Workshop Report:

Reducing the Bycatch of Seabirds, Sea Turtles, and Marine Mammals in Gillnets

21-23 January 2015

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Organized by AMERICAN BIRD CONSERVANCY BirdLife INTERNATIONAL

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National Conservation Training Center
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EXECUTIVE SUMMARY

The focus of the workshop was on technical methods of bycatch reduction of sea turtles, seabirds, and sea mammals in gillnets. The workshop was carried out 21-23 January 2015 with 35 participants from seven countries and 17 organizations, representing collective expertise from fishermen, academia, government employees, and conservation Non-Governmental Organizations (NGOs).

The workshop objectives were to identify proposed gillnet bycatch mitigation methods, develop plans for trialing those methods, estimate the costs of trials, and identify teams who would work to carry out the trials.

The workshop began with a series of presentations to provide background for the discussions to follow. This included presentations on where gillnet bycatch is known to occur; on the factors that influence bycatch probability; on the sensory abilities of the bycatch species to detect various potential mitigation methods; and on the results of previous workshops on gillnet bycatch reduction. Presentations also described bycatch reduction methods now being trialed, and gave a case study of successful technical mitigation for seabirds in the US Pacific Northwest.

Workshop subgroups proposed bycatch reduction methods that can be placed into two categories:

- Active methods, including net lights and pingers in various configurations.
- Passive methods, such as high-contrast panels placed within nets, streamers, or colored nets or portions of nets.

To encourage industry support for such measures, a key aspect of all proposed methods was that they should maintain the level of target catch, to the extent possible, while reducing bycatch.

Based on the proposed mitigation methods, workshop subgroups proposed a set of trial projects. For each project or set of projects, a region was identified where the project could be carried out, ensuring:

- Adequate bycatch levels to detect the efficacy of mitigation measures.
- The necessary infrastructure and partners present to carry out trials.
- Representation across the taxa groups.
- Good prospects of financial support for the project.

Key actors and leaders were identified for each project. The proposed projects fell into five regional groupings:

- North Pacific: With a focus on seabird bycatch (particularly alcids[1]) in salmon driftnets, trials of net striping, pingers, high-visibility sections, and dropped headlines were proposed. A specific North Pacific salmon driftnet workshop was suggested, to examine common approaches to bycatch mitigation.
- Northwest Atlantic: The workshop proposed trials of net lights, double-weighted lead lines, colored nets, and high-visibility sections in Newfoundland gillnet fisheries, where there are already strong connections between fishermen, academics, NGOs and management authorities. The focus here would be on seabirds, porpoises, and pinnipeds. Sea turtle-focused projects testing low-profile nets were proposed off the US east coast.
- Northeast Atlantic: The group recommended trials of net lights and high-visibility panels placed in nets on the south coast of England to look at effects on cetaceans and proposed trials of the same methods in the Baltic Sea, focusing on sea duck bycatch (ongoing work by BirdLife International (BLI) in Lithuania, potentially some new work in Latvia or Germany).
- South America: In Chile, where seabird (penguins and shearwaters in particular), sea turtle, and cetacean bycatch is of particular concern, the group proposed the continuation of a project on high-visibility net panels being led by the Albatross Task Force (ATF). In Peru, the continuation of mitigation projects testing net lights and subsurface nets for reduction of bycatch of sea turtles, seabirds, and sea mammals, led by ProDelphinus working with various partners, was proposed. The workshop groups noted that southern Brazil is an important to place to link with existing projects and partners to improve understanding of the visual capacities of target and bycatch species.

In addition, a laboratory project on seabird underwater hearing capacity was proposed, but not at a specific site. The tests would need to be carried out at a research facility with access to captive live birds and large seawater tanks, such as the US Geological Surveys (USGS) Patuxent Wildlife Research Center (Maryland, USA) or one of the large aquariums.

The crucial next steps following the workshop are to push forward the proposed projects, seeking financing and support of various partners and stakeholder groups. In addition, it is clearly necessary to gain a deeper understanding of how marine mammals, seabirds, and sea turtles interact with gillnets. Although this can be difficult because of the nature of the fisheries, it will be crucial in informing the design of mitigation measures. Participants agreed that information-sharing on best practice and lessons learned across projects is very important, something the workshop organizers will seek to facilitate.

[1] Alcids (the family Alcidae) include the birds sometimes referred to as “auks,” such as Little Auk, auklets, murres and murrelets, puffins, guillemots, and the Razorbill.

Introduction

In the course of normal fishing practice, gillnets and other entangling nets capture and kill large numbers of seabirds, sea mammals, and sea turtles. Across these taxa, many threatened species are known to be caught, and in some cases gillnet bycatch is suspected to be the major driver of population declines. Even in fisheries capturing no threatened species, gillnet bycatch can kill sufficient numbers of individuals to cause concern among the public and government agencies. Significantly, the United Nations Food and Agricultural Organization (FAO) Code of Conduct for Responsible Fisheries stipulates that minimization of non-target catch is an important aspect of fishing responsibly. Finding effective technical solutions to this problem that can be incorporated into the daily operations of fisheries is thus a conservation priority.

Although some mitigation methods have been developed, tested, and proven effective for other fishing gears, methods to reduce gillnet bycatch of birds, mammals, and turtles have had much less development to date, with only a few exceptions. In addition, little research has been conducted on measures that will reduce impacts across multiple taxa. This may be explained, in part, because gillnet fisheries are often small-scale operations, highly dispersed along coastlines with variable regulatory regimes, have low profit margins (in some cases they are subsistence fisheries) and, often, are subject to lower levels of monitoring and surveillance compared to larger commercial fisheries. All of these factors can make it seem difficult to understand the scale of the bycatch problem, engage with fishermen, and find solutions. Larger commercial gillnet fisheries do exist, however, including on both the east and west coasts of Canada, west coast USA, and in Danish waters.

Experience from working with other fisheries tells us that working collaboratively with industry to find solutions is essential, and the only way to deal with some of these gaps in our understanding is to start addressing them. This means monitoring bycatch and testing mitigation ideas in active fisheries and adjusting measures according to fishermen's knowledge. To support uptake of these measures by fishermen, proposed methods should not only be practical to deploy, but should, to the extent possible, maintain the same levels of target fish catch as before implementation of the bycatch reduction method.

It is in this spirit that this workshop was co-organized by the American Bird Conservancy (ABC) and BirdLife International (BLI), with funding gratefully received from the Walton Family Foundation and the David and Lucile Packard Foundation, respectively. Cross-disciplinary experts were convened to focus on prospective technical solutions to the problem of gillnet bycatch. This report represents a summary of the key objectives and findings of the workshop and the proposed next steps.

Objectives

The main objectives of the workshop were to identify possible gillnet bycatch reduction methods that could be effective across taxonomic groups (seabirds, sea turtles, and sea mammals) and produce specific projects and plans for testing those methods. The perspective of the workshop was global in scope, and covered the class of fishing gears defined by the FAO in its International Standard Statistical Classification of Fishing Gear as gillnets and entangling nets:

- Set gillnets (anchored)
- Driftnets
- Encircling gillnets
- Fixed gillnets (on stakes)
- Trammel nets
- Combined gillnets-trammel nets

The workshop was results-oriented, focused on identification of potential solutions and how to test and implement them. Specific objectives included:

- Identification of proposed bycatch mitigation methods.
- Planning for trialing and testing of those methods.
- Estimation of the costs of trialing and testing.
- Identification of the appropriate actors (researchers, agencies, or fishery organizations) to carry out trials and tests.
- Proposing a timeline for trials and tests.

The workshop also served as an opportunity for a broad array of participants to collaborate, share the latest information and expertise as well as lessons learned, and focus minds on finding solutions.

Out of Scope Methods

While all present at the workshop recognized the contribution of time or area closures, gear switching, and other means of avoiding bycatch, the aim of the workshop was to address technical approaches to modify fishing gear to reduce bycatch, with minimal impact on both the target catch and the functional operation of the gear.

In the course of the three days, there were, however, some discussions of methods that were out of scope for this workshop. Recognizing the importance of these discussions, the key points—as well as some of the broader context for the way forward—have been included in the Additional Recommendations in the Appendix.

The Workshop

The US Fish and Wildlife Service (USFWS) graciously hosted the workshop at the National Conservation Training Center (NCTC) in Shepherdstown, West Virginia, USA, on 21-23 January 2015.

