Workshop Report: Economic Aspects of Bycatch Reduction

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Introduction and Background

The National Marine Fisheries Service's (NMFS) National Bycatch Reduction Strategy[1] guides NMFS' efforts to reduce bycatch and bycatch mortality. To aid in the implementation of the Strategy, NMFS' Office of Science and Technology (OST) formulated an action item to advance ideas, solutions, and research regarding economic aspects of bycatch reduction in U.S. fisheries. To advance these ideas and solutions, OST convened a workshop on the economic aspects of bycatch reduction at the Scripps Institution of Oceanography in La Jolla, CA on October 29-31, 2019. The workshop focused on incentive-based approaches to bycatch reduction. Workshop participants included researchers from multiple disciplines as well as fisheries managers and stakeholders (see list in Appendix A). The goal of the workshop was to discuss the application of economic research to real-world bycatch problems using a case-study approach.

Workshop organizers selected case studies to represent a variety of geographic regions, types of fisheries (including recreational and commercial fisheries), and those that interacted with protected species and seabirds. Case study leads presented the salient features of the fishery and described the bycatch issue along with steps taken to reduce bycatch and discard mortality. Workshop participants then discussed potential additional solutions. Discussions of solutions fell under three broad categories: 1) market-based incentives, 2) direct regulatory approaches, and 3) intrinsic motivation (e.g., altruism, social norms) approaches. The goal was to provide a menu of approaches for reducing bycatch in each of the case study fisheries.

After a welcome to La Jolla by Kristen Koch, the Science and Research Director of the Southwest Fisheries Science Center, David Detlor, the Acting Director of the Office of Science and Technology, provided an overview of the National Bycatch Reduction Strategy. Doug Lipton, NOAA Fisheries Senior Scientist for Economics, guided workshop participants through the ways economists think about problems such as bycatch in fisheries. Rebecca Lent, Executive Director of the International Whaling Commission (IWC), provided an overview of a recent IWC bycatch workshop. Dale Squires, an economist with the Southwest Fisheries Science Center, presented the theoretical underpinnings of the tools within economics that can be, and are, used to address fisheries bycatch issues. A day and a half of presentations and detailed discussion of eight current bycatch case studies followed these series of opening remarks. The final half day of the workshop focused on identifying overarching themes and possible solutions that emerged from the case studies, discussing the practicability of implementing the solutions, and recommending future collaborative efforts that could be initiated to foster continued exploration of bycatch solutions.

Based on review of the case studies and workshop discussions, workshop participants realized that solutions to bycatch issues must come from a multi-disciplinary perspective. Each bycatch case study showed that, due to the complexity of bycatch problems, using just one approach, whether it be a technology change, direct regulation, market-based incentive, consumer/public/fishermen/angler education program, or change in social norms, cannot single-handedly address the bycatch problem. Further, tools used in one case will not necessarily apply to another. Sets of solutions must be tailor-made on a case-by-case basis. Workshop participants also found that bycatch problems must be addressed early so they do not become so severe that no set of solutions can eliminate the bycatch and restore the population to a healthy level.

[1] https://www.fisheries.noaa.gov/national/bycatch/national-bycatch-reduction-strategy

Opening Remarks

Three speakers provided background and context for the workshop: David Detlor, Doug Lipton, and Rebecca Lent.

David Detlor described NMFS's focus on documenting and mitigating bycatch levels in our nation's fisheries over the past two decades. In 1999, NMFS established of the National Observer Program, which provides support and policy coordination for regional observer programs as they deploy almost 1,000 observers each year to characterize discards at sea and record fisheries interactions with protected species and seabirds. In 2011, the National Observer Program published the first National Bycatch Report, which comprehensively documented bycatch of fish and protected species in major U.S. fisheries; updates were published in 2014, 2016, and 2019. In 2016, OST contributed to NMFS's National Bycatch Reduction Strategy, which was designed to guide NMFS bycatch monitoring, estimation, research, conservation, and management, as well as enforcement of bycatch regulations and communication about bycatch issues. The strategy was motivated by the fact that "impacts from bycatch and bycatch mortality vary across fisheries, and can have adverse biological, economic, and social consequences." Most importantly, from the perspective of this workshop, the strategy provides guidance for NMFS by identifying the importance of improving the understanding of economic and social factors to help address and mitigate bycatch issues and identify regulatory and market incentives that might increase utilization of catch that normally would become economic discards. More specifically, the strategy calls on NMFS to 1) "analyze the effectiveness of incentive-based approaches to environmental management, (e.g., catch shares, risk pools, cooperatives, dynamic area management), and consider their application to bycatch reduction programs," and 2) "improve understanding of the socio-economic and other environmental trade-offs of bycatch reduction to better inform stakeholders and to support management decisions and post-regulation analyses." OST is now developing the strategy's implementation plan, of which this workshop is a part.

Doug Lipton shared some insights into the role economics can play in reducing bycatch. Although engineered approaches such as those supported through the NMFS Bycatch Reduction Engineering Program are important, they cannot be the sole remedy for bycatch problems. Other tools are needed, and the field of economics can provide tools that have been successful in addressing other natural resource challenges. Doug shared some examples that came to light just prior to the workshop. An October 2019 Washington Post article[2] made the case that a tax on carbon emissions is a powerful way of combating climate change. Another October 2019 article in the Bay Journal[3] provided an example of the role of uncertainty in setting pollution limits. Doug made further comparisons with studies[4] that showed that a nutrient credit trading scheme in the Chesapeake Bay could achieve results at half the cost of using engineered approaches alone. He reported that the state of Maryland recently began implementing the trading system. Doug shared some thoughts on the potential for aquaculture to be a bycatch reduction backstop technology, that is, although wild harvest of fish has no pre-harvest cost, there is a high bycatch cost. Aquaculture, on the other hand, has pre-harvest costs but little if no bycatch cost, depending on the technology. Lastly, Doug discussed the idea of finding an optimal level of bycatch reduction, which is

[2] https://www.mpnnow.com/news/20191021/guest-view-compelling-case-for-carbon-tax

[3] https://bloximages.newyork1.vip.townnews.com/bayjournal.com/content/tncms/assets/v3/editorial/4/22/4222148e-fa54-11e9-a315-d77a8f584384/5db845d54728e.pdf.pdf (see page 11)

[4] http://www.chesbay.us/Publications/nutrient-trading-2012.pdf and https://www.researchgate.net/publication/331502832_The_potential_for_nutrient_credit_trading_or_economic_incentives_to_expand_Maryland_oyster_aquaculture

determined by the broadly defined marginal benefits and costs of decreasing bycatch, the role of markets, eco-labeling, incentives, taxes, and subsidies in fisheries bycatch reduction.

Rebecca Lent described the IWC's Marine Mammal Bycatch Initiative that was launched in 2016. Independently funded, the initiative was motivated by the fact that bycatch is the worldwide, number-one source of human-caused mortality of marine mammals. She told the workshop about the Initiative's first meeting this year in Kenya, where participants discussed the extent of marine mammal bycatch in data-poor, small-scale gillnet fisheries in the Indian Ocean. She related that these fisheries need collaborators and assistance with designing and implementing multi-taxa, multi-disciplinary approaches to bycatch monitoring and mitigation. Those approaches need to include managers, industry, scientists and conservationists, and to integrate economic and sociological factors with technological solutions. The Initiative identified a need for low-tech mitigation technology, for example, light-emitting diodes and "coke-bottle pingers", rapid bycatch assessment methods, and crew or small-scale electronic monitoring.

Mitigating Fisheries Bycatch: Regulatory Framework, Economic Instruments, and Technological Change

Dale Squires described the various economic tools related to bycatch mitigation. His remarks are summarized here.

Bycatch mitigation requires an interdisciplinary approach due to its multiple facets: 1) biological (life history of the bycatch and target species), 2) technical (gear and equipment design and operation), 3) producer behavior (how vessels and firms in the supply chain respond to direct and incentive-based bycatch mitigation regulations), and 4) consumer behavior (how they respond to information or eco-labels and price changes).

Both the Magnuson-Stevens Fishery Conservation and Management Act (MSA) and the Bycatch Reduction Strategy definitions of bycatch exclude catch that is sold. However, for this discussion of economic aspects of bycatch, a broader definition is used that includes incidental/non-target catch that is sold.[5] And so, here, bycatch is classified into two types according to characteristics of its price (or lack thereof). The first type is non-target species that are commercially harvested and sold but not at the ecologically and economically optimum level. The non-target species may, for example, be harvested at the incorrect age or size. The market price for this type of bycatch does not fully capture the costs of foregone biodiversity and ecosystem services, i.e., the "external costs". In short, the bycatch is underpriced and markets are said to be incomplete. Bigeye tuna harvested in conjunction with skipjack tuna under drifting floating aggregator devices is an example of this first type of bycatch. The second type of bycatch corresponds to threatened or endangered species that are protected in some manner and do not have a market price, or other discarded unsalable or illegal catch. Examples include seabirds and sea turtles bycaught by pelagic longline vessels and coastal marine mammals caught in drift gillnets. Markets

[5] The MSA defines bycatch as "fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards. Such term does not include fish released alive under a recreational catch and release fishery management program." The National Bycatch Reduction Strategy defines bycatch more broadly as "discarded catch of marine species and unobserved mortality due to a direct encounter with fishing vessels and gear." Beyond this particular discussion of broad economic aspects of bycatch, bycatch was not specifically defined for the workshop or for this report. However, the definition in the National Bycatch Reduction Strategy better aligns with the theme of the workshop given the mix of types of bycatch case studies presented and discussed.

are said to be missing. In short, in both cases, the bycatch is "unpriced" (in the sense that information is unavailable to assess the true cost to society).

The bycatch issue, from an economics perspective, comprises four basic components ("externalities" in economics[6]) that collectively create the issue. First, bycatch is incidentally created at the vessel level while vessels pursue their target species. Vessel behavior and decision-making respond to ex-vessel market prices, environmental conditions, resource abundance and availability, the regulatory framework, and other factors. The ex-vessel market prices for the target species reflect the supply by vessels and the demand for the target species ultimately formed in consumer markets and passed down through the supply chain through prices. Ex-vessel prices for target species do not include the (external) cost to society of the bycatch. The bycatch may not even have a price, such as with a species protected under the ESA.

Second, most information about bycatch production (in terms of how often or how much bycatch is encountered, but perhaps not information about the biological, economic, or social impacts) is held at the vessel level, with typically progressively decreasing amounts held by firms in the supply chain and finally consumers of the target species. Because of this asymmetric information about bycatch associated with target catch, the target species market prices that do not include the (external) cost of bycatch and underpriced bycatch species, consumers and firms in the supply chain cannot make fully informed and socially optimal decisions. Without full information about bycatch that is reflected in prices for target species that exclude the (external) cost of bycatch or underpriced bycatch, consumers tend to consume "too much" target species with their associated bycatch and bycatch species with incomplete market prices. Consumers fully informed about bycatch and facing prices of target and priced bycatch species that contain the (external) cost of bycatch would alter their behavior and make different choices about target and priced bycatch species to consume. Whether consumer choices sufficiently change, and whether those choices transmit through the supply chain to vessels to the degree that bycatch is reduced, remains an open question.

When market prices for target and priced bycatch species do contain information about the economic-ecological (external) costs of bycatch and losses in biodiversity and ecosystem services, resources are allocated in a way that is more economically efficient and ecologically optimum. Market prices that contain otherwise unpriced (or underpriced) costs of bycatch and biodiversity losses allow vessels to make harvest decisions and consumers to make seafood consumption decisions that reflect the value of bycatch to society and the ecosystem (i.e., account for the "external costs"). Without seafood prices incorporating these "external costs," both target species and bycatch are overharvested and harvested in the wrong mix with excessive bycatch relative to target species catch. These market prices must be transmitted throughout the supply chain to the vessel.

A third component of the bycatch issue is the technology for harvesting target species that reduces the bycatch and discard mortality rates. Bycatch-reducing technology can be costly to develop and utilize, and developers of such technology bear this cost but do not enjoy the full benefits from its development because other users ("free riders") can adopt the new technology without responsibility for its development and costs. Consequently, socially optimal technology is not typically developed and employed by the private sector to the socially optimal level. Therefore, without some type of technology

[6] An externality is an unintended negative or positive outcome of an economic activity that impacts producers (vessels and firms in the supply chain) or consumers. "External costs" are costs of bycatch unaccounted for in market prices of the target species. "External benefits" are benefits unaccounted for in market prices. Externalities can also be defined in terms of cost and benefits that are not borne or received by those who cause them.

policy, whether private or public, the incentives to develop and employ this technology and the bycatch mitigation efforts will be inadequate.

A fourth component of the bycatch issue arises when the bycatch species is transboundary through a straddling stock or a highly migratory species across multiple political jurisdictions. Unilateral bycatch mitigation can then be ineffective due to spillovers or conservation leakages that lead to less conservation than expected. That is, as unilaterally regulated producers in one jurisdiction reduce their production of both target and bycatch species, target species production shifts to the other jurisdiction(s) (production leakage) and has its own bycatch (conservation leakage). Should the target species then be imported back into the unilaterally conserving jurisdiction, there is a trade leakage, and the resulting consumption is a consumption leakage. Multilateral rather than unilateral bycatch mitigation is required.

Bycatch mitigation can be approached as regulation of an industry (fishing) with an adverse environmental impact (bycatch). Many other industries have similar issues, and experiences from private and public regulation of air and water pollution, forestry, water usage, energy conservation, climate change and its mitigation, transportation, and terrestrial conservation can impart lessons for bycatch mitigation. Issues around technological change to reduce the bycatch-catch ratio, i.e., bycatch-saving technological change, as well as policy to induce this technological change, can also be informed by technological changes designed to reduce adverse environmental impacts in other sectors. Key lessons include:

1. As industries mature and gain experience with regulation, direct regulation tends to decline and are replaced by incentive-based approaches, leaving a mixture of both.
2. All four components (externalities) of the bycatch issue must be addressed for full resolution, i.e., multiple policy instruments are required for multiple externalities unless the externalities are closely linked.
3. Technology policy becomes increasingly important due to the reliance upon bycatch reducing technological change to reduce bycatch (especially through reducing the bycatch-target catch ratio).
4. A holistic approach is required that addresses all sources of mortality (bycatch mortality across the full population range and life history of the bycatch species).
5. Regulations can be (strategic) substitutes and complements. That is, some regulations substitute for one another and other regulations complement one another.
6. It is important to understand uncertainty and who bears the risk of bycatch and bycatch mitigation.
7. The design of monitoring, control, surveillance, compliance, and enforcement and who bears the costs need to be considered at the start, along with criteria for choosing among regulations and their design, monitoring, control, surveillance, and enforcement.
8. Conditionality (regulatory outcomes conditional upon verifiable performance) and additionality (bycatch reduction beyond what would have otherwise happened) become more important for understanding the true efficacy of regulation on bycatch mitigation.
9. The focus of policy instruments on performance, process, or technology and the strength and type of incentives that are generated is important.
10. Individuals or groups are the focus of the regulations.

