Fishers and whales in Iceland: Whale interactions with fishing gear from the fishers' perspective, with a focus on humpback whales (*Megaptera novaeangliae*)

Charla J Basran[1,2]* and Marianne H. Rasmussen[2]

Contact e-mail: cjb2@hi.is

ABSTRACT

In Iceland, and many other places globally, the detrimental impacts of whale interactions with fishing gear on both fisheries and whales are not well understood or managed. This study conducted anonymous questionnaires of Icelandic fishers and interviews of capelin purse seine boat captains to gather first-hand knowledge of the issues the fishers face due to whale interaction with their fishing gear. Results suggest that the humpback whale is the most common of the large whale species to become entangled or encircled in fishing gear and cause damage; however, on occasion other large whale species are interacting with gear as well. Interactions between humpback whales and fishing gear appears to be primarily concentrated in the north/northeast and southwest of the country where there is high fishing effort as well as a known humpback whale feeding habitat. Humpback whale interactions with gear occurred most often with capelin purse seines, which are targeting humpback whale prey, and data suggests that bycatch of whales in this fishery may be under-reported. Damage and losses due to whale collisions with gear were reported to cost fishers up to a maximum of 55.000.000ISK per incident, suggesting this can be a costly issue for which mitigation measures should be explored. The use of acoustic 'pingers' is one mitigation measure that has been previously tested by capelin purse-seiners and is something that captains indicated they would be interested in continuing to try. The creation of a whale entanglement/whale-gear interaction reporting system in Iceland would aid in gathering more data, quantifying these events and determining what the consequences are to both the fishers and the whales. This study provides new information about the consequences of large whale interactions with Icelandic fisheries and suggests that future collaboration with fishers can provide insight contributing to best management practices for sustainable fishing and whale conservation.

KEYWORDS: INCIDENTAL CATCHES; FISHERIES; HUMPBACK WHALE; PURSE-SEINES; ICELAND SEA

INTRODUCTION

Interactions between commercial fishing and cetaceans are of increasing global concern. Fifty years ago, the global fish capture was 60 million tonnes, increasing to 80 million tonnes 20 years ago and to 90.5 million tonnes in 2016 (FAO, 2018). Some fisheries directly target cetacean prey species, such as capelin (*Mallotus villosus)* and herring (*Clupea harengus*), which is likely to increase interaction between cetaceans and fishing gear. In addition to expanding fisheries and fisheries targeting cetacean prey, many cetacean populations, particularly the humpback whales (*Megaptera novaeangliae*), have been increasing since their protection (Wedekin *et al*., 2017; Zerbini *et al*., 2019) which further increases the likelihood of negative fisheries interactions.

[1] Department of Life and Environmental Sciences, University of Iceland, Reykjavik, Iceland.
[2] Húsavík Research Centre, University of Iceland, Húsavík, Iceland.

The interactions between cetaceans and fishing can be detrimental to both the animals and the fishers. An entanglement in fishing gear can lead to injury or death of the whale which can affect the species at the population level (Mazzuca *et al*., 1998; Cassoff *et al*., 2011; Knowlton *et al*., 2012; Robbins, 2015). The creation of stronger synthetic net and line material in fisheries has likely increased the risk of cetaceans becoming fatally entangled or seriously injured since this material is more durable and difficult to break (Volgenau *et al*., 1995). Interactions between whales and gear also causes financial loss to fisheries in terms of gear damage, down-time for repairs and loss of catch (Lien, 1979; Lien and Aldrich, 1982), particularly large whale interactions such as humpback whales. For humpback whales, it is estimated that the studied populations in Iceland, the Gulf of Maine, and Alaska are entangled in fishing gear at a rate of 2%, 14-17% and 8% per year respectively (Basran *et al*., 2019; Robbins, 2012; Neilson *et al*., 2009). Possibly due to the concern over negative consequences for the fishing industry, under-reporting of bycatch and interactions with large marine mammals is common (e.g. Baker *et al*., 2006; Robbins, 2011; Reeves *et al*., 2013). Fishers may have valuable information regarding this issue, but it is rarely quantified in order to implement necessary protective measures by scientists, managers, or policy makers.

In Iceland, export of fishing products is the third highest grossing industry, and 1582 commercial fishing vessels were registered in 2019 (Statistic Iceland a, b). Methods used for catching commercial fish species include: gillnets; demersal seines; purse seines; trawls; and hand/long-lines (ICES, 2019). These methods have all been implicated in cetacean entanglements in previous studies around the world (e.g. Reeves *et al*., 2013; Archer *et al*., 2004; Rossman, 2007; Pusineri and Quillard, 2008). It is mandatory in Iceland that fishers report any catch of cetaceans in their logbooks (Atvinnuvega- og nýsköpunarráðuneyti, 2020) and several cetacean species have been reported, including harbour porpoises (*Phocoena phocoena*), white-beaked dolphins (*Lagenorhynchus albirostris*), minke whales (*Balaenoptera acutorostrata*), humpback whales, and fin whales (*Balaenoptera physalus*) (Marine and Freshwater Research Institute, unpub. data). Fishers in Iceland tend to complain specifically about humpback whales colliding with, being encircled in, or becoming entangled in their gear and causing damage (pers. obs.). The humpback whale population in the central north Atlantic is estimated to be approximately 10,000 individuals and the majority of sightings from surveys occurred in the north and northwest of Iceland (Pike *et al*., 2019). An estimated 25% of Icelandic humpback whales have scarring indicating they have been entangled in fishing gear at least once and some of these entanglements are known to have occurred locally in Iceland (Basran *et al*., 2019).

Interviews and written questionnaires are used to gather eye-witness accounts and expert knowledge from resource-users, including the fishers. Using these methods to engage with fishers can improve the relationship between fisheries and research institutes and can therefore lead to increased data and better fisheries management (Johnson and Densen, 2007). This method has been used to study experiences and effects of whale depredation on fisheries in Alaska, USA (Peterson and Carothers, 2013), seal-fisheries interactions in Greece and Cornwall, England (Glain *et al*., 2001), gear damage caused by whales and sharks in Newfoundland and Labrador, Canada (Lien and Aldrich, 1982), fisher knowledge of marine megafauna bycatch off Mayotte Island, Mozambique (Pusineri and Quillard, 2008), cetacean-fisheries interaction in Galicia, Spain (Goetz *et al*., 2014) and Bahia, Brazil (Seminara *et al*., 2019) and marine mammal bycatch in the South China Sea (Liu *et al*., 2016), Victoria, Australia (Norman, 2000), Northwest Spain (López *et al*., 2003), artisanal fisheries in African, Asian and Caribbean countries (Moore *et al*., 2010) and Iceland (Ólafsdóttir, 2010). Surveys of fishers and onboard observation can be useful tools to collect eye-witness accounts of whale-gear interactions and specific details of these incidents that cannot be inferred using conventional methods of studying whale entanglements (Knowlton *et al*., 2005). Observations of whales interacting with fishing gear are considered to be rare and fishers are the most likely people to be able to provide first-hand insight. This study used questionnaires, with Likert-type scales for frequency, yes/no, multiple-choice and open-ended questions, as well as semi-directed interviews, to collect information about whale-gear interactions. Data included entanglements, collisions and encirclements of whales in Icelandic fisheries from the fishers' perspective, primarily focusing on humpback whales. Rarely reported details of the events were collected such as location, fishing gear used, and damage sustained to the gear. Likert-type scale and yes/no question responses were statistically compared using Wilcoxon Rank Sum tests. The information collected in this study aids in creating a clearer understanding of the issues surrounding interactions between whales and Icelandic fisheries, which can in turn be used to improve fisheries management for mitigating financial losses to fishers and improving whale conservation.

METHODS

An anonymous questionnaire about cetacean sightings and entanglement in/interaction with fishing gear was designed to gather information from fishers in all types of fishing industries in Iceland. The aim was to gather answers from any fisher, not just those that had whales interact with or become entangled in their gear. Experience of the fishers and job onboard was not considered when inviting participants. The questionnaire was primarily focused on entanglement and gear interactions involving humpback whales (Appendix 1). It was created in English and translated into Icelandic prior to distribution. Pilot-project questionnaires were distributed first in 2013, and then finalised questionnaires were used 2015-2018.

A total of 40 registered commercial fishing companies were contacted about the questionnaire through email, phone, and/or post either through contacting the company office or making contact directly with fishers working for the companies. A list of companies with active fishing vessels was compiled using Marine Traffic and Skipaskrá (the Icelandic ship list) and questionnaires were sent to companies in all parts of the country. Contact about the questionnaire was attempted with all companies identified as operating two or more vessels (n = 25) and 15 single-boat companies for which contact information could be found. Types of vessel, fishing gear, and species fished was not considered when compiling the list, to minimise potential bias in responses. Ultimately, the companies covered all gear-type categories used in Iceland (hooks and line, gillnets, trawls and seines). The first effort to contact the companies was conducted through email. Secondly, the largest and most successful effort was through post, for which 158 questionnaires with a pre-paid and pre-addressed envelope were sent to 24 different companies. The number of blank surveys sent to a company corresponded with the number of fishing vessels the company had (2 per vessel). The companies to which the questionnaires were mailed included those which did not respond to the initial email contact within one year. Phone contact was attempted with companies which did not answer through email or post, in order to assess if they would be willing to answer the questionnaire. Lastly, the largest remaining companies (operating three vessels or more) which had not answered through any method were contacted by email one final time shortly before concluding the study. In addition, in-person and social media contact was made with various seasonal fishers requesting participation in the questionnaire. An online link to the questionnaire was available for one month, and this did not require the participants to provide the company that they worked for.