The workshop brought together participants (Table 1) with a wide variety of expertise and experience from within non-governmental organizations (NGOs), government, fishermen, and academia. Seven countries and seventeen organizations were represented.

Table 1. Participants in the Workshop on Reduction of Bycatch of Seabirds, Sea Turtles, and Sea Mammals in Gillnets, 21-23 January 2015, along with their primary areas of expertise and institutional affiliations.

Name	Area of Expertise	Affiliation
Len Carr	Fishing	British Columbia gillnet fisher
Rory Crawford	Seabirds	BirdLife International
Jennie Dean	Sea turtles	National Fish and Wildlife Foundation
Tony Doyle	Fishing	Newfoundland fisher
Shannon Fitzgerald	Seabirds	US National Marine Fisheries Service
Carina Gjerdrum	Seabirds	Canadian Wildlife Service
Scott Hall	Seabirds	National Fish and Wildlife Foundation
Pingguo He	Cetaceans, fish behavior	Univ. Massachusetts at Dartmouth
Scott Johnston	Seabirds	US Fish and Wildlife Service
Ellen Keane	Sea turtles	US National Marine Fisheries Service
Jeffrey Mangel	Sea turtles, cetaceans, seabirds	ProDelphinus, Peru
Graham Martin	Sensory biology	University of Birmingham, UK
Henry Milliken	Fisheries	US National Marine Fisheries Service
Shannon Moore	Fishing	Puget Sound Gillnet Fishermen
Ken Morgan	Seabirds	Canadian Wildlife Service
Bill Montevecchi	Seabirds	Memorial University of Newfoundland
Hannah Nevins	Seabirds	American Bird Conservancy
Simon Northridge	Cetaceans	Sea Mammal Research Unit
Mike Parr	Seabirds	American Bird Conservancy
Bill Perry	Seabirds	US Fish and Wildlife Service
Caroline Pott	Seabirds	American Bird Conservancy
Jean-François Rail	Seabirds	Canadian Wildlife Service
Mayumi Sato	Seabirds	BirdLife International
Cleo Small	Seabirds	BirdLife International
Brian Spears	Seabirds	US Fish and Wildlife Service
Cristián Suazo	Seabirds	Albatross Task Force, BirdLife International
Laura McFarlane Tranquilla	Seabirds	Bird Studies Canada
John Takekawa	Seabirds	Audubon Society
Bryan Wallace	Sea turtles	Stratus Consulting
George Wallace	Seabirds	American Bird Conservancy
John Wang	Fisheries, sea turtles	US National Marine Fisheries Service
Tim Werner	Cetaceans	New England Aquarium
David Wiedenfeld	Seabirds	American Bird Conservancy
Laurie Wilson	Seabirds	Canadian Wildlife Service
Ramūnas Žydelis	Seabirds	DHI

Participants in the Workshop on Reduction of Bycatch of Seabirds, Sea Turtles, and Sea Mammals in Gillnets, 21-23 January 2015.

Two publications and one set of maps were prepared beforehand specifically for the workshop. The objective of these was to provide background on key issues relevant to the workshop, including the sensory capacities of seabirds, sea mammals, and sea turtles, the common features of bycatch events, which mitigation methods have already been tested, and mapping of gillnet bycatch hotspots. These three items are:

- Martin, G. R, and Crawford, R. 2015. Reducing bycatch in gillnets: a sensory ecology perspective. Global Ecology and Conservation 3: 28–50.
- Northridge, S., and A. Coram. (October 2014 draft). A review of common aspects of bycatch events across taxa.
- Maps of bycatch hotspots by Bryan Wallace based on Lewison et al. (2014).

Presentations

The workshop began with a series of overview presentations that introduced all the attendees to the current state of knowledge of gillnet bycatch and bycatch reduction methods as well as the results of previous and current trials of potential methods in the USA, Lithuania, and Peru. Sensory biologist Graham Martin presented information on the sensory capacities, particularly underwater vision, of various organisms and how this ought to inform mitigation measure design. The final presentation, made by a gillnet fisherman, was a case study of seabird bycatch mitigation from the US/Canadian border in Puget Sound.

Following is a brief summary of each of the presentations given on the first day of the workshop and a summary of the discussion that followed.

Global Bycatch of Seabirds, Mammals, and Turtles in Net Fisheries

Presented by Bryan Wallace and Ramūnas Žydelis

Net fisheries are typically small-scale, close to shore, and poorly monitored, making assessments of bycatch of non-target species highly challenging. Nevertheless, available knowledge allows us to make generalizations, and to identify major knowledge gaps and bycatch hotspots.

Diving seabirds are most abundant at temperate and sub-polar latitudes where interactions with net fisheries take place. Seabird bycatch in fishing nets is poorly understood from tropical regions. The highest bycatch of seabirds in terms of numbers has been reported from the northwest Pacific, north Atlantic, and the Baltic Sea regions. However, the most significant bycatch in terms of population impacts occurs in the southern hemisphere, where mortality levels of Humboldt (*Spheniscus humboldti*) and Magellanic (*Spheniscus magellanicus*) penguins are likely unsustainable.

The majority of pinniped (seals and sea lions) and odontocete (porpoises and other toothed whales) species, as well as some large baleen whales, have been recorded as bycatch in net fisheries. Despite measureable progress in reduction of bycatch of these species in some regions, knowledge about bycatch of marine mammals remains highly fragmented. Mortality in fishing nets has been identified as the major threat to small endemic populations living in coastal waters.

Sea turtles, in contrast to diving seabirds and many marine mammals, live primarily in warm tropical and subtropical waters where interactions with net fisheries take place. Similar to other taxa, bycatch mortality in absolute numbers does not always correspond to population impacts. Regions with relatively high bycatch impacts on sea turtle populations include the eastern Pacific and southwest Atlantic oceans, and the Mediterranean Sea. Major knowledge gaps about sea turtle and net fishery interactions exist off both coasts of Africa, in the northern Indian Ocean, and throughout southeast Asia, all areas with threatened sea turtle populations and high levels of small-scale net fishing activity. It is often the case that the same sea turtle populations are affected by different fisheries using net, longline, and trawl gear.

Net bycatch has the highest cumulative severity across air-breathing megafauna taxa of any major fishing gear category. Given differences in distributions among seabird, marine mammal, and sea turtle species, few regions exist with high bycatch of all three taxa. The southwest Atlantic and southeast Pacific, however, could be named as such places. There are huge data gaps in the existing knowledge about bycatch. Even when available, bycatch data are inherently difficult to summarize due to the high variety of metrics used to measure fishing effort and bycatch rates. The ubiquity of net fishing worldwide and its documented and estimated impacts on air-breathing megafauna warrant increased efforts to test and implement sound bycatch mitigation solutions to reduce impacts of net bycatch on vulnerable populations of seabirds, marine mammals, and sea turtles.

Discussion:

It was noted that while filling data gaps around the world may seem difficult (particularly in artisanal, widely dispersed fisheries), methods are available to begin to build our understanding. Rapid assessments of bycatch are possible using interview techniques (see e.g., Moore et al. 2010), extrapolating from what type of gear/gillnets are being used in an area and whether bycatch species are potentially present. It was further noted that developing bycatch reduction methods where resources are available and filling data gaps on bycatch levels are not mutually exclusive goals, and both should and could be pursued in priority areas.

The substantial challenge of finding cross-taxa solutions was raised. To be effective across taxa, techniques would need to account for the differing sensory capacities of the groups, and it may be that a solution for one group poses different challenges for other groups. The difficulty in finding a geographic region where testing of techniques could encounter all three groups sufficiently frequently that an adequate sample size can be obtained will be an important issue, although southern Brazil and Peru were flagged as good candidates based on current information.

Bycatch rate estimates do not always account for species' density, so it may be possible to find some locations with adequate sample sizes in spite of lower densities. On the theme of species density, some participants recommended that bycatch rates should be contextualized within density for particular species, the amount of observed effort, and mitigation measures in place. All these factors will affect the bycatch rate and make direct comparisons among different fisheries challenging.

It was broadly acknowledged that deciding where to undertake trials also needs to consider feasibility (e.g., on-the-ground capacity, industry willingness to engage, etc.). It will be necessary to weigh risk (i.e., engaging with new fleets, or those with particularly low capital) and reward (i.e., working in fisheries capturing particularly threatened species).

Although many suggest that bycatch reduction efforts should make an effort to take into account population-level impacts on the bycatch species, FAO guidelines recommend assessing and minimizing bycatch, irrespective of population-level impacts.

