COST-BENEFIT ANALYSIS FOR MITIGATION MEASURES IN FISHERIES WITH HIGH BYCATCH

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Cost-Benefit Analysis for Mitigation Measures in Fisheries with High Bycatch

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Executive Summary

Bycatch is a major conservation and welfare issue for cetaceans in European waters. Harbour porpoises and common dolphins are frequently reported to be bycaught in static nets (gillnets and entangling nets) and trawls. Despite European legislation to monitor and mitigate cetacean bycatch in fisheries where it has a negative impact on the conservation status of a species, bycatch still occurs at high rates in several fisheries in the ASCOBANS Agreement Area. The lack of compliance by some countries has resulted in legal challenges from the European Commission for implementation of the required measures.

There are two main parts covered in this report. The first part reviews different mitigation measures (acoustic deterrent devices, porpoise alerting devices, reflective nets, acrylic echo enhancers, lights and various technical modifications and changes to fishing practices) that have been trialled in the ASCOBANS region. The cost of implementation and pros and cons of each method are discussed in detail in the relevant sections.

Acoustic deterrent devices (ADDs) (commonly referred to as ‘pingers’) are presently the only proven mitigation method in the ASCOBANS region with up to 100% bycatch reduction in the Danish North Sea and Celtic Sea. ADDs are mandatory in some fixed gear fisheries and have been the principal mitigation measure to reduce harbour porpoise bycatch in static gillnets because they require little or no change in fishing practices and gear. Trials with ADDs have also been conducted in purse-seines and pelagic trawls. ADDs are readily accessible in Europe and the cost of implementation ranges between 1,000-2,800 Euros based on a 4,000 m long gillnet.

The Porpoise Alerting Device (PAL) works by generating aggressive harbour porpoise communication signals. Trials using PAL on gillnets have been conducted with varying levels of success. Trials in the western Baltic reduced harbour porpoise bycatch by around 70% but trials in other areas were not effective. The cost of implementation is around 3,000 Euros for a 4,000 m long gillnet.

Acrylic echo enhancers are acrylic glass spheres that have been placed on gillnets at 30 cm intervals vertically and horizontally to increase the acoustic reflectivity of the net. Trials have been limited to date but have shown a reduction in bycatch in the Black Sea; however, further trials are needed. The cost of implementation ranges between 2,400-5,000 Euros based on a 4,000 m long gillnet, depending on the height of the net.

Light emitting diodes (LEDs) have been trialled to increase the visual detectability of surface driftnets and bottom set gillnets in Peru, with cetacean bycatch reduced by over 65%. Trials are currently being conducted off the southwest coast of England. The cost of implementation ranges between 1,500-3,000 Euros depending on the spacing of the LEDs along the net.

Rigid and soft exclusion devices to prevent cetacean bycatch were trialled in trawl fisheries in the NE Atlantic in the early 2000s. However, none of the devices were fully effective and research since then has focused on ADDs. Technical measures such as changing net height, twine diameter, and the acoustic properties of the twine are also discussed in the report.

Changes to fishing practices such as fishery closures have been effective in other areas of the world, e.g., New Zealand. However, it is difficult to ensure that bycatch outside of the protected area does not increase. For endangered cetacean species, this is probably the most effective mitigation measure to ensure that gear is removed from the area. Soak time and fishing effort are normally a function of catch rate, and therefore a shorter soak time is likely to have an impact on target species catch rates as well. Fishing depth and fishing time have been shown to potentially mitigate cetacean bycatch in the NE Atlantic, e.g., banning night-time fishing and fishing in depths over 250 m would likely significantly reduce common dolphin bycatch off Galicia, NW Spain.

In general, most mitigation measures within the ASCOBANS region are for static nets. However, there is no ‘one size fits all’ method even for similar gears in different regions. Mitigation measures and their effectiveness need to be assessed on a case-by-case basis for each fishery, area and species at risk, and trials should be conducted in operational fisheries. Regardless of the cost-benefit for each mitigation measure, countries must implement effective mitigation measures and comply with their legal obligations to prevent and reduce cetacean bycatch, or no mitigation measure will be sufficient.

The second part of the report reviews alternative fishing methods to replace static nets (i.e. gillnets and entangling nets). The cost of implementation, and pros and cons of the different gears, are discussed in depth in the relevant sections.

Small-scale nets have been trialled in the Baltic with a high catch efficiency, low discard rate and no marine mammal bycatch observed although their use in some areas might be limited to sandy substrates. Switching to a Danish seine net is around 44,000 Euros for a small-scale boat.

Jigging and long-lines can be very selective gears if the right size of hook and bait are used and they have a low discard rate, but catch efficiency is lower than gillnets. Depredation by seals and seabird bycatch are issues for

longlining in the ASCOBANS region, which may render their use problematic as an alternative gear to gillnets if mitigation measures are not applied.

The use of fish pots and traps as an alternative to gillnets in the Baltic Sea has been led by the need to reduce the amount of catch and gear damage caused by seals. Fish pots appear to be the most efficient gear without additional issues such as seabird bycatch. In fish pots, the catch efficiency can vary greatly between pots and seasonally. There is also the risk of cetacean entanglement in some areas. A small-scale vessel changing to 100 pots will cost around 46,000 Euros.

Pontoon traps, fyke nets and pound nets have also all been trialled as alternatives to gillnets in the Baltic. However, their use is limited to coastal waters. Marine mammal bycatch is low and if animals do enter the nets they can be released alive. Seals and cormorants have been reported to cause damage to fish catch in the nets. Switching to a pontoon fish chamber or fyke net costs around 5,000-7,000 Euros and 2,000 Euros, respectively. Switching to alternative gears for small-scale fishers might be complicated and/or expensive. Whilst gears need to be catch efficient, fisheries need to develop sustainable fishing methods that are good for both fishers and the environment, whilst ultimately aiming towards zero bycatch for cetaceans.

Overall, fisheries need to be viable, economically profitable, and sustainable. Close collaboration between industry, scientific institutions and government is essential for mitigation measures or for the switch to alternative gears to be successful. It is imperative that mitigation measures and alternative gears are tested in commercial fisheries. Furthermore, countries need to comply with their legal obligations to prevent and reduce cetacean bycatch by implementing mitigation measures in all gears with high levels of cetacean bycatch.

1. Introduction

The incidental capture of cetaceans in active fishing gear is called 'bycatch'. Bycatch has long been recognised as a serious threat to cetaceans world-wide (International Whaling Commission (IWC), 1994; Read, 2008). In European waters, bycatch is considered the main anthropogenic threat and a major conservation issue (e.g. Lowry and Teilmann, 1994; Tregenza *et al.,* 1997a, 1997b; Tregenza and Collet, 1998; López *et al.,* 2003; Skóra and Kuklik, 2003; Fernández-Contreras *et al*., 2010; ICES WGBYC, 2015; Peltier *et al.,* 2016; ICES WGBYC, 2019, ICES WGMME, 2015, 2019). Bycatch is not only a conservation issue, but also an important welfare issue (Soulsbury *et al.*, 2008; Dolman *et al.,* 2016). Bycatch can also be time-consuming, costly, and dangerous for fishers (Leaper and Calderan, 2018).

Several small cetacean species are reported as bycaught in the ASCOBANS region although the main two species recorded are the common dolphin (*Delphinus delphis*) and harbour porpoise (*Phocoena phocoena*). Both species are frequently reported as bycatch in static nets (mainly gillnets and entangling nets) (e.g. Lowry and Teilmann, 1994; Tregenza *et al.,* 1997a, 1997b; López *et al*., 2003; Skóra and Kuklik, 2003; Northridge *et al.*, 2019) whilst common dolphins are reported to be bycaught in large numbers in demersal and pelagic trawls (Tregenza and Collet, 1998; Morizur *et al.*, 1999; López *et al.*, 2003; Fernández-Contreras *et al.,* 2010; Mannocci *et al.,* 2012). Common dolphins are also reported to be bycaught in purse-seines off the Northwest Iberian Peninsula (NW Spain and Portugal), where the survival rate of encircled cetaceans is high (Aguilar, 1997; Wise *et al.,* 2007; Goetz *et al.,* 2014; Marçalo *et al.,* 2015). Nonetheless, there is a need to mitigate interactions to avoid entanglements and improve the techniques to release cetaceans from the seine (Marçalo *et al.*, 2015). The Convention on the Conservation of Migratory Species of Wild Animals (CMS) recently produced guidelines for the safe and humane handling and release of cetaceans from fishing gear and covers purse-seines (Hamer and Minton, 2020). Figure 1a and b show typical small-scale fishing boats in Galicia, NW Spain.

1.1. Legislation and International Commitments

Concerns over the impact of bycatch on cetacean populations has led to the drafting of various legislation and regional agreements within the ASCOBANS region. These include:

Figure 1a. Typical small-scale purse-seine boat in Galicia, NW Spain © Fiona Read

Figure 1b. Typical small-scale gillnet boat in Galicia, NW Spain © Fiona Read

EU Habitats Directive[1]

The main objective of the Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (the 'Habitats Directive' 92/43/EEC) is to maintain and restore biological diversity. All cetaceans are listed in Annex IV as species in need of strict protection throughout European waters from killing, incidental capture (e.g. bycatch), and disturbance. Member States are required to establish a monitoring programme for bycatch of species listed in Annex IV. Harbour porpoise and bottlenose dolphin (*Tursiops truncatus*) are also listed also in Annex II, requiring Member States to designate Special Areas of Conservation (SAC) for their protection.

The management of fisheries within the ASCOBANS area is currently in a state of flux. As of 1 February 2020, the UK left the EU, becoming an Independent Coastal State, and entered into a transition period in which fisheries management was maintained through the CFP. From 1 January 2021 the transition period ended, with the UK taking responsibility for fisheries management within its Exclusive Economic Zone (EEZ). Under the UK-EU Trade and Cooperation Agreement (TCA)[2] existing EU quota in UK waters will be transferred to the UK until June 2026 with agreements in place for each fishing stock and access to each other's waters through a fishing vessel licencing system. Negotiations on future fisheries management within the ASCOBANS area are currently ongoing.

Fisheries legislation relevant to the ASCOBANS region includes:

EU Common Fisheries Policy[3]

The basic legislation for EU fisheries policy and law is Regulation 1380/2013 of the Common Fisheries Policy (CFP). This Regulation underlines the need to protect marine biodiversity and ecosystems and for fisheries to be managed in a way that is consistent with other EU environmental legislation including the Habitats Directive and Marine Strategy Framework Directive (MSFD). Technical measures which the EU may adopt on the basis of Regulation 1380/2013, include *'specific measures to minimise the negative impact of fishing activities on marine biodiversity and marine ecosystems, including measures to avoid and reduce, as far as possible, unwanted catches'*. The EU regulates fishing activities of Member States through the CFP for all vessels outside 12 nm, and between 6-12 nm for vessels of other nations with a right to fish in a

1 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043
2 https://ec.europa.eu/info/strategy/relations-non-eu-countries/relations-united-kingdom/eu-uk-trade-and-cooperation-agreement_en
3 https://ec.europa.eu/fisheries/cfp_en

nation's waters. Nations manage fisheries inside 12 nm but must negotiate with the EU where measures are to be introduced that could affect other nations with a right to fish in their waters.

Within the CFP, the following are Regulations that are relevant to marine mammal bycatch:

Council Regulation for the conservation of fishery resources through technical measures in the Baltic Sea, the Belts and the Sound (EC 2187/2005)[4] is a Baltic bycatch reporting obligation for the assessment of cetacean bycatch in gillnets, trammel nets and entangling nets.

Within the **Data Collection Framework (DCF) Council Regulation (EC 199/2008)**[5], there is a requirement for observers to monitor all discards and incidental catches in several fisheries in the ICES area. In 2016, **Implementing Decision EU 2016/1251**[6] was adopted to establish a programme for the collection, management and use of data in fisheries and aquaculture, and included cetacean bycatch in the Annex under Chapter 3.

Council Regulation (EC) 812/2004[7] was specifically for monitoring of fisheries in order to reduce incidental catches of cetaceans. The main requirements included a ban of driftnets in the Baltic in 2008, mandatory use of acoustic deterrent devices (ADDs, e.g. 'pingers') for vessels ≥ 12 m involved in fixed gear fisheries in specific International Council for the Exploration of the Sea (ICES) areas and periods of the year, observers on some vessels of ≥ 15 m length and annual reporting to the Commission. Council Regulation 812/2004 was repealed in August 2019 and replaced with the Regulation on the Conservation of Fisheries Resources and the Protection of Marine Ecosystems through Technical Measures (EU 2019/1241).

Regulation on the Conservation of Fisheries Resources and the Protection of Marine Ecosystems through Technical Measures (EU 2019/1241)[8] came into effect in 2019. The Regulation aims to optimise technical measures to minimise impacts of fishing gears on sensitive species and habitats including the overall objective to minimise and where possible, eliminate bycatch. For cetacean bycatch monitoring and mitigation requirements, the Regulation is largely comparable to EC 812/2004 although it lacks some specific details such as specifications of acoustic deterrent devices and reporting requirements. Member States should introduce additional restrictions on specific fishing operations where scientific evidence shows a serious threat to the conservation status of a species or habitat.

In July 2020, **Commission Implementing Regulation (EU) 2020/967**[9] was published and lays down the detailed rules on the signal and implementation characteristics of ADDs for Regulation (EU) 2019/1241. The technical specifications and conditions of use of ADDs listed in (EU) 2020/967 is the same as those in Regulation EC 812/2004, and Member States will still require a derogation to use ADDs at the louder end of the range of 'pingers' such as Fishtek Marine's anti-depredation pingers or STM's Dolphin Deterrent Devices (DDD) (see ADD section for more details).

EU Marine Strategy Framework Directive[10]

EC Council Directive 56/2008 (Marine Strategy Framework Directive, MSFD) was adopted in 2008 and aimed to achieve or maintain Good Environmental Status (GES) in the marine environment of the EU by 2020. Member States are required to develop a marine strategy to achieve GES within a given timeframe and follows an 'adaptive management approach' requiring the Marine Strategies to be kept up-to-date and reviewed every six years. Member States are required to establish threshold values for the mortality rate from incidental catches per species. Methods for setting such threshold values are a subject of ongoing discussion within a number of bodies but there is currently no agreed EU wide approach and GES was not achieved by 2020.

United States Marine Mammal Protection Act Import Rule[11]

The United States (U.S.) Rule requires nations exporting fish and fish products to the U.S. to be held to the same standards as U.S. commercial fishing operations. The Rule implements provisions of the

4 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:32005R2187
5 https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:060:0001:0012:EN:PDF
6 https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32016D1251&from=EN
7 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32004R0812
8 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R1241
9 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R0967
10 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0056
11 www.federalregister.gov/documents/2016/08/15/2016-19158/fish-and-fish-product-import-provisions-of-the-marine-mammal-protection-act
12 https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-protection-act

Marine Mammal Protection Act (MMPA)[12] that aim to reduce marine mammal bycatch in commercial fishing operations. Measures include procedures to reliably certify that fish or fish products exported to the U.S. are not caught in fisheries where marine mammal bycatch is high. Governments must apply for a comparability finding for each of its fisheries. The Rule came into effect in 2017 and there is a 5-year exemption period to enable nations to assess their relevant fisheries and enact mitigation programmes. Notably, it has been agreed that the ASCOBANS 1% of best population estimate is an equivalent threshold to their Potential Biological Removal (PBR) approach for determining whether bycatch is an issue for common dolphins in the European NE Atlantic (ICES WKEMBYC, 2020).

Regional Agreements

ASCOBANS

The Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) is a regional agreement concluded under the auspices of the 1979 Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention or CMS)[13]. ASCOBANS requires Parties *"to achieve and maintain a favourable conservation status for small cetaceans"*. Within the Agreement, contracting Parties have international obligations for the conservation, research, and management measures prescribed in the Conservation and Management Plan, annexed to the Agreement, which includes bycatch. At the Eighth Meeting of the Parties in 2016, ASCOBANS adopted Resolution 8.5 on monitoring and mitigation of small cetacean bycatch, which was subsequently updated at the Ninth Meeting of the Parties in 2020[14]. The Resolution aims *"to ultimately reduce bycatch to zero"*.

In 2008, the range covered by ASCOBANS was extended westwards and southwards to include Ireland, Spain and Portugal. The extension was formally accepted by all Parties except Belgium and Lithuania although to date, Ireland, Spain and Portugal are not signatories.

