Symposium on Fisheries Depredation by Killer and Sperm Whales: Behavioural Insights, Behavioural Solutions
October 2-5, 2006, British Columbia, Canada

Section 7.d.ii. contains background information, principal findings and advice, workshop reports, and abstracts from oral presentations given at the Vancouver Symposium in 2006.

Workshop Reports

Workshop 1: Insights into killer and sperm whale depredation from fisheries interactions involving other marine mammal species

Workshop 2: Insights into the prevention of depredation from knowledge of whale behaviour and impacts of depredation on whale populations

Workshop 3: Implications of depredation for fishers, fisheries management and fish conservation

Workshop 4: Reducing or eliminating depredation through gear modifications

Workshop 5: Methods of depredation deterrence: passive, active, temporal/synchronicity

Workshop 6: The use of acoustic information by depredating whales and implications for deterrence

Workshop 7: Preventing the spread of depredation and the role of discard feeding in the spread of depredation

Workshop 8: Quantifying depredation and establishing documentation protocols

Special Session: Determining group priorities for research needs, gear modifications and mitigation techniques

Abstracts

Dahlheim, M.E. - Killer whale (Orcinus orca) depredation on longline catches of bottom fish in Alaskan waters

Dyb, J.E. - Experiences of the Norwegian longline fleet with ‘pingers’ and ‘scramblers’

Straley, J., V. O’Connell, L. Behnken, A. Thode, J. Liddle, and S. Mesnick - Sperm Whale and Longline Fisheries Interactions in the Eastern Gulf of Alaska

Thode, A., J. Straley, C. Tiemann, K. Folkert, V. O'Connell, and L. Behnken - Observations of potential acoustic cues that attract sperm whales to longling activities in the Gulf of Alaska

Walsh, S.A. - The interaction of cetaceans with the longline fishing industry in Samoa, South Pacific

Waples, D.M., A.J. Read, K.W. Urian , L.E. Williams, and D. Swanner - Depredation by small cetaceans

http://www.killerwhale.org/depredation/Background.html

Background

Fisheries depredation (removal of fish from fishing gear) by toothed whales is a widespread problem in many oceans of the world. The negative impacts of depredation include economic losses to fishermen, increased pressure on fish stocks, and injury or mortality of whales caused by deterrent methods, entanglement, or accidental hooking. Because it provides an additional food supply, depredation also has the potential to cause whale populations to increase beyond their natural carrying capacity, and/or for previously-existing behaviours related to hunting or seasonal movements to be lost.

In 2002, a workshop in Samoa produced a report entitled Interactions between Cetaceans and Longline Fisheries, which focuses on the South Pacific and contains background papers on specific fisheries affected by depredation. The report provides general recommendations regarding possible methods for reducing depredation, improving data collection, identifying whale species involved in depredation, and increasing the awareness of depredation among governmental and non-governmental agencies.
Symposium Objectives The 2006 symposium focused on depredation by killer and sperm whales, and built on progress made in Samoa. Its objectives were:

A) to broaden understanding of :
· cues and behaviours whales use to locate gear and remove fish · variability of depredation behaviours within and between species · spread of depredation between groups of whales · extent of losses resulting from depredation · implications of depredation for fisheries management

B) to produce specific guidelines for the fishing industry and fisheries management agencies on:
· how fishing operations can be modified to reduce or eliminate depredation · preventing depredation from spreading to new or existing fisheries experiencing no depredation at this time

The first part of the symposium consisted of presentations focused on:
· aspects of natural behaviour and social organisation of killer and sperm whales, with emphasis on populations involved in depredation · case-history examples of killer and sperm whale depredation with special emphasis on the behaviour of the whales involved and associated changes in their social structure, ecology, or demography · impacts of depredation on the fishing industry · methods of passive deterrence, including modification of fishing behaviours, timing, and /or gear · methods of active deterrence · examples of successful measures used to reduce human conflict with species other than cetaceans.

The second part of the meeting was comprised of in-depth, workshop-style group discussions focused on reducing the extent of the problem where it currently exists, limiting its spread to other fisheries and other regions, and producing guidelines for fishermen and fisheries managers affected by killer and sperm whale depredation.

http://www.killerwhale.org/depredation/PrincipalFindings.html

Principal Findings and Advice

Below is a quick summary of the key findings of the meeting:

1) The problem of depredation (the raiding of fishing gear) by killer whales and sperm whales is growing around the world. This increase likely reflects a) diminishing natural food supplies for these species, and b) the transmission of depredation behaviours between whales by social learning. Hook and line fisheries are most affected, whereas depredation of net fisheries by these species is very rare.

2) Depredation is much easier to prevent or control before it becomes an entrenched behaviour. It is very difficult to control the behaviour of whales that have become dependent on depredation.

3) Depredation by killer and sperm whales is not widespread in BC yet, but appears to be increasing and could become a serious problem in several years. At present, the fishers most affected are commercial salmon trollers and sport fishers targeting chinook and coho salmon.

4) Depredation is a severe problem in Alaska. In the Alaskan panhandle, sperm whales depredating the valuable sablefish (black cod) fishery are the main problem. Along the NW coast of Alaska and the Aleutian Island chain, the main problem is killer whales that raid sablefish and halibut fishers. In the southern ocean, the lucrative toothfish (Chilean sea bass) fishery is seriously affected, whereas in the tropics, various species of tuna are taken.

5) The principle problem posed by depredating whales to fishers is the loss of catch. Gear damage is relatively minor and rare, and the whales do no appear to pose a danger to fishers.

6) As well as causing serious problems to fishermen, depredation harms whale populations in at least two ways. First, efforts to deter depredating whales can cause injury. Second, dependence on depredation can cause whales to lose natural behaviours, harming their populations in the long run.

7) Various research projects are being initiated to look for ways to reduce or prevent depredation. Most promising among these are acoustic devices and modifications to fishing gear, particularly the conversion of hook and line gear to pots and traps. Research will be conducted collaboratively with both fishers and researchers.

8) Because no "quick fix" solution exists at present, the best immediate advice for fishermen is a strict "do not reward" policy. Long-line fishers should drop their gear and troll fishers should remove theirs from the water when whales approach; both should only resume fishing when whales have left the area.

Workshop Summaries

Workshop 1: Insights into killer and sperm whale depredation from fisheries interactions involving other marine mammal species
Leader: Vicki Cornish
Rapporteur: Emma Pethybridge

The objectives of the workshop were to 1) examine the problem of depredation in fisheries by small cetaceans, 2) identify commonalities in depredation and behavioral patterns, and 3) discuss possible solutions that may be applicable across species and fisheries. The workshop participants were asked to relay observations and experiences from various fisheries to better understand the scope of the problem, the fisheries affected, research that has been conducted to date, and actions that can be taken by fishermen and fisheries managers to reduce depredation and its impacts on small cetaceans. The goal of the workshop was to help guide the work of others in the immediate future.

How have human behaviours influenced the spread of depredation in other fisheries?
Marine mammals in captivity readily learn novel behaviours that yield predictable rewards, and often adapt quickly to consistent schedules and routines. Fisheries management actions often contribute to the predictability of fishing, by restricting fishing to consistent areas and times. This predictability likely contributes to the spread and severity of depredation.

In addition, the activities and practices of fishermen may contribute to an increase in depredation. In Hawaii, dolphins and whales are considered spiritual animals, and fishermen will give them some of the catch as a spiritual offering that symbolizes taking but also giving back. Shrimp and crab pot fishermen that dump unwanted fish in the presence of dolphins train them to associate fishing boats with food. This may create a problem for other fishermen, notably hook and line fishermen, who subsequently experience higher levels of catch stealing by dolphins. Dressing fish on the boat may also have an influence, as the heads and guts of dressed fish are typically thrown overboard. Some fishermen in Alaska reported that they purposely dump offal to deter whales from eating the target catch, and as a result they have less of a problem with depredation than boats that don't provide offal.

Depredation in Spain
In Spain, bottlenose dolphins are abundant and remove mullet from both gillnet and trawl nets, damaging nets in the process. Reports of depredation are increasing, but it is not known if the problem is increasing in frequency, or if more fishermen are speaking up about it in order to solicit help in solving the problem.

Fishermen have been interested in using pingers to acoustically deter dolphins, but researchers are not optimistic that they will work well in reducing depredation. Pingers were banned from use in 2005 over concerns that they disturbed dolphins. Trials with acoustic deterrence devices (e.g., alarms) around fishing activities have shown that animals may initially be deterred but quickly become used to the sound, overcome their discomfort, and continue to depredate.

In the Atlantic US
In the Atlantic pelagic longline fishery, where depredation by pilot whales on swordfish and tuna catches is a problem, a multi-stakeholder team developed a take reduction plan to reduce interactions. The plan calls for shortening the length of the main line to no more than 32 km the area that experiences the highest rates of both depredation and interactions with fishing gear. The team focused first on strategies that would reduce the probability that whales would detect fishing activity, and then on strategies that would reduce the probability of depredation, and

lastly on strategies that would reduce the extent of harm to depredating marine mammals from entanglement or hooking.

Is bait or the catch targeted for depredation?
There are questions regarding whether whales are stealing the bait or the catch. Whales in Alaska are clearly feeding on the live catch and not the dead bait. However, this question has not been resolved for other fisheries. In cases where whales are stealing the catch, there are questions as to whether these fish species are part of the whales' normal diet. Researchers need a better understanding of the normal diet of whales in these areas. Biopsies and isotopic analyses could help identify typical prey items as well as prey of depredating whales.

Why do whales and dolphins depredate?
More information is needed regarding what causes whales and dolphins to start depredating on fishing gear. Declines in traditional prey species may be a factor. Depredation may have given whales an opportunity to expand their diet – to try something new. There was speculation that younger animals in the population are the first to experiment with novel food sources such as hook-caught fish. If true, this may explain why depredation behaviours sometimes spread within a whale or dolphin population rather slowly. In contrast, if mothers learned depredation first, it is expected that the behaviours would be picked up by their offspring rapidly.

It is not known if individual animals within a group have preferences for different prey species. Social factors may also significantly affect patterns of depredation. For example, tradition appears to play a strong role in the dietary preferences and feeding behaviours of killer whales, which appear generally slower than other whales and dolphins to turn to depredation. However, when depredation behaviour does become entrenched in killer whale populations, the whales can become extremely efficient and difficult to deter. Their seasonal distribution may change in order to take advantage of prey acquired by depredation, and it appears likely that populations could eventually become dependent on depredation. In contrast, other whales and dolphin species may take advantage of fisheries more quickly than killer whales but never become as efficient, singled-minded, or dependent.

It is not understood why depredation happens in some areas and not in others. It may be linked to the availability of food, or it may be a localized behavior and there hasn't yet been a transfer of behavior or exchange of animals between areas.

Methods to avoid depredation
Regardless of which deterrents are used, researchers need to test new deterrents and fishermen need assurances they will work. There is annual variability in both fishing success and depredation rates. Unfortunately, there has to be a fairly high interaction rate in order to test different mitigation strategies. Researchers also have to make the best use of scarce research dollars when choosing which new strategies to test. It may be necessary to do a cost-benefit analysis of different strategies first.

<u>Prevention</u>
Prevention is better than cure – if a deterrence or a barrier is used initially, animals would not learn the behavior and would not be motivated to go after the catch. However, once whales know where the fish are and how to get to them, they will not be deterred by noise or barriers.

<u>Changing the pattern of the fishery</u>
If depredation is linked to the predictability of fishing, it may be advantageous to change the starting date or length of the fishing season to keep one step ahead of the whales. Over time

whales learn new patterns, so fishermen might have to change their fishing patterns from time to time to keep whales away. In general, much more information is needed on whale movement patterns and normal feeding behavior to avoid fishing in areas and at times when whales are typically present.