The questionnaire started with a short explanation of the project, stating the goal was to gather information from fishers about cetacean sightings and entanglement in/interaction with fishing gear and the impacts of these incidents. It was made clear that all participants would be kept anonymous. The question methods used were Likert-type scales for frequency (where answers are selected on a scale, i.e. from never to very often), yes/no, multiple choice and open-ended. Both the pilot survey and the continued survey first asked generally about cetacean sightings while fishing, then about humpback whale sightings specifically. It went on to ask about cetacean entanglement or interactions in general, then about humpback whales specifically. The continued survey, from 2015, inquired if humpback whale entanglement/interaction had occurred in the past 5 years, giving a more reliable time range for these incidents (from 2010-2018). If the participant answered yes to having had a humpback whale interaction, they were requested to supply details of the incident including date, gear-type, target fish species, location, and what (if any) action was taken (in both versions of the survey). Next, the continued survey asked if the fisher had experienced any gear damage due to whales in the past 5 years. If they answered yes, they were asked to supply details including whale species, location, gear type, type of damage, and estimated costs of the damage and down-time. Lastly, the continued survey inquired about the reporting of whale entanglement/interaction incidents and what the reason(s) would be for the participant to not report an incident.

Data from the questionnaires were compiled and visualised for the results. The Likert-type scale question responses regarding frequency of observing animals entangled in/interacting with fishing gear were updated to 'never', 'once' and 'more than once' to give more exact answers in the finalised survey started in 2015. To compile the data for these questions including the pilot survey, the categories were 'never', 'once + occasionally', and 'more than once + often'. Statistical comparisons between answers to Likert scale and yes/no question responses were conducted using Wilcoxon Rank Sum tests performed in the statistical software program R (R Foundation

for Statistical Computing version 3.1.6) and mean ranks for comparison were calculated using SPSS (IBM SPSS version 25.0). Data could only be included in statistical analysis when the respondent answered both the questions.

In addition to the questionnaire, five capelin purse-seine vessel captains took part in semi-directed interview, four of which were current captains and one who was retired. The interviewer asked both closed questions and open-ended follow-up questions to guide the interview, allowing the respondent to provide detailed answers of varying length and scope (Adams, 2015). The five captains were chosen as they had all experienced incidents with humpback whales and were all willing to be interviewed in-person or over the phone with the conversation being audio recorded. Three interviews were conducted in English and two in Icelandic, and the interviews were later transcribed. These interviews were conducted to gather in-depth information about humpback whales interacting with capelin purse seines in Iceland, given the capelin fishery was the industry that reported the most incidents.

RESULTS

A total of 60 completed questionnaires were returned, and 59 were used for analysis. Two questionnaires were returned in the same envelope and contained the exact same answers and therefore were counted as one. Fifteen companies (37.5%) of the ones which were known to have been contacted (through email, post or personal contact) returned at least one questionnaire. The majority of questionnaire respondents reported seeing whale species (spp.) 'often' or 'very often' while fishing in Iceland (57.6%) (Fig. 1). Nearly half (47.5%) also reported seeing specifically humpback whales 'often' or 'very often'. In addition, 55.9% reported seeing dolphins and/or porpoises 'often' or 'very often' while fishing and only 8.5% reported seeing pinnipeds 'often' or 'very often'.

Over one-quarter (n = 19, 32.2%) of respondents reported that they had observed whale spp. interact with their fishing gear at least once, and 13.6% (n = 8) reported this happening more than once (Fig. 2). Three of those who answered 'Never' to observing whales in their gear provided details of an observed whale-gear interaction in a later question, and therefore it was assumed they misunderstood the initial question and their answer to whether they had observed whales interacting with their gear was changed to 'Once'. Of the eight that reported this happening more than once, one report stated the species were unknown, two reports indicated they had seen different species in their gear (a humpback whale and a blue whale (*Balaenoptera musculus*) and humpback whale and orca (*Orcinus orca*)) and the remaining five reports indicated they had seen only humpback whales in their gear more than once. In addition, nearly half (47.5%) of respondents reported having dolphins and/

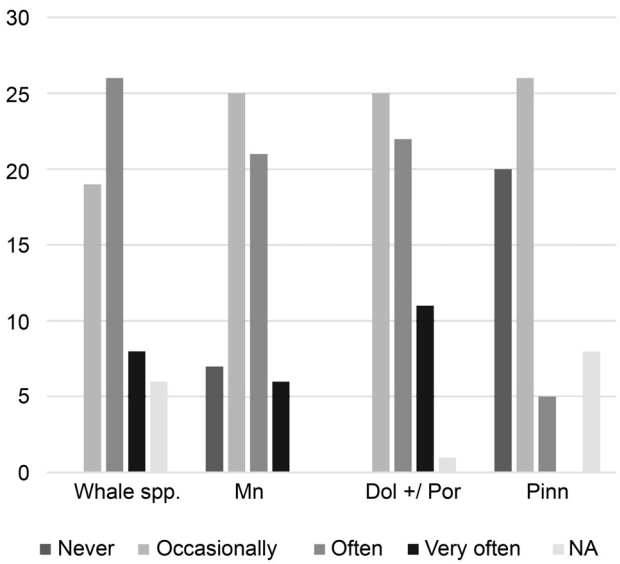

Fig. 1. Graphs showing how often questionnaire respondents reported seeing whales of any species (Whale spp.), humpback whales (Mn), dolphins and/or porpoises (Dol +/ Por) and pinnipeds (Pinn) while fishing in Iceland.

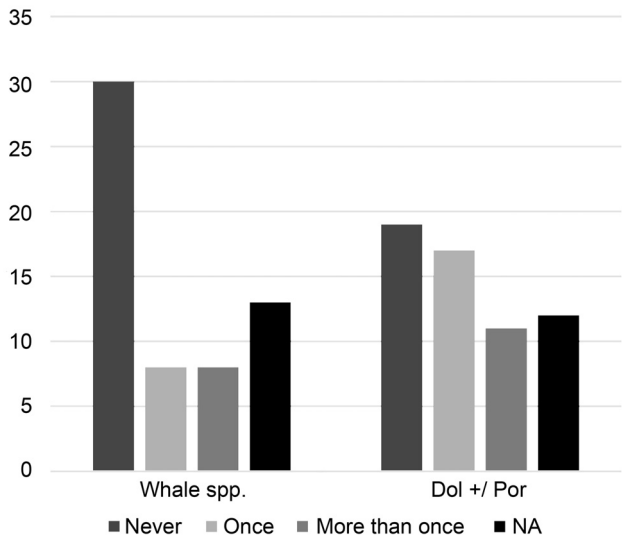

Fig. 2. Graph showing how often questionnaire respondents witnessed whales of any species (Whale spp.) and dolphins and/or porpoises (Dol +/ Por) interacting with their fishing gear while fishing in Iceland.

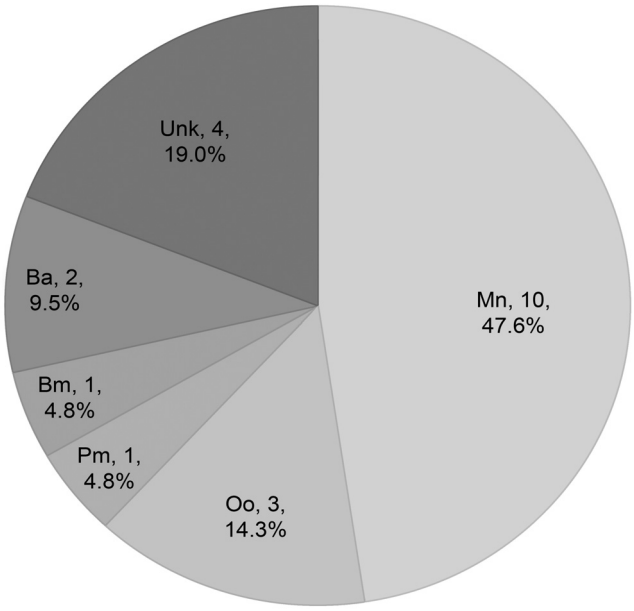

Fig. 3. Graph showing the number of each species of whale, and the percent of the total that each species represents, that questionnaire respondents reported witnessing interacting with their fishing gear while fishing in Iceland. Mn = humpback whale, Oo = orca, Pm = sperm whale, Bm = blue whale, Ba = minke whale, Unk = unknown.

or porpoises in their gear at least once, and 18.6% reported this happening more than once. Ten observed whale-gear interactions involved humpback whales (47.6%), three involved orcas, two involved minke whales, and there was one report each of sperm whale (*Physeter macrocephalus*) and blue whale interactions (Fig. 3). There were an additional four reports where the species were not reported and listed as unknown.

Of the ten humpback whale-gear interactions, six (60%) occurred in capelin purse seine nets, one occurred in a cod set net, two occurred in cod/haddock hooks-and-lines, and one report had no details (Table 1). Five respondents who reported having humpback whales in their fishing gear reported that they delayed closing the net, opened the net, or sunk the net in order to try to let the whale(s) out. All five of these respondents had whales in their capelin purse seine net. One respondent, who reported having a humpback whale entangled in their cod set net, reported cutting the whale out to release it. The other five respondents who reported having humpback whales in their gear either reported they took no action or did not provide any details. There was location information reported for eight of the ten observed humpback whale-gear interactions. Most of the incidents occurred in coastal waters in the southwest (n = 3) and northeast (n = 4). One reported incident occurred

Table 1

Details provided by questionnaire respondents about witnessed humpback whale interactions with their fishing gear in Iceland. NA = no response was provided.

