PROTECTED SPECIES & LONGLINE MUSSEL AQUACULTURE INTERACTIONS

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NOS-NCCOS-211
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Cover photo: Spring Bay Seafoods
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SPRING BAY SEAFOODS

INTRODUCTION AND BACKGROUND

Purpose

This report summarizes the current state of knowledge regarding documented and potential interactions of species listed under the Endangered Species Act as amended (ESA; 16 U. S. C. § 1531–1543), such as sea turtles and marine mammals, with off - shore longline mussel culture gear. Its primary purpose is to strengthen the ability of the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Greater Atlantic Regional Fisheries Office (GARFO) to make science-based decisions and recommendations as part of the review and consultation process required to permit aquaculture operations in federal waters.

The information in this report is useful for guiding the regulatory process of Protected Resources Division (PRD) consultations to meet the agency goals of advancing aquaculture in the open ocean while still meeting its mandates under the ESA. In addition to summarizing what is known and providing a state of science analysis, the report includes a preliminary risk analysis and needs assessment to highlight the greatest potentials for harmful interactions between aquaculture and marine mammals and sea turtles, identify critical areas of research, and inform decisions about collaborative projects to further knowledge and protect imperiled species. We gathered relevant publications and data on marine mammal and sea turtle interactions with specific gear types used in commercial marine aquaculture and explored protected species interactions with potentially correlated fishing gear. We used this information to provide management options to help coastal managers to make informed science-based recommendations about permitting, siting and managing aquaculture in a manner consistent with federal mandates to protect imperiled species, while also supporting the production of sustainably grown seafood.

Table 7 Overview of potential marine mammal interactions with shellfish farming (adapted from Clement 2013)

Effects	*Management Options*
Habitat exclusion or modification leading to less use or less productive use	Careful site selection and consideration of area covered.
Potential for entanglement	Regular maintenance of farm structures, including keeping lines secured and anchor warps under tension
Underwater noise disturbance	
	Ensure waste material and debris is collected and disposed of correctly
	Monitoring of presence of marine mammal species in vicinity of farm

farm structures as well as species that do. In general larger, less agile species with flippers and fins that extend relatively far from the body (Keeley et al. 2009) and gaping mouths (see Cassoff et al. 2011 for a description of how gaping mouths may make some whales more prone to oral entanglement) may be more likely to have negative physical interactions. It is largely unknown how marine animals perceive man-made structures in the ocean, and therefore using visual, auditory, or other sensory cues to elicit an aversion behavior often involves tentative investigation (Tim Werner, New England Aquarium, pers. comm.). Because pinnipeds do not commonly feed on shellfish, they may be less likely to visit farms (Nash et al. 2000, Würsig & Gailey 2002). Though there is concern about potential indirect ecosystem effects that may affect marine mammals, there is currently little or no research in that area. Table 7 summarizes the findings and recommended management options from New Zealand.

Other Countries

In addition to the interactions listed above, there are a few reports from other countries regarding entangled protected species (Table 8). In a report on right whale entanglements in Argentina from 2001–2011 there is a report of a single right whale entanglement in 2011 which may have involved mussel spat collection lines, but this was not confirmed (Bellazzi et al. 2012). There are reports of two fatal marine mammal entanglements in mussel farms in Iceland (Young 2015). In 1998 a harbor porpoise *Phocoena phocoena* and in 2010 a juvenile humpback whale were reported entangled. Single dropper spat collection lines were involved in both incidents.

