Identifying Effective Sperm Whale (*Physeter macrocephalus*) Depredation Deterrent Strategies for Washington Coast Commercial Longline Fishermen

by

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ABSTRACT

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Depredation is defined as marine mammals interacting with fishing gear for the purpose of obtaining caught fish. This problem is found in oceans worldwide (Symposium 2006, McPherson et. al. 2010**)**. Sperm whales (*Physeter macrocephalus*) have been documented depredating the Alaskan longline fishery starting in the late 1970s and continuing into the present day with no sign of stopping (Hill et. al. 1999). As recently as 2008, fishing vessels off of the Washington coast have reported sperm whale interactions. This thesis will examine sperm whales in general, the effects of depredation on both the whales and fishermen, important scientific findings, avoidance strategies, and the search for effective deterrents. Numerous deterrent strategies have been employed over the years with mixed results. By examining what works, what doesn't work, and what is currently being tested, the author will provide Washington coast fishermen and fisheries managers with a list of available options for economically and effectively dealing with sperm whale depredation.

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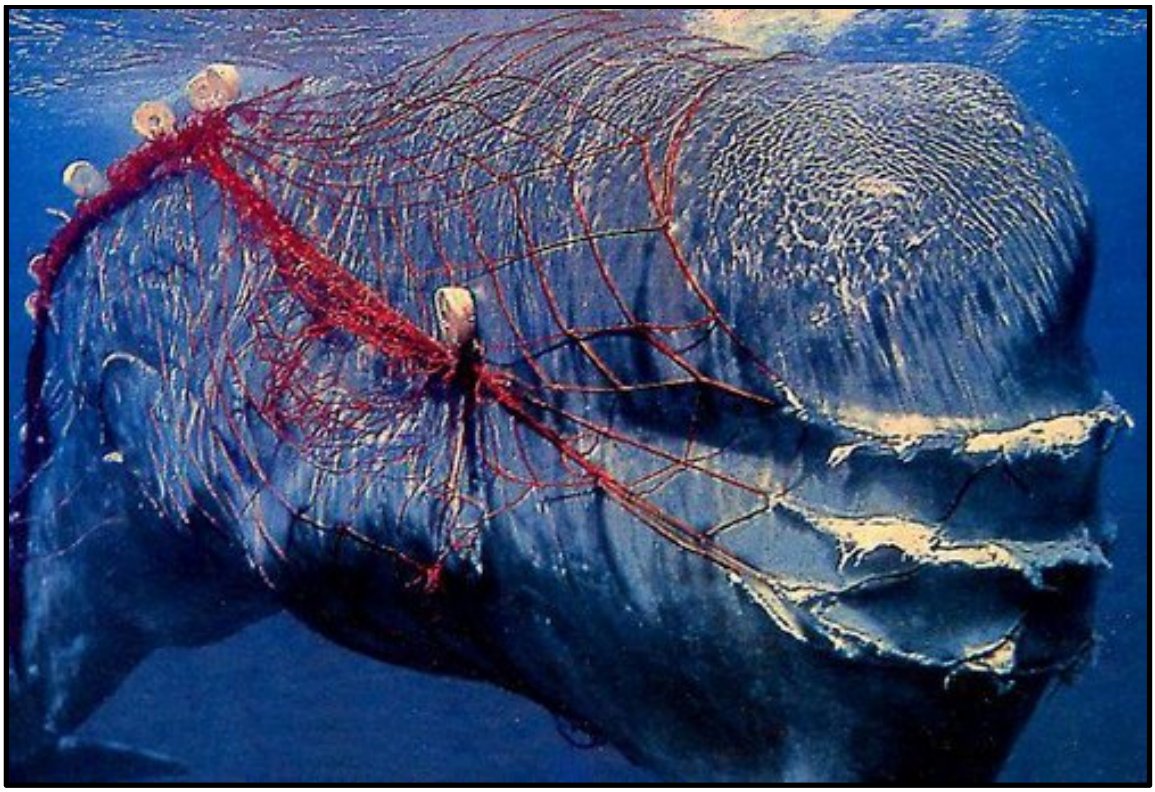
Depredation

Depredation is defined as the interaction of marine mammals with fishing gear to obtain caught fish (Gilman et. al. 2006). This problem has been documented worldwide in a variety of different fisheries (Donoghue et. al. 2003, Hamer et. al. 2010, McPherson Per. Com 2012, O'Connell Per. Com 2012). Longline fisheries and driftnet fisheries are most susceptible to this phenomenon because marine mammals are attracted to the fishing gear by the lure of easily obtained food (Donoghue et. al. 2003). As a result, marine mammals risk the danger of becoming entangled in the fishing gear, causing their injury or death (Hamer et. al. 2010).

Picture 1 – Entangled sperm whale



A sperm whale entangled in a driftnet. Courtesy of Tumblr.com http://species-endangered.tumblr.com/

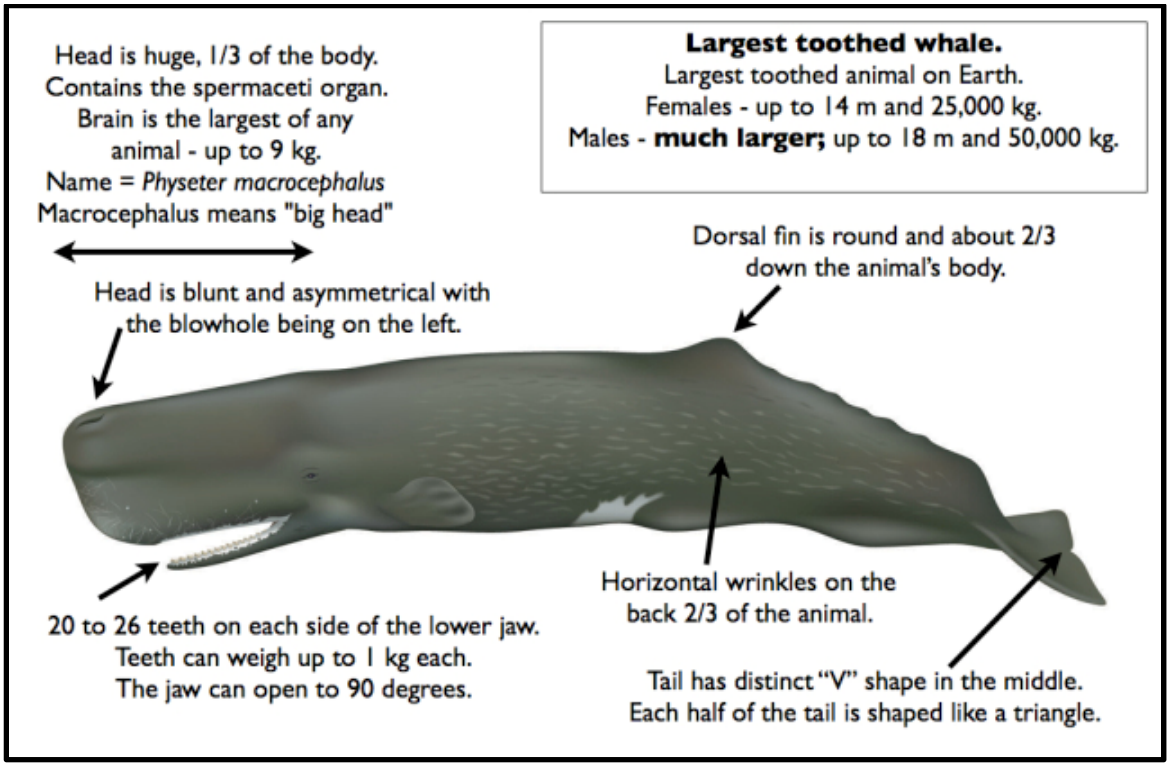
Depredation also causes marine mammals to deviate from their natural feeding behavior and potentially consume an otherwise unobtainable food source. Fish that under normal conditions could avoid marine mammals are easy prey when hooked or entangled in fishing gear. This added food source could lead to an abnormal increase in marine mammal populations, which normally would not be sustainable under normal foraging behavior (Straley Per. Com 2012). In addition, fishermen may also harass marine mammals in an effort to protect their catch, also potentially causing injury or death to the marine mammals (Hamer et. al. 2010).

Sperm Whales

This thesis addresses sperm whale depredation in the Northeastern Pacific Ocean, specifically in waters off of the Washington outer coast. By the time the International Whaling Commission (IWC) banned commercial whaling in 1986, sperm whales had been hunted almost to the point of extinction (Calambokidis Per. Com 2012). Even today, they are listed as an endangered species. Their exact population size is unknown but is estimated to be in the low hundred thousands, well below their pre-whaling numbers, which were estimated at over one million worldwide (Calambokidis Per. Com 2012). Females and calves in the eastern Pacific Ocean typically forage off the southern California/Mexican coast, utilizing the warm water conditions (Christal et. al. 2001). By contrast, adult males in the eastern Pacific Ocean migrate up the U.S. Pacific coast into Alaskan waters to highly productive feeding grounds. There, the males remain for years living mostly a solitary life, although they have been known to form loose groups (Calambokidis Per. Com 2012, Christal et. al. 2001). These males are the cause of sperm

whale depredation occurring to the longline fleets from Washington State up into Alaska waters.

Figure 1 – The sperm whale



The sperm whale (*Physeter macrocephalus*). Image by Uko Gorter Natural History Illustrations. Courtesy of The Marine Detective. http://themarinedetective.com/tag/whale/

To date, the vast majority of sperm whale depredation is occurring in Alaskan waters with only intermittent reports of fishermen/whale interactions off the Washington coast. This has the potential to change in the coming years as the sperm whale populations continue to grow and to learn depredation behavior from older whales (Straley Per. Com 2012). Sperm whales are the largest of the toothed whales, with adult males reaching around sixty feet in length and weighing in excess of fifty tons (Calambokidis Per. Com 2012, Christal et. al. 2001). They typically feed along the

continental shelf and forage dive to average depths of 400 to 500 meters, preying on squid and fish (Mathias et. al. 2009). Normal sperm whale foraging dives last an average of 30 to 35 minutes (Thode et. al. 2006). Sometime in the late 1970s, sperm whales slowly lost their fear of ships, which stemmed from earlier whaling days, and began, to associate boats with food. Vessels no longer meant death to the whales but instead became a source of easily obtained food (Straley Per. Com 2012).

In 1985, because of an increasing trend of whale interactions and lost catch, some Alaskan longline fishermen began documenting sperm whale interactions and have observed that the problem has gotten progressively worse over time (Straley Per. Com 2012, O'Connell Per. Com 2012). This can be attributed to the increase in sperm whale populations (Calambokidis Per. Com 2012) and to the lack of commercial whaling. In addition, in 1995 Alaska implemented Individual Fishing Quotas (IFQ) into their longline fisheries (Straley et. al. 2011). Instead of a derby style fishery only lasting a couple of weeks each year, fishermen now have an individual quota, which means they can fish at any time they choose. This has led to a season lasting up to eight months each year and has provided a much greater opportunity for sperm whales to prey on caught fish (Straley et. al. 2011). Based on these trends and changes to the fisheries, the cases of sperm whale depredation are expected to increase and the problem area to expand.

