to these results, the seasonal variable could be an explanatory factor for the proportion of pouting caught in the test trawl. However, little data has been collected and the differences vary greatly from one pair to another.

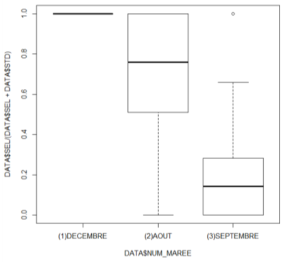



```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(4)JUILLET")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.55956  -0.39532   0.07059   0.51177   1.28592

Coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)           0.5920     0.3467   1.707   0.0878 .
NUM_MAREE(1)OCTOBRE  -0.6623     0.4619  -1.434   0.1517
NUM_MAREE(2)MARS     -0.8435     0.4244  -1.987   0.0469 *
NUM_MAREE(3)JUIN     -0.4398     0.4200  -1.047   0.2951
DIURNEOUI             0.2726     0.3530   0.772   0.4400
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 99.307  on 201  degrees of freedom
Residual deviance: 93.274  on 197  degrees of freedom
AIC: 278.18

Number of Fisher Scoring iterations: 3
```

BREZGLOW

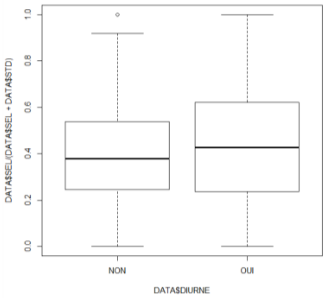
HORSE MACKEREL: The “seasonal” variable seems to be an explanatory factor for the proportion of horse mackerel caught in the test trawl as compared to the standard trawl, and the p-value is < 0.05.

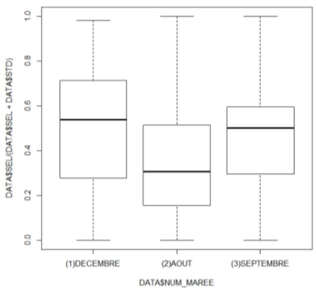





```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(3)SEPTEMBRE")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.6800  -0.6432  -0.1161   0.5496   1.6118

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)            -0.9805     0.4050  -2.421   0.0155 *
NUM_MAREE(1)DECEMBRE   18.0367  2399.5448   0.008   0.9940
NUM_MAREE(2)AOUT        2.1121     0.4845   4.359  1.3e-05 ***
DIURNEOUI              -0.4902     0.4831  -1.015   0.3103
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 67.191  on 92  degrees of freedom
Residual deviance: 43.053  on 89  degrees of freedom
AIC: 97.596

Number of Fisher Scoring iterations: 15
```

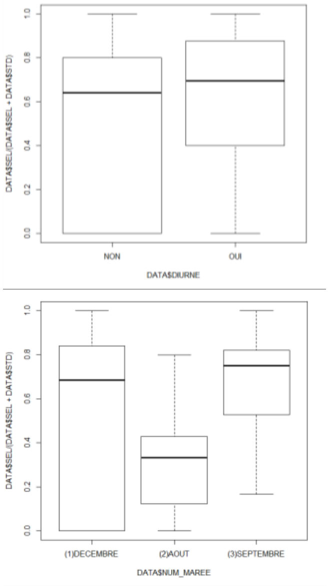
WHITING: The “seasonal” variable seems to be an explanatory factor for the proportion of whiting caught in the test trawl as compared to the standard trawl, and the p-value is < 0.05.





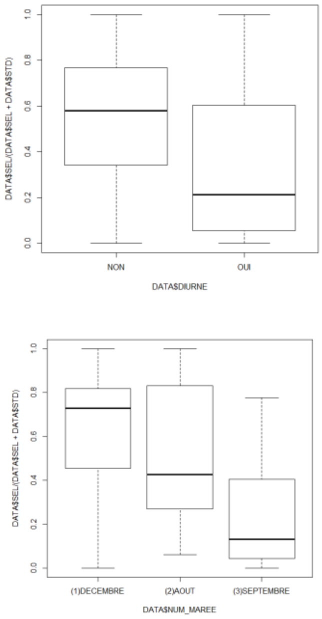

```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(2)AOUT")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.21702  -0.36770   0.01986   0.35635   1.51658

Coefficients:
                       Estimate Std. Error z value Pr(>|z|)
(Intercept)             -0.7693     0.2748  -2.799  0.00512 **
NUM_MAREE(1)DECEMBRE     0.7171     0.4583   1.565  0.11761
NUM_MAREE(3)SEPTEMBRE    0.6113     0.3314   1.844  0.06511 .
DIURNEOUI                0.1449     0.3053   0.475  0.63510
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 59.583  on 182  degrees of freedom
Residual deviance: 54.928  on 179  degrees of freedom
AIC: 240.83

Number of Fisher Scoring iterations: 3
```

YELLOW GURNARD: According to these results, the seasonal and diurnal variables are not explanatory factors for the proportion of yellow gurnard caught in the test trawl.



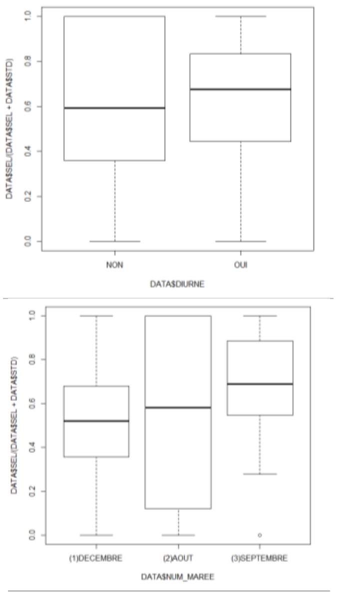

```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(2)AOUT")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.3582  -0.6318   0.1780   0.6333   1.1960

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)            -0.7764     0.9627  -0.806    0.420
NUM_MAREE(1)DECEMBRE    0.7327     1.0277   0.713    0.476
NUM_MAREE(3)SEPTEMBRE   1.4831     1.1534   1.286    0.198
DIURNEOUI               0.4592     0.6968   0.659    0.510

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 28.119  on 43  degrees of freedom
Residual deviance: 25.853  on 40  degrees of freedom
AIC: 63.152

Number of Fisher Scoring iterations: 3
```

MACKEREL: According to these results, the seasonal and diurnal variables are not explanatory factors for the proportion of mackerel caught in the test trawl.