Conflict with other species

Evidence of conflict between killer whales and other species may be useful in developing deterrents. In the Strait of Gibraltar, killer whales disappear when pilot whales arrive in the area. This seems curious because killer whales are bigger, although pilot whales are more aggressive. There are typically 6 killer whales in a group, whereas pilot whale groups are larger (perhaps 15 or more). In Alaska, researchers have seen Pacific white-sided dolphins harassing killer whales.

Acoustics

Researchers have tried playing sounds of competitors or harassers to deter certain marine mammals from an area, but have had only limited success. Marine mammals habituate to underwater sounds fairly quickly. This may be because the sounds don't mimic real life very well, in terms of the variety of sounds or the context that the sound is being used in. Sound devices in general don't seem to work in the long term. Note that this subject is discussed in much more detail in the workshop summary on acoustics.

Shooting

Some fishermen have shot at marine mammals in the past, but it is no longer an accepted practice and to a large degree fishermen have learned to live with depredation and loss of catch. It may not be a good situation, but at least in some fisheries the problems are manageable.

Government regulations

In some areas, the ideas that fisheries managers have come up with have not been taken up by fishermen voluntarily. These include communication between captains and not dumping offal. It may be more effective to put regulations in place so that fishermen comply with these avoidance techniques. If marine mammals are to be trained to avoid fishing vessels, it will require 100% compliance from all who are fishing in the area.

Suggestions for future research:

Develop a better understanding of the problem through baseline observations and analysis of existing data. More information is needed on the depredators (food habits, movement patterns (in time and space), population distribution and abundance, the age and sex of animals that are depredating). If possible, identify individuals using photos to determine if it is the same whales depredating.

Know the fishery well and ensure that realistic data describing the fishery is being collected. An understanding of where and when fishing takes place, and how the fishery has changed over time may provide insight into why depredation is taking place. Solutions may depend in part on how adaptive the fishery is. Is it flexible in terms of timing, and can fishermen stop fishing if whales are present?

Acoustic studies may provide some keys to avoiding depredation. These are elaborated on in Workshop 6.

Develop a better understanding of the impact of discharging offal and/ or discarded fish on depredation. Whales are learning to feed near boats (through positive reinforcement), which is then prompting depredation.

Develop a better understanding of the impact of depredation on the social structure, group size and dietary habits/preferences of whales. Are there potential effects on fitness, parasites, hunting abilities, disease resistance on whales, or on the carrying capacity of the area?

Consider the impact of interactions between depredating species and their possible implications for deterrence.

Use video equipment or acoustic recorders or echo-sounders to learn more about the ways that depredation occurs.

Suggestion for managers
Provide education and awareness amongst fishermen/stakeholders in different areas, and facilitate communication between and within groups of managers, fishermen, scientists, and other stakeholders directly involved with the problem.

Management solutions should be considered in the context of ecosystem management. For example it may be possible to allow for full retention of valuable species. The fishery needs to be managed adaptively.

What are practical solutions that fishermen can apply immediately?
Be aware of the presence of whales, using visual observations, hydrophones, acoustic detection, etc.

Do not provide any positive reinforcement (no intentional feeding and no discharging offal or discarding fish in the presence of whales across fisheries). Although some fishermen have found it beneficial to do this, it is a short term solution that causes more problems in the long run.

Reduce engine noise associated with fishing.

Stop fishing when depredation is taking place.

Share information amongst the fishing community about what works and where the whales are at any given time.

Use shorter lengths of gear so that it can be hauled more quickly.

Actively monitor the situation, such as through the placement of observers on board (although this may present some challenges because some fishermen may be reluctant or unable to accommodate an additional person on board). The observers need to be well trained on species identification and behavior. Observers must also be able to generate data in a useable form – i.e., there must be a user friendly data collection scheme.

What are measures/applications that DON'T work?
Although acoustic alarms may be effective in the short term, the workshop participants do not believe that they are a long term solution once depredation behaviours are well-established. Habituation is almost inevitable, given that marine mammals are intelligent and behaviourally flexible and fully capable of learning that the impact of alarms is outweighed by the benefits of extra food.
Discharging offal in the presence of whales does not work in the long run, it makes the problem worse.

Workshop 2: Insights into the prevention of depredation from knowledge of whale behaviour and impacts of depredation on whale populations

Leader: Lance Barrett-Lennard
Rapporteurs: Caitlin Rodwell-O'Connell and Kathy Heise

The primary purpose of this workshop was to allow researchers and fishers to jointly discuss strategies for reducing or preventing depredation based on ongoing behavioural research and real-life observations of depredation. The workshop participants also briefly discussed the potential impact of depredation on whale populations. They agreed at the outset that the complex social behaviours of killer whales and sperm whales likely affect how depredation occurs, and that not all members of a population should be expected to respond in the same way to the opportunity to depredate. They also agreed that since both species have strong behavioural traditions, once a behaviour (such as depredation) becomes entrenched in a population it is likely to be difficult to change.

What do we know about whale behaviour that makes them likely to depredate?
Both sperm whales and killer whales have very good underwater hearing, and they also use echolocation to help them acquire information about their environment. Since light transmits relatively poorly in water while sound propagates efficiently over great distances, whales generally rely on hearing more than they do vision. They are able to distinguish the sounds of different vessels, and can associate certain sounds (such as those produced by hydraulic winches) with certain activities (such as hauling gear). Thus it is very hard for a vessel to hide its activities from whales. It is known that many of the bottom fish depredated by killer whales are hauled up from depths exceeding the whales' maximum dive range, and that it therefore provides a resource that they would not otherwise have access to. Whales are capable of learning complex behaviours such as techniques for removing fish from gear with minimal risk of injury. Both species are capable of learning such techniques from other members of their social group, so that once developed by one or a few individuals, the behaviours can spread.

Where does depredation occur?
Depredation occurs in areas where whales occur naturally. Depredation seems more likely to occur in areas where whale populations are growing, compared to areas where whale populations are in decline.

Some fishermen noted that when they fish in gullies, they are not bothered by whales. The reason for this was unknown. If they fish in shallower areas, they are more likely to be depredated.

Why does depredation occur?
Depredation occurs because whales are rewarded with food, particularly in areas where fish abundance is low or high quality fish are difficult to acquire.

Both killer whales and sperm whales can use echolocation to obtain information on the size and species of fish on the line.

How do whales detect fishing activity?
As described above, whales appear to use sound to locate vessels that are actively fishing. They recognize vessel noise and hydraulic noise. Some fishermen have spent a great deal of money trying to make their vessels quieter, but it has not significantly reduced the frequency with which they are targeted by depredating whales. This apparent contradiction may be explained

if whales cue in on cavitation sounds produced by vessels accelerating or hauling at high power, since these sounds are intense, travel great distances, reliably indicate fishing, and cannot be reduced by insulating engine compartments, uncoupling mechanical devices from the hull, etc.

Sperm whales appear to depredate any vessel fishing in the area, without showing preference for a particular vessel. This may be because all of the vessels respond in the same way to depredation, ie they continue to haul their gear. It is possible that if some vessels stop hauling their gear, or drop it back into the water, sperm whales will learn to start targeting only those vessels that continue to bring fish on board. This would be a worthwhile research project.

There is a general feeling that killer whales recognize boats from one year to the next, and some fishermen feel that they recognize individual humans. They do interact differently with different vessels, for reasons that are not known.

Sperm whale sounds travel further underwater than vessel noise, suggesting that fishermen should use hydrophones to detect sperm whales, and only set when they cannot hear them.

How do whales interact with the gear when they are depredating?
It seems as if killer and sperm whales interact differently with fishing gear. Killer whales appear to be more conservative than sperm whales in terms of the risks that they will take to remove a fish from the line. It is likely both species use a variety of methods to remove fish from the line.

Despite their size, video footage shows that killer whales are capable of very delicate precise movements, which allows them to quickly take fish off the line. They do not damage the fishing gear when they do this.

Video footage from Alaska shows sperm whales raiding longline gear, and the line did not move when fish were taken, suggesting that sperm whales suck the fish off the line. Since they have massive tongues, it is possible that they could create enough suction to do this. Sperm whales do damage the line occasionally.

Sperm whales also tug on the gear. It is possible they can ‘twang’ the gear (pull hard on the line and then release it) to shake fish, particularly soft-mouthed species such as blackcod (sablefish), off the line. In Alaska when a line is ‘twanged’, rockfish float to the surface, although they are not taken by the whales. Perhaps sperm whales consume other more desirable species.

What effect does depredation have on whale populations?
Depredation is not known to have had population level effects on killer or sperm whales. In the long run, however, food augmentation may lead to increased population size and/or dependency. On the other hand, injury from depredation or depredation deterrence could reduce whale numbers. In the early 1980’s in Prince William Sound black cod fishers shooting at depredating killer whales caused a number of serious injuries but had little success in reducing depredation.

What does NOT discourage depredation?
Retaliation appears to have little affect. As noted above, even shooting does not generally prevent depredation---it simply encourages the whales to be more evasive and to surface further from the boat.

Suggested Future Research Actions

Examine whether electricity could be used to deter whales from taking fish while the lines are being hauled (it would probably deter fish if used while fishing).

It is possible that if some vessels stop hauling their gear, or drop it back into the water, sperm whales will learn to start targeting only those vessels that continue to bring fish on board. It would be worthwhile to test whether sperm whales respond to this change in human fishing behaviour.

Workshop 3 :Implications of depredation for fishers, fisheries management and fish conservation
Leader: Marilyn Joyce
Rapporteur: Emma Pethybridge

This workshop focused on the implications of depredation for fishers, as well as for fisheries management and conservation. The most significant implication for fishers are the economic losses associated with the loss of their catch, but other consequences such as time loss and stress were also discussed. In fisheries where depredation occurs widely, managers are potentially faced with the need to incorporate losses due to depredation in their stock assessments. Improved data collection methods that describe and quantify the extent of depredation are key to developing effective management strategies to address the issue. It is also important that the species that is depredating is clearly identified, since there is little point coming up with management strategies for killer whales if it is in fact sharks that are doing the damage.

IMPLICTATIONS OF DEPREDATION FOR FISHERS:

Lost or damaged fish
When depredating, both killer and sperm whales may take the entire fish off the line, or leave the heads on the line. Killer whales may also leave rake marks on fish, thereby reducing their economic value. Economic losses associated with lost or damaged fish are the biggest problem that depredation presents to fishermen. The type of damage to fish can vary from year to year (within the same species of predator doing the damage).

Damage to fishing gear
In some areas, whales take both fish and gear, whereas in others the hooks are straightened or only the heads remain on the hook. For many fishers, the loss of fishing gear is considered to be a negligible cost relative to the loss of fish. Some fishermen reported seeing depredating whales with lures hanging out of their mouth, so these are obviously not a significant deterrent.

Frightening target species
For some species, such as tuna, predators such as pilot and false killer whales will cause them to react, which can lead to gear damage. Killer whales do not appear to frighten black cod, but do cause Chinook salmon to react. However when fish are not being caught, it is difficult to determine whether the fish are simply not present, are being affected by the presence of predators, or are being captured by the depredators before the gear is brought on board.

Lost time and increased costs
Depredation results in a general increase in fixed costs associated with fishing less efficiently (bait, fuel, wages, insurance etc.). If fishing is being done during restricted periods of time, there may be costs associated with losing gear due to increased risk taking. If gear needs to be dropped in order to avoid feeding the whales, this also extends the time needed to fish and therefore increases costs.

Stress
Losing fish to depredating whales is demoralizing for the crew, particularly because it is difficult to ‘outsmart the whales’. They feel pressure to make decisions without having enough information or knowledge to solve the problem. If the fishing period is extended this also adds pressure to the family lives of crew members.

