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Marine Mammal Non-Lethal Deterrents:

Summary of the Technical Expert Workshop on Marine Mammal Non-Lethal Deterrents, 10-12 February 2015, Seattle, Washington

Workshop Steering Committee:
Kristy J. Long (Chair)
Monica L. DeAngelis
Laura K. Engleby
Deborah A. Fauquier
Amanda J. Johnson
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Simon P. Northridge

United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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This Technical Memorandum contains summaries of plenary and subgroup discussions that occurred during Days 1-3 of the workshop. While many of the comments and suggestions provided by the individual participants represent shared opinions among the participants, the intent of these discussions was not to reach consensus recommendations. Instead, the intent was to gather input from each individual participant based on his or her expertise and experience. For this reason, the discussions summarized in this Technical Memorandum do not represent consensus recommendations from the workshop participants to NMFS.

This Technical Memorandum contains recommendations of Federal Government participants concerning the guidance and process for evaluating deterrent devices and techniques and determining which deterrents to consider for NMFS' approval or prohibition. These recommendations do not represent official NMFS policy.

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OVERVIEW AND PURPOSE

The NOAA's National Marine Fisheries Service (NMFS) Office of Protected Resources (OPR) hosted a workshop at the Alaska Fisheries Science Center (AFSC) in Seattle, Washington, February 10-12, 2015, to identify safe methods for deterring marine mammals from damaging fishing gear and catch, damaging personal or public property, or endangering personal safety. This provision of the Marine Mammal Protection Act is found in Section 101(a)(4).

The three-day workshop brought together a diverse set of experts in marine mammal biology and ecology, veterinarians, and managers with the goal of evaluating the risks to marine mammals associated with various deterrent methods and technologies. The OPR intends to use the workshop results to inform its development of national guidelines on safely deterring marine mammals listed as threatened or endangered under the Endangered Species Act (ESA) and non-ESA-listed marine mammals, under NOAA's jurisdiction.

Specific workshop objectives included:

- Examine currently employed marine mammal deterrence [1]methods and technologies;
- Develop criteria by which to evaluate whether available deterrence measures are likely to result in mortality or serious injury (M/SI);
- Identify the methods and technologies that are likely non-lethal as well as those likely to result in mortality or serious injury of pinnipeds, mysticetes, and odontocetes for both ESA-listed and non-ESA-listed species; and
- Develop a process for evaluating and approving deterrence measures developed in the future.

See **Appendix A** for the workshop agenda.

PARTICIPANTS

The workshop was attended by 36 participants, including NOAA staff from headquarters (OPR, Office of General Counsel, Office of Law Enforcement) and each NMFS region and science center, as well as Marine Mammal Commission staff, veterinarians and others with expertise in marine mammal biology and ecology. The workshop, which included participants from the U.S., Scotland and Australia, was facilitated by Scott McCreary with CONCUR, Inc., and Bennett Brooks with the Consensus Building Institute. See **Appendix B** for a listing of all workshop participants.

WORKSHOP ORGANIZATION AND MATERIALS

To prepare for the workshop, NMFS convened a Steering Committee to help shape the workshop structure and agenda, identify candidate participants, and develop materials for use before and during the workshop.

The Steering Committee, which included both NMFS and non-NMFS members and met 10 times via teleconference, was instrumental in guiding workshop preparation. Kristy Long, OPR/Alaska

[1] The focus of the workshop was on protecting fishing gear/catch and/or personal property and not on reducing bycatch.

Region, spearheaded planning for the workshop. Other Steering Committee members included the following: Monica DeAngelis, NMFS West Coast Region; Laura Engleby, NMFS Southeast Region; Deborah Fauquier, NMFS OPR; Amanda Johnson, NMFS Greater Atlantic Region; Scott Kraus, New England Aquarium; Simon Northridge, University of St. Andrews. The Steering Committee teleconferences were facilitated by Scott McCreary, CONCUR, Inc., and, Bennett Brooks, CBI.

Based on the Steering Committee work, the following materials were developed or provided to inform deliberations, with much of the material distributed prior to the workshop.

- A listing of candidate deterrents to be evaluated
- A detailed literature review and associated summary tables of active and passive deterrents associated with mysticetes, odontocetes, and pinnipeds
- A matrix and associated guide outlining criteria for evaluating each candidate deterrent
- Summary of public comments in response to a *Federal Register* Notice seeking input on candidate deterrents to evaluate
- NMFS policy for distinguishing serious from non-serious injuries
- Listing of ESA-listed marine mammals by species
- USFWS deterrence guidelines for polar bears

DISCUSSION SUMMARY - WORKSHOP

The workshop began with a brief welcome from Dr. John Bengtson, Director of the National Marine Mammal Laboratory at the NMFS Alaska Fisheries Science Center. Dr. Bengtson noted the workshop is an important and significant step in helping NMFS develop guidelines that provide tools for fishermen and private citizens to protect their fishing gear and private property while, at the same time, ensuring NMFS meets one of its core missions – protecting marine mammals. J. Bengtson's remarks were followed by a review of the workshop purpose, agenda and meeting protocols, as well as participant self-introductions.

Presentations

The morning of Day One centered on a series of presentations intended to provide all participants with a common understanding of workshop focus and task. Presentations included the following:

- Workshop Overview. K. Long summarized workshop objectives, scope, approach, current legal framework for deterrents, intended work products and post-workshop process. Key points included the following:
    - The workshop is focused on impacts to marine mammals under NMFS' jurisdiction: cetaceans and pinnipeds (excluding walrus), including 15 ESA-listed marine mammals, and particularly those impacts that result in mortality and/or serious injury.
    - The workshop is not intended to focus or reach conclusions on the efficacy of various deterrent methods. Rather, participants are to focus on assessing impacts to marine mammals.
    - The workshop is not consensus-seeking. Rather, it is intended to capture the range of participants' perspectives and any underlying rationales.

- Given the paucity of data on potential impacts to marine mammals, the intent of the workshop is to gather "expert elicitation" – in other words, a synthesis of opinions based on research, case studies and professional judgment.
- The intent of the workshop is to gather input on "guidelines" for deterring non-ESA-listed marine mammals (e.g., acceptable for use by general public, requiring specific training/authorization, not approved for use, requires additional research), as well as "specific measures" related to ESA-listed marine mammals (e.g., what specific devices can/cannot be used and any related restrictions)
- Following the workshop, NMFS will consider the expert advice and determine which guidelines and specific measures, if any, to move forward as part of a federal action. Any proposed actions will be published in the *Federal Register* and made available for public review and comment

- Candidate deterrents. M. DeAngelis provided an overview of the preliminary devices and techniques to be considered in the workshop. She noted that the listing of deterrents, including both active (acoustic, chemosensory, tactile, visual) and passive (acoustic, visual, physical barrier, gear modifications), was developed based on a review of literature, Steering Committee input and suggestions put forward in response to the *Federal Register* Notice. (The *Federal Register* Notice and the public comments received are available at http://www.regulations.gov/#!docketDetail;D=NOAA-NMFS-2014-0146.)

- Literature review. A. Johnson provided a summary of the literature review, by taxa, for different deterrent types. The detailed literature review underscored the lack of research focused on evaluating the potential impacts of various deterrent types on marine mammals. Rather, most of the research to-date, understandably, has centered on better understanding the efficacy of deterrents, but that information is also limited. See **Appendix C** for summary of literature review by taxa.