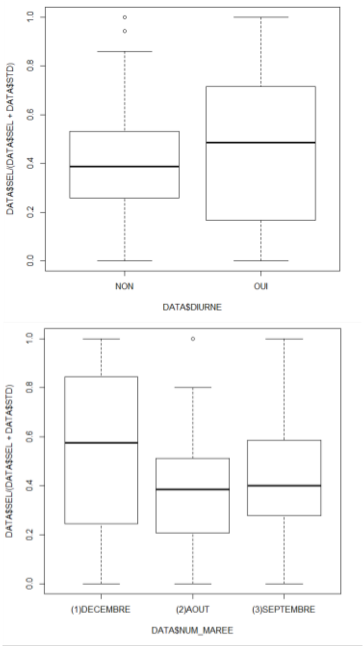

```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(2)AOUT")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.3986  -0.4530  -0.0392   0.4227   1.5890

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)             0.3616     0.3631   0.996   0.3193
NUM_MAREE(1)DECEMBRE    1.4361     0.8964   1.602   0.1092
NUM_MAREE(3)SEPTEMBRE  -0.6586     0.6402  -1.029   0.3036
DIURNEOUI              -1.2914     0.6783  -1.904   0.0569 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 40.007  on 77  degrees of freedom
Residual deviance: 27.820  on 74  degrees of freedom
AIC: 96.217

Number of Fisher Scoring iterations: 4
```

PLAICE: According to these results, the seasonal and diurnal variables are not explanatory factors for the proportion of plaice caught in the test trawl.



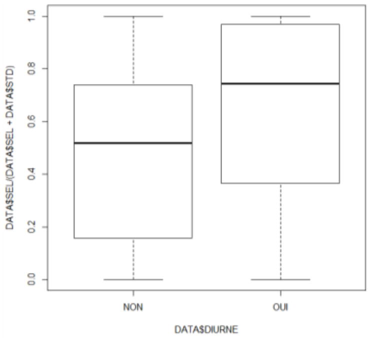

```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(2)AOUT")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.51996  -0.45524  -0.01701   0.80043   1.17553

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)            0.12040    0.36058   0.334    0.738
NUM_MAREE(1)DECEMBRE  -0.20162    0.57980  -0.348    0.728
NUM_MAREE(3)SEPTEMBRE  0.65638    0.43532   1.508    0.132
DIURNEOUI              0.08563    0.39816   0.215    0.830

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 68.880  on 109  degrees of freedom
Residual deviance: 65.685  on 106  degrees of freedom
AIC: 146.55

Number of Fisher Scoring iterations: 3
```

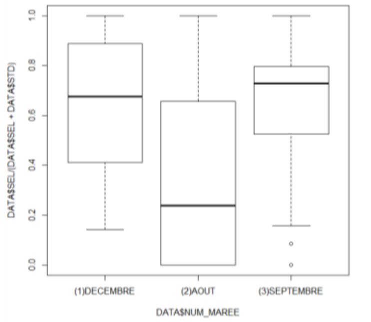
RED MULLET: According to these results, the seasonal and diurnal variables are not explanatory factors for the proportion of red mullet caught in the test trawl.




```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(2)AOUT")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.25864  -0.44409   0.01632   0.33277   1.39908

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)            -0.5074     0.3477  -1.460    0.144
NUM_MAREE(1)DECEMBRE    0.6964     0.5706   1.221    0.222
NUM_MAREE(3)SEPTEMBRE   0.2426     0.5164   0.470    0.639
DIURNEOUI               0.1823     0.4497   0.405    0.685

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 30.836  on 88  degrees of freedom
Residual deviance: 29.160  on 85  degrees of freedom
AIC: 122.02

Number of Fisher Scoring iterations: 3
```

POUTING: According to these results, the seasonal variable could be an explanatory factor for the proportion of pouting caught in the test trawl. However, little data has been collected and the differences vary greatly from one pair to another.






```
> DATA$NUM_MAREE<-relevel(DATA$NUM_MAREE,ref="(3)SEPTEMBRE")
> glm1<-glm(formula = (SEL/(SEL+STD))~ NUM_MAREE+ DIURNE, family = binomial(logit), data = DATA)
Warning message:
In eval(family$initialize) :
  nombre de succès non entier dans un glm binomial !
> summary(glm1)

Call:
glm(formula = (SEL/(SEL + STD)) ~ NUM_MAREE + DIURNE, family = binomial(logit),
    data = DATA)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.35415  -0.63666   0.00563   0.39652   1.60627

Coefficients:
                     Estimate Std. Error z value Pr(>|z|)
(Intercept)            0.4064     0.3543   1.147  0.25129
NUM_MAREE(2)AOUT      -1.3745     0.4758  -2.889  0.00387 **
NUM_MAREE(1)DECEMBRE  -0.1674     0.6506  -0.257  0.79696
DIURNEOUI              0.6774     0.4506   1.503  0.13273
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 60.356  on 95  degrees of freedom
Residual deviance: 48.416  on 92  degrees of freedom
AIC: 116.3

Number of Fisher Scoring iterations: 4
```

H. Species landed and discarded during PISCES experimental fishing trips (standard trawl)

Landings

Espèces	Tonnages (Kg)	%
Merlan	3446,476789	53,69%
Maquereau commun	577,2323037	8,99%
Encornet	570,6970893	8,89%
Chinchard d'Europe	548,9219193	8,55%
Petite roussette	259,3770704	4,04%
Rouget de roche	204,0915925	3,18%
Limande	171,6703333	2,67%
Tacaud commun	168,8845425	2,63%
Seiche commune	114,9453938	1,79%
Grondin perlon	89,35877548	1,39%
Plie d'Europe	75,71877985	1,18%
Grondin rouge	60,06462254	0,94%
Dorade grise	29,76786207	0,46%
Morue de l'Atlantique	26,17946663	0,41%
Limande sole	14,46373637	0,23%
Émissoles nca	10,94671264	0,17%
Saint Pierre	9,05622729	0,14%
Bar européen	7,74994086	0,12%
Flet d'Europe	6,421333333	0,10%
Sole commune	5,987132184	0,09%
Hareng de l'Atlantique	4,113666667	0,06%
Barbue	3,812666667	0,06%
Grande vive	3,361166667	0,05%
Turbot	3,110333333	0,05%
Baudroies, etc. nca	2,809333333	0,04%
Congre d'Europe	1,941935484	0,03%
Raie bouclée	1,605333333	0,03%
Sole-pole	0,301	0,00%