Picture 2 – Sperm whale fishing vessel interaction

A photograph of a sperm whale following a longline fishing vessel. Courtesy Southeast Alaska Sperm Whale Avoidance Project (SEASWAP). Photo by Heather Vukelic. http://www.seaswap.info/background/index.html

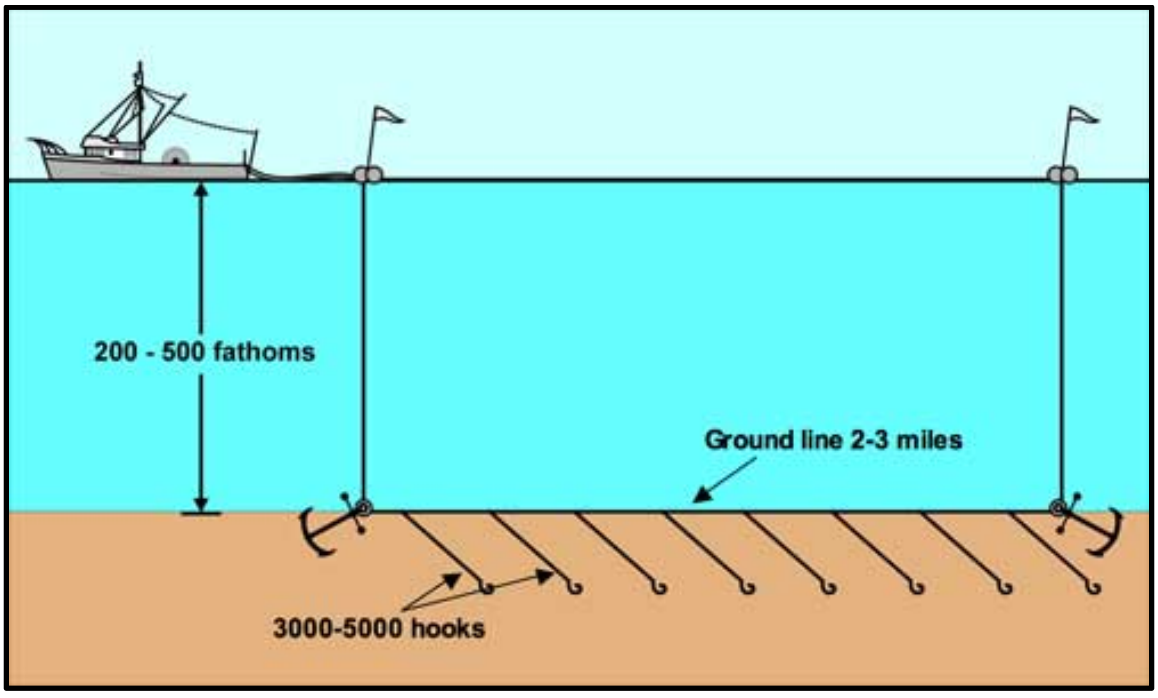
Perhaps more importantly, this problem is spreading. As this is a learned behavior, the adult males teach the younger males how to depredate (Straley Per. Com 2012). Beginning in 2008-2009 and continuing each year to the present day, Quinault tribal longline fishermen off the outer coast of Washington have also begun reporting incidents of sperm whale depredation in their blackcod (*Anoplopoma fimbria*) and halibut (*Hippoglossus stenolepis*) longline fisheries (Charley Per. Com 2008, Frank Per. Com 2013, Rhoads Per. Com 2013). These initial reports from the fishermen themselves have led to the investigation of this phenomenon in Washington waters and the conception of

this thesis. Without the direct interaction between fishermen and fisheries managers, this emerging problem could have gone unnoticed for years. As depredation is a learned behavior (Straley Per. Com 2012), it is vital for fishermen and researchers to work together to find a solution along the Washington coast before it becomes as big an issue as it is in Alaska.

Longline Fishing Operation

A typical longline operation consists of a fishing vessel steaming out to the fishing grounds and dropping an anchor with a buoy line attached (the buoy marks one end of the fishing gear at the surface).

Figure 2 – Longline Operation



A diagram of a typical longline operation. Courtesy of Southeast Alaska Sperm Whale Avoidance Project (SEASWAP). http://www.seaswap.info/background/longlining.html

A separate line is also attached to the anchor. This “longline” is then laid out on the sea floor. “Gangions” or small lengths of line attached to the longline at intervals of three to six feet have hooks and bait attached at the opposite end. Longlines can sometimes stretch for miles, but off the Washington coast, they are typically an average of 1,800 feet in length (Charley Per. Com 2008, Frank Per. Com 2013, Rhoads Per. Com 2013). At the opposite end of the longline, another attached anchor secures the gear to the bottom, and another line and buoy mark the location on the surface. This entire setup is called a “skate” or “set” and a Washington coast fisherman will typically fish with an average of four to six sets at a time but this can vary from vessel to vessel (Charley Per. Com 2008, Frank Per. Com 2013, Rhoads Per. Com 2013).

The skates are left on the ocean floor between one and four hours to “fish” (soak time). Then the fisherman retrieves the longline, hauling it back on board by winding it around a steel drum, which uses the ship hydraulics to rotate. Fish are removed from the hooks as they come aboard, and the gear is readied for the next set. Depending on which species of fish the fishermen are targeting, they will adjust their set locations to habitat types and known “hot spots” frequented by their target species (Charley Per. Com 2008, Frank Per. Com 2013, Rhoads Per. Com 2013).

The greatest density of fish populations lie in Alaskan waters, therefore, the majority of longline fishing takes place in Alaskan waters. To illustrate this point the International Pacific Halibut Commission (IPHC) scientists estimate 94% of the Pacific Halibut reside in Alaskan waters, 5% of the Pacific Halibut live in Canadian waters, and the remaining 1% of the Pacific Halibut live in Washington/Oregon/California waters (Webster et. al. 2013). Compared to the Alaskan fisheries, Washington has far fewer

boats fishing on a much smaller fish population and therefore, any loss to sperm whales is noticeable. This distribution also demonstrates why sperm whale depredation is a greater issue in Alaska; that is where the majority of fish are concentrated (Straley Per. Com 2012, Dykstra Per. Com 2012, Peterson Per. Com 2012, O'Connell Per. Com 2012).

Table 1 – Alaskan/Washington Longline Fleet Comparison

Alaksan/Washington Fleet Comparison					
Year		**WA Tribal Registered Longline Fishing Vessels**	**WA State Registered Longline Fishing Vessels**	**Total WA Registered Longline Fishing Vessels**	**AK LongLine Registered Fishing Vessels**
2010		158	59	217	2872
2011		168	67	235	2826
2012		209	58	267	2767
2013		208	N/A	N/A	1645

Table 1 compares the sizes of Alaskan and Washington tribal and non-tribal fleets from 2010 through 2013. It should be noted that the majority of the tribal fleet fish inside the Strait of Juan de Fuca and North Puget Sound. Only about 40 tribal boats fish the outer coast where sperm whale depredation has been reported. It should also be noted that registered fishing vessels does not necessarily mean they are actively fishing. The above data was obtained from Alaska Department of Fish and Game (ADFG), Washington Department of Fish and Wildlife (WDFW), and the Northwest Indian Fisheries Commission (NWIFC)

Economic Loss

The fishermen suffer the effects of depredation from loss of catch (income) and a potential loss of or damaged gear (investment) (Straley Per. Com 2012). Depending on the percent of lost catch, the economic impact can be staggering. During the 2013

Washington coast longline season, fishermen made an average of $5.40 a pound for halibut (*Hippoglossus stenolepis*) and an average of $3.50 a pound for blackcod (*Anoplopoma fimbria*) (prices obtained from Quinault Tribal Enterprises (QTE)) (Heathers Per. Com 2013); a 5% to 10% loss from depredation can equate to substantial loss of revenue (see tables 2 and 3 on the following pages).

At present, there are only intermittent reports of sperm whale depredation off the Washington outer coast and no reports of depredation occurring in the Strait of Juan de Fuca or North Puget Sound according to Tribal and state managers. If the problem is simply tolerated or ignored, there is real potential for depredation to occur more frequently and over a larger area. The fishermen are the ones that brought attention to the problem and they also must be a part of the solution. This lesson can be learned from looking at Alaska. The Alaskan Longline Fishermen's Association (ALFA) has partnered with scientists from the Southeast Alaska Sperm Whale Avoidance Project (SEASWAP) in an effort to work together to find an effective deterrent (Straley et. al. 2011). The fishermen report whale interactions and offer possible solutions based on their knowledge. SEASWAP develops deterrent strategies based on the fishermen's input and known scientific research, and employs the fishermen to test these strategies and report the results (Straley et. al. 2011).

The potential economic loss in the following figures should convince most fishermen of the need for action. A Washington coast fisherman will have to spend more on fuel, more on bait, and stay out longer to bring in the same amount of fish if a sperm whale is depredating his or her lines during each haul.

Table 2 - Potential Economic Loss in the WA Coast Halibut Fishery from Depredation

Washington Coast Halibut Fishery						
	Total Allowable Catch in Pounds	Average Price Paid Per Pound	Total Financial Value	1% Financial loss From Depredation	5% Financial Loss From Depredation	10% Financial Loss From Depredation
2010						
Tribal Commercial	253,072	$4.75	$1,202,092.00	$12,020.92	$60,104.60	$120,209.20
State Commercial	141,865	$4.75	$673,858.75	$6,738.59	$33,692.94	$67,385.88
2011						
Tribal Commercial	293,200	$5.00	$1,466,000.00	$14,660.00	$73,300.00	$146,600.00
State Commercial	159,380	$5.00	$796,900.00	$7,969.00	$39,845.00	$79,690.00
2012						
Tribal Commercial	321,650	$6.25	$2,010,312.50	$20,103.13	$100,515.63	$201,031.25
State Commercial	173,216	$6.25	$1,082,600.00	$10,826.00	$54,130.00	$108,260.00
2013						
Tribal Commercial	314,300	$5.40	$1,697,220.00	$16,972.20	$84,861.00	$169,722.00
State Commercial	173,391	$5.40	$936,311.40	$9,363.11	$46,815.57	$93,631.14

It is speculated that sperm whales in Alaska are depredating up to 10% of the catch. By looking at halibut catch limits for WA from 2010 through 2013, the price paid per pound, the total financial value, 1% loss, 5% loss, and 10% loss, it quickly becomes clear why it is important to deter depredation and prevent the behavior becoming established along the Washington outer coast. The economic loss can be quite large. Note that about half of the tribal total allowable catch (TAC) is caught within the Strait of Juan de Fuca and North Puget Sound where there have been no reports yet of sperm whale depredation, however that could change in the future. The above data was obtained from Washington Department of Fish and Wildlife (WDFW), the Northwest Indian Fisheries Commission (NWIFC), and Quinault Tribal Enterprises (QTE).