Report	Date	Target fish	Gear type	Action taken in attempt to release whale
Within 5 years of questionnaire (2010–18)				
1	02/2016	Capelin	Purse seine	Delay closing the net to let the whale escape
2	03/2016	Capelin	Purse seine	Delay closing the net to let the whale escape
3	03/2015	Cod	Net	Cut out of the net
4	06/2014–2016	Cod, haddock	Hooks and line	NA
5	NA	NA	NA	NA
6	'every year' (2014–18)	Capelin	Purse seine	NA
7	2018	Capelin	Purse seine	Delay closing the net to let the whale escape
8	06, 07/2012–13	Cod	Hooks and line	NA
Prior to 2010				
9	12/1979	Capelin	Purse seine	Sunk the cork line and let the whale swim over
10	07, 08/1995	Capelin	Purse seine	Open the net

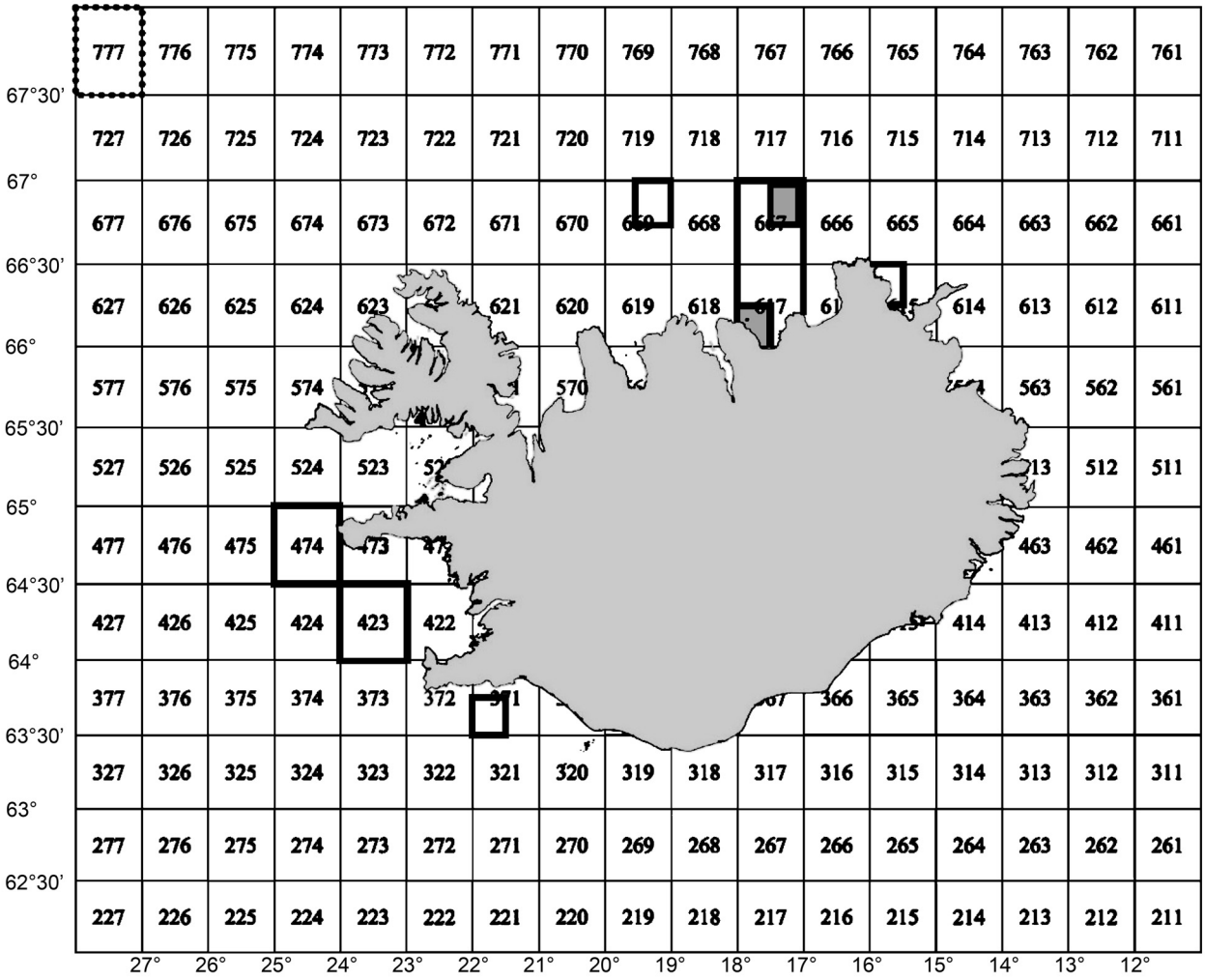

Fig. 4. Map showing the eight locations in the fishing grounds where respondents witnessed and reported location of humpback whales interacting with their fishing gear around Iceland. Solid black outlined boxes indicate reported locations, grey-shaded boxes indicate two locations given in the same report, however the report was counted as one witnessed event since it was unclear if they were reporting two incidences or estimating where one incident occurred. The dotted box indicates a report of an incident 'southeast of Scorsebysund' only indicating that this would be in open ocean to the far northwest of Iceland.

in offshore Icelandic waters 'southeast of Scoresbysund' (Fig. 4). One respondent simply wrote that they have seen humpback whales in their net in 'all areas' of the capelin fishing grounds, while the final respondent did not provide a location.

There were twelve reports of whale spp. damaging fishing gear between 2010–2018 (Table 2). Of these, seven (58.3%) were humpback whales, two were orcas, one was a minke whale and in one report the species was left blank and considered unknown. The question specifically asked about whales, but one questionnaire response included damage due to a white-beaked dolphin and this was kept in the data as the seventh report. Five reports of damaged gear involved purse seines (four humpback whale and one orca), three involved nets (one humpback whale, one white-beaked dolphin and one unknown), three involved hooks-and-lines (two humpback whale and one minke whale) and one involved a trawl (orca). Those that reported monetary loss due to damage in the continued questionnaire (damage occurring between 2010–2018) estimated monetary damage and losses caused by whales ranged from only 10.000 (for broken leader lines) up to 10.000.000 (for torn purse seine nets) Icelandic krona (ISK) (approximately $80 up to $80,000 USD [Sept 2019]).

Those respondents who had observed whale spp. interacting with their fishing gear (at any time) (n = 16, mean rank (MR) = 22.22) did not significantly differ in their responses to how often they observed whale spp. while fishing compared to those who had not observed an interaction (n = 25, MR = 20.22) (W = 180.5, p = .578). Similarly, those who reported having their gear damaged by whale spp. between 2010–2018 (n = 9, MR = 12.94)

Table 2

Details provided by questionnaire respondents about damage their fishing gear sustained due to whales in Iceland. La = white-beaked dolphin, Mn = humpback whale, Oo = orcas, Ba = minke whale, NA = no response was provided.

Report	Whale species	Gear type	Damage	Issues	Monetary loss estimate (ISK)
1	La*	Net	Holes in net	Loss of catch through holes	NA
2	NA	Net	Net torn	NA	NA
3	Mn	Purse seine	Holes in net	Loss of catch while trying to let whale escape; monetary loss repairing holes	500.000–1.000.000
4	Mn	Purse seine	Holes in net	Loss of gear, catch, time; high risk of injury to the crew	5–10.000.000
5	Mn	Net	Net torn/destroyed	Net unusable	NA
6	Oo	Trawl	Holes in net	None	NA
7	Oo	Net	Holes in net	Loss of catch through holes; loss of time for repairs	Minimal, but shortens lifespan of the gear
8	Mn	Hooks and line	Broken lines	NA	NA
9	Ba	Hooks and line	Broken leader lines	Two broken leaders	10.000
10	Mn	Purse seine	Net torn	Loss of gear, catch	10.000.000
11	Mn	Purse seine	Net torn	Loss of time and money for repairs	2–3.000.000
12	Mn**	Hooks and line	Broken lines	NA	NA

*The question specifically asked about damage due to whales and did not include dolphins. One respondent still detailed damage due to a white-beaked dolphin so it was included as extra data. **This report came from the pilot survey which did not ask about damage by any whale species, but only asked about humpback whales. This report is included here but not in statistical analysis since the question was not the same.

did not differ in their responses to how often they observed whale spp. while fishing compared to those who reported no gear damage (n = 17, MR = 13.79) (W = 81.5, p = .793). However, those respondents who had observed humpback whales interacting with their gear (n = 10, MR = 40.5) reported seeing humpback whales significantly more often while fishing than those who had not observed humpback whale interactions (n = 46, MR = 25.89) (W = 110, p = .006). Those respondents who had not observed a humpback whale interaction more often reported they saw humpback whales 'never' or only 'occasionally' while fishing. There was a trend in the data that suggested that respondents who reported having their gear damaged by whales between 2010–2018 (n = 10, MR = 19.1) also reported seeing humpback whales more often than those who reported no gear damaged in the past between 2010–2018 (n = 20, MR = 13.7), however this difference was not significant (W = 64, p = .096). Those respondents who reported having their gear damaged between 2010–2018 (n = 9, MR = 19.11) reported observing an interaction (at any time) significantly more often than those who reported no gear damage (n = 16, MR = 9.56) (W = 17, p = .0004). Only two (12.5%) of the respondents who reported observing a whale interact with their fishing gear 'once' or 'more than once' reported that they had no gear damage.