The following plans have been adopted by Parties, with several actions and recommendations to monitor and mitigate bycatch in the relevant regions:

i) ASCOBANS Conservation Plan for Harbour Porpoises (*Phocoena phocoena L.*) in the North Sea (ASCOBANS, 2009)
ii) ASCOBANS Conservation Plan for the Harbour Porpoise Population in the Western Baltic, the Belt Sea and the Kattegat (ASCOBANS, 2012)
iii) ASCOBANS Recovery Plan for Baltic Harbour Porpoise (also called the Jastarnia Plan) (ASCOBANS, 2016 revision)
iv) ASCOBANS Species Action Plan (SAP) for North-East Atlantic Common Dolphin (Delphinus delphis) (ASCOBANS, 2019)

HELCOM

The Baltic Marine Environment Protection Commission or Helsinki Commission (HELCOM) is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area'. The main objective of HELCOM is for a *'healthy Baltic Sea environment with diverse biological components functioning in balance, resulting in a good ecological status and supporting a wide range of sustainable economic and social activities*'. HELCOM Recommendation 17/2[15] and the Baltic Sea Action Plan[16] call for protection of harbour porpoise in the Baltic Sea with the aim to significantly reduce bycatch rates to close to zero.

OSPAR

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) (replacing the Oslo and Paris Conventions) is the mechanism by which 15 Governments and the EU co-operate to protect the marine environment of the North-East Atlantic. The aim of the Convention is *'to prevent and eliminate pollution and to protect the maritime area against the adverse effects of human activities'*. Harbour porpoise is included in the OSPAR List of Threatened and/or Declining Species and Habitats for the Greater North Sea and Celtic Seas due to evidence of declines in populations, their sensitivity, and bycatch[17]. OSPAR also have a network of Marine Protected Areas (MPA) which include harbour porpoise sites[18].

13 www.ascobans.org/es/documents/agreement-text
14 www.ascobans.org/en/document/monitoring-and-mitigation-small-cetacean-bycatch-0
15 www.helcom.fi/wp-content/uploads/2019/06/Rec-17-2.pdf
16 www.helcom.fi/baltic-sea-action-plan/
17 https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/marine-mammals/harbour-porpoise-bycatch/
18 https://www.ospar.org/work-areas/bdc/marine-protected-areas

Overview of Legislation in the ASCOBANS Area

Despite the various legislation and regional commitments, high levels of bycatch still occur throughout the ASCOBANS region especially for the Baltic Proper harbour porpoise (HELCOM, 2013a; IWC WGBYC, 2020), common dolphin in the NW Iberian Peninsula, Celtic Sea and Bay of Biscay (Goetz *et al.,* 2014; Peltier *et al*., 2020; 2021, ICES WGBYC 2020), harbour porpoise in the North Sea and Channel, (ICES WGBYC, 2015; Kindt-Larsen *et al*., 2016; Northridge *et al*., 2019) and the Iberian harbour porpoise (Read *et al*., 2013; Read, *et al*., 2020; Pierce *et al.*, 2020). Following reviews on the effectiveness of EC 812/2004 by the European Commission in 2009 and 2011, Member States were urged to improve implementation (European Commission, 2009; 2011). Implementation has not improved in more recent years (ICES bycatch reports[19]; Read *et al.*, 2017; STECF, 2019) and the limited monitoring by Member States has impeded the application of effective mitigation of cetacean bycatch in most fisheries (ASCOBANS, 2015). Without data from monitoring, mitigation options need to be considered, implemented and evaluated based on expected risk and reduced risk estimates (Leaper and Calderan, 2018).

Objective

The present report focuses on gear modifications/ specific measures that have been used to date in the ASCOBANS region to mitigate cetacean bycatch. The state of knowledge, cost of implementation, availability and the pros and cons of each method are discussed. The costs of implementation for each method have been presented in relation to the length of gear (m) irrespective of vessel length.

The second section of the report reviews alternative gears to static nets and to a lesser extent, trawls. Potential changes in bycatch rates, target species catch rates, costs associated with changing gears, and the pros and cons of alternative methods, are discussed.

19 http://www.ices.dk/news-and-events/news-archive/news/Pages/Catch-the-latest-round-of-bycatch-advice.aspx

2. Bycatch Mitigation Measures

2.1. Acoustically Detectable Nets

2.1.1. Acoustic Deterrent Devices

2.1.1.1. Current knowledge

Acoustic deterrent devices (ADDs) are small electronic devices that emit low intensity sounds. The sound pressure levels in devices commonly used are generally around 145 dB re 1 μPa @ 1m, although some devices emit up to 165 dB dB re 1 μPa @ 1m (100 x the power). Depending on the type of ADD, they will produce either a constant frequency with pulses repeated at a set interval (e.g. every 4 seconds) or randomised signals which may be at set or random intervals (Kindt-Larsen *et al*., 2019). ADDs operate at varying frequencies and different sound pressure levels. ADDs are often referred to as 'pingers'. In addition to mitigating cetacean bycatch, relatively high output emitters (>185 dB) are used as a form of mitigation to exclude animals from areas where there is a risk of interactions e.g. aquaculture facilities, pile driving at offshore wind farms or detonation of unexploded ordnance. These relatively high output emitters should be referred to as Acoustic Harassment Devices (AHDs) rather than ADDs. The type of acoustic device required will depend on the application of the device(s). McGarry *et al*. (2020) provide a good overview of the different devices available and their application. The hypotheses for how ADDs work are discussed in Dawson *et al.* (2013). The authors concluded that they most likely work by deterring small cetaceans away from the area.

To date, ADDs have been the principal mitigation method used to reduce harbour porpoise bycatch in static gillnets and require little or no change in fishing practices and gear (Dawson *et al*., 2013). In the ASCOBANS region, trials with ADDs to mitigate harbour porpoise bycatch in gillnets started in the mid-1990s in the Danish North Sea and Celtic Shelf fisheries (Larsen, 1999; Northridge *et al.,* 1999; Carlström *et al*., 2002). ADD effectiveness and economic viability differs between gear types, species and fisheries, with it more likely to be economically viable to deploy ADDs on gear contained within a relatively small range (e.g. gillnets, trawls) than using pingers to deter marine mammals from longlines, which can extend over tens of kilometres (Hamilton and Baker, 2019).

Under EU Regulations, the use of ADDs is mandatory for vessels ≥ 12 m involved in fixed gear fisheries (bottom-set gillnets and entangling (trammel) nets) in some specific ICES areas and periods of the year with specific net lengths and mesh sizes in the North Sea. Although bycatch of common dolphins and harbour porpoise in gillnets had been reported (e.g. Tregenza *et al.*, 1997a, 1997b), when EC Regulation 812/2004 was drafted in the early 2000s, the true extent of cetacean bycatch remained poorly understood.

The Regulation was drafted without a thorough understanding of the effectiveness of particular acoustic thresholds and/or frequencies in relation to different cetacean species. Therefore, the specifications of the ADDs described in the Regulation were aimed at reducing harbour porpoise bycatch and were not necessarily effective for common dolphins (Northridge *et al*., 2011). The "dinner bell" effect of ADDs has been suggested as an issue for animals intentionally using ADDs to detect and depredate on active nets, especially pinnipeds (e.g. Dawson, 1991; Read *et al.,* 2003; Carretta and Barlow, 2011). In recent years, most ADDs have been designed to be 'seal safe' (e.g. pingers manufactured by Future Oceans[20] and Fishtek Marine[21]), i.e. above the hearing range of pinnipeds which is estimated to be within 0.5 and 40 kHz (Kastelein *et al*., 2009; Todd *et al.,* 2019).

Various ADDs have been tested throughout the ASCOBANS region for bycatch mitigation under EU legislation and scientific research trials mostly to comply with EC 812/2004 obligations. However, the results of the trials have not been consistent (see details below) and overall implementation and compliance of EC 812/2004 was very patchy (Read *et al*., 2017). Following the introduction of EC 812/2004, the European Commission requested the International Council for the Exploration of the Sea (ICES) for advice on effectiveness. This subsequently became a standing request and the ICES Working Group on Bycatch of Protected Species (ICES WGBYC)[22] have since undertaken annual assessments. Almost all of the assessments have advised that there was insufficient monitoring by Member States. The ICES WGBYC reports as well as Dawson *et al.* (2013) give a good overview of studies conducted to determine the effectiveness of ADDs by different countries. Figure 2 shows some of the ADDs that have been used in the ASCOBANS region to reduce the chance of cetaceans becoming entangled in fishing gear.

Trials to reduce harbour porpoise bycatch using pingers have been successful in the Danish North Sea and Celtic Sea, reducing bycatch rates by between 63 and 100% whilst having no impact on target species (e.g. Larsen, 1999; Larsen *et al.*, 2013; ICES WGBYC 2019, 2020). In 2016, it was estimated that around 200 harbour porpoises were 'saved' by the use of ADDs in UK gillnet fisheries (Northridge *et al.,* 2017a) although this was only around 15% of the estimated annual total. Whilst several Member States reported using ADDs between 2006-2017 in annual reports submitted to ICES, limited

20 https://www.futureoceans.com
21 https://www.fishtekmarine.com/deterrent-pingers
22 https://www.ices.dk/community/groups/Pages/WGBYC.aspx

Figure 2. Some of the ADDs that have been used in the ASCOBANS region to reduce the chance of cetaceans becoming entangled in fishing gear. From left to right, Future Oceans Dolphin Pinger, FishTek Marine banana pinger, STM Products DDD 03L and DDD 03H. © Manufacturers

information exists on the impact of ADDs on bycatch rates. Furthermore, in 2013, ICES changed to reporting bycatch rates by ICES fishing area and species rather than by country, although implementation of ADDs is on a country basis.

Trials by the UK, Ireland, and France found that none of the ADDs described by EC 812/2004 were suitable for nets in operation. The main issues with the devices specified in the Regulation were i) the need for devices every 100-200 m in nets around 2-4 km long, ii) high levels of damage and/or loss of the devices, iii) potential dangers to fishers during handling of the gear, and iv) ADDs specified may only be effective for harbour porpoise (Seafish, 2003; 2005; Cosgrove *et al*., 2005; Le Berre, 2005; Northridge *et al.,* 2011; ICES WGBYC, 2012).

The majority of ADD trials and implementation have been in static nets. However, a large number of small cetaceans, predominantly common dolphins, are caught in trawls. In 2007 and 2008, IFREMER (French Research Institute for Exploitation of the Sea) and a French company called Ixtrawl developed and tested a prototype pinger, the CETASAVER, for use in the French pelagic pair trawl fishery for European sea bass (*Dicentrarchus labrax*). A 50-70% reduction in the bycatch rate of common dolphins was found when the CETASAVER was deployed (Morizur *et al*., 2008). No further information on the trials or device has been reported. In 2009, France stopped undertaking ADD trials in gillnets (Read *et al*., 2017).

At-sea trials with six different ADD devices including Dolphin Deterrent Devices (DDD) (devices at the louder end of the range of 'pingers') produced by STM Industrial Electronics and CETASAVER were tested on common dolphins[23] with no evasive behaviour observed (Berrow *et al*., 2008). In 2008 and 2014, the UK and France, respectively, successfully applied for derogations of EC 812/2004 to use DDDs. A derogation was required due to the specifications of the DDDs not being in accordance with ADDs under the Regulation. Trials using DDDs in the UK pelagic pair trawl fishery for European sea bass in the Western Channel showed promising results with between 75-90% reduction in common dolphin bycatch in trawls with DDDs (Northridge *et al*., 2011, 2012) until this fishery closed in 2015. Following the initial results from the UK fleet, Ireland voluntarily implemented DDDs in the albacore tuna (*Thunnus alalunga*) pelagic trawl fleet. Information on the trials is very limited although between 2005-2012 (the last two years with DDDs voluntarily implemented) no cetacean bycatch was observed in the tuna fishery (ICES WGBYC, 2013, 2014). No studies were carried out to evaluate effectiveness of DDDs in static nets and compliance was low in France with only 9 of 77 vessels requiring ADDs using them (ICES WGBYC, 2019). Between February and April 2018, trials were performed to test the efficiency of DDDs in French midwater pair trawlers in the Bay of Biscay. A 65% reduction in cetacean bycatch was modelled for the fleet based on the observed results (Rimaud *et al*., 2019). In general, there is a lack of studies on the effectiveness of ADDs for reducing common dolphin bycatch (Northridge *et al*., 2019; Tindall *et al*., 2019) and ADDs did not appear to be a consistently effective deterrent for common dolphins

23 https://www.stm-products.com/en/products/fishing-technology/

during controlled at-sea trials despite the absence of the operational noise of the trawler (Berrow *et al.,* 2008).

Previous ADD trials were performed in purse seines, gill and trammel nets, and beach seines in the western coast of Portugal under the EEAGrants SAFESEA (2009-2011) and LIFE+ MarPro (2011-2017) projects (Vingada *et al.,* 2011; Vingada and Eira, 2017). The trials revealed that ADDs (Future Oceans 70 and 10 kHz, 145 dB) contributed to common dolphin and harbour porpoise bycatch mitigation. In the particular case of trammel nets, there was a 52% decrease in common dolphin bycatch mortality and an 83% decrease in harbour porpoise bycatch mortality (Pereira *et al*., 2019a). Following the LIFE+ MarPro project results, a National Regulation (Portaria 172/2017) issued by the Portuguese Ministry of the Sea stipulated that beach seines should be equipped with ADDs. To promote compliance, the ConMAR project (Fundo Ambiental) offered ADDs to the beach seine fishery in north-central Portugal in 2019. However, there was no monitoring of these ADDs in the beach seine fishery due to lack of funding. Trials using ADDs (DDD and DiD) adapted to set nets (to reduce depredation by bottlenose dolphins) and purse seines started in the Algarve, southern Portugal in 2018 under the Mar2020-iNOVPESCA project.

Optimal spacing of ADDs is critical to their effectiveness. ADDs need to be spaced far enough apart to minimise the cost implications of the devices but close enough to be effective at mitigating bycatch along the entire gear as any gaps could result in bycatch. Due to the nature of the gear, there is less of a financial impact of ADDs for trawlers than gillnets, e.g. 3-4 DDDs are required for each trawl (Northridge *et al*., 2011). Harbour porpoise bycatch in the Danish North Sea gillnet fishery was reduced by 100% when ADDs (Aquatec AQUAmark 100) were spaced at intervals of 455m and by 78% when ADDs were spaced at 585m intervals (Larsen and Krog, 2007; Larsen *et al.,* 2013). Following the original trial, Denmark and Ireland applied for derogations to increase the spacing of ADDs in gillnets to 455m and 500m, respectively. The ADD (AQUAmark 100 by AQUATec Group[24]) used in the Danish fisheries under the derogation is no longer available so fishers have changed to a 10 kHz ADD but it is not as effective, and the distance between devices is 200m (ICES WGBYC, 2020). In the UK, DDDs are placed on gillnets at 4km intervals (based on a 2km effective range) (Coram and Northridge, 2018), although the manufacturer recommends around 400m between devices (STM Products, Pers. Comm.). It is not known why the spacing used differs from the manufacturer's recommendations or the potential implications on the results. It is also often not clear how the manufactures came to their spacing recommendations. Using pingers at 400m intervals instead of 4km will significantly increase the cost of implementation and potentially discourage their use by fishers. In the UK, if pinger use is not mandatory, the vessel needs a licence to disturb to use them; this is a daunting process and is likely to dissuade fishers from applying.

Whilst the aim of ADDs is to deter animals from nets to avoid bycatch, there has been concerns about the impact of displacement (e.g. Dawson *et al*., 2013; Kyhn *et al*., 2015). Should displacement by ADDs be negative and worse than bycatch itself, then the effective range of displacement is likely to be a function of the acoustic characteristics of the ADD being used. With higher source levels and lower frequencies propagating further in water than lower sources and higher frequencies.

That said, new evidence by Omeyer *et al*. (2020) and anecdotal observations by fishers deploying ADDs (50-120 kHz and 145 dB) counter these perceptions. Omeyer's study on the banana pinger showed that there was 1) a very small range of ADD effect, 2) rapid-reoccupation of sea areas by harbour porpoise when the ADD stopped, 3) no evidence of habituation and 4) an absence of any long-term effect on behaviour. The general conclusion was that banana pingers are likely to reduce harbour porpoise bycatch in gillnet fisheries without negative consequence.