Negative publicity
Fishermen are concerned that there may be negative publicity around depredation, and they do not want to be perceived as threatening populations of whales. Entanglement or accidental hooking that may lead to mortality of depredating whales is also a concern. There needs to be more education on acceptable practices to deter whales. There was acknowledgement that there needs to be more communication between researchers, managers and regulators, but this presents a bit of a conundrum because this may invite a mandate to fix the problem at a time when there are not yet clear solutions. However there may be a time when fishing companies or their products could be eco-labelled to show that the fish were caught using best fishing practices.

Safety concerns
Depending on the situation, there may be issues related to safety, particularly if it is necessary to change fishing seasons to avoid times when whales may be present. An entangled whale may also pose a risk to the crew as they attempt to disentangle the whale. As whales become more habituated to boats, they may put the crew or themselves at risk.

IMPLICATIONS OF DEPREDATION FOR FISHERIES MANAGEMENT AND FISH CONSERVATION
There were several key questions that may influence how fisheries affected by depredation are managed.

1) Are the depredators taking natural prey or are they switching?
2) How well understood are the population dynamics of the depredated species?
3) Can the depredation be quantified easily (ie are heads being left or are the hooks simply empty?

If the whales are depredating species that they normally prey on, then to some extent the depredation may be a component of natural mortality. Knowledge of the natural diet of depredating whales is helpful in this regard. If the whales are taking species that they normally wouldn't prey on, this additional mortality needs to be incorporated in population models to avoid the risk of overfishing.

Knowledge of what changes may be occurring in both the depredator and the prey populations is also important. For example, are whale numbers increasing and /or are fish populations declining, and is this driving the whales to depredate?

Establishing methods for quantifying depredation is a challenge for managers, and is the focus another workshop at this symposium. It may be done in a number of ways. For example, the SEASWAP program in Alaska involves fishermen reporting depredation events through both an observer program and through log book data. The observer program is probably the best way to collect data but the program isn't always feasible. An alternative method that is being tested may be for cameras to be placed on board. The costs associated with such programs may be paid by the fishermen, or shared across the fishery.

Better data collection is key to understanding the locations and extent of depredation, and fishermen need to be convinced that the data that they help to collect are valuable. It may even be worthwhile for fishermen to be given cameras so that they can document individual depredating whales. Areas where depredation are not occurring also provide meaningful data in establishing baseline levels. Collection of data also has positive public relations benefits by being able to show that fishing practices are "in good order".

Workshop 4: Reducing or eliminating depredation through gear modifications

Leaders: Greg Beam and Nellie Warner
Rapporteur: Emma Pethybridge

The focus of this workshop was to discuss gear modifications for pot fisheries, demersal longlining, pelagic longlining, and sport fishing that might reduce depredation. Different fishing methods were discussed, including where the gear was used and in which fishery. We made an effort to develop gear modifications that could be beneficial. We did not exclude ideas based on cost or safety which allowed even the most radical ideas to be recorded. Additionally, we did not consider prohibitions by marine mammal protection regulations in our brainstorming session.

Pot fishing gear

Pot gear is a fishing method in which baited mesh pots are deployed from a vessel and allowed to soak on the bottom. Fish as large as or greater than the legal size swim in and cannot exit the pot. This type of fishing is commonly used in the Aleutian Islands in the North Pacific, Southern Ocean, British Columbia and Australia. The main advantage of pot gear is its efficiency as quotas can be filled in a very short time. In some areas switching from longlining to pot fishing has resulted in higher yields. The gear is inexpensive, although the cost of switching from longline to pot gear can be prohibitively expensive. Vessels need to be modified to hold pots and more crew are needed to deploy them. The disadvantages of pot gear are by-catch including non-targeted species and undersize fish, as well as loss of gear on the bottom. This “ghost gear” can lead to difficult snarls with longline operations and the two methods usually cannot be employed in the same fishing area.

Around the Falkland Islands there have been experiments with the use of demersal longlines and pots in the Patagonian toothfish fishery. Depredation of pot gear in the Southern Oceans currently does not occur. Some fishermen report significant by-catch problems and entanglement issues with seals and whales. In Australia marine protected areas determine the type of fishing gear to be used in each area. Currently depredation on pot gear is minimal. In Canada pot gear is used to achieve a reasonable yield and decrease rock fish by-catch with the objective of eventually using pot gear to catch halibut. Evidence of depredation in the North Pacific includes sperm whales following pot vessels and eating discarded by-catch, and possibly killer whales crushing pots to steal catch.

Improvements and modifications of pot gear to reduce depredation mainly focus on reducing by-catch and include thickening escape rings and dumping offal away from the fishing grounds. Fishermen report that the size of the average fish caught is decreasing which leads to a greater need to minimize the catch of undersize fish through alterations of escape rings. Dumping offal away from fishing grounds severs the positive feedback whales receive when they associate with vessels that dump food in front of them.

Possible changes to methodology and equipment include the use of live bait, reduction of soak time to limit the amount of time available for mammal interactions, and the use of excluder bars. Comparing depredation rates between longlines and pot gear with excluder bars was proposed. Large scale solutions such as re-designing fishing areas with fewer boats and re-allocating quotas may be possible but will vary regionally with respect to bathymetry, stock size, politics, and current fisheries. In general pot gear does

not experience the quantity or severity of depredation that are seen in longline fisheries, but it is still valuable to examine the fishing method for any possible mitigation methods to reduce depredation.

Demersal longline fisheries

Demersal longline fishing employs the use of a ground line with attached hooks that, like pot gear, is deployed by a vessel and allowed to soak for the desired amount of time on the bottom of the ocean and then retrieved hook by hook. Different methods are used to attach hooks and spacing distances can vary. The advantage of demersal longline fishing operations includes lower environmental impact compared with other commercial and industrial fishing methods. The disadvantages of longlining can include costly gear losses when line becomes snarled or tangled and must be cut, and occasional entanglement of marine mammals due to depredation activities.

Demersal longline fishing operations exist in most of the world's oceans and experience widespread depredation. A variety of animals, including killer whales, sperm whales, pilot whales, elephant seals, sharks, etc. may depredate, but species vary both spatially and temporally. It can be difficult to determine how much catch is lost due to depredation because gear sits on the bottom and it is not clear if fish are consumed, or lost due to snagging.

Strategies to reduce depredation

Three main strategies emerged during this session and include:

1) deployment of alternative types of gear with physical modifications,
2) change of vessel and operator behavior to reduce acoustic clues for animals, and
3) regulatory changes to reduce the amount of time and space animals and fishing operations share.

However, it is important to remember that any strategy to reduce depredation needs to be evaluated in terms of harm to whales, ocean pollution, and elevated by-catch rates. No ideas were excluded from this discussion with regards to these concerns.

<u>Modifications to demersal longline gear</u>

Gangion length

Currently one third of halibut fishermen use gangions or clip on gear in the North Pacific while only a few vessels in South Georgia do so. It is possible that clip on gear may be somewhat of a deterrent to whales, although gangion was found in the stomach of a killer whale. Experimentation with gangion length may shed light on the acoustic clues that are used by depredating whales.

Floating the longline

Floating a longline off the bottom may allow the continued use of traditional longline gear with attached hooks. Floating the line reduces the chance of snagging fish on the bottom which would help quantification efforts. Unfortunately a floated line takes longer to sink and raises the risk of bird by-catch. Australia enforced 25% observer coverage when floated longlines were on trial to look for potential increases in bird by-catch. It was found that birds were not at a higher risk but there was an increase in grenadier by-catch (a non-targeted fish species), which may be in part due to its high abundance that year.

Friendly octopus
In the Ross Sea fishermen are experimenting with a longline gear set-up called the 'Friendly Octopus' which was first used in the Falklands with some success. This method uses a mother line with lines coming off- like a traditional longline- but then each line has two additional lines stemming off. The intersection line that is attached to the mother line has dangling ropes attached to it so that when the line is being hauled the ropes shield the baited hooks. The whales don't like the hanging ropes and it deters them from trying to remove fish.

Moving crucifier
A variation of the Friendly Octopus is to use a cage that encases the fish. The cage is attached to the line at the vessel when it is time to haul and it would slide down the line and shake fish into it. When the 'Moving Crucufier' reaches the end of the line it would be hauled up and whales would not be able to pick fish off as they are hauled. If the cage could not support an entire set, it may be more effective and efficient to use multiple cages or a fixture that would clump sections of the line. The bushel method may increase the difficulty of depredation. Any of these methods could be used in conjunction with a weighted mother line that would disguise or reduce acoustic clues that reveal the presence of a line in the water.

<u>Additions to the longline brainstorming session: Modifying gear</u>
This discussion was a brainstorming session and no ideas were excluded, nor did we constrain ourselves by considering proposals that would be prohibited under any marine mammal protection regulations.

1) Visual deterrence methods include adding flashers or snarls. Adding a piece that would flutter would change the sound the line makes in the water and may give fishermen a window to fish without experiencing depredation before the whales adapt to the new sound.
2) Lines could be outfitted with firecracker-type devices that could ping when a whale got too close. The cracker could be heat sensitive so that it would go off only when warm-blooded mammals approached.
3) The suggestion of placing a J-hook every ten hooks and attaching a chili pepper dart generated a lot of conversation.
4) Soaking the line in a solution that repelled whales, as has been used for sharks.
5) Knots of rope or spacers added periodically to the line could prevent sperm whales from "flossing" the line, thereby stopping the whale from knocking off fish as the line runs up inside its mouth during hauling.
6) The addition of dummy hooks to a line so that fish are only present on every other hook.
7) Acoustically it might be beneficial to set a turbine next to a longline that could create turbulence and hide the sound of the line.
8) Place a robot next to the line to be used to guard the line through visual or acoustic tactics by remote control.
9) If killer whale depredation is the main problem hauling the line through the hull of the boat can be effective not only for killer whales but also for bird avoidance. This 'Moon Pool' set up has been tried in South Georgia.

<u>Modifications to Vessel Operator Behaviour</u>
Acoustic signals attract whales to longline operations, and changes in hauling speed and vessels shifting in and out of gear are cues that whales associate with access to fish. Experiment with reducing these sounds may help to reduce the ease with which whales discover fishing activity.

Leave the fishing grounds before dumping offal.

Experiment with the type or distribution or weights may be worthwhile. Longlines are weighted every 40 m, and these weights need to be removed which takes time therefore increasing a whale's opportunity to depredate. Generally the last portion of the longline to be hauled experiences less depredation, likely because the line is straight. Lines that are curved or have a bow (due to currents) as they are hauled likely make it easier for the whales to depredate. Straightening the line with anchors or different weight patterns may change the line trajectory and reduce depredation.

Regulatory Changes

Using regulatory changes to reduce depredation lowers the amount of time whales are in the same vicinity as fishing operations. Shortening seasons and therefore not fishing year-round teaches whales that depredation on fishing gear is not a reliable food source. In Alaska there are relatively few depredation incidences from February through May, but increases in June and July. Ending the season earlier in the year may reduce depredation, although the weather can make fishing more difficult. Splitting the season such that there is a break during historically high depredation months may also prove effective.

Pelagic longline fisheries

Pelagic longlining occurs in the swordfish fishery in Brazil and also in the Indian Ocean. Some of the first cases of depredation were reported in the tuna fishery in the South Pacific. The South Pacific is especially complicated because of new, fledgling countries with overlapping territories, and little assessment or regulation ability. The issue of depredation is further complicated by the presence of large fishing fleets from Korea and Taiwan in the area.

A major difference between demersal and pelagic gear is that demersal gear is mostly depredated upon during the haul, whereas pelagic longlines are depredated at other times. It is not always possible to see the animals depredating the line when it is pelagic - it may only be noticed at the end of the haul. In general deeper lines usually experience fewer depredations than shallower lines, but this varies by target species and location. In pelagic longlining the rate and incidence of depredation is affected by whether the gear is set inward or outward of the continental break.