Bycatch mitigation occurs through some combination of private and public regulation. Private regulation occurs when producers and consumers reduce their production and consumption of target and priced bycatch species and thereby reduce the bycatch-catch ratio and in some instances the overall level of

bycatch. Private regulation can be voluntary, typically in response to a "credible threat" of loss of market access, lower market prices, higher operating costs, or public regulation (typically strong direct regulation). Private regulation can also arise due to intrinsic motivation, which tends to be more important when economies are less market oriented.[7] Public regulation occurs through either direct regulation, also called "command-and-control", or incentive-based approaches, also called market-based. Direct regulation occurs through three types of standards:[8] (1) technology standards, which are mandatory design and equipment requirements that include operating standards, such as gear design and operation; (2) process standards, which place a target or limit on inputs (capital, fuel, labor, or effort) and their usage, such as limits on the number of floating fishing aggregator devices, days fished, or time-area closures; and (3), performance standards, which place a target on outcomes (performance) but do not specify how the target is met, such as bycatch quotas or limits. There is no one-size-fits-all regulatory approach or even a set of policy instruments within the class of direct or incentive-based regulation. That is, bycatch mitigation and the choice of private and public regulation and policy instruments must be blended and tailor-made.

Private regulation through intrinsic motivation provides a decentralized approach to bycatch reduction. There are many types of intrinsic motivation, including social and personal norms, pure and impure altruism, warm glow giving, and image motivation. Social norms, perhaps the most important form of intrinsic motivation, are explicit or implicit rules specifying which types of behavior are acceptable within society or a group. Their social function is to resolve problems of collective action and coordination, and they coalesce from decentralized, uncoordinated behavior of many interacting individuals. Social norms can be long-lasting and self-sustaining, but they can also be slow to affect behavior and can require special and lengthy preparation.

In comparison to extrinsic motivation (and economic incentives in particular), intrinsic motivation tends to work slower, can erode over time, and is less important and effective the more society is organized through markets. Intrinsic and extrinsic motivation can interact through crowding effects. Crowding out (in) is a negative (positive) interaction, in which there is substitution (complementarity) between extrinsic and intrinsic motivation, and extrinsic motivation can be counter-productive (reinforcing) to bycatch reduction. Substantial recent research shows that crowding out can be important and is more widespread than initially thought.

Private regulation can also occur as a decentralized and self-regulating approach to bycatch reduction through bargaining and voluntary actions by producers and consumers. Voluntary bycatch reduction refers to a class of policies, programs, and initiatives under which parties voluntarily agree to participate rather than due to a legal requirement or force. Important voluntary actions include product standards and certification and eco-labels to reduce the asymmetric information problem, i.e., to provide additional information to firms in the supply chain and consumers (where there is typically less information about the bycatch the closer to the final market compared to producers). Voluntary actions often occur only under the pressure of a credible threat from an environmental non-governmental organization (e.g., market boycotts) or a government (e.g., stringent direct regulation). Bargaining can occur between an at-

[7] *Intrinsically motivated behavior* arises from within the person, or performing an activity for its own sake rather than the desire for some external reward. Intrinsic motivation is driven by internal rewards (e.g., feeling good about being environmentally conscious) and costs to the person (e.g., shame, guilt, and ostracism). *Extrinsically motivated behavior* is a person's behavior that aims to earn external rewards or avoid punishments. Economic incentives are a form of extrinsic motivation.

[8] *Standards* for bycatch mitigation are a limit on behavior of an anthropogenic source of bycatch.

sea producer or firm in the supply chain and an environmental non-governmental organization. Successful bargaining requires limited information and transaction costs, well-defined rights and defined objects subject to bargaining, such as bycatch.

Under direct public regulation, the government or regulatory body directly regulates producer and consumer behavior and decision-making through some combination of technology, process, and producer standards (as discussed above). Direct regulation has advantages: (1) better knowledge of the impact on producer or consumer behavior with compliance, (2) lower levels of risk for producers or consumers when regulatory requirements are well defined and established (since the results from compliance are more likely to be better known and compliance is easier and less costly in these instances), and (3) relatively low administrative costs if compliance can be easily monitored and enforced. Direct regulation also has a number of disadvantages, including: (1) information may be withheld by producers (e.g., producers may not share information about how they might alter production patterns with their comparatively greater knowledge of animal behavior and oceanographic conditions), (2) "one-size-fits-all" regulations can limit producer and consumer responses and flexibility, and (3) regulations tend to be top-down rather than bottom-up because information available to the regulator is limited. Because not all of the producer or consumer information is available, direct regulation does not fully engage all bycatch reduction channels. Direct regulation, by imposing a "one-size-fits-all" and inflexible approach on all producers and consumers, irrespective of its impact upon bycatch, is not cost-effective and does not incentivize producers and consumers to further decrease bycatch. That is, vessels are not able to choose the most cost-effective method to reduce bycatch. Furthermore, options are not available that could result in the most cost-effective distribution of bycatch reduction across all vessels.

Incentive-based policy instruments work by pricing bycatch to incorporate the external costs of bycatch into the cost fishermen pay to take bycatch or the price consumers pay for the fish that were taken with bycatch. Pricing bycatch requires a formal or informal bycatch target, whether a property rights approach (e.g., cap-and-trade), a tax, or a liability law approach is applied. By including the bycatch costs into the production costs of target and underpriced bycatch species, producers and consumers adjust their behavior and decision-making to alter the scale of production and consumption, and their mix, of the target and underpriced and unpriced bycatch species. The costs at the vessel level are shared from the vessel through the supply chain according to their ability to pass on these costs (their price elasticities of demand) and vice versa when starting with consumers. Incentive-based approaches allow producers and consumers to utilize their detailed information that is typically unknown to the regulator in designing their bycatch reduction solutions. Bycatch policy instruments based on performance or outcomes tend to generate stronger incentives for bycatch reduction compared to policy instruments based upon process. Incentive-based policy instruments can be: (1) placed upon either individuals or groups, with advantages and disadvantages for either approach, depending upon the situation; (2) direct, with positive or negative incentives (i.e., rewards and punishments) upon individuals or groups; and (3) indirect, notably community-based conservation or integrated conservation and development projects. Indirect approaches may, in some cases, support economic activities that yield habitat protection and conservation as an indirect result.

The following is a list of incentive-based policy instruments. They can be applied to individuals or groups and according to technology, process, or standards. They can be used to incentivize real-time spatial management or dynamic ocean management. To achieve the desired results, incentives should be directly linked to, and rewards or punishments conditional upon, verifiable bycatch reduction goals

(conditionality) and only for new bycatch reduction that otherwise would not have occurred in the absence of the incentive-based policy instrument (additionality)[9].

1. Taxes on production (levied on target species, effort, or bycatch, includes full retention programs, double dividend possible)[10]
2. Taxes on consumption and supply chain (double dividend possible)
3. Subsidies (subsidize "green" gear)
4. Penalties and rewards/credit systems (indirect tax-subsidy hybrid instrument)
5. Deemed values [11]
6. Bycatch insurance/risk pools
7. Trade measures
8. Harvest priority programs
9. Supply chain standards and certification, traceability
10. Tournaments and prizes for bycatch-reducing technological change
11. Profit-sharing and payments for ecosystem services[12]
12. Assurance (environmental) bonds
13. Gear deposit-refund[13]
14. Develop markets for fish that typically are discarded
15. Conservatory offsets[14]

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[9] Conditionality corresponds to moral hazard (actions by producers after the conservation policy that are not covered or controlled by the policy and are typically not fully observed by the regulator) and additionality corresponds to adverse selection (participants may be more at-risk or inclined to "cheat" than is anticipated by the regulator) when information is asymmetrically held by the regulator (principal) and the producer (agent). Producers generally hold more relevant information than the regulator about producer ability and actions to reduce bycatch, hence there is asymmetric information.

[10] The closer a tax is levied on the problem, the stronger and more direct the incentive. Thus, a bycatch tax levied on bycatch itself creates a stronger incentive than a tax levied on target catch. Similarly, a bycatch tax levied on actual performance – bycatch -- creates a stronger incentive than a bycatch tax levied on process such as the number of sets or days fished. A tax is a double dividend where the first dividend is the incentive created by the tax, and the resulting change in vessel behavior and decision-making that reduces bycatch, and the second dividend occurs when the tax revenues are used for bycatch reduction. These taxes on external costs are called Pigovian because they internalize the external cost, thus increasing economic welfare.

[11] A deemed value is indirect tax-subsidy/penalty-reward, two-part policy instrument. A deemed value is a price for bycatch with a commercial market that is set high enough to incentivize a vessel to land the bycatch (the subsidy or reward) but not as high as the market price so as to not incentivize catching even more of the bycatch (the tax or penalty). Under certainty, the penalty is set at the level sufficiently high to ensure the vessel earns higher profits by not exceeding the allowable bycatch limit than by not complying. With uncertain bycatch impact, the vessel cannot avoid the penalty with certainty. Instead, the vessel must weigh the additional cost of not meeting the limit against the additional expected gains, which reflects the magnitude of the penalty avoided and the effect that the additional avoidance has on the likelihood that the limit will be exceed and the penalty imposed. Under uncertainty, the penalty must set to ensure that this balancing leads to efficient avoidance, rather than too much or too little avoidance. Alternatively, the penalty could be proportional to the amount by which the quota is exceeded (or fallen short of).

[12] Payments for ecosystem services are payments for conservation of biodiversity or ecosystem services – here bycatch mitigation.

[13] Gear-deposit refunds are another indirect tax-subsidy/penalty-reward, two-party policy instrument. The deposit is the tax or penalty and the refund is the subsidy or reward.

[14] Standard or orthodox offsets are conservation that is in-kind (same species and stock) but off-site (not on the fishing ground but, for instance, on the nesting site for sea turtles) that compensate for any residual biodiversity (bycatch) losses after first avoiding bycatch, minimizing bycatch, and restoring (on-site and in-kind) bycatch. This

16. Tradable bycatch rights and credits
17. Multispecies ITQs
18. Transferable habitat impact quotas
19. Conservation easements and concessions
20. Conservation credits and biobanking
21. Environmental liability (similar to strict liability but without judgement-proof issue)
22. Community based conservation (indirect incentive approach)
23. Integrated conservation and development projects (indirect incentive approach)[15]

Case Studies

Amendment 80 Sector Bering Sea Non-Pollock Groundfish Trawl (Multispecies Trawl Flatfish)

John Gauvin, Alaska Seafood Cooperative, Seattle, Washington

Fishery and Target Species: The Amendment 80 sector mixed or multispecies flatfish, bottom-trawl fishery in the Bering Sea is the largest and highest-value flatfish fishery in the world. It supplies domestic and global markets with an excess of 200,000 metric tons (round weight) of flatfish with a first wholesale value of over US$170 million annually. The total value of the fishery is approximately US$450 million annually when Pacific cod and other target and incidental species that the Amendment 80 sector harvests are included. The fishery principally targets flatfish species including yellowfin sole, rock sole, arrowtooth flounder, and flathead sole, as well as Pacific cod and other Alaska groundfish with the exception of walleye pollock. Vessels are small to medium (by Alaska standards) trawl catcher-processors ranging in length from 125 to 270 ft. Primary processing (heading, gutting, and freezing) occurs on-board vessels.

Bycatch Species: Bycatch in the Amendment 80 sector fishery falls into two categories: (1) prohibited species catches (PSCs) and (2) lower-valued groundfish. Prohibited species catches include Pacific halibut, red king crab, and snow and tanner crabs, which are reserved for fixed gear fisheries in Alaska via regulation. Federal trawl fisheries operate with bycatch "hard caps" for these species, meaning that if the PSC cap is reached, fishing by the fishery/sector must cease for the year. These prohibited species cannot be retained and must be discarded with minimal injury to the extent other catch handling regulations allow that to occur. Prohibited species catch caps are subdivided by sector to help avoid one sector's PSC catch from affecting another. Lower-valued groundfish include sculpin, small pollock, and grenadiers, as well as small-sized or lower-valued flatfish. Vessels could retain these lower-valued fish, but fishermen discard the fish because they are less valuable and would take up limited hold space on vessels.

type of offset directly addresses this residual biodiversity loss with an aim of no net loss or even a net gain in biodiversity. Conservatory offsets are biodiversity offsets that are applied earlier than simply addressing residual biodiversity losses after first avoiding, minimizing, and restoring biodiversity. Conservatory offsets could substitute for avoidance, minimization, or restoration or could complement them, depending on the situation at hand. Conservatory offsets facilitate cost-effective bycatch mitigation.

[15] Indirect incentive approaches do not directly reward or punish (directly incentivize) bycatch reduction. Instead, indirect incentive bycatch reduction rewards activities (e.g., creates employment) in which conservation is an additional outcome but is not the direct objective of the indirect conservation policy instrument.

Current Bycatch Measures: Bycatch management regulations for this fishery include the PSC caps described above as well as a requirement for vessels to carry two full-time NOAA Fisheries observers who collect data on target and bycatch species from each haul. Vessels must weigh all catch on NOAA Fisheries-approved, motion-compensated scales after observer sampling. Additionally, the bottom-trawl gear used in this fishery must be equipped with elevated sweeps, which are rubber discs attached to cables at 15-m intervals. The discs elevate the extended cables between the net and the trawl doors. The North Pacific Fishery Management Council (NPFMC) mandated elevated sweeps (79 FR 2794) because research has shown they reduce catches of seafloor invertebrates (such as crabs) and lessen impacts on seafloor habitat. Starting in the first year of Amendment 80, the companies in the sector exceeded the end goal for the phased-in reduction in discards under the NPFMC's Groundfish Retention Standards (GRS) program. The GRS program, implemented simultaneously with Amendment 80, mandated increases in groundfish retention that increased to 85% retention (of round weight of catch) over five years. The NPFMC's review concluded that the Amendment 80 program effectively resulted in retention above 85% in the first year of the program and each following year covered by the review.

Current Challenges: Some vocal advocates for additional reductions in Amendment 80 PSC allowances feel that the program has increased economic viability of the Amendment 80 fishery. Therefore, additional cuts in bycatch are "practicable" under their interpretation of the Magnuson-Stevens Fishery Conservation and Management Act's National Standard 9, which requires conservation and management measures to minimize bycatch to the extent practicable. The Amendment 80 fishery has undergone two rounds of reductions of its halibut PSC cap since the start of the program. The first was included in the NPFMC's approval of Amendment 80. That reduction occurred in phased-in amounts of 50 metric tons (mt) for each of the first four years of the program. This reduced the allowance available to the Amendment 80 boats from 2,525 mt in 2008 to 2,325 mt by 2013. In 2016, in response to lower levels of harvest for the directed halibut fishery in the Bering Sea (and considerable pressure from halibut fishermen), the NPFMC approved a further 25% reduction in halibut bycatch allowance for the Amendment 80 fisheries. This reduced halibut available to the sector to 1,743 mt, for an overall reduction of 31% from what the sector could utilize pre-Amendment 80.

The fishery has managed to stay below its reduced halibut PSC cap, but in recent years operating costs (fuel and time cost of moving away from areas with high halibut bycatch) have increased along with increases in indirect or opportunity costs through reductions in the harvest of target species. The major factor determining costs appears to be the varying degrees of spatial/temporal overlap of flatfish fishing and areas where halibut are concentrated. In recent years, this overlap has been extensive, and there is no way of knowing if these conditions will persist into the future. With the sector's bycatch avoidance efforts fully in effect, the Amendment 80 sector feels additional reductions in halibut bycatch will further decrease the already diminishing marginal returns from bycatch avoidance methods and technologies. Operational efficiencies for target species harvest have declined since 2017, and since 2017 the sector's total groundfish catch has declined each year.

Tools such as halibut excluders that can reduce halibut bycatch by 50%-65% also allow escapement of approximately 25% of the target catch. As a result, fishing is less efficient, and boats have to tow longer to fill the net, which increases halibut encounters. In addition, the Amendment 80 fishery has worked hard to reduce mortality rates for the halibut it does catch. This mortality reduction effort includes a five-year exempted fishing permit and research collaboration with the Alaska Fisheries Science Center to develop ways to reduce mortality rates by rapidly returning halibut to the water from the deck while still fully accounting for the number, weight, and condition of the halibut. However, sorting halibut on deck takes time and can increase direct costs such as fuel, and indirect or opportunity costs as captains report a daily reduction of 20-25% in production rates for target fish due to the amount of time needed to sort, collect data from, and return halibut to the sea.