Over one-third of respondents (35.1%) did not answer the question about why they would not report catching a whale in their net, and over one-quarter (29.7%) of respondents reported they would always report what they are required to, or they have had nothing to report (Fig. 5). Furthermore, 16.2% of respondents answered

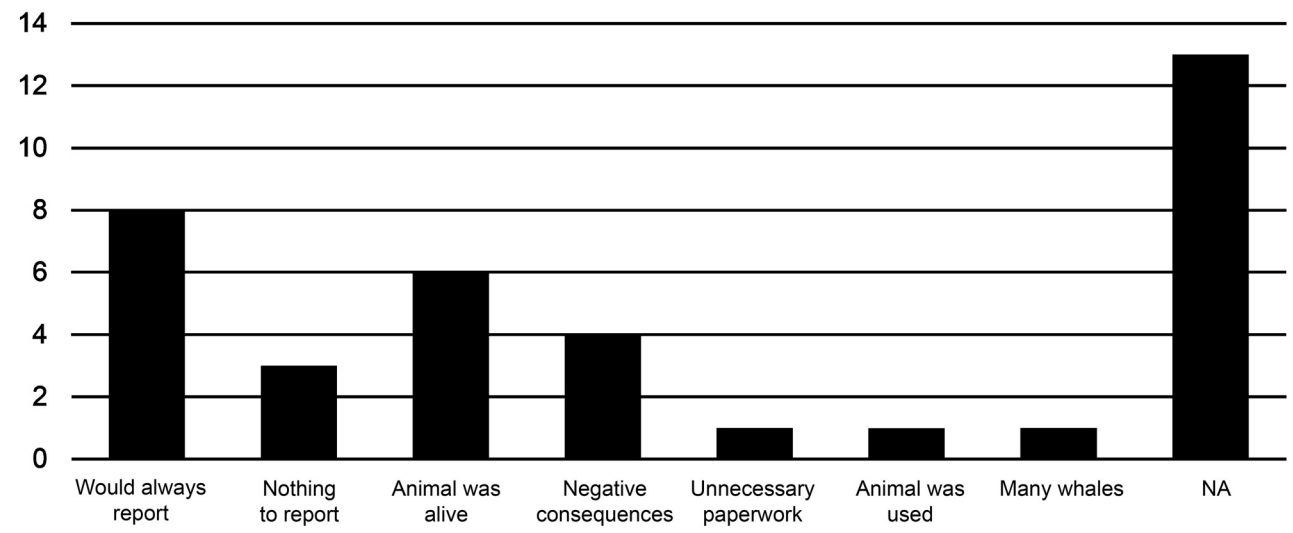

Fig. 5. Graph showing reasons (if any) that questionnaire respondents provided for not reporting whales in their fishing gear in Iceland.

Table 3

Summary of capelin purse seine boat captain interview responses.

Mn = humpback whale, Issues with Mn = response to 'Are issues with humpback whales increasing over time?'. Incidences within 5 years = response to 'How many incidences with humpback whales in your net have you experienced over the last 5 years?' Costs of issues = response to 'What are the costs of humpback whale(s) in your fishing net?'.

Interview	Years as captain	Issues with Mn	Incidences within 5 years	Costs of issues	Mn injured or deceased	Marine mammals besides Mn in net	Aware of pingers	Willing to try pingers
1	10	Increasing	10	Destroyed net: 10 million isk	No	No	Yes	Yes
2	10	Always occurred in the north, but increasing	Many. 17 whales in one season previously	Loss of catch + destroyed net: 55 million isk	Once (deceased)	No	Yes	Yes
3	31	Increasing problem for 20 years	Many. 9 whales at one time once (10 years ago)	NA	Twice (deceased)	No	Yes	Yes
4	18	Increasing problem. Was rare to see Mn 25–30 years ago	5 or 6	Sometimes 10–20 million isk	No	No	Yes	Yes
5	18	Increasing problem. Increased a lot 1990–2000	NA	NA Little thought was given to the cost	Yes (sometimes injuries to the pectoral fins or tail)	No	Yes	NA (retired now but believes they could work, especially in the dark)

that they would not report their incident(s) with whales since they believed the animal was released or escaped alive. Additionally, 10.8% answered they would not report their incident(s) with whales for fear of negative consequences to the fishing and 8.1% gave their own explanation in the 'other' answer section.

Five capelin purse seiner captains were interviewed about their experiences with humpback whales in their purse seine nets and their responses are summarised in Table 3. Four were current captains and one retired in 2007. All the captains reported that the number of incidents of encircling humpback whales in capelin purse seines has been increasing over the years. One captain stated that 25–30 years ago it was a 'special' event to see a humpback whale while fishing but more recently there is always many humpback whales in the fishing area, even in shallow waters. Another captain stated he noticed the number of incidents with humpback whales greatly increased between 1990–2000. All four current captains reported having incidents with humpback whales in their seine nets within the past five years. One captain estimated having 'five or six' incidents, one estimated having ten incidents, and two stated they have just had 'many' incidents, including nine whales in the net at one time (though this was prior to 2010) and 17 whales in their net in just one fishing season (approximately 10 years ago). All five captains discussed the measures they take to try to remove the whales from the seine net. Four of the five specifically noted that, ideally, they would leave the net partially open to let the whale(s) find their way out on their own, though they report that this is rare. One captain stated there was a '30:70' percent chance that they would be able to find their way out versus tearing a hole in the net. If the net is already closed around the whale(s) when the crew discovers them, all five captains reported that the main option is to sink the float line of the net so the whale(s) can hopefully escape by going over the top.

Three out of the five captains estimated that gear damage and losses (such as loss of catch, loss of fishing time and damage repairs) due to humpback whale(s) in their purse seine net cost them 10.000.000 to 55.000.000 ISK (approx. $80,000 to $450,000 USD). Two out of the five captains reported that a humpback whale had drowned in their net at least once, with one of them reporting that this had happened twice. A third captain reported that whales sometimes had injuries to their pectoral fins or tail, likely caused by the fishing gear. All five captains also reported they were aware of acoustic alarm devices known as 'pingers' which are advertised as a possible mitigation method for humpback whales entering purse seine nets. The four current captains reported they were willing to try the pingers and they had in fact previously experimented with them. However, the pingers previously used were not designed specifically for humpback whales and the captains did not find them to be effective in reducing the number of humpback whales encircled in and damaging their seine nets. Pingers were not used during the time the retired captain was fishing; however, he reported he believes the pingers could aid in minimising interaction with humpback whales, particularly in the dark.

DISCUSSION

Questionnaire results showed that cetaceans are often seen in Icelandic waters by fishers, including nearly half of respondents reporting seeing humpback whales specifically. Statistical comparison of the questionnaire responses determined that those respondents who observed humpback whale(s) interact with their gear reported that they saw humpback whales significantly more often than those that did not observe an interaction. Additionally, those who reported having their gear damaged by humpback whales revealed a trend in reporting seeing the humpback whales while fishing more often, though this was not significant. This supports the view that those fishers who are seeing humpback whales frequently while fishing in the humpback whale feeding habitat, have an increased chance to observe a whale-gear interaction and therefore an increased chance of having their gear damaged. Humpback whales are the third most abundant baleen whale species in Icelandic waters (Pike *et al*., 2019); however, these results support that humpback whales are the most commonly entangled large whale species in Iceland and most commonly cause damage and issues for fishers. This is likely due to their preference for coastal habitat which overlaps with commercial fishing, as shown by the reported locations where humpback whales were observed interacting with fishing gear. Though the number of reported locations was low, the majority were concentrated in the north/northeast and southwest of Iceland. These are two areas that are known for humpback whale sightings (Pike *et al*., 2019; Pike *et al*., 2009) and are also areas with high fishing efforts using nets, hooks-and-lines, trawls and purse seines (Hafrannsóknastofnun, 2017). The results from the questionnaire reflect where it would be likely for humpback whales and commercial fishing to overlap both spatially and temporally. In addition, the estimated summertime subpopulation of humpback whales around Iceland increased by approximately 12% per year between 1987–2001 (Pike *et al*., 2009) and has remained generally stable since (Víkingsson *et al*., 2015). This increase in the Icelandic subpopulation is reflected in the interview responses from the capelin purse seiner captains and is likely another large contributing factor to humpback whales being the most reported species observed interacting with fishing gear. Entanglement scar analysis conducted in Iceland also supports that humpback whales from the Icelandic subpopulation are often becoming entangled in fishing gear (Basran *et al*., 2019), and this is also a known issue in several other areas including eastern Canada (Lien and Aldrich, 1981; Benjamins *et al*., 2012), eastern USA and Alaska (Robbins, 2012; Neilson *et al*., 2009), Australia (How *et al*., 2015), Ecuador (Alava *et al*., 2012) and Colombia (Capella *et al*., 2001).

Eight of 14 respondents who reported observing whale(s) interact with their fishing gear (and reported the species of whale) (57.1%) saw humpback whales in their gear within five years of completing the questionnaire (between 2010–2018), or an average of at least one observed humpback whale interaction per year since 2010. In actuality, there are likely more observed interactions between humpback whales and fishing gear within that timeframe, exemplified by one respondent who wrote in his answer that he sees this 'every year' but did not provide more specific details on year and month. In addition, one capelin purse seiner captain stated in his interview that he had observed 17 humpback whales in his net in one season. Since the continued questionnaire (2015–2018) asked about humpback whales interacting with gear within the past 5 years (2010–2018) in order to look at a more accurate time frame, some respondents may have observed humpback whale entanglements prior to 2010 and the survey did not collect that information. The pilot survey did not use a timeframe and collected two reports (14.3%) from prior to 2010, one from 1979 and the other from 1995. Furthermore, one capelin boat captain reported he had nine humpback whales inside his capelin purse seine at one time approximately ten years ago (meaning it could have been shortly before 2010). These reports show that humpback whale-gear interactions were occurring prior to 2010 but this issue likely became more common since the mid-1990s due to the increased humpback whale population.

The capelin purse seine industry has been recognised in Icelandic media as having issues with humpback whales in their gear (pers. obs.). The questionnaire responses reflect this observation, with six out of ten observed reports of humpback whales interacting with gear occurring in the capelin purse seine industry. This is most likely due to the capelin purse seine fishery directly targeting humpback whale prey (Sigurjónsson and Víkingsson, 1997). This has also been observed in the tuna purse seine fishery in the Atlantic Ocean west of Africa, where tuna fishing primarily takes place in areas with high baleen whale prey density, resulting in 122 recorded baleen

Table 4

Summary of officially reported humpback whale bycatch in Icelandic fisheries (Marine and Freshwater Research Institute, unpub. data; Víkingsson *et al*., 2004, 2005; Víkingsson, 2011).

