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60 years of development in the selection systems used in bottom trawls for gadoid species

A review of the literature produced in the period between 1963 and 2021

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Contents

1. Summary of research conducted in the selectivity of bottom trawls for gadoid species in the period between 1963 and 2021

This document is a collection of research conducted throughout the last 60 years concerning the selectivity of bottom trawls for gadoid species. While the primary focus in this work was to summarize research conducted in the North -East Atlantic and Barents Sea, studies are also included from fisheries deploying similar gears in the USA, the Mediterranean, the Baltic Sea, the Pacific and regions throughout the Atlantic Ocean. As well as selectivity studies regarding gear modifications to bottom trawls, studies were also included that provided new knowledge concerning selectivity of important bycatch species, advances in methodologies used, research in fish behavior as well as various other gear related studies where trawl selectivity was impacted.

1.1 Early studies

Several early selectivity studies stemmed from interest from ICES seeking to alleviate problems of discard such as that conducted by Beverton (1963) in order to understand in more detail the degree of escapement that occurred in the codend. Particular focus was on the rows of meshes immediately in front of the bulk of the catch bulk in the codend. Escapement was found to be highest in this area of the codend compared to areas situated more forward in the trawl. Studies from ICES followed that sought to improve trawl selectivity by comparing for example double and single codends (Hylen and Smedstad, 1974), different headline lengths (Warren and Lovewell, 1976), horizontal separator panels (Main and Sangster, 1976) and lastridge rope designs (Isaksen and Valdemarsen, 1990).

1.2 Mesh size and configuration

Armstrong et al, (1990) highlighted the potential that finding a suitable mesh size coupled with other gear design factors can have on the selection efficiency. With the selectivity systems predominantly used today in the Barents Sea (the Flexigrid or Sort-V combined with a size selective codend), it is known that most of the fish escape through the grid section in a sequential selection process (Brinkhof et al., 2020), however it has been found that the selective properties of the codend are still unfavorable when it comes to undersized fish (Sistiaga et al., 2016a). According to Jørgensen and Ingolfsson (2006) however, the difference in efficiency between the codend compared to the sorting grid is not significant. Diamond mesh and square mesh of the same size can have significant differences in terms of the subsequent selection they produce for different gadoid species (Halliday et al., 1999; He, 2007) as well as the survivability that can be expected for escaping individuals (Suuronen et al., 2005). Unsurprisingly, larger mesh sizes are expected to retain larger fish, however, a square mesh compared to a diamond mesh codend of the same size can have a much narrower selection range (SR) and enable additional release of flatfish species that are often caught as bycatch in the demersal gadoid fisheries (He, 2007).

1.3 Escape windows and panels

Devices such as mesh windows or panels were shown to have good potential at increasing 50% retention length (L50) while maintaining or reducing the SR if placed optimally in the codend (Madsen et al., 2002; O'Neill et al., 2006; Grimaldo et al., 2007; Grimaldo et al., 2008). In the North-East Atlantic, square mesh panels and sorting grids are the two most-applied technical devices in the bottom trawl fishery to supplement the selection of diamond mesh codends (Sistiaga et al., 2018). Some variation is given with these results in the literature however, as different configurations and installations of the panels have led to varying results (Bullough et al., 2007; Herrmann et al., 2015; Brčić et al., 2016). Mesh windows may be a more optimal alternative compared to diamond mesh in terms of survivability, in particular for larger individuals (Suuronen et al., 2005; Grimaldo et al.,

2008). This can be an economical alternative to changing the entire mesh size as fishermen may still keep their standard gear, only adjusting the mesh in a section of the codend.

1.4 Rigid sorting grids

In efforts to supplement diamond mesh codend size selectivity, developments of rigid sorting grids as excluder devices began in the late 1980s in the North East Atlantic (Larsen, 1989). Today, sorting grids are one of the key mandatory selective gears enforced in the Barents Sea gadoid fishery. These became more common place following experiments that were done in Norway and Russia (Larsen and Isaksen, 1993; Isaksen et al., 1996) to reduce the high levels of juvenile fish retention that was being observed by fishermen. By 1997 the Sort-X and the Sort-V grid systems (Isaksen et al., 1996; Norwegian Directorate of Fisheries, 2017) with a minimum bar-spacing of 55 mm became mandatory. However, there were many reports from fishermen of concerns regarding safety at sea during the handling of these gears, particularly during bad weather conditions as these grids were made of steel. Further, studies have argued that the codend compared to the grid could have similar selection efficiency (Graham et al., 2004; Kvamme and Isaksen, 2004) and that the added selection by adding the sorting grid could have been achieved by increasing the mesh size alone by 20 mm (Jørgensen et al., 2006). Alternative grid designs were however then trialled using various plastic materials. A grid system called the Flexigrid was successful during these trials and was made of Polyamide (PA) bars and rubber frames. This system was lighter, smaller, more flexible, and therefore could alleviate the handling issues faced by fishermen (Angell et al., 2001). As a result, this grid system became legalized in 2002. In analyses of the individual contributions of the grids and the diamond mesh codend in a flexigrid system (Sistiaga et al., 2016; Brinkhof et al., 2020) it was found that 77% of haddock as well as 16% of cod above the minimum size escaped from this configuration (Brinkhof et al., 2020). This leads to added fishing effort required in order to compensate for the loss of legal sized fish and the associated greenhouse gas emissions that it produces. This is also reflected as added damage to the seabed and more retention of bycatch. Sistiaga et al (2016a) however found higher retention probabilities above and below the MRL both for cod and for haddock. A primary explanation for the variability in efficiency recorded by the flexigrid can be the angle at which the grids are installed at. A higher grid angle can lead to higher grid contact values, and therefore the development of methods to reduce this variation in grid performance may be beneficial.

Ongoing challenges have been in relation to the reduced speed of water flow through the grid section as this can increase the potential for blockages to occur and thereby reduce the selective potential of the grid. Changing from the standard 2-panel codend design to a 4-panel design has improved this as well as selectivity of the system somewhat (Grimaldo et al., 2015; Sistiaga et al., 2016a). However, the lifting panel that is usually used has been described as a major source of the reduction in flow (Gjøsund et al 2013). Therefore, alternatives are sought that can still maintain sufficient grid contact.

1.5 Selectivity at the mouth of the trawl

Investigations by Warren and Lovewell (1976) found that shortening the headline and reducing the size of the wings reduced catches of shrimp as well as gadoid bycatch in the Nephrops and whitefish fishery in the North Sea. Ingolfsson and Jørgensen (2006) identified the fishing line to also play a significant role in fish selection, particularly for cod, whereby up to one third of cod that would be caught by the mouth of the trawl were shown to escape below the fishing line. Modifications at the mouth of the trawl that affect bottom contact with the seabed have also been an important area of continued focus (Winger et al., 2004; Sistiaga et al., 2015). For gadoid species however it is difficult to maintain the herding mechanism created by the bottom contact of the gear, with significant

reductions observed for both cod and haddock catches when the degree of bottom contact is reduced (Sistiaga et al., 2015; Sistiaga et al., 2016b).

The vertical distribution of fish as they enter the bottom trawl has also been explored numerous times in the literature (e.g; Beutel et al., 2008; Krag et al., 2010; Sistiaga et al., 2015; Karlsen et al., 2018). Cod were shown to predominantly orientate themselves downwards as they enter, while haddock and saithe swim more upwards. Differences may also depend on length differences in the species. For example, Krag et al, (2010) saw smaller cod swam lower more frequently in the trawl during the night compared to trials conducted during the day. Differences between gadoid species may also have a high dependence for how far aft the separator devices are installed, as haddock for example tend to enter at all levels but swim upwards as they move aft (Engås et al, 1998). This tendency for haddock was harnessed in a USA haddock fishery when the mesh size of lower and upper wings was increased as well as the side panels and the lower belly in order to increase escapement for cod, while no impact on the retention of haddock was observed (Beutel et al., 2008). The topless trawl design tested by Krag et al, (2015) in the Nephrops fishery was also successful at releasing haddock over the headline as well as cod when this was installed at a lower height, with differences in escape being length dependent for both species.

1.6 Other miscellaneous studies

Several methodology studies are presented in this review that over time have shaped the way experiments have been designed in order to minimise sources of error and produce estimates that best describe selection processes taking place while fishing (Cadigan and Millar, 1992; Wileman et al, 1996; Millar and Fryer, 1999; Zuur et al, 2001; Herrmann 2005; Sistiaga et al., 2009; Herrmann et al., 2016). Improvements made to survey sampling methods (Engås and Godø, 1989; Dremiere et al, 1999; Herrmann et al., 2016) have helped to reduce instances of underestimation made during surveying with trawls. Many selectivity studies implement covers to quantify the change in escapement through a device of interest. Madsen and Holst (2002) assessed the efficacy of this experimental design with findings suggesting that covers can significantly affect the passage through devices such as square mesh windows. Techniques such as the paired gear method were also shown to have shortcomings in estimating the true variability between selection systems compared to the covered codend method (Herrmann et al., 2007; Sistiaga et al., 2009). Selecting the paired gear method rather than the covered codend method can have consequences if the same number of individuals are measured during sampling. The paired gear method was shown to require a much higher sampling effort to achieve a specific uncertainty level compared to the covered codend method (Herrmann et al., 2016). Other modern approaches that also consider the contact likelihood on grids as well as the angle of attack can help to explain the individual contribution of each of the selective gears more precisely (Sistiaga et al., 2010; Herrmann et al., 2013). In this situation, attaining precise results can be dependent on the experimental design, for example, the number of compartments that is used during the data collection process.

The survival of fish after they escape from a bottom trawl is an important factor when estimating the total impact of bottom trawling operations (Breen et al., 2007). Soldal et al, 1993 and Sangster et al, 1996 found that survival was high in general, with slightly more mortalities for haddock compared to cod and saithe. Sangster et al., (1996) found a length-dependent relationship for mortality after escape, with smaller individuals being less likely to survive. The relationship between survivability and mesh size however could not be determined. Suuronen et al., (2005) identified temperature as a determinant of survival after escape, with higher sea temperatures leading to higher risk of mortality for cod.

Various types of different stimuli have been shown to affect selectivity of fish in a bottom trawl, for example differences of trawling during day conditions compared to the night (Engås and Ona, 1990; Aglen et al., 1997). Gadoids behaved more consistently during the night and showed less frequent attempts at escape over the trawl compared to during the day, while gadoids also entered the mouth much more irregularly in space in the day compared to the night. Other forms of stimulation can also affect gadoid behavior in a bottom trawl. Mechanical stimulation for example fluttering float lines can affect haddock escape through a square mesh section, while cod seem to show much more reluctance to react to these as well as forms of light stimulation (Grimaldo et al., 2018).

1.7 Current status in gadoid bottom trawling technology and future recommendations

In recent years, pressure from the consumer and other industry stakeholders has been mounting to improve the bottom trawl fishery in numerous ways. While bycatch reduction remains high on the agenda, research is also needed to improve the quality of the final marketable product caught. The impact that this fishery has on the environment must also be considered, for example by reducing fuel consumption, moving towards biodegradable materials in the twine used as well as minimizing the unaccounted-for mortality. This can be a difficult task in a fishery involving multiple target and non-target species (Winger et al., 2010) as well as gear components and selection processes that take place during the fishing process (Suuronen et al., 2020).

As rigid grid designs used in the North-east Atlantic bottom trawl fishery for gadoid species have shown undesirable catch patterns and are difficult to maneuver, alternatives are needed that improve selectivity and regulate the catch quantity in order to preserve the quality of the catch (Brinkhof et al., 2018a; Ingolfsson and Brinkhof, 2020). Lastridge shortening has gained interest in recent years (Ingolfsson and Brinkhof et al., 2020, Herrmann et al., 2020) as it is thought that the diamond meshes become more open and the release of juvenile fish is increased due to the higher flow through the meshes.

Improving the quality of the catch by regulating the catch quantity during fishing at the sea floor will reduce the degree of deterioration that occurs on the catch before the catch reaches the surface (Madsen et al., 2008; Grimaldo et al., 2007, Brinkhof et al., 2021). The standard knotted codend design used today in the North-East Atlantic has been shown to inflict damages to atleast 90% of cod caught (Tveit et al., 2019; Digre et al., 2010; Olsen et al., 2013). Configurations using T90 mesh orientation may provide more favourable quality (Wienbeck et al., 2011; Digre et al., 2010). But more development is still needed to suit innovations such as that made by Brinkhof et al, (2018a) to industry scale use, as a new quality improving codend design could add significant value to the industry while simultaneously avoiding additional retention of juvenile fish.

Reference list

Aglen, A., Engås, A., Huse, I., Michalsen, K., Stensholt, B., 1997. Vertical distribution of cod, haddock and redfish; Impact on bottom trawl and acoustic surveys in the Barents Sea. ICES.

Angell, S., Lilleng, D., Vollstad, J., Grimaldo, E. 2001. Selectivity experiments with 55 and 60 mm Flexigrid in the bottom trawl fishery for cod. Experiments on board "Bliki" 11– 23 June 2001. SINTEF Fisheries and Aquaculture. SINTEF Fisheries and Aquaculture., STF80 A013, 19 (*in Norwegian*).

Armstrong, D.W., Ferro, R.S.T., MacLennan, D.N., Reeves, S.A., 1990. Gear selectivity and the conservation of fish. J. Fish Biol. 37, pp. 261–262.

Beutel, D., Skrobe, L., Castro, K., Ruhle, P., Ruhle, P., O'Grady, J., Knight, J., 2008. Bycatch reduction in the Northeast USA directed haddock bottom trawl fishery. Fish. Res. 94, pp. 190–198.

Beverton, R.J.H., 1963. Escape of Fish Through Different Parts of a Codend . In ICNAF Spec. Publ. 5, pp. 9–11.

Brčić, J., Herrmann, B., Sala, A., 2016. Can a square-mesh panel inserted in front of the codend improve the exploitation pattern in Mediterranean bottom trawl fisheries? Fish. Res. 183, pp. 13–18.

Breen, M., Huse, I., Ingólfsson, I., Madsen, N., Soldal, A. V., 2007. SURVIVAL: An assessment of mortality in fish escaping from trawl codends and its use in fisheries management. Final Report.

Brinkhof, J., Olsen, S.H., Ingólfsson, O.A., Herrmann, B., Larsen, R.B., 2018a. Sequential codend improves quality of trawl caught cod. PLoS One 13, e0204328.

Brinkhof, J., Larsen, R.B., Herrmann, B., Olsen, S.H., 2018b. Assessing the impact of buffer towing on the quality of Northeast Atlantic cod (*Gadus morhua*) caught with a bottom trawl. Fish. Res. 206, pp. 209–219.

Brinkhof, J., Herrmann, B., Larsen, R.B., Veiga-Malta, T., 2019. Effect of a quality-improving cod end on size selectivity and catch patterns of cod in bottom trawl fishery. Can. J. Fish. Aquat. Sci. 76, pp. 2110–2120.

Brinkhof, J., Larsen, R.B., Herrmann, B., Sistiaga, M., 2020. Size selectivity and catch efficiency of bottom trawl with a double sorting grid and diamond mesh codend in the North-east Atlantic gadoid fishery. Fish. Res. 231, 105647.

Brinkhof, J., Herrmann, B., Sistiaga, M., Larsen, R.B., Jacques, N., Gjøsund, S.H., 2021. Effect of gear design on catch damage on cod (*Gadus morhua*) in the Barents Sea demersal trawl fishery. Food Control 120, 107562.

Bullough, L.W., Napier, I.R., Laurenson, C.H., Riley, D., Fryer, R.J., Ferro, R.S.T., Kynoch, R.J., 2007. A year-long trial of a square mesh panel in a commercial demersal trawl. Fish. Res. 83, pp. 105–112.

Cadigan, N.G., Millar, R.B., 1992. Reliability of selection curves obtained from trouser trawl or alternate haul experiments. Can. J. Fish. Aquat. Sci. 49, pp. 1624–1632.

Digre, H., Hansen, U.J., Erikson, U., 2010. Effect of trawling with traditional and "T90" trawl codends on fish size and on different quality parameters of cod *Gadus morhua* and haddock *Melanogrammus aeglefinus*. Fish. Sci. 76, pp. 549–559.

Dremière, P.Y., Fiorentini, L., Cosimi, G., Leonori, I., Sala, A., Spagnolo, A., 1999. Escapement from the main body of the bottom trawl used for the Mediterranean international trawl survey (MEDITS), in: Aquatic Living Resources. ESME - Gauthier-Villars, pp. 207–217.

Engås, A., Godo, O.R., 1989. Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. ICES J. Mar. Sci. 45, pp. 269–276.

Engås, A., 1998. A species-selective trawl for demersal gadoid fisheries. ICES J. Mar. Sci. 55, pp. 835–845.

Engås, A., Ona, E., 1990. Day and night fish distribution pattern in the net mouth area of the Norwegian bottom-sampling trawls. 123-127. ICES.

Gjøsund, S.H., Grimaldo, E., Sistiaga, M., Hansen, K., 2013. Hastighetsmålinger i 2- og 4-panel enkeltristseksjoner (Velocity measurements in 2- and 4-panel single grid sections)., 27. SINTEF Fiskeri og havbruk.

Graham, N., O'Neill, F.G., Fryer, R.J., Galbraith, R.D., Myklebust, A., 2004. Selectivity of a 120 mm diamond cod-end and the effect of inserting a rigid grid or a square mesh panel. Fish. Res. 67, pp. 151–161.

Grimaldo, E., Larsen, R.B., Holst, R., 2007. Exit Windows as an alternative selective system for the Barents Sea Demersal Fishery for cod and haddock. Fish. Res. 85, pp. 295–305.

Grimaldo, E., Sistiaga, M., Larsen, R.B., 2008. Evaluation of codends with sorting grids, exit windows, and diamond meshes: Size selection and fish behaviour. Fish. Res. 91, pp. 271–280.

Grimaldo, E., Sistiaga, M., Herrmann, B., Gjøsund, S.H., Jørgensen, T., 2015. Effect of the lifting panel on selectivity of a compulsory grid section (Sort-V) used by the demersal trawler fleet in the Barents Sea cod fishery. Fish. Res. 170, pp. 158–165.

Grimaldo, E., Sistiaga, M., Herrmann, B., Larsen, R.B., Brinkhof, J., Tatone, I., 2018. Improving release efficiency of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) in the Barents Sea demersal trawl fishery by stimulating escape behaviour. Can. J. Fish. Aquat. Sci. 75, pp. 402–416.

Halliday, R.G., Cooper, C.G., Fanning, P., Hickey, W.M., Gagnon, P., 1999. Size selection of Atlantic cod, haddock and pollock (saithe) by otter trawls with square and diamond mesh codends of 130-155 mm mesh size. Fish. Res. 41, pp. 255–271.

He, P., 2007. Selectivity of large mesh trawl codends in the Gulf of Maine. I. Comparison of square and diamond mesh. Fish. Res. 83, pp. 44–59.