Table 3 - Potential Economic Loss in the WA Coast Blackcod Fishery from Depredation

Washington Coast Blackcod Fishery						
	Total Allowable Catch in Pounds	Average Price Paid Per Pound	Total Financial Value	1% Financial loss From Depredation	5% Financial Loss From Depredation	10% Financial Loss From Depredation
2010						
Tribal Commercial	887,706	$5.40	$4,793,612.40	$47,936.12	$239,680.62	$479,361.24
State Commercial	1,441,706	$5.40	$7,785,212.40	$77,852.12	$389,260.62	$778,521.24
2011						
Tribal Commercial	748,186	$6.25	$4,676,162.50	$46,761.63	$233,808.13	$467,616.25
State Commercial	1,429,522	$6.25	$8,934,512.50	$89,345.13	$446,725.63	$893,451.25
2012						
Tribal Commercial	726,140	$3.50	$2,541,490.00	$25,414.90	$127,074.50	$254,149.00
State Commercial	1,006,100	$3.50	$3,521,350.00	$35,213.50	$176,067.50	$352,135.00
2013						
Tribal Commercial	544,261	$3.50	$1,904,913.50	$19,049.14	$95,245.68	$190,491.35
State Commercial	N/A	N/A	N/A	N/A	N/A	N/A

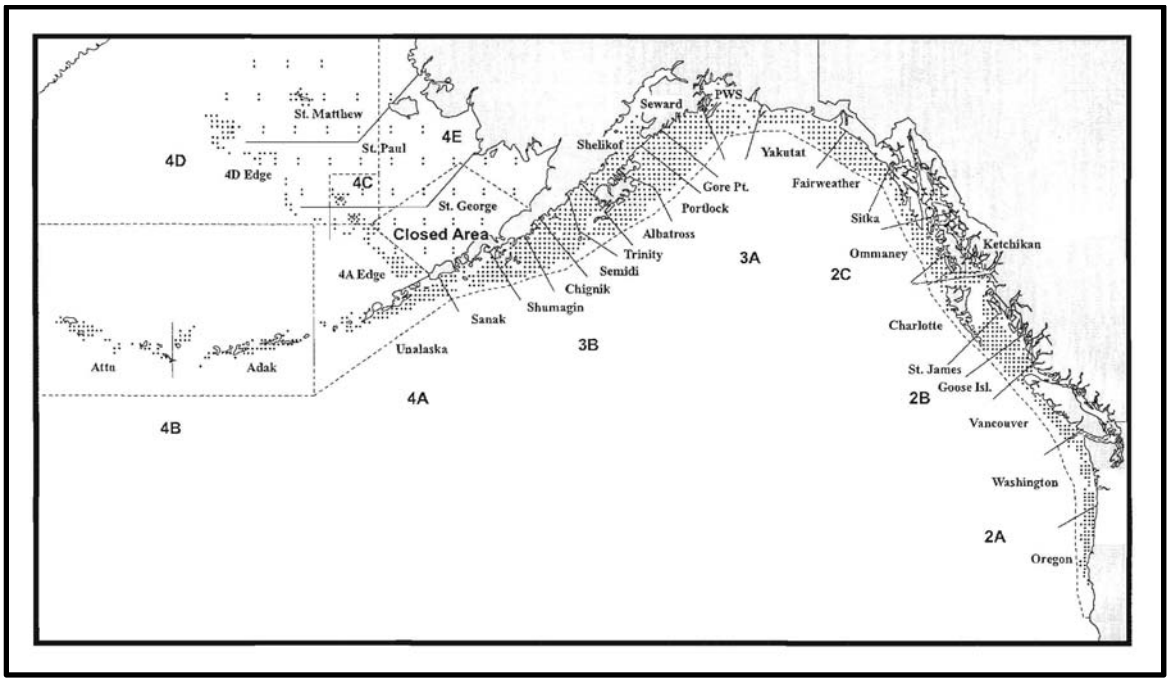
It is speculated that sperm whales in Alaska are depredating up to 10% of the catch. By looking at blackcod catch limits for WA from 2010 through 2013, the price paid per pound, the total financial value, 1% loss, 5% loss, and 10% loss, it quickly becomes clear why it is important to deter depredation and prevent the behavior becoming established along the Washington outer coast. The economic loss can be quite large. The above data was obtained from Washington Department of Fish and Wildlife (WDFW), the Northwest Indian Fisheries Commission (NWIFC), and Quinault Tribal Enterprises (QTE). State commercial data for 2013 was not yet available at the time of publication.

Effects on Stock Assessment

Fisheries managers also potentially suffer from the effects of marine mammal depredation. Fish losses from sperm whale depredation during stock assessment surveys and during the actual fishery are not directly accounted for (Symposium 2006, Dykstra Per. Com 2012). Thus, fisheries managers run the risk of overestimating a stock in which depredation occurs, potentially leading to declining populations and an unsustainable

harvest rate. In other words, each year fisheries stock managers attempt to assess specific species populations through the use of setline surveys and other collected data.

Figure 3 – Halibut Setline Survey Locations



The small dots indicate the locations of the International Pacific Halibut Commission's (IPHC) annual setline surveys used to estimate the annual halibut population size and from that information, set the yearly sustainable harvest limits. Courtesy of the International Pacific Halibut Commission. http://www.iphc.int/home.html

Longline sets are placed in predetermined spots throughout the species range and the obtained catch is recorded (Dykstra Per. Com 2012). Scientists can then estimate the entire population based on number of fish caught in these survey sets and other data collected by extrapolating the numbers. Catch limits are then derived for the upcoming season (Dykstra Per. Com 2012). Fishermen were concerned that fish lost by depredation, either in the set line surveys or during the actual commercial fishery, were not being accounted for and therefore, scientists did not have an accurate understanding of the

stock. The International Pacific Halibut Commission (IPHC) addressed these concerns in their 2010 RARA research publication;

> Commercial fishers often express concern over how the impacts of depredation are interpreted by the IPHC, both from their fishing logs and from the stock assessment survey. Of particular concern to harvesters is the perception that the mortality resulting from depredation in the commercial fishery is not accounted for by assessment scientists. While this perception is widespread, it is incorrect. Any mortality on halibut will be apparent in the stock assessment because the mortality affects numbers of fish at each age, which the assessment is designed to estimate. However, it is certainly true that the assessment will not be able to differentiate depredation mortality from other sources of mortality in the same areas. In this sense, the assessment will accurately account for depredation mortality but will not necessarily assign it to the correct source. The mortality should correctly be assigned as fishing mortality because the fish were already on the hook when depredated.
>
> Managers also struggle to understand when and how to screen survey data that may have suffered depredation interference. Agencies generally have some pre-established screening methods for determining when data are acceptable for inclusion in stock assessment analysis. Currently, the IPHC deems a station to be effective when the data obtained from that set can be used in the stock assessment analysis. If the gear did not fish properly, or the catch is not representative of what might have been caught under normal circumstances, the station is rated ineffective. For a set to be defined as ineffective due to whale depredation, there must be whales present in the area during haul back and the sum of damaged gear and damaged catch must be greater than 10% of the hooks set. This threshold is somewhat arbitrary, and more years of depredation data will help us refine this threshold.
>
> - Dykstra, C. L., and Eric Soderlund. 2010. Categorizing marine mammal depredation on IPHC standardized setline surveys. *IPHC Report of Assessment and Research Activities 2010*. http://www.iphc.int/publications/rara/2010/2010.435.CategorizingmarinemammaldepredationonIPHC.pdf

Important Research Findings

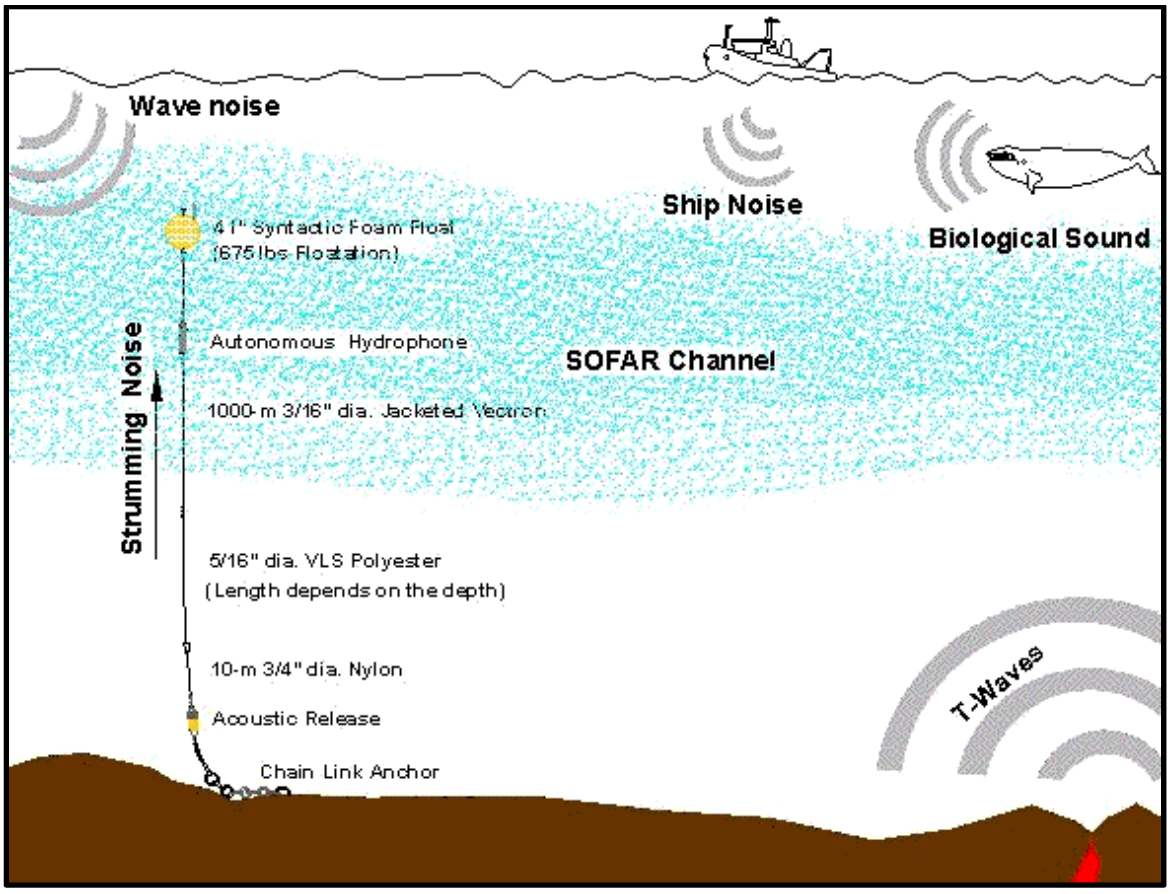
As the problem of sperm whale depredation grew progressively worse in Alaska, the Alaskan Longline Fishermen's Association (ALFA) called for action from the

scientific community to investigate solutions, as they were no longer willing to accept the rate of lost catch without attempting to identify solutions. At the rate of their lost income, a major concern was that it would no longer be economically profitable to continue fishing.

The Southeast Alaskan Sperm Whale Avoidance Project (SEASWAP) was formed in 2003 to research sperm whale depredation behavior and to identify mitigation strategies fishermen could employ to limit or eliminate whale interactions (Thode et. al. 2008, Straley et. al. 2011, Straley Per. Com 2012). One of the first items SEASWAP wanted to quantify was how whales were able to identify fishing vessels that were engaged in longline retrieval (hauling their catch aboard), as opposed to normal vessel activity. If this "Pavlov's bell" could be identified, stopping depredation might be as simple as removing the signal the whales were homing in on (Thode et. al. 2008, Straley et. al. 2011, Straley Per. Com 2012).

It had been observed by fishermen that sperm whales tended to keep their distance from ships until the vessel began retrieving their longline and catch (Dykstra Per. Com 2012). It was speculated that the whales heard the hydraulics being engaged (used to recover the longline) through the water and zeroed in on the ship (Thode et. al. 2007, McPherson 2011, Dykstra Per. Com 2012). Utilizing the help of Alaskan longline fishermen, SEASWAP set up an experiment. By lowering hydrophones (underwater microphones) into the water and then listening as another ship in close proximity engaged and disengaged their hydraulics, researchers learned that the sound was barely audible and was therefore, not the clue the whales were responding to (Thode et. al. 2007, McPherson 2011, Dykstra Per. Com 2012).