Future Directions and Research, including Economic Research: The two review documents focusing on Amendment 80 bycatch performance and bycatch reduction incentives (NPFMC 2014, Abbott et al. 2015) provided important insights into the means by which the program affected bycatch. However, these studies are now dated and do not reflect important changes in bycatch regulations and perspectives realized over the past few years. As the NPFMC explores ways to index the halibut bycatch cap to abundance of halibut, and considers additional bycatch reduction measures in the context of what is practicable, analysis of how PSC abundance and spatial overlap affect practicability would be very useful in the management context. Specifically, in light of bycatch reduction achievements and ongoing stakeholder interest in bycatch reduction, researchers should examine whether PSC bycatch reductions achieved by Amendment 80 are simply commensurate with PSC population abundance changes, occurring in spite of PSC population abundance changes, or in excess of PSC population abundance changes.

In addition, the spatial footprint of the flatfish fishery comprises less than 10% of the Bering Sea shelf in a given year. Where the fishery occurs within that footprint also varies considerably week to week. From the perspective of being on the water and operating under the constraint of vessel-specific bycatch caps, a doubling or reduction in PSC biomass by 50% year to year could have less effect on the ability to avoid PSC bycatch than the relative degree to which PSC species occur in the areas that have economically viable catch rates for flatfish. Examining bycatch performance in the context of degree of spatial/temporal overlap in the past could be a helpful area of future research, even though related data to analyze the degree of spatial overlap are not necessarily straightforward to assemble or work with. To deal with this challenge, NOAA Fisheries could conduct surveys at different times of the year to provide seasonal information about PSC species distribution against which managers and scientists could compare changes in fleet fishing locations and bycatch rates. However, this would be a costly approach to bycatch management and is probably not feasible given current budget constraints. Alternately, NOAA Fisheries could conduct modified surveys through cooperative efforts with industry where industry boats would perform randomized survey-like tows based on a grid design. This would require some means of standardization of commercial fishing gear and towing variables such that it would mimic or be comparable to data from a survey. Such a cooperative survey program might also require standardization of trawl effort or possibly indexing industry gear to survey trawls. Use of a model-based approach to use observer data from commercial fishing boats might also be considered. However, challenges related to using data that include the use of halibut excluder devices, different towing speeds, fishing for different target species, and all of the related effects on catch rates for PSC appear to be daunting for a model-based approach.

Workshop discussion focused on whether a catch-share system,[16] or even an experimental catch-share fishery, could help address bycatch challenges. A workshop participant suggested that the fishery should retain dead halibut bycatch, which creates an implicit bycatch tax. Another participant suggested that a limited survey of fishing grounds prior to fishing could help determine low-bycatch areas, but others felt that the overlap of bycatch and target species was too dynamic for such a survey to be effective. In addition, one workshop participant suggested that halibut bycatch could be classified by life stage when determining mortality rates for halibut, as opposed to applying a single rate. In this way, the population impacts of bycatches can be "weighted" by other variables than the number (e.g., reproductive value, etc.). A participant also suggested that analysts needed to develop methods to measure the effectiveness of bycatch reduction in a counterfactual manner instead of focusing on before-and-after effects and correlations. Further, a workshop participant suggested that managers should consider social and cultural implications of allocation in light of Alaskan native communities that interact with this fishery.

[16] A catch-share system could allow for trading of bycatch species quota at the sector or individual level.

Vaquita Bycatch in Small-Scale Commercial Gillnet Fisheries in the Upper Gulf of California, Mexico

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The vaquita, a small porpoise found only in the upper Gulf of California in Mexico (Figure 1), is on the verge of extinction due to bycatch in gillnets. The remaining individuals appear to inhabit a small area near San Felipe referred to as the Zero Tolerance Area (ZTA), which lies within the legally defined Vaquita Refuge (Figure 1). Continued high levels of illegal gillnetting have caused vaquita numbers to decline more than 98% from an estimated 567 in 1997 (Jaramillo-Legoretta et al. 1999). Since about 2011, the rate of vaquita decline increased because of illegal gillnets used to poach totoaba, a large and endangered fish whose swim bladders are prized in China (EIA 2016, Crosta et al. 2018). Despite actions taken by the Government of Mexico, the vaquita's steep decline has continued to the point where, without immediate and effective action, extinction is inevitable. The most recent field effort in fall 2019 estimated that only about 9 individuals remain (Rojas-Bracho et al. 2020). All appeared in robust health, including 3 calves, which suggests that these survivors could recover if protected (Rojas-Bracho et al. 2020).

Fishery and Target Species: The vaquita population declined because of unsustainable bycatch in small-scale commercial gillnet fisheries that targeted several species, including brown and blue shrimp (mainly exported to the United States) and several species of fish, including corvina, sharks, rays, bigeye croaker, and Spanish mackerel (mainly consumed domestically) (D'Agrosa et al. 2000, Rojas-Bracho et al. 2006). Vaquita are also caught in gillnets set for totoaba, a large sciaenid. Formerly abundant, totoaba were decimated due to intensive overfishing for their swim bladders and meat, and juvenile totoaba were also bycaught in commercial trawl shrimp fisheries (Cisneros Mata et al. 1995). After fishing effort and captures peaked in the 1940s, the population plummeted. Mexico banned fishing for totoaba in 1975, and the species was placed on the U.S. Endangered Species list, listed on CITES Appendix I, and listed as "Critically Endangered" by the IUCN. In the early 2010s, the species had recovered sufficiently to support a rapid increase in illegal poaching with gillnets, driven by renewed demand for swim bladders in China, where they are used in traditional medicine and as investments (Crosta et al. 2018). The price of dried swim bladder in southern China can be as high as US$80,000 per kilogram or more, and fishermen in the Upper Gulf can receive US$3,500-8,500 per kilogram (Crosta et al. 2018; EIA 2016, 2019).

Two fishing communities adjacent to vaquita habitat are dependent on gillnet fisheries: San Felipe in Baja California (population ca. 19,000) and El Golfo de Santa Clara in Sonora (population ca. 3,000). Their gillnets are typically 600 to 1,000+ meters in length, with mesh sizes from ca. 7 to 30 cm depending on the target species. The nets are deployed from pangas (fiberglass, outboard-powered boats six to eight meters long), typically crewed by two or three fishermen (Cudney and Turk Boyer 1998). Before the resurgence of totoaba poaching, shrimp was the most valuable target species, at about US$9M per year at the ex-vessel level, based on 2014 data from Conapesca (Garcia-Caudillo[17]).

Bycatch Species: Since the resurgence of illegal gillnet poaching for totoaba, vaquita numbers have declined precipitously at about 50% per year (Thomas et al. 2017, Jaramillo-Legorreta et al. 2019). As vaquita abundance decreased, their geographic range also decreased and the species now spends most of its time within a very small area toward the western margin of the Vaquita Refuge (Figure 1). In addition

[17] Garcia-Caudillo, J.M. 2020. Personal commun. Pesca Responsable, Boulevard Zertuche 937, Ensanada, Baja California Norte, 22890 Mexico.

to vaquita, sea turtles, seabirds, sharks, rays, non-target finfish, sea lions, dolphins, and whales also are caught in gillnets in the upper Gulf of California (CIRVA 9, 2017).

Vaquita was listed under CITES Appendix I in 1976, added to the U.S. Endangered Species list in 1985 and the Mexican List of Species at Risk of Extinction (Norma Oficial Mexican NOM-059 Semarnat) in 1994, and listed as "Critically Endangered" in 1996 by the IUCN.

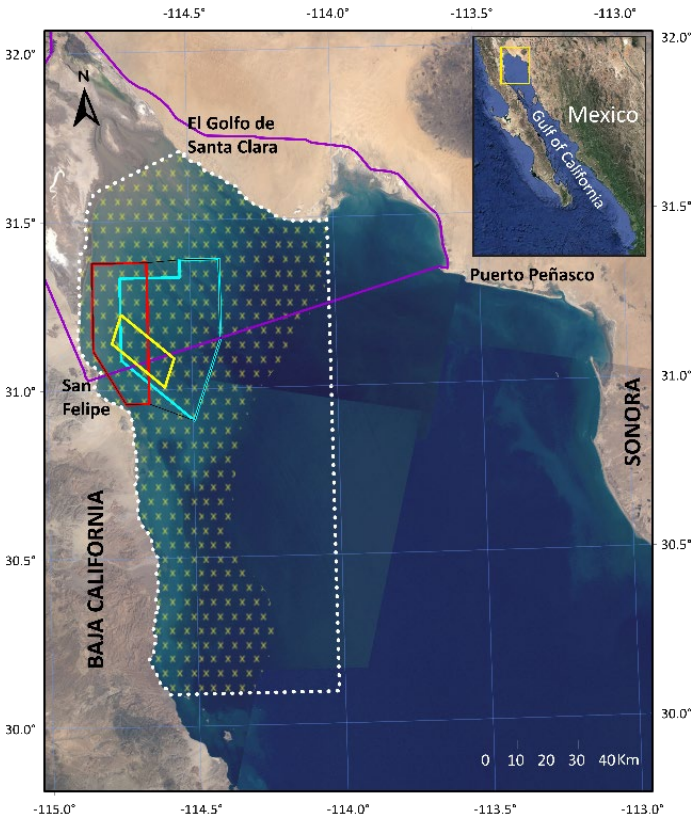

Figure 1. Historical distribution of vaquitas (yellow hatched area) in the northern Gulf of California. The Upper Gulf of California and Delta of the Colorado River Biosphere Reserve (outlined in purple) were designated by UNESCO in 1995 because of the unique habitat and presence of endangered species. The Vaquita Refuge was agreed to in 2005 and enacted in 2008 as a no fishing zone (in blue). A Gillnet Exclusion Zone (2015), where fishing with gillnets is banned but other types of fishing are allowed, was given straight boundaries (dotted white) to facilitate enforcement. Due to continued decline in vaquita numbers, an enhanced enforcement zone (in red) was designated in 2018 in the area where the remaining vaquitas are thought to spend most of their time and where there are high levels of totoaba poaching. The Zero Tolerance Area (ZTA) is where CIRVA recommends nets must be removed within hours of being set (in yellow) (CIRVA 11, 2019). Despite designated protected areas, gillnets continue to be used and vaquita numbers continue to decline. Landsat satellite composite imagery provided by United States Geological Survey, National Aeronautics and Space Administration (NASA) and Esri, Inc. Projection UTM. Datum WGS84. Figure and caption adapted from Jaramillo-Legorreta et al. 2019 and CIRVA 11 2019.

Current Bycatch Measures: The Government of Mexico has applied a diverse array of policy instruments and spent an unprecedented amount of money to save vaquita. Despite these investments, the efforts have failed to eliminate gillnets or save the species from continued steep decline (Figure 2; for review, see Rojas-Bracho et al. 2006, Bobadilla et al. 2011, Rojas-Bracho and Reeves 2013, Cisneros and Vincent 2016). Between 2007 and 2018, the Mexican government invested an estimated US$145M, primarily to

pay fishermen not to fish with gillnets, as well as investing in gear buy backs and substitutions, with limited investment in the development of alternative gears and livelihoods (Sanjuro, unpubl. data). In addition, the Government of Mexico funds and supports a substantial multi-agency enforcement effort. Reform of the Federal Penal Code and the Law against Organized Crime by the Chamber of Deputies (Mexican Congress) in 2017 made illegal poaching of totoaba a major felony related to organized crime, and increased the penalties. Yet prosecution rates are low and do not deter illegal fishing with gillnets. Current and past bycatch migtigation efforts and their impacts are briefly reviewed below.

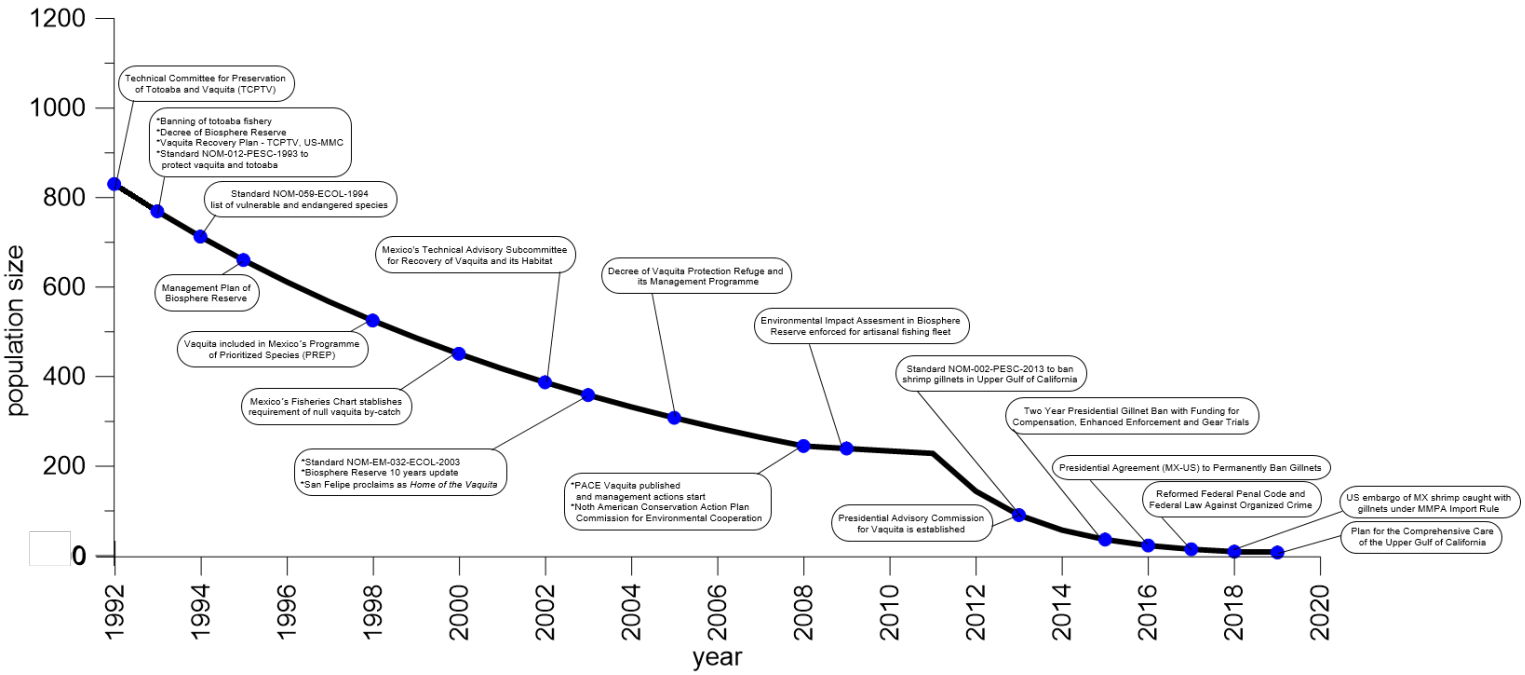

Figure 2. The decline of vaquitas has been continual. Many laws and regulations were enacted, but they mostly or entirely failed to reduce the gillnets encountered by the species. See text and reviews in Rojas-Bracho et al. 2006, Bobadilla et al. 2011, Rojas-Bracho and Reeves 2013, and Cisneros and Vincent 2016 for more information. Figure adapted from CIRVA 5 (2014); updated by A. Jaramillo, Oct 2019.