Date	Gear type	No. of animals	Location
2003	Gillnet	3	NA
2003	Bottom trawl	1	NA
01/2004	Purse seine	1	NW Iceland
27/09/2010	Mussel farm line	1	NW Iceland
03/2016	Gillnet	1	NA

whale encirclements in purse seines between 1995–2011 (Escalle *et al*. 2015). One Icelandic capelin purse seiner captain reported that he believed there was at least one occasion where the humpback whales purposely targeted the purse seine and entered the net while feeding on the capelin that were inside. Associated feeding with fishing vessels is a known phenomenon involving odontocete species such as orcas and sperm whales (e.g. Peterson and Carothers, 2013; Sigler *et al*. 2008; Mul *et al*. 2020) but this has not been clearly identified for baleen whales such as the humpback whale.

Although it is considered rare, two out of five capelin purse seiner captains said they had observed at least one humpback whale accidentally drown in their purse seine net. Humpback whale incidental mortality in purse seines has also been reported in the Atlantic tuna fishery off Western Africa (Escalle *et al*., 2015). If a marine mammal is caught as bycatch, it is required by Icelandic law that this information is submitted to the Directorate of Fisheries (Fiskistofa) through a mandatory logbook (Government of Iceland, 2018); however, in the last ten years of reporting there is no record of incidental mortality of a humpback whale in a purse seine (Marine and Freshwater Research Institute, unpub. data). The only record of humpback whale bycatch in a purse seine comes from 2004. In fact, there are only seven records of bycatch of a humpback whale in Iceland in any fishing gear since reporting began in 2002 (Table 4). Humpback whale entanglement reporting is also known to be low in the Gulf of Maine where, despite a developed reporting system, detection and reporting was estimated to be only 5.7% (Robbins, 2011). Given there were three times more reports of humpback whale deaths in purse seines reported in the interviews than shown in the bycatch records for the last 10 years, this suggests bycatch of humpback whales is largely under-reported. Currently there are no quantitative estimates of fatal entanglements of humpback whales in Iceland outside of the official bycatch reports. The fate of the majority of whales which are known to have been entangled in the Icelandic subpopulation is not known (Basran *et al*., 2019). However, there are incidental records of stranded humpback whales in Iceland for which entanglement in fishing gear was deemed the likely cause of death (Víkingsson and Ólafsdóttir, 2003; Víkingsson *et al*., 2004; 2005; Víkingsson, 2011), which further suggests this is an under-reported issue. Although, it is important to note that it is not known if any of the opportunistic records of mortality due to entanglement were actually observed by the fishers when the whales became entangled in gear. It is possible the whales escaped unobserved and then died at a later date and were therefore not reported as bycatch.

Other large whale species reported interacting with fishing gear included a sperm whale, orcas, minke whales and a blue whale, exemplifying that this is at least occasionally an issue for a wide range of Icelandic whale species. There are reports dating back to 1970 of orcas interacting with halibut longline fisheries in Iceland and depredating fish from the lines (Samarra *et al.* 2018) and reports from the 1950s of orcas destroying seine nets (Anonymous, 1956). However, there is no recent information on orcas interacting with herring seines or trawls in Iceland apart from the reports collected in this study. The third report of orcas interacting with gear in this study did not provide details on gear type, though the same respondent reported a humpback whale in their capelin purse seine. Similarly, there are reports of sperm whales interacting with longlines in Iceland (Samarra *et al*. 2018), but there are no published reports of interactions with trawls prior to the reports collected in this study. However, sperm whales have been documented feeding in association with halibut trawls in the northwest Atlantic (Karpouzli and Leaper, 2004). Documentation of scarring on minke whales in Iceland provided evidence that supports the reports in this study that some individuals are interacting with, and potentially becoming entangled in, fishing gear (Bertulli *et al.,* 2012). In addition, there is one report of minke whale bycatch in a

mid-water trawl in Iceland (Marine and Freshwater Research Institute, unpub. data). Globally, there is little documentation of blue whale entanglement or interaction with fishing gear (Basran and Rasmussen, 2020) and there are no published reports of this in Iceland prior to the report collected in this study. The gear-type was not clearly specified for the blue whale interaction, however the same respondent specified having a humpback whale interact with their hook and line gear, so there is a strong possibility the same gear-type was involved in the blue whale interaction. In addition to orcas and larger whale species, almost half of questionnaire respondents reported that they have had porpoises and/or dolphins in their gear. Bycatch of these small cetacean species is already a well-known issue in Icelandic fisheries (ICES, 2018; Marine and Freshwater Research Institute, 2018; Pálsson, 2015).

Gear damage caused by whales was reported in all the general gear-types used in Iceland. As suspected, those who reported that they had observed a whale interact with their fishing gear also reported that their gear had been damaged by whales significantly more often than those who had not observed whales interact with their gear. This confirms that when whales interact with fishing gear, they cause damage the majority of the time; however, the damage can range anywhere from minimal to severe in terms of financial costs. Damage to hooks-and-lines caused little financial loss to the fishers, with the report stating two broken leader lines (broken by a minke whale) costed the fishers ca. 10.000 ISK (ca. $80 USD). However, a whale entanglement in fishing line can be serious for the animal if the line ends up wrapping tightly around the body, which has been seen in Skjálfandi Bay, Iceland previously (University of Iceland's Húsavík Research Centre unpub. data) (Fig. 6). Damage to a net caused by orcas was also reported as having 'minimal' costs but did decrease the integrity of the net and shortened the time it was in working order. Damage to a purse seine net, including loss of catch and downtime, caused by humpback whale(s) was reported to cost up to 10.000.000 ISK (ca. $80,000 USD) in the questionnaire and up to 55.000.000 ISK (ca. $450,000 USD) in the interviews of captains. In the majority of cases, humpback whales likely escape from purse seines without serious injury or long-term consequences to the animal, but these events can have serious impacts on the profits of the fishers. In Galicia, Spain, it was also purse seine fisheries that reported being the most affected by gear damage caused by cetaceans, and the majority of incidents caused significant economic loss to fisheries targeting shoaling pelagic fish species (like capelin), though in that study the damage was not caused by large whales (Goetz *et al*., 2014). The capelin fishing season in Iceland is currently only approximately three months long (from January through March) (Síldarvinnslan hf., n.d.) and purse-seining is weather (sea state) dependent (Davis, 1970) meaning gear damage due to humpback whales and loss of fishing time to repair this damage can in some cases cost up to an estimated 11% of the revenue of an average fishing season (Geir F. Zoega, pers. comm., 20 January 2020).

Only two respondents who said they observed a whale interact with their gear reported that they had no damage. In those two cases one whale was reported to be a sperm whale in a trawl net and the other was reported as unknown. Two respondents who reported having their fishing gear damaged by whales reported that they did not observe any interactions between whales and their gear, however they saw the animals, which

Fig. 6. Image showing a humpback whale in Skjálfandi Bay, Iceland with monofilament line (like that used for long-lining) wrapped tightly around the tail stalk causing deep lacerations. (©Húsavík Research Centre).

they attributed the damage to, in the vicinity. This is similar to interview results from Galicia, Spain, where cetaceans were observed around the fishing gear 90% of the time that gear damage occurred (Goetz *et al*., 2014). One of the cases in this study involved orcas and in the other case the species was not reported and listed as unknown. For the case involving orcas, the respondent provided details that they discovered holes in their trawl net while they had orcas around the ship, but they did not observe whales in the net. There are previous reports of orcas associating feeding with fishing operations and becoming incidentally caught in gear (Fertl and Leatherwood, 1997), so it is not unlikely that the orcas were doing something similar in this case. The report exemplifies that some species, such as orcas, may be targeting fishing and damaging gear from the outside but are still not actually observed interacting with the gear or becoming entrapped. The other case also suggest that gear may sustain damage that the fishers attribute to whales even though they did not observe the interaction and therefore the species and other details of the interaction are simply not known.

Of the 40 companies that were contacted, 37.5% provided at least one completed questionnaire; however, the actual total number of questionnaires collected was low. The majority of fishing companies were contacted through more than one method (email, post, phone) and never provided any response. This may be reflecting an unwillingness to provide details about a negative consequence of fishing, potentially due to concerns over the possibility of this leading to fishing restrictions, a view that the issue of whale entanglement is not of high importance or interest, or simply that the companies or fishers could not spare the time to participate. Given that 35% of respondents did not answer the question about what their reason would be to not report whale entanglement and 11% answered that they were concerned about negative consequences to the fishing industry, this further suggests that this is an issue that some fishers are not willing to talk about openly, despite their answers being anonymous. It is also possible that the total number of questionnaire replies was low because each company or each ship that received the questionnaire only filled one out on behalf of all the fishers working there, opposed to having more than one crew member complete a questionnaire individually. The benefit to this is that it is unlikely that the same whale-gear interaction incident was reported more than once in this study. Contacting more fishers directly, opposed to going through the company managers or captains, could result in a higher number of completed questionnaires, though this may result in repeated information. Furthermore, there is the possibility that fishers who had observed whales interacting with their gear or had their gear damaged were more inclined to complete the questionnaire than those who had not; however, second and third contact with companies who did not initially respond was attempted in order to minimise this bias. Further effort to collect follow-up questionnaires could determine if this bias exists in the results reported in this study. Additionally, humpback whales are considered a highly recognisable species (Clapham, 2018) and this could bias the reporting of sightings and gear-interaction observations. However, a recent survey of Icelandic fishers found humpbacks were frequently misidentified from photographs (Stoller, 2020), suggesting there should be minimal bias towards humpback whale reports from fishers solely because they can identify them.