Discards

Espèces	Tonnages (Kg)	%
Merlan	2650,033429	36,46%
Chinchard d'Europe	1615,675212	22,23%
Limande	1454,076261	20,01%
Plie d'Europe	581,3128561	8,00%
Tacaud commun	349,3463486	4,81%
Petite roussette	260,1346513	3,58%
Limande sole	95,07168872	1,31%
petit tacaud	69,54086308	0,96%
Hareng de l'Atlantique	39,0469395	0,54%
Maquereau commun	21,38163452	0,29%
Bar européen	20,46547142	0,28%
Grondin gris	19,85255939	0,27%
Grondin rouge	15,7775934	0,22%
Morue de l'Atlantique	15,46063647	0,21%
Raie lisse	10,1069352	0,14%
Grondin perlon	8,807038508	0,12%
Daurade Royale	7,074232621	0,10%
Sprat	6,836458656	0,09%
Callionymus	6,033322796	0,08%
Émissoles nca	5,330005767	0,07%
Rouget de roche	3,633795772	0,05%
Saint Pierre	3,26959256	0,04%
Aiglefin	2,784160072	0,04%
Flet d'Europe	2,143814034	0,03%
Dorade grise	2,142287535	0,03%
Raie bouclée	1,858779103	0,03%
Callionymus lyra	0,732735821	0,01%
Sardine	0,250889772	0,00%
Seiche commune	0,237992475	0,00%
souris de mer	0,017247678	0,00%

I. Species landed and discarded during Brezglow experimental fishing trips (standard trawl)

Landings

Espèces	Tonnages (Kg)	% cumulé
Merlan	1 791,14	39,75%
Encornet	1 266,14	67,85%
Maquereau commun	249,99	73,40%
Petite roussette	191,85	77,65%
Rouget de roche	143,79	80,85%
Raie bouclée	122,81	83,57%
Chinchard d'Europe	117,41	86,18%
Seiche commune	100,15	88,40%
Limande	94,53	90,50%
Grondin perlon	84,54	92,37%
Tacaud commun	66,85	93,86%
Émissole tachetée	59,65	95,18%
Grondin rouge	47,87	96,24%
Bar européen	44,27	97,22%
Plie d'Europe	41,79	98,15%
Limande sole	38,10	99,00%
Raie lisse	17,59	99,39%
Sole commune	12,44	99,66%
Morue de l'Atlantique	10,89	99,91%
Grande vive	2,20	99,95%
Dorade grise	1,40	99,99%
Saint Pierre	0,65	100,00%

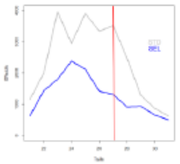
Discards

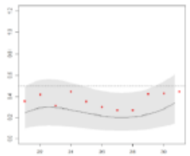
Espèces	Tonnages (Kg)	% cumulé
Merlan	2 726,33	59,85%
Chinchard d'Europe	440,09	69,51%
Limande	425,36	78,85%
Plie d'Europe	219,67	83,67%
Tacaud commun	213,01	88,35%
Bar européen	175,74	92,20%
Limande sole	98,04	94,36%
hareng	88,63	96,30%
Petite roussette	53,78	97,48%
Maquereau commun	43,89	98,45%
petit tacaud	32,43	99,16%
Grondin rouge	8,80	99,35%
Grondin perlon	8,15	99,53%
Rouget de roche	6,24	99,67%
Morue de l'Atlantique	5,53	99,79%
grondin gris	5,00	99,90%
Raie bouclée	1,42	99,93%
Émissole tachetée	1,42	99,96%
Seiche commune	0,83	99,98%
Raie brunette	0,47	99,99%
Encornet	0,26	100,00%
sardine	0,20	100,00%

J. Project summary sheet

LE BREZGLOW

Species	Var. landings rate (mean)	Var. landings rate (total weight)	Var. discards rate (mean)	Var. discards rate (total weight)
Horse mackerel	**+ 125%**	**+ 58%**	**+ 2%**	**-33%**
Whiting	**+ 2%**	**-24%**	**-12%**	**-32%**





WHITING

Brezglow leads to a reduction in catches only for the fishing trip in August, but with a high level of variability within the pairs.

HORSE MACKEREL : No differencies.

4 Conclusion

This project enabled an improved understanding of the behaviour of different species in response to light to be obtained. The analyses carried out show that **whiting tends to shun the light, and that horse mackerel is equally attracted by the light but could be repelled by it when it is flashing.**

The configurations of lights/SMPs that were tested enabled **catches of whiting to be reduced over two fishing trips** (one fishing trip for each system) **for all sizes of fish – which therefore results in commercial losses.** Adjustments could be made so as to prevent individuals larger than the MCRS (Minimum Conservation Reference Size) from escaping, e.g. the use of T90 netting which is more suitable for this species. Indeed, various studies underline the efficiency of T90 for selectivity in relation to whiting, and it is considered to be more appropriate for selection roughly in line with the MCRS (as confirmed by the results of the SMP/T90 comparison carried out within this project). The efficiency of the lights could also be improved by varying their brightness and adjusting their position on the trawl net (installing them further above the selective panel).

Finally, the results may suggest the influence of criteria linked to the season or the zone such as ambient light or turbidity.

As regards horse mackerel, the configurations that were tested were unable to improve selectivity.

[1] *Gauduchon T., Cornou A., Quinio-Scavinner M., Goascoz N., Dubroca N. (2020). Captures et rejets des métiers de pêche français Résultats des observations à bord des navires de pêche professionnelle en 2018. OBSMER.*

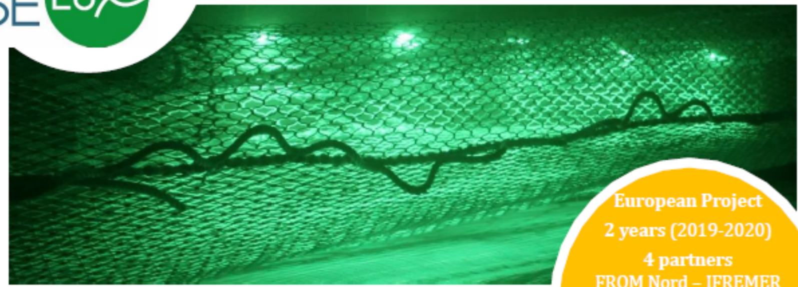
FROM NORD — Ifremer — LeDrezen

THE SELUX PROJECT

Can light improve the efficiency of selective devices used by artisanal trawlers fishing in the English Channel and the southern North Sea?