Research has been conducted in other countries to evaluate how marine mammals may be affected by nearshore mussel farms. In Yaldad Bay in southern Chile, Heinrich

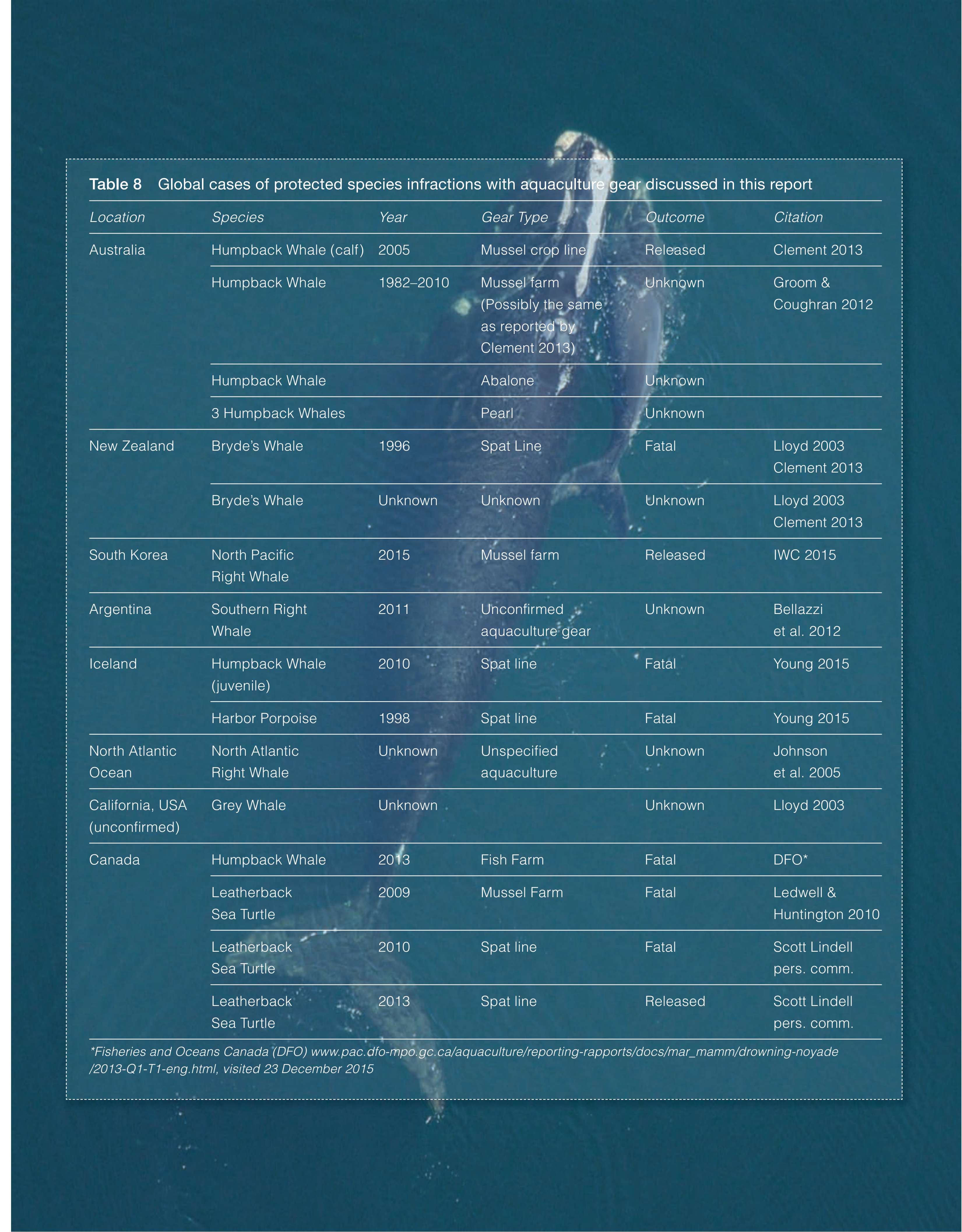

Table 8 Global cases of protected species infractions with aquaculture gear discussed in this report