Protected areas designed to save vaquita from harm have failed to do so. The unique habitat and presence of endangered species led to the designation of the upper Gulf of California as a UNESCO Biosphere Reserve in 1995 and, in 2005, the Gulf of California with its natural beauty and high level of endemism was inscribed as an UNESCO World Heritage Site and global priority for biodiversity conservation. A Vaquita Refuge was created in 2005 and a management plan, including a "No Take Zone," was established in 2008. With the resurgence of totoaba poaching, a Gillnet Exclusion Zone was designated in 2015 to delinate where gillnets could not be used but other methods of fishing were allowed and in 2018, as totoaba poaching continued, an enhanced enforcement zone was recognized in the area where the reamining vaquita are thought to spend most of their time and where high levels of poaching occur (Figure 1). In 2019, a Zero Tolerance Area (ZTA) was recommended by CIRVA to delimit where nets must be removed within hours of being set to protect the area in which the remaining vaquita have been observed (Figure 1). Just 14 years after the initial declaration, UNESCO declared the region a World Heritage Site in Danger[18] due to the lack of enforcement, increase in illegal fishing, and continued decline of vaquita.

[18] https://whc.unesco.org/en/decisions/7490

Fisheries regulations were enacted to address vaquita bycatch but have been ineffective in transitioning the region's fisheries away from gillnets. Regulations were passed by the Government of Mexico to transition Upper Gulf of California fisheries to new gear types (2013), ban gillnets for two years with compensation for not fishing in closed areas (2015), and permanently ban gillnets in vaquita habitat (with exceptions for two species; 2017). Despite ca. US$100M in financial compensation (Sanjuro, unpubl. manuscript), problems with the distribution of funds rendered this program ineffective in reducing gillnetting (Crosta et al. 2018, UNESCO 2018). An opportunity was also missed to tie the compensation payments to participation in training or experimental alternative gear fisheries. Without sufficient transparency or oversight by the agencies dispensing the compensation, irregularities in the distribution of funds were counterproductive; some permit holders reaped substantial profits (some later implicated in totoaba poaching), while fishing families had inadequate income and compromised food security (Pasini et al. 2017, Crosta et al. 2018, UNESCO 2018). Unfortunately, totoaba poaching ended up being the only option for some fishermen (Crosta et al. 2018).

Projects by the Mexican fisheries agency, conservation organizations, and fisheries consultants to develop alternative fishing gears have been on and off since 2004, but have never been well funded, supported, or socialized (Herrera et al. 2017). Promising gear designs are available. For example, skilled fishermen have demonstrated the capacity to operate a modified small trawl for shrimp in a profitable way (Herrera et al. 2017). However, most fishermen, who have been fishing with gillnets all their lives, show little motivation to use—or outright reject—the new gears. Fishermen lack opportunities for trials or training, and delays in the authorization of fishing permits have impeded the transition to alternative fishing methods (Herrera et al. 2017). Efforts to develop alternative livelihoods beyond commercial fishing have shown some success but have similarly received relatively little funding or support (Ávila-Forcada et al. 2020). Since the current administration took office in 2018, fishermen in the Upper Gulf of California are no longer receiving compensation for the gillnet closure. Without alternative fishing gears available to them, and with the risk of arrest and prosecution low, fishermen are fishing illegally with gillnets for totoaba and for shrimp, shark, and other finfish (Rojas-Bracho et al. 2020)[19,20,21] .

Since the resurgence of totoaba poaching, domestic, bi-lateral, and multi-lateral efforts have attempted to address illegal wildlife trafficking and the organized criminal activity behind it. Previous administrations enhanced enforcement and inter-institutional efforts were coordinated, led by the Mexican Navy.
Yet illegal fishing and poaching of totoaba has continued and even escalated (UNESCO 2018, 2019). A number of high-level, multi-lateral meetings to coordinate anti-totoaba trafficking efforts have taken place among Mexico, multiple agencies in the United States, and China. A number of independent investigative studies have identified the criminal trafficking routes (C4ADS 2017, Crosta et al. 2018, EIA 2019). There have also been several well-publicized arrests followed by prosecutions in the United States and China for totoaba trafficking[22]. In Mexico, enforcement agencies have seized large quantities of totoaba swim bladders[23], but there is a lack of evidence that the seizures have led to any meaningful prosecutions or penalties (EIA 2019). Despite the continuation of the inter-institutional enforcement efforts, totoaba trafficking has escalated with cartels joining the trafficking in 2013, violence is more routine, and corruption enables the illegal trade in totoaba (C4ADS 2017, Pasini 2017, EIA 2019).

[19] https://iucn-csg.org/northern-gulf-of-california-world-heritage-site-listed-as-in-danger/
[20] https://iucn-csg.org/december-2019-february-2020-vaquita-update/
[21] https://seashepherd.org/news/sea-shepherd-reveals-unbridled-poaching-as-80-skiffs-raid-habitat-of-critically-endangered-vaquita-porpoise/
[22] https://www.scmp.com/news/hong-kong/law-and-crime/article/3088021/five-arrested-and-fish-bladders-worth-hk25-million
[23] https://iucn-csg.org/over-800-totoaba-swim-bladders-seized-april-2018-update/

Stakeholder engagement, public awareness, and international organizations brought attention to the plight of vaquita. The most formal effort to build cooperation between the government and the fishing sector (differing from numerous ad hoc listening sessions) was the creation of the Group of Monitoring and Evaluation by the Ministry of the Environment in 2008–2013. This effort showed promise in creating a framework for building trust, cooperation, and buy-in with bycatch mitigation efforts. But the effort was not sustained, and the current administration failed to heed requests by the fishing cooperatives for intervention, protection, and support[24]. For decades international science and conservation organizations have raised concern with the Government of Mexico over the status of vaquita, including the International Whaling Commission, IWC; International Union for Conservation of Nature, IUCN; and Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES. Public campaigns and the media regularly carry news about vaquita and totoaba issues in Mexico, the United States, and China, and in major media outlets around the world. Targeted campaigns have focused on buyers of swim bladders in China and recent arrests have been widely publicized. Reports detailing illegal totoaba trafficking (C4ADS 2017; Crosta et al. 2018; EIA 2016, 2019) and a major motion picture (*Sea of Shadows*[25]) provide publicly available evidence of illegal totoaba poaching controlled by organized crime associated with the drug trade.

The United States and Mexico have taken extensive bi-lateral efforts to try to save the vaquita under conservation, fisheries, and trade negotiations, including a Presidential Agreement to ban gillnets in 2016. Until recently, seafood, particularly shrimp, from the upper Gulf of California was imported into the United States. In 2018, after litigation, the United States banned the importation of shrimp, chano, curvina, and sierra caught with a gillnet in the vaquita's habitat under the new U.S. Marine Mammal Protection Act (MMPA) Import Provisions Rule[26]. The rule requires nations exporting fish and fish products to the United States to be held to the same standards as U.S. commercial fishing operations[27]. The ban was followed by a finding of "comparability" that allowed imports of products caught in the same region with alternative gears[28]. However, the comparability finding has since been revoked due the current Government of Mexico's failure to implement a comparable regulatory program, or enforce its existing regulations[29]. The U.S. embargo now includes shrimp, chano, sierra, curvina, anchovy, herrings, sardines, mackerels, croaker, and pilchard caught in the Upper Gulf of California[29]. Most recently, the plight of vaquita is identified as an issue of concern in the new U.S., Mexico, Canada Agreement on trade (USMCA). Yet even these economic pressures have failed to prevent illegal fishing, mobilize the Government of Mexico to improve its regulatory regime or increase enforcement, or prevent the continued decline of vaquita.

In recent years, engagement with industry has also increased, including connecting local fishermen considering alternative gears (e.g., Pesca ABC[30]) with U.S. buyers interested in sustainably sourced products, training processors in traceability procedures, and outreach to sustainable seafood wholesalers/retailers to lay the groundwork for introducing "vaquita friendly" shrimp and finfish caught

[24] https://medioambiente.nexos.com.mx/?p=498

[25] *Sea of Shadows*, directed by Richard Ladkani (2019; Washington, DC: National Geographic Documentary Films). Available at https://www.nationalgeographic.com/tv/movies-and-specials/sea-of-shadows

[26] https://www.federalregister.gov/documents/2018/03/16/2018-05348/fish-and-fish-product-import-provisions-of-the-marine-mammal-protection-act-list-of-foreign

[27] https://www.federalregister.gov/documents/2016/08/15/2016-19158/fish-and-fish-product-import-provisions-of-the-marine-mammal-protection-act

[28] https://www.federalregister.gov/documents/2018/12/06/2018-26418/implementation-of-fish-and-fish-product-import-provisions-of-the-marine-mammal-protection

[29] https://www.govinfo.gov/content/pkg/FR-2020-03-09/pdf/2020-04692.pdf

[30] Pesca ABC is an acronym in Spanish for the organization Alternative Fisheries of Baja California, which promotes the use of alternative fishing gear.

without gillnets. This work has included initial net earnings analyses, revealed preference studies, and valuation of potential eco-labels for "vaquita friendly" shrimp. The Mexican Shrimp Council—composed of the largest shrimp harvester, exporters, and importers—has also engaged, and pledged publicly in 2019 to not buy any product from gear or harvest zones that would endanger vaquita.

The failure of measures to reduce or elimate bycatch has not been due to a lack of science. Vaquita is one of the best-monitored marine mammal species in the world. Multiple surveys have been conducted throughout the upper Gulf of California using both visual methods and innovative acoustic monitoring methods (most recently, Jaramillo-Legoretta et al. 2019). Since 1997, the Comité Internacional para la Recuperación de la Vaquita (CIRVA) has advised the Government of Mexico on actions necessary to conserve vaquitas. CIRVA's primary recommendations were to eliminate gillnet fishing, develop and implement alternative fishing methods, and establish other livelihoods. Leading experts on fishing gears were convened to provide advice on alternative designs (Expert Committee on Fishing Technologies, ECOFT). In 2017, an intensive, multi-institutional program (Vaquita CPR) overseen by the Mexican Ministry of the Environment attempted to save vaquita by capturing the remaining individuals and placing them in protected enclosures until gillnets could be removed from their habitat. Despite assembling the world's experts in live cetacean capture, the effort was unsuccessful and operations were suspended when an adult female died (Rojas-Bracho et al. 2019).

To date, the most effective bycatch measure introduced into the Upper Gulf has been the multi-institutional gear removal program, which has removed well over 1,000 active and inactive (ghost) gillnets from vaquita habitat and has also saved hundreds of other bycaught species[31]. This effort was initiated in 2015 by Mexico's National Institute of Ecology and Climate Change, led on the water by Sea Shepherd Conservation Society, and employs local fishermen. Recent efforts are focused in the Zero Tolerance Area to protect the remaining vaquita[32]. The gear removal effort has led illegal fishermen to employ a variety of additional measures to protect their nets, and confrontations have become increasingly aggressive (CIRVA 11, 2019). Net removal is critical for protecting the remaining vaquita, but it is not enough to stop the flow of gillnets into the region.

Current Challenges: Current challenges are numerous and daunting. The totoaba trafficking crisis has escalated and with it violence, corruption, fear, and insecurity in the local communities (C4ADS 2017, Pasini 2017, EIA 2019, UNESCO 2019). Illegal poaching for totoaba continues to be highly lucrative and there is little risk of being caught or prosecuted[32]. One night of illegal poaching, with a catch of just a few totoabas, can earn a local fisherman more than he might otherwise make in a year (Crosta et al. 2018). Without alternative gears or continued government compensation for not fishing, fishermen have few options and are on the water with illegal gillnets (Rojas-Bracho et al. 2020)[33]. Organized crime is gaining increasing control of the region's fisheries (totoaba, and now shrimp and shark) and local communities (C4ADS 2017; local fishermen, personal communication to Rojas-Bracho). Fishermen collaborating with the cartels likely have a lower expected rate of being caught or prosecuted, adding to the incentives for illegal fishing (C4ADS 2017). The few fishermen experimenting with new gears do so at great personal risk and with little support, but are motivated by potential access to U.S. markets (personal communication from local fishermen and leaders of fishing cooperatives to senior author and Rojas-Bracho). Weak fisheries management in the area has resulted in an open-access, overcapitalized fishery (Pasini et al. 2017). Conservationists and vaquita researchers working in the Upper Gulf of California have been threatened, and theft of acoustic monitoring equipment has compromised the scientific

[31] https://seashepherd.org/news/sea-shepherd-removes-over-1000-pieces-of-illegal-fishing-gear-from-vaquita-habitat/

[32] https://iucn-csg.org/december-2019-february-2020-vaquita-update/

[33] https://seashepherd.org/news/sea-shepherd-reveals-unbridled-poaching-as-80-skiffs-raid-habitat-of-critically-endangered-vaquita-porpoise/

monitoring program. Time is running out for vaquita and these many obstacles demonstrate the serious challenges facing efforts to save them.

Future Directions and Research, including Economic Research: Conservation goals in the Upper Gulf of California can be met only with a concerted effort to address the demand for and illegal trafficking of totoaba swim bladders and the underlying issues of fisheries management, governance, corruption, and poverty. Despite unprecedented investment by the Government of Mexico, without a coordinated domestic and international effort to address criminal and security issues in the region, the totoaba and the vaquita could both be lost, leading to further deterioration of the local economies (C4ADS 2017).

The situation for vaquita is dire, yet some lessons from this case study can be applied to other protected species subject to bycatch in coastal, small-scale fisheries.

Conservation policy is often framed as a binary choice between direct regulation (top-down) or incentivization (bottom-up). However, as the vaquita situation shows, conservation can be more complex and context-dependent, and can require both a top-down and bottom-up approach; this is often referred to as a "carrots and sticks" strategy. A key point is to start early and to take a holistic approach.

Enforcement is a key component of ensuring that top-down policies are implemented, but strong regulations place heavy responsibility on enforcement; costs are often prohibitive and may not be effective without sufficient capacity or with corruption challenges. With a 'carrots' or incentivization approach, compliance can be enhanced by engaging local communities throughout the process and developing alternative and socially acceptable ways of making a viable living. A fundamental misstep in the Upper Gulf was the missed opportunity to follow advice of CIRVA more than 20 years ago, calling for development of alternatives to gillnets, and taking note of the broader socio-economic landscape when there was still time (CIRVA 9, 2017, Table 1). These alternatives must yield comparable net income levels, taking into account factors such as risk and preferences. Focusing on finding legal livelihoods and supporting legal fishermen able to make a good living—with a stake or ownership of their own resources—are important components of policies to address bycatch and also to reduce illegal trade in wildlife (Felbab-Brown 2017).

A multi-disciplinary approach can provide a critically important basis for developing a new structure of incentives in which legal activities benefit the community. Collecting and analyzing economic data on alternative gear types, for example, would identify the fishing techniques that may allow for economically viable and ecologically sustainable fisheries. New fishing gears have been developed and evaluated, but they require further training and socialization for those who use them. These gears also require authorization and environmental assessment under the appropriate laws and management authorities. Furthermore, collection and analysis of social and economic data on investment in community well-being, education, and training would help address livelihood options and diversify local economies.

Market incentives, whether in the form of carrots (market access, ecolabels, higher prices) or sticks (import prohibitions), can play a role. At least some fishermen have been involved in the development of new gears, and they and others continue to show interest. Their expertise could be invested in pilot studies of new fisheries and of the market. Studies of retail price premiums for eco-labelled shrimp provide the first evidence of higher market prices for wild, sustainably harvested Mexican shrimp (Mesnick et al., this case study). The U.S. embargo, CITES prohibitions on totoaba, and the USMCA on trade, are inspiring some additional fishermen to express interest in using the alternative gears (V. Towns, Museo de Ballena, personal communication to S. Mesnick; local leaders of fishing cooperatives, personal communication to L. Rojas-Bracho). The U.S. MMPA import regulation provides an incentive for nations to undertake marine mammal bycatch monitoring and mitigation to retain access for their seafood products sold in the

U.S. market. Economists can help develop capacity in importing countries, evaluate costs and earnings, and find supply chain efficiencies.