Figure 4 – Acoustic Hydrophone Deployment



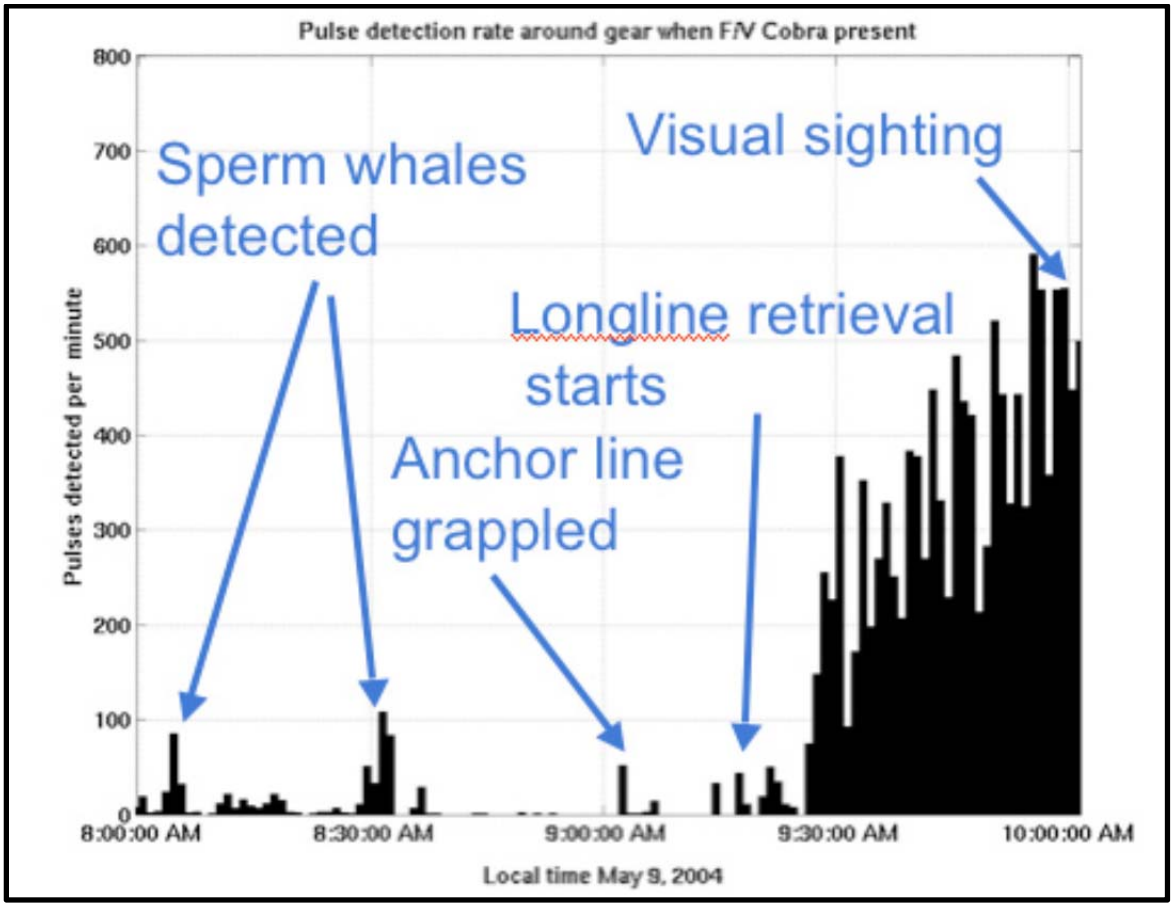
A diagram illustrating the deployment of an acoustic hydrophone for the purpose of recording sperm whales and ship noise. Courtesy of NOAA Ocean Explorer Technologies for Ocean Acoustic Monitoring
http://oceanexplorer.noaa.gov/technology/tools/acoustics/acoustics.html

After eliminating this theory, hydrophones were again used in subsequent testing around an active fishing vessel with surprising results. The tests showed that as a fishing vessel retrieves its longline gear, the captain has to constantly switch the vessel in and out of gear to keep the ship directly over the longline. Each time the prop is reengaged, cavitation (bubbles produced from the prop spinning) occurs. This distinct sound could be heard by sperm whales more than five kilometers away (Dykstra Per. Com 2012, McPherson 2011, Thode et. al. 2007, Straley Per. Com 2012). In fact, because each boat

has a different size prop and therefore makes its own distinct sound, the whales could actually recognize individual vessels and target boats that typically brought in larger catches (Dykstra Per. Com 2012).

To test their findings, researchers had a boat captain steam several miles away from a set of active fishing gear. The captain then shifted his boat in and out of gear mimicking longline retrieval behavior. Sperm whales were sighted in the area within five minutes, thus confirming the results (Dykstra Per. Com 2012, McPherson 2011, Thode et. al. 2007, Straley Per. Com 2012). The captain was able to "summon" whales by simply using his ship's prop to cause cavitation and produce sound. This single finding identified the acoustical signal that whales equated to an easily acquired source of food and that attracted them to the fishing vessels.

Figure 5 – Acoustical Hydrophone Data Dduring a Depredation Event



This graph was created from acoustical hydrophone data gathered on May 9, 2004. The ship's hydraulics were engaged when the anchor line was grappled (9:07 AM), but the whales did not react until 9:27 AM when the ship began cycling in and out of gear. This is clear evidence the whales are attracted to the sound of prop cavitation and not to the sound of ship's hydraulics. Courtesy of Thode et. al. 2006.
http://doc.nprb.org/web/04_prjs/f0412_final_report.pdf

Next, SEASWAP, with the Acoustical Society of America, wanted to document normal sperm whale foraging behavior and compare it to depredation behavior. To accomplish this, passive acoustic recordings of sperm whale "clicks" (the sounds sperm whales make that aids them in echolocation) were collected from hydrophones deployed from small boats and fishing gear and an acoustic multi-path was used which can derive

the range and depths of the target animal. In addition, depth-recording tags were attached to eight animals, providing 80 hours of dive profile data (Thode et. al. 2009).

Picture 3 – Sperm Whale Tagging

A researcher preparing to affix a suction cup recording tag to a whale. These tags will typically remain affixed to the whale for up to 48 hours. Courtesy of Discovery of Sound in the Sea http://www.dosits.org/

Recordings were made both while whales were foraging naturally and when they were observed actively depredating longline gear during retrieval. The results between the two different types of feeding behavior were distinct (Thode et. al. 2009, Straley Per. Com 2012). During normal foraging, whales dove to depths of 200 to 400 meters and stayed submerged for an average of 29 minutes (Sigler et. al. 2008, Mathias et. al. 2009, Mathias et. al. 2012). By contrast, depredating whales dove to less than 100 meters and stayed submerged an average of five minutes per dive (Thode et. al. 2009, Mathias et. al.

2012). During depredation, the longlines with caught fish attached are being hauled to the surface; therefore, there is no need for the whales to make deep dives for extensive periods of time. They just stay close to the boat and fishing gear, and surface frequently. Much less energy is expended because there is no need to chase after their prey.

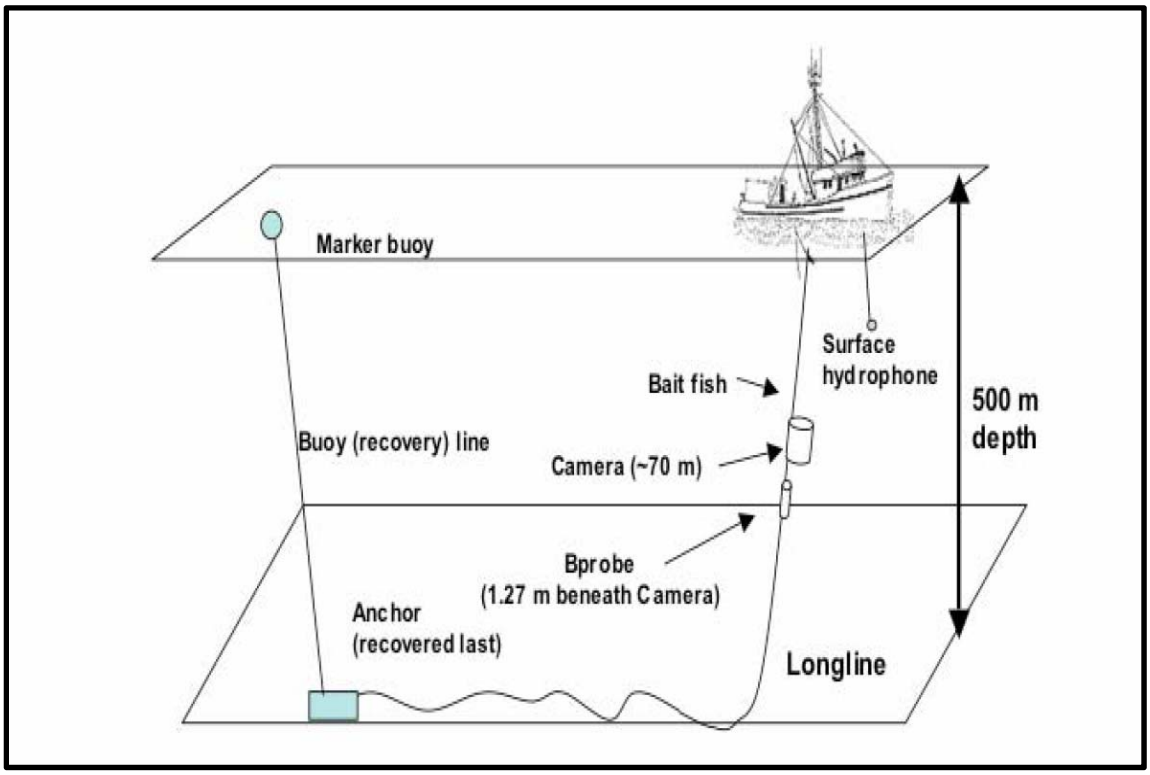
Sperm whales produce clicks to help in echolocation of food (Mathias et. al. 2009, Miller et. al. 2004). When they are actively foraging, their normal rate of clicks increases to 10 per second or greater (Wild Per. Com 2012, Miller et. al. 2004). These increased rates of clicks help the sperm whale target and locate its prey (Straley Per. Com 2012, Miller et. al. 2004). In addition, it is speculated that in some marine mammal species, including the sperm whale, the increased rate of clicks might actually stun the prey fish, making acquisition even easier for the whales (Calambokidis Per. Com 2012). This acoustic activity is called a "creak" (Mathias et. al. 2009, O'Connell Per. Com 2012, Straley Per. Com 2012). Creaks, followed by a period of silence, indicate a prey capture event (Thode et. al. 2009, Straley Per. Com 2012, Miller et. al. 2004).

During depredation, scientists using acoustical hydrophones recorded a creak rate twice that of a normal foraging sperm whale (Thode et. al. 2009, Miller et. al. 2004). From this study, it is clear that depredation is not a normal foraging activity for sperm whales. The difference between dive depth and duration is significant (Thode et. al. 2009). In addition, based on the creak data obtained, it would appear that sperm whales are twice as effective at acquiring prey from depredation as during normal foraging (Miller et. al. 2004). In one case, a tagged sperm whale stopped producing creaks for five hours after a depredation event, possibly indicating just how effective foraging off a longline is (as there is no need to forage for an extended period of time) (Thode et. al.