SELUX

<u>Summary of the results</u>



Selectivity is a major challenge for the artisanal trawlers fishing in the eastern English Channel and the southern North Sea. In order to comply with **the Landing Obligation** that has been in force since 2019 and to maintain the fleet's long-term **economic viability**, a significant reduction of by-catches is essential. For these ships, the by-catches which are managed by a Total Allowable Catch (TAC) system, and which are therefore affected by the landing obligation, account for up to 52.1% of their total catches (Gauduchon & Al., 2020)[1].

A project that is funded by:

Certification: aquimer

Aim of the project: To test the combining of the two lighting systems with the Square Mesh Panel (SMP) which is mandatory **in the North Sea**

Lighting systems tested:

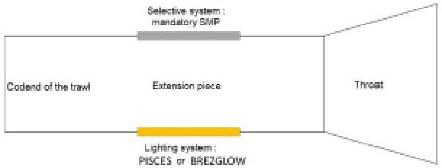
"Brezglow" phosphorescent wire manufactured by Le Drezen company

PISCES LED lights manufactured by SafetyNet company

1 Preliminary trials

Two preliminary fishing trips lasting 5 days were organised in the spring of 2019 in order to observe the behaviour of whiting and horse mackerel in response to the lighting systems and to **define the ideal location on the trawl for these lighting systems.**

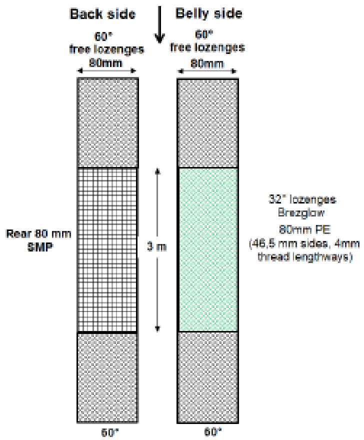
The results of these fishing trips highlight the fact that (at night) these lights and also the Brezglow phosphorescent wire **tend to repel whiting.** In order to encourage small whiting to escape, the **light must therefore be installed on the side opposite the square mesh panel.**



2 Configurations tested

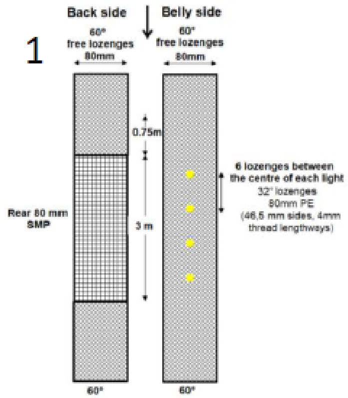
BREZGLOW

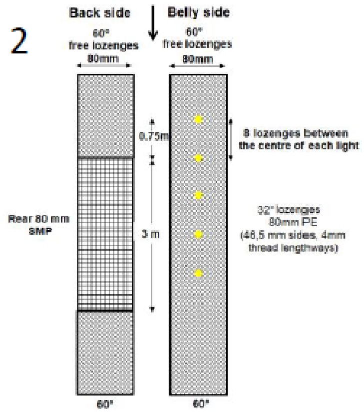
System tested in a single configuration on three 5-day fishing trips between December 2019 and September 2020 in zones 7d and 4c.



PISCES

System tested, in 2 configurations, over four 5-day fishing trips in zones 7d and 4c between October 2019 and June 2020. After the 1st fishing trip, it was decided to add another **PISCES** and **to install one of them above the SMP** so as to encourage the fish to ascend towards the SMP more quickly. It was also decided to use the PISCES in **flashing mode** because it was thought that horse mackerel tended to be repelled by flashing light.



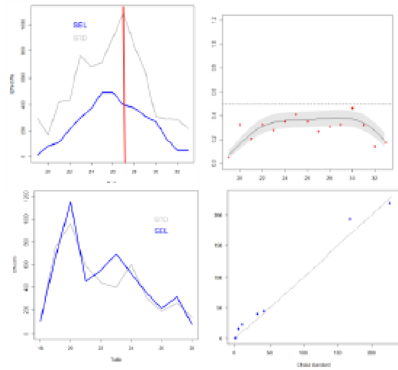


3 Results

The above results were obtained by comparing catches achieved using the test trawl to those achieved with the reference trawl.

PISCES

Species	Var. landings rate (mean)	Var. landings rate (total weight)	Var. discards rate (mean)	Var. discards rate (total weight)
Horse mackerel	+ 101%	+9%	+ 84%	+9%
Whiting	-14%	-7%	-8%	-3%



WHITING

The presence of PISCES leads to a reduction in catches only for the fishing trip in the month of March (green flashing light), and this applies to all sizes.

HORSE MACKEREL

In night-time hauls the presence of PISCES leads to an increase in catches (attraction). If only the hauls using flashing PISCES devices are analysed, there is no discernible difference (graph).

K. SMP/T90 trials technical document

Laboratoire technologies halieutiques
Département sciences et technologies halieutiques

Compte-rendu

Campagne Selux Navire Saint Jacques II, 17-21 Août 2020				
établi le : 7/01/21	par : F. MORANDEAU	Réf : DSTH/LTBH	n° analytique : P112-0022-01-MS	Thème/prog : SELUX

Objet : Campagne de sélectivité comparaison d'un panneau en T90 a un panneau en PMC. Méthodologie avec poche couvrante à double cul.

Diffusion :

Diffusion : confidentielle ☐ restreinte ☐ libre ☐

1 Objectifs

L'objectif premier du projet Selux est de tester les dispositifs sélectifs existant comme le panneau à maille carrée ou à maille tournée en T90 tout en utilisant la lumière comme optimisateur sélectif. Ce qui est visé avec la lumière c'est de permettre une réduction optimale des rejets de merlan et de chinchard et de conserver les espèces commercialisables. Il a été étudié sur la flottille des chalutiers Boulonnais de plus de 18m que 33% des captures de merlan sont rejetées en moyenne, et 83% pour le chinchard. A elles deux, ces espèces représentent 37% des rejets totaux. Toujours dans le cadre de Selux il a été a proposé également de réaliser une marée pour comparer le T90 et PMC qui permette d'avoir des résultats statistiques tout en fournissant une idée de la différence de sélectivité entre les deux dispositifs. En arrière-plan de cette campagne en mer il faut garder en tête que **l'objectif principal reste l'amélioration du PMC** 80, seul dispositif sélectif inscrit dans la règlementation européenne.