Assessment of population-level impacts was recognized as useful, particularly in setting priorities, but the general goal of this workshop was to focus on bycatch where it is happening *regardless* of population status, rather than to suggest demographic analyses.

Werner et al. (2006) was highlighted as a review of bycatch mitigation techniques which have been tried in the past for all three groups.

Why Do Non-Targets Get Caught in Gillnets?

Presented by Graham Martin

Sensory capacities and perceptual challenges faced by gillnet bycatch taxa result from fundamental physiological limits on vision and constraints arising within underwater environments. To reduce bycatch in seabirds, sea turtles, pinnipeds, and blue-water fishes, individual animals must be alerted to the presence of nets using visual cues. Cetaceans will benefit but they also require warning with cues detected through echolocation. Characteristics of a visual warning stimulus must accommodate the restricted visual capacities of bycatch species and the need to maintain vision in a dark-adapted state when foraging. These requirements can be provided by a single type of visual warning stimulus: panels containing a pattern of low spatial frequency and high internal contrast. These are likely to be detectable across a range of underwater light environments by all bycatch prone taxa, but are unlikely to reduce the catch of target fish species. Such panels should also be readily detectable by cetaceans using echolocation. Use of sound signals to warn about the presence of gillnets is not recommended because of the poor sound localization abilities of bycatch taxa, cetaceans excepted. These warning panels should be effective as a mitigation measure for all bycatch species, relatively easy to deploy and of low cost.

Discussion:

The importance of distinguishing between improving the detection of a net by a potential bycatch species and warning it away from the net was raised. How can the bycatch species be prevented from approaching the net, even if they can see it? Little is known, so it will be necessary to experiment to find out what methods deter a species from approaching a net as opposed to only improving an animal's ability to detect the net.

There was an extensive discussion of the mechanisms of gillnet bycatch—what type of interaction is occurring? One consideration is whether the potential bycatch species encounters a net intentionally or accidentally. For example, dolphins might be attracted to nest to prey upon higher concentrations of fish, versus seabirds encountering nets "by surprise" when foraging on smaller prey that are not being targeted by the fishery. Len Carr (a salmon driftnet fisherman) suggested that, in his experience, birds get caught most often when fishers inadvertently "chase" them into the net. This is similar to the interactions reported by Shannon Moore, also a salmon driftnet fisher, whereby birds drift on currents towards the nets, and when "spooked" by the floats on the corkline, they dive into the mesh. Therefore, both sensory physiology and animal behavior (and the interaction between them) need to be considered in the design of mitigation measures, though it may be difficult to combine these two factors.

The use of "solid" panels that do not allow flow-through of water was discussed, particularly in the context of ensuring that any modifications allow the net to continue to fish well. Several fishers noted the risk that panels may cause net lofting. Would striped mesh (rather than solid panels) work? Graham Martin's work would suggest not: high internal contrast is required to make objects visible, and this is not achieved by tweaking net color at depth (though this could be effective in a surface-set fishery, depending on the type of interactions).

The potential for moving/reflective objects was queried. Would it be possible to attach a flexible material to a net, perhaps something reflective like a fish scale, so that as the current moves it, a seabird or other potential bycatch species would detect movement rather than only light or color? Martin replied that movement of an object would likely increase its detectability. An example is the use of oscillating objects on power lines, which are known to have higher detectability and to reduce bird collisions. However, in developing the suggestion of the net panel, Martin was aiming to come up with something as simple as possible.

There was a query about Martin's hesitation in the paper published for the workshop (see page 5 in Martin and Crawford 2015) about the use of lights on nets. One of the potential benefits of lights is that the frequency can be adjusted to suit relevant bycatch species. Graham explained that light can disrupt the eye's adaptation to darkness, thereby reducing the potential bycatch species' ability to actually see the net. It thus depends on what sort of interactions animals are having with nets—whether they are approaching them from a distance, with light gradually increasing in intensity (likely to be less problematic), or encountering lights suddenly (e.g., while coming to the surface after a foraging trip) and being "dazzled" by them. Regardless, lights used to illuminate nets have been shown to reduce bycatch, but may have varying levels of efficacy depending on ambient light.

There was a brief discussion on what birds can hear underwater. There has actually been little research on this or on hearing in fish. One problem with using auditory cues to reduce bycatch is that birds will likely have difficulty in detecting the source of the sound because of poor abilities to detect directionality.

Bycatch Reduction: What Factors Influence Bycatch Probability? Which Might We Focus on to Reduce Bycatch? What Has Been Tested?

Presented by Simon Northridge

This presentation addressed the factors that might influence bycatch probability, which of these factors had been tested, and which might be focused on to help find ways to reduce the probability of bycatch. There has been an exponential increase in scientific studies on bycatch of birds, mammals, and turtles over the past few decades, but most of these studies have focused on quantifying bycatch, whereas relatively few have tried to understand how or why it occurs or how to solve it.

Understanding how the process occurs is crucial to finding ways to preventing bycatch. Studies of relevance include trials of putative mitigation measures, statistical analyses of observer data, and dedicated experimental studies that try to determine the importance of specific factors in controlling bycatch rates. Reviewing such studies, 28 factors were identified, and these were categorized as "environmental" (weather, water, or time related), "operational" (factors controlled during a fishing trip such as location and soak duration), "technical" (aspects of the gear determined when it is rigged) and "sensory or behavioral" (responses of the animals to stimuli). No single factor stood out as being most important across taxa.

Several factors can probably be discounted for further research directed towards immediate mitigation (e.g., turbidity, target species, water temperature) as they cannot be controlled within a fishery. Net length and soak time are most likely linearly related to bycatch rates, and therefore show no real scope for management measures if fish catch rates are to be maintained. Measures that change animal behavior (including acoustic and visual cues) have been shown to work but may be hard to implement or enforce and rely on batteries.

Several other factors seemed to be implicated in determining bycatch rates of at least two taxa. These were wind, season, location, depth of the net in the water column, corkline type, twine type, and twine diameter.

Three factors stood out as having been demonstrated to affect bycatch rates in all three taxa. These were the water depth (for bottom set nets), mesh size, and net height (including nets that are tied down). All three deserve further investigation as potential mitigation measures.

Overall, relatively little experimental work has been conducted to understand the bycatch process, though a lot of attention has been paid to statistical analysis of observer data that address correlation but not necessarily causation. It seems there is little chance of a single solution to controlling bycatch of protected species. Careful manipulation of fishery related parameters may provide a range of solutions to specific problems, while patient, collaborative work with fishing communities will be required to ensure any mitigation measures are successfully implemented.

Discussion:

> Ideally, solutions and techniques must be readily enforceable so that non-compliance can be easily identified. This has been one of the issues with pingers to deter cetaceans from approaching gillnets.
>
> There was some discussion on whether different net materials could be used. This is unlikely to find favor with industry as other net materials like hemp have fallen from usage because they are not good at catching fish.

Summary of Workshop on Sea Turtle and Atlantic Sturgeon Bycatch Reduction in Gillnet Fisheries (2013)

Presented by Ellen Keane

This workshop brought together fishermen, conservationists, state and federal managers, researchers, and gear technologists to discuss potential technological solutions to reduce the bycatch of Endangered Species Act-listed species (sea turtles and Atlantic sturgeon) in fisheries off the US coast from Maine through Virginia. The presentation here focused on the sea turtle bycatch reduction component; covering research, including illuminated and low profile gillnets, conducted by the US National Marine Fisheries Service's (NMFS) Northeast and Pacific Islands Fisheries Science Centers and their research partners. The importance of conducting bycatch reduction work in areas of sufficiently high bycatch to ensure that the data are robust was highlighted. In addition, strong partnerships and collaborations are crucial to successful research. The workshop was very productive and generated several ideas to be tested further. The workshop report can be found at http://www.greateratlantic.fisheries.noaa.gov/protected/seaturtles/docs/gillnetworkshopfinalreport_april2013.pdf.