Workshop discussion of vaquita bycatch centered on high levels of illegal fishing or poaching and the infiltration of organized crime, lack of effective enforcement and rule of law, and the dire state of the vaquita population. Despite recommendations for possible economics-related solutions—such as buyouts, high value and sustainable fisheries, and the development of diversified economies such as sportfishing, ecotourism, and green energy—the highly lucrative, illegal economy for totoaba swim bladders, driven by external demand from China, eclipes efforts to develop such economic and legal alternatives.

Cod Bycatch in the Northeast Recreational Haddock Fishery

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Fishery and Target Species: The Northeast recreational haddock fishery is part of a mixed-gear recreational groundfish fishery that targets Gulf of Maine (GOM) haddock but encounters multiple species.

Bycatch Species: GOM Atlantic cod are a bycatch species in the Northeast recreational haddock fishery.

Current Bycatch Measures: GOM haddock and Atlantic cod recreational fisheries are managed through possession and size limits. Seasonal area closures are also in place to protect Atlantic cod spawning stock biomass. There are no gear-specific bycatch requirements.

Current Challenges: Although haddock abundance in the GOM currently is estimated to be at an all-time high, GOM cod is subject to a rebuilding plan, and abundance remains well below biomass targets despite substantial reductions in Allowable Biological Catches since 2011 (both recreational and commercial). As anglers fishing for haddock in the GOM often encounter cod, developing regulations that allow for increased harvest of haddock while keeping cod mortality below historically low Annual Catch Limits (ACLs) has been difficult. Since 2013, the New England Fishery Management Council (NEFMC) has relied on a bioeconomic model, developed by the NEFSC, to determine the regulatory measures that would allow the recreational fishery to meet but not exceed separate GOM cod and haddock ACLs each year. In recent years, the model's results have become increasingly contentious because, in order to keep GOM cod recreational mortality from exceeding historically low ACL levels, managers have not only prohibited the harvest of GOM cod but also implemented stringent GOM haddock restrictions. These restrictions in turn reduce GOM cod mortality in the model through a mechanistic reduction in recreational fishing effort. Restricting GOM haddock harvest to reduce cod mortality has been controversial among recreational anglers given the existing unprecedented large biomass of GOM haddock. This management strategy also is problematic due to the open-access nature of recreational fishing and the lack of enforcement of catch regulations.

Future Directions and Research, including Economic Research: The NEFSC's bioeconomic model provides high-quality science in support of management and has integrated economics into the fishery management process. However, managers have erroneously assumed that angler behavior and stock levels would remain constant when estimating how proposed regulations would affect mortality. Scientists at the New England Aquarium and the Massachusetts Department of Marine Fisheries, among others, have conducted research to determine discard mortality rates of both GOM cod and bycatch (e.g., Capizzano et al. 2019) and methods to reduce such mortality. Managers may develop new regulatory actions based on this research. There are no incentive-based policies in place to reduce GOM cod bycatch; instead, management relies on season, size, and bag limits, which are a direct cause of regulatory discards and may dissipate value to anglers and for-hire vessel owners.

Research on angling management organizations in European countries has shown that if fishing rights are given to the organizations, they invest heavily in resource management and compliance (e.g., Daedlow et al. 2011). However, this would be hard to accomplish in the United States because of the public trust doctrine that requires nearly free, unrestricted access to marine recreational fishing for everyone. Rights-based management approaches have been tested and implemented in at least two for-hire recreational fisheries in the United States, and although the results have been mixed (e.g., Abbott and Willard 2017), the approaches resulted in reduced discarding behavior. Although a rights-based management approach is a possibility for the GOM for-hire fishing fleet, private boat discarding of GOM cod is responsible for approximately 90% of GOM cod mortality.

Incentive-based avoidance approaches are difficult to implement in real-world marine recreational fisheries because monitoring, measuring, and enforcement issues limit the feasibility of such systems. Therefore, the primary management focus in the GOM has been on reducing recreational discard mortality rates through outreach efforts to educate anglers on proper release techniques and encouraging the use of descending devices and circle hooks. Despite these efforts to educate anglers, improve social norms, and reduce discard mortality rates, incidental catch of GOM cod remains a critical issue with no foreseeable solution.

Workshop participants discussed whether it would be possible to perform a cost analysis of reducing commercial discard mortality versus recreational discard mortality, as well as whether fishing organizations would be likely to promote the use of descending devices to reduce the effects of barotrauma on fish. According to workshop participants, rights-based management seems unlikely for the for-hire industry at this point.

California Large Mesh Drift Gillnet Fishery: Bycatch and Regulatory Changes since the 1980s

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Fishery and Target Species: The California large-mesh drift gillnet (DGN) commercial fishery uses one-nautical-mile-long drift gillnets with greater than 14-inch mesh to target swordfish. This fishery currently comprises around 20 vessels operating primarily out of Southern California, down from nearly 300 vessels in the 1980s. Managers have implemented a series of protected species bycatch-reduction measures, which caused the fleet size to decrease.

Bycatch Species: Cetaceans and sea turtles

Current Bycatch Measures: This fishery is subject to various time-and-area closures, including closed three nautical miles from shore year-round, closed 75 nautical miles from shore from May 1 to August 15, and closed 200 nautical miles from shore from February 31 to April 30. In addition, boats in this fleet are excluded from the seasonal Pacific Leatherback Conservation Area (PLCA) closure in Central and Northern California from August 15 to November 15. During El Niño years, the fishery is closed east of the 120th meridian west. Fishermen are required to use acoustic pingers and 36-foot or greater buoy lines. Since the introduction of the pinger and buoy line requirements, the fishery's bycatch of beaked whales has been 0, and small cetacean bycatch has been reduced by over 50%. In addition, the PLCA and El Niño closures reduced sea turtle bycatch. The fishery has operated under the Marine Mammal Protection Act take reduction team (Pacific Offshore Cetacean Take Reduction Team) since 1996. However, these measures over time resulted in a general southward shift of the homeports of participating vessels due to "northern" vessels leaving the fishery, which has shortened the effective fishing season primarily from October to January. In February 2020, NMFS issued a final rule as originally recommended by the Pacific

Fishery Management Council (PFMC), implementing hard caps in compliance with a federal court decision. Revisions to that rule are possible to minimize the economic impacts to the fleet while potentially incentivizing changes in fishing behavior to keep rare-event bycatch events, i.e., of protected species, to a minimum. At its March 2020 meeting, the PFMC decided to further discuss potential options to revise the hard caps rule at the September 2020 meeting.

Current Challenges: Despite substantial decreases in bycatch and bycatch rates from the 1980s to today due to management measures, environmental non-governmental organizations (NGOs) remain focused on closing the fishery. Recently the DGN permits were federalized as transferable limited entry permit under the West Coast Highly Migratory Species Fishery Management Plan. This fishery's products compete to a great degree with imported swordfish from multiple international fisheries (primarily longline) as well as domestic longline-caught swordfish. A recent proposed state of California buy-out plan offered likely insufficient incentive for meaningful participation by fishery participants.

The PFMC in September 2019 recommended approval of a deepset buoy gear (DSBG) fishery as an additional swordfish gear. DGN fishery participants willing to "trade in" their permits are given an advantage in qualifying for DSBG permits, providing an incentive to switch methods.

Future Directions and Research, including Economic Research: Catalina Offshore Products and a number of partners are conducting a Saltonstall-Kennedy Grant project to increase utilization of underutilized catch such as opah and thresher shark. Improved understanding of fine-scale habitat use of swordfish and bycatch species allows more precise targeting of swordfish in areas with lower likelihood of bycatch. The development of EcoCast, a real-time data tool to help fishermen and managers allocate fishing effort to optimize the harvest of target fish while minimizing bycatch of protected species, has shown potential for bycatch reduction in this fishery. NMFS' Southwest Fisheries Science Center scientists and their partners have produced many documents analyzing the impacts of rule changes on the fishery (e.g., Urbisci et al. 2016) and transfer effects (conservation, production, and trade leakages) of this fishery's management measures (e.g., Mason et al. 2019). It is unclear how the DGN fishery will continue to operate under the existing management regime in which the DGN fishery's bycatch has been substantially reduced to below authorized and legal levels. At the same time, the fishery is now much smaller, as noted earlier, and there has been an increased U.S. seafood consumer reliance on imported swordfish.

Discussions at the workshop focused on outreach and communication campaigns conducted by environmental NGOs and the DGN fleet, as well as ideas to increase the value of DGN catch domestically and the detrimental transfer effects of DGN fishery restrictions on protected species and other bycatch species that come with swordfish imports. Workshop participants also discussed, in light of the apparently insufficient California buyout program, conducting the buyout program for the fishery as a reverse auction and querying the fleet regarding what it would be willing to accept as a buyout. Participants also discussed the need to identify when additional investments in reducing bycatch are no longer economically feasible for a fishery, as well as the pressure placed on observers in fisheries with hard bycatch caps that can shut down a fishery.

North Atlantic Right Whales in Relation to the U.S. Lobster Fishery, Joint Research, NOAA and DFO Canada

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Fishery and Target Species: The Northeast American lobster trap/pot fishery consists of approximately 6,500 vessels that land 71.6 metric tons of lobster valued at US$574 million. The fishery ranges from Connecticut to Maine and occurs in federal and state waters. Commercial and recreational lobster fisheries operate in the Northeast; this case study focuses on the commercial fishery.

Bycatch Species: North Atlantic right whales (NARW) are listed as Endangered under the U.S. Endangered Species Act and Canadian Species at Risk Act, and Critically Endangered on the International Union for the Conservation of Nature's Red List (IUCN 2019). Leading causes of mortality are lethal fishing gear interactions and ship strikes. Entanglements and ship strikes occur in both U.S. and Canadian shelf waters as the whales typically migrate in the spring from winter calving zones off Florida and Georgia up the east coast of North America to feeding and breeding areas in both countries.[34] The lobster fishery, one of the most valuable commercial species caught in the U.S., interacts with the NARW western stock. Over the last 10 years, entanglement in fishing gear has been the leading cause of death, primarily in the buoy lines used by lobster, crab, and other trap fisheries. The population has been declining since 2010 (Pace et al. 2017), and entanglement severity affects health, reproduction, and survival (Knowlton et al. 2016; Robbins et al. 2015).

Current Bycatch Measures: Measures to reduce entanglements for NARWs and other large whales began in 1997 with the first Atlantic Large Whale Take Reduction Plan ("ALWTRP" or "the plan"), while implementation of measures to reduce mortality from ship strikes began in 2008. Management measures to reduce NARW interactions in commercial fisheries included closed areas and gear modifications. In 2002, two new measures were introduced: Dynamic Area Management (DAM) that allowed real-time access restrictions (i.e., avoidance via closures) or technology standards (i.e., minimization via mandated gear modifications), and Seasonal Area Management (SAM), which had spatially and temporally fixed technology standards. The next set of policy instruments were complete seasonal closures limited to critical habitat (i.e., the Great South Channel, Massachusetts Restricted Area), plus broad-based gear modifications in 2007 requiring the use of sinking ground line (72 FR 57103) and a reduction in the number of vertical lines in the water in 2014 (79 FR 36585). These global broad-based gear modification rules replaced the DAMs and SAMs in 2009.

Current Challenges: Despite decades of various management measures, North Atlantic right whales are not recovering. A promising solution going forward is rope-less fishing gear, which would remove vertical lines from the water.[35] Scientists and managers are currently field-testing different rope-less fishing gear prototypes in the nearshore and offshore lobster fisheries; however, rope-less fishing is a long-term solution.

The major challenge today is that the effectiveness of the plan cannot be assessed directly with management measures implemented. While the MMPA makes an annual assessment of whether a species needs additional protection based on average annual observed mortalities relative to the potential biological removal level, the principal purpose of the ALWTRP is to reduce the likelihood and severity of entanglement by large whales, especially NARW, in commercial fixed-gear fisheries, including lobster. However, unlike the take reduction planning process for other species, it was challenging to assess whether the plan would achieve a reduction in the entanglement rate as data were lacking on

[34] New England waters and the Canadian Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence.
[35] https://ropeless.org/2019-ropeless-agenda-and-presentations/

entanglement or bycatch rates and the impacts of fishing practices, gear characteristics, area, and/or environmental factors on those rates (Borggaard et al. 2017). To this day the data issue remains. Based on data for 2000 to 2017, only 38% of NARW carcasses were detected annually (Pace 2019). In addition, the ability of NARW to carry gear from the point of the initial entanglement creates significant uncertainty in assigning the location, type and configuration of the gear involved in an entanglement, despite gear marking requirements since the first plan in 1997 (NMFS 1997). It is this combination of technical difficulties in linking entanglement, serious injury and mortality numbers and rates with specific fisheries, coupled with the statistical rarity of observing entanglements for large whales, that makes it challenging to not only measure the overall effectiveness of the plan and even more difficult to assess the success of any single instrument. However, because the NARW is not recovering, additional measures for the ALWTRP are underway.

Future Directions and Research, including Economic Research: NOAA Fisheries is working with partners to reduce anthropogenic mortality (commercial fishing and shipping) below the potential biological removal (PBR) threshold as defined by the Marine Mammal Protection Act (MMPA), while minimizing impacts on commercial fishery revenues/profits if possible. To reach the PBR goal, the ALWTRP team's objective is to develop management measures that will reduce the risk of NARW entanglement by 60-80%.[36] Management measures under consideration include time/area closures, vertical line (numbers) reductions, and use of weak end lines.

The Take Reduction Team (TRT) reconvened in 2018. A right whale decision support tool (DST) was developed for the ALWTRP team along with others to understand and mitigate the relative risk of NARW entanglement in fishing gear in different geographic locations off the northeastern United States.[37] However, the current DST does not include an economic component to evaluate alternative policy instruments designed to reduce the risk of entanglement. With this in mind and prior to the TRT reconvening, a collaborative NOAA/DFO economic research project to address this need was initiated in 2017.

The long-term project underway entitled "U.S.-Canada collaborative evaluation of policy instruments to protect North Atlantic Right Whales" is designed to provide evidence-based analysis to predict fishermen's behavioral harvesting responses to management measures designed to achieve various levels of protection for NARW. The overarching question is, are the NARW management measures not working or is there not enough protection? This cannot be assessed from the perspective of a single country or solved with a single policy instrument. The end goal of this collaborative long-term project is to overlay a U.S.-Canada predictive behavioral harvester model with a predictive NARW biological model to assess real-time impacts of management measures proposed to reduce the risk of entanglement. Phase 1, which examines past measures, has been completed and uses these results to build the behavioral harvester model in phase 2.