2 Contexte

Concernant le montage des mailles, les merlans passent plus facilement à travers le PMC que dans le T90. D'après les résultats du projet REJEMCELEC, avec un PMC 80mm il y a une perte des merlans sur l'ensemble du spectre de taille jusqu'à 36 cm, alors qu'avec le T90 on constate un très bon échappement des tailles sous TRMC (Tailles Minimales de Référence de Conservation), et dans une moindre mesure des individus de27-32cm. La pêche et la valorisation financière des plus gros individus pourraient potentiellement compenser la perte de tonnage liée à la bonne utilisation des dispositifs sélectifs (mailles + lumière). Néanmoins Il faut veiller à conserver un équilibre. Les professionnels présents ont rappelé **ne pêcher quasiment aucun merlan supérieur à 32cm.** (principalement du merlan 27-32cm). Les principaux rejets de merlan sont de taille 23-27 cm.

3 Moyens techniques et méthode

Pour comparer les deux panneaux sélectifs, une poche couvrante avec deux culs de récupération a été montée sur le dessus du dispositif de sélectivité afin de quantifier le nombre et le poids de merlan s'échappant. L'ensemble du dispositif est assemblé avec un petit maillage de 40 mm (jauge) soit la moitié moins que le maillage du cul de chalut standard et des dispositifs sélectifs de 80 mm (jauge). Les deux panneaux sélectifs sont jointés sur 3 m dans le sens de la longueur et intégré dans un « kit rallonge de chalut » de 5 m de longueur. La largeur de chaque panneau sélectif est de 1.21m (Fig.1).

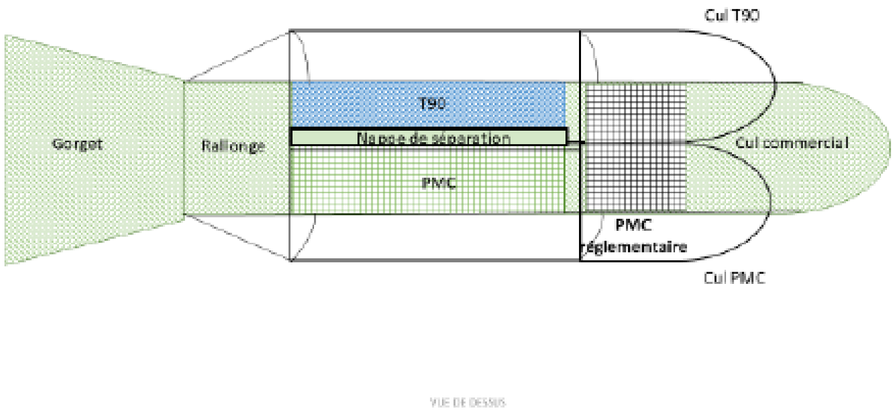


Figure 1 : Vue de dessus du dispositif poche couvrante double cul

3.1 Dispositif sélectif

Les deux panneaux sélectifs ont été aboutés l'un à l'autre dans le sens de la longueur. Deux dispositifs sélectifs ont été réalisés de tel sorte que les deux panneaux T90 et PMC puissent chacun être testés côté bâbord et côté tribord, ce qui statistiquement permet d'éliminer l'effet position des poches. Deux chaluts identiques ont donc été mobilisés pendant la campagne, un chalut tribord monté avec le T90 côté tribord et inversement pour le second chalut bâbord avec le T90 côté bâbord (Fig.2). A travers ces deux configurations ce qui a été recherché c'est une certaine homogénéité de comportement du merlan au contact des différents types de mailles sélectives (PMC et T90). En effet les ouvertures de maille sont différentes à cet endroit. La géométrie du chalut au fond et les poches couvrantes peuvent varier également en fonction du courant, notamment dans les secteurs fréquenté pendant les essais (fort courant avec de grand coefficient de marée).

Rappel :
Le panneau en maille T90, est fabriqué avec du maillage losange dont le principe consiste à donner une rotation de 90°. Le vide de maille est ainsi plus constant (plus ouvert) pendant le chalutage.
Le panneau à maille carré est également avec du maillage losange dont le principe consiste à donner une rotation de 45° l'objectif c'est que le vide de maille est également plus grand (plus ouvert) pendant le chalutage.

Les dimensions des panneaux ont la même surface et son conforme à la longueur réglementaire de 3m.

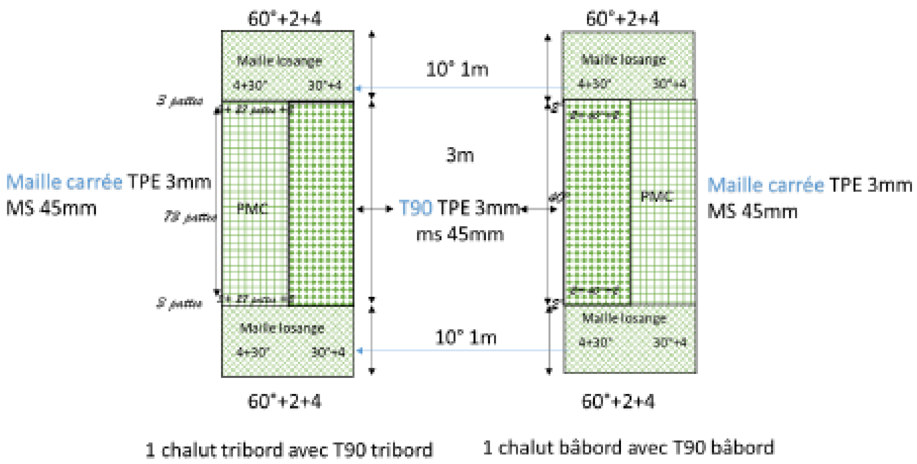


Figure 2 : Caractéristiques des panneaux sélectifs T90 et PMC

3.2 Dispositif poche couvrante

La conception de la poche couvrante a été réalisé à partir du manuelle de sélectivité « MANUAL OF METHODS OF MEASURING THE SELECTIVITY OF TOWED FISHING GEARS » (ICES COOPERATIVE RESEARCH REPORT NO. 215 by Wileman et all).

La poche couvrante est composée de 22 pièces en tous avec 6 panneaux latéraux A-E- I et D- H- K (coupe n et 1n1b. Fig.4) et avec 4 panneaux supérieurs B-C- F-G (coupe n et 1n1b) qui couvrent la zone d'échappement et la zone du gorget. La longueur totale de ces 4 panneaux est de 4.65 m soit 1.65 m de plus que la longueur des panneaux sélectif et respect en cela les recommandations du manuel. Le nombre de maille au niveau de la circonférence est 348 mailles de 40mm E-F G H dans le sens T et N (13.9 m) dans ce cas.