Location	*Species*	*Year*	*Gear Type*	*Outcome*	*Citation*
Australia	Humpback Whale (calf)	2005	Mussel crop line	Released	Clement 2013
	Humpback Whale	1982–2010	Mussel farm (Possibly the same as reported by Clement 2013)	Unknown	Groom & Coughran 2012
	Humpback Whale		Abalone	Unknown	
	3 Humpback Whales		Pearl	Unknown	
New Zealand	Bryde's Whale	1996	Spat Line	Fatal	Lloyd 2003 Clement 2013
	Bryde's Whale	Unknown	Unknown	Unknown	Lloyd 2003 Clement 2013
South Korea	North Pacific Right Whale	2015	Mussel farm	Released	IWC 2015
Argentina	Southern Right Whale	2011	Unconfirmed aquaculture gear	Unknown	Bellazzi et al. 2012
Iceland	Humpback Whale (juvenile)	2010	Spat line	Fatal	Young 2015
	Harbor Porpoise	1998	Spat line	Fatal	Young 2015
North Atlantic Ocean	North Atlantic Right Whale	Unknown	Unspecified aquaculture	Unknown	Johnson et al. 2005
California, USA (unconfirmed)	Grey Whale	Unknown		Unknown	Lloyd 2003
Canada	Humpback Whale	2013	Fish Farm	Fatal	DFO*
	Leatherback Sea Turtle	2009	Mussel Farm	Fatal	Ledwell & Huntington 2010
	Leatherback Sea Turtle	2010	Spat line	Fatal	Scott Lindell pers. comm.
	Leatherback Sea Turtle	2013	Spat line	Released	Scott Lindell pers. comm.

**Fisheries and Oceans Canada (DFO) www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/docs/mar_mamm/drowning-noyade/2013-Q1-T1-eng.html, visited 23 December 2015*

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Table 9 Nuisance pinnipeds killed under license in British Columbia from 1990–2010 (Fisheries and Oceans Canada visited 01 June 2015)

Year	*Harbor Seal*	*California Sea Lion*	*Steller Sea Lion*
1990	211	0	0
1991	391	3	11
1992	423	3	5
1993	483	14	9
1994	414	3	3
1995	577	24	6
1996	512	57	27
1997	542	59	37
1998	391	92	63
1999	499	147	103
2000	426	243	49
2001	298	92	30
2002	123	20	17
2003	48	14	3
2004	120	6	0
2005	69	9	0
2006	121	3	0
2007	93	7	0
2008	32	5	0
2009	50	22	0
2010	56	170	0

dollars for an individual farm, but can total millions of dollars for a single country in a year. The growth of the fish farming industry and concomitant expansion of pinniped populations has tended to increase the number of interactions, but previously used lethal control methods are less viable due to conservation objectives and regulatory protection. Typically, only single individuals may be killed and only after multiple forays into the farm with repeated attempts to deter the animal. They note that the United States has even stricter regulations with respect to lethal removal, and it is not expected that lethal control will be readily allowed in the United States.

Other countries with large marine fish aquaculture sectors allow farms to undertake lethal methods of predator control, and illegal culling is also occurring (Northridge et al. 2013). In Canada, public reports on authorized marine mammal control activities at salmon farms are available on the government's Fisheries and Oceans Canada website (DFO 2011, 2013, 2015). Table 9 shows a decreasing trend in the number of marine mammals killed in British Columbia salmon farms, despite concurrent increases in both the number of fish farms and seal and sea lion populations.