- Criteria to assess/characterize deterrents. S. Kraus provided an overview of the criteria to be used to characterize and assess the potential impacts of various deterrents on marine mammals. The criteria headings, summarized in table format by the Steering Committee prior to the workshop and then further refined in discussion with workshop participants, focused on the following:

Identifying the deterrent types to be evaluated. These included the following categories (initially based on lit review and updated according to workshop discussions)[2]:

Active – Acoustics (in air or in water)[3]

- Acoustic deterrent devices - alerting function with source levels <135 dB for pinnipeds and <179 dB for cetaceans) (e.g., pingers, certain types of pipe-banging)
- Acoustic harassment devices - scaring function with source levels ≥ 135 dB for pinnipeds and ≥ 179 dB for cetaceans (e.g., OrcaSaver)

[2] As a result of the pre-workshop exercise, "avoidance" was removed from the list of deterrents to discuss at the workshop given avoidance techniques should be employed prior to attempting deterrence; avoidance in and of itself is not a deterrent.
[3] See "Challenges in binning active acoustics by sound characteristics and assessing potential impacts to marine mammals" on p. 7.

- Explosives (e.g., seal bombs, cracker shells, firecrackers)
- Banging/vibrations (e.g., using pipes/anvils and hammers)
- Predator sounds/vocalizations
- In-air noisemakers (e.g., starter pistols, screamer rockets, horns)

Active – Chemosensory

- Taste or smell deterrent (e.g., hot sauce)
- Learned aversion/emetics (e.g., lithium chloride)
- Chemical irritant (e.g., mace, pepper spray)

Active – Tactile (physical contact)

- Fixed sharp objects on a structure (e.g., tacks or nails on a dock, barbed wire)
- Propelled penetrating ammunition/objects (e.g., live ammunition, buck shots, bird shots, nail guns)
- Propelled non-penetrating objects (e.g., paint balls, rubber bullets, rubber-tipped arrows)
- Manual blunt and non-penetrating (e.g., blunt tip bull pole, broom)
- Water deterrents (e.g., hoses, bubble curtains, sprinkler)
- Manual sharp penetrating (e.g., hooks, sharp-ended poles)
- Sharp penetrating projectiles (e.g., archery arrows, blow darts)
- Pulsed power device (a shock-wave generator[4])

Active – Visual

- Vessel chasing
- Lasers
- Unmanned aerial systems (e.g., drones)

Passive – Acoustics (e.g., chains, tin cans on a dock)

Passive – Visual

- Flashing light
- Flags/pinwheels/streamers
- Air dancers
- Colored fishing gear
- Predator shapes

Passive – Physical barriers

- Anti-predator netting
- Electric field in water
- Rigid fencing in air
- Gates or closely spaced poles
- Bull rails

Passive – Gear modifications

- Devices to protect gear/catch (e.g., net sleeves/rods/spikes)
- Excluder devices

Categorizing the potential impacts associated with each deterrent. The Steering Committee identified a series of categories to characterize potential impacts to marine mammals (both likelihood and severity) from each of the deterrents to be evaluated. These potential impacts included the following: physical trauma, acoustic trauma, masking, toxicity, infection, chronic stress, decreased individual fitness, and broad-scale impact through displacement. Participants also were asked to categorize potential impacts to non-

[4] Note: This pulsed power device is distinct from the "GenusWave," which is both acoustic and tactile.

target species (assuming a worst-case scenario). Likelihood of impact was scaled on a range from 0-100%; potential severity of impact was binned into one of five categories: none/not applicable; trivial; moderate; severe; unknown.

Each workshop participant was asked to complete as many rows in the table for as many species or taxa for which they were comfortable and based on his/her expertise. Each row corresponded to a deterrent device category. These initial responses were then summarized on a consolidated table that served as the starting point for workshop discussions.

Discussion Themes

The bulk of the workshop focused on a series of breakout sessions and plenary discussions intended to (1) better understand the potential impacts associated with each deterrent and (2) articulate possible guidelines for their use going forward. To foster discussions across both taxa and deterrents, a series of three breakout sessions were held – each followed by reports back in plenary. The primary focus for the breakout sessions, each of which had a group lead and rapporteur, was as follows:

- <u>Breakout Session #1A, B, and C (organized by taxa – pinnipeds, odontocetes, mysticetes)</u>: The primary focus of this breakout session centered on gauging participant perspectives on the likelihood and severity of impacts on each taxa related to each deterrent (assuming worst-case scenario), as well as articulating any key assumptions driving the risk assessment.

- <u>Breakout Session #2A, B, and C (organized by deterrent type – passive, active-acoustic, active-other)</u>: Using the results from the Breakout Session #1 deliberations, participants focused primarily on reviewing and refining impact characterizations across deterrent type and identifying strategies to mitigate worst-case scenario impacts by stipulating possible conditions on use and user groups (i.e., ranging from general public to trained individuals).

- <u>Breakout Session #3A, B, and C (by taxa, same as Breakout Group Session #1)</u>: Using the results of Breakout Session #2 deliberations, participants focused on articulating specific guidelines for use for each deterrent type by taxa (and the associated rationale) and identifying potentially prohibited deterrents, as well as articulating critical unknowns and identifying specific measures related to ESA-listed marine mammals.

Breakout group and plenary discussions generated the following primary themes and outcomes:

- ***Deterrent categories revised.*** Breakout group discussions led participants to refine the listing of deterrents to more fully capture the range of devices/methods and better aggregate them according to like characteristics. Changes included: aggregating vessel noise/chasing into one category under active visual; shifting passive acoustics to the passive deterrent category (rather than the active category); adding additional deterrents to the list (water deterrents, anvils/hammers, learned aversion/emetics, lasers, electric fields in water, unmanned aerial systems (e.g., drones)); and adding greater specificity to physical contact deterrents (both propelled and manual) to distinguish between penetrating and non-penetrating objects.

- ***Ranges of impact likelihood and severity identified**.* While the perceived risks to marine mammals associated with many deterrents varied across taxa, participants generally agreed to a fairly narrow band of expected impacts (both likelihood and severity) within each taxa. The greatest diversity of views within each of the three taxa focused on the following: the likelihood and severity of infection tied to sharp penetrating objects; and the likelihood and severity of physical impacts from the manual use of blunt, non-penetrating objects. The odontocetes breakout group also had its widest range of views on potential chronic stress and decreased individual fitness tied to the use of propelled non-penetrating objects. The mysticetes experts also had varied views on the likelihood and severity of several impacts tied to acoustic harassment devices with source levels greater than 180 dB, pipe banging, and vessel chasing (depending on vessel size).

- ***Assessment and acceptability of risk varied widely by taxa.*** Not surprisingly, the assessment and acceptability of risk varied widely by taxa, with the mysticetes group being the most precautionary (identifying just 4 deterrents for general use as opposed to 11 within the odontocetes and pinnipeds breakout groups). The majority of mysticetes are endangered species, for which literature and research on the impacts of deterrents were very limited. In general, the mysticetes group felt more information was needed on potential regional and stock-specific impacts before it could consider more deterrents for general use.

- ***Deterrent categories to be potentially prohibited for use identified within each taxa.*** While there were divergent views on the impacts of a number of deterrents within each taxa, there were a number of deterrents broadly identified for potential prohibition in each of the taxonomic-specific breakout groups. These include the following:

    - <u>Odontocetes</u> (both non-ESA and ESA-listed): Seal bombs; cracker shells; taste or smell deterrents; chemical irritants; propelled penetrating ammunition/objects; manual sharp penetrating objects such as hooks and sharp-ended poles; sharp penetrating projectiles (e.g., arrows, blow darts, nail guns); fixed sharp objects on a structure; lasers; and anti-predator netting.

    - <u>Mysticetes</u> (both non-ESA and ESA-listed): Acoustic harassment devices; seal bombs; cracker shells/pyrotechnics; predator sounds/vocalizations; in-air noisemakers capable of shooting live ammunition; vessel chasing; anti-predator netting; electric field in air; electric field in water. Additionally, the group identified acoustic deterrent devices for NMFS to consider prohibiting for ESA-listed North Atlantic and North Pacific right whales. The group did not complete discussions on a number of the physical contact deterrents.