Summary of Workshop on International Marine Mammal Gillnet Bycatch Mitigation (2011)

Presented by Tim Werner

Gillnet bycatch is the most immediate threat to many species and populations of marine mammals, something that has been identified for more than a quarter century by the International Whaling Commission (Perrin et al. 1994), among other agencies. Despite long recognition of the problem, solutions remain few. In 2011, the Consortium for Wildlife Bycatch Reduction, based at the New England Aquarium, convened a workshop to review techniques for reducing marine mammal bycatch in gillnets. The workshop, supported by NMFS, involved 48 participants from 14 countries, including representation from academia, NGOs, governments, deterrent manufacturers, and the fishing sector. Techniques reviewed during the workshop consisted of those evaluated or implemented as part of strategies to “fish better” rather than “fish less” (Hall et al. 2007), and were categorized as follows: (1) acoustic deterrents; (2) non-acoustic deterrents; (3) time-area closures; and (4) gear switching, or fishing with a type of gear other than gillnets (e.g., longlines, traps, trawls). Outputs from the workshop form part of a Special Issue of Endangered Species Research, including a paper by Reeves et al. (2013) that updated knowledge on the bycatch of marine mammal species worldwide, and which considered other types of entangling nets (shark or beach nets deployed in Australia, South Africa, and Hong Kong; and some predator barriers erected around aquaculture facilities).

Preliminary Results from Bycatch Mitigation Testing in Lithuanian Gillnets

Presented by Rory Crawford

This brief presentation highlighted some preliminary bycatch mitigation work undertaken by the Lithuanian Ornithological Society and supported by the BirdLife International Marine Program in the bottom-set cod gillnet fishery in the Baltic Sea. The primary bycatch in this fishery is sea ducks, particularly Velvet Scoter (*Melanitta fusca*) and Long-tailed Duck (*Clangula hyemalis*), though loons[2] are also captured. The project has carried out a small number of trials that followed similar principles to successful experimentation in the Puget Sound in the 1990s (see Melvin et al. 1999). Standard monofilament cod gillnets were modified in two ways; one had the upper 10% of the meshes (equivalent to 40 cm in a net of 4 m height) replaced with thick, white twine, and the other had the upper 25% of the meshes (equivalent to 1 m in a net of 4 m height) replaced with the same thick white twine. Their efficacy in reducing bycatch was tested alongside standard nets. The small number of trials did not allow for statistically significant sample sizes, but the limited preliminary evidence suggests that birds are still captured in these nets, quite possibly because the deep setting depths of the fishery render the “higher visibility” white netting as invisible as the standard monofilament. While these results are far from conclusive, the type of fishery (bottom-set) and our knowledge of the sensory capacities of the bycaught species (likely to be quite severely limited at depth) suggest that perhaps more obvious means of alerting sea ducks to the net are required.

Bycatch Mitigation Research

Presented by Jeffrey C. Mangel

ProDelphinus, a Peruvian NGO, has current projects in six coastal ports where it monitors Peru’s small-scale fisheries that total over 10,000 vessels and 40,000 fishermen. These small-scale fisheries are open-access and subject to little regulatory control, a situation that makes monitoring and management difficult. ProDelphinus research has identified bycatch of seabirds,

[2] In European usage, the loons are referred to as divers.

sea turtles, marine mammals, and undersized sharks in these fisheries. Bycatch sometimes occurs at very high levels and can include threatened and endangered species. To address this bycatch problem ProDelphinus has tested many mitigation technologies, including circle hooks, line cutters, acoustic alarms, weighted swivels, sub-surface nets, net illumination, and awareness-raising programs. Two ongoing initiatives involve testing of sub-surface nets and continued testing of net illumination. Analysis of the net illumination data indicated significant declines in sea turtle and seabird bycatch without affecting target catch rates. Estimates of the cost of implementation of net illumination in one of the test areas that interacts with over 300 sea turtles per annum range from USD$19,000 to $33,000 for the demersal set net fishery. Because the lightsticks used to illuminate nets are very robust, the implementation costs could be amortized over the three year life of the gear.

Discussion:

> The issue of what was considered "bycatch" was raised. In some artisanal fisheries, nothing is considered bycatch—it is all retained and becomes a meal (even turtles, marine mammals, and seabirds). This is true to an extent in Peru. Along the southern coast, the local people do not eat turtles as much as they do in the north. The fishermen do not often eat seabirds, and sea turtles are usually released alive. About half of the dolphins caught are used as bait and the other half discarded. This issue needs to be considered when thinking about the feasibility of developing projects to reduce bycatch; it is important as fishers are less likely to want to reduce the catch of something that is consumed.

Puget Sound Gillnet Salmon Fishery: Background and Bycatch Reduction Methods for Seabirds

Presented by Shannon Moore

The presentation outlined specific dates and events affecting changes in the Puget Sound (Washington State, USA) salmon fishery:

- The US Migratory Birds Act Treaty, 1918
- The US Marine Mammal Protection Act, 1972
- The US Endangered Species Act, 1980
- Marbled Murrelet (*Brachyramphus marmoratus*) listing under US ESA provisions, 1992
- On-board fishery observer program, 1993 – 1995
- Gillnet testing by University of Washington Sea Grant program, 1996, and seabird deterrent methods implemented, 1997 (see Melvin et al. 1999)

Identifying the timing of interactions between seabirds and fishermen was the key to developing a strategy in reducing impacts. Traditional fishing hours were changed to avoid times of day when the greatest number of seabirds were present, i.e., dawn and dusk. High impact shorelines were closed to gillnet fishing. In addition, a large seabird refuge has been established in the San Juan Islands.

In addition to these methods, non-treaty gillnet fishermen are now required to employ a seabird deterrent strip of webbing in the top 20 meshes of the gillnet. Puget Sound Treaty fishers (First Nation fishermen) have not yet adopted seabird deterrent methods.

BYCATCH REDUCTION METHODS

Following the introductory talks, the group focused on one of the core objectives of the workshop: the identification of promising ideas for bycatch reduction in gillnet fisheries. There was an open discussion of potential mitigation ideas, not only those presented by the speakers, but novel ideas were also welcomed. The full list is reproduced in the right hand column of Table 2 below.

Thematic Discussion

The list of mitigation ideas was then grouped into broad categories, indicated below:

Table 2. Mitigation ideas grouped into themes.

Thematic Category	Mitigation Ideas
Methods Using Lights to illuminate nets	Lightsticks on nets Lights of different colors, LEDs, or UV
Other Visual Methods	High visibility panels (solid panels attached to net) High visibility webbing (partial net) Weaving colors through nets High visibility monofilament (entire net) High contrast rope in mesh Weaving reflective elements in upper panels or sections of nets Moving/twisting elements or streamers Tori lines/reflective ribbons on corkline Silhouettes or predator mimics placed in nets Color floats for surface nets
Above Water Methods	Tori lines above water over the net Kites or drones flown over net Raptor silhouettes
Net Type and Setting	Low profile nets Tie downs to reduce profile of net Net height Depth at which net is set Headline drops Altered float lines

Thematic Category	Mitigation Ideas
Time of Day of Setting and Methods of Operating Nets	Adjust time of day for setting and hauling times Soak times Nocturnal setting Sensors to indicate when something is in the net (alarm, light) Net-checking frequency
Acoustic Methods	Above-water sound deterrent Multi-frequency pingers Audio recordings of predators
Other	Risk analysis Tracking and ship surveys Area closures Seasonal closures Identify and target fishers who can afford bycatch avoidance gear vs. those who cannot and should, therefore, be targeted with education or other tools Diving bird evasive behavior tests Gear-switching (not in scope of this workshop)

These broad themes guided break out groups, which were formed to allow more comprehensive discussion of the mechanics of what might be tested and how. The discussions of these groups are summarized below, grouped by theme.

Net Illumination and Pingers

Lights

The discussions of this group were helpfully informed by the US National Marine Fisheries Service's Pacific Islands Fisheries Science Center (NOAA-PIFSC) work on the effects of net lights on sea turtle bycatch. Since this work has focused on turtles, it is necessary to investigate how other taxa might interact with net lights. ProDelphinus's work in Peru (see presentation summary above) indicates that lighting has the potential to reduce seabird bycatch too. Studies to date indicate target species catch is not impacted in illuminated nets. Net lights used in trials with sea turtles have the following characteristics:

- LED lights
- Battery-powered using AA batteries
- Last about one month before batteries must be replaced
- Cost $8 - $9 each for versions produced in Korea, and cheaper Chinese versions available for $4-$6
- Lights are attached to the net headline every 5 m to 10 m
- Lights are robust to 300 m – 400 m depth

These lights are actually designed for use in longline fisheries, but at least one company is working on developing a light more tailored to gillnet purposes.

Pingers

Acoustic deterrents may include pingers or other deterrents such as playback (above or below water) of predator calls. Discussion within the workshop group focused on pingers (and pinger-type deterrents) rather than any of the other acoustic deterrents proposed.