High numbers of ADDs will be used in areas with high gillnet numbers. It is also important to understand which sub-group(s) of a population is being displaced by the use of ADDs (Kyhn *et al*., 2015). It has been suggested that the deterrent effect of ADDs may be different for foraging vs travelling dolphins (Anon, 2007). However, Berrow *et al*. (2008) found the reaction of common dolphins to ADDs was not associated with behaviour. Before ADDs can be fully implemented to mitigate bycatch, the large scale and long-term impacts need to be understood especially in critical habitats and Marine Protected Areas such as Natura 2000 sites (Teilmann *et al.*, 2015). Furthermore, particular attention should be given to the use of ADDs in Marine Protected Areas where low abundance cetacean populations persist, such as the Iberian harbour porpoise population, which coexists with an extremely high density of coastal gill and trammel nets.

The use of ADDs may potentially impact the catch rate of the fishery's target species. Herring (*Clupea harengus*) were not affected by the use of ADDs in the Baltic Sea (*n* = 25,407 fish captured) (Culik *et al*., 2001). European sardine (*Sardina pilchardus*) showed no response to a ADD in a tank experiment (Goetz *et al*., 2015). On the other hand, Kastelein *et al*. (2007) found that Atlantic herring, European seabass and thicklip grey mullet (*Chelon labrosus*) showed aversive behaviour when exposed to four of seven commercial ADD models. Comparisons of actual catches in nets with and without ADDs are required to measure the effect of ADDs on fisheries (Kastelein *et al.*, 2007). Modern ADDs which are high frequency and seal safe – transmit well outside the hearing range of fish so there should be no impact

24 http://www.aquatecgroup.com/

on target species. Comparisons of actual catches in trammel nets with and without ADDs under the LIFE+ MarPro project in the western coast of Portugal showed no significant differences between target species catch per unit effort (CPUE) (Pereira *et al*., 2019b).

For harbour porpoise in the North Sea, displacement is unlikely to be problematic for the population given the large ranges of the animals and the habitat available (Sveegaard *et al.,* 2011). If ADDs are fully implemented in the respective gillnet fisheries a loss of <1% of habitat is estimated (Larsen and Hansen, 2000; Northridge *et al.,* 2011; Coram and Northridge, 2018). Other causes of anthropogenic disturbance(s) such as wind farm construction should also be considered in future models for habitat disturbance (Nabe-Nielsen *et al.*, 2014).

Puck Bay, southern Baltic Sea, is an area with a high density of harbour porpoise and intense gillnet fishing (Skóra and Kuklik, 2003). Despite the high bycatch rate in the area, the area is outside of the Natura 2000 sites and was not covered under EC 812/2004. However, it is covered by Article 12 of the Habitats Directive requiring bycatch mitigation. In 2010, an acoustic barrier using ADDs (AQUAmark 100) was installed across the entire bay (around 17 km wide) in 2010. No bycatch was reported during the experiment. However, this was a short-term solution and other methods to mitigate bycatch need to be implemented.

Habituation of small cetaceans to ADDs is difficult to assess because it requires knowledge that the same individuals are being exposed to the ADDs. Several factors will influence the potential for habituation such as signal frequencies, source level, how often the animal encounters the ADD signals, and the behaviour of the animals to ADDs. Habituation of harbour porpoise has been observed in some fisheries (e.g. Cox *et al.*, 2001; Carlström *et al.*, 2009; Kyhn *et al.,* 2015) but not in others (e.g. Carretta and Barlow, 2011; Sørensen and Kindt-Larsen, 2016; Northridge *et al*., 2019). It should be noted that the former studies used the 10kHz 4-second spaced signal. ADDs such as the FishTek Marine banana pinger and Future Oceans Dolphin Pinger have a randomised frequency and ping structure designed to eliminate habituation. The bycatch rate of harbour porpoise has not increased in fisheries using ADDs long-term (Palka *et al.*, 2008; Dawson *et al*., 2013). Habituation can be avoided by varying signals such as the signal type and area (Kindt-Larsen *et al*., 2019). In the ASCOBANS region, ADD use has been limited in most fisheries and so the long-term effects are unknown although Northridge *et al.* (2019) found no evidence of ADD habituation for harbour porpoise in UK fisheries.

The use of 'responsive' or 'reactive' pingers in static nets, which have been developed to only emit sounds in response to cetacean echolocations, could reduce the likelihood of pinger habituation for some species as well as reducing noise pollution (Leeney *et al*., 2007; Waples *et al.,* 2013; Hamilton and Baker 2019).

In quality control tests, the same brand and model of ADDs were found to emit different frequencies (Kraus *et al.*, 1995, Dawson *et al.*, 2013) suggesting that quality control of ADDs needs to improve and an independent accreditation system might improve confidence in ADD quality (Dawson *et al.*, 2013). In several fishery trials, practicality and reliability issues have been associated with using pingers (e.g. Cosgrove *et al*., 2005; Seafish, 2003; 2005; Le Berre, 2005; Krog and Larsen, 2007).

Conducting bycatch reduction experiments with ADDs can be very costly (Kindt-Larsen *et al.*, 2019) and nearly all studies have been on harbour porpoise. Studies traditionally measure harbour porpoise presence by acoustic encounters which relies on harbour porpoises echolocating around acoustic detection devices (e.g. Cetacean – Porpoise Detector (C-POD), Chelonia Limited). Harbour porpoise have been found to echolocate less frequently in the vicinity of active ADDs (Cox *et al*., 2001; Omeyer *et al*., 2020), and background noise may also mask the noise of ADDs in some areas (Hardy *et al.*, 2012; Omeyer *et al.*, 2020).

Experimental set-ups are often not reflective of the real situation and do not appear to represent harbour porpoise around nets, therefore ADDs need to be tested directly in fisheries with high bycatch rates (Kyhn *et al.,* 2015). Knowing that ADDs can significantly reduce bycatch rates emphasises that welfare considerations need to be accounted for when conducting trials using nets without ADDs if fishing effort is increased. Determining mitigation efficacy should include species- and fisheries-specific testing with adequate scientific rigour, and a quantitative target to enable efficacy assessment, although undertaking adequate testing, including a control of no-deterrent, are often difficult to implement for ethical reasons (Hamilton and Baker, 2019). Trials should also consist of an array of devices such as in a real fishery situation rather than an individual stationary device.

Despite legislation on the mandatory use of ADDs in certain fisheries in the ASCOBANS region, adequate implementation is low and compliance has not been fulfilled by most Member States (ICES bycatch reports[25]; Read *et al*., 2017; STECF, 2019) and the measures are not sufficiently reducing bycatch (Read *et al*., 2017; STECF, 2019; Dolman *et al.*, 2021; Rogan *et al*., 2021). Infringement of mandatory ADDs (either lack of devices or devices not functioning) was mentioned by Denmark, France, Germany, Ireland, Poland, Sweden and the UK in their EC 812/2004 reports. It is hard to determine if an ADD stopped working during the last fishing operation or previously. Cetacean bycatch was 10 times higher in gillnets with malfunctioning ADDs than nets without ADDs (Carretta and Barlow, 2011). If ADDs are to be

25 http://www.ices.dk/news-and-events/news-archive/news/Pages/Catch-the-latest-round-of-bycatch-advice.aspx

used as a mitigation method, compliance needs to be enforced effectively. In order to test the functionality of individual devices, Fishtek Marine that manufacture the 'banana pinger' used in Omeyer *et al.* (2020) has made a low cost pinger detector. They have also made spare 'bananas' (the rubber carriers) so that the carriers can be attached on the gear allowing the ADD devices to be switched between gears with ease.

The specifications of the different ADDs will assist in determining which device would be most effective for different fisheries, e.g. efficient at reducing bycatch whilst being economically feasible, not causing excess acoustic pollution, displacement, habituation and the speed at which the gear is shot. There may be the need to assess potential 'trade-offs' e.g. one device in a short gear may be cheaper and have a smaller acoustic footprint on the habitat than a different device in a longer gear. Habitat exclusion caused by high ensonification would be against the Habitats Directive, therefore it is imperative that 'louder' ADDs such as the DDD are not be used in coastal fisheries where the gillnet is generally less than 1 km in length, and/or several smaller nets are set in high density grids perpendicularly to the coast.

Overall, the benefit of using ADDs as a mitigation method needs to be assessed on a case by case basis and will depend on the size of the area, the importance of the area for the species being mitigated and the level and distribution of fishing effort in the area (Kindt-Larsen *et al.*, 2019). Alternative long-term solutions to ADDs should be sought for critical habitats, e.g. SACs (Carlström *et al.*, 2009; ASCOBANS, 2016). If ADDs are to be used in a SAC (or affect a feature of the SAC) for a prolonged period of time, a Habitats Regulations Appraisal/Assessment (HRA) may be required (McGarry *et al*., 2020). Effective bycatch mitigation strategies often comprise a suite of management measures (Hamilton and Baker, 2019).

2.1.1.2. Cost of implementation

The cost of implementing ADDs depends on the device used, the spacing of the devices and the length of the gear. Table 1 gives an overview of the costs for six different devices from three manufacturers that are presently used in the ASCOBANS region. The prices exclude carriage or any country specific tax and import duties (if applicable).

The AQUAmark 100 was used for many projects, especially in the Danish North Sea and Baltic Sea. However, production has stopped so the cost of this device has not been considered. All the devices in Table 1 are available throughout the ASCOBANS region and globally.

The spacing in Table 1 refers to the spacing as specified by the manufacturers and not individual country's derogations or the results from scientific studies.

2.1.1.3. Pros

- Readily accessible in Europe
- No substantial changes to fishing behaviour or gear required
- Easy to deploy and operate
- Good effective range (range is device dependent)
- Can be adapted for use in different gears, e.g. DDDs are being used in static nets, trawls and purse seines
- Functionality of some devices can be checked on-board or underwater using a suitable hydrophone
- Internal shock-absorber to prevent accidents on-board
- Long battery life (around 2 years of normal operation). Batteries are replaceable/rechargeable
- Automatically activates when submerged in water

Trawl specific pros

- Can be attached to different parts of the gear (e.g. floatline, end ropes, bridles)

Static net specific pros

- Attaches to the gillnet headline, no need for specialised fishing gear or gear adaptations
- Trials to reduce harbour porpoise bycatch using pingers have been successful in the Danish North Sea and Celtic Sea, reducing bycatch rates by between 63 and 100%

2.1.1.4. Cons

- Results are not uniform. Effectiveness of devices varies by species, fisheries, fishing metiers and geographical areas. For some species and fisheries there is no evidence that ADDs are effective
- Distance between devices needs to be confirmed for each device and area
- Acoustic pollution
- Ambient noise may mask the deterrent effect of the pingers
- Potential impacts on catch rate of target species
- Need continuous energy
- 'Dinner bell' effect for seals although several devices are now 'seal safe'
- Require regular maintenance
- Minor lapses in compliance and reliability of the ADDs may result in higher bycatch rates
- May not be effective on all groups of animals (travelling v foraging animals)

Trawl specific cons

- Some models may interfere with setting and hauling

Static net specific cons

- Potential for displacement from important habitat(s)

Table 1. Number of devices and the estimated cost of different ADDs for different gear lengths

Manufacturer	Device	Frequency (kHz)	Sound pressure level (dB)	Cost per device (Euros)	Spacing (m)	Gear	Length of gear (m)							
								1,000	2,000	4,000	6,000	8,000	10,000	12,000
Future Oceans	Porpoise and Dolphin Pinger	10	132	67	100	Set net	No. devices	10	20	40	60	80	100	120
							Cost**	670	1,340	2,680	4,020	5,360	6,700	8,040
Future Oceans	Porpoise and Dolphin Pinger*	60-120*	145	78	200	Set net	No. devices	5	10	20	30	40	50	60
							Cost**	335	670	1,340	2,010	2,680	3,350	4,020
Fishtek Marine	Porpoise Deterrent Pinger (banana pinger)	10	132	53.5	100	Set net	No. devices	10	20	40	60	80	100	120
							Cost**	535	1,070	2,140	3,210	4,280	5,350	6,420
Fishtek Marine	Porpoise & Dolphin Deterrent Pinger (banana pinger)	50-120	145	53.5	200	Set net	No. devices	5	10	20	30	40	50	60
							Cost**	268	535	1,070	1,605	2,140	2,675	3,210
STM Products	DDD-03L	5-500	165	255-300 (mean 277)	400	Set net	No. devices	3	5	10	15	20	25	30
							Cost**	693	1,385	2,770	4,155	5,540	6,925	8,310
STM Products	DDD-03H	5-500	165	255-300 (mean 277)	400	Set net	No. devices	3	5	10	15	20	25	30
							Cost**	693	1,385	2,770	4,155	5,540	6,925	8,310
STM Products	DDD-03H	5-500	165	255-300 (mean 277)	NA	Trawl	1,200-1,400 (3-4 devices required per trawl, Northridge *et al.*, 2011)							

***previously Dolphin Pinger 70kHz**
****Total cost (Euros) shown in darker cells**

- Unknown if displacement is the same for all individuals or sub-groups of the population
- May silence the echolocation of cetaceans

2.1.2. Porpoise Alerting Device (PAL)

2.1.2.1. Current knowledge

The Porpoise Alerting Device (PAL) has been developed by F3: Forschung in Germany. PAL works by generating aggressive harbour porpoise communication signals based on those observed during behaviour studies at the Fjord and Belt Centre, Kerteminde, Denmark (Clausen *et al.,* 2011). PAL transmits continuously in cycles by randomly generating 1-3 warning signals followed by a pause for 8-30 seconds during each cycle. Each cycle is different so it is thought that habituation is unlikely. PAL has been designed with the help of fishers so the devices are user friendly. The devices are attached to the headrope of the gillnet and spaced at 200 metre intervals.

During at-sea trials, PAL and C-PODs were attached to four mooring buoys in the Little Belt in Danish waters and porpoise behavioural responses were also recorded from land. The life-like synthetic signals of the PAL increased the minimum distance of porpoises to the sound source by around 19 metres and intensified their echolocation by around 10%. It is thought that these effects lead to an earlier perception of unmarked hazards (such as gillnets) and a reduction in the collision probability (Culik *et al.*, 2015a) rather than act as a deterrent to the area or cause a reduction in echolocation as observed with ADDs such as 'pingers' (Teilmann *et al.,* 2006; Carlström *et al*., 2009). PAL is directional so the devices need to be attached facing the same direction to avoid acoustic 'holes' (Culik *et al.,* 2015b; Chladek *et al.,* 2020).

In trials in the Western Baltic Sea, professional fishermen conducted their normal fishing activities with 50% of gillnets equipped with PAL (1 device every 200 metres) and the other 50% (without PAL) acted as the control nets. The control nets were placed at least 500 metres away from the nets with PAL. All other characteristics of fishing activities were the same (e.g. mesh size, net length and height, depth, setting time, fishing duration, etc.). The target species of the fishery were cod (*Gadus morhua*) and turbot (*Scophthalmus maeoticus*). Fisheries data and bycatch were recorded by fishers in addition to fisheries observers and remote electronic monitoring on some vessels. Between 2014 and 2016, a total of 2649 net hauls were analysed from 778 trips. No impact on target species was observed (Chladek *et al.,* 2020). The nets with PAL had over 70% reduction in harbour porpoise bycatch. Five harbour porpoise were bycaught in nets with PAL compared to 18 in the control nets (Chladek *et al.,* 2020). Ruser (2019) reported that there was no reduction in harbour porpoise strandings in the area during the study by Chladek *et al.* (2020). However, evidence of fisheries-interactions in the stranded porpoises was not reported.

In contrast, studies in the Danish North Sea and Iceland have not been successful. In the Danish North Sea and Icelandic waters, using the same signal of PAL as in the Baltic trials, the rate of harbour porpoise bycatch was not significantly different in standard nets to those equipped with PAL. In Iceland, nearly all the porpoises bycaught in the gillnets equipped with PAL were adult males (Boris Culik, Pers. Comm.; ICES WGBYC, 2019) indicating a potential attraction to the devices.

Porpoises in the Fjord and Belt Centre originate from the Danish Belt Sea (Verfuß *et al.,* 2005) and the PAL has been based on their communication signals, suggesting that the PAL signals may need to be harbour porpoise population specific (Culik *et al.,* 2017).

Overall, initial studies with PAL are promising at reducing harbour porpoise bycatch in the western Baltic but have been ineffective elsewhere. There are still knowledge gaps that need to be investigated, e.g. sound propagation along the nets, does deterrence or behaviour change(s) occur (see Ruser (2019) for an overview), and the potential for use in other areas with population specific warning sounds.

2.1.2.2. Cost of implementation

Table 2 gives an overview of the cost of implement PAL in different length set-nets. The cost of PAL is 150 Euros per device. The price excludes carriage or any country specific tax and import duties (if applicable).