    - <u>Pinnipeds</u> (both non-ESA and ESA-listed): Propelled penetrating ammunition/objects; manual sharp penetrating objects such as hooks and sharp-ended poles; sharp penetrating projectiles (e.g., arrows, blow darts, nail guns); and lasers.

- ***Deterrent categories appropriate for potential general use.*** The discussions identified a handful of deterrents that were broadly seen as potentially acceptable for general use (or not applicable) across taxa. These deterrents included: in-air noisemaker (excluding gunshots, includes starter pistols); vessel noise (as distinct from vessel chasing); all passive visuals; and water deterrents. Within each taxa, additional deterrents were seen as appropriate, as described below. It is important to note that individual workshop participants also identified a number of caveats or conditions associated with general use (e.g., horns and other noisemakers acceptable for general use with time limit for exposure; non-penetrating objects should not be aimed at the blowhole or eye).

- Odontocetes (non-ESA and ESA-listed): firecrackers (with restrictions on use); pipes/anvil/ hammer (but with concerns for ESA-listed); vessel noise (as decoy only); in-air noisemakers; manual blunt and non-penetrating physical contact; water deterrents; and rods/nets/sleeves around bait/catch. For non-ESA only: acoustic deterrent devices at exposures below thresholds known to lead to the onset of permanent threshold shifts (PTS) for the most sensitive species/geographies; predator sounds/vocalizations.

- Mysticetes (non-ESA and ESA-listed): vessel noise (no chasing); in-air noisemakers such as starter pistols (but not gunshots and further research needed on drones/airplanes); water deterrents; colored lines; and all passive visuals. There were no ESA-listed distinctions cited, as the majority of mysticetes are currently ESA-listed.

- Pinnipeds (non-ESA and ESA-listed): in-air noisemaker; water deterrents; all passive visuals; colored lines; anti-predator netting; electric field-in air; rigid fencing in water; rods/nets/sleeves around bait/catch, and gates or closely spaced poles. For non-ESA only: acoustic deterrent devices.

- ***Challenges in binning active acoustics by sound characteristics and assessing potential impacts to marine mammals.*** Workshop participants struggled to appropriately characterize the level of acoustic trauma associated with pingers and other acoustic deterrents when considering acoustic impacts in terms of serious injury and mortality. In general, acoustic deterrent devices (ADDs, source levels below 135 dB for pinnipeds, and below 179 dB for cetaceans) were expected to be below the level that would cause a temporary threshold shift[5] (TTS) in hearing for the most sensitive species, while acoustic harassment devices (AHDs) were considered more problematic given the associated pain and trauma intended to occur (a point emphasized in the pinniped group report out on Day Three). However, there were important distinctions both across and within taxa, as well as additional considerations that influence how a species could be affected by acoustic deterrent methods. Workshop participants (particularly within the mysticetes and acoustics breakout groups) suggested that the range of unknowns (from species-specific distinctions to varying device frequency) make it difficult to assess likely impacts of ADDs and AHDs. Moreover, participants noted that the potential acoustic impacts from the devices likely vary widely based on an array of sound characteristics (e.g., duration of use (intermittent or continuous), source level and frequency, duty cycle, density and mix of devices, etc.), as well as species' behavioral characteristics (e.g., motivation - starving versus well-fed marine mammals and accessing food, frequency used for communication or foraging, skittish versus bolder species, exposure tolerance, etc.). Accordingly, rather than

[5] Temporary threshold shift (TTS) is a temporary, reversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range above a previously established reference level. PTS is a permanent, irreversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range above a previously established reference level.

attempting to define specific decibel levels associated with varying levels of acoustic trauma, participants instead recommended to consider characterizing deterrent devices based on an array of sound characteristics (e.g., estimated exposure) and then evaluating the impacts and implications (i.e., TTS versus permanent threshold shift (PTS)) for the physiological and/or behavioral responses of marine mammals by species and region. One participant noted that the University of St. Andrews Sea Mammal Research Unit has developed a model called "Sound Explorer Tool," which considers characteristics of a specific sound source and provides cumulative sound exposure levels. Additionally, an ongoing effort within the Agency to assess the effects of anthropogenic sound on marine mammal hearing (NOAA Acoustic Guidance) is expected to yield information (updated threshold levels for onset of PTS and TTS) that can then be used to assess needed guidelines by species and region.

- ***Emphasize and manage to the most sensitive species in devising deterrent guidelines for specific applications and geographies.*** Given the spatial and temporal co-occurrence of some assemblages of marine mammals, several groups recommended that deterrents (particularly acoustics) be managed based on the potential impacts to the most sensitive species present in a given geography. This approach was particularly important to many in the mysticetes breakout group given the number of ESA-listed species within the taxa. The group also discussed how consideration should be given to non-target marine mammal species present in an area and sensitive to a deterrent that is targeting another species (e.g., using pingers for deterring humpback whales may exclude harbor porpoises from important habitat).

- ***Balance an appropriately precautionary approach with need for legal and effective deterrents.*** A number of workshop participants called for the Agency to balance the precautionary approach recommended by many workshop participants with the need to ensure legal, non-lethal deterrents are made available as tools to individuals needing to protect property, catch or personal safety. The Agency, these individuals said, needs to weigh the uncertain impacts associated with some deterrent devices (or the improper use of these deterrents) with certain risks (e.g., individuals resort to using illegal methods such as firearms to shoot live ammunition because they feel there are no other tools are available for non-lethal deterrence). As well, a lack of legal deterrents, some participants noted, could also lead to increased bycatch or other impacts to the animals (e.g., retaliation by intentional injury or killing). These assessments, several participants noted, need to be informed by taxa-, species- and geography-specific considerations.

- ***Ongoing concern about population-level impacts and cumulative effects.*** Several workshop participants cited concerns about the potential for population-level impacts (e.g., displacement), particularly as it relates to the ensonification of some biologically-important areas and the extent of deterrent use in the ocean, should certain deterrents be approved (e.g., the extent and density of pingers in the Gulf of Maine). Concerns were also cited regarding the cumulative effects of deterrents leading to chronic stress. There were insufficient data to adequately engage these concerns during the workshop, but it was noted that such considerations can and will be discussed as part of any subsequent environmental analysis. It was further noted that the Agency is required to consider and evaluate population-level impacts and cumulative effects as part of its environmental analysis.

- ***Lack of documented impact to marine mammals does not equate to effectiveness of deterrence.*** At numerous points during the workshop, individual participants emphasized that a low expected impact to marine mammals does not necessarily mean a deterrent will be effective. It simply means it either has a low likelihood or a less severe impact (or both) to marine mammals. Several participants recommended that any subsequent guidance by the Agency underscore this point so the general public does not mistakenly perceive approved deterrents to be an endorsement of effectiveness. Similarly, several participants also noted that the lack of a response to a deterrent does not necessarily mean the deterrent is not causing an impact to the exposed individual.

- ***Balancing costs and benefits.*** Several individual participants suggested that the risk (and associated sensitivity) of using an individual deterrent needs to be considered in a broader context and include the size and status of the marine mammal population under consideration when evaluating the acceptability of deterrent use (e.g., the acceptability of a lower-risk deterrent could vary with populations ranging from only hundreds of marine mammals to those with tens of thousands of individuals in a growing population). Alternatively, the Agency also needs to consider whether the uncertain benefits associated with ineffective or unproven deterrents outweigh the known risks of the deterrent (even if those risks are seen to be low). Others suggested that any future considerations regarding deterrent costs and benefits should include fishing industry representatives.