Herrmann, B., 2005. Effect of catch size and shape on the selectivity of diamond mesh cod-ends: I. Model development. Fish. Res. 71, pp. 1–13.

Herrmann, B., Frandsen, R.P., Holst, R., O'Neill, F.G., 2007. Simulation-based investigation of the paired-gear method in cod-end selectivity studies. Fish. Res. 83, pp. 175–184.

Herrmann, B., Sistiaga, M., Larsen, R.B., Nielsen, K.N., Grimaldo, E., 2013. Understanding sorting grid and codend size selectivity of Greenland halibut (*Reinhardtius hippoglossoides*). Fish. Res. 146, pp. 59–73.

Herrmann, B., Wienbeck, H., Karlsen, J.D., Stepputtis, D., Dahm, E., Moderhak, W., 2015. Understanding the release efficiency of Atlantic cod (*Gadus morhua*) from trawls with a square mesh

panel: Effects of panel area, panel position, and stimulation of escape response. ICES J. Mar. Sci. 72, pp. 686–696.

Herrmann, B., Sistiaga, M., Santos, J., Sala, A., 2016. How many fish need to be measured to effectively evaluate trawl selectivity? PLoS One 11, e0161512.

Herrmann, B., Sistiaga, M., Larsen, R.B., Brinkhof, J., Gjøsund, S.H., Jacques, N., Santos, J., 2020. Catch pattern and size selectivity for a gear designed to prevent fish injuries during the capture process in a North-East Atlantic demersal trawl fishery. Reg. Stud. Mar. Sci. 40, 101525.

Hylen, A., Smedstad, O.M., 1974. Observations from the Barents Sea in spring 1973 on the discarding of cod and haddock caught in bottom and midwater trawls fitted with double cod ends.

Ingólfsson, Ó.A., Brinkhof, J., 2020. Relative size selectivity of a four-panel codend with short lastridge ropes compared to a flexigrid with a regular codend in the Barents Sea gadoid trawl fishery. Fish. Res. 232, 105724.

Isaksen, B., Valdemarsen, J.W., 1990. Codend With Short Lastridge Ropes to Improve Size Selectivity in Fish Trawls. ICES CM 1990/B:

Isaksen, B., Lisovsky, S., Larsen, R.B., Sakhnoe, V., Gamst, K., Misund, R., 1996. Joint Russian–Norwegian Selectivity Experiments on Cod (*Gadus morhua*) in the Barents Sea, 1995, Fisken og havet.

Ingólfsson, Ó.A., Jørgensen, T., 2006. Escapement of gadoid fish beneath a commercial bottom trawl: Relevance to the overall trawl selectivity. Fish. Res. 79, pp. 303–312.

Jørgensen, T., Ingólfsson, Ó.A., Graham, N., Isaksen, B., 2006. Size selection of cod by rigid grids-Is anything gained compared to diamond mesh codends only? Fish. Res. 79, pp. 337–348.

Karlsen, J.D., Krag, L.A., Herrmann, B., Lund, H.S., 2019. Using vertical distribution to separate fish from crustaceans in a mixed species trawl fishery. Can. J. Fish. Aquat. Sci. 76, 1781–1794.

Krag, L.A., Holst, R., Madsen, N., Hansen, K., Frandsen, R.P., 2010. Selective haddock (*Melanogrammus aeglefinus*) trawling: Avoiding cod (*Gadus morhua*) bycatch. Fish. Res. 101, pp. 20–26.

Krag, L.A., Herrmann, B., Karlsen, J.D., Mieske, B., 2015. Species selectivity in different sized topless trawl designs: Does size matter? Fish. Res. 172, pp. 243–249.

Kvamme, C., Isaksen, B., 2004. Total selectivity of a commercial cod trawl with and without a grid mounted: Grid and codend selectivity of north-east Artic cod. Fish. Res. 68, pp. 305–318.

Larsen, R.B., 1989. A pilot test with a new technology in bottom trawls to avoid catch of juvenile fish (*in Norwegian*).

Larsen, R.B., Isaksen, B., 1993. Size selectivity of rigid sorting grids in bottom trawls for Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*), ICES mar. Sei. Symp.

Main, J., Sangster, G.I., 1985. Trawling experiments with a two-level net to minimise the undersized gadoid by-catch in a Nephrops fishery. Fish. Res. 3, pp. 131–145.

Madsen, N., Holst, R., 2002. Assessment of the cover effect in trawl codend selectivity experiments. Fish. Res. 56, pp. 289–301.

Madsen, N., Holst, R., Foldager, L., 2002. Escape windows to improve the size selectivity in the Baltic cod trawl fishery. Fish. Res. 57, pp. 223–235.

Madsen, N., Skeide, R., Breen, M., Krag, L.A., Huse, I., Soldal, A. V., 2008. Selectivity in a trawl codend during haul-back operation-An overlooked phenomenon. Fish. Res. 91, 168–174.

Millar, R.B., Fryer, R.J., 1999. Estimating the size-selection curves of towed gears, traps, nets and hooks. Rev. Fish Biol. Fish. 9, pp. 89–116.

Norwegian Directorate of Fisheries. 2017. J-181-2017: Regulations on the use of sorting grid systems in fishing with large-mesh trawls (*in Norwegian*). Valid from: 24.10.2017.

Olsen, S.H., Tobiassen, T., Akse, L., Evensen, T.H., Midling, K.T., 2013. Capture induced stress and live storage of Atlantic cod (*Gadus morhua*) caught by trawl: Consequences for the flesh quality. Fish. Res. 147, pp. 446–453.

O'Neill, F.G., Kynoch, R.J., Fryer, R.J., 2006. Square mesh panels in North Sea demersal trawls: Separate estimates of panel and cod-end selectivity. Fish. Res. 78, pp. 333–341.

Sangster, G.I., Lehmann, K., Breen, M., 1996. Commercial fishing experiments to assess the survival of haddock and whiting after escape from four sizes of diamond mesh cod-ends. Fish. Res. 25, pp. 323–345.

Sistiaga, M., Herrmann, B., Larsen, R.B., 2009. Investigation of the paired-gear method in selectivity studies. Fish. Res. 97, pp. 196–205.

Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R.B., 2010. Assessment of dual selection in grid-based selectivity systems. Fish. Res. 105, pp. 187–199.

Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R.B., Tatone, I., 2015. Effect of lifting the sweeps on bottom trawling catch efficiency: A study based on the Northeast arctic cod (*Gadus morhua*) trawl fishery. Fish. Res. 167, pp. 164–173.

Sistiaga, M., Brinkhof, J., Herrmann, B., Grimaldo, E., Langård, L., Lilleng, D., 2016a. Size selective performance of two flexible sorting grid designs in the Northeast Arctic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) fishery. Fish. Res. 183, pp. 340–351.

Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R.B., Tatone, I., 2016b. The effect of sweep bottom contact on the catch efficiency of haddock (*Melanogrammus aeglefinus*). Fish. Res. 179, pp. 302–307.

Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R.B., Olsen, L., Brinkhof, J., Tatone, I., 2018. Combination of a sorting grid and a square mesh panel to optimize size selection in the North-East Arctic cod (*Gadus morhua*) and redfish (*Sebastes* spp.) trawl fisheries. ICES J. Mar. Sci. 75, pp. 1105–1116.

Soldal, A. V., Engås, A., Isaksen, B., 1993. Survival of gadoids that escape from a demersal trawl, ICES mar. Sei. Symp.

Suuronen, P., 2005. Mortality of Fish Escaping Trawl Gears. Food & Agriculture Org.

Suuronen, P., Gilman, E., 2020. Monitoring and managing fisheries discards: New technologies and approaches. Mar. Policy 116, 103554.

Tveit, G.M., Sistiaga, M., Herrmann, B., Brinkhof, J., 2019. External damage to trawl-caught northeast arctic cod (*Gadus morhua*): Effect of codend design. Fish. Res. 214, pp. 136–147.

Warren, P.J., Lovewell, S., 1976. Further consideration of two types of trawl used in a whitefish/Nephrops fishery.

Wienbeck, H., Herrmann, B., Moderhak, W., Stepputtis, D., 2011. Effect of netting direction and number of meshes around on size selection in the codend for Baltic cod (*Gadus morhua*). Fish. Res. 109, pp. 80–88.

Wileman, D.A., Ferro, R.S.T., Fonteyne, R., Millar, R.B., 1996. Manual of methods of measuring the selectivity of towed fishing gears, ICES, Cooperative Research Report No. 215.

Winger, P.D., Eayrs, S., Glass, C.W., 2010. Fish Behavior near Bottom Trawls, in: Behavior of Marine Fishes: Capture Processes and Conservation Challenges. Wiley-Blackwell, pp. 65–103.

Zuur, G., Fryer, R.J., Ferro, R.S.T., Tokai, T., 2001. Modelling the size selectivities of a trawl codend and an associated square mesh panel. ICES J. Mar. Sci. 58, pp. 657–671.

2. List of selectivity research conducted in the bottom trawl fishery for gadoid species

Title: Escape of Fish Through Different Parts of a Codend		
Author(s): Beverton	Institution: ICES	Year: 1963
Document type: Article	Gear type: bottom trawl	Location: Barents Sea
Objectives: To test the inference that most of fish escape through the first few rows of open and stretched meshes above the 'bag' (bulge) of the codend. This was measured by the escapement of demersal as well as pelagic species through a covered codend divided transversally into 4 compartments.		
Results: Results were collected for whiting, dab and horse mackeral. For all species, approximately 95% escaped through the aft most compartment. Fr all species, more escapement was also seen through the first compartment covering the rear of the belly compared to the middle two compartments. However. the first compartment covered a greater area of net as well as net that had a larger mesh size, therefore the true frequency of escapement, in particular for dab, was probably less from this compartment compared to the middle two. The results highlight the high degree of escapement that can be expected through the last few rows of 'clear' meshes in front of the bag/ bulge of the codend.		

Title: Observations from the Barents Sea in spring 1973 on the discarding of cod and haddock caught in bottom and midwater trawls fitted with double cod ends		
Author(s): Hylen and Smedstad	Institution: ICES	Year: 1974
Document type: Article	Gear type: bottom and midwater trawls	Location: Barents Sea
Objectives: To observe discarding onboard commercial trawlers using bottom and midwater trawls with double and single codends. These had a 130 mm codend. Some hauls used a double codend type chafer fastened to the anterior end of the codend. This had the same mesh size as the codend.		
Results: Discarding of cod caught using a trawl fitted with a double cod end was 27% by numbers and 11% by weight. For the midwater trawl catches 39% of cod was discarded by number and 22% by weight. Discarding of haddock from the same bottom trawl hauls was 3 - 7% by weight and no discarding was observed from the midwater trawl catches.		

Title: Further consideration of two types of trawl used in a whitefish/Nephrops fishery		
Author(s): Warren and Lovewell	Institution: ICES	Year: 1976
Document type: Report	Gear type: Shrimp and prawn trawl	Location: North Sea
Objectives: Comparing the catch from a standard Nephrops/whitefish trawl with that of a Gulf of Mexico penaeid shrimp trawl. Both trawls were constructed with a 35 mm unimesh but the headline lengths differed by a factor of two; the prawn trawl had a 86 foot headline and long wings and the Gulf trawl had a 41 foot headline and short wings.		
Results: The angle between the towing warps for both trawls was approximately similar, despite the different headline lengths. Catches of shrimp as well as gadoid bycatch were consistently smaller in the Gulf trawl compared to the “prawn” trawl. The Gulf trawl however caught more Nephrops than the “prawn” trawl. Longer wings may have encouraged Nephrops escape.		

Title: Trawling experiments with a two-level net to minimise the undersized gadoid by-catch in a Nephrops fishery		
Author(s): Main and Sangster	Institution: ICES	Year: 1976
Document type: Article	Gear type: Fish/prawn trawl	Location: Scottland
Objectives: To compare the ability of a 70 mm separator panel inserted horizontally 75 cm above the footrope in a fish/prawn trawl to separate haddock and whiting from Nephrops and groundfish (cod, flatfish and skates).		
Results: By using the separator trawl, it was possible to separate the majority of haddock (89%) and whiting (55%) into the top codends when the 75 cm panel was used. Of these, 60.2 and 52.3% were smaller than 27 cm. Fish caught in the top codend were of higher quality compared to more damaged fish in the lower codend.		

Title: Selectivity experiments with square mesh codends in bottom trawl		
Author(s): Isaksen and Valdemarsen	Institution: -	Year: 1986
Document type: Article	Gear type: two sizes of diamond mesh and square mesh codend	Location: Barents Sea
Objectives: To reduce retention of small cod and haddock using square mesh codends compared to diamond mesh, and to compare selection curves produced sing the covered codend method and the alternate haul method (using trouser trawl).		
Results: The modified trouser trawl method was favoured over the covered codend method. Square mesh codends gave a higher 50% retention length and selection factor compared to the diamond mesh codend for both cod and haddock. Noted difficulties with emptying large catches when using the square mesh codend due to the fixed circumference.		

Title: The effect of different sweep lengths on length composition of bottom sampling trawl catches		
Author(s): Engås and Godø	Institution: -	Year: 1987
Document type: Article	Gear type: Different sweep lengths on a standard sampling trawl	Location: Barents Sea
Objectives: To compare length and species selection by a standard sampling trawl configured with 4 different sweep lengths.		
Results: Total catch increases with increasing sweep length. Small fish are underestimated by trawls configured with longer sweeps but no species selection was observed throughout the trials.		

Title: Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results		
Author(s): Engås and Godø	Institution: -	Year: 1989
Document type: Article	Gear type: Sampling trawl	Location: Barents Sea
Objectives: Due to problems with underestimation by sampling trawls from IMR of undersized individuals, experiments were carried out with small collection bags attached under the trawl in order to quantify this loss.		
Results: A length dependent escape of cod and haddock was found beneath the trawl; small fish are easily able to pass beneath the ground gear and cause underestimation of these length classes in the survey estimations.		

Title: Gear selectivity and the conservation of fish		
Author(s): Armstrong, Ferro, MacLennan and Reeves	Institution: -	Year: 1990
Document type: Article	Gear type: Trawls and seines	Location: Barents Sea
Objectives: A discussion on important factors related to gear design that should be considered in order to attain optimal selectivity, to preserve juvenile stocks for harvest at maturity and to reduce the risk of future stock collapse.		
Results: The complexities of species and size specific measures that must be compromised for good selection is highlighted. An overview is provided on the selection ogive and how it depends on the design of the gear. Choosing a mesh size appropriate to the fishery in question is outlined as an important aspect of fisheries management to reduce the retention of undersized fish. This as well as other gear design factors must be balanced with what is practically possible for fishermen.		

Title: Codend with short lastridge ropes to improve size selectivity in fish trawls		
Author(s): Isaksen and Valdemarsen	Institution: ICES	Year: 1990
Document type: Article	Gear type: Trawls and seines	Location: Barents Sea
Objectives: To test the efficiency of a 135 mm codend with 12-15% shortened lastridge ropes.		
Results: The selective potential of a 135 mm codend with 12-15% shortened lastridge ropes was comparable to a regular 155 mm codend. The codend held its shape well in the water during fishing as the catch accumulated. Practical use and implementation of lastridge shortening is compared to square-mesh panels.		

Title: Day and night fish distribution pattern in the net mouth area of , the Norwegian bottom-sampling trawl		
Author(s): Engås and Ona	Institution: -	Year: 1990
Document type: Article	Gear type: bottom-sampling trawl	Location: Barents Sea
Objectives: To analyse the position of gadoids in the mouth of the trawl in different ambient levels of light. Using a high-frequency scanning sonar mounted as a net sonde, observations were made for day and night trials using a Norwegian bottom-sampling trawl.		
Results: At night the fish entered the middle of the trawl, close to the bobbins, and no fish were observed escaping over the headline. During observations in daylight the fish entered more irregularly, using the whole opening of the trawl, and haddock were lost over the headline. The observations indicate that the herding process during bottom trawling may be equally efficient by day and night, and that hearing must play a significant role in this process under non-visual conditions.		

Title: Reliability of selection curves obtained from trouser trawl or alternate haul experiments		
Author(s): Cadigan and Millar	Institution: ICES	Year: 1992
Document type: Article	Gear type: Trawl selectivity	Location: Barents Sea
Objectives: To compare the efficiency of two traditional methods for fitting selectivity curves which consider the "proportion retained. These were compared to a third method which instead is calculated by considering the proportion of the total catch from the test and control in relation to that which is in the test codend alone.		
Results: The third method (SELECT method) was found to display little or no bias and consistently had the lowest mean square error of the three methods. The first two methods always overestimated L50 and exhibited considerable bias in their estimates.		

Title: Survival of gadoids that escape from a demersal trawl		
Author(s): Soldal, Engås and Isaksen	Institution: -	Year: 1993
Document type: Article	Gear type: Bottom trawl	Location: Barents Sea
Objectives: To examine the vulnerability of saithe, cod and haddock towards gear damages inflicted by the catch process of bottom trawls. Simulated net injuries were inflicted on penned gadoid individuals who additionally were forced to swim through net panels. Physical exhaustion was also induced by swimming cod and haddock on a treadmill in order to simulate the swimming activity in the trawl mouth and belly.		
Results: This study suggested that a high survival rate can be expected for gadoids escaping a bottom trawl. No immediate mortality was observed for cod and saithe, whereas about 10% mortality was found for haddock. Both saithe and haddock developed infections in the wounded skin areas, leading to a delayed mortality of about 10%. Full-scale field experiments during bottom trawling for cod and haddock in the Barents Sea supported the low mortality rates found in the small-scale tests. No mortality was observed for cod, while for haddock it was less than 10%.		

Title: Size selectivity of rigid sorting grids in bottom trawls for Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*)		
Author(s): Larsen and Isaksen	Institution: -	Year: 1993
Document type: Article	Gear type: Rigid 55 mm grid	Location: Barents Sea
Objectives: To determine the size selectivity in trawls on cod and haddock when a 55 mm grid section is inserted in the grid section of a trawl, ahead of the codend. Selectivity was measured using a cover over the grid section and a blinded codend. This was intended to improve selectivity of the codend as selection could only occur there in a small section, ie; a few rows ahead of the accumulating catch		
Results: Selection ranges on cod and haddock ranged from 4.6 cm to 8.5 cm while 50% retention lengths of 47.8 cm and 50.2 cm were obtained.		

Title: Experiences using the constraint technique on bottom trawl doors		
Author(s): Engås and Ona	Institution: ICES	Year: 1993
Document type: Article	Gear type: Bottom trawl doors	Location: Barents Sea
Objectives: The constraint technique was tested on two different trawls used in Norwegian surveys; a GOV trawl and a Campelen trawl. The constraint technique involves a rope attached between the two warps in order to minimize the variability in trawl geometry with depth during trawling.		
Results: The systematic variability in geometry of the two trawls could be significantly reduced when the constraints were used. Handling and practical problems of the rope were minimal when conditions at sea were fair, and this technique was adopted for surveying shrimp using bottom trawls in the Barents Sea and Svalbard area and is expected to also be used for cod and haddock surveying in the near future.		