2009). Because of this, sperm whales are unlikely to stop depredation on their own; rather, this activity will continue to increase over time unless an effective deterrent is identified (Symposium 2006).

Another breakthrough finding occurred in 2006. SEASWAP, working with researchers from SCRIPPS Institute of Oceanography and commercial fishermen, attempted to film sperm whale behavior while depredating (Thode et. al. 2009). Scientists accompanied a fishing vessel actively fishing for blackcod. As the crew prepared to retrieve its longline gear, hydrophones were lowered into the water to confirm the presence of sperm whales. A camera was lowered into the water facing the surface (to utilize ambient light) to a depth of 100 meters (Thode et. al. 2009).

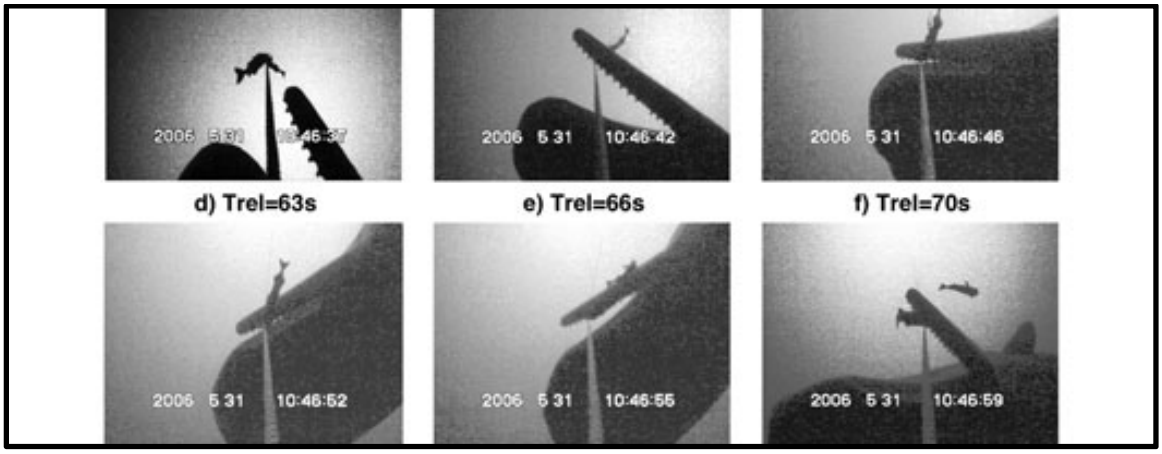
Figure 6 – Video Documentation Experiment Layout



A diagram displaying camera placement on a longline used to film sperm whale depredation. Courtesy of Thode et. al. 2009
http://doc.nprb.org/web/06_prjs/626_final%20report_June09.pdf

Bait fish (in this case, blackcod) were attached to the line above the camera. The resulting footage clearly shows a sperm whale entering into the field of view, grasping the longline with its jaw, and "twanging" the longline like a guitar string to dislodge one of the bait fish (Thode et. al. 2009, Per. Com 2012). As the fish drifts out of camera view, the whale detaches from the line and swims out of view as well, presumably going after the bait fish to consume it. This is the first time underwater sperm whale depredation has been caught on tape.

Picture 4 – Still Shots of Sperm Whale Depredation



Still shots of a video filmed by Scripps Institute of Oceanography clearly showing a sperm whale grabbing a longline in its jaws and shaking loose a blackcod. Courtesy of Scripps Institute http://scrippsnews.ucsd.edu/Releases/?releaseID=995

What is amazing and groundbreaking about this footage is that the whale never touches the fish and there was no evidence of the depredation on the hook. Up to this point, depredation was assumed to have occurred when mangled fish, heads, lips, or bent hooks were observed on the haul back (Dykstra Per. Com 2012). If the hooks were empty at haul back, it was assumed that the bait either fell off during the gear set or smaller scavenger fish ate the bait while the line was on the bottom. Empty hooks were never before attributed to sperm whale depredation. This footage clearly depicts how whales can depredate a line and leave behind no evidence of their behavior (Straley Per. Com 2012, O'Connell Per. Com 2012).

The implications of this single finding meant that the amount of depredation believed to be occurring could have been severely underestimated (it was previously thought sperm whales were taking only 5% to 10% of the overall catch per set depredated based just on the evidence left on hooks) (Dykstra et. al. 2010, Hill et. al. 1999). This

single finding could have substantial impact on setline data used for population stock assessments of commercial fish species. Empty hooks recovered from set line surveys might actually have been caught fish that were preyed upon by sperm whales; potentially skewing the overall assessment.

Picture 5 – Remains of a Halibut after Sperm Whale Depredation

An Alaskan longline fisherman holds up the remains of a halibut that was depredated by a sperm whale. Courtesy of Wild Whales B.C. Cetacean Sightings Network. Photo by Dan Falvey. http://wildwhales.org/conservation/threats/depredation/

Deterrent Methods and Effectiveness

The reward to sperm whales is too great for them to stop depredating on their own, and not taking action to stop this phenomenon is unacceptable to fisherman because of the loss of their gear and income. Over the years, numerous devices and strategies have been devised, tested, employed, and discarded in different fisheries throughout the world. This thesis examines the more popular deterrent methods, rates their effectiveness, and identifies the most cost-effective and successful methods for Washington coast longline fishermen to employ in their fishing operations. These recommendations are based on peer-reviewed scientific studies, advice and recommendations from research organizations, reports from fishermen, communications with scientists, the success rate of past and present deterrent strategies, and known fishing grounds and ocean conditions specific to Washington coast fishermen. The majority of these strategies and devises come from lessons learned in Alaska. Alaskan fishermen and SEASWAP have been dealing with this issue for decades and much of their knowledge and experience can be applied directly to the Washington coast longline fishery.

Acoustical deterrents – The Southeast Alaska Sperm Whale Avoidance Project (SEASWAP) and their scientists have conducted extensive research into acoustical deterrents and have published their findings in peer reviewed scientific journals. Overall, acoustic harassment devices are ineffective as long-term strategies (McPherson 2011, Symposium 2006). Fishermen have used seal bombs, pingers, recordings of killer whales, and other sounds with limited success. Sperm whales appear to be initially deterred by the sounds, but the draw of easy prey and the subsequent acclimation of the whales to the

sounds render this strategy ineffective in the long run (Straley Per. Com 2012, Dykstra Per. Com 2012).

One exception is an approach where a dummy buoy with recordings of a ship cycling in and out of gear is dropped several miles from the actual fishing gear while the ship then steams back to the actual fishing gear and hauls it in as fast as possible. This tactic will work sometimes, but the whales eventually realize they have been fooled at the dummy buoy and will then show up at the actual fishing spot (Thode et. al. 2008, Thode et. al. 2007, Straley Per. Com 2012). Ongoing research using a slightly modified method remotely triggering the playback device will continue in Alaska during the 2013 fishery (Wild Per. Com 2013).

All these devices however, are a relatively inexpensive investment and can be very successful in the short-term. For Washington coast fishermen who only encounter sperm whales on an intermittent basis, this type of deterrent could be quite effective and should be considered, particularly since it is presently thought that there is no resident whale population off the Washington coast. (It is presently believed that sperm whales migrating up the coast to Alaska depredate the Washington fleet as they swim past) (Straley Per. Com 2012, O'Connell Per. Com 2012, Calambokidis Per. Com 2012). It is possible, therefore, that these whales could be easily chased off before they become acclimated to the sounds and simply continue their migration north in search of food.

Dummy Sets – This method is also recommended by SEASWAP based on limited experimentation and field studies (Straley Per. Com 2012, Thode et. al. 2009). Fishermen have also dropped dummy sets in an attempt to divert whales from the real set. These

decoys are simply an anchor, line, and buoy that look exactly like actual fishing gear. By dropping these dummy sets several miles from their actual fishing gear, fishermen can sometimes lure the whales far enough away that they are able to retrieve their gear before the whales figure out the ruse and show up at the actual fishing gear (O'Connell Per. Com 2012). This is especially effective if the whales are actually following the vessel around and if they remain around the dummy set (Thode et. al. 2009). The results of this method are intermittent at best; in addition, there is the added cost of fuel, gear, and time. Thus, this is not usually a recommended method. However each fisherman is urged to weigh the pros and cons and decide for themselves if it is worth it for them.

Group Hauls – This strategy was actually thought up and implemented by Alaskan fishermen themselves in their own efforts to find a solution (Straley Per. Com 2012). Occasionally boats will team up and while one hauls in gear, the other boat will be positioned several miles away, cycling in and out of gear in an attempt to draw the whales away from the actual fishing vessel.

A similar strategy is that boats fishing in the same area will sometimes coordinate with each other to simultaneously haul in their gear (Per. Com 2012). This way, any whales present will be split between all the boats, thus spreading the potential loss of catch out among all the boats. This method has been employed by Southeast Alaskan longline fishermen for several years with limited to good success; moreover, the results are better than doing nothing (Straley Per. Com 2012, O'Connell Per. Com 2012).

It is recommended that this method should also be tried by Washington coast fishermen because of its low cost and potential success. This method is also made easier

because the fishermen tend to be in close proximity of each other on the fishing grounds (Charley Per. Com 2008, Frank Per. Com 2013, Rhoads Per. Com 2013).

Circle Haul - SEASWAP and the North Pacific Research Board (NPRB) have suggested a maneuver called a circle haul, where a fisherman steers his boat backwards in a circle while hauling in the gear in order to stay on top of the line, instead of shifting in and out of gear (Straley Per. Com 2012, O'Connell Per. Com 2012, Thode et. al. 2009). This way, there is no cavitation to alert the whales. The drawbacks are that only certain types of boats can accomplish this maneuver due to their design and the ocean needs to be relatively flat and calm, which is a rare occurrence in the Northeastern Pacific Ocean (Straley Per. Com 2012, O'Connell Per. Com 2012).

For Washington coast fishermen, the longline season usually begins in March (Jones Per. Com 2013), when weather and surf conditions are less than ideal. Under such conditions, it would be nearly impossible to perform this maneuver. However, depending on the amount of available fish to be caught each season (total allowable catch or TAC) and the amount of fishing effort (boats participating), the season can extend into the summer months, when the ocean conditions are much calmer (Frank Per. Com 2013, Rhoads Per. Com 2013). It is recommended that if conditions permit and the boat is capable, this method should be tried. By avoiding cavitation sounds, the whales are less likely to show up and depredate a fisherman’s catch.

Hydrophone - Fishermen are encouraged to use a hydrophone ($200 - $400) to listen for whales when preparing to haul in gear (Straley Per. Com 2012, O'Connell Per. Com 2012). This is a standard device used by scientists conducting any type of marine

mammal research. A hydrophone will alert the fisherman if whales are present even if they are submerged and not visible (surfacing) (Straley Per. Com 2012, O'Connell Per. Com 2012). This added information can assist fishermen in their decision making.

If whales are present, or appear during haul-in, fishermen are encouraged to drop their gear and/or wait until the whales leave the area before retrieval (Straley Per. Com 2012, O'Connell Per. Com 2012). Fishermen can also maneuver their boats into shallow water in an attempt to lose a whale. The whale's echolocation does not work as well in shallow water as discovered in field studies and observations, so they lose track of the ship (Straley Per. Com 2012, O'Connell Per. Com 2012, Dykstra Per. Com 2012).

These techniques will cost the fishermen time and money (both in the purchase of the hydrophone and in the extra gas), so they must weigh the odds and make a decision which is best for them. If the cost of gas is low and the price paid for blackcod or halibut is high, this is a beneficial strategy and recommended to Washington coast fishermen.