Phase 1 consists of a case study that conducts a retrospective analysis of dynamic and static spatial measures used between 2002 and 2009 as part of the ALWTRP, with a focus on the American lobster fishery (Bisack, unpubl. manuscript). Ex-post or retrospective analyses have focused on biological outcomes rather than social or economic responses or outcomes. This case study is a first step to address this gap and provides an opportunity to examine the strengths and challenges of a range of previous policy instruments that can support future instrument design (Bisack and Magnusson 2016), including compliance (Bisack and Das 2015; Bisack and Clay 2020). The combination of regulations implemented in the ALWTRP illustrates the bycatch mitigation hierarchy, avoids impacts (closures) and minimizes

[36] https://www.fisheries.noaa.gov/new-england-mid-atlantic/endangered-species-conservation/north-atlantic-right-whale-recovery-plan-northeast-us-implementation-team

[37] https://www.fisheries.noaa.gov/event/peer-review-right-whale-decision-support-tool

unavoidable impacts (technical standards) (Squires and Garcia 2014). Biological and economic implications of the DAM program relative to other spatial measures during the same period, using available spatially and temporally explicit data on whale density and fishing effort, were utilized to develop a NARW relative risk of entanglement index (RREI). Results of Bisack and Magnusson's case study indicate: (1) the DAM program did provide spillover protection beyond the predictable times and areas where NARW aggregate year after year; (2) while the share of ocean with DAM zones was small, during certain periods they provided a significant reduction in potential entanglement risk; and (3) the high degree of spatial overlap of the DAM areas across years prior to 2009 may have created an indirect economic incentive for some fishers to adopt the modified gear throughout the year and across areas, reducing the economic impact of the broad-based gear measures that followed in 2009. Going forward, if sufficient uncertainty about effectiveness of gear modification exists, then perhaps more targeted closures (SAM/DAM like) among a suite of instruments would be more effective and less costly. An economic benefit-cost framework to evaluate public and private sector trade-offs of various right whale protection plans and whether there is an incentive for the private sector to invest in scientific data collection (Bisack and Magnusson 2014) to reduce the risk of entanglement (i.e., more data can provide more knowledge), is under way in phase 2, developing a predictive harvester model.

It would be prudent if NOAA Fisheries could invest funds in developing predictive behavioral economic commercial harvester models for protected species. At a national level, NOAA NMFS has contracted out economic analyses in support of proposed ESA and MMPA regulations. Social science models and research need to keep pace with the advancing biological models. At a 2019 meeting the NARW Northeast U.S. Implementation Team (NEIT) identified five goals that relate to social sciences: (1) provide dynamic and flexible management, (2) promote fishermen education and buy-in, (3) understand where the threats are, (4) enhance communication between the U.S. and Canada Network; and (5) ensure full fishermen compliance. These are just a few examples developed by the thinking of the NEIT. One management measure will not solve this problem. Designing policy instruments is a complex task and requires multiple instruments and perhaps new approaches, such as instruments that modify or nudge fishermen's behavioral responses through incentives or disincentives (Bisack, unpubl. manuscript). Future public and private sector costs could be reduced through continued advances in technology such as acoustic monitoring. A multidisciplinary team approach will improve the chance of designing successful management measures to allow NARW recovery.

Workshop participants discussed the sociologically complex environment related to NARW conservation, where historic traditions related to the lobster fishery and territoriality have created political challenges for managers who would like to see the number of traps reduced. Participants also mentioned that research on the optimal number of traps in the lobster fishery could yield information on effects of trap numbers on catch per unit effort and costs.

Reducing Seabird Bycatch in Alaskan Longline Fisheries

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Fishery and Target Species: The Alaskan longline fishery is one of the largest (US$300 million ex-vessel value, 1,000 vessels) and most diverse commercial demersal longline fisheries in the world. Mostly separate fleets target four species occurring at different depths:

1. Sablefish – 300 vessels, US$88 million ex-vessel, mean depth = 581 m
2. Pacific halibut – 900 vessels, US$119 million ex-vessel, mean depth 295 m
3. Pacific cod – 130 vessels, US$88 million ex-vessel, mean depth = 117 m
4. Greenland turbot – 7 vessels, US$240,000 ex-vessel, mean depth = 598 m

Seabird Bycatch Species: Seabird bycatch in Alaskan longline fisheries includes several species. Northern fulmar and gulls make up the bulk of bycatch, although the bycatch of short-tailed albatross, Laysan albatross, and black-footed albatross are the principal conservation concern. Alaska longline fisheries also interact with short-tailed and sooty shearwaters.

Current Bycatch Measures: Streamer lines (aka bird scaring or tori lines) were shown to be the best option for reducing seabird bycatch per unit effort (BPUE) of surface foraging birds, a guild that includes the albatrosses, by 88% to 100% compared to controls of no deterrent in the two fisheries examined (Melvin et al. 2001). A streamer line consists of a line running from a high point on a vessel to a towed device to create drag. The forward movement of the vessel lifts a section of line into the air. Streamers suspended from this aerial section scare birds from baited hooks as the hooks sink from the surface. The fishing industry adopted streamer lines with performance and material standards on a voluntary basis in 2002 and by regulation in 2004.

Required bycatch measures vary by vessel length, gear type, vessel infrastructure and fishing location. With the exception of vessels lacking appropriate infrastructure or fishing inside waters where albatrosses do not occur, deploying streamer lines is required to decrease seabird bycatch while setting longlines. Paired streamer lines fence off the area in which birds have access to baited hooks and are robust regardless of wind direction. Analysis of 23 years of fisheries observer data (1993 to 2015), which spanned the periods before (1993 to 2001) and after (2002 to 2015) the adoption of streamer lines, showed that seabird BPUE declined by 77% to 90% with the adoption of streamer lines. This adoption saved an estimated 9,400 albatrosses and 141,000 other seabirds over 14 years (Melvin et al. 2019). No short-tailed albatross were caught in these fisheries from 2002 to 2009, and 4 short-tailed albatross total were caught over the 14 years of streamer line use (all in the cod fishery).

Current Challenges: Seabird bycatch in longline fisheries, which is the primary at-sea threat to albatross and petrel populations (Croxall et al. 2012), has been linked to population declines, and poor recovery of seabird populations. Attracted to fishing vessels to forage on discharged offal and used baits, seabirds can become hooked and drown on baited hooks as they sink during longline deployment. The annual mortality of seabirds attributable to longline fisheries has been estimated in the hundreds of thousands of birds (Anderson et al. 2011). The seabird conservation concern is most acute for albatrosses and petrels due to a life history that is highly sensitive to adult mortality. Adult mortality at sea has the most influence on population trajectories and recovery (Heppell et al. 2000; Bakker et al. 2018). Albatrosses spend most of their lives foraging over vast expanses of the mid to high latitude oceans where they overlap with multiple fisheries. With 70% of 22 species threatened with extinction, albatrosses are the most threatened of any bird family (Robertson and Gales 1998; Tuck 2011; IUCN (International Union

for the Conservation of Nature) 2017). In addition to negative effects on seabird populations, seabird depredation of baits from longline hooks can increase fishing costs and compromise fishing efficiency. In some fisheries, unchecked seabird bycatch can lead to lost fishing access, negative perceptions of the fishery, and reluctance to purchase catch from high-bycatch fisheries (Kelleher 2005).

Although the fishery has not exceeded incidental take limits for short-tailed albatross, and bycatch rates have been dramatically reduced since the adoption of streamer lines, hundreds of Laysan and black-footed albatrosses and thousands of northern fulmars and gulls continue to be killed each year in Alaskan longline fisheries. Takes of the non-albatross species are not a conservation concern at the population level, but longline takes of all three albatross species that occur in the North Pacific do pose a conservation threat, especially when considered in the context of suspected high levels of mortality in the many non-U.S. longline fisheries operating throughout the range of these albatrosses.

Future Directions and Research, including Economic Research: Consistent with two earlier studies exploring drivers of seabird BPUE in Alaskan longline fisheries (Dietrich et al. 2009; Dietrich & Fitzgerald 2010), Melvin et al. 2019 showed that particular vessels had the highest seabird BPUE regardless of other measured factors. Melvin et al. 2019 identified three vessels that accounted for 46% to 78% of the albatross bycatch and 31% to 51% of the non-albatross species bycatch over 3 years (2013 to 2015) depending on the fishery. Outreach and education aimed at these operators may be a first step to reduce this bycatch. Operators of vessels with high BPUE may be unaware of their performance relative to their peers and may lack understanding of the need for seabird conservation or how best to achieve it. A strategic outreach approach could help management direct scarce resources to where they are most needed.[38]

Melvin et al. 2019 found that night setting of longlines reduced BPUE of most seabird species and increased CPUE of target fish species (i.e., sablefish and cod) and nontarget fish species, which are often discarded. The BPUE of northern fulmar, the bird most caught in Alaskan longline fisheries, was the only seabird in this assemblage caught at significantly higher rates (by 40%) during night sets. Therefore, night setting fails to meet a basic best practice measure for seabird bycatch reduction: reduce seabird bycatch without increasing the bycatch of other species. This trade-off between the conservation of species of special conservation concern, the albatrosses, versus an abundant species with minimal conservation concern, the northern fulmar, creates a challenge to fishery managers. In a fishery where the take of six short-tailed albatrosses could close a US$300 million fishery with over 1,000 vessels, managers might opt for albatross conservation as the overriding priority.

No research has occurred on economics, incentives, or market mechanisms to reduce seabird bycatch in Alaskan longline fisheries. Currently there is no penalty, economic or otherwise, to an individual vessel or fisherman if an endangered short-tailed albatross or other seabird is caught. Exceeding incidental take limits would penalize the entire groundfish longline and trawl fleets (6 birds in two years) and/or the entire Pacific halibut fleet (two birds in two years). Nor are there penalties for vessels with high bycatch rates. Economic penalties for high bycatch rates or endangered species bycatch could prove beneficial to reducing seabird bycatch but also could silence fishermen on the extent of bycatch or deter them from coming forward to seek assistance.

Workshop discussion focused on detection of vessel effects, that is, identification of vessels with anomalously high bycatch rates. Workshop participants identified MSA confidentiality requirements, as well as limits on the amount of socioeconomic data and other data collected by observers (e.g., level of

[38] Efforts are underway to provide operators with such information.

skipper experience, gear characteristics), as obstacles to addressing vessel effects. Participants also raised the issues of individual vessel bycatch quotas and possible changes to seabird behavior and ecosystem disturbance due to the "food subsidy" provided by fishing vessels. Another participant pointed out that early extensive research set the stage for managers to approve the successful bycatch reduction measures for this fleet in a rapid manner.

Bycatch Issues in the Gulf of Mexico Red Snapper Fishery

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Fishery and Target Species: The red snapper resource supports important commercial and recreational fisheries in the Gulf of Mexico (GOM). The red snapper annual catch limit (ACL) is shared between the commercial (51%) and recreational sectors (49%). The resource is not overfished and overfishing does not occur, but the resource has not yet recovered to the Gulf-wide rebuilding target. The GOM red snapper can be a target or bycatch species depending on the fishery and fishing practices.

Private anglers, charter boats, and headboats target red snapper during the relatively short open season. Most red snapper discards occur during the recreational closed season when its retention is forbidden. The red snapper recreational fishery is mainly regulated with minimum size limits, bag limits, seasonal closures, and quotas (Hood et al. 2007). Data from the Marine Recreational Information Program and Louisiana Recreational Creel Survey are used to estimate effort of the private angling component for each Gulf state, except Texas. From 2012 through 2016, the private angling component of the recreational sector took an average of at least 228,122 directed angler trips annually (GMFMC 2018). Those were trips where red snapper was the primary or secondary target or was caught by anglers. About 1,330 GOM vessels are permitted as charter or headboats in the reef fish fishery (GMFMC 2018). About 95% of these vessels are charters and the remainder headboats. Charters take, on average, about 201,348 directed angler trips per year.

Red snapper bycatch also occurs in the commercial reef fish fleet, which comprises vertical line and longline vessels. Both types of gears jointly catch red snapper with other species (e.g., vermilion snapper). Broadly speaking, the vertical line fleet mostly catches red snapper (it catches in excess of 95% of the red snapper quota), whereas the longline fleet largely catches groupers (such as red grouper), especially in the eastern Gulf. In 2018, 450 commercial vessels landed about 6.3 million pounds (mp) (gwt) of red snapper worth $US30 million in dockside revenues (SERO 2019).

Bycatch Species: Recreational and commercial fisheries targeting red snapper discard some of the red snapper they catch. Fishermen targeting other species also catch and discard red snapper. The most recent red snapper stock assessment estimated that the recreational fleet was responsible for 68% of the total discards (on a weight basis), the commercial reef fish fleet (vertical and longline vessels) for 27%, and the shrimp trawl fleet for the remaining 5% (Southeast Data, Assessment, and Review, SEDAR 52). Due to fleet-specific differences in estimated discard mortality rates, the recreational fleet, commercial reef fish fleet, and shrimp trawl fleet are responsible for 40%, 46% and 14% of dead discards (on a weight basis), respectively. These estimates are based on a 9-year average starting in 2007, when the red snapper individual fishing quota (IFQ) program began, through 2015.[39]

[39] These 9-year averages translate to about 4.6 million pounds (mp) for recreational sector, 1.85 mp for the commercial sector (exc. shrimp), and 0.32 mp for the shrimp trawl. The 9-year red snapper ACL average for both sectors was 8.4 mp. These figures are all in whole weight.

Current Bycatch Measures: In 1997, Amendment 9 to the FMP for the Shrimp Fishery of the Gulf of Mexico, U.S. Waters (Shrimp FMP) (effective in 1998) mandated the use of bycatch reduction devices (BRDs) to reduce red snapper bycatch, mostly of age 0 and 1 fish. In 2007, the Joint Amendment 27/14 to the GMFMC's Shrimp and Reef Fish FMPs established a target red snapper bycatch mortality goal for the shrimp fishery in the western Gulf. Specifically, it established a target reduction goal for red snapper mortality of 74% less than the benchmark of years 2001-2003, reducing the target goal to 67% in 2011, eventually reducing the target to 60% by 2032. In 2019, Amendment 18 to the Shrimp FMP reduced the target reduction goal for shrimp effort threshold from 67% to 60% below the baseline effort in the years 2001-2003. However, many studies that examined BRD performance showed that bycatch reduction was extremely variable depending not only on the design of the BRD but also the placement of the BRD in the net and fishing practices and conditions (Diamond 2004). Diamond (2004) presents a detailed summary of these studies, which suggests that their efficacy is species-specific.

On January 1, 2007, the Gulf of Mexico Fishery Management Council (GMFMC) implemented Amendment 26 to the Gulf of Mexico Reef Fish FMP, which introduced the red snapper IFQ program to reduce overcapacity in the commercial fishery and mitigate race to fish conditions. Although reducing bycatch was an ancillary goal, the five-year review of the program suggested that further policy interventions were required to reduce discarding in the eastern Gulf, even though overall discarding had decreased (Agar et al. 2014). At the time the IFQ program was implemented, the red snapper minimum size limit was reduced from 15 inches to 13 inches.

Amendment 27 to the Gulf of Mexico Reef Fish FMP (effective on June 1, 2008) mandated that all commercial fishermen and anglers fishing for reef fish species in federal and state waters use de-hooking devices, venting tools, and non-stainless circle hooks when using natural baits either alive or dead (GMFMC 2007). Since the venting tools requirement was implemented, several studies have questioned its usefulness since some reef fishes caught in shallow waters may not need venting. Unnecessary venting increases handling stress and reduces survival. In 2013, the venting tool requirement was repealed to provide fishermen with more discretion when releasing reef fish, but the GMFMC did not prohibit its use or other release devices such as descending devices.

Current Challenges: The decision to discard incidentally-caught red snapper is influenced by regulatory and economic considerations. Regulatory discarding is caused by retention prohibitions, and economic discards occur when fishermen discard species or sizes with low or no commercial value to make room for more valuable species or sizes. Economic discarding also occurs when fishermen throw away fish because they are unwilling or financially unable to lease (or purchase) quota. These economic discards account for most of the commercial red snapper discards in the reef-fish fishery. The incidental take of red snapper occurs in both recreational (private anglers and for-hire operations) and commercial fisheries. High bycatch levels result in forgone yields and lower quota levels.