- ***Numerous potential research needs identified by participants.*** Not surprisingly, all three taxa-specific groups identified a number of areas where more research is needed to better understand the likely impacts of certain deterrent devices/techniques on the various marine mammal species. There were also suggestions to, when possible, build cooperative research efforts with fishermen. Among the most frequently suggested research needs were: audiograms and/or behavioral responses to sounds to better inform calculating levels likely to cause TTS/PTS; better understanding the impact of signal output characteristics on marine mammals (frequency and other acoustic characteristics rather than just the decibel level); and, impacts and effectiveness of drones/planes (shadow and noise), and pulsed power device (e.g., a new one under development by Hydroacoustics, Inc.). Other research needs cited by taxa included the following:

    - Mysticetes: Potential impacts from banging/vibrations tied to the use of pipes/anvils/hammers; from propelled non-penetrating objects; and, from predator shapes
    - Odontocetes: Potential impacts from the use of colored lines, electric fields in water and excluder devices
    - Pinnipeds: Potential impacts from the use of predator sounds/ vocalizations, taste/smell deterrents, chemical irritants, electric field in-water and excluder devices

Other comments included the following:

- The critical need to allow for differentiation across regions and species when drafting guidelines and measures for both non-listed and ESA-listed species, respectively. This differentiation, highlighted at various points during the workshop, is needed to accommodate the conditions encountered where and when the deterrent is to be used.
- The importance of considering enforceability when developing guidelines/specific measures/prohibitions. The more black and white, (e.g., allowed to use or not allowed to use), the easier it is for OLE to effectively enforce. Additionally, public perception and/or public safety issues associated with allowing certain deterrents should be recognized.

- The need to distinguish among deterrents acceptable for use by the general public and those being used by trained managers. Similarly, it is important to consider the potential for individuals to misuse devices/techniques and whether that misuse may readily cause M&SI.
- Using existing and or new Stranding Program data, as possible, to evaluate physical impacts to marine mammals for approved deterrent devices. Others, however, cautioned against overburdening the already strapped Stranding Program network with collecting additional data.
- Share identified research needs with the relevant Science Review Groups (SRG), as they may opt to incorporate these information gaps into their research priorities.
- It was noted that others who supply funding may also be interested in supporting identified research needs.
- The importance of using an appropriately precautionary approach to deterrents while giving practical consideration to the risks associated with bycatch. Several participants noted that some practices/devices that might be deemed unacceptable by the Agency for use by the general public should be allowed for use by fishermen, given the potential benefits associated with bycatch reduction. (K. Long noted that, while an important concern, there are other mechanisms available to the Agency to address M/SI incidental to commercial fishing, such as MMPA Section 118.)
- The importance of considering the potential to generate increased (and inevitable) marine debris when considering which in-water deterrents are appropriate to use.
- The potential to evaluate deterrent devices/techniques in the future based on enforcement violations and complaints.
- The secondary impacts of deterrents on fish species in addition to marine mammals (it was noted however that fishes are generally low-frequency specialists not affected by most pingers).
- The need to consider cryptic mortality from deterrents (unseen animals may be affected).
- The potential for active acoustics to lead to increased entanglement of depredating animals (i.e., where the "deterrent" actually becomes an attractant).

Participants also spent time prior to the end of the workshop providing guidance on strategies to refine input on deterrents, both in the near- and longer-term. Individual comments included the following:

- Interest in gathering data to better assess the use, impacts (i.e., are impacts as low as predicted) and efficacy associated with approved deterrents. Various methods were suggested – from mandatory logbooks and observer data to voluntary self-reporting or Stranding Program data (as noted earlier) – but no single approach garnered broad support. Aquaculture sites were also seen as a potential source of reliable data given the relatively bounded geographies, controlled conditions, and prospect for strong record keeping. Regardless of approach, the Agency needs to identify key data needs and criteria to drive any subsequent data collection effort.

- Participants discussed possible strategies for testing deterrents that were characterized as requiring more study. Some suggested considering conditional approvals, followed by studies to assess impacts and, as needed, revising of guidelines. (The concept of conditional approvals, though, was not widely supported.) Others suggested focusing first on geographies with higher takes and depredation to test deterrents in cooperation with fishermen, then adjust guidelines based on results. When possible, participants also recommended focusing on those areas and marine mammal populations with a more robust baseline data set.

- For new deterrents, participants did not support creating a detailed standing process to re-evaluate and revise the guidelines to produce a comprehensive update. Rather, they recommended the Agency craft guidelines in a manner that enable new devices to be readily categorized and assessed by the public and the Agency using existing guidelines. To foster peer review, any ongoing Agency determinations on new candidate deterrents could be sent to the relevant SRG for review and comment.

DISCUSSION SUMMARY – FEDERAL-ONLY SESSION

Following the workshop, NMFS convened a federal-only session (including those in attendance with SRG appointments) to consider workshop results and identify any initial recommendations regarding Agency guidance and/or next steps.

The bulk of the discussion centered on (1) reviewing the analysis put forward by each breakout group (session #3) and (2) then considering initial recommendations related to candidate guidelines for non-listed marine mammals and specific measures for ESA-listed species.

The group first looked across the report-backs by each group to identify common themes (e.g., prohibit, more research needed, etc.). Where there were gaps in analysis – for example, the mysticetes group not finalizing discussions on some physical contact deterrents – participants reviewed more detailed notes of individual comments from each breakout group.

The Federal-only participants put forward the following preliminary guidelines for consideration in further Agency deliberations and analyses:

- Prohibited for general use
    - All explosives (as defined by ATF; cetaceans only)
    - Any firearm capable of using live ammunition (cetaceans only)
    - Live ammunition (all taxa)
    - Sharp penetrating objects – manual and projectiles (all taxa)
    - Taste/smell deterrent (all taxa)
    - Chemical irritants (all for odontocetes, mace and bleach for pinnipeds)
    - Poisons and toxins – specific list to be fleshed out later (all taxa)

The Federal-only group considered prohibiting several other deterrents, but determined that more discussion is needed before developing specific guidance. These included the following:

- Any firearm capable of using live ammunition for pinnipeds – Participants recognized the potential for abuse, but there was reluctance on the part of some in the group to prohibit the use of cracker shells, which are discharged via a firearm. One possibility for future consideration: allow only for trained personnel via MMPA section 109(h).

- Vessel chasing – Participants agreed that more discussion is needed to assess the appropriateness by species and region, as well as to develop a workable definition of vessel chasing (versus patrolling a net).

- Anti-predator netting – Again, participants recognized the potential for this deterrent with pinnipeds, but expressed concerns that it could lead to M/SI of cetaceans or other non-target species (e.g., sea turtles, sturgeon, seabirds, etc.) as well as become marine debris.

Other discussion points in the federal-only session included the following:

- ***Acoustics.*** Participants in the federal-only meeting discussed a strategy for linking future deterrents guidelines with the NMFS's ongoing effort to develop guidance for assessing the effects of anthropogenic sounds on marine mammal species under its jurisdiction (i.e., NOAA Acoustic Guidance updating TTS/PTS onset thresholds). Participants recommended the following next steps:

    - Step 1: Create a list of acoustic devices and associated specifications
    - Step 2: Based on specifications, identify cumulative sound exposure level over 24 hours
    - Step 3: Consider TTS/PTS onset thresholds for the most sensitive species at a regional level (drawing on NOAA's ongoing effort)
    - Step 4: Identify which devices, based on the cumulative sound exposure level, are above or below TTS/PTS onset thresholds. Develop guidelines and prohibitions as appropriate, likely by geographic region and/or seasonality (where migratory species occur).
    - Step 5: Articulate a process to evaluate new devices in the future.

  Participants agreed that a separate process – likely engaged through the environmental assessment – is needed to evaluate population-level displacement effects. Further discussion is also needed to address cumulative sound exposure impacts – both by season and region.

  Based on the discussion, NMFS is to convene an acoustics working group (M. DeAngelis, S. Horstman, M. Castellote, B. Mansfield, D. Palmer) to work with A. Scholik-Schlomer and K. Long to address next steps.