Modifications to Pelagic Longline Gear

There are many potential gear modifications from demersal longlining that can be applied to pelagic longlining. Additionally, the majority of participants in the discussion had demersal longline backgrounds. Along with the need to evaluate gear modification for the effects on whales, by-catch, and pollution, it was also necessary to consider how changes in gear may affect the marketability of the targeted species. Especially in tuna fisheries, the quality and condition of the catch when brought to market is critical financially for fishermen. For example, the length of the gangion has a measurable effect on the quality of tuna for the Japanese sashimi market.

Suggested modifications include shortening the main line to reduce the amount of gear in the water and shorten hauling time. Hauling and setting different lines at full speed has been tried but it is potentially dangerous because there is little time for fishermen to rest. Experimenting with hauling and setting times may be effective to determine if depredation is more likely to occur during dark or light hours. However, in

Brazil, when the fishery focused on new target species, the hauling and setting times had to change, but before long depredation started again. Hook spacing and vessel operation techniques as discussed for demersal gear have the potential to reduce depredation. Switching to a rod and line fishery or pot gear would be impossible because the size of the fish caught can reach up to 80kg.

Trolling and sport fisheries

Trolling and sport fisheries operate on a smaller scale than longline and pot gear operations. In recent years depredation on commercial and sport troll gear has increased in British Columbia. The outside lines, those that run farthest abeam of the boat, suffer the most amount of depredation presumably because they are farthest from the vessel and therefore there is less gear to get snagged or caught up with. The only solution being employed to date is to pull the lines when whales are present. Possible gear modifications include using a dummy line outside the outside line without gear to protect inner lines from depredation or run shorter lines that end closer to the vessel. Overall, the same need to increase our understanding of the process of depredation exists for sport and commercial trolling fisheries.

Workshop Notes: Methods of depredation deterrence: passive, active, temporal/synchronicity

Leader: Tory O'Connell
Rapporteur: Chris Lundsford

This workshop focused on methods to deter killer whales depredating longline and troll gear, sperm whales depredating demersal longlines, and pilot whales and other small cetaceans depredating pelagic longline gear. Passive and active methods of deterrence, the timing and synchronicity of the fishery, and trying to identify knowledge gaps that need to be filled in order to successfully deter whales from depredation were the main discussion points. Understanding how whales interact with gear was identified as a major knowledge gap.

Killer Whales and Demersal Longline Fisheries
When killer whales depredate longline gear, there are often a number of whales and they can be extremely efficient at removing fish off lines. Below is a discussion of methods of deterrence that have been attempted and their varying degrees of success, as well as ideas that may be worthwhile testing in the future.

Change the timing and/ or area of the fishery
It may be possible to change the timing of the fishery so that there is an abundance of preferred prey for killer whales. This was done in Prince William Sound, Alaska. The sablefish season was changed to the month of August, when chinook salmon, the preferred prey of killer whales, are in abundance. This reduced depredation on longline gear (see Matkin abstract, this symposium, for more details).

Changing the area of the fishery has had limited success in some areas, and yet not in others. In Australia, traveling 160 km was effective. In Alaska, fishermen had to move at least 115 km but did achieve limited success.

In British Columbia, killer whales began depredating salmon caught using trolling gear during a year when the fishing fleet was heavily concentrated in a small area. The whales learned they could easily travel from one vessel to the next. Dispersing the fishery over a larger area would reduce the rate at which whales depredate.

Long distance changes in the location of the fishery were tried in the Crozet Islands, but unsuccessfully. This year-round fishery was moved 550 km away from the old grounds, but killer whales quickly moved to the new area. Killer whales are able to hear and easily follow vessels as they move around. That said, participants felt that a spatial and temporal change may be a short term solution to the problem.

Visual cues
Hiding flags that mark the ends of the longline did not work.

Magnetism, electrical fields and currents
The group also discussed the use of magnets or electrical fields or DC current to deter whales. More research needs to be done to determine whether any of these would be feasible and effective deterrents. Studies could be done on captive whales to determine what thresholds would be necessary to generate an effect.

Acoustic deterrents

Underwater sounds may be useful in deterring whales, but much more research needs to be done. Commercially available sound sources such as the Orcasphere have been used to deter whales with limited success (see abstracts by Brotons et al., Dyb, Karyakin this symposium). Suggestions were made to incorporate squeaky 'toys' which make a sudden noise may provide a temporary deterrent. There was some feeling that turning on a sound source that produced white noise in response to whale sounds may be most effective, although at this point this technology is difficult and may be cost prohibitive. Information would also be needed as to what thresholds might be needed.

In Spain, killer whales leave when pilot whales are heard in the area. It might be possible to play pilot whale sounds to spook killer whales, but likely they will quickly habituate to the broadcast sounds. Playing sounds of killer whales from a different area is not recommended, since in the past killer whales have reacted strongly (ramming the boat) to the sounds of whales that are not part of the local community.

If a whale was tagged and tracked it might be possible to co-ordinate the use of acoustics such that sounds would only be broadcast when whales were within a certain range. This would reduce the rate at which whales become habituated to the sound.

Sperm whales

Unlike killer whales, generally there are only a small number of animals that target a vessel to depredate. They may also be less efficient than killer whales at taking the fish off the line.

Changes in fishing methods

During longlining depredation tends to happen during the middle of the haul, which may be because the line is taut at the beginning and end of the set, whereas it has a large bow during the middle. It is possible that the orientation of the fish may make them easier to remove in these circumstances. There may be modifications to the line that could be made to reduce the bowing of the line such as placing weights between the skates, which may make the line harder for the whales to manoeuvre around.

Reduced soaking time may reduce the probability of an interaction and changes in the spacing of the hooks may be worthwhile to experiment with. Deep shorter sets can be very inefficient – so there may be a happy medium where the sets are short enough to decrease depredation without being too inefficient. Experiments with knots in the line or the use of streamer lines may be worth trying as well.

Changes in fishermen's behaviour

In Sitka, Alaska, fishermen haul the gear as fast as possible when whales start to depredate. It may be better for them to drop their gear if possible.

There were different opinions on whether to discharge offal in the presence of whales. Some felt that it reduced the rate at which depredation occurred, but others felt that it encouraged depredation. In areas where depredation is not occurring, discharging offal in the presence of whales should not be done, since whales begin to associate boats with food.

Changes in the timing and/or area of the fishery

As per the discussion with killer whales, it may be worthwhile to change the timing of the fishery, or to develop a split season with an extended rest period in the middle of the season, when no gear is allowed on the grounds. Short openings may also be beneficial.

Summary

There is a need to understand the mechanics of depredation for both killer and sperm whales in order to most effectively develop deterrents to depredation. As well, a better understanding of the distribution of whales, their behaviour and biology is important. Avoiding interactions with whales, including not fishing when they are in the area and not discharging offal in their presence are key factors in deterring whales, although these may not always be practical solutions. The use of acoustics to deter whales holds much promise, both as a means to avoid depredation from happening in the first place, and in deterring it once it has begun. Much of the discussion around this was expanded in the workshop on Acoustics (this symposium).

Workshop 6: The use of acoustic information by depredating whales and implications for deterrence
Leader: Aaron Thode
Rapporteur: Aaron Thode

Better insight into understanding how whales use underwater sound is critical to our understanding of how whales depredate fishing gear, and to find ways to deter them from this behaviour. Whales may acquire information about their environment 'actively' by putting sound into the water, such as echolocation clicks, or they may do so 'passively', by listening and making deductions from what they hear. These two different methods of using sound combine to enable whales to undertake their normal daily activities. Depredating whales are able to passively listen for sounds that fishing vessels make, to determine whether or not it is worthwhile to approach the gear. As the whales move closer to the fishing vessel, they are able to use their own active mechanisms (echolocation, vision) to acquire further information. It is not possible to precisely state the distances at which whales cue in on fishing activity because the propagation of sound underwater is complex, and it depend on a number of factors such as the frequency range and intensity of the boat noise, the underwater bathymetry, the sound speed profile and the state of the sea.

In this workshop, acoustic information (sound) was divided into long, medium (1 km) and short (a few meters) ranges, and discussed accordingly. A number of research goals and deterrence methods were also identified.

Note: To better understand the role of sound underwater, it is important to remember that whales are adapted to use sound much the way humans use vision to acquire information about their environment. That combined with the fact that sound travels much further underwater than it does in air points to the need for a greater understanding of underwater acoustics.

What are the sounds that whales may use to detect fishing activity?
Engine and propeller noise, particularly changes in speed and gear, as vessels jog to stay in position, likely provide key information to whales that the vessel is actively engaged in bringing fish on board.

Hydraulic noise may provide information to whales, although in Prince William Sound, boats fishing side by side took turns hauling gear, but killer whales were able to quickly determine which vessels were actively fishing and which were simply turning their hydraulics on and off. This may reflect the difference between a boat that is actively jogging in position compared to one that is drifting.

The tapping of the line with a gaff (longliners)

Echosounders in the 28-200 kHz range are detectable by whales.

What are the long range cues that whales use to enable them to depredate?
It appears that killer whales can hear vessel noise from 50 to 70 km away, whereas sperm whales may respond to vessels within 20 km or possibly farther. Boats tend to have their own underwater noise 'signature', that can enable whales to distinguish between boats. Whales may use this information to decide whether to move towards the vessel or not. Using hydrophones to record vessel noise while it is engaged in different activities may help to provide valuable feedback as to the cues that whales may use.

What are the medium range (<1 km) cues that whales use?
Within a kilometre, whales can use echolocation to acquire information, as well as to continue to listen passively to sounds. Whales may visually cue in to the lights, particularly sodium lights, that are used in some areas (particularly Alaska). It is possible that whales may also be able to detect the radio frequencies by boats, although more research is needed.

Echolocation functions for whales much in the same way sonar does for boats: the size of the airspace determines the target strength, and can provide information on the type, size and condition of the fish that are being caught. Tangles in the line may also generate bubbles that whales may be able to detect using echolocation. It may confuse whales into thinking that a large fish is on the line, but more research is needed to better understand this phenomenon.

Sounds that whales may be able to hear passively include gear being dropped on deck, the strumming of the line (which may make different sounds depending on whether there are hooked fish or not, as well as the species of fish caught [some fish spin, others lie flat]), tangles in the line, hydraulics being turned on and off, as well as listening to the communication signals or echolocation signals of other whales.

Both killer whales and sperm whales are able to recognize different vessels, and they may also be aware of the 'fishing routine' that certain boats follow. This could be particularly true for vessels that set their lines for relatively short periods of time (due to the presence of sea lice or lack of freezer facilities on board, so that they must return to port frequently). The whales therefore stay in the area in anticipation of gear being hauled aboard because they expect to be rewarded.

What are the short range (within a few meters) cues that whales use?
Whales likely echolocate and use visual cues to detect the species and size of fish on the line. They seem able to detect when a fish is hooked in the stomach, and leave the fish alone. In some areas, such as South Georgia, whales do not depredate fish that are damaged by sea lice. As well, fish that are caught produce sounds as they struggle, which are likely detectable by whales.

Methods to deter whales using acoustics- Suggestions for further research
The group felt that some of these proposed suggestions may take years to be effective.

<u>Before vessels begin fishing:</u>
1. Visual and acoustical monitoring for the presence of whales and avoid fishing in areas/ time periods, where whales may be in area.

2. Retrofitting vessels so that they are quieter underwater. This suggestion has high costs associated with it but can be effective in reducing the distance that whales may be able to detect a vessel.

<u>Once vessels are out in the fishing grounds:</u>
1. Change vessel handling behaviour, to avoid dramatic changes in speed or gear, since these sounds transmit very easily underwater. It may be useful to measure boat noise during various stages of hauling.
2. Co-ordinate communication with other fishing vessels to the maximum extent possible. A resounding conclusion throughout all of the workshops was that it is important that there be a commitment across the fleet not to feed the whales.