Les doubles culs des poches couvrantes sont constitués de 8 pièces M - M'et N-N 'et J -j'- K- k'' (coupe n et 8b1n). La longueur totale de ces culs est de 4 m et ont été prévu pour être manipuler facilement à bord du navire et ne pas masquer le pmc réglementaire.

Les deux volumes de récupération des espèces qui s'échappent aux travers des panneaux sélectifs sont créés par une nappe de séparation comprenant 4 panneaux O-P-Q-R (coupe ab et n). La longueur est au moins égale à B-C-F-G-k'-J'. La hauteur de cette nappe de séparation est de 1.50 m (hauteur théorique). La nappe séparatrice est aboutée en haut et en bas (entre les panneaux sélectif) par des ralingues.

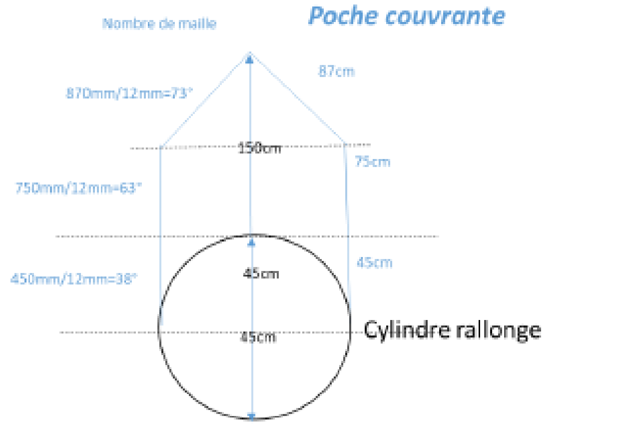
L'ensemble des pièces sont rassemblés une à une dans le sens de la longueur par trois mailles (ailière) ce qui permet une plus grande résistance pendant les manoeuvres de virage de la capture.
Les pièces sont aboutées au-dessus du gorget et de la rallonge du chalut par l'ajout d'une ralingue en PA dia.de 8mm.

Bases de calcul :
Maillage de poche couvrante 40mm (jauge) 23 mm côté de maille dia 4mm.
Calcul de la ½ circonférence maillage de 80mm losange : 46.5mm*cos75 = 46.5mm*0.259 = 12.03*2 = 24mm*60mailles = 1440mm

Nombre de mailles de 40mm sur la 1/2 circonférence :
- Ouverture d'une maille 23mm*COS 75 = 23mm*0.259 = 5.9*2= 12mm
- 1440mm/12mm = 120 mailles de 40mm
- 120°/ 4 (nappes) = 30

Calcul de la nappe séparatrice : Position vertical 1500mm au-dessus du T90.
Nombre de mailles 1500mm/ 12mm = 125 ° (arrondi 124 pour ajustement des coupes)

Figure 3 : Ouverture verticale théorique de la poche couvrante



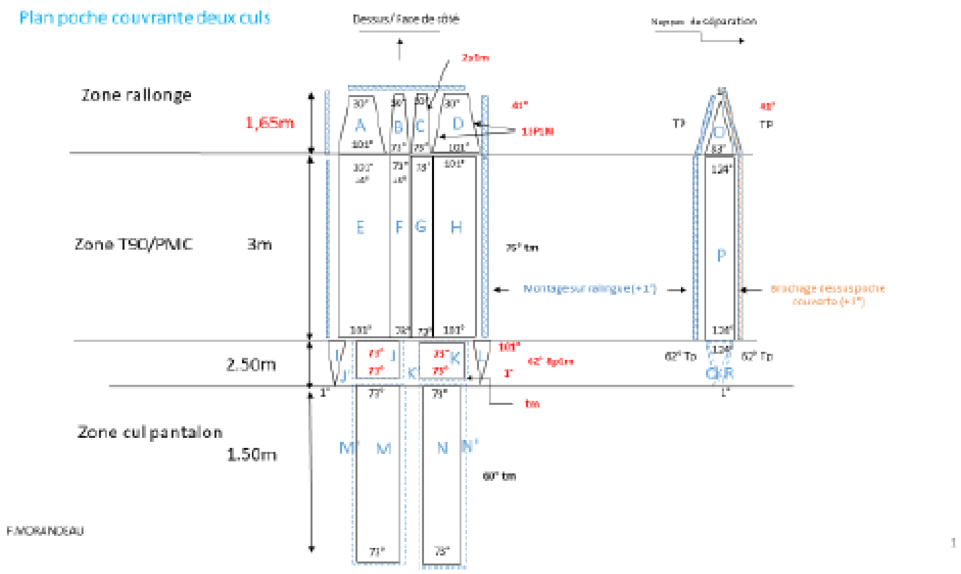


Figure 4 : Plan de la poches couvrante deux culs vue de dessus longueur et nombre de maille

Afin d'éviter le mascage de la poche couvrante sur les mailles T90 et maille carrée, 19 flotteurs de 4 litres et 4 kites ont été ajoutés. Les flotteurs de 4 litres sont mis entre A et B (6 flotteurs), 1 chapelets de 5 flotteurs entre

F et G et 2 autres chapelets de flotteurs sont positionnés en E et F. Le total de la flottabilité est de 67.2 kgf (3.2 kgf par flotteurs).

Les deux kites positionnés sur le dessus avant de la poche couvrante premettent de l'ouvrir verticalement et les deux mis sur les faces de côté permettent de l'écarté horizontalement. Des petits flotteurs sont montés de chaque côté des kites sur le dessus afin de les maintenir avec un angle vers le haut (8 flotteurs FOY1155A de 800grs soit 6.4 kgf de flottabilité).Sur les kites de côté une chaine (poids 1.1kg) à été mis sur le bas tandis que sur le haut se sont les 2 flotteurs (flotteurs FOY1155A de 800grs soit 1.6 kgf de flottabilité) afin de les maintenir à la verticale (Fig. 5).