Title: Joint Russian-Norwegian selectivity experiments on cod (*Gadus morhua*) in the Barents Sea, 1995		
Author(s): Isaksen, Lisovsky, Larsen, Sakhnoe, Gamst, Misund	Institution: Havforskningsinstituttet	Year: 1996
Document type: Report	Gear type: Sort-X and the Russian single grid sorting system	Location: Barents Sea
Objectives: To determine selectivity differences between the Sort-X and the Russian single grid sorting system used in the Barents Sea in order to establish sorting grids to be established in the fishery. Both grids used had a bar-spacing of 55 mm.		
Results: The Norwegian sorting system (sort-X) gave a slightly better selection than the Russian one. The sort-X selection curve was slightly sharper with a SR of 11 cm compared to 15 cm for the Russian single grid system. Both systems had a very good release of small fish; with an escape rate for fish smaller than 42 cm of 93-94% and of fish smaller than 47 cm of 88-89%. When the sorting systems were used during commercial fishing without any kind of cover net, Norwegian and Russian trawls gave almost equal length distributions of fish, whereby introduction of either of the systems to the fishery would undoubtedly improve selection in bottom trawls.		

Title: Commercial fishing experiments to assess the survival of haddock and whiting after escape from four sizes of diamond mesh cod-ends		
Author(s): Sangster, Lehmann and Breen	Institution: -	Year: 1996
Document type: Article	Gear type: Bottom trawl diamond mesh codend	Location: Inner Sound, Scotland
Objectives: To investigate the survival of haddock and whiting following escape from 70, 90, 100 and 110 mm diamond mesh in the codend when towed at 2.9 knots by a 550 hp commercial fishing vessel.		
Results: Survival of the control fish was 100% for both species analysed. For small individuals that escaped, chances of survival were much lower than for larger individuals, suggesting that survival may be a more complex function of length. No relationship could be found between survival and mesh size for both species for any of the mesh sizes tested.		

Title: Manual of methods of measuring the selectivity of towed fishing gears		
Author(s): Wileman, Ferro, Fonteyne, Millar	Institution: ICES	Year: 1996
Document type: Article	Gear type: Towed fishing gears	Location: -
Objectives: To update the sections of a previous FAO manual describing methods for measuring the selectivity of fishing gears to give a more in depth description of existing approaches for work done with towed gears. This follows improvements to understanding of the principles of fish selection by gears to include important new parameters known to have a significant effect on selection and that need to be included in measurements taken at sea. This manual also includes developments that have been made to statistical models and the technique of analyses implemented using modern technology.		
Results: The manual provides a means to gear technologists for planning, designing, conducting, analysing and reporting their experiments, described in chronological order.		

Title: Vertical distribution of cod, haddock and redfish; lmpact on bottom trawl and acoustic surveys in the Barents Sea		
Author(s): Aglen, Engås, Huse, Michalsen and Stensholt	Institution: ICES	Year: 1997
Document type: Report	Gear type:	Location: Barents Sea
Objectives: To collect bottom and pelagic trawl catch data over a 10-day period in a selected location in the Barents Sea, near the North Cape Bank. To do this, trawl samples and acoustic data were analysed and positions of cod, haddock and redfish were extracted and related to measurements of light, current and temperature.		
Results: High acoustic values could only be extracted during a few hours of the day. These recordings were found to be large haddock ascending from the bottom, when sampled using the pelagic trawl. When the pelagic trawl was used at night, the recordings were dominated by small haddock and small redfish. The bottom trawl data collected indicated higher variability and larger catches during the day compared to the night time. However, this data was lower in variation compared to that collected using acoustic readings. The findings were in accordance with the pelagic data collected for small haddock and small redfish, displaying their migrations clearly to the sea floor during the day. Cod was found to remain on the sea floor in general throughout the day and the night recordings made.		

Title: A species-selective trawl for demersal gadoid fisheries		
Author(s): Engås, Jørgensen and West	Institution: -	Year: 1998
Document type: Article	Gear type: Horizontal square mesh panel	Location: Barents Sea
Objectives: To test a species selective bottom trawl for separating cod from haddock and saithe. The sorting sytem was composed of a horizontal square mesh panel (150 mm bar length) dividing the trawls body and extension section into upper and lower compartments leading aft into vertically separated trouser codends.		
Results: During the first cruise approximately 90% of the haddock and 70% of the saithe were caught I the upper codend, with 70% of the cod in the lower codend. During the second cruise 90% of the haddock and 60% of the saithe were caught in the upper codend with 65% of the cod caught in the lower codend. Video recordings indicated a tendency for haddock to enter the trawl at all levels but subsequently, several that entered low attacked upwards through the separating panel as they moved aft.		

Title: Escapement from the main body of the bottom trawl used for the Mediterranean international trawl survey		
Author(s): Dremiere, Fiorentini, Cosimo, Leonori, Sala, Spagnolo	Institution: -	Year: 1999
Document type: Article	Gear type: Bottom trawl	Location: Mediterranean
Objectives: To assess escapement through the body or under the footrope of a Mediterranean sampling trawl using visual observations and by attaching small collection bags to the outside of the trawl body as well as under the footrope.		
Results: Data were collected for Norway lobster, greater forkbeard, hake, common pandora, poor cod, red mullet, horned octopus and blue whiting. Escapement was found to be highly species dependent. Significant escapement of many species occurred in the lower part of the side panels. Norway lobster had the highest escapement rate (64 %), mainly represented by small individuals. The escapement of greater was also high (53 %). For hake, common pandora and poor cod rates ranged from 10 to 16 %. The escapement of red mullet was very low despite their great abundance. Blue whiting escaped mainly through the mid-height part of the side panel. This great variability of escapement values could affect the proportion rates of the species sampled during a standard survey. Different escape behaviours among size classes were observed for blue whiting, poor cod and common pandora, with smaller individuals tending to escape towards the bottom and larger ones towards the higher parts of the trawl body. In the species where the escape rate was size-dependent, therefore, the size-frequency distributions obtained from the codend catch may not reflect actual size-frequency distributions.		

Title: Size selection of Atlantic cod, haddock and pollock (saithe) by otter trawls with square and diamond mesh codends of 130-155 mm mesh size		
Author(s): Halliday, Cooper, Fanning, Hickey, Gagnon	Institution: -	Year: 1999
Document type: Article	Gear type: Otter trawl	Location: Atlantic, Canada
Objectives: To examine the size selection of square or diamond mesh codends of mesh sizes between 130-150 mm for cod, haddock and pollock. This was done using a trouser trawl in the parallel tow method.		
Results: Square mesh codends gave an L50 approximately 10% higher for cod and haddock than for the diamond mesh codends of the same mesh size. The SR for cod and haddock was approximately 30% smaller for the square mesh configuration than for the diamond mesh configuration. Parameter estimates for pollock were too few to allow confident conclusions, but were generally similar to those from the other species.		

Title: Estimating the size-selection curves of towed gears, traps, nets and hooks		
Author(s): Millar and Fryer	Institution: -	Year: 1999
Document type: Article	Gear type: -	Location: New Zealand
Objectives: The paper presents a general statistical methodology for analysis of selectivity data. This formal statistical modelling of selectivity is built on explicity definitions of the selection process and specification of underlying assumptions and limitations, and this gives the resulting estimates of gear selectivity a clear interpretation.		
Results: Particular emphasis is given on ensuring an adequate number of hauls, while measuring more fish on each haul had a comparatively smaller effect. Application of the methodology to studies using subsampled catch data and to towed gears having windows or grids is outlined as well as examples provided. The analysis of data from replicate deployments is covered in detail, with particular regard to modelling the fixed and random effects of between-haul variation. Recent developments on the design of selectivity experiments are introduced and demonstrated.		

Title: Modelling the size selectivities of a trawl codend and an associated square mesh panel		
Author(s): Zuur, Fryer, Ferro and Tokai	Institution: -	Year: 2001
Document type: Article	Gear type: square mesh panel	Location: Scotland
Objectives: To develop a methodology for modelling the data collected from covered square meshed panels inserted in the codend or extension piece of a bottom trawl.		
Results: The framework allows a wide selection of possible curves to be produced, depending on the type of data collected. The model is fitted to data collected for haddock and whiting using a covered square mesh panel and a covered codend. Three different curves were used to describe the selectivity of the panel (panel available-curves, codend contact-curves and codend available-curves) by three different models, the logistic, the Richards and the contact logistic model. In general the contact logistic model provided the best fit to the individual haul data.		

Title: Escape windows to improve the size selectivity in the Baltic cod trawl fishery		
Author(s): Madsen, Holst, Foldager	Institution: -	Year: 2002
Document type: Article	Gear type: Escape windows	Location: Baltic Sea
Objectives: To compare the efficiency of square mesh escape windows when inserted in the upper panel of the codend compared to the standard codend. Three nominal codend mesh sizes were tested (105, 120 and 140 mm nominal mesh size) against three different window configurations (110, 125 and 135 mm nominal window mesh size). A twin trawl setup with the covered codend method was used.		
Results: A 105 mm mesh size codend fitted with a single top window had a substantially higher L50 than the standard codend with a mesh size equal to that of the window. A window codend was also predicted to have a substantially lower SR if the window mesh size was selected to give the same predicted L50 as a standard codend. SR was positively correlated with mesh size and hence L50- a finding which had not been well documented, assuming it was a constant parameter previously.		

Title: Assessment of the cover effect in trawl codend selectivity experiments		
Author(s): Madsen, Holst	Institution: -	Year: 2002
Document type: Article	Gear type: Bottom trawl	Location: Baltic Sea
Objectives: A codend fitted with a square mesh window and surrounded by a cover was tested against a similar uncovered codend in a twin trawl setup. This was done in order to assess whether or not the cover impacts coded selectivity. To maintain sufficient clearance, kites were attached to the cover. The selectivity of the codend with the cover was determined by the covered codend method while that of the uncovered codend was determined by the twin trawl method. The selectivity data was then analysed using the SELECT approach.		
Results: 21% fewer cod entered the codend with the cover compared to the codend without the cover. The L50 was 2.4% lower for the codend with cover but not significantly different. The parameter variance and the between-haul variance in the L50 was significantly lower for the covered codend. The SR was 15.8% lower for the codend with the cover but not significantly different. Retention rates of cod in the 35–55 cm length classes were estimated to have been higher in the covered codend setup.		

Title: An investigation of the relationship between sea state induced vessel motion and cod-end selection		
Author(s): O'Neill, McKay, Ward, Strickland, Kynoch and Zuur	Institution: -	Year: 2003
Document type: Article	Gear type: Bottom trawl	Location: Scotland
Objectives: To investigate the effect of sea state induced vessel motion on codend selectivity. The study was divided into 3 parts. The first establishes the relationship between vessel motion and codend dynamics. The second analyses hydrodynamics and catch dynamics of a codend pulsing in a flume tank. The final part compares direct observations of the hydrodynamics, catch dynamics and fish behaviour of pulsing codends at sea.		
Results: Part 1 of the study confirmed that the pulsing of the codend is a response to sea state induced vessel motion. Part 2 concluded that the dynamic forces acting on the catch must generally be small. Three categories of longitudinal codend motion are identified and a qualitative description of the hydrodynamic forces that are acting is presented. Part 3 found longitudinal pulsing of the codend to be an important factor generating dynamic movement of the codend. Dynamic forces acting on the fish ahead of the catch are small and the main component of the movement of these fish relative to the codend arises as a result of the displacement of the codend.		

Title: Total selectivity of a commercial cod trawl with and without a grid mounted: grid and codend selectivity of north-east Artic cod		
Author(s): Kvamme and Isaksen	Institution: -	Year: 2004
Document type: Article	Gear type: Cod trawl with and without a rigid grid	Location: Barents Sea
Objectives: To test and compare the selectivity of the total cod trawl with and without the grid section (as developed by Larsen and Isaksen, 1993). This was done using 3 experimental setups; a trawl codend without a grid and a covered codend (C), a trawl with a 55 mm grid and grid cover and codend without a cover (G) and a trawl with the grid, grid cover, codend and covered codend (GC). The two gear types were studied during the same experiment, with the same vessel and method, within the same area and during the same period of time.		
Results: The estimated selection range was about 10 cm for both the grid and the codend selection. Selection of the grid (G) and codend (C) setups did not differ significantly. Selection of the grid in the GC setup had to be left out as it was near double that of the G setup and was very probable that this was caused from methodological problems.		

Title: Selectivity of a 120 mm diamond codend and the effect of inserting a rigid grid or a square mesh panel		
Author(s): Graham, O'Neill, Fryer, Galbraith, Myklebust	Institution: -	Year: 2004
Document type: Article	Gear type: 120 mm diamond mesh codend, 110 mm square mesh panel, 35 mm selection grid	Location: North Sea
Objectives: To test the efficiency of a 120 mm diamond mesh codend, a 120 mm codend fitted with a 110 mm square mesh panel and a 120 mm codend with a 35 mm selection grid fitted in the extension in the North Sea for cod, haddock and saithe selectivity.		
Results: Saithe and cod results are based on limited data and so should be treated with caution. For haddock there was no significant difference for the standard codend and the codend+panel. When the codend+grid was tested, the SR was 1 cm smaller compared to the standard codend and the codend+ panel. For saithe and cod there was no significant difference found for selectivity between the nets.		

Title: Mitigation measures against seabed impact of mobile fishing gears		
Author(s): Winger Fonteyne, Pol, MacMullen, Løkkeborg, Marlen, Moth-Poulsen, Zachariassen, Sala, Thiele, Hansen, Grimaldo, Revill and Polet	Institution: ICES-FAO	Year: 2004
Document type: Report	Gear type: Mobile fishing gears	Location: -
Objectives: A summary report of measures that are being taken to reduce physical impacts made by mobile fishing gears on the seabed as well as mitigating the negative effects on the benthic communities. In particular, measures that improve fishing efficiency and therefore the fishing time required were investigated, as well as alternative gears that demand less seabed contact in general.		
Results: Gear modifications which have less seabed effects include measures to reduce the seabed contacting area of trawl footgears, the use of semi-pelagic trawls for shrimps, provision of dropout aft-belly openings in beam trawls, adoption of “sweepless” trawls for whiting, and “wheeled” footgears to replace rockhoppers. The “Active Trawl” system and the “Auto-trawl” system showed good potential for reducing seabed contact as well as the use of kites and depressors in trawls, but some of these were still in early development stages.		

Title: Escapement of gadoid fish beneath a commercial bottom trawl: Relevance to the overall trawl selectivity		
Author(s): Ingólfsson and Jørgensen	Institution: -	Year: 2005
Document type: Article	Gear type: bottom trawl	Location: Barents Sea
Objectives: To quantify the escapement of gadoid species beneath the fishing line of a commercial bottom trawl under typical fishing circumstances. Collection bags were placed behind the footgear underneath the trawl, with the headline of the bags connected to the fishing line of the trawl. The groundgear used on the trawl was a 60 cm diameter rockhopper gear. Measurements for cod, haddock and saithe were made.		
Results: Approximately one third of cod and one quarter of haddock that could have been retained by the mouth of the trawl escaped below the fishing line. Escapement for cod depended on length with approximately 50% of cod of length 38.5 cm escaping. Length dependance for escapement of haddock was less pronounced, with on average, 7% of individuals passing under the fishing line. Saithe escapement was also not identified as being length dependent, with an average escape rate observed at 7.2%. Video recordings revealed a large proportion of roundfish being struck by the gear and subsequently being overrun by the gear.		

Title: Escape mortality of trawl caught Baltic cod (*Gadus morhua*) — the effect ofwater temperature, fish size and codend catch		
Author(s): Suuronen, Lehtonen and Jounela	Institution: -	Year: 2005
Document type: Article	Gear type: bottom trawl	Location: Baltic Sea
Objectives: To measure the mortality of cod that escape through trawl codend meshes in a commercial cod trawl. A 120 mm diamond mesh codend, a Danish 105 mm escape window codend, and a 105 mm square mesh top panel Bacoma codend were compared. Escapees were collected during the last 20 min of each haul using a caging method. These fish were then held in cages anchored on the seabed and checked daily by divers.		
Results: Mortality of cod was low when they were kept in normal temperatures (<10°C) for all codend types. Higher mortalities were observed when the water temperature used was approximately 15°C, however these temperatures are not typical for cod to experience under commercial conditions during the trawling process. A somewhat higher mortality was predicted for larger fish that escaped from the 120 mm diamond mesh codend while in the 105 mm escape window codend the effect was reversed. In the Bacoma window codend the number of dead escapees was very low in all length groups.		

Title: Effect of catch size and shape on the selectivity of diamond mesh cod-ends I. Model development		
Author(s): Herrmann	Institution: -	Year: 2005
Document type: Article	Gear type: Diamond meshed codends	Location: -
Objectives: An outline for an individual-bases model to simulate the fish selection process in a diamond-mesh codend of a towed fishing gear. This model is called PRESEMO.		
Results: A simulation took only a few minutes and could account for up to four different populations entering the codend during the tow duration. Each fish is assigned a weight, girth, width and height according to its length, and is assumed to have an elliptical cross-section. Further, indivivduals are allocated a period of travel time down the cod-end, a period for swimming in the cod-end without being exhausted, a period between escape attempts and a packing density for those swimming ahead of the catch. An escape attempt is deemed successful if a fish can pass through the mesh opening at the position in the cod-end where the escape attempt takes place. The mesh opening value is obtained and the codend shape is updated continuously as the catch size increases. At the end of a simulation, a logistic function is automatically fitted to the selection data to obtain estimates of the 50% retention length and the selection range.		

Title: Effect of catch size and shape on the selectivity of diamond mesh cod-ends II. Theoretical study of haddock selection		
Author(s): Herrmann	Institution: -	Year: 2005
Document type: Article	Gear type: Diamond meshed codends	Location: -
Objectives: To compare results collected from a sea trial with those collected from a series of computer simulations using PRESEMO. The data was for haddock caught using a diamond mesh codend, and total catch, by-catch, entry time of by-catch and the codend shape as the catch built up were analysed. Assuming a constant codend shape as catch accumulated was also investigated.		
Results: The simulations indicated that the L50 increases with both the total catch and the by-catch weight. They also indicated that the entry time of the by-catch may have an important influence on both the L50 and the SR. The shape of the catch in the cod-end had a similar effect, for the cases analyzed. Different codend shapes showed very large differences in the values for L50 as well as more narrow SRs, assuming that the shape of the codend remained constant during the tow. The simulations strongly indicated that the change of shape of the diamond mesh cod-end as the catch builds up during towing is a major contribution to the SR.		