3. Minimize time in the areas that are characteristic of where fishing is taking place. Do not loiter in the area unless actively engaged in fishing.
4. Be unpredictable in travel and setting patterns.
5. Use hydrophones, both remotely and on individual boats if possible, to acquire information before committing to setting the gear.
6. Set false cues, such as long lines without hooks, so that the whales begin to lose their association of longlines with food.

Possible useful actions over medium range distances (1 km) while fishing:
1. Use fake visual (and possible auditory) cues, such as dummy gear
2. Mask the presence of gear using underwater noise
3. Experiment with the echosounder on and off to see what effect if any it has.
4. Use quiet auxillary systems
5. Minimize sodium and / or deck lights
6. Retain offal and discard when whales are not in the area. Again, this is consistent with developing policies to not feed whales.

Short range solutions to be studied (within a few meters):
1. Shorten the lengths of the gangions
2. Use hydrophones while hauling to determine when whales may be in area. This may be more reliable than relying on visual sightings of whales for determining when to return gear into the water to avoid feeding the whales.
3. Develop passive acoustic reflectors that reflect sound back to the whales.
4. Develop sources of active acoustic devices* that produce
    a) sounds that mask fishing activity
    b) predator sounds, such as killer whales
    c) bubbles, or bubble sounds
    d) pinging noises

    Such work would likely need to be performed by fishermen themselves, with researchers in an observation capacity. Otherwise, obtaining permits for such work could take years.

5. Measure the frequency range and characteristics of echolocation signals used to home in on fish using underwater video and acoustic recorders on the line.

*These should be compatible with marine mammal protection regulations or guidelines within the relevant government jurisdiction.

Workshop 7: Preventing the spread of depredation and the role of discard feeding in the spread of depredation
Leader: Naomi Rose
Rapporteur: Lance

This workshop focused on understanding why depredation behaviours develop over time, and the factors that may increase the rate at which they spread throughout an area. There was a consistent message throughout this workshop that changes in human behaviours (ie the way that fisheries are conducted) will be the only way to avoid or reduce the spread of depredation. Innovative fishing methods will be required in areas where depredation is already a serious problem (as discussed in the workshops on gear modifications, deterrence and acoustics).

Discards from fishing vessels include undersize fish, non-targeted species, and offal (internal organs etc. that are removed from the fish before they are processed).

What role does discard feeding play in the spread of depredation?
The role of discard feeding was somewhat controversial in this workshop. Some fishermen felt it helped to stop whales from feeding directly on the catch. However, the general consensus was that even though discard feeding may help to avoid depredation in the short term, over the long term it was likely to increase depredation as whales became accustomed to approaching vessels and associating them with food.

The release of undersize fish presents some challenges if fishermen are trying to follow a policy of not feeding the whales. In the case of black cod it was thought that they generally were able to swim away so quickly that they were not a significant source of food for whales.

In some areas, grinder pumps are used to process offal before it is discarded, which likely reduces feeding by sperm whales, but killer whales are able to feed on ground offal. In Australia offal may not be released around the gear, and there is a strict protocol to ensure that it sinks quickly. In any area, it would be best to dump offal all at once, in order to reduce the number of possible feeding (and learning) opportunities by whales.

There is also a potential 'ripple effect' associated with discharging offal: species other than killer and sperm whales may feed on it and come to rely on its availability. This has happened in Canada where bald eagles began to rely on offal from the shrimp fishery, and when this source of food ended, the eagles attacked great blue herons causing significant declines in the blue heron population.

Which areas are vulnerable to whale depredation beginning?
- British Columbia (BC) longline fishery for sablefish (black cod)
- BC salmon troll fishery (just beginning)
- BC sportsfishery (just beginning)
- BC halibut fishery
- Southeast Alaska halibut fishery
- South Australia fisheries (due to their proximity to Tasmania, where killer whale depredation is a large problem)
- Denmark Strait, between Greenland and Iceland
- Others?
- In Australia depredation is only a problem in Tasmania, but it could spread to South Australia. Very little is known about killer whales in these areas.

Specific advice to fishermen to prevent depredation from spreading

- Don't feed the whales
- Stop fishing if possible if whales appear. It is especially important to not haul gear while they are in the vicinity
- Establish ways for fishermen to communicate with each other on the fishing grounds re: the presence of whales in the area (eg. speakers on deck)

General steps that should be taken in British Columbia to prevent depredation from spreading

A public education program is essential. Information and guidance on how to interact with depredating whales could be included in sportsfishing brochures that are issued as a part of government licensing programs. Commercial trade associations could also include information in their magazines. Encouraging the salmon troll and sports fishery to work together would benefit both. An outreach educational program that targets fishing lodges could be very useful in reducing the spread of depredation.

Why doesn't depredation occur everywhere?

Both killer whales and sperm whales are relatively slow to change their behaviours, although once they do change, the behaviour can spread quickly through the population. This is especially so for killer whales, and it is likely that sperm whales change their behaviours more slowly.

The motivation for whales to change their behaviours is reduced when prey is abundant. When favoured prey become less abundant, there is increasing motivation for the whales to change.

Workshop 8: Quantifying depredation and establishing documentation protocols
Leader: Chris Lunsford
Rapporteurs: Vicki Cornish and Kathy Heise

Quantifying depredation rates is a crucial component for assessing the impacts of depredation of fishing gear by cetaceans. Quantifying depredation allows researchers to monitor trends in depredation, estimate economic losses to industry, assess and compare depredation levels from different regions, and help evaluate mitigation efforts. This workshop took advantage of the diverse knowledge of participants and focused on developing standardized methodologies for quantifying depredation. During this workshop participants identified four components to consider when quantifying depredation rates: 1) define depredation; 2) detect depredation; 3) measure depredation; 5) standardize and report depredation.

What is the definition of depredation
In 2002, a workshop in Samoa produced a report entitled Interactions between Cetaceans and Longline Fisheries. During the Samoa Workshop, participants defined depredation in the present context as "*the removal of hooked fish or bait from longlines by cetaceans."*

While this definition of depredation is true for the majority of regions, participants in this workshop emphasized that depredation by cetaceans is not restricted to longline gear. Other capture methods, such as gillnet fisheries, have also documented depredation events.

Samoa Workshop participants concluded that the standard index of depredation rate should be defined as, "*damaged fish (number or weight) as a percentage of the total catch in a given fishery."* It was noted, however, that *"this index may underestimate the true impact of depredation because, e.g. some fish that would have been caught are scared away from the longlines, some caught fish may be stripped away entirely leaving a bare hook and therefore no evidence of depredation. Alternatively, the index could be positively biased if damage by sharks and other organisms has been wrongly attributed to whales."* Participants from this workshop suggested the index definition should be more robust and should be measured as total loss to the fishery rather than only damaged fish on the line. Total loss could be interpreted as physical loss such as damaged fish or broken hooks and/or economic loss such as value of catch or extra fishing effort.

How to detect depredation
Participants in this workshop shared their expertise and experiences to help identify indicators for detecting depredation. It was agreed that the standard index definition "*damaged fish (number or weight) as a percentage of the total catch in a given* fishery" is too limited because many depredation events do not leave evidence of damaged fish and are not easily detected.

In Alaska, killer whales often remove the entire fish from every hook or leave only lips on hooks making it easy to detect depredation. Sperm whales, however, rarely strip the entire line and evidence of depredation is mangled fish instead of bare hooks and occurs sporadically. Also, gear is occasionally interfered with and the only indicator of depredation is straightened hooks. Fishermen in Alaska also report bare hooks are commonly associated with depredation. In the Southern Oceans killer whales leave parts of toothfish on the hook but damaged fish are often not a good indicator of depredation. In pelagic longline fisheries, there is also the potential of cetaceans scaring targeted species away from the hooks and removing baits before the fish can be hooked. Discussions clearly indicated that detecting depredation is fundamental to accurately quantifying depredation. Participants agreed that most depredation estimates are likely

conservative because more depredation is likely occurring than what is evidenced by damaged fish left on the line.

Discussions focused on what observations may be helpful for detecting depredation. The most common signs of depredation are presence of cetaceans and evidence of depredation. However, evidence of depredation is not always present. Conversely, many observations have shown that presence of cetaceans is not necessarily correlated with depredation but cetacean behavior may be. Diving behavior and cetacean location in relation to the vessel may be correlated with depredation behavior and should be researched.

Participants came up with the following indicators as useful guidelines for detecting depredation:

- Presence of cetaceans
- Observed depredation (surface observations)
- Evidence of damaged fish on the line
- Evidence of damaged gear
- Gear/cetacean interactions (tugging, entanglement)
- Bare hooks
- Cetacean behavior (diving, location in relation to vessel)

How to measure depredation

Samoa workshop participants stated, *"There is a need for standard methods to quantify longline losses due to depredation caused not only by cetaceans but also by other organisms such as sharks, bony fish and squid."* To effectively measure depredation an index of catch rate must be available. The most common measurement used in fisheries is catch-per-unit-effort calculations.

For longline fisheries the unit of effort may be individual hooks or entire sets. Catch can be measured in numbers or weight and catch rates can be computed using the ratio of catch to total effort. Participants stressed caution about the problems associated with estimating total catch loss when there are difficulties in identifying depredation. This clearly supports the importance of being able to measure depredation effects. CPUE indices are not reliable if there are problems with detecting depredation. Ideally, CPUE indices should be done for sets when depredation is occurring and for sets when depredation isn't occurring to allow for comparison tests. Participants agreed CPUE analyses are useful for measuring depredation and are preferable over more rudimentary techniques.

Defining a standard measurement of depredation is challenging due to the diversity of fisheries that are affected by depredation. Ideally, gear is standardized and catch is recorded by hook such as in research studies in Alaska. More often, however, gear is not standardized and catch is subsampled or data is obtained through logbook information or skipper's estimates. Dedicated research cruises will often have better quality data than observer collected or fishermen reported data. Data analyses and measurements of depredation will be dependent on the fishery, the type of data collected, and the quality of the data. Participants agreed a standard measurement is desirable and should be pursued but is unlikely.

Discussions instead focused on utilizing ongoing studies and current data collections to help identify information necessary for measuring depredation. Depredation observations are being made in many fisheries around the world and many data collections have been developed to record depredation. Group recommendations were to make these forms available on the depredation website so interested parties could review a variety of sampling forms from a diverse set of fisheries and identify important data fields that were relevant and achievable for

their respective studies. For example, forms used for SEASWAP are for fishermen and are designed to be simple and quick and are likely adaptable to many fisheries. Several of the forms discussed in the workshop were:

Contact Person	Type of Form
Jan Straley	Alaska sperm whale
Vicki Cornish	Southeast US small cetaceans
Luciano Dalla Rosa	Brazil killer whales
James Clark	South Georgia sperm/killer whales

These should be available on the web site (www.depredation.org).

Participants reviewed several forms and came up with necessary data fields which could be used to help measure depredation:

- Cetacean presence (Y/N) and numbers present
- Measure of effort – e.g. # hooks hauled, # sets made, days of fishing
- Measure of catch – e.g. # fish caught/ weight of fish caught
- Suspected depredation and when/where it occurred during fishing operations
- Evidence of depredation – e.g. # of damaged fish, # of damaged hooks

Additional fields that should be considered and may provide valuable information to help understand depredation include:

- Deterrent techniques employed and depredation response
- Cetacean behavior during depredation
- Cetacean pictures for identification
- Gear modifications in response to depredation such as hook size or hauling speed
- Fishing locations and depredation response
- Oceanographic observations such as sea state or water temperature
- Acoustic behavior and hydrophone observations
- Fishing practices – e.g. offal discharge

To ensure the appropriate data is collected the group suggested canvassing experienced observers of depredation such as fishermen and researchers and conducting informal surveys. Proper training and experience of depredation observers was also mentioned as important components for accurately measuring depredation.