Table 2. The number of devices and cost of implementing PAL in different gear lengths

Length of gear (m)	1,000	2,000	4,000	6,000	8,000	10,000	12,000
No. of devices required*	6	11	21	31	41	51	61
Total cost (Euros)	900	1,650	3,150	4,650	6,150	7,650	9,150

**1 device per 200 m of net plus 1*

26 http://www.f3mt.net/harbour-porpoise---pal.html

The PAL devices are serviceable. After 2-3 years' operation, PAL devices are refurbished at a cost of 30 Euros (excluding tax) per device. In Germany, 99% of 1500 devices were able to be refurbished and updated with the latest software, a new battery and a new O-ring after 3 years of use. The ability to refurbish the PAL devices after 2-3 years of operation makes them a long lasting and sustainable mitigation measure so long as they are effective.

Devices are produced in Germany by F3: Forschung[26] and are available throughout the ASCOBANS region and globally.

2.1.2.3. Pros

- Shown to significantly reduce harbour porpoise bycatch in gillnets in the western Baltic by around 70%
- No impact on the catch rate of target species
- No impact on current fishing practices or processing time
- Increases harbour porpoise echolocation
- Habituation is unlikely due to the variation in signals emitted
- Attaches to the gillnet headline, no need for specialised fishing gear or gear adaptations
- Buoyant in water so helps pull nets open and reduces loss during operation
- Easy to deploy and operate
- Long battery life (around 2 years of normal operation). Batteries are replaceable
- PAL software and/or acoustic signal can be updated
- PAL device can be checked on-board with the naked ear, using a bat detector or underwater using a suitable hydrophone
- Internal shock-absorber to prevent accidents on-board
- Automatically activates when submerged in water

2.1.2.4. Cons

- Directional
- Need continuous energy
- Further evidence required to determine if population specific communication signals are required
- So far, only effective in the western Baltic and not in other trialled areas – consequence of different population communication signals?
- Further research on sound propagation and behaviour changes are required

2.1.3. Reflective Nets

2.1.3.1. Current knowledge

The theory behind the use of acoustically reflective gear to reduce cetacean bycatch is the assumption that cetaceans become entangled because they do not detect the net (Larsen *et al.,* 2007). Increasing the sound reflective properties of gillnets such as with the addition of barium sulphate has been successful at reducing harbour porpoise bycatch in the Bay of Fundy, Canada (Trippel *et al.*, 2003, 2008) although Cox and Read (2004) found no difference in the echolocation rate or click intensity of harbour porpoise around barium sulphate gillnets.

Within the ASCOBANS region, attempts have been made to change the acoustic properties of gillnets to increase their detectability to echo-locating cetaceans, mainly harbour porpoise. In nets with barium sulphate, Northridge *et al.* (2003) found that the bycatch rate of porpoises and seals was higher compared to the control nets. The authors proposed that this was not due to the acoustic properties of the nets, but rather that the nets with barium sulphate had a slightly smaller mesh size and a thicker twine so a larger amount of force would be required to break the net.

Larsen *et al.* (2007) conducted at-sea trials in the Danish North Sea with high-density iron-oxide gillnets. The iron-oxide nets were manufactured specifically for the experiment based on the same specifications (twine size and mesh size) of the control nets. However, the iron-oxide nets produced differed in colour and stiffness. The study showed a significant reduction in harbour porpoise bycatch in the iron-oxide nets, but also a significantly lower catch rate of cod, the main target species. The trials were halted due to reduced catch of target species making the iron-oxide nets financially unviable. The differences in harbour porpoise bycatch could be due to acoustic reflectivity, stiffness, buoyancy and/or colour, but were likely due to the difference in stiffness, as reported previously by Cox and Read (2004). In contrast, Bordino *et al.* (2013) found no reduction in bycatch of franciscana (*Pontoporia blainvillei)* in Argentina in gillnets with increased reflectivity nor stiffness. In Portugal, although promising results were shown in initial trials using nets with barium sulphate under the SAFESEA project (Vingada *et al.*, 2011), trials were discontinued under the LIFE+ MarPro project in the western coast of Portugal because fishers found that barium sulphate nets were very stiff and easily entangled, leading to lower target catches.

2.1.3.2. Cost of implementation

Reflective nets are made to order based on the specific requirements of individual fisheries. No costs have been determined due to the lack of successful trials in the ASCOBANS region.

2.1.3.3. Pros

- No habituation
- No noise pollution
- No need for energy source
- Relatively low cost (one time expenditure for the modified net) if replacing damaged/end of life net

2.1.3.4. Cons

- Ineffective if small cetacean encountered net when it was not echolocating (see Hamilton and Baker, 2019)
- Different and conflicting results. The majority of studies have been inconclusive whether bycatch is reduced due to the increased detectability or increased stiffness of the modified nets
- Potential for a significant impact on target species catch rates
- Nets have to be specifically manufactured in the Middle East or USA and imported into Europe
- Limited information to date on ease of handling and relative cost

2.1.4. Acrylic Echo Enhancers

2.1.4.1. Current knowledge

The Thünen-Institute for Baltic Sea Fisheries in Germany is currently undertaking a project to 'develop alternative management approaches and fishing gear and techniques towards minimising conflicts in gillnet fisheries and conservation objectives and subject of protection in the Baltic Sea' (Project STELLA). Within the project, gillnet modifications are being designed and tested with the aim to reduce bycatch of harbour porpoises (and birds). A stimulation study was conducted on various objects to enhance the acoustic reflectivity of gillnets to harbour porpoise. Initial results indicated that acrylic glass spheres ('pearls') of < 10 mm diameter hung on the gillnet at 30 cm intervals (vertically and horizontally) created a resonance effect at the peak frequency used by harbour porpoise (130 kHz). Echograms taken with the sonar of the fisheries research vessel 'Clupea' showed that the 'pearl net' (the net with the acrylic glass spheres) were highly visible at 120 kHz compared to the standard gillnet, although at 38 kHz only the float line and lead line were visible for both nets (ICES WGFTFB, 2019; Kratzer *et al.*, 2020).

A commercial trial of the pearl net was conducted in summer 2019 in the Black Sea turbot fishery. Whilst the lower number of harbour porpoises (*Phocoena phocoena relicta*) bycaught in the pearl nets compared to the control nets was not statistically significant, this is probably a reflection of the low bycatch rate overall and the low number of hauls (only 10 hauls to date) (Kratzer, 2020).

The gillnet modifications are still in the prototype phase and further work is required to determine any potential impacts on target species, handling challenges of the net, or the behaviour of harbour porpoises around the modified gillnet. The 30 cm matrix of pearls is thought to be a conservative estimate. However, behavioural studies will need to be conducted before the distance between the pearls can be increased. The addition of pearls hung in the gillnets is a relatively low cost modification and early trials indicate that will not impact the fishing technique(s) of the fishery. The pearl nets cleared the commercial net stacker (the machine used to untangle the gear and remove algae) without damaging the spheres and therefore no specialised equipment is required (ICES WGBYC, 2020; Kratzer, 2020). There is the potential for an increase in marine litter if the pearls fall off the net or the nets are damaged and lost.

2.1.4.2. Cost of implementation

The pearls currently cost two Euro cents per piece and need to be attached manually, which is relatively time consuming at the outset of the project. Acrylic glass spheres are readily available in most, if not all, countries. Tables 3a and b give an overview of the cost of implement acrylic glass pearls in different lengths of set nets.

2.1.4.3. Pros

- Habituation is unlikely
- No noise pollution
- No need for energy source
- Relatively low cost (one time expenditure for the modified net)
- Initial results in the Black Sea turbot fishery indicate a lower rate of harbour porpoise bycatch in pearl nets
- No impact on fishing technique in initial trials
- Similar technique could be applied for other cetaceans

2.1.4.4. Cons

- Potential impact on target species has not been studied
- Harbour porpoises may not notice the netting or respond to it if their attention is directed at fish
- Pearls have to be manually attached to the nets (time consuming), thus an automated process needs to be developed
- Potential increase in marine litter if the pearls become unattached from the net

2.2. Visually Detectable Nets

2.2.1. Lights

2.2.1.1. Current knowledge

The use of lights to increase the visual detectability of nets has shown promising results in surface driftnets and bottom set gillnets in Peru (Mangel *et al.,* 2018; Bielli *et al.*, 2020). In Bielli *et al.* (2020), green visible spectrum light emitting diodes (LEDs) powered by two AA batteries were placed inside a hard, plastic waterproof housing. The LEDs were attached to the floatline of the net at 10 metre intervals. On the nets with LEDs, the cetacean bycatch probability per set was reduced by 66.7% and 70.8% for bottom set nets and driftnets, respectively. The trials by Bielli *et al.* (2020) were conducted at night, therefore further tests should be conducted in a variety of different natural light and turbidity conditions (IWC,

Table 3a. Number of pearls and cost for different length gear in nets 3 metres high

Length of gear (m)	1,000	2,000	4,000	6,000	8,000	10,000	12,000
Total pearls required	30,000	60,000	120,000	180,000	240000	300,000	360,000
Total cost (Euros)	600	1,200	2,400	3,600	4,800	6,000	7,200

Table 3b. Number of pearls and cost for different length gear in nets 6 metres high

Length of gear (m)	1,000	2,000	4,000	6,000	8,000	10,000	12,000
Total pearls required	63,333	126,667	253,333	380,000	506,667	633,333	760,000
Total cost (Euros)	1,267	2,533	5,067	7,600	10,133	12,667	15,200

2020). However, the effect of LEDs on reducing bycatch may have been overestimated due to the lower effort of the nets with LEDs compared to the control nets (Authier and Caurant, 2020). Sea turtle, seabird and fish bycatch was also significantly reduced with the presence of LEDs (Mangel *et al.*, 2018; Allman *et al.*, 2020; Bielli *et al.*, 2020; Southworth *et al.*, 2020) although Field *et al.* (2019) found contrasting results for seabirds in the Baltic. No impact on catch efficiency or target species was reported in gillnets with LEDs (Mangel *et al.*, 2018; Field *et al.*, 2019; Allman *et al.*, 2020; Bielli *et al.*, 2020). There is the potential for an increase in marine litter if the LEDs become unattached to the nets.

Within the ASCOBANS region, a small-scale trial on the use of pingers, LEDs and a combination of both started at the end of 2019 in bottom-set gillnets off Cornwall, South West England by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) (Al Kingston, Pers. Comm.). The Netlight devices need to be spaced between 10 and 20 metres along the net. It was too early in the project to have any results at the time of writing the present report. No consideration is being given to the colour of the light in the present UK trial. For turtles, green light is effective for reducing bycatch although it is not fully understood why (e.g. Mangel *et al.*, 2018; Allman *et al.*, 2020).

2.2.1.2. Cost of implementation

Tables 4a and b give an overview of the cost of implementing LEDs in different length set nets. The cost of implementing LEDs is relatively low. The current trials in the UK are using Netlight from Fishtek Marine[27]. The devices are available for distribution within the ASCOBANS region and globally. The cost is based on the number required: price per light varies between £5.35-£9.50 (approx. 6.00-10.60 Euros) depending on the quantity required. The price excludes carriage or any country specific tax and import duties (if applicable). Ortiz *et al.* (2016) suggested that solar powered LEDs could reduce the cost and waste of normal batteries currently used in LEDs for fishing gear.

2.2.1.3. Pros

- Low cost and robust
- LEDs have a long life expectancy
- Potential to reduce multi-taxa bycatch e.g. in fisheries with cetacean and seabird bycatch. However, verification will need to be species and fishery-specific
- No impact on catch rates of target species

2.2.1.4. Cons

- No data presently for the ASCOBANS region
- Potential for increased tangles in the net due to the devices present
- Potential increase in marine litter if the LEDs become unattached from the net

2.3. Trawl Technical Modifications

2.3.1. Exclusion Devices

2.3.1.1. Current knowledge

Exclusion devices have been trialled in trawl fisheries to reduce bycatch of marine megafauna, including cetaceans (Anon, 2007; Stephenson *et al.*, 2008; Allen *et al.*, 2014). To reduce cetacean bycatch, exclusion devices have been used in pelagic single and pair trawls and demersal trawls (e.g. Anon, 2007; Northridge *et al.*, 2011;

[27] https://www.fishtekmarine.com/netlight/

Table 4a. Number of LEDs and cost for different length gear based on 1 device per 10 m of net

Length of gear (m)	1,000	2,000	4,000	6,000	8,000	10,000	12,000
No. of devices required	100	200	400	600	800	1,000	1,200
Total cost (Euros)	760	1,520	3,040	4,560	6,080	7,600	9,120

Table 4b. Number of LEDs and cost for different length gear based on 1 device per 20 m of net

Length of gear (m)	1,000	2,000	4,000	6,000	8,000	10,000	12,000
No. of devices required	50	100	200	300	400	500	600
Total cost (Euros)	380	760	1,520	2,280	3,040	3,800	4,560

Allen *et al.*, 2014). Excluder devices are an additional section of netting or a rigid device placed between the entrance and the cod-end of the net to prevent non-target species such as cetaceans from entering the net (front-located exclusion device) or cod-end (rear- located exclusion device). The aim of the device is to direct the bycaught animals to an escape panel/hatch in the net.
The design of exclusion devices requires knowledge of both the target and bycaught species including their size and behaviour (spatial and temporal) to ensure that the bycaught animals are excluded whilst ensuring that there is no loss to the quality of the catch or the CPUE. Exclusion devices need to be specific to the area, fishery and gear (e.g. pair trawl and single trawl would probably require different types of exclusion devices due to handling difficulties with the much larger net of a pair trawl). The design needs to ensure that the target species (and other similar sized species) will pass through the grid but the large bycaught species are prevented.

Exclusion devices can be rigid or soft depending on the material they are made from. Rigid grids tend to be towards the back of the net and are usually a metal grate made of stainless steel. Cetaceans are prevented from entering the cod-end by the grid and excluded from the net via an escape panel. The spacing and location of the grid (top or bottom of the net) is species dependent. Allen *et al.* (2014) suggested the use of top-opening escape hatches to reduce bottlenose dolphin bycatch in the Western Australian Pilbara fishery due to the tendency of dolphins to swim upwards and push on the upper part of the nets when attempting to escape the net by surfacing, although there have not been trials in this fishery to test top-opening escapes (Hamilton and Baker, 2019). In this fishery, bottlenose dolphins are known to deliberately enter the trawls for foraging and socialising (Stephenson *et al.*, 2008). In trawls in the NE Atlantic it is thought that bycaught cetaceans are captured during or just prior to hauling (Morizur *et al.*, 1999).

Soft grids are generally made from fishing mesh, rope or bungee cords. Soft grids can be in the front of the net to prevent cetaceans entering through the grid at the trawl entrance or within the net to prevent cetaceans entering the cod-end. Trials of soft grids deployed at the front of nets have usually resulted in unacceptable impacts on target species catch and the grids can become distorted, increasing the risk of bycatch (Hamilton and Baker, 2019). Within the ASCOBANS region, exclusion devices have been trialled within the various projects including the NEphrops and CEtacean Species Selection Information and TechnologY (NECESSITY) project. During the NECESSITY project, several exclusion devices were trialled. IMARES (Dutch Institute for Marine Resources and Ecosystem Studies) conducted sea trials with pelagic trawls, initially using a series of ropes hung within the net. However, the trials were stopped because there was an adverse effect on the target species catch. A tunnel barrier in the mid-section of the trawl was also trialled and had no impact on fish catches, but the effectiveness to reduce bycatch was undetermined because no cetacean reactions were observed. AZTI Fundación in Spain trialled two different escape holes in the top of the net with a vertical rope barrier in the net during commercial fishing activities. Interactions with cetaceans were limited but no impacts on the hydrodynamics of the net or target and non-target fish behaviour were observed.

IFREMER tested two different types of soft barriers and escape holes on research and commercial vessels. The first (a square mesh barrier with two escape holes with bungee cords) was not found to be fully effective and the second (a larger barrier fitted with stainless steel studs to increase the acoustic reflectivity to cetaceans) was unproven to reduce bycatch but was found to increase the drag, potentially causing net damage making it unviable for commercial fishing vessels. During the NECESSITY project, in trials by IFREMER and the University of St Andrews in the pelagic trawl fishery for European sea bass, common dolphins were observed escaping via rigid exclusion grids with different escape hatches at the top of the trawl in trials and dolphin survival was thought to be very high. Some dolphins did not appear to recognise the escape panels and were reported to be in an exhausted state in front of the device. In one design, the grid became blocked by the fisheries' target species. It was estimated that only a quarter of dolphins approached the grid and exited the net via the escape panel (Anon, 2007).