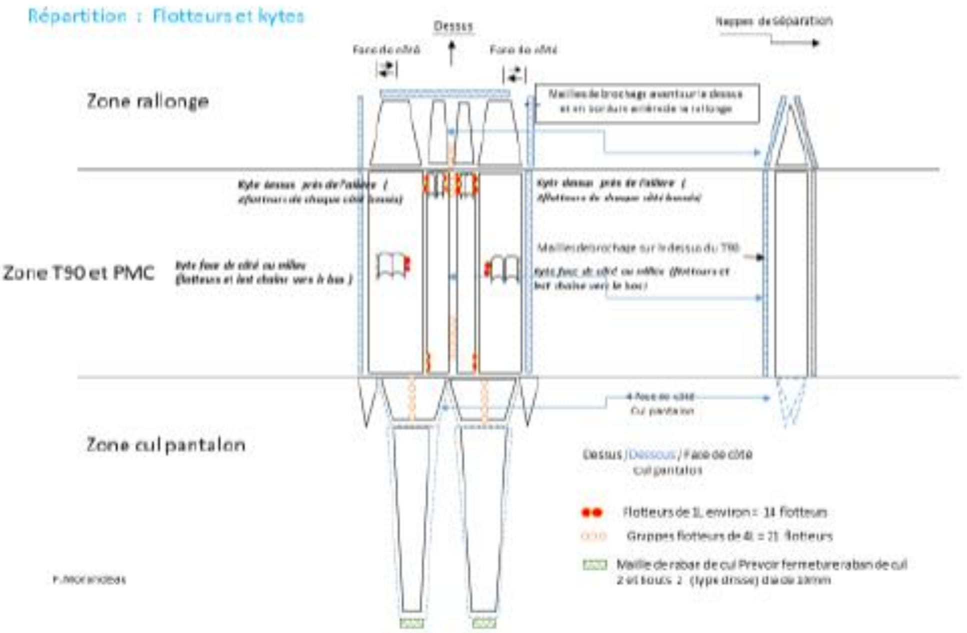
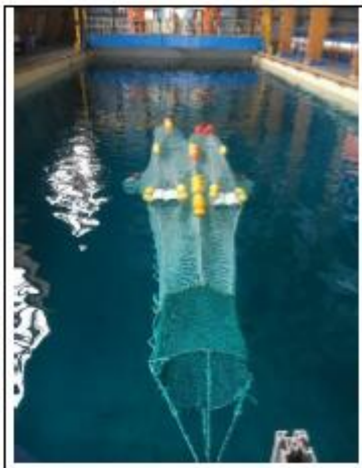


Figure 5 : Vue de dessus de la poche couvrante avec la répartition des flotteurs et de kytes

Poche couvrante double poche sur chalut



Photos n° 1: Essais bassin de Brest

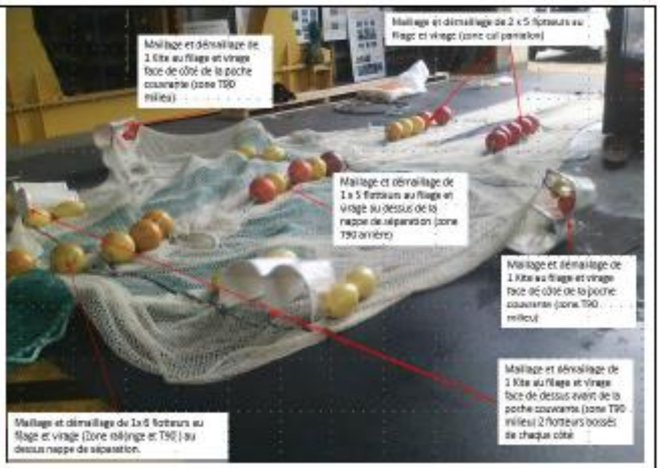


Photo n°2 : Dispositif poche couvrante kites et flotteurs

Résultats

Deux kits de sélectivité (comprenant la rallonge, avec sur le dessus le T90, le PMC et les *poches couvrantes avec doubles cul) ont ensuite été inclus au niveau de la rallonge des chaluts (2) du Saint Jacques II.*
Le montage du dispositif sur les chaluts a nécessité **deux heures de travail le matin du vendredi 14 août 2020.** En effet, le protocole de mesures impose que les deux panneaux soient inversés tribord/bâbord alternativement.
Deux kits de sélectivité ont donc été montés sur deux chaluts différents ayant les mêmes caractéristiques.
A chaque virage et filage du chalut, il faut greffer les kites et les flotteurs. Cette opération allonge la durée de la manoeuvre d'environ 10 minutes (X 2 20mn) par traits.
Le nombre de trait minimum avait été estimé à un minimum de 10 traits.

Sur l'ensemble de la campagne nous avons eu du beau temps. Ainsi 18 opérations ont été réalisé dont 14 traits validés avec la poche couvrante à deux culs. Sur l'ensemble un seul trait n'a pas été validé car une des culs s'est emmêlé au niveau des zones M et K (voir plan ci-dessus) et n'a pas réalisé de capture pendant le chalutage.

Tableau 1 : déroulement des OP et nombre de traits validés

NUM_OP	NUM_TRAIT	PARTIE	DEROUL+F:XEMENT_OP	ETAT_MER	DATE_FIN	DUREE_OP	LAT_DEB_OP	LONG_DEB_OP	LAT_FIN_OP	LONG_FIN_OP	ZONE	RECTANGLE	PROF_ENGIN
1	1	CUL	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	17/08/2020 16:35	180	51.69148	2.07595	51.82253	2.20085	27.4.c	32F2	54
2	1	POCHES		2 - belle, vagues de 0.1 à 0.5 mètres	17/08/2020 16:40	5	51.69148	2.07595	51.82253	2.20085	27.4.c	32F2	54
3	2	POCHES	Normal	3 - peu agitée, vagues de 0.5 à 1.25 mètres	18/08/2020 00:50	120	51.7791	2.16137	51.80883	2.18927	27.4.c	32F2	48
4	3	CUL	Normal	3 - peu agitée, vagues de 0.5 à 1.25 mètres	18/08/2020 10:30	120	51.74272	2.11968	51.79302	2.17333	27.4.c	32F2	48
5	3	POCHES	Normal	3 - peu agitée, vagues de 0.5 à 1.25 mètres	18/08/2020 10:35	5	51.74272	2.11968	51.79302	2.17333	27.4.c	32F2	48
6	4	POCHES	Normal	3 - peu agitée, vagues de 0.5 à 1.25 mètres	18/08/2020 14:00	120	51.81737	2.2009	51.81417	2.1924	27.4.c	32F2	48
7	5	POCHES	Normal	3 - peu agitée, vagues de 0.5 à 1.25 mètres	18/08/2020 17:15	120	51.79557	2.17582	51.75677	2.1355	27.4.c	32F2	50
8	6	POCHES	Normal	3 - peu agitée, vagues de 0.5 à 1.25 mètres	18/08/2020 20:40	120	51.73998	2.11513	51.73177	2.10928	27.4.c	32F2	47
9	7	POCHES	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	18/08/2020 23:40	120	51.75533	2.13278	51.79878	2.17995	27.4.c	32F2	47
10	8	CUL	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	19/08/2020 10:30	120	51.72077	2.09895	51.77162	2.15532	27.4.c	32F2	50
11	8	POCHES	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	19/08/2020 10:35	5	51.72077	2.09895	51.77162	2.15532	27.4.c	32F2	50
12	9	POCHES	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	19/08/2020 13:30	120	51.734	2.1098	51.80219	2.18315	27.4.c	32F2	48
13	10	POCHES	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	19/08/2020 17:30	130	51.79519	2.17647	51.74675	2.12367	27.4.c	32F2	47
14	11	POCHES	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	19/08/2020 20:35	120	51.76363	2.14212	51.69047	2.07012	27.4.c	32F2	50
15	12	POCHES	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	19/08/2020 23:35	120	51.6927	2.0734	51.74114	2.11635	27.4.c	32F2	50
16	13	CUL	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	20/08/2020 13:35	90	51.76877	2.14888	51.8158	2.19427	27.4.c	32F2	49
17	13	POCHES	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	20/08/2020 13:40	5	51.76877	2.14888	51.8158	2.19427	27.4.c	32F2	49
18	14	POCHES	Normal	2 - belle, vagues de 0.1 à 0.5 mètres	20/08/2020 16:50	120	51.79742	2.17933	51.80295	2.17945	27.4.c	32F2	48