Shorter Longlines – Another strategy fishermen have implemented themselves is the use of shorter longlines so they can get their gear on board faster, before the whales appear, which avoids the depredation entirely. However, the problem with shorter longlines is that the fishermen need to make more sets (to have the same amount of actively fishing hooks), which gives the whales more time to find the boat during a haul-in (Straley Per. Com 2012, O'Connell Per. Com 2012).

As with the use of a hydrophone, each fisherman must determine whether this strategy is in his or her best interest in the long-term. If whales are already present in the area, it might make sense to set more hooks so that even though the whales are preying

on the catch, the chance of landing more fish increases. In general, this method of shorter longlines would work best for fishermen with smaller boats (less operating expense and therefore fewer sets needed to make the trip profitable) (Rhoads Per. Com 2013).

Night Hauling - It was once thought that sperm whales were attracted to fishing boats by the sea birds that are constantly around during a haul. Alaskan fishermen tried hauling gear only at night with no success (Thode et. al. 2007). Since it is now known that the whales are attracted by cavitation and not sea birds (thanks to experiments by Alaskan commercial fishermen and SEASWAP), this method is completely ineffective.

Echosounder - Another speculation was that the whales would hear the fishing vessel's echosounder (an electronic device that depicts current water depth) and thus target the boat. Experiments from Scripps Institution of Oceanography with commercial fishermen setting and retrieving gear with the echosounder both on and off showed no statistically significant difference (Thode et. al. 2007). As with night hauling, since it is now known that the whales are attracted by cavitation, this method is also completely ineffective and should not be tried.

Avoiding Whale Hotspots - It has been recommended that fishermen avoid known sperm whale "hotspots" when setting gear. However whales, like fishermen, know the areas where the fish are abundant. Sperm whale "hotspots" are usually on prime fishing ground (Straley et. al. 2005); therefore, this method is undesirable. One exception to this would be if a fisherman had a smaller vessel and knew an area where fishing was merely average. Since smaller boats are cheaper to operate and a profit can be made with a smaller amount of catch (Rhoads Per. Com 2013), it might be desirable to fish in an area

with less fish but also no competition from whales. Again, this is a situation where each fisherman must individually decide what is best for him or her.

Firearms - There have been reports of frustrated fishermen shooting at surfacing sperm whales with rubber bullets, pepper shot, bullets, and other propellants. Most likely, the projectiles will not penetrate the blubber layer of the whales, which are several inches thick (Calambokidis Per. Com 2012). However, if the whale does feel anything, they likely attribute the pain to surfacing and not feeding, which merely causes them to take longer dives while continuing to depredate the line (Symposium 2006). More importantly, this method is in direct violation of the Marine Mammal Protection Act, for which fishermen face harsh penalties and large fines. No fisherman, no matter how frustrated, should ever shoot at whales. This method is definitely not recommended.

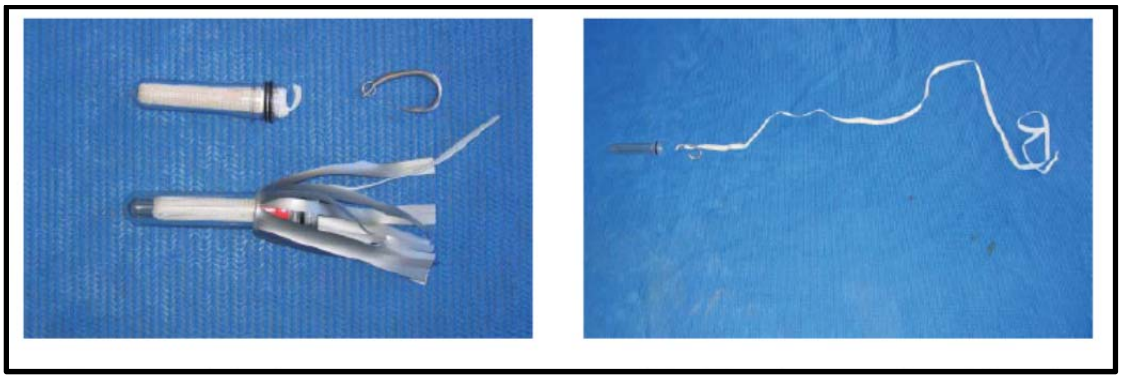
Eliminate Offal Discharge – Clear documentation (eyewitness reports, photographs, etc.) exists that shows marine mammals being attracted to vessels discharging offal (Straley Per. Com 2012, O'Connell Per. Com 2012). Offal is the discarded heads and guts of cleaned fish and leftover bait. This material is sometime tossed over the side of the boat, along with any by-catch (non-target species) while hauling in gear. Researchers urge fishermen to retain all offal so as to not further encourage whales to seek out active fishing boats (Straley Per. Com 2012, O'Connell Per. Com 2012).

The view on this is from fishermen is mixed; some fishermen agree with not encouraging the whales to associate boats with food, while others point out that whales already know to approach fishing boats and if they provide a source of food (offal) the whales will leave their commercial catch alone (Straley Per. Com 2012, O'Connell Per.

Com 2012). Scientists generally feel the least amount of contact and intervention with marine mammals is best. As with other methods, each fisherman will need to determine what is in his or her best short- and long-term interest in each distinct situation.

Streamer Devices - In other parts of the world, streamer devices placed next to each hook have been employed with very encouraging results (McPherson et. al. 2010). Originally developed for the Patagonian toothfish (*Dissostichus eleginoides*) fishery off the Chilean coast, scientists and fishermen have documented a sharp decline in depredation with the inclusion of these devices (McPherson et. al. 2010, Hamer et. al. 2011, Donoghue et. al. 2003). The underlying idea is that when a fish grabs the bait and is hooked, the movement will dislodge streamers that will dangle around the fish (especially during a haul-in of the line). It is believed that the movements of these streamers, which are made of metallic tape, confuse the whale so it is unable to tell (see) what its echolocation is fixed on and therefore does not take the caught fish (McPherson et. al. 2010, Hamer et. al. 2011, Donoghue et. al. 2003).

Picture 6 – Streamer Lines



On the left is a picture of two types of streamer line containers which are placed above each hook. On the right is a picture of a deployed streamer line. These devices are currently being used successfully in the Coral Sea longline fisheries. Courtesy of McPherson et. al. 2010. http://www.iotc.org/files/proceedings/2010/wpeb/IOTC-2010-WPEB-Inf17.pdf

However, the cost associated with purchasing one streamer for every hook, the time involved in preparing the gear for deployment, and the time needed after each haul to reset the gear makes this strategy less desirable. This technique has not caught on in the Northeastern Pacific longline fisheries, and for the reasons stated previously, is not recommended. If conditions off the Washington coast change and sperm whale depredation becomes more prevalent and harmful to the fishing industry, this deterrent may become a more worthwhile strategy and investment to protect the catch. At present however, there is simply not enough depredation taking place along the Washington coast to warrant the inclusion of streamer lines into the longline sets.

Leave the Area While Gear is Soaking - Scientists and fishermen both agree: head directly to your fishing area, quickly set your gear, and move your vessel five to six miles away, preferably towards shallow water (200 fathoms or less) to let your gear soak (Straley Per. Com 2012, O'Connell Per. Com 2012, Dykstra Per. Com 2012). It has been observed and documented by Alaskan fishermen that whales will wait with a fishing vessel next to its set until gear retrieval to depredate the line (Straley Per. Com 2012, O'Connell Per. Com 2012, Dykstra Per. Com 2012). By moving away from the gear, one can draw the whales off the actual retrieval spot. Shallow water tends to confuse the whale's echolocation and a fisherman can sneak away (Straley Per. Com 2012, O'Connell Per. Com 2012, Dykstra Per. Com 2012).

For retrieval: head directly back to the gear and haul in the line as quickly as possible. If no whales are immediately present, it typically takes them about an hour or two to show back up. By working fast, a fisherman can have a large portion of the longline onboard before the whales return. This strategy is strongly recommended for the

Washington coast; especially if whales are present during the set or if there have been reports of recent sperm whale activity in the area by other fishermen.

Deterrents Currently under Development:

The demand from the commercial longline fishing industry to develop an effective, cost-efficient device or method to deter depredation is great. As sperm whale populations continue to increase due to the end of commercial whaling, so too will the rate of depredation unless something changes to discourage this behavior. SEASWAP, with the assistance of Alaskan longline fishermen, are presently working at developing and field testing several new types of depredation deterrent gear that show promising results (O'Connell Per. Com 2012, Straley Per. Com 2012, Wild Per. Com 2013). Washington coast fishermen and fisheries managers are encouraged to pay special interest to these test results.

Acrylic Beads - Researchers for SEASWAP noticed that whales left fish alone if they were near a tangle in the longline (Straley Per. Com 2012). They speculated that the whale's echolocation did not know what it was looking at, similar to the streamer devices described previously (Dykstra Per. Com 2012). They proposed attaching a 28mm acrylic bead onto each gangion (the length of line coming off the longline), just above the hook. The idea is that to the sperm whale's echolocation, the entire longline will "light up" due to the beads, confusing the whale and limiting depredation (like radar reflectors on sailboats) (Straley Per. Com 2012, O'Connell Per. Com 2012, Dykstra Per. Com 2012).

This idea has real potential to be a very inexpensive addition to a longline without adding extra time to prepare the gear after each haul. Experimental gear testing was

conducted during the 2012 longline season in Southeast Alaskan waters (O'Connell Per. Com 2012, Straley Per. Com 2012). Unfortunately it appears these beads had no statistically significant effect in deterring sperm whale depredation (Wild Per. Com 2013). It is speculated the acrylic beads were not able to alter the acoustic signal enough to confuse the whale's echolocation (Wild Per. Com 2013). Researchers are in the process of preparing the final report for publication. If this deterrent had been found to be effective, acrylic beads could have easily and affordably been used by Washington coast fishermen. Acrylic beads are relatively inexpensive and after the initial output of labor to attach the beads to each gangion, no additional time or labor would have been required. It is unfortunate the results of this test weren't more favorable.

Picture 7 – Acrylic Beads on a Longline

The photograph on the left shows rolls of longline with blue acrylic beads attached. The photograph on the right shows Jan Straley holding up a gangion with an acrylic bead above the hook. Courtesy of Alaska Sustainable Fisheries Trust.
http://thealaskatrust.org/whale-research.php

Bubbler - Also in research and development at SEASWAP is a device known as a "bubbler"; essentially a container full of compressed air much like those used in SCUBA (self-contained underwater breathing apparatus) diving (O'Connell Per. Com 2012,

Straley Per. Com 2012). The container is lowered overboard underneath a longline during a haul. At depth, the container releases a steady stream of bubbles in an attempt to disrupt the whale's echolocation (much like a fighter jet releasing chaff to confuse missile guidance systems) (O'Connell Per. Com 2012, Straley Per. Com 2012). It is hoped that this device will be able to generate a "wall of bubbles"; enclosing the longline and "concealing" the caught fish from the sperm whale's echolocation (O'Connell Per. Com 2012, Straley Per. Com 2012). As with the acrylic beads, this would be a relatively inexpensive deterrent to purchase and operate. After the initial purchase of the canister, the only other expense would be refilling the canister with compressed air after each fishing trip. Further use of this strategy will determine whether it is an effective deterrent and investment.