Overall, the NECESSITY project concluded that none of the excluder devices were fully effective and at best, only a 20% reduction in bycatch was likely. The project concluded that the position of the exclusion device needs to be as far forward in the trawl as practically possible. The main issue to overcome is the escape mechanism. Those need to be numerous enough that dolphins are able to detect and use them whilst ensuring that the target species of the fishery is not jeopardised (Anon, 2007). The addition of light-emitting diodes (LEDs) to a trawl square mesh panel has proven beneficial for reducing fisheries bycatch (non-target species and undersized fish) (Southworth *et al.,* 2020).

Work on exclusion devices in the UK bass fishery was halted in 2006 after GreenPeace intervened and damaged the trial gear and caused a navigational hazard for the vessel. Since then, both IFREMER and the University of St Andrews have focused on the use of ADDs for mitigating bycatch.

2.3.1.2. Cost of implementation

No costs of implementing exclusion devices in the trawl fisheries have been discussed due to the lack of successful trials in the ASCOBANS region and the fact that each fishery and vessel requires a unique design. Testing of the design in flume tanks before application in the sea is recommended but is likely to be expensive.

2.3.1.3. Pros

- Dolphins have been observed using exclusion devices although the trials have been very limited
- Survival rate of dolphins able to escape is likely to be very high
- Flexible grids have been reported to be easier to handle than rigid grids
- Once the design has been finalised and tested, there is very low additional costs to the fishery
- Integrated into the gear so easy to store

2.3.1.4. Cons

- Limited success in the ASCOBANS region to date
- The behaviour of dolphins has not been uniform in trials
- Logistically and financially more challenging to test than other mitigation methods, such as ADDs
- Exclusion device needs to be designed for individual fisheries/vessels based on fishing characteristics, target species and the non-target species likely to be bycaught
- Expensive video surveillance is required to determine bycatch rate and effectiveness of the exclusion device(s)
- Welfare issue for animals unable to escape or getting entangled/injured in the escape panel
- Positioning of the device within the trawl is critical
- Challenging to design grids for cetaceans to escape in fisheries with large target species (e.g. potential for grids to get blocked)
- Flexible grids are likely to become distorted during fishing resulting in fish losses, adverse effect on the fisheries target species (e.g. reduction in the quality of the catch) and an increased risk of bycatch
- May increase drag and, therefore, fuel costs
- Potentially difficult to install, maintain and handle in large pelagic trawls
- Development of the exclusion device/grid is likely to be expensive, although once completed, cost to fishery is minimal
- Lack of baseline knowledge required for effective application of exclusion devices in the ASCOBANS region, e.g. when are dolphins entering the trawl: during deployment, fishing operation or hauling of the gear?

2.4. Gillnet Technical Modifications

2.4.1. Net Height

2.4.1.1. Current knowledge

Net height can be reduced by making shorter nets at the point of manufacture. Net height can also be adjusted using tie-downs which reduce the vertical profile of the gillnet in the water column. The use of tie-downs is mandatory in some fisheries in the United States and has been shown to reduce harbour porpoise and common dolphin bycatch (Palka, 2000; Fox *et al.,* 2011) although they are probably only useful for some target species e.g. flounder (Northridge *et al.,* 2017b). Noack (2013) investigated the difference in catch rates in the southern Baltic between a standard gillnet (2.5 m high) and a lower gillnet (0.4 m high). The lower gillnet only achieved one fifth of the catch and less species overall than the standard gillnet. Fish did not entangle in the lower gillnet in the same way they do in the standard gillnet, and were seen 'falling out' of the gear during hauling. As a result, the lower gillnet was not considered a viable alternative in the study. If lower gillnets are to be further considered or used, the hauler and cleaning machine would need to be modified in order to prevent loss of the catch.

2.4.1.2. Pros

- Unlikely to require significant changes in fishing practices

- No impact on catch rate in some fisheries (tie-downs)

2.4.1.3. Cons

- Difficult to determine optimum net height
- Catch rate and number of species are reduced in lowered gillnets compared to standard gillnets
- Fish may not fully 'entangle' and are lost during hauling in lower gillnets
- Requires modified hauler and cleaning machine to use for lower gillnets
- Tie-downs are only useful in some fisheries

2.4.2. Twine Diameter

2.4.2.1. Current knowledge

Thinner twine diameter may allow animals to break free from the net more easily when bycaught (Northridge *et al.,* 2003). The health and survival of animals that are able to break free is undetermined and thinner twine may also increase bycatch unaccounted for if animals drop out the net during hauling (FAO, 2018). There will be significant costs associated with repairing and/or replacing panels of netting. In Galicia, NW Spain, shoaling species such as sardine (*Sardina pilchardus*) are targeted using artisanal driftnets in the summer months. During interviews, 100% of fishers using these driftnets reported gear damage, mainly by bottlenose dolphins (Goetz *et al.,* 2014). In some fisheries, twine diameter may only permit larger, robust species such as bottlenose dolphins from escaping capture and therefore be a welfare issue for smaller species, such as harbour porpoise or common dolphin (Fiona Read, Pers. Comm. with gillnet fishers in Galicia and Portugal). In theory, a thinner twine diameter might decrease detectability of a net, potentially leading to bycatch unless used in conjunction with another mitigation method, although this would require further investigation.

Trials in the UK on how twine diameter may affect cetacean bycatch rates were started by the University of St Andrews in late 2019, but there were no results at the time of writing (Al Kingston, Pers. Comm.) due to the prevention of field work during the COVID-19 pandemic.

2.4.2.2. Pros

- Unlikely to require significant changes in fishing practices

2.4.2.3. Cons

- Potential for changes in catch rates with changes in twine diameter
- Significant costs associated with frequent gear damage
- Thinner twine might decrease detectability and, therefore, bycatch

2.5. Changes to Fishing Practices

2.5.1. Fishery Closures

2.5.1.1. Current knowledge

Fishery closures can be an effective mitigation measure for reducing bycatch in areas with high bycatch risk (Murray *et al*., 2000) by focusing on reducing the overlap spatially and/or temporally (O'Keefe *et al*., 2014). In order for fishery closures to be developed, there needs to be sufficient temporal and spatial data on the fisheries and cetaceans using the area, including the bycatch risk of individual species to the relevant fisheries, data on the factors influencing cetacean-fishery interactions and the proportion and area where effort may be displaced to. The type and resolution of the data required for such a management approach to be effective is not currently collected in the ASCOBANS area. Fishery closures are different from Marine Protected Areas (MPAs) designated for conservation purposes. Management measures within and outside MPAs are often not very different (Pinn, 2018). In general, MPAs tend to be more permanent than fishery closures. The latter are often temporary measures until the target species stock recovers, e.g. the Baltic cod[28] and UK sea bass[29].

Fishery closures need to be well managed in order to have support from local fishers e.g. local fishers believe that the closure of the Hawke Box on the Labrador continental shelf to trawls and gillnets is the reason they still have a viable pot fishery for snow crab (*Chionocetes opilio*) (Kincaid and Rose, 2014). When regulations are fair, effective, easy to follow and enforceable, fishers are more likely to cooperate (Murray *et al.,* 2000). In addition, bycatch reduction objectives are more effective when there is a collaborative effort between fishers, scientists and managers (Croxall, 2008; O'Keefe et al., 2014). Contingency measures will need to be in place to support fisheries unable to switch target species or area when fishery closures are enforced.

Porpoises are highly mobile with changes in distribution recorded at tidal, diurnal, seasonal and regional scales (e.g. Johnson *et al*., 2005; Marubini *et al.*, 2009; Embling *et al.,* 2010; Gilles *et al.,* 2016; Benjamins *et al.,* 2017; Peschko *et al.,* 2017; Waggitt *et al.,* 2020). Fishing effort is also highly variable (e.g. Guiet *et al.,* 2019). The variability in distribution of harbour porpoise and fishing effort makes the identification of appropriate fisheries closure areas difficult (Read and Westgate, 1997). These temporal and spatial variations may also result in an area closure that leads to an increase in harbour porpoise bycatch elsewhere if fishing effort is displaced rather than removed (Murray *et al.,* 2000; Slooten, 2013; Pinn, 2018).

28 https://www.consilium.europa.eu/media/46485/20201019-baltic-tacs_table-ii_updated.pdf
29 www.gov.uk/government/publications/bass-industry-guidance-2020/bass-fishing-guidance-2020#:~:text=1.,retained%20per%20fisherman%20per%20day

Diet analysis has been used to investigate the potential for temporal-spatial overlap of fisheries and cetaceans for competition for the same target species (target species of the fishery and prey species for cetaceans). In the Bay of Biscay, sardine, anchovy (*Engraulis encrasicolus*), sprat (*Sprattus sprattus*) and horse mackerel (*Trachurus trachurus*) are important prey for common dolphin (Meynier *et al.,* 2008) and targeted by fisheries (e.g. Peltier *et al.,* 2021). No European sea bass was recorded in the stomach contents of common dolphin bycaught in the UK sea bass fishery (Northridge *et al.*, 2003). Despite high bycatch rates in the sea bass fishery, it seems unlikely that sea bass directly influence the distribution of common dolphin (Northridge *et al.,* 2003). In contrast, common dolphin and fisheries with high bycatch rates are exploiting many of the same resources in Galicia, NW Spain and Portugal (e.g. Méndez Fernández *et al.,* 2012; Santos *et al*., 2013; Margarido, 2015; Pinheiro, 2017). The main prey species of harbour porpoise in the Baltic Sea and NE Atlantic are also targeted by commercial fisheries (Santos and Pierce, 2003; Read *et al.*, 2013; Aguiar, 2013; Andreasen *et al.,* 2017; Pinheiro, 2017). Seasonal variation in cetacean diet and fisheries distribution may assist in determining effective fishery closures.

Closure of the sink net fishery in the Gulf of Maine, US, to reduce harbour porpoise bycatch was implemented in 1994. The closure was unsuccessful due to the area being too small, the closure too short and the fishermen not perceiving the regulations to be fair (Murray *et al.,* 2000). However, the combination of fishery closures and ADDs reduced harbour porpoise bycatch from 2,900 animals annually in 1990 to 323 in 1999 (Read, 2013). Based on stimulation models, the overall success of harbour porpoise bycatch mitigation in inner Danish waters depends upon the implementation of both fishery closures and ADDs (van Beest *et al.*, 2017).

Fishery closures will be an essential tool for removing fishing gear from the habitat of critically endangered species. In New Zealand, closures for gillnet and trawl fisheries have slowed the population declines in some areas of Hector's dolphin (*Cephalorhynchus hectori*) and Maui's dolphin (*Cephalorhynchus hectori maui*) (Gormley *et al.*, 2012; Slooten, 2013). Although bycatch outside of the protected areas is still causing the populations to decline overall (Slooten, 2013) and extinction is still the expected outcome (Gormley *et al.,* 2012).

There are two formal examples of fisheries closures in the ASCOBANS region in related to cetacean bycatch: 1) the driftnet ban under EC Regulation 812/2004 that came into force in 2008. In the Baltic, it was hoped the ban would prevent harbour porpoise bycatch. However, bycatch still occurs mostly due to the ban not having been applied to semi-driftnets because they are anchored at one end (Pawliczka, 2018); it is likely to be at a level preventing recovery of the population; and 2) In July 2019, the European Commission announced a ban on gillnet fisheries for cod in the Eastern Baltic Sea until the end of 2020 although there was a quota for bycaught cod[30]. The ban has been extended to the end of 2021 with an extra 70% decrease in the bycatch quota[31]. Whilst the ban was to prevent the 'impending collapse' of the eastern Baltic cod population, it may also benefit the Baltic harbour porpoise by preventing bycatch.

Whilst not formally a closure of the fishery or the area, in 2010 an acoustic barrier using ADDs (pingers) was installed across Puck Bay in the southern Baltic Sea. Puck Bay can be an important area for harbour porpoise with a high bycatch rate (Skóra and Kuklik, 2003). No porpoise bycatch was reported during the experiment; however, this was only a short-term solution. The ADD barrier has since been removed and high bycatch rates of harbour porpoise are still reported on occasions (Hel Marine Station, unpublished data).

Due to high numbers of bycaught common dolphins, the UK implemented a ban on sea bass pair trawling within 12 nautical miles (nm) of the coast for UK registered vessels in 2005. The European Commission refused to implement the 12 nm ban for other Member States and so between 6-12 nm the vessels of Member States could still use the gear in UK waters whilst the UK fleet could not. Despite the ban, common dolphins continue to be recorded in high numbers annually in strandings (e.g. Deaville *et al.,* 2011; Peltier *et al.,* 2016) so it is unclear how effective the 12 nm ban has been, if the issue has been moved further offshore, or if bycatch occurs in other fisheries in the region (Read *et al.,* 2017) and most likely other fisheries are involved.

Following advice from ICES Working Group on Marine Mammal Ecology (WGMME) and WGBYC including a follow-up workshop, Emergency Measures to minimize bycatch of common dolphin in the Bay of Biscay and harbour porpoise in the Baltic Sea (WKEMBYC) in April 2020 were recommended. ICES proposed a combination of fishery closures and ADDs to the European Commission (ICES, 2020). ICES also recommended a reduction of fishing effort in certain fleets to ensure that effort was not displaced, and an increase in monitoring to evaluate the effectiveness of the emergency mitigation methods. In July 2020, the Commission issued 'Letters of Notification' to Spain, France and Sweden in relation to their failings to prevent bycatch. This is the first stage of the legal challenge process. To be considered effective, fishery closures should result in significantly lower bycatch rates, be economically viable for the fishery, be successfully enforced (Murawski, 1994), and cover an area large enough to prevent a high proportion of bycatch events (Murray *et al.,* 2000; Hoos *et al.,* 2019). Fishing effort and fishing pressure should not be displaced to another area which may lead to increased bycatch outside the closed area (O'Keefe *et al.,* 2014; Hoos *et al.,* 2019). In some

30 https://ec.europa.eu/commission/presscorner/detail/en/IP_19_4149
31 https://www.consilium.europa.eu/media/46485/20201019-baltic-tacs_table-ii_updated.pdf

cases, there may need to be a compromise between the bycatch reduction goal and the economic viability of the fishery (Murray *et al.,* 2000). Follow-up monitoring is required to determine the effectiveness of the fishery closure(s) and assess the need to modify boundaries or regulations (Slooten, 2013; Hoos *et al.,* 2019), making them expensive to enforce (Bordino *et al.,* 2013). It will be challenging to enforce compliance in fishery closures in international waters (Monteiro *et al.*, 2010).

2.5.1.2. Cost of implementation

Implementation of fishery closures may have substantial socio-economic impacts on regions dependent on fishing activities. For example, Galicia, NW Spain is an area with high cetacean-fisheries interactions. Around 30,000 people are employed in the Galician fishing industry directly, excluding associated employment such as processing and aquaculture (Galician Ministry of Fisheries, 2010; Read, 2016). Given these various considerations, the cost of implementing fishery closures is so complex that it is beyond the scope of this report.

2.5.1.3. Pros

- Significant reduction in bycatch if managed effectively, i.e. fishing effort is removed not displaced
- For critically endangered cetaceans, fishery closures will be an essential tool for removing fishing gear from habitat

2.5.1.4. Cons

- No evidence to indicate protected areas (areas with fishery closures) are an effective measure for reducing cetacean bycatch
- Requires robust spatial and temporal information on relevant fisheries, cetacean species at risk and factors influencing bycatch
- Bycatch needs to be predictable in space and time, and to date, the data requirements are not being met
- Fishery closures will shift fishing effort/pressure to other species and areas
- Need to account for inter-annual variations in timing and distribution of bycatch
- Species and fishery specific
- Expensive to enforce and monitor, especially in international waters
- Success will depend on support from the fishing industry
- The combination of fishery closures and ADDs is likely to be more successful at reducing small cetacean bycatch than a fishery closure in isolation
- Potential socio-economic issues for fishers impacted by fishery closures

2.6. Soak Time/Fishing Effort

There is some evidence that soak time and fishing effort are factors influencing bycatch of small cetaceans (Northridge *et al*., 2017b; Leaper and Calderan, 2018). Higher fishing effort, either with increased gear set or longer soak times may influence the probability of animals encountering and becoming caught in the gear. Whilst shorter soak time or reduced gear set may reduce bycatch rates, soak time and fishing effort are normally a function of catch rate, therefore a shorter soak time or less gear is likely to have an impact on target species catch rates too (Northridge *et al*., 2017b; Leaper and Calderan, 2018). This is likely to apply to trawls as well as gillnets. Soak time is unlikely to be an effective standalone mitigation method.