Workshop participants briefly discussed how to estimate the magnitude of loss when fish are removed or damaged. Several groups, such as the South Georgia Observers and the International Pacific Halibut Commission, have developed relationships between head size or lip width to body size to help address how much fish was lost. Incorporating these types of methods are innovative techniques for reducing the uncertainty associated with estimating losses to depredation.

Finally, the Samoa workshop *identified "There is a lack of baseline data and statistics to corroborate alleged increases in depredation rates as a fishery develops. Therefore, it is important to monitor meticulously the development of any new fishery for interactions with cetaceans."* Participants from this workshop strongly agreed and want to stress the importance of measuring catch and effort in regards to depredation even if the fishery currently has no interactions with cetaceans. Baseline data is integral to measuring the effect of depredation.

Standardizing and reporting depredation globally

Workshop participants agreed that reporting standards are necessary due to the global extent and diversity of studies addressing depredation. Measurements of depredation should be presented so conclusions can be drawn and comparisons to other studies can be made. CPUE analyses are preferable but numerous methodologies will suffice if properly defined data and information accompany the estimates. Suggested measurements for quantifying depredation and reporting reduction in catch due to depredation may include:

- catch numbers
- catch weight
- proportion of catch
- catch rates
- economic value

To successfully quantify depredation studies should define what depredation is, explain how depredation was detected, express how depredation was measured, and report all findings in a standardized format similar to other depredation literature.

Determining group priorities for research needs, gear modifications and mitigation techniques

Leader and Rapporteur: Simon Walsh

This extra session was offered fairly spontaneously, and the goal was to use the group's combined experience and knowledge to prioritise the potential options available for research needs, gear modifications and mitigation techniques.
This prioritisation process was necessary, as over the previous days the participants had generated literally dozens of mitigation options – which would be extremely costly in terms of time and money to test each alternative individually. A different approach was used in order to attempt to use the collective knowledge / experience of the workshop participants to determine the methods most likely to be worthy of further investigation.

Separate lists were produced on butcher's paper that highlighted the available options for each of the three categories (research needs, gear modifications and mitigation methods). Participants were then asked to identify their preferred top three options by placing a single tick next to them, on each of the category sheets.

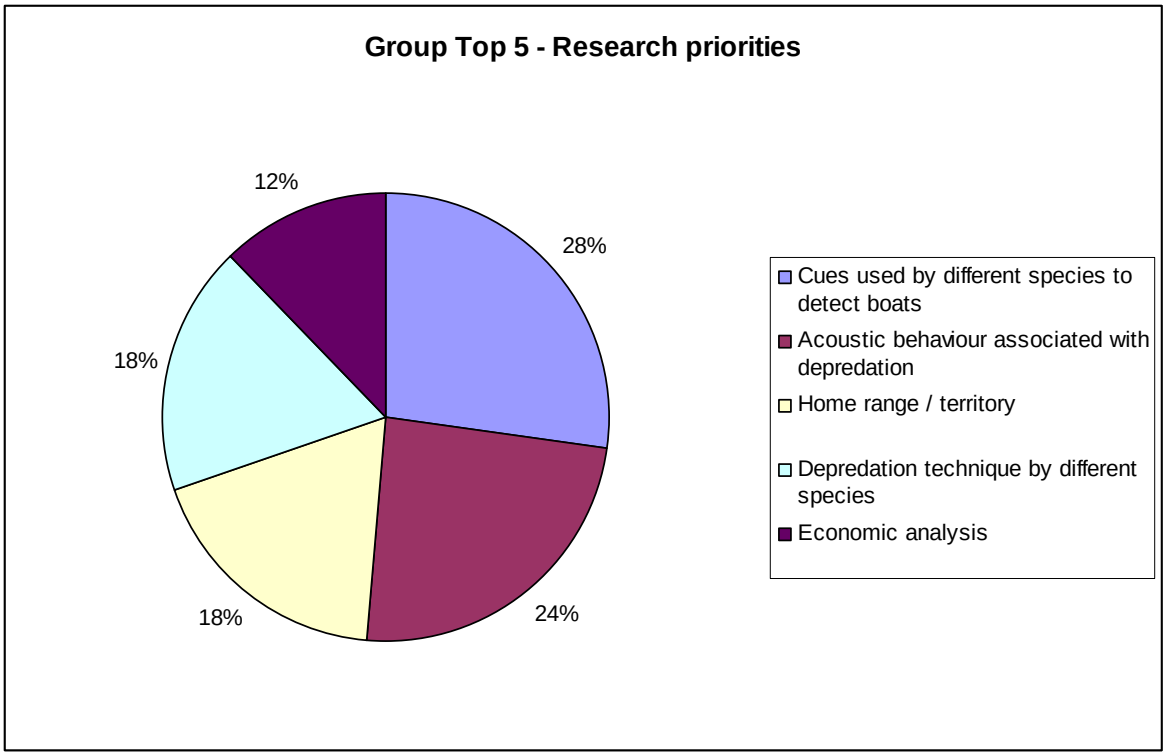
Pens were provided to do this, using a different colour to identify each main stakeholder group (blue for fishermen, green for researchers and red for managers). This enabled any distinctions between the stakeholders responses to be noted. At the conclusion of the workshop, the lists were marked by the attendees and results are shown below.

Results

The group ranked the following as their top 5 **research priorities:**

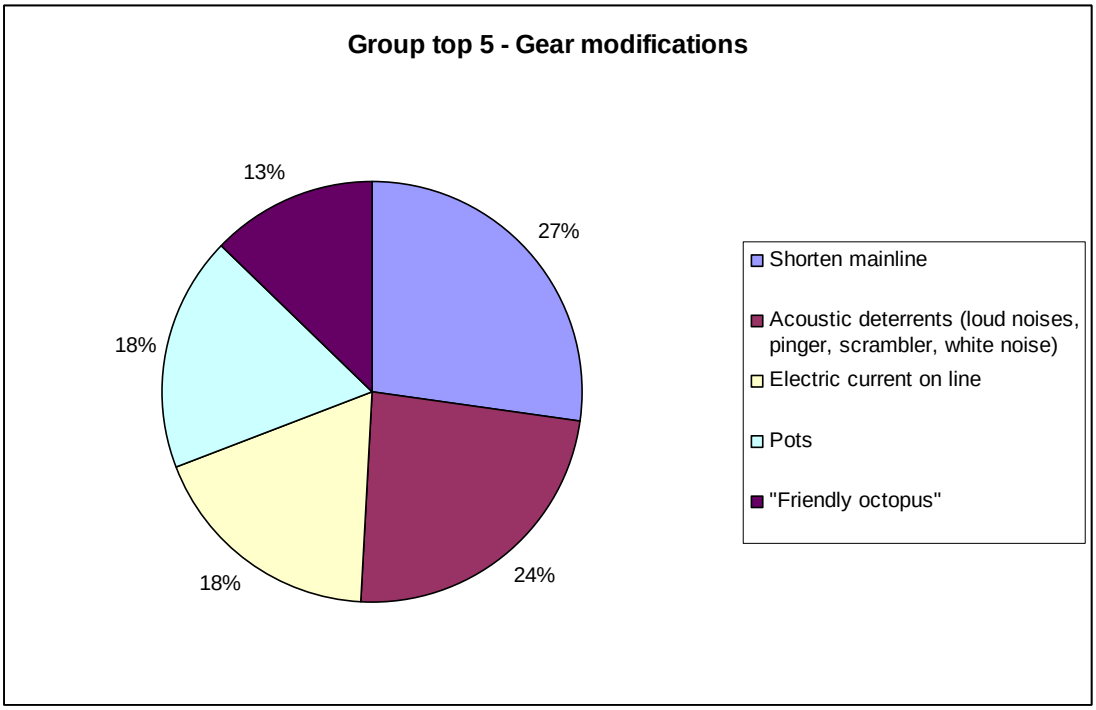
(N.B. The percentages below refer to the proportion of <u>all</u> responses; and the pie charts identify percentage as a proportion of the <u>top 5</u>):

- Cues used by different species to detect boats 16.1%
- Acoustic behaviour associated with depredation 14.3%
- Home range / territory 10.7%
- Depredation technique by different species 10.7%
- Economic analysis 7.1%



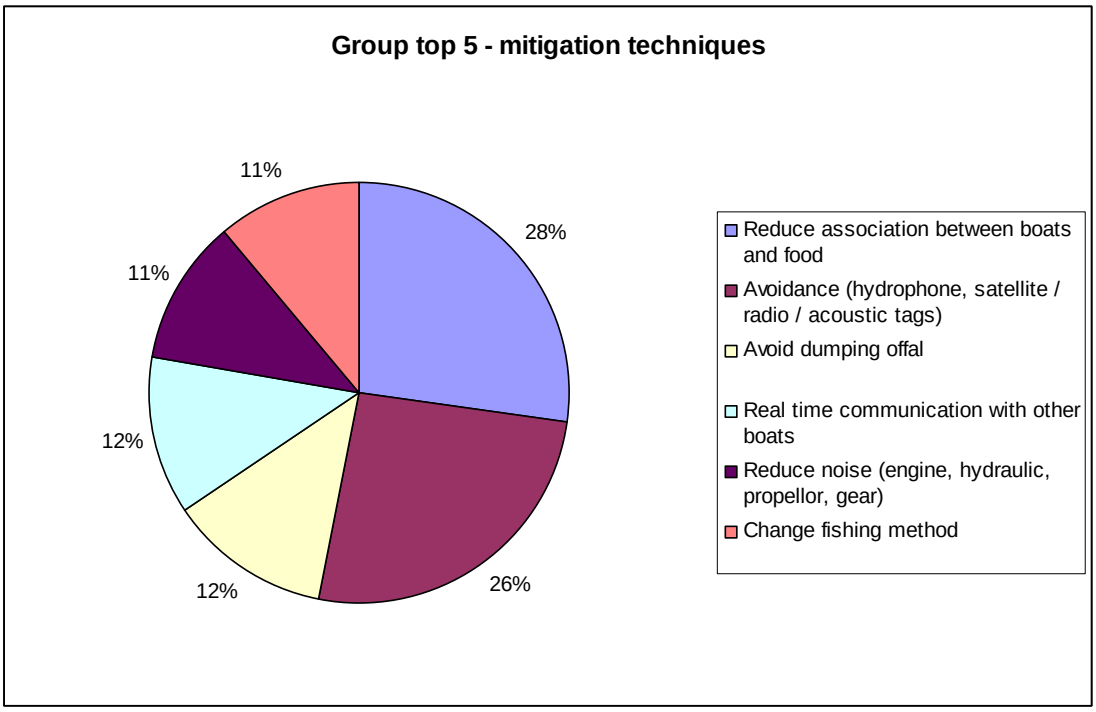
These were the top 5 ranked **gear modifications**:

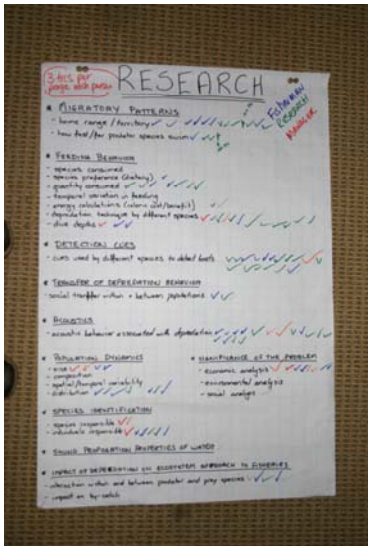
- Shorten mainline 14.9%
- Acoustic deterrents (loud noises, pinger, scrambler, white noise) 12.9%
- Electric current on line 9.9%
- Pots 9.9%
- "Friendly octopus" 6.9%



The highest priority top 5 (6 as two are equally ranked) **mitigation techniques** were:

- Reduce association between boats and food 20.2%
- Avoidance (hydrophone, satellite / radio / acoustic tags) 19.3%
- Avoid dumping offal 9.2%
- Real time communication with other boats 9.2%
- Reduce noise (engine, hydraulic, propellor, gear) 8.3%
- Change fishing method 8.3%





Example of completed tally sheet.