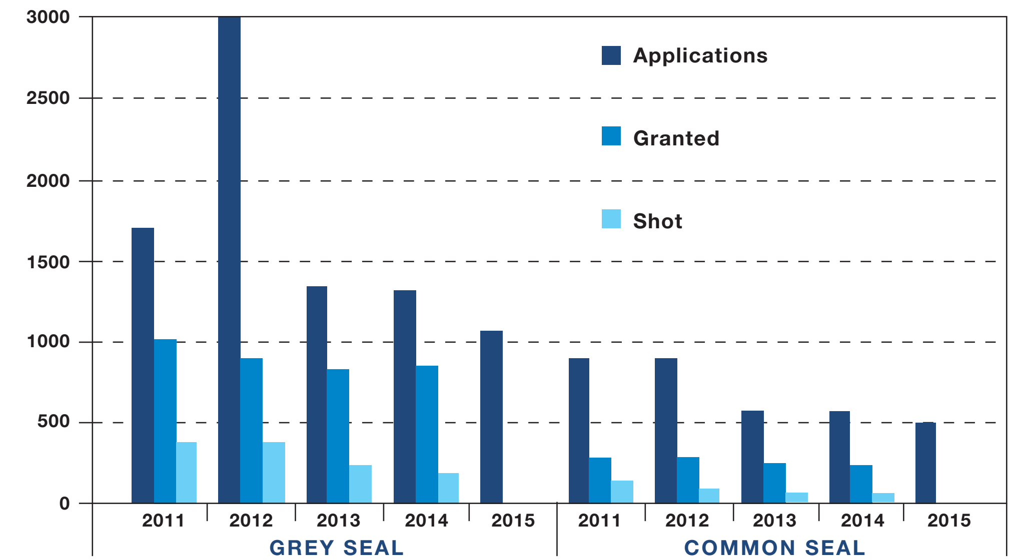


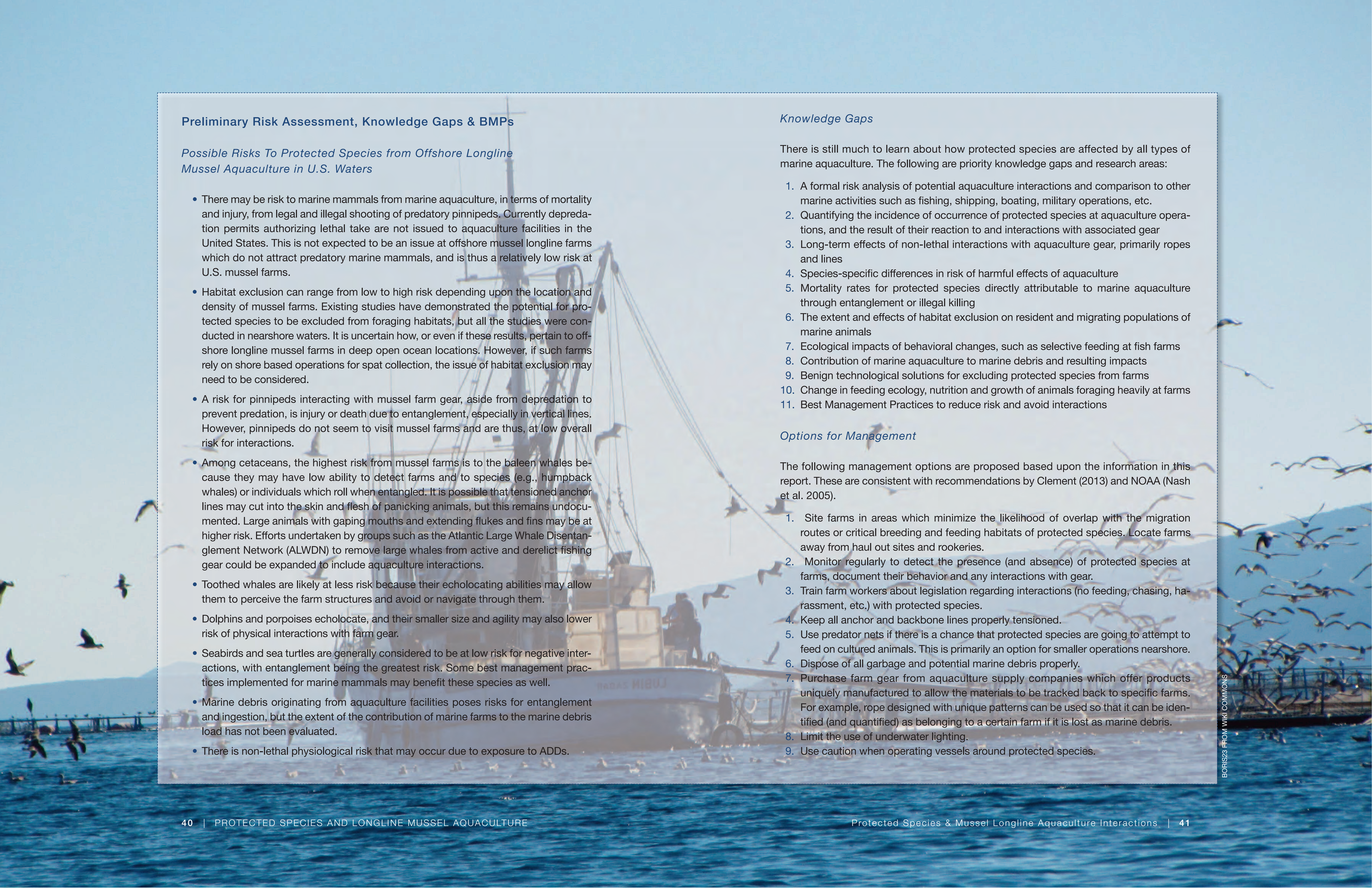
Figure 3. Comparisons of grey and common seal depredation permit applications submitted, applications granted, and numbers of actually shot in Scotland from 2011–2015. Adapted from government data (Scottish Government 09 December 2015).