There is evidence that pingers work for at least some marine mammals, such as harbor porpoise (*Phocoena phocoena*), but pinger effectiveness is a more open question for seabirds. Previous studies (for example, Melvin et al. 1999) have been inconclusive, showing potential deterrence for one bird species (e.g., Common Murre[3] *Uria aalge*) but not for others (e.g., Rhinoceros Auklet *Cerorhinca monocerata*). One way to address this issue is to obtain a sensory baseline and investigate what bycatch-susceptible birds can actually hear underwater.

In addition, some studies (including Melvin et al. 1999) indicate that pingers can attract seals (and other net predators) to fishing gear—the "Dinner Bell'' effect. This can have negative effects on implementation if fishers view the pingers as increasing loss of catch to predators.

The pinger frequencies that have been tested have generally been in these ranges:

- 70 kHz for small cetaceans
- 10 kHz for porpoises
- 3 kHz for humpback whales (*Megaptera novaeangliae*)
- 1.5 kHz for Common Murres
- 200, 400, 300, 500 Hz for sea turtles

Note that, given the wide range of frequencies that different taxa can hear, no pinger emitting in a single range would be able to deter all species groups.

Some important considerations on the proposed use and testing of pingers include:

- The development of variable pingers (pingers emitting at irregular intervals to reduce habituation).
- The development of multi-frequency pingers (pingers that emit on more than one frequency, to deter species groups with different acoustic detectabilities and responses).
- It may be possible to combine pingers with lights to provide a multi-species deterrent.
- Battery life (relates to cost for replacement batteries and effort required to maintain the pingers).

[3] In European usage, this species is referred to as Common Guillemot.

- Significant research and development will be required to produce pingers for testing with new species. These costs may be as much as $500/unit, including battery, recorder, speaker, cable, pelican case), or more substantial for the development of a multi-frequency, variable device. John Wang's research group at NOAA-PIFSC has useful experience to call upon with the development of their turtle "pingers."
- Habituation of the target organisms to pingers may reduce their efficiency as a deterrent.
- Ambient noise issues at sea may override any deterrent effect of pingers. Likewise, common use by many fishers of pingers may exacerbate ocean noise issues and make the pingers on any one net less effective.
- Training of fishers to properly maintain and deploy pingers is critical; cetaceans may be more likely to be caught in a net if just one pinger is not operating correctly.

It was further noted that there might be additional techniques in use in the aquaculture industry (not represented at this workshop) which would be worth exploring.

This group thought that Go Pro cameras might be a good way of documenting net interaction behavior in all trials (not just light or sound measures).

Other Visual Methods of Increasing Net Visibility

Passive methods of increasing net visibility do not include the use of any lights or lightsticks; i.e., they are still visual methods, but are "lower tech." As the methods are passive, an important consideration for their use is that they would likely be more effective in surface-set or near-surface fisheries, where sufficient ambient light is available for the net to be visible to the potential bycatch species.

Methods of passively increasing net visibility can have several components. Some of these include:

- Reflective materials.
- Streamers incorporated into the net.
- Solid, high-visibility panels, such as those proposed in Martin and Crawford (2015), currently being tested by Cristián Suazo (Albatross Task Force) in Chile, or similar to a Secchi disk, placed within the net.
- Making the net itself more visible, by using white or different colors of net twine, or a white or colored rope woven through the net. There are many possible configurations for this, such as only modifying the top section or top few meshes of the net, to modifying vertical segments of the net, to modifying the entire net.

Reflective Materials

In the Japanese right-eye flounder (Pleuronectidae) fishery, highly reflective compact discs (CDs) were hung on the nets to deter seabirds from becoming caught in the nets, with somewhat promising results. Some additional small-scale studies have been carried out on the method, but need translation from Japanese. The use of CDs as a deterrent for seabirds has the advantage of being very inexpensive, but apart from being of doubtful efficacy, CDs became tangled in the nets during setting and hauling. It is possible that reflective materials used in this way could potentially attract more of the target fish or bycatch species to the nets, but it may also repel the target species; the verdict on reflective materials remains inconclusive.

Streamers

Streamers incorporated into a net would potentially have the advantage of being readily visible because of their movement with water currents passing through the net. Streamers would potentially be of two basic types:

- Mesh streamers, with a width and length approximately the same as the mesh size, so that the streamer would be roughly the same size as one mesh square. The streamer would be attached along one edge to a net mesh.
- Ribbon streamers, narrow and much longer than the mesh size, attached or tied into the net.

Mesh streamers, which are short and wide, may be less likely to tangle either with one another or with the net itself. Ribbon streamers are longer and narrower, and may be more visible and present more movement. Streamers would seem to be most likely effective in increasing net visibility to seabirds and pinnipeds.

Various factors would need to be considered for testing of net streamers. These would include:

- Streamer length: Compare mesh streamers with ribbon streamers.
- Streamer coverage: What proportion of a net would have to be covered with streamers to increase its visibility? This may be based on the results of tests of high visibility panels, for which the size of one panel is recommended at 60 cm.
- Streamer spacing: How often would streamer areas have to be repeated? This may be based on the results of tests of high visibility panels, for which panels are placed at 4 m spacing.
- Streamer color: Compare various streamer colors versus black/white; also consider using reflective materials.

Testing of control and treatments (streamers) should be carried out at the same time (preferably a specific period) using either small nets of each treatment and control or a larger net partitioned into control and treatment. This would increase the ability to detect actual differences in target catch and bycatch between the controls and treatments.

To deter birds from the area near a surface-set net or one set in shallow water, one idea is to set above-water streamers. These streamers would be similar to a tori line, set in the air, possibly suspended from a line strung 2 m above the surface of the water between poles placed on buoys at the ends of the net. Such streamers might discourage birds from approaching the area where the net is set or from diving in that area. However, this idea was dismissed as being too difficult to deploy and maintain.

High-Visibility Panels
Solid, high-visibility panels meeting the specifications described in Martin and Crawford (2015) (marked in a 60 cm x 60 cm black-and-white checkerboard grid) will soon be tested in Chile. The test fishery is a surface-set fishery in the summer and a demersal-set fishery in the winter. Nets are 5 m x 40-50 m and each boat carries up to six nets. The panels will be fixed in the center of the net, 4 m from one another in horizontal distance. A major concern has been to maintain the fishing operability of the net; i.e., panels might cause the net to "loft" in strong currents. In Chile, the nets are generally deployed in sheltered coastal areas without extreme water movements, but so that this method can be exported or experimented with in a variety of conditions, solutions to this problem should also be trialed.

Ideas to improve panel deployment included:

- Anchoring panels only from the top, and on either side of the net, allowing for water movement through the net.
- Cutting slits into the panels.
- Cutting the panel into strips.
- Increasing the number of holes in the panel.

A selection of these options will be tried in Chile to see what works best in terms of maintaining optimum performance of the net. There are various potential materials for panel construction; ideally any material should be flexible, lightweight and robust.

Net Coloring and Colored Materials as Component of Nets
Incorporating the principle of the high contrast panel (black/white) into actual net construction was also considered. This included weaving colors into the net, incorporating color stripes into the net windows, strips of different net materials in vertical stripes, the incorporation of orange mesh to increase visibility for marine mammals and the use of white monofilament in monofilament nets (which might be more visible to non-target catch). There are ongoing trials in Japan testing stripes painted on to net meshes, but they have so far had no effect on bycatch rate (fide Mayumi Sato).

The group also discussed comparing target catch and bycatch rates in: (1) entirely white, (2) entirely green monofilament nets, and (3) nets with strips/stripes of each. It was noted that if the white strips were perceived by animals, the inter-strip spacing would need to be narrow enough to provide the animal with the notion that the obstacle continued. If the contrasting strips are too wide, animals might, at the end of the strip, perceive that the obstacle had ended, and the net might end up entrapping the animal. Graham Martin estimated that strips/stripes should be of a minimum 0.5 m threshold.

Entanglement in larger ropes (which connect pots to one another or nets to surface lines/buoys) poses a problem to large whales. Ideas to make the ropes or lines more visible to the whales included orange lights or orange ropes and lights (beyond the photic zone). This work was considered as not as broadly applicable across taxa as panels, for instance, but it was agreed that testing of orange lines should be pursued.

It was reported that glow rope has been tested in the lines of lobster pot and gillnet gear. It was found that its glow property does not have high durability over repeated setting and hauling (fide Tim Werner).