The results from the questionnaires and interviews reveal that mitigating whale-gear interactions in Iceland would be in the best interest of both fisheries and whale conservationists, particularly for the humpback whale. One possible mitigation method against humpback whale entanglements and gear damage is the use of acoustic alarms or 'pingers'. These devices make a sound which serves to warn the whales of the gear in the water and hopefully prevent them from swimming through it (Erbe and McPherson, 2012). They can be used on set nets, trap lines, and purse seines (Future Oceans, n.d.). Special consideration to whale-gear interaction mitigation should be given to the Icelandic capelin fishery given the high number of incidents they report compared to other fisheries. The five capelin purse seiner captains who were interviewed in this study expressed that they knew about these pingers, and those who are currently working would be willing to try them on their nets to prevent gear damage. Testing of these pingers in the Icelandic capelin purse seine fishery has shown preliminary signs of success in preventing gear damage when whales were incidentally encircled in the seine (Basran *et al*., 2020). Given that the Icelandic capelin fishing season is short and only operating at a specific time of the year, other management strategies such as area or seasonal closures are not a politically viable option for this fishery, apart from the area closures that can be put in place for protection of the juvenile capelin stock (ICES, 2017). Another possible management strategy to minimise whale-gear interactions could be to switch the fishing

method solely to pelagic trawling. Pelagic trawling is a second method of fishing capelin used in Iceland by commercial fisheries, which is currently only permitted in certain areas in the Northeast (ICES, 2017). Trawls are considered one of the gear-types which have the least interactions with large baleen whales, such as the humpback whale (Fertl and Leatherwood, 1997), meaning lower incidents of whales becoming entrapped in the gear and therefore less gear damage. However, it has been hypothesised that there are cons to using the pelagic trawl in terms of there being a higher incidental mortality of juvenile capelin and the possibility of separating or disrupting the migrating capelin schools which could impact the spawning (ICES, 2017). Due to fluctuating capelin stock sizes and low stock estimates in recent years, the Icelandic capelin fishery has received low or no quota to fish capelin (ICES, 2017; Bardarson and Jonsson, 2017, 2018; Bardarson *et al*., 2019). The capelin fishery continues to be a sensitive and debated topic in Iceland, with some fishers blaming the whale population not only for damage to their gear while fishing, but also contributing to the low capelin stocks that have been recorded (pers. obs.). Continued, open discussions of the issues fisheries in Iceland are facing due to interactions with whales, considering pros and cons of management strategies to address this, should be planned for the future in the best interest of sustainable commercial fishing and whale conservation. This is particularly important for the currently unstable Icelandic capelin fishery.

Overall, the questionnaires and interviews conducted for this study provide detailed insight into the issue of whale entanglement in Icelandic fisheries. The data shows that the humpback whale is the most common of the large whale species in interacting with fishing gear and causing damage. Interview responses revealed little-known information that encirclement of humpback whales in purse seines in Iceland can be detrimental to the animal, with two captains reporting having seen them incidentally drown and one captain reporting the whales sometimes incurred injuries. Questionnaire and interview responses also revealed that whale-gear interactions can be highly detrimental to the fishers in terms of financial losses due to gear damage and associated costs. Further effort into collecting expert knowledge from fishers on these issues is required in order to advise better management. Creation of an anonymous whale-gear interaction reporting system in Iceland would aid in being able to more clearly quantify how often these events are observed, the financial losses the fishing industry is incurring due to this issue and the extent at which bycatch of large whales is being under-reported. This could be done through additional reporting in the mandatory fishing logbook system, or through an email or messaging group network or smartphone application where reports could be sent to researcher(s) maintaining a database.

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REFERENCES

Adams, W. 2015. Conducting semi-structured interviews. pp.492–505. *In*: K.E. Newcomer, H.P. Hatry and J.S. Wholey (ed.) *Handbook of Practical Program Evaluation.* Jossey-Bass Publishers. iiii+912pp.

Alava, J.J., Barragán M.J. and Denkinger J. 2012. Assesing the impact of bycatch on Ecuadorian humpback whale breeding stock: A review with management recommendations. *Ocean Coast. Manage*. 57:34–43. [Available at: *https://doi.org/ 10.1016/J.OCECOAMAN. 2011.11.003*].

Anonymous. 1956. War against killer whales near Iceland. *Norsk Hvalfangsgt-Tidende/The Norwegian Whaling Gazette* 10:570–73.

Archer, F., Gerrodette, T., Chivers, S. and Jackson, A. 2004. Annual estimates of the unobserved incidental kill of pantropical spotted dolphin (*Stenella attenuata attenuata*) calves in the tuna purse-seine fishery of the eastern tropical Pacific. *Fish. Bull.* 102(2):233–44.

Atvinnuvega- og nýsköpunarráðuneyti. 2020. Reglugerð um skráningu og rafræn skil aflaupplýsinga. Available from: *https://www.reglugerd.is/reglugerdir/eftirraduneytum/atvinnuveganyskopunarraduneyti/nr/21887?fbclid=IwAR22yQZymRXDeS0EpXUh6z-VlFWMMh1GGEc5BvKlSqnhLO8apKmIuR0l0eo*].

Baird, R.W., Stacey, P.J., Duffus, D.A. and Langelier, K.M. 2002. An evaluation of gray whale (*Eschrichtius robustus*) mortality incidental to fishing operations in British Columbia, Canada. *J. Cetacean Res. Manage.* 4(3):289–96.

Baker, C.S., Lukoschek, V., Lavery, S., Dalebout, M.L., Youg-un, M., Endo, T. and Funahashi, N. 2006. Incomplete reporting of whale, dolphin and porpoise 'bycatch' revealed by molecular monitoring of Korean markets. *Anim. Conserv.* 9:474–82. [Available at: *https://doi.org/10.1111/j.1469-1795.2006.00062.x*].

Basran, C.J., Bertulli, C.G., Cecchetti, A., Rasmussen, M.H., Whittaker, M. and Robbins, J. 2019. First estimates of entanglement rate of humpback whales *Megaptera novaeangliae* observed in coastal Icelandic waters. *Endanger. Species Res.* 38:67–77. [Available at: *https://doi.org/10.3354/ESR00936*].

Basran, C.J. and Rasmussen, M.H. 2020. Conflicts Between Arctic Industries and Cetaceans. *In:* E. Pongrácz, V. Pavlov and N. Hänninen (eds.) *Arctic Marine Sustainability: Arctic Maritime Businesses and the Resilience of the Marine Environment.* Springer Nature, Cham, Switzerland. i+485pp.

Basran, C.J., Woelfing, B., Neumann, C. and Rasmussen, M.H. Behavioural responses of humpback whales (*Megaptera novaeangliae*) to two acoustic deterrent devices in a northern feeding ground off Iceland. *Aquat. Mamm.* 46(6):584–602. [Available at: *https://doi.org/10.1578/AM.46.6.2020.584*].

Bardarson, B. and Jonsson, S.Th. 2017. Preliminary cruise report: Acoustic assessment of the Iceland-Greenland-Jan Mayen capelin stock in autumn 2017. Marine Research Institute, Iceland. [Available at: *https://www.hafogvatn.is/static/extras/images/technical_annex_autumn2017292.pdf*].

Bardarson, B. and Jonsson, S.Th. 2018. Preliminary cruise report: Acoustic assessment of the Iceland-Greenland-Jan Mayen capelin stock in autumn 2018. Marine Research Institute, Iceland. [Available from: *https://www.hafogvatn.is/static/extras/images/technical1100275.pdf*].

Bardarson, B., Jonsson, S.Th., Heilmann, L. and Jansen, T. 2019. Preliminary cruise report: Acoustic assessment of the Iceland-East Greenland-Jan Mayen capelin stock in autumn 2019. Marine Research Institute, Iceland. [Available from: *https://www.hafogvatn.is/static/extras/images/Technical_report1167296.pdf*].

Benjamins, S., Ledwell, W. and Davidson, A.R. 2012. Assessing changes in numbers and distribution of large whale entanglements in Newfoundland and Labrador, Canada. *Mar Mamm Sci*. 28(3):579–601. [Available at: *https://doi.org/10.1111/j.1748-7692.2011.00511.x*].

Bertulli, C.G., Cecchetti, A., Van Bressem, M-F. and Waerebeen. 2012. Skin disorders in common minke whales and white-beaked dolphins off Iceland, a photographic assessment. *J. Mar. Anim. Ecol.* 5(2):29–40.

Capella, A.J., Flórez-González, L. and Falk, F.P. 2001. Mortality and anthropogenic harassment of humpback whales along the Pacific coast of Colombia. *Memoirs of the Queensland Museum* 47(2):547–53.

Cassoff, R.M., Moore, K.M., McLellan, W.A., Barco, S.G., Rotstein, D.S. and Moore, M.J. 2011. Lethal entanglement in baleen whales. *Dis Aquat Organ*. 96:175–85.

Clapham, P.J. 2018. Humpback Whale *Megaptera novaeangliae*. pp. 489–492. *In:* B. Wursig, J.G.M. Thewissen and K.T. Kovacs (eds.) *Encyclopedia of Marine Mammals.* Elsevier Academic Press, London, UK. iii+1190pp.

Erbe, C. and McPherson, C. 2012. Acoustic characterisation of bycatch mitigation pingers on shark control nets in Queensland, Australia. *Endanger. Species Res*. 19(2):109–21. [Available at: *https://doi.org/10.3354/esr00467*].

FAO. 2018. The State of World Fisheries and Aquaculture – Meeting the sustainable development goals. Licence CC BY-NC-SA 3.0 IGO. 210pp. [Available at: *http://www.fao.org/3/i9540en/i9540en.pdf*].

Fertl, D. and Leatherwood, S. 1997. Cetacean interactions with trawls: A preliminary review. *J. Northw. Atl. Fish. Sci.* 22:219–48. [Available at: *https://doi.org/ 10.2960/J.V22.A17*].

Future Oceans. n.d. *Pinger Technical Specifications and Attachment Instructions.* 2pp. [Available at: www.futureoceans.com/faq].

Glain, D., Kotomatas, S. and Adamantopoulou, S. 1999. Fishermen and seal conservation: surey of attitudes towards monk seals in Greece and grey seals in Cornwall. *Mammalia* 65(3):309–17.