2.7. Fishing Depth

2.7.1. Current knowledge

The probability of capture is influenced by the depth of feeding and dives (Northridge *et al.,* 2017b). Determining the zones with the highest bycatch rates will require data on the behaviour of the fishery's target species and the species potentially interacting with the fishery. Determining the impact of depth on bycatch rate is complicated. Fishing depth will depend on the target species, which in turn is influenced by twine diameter and the twine material used (in gillnets) and mesh size (trawls and gillnets). In Galicia, NW Spain, Fernández-Contreras *et al.* (2010) found that bycatch of common dolphins could be significantly reduced if pair trawlers only operated in water deeper than 250m and almost eliminated if they were restricted to waters over 300m with little impact on the main target species, blue whiting (*Micromesistius poutassou*), although the additional costs of fuel and time would need to be accounted for. In Portugal, small gill and trammel nets are set in low depth areas (less than ¼ nm from the coast), which constitutes an illegal fishing operation, leading to harbour porpoise bycatch. Increasing surveillance and enforcement to deter the use of nets in low depth areas could contribute to decreasing harbour porpoise mortality (Vingada and Eira, 2017).

2.7.2. Pros

- Little to no change to gear required
- Reduced chance of interactions as highest catch risk areas is avoided (effectively fishery closure areas)

2.7.3. Cons

- Unlikely to work for different species in the same area, or the same fishery in different areas
- Needs to be assessed for individual fisheries
- Potentially complicated to implement
- Additional costs for travelling to fishing grounds further offshore

2.8. Fishing Time

2.8.1. Current knowledge

Time of day can potentially have an impact on bycatch rates due to the activity level of animals around the nets and visibility. There are no studies investigating time of day as a factor for bycatch of small cetaceans in gillnets (Northridge *et al.,* 2017b). Within the Bottlenose Dolphin Take Reduction Plan (BDTRP) in the United States, there are time (month) and area restrictions where gillnets with a mesh size over 5 inches (~12.5 cm) are not permitted to be set at night[32].

In the NE Atlantic, most bycatch of small cetaceans in trawls occurs during nocturnal trawling (Aguilar, 1997; Morizur *et al.,* 1999; López *et al.,* 2003; Fernández-Contreras *et al.,* 2010; Goetz *et al.,* 2014). During interviews about cetacean-fisheries interactions, fishers reported that it was rare not to catch dolphins during pair trawling at night (Aguilar, 1997) and all 18 dolphins bycaught were caught during night trawling in the study by Morizur *et al.* (1999). Limiting trawling, especially pair trawling, to hours of daylight may significantly reduce cetacean bycatch. Fishing with a diurnal pattern may affect the target species catch and in some fisheries, tows may operate over many hours of day and night (Anon, 2007). Restrictions on night trawls would require significant controls at sea (ICES WKEMBYC, 2020).

2.8.2. Pros

- Little to no change to gear required
- Bycatch in trawls may be significantly reduced if trawls only operate during daylight

2.8.3. Cons

- Needs to be assessed for individual fisheries
- Challenging to enforce if vessels do not use their tracking system(s) as legally required, or for small vessels < 12 m that are not required to carry a vessel monitoring system (VMS).

2.9. Mitigation Discussion

Presently, for static nets and to some extent trawls, ADDs are the only proven mitigation method in the ASCOBANS Agreement Area, although several of the methods discussed have shown promising results from trials. ADDs are readily available and have been shown to mitigate harbour porpoise and common dolphin bycatch (e.g. Larsen, 1999; Larsen *et al.,* 2013; Northridge *et al.,* 2011, 2012; Pereira *et al.,* 2019a; Omeyer *et al.,* 2020). Depending on the device used, implementation of ADDs in fixed set nets (e.g. gillnets) 4000 m long ranges between 1,070-2,700 Euros. The banana pinger is the most cost-effective ADD, assuming the 50-120 kHz device is used at 200 m intervals. The DDD device is the most expensive at 2,700 Euros if used at 400 m intervals. Other methods discussed require further development including testing in active fisheries. The costs are mostly within the range of ADDs (around 1,500-5,000 Euros).

Whilst ADDs are the 'tried and tested' method, they should only be used as an interim measure until alternative gears are available (ASCOBANS, 2016). It is reasonable that a combination of mitigation methods is best e.g. fishery closures and ADDs (e.g. Read, 2013; van Beest *et al.,* 2017). The use of ADDs in important habitats, e.g. SACs, can be controversial. It has been suggested to limit the use of ADDs in important habitats (Carlström *et al.,* 2002; Kyhn *et al.,* 2015), although Natura 2000 does not necessarily mean that fisheries are limited in the area. To the best of my knowledge, there is only one SAC within the ASCOBANS Region presently to have fisheries measures to prevent cetacean bycatch aside from the measures in current legislation. The harbour porpoise SAC off the island of Sylt in the Eastern German Bight has a net height limitations of 1.5 m rather than 2 m for German (but not other Member State) gill netters.

A significant shortfall in previous legislation was that the requirement of mitigation methods was dependent on the length of the vessel and not the length of the gear in use (ICES WGBYC, 2012, 2013; Read *et al.,* 2017) and specific areas (Koschinski and Strempel, 2012; Read *et al.,* 2017). For example, despite the vast number of vessels using gillnets in Portugal, Germany and Spain, very few vessels (0%, 3% and 13%, respectively) are required to use pingers, mostly due to the vessels being < 12m or operating outside of the specific area(s) (Koschinski and Strempel, 2012; Goetz *et al.,* 2014; Read *et al.,* 2017). Monitoring and mitigation of cetacean bycatch in semi-drift nets is now required because they have been classified as gillnets under the Regulation on the Conservation of Fisheries Resources and the Protection of Marine Ecosystems through Technical Measures (EU 2019/1241). To date, mitigation measures have not adequately reduced bycatch in European fisheries (Read *et al.,* 2017; STECF, 2019; Dolman *et al.,* 2021; Rogan *et al.,* 2021). However, mitigating bycatch is more complex than fulfilling the legislation, e.g. even with full compliance of the UK fisheries with pingers under EC 812/2004, in 2016 the estimated annual reduction in porpoise bycatch was estimated to be only 15% (Northridge *et al.,* 2017a).

To date, the majority of studies on bycatch mitigation have been short-term scientific studies, and many of the trialled mitigation measures have not proven sufficiently effective to implement. To determine the effectiveness and efficiency of a mitigation measure there needs to be fishery scale testing to deliver robust evidence, and

[32] www.federalregister.gov/documents/2012/07/31/2012-18667/taking-of-marine-mammals-incidental-to-commercial-fishing-operations-bottlenose-dolphin-take

fisheries trials need to be undertaken with a sufficient number of vessels and over a number of fishing seasons in order to demonstrate effectiveness and to take into account the variability in species distribution and fishing effort (see Hamilton and Baker, 2019). For many individual fishers, bycatch is a rare event which further complicates understanding that cumulatively across the fishery, these rare events may lead to a conservation issue (e.g. MacLennan *et al.,* 2020).

It is unlikely that a 'one-size fits all' approach can be taken for bycatch mitigation, even for similar gears in different areas. Mitigation measures and overall effectiveness will need to be assessed on a case-by-case basis for each fishery, area, and species at risk (Hamilton and Baker, 2019). Any measures to reduce bycatch need to have minimal impact on the target CPUE and the operation of the gear. Prior to conducting any mitigation trials, welfare and ethical considerations need to be accounted for. The Baltic Proper harbour porpoise population is critically endangered (Hammond *et al.*, 2008) and any bycatch may impact the viability of the population.

Cetaceans are transnational mobile species, and fisheries are not confined to national waters. It is, therefore, essential that Member States collaborate to improve bycatch mitigation methods (Read *et al.,* 2017). Mitigation measures should be practical, industry driven and readily enforceable so that compliance can be easily determined, although some measures are easier to identify than others. However, mitigation will only be successful if the measures are compulsory and there are consequences (e.g. fines, fishing quotas/ licences reduced) for non-compliance. Compliance of mitigation measures such as ADDs is generally the responsibility of the vessel owner with the government overseeing regulation and enforcement. All fishing events that do not comply with regulations should be considered illegal, unreported and unregulated (IUU). Overall, EU fisheries/countries that do not abide by legislation and are not putting mitigation measures into practice should face infraction proceedings from the European Commission. In July 2020, the Commission started legal action against France, Spain and Sweden for failing in their legal duty to protect cetaceans from fisheries interactions[33]. This is the first time that legal action has been taken by the Commission in relation to cetacean bycatch.

Stakeholder collaboration and effective mitigation requires an adaptive approach to fisheries management with achievable aims in a fixed time-scale and regular evaluation of the fishery. In fisheries where the chosen mitigation measure is not effectively reducing bycatch, alternative measures need to be identified, adequately tested, and recommended based on scientific advice (Dolman *et al.,* 2016).

Education, outreach and enforcement are all critical components of effective implementation plans (Dawson *et al.*, 2013). These are only achievable with a close collaboration between industry, scientific institutions and government (Northridge *et al.,* 2011) and appropriate incentives (e.g. grants for mitigation methods to be implemented) (Komoroske and Lewison, 2015).

Overall, regardless of the cost-benefit for each mitigation measure, if countries are not implementing effective mitigation measures and complying with their legal obligations to prevent and reduce cetacean bycatch, no mitigation measure will be sufficient.

33 https://ec.europa.eu/commission/presscorner/detail/en/INF_20_1212

3. Alternative Gears

The majority of European studies investigating alternative fishing methods to mitigate marine mammal bycatch have been conducted in the Baltic Sea where the harbour porpoise is listed as being critically endangered. Harbour porpoise bycatch in trawls is very rare in the Baltic Sea (Skóra and Kuklik, 2003) so the focus has been to reduce harbour porpoise in static nets. Static nets will always present a significant risk to small cetaceans because they target fish species of similar size (Read, 2013; Leaper, 2021). However, the work on alternative gears has largely been led by the need to develop gears to reduce interactions with seals. Seals cause considerable damage to catch and gear in a variety of fisheries (Suuronen *et al.,* 2006; Vetemaa and Ložys, 2009; Königson *et al.,* 2015a).

There is still a role for currently implementing and improving monitoring and mitigation measures, but there is also a strong imperative for alternative approaches such as alternative gears for fisheries with high bycatch levels. In order for an alternative gear to be successful from a fisheries perspective, it needs to be economically feasible and have no negative impact on target species or catch rates (unless the catch is of high value). Most of the alternative gears discussed are Low Impact Fuel Efficient (LIFE) gears. LIFE gears ensure that fishing occurs using a low amount of fuel with low impact on the environment to improve the economic viability and environmental sustainability of fishing operations (Suuronen *et al.,* 2012). The following section discusses potential alternative gears, mainly as a substitute for gillnets.

3.1. Small-Scale Seine Nets

3.1.1. Current knowledge

There are several different types of seine nets used in the ASCOBANS region. In the context of 'alternative gears' to reduce bycatch of small cetaceans, the relevant types of seine nets are the anchored seine and the fly shooting seine. It should be noted that only the small-scale approach for the fly-shooting seine is being discussed. Beach seines are used occasionally in Cornwall, UK to catch sea bass and mullet, and are reported to have no cetacean bycatch[34]. Recreational beach seines were banned below the water mark in Belgium in 2001 and in the intertidal zone in 2015 after stranded harbour porpoises, harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) showed evidence of bycatch during necropsies (Read *et al.,* 2017). Beach seines are still in use in Portugal and have a high level of harbour porpoise bycatch (e.g. Read, 2016; Vingada and Eira, 2017; Read *et al.,* 2020). The difference between Portugal and Cornwall is the small-scale beach seine in Cornwall is manually hauled by fishers. In contrast, the once artisanal beach seine in Portugal is now a modern fishery. The assembly of cables and net should not be longer than 3.5 km and the seine is hauled by tractors. The highest concentration of beach seines occurs in the central coast where a large portion of the Iberian harbour porpoise also occurs (Vingada and Eira, 2017). Even though beach seines in Portugal operate seasonally (May-October usually), each seine can be set several times a day (up to 3 to 4 times) leading to a high fishing pressure in a small area over a relatively short period of time. Apart from harbour porpoises, bycatch of large groups of common dolphins also occurs. In 2016, over 80 bycaught animals were registered in only one beach seine event. In most cases, animals are hauled to the beach while they are still alive. Other problems are associated with beach seines in Portugal such as leatherback turtle (*Dermochelys coriacea*) bycatch, seabird bycatch, undersize fish catch and bottom destruction (Catarina Eira, Pers. Comm.).

Trials with small-scale Danish seines have been reported in the Baltic by Sweden, Denmark, and Germany. Danish seines are designed to be used on-board vessels, generally <10m in length, normally using gillnets (ICES WKEMBYC, 2020; ICES WKING, 2020) although some modern vessels are up to 40 m in length. Figure 3 shows a small-scale Danish seine net being set during gear trials. Results of the trials so far indicate that the catch efficiency is equal to or higher than other alternative gears (e.g. pots), discards are low, and no small cetacean bycatch has been observed (ICES WGBYC, 2019; ICES WKEMBYC, 2020). In contrast, HELCOM (2013b) suggested that demersal seines have more of an impact than gillnets on benthic habitats although gillnets and trammel nets were more destructive for seabirds and marine mammals. Initial trials in Denmark comparing catches of cod in gillnets and Danish seines indicate that the Danish seine has potential for good size and quality of cod but more technical work is required to develop the gear (ICES WKING, 2020; Larsen *et al.,* 2020). The use of Danish seines may be somewhat limited to areas with a sandy substrate to prevent the ropes getting stuck on the seabed in muddy and/or stony areas (ICES WKING, 2020; Larsen *et al.,* 2020). Overall, it is still too early to recommend the use of small-scale seines as an alternative gear to static nets (Finn Larsen, Pers. Comm.).

The cost of implementation, pros and cons discussed below refer to the Danish seine due to the on-going trials as an alternative gear to gillnets in the Baltic.

3.1.2. Cost of implementation of the Danish Seine

The cost of adapting a small-scale vessel to use a seine

34 https://www.cornwallgoodseafoodguide.org.uk/fishing-methods/beach-seine-netting.php

Figure 3. Small-scale Danish seine net being set during gear trials in the Storebælt (Great Belt). © Thomas Noack.

net is quite expensive. In the trials in Denmark, the seine net and ropes costs around 12,000 Euros and the hauling system (two winches and drums) is around 32,000 Euros (Finn Larsen, Pers. Comm.). If demand was higher and more systems were manufactured, the price might be lower, but presently to change to a Danish seine net is around 44,000 Euros.

3.1.3. Pros of the Danish Seine

- Equal or higher catch efficiency than other alternative gears (e.g. pots)
- No bycatch of small cetaceans
- Low level of discards
- Reduced depredation and gear damage by seals
- No noise pollution
- Small-scale vessels are LIFE gear (low impact and fuel efficient)

3.1.4. Cons of the Danish Seine

- Demersal seines may impact on the seabed more than gillnets
- Use may be limited to sandy areas to prevent damage to the ropes

3.2. Jigging Machine

3.2.1. Current knowledge

Jigging is a low impact, automatic fishing method with hooks fixed on a line and a heavy weight on the end. Jigging machines can be used for demersal and pelagic species, including mackerel (*Scomber scombrus*) and whitefish species, e.g. sea bass, pollack (*Pollachius pollachius*), saithe (*Polachius virens*) and cod. The catch is of high quality, meaning it can achieve a higher market price and a potential 'eco-label'.

The hooks are 'jigged' in the water column to lure the fish. The depth of the hooks is set to the depth of the target species, making them selective. Pressure sensors detect when there is sufficient catch on the hook and automatically haul the catch to the surface and strip the hooks. The machines are installed on the side of a boat. Vessels can be equipped with, and use, multiple jigging machines in tandem, all controlled by one on-board computer and so can be manned with a small crew of 1-2 people. Jigging machines are portable and compact so they are ideal for the small, coastal vessels found throughout the ASCOBANS region, especially in the Baltic Sea.

Jigging machines can also be used in conjunction with other gears, e.g. during fishery closures for trawls and/or gillnets or offer an alternative target species when quotas or market price or target species are low (Baukus *et al.*, 2011). MacDonald *et al.* (2007) investigated the commercial potential of a jig fishery in inshore waters around Shetland, UK. They concluded that it could be commercially viable but only on a seasonal basis. The University of Rostock and Thünen Institute of Baltic Sea Fisheries in Germany conducted trials with jigging machines mainly targeting cod. The results showed that the gear is fit for use in working conditions in the Baltic but that the yield was less than a quarter of the standard gillnet, and over 50% of the fish were undersized. Many fish also had injuries due to the hook or change in pressure during hauling although using a different hook size and slowing hauling speed may prevent these issues (Noack, 2013).