As the red snapper stock recovered and expanded along the western Florida shelf, where it had been less abundant in the recent years, eastern Gulf fishermen, who mainly caught red grouper and other shallow-water groupers, increasingly began catching more red snapper. Since these 'grouper' fishermen received little or no initial allocation when the IFQ program was created, they were required to lease or purchase IFQ shares to land them. Although many grouper fishermen bought IFQ allocation and shares ("allocation" is the term used in the southeast for "rental or leased quota") to avoid discarding red snapper and to make a small return, many refused and kept discarding them to make room for other species (Cullis-Suzuki et al. 2012; Agar et al. 2014).

Trawlers targeting penaeid shrimp also regularly catch and discard significant amounts of federally managed finfish, including juvenile red snapper (mainly ages 0 and 1), Spanish mackerel, and weakfish (Watson et al. 1999). Species such as juvenile red snapper with low or no commercial value are often

discarded to store shrimp that are more valuable. SEDAR 52 (2017) estimated that, on average, about 9 million age 0 and 1 red snapper were caught in shrimp trawls between 2007 and 2015. The majority of the discarded fish are either dead or dying (Parsons and Foster 2015).

Most of the recreational red snapper discards happen because of retention restrictions due to the short recreational fishing season.

Future Directions and Research, including Economic Research: Much of the early economic bycatch research focused on the development of bioeconomic models to examine the performance of BRDs (Ward 1994; Gillig et al. 2001; Griffin and Woodward 2011). However, the more recent research has benefitted from policy trials that rely on market-based mechanisms such as catch shares and the Gulf headboat collaborative (Agar et al. 2014; Abbott and Willard 2017). The current red snapper experience shows a stark contrast between commercial and recreational management outcomes. Commercial discards are largely influenced by the cost and limited availability of allocation (rental quota) and minimum size regulations, whereas the recreational sector discards are mainly influenced by the long closed season and minimum size regulations.

Based on these sources of discard mortality, policies designed to mitigate discarding in the commercial sector should try to facilitate access and/or make allocation/shares more affordable, especially to those fishers who did not receive initial allocation, and to potential new entrants. To this end, it would be useful to build on the experience of a short-lived quota subsidy program and existing quota banks.

In 2011-2012, an anonymous NGO working with a fishing association called Gulf Fishermen's Association (GFA) began a red snapper quota subsidy program. The program sought to encourage fishermen to participate in IFQ management, land red snapper instead of discarding it (particularly in the eastern gulf), help them make a profit even with leased quota (which was subsidized), and help build local markets for fish.

Another potential mechanism to reduce bycatch would be to expand the use and scale up existing quota banks such as the Gulf of Mexico Reef Fish Shareholder's Alliance Quota Bank. The Alliance launched the first Quota Bank in the GOM in 2015 to reduce red snapper discards in the eastern Gulf and to support the next generation of commercial red snapper fishermen. The bank works by facilitating access to red snapper allocation (quota) at market prices. Additionally, regulatory changes to the IFQ program such as reducing share caps and creating allocation caps could be another way to increase the availability of allocation in the market.

Although BRDs' usefulness in actual commercial fishing operations has not lived up to expectations (Diamond 2004), Foster (2004) observes that the poor performance of BRDs is partly due to changes in fishing practices (e.g., faster towing speeds, modified retrieval procedures) aimed at minimizing shrimp loss without the attendant concern for reducing red snapper bycatch. Despite these setbacks, there is ongoing research to continue to improve BRD designs and performance by taking advantage of behavioral differences between the target and bycatch species (Parsons and Foster, 2007; Parsons et al. 2012; Parsons and Foster, 2015). For example, Parsons and Foster (2007) found that red snapper were strongly negatively phototactic (i.e., move away from light sources) and that dark-adapted red snapper will voluntarily select non-illuminated areas over illuminated ones (shrimpers trawl at night). This information could be used to facilitate the escape of red snapper from shrimp trawls.

On the recreational side, it would be worthwhile to build on the experience of the Gulf Headboat Collaborative (HBC). The HBC obtained an exempted fishing permit (EFP) from NOAA Fisheries to evaluate the viability of an allocation-based management strategy (i.e., temporary catch share program for headboats) for improving the conservation of marine resources and economic stability and performance of

the headboat sector. Abbott and Willard (2017) report that this pilot program was able to smooth out the allocated species throughout the season (no recreational derbies) as many operators were able to limit customers to 1 red snapper per trip (there was a 2-bag limit). They also report increases in profits. Another interesting outcome of the program was that red snapper discard as share of the catch fell 28% (21% in 2014) and 34% (18% in 2015) relative to 2013 levels. In 2013, 6.8 (8.6) red snapper were discarded for every 10 red snapper caught (Abbott and Willard, 2017). Abbott and Willard (2017) note that most of the reductions were caused by decrease in mandatory regulatory discards during formerly out-of-season times.

Quota banks could also be expanded to include for-hire operators, who, like commercial fishermen, make a living from fishing and want to ensure that the resource stays healthy. Another possibility to reduce bycatch would be to establish bycatch quotas to encourage commercial and for-hire fishermen to reduce bycatch since they could sell their unused allocation. Policies to help reduce dead discards in the private angler sector may include a requirement to purchase tags and/or endorsements to keep the fish. Tags and endorsement have the potential to constrain catches, extend the fishing season (the main source of bycatch mortality in recreational sector), provide catch and effort data, and collect revenues and achieve "economic" efficiency (if auctioned).

The use of circle hooks and de-hooking devices may have contributed to reducing bycatch, but few comprehensive studies have examined their performance. Evaluation of circle hook efficacy is challenging because the GMFMC did not set a required hook size. Nevertheless, Sauls and Ayala (2012) found that lethal injuries for red snapper were reduced to 6.3% with circle hooks from 17.1% with other hook types, which was a 63.5% reduction. In addition, Patterson et al. (2012) noted that requiring the use of larger circle hooks in the GOM recreational reef fish fishery could increase the number of red snapper discards because species diversity of the catch decreases substantially as hook size increases.

Education and outreach programs can increase bycatch awareness and promote voluntary changes in fishing behavior by fostering conservation-minded informal institutions (Cooke et al. 2013). Cooke et al. (2013) argue that the reliance on these voluntary norms of "virtuous" stewardship behavior are preferred to formal or mandated rules because they can increase compliance and reduce enforcement, monitoring, and other transaction costs. Post et al. (2002) note that outreach and communication efforts may be costly in the beginning but may pay off in the long run by saving on monitoring and enforcement costs. For the commercial and for-hire sector, given their relatively small size (at least at the port level), targeted education and outreach over time could help build social norms against wasteful discarding. Peer pressure can be a powerful source of pro-conservation behavior (Cooke et al. 2013). Developing social norms to minimize bycatch in the private angler component likely will be more challenging because red snapper have become easier to catch and have become increasingly larger. Regardless, state fishery management agencies could require private anglers, commercial fishermen, and for-hire operators to watch a video or take a test focused on ways to minimize stress and injury to red snapper as part of the process of obtaining fishing licenses. The use of nudges also could be explored (MacKay et al. 2018). Workshop participants discussed the difficulty of using real-time spatial management to reduce discards due to few identified red snapper spawning aggregations. Discussions also focused on the lack of inter-sector quota trading due to insufficient catch histories for charter boats, which would be needed to establish such a program. In addition, it was noted that some Council members were opposed to the use of market-based approaches (i.e. privatizing) to regulate the recreational sector.

Hawaii Swordfish (Shallow-Set) Longline Fishery and Sea Turtle Bycatch

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Fishery and Target Species: The Hawaii pelagic longline is a year-around and limited-access fishery capped at 164 permits. In 2018, 142 active longline vessels landed over 35 million pounds of pelagic fish valued at US$109 million. The Hawaii longline fishery consists of two components: a shallow-set fishery which targets swordfish and a deep-set fishy which targets bigeye tuna. All vessels in the fishery can fish with both shallow-set and deep-set gear, but not on the same trip.

Bycatch Species: The Hawaii deep-set and shallow-set longline fisheries both interact with North Pacific loggerhead and leatherback sea turtles, although the shallow-set fishery is more inclined toward higher interaction rates as swordfish and sea turtles occupy similar depth habitat. Both turtles are listed as endangered under the Endangered Species Act (ESA). The North Pacific loggerhead turtle distinct population segment (DPS) nests only on the coasts of Japan. This population has declined 50 to 90% over the last 60 years. However, the overall nesting trend in Japan has been stable or increasing over the last decade[40]. As of 2016, the Pacific leatherback turtle is one of eight species that NOAA considers the most at risk of extinction in the near future[41]. NOAA Fisheries focuses recovery efforts on stabilizing and recovering the populations of these endangered species to prevent their extinction. A new population vulnerability assessment completed by the Pacific Islands Fisheries Science Center indicates that the North Pacific loggerhead population exhibits a long-term increasing trend at a mean estimated population growth rate of 2.4%, while the Western Pacific leatherback turtle population exhibits a long-term declining trend at a mean rate of 6.1% (Martin et al, 2020).

Current Bycatch Measures: Due to the concern over high levels of incidental sea turtle bycatch, a court-ordered seasonal closure of the swordfish fishery took place in 1999 and full closure in 2000. In 2001, NOAA Fisheries and the Western Pacific Fishery Management Council began developing conservation and management measures aimed at reducing sea turtle bycatch in the fishery. In 2004, NOAA Fisheries reopened the fishery with a suite of regulations (69 FR 17329, April 2, 2004) including requirements for: (1) circle hooks instead of J hooks; (2) fish as bait instead of squid; (3) annual hard cap of 17 loggerhead and 16 leatherback sea turtles; and (4) an annual effort cap (2,120 sets, which was 50% of the historical level, and the effort cap was removed in 2010).

The loggerhead and leatherback hard caps were set equal to the incidental take statement included in the biological opinion issued by NMFS for the continued operation of the fishery. To monitor the turtle hard caps, NOAA Fisheries required 100% observer coverage for the shallow-set swordfish fishery. If the shallow-set longline fishery reaches the hard cap for either loggerhead or leatherback turtles, the fishery is immediately closed. During a closure, regulations prohibit Hawaii longline vessels from shallow-set fishing north of the Equator for the remainder of the calendar year.

Since implementing the annual fleet-wide hard cap measure in 2004, NOAA Fisheries has revised these caps four times for loggerhead turtles and one time for leatherback turtles in response to new biological opinions issued by NMFS. In the past 15 years, NOAA Fisheries closed the shallow-set longline fishery four times (2006, 2011, 2018, and 2019) because the fishery reached the hard caps. In March 2006 and March 2019, NMFS closed the fishery for reaching the loggerhead hard cap. In November 2011, NMFS closed the fishery for reaching the leatherback hard cap. NMFS also closed the fishery in May 2018 due to court order.

[40] https://www.fisheries.noaa.gov/species/loggerhead-turtle

[41] https://www.fisheries.noaa.gov/resource/document/species-spotlight-priority-actions-2016-2020-pacific-leatherback-turtle

Under the new regulations, the Hawaii shallow-set longline fishery has reduced loggerhead and leatherback turtle bycatch by approximately 95% and 86%, respectively, by comparing the total numbers of bycatch during the period of 1994 to 2000 to the period of 2004 to 2017[42]. The sharp reduction of total sea turtle bycatch was mainly attributable to two factors: the first is the result of hook-and-bait requirements and the second is the lower swordfish fishing effort after the fishery re-opened, compared to the period prior to 2000. The loggerhead bycatch rate (number of sea turtle per 100 hooks) was reduced by 86% only after the hook-and-bait policy was implemented (Pan and Li, 2015). On the other hand, the swordfish fishery has not recovered to the historical level even after the effort cap was removed in 2011. This was probably due to the great uncertainty facing the fishermen as the fishery could be closed unpredictably during their fishing season. Since 2004, the fishery has experienced multiple closures as it reached the turtle interaction limits.

Current Challenges: Due to the 2001 court ordered fishery closure, fishing effort and landings of swordfish declined sharply for the shallow-set swordfish fleet (Figure 3). Even after it re-opened, the fishery has still not recovered to its historical level, resulting in forgone fishing opportunities. The four fishery closures resulted in the loss of upfront costs for incomplete trips and costs related to long trips back to port to switch gear because a vessel is not allowed to use both types of gear on the same trip. In addition, the domestic swordfish market has faced uncertainty due to the potential for fishery closures. When vessels switch from targeting swordfish to bigeye tuna, they put additional pressure on bigeye tuna stocks and the catch limits distributed by international fishery management organizations.

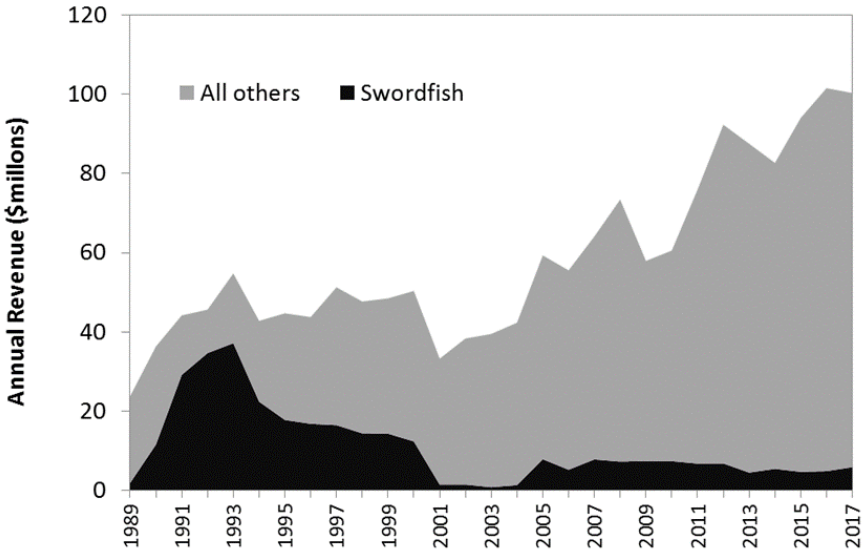

Figure 3. Swordfish revenue in comparison with other species in Hawaii longline, 1989–2017.

On the other hand, the lack of similar international requirements for competing fisheries has led to a spillover effect (Chan and Pan 2016). Figure 4 illustrates trends in U.S. and non-U.S. swordfish production. The study by Chan and Pan (2016) indicated one to one production replacement in swordfish

[42] The total number of bycatch was provided by Western Pacific Regional Fishery Management Council. The percentage reduction was calculated by comparing the total bycatch before the policy period (1994 to 2000) vs. after the policy period (2004 to 2017). Total bycatch from 1994 to 2000 are estimates from available bycatch data recorded from a small portion of all trips by Pacific Islands Fisheries Science Center. The data since 2004 were actual bycatch observed from the shallow-set (swordfish) fishery.

harvest, which means a decrease of one unit of U.S. production is associated with an increase of one unit of non-U.S. production. As the number of interactions and interaction rates in the Hawaii longline swordfish fishery are relatively low compared to the other longline fisheries in the Pacific Ocean (Lewison et al. 2004, Chan and Pan 2016), reduced swordfish production by the Hawaii longline fishery was not necessary to contribute to overall conservation of sea turtles in the Pacific, but might "significantly" increase stock-wide turtle bycatch due to the spillover effect. In addition, market transfer effect provides the potential for a spillover effect. Rausser et al. (2009) estimated that the annual market transfer effect of 1,602 metric tons of additional U.S. imports of swordfish due to the closure of the Hawaii swordfish fishery in 2001−2004 led to an additional 2,882 sea turtle interactions. Moreover, the current stock assessment findings suggest the fishery is not a major driver of population trends for the western Pacific leatherback or North Pacific loggerhead (Martin et al. 2020).