Net Type and Operational/Deployment

Net type and deployment can have significant effects on levels of bycatch. One fishery in particular was discussed (US East Coast bottom-set monkfish fishery). The main groups of bycatch species in this fishery are sea turtles and marine mammals. This fishery has extraordinarily long soak times (four days), so changing time of day or soak time was not a feasible option to maintain levels of target catch. Concrete modifications apart from those already trialed by NMFS (see 2013 workshop information, link in presentation summary above) were not forthcoming.

BYCATCH REDUCTION MEASURE TRIAL PROJECTS

Using some of the most promising mitigation ideas discussed in the breakout groups, participants were then divided into geographic regions (based on participants' knowledge of and connection to these areas). This meant that various ideas for bycatch reduction projects could be developed in distinct fisheries, maximizing the potential to understand issues and build knowledge. Four regions (north Pacific, northwest Atlantic, northeast Atlantic, South America) were selected to discuss the details of where and how some of the techniques and approaches discussed above might be tested.

Groups were asked to consider or determine:

- Fishery characteristics (bycatch, net deployment).
- Intervention or trial to be carried out.
- Existing capacity and research in the region.
- Links to industry (existing or potential).
- Seasons in which work would be executed/seasonal considerations.
- Estimate of cost to execute trial.

North Pacific

This group determined that there were three techniques worth testing in this region, two of which have ongoing or previous work; the third would be the biggest initiative.

- Net striping: the Japanese government is still running trials in the Japanese Exclusive Economic Zone (EEZ). Once there is more news from these and Chilean net panel trials, it would be easier to decide if or where else in the region to test these.
- Pingers: these have had moderate success in reducing Common Murre bycatch in the Puget Sound salmon fishery, but the data need analyzing and follow up. Important to investigate "dinner bell" effects too.
- Net modifications with high visibility sections.

The potential to export the experience of Puget Sound around the Pacific Rim was viewed as holding substantial promise, given the prevalence of salmon driftnets in the region. However, the experience of gear modifications in Puget Sound needs to be appropriately crystallized before we can think about exporting a set of techniques, for example, to other salmon driftnet fisheries in the North Pacific. There was broad agreement that repeating the Melvin et al. (1999) study (which integrated a top section with 20 "deterrent" high density meshes and at different times of day) could be valuable, particularly to confirm that target catch can be maintained[4].

Fishery: Drifting nets of varying lengths; Russian and Japanese nets tend to be much longer, on the order of kilometers more, than those of other countries in the fishery; it was also noted that basic information on the variety of fisheries along the coast and in the North Pacific is lacking.

Bycatch: Predominantly alcids.

Mitigation measure being tested: Add high visibility sections to the top of nets, using four different pane types: (1) unmodified mesh, (2) with the top 20 meshes modified to be high visibility, (3) with the top 10 meshes modified, and (4) with a drop line instead. The design would need to maintain either the catching area the same or absolute depth the same. The trials would need to be run at dusk, dawn, and at three times during the day. It was emphasized that depending on the target species, the drop line arrangement might render the gear much worse for fishing, because if the target species travels higher in the water column, drop lines might miss the species altogether. Many Puget Sound fishermen have expressed a keen interest in testing dropped headlines in particular. Presently, these fishermen cannot hang their nets this way without approval of the Washington Department of Fisheries.

Existing Capacity: The Pacific Salmon Commission, which has funds to support this kind of work, was highlighted as an important partner to engage. The governmental bodies of Washington Department of Fish and Wildlife, US National Ocean and Atmospheric Administration, Department of Fisheries and Oceans (Canada) as well as tribal/treaty fishing governments are important and willing stakeholders/conveners.

Links to Industry: Two participants (one each from Canada and the US) agreed to speak with their fellow fishermen and garner support/engagement within the fishing community.

Seasons: Summer 2017/2018

Cost: Estimated $450,000 over two seasons, (15 days per season) with salmon catch in experimental nets to offset budget. The estimated income that fishermen could provide as match from six to eight fishing boats is estimated to be in the range of $65,000 to $75,000 per season.

North Pacific workshop idea: In addition to the specific project discussion, it was agreed at the workshop that building connections between North Pacific salmon fisheries would be useful as a means of sharing management experiences and bycatch mitigation ideas. Several participants left

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[4] NB: Post workshop follow-up discussions have determined that the key first step in the Puget Sound fishery is to monitor bycatch in the fishery to examine the ongoing efficacy of the bird "deterrent" meshes.

the meeting with an action to advance the idea of a separate workshop that focused on North Pacific salmon driftnet fisheries.

Northwest Atlantic

There are seven possible projects proposed for gillnet fisheries in the northwest Atlantic. Of these, five are proposed for trialing in Newfoundland waters. For all five of these Newfoundland projects, the team of collaborators and capacity to carry out the work would be the same. Team members would include Memorial University of Newfoundland (Bill Montevecchi and collaborators), Canadian Wildlife Service (Carina Gjerdrum, Jean-François Rail, and others), Canadian Department of Fisheries and Oceans, US Fish and Wildlife Service, Bird Studies Canada (Laura McFarlane Tranquilla), and the Fish, Food and Allied Workers (the fishermen's union; contact through Tony Doyle). These team members are already involved in bycatch reduction research and implementation, and there are many strong relationships already existing. In addition, there is good baseline information on bycatch for each fishing sector, including work by April Hedd (2015) and Regular et al. (2013) showing population effects.

The sixth and seventh projects listed here would have different teams of collaborators. The last project would not necessarily be tied to the northwest Atlantic region because it would be a laboratory study and could therefore be carried out at several possibly different locations.

Newfoundland projects:

Bottom-set Cod Fishery: LED Lights
Fishery: Bottom-set cod fishery
Bycatch: Seabirds, mainly Northern Gannets (*Morus bassanus*), but also alcids, shearwaters, porpoises and pinnipeds.
Mitigation measure being tested: LED lights
Cost: Approximately $100,000

Surface-set Herring Fishery: LED Lights
Fishery: Surface-set herring fishery
Bycatch: Seabirds, mainly Northern Gannets, but also alcids, shearwaters, cormorants, gulls, porpoises, pinnipeds, whales.
Mitigation measure being tested: LED lights
Cost: Approximately $100,000

Bottom-set Cod Fishery: Striped Nets
Fishery: Bottom-set cod fishery
Bycatch: Seabirds, mainly Northern Gannets, but also alcids, shearwaters, porpoises and pinnipeds.
Mitigation measure being tested: Striped net (net with twine or monofilament of a different color woven in)
Cost: Approximately $100,000

Bottom-set Cod Fishery: White Nets
Fishery: Bottom-set cod fishery

Bycatch: Seabirds, mainly Northern Gannets, but also alcids, shearwaters, porpoises and pinnipeds.

Mitigation measure being tested: White monofilament net (entire net constructed of white monofilament)

Cost: Approximately $100,000

Surface-set Herring Fishery: Double-weighted Lead Lines

Fishery: Surface-set herring fishery

Bycatch: Seabirds, mainly Northern Gannets, but also alcids, shearwaters, cormorants, gulls, porpoises, pinnipeds, whales.

Mitigation measure being tested: Double-weighted lead line to maintain the net vertically in the water, so that it does not loft when full of herring and become more horizontal. This could potentially reduce Northern Gannet interactions.

Cost: Approximately $100,000

Other projects:

Mid Atlantic Monkfish Fishery: Low-profile Nets

Fishery: Mid-Atlantic monkfish fishery

Bycatch: Sea turtles

Mitigation measure being tested: Low-profile nets with LED lights. The low-profile nets would be tested first, with LED lights as a potential second phase.

Existing capacity and research: This would be part of an ongoing project led by US NMFS (Henry Milliken) and would, therefore, have much already-existing capacity and infrastructure.

Cost: Approximately $200,000

Laboratory Trials of Pingers on Seabirds

Laboratory behavioral experiment: The objective would be to determine if pingers can be used to deter seabirds from nets. The test would be to determine what sound frequencies seabirds can detect underwater. Prior to initiating the project, Bill Montevecchi will review a thesis carried out at the Patuxent Wildlife Research Center (Maryland, USA) on Northern Gannet hearing and seismic effects to assess how it relates to the project proposed here.

Bycatch: Seabirds

Existing capacity and research: The experimental setup would require large seawater tanks and access to live seabirds. A site proposed for the hearing physiology studies is at the US Geological Survey's Patuxent Wildlife Research Center (Maryland, USA). However, actual experiments might be considered at a large marine aquarium such as Monterey Bay Aquarium (California, USA), New England Aquarium (Boston, Massachusetts, USA), or the National Aquarium (Baltimore, Maryland, USA). The project could be carried out as a graduate student research project.