The website also provides information about the numbers of accidental marine mammal drownings at fish farms from 2011–2014. These are often animals which become tangled underwater in the cage netting or other farm gear. Between 2 and 20 animals—mostly seals and sea lions, but including one humpback whale in 2013—drowned annually.

In Scotland, shooting of seals is also licensed for aquaculture operations and the government posts information about seal depredation licensing on its website (Scottish Government 2015). Figure 3 depicts data from the website reflecting the number of licenses requested and issued, and the resulting number of animals killed from 2011 to 2015. In 2010, new marine mammal conservation legislation was enacted which reduced the shooting of seals. Prior to 2002, on average 312 seals were shot per year (Department of Energy and Climate Change (UK) 2009). There is a decreasing trend in the numbers shot since 2011.

Würsig and Gailey (2002) reviewed the conflicts between aquaculture and marine mammals and potential resolutions. They report on the damage and financial loss that marine mammals, especially pinnipeds, may inflict on commercial fish farms. The need for nonlethal management options to reduce conflicts was recognized, with the goal of decreasing impacts to non-target animals and preventing the killing, both licensed and illegal, of pinnipeds. Six options for reducing marine mammal impacts are discussed: harassment, aversive condition, exclusion, nonlethal removal, lethal removal and population control. Harassment by chasing, explosives, and ADDs have been found to be only somewhat effective and generally only in the short term until animals become habituated. In fact, it is possible that over time noise harassment devices may actually become attractants to habituated individuals who come to recognize the sound as an unpleasant dinner bell. Predator models and sound devices (imitating killer whales for example) are also not very effective.

HARASSMENT BY CHASING, EXPLOSIVES, AND ADDS HAVE BEEN FOUND TO BE ONLY SOMEWHAT EFFECTIVE AND GENERALLY ONLY IN THE SHORT TERM UNTIL ANIMALS BECOME HABITUATED.



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Preliminary Risk Assessment, Knowledge Gaps & BMPs

Possible Risks To Protected Species from Offshore Longline Mussel Aquaculture in U.S. Waters