Title: Size selection of cod by rigid grids – Is anything gained compared to diamond mesh codends only?		
Author(s): Jørgensen, Ingólfsson, Graham and Isaksen	Institution: -	Year: 2006
Document type: Article	Gear type: cod trawl grid and codend	Location: Barents Sea
Objectives: To compare the selectivity of the 135 mm mesh trawl codend with the combined 135 mm mesh trawl and Sort-V 55 mm grid setup introduced. This is then compared to the selectivity of a trawl without a grid but with a 155 mm mesh codend instead.		
Results: The experiments showed that the grid and mesh combination did not have a sharper size selection than codend meshes. The selectivity of the 155 mm codend was similar to that of the grid and codend selectivity, therefore showing that the introduction of the latter into the legislation effectively only increased L50 and corresponded to an increase in codend meshes by approximately 20 mm.		

Title: Square mesh panels in North Sea demersal trawls: Separate estimates of panel and cod-end selectivity		
Author(s): O'Neill, Kynoch and Fryer	Institution: -	Year: 2006
Document type: Article	Gear type: Square mesh panel	Location: North Sea
Objectives: To assess the selectivity of a trawl with no square mesh panel compared to a trawl with a 90 mm square mesh panel inserted 3–6, 6–9 and 9–12 m from the cod-line.		
Results: This study suggested that using a square mesh panel in the codend can have clear benefits in reducing the degree of retention of undersized haddock. Smoothers were used to show that, for haddock and whiting, all three trawls with square mesh panels were more selective than the net without a panel. For whiting, the nets with a panel in the 6–9 and 9–12 m positions were more selective than the net with the panel in the 3–6 m position. The same result was suggested for haddock, but only at a marginal level of significance. For haddock, a six-parameter model was fitted to a subset of the data and was found to provide a better fit for the dual selection process of the codend and panel compared to the standard logistic curve.		

Title: Selectivity of large mesh trawl codends in the Gulf of Maine I. Comparison of square and diamond mesh		
Author(s): He	Institution: -	Year: 2007
Document type: Article	Gear type: Diamond and square mesh codends	Location: Gulf of Maine, USA
Objectives: To compare the selective properties between five different mesh sized codends. Using the covered codend method, 152, 165 and 178 mm mesh size was tested for diamond meshed codends and 165 and 178 mm mesh sizes was tested for square meshed codends. A new hydrodynamic codend cover design was used for the experiments which was expended using 12 water-bourne kites. Data was collected for cod and haddock as well as for four flounder species.		
Results: The results indicate that larger codend mesh sizes retained larger fish for all species for both diamond and square mesh codends. The mesh shape had no significant effect on the L50 for roundfish while the square mesh codends had significantly smaller L50s for flounders. The square mesh codend had a narrower selection range than the corresponding diamond mesh codend for both cod and haddock.		

Title: Simulation-based investigation of the paired-gear method in cod-end selectivity studies		
Author(s): Herrmann, Frandsen, Holst and O'Neill	Institution: -	Year: 2007
Document type: Article	Gear type: Paired gear and covered codend gear	Location: -
Objectives: To compare the selectivity of trawls estimated using the paired-gear method compared to the covered codend method. A modified version of the codend selectivity simulator PRESEMO is used to simulate the data that would be collected from a paired-gear experiment where the test codend also has a small mesh cover.		
Results: It is demonstrated that extreme parameter estimates as well as discrepancies between the paired-gear and covered cod-end experiments do not necessarily reflect physical or biological mechanisms. This phenomenon may help explain cases in the literature where the covered codend and paired-gear methods produce different estimates of codend selectivity.		

Title: SURVIVAL: An assessment of mortality in fish escaping from trawl codends and its use in fisheries management		
Author(s): Breen, Huse, Ingólfsson, Madsen and Soldal	Institution: -	Year: 2007
Document type: Report	Gear type: Trawl	Location: Barents Sea
Objectives: To develop sampling techniques that overcome biases in escape mortality estimation and to test these techniques directly against previous protocols. Methods to investigate selectivity and survival of fish escaping at the surface, in a side-trawler fishery was also done. This work also investigated the effect of repeated encounters by fish with trawls and whether escape mortality could be attributed to seasonal variations. These findings were then utilized using modelling techniques and their potential to contribute to stock assessments and other applications to stakeholder groups was assessed.		
Results: A new and improved protocol for survival studies was successfully developed including a new sampling cover that does not affect the flow of water around the trawl codend, thus collecting fish without exposing them to additional stressors. The proportion of gadoids escaping at the surface was estimated using the multi-sampler technique showing that a significant proportion of fish escape when the gear has reached the surface during haul back of the trawl. For estimations of repeat encounters by cod, PIT tags were successfully used, showing that approximately 8% are recaptured by sampling trawls atleast once. Survival after repeat encounters was generally high (99% for cod and haddock approximately). No significant seasonal variations in selectivity and survival of escaping haddock or whiting was found between spring and summer periods. Throughout each period, mortality for these species was length dependent with the majority of dead fish being less than 15 cm long. Escape per se was not found to be the reason for death of haddock and whiting. Due to the length dependent mortality it was argued that death could be as a result of injuries and stress experienced during the capture process, and not as a result of escapement. Escapement was however found to cause mortality for larger haddock individuals. These were also contributed towards by stressors associated with surface escape, such as elevated temperature, sea state and the physical condition of the individual.		

Title: Separating species using a horizontal panel in the Scottish North Sea whitefish trawl fishery		
Author(s): Ferro, Jones, Kynoch, Fryer and Buckett	Institution: -	Year: 2007
Document type: Article	Gear type: Horizontal panel	Location: Scotland
Objectives: To develop a species-selective trawl gear that improves the exploitation pattern of North Sea cod, while maintaining the catch of other important commercial species by fitting a trawl with a horizontal panel in the tapered part of the net to separate species into an upper and lower compartment. Trials were conducted on research vessels to measure separation performance for nine species in different light conditions, at different towing speeds, and with different lengths of panel.		
Results: Most haddock, whiting, and saithe were found to pass above the panel, whereas most cod, flatfish, and monkfish passed below it. The towing speed and panel length had no significant effect on the separation. At lower light levels during the night fewer dab, sole, plaice, and cod passed below the panel. Using acoustic data collection methods, it was suggested that the height at which fish enter the net mouth may be influenced by the light level and water clarity.		

Title: Exit Windows as an alternative selective system for the Barents Sea Demersal Fishery for cod and haddock		
Author(s): Grimaldo, Larsen and Holst	Institution: -	Year: 2007
Document type: Article	Gear type: Exit windows	Location: Barents Sea
Objectives: Trouser trawl experiments were performed to assess the cod and haddock selection capacity of a codend fitted with two 130 mm exit windows. These windows were 10 meshes high and 45 meshes long and were inserted in the rearmost part of the codend. This was done in order to find a potential alternative to the rigid grid system used in this fishery.		
Results: This design was very efficient in releasing large amounts of undersized fish and the L50 was far above the MLS for both the analysed species. For cod, the mean L50 values varied between 53.6 and 57.3 cm and the mean SR values varied from 6.8 to 9.3 cm. Haddock was measured during two trials with the mean L50 at 50.5 and 50.6 cm and the mean SR values at 6.3 and 6.0 cm. Total catch weights varied between 0.7 and 6.6 metric tonnes. In some cases, an important effect of catch weights on the L50 could be detected. This experiment indicated that 130 mm exit windows in a 135 mm codend can considerably reduce catches of undersized fish. The L25 means found for cod and haddock in this study were well below the MLS for these species.		

Title: A year-long trial of a square mesh panel in a commercial demersal trawl		
Author(s): Bullough, Napier, Laurenson, Riley, Fryer, Ferro and Kynoch	Institution: -	Year: 2007
Document type: Report	Gear type: Square mesh panel	Location: Shetland, Scotland
Objectives: To evaluate the effects of a square mesh panel on the catches of a demersal trawl during normal commercial fishing operations over a period of 1 year. A 100 mm codend fitted with a 90 mm square mesh panel between 6.3 and 9.3 m from the cod-line was compared with an identical codend with no panel, attached to the same net, using the alternate haul method.		
Results: The square mesh panel significantly reduced the catch of undersized whiting and of whiting greater than the minimum landing size by up to lengths of about 32 cm. However, the square mesh panel had no significant effect on the catches of haddock or cod. Hauls with a small-mesh codend showed that large numbers of small haddock were present in the areas where the trials were carried out. Few of these fish were retained by the standard codend, either with or without the square-mesh panel, suggesting that fitting the square mesh panel did not improve the selectivity of the codend design used in these trials.		

Title: Selectivity and escape percentages during three phases of the towing process for codends fitted with different selection systems		
Author(s): Grimaldo, Larsen, Sistiaga, Madsen and Breen	Institution: -	Year: 2007
Document type: Article	Gear type: A conventional codend, one with escape windows and one with a sorting grid	Location: Barents Sea
Objectives: The selectivity of cod and haddock escaping from three different selection systems (a conventional diamond-mesh codend, a codend fitted with escape windows, and a codend fitted with a sorting grid) using the covered codend technique, was analysed. A MultiSampler attached to the codend enabled the fish entering the codend to be partitioned as they escaped. Escapement was analysed at depth, during haul back and at the surface.		
Results: For escaping individuals at depth, the diamond mesh codend allowed significantly fewer individuals to pass through than the two other configurations. This was opposite for escapement at the surface, with the diamond mesh codend releasing significantly more compared to the exit windows or the sorting grid. No difference was found in the percentages of escaping fish between the codend with escape windows and the codend fitted with the sorting grid. Thus, the codends with escape windows and the sorting grid functioned most efficiently in terms of reducing the stress and injury likely caused for fish as fewer were brought to the surface. When analysed with respect to the whole haul, all three selection systems yielded similar selection values (narrow SR) for cod and haddock; and only differences in the L50 of cod were detected among them. When analysed by towing phase however, the selectivity parameters estimated at depth for both species were mostly lower than those estimated for the whole haul. This difference was, however, more pronounced when comparing the L50 and SR estimates for the haul back and at the surface with that of the whole haul.		

Title: Selectivity in a trawl codend during haul-back operation—An overlooked phenomenon		
Author(s): Madsen, Skeide, Breen, Krag, Huse and Soldal	Institution: -	Year: 2008
Document type: Article	Gear type: A conventional codend, one with escape windows and one with a sorting grid	Location: Scotland
Objectives: To estimate selectivity of a trawl codend during towing, haul-up and at the surface. The selectivity of a 99 mm mesh size codend was analysed using a codend cover fitted with a MultiSampler, which was acoustically triggered to take separate samples at the three different haul phases. Data were collected for haddock, whiting and Norway lobster.		
Results: This experiment clearly indicated that escapement is considerable during the haul back and surface towing periods of fishing. The mean escapement at the surface was 16, 12 and 38% for haddock, whiting and Norway lobster respectively, while 17, 8 and 28% escaped during the haul-back phase. The selectivity parameters L50 and SR were estimated and compared for the three different phases and for the whole haul for haddock, whiting and Norway lobster. For all three species there was no significant difference in L50 between the three phases analysed. There was also no significant difference for whiting and Norway lobster when comparing the SR of the three phases, whereas the SR was significantly lower for haddock when comparing the surface phase with towing and haul-up. The estimate of L50 when towing was about 6 cm lower for haddock and whiting and 9 mm for Norway lobster compared to the selection curve estimated conventionally for the whole haul. The effect of sea state, duration and codend catch were also estimated for the individual phases and for the whole haul. A significant effect of at least one variable was found in all phases.		

Title: Bycatch reduction in the Northeast USA directed haddock bottom trawl fishery		
Author(s): Beutel, Skrobe, Castro, Ruhle Sr., Ruhle Jr., O'Grady and Knight	Institution: -	Year: 2008
Document type: Article	Gear type: large mesh faced bottom trawl	Location: Northeastern USA
Objectives: To test the performance of an 'Eliminator Trawl' configured with large meshed upper and lower wings, side panels and lower belly in order to retain haddock and release cod and other species. The experiments were conducted on two vessels using side by side catch comparison hauls with the conventional net as a control.		
Results: The Eliminator Trawl successfully reduced catches of cod as well as six other important bycatch species while not leading to any additional loss of the target species, haddock, making this net design an efficient tool in enabling access to closed areas in this fishery.		

Title: Size selectivity patterns in the North-east Arctic cod and haddock fishery with sorting grids of 55, 60, 70 and 80 mm		
Author(s): Sistiaga, Grimaldo and Larsen	Institution: -	Year: 2008
Document type: Article	Gear type: Sorting grids	Location: Barents Sea
Objectives: To estimate the change in selectivity parameters when changing the grid bar spacing. Four different bar spacings were tested; 55, 60, 70 and 80 mm, of steel material. These were combined with a 135 mm codend. It was also sought to investigate the relationship existing between selectivity parameters (L50 and SR) and bar spacing. Selectivity was measured for cod and haddock.		
Results: There was little variation found in the selectivity parameters when the bar spacing was increased from 55 to 70 mm for haddock. For cod, no differences in selectivity were found between the 55 and the 60 mm grids or the 70 and 80mm grids, but the first two differed significantly from the latter. The increase of bar spacing from 55 to 80 cm led to an increase in the mean L50 from 56.08 to 73.33 cm and the mean SR to increase from 7.46 to 14.28 cm. The selection curves moved to the right and lost sharpness, and the 95% confidence areas increased gradually as the bar distance of the grid widened. A linear relationship was found for cod and haddock when comparing the L50 with the bar spacing.		

Title: Evaluation of codends with sorting grids, exit windows, and diamond meshes: Size selection and fish behaviour		
Author(s): Grimaldo, Sistiaga and Larsen	Institution: -	Year: 2008
Document type: Article	Gear type: Sorting grids	Location: Barents Sea
Objectives: A 135 mm diamond-mesh codend fitted with a 55 mm sorting grid (sort-V) was tested against a 135 mm diamond-mesh codend fitted with two lateral exit windows and a codend built entirely of 155 mm diamond mesh. Cod and haddock selection was quantified.		
Results: SRs calculated for all three codends were similar, approximately 8 cm for cod and 6 cm for haddock. The L50s were all far above the MLS in this fishery. Underwater observations revealed that most of the fish escaped from the grid and exit-window codends as soon as they reached the vicinity of the sorting device. In contrast, fish remained inside the diamond-mesh codend for a longer time, and consequently were more exposed to physical damage before escape. In addition, many fish escaped from this codend during haul back and these fish were not likely to survive due to the rapid changes in pressure.		

Title: Investigation of the paired-gear method in selectivity studies		
Author(s): Sistiaga, Herrmann and Larsen	Institution: -	Year: 2009
Document type: Article	Gear type: Sorting grids	Location: Barents Sea
Objectives: to investigate whether the patterns of the deviations between the paired-gear and covered codend methods observed in the simulation study by Herrmann et al., (2007) also occur in data collected at sea. Furthermore, we investigated whether these patterns occur for cod and haddock and for grid-based systems in addition to diamond mesh codends.		
Results: When using the paired-gear method, the distribution of the estimated L50 and SR is wider; the distribution of the estimated split parameter (sum of the fish in the test codend and the cover, divided by the total number of fish retained by the whole gear) has a higher variability than the true split; the estimated mean L50 and SR can be biased; the estimated between-haul variation is different from that estimated by the covered codend. The variation of the L50 and the SR decreases when the number of fish in the codend increases, but they do not necessarily progress towards zero. This is positively correlated with the deviation between the split and the true split. The authors recommended that the methodology used to obtain selectivity estimates using the paired-gear method should be reviewed.		

Title: Assessment of dual selection in grid based selectivity systems		
Author(s): Sistiaga, Herrmann, Grimaldo and Larsen	Institution: -	Year: 2010
Document type: Article	Gear type: Sorting grids	Location: Barents Sea
Objectives: To investigate the potential for a new method of assessing dual selection in grid-based selectivity systems. The parameter 'grid contact likelihood' was compared to models previously used and tested using cod and haddock catch data.		
Results: For the three cases tested in this study, the fit of the new model (dual selection considering the grid contact likelihood) is superior to that of the logit model. Using the new model instead is most important when comparing devices that have a big difference in selective properties, such as a 80 mm grid compared to a 135 mm codend, and less so for example with a 55 mm grid compared to a 135 mm codend. For cod and haddock, the new model was found to be relevant for modelling selection. A greater amount of haddock contacted the grid compared to cod, and the L50 was significantly higher for both species on the grid compared to the codend suggesting higher escapement on the grid compared to the codend. The importance of a three-compartment setup for such studies was highlighted compared to a two compartment setup in order to avoid imprecise estimates of grid contact, grid L50, grid SR, codend L50 and codend SR. The two-compartment setup may only be suitable for estimates of combined grid and codend selectivity.		

Title: Fish behavior near bottom trawls		
Author(s): Winger, Eayrs and Glass	Institution: -	Year: 2010
Document type: Article	Gear type: Bottom trawl	Location: Global
Objectives: A review of the current knowledge of fish behaviours in relation to bottom trawls, building on previous reviews. The study summarises more than 100 studies since the 1960s on fish behavior in response to visual and auditory stimuli produced by the vessel, doors, sand clouds, sweeps, footgear, and trawl netting. Individual variabilities in behaviours is also assessed in terms of maximizing benefits and minimizing costs at the individual level. Finally, an anti-predator behaviour model is also applied.		
Results: The following subject areas were reviewed; • Learning behaviors of fish is explored, based on encountering the trawl on more than one occasion, learning from other individuals (social learning), learned avoidance behaviour, etc. • Physiological influence on response threshold, motivational state, swimming capabilities for escape in a trawl and mesh penetration capability • Motivational state related to tradeoff of maximizing benefit and minimizing cost at the individual level. • The impact of extrinsic factors such as water temperature, fish density and light level were reviewed.		

Title: Selective haddock (*Melanogrammus aeglefinus*) trawling: Avoiding cod (*Gadus morhua*) bycatch		
Author(s): Krag, Holst, Madsen, Hansen and Frandsen	Institution: -	Year: 2010
Document type: Article	Gear type: bottom trawl	Location: North Sea
Objectives: Behavioral differences (behaviour during the day and night as well as swimming behaviour differences) between cod and haddock are utilized in order to separate cod from haddock. A selective trawl is used that raises the fishing line 60 cm above the sea bed. Sampling bags with a small mesh size were attached beneath the fishing line in order to retain escapees. Whiting, saithe, lemon sole, and plaice were included in the analysis.		
Results: Total catches of cod were reduced by 55% during the day and 82% at night, and 99% of the marketable haddock was caught during the day and 89% at night. Cod escape rates were highly length dependent: smaller cod escaped the trawl in greater numbers than larger individuals did. At night the proportion of smaller individuals caught in the lower compartments was higher compared to during the day.		