After the initial field testing during the 2012 Alaskan longline season, problems with the design were discovered (Wild Per. Com 2013). The canister was not allowing enough bubbles to escape at the same time. Instead of a "wall of bubbles", there was merely a trickle. After the first series of unsuccessful field tests, the bubbler has been sent back to the engineering department for modifications (Wild Per. Com 2013). Hopefully the difficulties can be worked out and future tests prove successful. Fishermen and fisheries managers are encouraged to listen for the latest updates on the bubbler's status and potential effectiveness.

Picture 8 – A Bubbler Device Currently in Development

A photograph of a prototype bubbler ready for field testing. This device is to be lowered off the stern of a fishing vessel during the hauling in of fishing gear with the hope of masking the fish in a wall of bubbles shielding them from sperm whale's echolocation. Courtesy of SEASWAP 2012. http://www.seaswap.info/index.html

Decoy Playback Experiments - Currently during the 2013 Alaskan longline season, experiments are underway testing the effectiveness of decoy playback devices (Wild Per. Com 2013). SEASWAP, having identified prop cavitation as the "dinner bell" that attracts the sperm whales to the fishing vessels, is attempting to use this "signal" to draw off the whales. The study design is relatively simple. A participating commercial fishing vessel will anchor a buoy at either three or six nautical miles (randomly selected) from their actual fishing set (Wild Per. Com 2013). Attached to the buoy will be a playback device with recordings of prop cavitation sounds. One hour before hauling in their gear, the fisherman activates the playback device remotely (Wild Per. Com 2013). The hope is any sperm whales in the area will be drawn to the decoy buoy while the fishing vessel prepares to retrieve their set. By the time the whales realize no fish are coming up by the

decoy buoy and find the actual fishing boat, hopefully the majority if not all of the gear will have been retrieved and the catch safe on board.

SEASWAP plans on outfitting 25 fishing vessels with the decoy playback buoys and carefully recording the results of each deployment throughout the season (Wild Per. Com 2013). Washington coast fishermen are encouraged to listen for results of these experiments. Depending on the effectiveness of this strategy/device, the initial investment cost of the necessary equipment, and the rate of increase in sperm whale interactions, this might be a viable option to deter sperm whale depredation along the Washington coast.

Conclusion:

The problem of sperm whale depredation is not going to go away on its own, especially because the reward of easily obtained food is too great for the whales to pass up (Straley Per. Com 2012, O'Connell Per. Com 2012, Dykstra Per. Com 2012). As the sperm whale populations continue to increase due to the end of commercial whaling, this problem is expected to worsen. The economic loss to fishermen, the uncertainty of standing fish stock to managers, and the danger to the whales themselves are all important reasons to find an effective deterrent to reduce or ultimately end depredation. The economic value of fish lost can be quite staggering from season to season, depending on the price paid per pound and the amount of fish to catch. What was not calculated was the cost of replacing lost or damaged gear, added fuel and bait costs, and extra time spent fishing. The bottom line is that a vessel that experiences any level of depredation on a fishing trip will experience some level of economic loss. Fishermen need to take steps to

reduce or prevent depredation in order to keep their operation profitable. Researchers and fishermen are committed to working with each other to develop and test new technologies that are effective, affordable, and safe to marine mammals (Straley et. al. 2011).

By employing the strategies recommended in this thesis, Washington coast longline fishermen can work towards reducing sperm whale depredation to their lines in a cost-effective manner. More importantly, methods that are currently being developed and tested are showing promising results. Acrylic beads did not meet scientists' expectations, but with adjustments in engineering design, bubblers have the potential to "confuse" sperm whales' echolocation and decrease depredation. Current testing of decoy buoys to document their effectiveness illustrates the collaboration between fishermen and scientists and their dedication to finding a workable solution. This collaboration between scientists and fishermen has been mentioned throughout this thesis and should be noted. Collaboration between scientists and fishermen is key to collecting data, testing new deterrents, and determining the feasibility of new deterrents in commercial longline operations.

By learning from the example set in Alaska, researchers and fishermen in Washington are highly encouraged to work together at finding a solution. What works up in Alaska might not necessarily work off the Washington coast. The ocean conditions, the benthic habitat, the weather patterns, the fishing seasons, and type of gear are all different. Washington coast fishermen need to try the recommendations put forth in this thesis and find what works. Talk to your fellow fishermen and fisheries managers about successes and failures. Spread word about strategies and methods that work. The entire

fleet needs to become involved in doing everything feasible to deter depredation. If some vessels do nothing and let depredation occur unhindered, the sperm whales will be encouraged to continue to seek out active fishing vessels. Fisheries managers need to actively educate their fleets. The managers have the resources available to gather research and findings and provide the information to the fishermen. State and tribal managers should collectively work together in a mutually beneficial partnership to discover the size and scope of the problem and compare notes on what types of methods and strategies are working.

In addition, as this is a worldwide problem, scientists all over the world (not just SEASWAP) are developing and testing new deterrent methods and strategies. Researchers gather at annual symposiums and conferences to compare notes and findings. With this focus, it is believed that it will only be a matter of time before an effective, low-cost, minimal-effort deterrent is identified, or a combination of strategies is proven successful.

Future Research Needs and Discussion:

The goal of this thesis is to provide a document that fisheries managers and fishermen along the Washington outer coast can utilize to educate themselves about sperm whales, depredation, important research findings, effective deterrent strategies, and ongoing research. More importantly, fishermen are needed to become part of the solution.

Identifying the Scope – Quinault longline fishermen have reported sperm whale depredation events to their fisheries managers beginning around 2008 and continuing through the present season. Inquiries were made to other Washington tribal fisheries

managers and to the Washington Department of Fish And Wildlife (WDFW) fisheries managers to see if they were also getting reports from their fishermen. None indicated any reports of sperm whale depredation from their fishermen. It is unlikely that Quinault fishermen are the only vessels encountering depredation. What is more reasonable is that no other fishermen are reporting these instances to their managers. A survey of all Washington coast fishermen is recommended to discover exactly how big the problem is and in what areas depredation is occurring and at what rate. This information is vital to understanding the scope of the problem.

Sperm Whale/Longline Interaction Logbook - Located on the following pages is a copy of a sperm whale/longline interaction logbook distributed by SEASWAP and currently used by Alaskan commercial longline fishermen (Straley Per. Com 2012, O'Connell Per. Com 2012, Dykstra Per. Com 2012). It is highly recommended that Washington coast longline fishermen make or obtain copies of this form, keep them on their vessels, complete them for every whale interaction, and submit the forms to their fisheries managers (Straley Per. Com 2012, O'Connell Per. Com 2012, Wild Per. Com 2013).

The intent of the sperm whale/longline interaction logbook is to document sperm whale depredation events to better understand the frequency and extent of the problem along the Washington coast. Obtaining this information from Washington longline fishermen is vital to better understand the scope of the problem (Straley Per. Com 2012, O'Connell Per. Com 2012, Wild Per. Com 2013). This problem could have gone unnoticed for years if it were not for Quinault Indian Nation longline fishermen bringing it to the attention of their fisheries managers (Charley Per. Com 2008, Frank Per. Com

2013, Rhoads Per. Com 2013). It is the fishermen themselves who need to take an active part in documenting depredation, collecting data, and collaborating with researchers and fellow fishermen.

Table 4 - Sperm Whale/Longline Interaction Logbook

SPERM WHALE / LONGLINE INTERACTION LOGBOOK

Fill out ONLY when Sperm Whales present		Estimated NM offshore _____		TARGET SPECIES:		Sablefish Halibut Both	
GPS Latitude:				GPS Longitude:			
YEAR		TRIP NUMBER		DATE SET		DATE HAUL	
VESSEL		SET NUMBER		TIME SET		TIME HAUL	

Sperm Whales present at set? YES NO	Number of Sperm Whales MIN_____ MAX _____ BEST GUESS_____	
Sperm Whales present at soak? YES NO	Number of Sperm Whales MIN_____ MAX _____ BEST GUESS_____	
During soak were you at ANCHOR or DRIFT?	If drift, were the whales by the GEAR BOAT BOTH	If anchor, were whales at gear when you returned? Y N
Sperm Whales present at haul? YES NO	Number of Sperm Whales MIN_____ MAX _____ BEST GUESS _____	
Were all the whales present at start of haul? Y N	If no record the number present at START OF HAUL_____ and those that JOINED DURING THE HAUL____	

BEHAVIOR	For this set:
Please circle all that apply: Follow Boat Resting Diving Feeding Milling up current Milling down current Approach boat Traveling (unassociated to boat) How close to vessel were whales surfacing? _____	# of Skates_____ order_____ Depth range of set (m)_____ Lbs. caught_____

Were any photos taken of the whales? YES NO	Were any other whales seen in area? YES NO	If yes, which ones? Humpback / Killer / Fin / Sei / Minke / Gray / Unknown

Whale Tails: Mark any scars or nicks noticed, also circle which side of the tail was photographed Dorsal / Ventral Dorsal / Ventral Dorsal / Ventral 	Please list any scarring or other distinctive features and where they were on the body of the whale

Was there evidence of damage to your catch? YES NO	# Heads _____	# Shredded _____	# Lips _____	Other _____
Were there any Grenediers caught? YES NO	If yes, approximately how many? FEW (1-10 per skate) SOME (10-30 per skate) MANY(30+)			
Did you do any avoidance behavior? YES NO	Were there any other boats fishing nearby? Y N	# boats w/in 5 mi_____ w/in 10 mi_____		
Please describe what type of avoidance behavior you performed?				

Are your sablefish DRESSED or ROUND	Are you dressing any other fish? YES NO	Halibut # _____ Other species _____#_____
Other Comments:		

Educating Fishermen - Also included on the following pages is a table listing the most common deterrent strategies available and rating their effectiveness for the Washington coast fishermen. This table was created for fisheries managers to copy and distribute to their fishermen for the purpose of easily educating them about their current options for dealing with sperm whale depredation. Just as fishermen need to take an active role in documenting interactions and collecting data, fisheries managers and researchers also need to work closely with the fishermen to share options, current and future research, and possible solutions (Straley Per. Com 2012, O'Connell Per. Com 2012, Wild Per. Com 2013). Alaska is a perfect example of what can be accomplished when fishermen and scientists work together toward a common goal. The fishermen brought this problem of sperm whale depredation to the attention of the scientists. The scientists relied on the fishermen to collect interaction data (sperm whale/longline interaction logbooks). Through experimentation and field studies, scientists were able to identify what attracted whales to actively fishing vessels (prop cavitation). Deterrent methods were proposed by scientists; fishermen tested the new strategies and reported their effectiveness to the scientists. Fishermen also developed different strategies on their own and passed the word to their fellow fishermen (i.e., group hauls). This partnership with fishermen and scientists continues today.

Table 5 – Educational Handout on Depredation Strategies for Fishermen

Deterrent Method	Brief Explanation	Pros	Cons	Effectiveness	Recommendation for WA Fishermen
Acoustical Deterrents	Devices such as seal bombs, pingers, recordings of killer whales, etc. utilized to chase off whales.	Very effective on the short term. Some devices such as seal bombs are relatively inexpensive.	Whales will become acclimated to the sounds and the deterrents will cease to work on the long term. Some devices are very expensive to purchase and maintain.	Very effective on the short term.	While these devices show great promise at deterring whales on the short term, there is a potential to cause harm to the whales. Therefore, in order to avoid hefty fines under the Marine Mammal Protection Act, these devices are not recommended.
Dummy Sets	The deployment of dummy fishing gear miles from the actual fishing gear in order to draw the whales off.	A relatively small investment of time and money to the fishermen	The whales will still be attracted to the sounds of an actual gear haul and will lose interest in the dummy set in search of real food.	Somewhat effective.	If the fishermen have whales following their vessel, it is recommended that this method be tried in attempt to fool the whales away from the actual fishing gear.
Group Hauls	Fishermen coordinate among themselves and either all haul at the same time, or one fisherman hauls in gear while another several miles off cycles in and out of gear in attempt to lure the whales away.	A relatively small investment of time and money to the fishermen.	During a group haul, depredation is still occurring.	This method has the potential to be quite effective when only a small number of whales are present.	Washington coast fishermen should try this deterrent method. It shows great promise for groups of whales fewer than 3 or 4. When more whales are present, another method should be tried.