Cost: Approximately $75,000

Northeast Atlantic

South Coast of England, UK

Two potential projects—one short term, the other in the longer term—were proposed for gillnet fisheries operating off the south coast of England. Both of these would be led by the Sea Mammal Research Unit (SMRU), based in St. Andrews, Scotland, and have links to their existing observer work in these fisheries.

Short term

Fishery: Inshore monkfish bottom set gillnet, operational February/March and September/October
Bycatch: Primarily harbor porpoise and common dolphin (*Delphinus* sp.), though also some seabirds (alcids)
Mitigation measure being tested: LED lights
Existing capacity and research: Existing capacity is high through the SMRU observer program, which also provides a solid baseline. Some mitigation testing has also been conducted through the observer program.
Industry links: These are strong in this region, established through the Cornish Fish Producers' Organization.
Cost: To be confirmed

Long term

Fishery: Bass driftnet, operational in autumn (particularly September-December)
Bycatch: Alcids
Mitigation measure being tested: Net panels and sunken headline trials
Existing capacity: As above, existing capacity through SMRU, although the Royal Society for the Protection of Birds would potentially be able to offer background support.
Existing research: This is well-established through SMRU.
Industry links: Good links between SMRU and the local Producers' Organization
Cost: To be confirmed

Latvia/Germany

BirdLife International is already working with partners in Lithuania on a bycatch mitigation testing project, which will likely look at net panels and net lighting. In terms of new work, linking this project with new work in Latvia or Germany was suggested. Advancing this further would need to be discussed with key partners in these countries. Iceland and Denmark were flagged as countries where further gillnet work would be useful.

Fishery: Bottom-set cod gillnet (key season October-April for overlap with sea ducks)
Bycatch: Sea ducks, loons (small number of alcids, harbor porpoise)
Mitigation measure being tested: LED lights
Existing capacity: Some work on gillnet bycatch, focused on gear-switching, is already being conducted by Naturschutzbund Deutschland (NABU; BirdLife Partner in Germany), supported by Bundesamt für Naturschutz (the state nature conservation authority). In Latvia,

there is some interest in working on the issue from the BirdLife Partner Latvijas Ornitologijas Biedriba.

Existing research: There is some baseline, raw data, and a more general Baltic-wide assessment of gillnet bycatch.

Industry links: There are well-established industry links in Germany, where NABU has worked on a "Fishing for Litter" project, as well as the gear-switching work. The links are potentially less well-established in Latvia, though there are links to an ongoing Marine Stewardship Council (MSC) assessment that includes cod gillnets and a previous LIFE+ project that looked at gillnet bycatch.

Cost: For a 2 year project, around 125,000 Euro was roughly estimated.

South America

There are some well-established bycatch projects running in South America (e.g., Peru and Chile) with links to gillnet work. There was some discussion of potential work in Brazil, an area of particular interest given the potential mammal-turtle-bird overlap in the region. However, owing to a lack of Brazilian representation at the meeting, the group felt unable to discuss this work in substantial detail. Proposals to work in Brazil should be discussed further with key groups in the region.

Chile

The Albatross Task Force in Chile has already commenced some work with gillnet fishermen to quantify bycatch and look at mitigation techniques.

Fishery: Bottom-set gillnets and driftnets; year-round fishing.

Bycatch: Leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles, shearwaters (driftnet fishery), common and dusky (*Lagenorhynchus obscurus*) dolphins, guano birds, Humboldt and Magellanic penguins (bottom-set gillnet fishery).

Mitigation measure being tested: High-visibility net panels

Existing capacity: The ATF in Chile has some capacity, though additional work will require further resource. Pacífico Laúd was highlighted as another potential NGO partner.

Existing research: The ATF is in the process of finalizing a gillnet seabird bycatch problem diagnosis with the Chilean government.

Industry links: Good links to industry through ATF.

Cost: Already paid for; additional funds required for future work.

Peru

ProDelphinus has already conducted mitigation trials in gillnet fisheries in Peru (dropped headlines, net lights, and pingers among other techniques; see Jeff Mangel's presentation summary above). Experiments will continue into 2015.

Fishery: Bottom-set gillnets for guitarfish; driftnets for sharks and rays.

Bycatch: Sea turtles including green, hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), Burmeister's porpoises (*Phocoena spinipinnis*), Guanay Cormorants (*Leucocarbo bougainvillii*), and Peruvian Boobies (*Sula variegata*) in bottom-set gillnet fishery; dusky, bottlenose (*Tursiops* sp.), and common dolphins, Burmeister's porpoises, Sooty Shearwater (*Ardenna grisea*), Peruvian Diving Petrel (*Pelecanoides garnotii*), green and olive ridley turtles in the driftnet fishery.

Mitigation measure being tested: LED lights will continue to be tested in the driftnet fishery; subsurface net trials will continue in the driftnet fishery. Lighting trials will also expand into Ecuador in 2015.

Existing capacity: ProDelphinus already undertaking work.

Existing research: Paper presented to Agreement on the Conservation of Albatrosses and Petrels (ACAP) organization on net lighting trials. There is considerable existing mitigation research and bycatch estimates using rapid assessment techniques.

Industry links: ProDelphinus has well-established links with industry in Peru.

Cost: Funded through mid-2015.

Brazil

As noted above, due to lack of Brazilian representation at the meeting, attendees felt unable to propose a project, but the below details were roughly sketched out.

Fishery: Bottom-set monkfish fishery; driftnet fishery for bluefish.

Bycatch: Leatherback, green, hawksbill, loggerhead, and olive ridley turtles. Magellanic Penguin, White-chinned Petrel (*Procellaria aequinoctialis*), franciscana (*Pontoporia blainvillei*).

Mitigation measure being tested: Suggestion is to better understand the visual capacities of target catch and bycatch species for key sites.

Existing capacity: Projeto Albatroz (Albatross Task Force in Brazil) and Projeto Tamar (Brazil) have close links. Other organizations in neighboring countries include Karumbé in Uruguay and the Programa Regional de Investigación y Conservación de Tortugas Marinas de la Argentina (PRICTMA) in Argentina.

Existing research: Some net illumination trials have already been undertaken by Projeto Tamar in Brazil; links with NMFS.

Industry links: Some strong existing links through Projeto Tamar and Projeto Albatroz.

Cost: To be confirmed

Funding Bycatch Reduction Projects

The group briefly discussed some potential avenues for funding the aforementioned projects. The following list (in alphabetical order) was developed as part of that conversation:

- ACAP Awards, Grants, and Scholarships: Possible funding related to ACAP-listed species; other small funding pots.
- Arctic Council: Opportunities linked to the circumpolar work plan of the Arctic Migratory Birds Initiative, which explicitly references gillnet bycatch.
- Bycatch Reduction Engineering Program: US, administered by NMFS.
- Deepwater Horizon funds: For work in northwest Atlantic; some smaller pots will be available before final settlement.
- European Maritime and Fisheries Fund: Budget still to be finalized at time of writing.
- Individual gear manufacturers might be solicited for donations or in-kind support.

- International Group of P&I Clubs: This is a shipping insurance ("protection and indemnity") cooperative that shippers pay into; if one of their insured member's ships grounds and spills oil, they may need to provide funds to mitigate damage, and in some cases may therefore support seabird projects.
- National Fish and Wildlife Foundation: Four programs with potential:
    - Pacific Seabird Program: Aligns with species priorities; Pink-footed Shearwater (*Ardenna creatopus*) work already ongoing, and World Wildlife Fund Russia working on demersal longline and salmon driftnet fisheries.
    - Sea turtle program: Focus on eastern tropical Pacific (ProDelphinus proposal on leatherbacks).
    - Marine and Coastal Program: Fisheries Innovation Fund focuses on bycatch reduction for fisheries contributing to US market.
    - Fisheries Improvement Program (FIP) Fund: For fisheries looking for certification, bringing expertise in to allow certification. At present only has one project funded (Honduran spiny lobster, *Panulirus argus*), but has potential for work in North Atlantic on turtles.
- Pacific Islands Marine Turtle Program: US government funding pot; February 2015 funding applications are open.
- Pacific Seabird Group: Small funds are available for conservation projects (available to citizens of any country within or bordering the Pacific Ocean except the USA, Canada, Japan, Australia, New Zealand, Mexico, South Korea, and Taiwan).
- Pew Lenfest Ocean Program: Focus on forage fish, Humboldt Current penguin work.
- The Rockefeller Brothers Fund.
- USFWS Cooperative Endangered Species Conservation Fund.
- US NMFS Fisheries National Cooperative Research Program: US-based; have previously funded bycatch reduction projects.
- US Office of Science and Technology International Programs (for NMFS scientists doing international work).