Goetz, S., Read, F.L., Santos, M.B., Pita, C. and Pierce, G.J. 2014. Cetacean-fishery interactions in Galicia (NW Spain): results and management implications of a face-to-face interview survey of local fishers. *ICES J. Mar. Sci.* 71(3):604–17. [Available at: *https://doi.org/10.1093/icesjms/fst149*].

Government of Iceland. 2018. *Fisheries Management*. [cited 8 Nov 2019] [Available from: *https://www.government.is/topics/business-and-industry/fisheries-in-iceland/fisheries-management/?fbclid=IwAR1vCaclCzSVm6OCY7OAprtA5Qe_rtEmm2573HLVwQbPG9LXiaDARIkuqVY*].

Hafrannsóknastofnun. 2017. Fisheries overview: State of marine stocks and advice 2017. Hafrannsóknastofun, June 2017 (unpublished). 5pp.

How, J., Coughran, D.K., Smith, J.N., Harrison, J., Mc Math, J., Hebiton, B. and Denham, A. 2015. Effectiveness of mitigation measures to reduce interactions between commercial fishing gear and whales. FRDC Project No 2013/03. *Fish. Res. Rep.* 267:635–45.

ICES. 2019. ICES Fisheries Overview – Icelandic Waters Ecoregion. 29 November 2019. ICES Advice 2019. 25pp. [Available from: *https://doi.org/10.17895/ices.advice.5706*].

ICES. 2017. Report of the North Western Working Group (NWWG): Capelin in the Iceland-East Greenland-Jan Mayen area. 27 April–4 May 2017. ICES CM 2017/ACOM:08. 300. 21pp. [Available from: *https://www.hafogvatn.is/static/extras/images/lodna_taekni225.pdf*].

ICES. 2018. Report from the Working Group on Bycatch of Protected Species (WGBYC). 1–4 May 2018. ICES CM2018/ACOM:25. 128pp. [Available from: *http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2018/WGBYC/wgbyc_2018.pdf*].

Johnson, T.R. and Densen, L.T. 2007. Benefits and organization of cooperative research for fisheries management. *ICES J. Mar. Sci.* 64:834–40. [Available at: *https://doi.org/10.1093/icesjms/fsm014*].

Karpouzli, E. and Leaper, R. 2004. Opportunistic observations of interactions between sperm whales and deep-water trawlers based on sightings from fisheries observers in the northwest Atlantic. *Aquatic Conserv. Mar. Freshw. Ecosyst*. 14:95–103. [Available at: *https://doi.org/10.1002/aqc.595*].

Knowlton, A.R., Marx, M.K., Pettis, H.M., Hamilton, P.K. and Krause, S.D. 2005. Analysis of scarring on North Atlantic right whales (*Eubalaena glacialis*): Monitoring rates of entanglement interaction: 1980–2002. Final Report to: National Marine Fisheries Service, February 2005. 20pp. [Available at: *ftp://ftp.library.noaa.gov/noaa_documents.lib/NOAA_related_docs/Analysis_Scarring_North_Atlantic_Right_Whales.pdf*].

Lien, J. 1979. A study of entrapment in fishing gear: causes and prevention. Progress Report, 1 March 1979.

Lien, J. and Aldrich, D. 1982. Damage to the inshore fishing gear in Newfoundland and Labrador by whales and sharks during 1981. CAFSAC Marine Mammal Committee Meetings, St. John's NFL, May 18–19, 1982. 37pp.

Liu, M., Lin, M., Turvey, S.T. and Li, S. 2017. Fishers' knowledge as an information source to investigate bycatch of marine mammals in the South China Sea. *Anim. Conserv*. 20:182–92. [Available at: *https://doi.org/10.1111/acv.12304*].

López, A., Pierce, G.J., Santos, M.B., Gracia, J. and Guerra, A. 2003. Fishery by-catches of marine mammals in Galician waters: results from on-board observations and an interview survey of fishermen. *Biol. Conserv.* 111:25–40. [Available at: *https://doi.org/10.1016/S0006-3207(02)00244-6*].

Marine and Freshwater Research Institute. 2018. Bycatch of seabirds and marine mammals in lumpsucker gillnets 2014–2017. Marine and Freshwater Research Institute, Reykjavik, Iceland, March 2018. 16pp. [Available from: *https://www.hafogvatn.is/static/files/skjol/techreport-bycatch-of-birds-and-marine-mammals-lumpsucker-en-final-draft.pdf*].

Mazzuca, L., Atkinson, S. and Nitta, E. 1998. Deaths and entanglements of humpback whales, *Megaptera novaeangliae*, in the main Hawaiian Islands, 1972–1996. *Pac. Sci.* 52(1):1–13.

Moore, J.E., Cox, T.M., Lewison, R.L., Read, A.J., Bjorkland, R., McDonald, S.L., Crowder, L.B., Aruna, E., Ayissi, I., Espeut, P., Joynson-Hicks, C., Pilcher, N., Poonian, C.N.S., Solarin, B. and Kiszka, J. 2010. An interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries. *Biol. Conserv.* 143:795–805. [Available at: *https://doi.org/ 10.1016/j.biocon.2009.12.023*].

Mul, E., Blanchet, M-A., McClintock, B.T., Grecian, W.J., Biuw, M. and Rikardsen A. 2020. Killer whales are attracted to herring fishing vessels *Mar. Ecol. Prog. Ser.* 652:1–13. [Available at: *https://doi.org/10.3354/meps13481*].

Neilson, J.L., Straley, J.M., Gabriele, C.M. and Hills, S. 2009. Non-lethal entanglement of humpback whales (*Megaptera novaeangliae*) in fishing gear in northern Southeast Alaska. *J. Biogeogr*. 36:452−64. Available at: *https://doi.org/10.1111/j.1365-2699.2007.01820.x*]

Norman, F.I. 2000. Preliminary investigation of the bycatch of marine birds and mammals in inshore commercial fisheries, Victoria, Australia. *Biol. Conserv.* 92:217–26. [Available at: *https://doi.org/10.1016/S0006-3207(99)00055-5*].

Ólafsdóttir, D. 2010. Report on monitoring of marine mammal bycatch in Icelandic fisheries, Statistics for 2009 and review of previous information. North Atlantic Marine Mammal Commission. NAMMCO SC/17/16. 15pp.

Pálsson, O.K., Gunnlaigsson, Th. and Ólafsdóttir, D. 2015. Meðafli sjófugla og sjávarspendýra í fiskveiðum á Íslandsmiðum/By-catch of sea birds and marine mammals in Icelandic fisheries. Hafrannsóknastofnun, Reykjavik, Iceland, Hafrannsóknir nr. 178. 2pp. [Available from: *https://www.hafogvatn.is/static/research/files/fjolrit-178.pdf*].

Peterson, M.J. and Carothers, C. 2013. Whale interactions with Alaskan sablefish and Pacific halibut fisheries: Surveying fishermen perception, changing fishing practices and mitigation. *Mar. Policy* 42:315–24. [Available at: *https://doi.org/10.1016/J.MARPOL.2013.04.001*].

Pike, D.G., Gunnlaugsson, T., Mikkelsen, B., Halldórsson, S.D. and Víkingsson, G.A. 2019. Estimates of the abundance of cetaceans in the central North Atlantic based on the NASS Icelandic and Faroese shipboard surveys conducted in 2015. *NAMMCO Sci. Publ.* 11. [Available at: *https://doi.org/10.7557/3.4941*].

Pike, D.G., Paxton, C.G.M., Gunnlaugsson, Th. and Víkingsson, G.A. 2009. Trends in the distribution and abundance of cetaceans in Icelandic coastal waters from aerial surveys, 1986–2001. *NAMMCO Sci. Publ.* 7:117–42. [Available at: *https://doi.org/10.7557/3.2710*].

Pusineri, C. and Quillard, M. 2008. Bycatch of protected megafauna in the artisanal coastal fishery of Mayotte Island, Mozambique Channel. *West. Indian Ocean J. Mar. Sci.* 7(2):195–206. [Available at: *https://doi.org/ 10.4314/wiojms.v7i2.48277*].

Reeves, R.R., McClellan, K. and Werner, T.B. 2013. Marine mammal bycatch in gillnet and other entangling net fisheries, 1990 to 2011. *Endanger. Species Res*. 20:71–97. [Available at: *https://doi.org/10.3354/esr00481*].

Robbins, J. 2012. Scar-based inference into Gulf of Maine humpback whale entanglement: 2010. Report EA133F09CN0253 to the Northeast Fisheries Science Center, National Marine Fisheries Service. Center for Coastal Studies, Provincetown, MA. 17pp. [Available at: *https://www.nefsc.noaa.gov/psb/docs/HUWHScarring(Robbins2012).pdf*].

Robbins, J. 2011. Scar-based inference into Gulf of Maine humpback whale entanglement: 2009. Report EA133F09CN0253 to the Northeast Fisheries Science Center National Marine Fisheries Service. Center for Coastal Studies, Provincetown, MA. 17pp. Available at: *https://www.nefsc.noaa.gov/psb/docs/HUWHScarring(Robbins2009).pdf*].

Robbins, J., Knowlton, A.R. and Landry, S. 2015. Apparent survival of North Atlantic right whales after entanglement in fishing gear. *Biol. Conserv.* 191:421–7. [Available at: *https://doi.org/10.1016/j.biocon.2015.07.023*].

Rossman, M.C. 2007. *Allocating Observer Sea Days to Bottom Trawl and Gillnet Fisheries in the Northeast and Mid-Atlantic Regions to Monitor and Estimate Incidental Bycatch of Marine Mammals*. NOAA Northeast Fisheries Science Center Reference Document 07-19. 17pp. Available at: *https://www.nefsc.noaa.gov/nefsc/publications/crd/crd0719/crd0719.pdf*].