3.2.2. Cost of implementation

The initial set-up costs involved in preparing an operational vessel to a jig fishery are substantial. MacDonald *et al.* (2007) investigated the feasibility of jig fishing in Shetland, UK. The costs include: cost of jigging machines (around 2,000 Euros each[35]), fitting the machines to the vessel, ensuring an adequate power supply for the machines and computer, and a sufficient supply of gear (filament, hooks, lures, sinkers and bait), in addition to the fishing licence. MacDonald *et al.* (2007) estimated that the cost is likely to extend into the 'tens of thousands' of Euros per vessel.

3.2.3. Pros

- Zero small cetacean bycatch
- Highly selective gear for species (but not size)
- Multiple jigging machines can be used in tandem
- Potential for high quality of catch with the correct hook size and hauling speed
- Potential for 'eco-labelling'
- More fuel efficient than trawling
- Little or no impact on the seabed
- Compact and easy to install even on small vessels
- Can be used in conjunction with other gear
- Up to eight jigging machines can be controlled by 1 on-board computer
- No noise pollution

3.2.4. Cons

- Not effective for some target species, e.g. flatfish, cod
- The impact of an increase in effort in areas not previously heavily fished may be substantial (see section 3.4.1. for the Lyme Bay example)
- Technical issues may not be as easy for fishers to repair without external help
- High cost to adapt vessels for fishing with jigging machines

3.3. Longlines

3.3.1. Current knowledge

Longlines can be very selective if the right hook size and bait are used for the target species, and fuel consumption is low (Schulz and Dolk, 2007). Longlines can be used for demersal and pelagic species and are used, to some extent, by most of the ASCOBANS Range States. Longlines can be fully automatic, including baiting the hooks, although small-scale vessels may still be manual. Very limited information exists for small cetacean bycatch in longlines in the ASCOBANS region. During interviews with fishers, bottlenose dolphin, common dolphin, striped dolphin and pilot whale were reported in demersal longlines off Portugal (Vingada *et al.,* 2012; Marçalo *et al.,* 2021). Bycatch in demersal longlines was reported in interviews for common dolphin, striped dolphin, bottlenose dolphin and pilot whale in the Portuguese coast between 2010 and 2012 (Vingada *et al.*, 2012). Bycatch in longlines is reported in other regions but mainly for medium-size odontocetes such as Risso's dolphin (*Grampus griseus*) and pilot whales (*Globicephala spp.*) (e.g. Gilman *et al.*, 2006; Hamer *et al.*, 2012; Werner *et al.,* 2015). Seals are often reported to depredate and cause damage to longlines in the ASCOBANS region (Königson *et al.,* 2015b). However, longline depredation is thought to be minor compared to gillnet depredation damage (Vetemaa and Ložys, 2009). Switching from static nets to longlines may cause a new bycatch problem for other taxa (Österblom *et al.,* 2002; Zydelis *et al.,* 2009). The Baltic Sea is a 'hotspot' for seabird bycatch (e.g. Almeida *et al.*, 2017; Field *et al.,* 2019). Seabird bycatch also occurs in longlines in the NE Atlantic (e.g. Fangel *et al.*, 2017; Vingada and Eira, 2017; Northridge *et al.,* 2020). Studies in Germany and Lithuania have recorded substantially less bird bycatch in longlines than gillnets (Mentjes and Gabriel, 1999; Vetemaa and Ložys, 2009), nonetheless, the levels are still high (e.g. Field *et al.,* 2019). The application of mitigation measures such as weighted lines and bird-scarers (e.g. streamers) have successfully reduced seabird mortality (e.g. Melvin *et al.*, 2014). Mitigation measures to prevent bycatch and/or depredation of cetaceans include weighted lines, systems to cover the catch as it is hauled, and weaker hooks, have all been trialled (Werner *et al.,* 2015 and references therein). All these experiments were conducted outside the ASCOBANS region where cetacean interactions are a particular issue for long-line fisheries.

Longlines generally have a low rate of discards (Erzini *et al.,* 2010) and a higher quality of catch due to the shorter soak time. An increase in quality generally means that the catch can achieve a higher market price. Studies have shown that the gear is fit for use in working conditions in the Baltic (Vetemaa and Ložys, 2009; University of Rostock and Thünen Institute of Baltic Sea Fisheries[36]). However, the results have not been consistent. Vetemaa and Ložys (2009) found no significant impact on the catch rate when targeting cod although fishers targeting salmon (*Salmo salar*) had a lower catch rate than normal when using longlines. In contrast, the trials by the University of Rostock and Thünen Institute of Baltic Sea Fisheries in Germany showed that the catch efficiency for longlines was much lower than gillnets when targeting mainly cod. Santos *et al.* (2002) reported a higher daily yield of hake (*Merluccius merluccius*) with longlines than gillnets in the Algarve, Southern Portugal. Differences in catch composition, catch rates and size selectivity may occur between gillnet and longline fishing on the same fishing grounds (Erzini *et al.*, 2010). For example, cod caught on hooks and in pots were found to be in a worse condition and from older age classes than those caught

35 https://www.cornwallgoodseafoodguide.org.uk/fishing-methods/beach-seine-netting.php
36 www.fairwaterfishing.co.uk/jiggingmachines.html

in gillnets (Ovegård *et al.,* 2012).

Longline fisheries are likely to be seasonal in some areas of the ASCOBANS region, e.g. the Baltic and the UK (Königson and Hagberg, 2007; Seafish[37]). Cod that are on the verge of spawning, do not feed and therefore are not caught by longlines, enabling recruitment (Koschinski and Strempel, 2012). In UK fisheries, as in some previous years, commercial fishing for sea bass has been spatially and temporally prohibited/restricted during 2020. Sea bass can only be caught as bycatch in fixed net fisheries, but vessels can land up to 5.7 tonnes per annum in hook and line fisheries[38].

In Iceland, targeting cod with longlines instead of gillnets has led to a reduction in harbour porpoise bycatch (Pálsson *et al.,* 2015). In the ASCOBANS region, longlines have the potential to be an alternative method to static nets for reducing bycatch of small cetaceans. The impact of longlines on seabird populations and depredation by seals may, however, render their use as an 'alternative gear' problematic if appropriate mitigation measures are not applied.

3.3.2. Cost of implementation

It was not possible to obtain costings for changing to longlines. The costs are likely to be similar to changing to jigging.

3.3.3. Pros

- Highly species and size selective
- Little evidence of bycatch of small cetaceans reported in the ASCOBANS region
- No impact on target species
- High quality of catch, therefore higher market price
- Potential for fishing in areas with restrictions for other gears, e.g. static nets and trawls prohibited
- Does not require a lot of space on-board, and therefore ideal for small vessels
- No noise pollution
-

3.3.4. Cons

- High levels of seabird bycatch
- Depredation of catch and gear damage by seals and cetaceans
- The impact of an increase in effort in grounds not previously heavily fished, may be substantial

3.4. Fish Pots

3.4.1. Current knowledge

In the Baltic, the development of pots as an alternative gear to gillnets in the cod fishery has been led by the need to reduce the significant amount of catch and gear damage caused by seals (Hemmingsson *et al.,* 2008; Königson *et al.,* 2009; Königson *et al.*, 2015a). Seals can become bycaught in the pots, although seal bycatch can be reduced by fitting a seal exclusion device (SED) at the entrance of the pot (Königson *et al.*, 2015a). The addition of a SED at the entrance of the pot changes the design of the pot and therefore impacts its efficiency (Thomsen *et al.*, 2010; Königson *et al.,* 2015a).

Pots are species and size selective with low gear construction costs compared to other gears and are classified as Low Impact and Fuel Efficient (LIFE) fishing gears (Suuronen *et al.,* 2012). Pots can be set as individual pots or several pots along a string. Pots have been demonstrated to be viable gear for the Baltic fishing conditions (Königson *et al.,* 2015a, 2015b) and a potential alternative gear for gillnets and longlines for targeting Atlantic cod (Schulz and Dolk, 2007; Königson *et al.,* 2015b). Environmental conditions (e.g. currents, water depth) and fishing practices (e.g. soak time, month, mesh size, bait) can have substantial impacts on target species catch levels (Königson *et al.,* 2015b; Meintzer *et al.,* 2018).

When the CPUE was compared between traditional methods (longlines and gillnets) and cod pots in the Swedish Baltic, the CPUE was equivalent when calculated as the average over the year (Königson *et al.,* 2015b). The CPUE of cod pots is highly variable seasonally and between individual pots (Noack, 2013; Königson *et al.,* 2015b). However, Noack (2013) found that pots are not an economical alternative to gillnets in the Southern Baltic due to the increased handling effort for fishers and low number of marketable fish compared to gillnets.

The benefits of pots are that fish trapped in pots stay alive until the gear is retrieved so the catch is generally thought to be of high quality due to the non-invasive method to capture the fish. Non-target species or under-sized fish can also escape or be returned to the sea, and catch is not lost if the gear cannot be retrieved during bad weather. Cod caught in pots were found to suffer less stress during capture and handling than cod caught in longlines (Humborstad *et al.,* 2016). Cannibalism may occur in pots with no escape panels for smaller cod (Ovegård *et al.,* 2011). Cod caught in pots (and on hooks) can be from older age classes and in a poorer body condition than those caught in gillnets (Ovegård *et al.,* 2012; Ljungberg *et al.,* 2020). It is thought that cod in a poorer body condition may have increased stimuli to bait and be more likely to enter baited pots than those in a better condition (Ljungberg *et al.,* 2020). Cod pots are also being trialled in Denmark but the trials are in the early stages (Finn Larsen, Pers. Comm.). The use of pots for flatfish, e.g. flounder and turbot, was also tested in Sweden. However, there was only a few fishing occasions and the catch rates were low, so the potential of this fishery is unknown (Nilsson *et al.,* 2018).

37 www.seafish.org/responsible-sourcing/fishing-gear-database/gear/long-line/
38 www.gov.uk/government/publications/bass-industry-guidance-2020/bass-fishing-guidance-2020#:~:text=1.,retained%20per%20fisherman%20per%20day

Figure 4. Typical fish pots used in Scotland to target nephrops and crabs © Fiona Read

For pots to be a viable gear in a commercial fishery, they need to be designed around efficiency, selectivity, safety, and the ease of use (Meintzer *et al.,* 2018). Any modifications can have an impact on the CPUE, e.g. an increased catch of cod in the Baltic was found to be linked to the use of funnel shaped entrances (Ljungberg *et al.,* 2016) and pot orientation in relation to the prevailing current (Meintzer *et al.,* 2017). Catch efficiency of five different cod pot designs for use in Canada in the Newfoundland and Labrador Atlantic cod fishery was compared by Meintzer *et al.* (2018). During the commercial fishing season, all five pot designs were effective at catching cod, demonstrating that based on the configuration of their fishing vessels, fishers can be flexible in the design of cod pots (size, shape and dimension).

One of the main issues for small vessels is the large amount of space that pots take up on-board the vessel. In Sweden, Nilsson *et al.* (2018) have designed and successfully tested a foldable pot targeting cod that is suitable for small vessels. Small-scale boats with gillnets are often crewed by one person but in some areas, such as the Baltic, pots often require two people to handle the gear (Noack, 2013) which may decrease the overall profit of the fishery. This needs to be accounted for when proposing pots as an alternative to gillnets.

Outside of the Baltic, the use of pots targeting whitefish as an alternative to trawling is being trialled off the west coast of Scotland[39]. Using pots in areas where there is a risk of cetacean entanglement is likely to be an issue (Leaper and Calderan, 2018; Read *et al.*, 2021), such as the west coast of Scotland (Northridge *et al.*, 2010; Ryan *et al.*, 2016; MacLennan *et al.*, 2020). Entanglement in pots is mostly assumed to be an issue for large whales, but recent results from interviews with pot fishers during the Scottish Entanglement Alliance (SEA) project showed that small cetaceans (as well as basking sharks (*Cetorhinus maximus*) and turtles) also can become entangled and nearly all of these are fatal (Read *et al.,* 2021). Figure 4 shows the typical pots used in Scotland. In order to prevent entanglements, modifications such as ropeless gear may become mandatory but would require the overall effectiveness and operational feasibility to be viable. Ropeless gear also requires the mobile sector to change their fishing methods so that the pots are not disturbed/removed (Sawicki, 2020). Ropeless gear will only prevent entanglements in the end lines. In the SEA project, minke whales (and basking sharks) were mostly found in the ground line therefore, the combination of ropeless and negatively buoyant rope would be better to mitigate bycatch of all species (Read *et al.,* 2021).

Conflicts often occur between the static and mobile sectors[40], and, therefore, the use of pots as an alternative to gillnets, should be limited to areas traditionally used by static gear. However, fishing restrictions, such as a limit on the number of pots per fisher, may need to be implemented. When Lyme Bay, southwest England, was designated as a Marine Protected Area and closed to towed bottom gear, many fishers switched to pots. This had a significant negative impact on income as the area became overfished. In 2011, voluntary measures were

39 https://fiscot.org/innovative-ways-to-catch-premium-white-fish/
40 https://www.europarl.europa.eu/RegData/etudes/STUD/2014/529070/IPOL_STU(2014)529070_EN.pdf

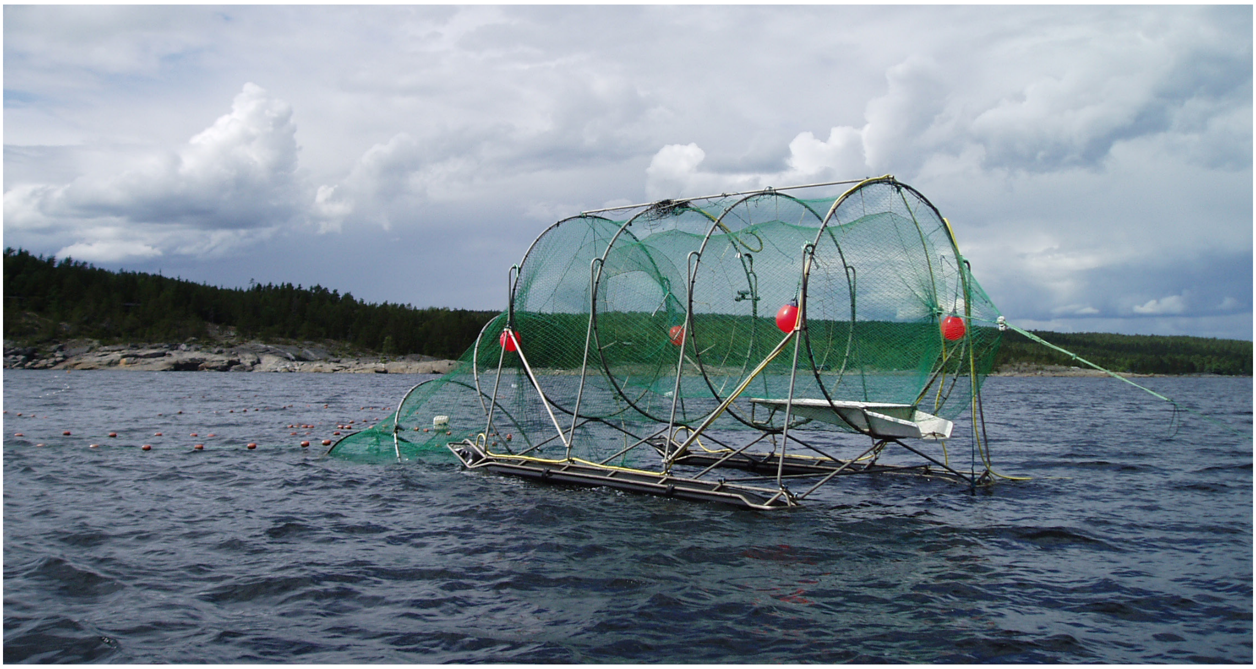

Figure 5a. A pontoon trap fish chamber being set in the northern Baltic. © Sara Königson

introduced that included restricting the number of pots in a string to 10 with a limit of 250 pots per fisher, and in 2016 the fishery was back to being viable and highly sustainable (Rees *et al.,* 2016, 2019).