- Cul = cul standard du chalut
- Poches = la poche couvrante avec ces deux culs.

Sur la totalité de la marée les échappements de merlan sont : pour le PMC de 17 923 kg et le T90 de 19 345 kg. Les structures en taille pour cette espèce montrent notamment un échappement du T90 légèrement plus important que le PMC pour les tailles < à 27cm et inversement au-delà (Fig. 6).

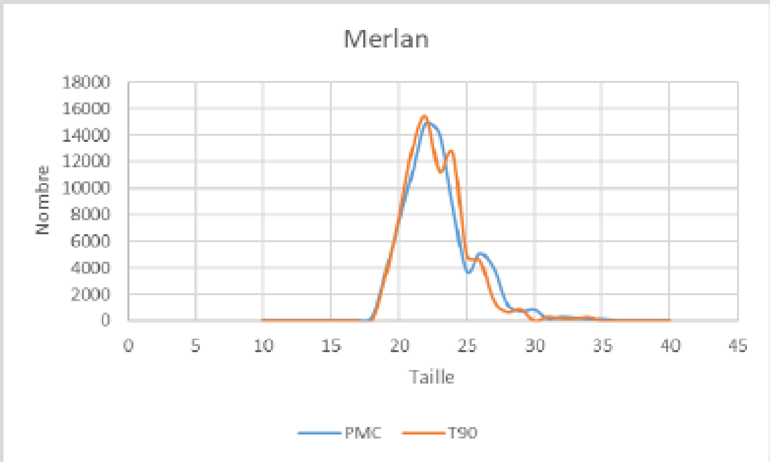


Figure 6 : Structure en taille des merlans échappés

Globalement le chinchard s'échappe plus dans le PMC avec 601kg contre 257 kg en T90 (Fig.7).

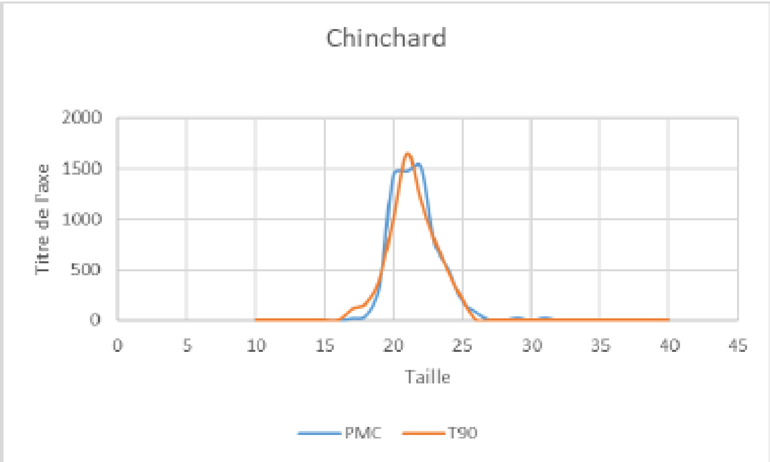


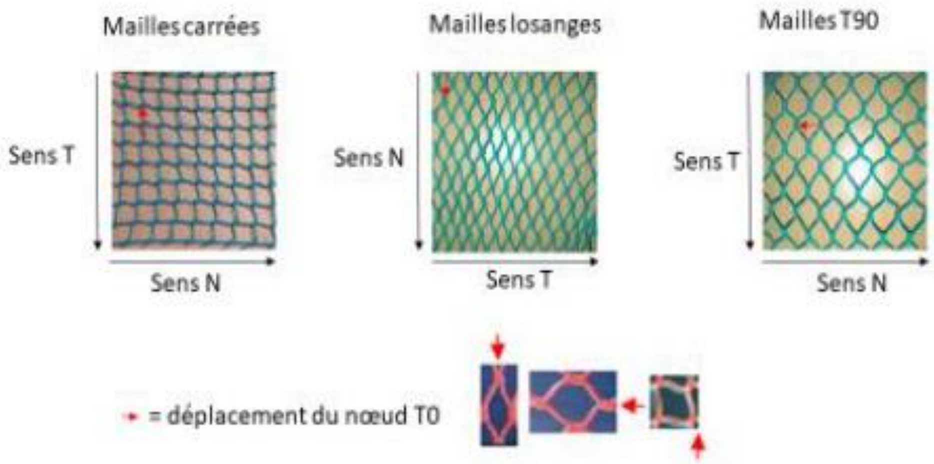
Figure 7 : Structure en taille des chinchards échappé

Conclusion

Concernant le merlan, le T90 répondrait plus largement aux objectifs de réduction de rejets dont la taille est inférieure à la PRMC tout en impactant moins les tailles commerciales. Le T90 présenterait donc un intérêt pour cette pêcherie car plus positivement sélectif que le PMC.A l'inverse pour le chinchard le PMC semble plus sélectif que le T90 pour l'ensemble du spectre de taille avec toutefois une grande variabilité dans les données de capture.

ANNEXES

Comparaison de l'ouverture des mailles de filet losange tournées de façon standard (T0), en T90 et carrée.



Virage de la poche couvrante deux culs :

Photos n° 3 : démaillage des flotteurs

Photos n°4 : virage des deux culs poche couvrante