- There may be risk to marine mammals from marine aquaculture, in terms of mortality and injury, from legal and illegal shooting of predatory pinnipeds. Currently depredation permits authorizing lethal take are not issued to aquaculture facilities in the United States. This is not expected to be an issue at offshore mussel longline farms which do not attract predatory marine mammals, and is thus a relatively low risk at U.S. mussel farms.
- Habitat exclusion can range from low to high risk depending upon the location and density of mussel farms. Existing studies have demonstrated the potential for protected species to be excluded from foraging habitats, but all the studies were conducted in nearshore waters. It is uncertain how, or even if these results, pertain to offshore longline mussel farms in deep open ocean locations. However, if such farms rely on shore based operations for spat collection, the issue of habitat exclusion may need to be considered.
- A risk for pinnipeds interacting with mussel farm gear, aside from depredation to prevent predation, is injury or death due to entanglement, especially in vertical lines. However, pinnipeds do not seem to visit mussel farms and are thus, at low overall risk for interactions.
- Among cetaceans, the highest risk from mussel farms is to the baleen whales because they may have low ability to detect farms and to species (e.g., humpback whales) or individuals which roll when entangled. It is possible that tensioned anchor lines may cut into the skin and flesh of panicking animals, but this remains undocumented. Large animals with gaping mouths and extending flukes and fins may be at higher risk. Efforts undertaken by groups such as the Atlantic Large Whale Disentanglement Network (ALWDN) to remove large whales from active and derelict fishing gear could be expanded to include aquaculture interactions.
- Toothed whales are likely at less risk because their echolocating abilities may allow them to perceive the farm structures and avoid or navigate through them.
- Dolphins and porpoises echolocate, and their smaller size and agility may also lower risk of physical interactions with farm gear.
- Seabirds and sea turtles are generally considered to be at low risk for negative interactions, with entanglement being the greatest risk. Some best management practices implemented for marine mammals may benefit these species as well.
- Marine debris originating from aquaculture facilities poses risks for entanglement and ingestion, but the extent of the contribution of marine farms to the marine debris load has not been evaluated.
- There is non-lethal physiological risk that may occur due to exposure to ADDs.

Knowledge Gaps

There is still much to learn about how protected species are affected by all types of marine aquaculture. The following are priority knowledge gaps and research areas:

1. A formal risk analysis of potential aquaculture interactions and comparison to other marine activities such as fishing, shipping, boating, military operations, etc.
2. Quantifying the incidence of occurrence of protected species at aquaculture operations, and the result of their reaction to and interactions with associated gear
3. Long-term effects of non-lethal interactions with aquaculture gear, primarily ropes and lines
4. Species-specific differences in risk of harmful effects of aquaculture
5. Mortality rates for protected species directly attributable to marine aquaculture through entanglement or illegal killing
6. The extent and effects of habitat exclusion on resident and migrating populations of marine animals
7. Ecological impacts of behavioral changes, such as selective feeding at fish farms
8. Contribution of marine aquaculture to marine debris and resulting impacts
9. Benign technological solutions for excluding protected species from farms
10. Change in feeding ecology, nutrition and growth of animals foraging heavily at farms
11. Best Management Practices to reduce risk and avoid interactions

Options for Management

The following management options are proposed based upon the information in this report. These are consistent with recommendations by Clement (2013) and NOAA (Nash et al. 2005).

1. Site farms in areas which minimize the likelihood of overlap with the migration routes or critical breeding and feeding habitats of protected species. Locate farms away from haul out sites and rookeries.
2. Monitor regularly to detect the presence (and absence) of protected species at farms, document their behavior and any interactions with gear.
3. Train farm workers about legislation regarding interactions (no feeding, chasing, harassment, etc.) with protected species.
4. Keep all anchor and backbone lines properly tensioned.
5. Use predator nets if there is a chance that protected species are going to attempt to feed on cultured animals. This is primarily an option for smaller operations nearshore.
6. Dispose of all garbage and potential marine debris properly.
7. Purchase farm gear from aquaculture supply companies which offer products uniquely manufactured to allow the materials to be tracked back to specific farms. For example, rope designed with unique patterns can be used so that it can be identified (and quantified) as belonging to a certain farm if it is lost as marine debris.
8. Limit the use of underwater lighting.
9. Use caution when operating vessels around protected species.

estimate of loggerheads in all U. S. mid-Atlantic gillnet gear was 350 turtles. Murray and Orphanides (2013) built models using fishery dependent and independent data collected between 1995–2007 to predict that the highest bycatch in commercial gillnet, dredge, and trawl gears, totaling 44 loggerheads per year, occurs in warm waters of the southern mid-Atlantic. Murray (2013) estimated interactions between loggerhead and other hard-shelled turtles and commercial gillnet gear in the mid-Atlantic from 2007–2011 using data collected by NEFOP observers and at sea monitors. Turtles observed were alive with or without injury, dead, or of unknown condition, and were mainly entangled by their head or flippers in the net mesh, free of the floatlines or lead lines. The field data was used in a general additive model to estimate that an annual average of 95 hard-shelled sea turtles, 89 of which were loggerheads, interacted with gillnet gear, resulting in an estimated 52 loggerhead mortalities. Highest interaction rates were estimated in the southern mid-Atlantic, in warm surface waters, and in large mesh gillnets consistent with the earlier Murray (2009) findings.