- ***Reporting requirements.*** Federal-only participants discussed candidate reporting requirements to ensure the Agency has the ability to track impacts and, as needed, adapt guidelines to minimize impacts to marine mammals. Participants identified a range of information needs, including: ESA-species-specific risk, behavioral responses, deterrent efficacy and efficiency, deterrent usage pre- and post-guidelines, economic impacts, impacts on species and users, and any other information that helps validate underlying assumptions related to expected trauma levels.

  Participants further discussed, but did not agree on, possible methods for gathering additional data on the use of approved deterrent methods. These included: voluntary online survey, focused individual surveys, self-reporting, targeting specific user groups, and mandatory reporting. Participants recommended that these various options be explored in the NEPA analysis.

- ***Research needs.*** Based on workshop deliberations, federal-only participants identified the following higher priority research activities:

- Audiograms. Need to improve methods for collecting audiograms from more species, particularly wild individuals, such as possibly having operators in strategic locations able to deploy to stranded or entangled marine mammals. Additionally, there is a need for research and development to devise new methods for gathering audiograms on large cetaceans. Obtaining audiograms for mysticetes is seen as the top priority.

- Behavioral response. Participants saw a need to better understand marine mammal behavioral responses to various deterrents, with a particular focus on species-level reactions to various pinger sounds and visual devices. For example, the Agency also needs to better understand which species are likely to put themselves at risk due to a motivation-based factor (e.g., remaining in an area to pursue food despite the presence of AHDs).

- Drones/planes impacts. Participants were eager to better understand the potential impacts of drones and planes on different animals (e.g., drones can cause pinnipeds to flush into the water). There was also interest in better understanding the FAA authorizations needed for drone use and the extent to which existing FAA guidelines ban harassment of animals.

Based on the discussion, participants agreed to develop and distribute to workshop participants a comprehensive list of candidate and priority research activities. The Agency is also expected to revisit and, as appropriate, refine research priorities based on its evaluation of the research needs identified during the workshop.

- ***Training/Authorization needs.*** For a number of categories, participants recommended deterrents be used only by individuals with specific authorization or training to use certain devices and methods, as incorrect or misuse of these particular methods have the potential to cause M/SI of marine mammals. The Federal-only discussion underscored that the training/authorization characterization actually has several different interpretations as discussed by workshop participants. In some cases, it meant suggesting or requiring "best practices" when using certain devices or methods. In other cases (for example, with seal bombs), it meant that only authorized individuals (e.g., someone with a formal letter of authorization from ATF) or classes of individuals (e.g., government employees) are permitted to use a device or technique. K. Long emphasized that the Agency is not contemplating developing and/or implementing any new training programs. It was also noted that Section 109(h) of the Marine Mammal Protection Act already gives federal, state or local government officials and employees the authority to act to protect public health and welfare.

Based on the conversation, federal participants identified the following next steps related to training and authorization needs noted by workshop participants:

- Identify which training recommendations are covered by Section 109(h)
- Consider shifting vessel chasing of odontocetes from the "training" designation to "prohibited" since government employees would still be authorized to use the deterrent method, as needed
- Review other "training" recommendations to assess the necessity of restating them as "prohibited" deterrents

- ***Proposed Rule.*** K. Long is to work with Agency colleagues to develop a proposed rule based on workshop feedback and follow-up conversations. Specific actions will focus on developing two lists: one for prohibited deterrents and one for those deterrents deemed "readily available and acceptable for general use." Guidance will likely be segmented into two streams: one for cetaceans and one for pinnipeds. As needed, K. Long will reach out to non-Agency colleagues if the specific expertise is not available within the Agency.

NEXT STEPS

The following next steps were identified based on workshop deliberations:

- NMFS is to convene an internal acoustics work group (M. DeAngelis, S. Horstman, M. Castellote, B. Mansfield, and D. Palmer) to help coordinate with A. Scholik-Schlomer and K. Long to further define species- and region-specific thresholds for ADDs and AHDs.

- NMFS is to convene 3 other internal work groups to develop guidelines, specific measures, and prohibitions for non-acoustic deterrents for mysticetes, odontocetes, and pinnipeds.

- K. Long is to consider the results of the workshop deliberations and work internally with NMFS colleagues to develop a proposed rule outlining guidelines and any ESA-specific measures. No formal follow-on discussions with workshop participants are anticipated, but NMFS may reach out to individuals to clarify or amplify points raised during the workshop. There is no specific timeline for developing a proposed rule.

- NMFS is to develop a comprehensive list of candidate research needs and priorities for distribution to workshop participants and each SRG.

- CONCUR is to develop a meeting summary highlighting key themes for review and confirmation by workshop participants. The summary is not intended to report back details from each breakout session, but – rather – focus on key crosscutting themes and recommendations generated across all three days of discussion.

- Participants were asked to forward information on any studies missing from the literature review to K. Long and A. Johnson.

For any questions or comments regarding this report, please contact Kristy Long (206-526-4792, kristy.long@noaa.gov), Scott McCreary (510-649-8008, scott@concurinc.net) or Bennett Brooks (212-678-0078, bbrooks@cbuilding.org).

APPENDIX A. Workshop Agenda

<u>DAY ONE: FEBRUARY 10, 2015</u>

8:45 AM Arrival, Greetings, and Welcome

9:00 AM Workshop Purpose, Introductions and Agenda Review
- Welcome – *J. Bengtson, Director of NMFS National Marine Mammal Lab*
- Meeting Purpose – *CONCUR, Inc.*
- Introductions – *All*
- Agenda and Meeting Protocols – *CONCUR, Inc.*

9:30 AM Workshop Overview – *K. Long & J. Forman*
- Approach and Scope
- Intended Work Product
  - General criteria for deterrent use
  - Non-lethal specific measures
- Agency next steps in decision-making

10:00 AM Preliminary devices and techniques to be considered – *M. DeAngelis*
- Broad overview: Characterize types and intents of deterrents
- Summarize deterrents to be considered during the workshop based on *Federal Register* notice responses, Steering Committee guidance, and broadly used methods/devices

10:30 AM Break

10:45 AM Literature review – *A. Johnson*
- What are the most compelling findings? What do we know? What are the critical uncertainties?
- Initial categorization
  - By taxa and deterrent

11:15 AM Initial Criteria for Characterizing/Assessing Deterrents – *S. Kraus*
- Introduce and confirm draft criteria
- Review strawman table developed based on draft criteria
- Considering effectiveness in workshop deliberations

12:15 PM Lunch

1:45 PM Overview: Concurrent Breakout Group Discussion #1

2:00 PM Concurrent Breakout Group Discussion #1 (By taxa)[6]

Breakout Group 1A: **Pinnipeds**

Breakout Group 1B: **Odontocetes**

Breakout Group 1C: **Mysticetes**

- Review and revise, as needed, potential impacts (likelihood and severity) on target and non-target species based on initial pre-workshop responses to the strawman criteria document
    - What's the group's collective sense of the potential impact and severity for each deterrent type?
    - Might these impacts vary based on user group or methods of use/application?
- Develop concise synthesis for presentation to plenary
    - Key revisions, emerging themes, information gaps

4:15 PM Plenary: Report back and discussion on Breakout Group Discussion #1

5:00 PM Final Observations and Preview of Day Two

5:15 PM Adjourn

DAY TWO: FEBRUARY 11, 2015

8:45 AM Arrival, Greetings, and Welcome

9:00 AM Overview: Concurrent Breakout Group Discussion #2

9:15 AM Concurrent Breakout Group Discussion #2 (By deterrent type, cross-taxa)[7]