Samarra, F.I.P., Bassoi, M., Béesau J., Elíasdóttir, M.Ó., Gunnarsson, K., Mrusczok M-T., Rasmussen, M., Rempel, J.N., Thorvaldsson, B. And Víkingsson, G.A. 2018. Prey of killer whales (*Orcinus orca*) in Iceland. PLoS ONE. 13(12): e0207287. [Available at: *https://doi.org/10.1371/journal.pone.0207287*].

Seminara, C.I., Barbosa-Filho, M.L.V. and Le Pendu, Y. 2019. Interactions between cetaceans and artisanal fishermen from Ilhéus, Bahia–Brazil. *Biota Neotrop.* 19(4):e20190742. [Available at: *http://dx.doi.org/10.1590/1676-0611-BN-2019-0742*].

Sigler, M.F., Lunsford, C.R., Straley, J.M. and Liddle, J.B. 2008. Sperm whale depredation of sablefish longline gear in the northeast Pacific Ocean. *Mar. Mamm. Sci*. 24(1):16–27. [Available at: *https://doi.org/10.1111/j.1748-7692.2007.00149.x*].

Sigurjónsson, J. and Víkingsson, G. A. 1997. Seasonal abundance of the estimated food consumption by cetaceans in Icelandic and adjacent waters. *J. Northwest Atl. Fish. Sci.* 22:271–87. [Available at: *https://doi.org/10.2960/J.v22.a20*].

Statistics Iceland (n.d.a) Vöru- og þjónustuviðskipti [cited 15 Nov 2019]. [Available at: *https://hagstofa.is/talnaefni/efnahagur/utanrikisverslun/voru-og-thjonustuvidskipti/*].

Statistics Iceland (n.d.b) The fishing fleet by region and type of vessels 2003–2019 [cited 10 Dec 2020]. [Available at: *https://px.hagstofa.is/pxen/pxweb/en/Atvinnuvegir/Atvinnuvegir_sjavarutvegur_skip/SJA05001.px/table/tableViewLayout1/?rxid=7aa007ee-29af-43bb-8e09-91d8a3192ddf*].

Stoller, A. 2020. Assessing the feasibility of citizen science to monitor change and cetacean distribution in Iceland. Unpublished master's thesis. The University of Edinburgh, Scotland.

Víkingsson, G.A. and Ólafsdóttir, D. 2003. Iceland. Progress Report on cetacean research, April 2002 to March 2003 with statistical data for the calendar year 2002. Paper SC/55/ProgRepIceland presented to the IWC Scientific Committee, May 2003, Berlin (unpublished). 8pp. [Paper available from the Office of this Journal].

Víkingsson, G.A., Ólafsdóttir, D. and Gunnlaugsson, H. 2004. Iceland. Progress report on cetacean research, April 2003 to April 2004 with statistical data for the calendar year 2003. Paper SC/56/ProgRep Iceland presented to the IWC Scientific Committee, July 2004, Sorrento, Italy (unpublished). 6pp. [Paper available from the Office of this Journal].

Víkingsson, G.A., Ólafsdóttir, D. and Gunnlaugsson, T. 2005. Iceland. Progress Report on cetacean research, April 2004 to May 2005 with statistical data for the calendar year 2004. Paper SC/57/ProgRep Iceland presented to the IWC Scientific Committee, June 2005, Ulsan, Korea (unpublished). 8pp. [Paper available from the Office of this Journal].

Víkingsson, G.A. 2011. Iceland. Progress report on cetacean research, May 2010 to April 2011, with statistical data for the calendar year 2010. Paper SC/63/ProgRep Iceland presented to the IWC Scientific Committee, June 2011, Tromsø, Norway (unpublished). 6pp. [Paper available from the Office of this Journal].

Víkingsson, G.A., Pike, D.G., Valdimarsson, H., Schleimer, A., Gunnlaugsson, Th., Silva, T., Elvarsson, B., Mikkelsen, B., Øien,N., Desportes, G., Bogason, V. and Hammond, P.S. 2015. Distribution, abundance, and feeding ecology of baleen whales in Icelandic waters: have recent environmental changes had an effect? *Front. Ecol. Evol*. 3(6):1–18. [Available at: *https://doi.org/10.3389/fevo.2015.00006*].

Volgenau, L., Kraus, S.D. and Lien, J. 1995. The impact of entanglements on two substocks of the western North Atlantic humpback whale, *Megaptera novaeangliae*. *Can. J. Zool.* 73:1,689–98.

Wedekin, L.L., Engel, M.H., Andriolo, A., Prado, P.I., Zerbini, A.N., Marcondes, M.M.C., Kinas, P.G. and Simões-Lopes, P.C. 2017. Running fast in the slow lane: rapid population growth of humpback whales after exploitation. *Mar. Ecol. Prog. Ser.* 575:195–206. [Available at: *https://doi.org/10.3354/meps12211*].

Whitty, T.S. 2014. Conservation-scapes: An interdisciplinary approach to assessing cetacean bycatch in small-scale fisheries. Doctor of Philosophy in Oceanography dissertation, University of California, San Diego, USA. 242pp. [Available at: *https://escholarship.org/uc/item/2619j4z8*].

Zappes, C.A., Simões-Lopes, P.C., Andriolo, A. and Di Beneditto, A.P.M. 2016. Traditional knowledge identifies causes of bycatch on bottlenose dolphins (*Tursiops truncatus* Montagu 1821): An ethnobiological approach. *Ocean Coast. Manage.* 120:160–9. [Available at: *https://doi.org/10.1016/j.ocecoaman.2015.12.006*].

Zerbini, A.N., Adams, G., Best, J., Clapham, P.J., Jackson, J.A. and Punt, A.E. 2019. Assessing the recovery of an Antarctic predator from historical exploitation. *R. Soc. Open Sci*. 6:190368 [Available at: *http://dx.doi.org/10.1098/rsos.190368*].

APPENDIX 1

This short survey is being conducted for a biology doctorate thesis at the University of Iceland focusing on whale entanglement/bycatch in fishing gear and fishing gear damage. **This survey will be treated anonymously, therefore no names of individuals or companies will be used in conjunction with the answers.** Thank you for your participation!

1. How often do you see marine mammals when you are fishing?

   - Whales Never Occasionally Often Frequently
   - Dolphins or Porpoises Never Occasionally Often Frequently
   - Seals Never Occasionally Often Frequently
   - Other _____ Never Occasionally Often Frequently

2. How often have you seen **humpback whales** in the area where you were fishing?

   Never Occasionally Often Frequently

3. Have you ever witnessed whales, dolphins, or porpoises entangled in the fishing gear deployed by your vessel (*Identify species if possible*)?

   - Whales (Species_____) Never Once More than once
   - Dolphins (Species_____) Never Once More than once
   - Porpoises (Species_____) Never Once More than once

4. Have you witnessed a **humpback whale** entangled in or interacting with your fishing gear **in the past 5 years**? YES NO (*If YES, please answer the following questions*)

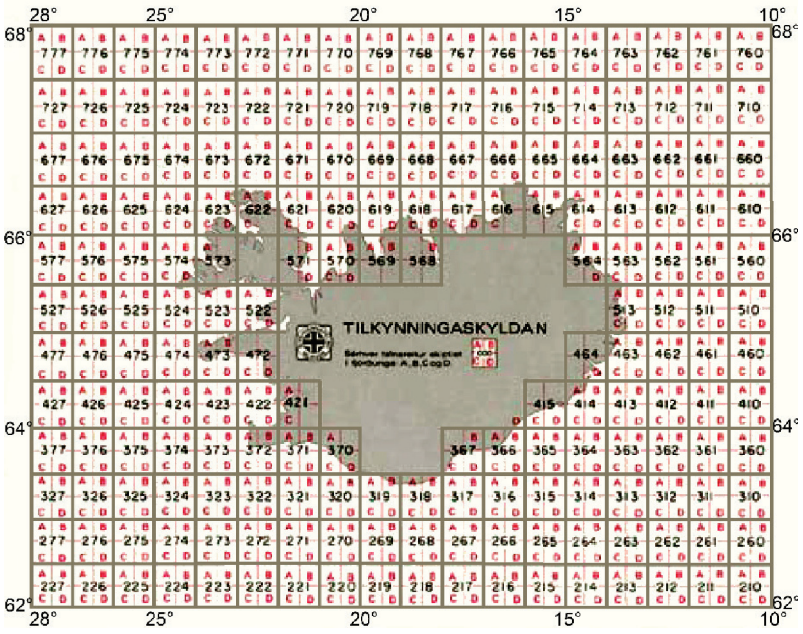
   When did this occur? Month_____ Year_____

   What type of fishing gear were you using? _____

   What type of fish were you fishing for? _____

   What area were you fishing in (*Please use the reference chart below)?* _____

   Did you take action to free the whale? How? _____



5. Has your fishing gear been damaged or lost due to what you believe was a whale swimming through it **in the past 5 years**? YES NO (*If YES, please answer the following)*

   Do you know what species of whale? YES (species_____) NO

   What type of gear was damaged/lost? _____

   How was the gear damaged/lost (broken lines, torn nets etc.)?
   _____
   _____

   Did this result in loss of catch or downtime? YES NO Please explain:
   _____
   _____

   Approximately how much money did this damage/loss cost?

   Are you willing to be contacted for interview about the whale entanglement issues you have witnessed/experienced? YES NO
   Contact information:_____

6. For what reasons would you **not** report bycatch of a whale, porpoise, or dolphin? (*Please circle all that apply*)

   DO NOT UNDERSTAND/WANT TO USE THE ELECTRONIC REPORTING SYSTEM

   THE ANIMAL WAS STILL ALIVE

   THE ANIMAL WAS USED (AS BAIT ETC.)

   CONCERNED ABOUT NEGATIVE CONSEQUENCES TO THE FISHING INDUSTRY

   OTHER _____