Sea turtles may also become entangled in vertical lines in the water column (NMFS & GARFO 2015). In response to high numbers of leatherback sea turtles found entangled in the vertical lines of fixed gear in the NE Region, NMFS established the Greater Atlantic Region Sea Turtle Disentanglement Network (STDN). Formally established in 2002, the STDN works to reduce serious injuries and mortalities caused by entanglements. From 2002 through 2014, the STDN documented 275 entanglements in vertical lines (Kate Sampson, NOAA, GARFO, unpublished data). Most of these lines are from pot fisheries (143) or are of unknown origin (131). One documented interaction was in aquaculture gear. Other lines in the water have also been documented interacting with sea turtles. These include modified pound net leaders, dive line, mooring line, and mooring surface systems. The majority of interactions are with leatherback sea turtles with green and loggerhead turtles being documented to a lesser extent. In general, hard-shell sea turtle entanglements are seen more commonly in the southern part of the NE region.

Many different kinds of line, including polypropylene, polyblend, polydacron, and nylon, have been documented to be involved in sea turtle entanglements in the Northeast. These line types represent both sinking and floating lines. The majority of the line is light colored. However, it is unknown if this is simply reflective of the line most commonly used in the fisheries. Entangling line typically does not have a lot of biofouling, so it is likely not derelict gear. There are also a variety of buoy shapes, including bullet, acorn, and round, involved in entanglements. The majority of sea turtle entanglements involve the front flippers and/or the head/neck (Kate Sampson, NOAA, GARFO, unpublished data).

The NEFOP monitored and/or characterized the Virginia pound net fishery while it was active in from 2002–2005 and 2009–2010. In 2004 and 2005, research was also conducted on modified pound net leaders. Forty-nine sea turtles (31 entanglements and 18 impingements) were recorded in leaders by NEFOP or during the experiments. Loggerhead, Kemp's ridley, and leatherback sea turtles were reported interacting with the leaders. These numbers represent minimum counts of sea turtles interacting with the gear. Some of these interactions resulted in mortality (NMFS 2014). The interactions during experiments to test a modified pound net leader were primarily with the traditional leader. However, one leatherback sea turtle was documented in 2004 in the modified leader. In 2005, the experimental design was changed to use hard lay line for the stiff vertical lines in the modified leader (Silva et al. 2011). Sea turtles may also be captured in the pound of the pound net. Sea turtles captured in the pound are generally alive and apparently uninjured as they are usually able to reach the surface to breathe.

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On June 23, 2006, NMFS implemented a final rule to require the use of a modified pound net leader in certain areas of the Virginia Chesapeake Bay at certain times to reduce sea turtle interactions (NOAA 71 FR 36024, June 23, 2006). The modified leader design consists of a combination of mesh and stiff vertical lines. The mesh (≤ 8 inches) is positioned at a depth no more than   the depth of the water. The vertical lines rise from the top of the mesh up to a top line to which they are attached and are hard lay lines spaced a minimum of 2ft apart. This gear is designed to reduce entanglement in or impingement on the leader.

Seabirds

Bycatch of seabirds in gillnets is known to occur. For example, Warden (2010), reports that from 1996–2007, the average annual gillnet bycatch in the Northeast was 74 common loons *Gavia immer*, and in the Mid-Atlantic annual estimates are 477 common and 897 red-throated loons *G. stellate.* The red-throated loon is a species of conservation concern, and these mortality estimates reflect about 60% of the Potential Biological Removal (PBR) levels. At a recent workshop to address bycatch reduction of marine life, proposed methods to decrease seabird bycatch in gillnets included net striping, pingers, high-visibility net sections, lighting and dropped headlines (Wiedenfeld et al. 2015). Very little specific information was found about sea bird entanglements that could directly inform aquaculture permitting.