NEXT STEPS

For the workshop to truly have an impact, a substantial amount of post-workshop work needs to be done:

- **Mitigation measure project advancement:** The project leads listed above will have to work to further develop proposed projects and secure funding. While some projects are already funded and underway, others are new ideas that will require financing. Given the networks built at the meeting, there is now a group of supportive colleagues that will be able to assist in developing projects; at the very least, the workshop organizers from BirdLife International will stay in touch with project leads to check in on progress.
- **"Other" project advancement:** Two other projects (the idea of a North Pacific driftnet workshop and further work on bird hearing) were proposed at the workshop. Several workshop attendees are involved in advancing these and the workshop organizers will ensure progress.

- **Understanding interactions with gillnets:** The lack of understanding of how bycaught animals interact with nets was identified as a major knowledge gap at the meeting. It will be important for this group—and the wider bycatch community—to communicate on this issue and further our understanding. The development of innovative techniques (e.g., the use of underwater cameras) is a particular area where sharing of technological expertise could help build understanding of gillnet interactions.
- **Sharing best practice across projects:** The development of gillnet bycatch mitigation techniques is at such an early phase that the sharing of successes, failures and lessons learned across projects run by workshop attendees (and the wider bycatch community) could help save limited resources and improve progress. Among the attendees, there is already substantial expertise available (and worth sharing) on calculating bycatch rates, working with fishermen and developing mitigation measures. All attendees' email addresses have been shared, and the organizers will look at the utility and appetite for a Google Docs (or similar) group to share information.

CONCLUSIONS

Unintentional bycatch of seabirds, sea turtles, and sea mammals in gillnets is a significant issue of conservation concern. It is clear that some methods of bycatch reduction not directly related to the gillnet gear itself, such as area or seasonal closures of fisheries or modifying the time of day in which fishing takes place, can be very important in reducing gillnet bycatch. However, the workshop focused on technical measures directly related to the fishing gear itself to reduce bycatch.

There are significant challenges to overcome in the development of technical bycatch reduction methods for gillnets for seabirds, sea mammals, and sea turtles. Each of these three taxonomic groups brings special problems and conditions, factors such as mobility, sensory abilities, and attraction to gillnets as a potential source of food. In addition, each of these groups has specific habitat requirements so that representatives of all three rarely overlap. Sea turtles prefer warmer waters, and most of the sea mammals and seabirds occur in colder regions. Because of these differences, finding a single technical solution that will work for all taxa in all regions is not possible. Further complicating the search for solutions is that proposed methods must not reduce catch of the target fish.

However, through the work and discussions during the workshop, some options for potential bycatch reduction measures became clear, as did future steps for trialing of the measures. The measures to be tested fall broadly into two categories: measures to increase the visibility of nets and auditory measures, using pingers to make sounds aurally detectable to potential bycatch species. Methods to increase the visibility of nets included use of high-visibility panels placed in nets, net lights, and various options for coloring the nets themselves. Pingers are known to work with cetaceans and are already being trialed for use in alerting sea turtles to the presence of nets, but testing is needed to determine if seabirds can detect pinger sounds underwater.

Testing of the proposed measures is already under way in some cases. Projects proposed either as new efforts or continuation of previously-begun work included trials in the Baltic Sea and off the southern coast of England; in Newfoundland waters and off the US east coast; in the north Pacific salmon fisheries; in Humboldt Current waters off Peru and Chile; potentially off the coast of southern Brazil; and some tests of sensory physiology in laboratories. Workshop groups identified the partners and teams to carry out the trials, and an important result of the workshop was the development of new connections and potential partnerships among those attending the meeting.

There are many new and innovative ideas for measures to reduce gillnet bycatch. The challenge of the workshop was to marshal the ideas and come up with plans to trial and prove them. There are many steps that will need to be taken before solutions can be proclaimed, but the enthusiasm and efforts of those attending the workshop will carry forward these tests and bring us ever closer to the goal: reducing the bycatch of turtles, marine mammals, and seabirds in gillnet fisheries.

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APPENDIX: RECOMMENDATIONS

Several issues were raised consistently throughout the meeting that were either outside the scope of the workshop, or were cross-cutting themes. It was acknowledged that the level of discussion they raised represented useful context for the workshop and should be incorporated into a series of recommendations in the final workshop report.

Context and overarching recommendations

- The group recognized that while the workshop represented a broad group of experts and interests (including fishers, academics, NGOs, government officials), there is a broader community of stakeholders (e.g., a wider range of fishermen, as well as contacts from all sectors in countries and continents not present at the workshop, such as Russia, Central America, Africa and Australasia) with whom the outputs of the workshop need to be discussed.
- The group agreed that a collaborative approach to research, that is, working with fishers and from the earliest possible stage, was the most likely to result in effective and accepted bycatch reduction measures. Further, the group acknowledged that bycatch research should recognize that fishers are more likely to employ measures that are cost-effective and operationally practicable for their fishery.
- The group agreed it was important to "tell the story" about the need to reduce bycatch with fishermen, to appreciate the overall picture and not just individual circumstances (i.e., while one vessel may only accidentally catch a small number of animals, this can add up to a substantial toll at the fleet scale). Critical elements of this include: (1) population estimates, trends and status for relevant bycatch-impacted species and (2) other threats which may be affecting populations.

Non-technical measures for reducing bycatch

The workshop focused on <u>technical</u> bycatch mitigation measures as the major gap in our knowledge for gillnets. However, the group felt it important to recognize that other types of measure are available and can be effective.

- The group agreed that, where economically, socially, and politically possible, alternative gear types or fishing methods should be viewed as a part of the bycatch mitigation toolbox.
- The group agreed that spatio-temporal measures also have a role to play in reducing bycatch in gillnet fisheries. For some taxa (e.g., seabirds), it may be possible to fine-tune spatio-temporal measures to reduce bycatch without impacting fishers too heavily (see Melvin et al. 1999). For others (e.g., some marine mammals) protected sites would have to be very large, and this could have a substantial impact on fishers.

Understanding interactions with gillnets

The group recognized that interactions of non-target species with gillnets are poorly understood. Future bycatch studies (whether monitoring or mitigation projects) should endeavor to better understand the nature and circumstances of interactions, whether through direct observation, cameras, or other technology.

Recommendations for filling data gaps

- The group agreed that there is a need to balance mitigation work against filling major bycatch data gaps in Africa, the Indian Ocean, South East Asia and parts of the Arctic (Žydelis et al. 2013; Wallace et al. 2013; Reeves et al. 2013), via both observer programs and rapid bycatch assessment approaches (e.g., in-port questionnaires). Further, there is a need to make the most of existing observer programs in gillnet fisheries, by incorporating fields on non-target vertebrate bycatch into observer protocols. Finally, existing, unprocessed observer data should be analyzed to better understand bycatch.
- The group agreed that, in addition to bycatch data gaps, there was a need to address gaps in fishing effort data in both small-scale and larger-scale gillnet fisheries. Effort data are often not recorded in gillnet fisheries (e.g., in the European Union, where only vessels larger than 12 m must be fitted with Vessel Monitoring Systems, meaning many small gillnet vessels are not electronically monitored).
- Similarly, incomplete knowledge of the geographic distributions of bycatch-vulnerable taxa (and its seasonal nature) needs to be addressed. There are several databases containing existing information, including SEAMAP, a forthcoming ABC mapping tool, and the BirdLife International Seabird Tracking Database and Marine IBA e-atlas.
- Elasmobranchs (sharks, rays, and mantas) were not covered by this workshop. With this group there are some complexities because in some cases this group of fish is the target catch. However, bycatch was recognized as a serious and growing issue for many species that merits consideration in bycatch reduction projects.
- The group agreed that consistent, harmonized data collection protocols should be developed. A subgroup will be set up to share existing protocols online and draw out the minimum reporting requirements.
- While there were differences in opinion over whether there was a need for consistent metrics for bycatch rates, it was agreed that a rate that incorporates a measure of effort (e.g., animals/m^2/day or animals/meter length/day) and a total estimated bycatch figure were both important when reporting.