Relevant Abstracts

Killer whale (*Orcinus orca*) depredation on longline catches of bottom fish in Alaskan waters

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Depredation by killer whales on longline catches of bottomfish has been documented in the Bering Sea and Aleutian Islands since the mid 1960's. Fish targeted include sablefish (*Anoplopoma fimbria*), greenland turbot (*Reinhardtius hippoglossoides*), Pacific halibut (*Hippoglossus stenolepis*), searcher (*Bathymaster signatus*), and arrowtooth flounder (*Atheresthes stomias*). Predation rates vary considerable by season with an average of 20% to 25% of the sets documenting the presence of killer whales during fishing operations. Fish are either damaged or completely stripped from the longline resulting in 70-80% of the longline caught fish consumed. Although interactions with killer whales and Alaskan longline operations have been documented now for nearly 40 years, it is not possible to determine if an increasing trend in killer whale depredation is occurring since reporting within the commercial fleet has been inconsistent. Available information (to include both photographic and genetic data) suggests that several, resident pods of killer whales are involved in these interactions.

Various methods have been tried to reduce or eliminate whale depredation on commercially valuable fish. Limited success has been achieved by 1) the use of dummy buoys, 2) long-distance movements greater than 60 nautical miles, 3) temporary cessation of fishing activities, 4) changing target species to Pacific cod, and 5) the use of pot gear. Most fishermen stated that shooting, seal bombs, and other techniques were ineffective means of driving the whales away. A summary of the methods employed to help reduce or eliminate these interactions is provided in Table 1. Possible other methods to help reduce or eliminate killer whale depredation on longline caught blackcod are given in Table 2. Three important factors must be properly evaluated when considering methods to reduce or eliminate marine mammal/fishery interactions: 1) the adverse effect on the mammals, 2) the adverse effect to the fishery, and 3) the feasibility of the method being used in the fishery (gear, costs, etc). In the case of killer whales, their depredation behavior is constantly being positively reinforced by food. Food represents the strongest reward known for shaping animal behavior. To alleviate fishery interactions involving marine mammals requires a high level of effort or harassment and a long-term commitment to properly reshape, if possible, the depredation behavior. If animals are killed during the fishery interactions (i.e., no learning can take place), this would also limit the possible solutions to an even greater extent.

Table 1. Summary of methods employed to discourage whale depredation on longline catches.

METHOD	RESULT	COMMENT
Seal Bombs	Not effective	Occasionally a startled response but whales did not leave area.
Decoy Boats	Not effective	Did not confuse whales.
Blank Sets	Not effective	Whales immediately returned to vessel with live, blackcod on lines.
Dummy Buoys	Some effect	Whales occasionally lost interest and left the area.
Combined Hauling	Not effective	Whales would move between vessels.
Stop Operations	Some effect	Occasionally helped.
Night Fishing	Not effective	No apparent difference in behavior.
Short Movements	Not effective	Movements < 60 nmiles
Long Movements	Some effect	Movements > 60 nmiles; vessels would out run whales.
Change of Target Species	Very effective	Switch to Pacific cod.
Shooting	Not effective	Whales still in area.
Explosives	Unknown	Not adequately tested.
Electrical Current	Not effective	No other information.
Trap Gear	Very effective	Depredation did not occur.
Tangle Imitators	Not effective	Did not confuse whales.
Acoustic Harassment	Unknown	Not adequately tested.
Bang Pipe	Not effective	No apparent difference in behavior.

Table 2. Possible methods to help reduce or eliminate killer whale depredation on longline caught blackcod.

METHOD	COMMENT
Sparker Devices	Attached to gangion; emits flash of light and transient sound to startle whales.
Rubber Bullets	Irritant to whales.
Electrical Current	Electrical shock to whales.
Masking of Sounds	Interference of acoustical stimulus responsible for attracting whales to vessel.
Playback Sessions	Recorded sounds from longline operations reproduced back into the water. No food reward associated with attraction to vessel.
Bubble Screen	Interference with active/passive acoustical sense or vision of whales.
Accessory Skiffs	Deployed from main vessel into vicinity of whales causing possible visual and acoustical harassment.
Sonic Devices	Acoustic harassment in frequency range that would be sensitive to whales' hearing.
Lithium Choride/ether	Strong emetic producing vomiting reaction.
Operant Conditioning	Behavioral modification of whales. Weak signal precedes strong, aversive signal.
Management Solutions	a) Gear modifications, b) pot gear, c) seasonal restrictions (fishing in an area when killer whale density may be low), d) actual fishery closure in areas with high levels of depredation.
Multiple/Cumulate Approaches	Various combinations of above.

Experiences of the Norwegian longline fleet with ‘pingers’ and ‘scramblers’

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The Norwegian longline fleet has since the mid 90s experienced an increasing problem with depredation by sperm whales (*Physeter macrocephalus*). There was a need to both describe the problem and to experiment with gear to reduce sperm whale depredation. A survey was therefore arranged onboard a commercial longliner during the Greenland halibut (*Reinhardtius hippoglossoides*) fishery in the Greenland waters. The goal was to observe and describe the activity of the whales, and to test acoustical devices and describe their effect on the whales. The project was intended to lay the foundation for later more extensive surveys, and was mainly conducted by the crew of the longliner.

Two different types of acoustic devices were tested. One acoustic device, a pinger was attached to the longline and the other, a scrambler, was lowered and operated from the vessel. The intention was that these devices create a sound barrier to prevent sperm whales from using their own sonar. The pinger was based on pingers used in gillnet fisheries to avoid entanglement with small tooth whales. These self-sustaining units were battery operated and periodically sent out different sounds. The signals were adjusted to match the sperm whales echolocation band, and the housing was modified to handle depths down to 2,000 m. Up to five units were attached to each longline set.

The scrambler was operated from the vessel and was comprised of a ceramic transducer, an amplifier and a computer. The resonance frequency was 11 kHz, and the omni beam pattern was +/- 1dB (up to 18 kHz). The effect on the amplifier was 2 kW. Pre recorded sounds were operated from the computer. White noise was mostly used, but it was also possible to send out other sounds and sweeps continuously or periodically. It was planned that the sounds should be used systematically. But as the frustration and the number of whales increased, the sounds were used at random whenever the crew thought they might have the biggest effect.

Except at the beginning of the survey, sperm whales were observed at every station. In the beginning 2 to 4 individuals were observed around the vessel, but the number increased with time. In the end up to 15 whales were observed simultaneously. The best fishing time was the period without any observations of sperm whales. As soon as sperm whales arrived the catches dropped, and the catches decreased more or less steadily until the end of the survey. The catches were also under the influence of the acoustic devices, forcing the whales further away from the vessel and showed an effect in the beginning. The average catch number pr set without whales observed was 240 Greenland halibut pr set. When the sperm whales arrived the average number dropped to 147 and 106 Greenland halibut per set respectively, with and without the use of the scrambler.

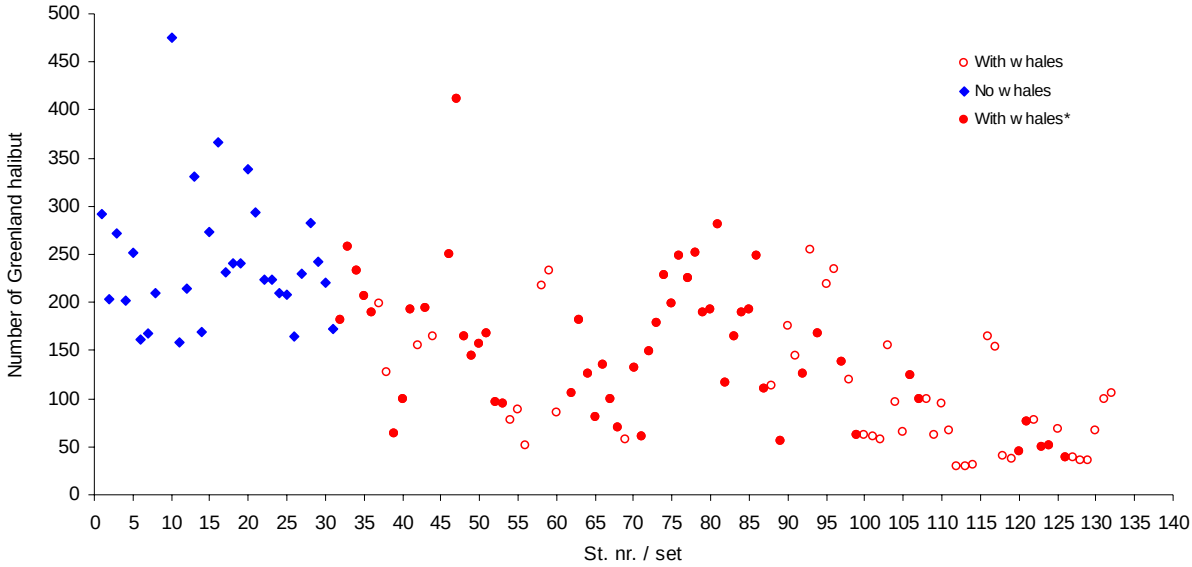

Figure 1 The catch number of Greenland halibut per set during the 30 day trip. The solid circles represent sets when the scrambler was used and the hollow circles represent sets without the use of the scrambler.

Under the influence of the scrambler the distance between the whales and the vessel was at its highest in the beginning of the trip. This distance decreased with time and by the end of the survey no difference in distance was observed with or without the scrambler. The average distance without the use of the scrambler also differed between sets, but there was no trend during the fishing period.

The fishermen found the scrambler most effective in the beginning of the survey. As soon as the scrambler was turned on, the whales came to the surface and swam rapidly away. But after a while the whales got used to the sounds and came back to the vessel. When this happened, the fishermen used a new sound and again the whales came to the surface and swam rapidly away. As in the first time, the whales became adapted to the sounds and came back. This cycle repeated with each new sound, but the adaptation time decreased with each new sound.

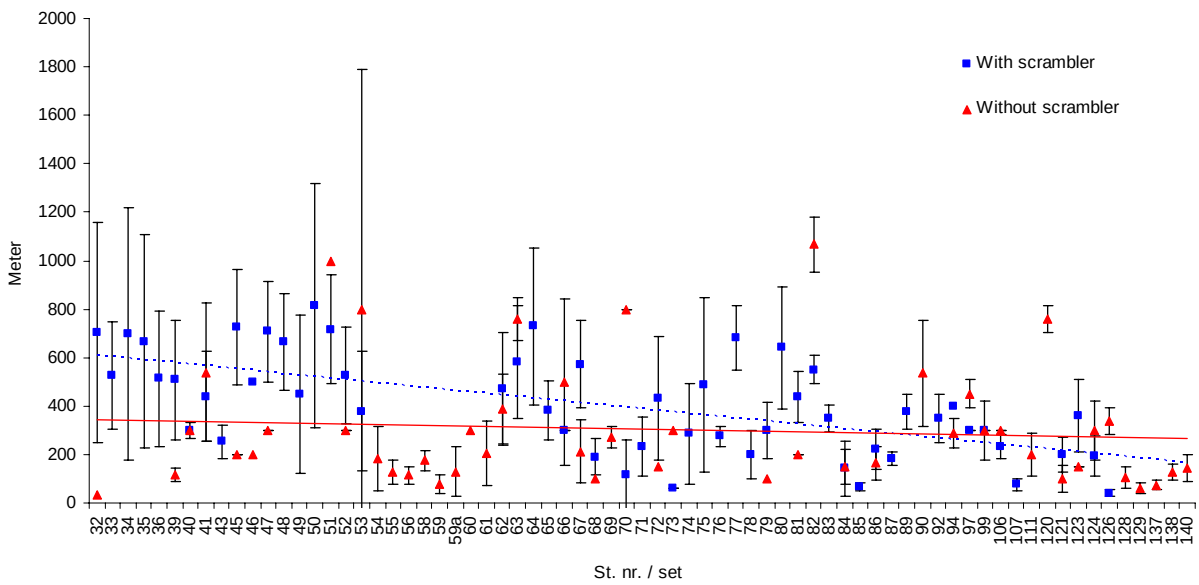

Figure 2 The average distance per set between each whale observation and the vessel. The observations are separated with and without the use of the scrambler.