Title: Selectivity studies in the Barents Sea bottom trawl gadoid fishery: Gear and methods		
Author(s): Sistiaga	Institution: -	Year: 2010
Document type: Article	Gear type: bottom trawl	Location: Barents Sea
Objectives: To positively contribute to the understanding of the selection processes that occur in the gear used in this fishery as well as alternative gears used in other seas and to develop improvements for the sampling methodologies and selectivity estimation approaches used today. The thesis summarises findings collected throughout five scientific publications for cod and haddock. The first two investigate alternatives to the obligatory grid and codend setup (a diamond mesh codend of 155 mm nominal mesh size and a diamond mesh codend of 135 mm with two lateral 142 mm nominal mesh size exit windows). The second analyses the effect on the selectivity of cod and haddock of increasing the grid bar spacing. The third paper investigates the paired gear method compared to the covered codend method following simulations made comparing these in 2007. Paper four presents the parameter 'grid contact' that takes place during dual selection and its importance in interpreting the selection process. The final paper is a multidisciplinary approach to size selectivity that combines recent methodological developments and technology, morphology-based selection approaches, sea trial results from the second, third and fourth papers as well as results from underwater observations.		
Results: The first and second papers found selection efficiency equivalent to the standard gear however video surveillance indicated additional release occurring during haulback with the 155 mm codend. Increasing the bar spacing increased the L50 and SR for both species. The third paper indeed found that the paired gear method has associated bias and thus that the covered codend method is a better alternative for use in selectivity studies. The 'grid contact' parameter was found to be an important component for assessing passage for fish through a dual selection system in the fourth paper. The final paper provides a global view of the selection process and differences in morphology were found to explain differences between L50's of up to 6 cm between the species.		

Title: Effect of trawling with traditional and ‘T90’ trawl codends on fish size and on different quality parameters of cod *Gadus morhua* and haddock *Melanogrammus aeglefinus*		
Author(s): Digre, Hansen and Erikson	Institution: -	Year: 2010
Document type: Article	Gear type: bottom trawl	Location: Barents Sea
Objectives: The effect of trawling on fish size and on different quality parameters of cod and haddock was evaluated using two trawls in a double rig fitted with a traditional and a novel ‘T90’ codend, respectively.		
Results: There was no difference between the two types of nets in terms of catch volume, but significantly slightly bigger fish were caught with the T90 than with the traditional trawl net. Haddock caught with the traditional trawl net had more external injuries related to the trawl gear than haddock caught with the T90 gear. The gaping frequency for cod caught with the traditional trawl net tended to be higher than cod caught with the T90 gear, but the difference was not significant. No other differences in fish quality between fish caught in the trawl nets were observed.		

Title: Effect of netting direction and number of meshes around on size selection in the codend for Baltic cod (*Gadus morhua*)		
Author(s): Wienbeck, Herrmann, Moderhak and Stepputtis	Institution: -	Year: 2011
Document type: Article	Gear type: mesh circumference, mesh orientation	Location: Baltic Sea
Objectives: The effect on selection of cod when turning the netting direction 90◦ (T90) and halving the number of meshes around in the circumference in a diamond mesh codend.		
Results: In general, the results agreed with predictions of a previous simulation-based study. Both modifications had a significant positive effect on the size selection of cod. The best selection results were obtained for a codend in which both factors were applied together. For that codend, very little between- haul variation in cod size selection was detected, especially compared to the reference codend in which none of the modifications were applied		

Title: Understanding the Size Selectivity of Redfish (*Sebastes spp*.) in North Atlantic Trawl Codends		
Author(s): Herrmann, Sistiaga, Nielsen and Larsen	Institution: -	Year: 2012
Document type: Article	Gear type: bottom trawl	Location: Barents Sea
Objectives: To use morphological characteristics of redfish species to understand results from trawl selectivity studies, more specifically, codend selection. Results were analysed for three species of redfish, *Sebastes marinus, Sebastes mentella and Sebastes fasciatus.* Codend size selectivity results for *S. marinus* were also extrapolated for the other two species mentioned, and finally new experiments were conducted with catch data of redfish caught in the Northeast Atlantic redfish trawl fishery.		
Results: Successful extrapolation of the FISHSELECT predictions for *S. marinus* to also explain and understand codend size selection of *S. mentella* and *S. fasciatus* indicates that the morphometric characteristics with respect to size selection in codends are similar for these species. Strong similarities were found regarding the effect of codend mesh size between the FISHSELECT predictions and the different sea trial results indicating that the size selection of *S. marinus* in diamond mesh codends to a large extent can be explained by morphological characteristics of the species, and less so for behavioural aspects. In particular, the compressability of the fish as well as the girth were found to be important morphological aspects that selectivity was dependant on.		

Title: Influence of grid orientation and time of day on grid sorting in a small-meshed trawl fishery for Norway pout (*Trisopterus esmarkii*)		
Author(s): Eigaard, Herrmann and Nielsen	Institution: -	Year: 2012
Document type: Article	Gear type: small-meshed trawl	Location: North Sea
Objectives: To develop and test a lightweight sorting grid to be used in the Norway pout fishery in order to overcome handling issues faced with other more heavy alternatives previously trialled in the fishery- as sorting grids were not yet a mandatory device. Thus a grid made from synthetic materials was developed for testing. Grid orientation (leaning backwards or forwards) as well as distinctions in day and night trials was also examined in terms of sorting efficiency. To make the results comparable to other fisheries containing different size structures, an additional objective was to carry out length-based analyses of the catch data. As very large catches were obtained in combination with an experimental population structure containing only a few length classes, a new methodological approach was needed to support the heavy subsampling required.		
Results: An estimated release of between 88.4 and 100% of the total number of haddock and whiting was found with the different grid orientation in distinct day and night hauls. However, bycatch reductions were not significantly different between day and night or between grid orientations, indicating that the grid rejection of haddock and whiting was not influenced by fish behavior. The loss of the target species, Norway pout, was low (between 5.6%and 13.7%) in comparison with the bycatch excluded, and clearly length dependent. Although results were not statistically significant, the grid rejection likelihood for particularly smaller Norway pout (<16 cm) was higher when fishing with the forwards-leaning grid during the night; this might be explained by behavioral and visual aspects for this species in relation to the gear.		

Title: Velocity measurements in 2- and 4-panel single grid sections (*in Norwegian*).		
Author(s): Gjøsund, Grimaldo, Sistiaga and Hansen	Institution: Sintef Ocean	Year: 2013
Document type: Report	Gear type: 4 and 2-panel grid section	Location: Barents Sea
Objectives: Large accumulations of cod in front of the selection grid have been observed using underwater recordings, and this is thought to be caused by the reduced speed of water flow through the grid section. This report establishes measures of water flow speed through the single grid system used in the Norwegian cod trawler fleet in order to identify key challenges and to establish a basis for improving the hydrodynamics through the grid section		
Results: The lifting panel is a major source of reduced flow of water in a grate section, and should be removed or substantially modified if grid contact can be maintained in another way. 4-panel sections have a significantly larger and more stable cross-section than 2-panel sections. This reduces the importance of boundary layers, and improves the installation of the grid and panel elements. Speed measurements in the trawl and grate sections must be interpreted with caution, as the speed can vary significantly both over a cross section and further back in the section.		

Title: Size selectivity of redfish (Sebastes spp.) in the Northeast Atlantic using grid-based selection systems for trawls		
Author(s): Hermann, Sistiaga, Larsen and Nielsen	Institution: -	Year: 2013
Document type: Article	Gear type: bottom trawl	Location: Barents Sea
Objectives: To investigate the size selection of redfish using morphological data for redfish through a grid-based selection system consisting of a 55 mm grid and a diamond mesh codend.		
Results: Not all redfish made physical contact with the sorting grids on their way to the codend, and therefore the escapement of some undersized redfish was dependant on the size selection in the codend. Most of the escapement occured through the grid rather than the codend. For one of the two grid systems investigated the increase in size selection obtained by increasing the grid-bar spacing was well in line with what could be expected based on the morphology of redfish. However, the size selection observed experimentally was significantly lower than the size-selective potential of the grids estimated based on the morphology of redfish. Computer simulations, suggested that a possible explanation for this difference could be that not all redfish that attempted escape through the grid made their attempt with an optimal angle of attack.		

Title: A comparative analysis of legislated and modified Baltic Sea trawl codends for simultaneously improving the size selection of cod (*Gadus morhua*) and plaice (*Pleuronectes platessa*)		
Author(s): Wienbeck, Herrmann, Feekings, Stepputtis and Moderhak	Institution: Sintef Ocean	Year: 2013
Document type: Article	Gear type: codend	Location: Baltic Sea
Objectives: Five different codend setups were assessed in order to improve selectivity of cod and plaice. The modifications included refining the selective performance of the current Bacoma codend by increasing the mesh size of the lower panel from 109 mm double twine to 129 mm single twine and increasing the mesh size in the upper square mesh panel from 132 to 147 mm. Finally, the design of the lower panel was made the the same as the upper panel; i.e. a full square mesh codend. These three experimental designs were tested in conjunction with the legislated codends; the Bacoma and the T90		
Results: The most effective setups tested were the T90 and the Bacoma codends with a modified lower panel (increased mesh size and single twine replacing the double twine). For the T90 codend, the selection parameters (L50 and SR) were 43.4 and 6.7 cm for cod, and 24.7 and 2.1 cm for plaice, respectively. The selection parameters for the modified Bacoma codend were 41.1 and 8.3 cm for cod and 25.2 and 3.9 cm for plaice, respectively. With respect to the minimum landing sizes for cod (38 cm) and plaice (25 cm) in the Baltic Sea at this time, this selection was appropriate for use commercially. The fully square mesh codend led to low retention of cod as well as high retention of small flatfish. Increasing the mesh of the upper panel led to a significant reduction in legal sized cod and plaice compared to the standard gear.		

Title: Understanding sorting grid and codend size selectivity of Greenland halibut (*Reinhardtius hippoglossoides*)		
Author(s): Herrmann, Sistiaga, Larsen, Nielsen and Grimaldo	Institution: -	Year: 2013
Document type: Article	Gear type: Bottom trawl	Location: Barents Sea and Norwegian Sea
Objectives: To study the size selectivity of Greenland halibut using the fish morphology-based FISHSELECT methodology. Size selectivity data from two sets of sea trials carried out in the Barents Sea (Sort-V gear) and the Norwegian Sea (Sort-X gear) were used as well as historical selectivity data collected for this species from 1981 and onwards.		
Results: Selectivity estimates differed significantly between the two trials carried out at sea. Despite similar bar spacings of the sort-x and sort-v configurations, the differences were found to be due to the differences in angle of attack. The ability of the fish to turn prior to contacting the grid determines this outcome. Accounting for angle of attack was found to be an important factor that should be included in future grid selectivity studies for flatfishes. The sea trials coupled with the historical data, showed significantly lower L50 values compared to what would have been expected using the FISHSELECT methodology. The historical data alone however gave selectivity estimates that fitted well with the FISHSELECT estimations.		

Title: Effect of the lifting panel on selectivity of a compulsory grid section (Sort-V) used by the demersal trawler fleet in the Barents Sea cod fishery		
Author(s): Grimaldo, Sistaga, Herrmann and Gjøsund	Institution: -	Year: 2015
Document type: Article	Gear type: bottom trawl, lifting panel	Location: Barents Sea
Objectives: To investigate the effect of the lifting panel on grid contact. This was done using a 4-panel Sort-V grid section with and without the lifting panel. This was done using the alternate haul method on two identical 2-panel trawls with transitional sections made to connect the 2-panel trawl bellies to a 4-panel grid section. The lifting panel used was with 80 mm netting. Small meshed grid covers were used to assess selectivity on both trawls as well as blinded codends over the 138 mm diamond mesh codend.		
Results: Presence of the lifting panel had a significant effect on grid contact. Without the lifting panel approximately one third of the fish that enter the grid section do not make contact with the grid. This is reduced to 18% when the lifting panel is included in the setup. Additionally, an improved grid section design was established in the fishery as the former as the 4-panel grid section together with a modified lifting panel provided improved flow conditions through the section compared to the 2-panel grid section and the former overdimensioned lifting panel design.		

Title: Understanding the release efficiency of Atlantic cod (*Gadus morhua*) from trawls with a square mesh panel: effects of panel area, panel position, and stimulation of escape response		
Author(s): Herrmann, Wienbeck, Karlsen, Stepputtis, Dahm, and Moderhak	Institution: -	Year: 2015
Document type: Article	Gear type: Square mesh panel, bottom trawl	Location: Barents Sea
Objectives: To investigate the selective potential of a square mesh panel in the codend of a bottom trawl based on its placement, area and the stimulation potential to led to an escape response by fish. Six different codend designs were tested. 1) A standard BACOMA codend 2) 50% shorter square mesh panel towards the aft 3) 50% shorter square mesh panel towards the extension piece 4) Identical to (3) but with fluttering ropes as a stimulation device 5) Identical to (3) but with an inclined panel stimulation device 6) Identical to (3) but with float ropes as the stimulation device		
Results: The selective potential of the BACOMA codend could not be matched by the other five designs studied. Square mesh panels inserted in an area of the codend that overlapped with the catch accumulation zone were most efficient, independent of the length of the panel. Panels that were positioned closer to the extension piece could release bycatch as efficiently as the panels inserted near the accumulation zone when they were coupled with a stimulation device.		

Title: Effect of lifting the sweeps on bottom trawling catch efficiency: A study based on the Northeast arctic cod (*Gadus morhua*) trawl fishery		
Author(s): Sistiaga, Herrmann, Grimaldo, Larsen, Tatone	Institution: -	Year: 2015
Document type: Article	Gear type: Trawl sweeps	Location: Barents Sea
Objectives: To compare the catch efficiency and herding behaviour of cod using a setup with lifted sweeps compared to one with sweeps towed on the seabed.		
Results: Lifting the sweeps was estimated to reduce cod catches by 33% compared to sweeps towed on the sea floor. Cod loss was length dependent and significant for lengths between 41 cm and 104 cm. Herding was negatively affected when sweeps were lifted, ie; fish were lost. Conversely, when the sweeps were on the seafloor, approximately 45% of cod could be herded into the catch zone of the gear.		

Title: Species selectivity in different sized topless trawl designs: Does size matter?		
Author(s): Krag, Herrmann, Karlsen, Mieske	Institution: -	Year: 2015
Document type: Article	Gear type: Topless trawl	Location: Kattegat and Skagerrak
Objectives: Using a twin trawl in the Nephrops fishery, the topless trawl was tested with a large trawl configuration and a smaller trawl configuration where the headline height would be higher and lower, respectively. Species specific effects were assessed for the target species, Nephrops, as well as the bycatch species, haddock and cod		
Results: Nephrops did not react to the high or the low headline height. Haddock showed a significant length dependent effect to both the high and the low headline, with most individuals above 32 cm escaping in both experiments. For cod, an effect could only be found when the low headline height was implemented. This was length dependent, with larger individuals >35 cm escaping from the gear in higher numbers than the smaller individuals.		

Title: Can a square-mesh panel inserted in front of the codend improve the exploitation pattern in Mediterranean bottom trawl fisheries?		
Author(s): Brčić, Herrmann and Sala	Institution: -	Year: 2016
Document type: Article	Gear type: Square-mesh panel	Location: Mediterannean
Objectives: To improve the selectivity of Atlantic horse mackerel, European hake, red mullet, poor cod, broadtail shortfin squid and deep-water rose squid through a square-mesh panel inserted in front of the codend. The square-mesh panel had a 50 mm mesh size and was mounted in the final tapered section of the trawl.		
Results: This configuration did not contribute significantly to the overall selectivity for any of the species analysed. Majority of escapement occurred through the codend. The poor release efficiency may have been due to the excessive distance of the panel from the codline (8 m) - a part of the net where fish have no chance to change direction and swim up through the panel meshes.		

Title: How Many Fish Need to Be Measured to Effectively Evaluate Trawl Selectivity?		
Author(s): Herrmann, Sistiaga, Santos and Sala	Institution: -	Year: 2016
Document type: Article	Gear type: Trawl	Location: Mediterannean, Barents Sea
Objectives: To provide general and understandable guidelines for specialists in trawl selectivity for determining the quantity of fish that should be length measured in order to attain selectivity parameters at a designated uncertainty level. The dependency of this uncertainty level on the experimental method used to collect data was also investigated as well as the potential effects of factors such as the size structure in the catch relative to the size selection of the gear. Simulated data was used for cod and red mullet from the Barents Sea and the Mediterranean Sea respectively.		
Results: The uncertainty in the selection parameters decreased with increasing number of fish measured and it was possible to describe this relationship using a power model. The sampling effort needed to achieve a specific uncertainty level for the selection parameters was always lower for the covered codend method compared to the paired gear method. In many cases, the number of fish that would need to be measured to maintain a specific uncertainty level was around 10 times higher for the paired-gear method than for the covered codend method. The trends observed for the effect of sampling effort in the two fishery cases investigated were similar; therefore, these guidelines should be applicable to other fisheries.		

Title: The effect of sweep bottom contact on the catch efficiency of haddock (*Melanogrammus aeglefinus*)		
Author(s): Sistiaga, Herrmann, Grimaldo, Larsen and Tatone	Institution: -	Year: 2016
Document type: Article	Gear type: Sweeps	Location: Barents Sea
Objectives: To measure the difference in bottom contact for a trawl that was rigged with sweeps at two different angles and lengths. The impact of this change was also observed for haddock selectivity using catch comparison and catch ratio analyses.		
Results: The configuration with the higher sweep angle and smaller difference in sweep length led to less bottom contact. A length dependency was also found for selectivity of haddock. Retention of haddock was higher for the setup with longer sweeps and this was length dependent for a small range of length classes. In general, the length of the sweeps that had actual contact with the seabed can be relevant for the fishing efficiency of a trawl on haddock. The results also indicate that the herding effect of the sweeps for haddock can be length dependent.		

Title: Size selection of redfish (*Sebastes* spp.) in a double grid system: Estimating escapement through individual grids and comparison to former grid trials		
Author(s): Larsen, Herrmann, Sistiaga, Grimaldo, Tatone and Onandia	Institution: -	Year: 2016
Document type: Article	Gear type: Grid designs	Location: Barents Sea
Objectives: To improve selectivity using a new double steel grid system consisting of a lower and an upper grid in a four-panel section. Selectivity of cod, haddock and two bycatch species of redfish were assessed. This was done measuring grid contact. The new gear had a cross sectional area 45% larger to that of the Sort-V gear and the second grid replaced the lifting panel typically used. This additional grid was intended to provide an additional sorting area and to simultaneously guide fish to the second, upper grid. The angle of the first grid was investigated using two different angles.		
Results: The proportion of redfish escaping through the two grids did not differ significantly. The release efficiency of the first (lower) grid was, however predicted to be significantly lower than that of the second grid when accounting for the actual fraction of redfish reaching the zones of the individual grids. An estimated 80% of the redfish made contact with at least one of the two grids. However, the release efficiency and overall size selection for redfish was not higher than what has previously been measured for redfish using the standard Sort-V gear.		