Deterrent Method	Brief Explanation	Pros	Cons	Effectiveness	Recommendation for WA Fishermen
Circle Hauls	Maneuvering one's vessel in reverse while circling one's gear while hauling in gear.	By using this technique, the fisherman will not have to continually be shifting in and out of gear and therefore will eliminate prop capitations sound which attracts whales.	This method can only be used on certain vessels when ocean conditions are relatively calm.	This method is highly effective at eliminating the sounds that alert whales to actively fishing vessels.	If the ocean conditions are right and the vessel is capable, this method is strongly encouraged.
Hydrophone	A listening device used to determine if whales are present before hauling in gear.	Fairly inexpensive (around $200 to $400).	The whales might be in the area for days; the fishermen can only wait so long.	Hydrophones are very effective at determining the presence or absence of whales	While a hydrophone does not deter whales, fishermen can determine if whales are actually present prior to hauling in gear. If whales are present, the fishermen can then incorporate another deterrent method to protect their catch. The purchase and use of a hydrophone is recommended.

Deterrent Method	Brief Explanation	Pros	Cons	Effectiveness	Recommendation for WA Fishermen
Shorter Longlines	Fishing with shorter longlines so the gear can be recovered before whales arrive at the site.	If whales are several miles off, this method can be quite effective and gear recovered before the whales arrive.	Shorter longlines means smaller catch. More sets would need to be made to equal out the loss. This means spending more time on the fishing ground, and therefore increasing the likelihood of a whale coming to investigate.	This method can be quite effective if no whales are in the immediate vicinity.	This method has the potential to be a quite effective strategy for fishermen with smaller vessels. The operating expense is lower; therefore, less fish would be needed to be caught in order to make a profitable trip.
Night Hauling	Hauling gear at night to avoid detection by whales.	There are no pros.	This method is completely ineffective.	This method simply does not work.	This method is not recommended simply because it does not work.
Echosounder	Turing off one's Echosounder prior to hauling in gear so the sound does not attract whales.	There are no pros.	This method is completely ineffective.	This method simply does not work.	This method is not recommended simply because it does not work.
Avoiding Whale Hotspots	Concentrating one's fishing areas where whales are known not to frequent.	By fishing in areas not populated by whales, the chances of attracting one increase dramatically.	Unfortunately, whales tend to inhabit the best fishing grounds.	Unfortunately, the whales are naturally attracted to where the fish are. Areas without whales are typically poor fishing spots.	If the fishermen know of an area where whales are absent, but fishing is good, by all means employ this strategy.

Deterrent Method	Brief Explanation	Pros	Cons	Effectiveness	Recommendation for WA Fishermen
Firearms	The use of firearms to deter whale depredation.	There are no pros.	This method simply does not work.	Due to the thickness of the whale's blubber layer, projectiles from firearms will have little to no effect on the whales. At the most, the whales would simple stay submerged longer but continue depredating.	In order to avoid hefty fines under the Marine Mammal Protection Act, and because this deterrent method is completely ineffective, this strategy is strongly discouraged.
Eliminate Offal Discharge	Retaining all by-catch and refuge from gutted fish until fishing activity is over.	By withholding extra potential food, whales will be less attracted to the vessel.	By not providing the whales extra food, they have only the caught fish to eat and therefore, the amount of depredation would be greater.	At this time there are mixed views on whether this is an effective method or not.	Washington coast fishermen are encouraged to try both withholding and discharge of offal and to report their finding back to fellow fishermen and researchers. This method is still up in the air.
Streamer Devices	A device attached above each hook that deploys a streamer when a fish is caught. The streamer helps mask the fish to the whale's echolocation.	This method is quite effective in the Coral Sea longline fishery.	The cost of added gear and time needed to attach the gear and to reset the gear after deployment is extensive.	This method is very effective and proven in other longline fisheries in the world.	Due to the added expense of time and money, this method is not recommended. The Washington coast simply does not have that big of a depredation problem to warrant this device. However, this might change in years to come.

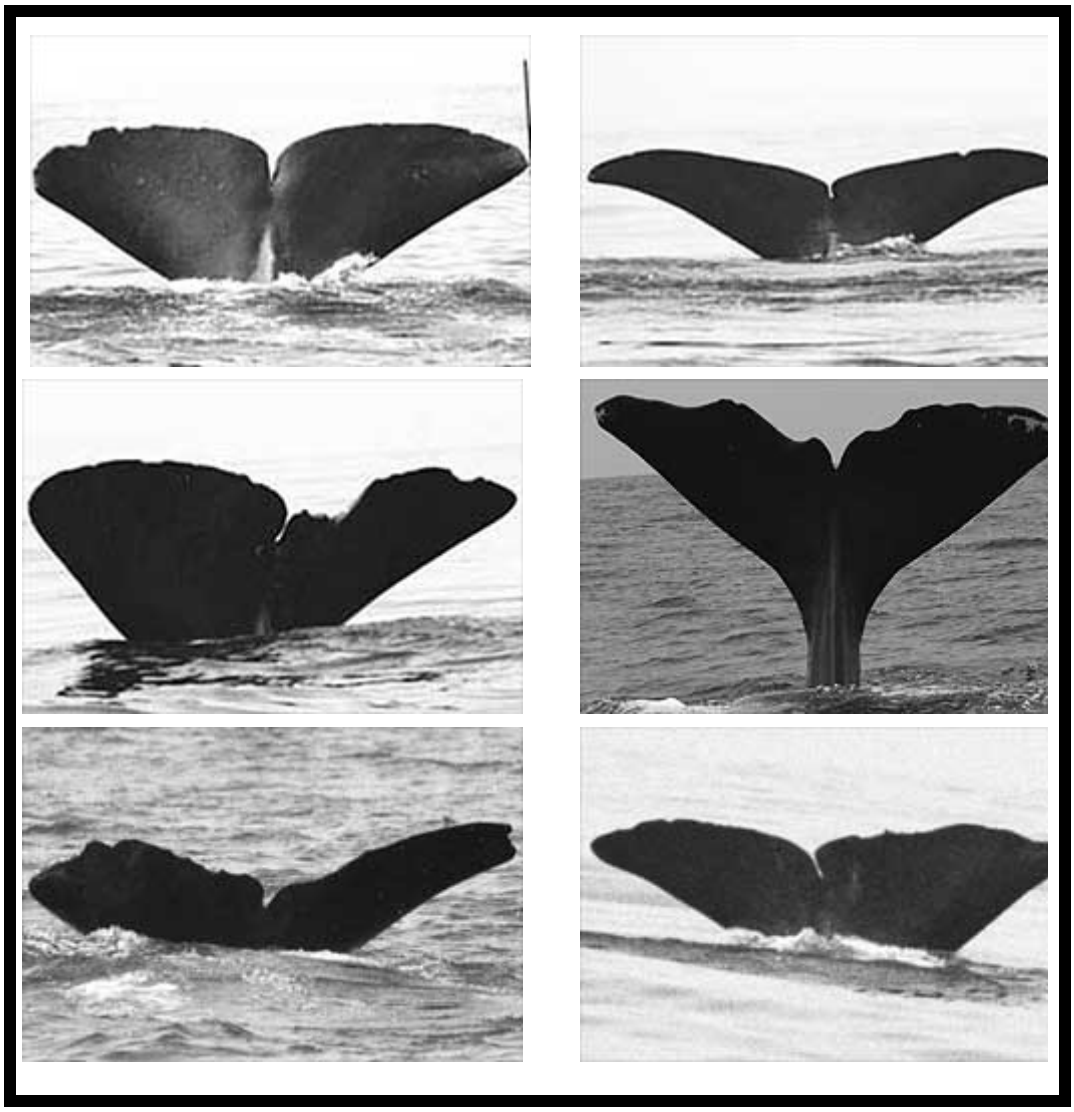
Sperm Whale Identification and Documentation - A vital piece of information presently missing is whether Washington coast has its own resident population of sperm whales or if whales migrating up to Alaska depredate the Washington longline fleet along the way, as is presently assumed (Straley Per. Com 2012, O'Connell Per. Com 2012, Calambokidis Per. Com 2012, Wild Per. Com 2013). Photo identification of suspect whales is required; an individual whale can be identified through pictures of its flukes (each whale's fluke has a distinctive shape and markings much like a person's fingerprint) (Straley Per. Com 2012, O'Connell Per. Com 2012, Calambokidis Per. Com 2012). Fluke pictures taken of sperm whales engaged in depredation along the Washington outer coast can be compared with whale photo catalogs from SEASWAP and Cascadia Research Collective (Straley Per. Com 2012, O'Connell Per. Com 2012, Calambokidis Per. Com 2012).

If the Washington coast photos match those from whale fluke pictures taken at a later date up in Alaska, it can be surmised that those whales migrated north and depredated the Washington fleet along the way. If Washington coast photos match pictures previously taken in Washington, it could potentially indicate that the whales are staying in the area (Straley Per. Com 2012, O'Connell Per. Com 2012, Calambokidis Per. Com 2012). One other possibility would be that whales depredating in Alaska for several years prey on the Washington fleet as they return south to breed with females.

Fishermen are encouraged to carry a camera on board their vessels and to photograph sperm whale flukes if possible. The date, time, and GPS coordinates of each encounter should be recorded and provided to fisheries managers with the photographs for distribution to researchers. Scientists are also encouraged to schedule research cruises

during longline fisheries for the purpose of obtaining fluke shots of sperm whales in the vicinity of fishing operations (Calambokidis Per. Com 2012). Fishermen are usually too busy in their work to stop what they are doing to photograph suspect whales. They are more interested in getting their gear on board as quickly as possible (Frank Per. Com 2013, Rhoads Per. Com 2013). A solution to this would be to have any fishery observers on board trained and equipped to photograph whales for identification purposes.

Picture 9 – Pictures of Individual Sperm Whale Flukes



Photos of sperm whale flukes showing distinct markings for each, which researchers can then use to identify individual whales. Through multiple sightings, the whale's movement can be tracked and documented. Courtesy of SEASWAP.
http://www.seaswap.info/study/photoid.html

Fishermen on the Front Line - A special note for fisherman: you are an important part of this research and need to take an active role in finding a solution. You are urged to use the recommendations and advice contained within this thesis. Try different sperm whale deterrent strategies and share with others what works and what does not. Invent and test

new strategies. We can learn much from following Alaska's example, but what works up in Alaska might not necessarily work on the Washington coast. Play an active role in assisting researchers with data collection and report all sperm whale interactions. With everyone coordinating and working together, a viable solution that benefits all stakeholders will certainly be found. The ultimate goal would be to keep sperm whale depredation to a minimum using methods that are affordable, easy for fishermen to incorporate into their longline operations, and prevent harm to the whales.

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