Breakout Group 2A: **Passive**

Breakout Group 2B: **Active – Acoustic**

Breakout Group 2C: **Active – Chemosensory, Tactile, Visual**

[6] *Afternoon break taken by each breakout group, as needed.*
[7] *Morning break taken by each breakout group, as needed.*

- Review, revise (as needed), and confirm potential impacts (likelihood and severity) for each deterrent type developed by Breakout Session #1 (where divergent views, capture range of views)
- Is there the potential to identify acceptable levels of risk (based on likelihood and severity) for each deterrent type by taxa and/or by species, as appropriate? If so, what are those levels?
  - Might these levels vary based on user group or methods of use/application?
  - How do we account for species where there is insufficient data?
- Begin identifying critical data gaps/research needs based on uncertainty surrounding likelihood and severity of impacts
- Develop concise synthesis for presentation to plenary
  - Key revisions, emerging themes, information gaps

11:15 AM Plenary: Report back and discussion on Breakout Group Discussion #2

12:15 PM Lunch

1:45 PM Overview: Concurrent Breakout Group Discussion #3

2:00 PM Concurrent Breakout Group Discussion #3: (By taxa and species)

Breakout Group 3A: **Pinnipeds**

Breakout Group 3B: **Odontocetes**

Breakout Group 3C: **Mysticetes**

- Develop candidate guidelines (levels and application related to deterrent types) for non-listed marine mammals for full workshop consideration
  - Bin devices and techniques into the following categories:
  - Readily available and acceptable for use by the general public
  - Requires specific training and/or authorization
  - Should only be used during imminent threat to personal safety
  - Should not be approved (e.g., due to risk of M/SI of target or non-target species, or for other reasons)
  - Would require additional research (as identified in Breakout Session #2) before evaluation and approval is possible
- Are there specific measures (devices or techniques) the Agency should consider approving for ESA-listed species? Which ones?
- Develop concise synthesis for presentation to plenary
  - Key revisions, emerging themes, information gaps

4:15 PM Plenary: Report back on Breakout Group Discussion #3

5:00 PM Final Observations and Preview of Day Three

5:15 PM Adjourn

Day Three: February 12, 2015

8:45 AM Arrival, Greetings, and Welcome

9:00 AM Additional Plenary and Breakout Discussions
- Additional discussion of results from Breakout Group #3

10:30 AM *Morning break*

10:45 Process to refine input: near-term and longer-term – *K. Long*
- Turning workshop products into formal NMFS guidance
    - Process overview and specifics
    - How to make changes/adapt in the future?
    - Process to use/update criteria for future deterrents

12:00 PM Next Steps
- Process for meeting summary production and review
- Other next steps

12:20 PM Final Remarks

12:30 PM Adjourn

1:45 PM – 5:30 PM Working session for Federal participants and those with SRG or MMC appointments only

APPENDIX B. Participant List

Steering Committee

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APPENDIX C. Summaries of Literature Review by Taxa

Mysticetes

ACTIVE – ACOUSTIC DETERRENTS (ADD < 180 dB; AHD > 180 dB)			
Species	**Deterrent**	**Recorded M/SI**	**Highlights from Studies**
Humpback whale	ADD	No M/SI reported; not evaluated	• 4 kHz pinger (135 dB re 1 µPa at 1 m) resulted in significantly fewer collisions between humpbacks and alarmed cod traps than control traps with no alarms [1]
	ADD	No M/SI reported; not evaluated	• 3 kHz pinger (135±5 dB re 1 µPa at 1 m) resulted in no observed deterrence/avoidance of pinger or change in behavior within the authors' pre-determined pinger detection/audibility zone (500 m radius around a moored pinger) • In this study, the pinger did not appear to act as a deterrent based on the authors' hypothesis that the active pinger would result in a reduced likelihood of approach • Possible future studies include using more complex acoustic signals and/or higher density arrays of existing alarms [2]
Humpback, fin, and minke whales	AHD	No M/SI reported; not evaluated	• Average sound pressure was 194 dB re 1 µPa at 1 m with energy concentrated around 10 kHz and a single harmonic at 20 kHz • Humpbacks and fins seemed to avoid area when high amplitude acoustic deterrent (HAAD) was on; minke whales showed no change or even some attraction when HAAD was on (in 1996) [3]
Gray whale	ADD	No M/SI reported; not evaluated	• 1-3 kHz warble with a source level of 170 dB re 1 µPa at 1 m yielded inconclusive results • Small sample size; equipment malfunction; bad weather [4]
PASSIVE – VISUAL			
Minke whale	Buoys and synthetic ropes with high contrast colors	No physical interaction with the ropes was observed	Black and white ropes seemed to be the easiest to detect [5]
North Atlantic right whale	Rope mimics of different colors	None (designed that way)	Red and orange were detected the greatest distance away [6]

Odontocetes

ACTIVE – ACOUSTIC DETERRENTS (ADD < 180 dB; AHD > 180 dB)			
Species	**Deterrent**	**Recorded M/SI**	**Highlights from Studies**
Harbor porpoise	ADDs	No M/SI reported; not evaluated; bycatch recorded for some fisheries studies (in pingered and control nets)	• Lab studies and controlled field studies (non-fisheries) – variety of devices, SLs, and frequencies tested [7-10, 20, 25, 29] o General avoidance of sound source; increased respiration rates in some cases o Moving away from sound to areas with more acceptable sound levels • Fisheries experiments – variety of devices, SLs, and frequencies tested [11-19, 21-24, 26-28] o Significant reduction in bycatch in pingered nets vs. non-pingered nets (gillnet fisheries)
	AHDs	No M/SI reported; not evaluated	• Sounds in this range generally designed for seal deterrence; secondary effects on HP tested • Significant displacement away from the sound source; decreased relative abundance/distribution • Possibility for habitat displacement • One study demonstrated no significant shift of HP groups away from device (device's peak frequency was 1 kHz, which is not highly sensitive for HP) [30-33]
Bottlenose dolphin	ADDs	No M/SI reported; not evaluated	• Lab study (one) – subdued reaction to pinger; spent less time in pool with pingered net • Fisheries experiments – variety of devices, SLs, and frequencies tested o Variable responses to pingers o Some bycatch reduction o Animals aware of nets (pingered and non-pingered) o Gillnet depredation issues – pingers tested to date have not eliminated this behavior ▪ Some evidence of depredation and net damage reduction with use of pingers (generally overseas) ▪ Some reduction in net interactions in U.S. but behavior not eliminated; one bottlenose dolphin (likely engaged in depredation) entangled in a gillnet with active deterrents o Trawl fisheries (one study) – no significant difference in dolphins inside pingered vs. non-pingered trawl nets [34-47]
	AHDs	No M/SI reported; not evaluated	One study – fish farm – no evidence of reduction in predation, presence of animals; strong food motivation [48]
Common dolphin	ADDs	No M/SI reported; not evaluated	• Drift gillnets – pingers generally effective in reducing bycatch; 1 study found no significant difference [34-35, 49-50] • Pelagic trawls – mixed results; dB in excess of 150 dB may be more effective; DDDs seem to be effective for reducing bycatch in bass pair trawl fishery in Western English Channel [39, 51-53]
Franciscana	ADDs	No M/SI reported; not evaluated; bycatch recorded	Two studies – bycatch significantly reduced in pingered nets; more effective using 70 kHz when compared to 10 kHz [54-55]
Hector's dolphin	ADDs	No M/SI reported; not evaluated	Two controlled studies – significant avoidance of pinger in one study (Dukane Netmark); avoidance of one of three experimental pingers in the other [56-57]