Title: Reducing flatfish bycatch in roundfish fisheries		
Author(s): Santos, Herrmann, Kieske, Stepputtis, Krumme and Nilsson	Institution: -	Year: 2016
Document type: Article	Gear type: Flatfish rigid escape windows	Location: Baltic Sea
Objectives: To reduce the bycatch of flatfishes in the Baltic sea roundfish fishery using rigid escape windows in a commercial twin trawler. The vessel was rigged with two trawls; one standard trawl gear and one incorporating the experimental gear. The extension piece was made with four net panels of 4 mm double twine and diamond mesh netting. The mesh size was 120 mm, and the number of meshes around was 4 × 25. A V-shape guiding device of 860 mm high and 200 mm wing length, was mounted in the centerline of the extension piece ahead of the windows, with the aim of directing fish from the central path of the extension towards the windows. Cod and the bycatch of two flat fish species was assessed, plaice and flounder.		
Results: Comparison of the catches from both trawls exhibited approximately a 68% reduction in flatfish bycatch for the trawl with the new windows mounted. In addition, the catch of undersized cod was reduced by approximately 30%, whereas losses of marketable cod were relatively minor (∼7%). Further simulations predicted that, in the commercial fishery, a reduction of more than 50% in flatfish bycatch could be achieved if this new device was adopted.		

Title: Size selective performance of two flexible sorting grid designs in the Northeast Arctic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) fishery		
Author(s): Sistiaga, Brinkhof, Herrmann, Grimaldo, Langård and Lilleng	Institution: -	Year: 2016
Document type: Article	Gear type: flexible sorting grid	Location: Barents Sea
Objectives: To compare the performance of a flexigrid design installed in a 4-panel grid section to that of the traditionally used 2-panel design. In particular, the study was interested in analysing the probability of contact on either of the two grids and subsequently escape, for undersized fish. This was done for cod and haddock. A single trawl with three compartments was used to test the 2-panel and the 4-panel design.		
Results: The 4-panel configuration released more undersized individuals compared to the 2-panel design, however both designs displayed similar grid contact values. The observed difference in undersized fish release could be attributed to the difference in shape of the two sections. This was observed using underwater video recordings. 3 of the 26 hauls conducted also revealed blockages when the 2-panel section was used. No blockages were observed using the 4-panel design, and this difference was significant. The video recordings also revealed differences in vertical separation between the two species with haddock escaping upwards and cod escaping downwards through the grids.		

Title: Bell-shaped size selection in a bottom trawl: A case study for Nephrops directed fishery with reduced catches of cod.		
Author(s): Lövgrena, Herrmann and Feekings	Institution: -	Year: 2016
Document type: Article	Gear type: selective grid and square mesh codend	Location: Barents Sea
Objectives: To fit a structural based model to the size selection process in order to investigate the contribution of the individual parts of the system. In the Swedish Nephrops fishery, trawls use a Nordmøre type sorting grid as well as a square mesh codend to avoid bycatches of cod while retaining Nephrops. The size selection curve for this system has a bell shape which is not sufficiently described by a monotonous selection curve. Therefore, a structural model aimed to describe the underlying physical and biological mechanisms that determine selection was applied. This model was then used in order to predict how changes to individual components in the system may affect selectivity.		
Results: This approach appropriately described the experimental size selection data for both Nephrops and cod. Furthermore, this approach provided a direct quantification of the selective processes of the individual parts of the system to the overall size selection in the fishing gear. This approach could act as a useful tool to fisheries managers seeking to improve existing fishing gear in use in the fishery.		

Title: Improving catch efficiency by changing ground gear design: Case study of Northeast Atlantic cod (*Gadus morhua*) in the Barents Sea bottom trawl fishery		
Author(s): Brinkhof, Larsen, Herrmann and Grimaldo	Institution: -	Year: 2017
Document type: Article	Gear type: semicircular spreading gear	Location: Barents Sea
Objectives: To improve the catch efficiency of cod by replacing the conventional rockhopper gear with a new semicircular spreading ground gear (SCSG). To do this the escape rate of cod below the fishing line was quantified by collecting escapees in a catch bag mounted behind the fishing line and these were compared with the retention of cod in the trawl codend. Length dependencies were thus measured between the two ground gears. Seasonal, diurnal and area-based differences in escape rate were also investigated.		
Results: The catch efficiency of the SCSG was significantly improved for a certain length class of cod for both cruises. The first cruise was conducted in the central region of the Barents Sea, the second took place towards the southeast of the Barents Sea. On the first cruise the catch efficiency was improved for cod between 45 cm and 100 cm, on the second cruise, this was for individuals between 81 cm and 100 cm. Overall, this confirms a significant improvement when the SCSG was used for cod of lengths between 39 and 105 cm, however this inference should only be used for individuals above the minimum size limits as smaller individuals should be expected to be affected by selective processes in the codend, trawl body and retainer bag. Diurnal comparisons did not reveal any changes to selectivity between different light conditions for the same gear, however the catch efficiency was higher using the SCSG for a given group of length classes, reaffirming the improved efficiency when this gear is used compared to the conventional rockhopper gear. Video recordings revealed that cod escaped frequently on the sides of the rockhopper gear and only in the central parts when the SCSG was used. Considerably larger mud clouds were also produced by the rockhopper gear compared to the SCSG.		

Title: Escape rate for cod (*Gadus morhua*) from the codend during buffer towing		
Author(s): Brinkhof, Herrmann, Larsen, Sistiaga	Institution: -	Year: 2017
Document type: Article	Gear type: Bottom trawl	Location: Barents Sea
Objectives: To quantify the escape rate and size selectivity of cod as a result of buffer towing. To do this, a new analytical approach is used which allows the same configuration to be used as in the commercial industry in order to minimize any sources of bias in the estimates. Data collection was done using the alternate haul method.		
Results: A significant reduction of cod was found for individuals up to the length of 42 cm, and 60 % of individuals of length 20 cm were estimated to escape as a result of buffer towing. For individuals of 30 and 40 cm length, 53 and 45% of individuals escaped due to buffer towing, respectively		

Title: Improving release efficiency of cod (*Gadus morhua*) and haddock (*melanogrammus aeglefinus*) in the Barents Sea demersal trawl fishery by stimulating escape behaviour		
Author(s): Grimaldo, Sistiaga, Herrmann, Larsen, Brinkhof and Tatone,	Institution: -	Year: 2018
Document type: Article	Gear type: mechanical and light stimulation devices	Location: Barents Sea

Objectives: To improve cod and haddock release efficiency through a square mesh section by using mechanical and light stimulation compared to the configuration without any stimulation device. This was done by comparing release results and by using underwater video recordings. The mechanical stimulator was produced by attaching two rows of fluttering lines with floats to the lower panel of the section. LED stimulation was done using eight green Electralume underwater fishing lights. Four were placed at the centre of the square mesh section to scare fish to the side panels and four were attached to each of the selvedges of the section but 20 meshes further back from the first four lights in order to stimulate escapement through the square meshes.

Fall through experiments were also conducted for cod and haddock through the square mesh section used and the results from this would then be used to infer whether the results were as a result of fish behaviour or release potential through the square meshes.

Results: From video recordings, both species did not attempt escape through the square mesh when no stimulator was used. For haddock, the release efficiency calculated was length dependent – decreasing with increasing length. For cod this was very low throughout all length classes without any stimulation. When the mechanical stimulators were used, both species responded by stopping infront of the device. However, the release efficiency for haddock doubled with stimulation compared to without, while cod release efficiency remained very low, showing strong reluctance to respond to the mechanical stimulation.

In response to the LED lights, haddock displayed a very erratic response compared to cod which just kept swimming in a regular way infront of the lights before falling back into the codend. Haddock turned quickly towards the square mesh panels or towards the codend. Several made contact with the trawl netting but many did not manage to escape due to having an incorrect orientation. Haddock release efficiency also decreased with increasing size, as seen for mechanical stimulation. Cod release efficiency remained low for individuals around the minimum catch size, confirming their reluctance to respond to these two forms of stimulation, compared to haddock.

Fall through experiments showed that overall the escape rates were not satisfactory for either type of fish when considering the minimum catch sizes in the Barents Sea (44 and 40 cm for cod and haddock, respectively). This was as the difference between the measured percent of fish that could pass through and those that actually passed through was high.

Title: Size selection of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) in the Northeast Atlantic bottom trawl fishery with a newly developed double steel grid system		
Author(s): Larsen, Herrmann, Sistiaga, Grimaldo, Tatone, Brinkhof	Institution: -	Year: 2018
Document type: Article	Gear type: Lower grid coupled with a Sort-V grid	Location: Barents Sea
Objectives: To examine an alternative design for the lifting panel used in a standard sort-v grid section in order to improve water flow. This involved replacing the lifting panel with an additional steel grid. The speed of fish passage through the section as well as the water flow was examined. And finally, the size selective performance of this alternative gear was investigated in order to quantify if it performed at least as well as the existing grid section.		
Results: The new 4-panel grid section had a stronger flow than the standard 2-panel sort-V configuration, however video recordings showed how this also negatively affected the grid contact. More active swimming behaviour by haddock than cod enabled more smaller haddock to escape than cod. Release of fish was lower through the first grid compared to the second, and more larger fish were released through the first grid when the angle was higher (40º) compared to when it was lower (35º). When comparing the double grid system to the flexigrid and the sort-v systems the double grid can be an alternative to the flexigrid due to its release efficiency of smaller cod and haddock. For the sort-v configuration, it releases more undersized fish but also more target sized fish compared to the double grid configuration.		

Title: Assessing the impact of buffer towing on the quality of Northeast Atlantic cod (*Gadus morhua*) caught with a bottom trawl		
Author(s): Brinkhof, Larsen, Herrmann and Olsen	Institution: -	Year: 2018
Document type: Article	Gear type: Standard gear	Location: Barents Sea
Objectives: To document the effects that buffer towing has on the quality of the whole fish as well as the fillet of the fish produced. Quality was measured by assessing gear marks, vitality, exsanguination, ecchymosis, skin abrasion, fillet gaping and fillet redness.		
Results: Buffer towing was found to have a clear negative effect on fish quality, increasing the probability of poor exsanguination by 307% and fillet redness occurrence by 209%. Furthermore, when the results from all catch indexes were combined, significantly better quality of cod from direct haul back was achieved, compared to the buffer towed fish.		

Title: Combination of a sorting grid and a square mesh panel to optimize size selection in the North-East Arctic cod (*Gadus morhua*) and redfish (*Sebastes* spp.) trawl fisherie		
Author(s): Sistiaga, Herrmann, Grimaldo, Larsen, Olsen, Brinkhof and Tatone	Institution: -	Year: 2018
Document type: Article	Gear type: Sorting grid and a square mesh panel	Location: Barents Sea
Objectives: To investigate the potential for a new sorting section comprised of a sorting grid and a square mesh panel to replace the standard grid section of the fishing sector. Selectivity was measured for cod and redfish. The new section was shorter and the sorting grid was installed upside down compared to the Sort- V section and the top panel was substituted by a square mesh panel. The steel grid was installed in the lower panel to act as the first sorting mechanism. Fish that respond to the grid with an avoidance response are guided upwards towards the second sorting device, the square mesh panel. In this sense, the new design combined the most commonly applied sorting devices in trawls into one system, where the second device is meant to sort at least part of those fish that avoid the first device		
Results: The grid in the new design was found to contribute to the largest proportion of fish release, while the release through the square mesh panel was low. However, the results showed that the grid was successful at guiding fish not escaping through the grid to a second selection process in the panel. However, the square mesh panel did not result in the intended release efficiency except for the smallest sizes of fish, most likely due to that the guiding angle of the grid and the square meshes in the panel used did not provide a suitable escape path for the desired size range of fish. Therefore, optimizing the mesh size/shape in the panel and/or the guiding angle for the grid potentially could led to the desired selectivity pattern in the new sorting section.		

Title: Selectivity of Different Alternative Cod Ends and Radial Square Mesh Escape Panels (RSEP)		
Author(s): Ceylan and Sahin	Institution: -	Year: 2018
Document type: Article	Gear type: Codend and radial square mesh escape panels	Location: Black Sea
Objectives: To test the selectivity of five different codends containing different mesh sizes, shapes and escape panels on red mullet as the target species as well as the bycatch of bluefish.		
Results: The L50 was improved for catches of red mullet when the escape panels were tested compared to the commercial setup. A 40 mm square mesh codend and a 50 mm diamond mesh codend led to very high L50 values and none of the designs tested enabled significant loss of the bycatch of bluefish. It was noted that future studies should include escape panels that cover a greater area than that applied in this study.		

Title: Using vertical distribution to separate fish from crustaceans in a mixed species trawl fishery		
Author(s): Karlsen, Krag, Herrmann and Lund	Institution: -	Year: 2019
Document type: Article	Gear type: bottom trawl	Location: Skagerrak
Objectives: A horizontally divided codend with small square meshes (40 mm) and a simple frame to stimulate fish to swim into the upper compartment was tested in order to separate Nephrops from bycatch species. The separator frame had two identical bars which were intended to stimulate fish to swim upwards while keeping the targeted Nephrops in the lower compartment. A length-based quantification of the species-specific separation efficiency was provided which enabled comparisons of the selectivity estimates with those made in other studies. Finally, length based diel differences in species separation was investigated in order to examine the influence of light intensity on the vertical distribution of the species.		
Results: The majority of the fish were separated successfully from Nephrops, but their preference was uniform. Less than 10% of the Nephrops entered the upper compartment. Length- based analysis revealed three patterns of separation efficiency among nine commercial species: length-dependent separation and preference for the upper or lower compartments. The separation efficiency should be improved for small roundfish and flatfish. There was little diel effect on the separation efficiency. The preference of fish for a compartment, taking the relative height of that compartment into account, was established for this and similar previous studies in order to enable comparison of these results.		

Title: Catch Efficiency of Groundgears in a Bottom Trawl Fishery: A Case Study of the Barents Sea Haddock		
Author(s): Larsen, Herrmann, Brinkhof, Grimaldo, Sistiaga and Tatone	Institution: -	Year: 2018
Document type: Article	Gear type: Rockhopper groundgear and Semicircular spreading gear groundgear	Location: Barents Sea
Objectives: The catch efficiency was assessed for the semicircular spreading gear (SCSG) compared to the standard rockhopper gear used by the industry. Catches of haddock were compared between the two gears using a retainer bag attached behind the footrope of both trawls. These comparisons were made during nocturnal and diurnal periods for haddock.		
Results: Using the SCSG improved the catch efficiency of haddock significantly compared to the standard gear. The degree of variation in improved efficiency varied between 4.5 and 12.3%. This was equivalent in a reduction in escapement below the gear of more than 70%. For the rockhopper gear, catch efficiencies were found to be as low as 76%, which corresponded with previous findings. And differences were found for the rockhopper gear between day and night experiments, while no such difference could be detected to occur when the SCSG was used. The SCSG also has good potential in commercial implementation due to its optimized efficiency for fuel consumption as it is lighter in weight compared to the rockhopper gear, as well as the reduced impact on the seabed that it has.		

Title: Sequential codend improves quality of trawl- caught cod		
Author(s): Brinkhof, Olsen, Ingólfsson, Herrmann and Larsen	Institution: -	Year: 2018
Document type: Article	Gear type:	Location: Barents Sea
Objectives: To investigate the extent of catch damage on cod caught using a conventional codend compared to a new sequential codend design. These catch damage differences as well as functionality differences were analysed and quantified between the two different codends. Catch damage was analysed based on poor exsanguination, ecchymosis, gear marks, pressure injuries and skin abrasions.		
Results: A significant improvement on cod quality using the sequential codend was found in this study. The conventional codend used in the industry was found to led to catch damages for 96.4% of fish caught, while using the sequential design led to five times fewer instances of catch damage. Furthermore, cod caught in the sequential codend had a 14%–32% increased probability of obtaining score 0 for all damage categories, except 'pressure injuries', depending on the damage category or category combination.		

Title: Catch and release patterns for target and bycatch species in the Northeast Atlantic deep-water shrimp fishery: Effect of using a sieve panel and a Nordmøre grid		
Author(s): Larsen, Herrmann, Sistiaga, Brinkhof and Santos	Institution: -	Year: 2018
Document type: Article	Gear type:	Location: Barents Sea
Objectives: To test a sieve panel design as an alternative to using the Nordmøre grid to mitigate bycatch of fish in the Norwegian trawl fishery targeting deep-water shrimp. The sieve panel installed in front of the Nordmøre grid as an additional sorting device was also explored. The sieve panel was installed at a low angle (ca. 9º) in the extension piece to encourage fish to swim towards the escape opening without making physical contact with the net. Effectiveness of the selection was also examined.		
Results: The bycatch reduction patterns differed significantly between the two devices and a more efficient bycatch reduction was obtained by combining them. However, while the loss of commercial-sized shrimp was only between 0 and 2% for the Nordmøre grid, it was between 37 and 56% for the tested sieve panel, making this completely unacceptable for commercial fishing		

Title: Catch quality and size selectivity in the Barents Sea bottom trawl fishery: effect of codend design and trawling practice		
Author(s): Brinkhof	Institution: UiT	Year: 2019
Document type: Article	Gear type: Bottom trawl	Location: Barents Sea
Objectives: To present the results of an investigation into the effects of buffer towing on the quality of the catch as well as a catch comparison method to present the impact of this fishing practice on size selectivity. Secondly, the thesis presents the potential applications of a new device named the 'dual sequential codend, in the gadoid bottom trawl fishery as an approach for improving catch quality. The size selectivity of this new device is also investigated.		
Results: By analysing the quality of the catch caught using buffer towing, it was shown to have a significantly negative impact. The size selectivity of the catch when this technique is used also was found to be significantly worse than when standard practices were used (Brinkhof et al., 2017, 2018a). The new sequential codend concept greatly improved cod quality, leading to five times more flawless cod than when the conventional gear was used (Brinkhof et al., 2018b, 2019). This design enabled minor increases of undersized cod however this should not impede its consideration for industrial use as the increase in quality that could be achieved outweighed the outcome of the minor increase of undersized cod retention.		

Title: Predicting optimal combinations of by-catch reduction devices in trawl gears: A meta-analytical approach		
Author(s): Melli, Herrmann, Karlsen, Feekings and Krag	Institution: -	Year: 2019
Document type: Article	Gear type: Bycatch reduction devices	Location: Skagerrak and Kattegat Sea
Objectives: To predict the selectivity of 100 bycatch reduction devices tested in the Skagerrak and Kattegak seas in the Nephrops fishery in previous studies, to select against cod and haddock, that could not otherwise be tested experimentally due to practical limitations. This was in order to identify combinations that show significant promise for improving selectivity based on different catch compositions and quota available to fishermen. Bycatch reduction device combinations were compared in terms of absolute selectivity and performance under realistic catch scenarios, under both single and multispecies scenarios.		
Results: The meta-analytical approach used worked sufficiently for utilizing existing knowledge in order to led to new insights. 15 potential combinations were identified for future investigation experimentally. The methodology determines whether the addition of any device and the associated complexity added to the gear has sufficient reduction of unwanted catches associated to it. The selectivity achieved is also not bound to the standard S-shaped curvature, and thus can be adapted to suit goals held by fisheries managers. This cost – effective approach to planning future studies could be applied to any well studied fishery implementing bycatch reduction devices. The findings must be followed up in experimentally however in order to determine any interactions between gear types as the approach assumes that each device operates independently.		