Vessel Strikes

Another large source of injury and mortality to marine species is vessel strikes (Waring et al. 2012, 2015). Marine aquaculture facilities inherently require the use of small and large vessels to transport materials, fish, feed, harvesting equipment and maintenance crews between farm sites and shore. This vessel traffic could also potentially impact protected species and is considered in permit review and consultations. Ensuring that no feed, live fish or carcasses are released from farm vessels during stocking, transport or harvest should decrease attraction of farm vessels to marine animals opportunistically seeking food sources.

ENSURING THAT NO FEED, LIVE FISH OR CARCASSES ARE RELEASED FROM FARM VESSELS DURING STOCKING, TRANSPORT OR HARVEST SHOULD DECREASE ATTRACTION OF FARM VESSELS TO MARINE ANIMALS OPPORTUNISTICALLY SEEKING FOOD SOURCES.

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farms. Breakaway lines have been included in proposals for offshore mussel farm gear configuration, but it is unknown how often it is actually installed. Modifications may be advantageous for farms as well as the animals as it may decrease damage to expensive farm gear. Some of the techniques such as acoustic deterrents are already being used—albeit with varying levels of success—at fish farms. The paper provides details of several dozen validation studies that may be useful for informing research and testing gear modifications to reduce negative interactions at farms.

The NOAA/NMFS Protected Resources Division Gear Research Team conducts and coordinates research and field trials on gear modifications that decrease harm to protected species (Salvador et al. 2002, 2003a, 2003b, 2006, 2008). Their work is done in collaboration with researchers from other agencies and institutes, and commercial fishers. Gear research projects have included testing different line materials, gear deployment strategies, netting materials, break away link designs, and time-release buoy systems. Gear types are tested on land and in water under varying loads to simulate the load forces of protected marine species. Alternative netting and line materials are deployed to evaluate their visibility and durability underwater. The mechanical, acoustic, time-release and galvanic weak link designs evaluated for use in fishery gear may also be useful for application at fish farms. Research has been done to better understand how certain species (especially species at high risk like humpback and right whales) interact with and are affected by specific gear. For example, data from studies looking at how different line materials affected baleen and skin tissues may be applied to aquaculture gear.

MODIFICATIONS MAY BE ADVANTAGEOUS FOR FARMS AS WELL AS THE ANIMALS AS IT MAY DECREASE DAMAGE TO EXPENSIVE FARM GEAR.

Recent research on the relative strength of ropes used in fishing gear and involved in entanglement of right and humpback whales found that injuries are more severe since the 1990s as material technology advanced to produce stronger ropes (Knowlton et al. 2015). The authors recommend using ropes with breaking strengths of less than 1700lbs to reduce the lethal entanglements risk to large whales by up to 72%. This modification could reduce whale mortality resulting from entanglement to below the PBR levels defined by NMFS, though no consideration was used for the real world feasibility of this reduced breaking strength line for fishing. Also, benefits to smaller whales (including juveniles), smaller marine mammals and sea turtles (Karp et al. 2011) may not be realized due to smaller body size. Any modifications to gear type may also need to take into account if and how the safety of commercial fishers may be affected. Such considerations for gear modification may also be applicable to marine aquaculture where similar types of lines may be used for marker buoys, farm maintenance and vessel operation.

Winn et al. (2008) used flippers and fluke tissues from adult and juvenile right whales, and a humpback whale collected during necropsy to assess relative impacts to the tissue under varying types of laboratory simulations of synthetic lines like those used in fisheries for float and ground lines. The calf tissue was most vulnerable, the adult right whale was most resilient, and the humpback tissue was intermediate. Baldwin et al. (2012) conducted lab and field experiments with life-sized models of right whale flippers to test how taut versus slack vertical 5/8 lines, such as those used

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