Fishers may use a large number of pots. During the SEA project, two fishers in Scotland were using 4,000 pots although the majority were using < 1,000 pots (Read *et al.,* 2021). In Sweden, most fishers use around 600 pots (Sara Königson, Pers. Comm.). Not all the pots can be stored on the vessel, but this is not an issue due to the nature of the fishery (pots can be hauled and reset without the need for dry storage) (Finn Larsen, Pers. Comm.). Fishers may use wet storage (when pots are stored in-situ but not actively fishing) for several reasons including to stake claim to certain fishing grounds (Leaper and Calderan, 2018). Minimising or preventing wet storage would reduce the risk of entanglements (Dolman and Brakes, 2018).

Overall, pots are a good alternative gear compared to gillnets in coastal fisheries. The pot design will need to be customised depending on the fishery's target species, fishing area, environmental conditions, etc., and for migratory/seasonally mobile species, pots may only be effective during certain times of the year otherwise additional mitigation may be required, such as a combination of ropeless gear and negatively buoyant rope.

3.4.2. Cost of implementation

The number of pots required, and therefore the cost of changing gear to pots, depends on the individual fisher's needs and the size of the vessel. The pots used in the trials being conducted in Denmark are around 460 Euros per pot. A net hauler (or similar technology) is required to haul the pots. It is estimated that a small-scale vessel around 10 m in length, with one fisher, can haul around 100 pots a day. Assuming a fisher will work 100 pots, the cost of changing to pots is around 46,000 Euros if a new hauler is not required.

3.4.3. Pros

- Highly species and size selective
- Low level of bycatch of small cetaceans reported in the ASCOBANS region
- No impact on target species
- LIFE gear (low impact and fuel efficient)
- Fish are caught alive, higher quality of fish (some species), and non-target and undersized animals can escape or be returned to sea
- Less stress during capture for the target species than other gears such as longlines and gillnets
- No noise pollution

3.4.4. Cons

- Cetacean (basking shark and marine turtle) entanglements and seal bycatch may occur. Gear modifications may reduce interactions but it is crucial to ensure the modifications are effective
- CPUE may be highly variable seasonally
- The impact of an increase in effort in grounds not previously heavily fished may be substantial
- Ideal pot design might be time-consuming and tricky to optimize for a commercial fishery
- Fish may be held for extended periods of time
- Labour costs might be higher than gillnets if more people are required to work the gear

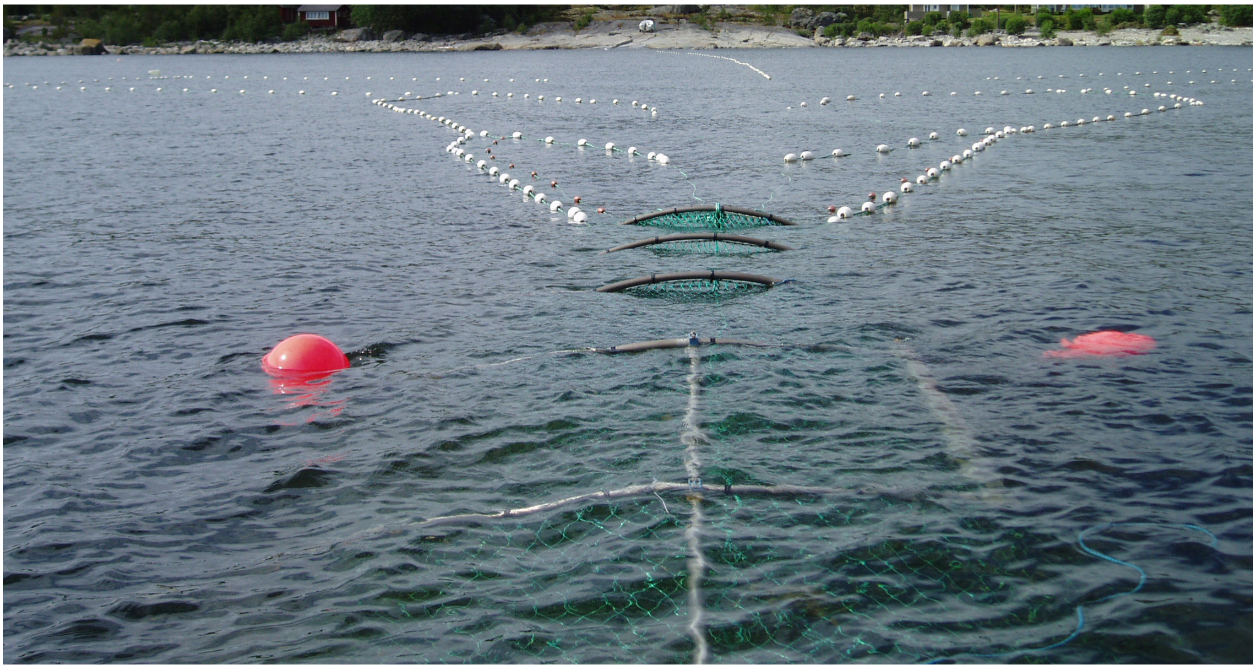

Figure 5b. The pontoon trap in situ with the floats indicating the location of the larger chambers. © Sara Königson

- Not suitable for open sea conditions

3.5. Fish Traps

Likewise, with the use of pots, the increase in seal-fishery interactions has largely led to the need for traps as an alternative fishing gear to gillnets in the Baltic. There are different types of traps used in coastal fisheries. The main ones are pontoon traps, pound nets, and fyke nets.

3.5.1. Pontoon trap

The pontoon trap is a leader net with a series of progressively smaller chambers and a fish holding chamber. Fish can easily enter the trap but it is hard to escape the holding chamber. The pontoon trap is a LIFE gear. Figure 5a and b show a typical pontoon trap in northern Sweden. Pontoon traps have been successfully tested in Swedish coastal waters for catches of whitefish and salmon although the trials for mackerel and herring (*Clupea harengus membras*) were unsuccessful due to the behaviour of the fish (Nilsson, *et al.*, 2018). In 2018-2019, pontoon traps were tested in Denmark by DTU Aqua, but the catch rates of both cod and flatfish were too low to continue with the trials (ICES WKEMBYC, 2020). Trials are being conducted in Germany by the Thünen Institute of Baltic Sea Fisheries, Rostock by replacing herring gillnets with pontoon traps to prevent bycatch of birds (ICES WKEMBYC, 2020) and reduce seal-fisheries interactions in Germany and Sweden (ICES WGFTFB, 2019).

The use of pontoon nets has reduced seal damage to trapped fish, and therefore the survival of trapped fish is high and the market value is increased. Pontoon nets also have low labour costs (Hemmingsson *et al.*, 2008) although they are not suitable for open sea conditions.

3.5.2. Fyke net

Fyke nets generally consist of a leader net with two nets (fish bags). Fish follow the leading net into one of the side nets where they are then trapped. Fyke nets are a LIFE gear. Fyke nets were commonly used in Swedish coastal waters to target eels (*Anguilla anguilla*) but cod and flounder were often among the bycaught species (Königson *et al.*, 2007). The Swedish eel fishery on the west coast has been banned for several years due to very low stock levels. Fyke nets are also used in the UK for a variety of fish including European eel (*Anguilla anguilla*) and salmon[41]. Seals and cormorants have been reported to cause damage to gear and catch in fyke nets (Königson *et al.*, 2003; Oksanen *et al.*, 2015). Repairing the net is time-consuming but catch and gear damage can also be a significant economic impact for the fishers (e.g. Königson *et al.,* 2003; MMO, 2018). Fishers using modified fyke nets had less gear damage and zero catch loss (Königson *et al.,* 2007), and the use of a SED reduced seal bycatch (Oksanen *et al.,* 2015). MMO (2018) gives a good overview of various non-lethal measures to reduce seal-fisheries interactions in static gear in the UK, which would also be applicable throughout the ASCOBANS Agreement Area.

41 www.seafish.org/responsible-sourcing/fishing-gear-database/gear/fyke-net

3.5.3. Pound net

A pound net is a series of nets anchored to the seabed. Fish enter the net via a funnel and swim into the pound net from which they cannot escape. Pound nets are used along the German and Danish Baltic coasts to catch eel in the autumn, and herring, mackerel and garfish (*Belone belone*) during the spring. Harbour porpoise have been found to enter pound nets but can be released uninjured because the mesh of the pound net is too small for them to become entangled, so they can breathe at the surface and make shallow dives (Teilmann *et al.,* 2008). Great cormorant (*Phalacrocorax carbo*) have been reported to heavily predate on fish in pound nets although the use of barrel nets can reduce this (Bildsøe *et al.,* 1998). There is no data published on the efficiency, etc., of pound nets or their use as an alternative fishing gear.

3.5.4. Cost of implementation

The cost of constructing trap nets varies depending on the type of trap. Each pontoon fish chamber costs between 5,000-7,500 Euros (Hemmingsson *et al.*, 2008; Vetemaa and Ložys, 2009), which is a significant outlay for small-scale fishers.

A typical fyke net in the UK and Sweden costs around 200 Euros. Depending on the characteristics, specially designed fyke nets range in price from 500-2,000 Euros (Peter Ljungberg, Pers. Comm.). It was not possible to obtain the cost of a pound net within the ASCOBANS region; however, in the US they are in the range of 8,000-10,000 Euros.

3.5.5. Pros

- Harbour porpoise survive capture and can be released alive (pound nets)
- No other cetacean bycatch
- LIFE gear (low impact and fuel efficient)
- Species and size selective
- High survival rate of target species in the traps, non-target and undersized animals can escape or be returned to sea
- High quality of fish in the traps (if mitigation for bird/seal predation is used)
- No noise pollution

3.5.6. Cons

- Not suitable for open sea conditions
- Potential for depredation and bycatch of cormorants and seals (if no effective mitigation is used)
- Labour costs may be higher than gillnets
- The impact of an increase in effort in grounds not previously heavily fished is unknown
- No information on the CPUE or gear efficiency compared to the traditional gears used
- Fishers need to be experienced in setting and hauling traps

3.6. Alternative Gear Discussion

The use of fish pots appears to be the most efficient gear without additional issues such as bycatch and/or catch/gear damage due to depredation of seals or birds. However, the use of alternative gears should be assessed on an individual basis.

The cost of developing new gears may be expensive and difficult (Leaper and Calderan, 2018). The majority of fishers in the ASCOBANS region operate from small-scale vessels, and it may be complicated for these vessels to adapt for alternative gear(s). With this in mind, switching to an alternative gear needs to be a long-term solution.

All of the proposed alternative gears are LIFE gears and also considered 'low technology'. Fishers will need to account for time to train and gain experience in working with any new gear. Once fishers are accustomed to working with the new gear, the efficiency of hauling and setting (especially for pots and traps) will improve.

In the NE Atlantic, bycatch occurs in high numbers in trawls, mainly pelagic and very-high-vertical-opening trawl fisheries, and offshore gillnets (e.g. Tregenza *et al.,* 1997a, 1997b; Tregenza and Collet, 1998; Morizur *et al.,* 1999; López *et al.,* 2003; Fernández-Contreras *et al.,* 2010; Mannocci *et al.,* 2012; Vingada *et al.,* 2012; ICES WGBYC, 2015, 2019; Peltier *et al.,* 2016; Vingada and Eira, 2017; Northridge *et al.,* 2019). It has not been possible to identify alternative gears for these vessels that would reduce bycatch. Although longlines can be used to target some species, e.g. hake, even with an eco-label certification the catch rate can be significantly less and may render any change unviable. In these fisheries, mitigation (fishery closures, ADDs or a combination of both) would seem to be a more feasible option.

Correct implementation of effective measures is critical and any fishing operation(s) needs to be controlled to some extent to ensure compliance (Hamilton and Baker, 2019). During fishing operations, the use of an alternative gear is easier to monitor and control than the use of most mitigation methods, e.g. it is easier to monitor a switch from gillnets to cod pots compared to monitoring functioning ADDs on gillnets. However, the use of alternative gears is harder to control than a blanket fishery closure, and the latter is unlikely to be effective if effort is displaced. The limited success of reducing cetacean bycatch in gillnets since the 1990s led the IWC Scientific Committee to conclude that '*there may be no technical option that can be implemented effectively, and the only solution is to stop using high risk fishing gears*' (IWC, 2020).

In the absence of data on the efficiency of a few of the proposed alternative gears in a commercial fishery, it is hard to assess the potential level of changes to catch rates for target and non-target species, as well as cetacean bycatch rates. Fisheries need to develop sustainable fishing methods that are good for both fishers and the environment, whilst ultimately aiming towards zero bycatch for cetaceans. CPUE in the alternative gear needs to be at least equal to that of the traditional gear in order to provide fishers with an incentive to change to an unfamiliar gear (Königson *et al.,* 2015b). However, other incentives such as a higher market price and eco-labels (discussed in more detail in the General Discussion) may also influence fishers to switch gear.

Due to the dire condition of the Baltic cod population, in July 2019, the European Commission announced that there would be a total ban on fishing for cod with gillnets in the eastern Baltic Sea through to the end of 2021. Whilst this ban may benefit harbour porpoise by reducing bycatch, the imperative need for developing alternative gears for targeting cod (such as pots and traps) should not be halted during this period, or postponed.

To assist with the development and implementation of alternative gears in the UK, Seafish[42] has developed a Financial Assessment Spreadsheet and Best Practice Guidance[43] for vessel owners (and trial supervisors). The spreadsheet provides *'a straightforward, standardised way for users to collect, analyse and compare gear trial results and assess the financial effectiveness of fishing modifications'*. Based on the overall costs of each trip and the market price of the catch, the spreadsheet allows users to assess the long-term financial implication(s) of modified gear. The database is currently aimed at UK fisheries but could be adjusted for the wider ASCOBANS region. A standardized approach to such work would facilitate future comparisons/reviews.

42 https://seafish.org/
43 https://seafish.org/gear-database/technical_info/best-practice-guidance-for-assessing-the-financial-performance-of-fishing-gear/

4. General Discussion

Fisheries need to be viable, economically profitable, and sustainable. To date and with the exception of ADDs, the majority of studies on mitigation methods and alternative gears to reduce cetacean bycatch have been conducted as experimental, scientific studies rather than in a commercial fishery. The success of any method(s) can only be fully determined in commercially operating fisheries (Hamilton and Baker, 2019).

The need for proven mitigation methods and alternative gears has been discussed. It is essential that there is a strong collaboration between all fisheries stakeholders (e.g. fishers, managers, policy advisers and scientists) to find workable solutions to cetacean bycatch whilst having no impact on the efficiency of the fishery (e.g. CPUE).

Eco-labelling of fish and fishery products can provide a mechanism to promote responsible fishing. Eco-label certifications (e.g. Marine Stewardship Council (MSC)) are awarded to fisheries that are managed sustainably and have minimal impacts on the wider ecosystem. There is often an economic incentive associated with an eco-label. The Cornish hake gillnet fishery in the UK has had MSC status since 2015 and all vessels have ADDs (the 'banana pinger' by Fishtek Marine) fitted to their gillnets, regardless of the vessel size44. Since the fishery obtained its certification, the fishery has seen various socio-economic benefits such as the price of hake caught in the fishery has increased and the fisheries reputation has improved (Davies and Williams, 2020). Consideration should be given to fishers that may prefer to use their original gear with additional mitigation measures rather than change to an alternative gear.

Overall, it is imperative that resources from ASCOBANS Parties and Range States are prioritised to reduce cetacean bycatch by continued development and robust testing of mitigation methods and alternative gears throughout the ASCOBANS region.

44 https://fisheries.msc.org/en/fisheries/cornish-hake-gill-net/@@view

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Abbreviations

ADD – Acoustic Deterrent Device

CEFAS – Centre for Environment, Fisheries and Aquaculture Science

CFP – Common Fisheries Policy

CMS – Convention of Migratory Species

C-POD – Cetacean – Porpoise Detector (Chelonia Limited)

CPUE – Catch per Unit Effort

DDD – Dolphin Deterrent Device

EEZ – Exclusive Economic Zone

GES – Good Environmental Status

HRA – Habitats Regulations Appraisal/Assessment

ICES – International Council for the Exploration of the Sea

ICES WGBYC – ICES Working Group on Bycatch of Protected Species

ICES WGMME – ICES Working Group on Marine Mammal Ecology

ICES WGFTFB – ICES Working Group on Fishing Technology and Fish Behaviour

IFREMER – French Research Institute for Exploitation of the Sea

IMARES – Institute for Marine Resources and Ecosystem Studies

IUU – Illegal, Unreported and Unregulated

LIFE – Low Impact Fuel Efficient

MMPA – Marine Mammal Protection Act

MPA – Marine Protected Area

MSC – Marine Stewardship Council

PAL – Porpoise Alerting Device

SAC – Special Area of Conservation

SED – Seal Exclusion Device

VMS – Vessel Monitoring System

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