Species	Deterrent	Recorded M/SI	Highlights from Studies
Humpback and snubfin	ADDs	No M/SI reported; not evaluated	One study – no significant change in behavior of either species to the presence of the pinger (Fumunda F10) [58]
Risso's dolphin	ADDs	No M/SI reported; not evaluated	Two studies • No change in depredation rates or animal behavior in the presence of pingers [59] • No reduction in bycatch in pingered vs. non-pingered nets (slightly higher bycatch rate in pingered nets) [49]
Striped dolphin	ADDs	No M/SI reported; not evaluated	One study – no reaction to the presence of the alarm (9-15 kHz; SL 145 dB) [60]
Tucuxi	ADDs	No M/SI reported; not evaluated	One study – tucuxi avoided quadrat with functional pingers; stayed about 5 m from pinger line; did not swim under pinger line [61]
Beaked whale	ADDs	No M/SI reported; not evaluated	Review of observer data for CA drift gillnets – bycatch reduced to zero with pinger usage [62]
False killer whale	AHD	No M/SI reported; not evaluated	Initial significant reduction in echolocation performance; performance improved over duration of expt to 85% [63]
Killer whale	AHDs	No M/SI reported; not evaluated	Significantly lower number of orcas in Broughton Archipelago when AHD was active; presence in Johnstone Strait relatively stable (no AHD); AHD purpose was seal predation reduction at salmon farms [64]
Beluga whale	Killer whale vocalization	Unknown	Beluga whales showed a strong avoidance to killer whale vocals as well as 2.5 kHz pulsed tones [65]
Other odontocetes[2]	ADDs	No M/SI reported; not evaluated; bycatch recorded; Bowles and Anderson study did not document any M/SI	• Sperm whale – no reduction in bycatch in pingered vs. non-pingered nets (slightly higher bycatch rate in pingered nets) [49] • Pilot whale – lower bycatch rate in pingered nets; significance unclear [34-35, 49] • White-sided dolphin – no significant bycatch reduction in pingered nets [49-50] • Long-beaked common dolphin – lower bycatch rate in pingered nets (not significant) [49-50] • No. right whale dolphin – no significant bycatch reduction in pingered nets [49-50] • Commerson's dolphin – spent significantly less time in test pool with pingered net; some animals swam through net [36] • Dusky dolphin – lower bycatch rate in pingered nets but not significant [35] • Burmeister's porpoise – two studies; bycatch reduced in pingered nets (fairly small bycatch sample) [34-35] • Dall's porpoise – lower bycatch rate in pingered nets but not significant [49]

PASSIVE - GEAR MODIFICATION (SPIKES AROUND CATCH, EXCLUDER DEVICES)			
Species	**Deterrent**	**Recorded M/SI**	**Highlights from Studies**
Harbor porpoise	Acoustically reflective nets	Bycatch recorded in control nets only; none in reflective	Significant reduction in bycatch in acoustically reflective nets [66-67]
	Higher tensioned nets (i.e., stiffer)	Bycatch recorded in control & higher tensioned nets	No significant difference in catch rates between single (control, standard) and double (experimental) rigged nets [52]
Bottlenose dolphin	Exclusion grid	Bycatch recorded in sets with grids	• Studies in Pilbara trawl fishery in Western Australia [43, 68-71] • Most of the studies conclude an unclear determination on effectiveness, although bycatch appears to be reduced with the use of grids • Dolphin behavior complex and include foraging, socializing, bouncing off nets
	Wire flaps	Not reported	• Small sample but device did seem to deter depredation in Florida king mackerel troll fishery [72]
	DEPRED	None reported	• DEPRED seemed effective during initial trials; after 3 trials, depredation mitigation effectiveness declined [73]
Common dolphin	Exclusion grid	Bycatch recorded in sets with grids	Exclusion grid shows promise; may need more escape holes; animals appear to detect presence of grid and try to escape ahead of the grid by going through the meshes or swimming out of the net; dolphins clearly can use the escape hatches [52]
Franciscana	Acoustically reflective and stiffened nets	Bycatch recorded in control and experimental nets	No significant difference in bycatch rates among the three net types (reflective, stiff, control) [74]
Vaquita	Gear switching	Gear trials – did not appear to have bycatch	Trawl gear options tested for replacing gillnet fishing with trawl fishing for blue shrimp; showed promise [75]
General marine mammals	Exclusion grid	No bycatch recorded; mammals avoided	Trials to examine trawl fishability with the inclusion of a marine mammal exclusion device (MMED) [76]

Species	Deterrent	Recorded SI/M	Highlights from Studies
False killer, pilot, melon-headed, sperm, killer whale, spinner dolphin	Physical or psychological protection of longline catch	One melon-headed whale interacted with control branchline; released alive but condition unknown	• Spiders and socks – no significant reduction in depredation [77] • Cages and chains – inconclusive, small sample size precludes ability to determine whether or not there was a statistical reduction in depredation [78] • Umbrella-and-stones – effective prevention of bycatch; however, reduction in sperm whale depredation rates unclear as there was a low level of interaction and damage during the study [79] • Significant reduction in depredation with the use of 3 modifications: (1) elimination of hook line, (2) addition of 15-20 m long vertical branch lines placed at 40 m intervals; each vertical branch line supports multiple short hook lines with bag of weights at its extremity (4 to 10 kg per branch line), and (3) attachment of buoyant net sleeve to each vertical hook line (covers catch while gear is hauled) [80] • DEPRED seemed effective during initial trials; depredation mitigation fairly stable across the 3 interaction events [73]

Pinnipeds

ACTIVE – ACOUSTIC DETERRENTS (ADD < 180 dB; AHD > 180 dB)			
Species	**Deterrent**	**Recorded M/SI**	**Highlights from Studies**
California sea lion (CSL); Steller sea lion	ADDs	Bycatch mortality	• Controlled study with gillnet/pinger – initial reactions of avoidance, with defensive and agonistic behaviors; normal behavior returned shortly after; took fish readily from pingered nets; pingers did not prevent contact with net [36] • Drift gillnet (short time series) – significant reduction in CSL bycatch in pingered vs. non-pingered nets [49] • Drift gillnet (longer time series) – no difference in bycatch in pingered vs. non-pingered nets; no "dinner bell effect" [50]
	AHDs	No M/SI reported; not evaluated	• Behavioral changes/adjustments to deal with sounds; temporarily deter • Leave area when AHD on and return when it's off • Possibly more effective on "new" animals vs. "repeat" ones • Increased effectiveness when used in combination with other measures (vessel hazing, seal bombs) [81-82]
	Explosives (seal bombs, cracker shells)	Anecdotal evidence of M/SI	• Variable responses [82] • Initial startle; temporary avoidance of area; eventual tolerance of noise [82] • Change.org 2011 seal bomb prohibition petition – fishermen put bombs into bait fish and feed to sea lions; M/SI [83]
South American sea lion	ADDs/AHDs	No bycatch or injuries reported	• Higher percentage of sea lion depredation attacks on pingered vs. non-pingered nets [54]

	AHDs	No M/SI reported; not evaluated	• In survey of fish farmers – use of AHDs deemed ineffective or effective for 2-4 months only [84]
			• Field AHD test at one salmon farm site showed significant reduction in predation when compared to another site [85]
			  o Short time in use (3 months)
			  o Authors caution AHDs are not effective when used solely but if used should be combined with other anti-predation methods (anti-predator netting, good farm location, and good fish mortality management)