It was hoped that the pingers would create a protective zone around the longline. This would lead to higher density of fish around the pingers, since whales would depredate other areas without the influence of the pingers. Pingers were also used before the whale's arrival. This period gave a significant difference in the catch in areas with and without pingers, where the catch was highest without the pingers. This indicates an effect of the pingers on the behaviour of the fish. This observation also repeated after the arrival of whales, were the highest densities of fish on the line were without any influence of pingers. On the other hand it was also observed areas on the sets completely without any fish, and no pingers were in these areas. There were always some fish around the pingers. If the pingers had an effect on both the fish and the whale, a pattern like this could be observed. But the data amount and quality were not sufficient to provide any clear conclusion.

The conclusion of the survey is that sperm whales reduce catch rates. The decrease in catch is explained by the increasing number of whales and the decrease in the distance between the boat and the whales, due to the reduced effectiveness of the scrambler. Smaller catches, especially in the beginning, would have been the situation without the acoustical gear. The scrambler was most effective, but the effect decreased by time and ended up having more or less no effect in the end. None of them worked as planned, as they seemed to have more of a 'scaring' effect then a 'shielding' effect.

Sperm Whale and Longline Fisheries Interactions in the Eastern Gulf of Alaska

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In the eastern Gulf of Alaska, depredation by sperm whales (*Physeter macrocephalus*) of demersal longline fishing gear set for sablefish (*Anoplopoma fimbria*) has occurred since the 1970s. Concern about the potential for entanglement with an endangered species and the growing economic losses to fishermen prompted ALFA to form the Southeast Alaska Sperm Whale Avoidance Project (SEASWAP). In 2003, the North Pacific Research Board funded this collaborative study among fishermen, scientists and managers to collect quantitative data on longline depredation. The goal of the study is to recommend deterrents or changes in fishing behavior to reduce depredation. SEASWAP fishermen and researchers collected acoustic, fishing, behavioral and photographic data. Acoustic findings will be presented by co-PI Thode. Fishermen recorded information on 124 sets. Researchers found fewer whales present at the set and while gear was "soaking" than at the haul. Whales were present about a third of the time at the haul and evidence of depredation was noted for 71% of these sets. When there was evidence of depredation the CPUE was significantly reduced by about 3% (t-test of difference in sablefish CPUE= -.0332, p=0.0228, 95% CI (-0.0047, -0.0616)). Genetic results determined the whales were male and 47 whales were individually photo-identified. Bayesian mark-recapture analysis estimated 96 (64, 134; 95% credible interval) whales in the study area. This study proved successful in monitoring sperm whales near fishing vessels, evaluating the magnitude of the depredation and recommending passive deterrents.

Based on these observations and the acoustic findings we have derived four low-cost depredation reduction techniques to quantitatively test in 2006: (i) circle hauls that minimize engine cycling, which seems to attract animals, (ii) deploying anchor lines that have no fishing gear attached (decoys), (iii) testing of an existing variant of fishing gear using acoustic reflectors and shortened gangions and (iv) changing the time of year the fishermen deploy their gear.

Observations of potential acoustic cues that attract sperm whales to longling activities in the Gulf of Alaska

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Various species of pinnipeds and odontocetes depredate on human fishing activities, of which the sperm whale (*Physeter macrocephalus*) is the largest documented species. While animals are known to follow vessels to deployment sites, depredating animals have also been observed to arrive after a haul begins, raising the question as to whether the animals are responding to distinctive acoustic cues inadvertently produced by the activity.In the eastern Gulf of Alaska, depredation of demersal longline fishing gear set for sablefish, (*Anoplopoma fimbria*) by sperm whales (*Physeter macrocephalus*) has occurred since the 1970s. Concerns about the potential for entanglements with an endangered species and the growing economic losses to fishermen prompted ALFA to form the Southeast Alaska Sperm Whale Avoidance Project (SEASWAP). In 2003, the North Pacific Research Board funded this collaborative study among fishermen, scientists and managers to collect quantitative data on longline depredation. SEASWAP fishermen and researchers collected fishing, behavioral, photographic and acoustic data. See Straley abstract in this workshop for details.

For the specific case of sperm whales, three prominent hypotheses for potential acoustic cues have included boat engine cavitation noise, activation of hydraulic winches, and potential low-frequency sounds produced by the fishing gear itself when hauled under strain. Passive acoustic recorders attached to longline gear deployments off Sitka have permitted continuous monitoring of the underwater noise environment, including sperm whale activity, before and during a longline recovery. Here we report evidence, based on three particular encounters in 2004 and 2005, that cavitation noise from changes in the propeller speed of ship engines is associated with changes in the acoustic activity of sperm whales, while the activation of ship hydraulics is not. No signals generated by the fishing gear itself could be detected in the data.

The interaction of cetaceans with the longline fishing industry in Samoa, South Pacific

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The longline fishery in Samoa has been subject to interactions with cetaceans since its inception around 1996. These interactions are characterised by 'dolphins' removing (depredating) bait from hooks and 'whales' depredating the catch itself.

Occurrences of cetacean by-catch through foul hooking or line entanglement appear to be rare, however most aspects of the interactions are poorly documented. Depredation impacts are mostly realised by the fishery in terms of damaged product and extra costs for fuel, bait and time; although there are unquantified reports of cetacean shooting by fishers. Exports of fish products particularly those from the longline fleet, comprise the single highest source of foreign revenue for Samoa.

A project has been established to firstly measure the scope and scale of these interactions and secondly, to trial a number of potential mitigation measures. Seed funding has been secured and partnerships developed with local, regional and international fishery organizations, conservation agencies and NGO's to tackle this issue.

The issue is characterised by a lack of information regarding the particular species involved in depredation. It is known that sharks also depredate longlines but the extent to which depredation in Samoa can be attributed to marine mammals or otherwise is uncertain. Research trips conducted by the author have shown false killer whales to be present during depredation events and rough-toothed dolphins to be actively engaged in removing baits.

Data on the amount of fish removed, and the times and areas of greatest or least depredation are unclear. An observer programme is currently under development to assist in determining the impacts of cetacean depredation in Samoan waters. A process of interviewing longline skippers combined with a review of fishermen's catch logs has also assisted in establishing broad patterns and trends surrounding the issue. Approximately 3 – 6% of longline sets are estimated to be subject to depredation activities to a greater or lesser extent.

Depredation by small cetaceans

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Our lab has a long standing interest in cetacean-fishery interactions. Recently we have been examining interactions between bottlenose dolphins and coastal gillnets, and pilot whales and pelagic longlines.

We studied interactions between bottlenose dolphins and Spanish mackerel coastal gillnets in North Carolina from 2003-2005. During this period we used a variety of methods to examine these interactions. We placed an observer aboard commercial boats and made observations of dolphins and their activities around nets, evidence of depredation and the catch of Spanish mackerel for each set. We also observed dolphins from an independent research vessel. From this platform we photographed the dorsal fins of individuals for photo-identification, conducted focal follows and deployed a hydrophone to record dolphin echolocation.

Dolphins encountered more than a quarter (26%) of all gillnets we monitored while aboard commercial gill net vessels (136 sets) and interacted with nets on most (64%) of these occasions. We observed a 38% reduction in Spanish mackerel catch when dolphins interacted with nets. Dolphins engaged in depredation typically approached the nets very rapidly and often from a distance. They spent a brief time with the net (rapid surfacing along the net's length, jumping over the net, pulling fish out of the net) and left just as quickly. The interaction typically took only several minutes. We analyzed acoustic recordings made during the focal follows and found no significant difference in the occurrence of echolocation behavior as a function of distance from the net.

In 2004 and 2005 we assessed the efficacy of Save Wave® acoustic alarms designed to reduce dolphin depredation. This was the first test of SaveWave® acoustic alarms in the U.S. We used the same methods previously described: observations from commercial boats, focal follows and acoustic recordings. The observer placed active or inactive (control) SaveWaves® on all nets each fishing day. We observed 151 sets (83 active and 68 control) and found no significant difference in total Spanish mackerel CPUE between active and control sets (p = 0.23). Observations from the commercial vessel showed that dolphins encountered control nets more frequently than active nets

(31% vs 5% respectively). Dolphins echolocation increased significantly within 500m of nets equipped with active devices ($p = 0.003$). Within this 500 m zone, echolocation was more frequent with active devices ($p = 0.0003$). Unfortunately, during the two years we tested the SaveWaves® we saw no incidences of dolphin depredation. Fishing was poor in both years and depredation occurred rarely, limiting our ability to draw conclusions about the effectiveness of the SaveWaves®. During both our commercial vessel observations and our focal follows we did observe dolphins interacting closely with both control and active nets. Given the data at hand, we cannot yet conclude that the SaveWaves® will deter dolphin depredation on Spanish mackerel gill nets.

The objective of the second project is to characterize the nature of pilot whale interactions with pelagic longlines. The longline fishermen we are working with in North Carolina primarily target yellowfin and bigeye tuna. Our work is multi-faceted. We are obtaining photo-id images to determine whether particular individuals consistently engage in depredation. We also are collecting skin samples from pilot whales to determine which of the two species (short or long-finned) interacts with the longline gear. We also plan to conduct focal follows of pilot whales around longline gear. A major component of our research involves placing acoustic recording equipment on longlines to document when in the fishing process pilot whales engage in depredation.

We completed a successful two-day trial research cruise in September 2006. There were no longline vessels working in proximity to us during these two days, so we were not able observe whales in association with fishing gear. We had three sightings of pilot whales and made acoustic recordings of each group. We collected six biopsy samples; all the whales were short-finned pilot whales. In addition, we took 590 digital images for photo-identification; many of the whales had very distinctive fins. Finally, five longline vessels are currently deploying acoustic recorders on their gear. To date we have analyzed acoustic recordings from two longline sets. We recorded pilot whales during the soak time of one set in which depredation occurred, as evidenced by two tuna which had been mostly consumed by pilot whales, leaving just the heads on the line.

Throughout the fall, winter and spring we will continue to work with fishermen to deploy recorders on their gear. We also plan to provide digital cameras to fishermen, so that they can document pilot whales that interact with their gear and perhaps provide dorsal fin images for photo-identification. Most of our remaining field work will be conducted in a ten-day research cruise during the spring of 2007. During this cruise we plan to record the vocalizations of pilot whales in the vicinity of longline

gear and obtain acoustic recordings of pelagic longline vessels during setting and haul-back for future playback experiments.

During the course of these projects we have learned several valuable lessons. The first is the importance of working directly with commercial fishermen. Their experiences and observations are invaluable in planning, conducting and interpreting experimental results. Secondly, not all animals in a population appear to engage in depredation. This is certainly true for bottlenose dolphins and it will be interesting to see if the same holds true for the pilot whales, animals with a very different social structure than bottlenose dolphins. Finally we learned the importance of using a variety of complementary methods to address these complex and logistically challenging questions.