Title: Effect of a quality-improving cod end on size selectivity and catch patterns of cod in bottom trawl fishery		
Author(s): Brinkhof, Herrmann, Larsen and Veiga-Malta,	Institution: -	Year: 2019
Document type: Article	Gear type: Quality improving codend	Location: Barents Sea
Objectives: To quantify and compare the size selectivity and catch pattern for cod of the standard codend with the dual-sequential codend described by Brinkhof et al. (2018). This was found to provide improved catch quality however concerns were raised regarding its selectivity. This new codend retains cod in an anterior section of the codend during towing and upon haul back a posterior codend section is opened using a hydrostatic codend releaser. This section is made entirely of small meshes therefore no escapement happens after fish enter this compartment. Since the anterior codend is identical to that used for a conventional codend, selectivity should be unaffected during fishing with the new gear. However, if selectivity of the conventional gear continues also during haul back, the fine meshed posterior section used in the new design would impact overall selectivity, leading to an increased total amount of undersized fish retained in the catch.		
Results: Size selectivity between the conventional and quality-improving codends differed significantly during the sea trials with the conventional codend releasing significantly more small cod, however when compared to the total selectivity this difference was found to be minor. As no significant difference in the catch pattern could be found between the two designs, the new quality improving codend may be used in the industry with low risk of retaining small cod.		

Title: Comparing size selectivity of traditional and knotless diamond-mesh codends in the Iceland redfish (*Sebastes* spp.) fishery		
Author(s): Cheng, Einarsson, Bayse, Herrman and Winger	Institution: -	Year: 2019
Document type: Article	Gear type: traditional and knotless diamond mesh codends	Location: Iceland
Objectives: To compare the effectivity of a traditional two-panel codend versus an experimental four-panel ultra-cross knotless mesh codend. This was done using the covered codend method measuring selectivity of redfish (*Sebastes norvegicus* and *S. viviparous*).		
Results: No significant difference in size selectivity was seen between the codends at lengths greater than 29 cm for *S. norvegicus* and 19 cm for *S. viviparous*. Conclusions for smaller length classes could not be reliable due to small catches. For *S. norvegicus*, both codends demonstrated a high retention ratio above the minimum reference length but also had a high retention below MRL. The actual proportion of catch below MRL was low however due to few small fish caught. Since these fish are difficult to tell apart and have similar morphologies, the size selectivity of the two codends for both species combined was analysed, resulting in similar results of no difference in size selectivity, but a large increase in actual catches below MRL, primarily *S. viviparous*. In general, the knotless codend does not improve the size selectivity or usability in the Iceland redfish fishery.		

Title: External damage to trawl-caught northeast arctic cod (*Gadus morhua*): Effect of codend design		
Author(s): Tveit, Sistiaga, Herrmann and Brinkhof	Institution: -	Year: 2019
Document type: Article	Gear type: knotless codend, 4-panel codend,	Location: Barents Sea
Objectives: to investigate the extent of external damage (gear marks, pressure injuries, ecchymosis and skin abrasion) present on trawl-caught cod and to examine whether the extent of damage could be reduced by introducing changes in the gear. The effect on damage by changing the 2-panel knotted codend used by the Norwegian trawler fleet to a 2-panel knotless codend or a 4-panel knotless codend was measured.		
Results: the probability for cod to be without any external damage was 9.4% (4.7%–15.8%) with the codend used in the fishery today. Thus, most fish in these catches are likely to have slight or moderate damage. Gear marks were the most frequent type of damage, with only 11.5% (6.0%–18.9%) of the cod being free of this type of injury. When gear marks were not considered in the analysis, 68.4% (58.8%–78.3%) of the fish was estimated to be flawless. Replacing the knotted netting in the codend increased the probability of obtaining fish without gear marks to 15.5% (6.2%–28.0%). However, the confidence intervals were wide, and this effect was not statistically significant. For the other three damage types, the estimated effects of changing the design of the codend were small and not statistically significant. Changing from a 2- to 4-panel codend was estimated to reduce the probability for gear marks by a further 1.7% (−13.4%–16.8%). However, this increase was not significant. Overall, the two codend design changes tested in this study did not significantly decrease the external damage present on trawl-caught cod. 1.		

Title: Size selectivity and length-dependent escape behaviour of haddock in a sorting device combining a grid and a square mesh panel		
Author(s): Herrmann, Sistiaga, Grimaldo, Larsen, Olsen, Brinkhof, Tatone	Institution: -	Year: 2019
Document type: Article	Gear type: Sorting grid and square mesh panel	Location: Barents Sea
Objectives: To test a new sorting grid system based on the sort-V system in use in the gadoid fishery. In the new system however, the grid was installed upside down and a square mesh panel (144.3 mm) was installed in the top panel of the four-panel grid section. The new grid configuration was aimed to act simultaneously as a lifting panel to guide additional bycatch to the panel for size selection. Selectivity was measured for haddock only, and a new modelling approach was implemented which accounted for differences in escape behavior for different length classes. The covered gear method was implemented to collect escaping individuals from the panel and the grid. The codend was also covered.		
Results: The new model applied was able to describe escapement better compared to previous models. Specifically, the results showed that the likelihood for smaller haddock to seek escape through the grid and the square mesh panel was higher than that for bigger haddock that would still have managed to escape through the devices if they had attempted to.		

Title: Effect of three different codend designs on the size selectivity of juvenile cod in the Barents Sea shrimp trawl fishery		
Author(s): Herrmann, Sistiaga, Larsen and Brinkhof	Institution: -	Year: 2019
Document type: Article	Gear type: square mesh panel, sorting cone	Location: Barents Sea
Objectives: To test the size selective performance of three different gear designs; the standard gear used in the Barents Sea deap water shrimp fishery, a codend with 35 mm square mesh panels (inserted towards the aft which covered the base panel and half of each of the side panels), and a square mesh sorting cone section. All codends were constructed with a 4-panel configuration.		
Results: The diamond mesh codend worked as expected, producing the signature bell shaped selectivity curve and retaining small cod most frequently between the sizes of 12 and 20 cm. The two other configurations tested did not led to significant changes to selectivity compared to the standard gear used in the industry.		

Title: Can a large-mesh sieve panel replace or supplement the Nordmøre grid for bycatch mitigation in the northeast Atlantic deep-water shrimp fishery?		
Author(s): Jacques, Herrmann, Larsen, Sistiaga, Brčić, Gokce and Brinkhof	Institution: -	Year: 2019
Document type: Article	Gear type: Sieve panel	Location: Barents Sea
Objectives: To investigate the size selectivity of redfish, polar cod and deep-water shrimp of the Nordmøre grid combined with four sieve panel configurations differing in mesh size (182 and 286 mm) and inclination angle (10 and 20°).		
Results: The sieve panels were unable to replace the Nordmøre grid as a stand-alone device due to increased catches of the bycatch species. However, combining the two devices provided promising results. Specifically, when a large-mesh sieve panel was placed in front of the Nordmøre grid, 20–40% fewer small redfish and polar cod in a specific size range entered the codend, while the loss of targeted shrimp was less than 5%.		

Title: Relative size selectivity of a four-panel codend with short lastridge ropes compared to a flexigrid with a regular codend in the Barents Sea gadoid trawl fishery		
Author(s): Ingólfsson and Brinkhof	Institution: -	Year: 2020
Document type: Article	Gear type: Shortened lastridge ropes, 4-panel codend, dynamic catch control system	Location: Barents Sea
Objectives: To test the efficiency of a new codend fitted with 30% shortened lastridge ropes, a dynamic catch control system (for regulating the catch quantity) as well as a 4-panel 153 mm mesh size codend. This was compared with the conventionally used 130 mm mesh size, 2-panel, flexigrid configuration and selectivity of cod, haddock and saithe was quantified.		
Results: The four panel codend significantly reduced the catches of cod, haddock and saithe individuals below the MLS by 90 (ci = 85–94), 92 (ci = 88–96) and 86 % (ci = 79–92) respectively, which, if used instead, would improve the selectivity measured by the flexigrid configuration. Approximately half of the fish between the lengths of 57-59.5 cm were lost however using this new design.		

Title: Stimulating release of undersized fish through a square mesh panel in the Basque otter trawl fishery		
Author(s): Cuende, Arregi, Herrmann, Sistiaga, Onandia	Institution: -	Year: 2020
Document type: Article	Gear type: Rope, floats and LED stimulation, Square mesh panel	Location: North Atlantic
Objectives: To improve the contact of fish on the square mesh panel used in the Basque mixed trawl fishery by stimulating fish to the panel. Four different configurations were tested; 1. No stimulation 2. Stimulation based on ropes 3. Stimulation based on ropes and floats 4. Stimulation based on LED lights Hake, horse mackerel and blue whiting selectivity using these configurations was analysed. The trawl was built in a four-panel configuration, with the square mesh panel (82.7 mm) built into the upper panel of the extension piece. The dual cover method was used to collect the selectivity data.		
Results: The stimulation mechanisms tested had no effect on hake and horse mackerel selectivity, however floats had a significant effect for blue whiting escape. While LED stimulation led to increased retention. In general, the additional release contributed by the square mesh panel was low, and this was confirmed by video recordings.		

Title: Size selectivity and catch efficiency of bottom trawl with a double sorting grid and diamond mesh codend in the North-east Atlantic gadoid fishery		
Author(s): Brinkhof, Larsen, Herrmann, Sistiaga	Institution: -	Year: 2020
Document type: Article	Gear type: Flexigrid and conventional codend	Location: Barents Sea
Objectives: When the size selective performance of the flexigrid section was investigated previously by Sistiaga et al. (2016) it did not consider the size selectivity of the legal diamond mesh codend. Thus, an estimate of total size selective performance still lacked from the literature for this setup, including individual contributions by the flexigrid and the codend. The catch efficiency was measured for fish above and below the minimum reference limit (MRL) as well as for a new flexigrid compared to a used flexigrid with a lower grid angle. This was demonstrated by supplementing size selectivity data with estimates of the actual catch efficiency of the gear, which was quantified using exploitation pattern indicators.		
Results: Sistiaga et al. (2016) reported a large proportion of undersized cod and haddock not being released through the flexigrid which therefore passed into the codend. Results from the current study however indicate that almost all undersized cod and haddock that passed into the codend were subsequently released by the codend meshes. The contact probability for the second grid was significantly higher than that for the first grid. This also included large proportions of release of fish above the MRL, where the second grid was responsible for 70.6% of cod loss and 80.2% of haddock loss by the gear. For individuals below the MRL, the second grid was responsible for 56.2% of cod loss and 55.9% of the haddock that were lost from the gear.		

Title: Catch pattern and size selectivity for a gear designed to prevent fish injuries during the capture process in a North-East Atlantic demersal trawl fishery		
Author(s): Herrmann, Sistiaga, Larsen, Brinkhof, Gjøsund, Jacques and Santos	Institution: -	Year: 2020
Document type: Article	Gear type:	Location: Barents Sea
Objectives: To test the efficiency of a new gear configuration to optimize fish quality but to have selective properties atleast comparable to the standard gear used in the cod and haddock bottom trawl fishery. Cod, haddock and redfish catches were measured. The new gear was composed of a large mesh segment, a subsequent quality/welfare preserving segment identical to the one used by Brinkhof et al. (2018) but without any acoustic releaser. Because no sorting grid was used, the size selectivity of this gear configuration relied completely on the sorting characteristics of the large mesh segment. The motivation for testing this new configuration was a perception that a quality/welfare preserving segment made out of high solidity netting would cause a partial flow blockage and deflect a significant portion of the water flow out through the large meshes in front of the high solidity segment. The hypothesis was that most fish would be guided by the water flow towards the large meshes and be size selected by them, thereby preventing capture of undersized fish.		
Results: The new gear was not successful at maintaining the selective potential of the standard setup. More juvenile individuals were retained for all three species in the new gear. The size selectivity results suggest that the water flow directed towards the large mesh panel was probably not as significant as intended, and not substantial enough to stimulate the escape of any of the three species investigated through the large mesh segment.		

Title: Effect of gear design on catch damage on cod (*Gadus morhua*) in the Barents Sea demersal trawl fishery		
Author(s): Brinkhof, Herrmann, Sistiaga, Larsen, Jacques and Gjøsund	Institution: -	Year: 2021
Document type: Article	Gear type: Compulsory grid and codend as well as a quality preserving codend design	Location: Barents Sea
Objectives: To improve the catch quality and strain put on targeted catch in cod fisheries by replacing the grid section and standard codend by a knotless, large-meshed section and a quality preserving codend (identical to that used by Brinkhof et al., 2018). This gentle codend was not closed during fishing as in the case for Brinkhof et al. (2018). The rationale behind this design was for the gentle codend to produce a 'bucket effect' whereby the water would push more undersized fish out sideways before they enter the gentle codend section. Simultaneously, this codend was expected to improve catch quality due to the reduced water flow through the section, reducing stress and strain on the catch. This study also investigated catch damage on cod when the compulsory grid and codend configuration of the fishery are used		
Results: When the alternative design was used, the probability that cod would have no catch damage compared to when the standard gear was used, increased by 6%. The alternative gear also led to a significant reduction in severity of all catch damage categories assessed for cod compared to the standard gear. All improvements in catch quality found in the alternative design compared to the standard design were lower than those achieved by Brinkhof et al. (2018) except for the category of scale loss. Thus, markings, ecchymosis and poor exsanguination could all be improved more when the quality preserving codend was closed during fishing, as done by Brinkhof et al, (2018).		

Title: Bycatch reduction in the deep-water shrimp (*Pandalus borealis*) trawl fishery with a large mesh top panel		
Author(s): Cerbule, Jacques, Pettersen, Ingólfsson, Herrmann, Grimaldo, Larsen, Brinkhof, Sistiaga, Lilleng and Brčić	Institution: -	Year: 2021
Document type: Article	Gear type: Large mesh top panel	Location: Barents Sea
Objectives: To test the ability of a large 200 mm mesh size, T90 top panel inserted in the last three sections (29.4 m) of the tapered belly to reduce the retention of bycatch while simultaneously not leading to additional loss of target shrimp. Greenland halibut, redfish and polar cod bycatch was analysed, as well as deap water shrimp. Data was collected using the paired gear method.		
Results: Bycatch of Greenland halibut and the smallest polar cod was significantly reduced, while no effect was found for redfish. No indication was given that the large mesh panel led to the loss of deep-water shrimp, for all length classes. The results of this study illustrate how a simple modification of a fishing gear can mitigate the bycatch problem in a shrimp fishery, without significant losses of the target species.		

Reference list

Aglen, A., Engås, A., Huse, I., Michalsen, K., Stensholt, B., 1997. Vertical distribution of cod, haddock and redfish; Impact on bottom trawl and acoustic surveys in the Barents Sea.

Armstrong, D.W., Ferro, R.S.T., MacLennan, D.N., Reeves, S.A., 1990. Gear selectivity and the conservation of fish. J. Fish Biol. 37, pp. 261–262.

Aud, V., Soldai, Arill, Engås, B.I., Soldai, A V, 1993. Survival of gadoids that escape from a demersal trawl. ICES mar. Sei. Symp 196, pp. 122–127.

Beutel, D., Skrobe, L., Castro, K., Ruhle, P., Ruhle, P., O'Grady, J., Knight, J., 2008. Bycatch reduction in the Northeast USA directed haddock bottom trawl fishery. Fish. Res. 94, pp. 190–198.

Beverton, R.J.H., 1963. Escape of Fish Through Different Parts of a Codend. In ICNAF Spec. Publ. 5, pp. 9–11.

Brčić, J., Herrmann, B., Sala, A., 2016. Can a square-mesh panel inserted in front of the codend improve the exploitation pattern in Mediterranean bottom trawl fisheries? Fish. Res. 183, pp. 13–18.

Breen, M., Huse, I., Ingólfsson, I., Madsen, N., Soldal, A. V., 2007. SURVIVAL: An assessment of mortality in fish escaping from trawl codends and its use in fisheries management. Final Report.

Brinkhof, J., 2019. Catch quality and size selectivity in the Barents Sea bottom trawl fishery: effect of codend design and trawling practice.

Brinkhof, J., Herrmann, B., Larsen, R.B., Sistiaga, M., 2017. Escape rate for cod (*Gadus morhua*) from the codend during buffer towing. ICES J. Mar. Sci. 75, pp. 805–813.

Brinkhof, J., Herrmann, B., Larsen, R.B., Veiga-Malta, T., 2019. Effect of a quality-improving cod end on size selectivity and catch patterns of cod in bottom trawl fishery. Can. J. Fish. Aquat. Sci. 76, pp. 2110–2120.

Brinkhof, J., Herrmann, B., Sistiaga, M., Larsen, R.B., Jacques, N., Gjøsund, S.H., 2021. Effect of gear design on catch damage on cod (*Gadus morhua*) in the Barents Sea demersal trawl fishery. Food Control 120, 107562.

Brinkhof, J., Larsen, R.B., Herrmann, B., Grimaldo, E., 2017. Improving catch efficiency by changing ground gear design: Case study of Northeast Atlantic cod (*Gadus morhua*) in the Barents Sea bottom trawl fishery. Fish. Res. 186, pp. 269–282.

Brinkhof, J., Larsen, R.B., Herrmann, B., Olsen, S.H., 2018. Assessing the impact of buffer towing on the quality of Northeast Atlantic cod (*Gadus morhua*) caught with a bottom trawl. Fish. Res. 206, 209–219.

Brinkhof, J., Larsen, R.B., Herrmann, B., Sistiaga, M., 2020. Size selectivity and catch efficiency of bottom trawl with a double sorting grid and diamond mesh codend in the North-east Atlantic gadoid fishery. Fish. Res. 231, 105647.

Brinkhof, J., Olsen, S.H., Ingólfsson, O.A., Herrmann, B., Larsen, R.B., 2018. Sequential codend improves quality of trawl caught cod. PLoS One 13, e0204328.

Bullough, L.W., Napier, I.R., Laurenson, C.H., Riley, D., Fryer, R.J., Ferro, R.S.T., Kynoch, R.J., 2007. A year-long trial of a square mesh panel in a commercial demersal trawl. Fish. Res. 83, pp. 105–112.

Cadigan, N.G., Millar, R.B., 1992. Reliability of selection curves obtained from trouser trawl or alternate haul experiments. Can. J. Fish. Aquat. Sci. 49, pp. 1624–1632.