Species	Deterrent	Recorded M/SI	Highlights from Studies
Harbor seal	ADDs	• Lab – no M/SI reported; not evaluated • Bycatch mortality	• Lab – reduced approach of and interaction with pingered net; however, contact with net still made despite presence of active pinger [36, 86] • No difference in bycatch or depredation in pingered vs. non-pingered nets [11] • Startle system significantly reduced depredation at aquaculture for a year [41]
	AHDs	No M/SI reported; not evaluated	• Varied responses (some startle; some show no response); behaviorally adapt [82] • Deterrence short-term; wanes with time; move to less noisy areas [82, 87] • Others show reduction in number of animals present in vicinity of device [88] • General ineffectiveness when used at aquaculture/fish farm sites [89] • Fewer animals and higher landings when device on; short-term perhaps better [90] • Reduced upstream movement but stable abundance of seals [91]
Gray seal	ADDs	• Bycatch mortality • No M/SI reported; not evaluated	• Likely no difference in bycatch in pingered vs. non-pingered nets [13] • Some depredation and gear damage reduction; increase in fish catch [92] • Habituation; flexible behavior; adjustments to avoid sound; tolerance by large, older males [92] • Short rise times lead to startle and sustained avoidance response; anxiety [93] • "Rough" sounds may more effectively deter [94]
	AHDs	• No bycatch • No M/SI reported; not evaluated	• Fewer animals and higher landings when device on; short-term perhaps better [90] • Reduced upstream movement but stable abundance of seals [91] • Gray seals generally more persistent than harbor seals [90]
Harbor and gray seals	Killer whale vocalization	Unknown	Seals demonstrated a strong aversive response by either swimming to a resting site and hauling out or moving away to a range of about 1 km from the playback [65]
Northern elephant seal	ADDs	• No observed injuries (lab study) • Bycatch mortality	• Little reaction to gillnet/pinger (lab); some evidence of reduced gillnet touching with pinger [36] • Reduction in bycatch in pingered vs. non-pingered nets [49-50]
Cape fur seal	Explosives (underwater firecrackers, rifle shots, arc transducer)	No M/SI reported; not evaluated	• Underwater firecrackers most effective when thrown in succession [95] • Rifle shots – satisfactory when fired in intervals of less than 15 seconds [95] • Arc transducer – satisfactory; varied by fishery; some reduction in seal numbers (trawl, not purse seine) [95]
	Predator sounds	No M/SI reported; not evaluated	• Killer whale sounds – little to no change; any behavioral changes temporary; resumed prior behavior [95]

ACTIVE – TACTILE (MANUALLY APPLIED, PROPELLED)			
Species	**Deterrent**	**Recorded M/SI**	**Highlights from Studies**
California sea lion (CSL); Steller sea lion	Rubber projectiles, paint balls	No M/SI reported; not evaluated	• Deterrence effect variable; limited; temporary [82]
	Rubber batons (bullets) or buckshots	No M/SI observed when used at Ballard Locks in mid-1980s	• Deterrence effect variable; limited; temporary [82]
Harbor seal	Mechanical feeding barrier	No M/SI reported; not evaluated	• Rope with cork floats spaced 1 m apart strung across river – initial short-term deterrence effect; then seals played with and habituated to it (small sample size) [87]
ACTIVE – CHEMOSENSORY (TASTE, SMELL AVERSION)			
California sea lion	Tainted bait (lithium chloride)	No M/SI	• In one study – definite aversion to tainted fish [96] • In another study – differing responses from two animals (possible explanations for this include amount of food eaten and speed of initial response to tainted bait) [97] • Field studies inconclusive; ingestion of tainted fish and responses difficult to measure [98]
Australian fur seal	Tainted bait (lithium chloride)	No M/SI reported; not evaluated	• Field study – the animal that took the tainted bait left the area [99] • Unclear if follow-up was conducted to see the duration of the effect and whether the animal came back [99]
ACTIVE – VISUAL (VESSEL CHASING)			
California sea lion; Steller sea lion	Boat hazing	No M/SI reported; not evaluated	• Field use – responses variable and temporary; animals learn to swim under boat; resist leaving area [82] • Most effective when used in combination with other techniques like underwater firecrackers [82]

PASSIVE - VISUAL (FLASHING LIGHTS, FLAGS, PREDATOR SHAPES)			
Species	**Deterrent**	**Recorded M/SI**	**Highlights from Studies**
California sea lion	Predator (killer whale) model	No M/SI reported; not evaluated	• News article – indicated the predator model appeared to be effective; length of time used not given; not a controlled study; other deterrence methods were being used at the same time [100] • When tested in field at Ballard Locks – short-lived or no deterrence effect; not practical [101]
South American sea lion	Predator (killer whale) model	No M/SI reported; not evaluated	• Model reportedly used at 2 fish farm sites – initially effective; effectiveness decline after about 2 months [84]
Seals (harbor, gray)	Predator (killer whale model)	No M/SI reported; not evaluated	• One Scottish salmon farmer reported effective use of predator model (reported in a news article) [102] • Another Scottish salmon farm company reported mixed results (reported in another news article) [103]
	Seal blinds	No M/SI reported; not evaluated	• Designed to hide dead fish in fish farms from pinnipeds to reduce depredation attempts [104] • No published literature to support the effectiveness of this deterrent strategy [104]
	Turning off bridge lights	No M/SI reported; not evaluated	• First night of lights off – fewer seals observed feeding; subsequent nights had progressive increase in seals feeding in residual light [87]
Australian fur seal	Floodlights	No M/SI reported; not evaluated	• Switching on bright lights at night when most attacks occurred; temporary deterrent. Animals initially swam away but eventually returned even when the lights were left on. It was thought that this would likely result in habituation. [99]
PASSIVE - PHYSICAL BARRIER (ANTI-PREDATOR NETTING, ELECTRIC FIELDS, CLOSELY-SPACED POLES)			
California sea lion	SL exclusion device	No M/SI reported; not evaluated	• SLEDs installed at entrances to fish ladders generally prevented CSL from entering; CSL continued feeding at the ladder entrance [82]
	Electric field	No M/SI reported; not evaluated	• CSL were extremely sensitive to a mild, underwater field of pulsed DC electricity; with food present, strong deterrence occurred at pulse widths ranging from 160 to 440 µS [105] • Follow up study to determine voltage effects on fish showed no effect on steelhead, white sturgeon, or Pacific lamprey but significant adverse effects to Chinook salmon behavior such that further tests were not conducted [106]
South American sea lion	Predator netting	No M/SI reported; not evaluated	• Survey of Chilean fish farmers – predator netting successfully prevents attacks if nets are maintained, kept taut, and are at least 1 m from net pens [84]
Seals (harbor and gray)	Predator netting	Reports of animals entangled in predator netting	• In Scotland fish farms – nets uncommon and problematic; no published data to support effectiveness [104] • In U.S. (Maine) – salmon farm survey responses indicated that predator nets are generally effective if they are maintained properly [89]
	Electric field	No M/SI reported; not evaluated	• Clear aversion to electric gradient; probable ability to prevent seals from entering small areas [107] • Seals stayed in feeder (food motivation) but were prevented from taking food with the gradient [107] • When gillnet was electrified – seals avoided the electrical section of the net [108]

Species	Deterrent	Recorded M/SI	Highlights from Studies
Australian/ New Zealand seals/SLs	Barriers to pinniped predation	N/A	• Review of existing predator deterrent systems and suggest refinements, which are untested [109] • Refinements suggested: tensioned predator nets (20%), outer handrail design, 2 m buffer between predator nets and grow-out nets, high jump fence to prevent animals from entering pens [109]
PASSIVE - GEAR MODIFICATION (SPIKES AROUND CATCH, EXCLUDER DEVICES)			
Australian fur seal	Seal exclusion device	Bycatch mortality	• Variable bycatch survival rate in trawls with grids installed, ranging from 8% to 66% over the years studied [110] • Effectiveness is unclear; lack of sufficient video footage; limited number of interactions [110] • Lack of understanding of complexity of interactions with the gear [110]
New Zealand sea lion	Sea lion exclusion device	Bycatch mortality	• Calculated 91% ejection rate from the grid into a cover net [111] • Indications of possible trauma from interaction with grid which could have been life-threatening had animal been ejected [111] • Future study indicated it was unlikely that head trauma was caused by interaction with grid and grids were responsible a substantial reduction in bycatch with widespread use beginning in 2004/2005 [112]

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