Cerbule, K., Jacques, N., Pettersen, H., Ingólfsson, Ó.A., Herrmann, B., Grimaldo, E., Larsen, R.B., Brinkhof, J., Sistiaga, M., Lilleng, D., Brčić, J., 2021. Bycatch reduction in the deep-water shrimp (*Pandalus borealis*) trawl fishery with a large mesh top panel. J. Nat. Conserv. 61, 126001.

Ceylan, Y., Cemalettin, S., 2018. Selectivity of Different Alternative Cod Ends and Radial Square Mesh Escape Panels (RSEP). Turk. J. Fish. Aquat. Sci. 19, pp. 451–461.

Cheng, Z., Einarsson, H.A., Bayse, S., Herrmann, B., Winger, P., 2019. Comparing size selectivity of traditional and knotless diamond-mesh codends in the Iceland redfish (*Sebastes* spp.) fishery. Fish. Res. 216, pp. 138–144.

Cuende, E., Arregi, L., Herrmann, B., Sistiaga, M., Onandia, I., 2020. Stimulating release of undersized fish through a square mesh panel in the Basque otter trawl fishery. Fish. Res. 224, 105431.

Dremière, P.Y., Fiorentini, L., Cosimi, G., Leonori, I., Sala, A., Spagnolo, A., 1999. Escapement from the main body of the bottom trawl used for the Mediterranean international trawl survey (MEDITS), in: Aquatic Living Resources. ESME - Gauthier-Villars, pp. 207–217.

Digre, H., Hansen, U.J., Erikson, U., 2010. Effect of trawling with traditional and "T90" trawl codends on fish size and on different quality parameters of cod *Gadus morhua* and haddock *Melanogrammus aeglefinus*. Fish. Sci. 76, pp. 549–559.

Eigaard, O.R., Herrmann, B., Rasmus Nielsen, J., 2012. Influence of grid orientation and time of day on grid sorting in a small-meshed trawl fishery for Norway pout (*Trisopterus esmarkii)*. Aquat. Living Resour. 25, pp. 15–26.

Engas, A., Godo, O.R., 1989. The effect of different sweep lengths on the length composition of bottom-sampling trawl catches. ICES J. Mar. Sci. 45, pp. 263–268.

Engas, A., Godo, O.R., 1989. Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. ICES J. Mar. Sci. 45, pp. 269–276.

Engas, A., Ona, E., 1993. Experiences using the constraint technique on bottom trawl doors.

Engås, A., 1998. A species-selective trawl for demersal gadoid fisheries. ICES J. Mar. Sci. 55, pp. 835–845.

Engås, A., Ona, E., 1990. Day and night fish distribution pattern in the net mouth area of the Norwegian bottom-sampling trawls. pp. 123-127. ICES.

Ferro, R.S.T., Jones, E.G., Kynoch, R.J., Fryer, R.J., Buckett, B.E., 2007. Separating species using a horizontal panel in the Scottish North Sea whitefish trawl fishery. ICES J. Mar. Sci. 64, 1543–1550. https://doi.org/10.1093/icesjms/fsm099

Gjøsund, S.H., Grimaldo, E., Sistiaga, M., Hansen, K., 2013. Hastighetsmålinger i 2- og 4-panel enkeltristseksjoner (Velocity measurements in 2- and 4-panel single grid sections)., 27. SINTEF Fiskeri og havbruk.

Graham, N., O'Neill, F.G., Fryer, R.J., Galbraith, R.D., Myklebust, A., 2004. Selectivity of a 120 mm diamond cod-end and the effect of inserting a rigid grid or a square mesh panel. Fish. Res. 67, pp. 151–161.

Grimaldo, E., Larsen, R.B., Holst, R., 2007. Exit Windows as an alternative selective system for the Barents Sea Demersal Fishery for cod and haddock. Fish. Res. 85, pp. 295–305.

Grimaldo, E., Larsen, R.B., Sistiaga, M., Madsen, N., Breen, M., 2009. Selectivity and escape percentages during three phases of the towing process for codends fitted with different selection systems. Fish. Res. 95, pp. 198–205.

Grimaldo, E., Sistiaga, M., Larsen, R.B., 2008. Evaluation of codends with sorting grids, exit windows, and diamond meshes: Size selection and fish behaviour. Fish. Res. 91, pp. 271–280.

Grimaldo, E., Sistiaga, M., Herrmann, B., Gjøsund, S.H., Jørgensen, T., 2015. Effect of the lifting panel on selectivity of a compulsory grid section (Sort-V) used by the demersal trawler fleet in the Barents Sea cod fishery. Fish. Res. 170, pp. 158–165.

Grimaldo, E., Sistiaga, M., Herrmann, B., Larsen, R.B., Brinkhof, J., Tatone, I., 2018. Improving release efficiency of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) in the Barents Sea demersal trawl fishery by stimulating escape behaviour. Can. J. Fish. Aquat. Sci. 75, pp. 402–416.

Halliday, R.G., Cooper, C.G., Fanning, P., Hickey, W.M., Gagnon, P., 1999. Size selection of Atlantic cod, haddock and pollock (saithe) by otter trawls with square and diamond mesh codends of 130-155 mm mesh size. Fish. Res. 41, pp. 255–271.

He, P., Winger, P., Fonteyne, R., Pol, M., Macmullen, P., Løkkeborg, S., Van Marlen, B., Moth-Poulsen, T., Zachariassen, K., Sala, A., Thiele, W., Hansen, U., Grimaldo, E., Revill, A., Polet, H., 2004. Mitigation measures against seabed impact of mobile fishing gears. Report of the ICES Fisheries Technology Committee Working Group on Fishing Technology and Fish Behaviour, Gdynia, Poland.

He, P., 2007. Selectivity of large mesh trawl codends in the Gulf of Maine. I. Comparison of square and diamond mesh. Fish. Res. 83, pp. 44–59.

Herrmann, B., 2005a. Effect of catch size and shape on the selectivity of diamond mesh cod-ends: I. Model development. Fish. Res. 71, pp. 1–13.

Herrmann, B., 2005b. Effect of catch size and shape on the selectivity of diamond mesh cod-ends: II. Theoretical study of haddock selection. Fish. Res. 71, pp. 15–26.

Herrmann, B., Frandsen, R.P., Holst, R., O'Neill, F.G., 2007. Simulation-based investigation of the paired-gear method in cod-end selectivity studies. Fish. Res. 83, pp. 175–184.

Herrmann, B., Sistiaga, M., Grimaldo, E., Larsen, R.B., Olsen, L., Brinkhof, J., Tatone, I., 2019. Size selectivity and length-dependent escape behaviour of haddock in a sorting device combining a grid and a square mesh panel. Can. J. Fish. Aquat. Sci. 76, pp. 1350–1361.

Herrmann, B., Sistiaga, M., Larsen, R.B., Brinkhof, J., 2019. Effect of three different codend designs on the size selectivity of juvenile cod in the Barents Sea shrimp trawl fishery. Fish. Res. 219, 105337.

Herrmann, B., Sistiaga, M., Larsen, R.B., Brinkhof, J., Gjøsund, S.H., Jacques, N., Santos, J., 2020. Catch pattern and size selectivity for a gear designed to prevent fish injuries during the capture process in a North-East Atlantic demersal trawl fishery. Reg. Stud. Mar. Sci. 40, 101525.

Herrmann, B., Sistiaga, M., Larsen, R.B., Nielsen, K.N., 2013. Size selectivity of redfish (Sebastes spp.) in the Northeast Atlantic using grid-based selection systems for trawls. Aquat. Living Resour. 26, pp. 109–120.

Herrmann, B., Sistiaga, M., Larsen, R.B., Nielsen, K.N., Grimaldo, E., 2013. Understanding sorting grid and codend size selectivity of Greenland halibut (*Reinhardtius hippoglossoides*). Fish. Res. 146, pp. 59–73.

Herrmann, B., Sistiaga, M., Nielsen, K.N., Larsen, R.B., 2012. Understanding the size selectivity of redfish (*Sebastes* spp.) in North Atlantic trawl codends. J. Northwest Atl. Fish. Sci. 44, pp. 1–13.

Herrmann, B., Sistiaga, M., Santos, J., Sala, A., 2016. How many fish need to be measured to effectively evaluate trawl selectivity? PLoS One 11, e0161512.

Herrmann, B., Wienbeck, H., Karlsen, J.D., Stepputtis, D., Dahm, E., Moderhak, W., 2015. Understanding the release efficiency of Atlantic cod (*Gadus morhua*) from trawls with a square mesh panel: Effects of panel area, panel position, and stimulation of escape response. ICES J. Mar. Sci. 72, pp. 686–696.

Hylen, A., Smedstad, O.M., 1974. Observations from the Barents Sea in spring 1973 on the discarding of cod and haddock caught in bottom and midwater trawls fitted with double cod ends.

Ingólfsson, Ó.A., Brinkhof, J., 2020. Relative size selectivity of a four-panel codend with short lastridge ropes compared to a flexigrid with a regular codend in the Barents Sea gadoid trawl fishery. Fish. Res. 232, 105724.

Ingólfsson, Ó.A., Jørgensen, T., 2006. Escapement of gadoid fish beneath a commercial bottom trawl: Relevance to the overall trawl selectivity. Fish. Res. 79, pp. 303–312.

Isaksen, B., Valdemarsen, J.W., 1990. Codend With Short Lastridge Ropes to Improve Size Selectivity in Fish Trawls. ICES CM 1990/B

Isaksen, B., Lisovsky, S., Larsen, R.B., Sakhnoe, V., Gamst, K., Misund, R., 1996. Joint Russian–Norwegian Selectivity Experiments on Cod (*Gadus morhua*) in the Barents Sea, 1995, Fisken og havet.

Isaksen, B., Valdemarsen, J.W., 1986. Selectivity experiments with square mesh codends in bottom trawl. ICES.

Jacques, N., Herrmann, B., Larsen, R.B., Sistiaga, M., Brčić, J., Gökçe, G., Brinkhof, J., 2019. Can a large-mesh sieve panel replace or supplement the Nordmøre grid for bycatch mitigation in the northeast Atlantic deep-water shrimp fishery? Fish. Res. 219, 105324.

Jørgensen, T., Ingólfsson, Ó.A., Graham, N., Isaksen, B., 2006. Size selection of cod by rigid grids-Is anything gained compared to diamond mesh codends only? Fish. Res. 79, pp. pp. 337–348.

Karlsen, J.D., Krag, L.A., Herrmann, B., Lund, H.S., 2019. Using vertical distribution to separate fish from crustaceans in a mixed species trawl fishery. Can. J. Fish. Aquat. Sci. 76, pp. 1781–1794.

Krag, L.A., Herrmann, B., Karlsen, J.D., Mieske, B., 2015. Species selectivity in different sized topless trawl designs: Does size matter? Fish. Res. 172, pp. 243–249.

Krag, L.A., Holst, R., Madsen, N., Hansen, K., Frandsen, R.P., 2010. Selective haddock (*Melanogrammus aeglefinus*) trawling: Avoiding cod (*Gadus morhua*) bycatch. Fish. Res. 101, pp. 20–26.

Kvamme, C., Isaksen, B., 2004. Total selectivity of a commercial cod trawl with and without a grid mounted: Grid and codend selectivity of north-east Artic cod. Fish. Res. 68, pp. 305–318.

Kynoch, R.J., Ferro, R.S.T., Zuur, G., 1999. The effect on juvenile haddock by-catch of changing cod-end twine thickness in EU trawl fisheries. Mar. Technol. Soc. J. 33, pp. 61–72.

Larsen, R.B., 1989. A pilot test with a new technology in bottom trawls to avoid catch of juvenile fish (*in Norwegian*).

Larsen, R.B., 1990. Testing a new sorting technology for commercial bottom trawls. Selectivity experiments during May 1990 on board "Remifisk" (*in Norwegian*).

Larsen, R.B., Herrmann, B., Brinkhof, J., Grimaldo, E., Sistiaga, M., Tatone, I., 2018. Catch Efficiency of Groundgears in a Bottom Trawl Fishery: A Case Study of the Barents Sea Haddock. Mar. Coast. Fish. 10, pp. 493–507.

Larsen, R.B., Herrmann, B., Sistiaga, M., Brinkhof, J., Santos, J., 2018. Catch and release patterns for target and bycatch species in the Northeast Atlantic deep-water shrimp fishery: Effect of using a sieve panel and a Nordmøre grid. PLoS One 13, e0209621.

Larsen, R.B., Herrmann, B., Sistiaga, M., Grimaldo, E., Tatone, I., Brinkhof, J., 2018. Size selection of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) in the Northeast Atlantic bottom trawl fishery with a newly developed double steel grid system. Fish. Res. 201, pp. 120–130.

Larsen, R.B., Herrmann, B., Sistiaga, M., Grimaldo, E., Tatone, I., Onandia, I., 2016. Size selection of redfish (*Sebastes* spp.) in a double grid system: Estimating escapement through individual grids and comparison to former grid trials. Fish. Res. 183, pp. 385–395.

Larsen, R.B., Isaksen, B., 1993. Size selectivity of rigid sorting grids in bottom trawls for Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*), ICES mar. Sei. Symp.

Lövgren, J., Herrmann, B., Feekings, J., 2016. Bell-shaped size selection in a bottom trawl: A case study for Nephrops directed fishery with reduced catches of cod. Fish. Res. 184, pp. 26–35.

Madsen, N., Holst, R., 2002. Assessment of the cover effect in trawl codend selectivity experiments. Fish. Res. 56, pp. 289–301.

Madsen, N., Holst, R., Foldager, L., 2002. Escape windows to improve the size selectivity in the Baltic cod trawl fishery. Fish. Res. 57, pp. 223–235.

Madsen, N., Skeide, R., Breen, M., Krag, L.A., Huse, I., Soldal, A. V., 2008. Selectivity in a trawl codend during haul-back operation-An overlooked phenomenon. Fish. Res. 91, pp. 168–174.

Main, J., Sangster, G.I., 1985. Trawling experiments with a two-level net to minimise the undersized gadoid by-catch in a Nephrops fishery. Fish. Res. 3, pp. 131–145.

Melli, V., Herrmann, B., Karlsen, J.D., Feekings, J.P., Krag, L.A., 2020. Predicting optimal combinations of by-catch reduction devices in trawl gears: A meta-analytical approach. Fish Fish. 21, pp. 252–268.

Millar, R.B., Fryer, R.J., 1999. Estimating the size-selection curves of towed gears, traps, nets and hooks. Rev. Fish Biol. Fish. 9, pp. 89–116.

O'Neill, F.G., Kynoch, R.J., Fryer, R.J., 2006. Square mesh panels in North Sea demersal trawls: Separate estimates of panel and cod-end selectivity. Fish. Res. 78, pp. 333–341.

O'Neill, F.G., McKay, S.J., Ward, J.N., Strickland, A., Kynoch, R.J., Zuur, A.F., 2003. An investigation of the relationship between sea state induced vessel motion and cod-end selection. Fish. Res. 60, pp. 107–130.

Sangster, G.I., Lehmann, K., Breen, M., 1996. Commercial fishing experiments to assess the survival of haddock and whiting after escape from four sizes of diamond mesh cod-ends. Fish. Res. 25, pp. 323–345.

Santos, J., Herrmann, B., Mieske, B., Stepputtis, D., Krumme, U., Nilsson, H., 2016. Reducing flatfish bycatch in roundfish fisheries. Fish. Res. 184, pp. 64–73.

Sistiaga, M., Grimaldo, E., Larsen, R.B., 2008. Size selectivity patterns in the North-east Arctic cod and haddock fishery with sorting grids of 55, 60, 70 and 80 mm. Fish. Res. 93, pp. 195–203.

Sistiaga, M., Herrmann, B., Larsen, R.B., 2009. Investigation of the paired-gear method in selectivity studies. Fish. Res. 97, pp. 196–205.

Sistiaga, M., 2010. Selectivity studies in the Barents Sea bottom trawl gadoid fishery: Gear and methods: A dissertation for the degree of philosophiae doctor, University of Tromsø, Faculty of Biosciences, Fisheries and Economics, Norwegian College of Fishery Science. 164 pp.

Sistiaga, M., Brinkhof, J., Herrmann, B., Grimaldo, E., Langård, L., Lilleng, D., 2016. Size selective performance of two flexible sorting grid designs in the Northeast Arctic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) fishery. Fish. Res. 183, pp. 340–351.

Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R.B., 2010. Assessment of dual selection in grid based selectivity systems. Fish. Res. 105, pp. 187–199.

Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R.B., Olsen, L., Brinkhof, J., Tatone, I., 2018. Combination of a sorting grid and a square mesh panel to optimize size selection in the North-East Arctic cod (*Gadus morhua*) and redfish (*Sebastes* spp.) trawl fisheries. ICES J. Mar. Sci. 75, pp. 1105–1116.

Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R.B., Tatone, I., 2016. The effect of sweep bottom contact on the catch efficiency of haddock (*Melanogrammus aeglefinus*). Fish. Res. 179, pp. 302–307.

Sistiaga, M., Herrmann, B., Grimaldo, E., Larsen, R.B., Tatone, I., 2015. Effect of lifting the sweeps on bottom trawling catch efficiency: A study based on the Northeast arctic cod (*Gadus morhua*) trawl fishery. Fish. Res. 167, pp. 164–173.

Suuronen, P., Lehtonen, E., Jounela, P., 2005. Escape mortality of trawl caught Baltic cod (*Gadus morhua*) - The effect of water temperature, fish size and codend catch. Fish. Res. 71, pp. 151–163.

Tschernij, V., Suuronen, P., 2002. Improving Trawl Selectivity in the Baltic, TemaNord, 515th ed. Nordic Council of Ministers.

Tveit, G.M., Sistiaga, M., Herrmann, B., Brinkhof, J., 2019. External damage to trawl-caught northeast arctic cod (*Gadus morhua*): Effect of codend design. Fish. Res. 214, pp. 136–147.

Warren, P.J., Lovewell, S., 1976. Further consideration of two types of trawl used in a whitefish/Nephrops fishery.

Wienbeck, H., Herrmann, B., Feekings, J.P., Stepputtis, D., Moderhak, W., 2014. A comparative analysis of legislated and modified Baltic Sea trawl codends for simultaneously improving the size selection of cod (*Gadus morhua*) and plaice (*Pleuronectes platessa*). Fish. Res. 150, pp. 28–37.

Wileman, D.A., Ferro, R.S.T., Fonteyne, R., Millar, R.B., 1996. Manual of methods of measuring the selectivity of towed fishing gears, ICES, Cooperative Research Report No. 215.

Winger, P.D., Eayrs, S., Glass, C.W., 2010. Fish Behavior near Bottom Trawls, in: Behavior of Marine Fishes: Capture Processes and Conservation Challenges. Wiley-Blackwell, pp. 65–103.

Zuur, G., Fryer, R.J., Ferro, R.S.T., Tokai, T., 2001. Modelling the size selectivities of a trawl codend and an associated square mesh panel. ICES J. Mar. Sci. 58, pp. 657–671.