Future Directions and Research, including Economic Research: A few economic studies addressed the trade-offs between sea turtle conservation and the livelihood of the Hawaii swordfish fishery, including Curtis and Hicks (2000), Pan and Li (2005), and Chan and Pan (2016). Future research may expand the trade-offs analysis in further detailed scale and/or with updated production data and trade data and bycatch rates data from different fisheries.

The Western Pacific Fishery Management Council has recommended new measures to further reduce sea turtle bycatch in the shallow-set swordfish fishery. If approved by NMFS, the measures would create individual trip interaction limits of two leatherback and five North Pacific loggerhead turtles, with accountability measures for reaching a limit and removal of the annual cap for loggerhead turtles. This trip limit system would prevent vessels with high interaction rates from fishing while allowing vessels with low rates to continue fishing within a calendar year. Sea turtle individual trip bycatch and vessel limits could provide incentives and rewards for fishermen who are able to maintain low interaction rates. Therefore, the purpose of the proposed policy is to enhance both the sea turtle conservation and the livelihood of the Hawaii swordfish fishery.

Possible future directions for this fishery could include the introduction of a "quota" across multiple years instead of caps for a single year, especially for relatively rare events such as sea turtle bycatch. For example, using a three-year rolling average of bycatch would allow flexibility to account for the inter-annual variations of bycatch rates. During 2004–2019, the amount of sea turtle bycatch was much lower than the caps set in most of the years. In the past 15 years, the average annual bycatch annually was 12.4 loggerhead turtles, while the average annual cap was 27. Thus, using a rolling average would allow fishermen to continue to fish if they have a relatively high-interaction year given that they are likely to have low numbers of bycatch in other years. Dynamic area management via temporary closures due to identified sea turtle interaction "hotspots" could be helpful as well, although challenging to implement.

The United States could promote adoption of similar sea turtle mitigation measures for longline fisheries in other countries, as well as promote the protection of sea turtle nesting sites worldwide. Because conservation acts for marine sea turtles cannot be isolated at the local level, the Hawaii longline swordfish fishery may serve as a model for international fisheries in terms of their observer coverage rates and sea turtle bycatch mitigation policies. Workshop participants discussed whether tariffs or Marine Mammal Protection Act import provisions could be an effective tool to ensure that countries importing swordfish to the United States use conservation measures comparable to those required for U.S. fisheries. Participants also discussed effects on other bycatch species (i.e., insular false killer whales) as shallow-set swordfish effort shifts to deep-set tuna effort.

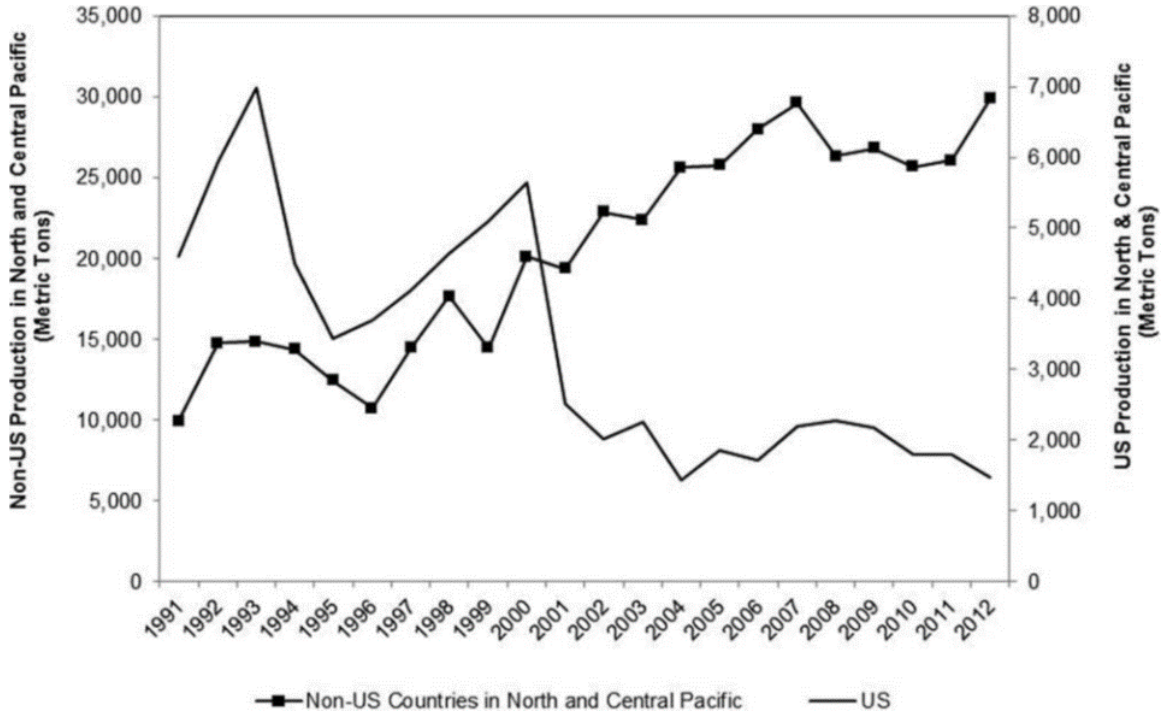

Figure 4. Production replacement between U.S. and non-U.S. swordfish product in North Pacific Ocean (Chan and Pan 2016).

Common Themes

Some common themes and suggestions emerged throughout the workshop, and these discussions highlighted the importance of utilizing multidisciplinary teams to view the challenges of reducing bycatch in commercial and recreational fisheries. Both the biology of the species involved and the socioeconomics of the fishery's fleet must be considered for a comprehensive understanding of the system. Management of bycatch reduction should combine top-down command-and-control regulation while incorporating market-based incentives and approaches. Multilateral cooperation tackles transboundary bycatch management challenges when the bycaught species and/or the fisheries involved are across state/federal or domestic/international borders. This workshop also served as a reminder to act and intervene to reduce bycatch of threatened species before they become endangered. Bycatch reduction becomes extremely costly once the population levels become too low. For any bycatch reduction strategy, tangible goals are required from the outset. What would be considered a success or a failure? What are the metrics of success (e.g., population numbers or vessel revenue)? To define these goals, multidisciplinary teams need to define the bycatch system of interest.

One of the first ways to define bycatch is by considering under which law(s) the bycaught species is protected: the Magnuson-Stevens Act, the Endangered Species Act, and/or the Marine Mammal Protection Act. These laws dictate the levels of protection for the bycaught species. For bycatch species of interest caught in both commercial and recreational sectors, it is important to understand bycatch levels in both sectors, the interplay between the two, and perhaps how allocation of certain species affects the bycatch levels of the at-risk species.

Workshop participants discussed some important requirements for managing bycatch:

1. Understanding how certain individual animals may be more valuable to a population, which could lead to redefining the bycatch limits and caps based on the loss of these individuals (e.g., reproductively mature females). Some of the case studies in this workshop emphasized the need to examine the transfer effects (conservation, production, and trade leakages) of potential fishery closures on transboundary species that travel across multiple jurisdictions and/or are caught by multiple fleets.
2. Ensuring there is adequate data to perform the estimates of bycatch levels, which are needed to set bycatch targets.
3. Determining optimal levels of observer coverage based on the components of the fishery as well as the costs of observer coverage, electronic monitoring, and data collection.

Recreational fisheries have challenges related to defining bycatch because the MSA neither defines nor has requirements for bycatch in recreational catch-and-release fisheries. However, the MSA does require, to the extent practicable, minimizing the mortality of fish released alive. Defining bycatch in recreational fisheries is an overarching challenge because without a definition, it is hard to identify when bycatch occurs and to address solutions. Part of the challenge in defining bycatch in recreational fisheries is the multiple reasons for taking a fishing trip other than catching a specific species to bring home. Sometimes anglers have a specific species in mind that they want to keep, and will release all other species caught. In other cases, anglers view a fishing trip as a way to spend time on the water with family or friends and catch whatever they encounter, even though they may release all or most of their catch. In this case, anglers do not often consider released fish as bycatch because they were not targeting anything specific. Targeted and non-targeted species may be caught and then released because of regulations such as bag limits or size limits. The open-access nature of the resource, in particular for private anglers, as compared to recreational for-hire vessels, makes it hard to observe and document the effects on mortality of released fish, as well as to conduct enforcement actions. Further, individual anglers often do not see their actions individually or as a group as large enough to have a negative effect on stock biomass. As possible solutions, workshop participants discussed further defining recreational bycatch; conducting angler outreach and education campaigns to increase awareness and to promote conservation through technologies such as descending devices; carrying out additional biological studies to better determine mortality rates for released fish; and exploring the use of rights-based management programs in for-hire recreational fisheries.

Workshop participants repeatedly discussed the concept of diminishing marginal returns to bycatch avoidance. Bycatch avoidance becomes very costly, both in terms of direct costs and opportunity costs of foregone catches, when bycaught species are rare. At what point do subsidies for avoiding protected species become excessive? What are the actual direct and opportunity costs and spillovers, if any, onto other species of bycatch avoidance? Recovery of bycatch populations can also raise bycatch rates and paradoxically lead to tightening of regulations. Should managers consider the carbon footprint of bycatch avoidance (e.g., using more boat fuel to avoid bycatch hot spots)? Researchers and managers should explore developing methods to measure the effectiveness and direct and opportunity cost of bycatch reduction in a counterfactual way rather than viewing bycatch reduction as a “before” and “after” scenario. Workshop participants also discussed whether fishermen who fish with low levels of bycatch, hence, more sustainably, receive the price premium and enter the high-value niche market for their products. It is unclear whether the profits from sustainability markers (e.g., eco-labels) make their way back to fishermen directly. Workshop participants suggested, however, that a concerted marketing effort could help make a difference to bring awareness to safe fishing practices through partnerships with local

chefs, food activists, and nonprofits and importantly with the firms in the supply chain. Standards set by firms in the supply chain, responding to incentives created by consumers, NGOs, or credible threats by governments for regulation, may be among the most effective ways of reducing bycatch. Participants at the workshop also discussed whether feasible alternative livelihoods were made available to fishermen who were either encouraged or required to leave a high-bycatch fishery. Situations are more complicated when illegal or unsustainable fishing practices are more profitable than the alternate, as was seen with gillnet/vaquita case study in the Upper Gulf of California, Mexico.

Fleet buy-in of the need to reduce bycatch is essential to solving these issues and often stems from credible risks or threats in the form of market measures and/or regulatory actions. Economic incentives are another possible tool to encourage fleet participation and buy-in. A recurring suggestion heard throughout the workshop was the emphasis on strong collaboration with the fishing industry at every step of the way of the bycatch reduction process to achieve better compliance and design and implement more effective and less costly bycatch mitigation measures. Researchers should tap into a fisherman's institutional knowledge about his or her gear and fisheries when bycatch reduction devices (BRDs) need to be developed or modified. This gear should be tested cooperatively with industry under normal fishing operations to the extent practicable and ideally through randomized control trials. Outreach to the fleet should be conducted throughout this process: about the need for bycatch reduction and/or if there is an oncoming regulatory action; the need for developing new or modified gear; the opportunity to test the gear cooperatively and the results from the research; and the Federal Register rulemaking process. Workshop participants suggested that outreach about changes in regulations could also be done through the regional fishery management councils. Gear development was also discussed in the workshop as functioning as a best shot public good (which only needs to be developed once and free riding is not an issue). If bycatch reduction devices (BRDs) were developed, the government may be able to help subsidize the adoption of these devices due to the network effects with increasing returns to adoption. Alternatively, the government could help finance a BRD engineering tournament and the prize to help incentivize the development of new technology.

Depending on the fishery, it may be beneficial to incorporate some flexibility within regulations for bycatch limits. For example, vessel-specific rather than fleet-wide bycatch caps would allow for individual vessels with less bycatch to continue fishing out their season rather than shutting down the entire fishery. When bycatch is a relatively rare event, bycatch mitigation over a multi-year time frame may be required. If there were a way to track bycatch rates at the vessel level, strategic outreach could be utilized to work with captains who struggle to lessen their bycatch or incidental takes. Further, captains who are successful and potentially more experienced at decreasing their bycatch could help mentor and work with the captains with high bycatch rates through outreach and workshops. If feasible, credit systems of indirect tax-subsidy could reward captains with low levels of bycatch and penalize the captains with high levels of bycatch (e.g., through more or less fishing days). Two other avenues for flexibility in bycatch limits are the formation of multi-vessel cooperatives with cooperative-specific bycatch levels. Additionally, managers could create a transferable quota program with multiple fisheries where one could transfer a bycaught species to a fishery where that species is their targeted catch (e.g., Pacific halibut in the Alaska Bering Sea flatfish fishery) or could transfer unused bycatch quotas (credits) to another vessel within the fishery. Managers and fishermen also could regulate bycatch in a flexible manner by exploring spatial and dynamic ocean management. Market-based measures could incentivize this real-time spatial management.

Next Steps, Future Opportunities, Potential Collaborations

Workshop participants discussed areas in which future collaborations and partnerships could be beneficial to solve bycatch issues. Following on one of the major themes from the workshop, i.e., that practical solutions need to draw from a wide variety of expertise and involve multiple institutions, workshop participants suggested that collaborations could be initiated among social scientists, political scientists, and fisheries managers as well as other governing bodies.

Workshop participants suggested other types of collaborations, including:

1. A workshop focused on small-scale artisanal fisheries
2. Work with the U.S. commissioners to The International Commission for the Conservation of Atlantic Tunas
3. Coordination with the International Whaling Commission's meeting of the Scientific Committee (Bycatch Expert Panel) in May 2020
4. The revival of the Kobe bycatch working group
5. Coordination with economics groups within the International Council for the Exploration of the Sea and the North Pacific Marine Science Organization
6. Research on bycatch with fisheries managers directly or through regional fishery management council scientific and statistical committees; formal mechanisms are needed to better integrate economic analyses into the fishery management process
7. Identification of avenues for integrating economics into stock assessments of bycatch species and, where appropriate, ecosystem assessments; a February 2020 NMFS workshop entitled SocioEconomic Aspects in Stock Assessments Workshop will focus on this topic

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Appendix A – Workshop Participants

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Lee Benaka (lee.benaka@noaa.gov), Fishery Management Specialist, Office of Science and Technology, NOAA Fisheries, Silver Spring MD. Role: Steering Committee Member

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David Detlor (david.detlor@noaa.gov), Acting Director, Office of Science and Technology, NOAA Fisheries, Silver Spring MD. Role: Presenter and Participant.

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John Gauvin (gauvin@seanet.com), Science Project Director, Alaska Seafood Cooperative, Seattle WA. Role: Case Study Lead.

Dr. Martin Hall (mhall@iattc.org), Head, Bycatch Programs, Inter-American Tropical Tuna Commission, La Jolla CA. Role: Participant.

Dr. Alan Haynie (alan.haynie@noaa.gov), Economist, Resource Ecology and Fisheries Management, Alaska Fisheries Science Center, NOAA Fisheries, Seattle WA. Role: Participant.

Dr. Dennis Heinemann (dheinemann@mmc.gov), Senior Advisor for Fisheries and Ecosystems, Marine Mammal Commission, Bethesda MD. Role: Steering Committee Member

Dr. James Hilger (james.hilger@noaa.gov), Economist, Socio-Economics Program, Southwest Fisheries Science Center, NOAA Fisheries. Role: Participant.

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Kristen C. Koch (kristen.c.koch@noaa.gov), Director, Southwest Fisheries Science Center, NOAA Fisheries, La Jolla CA. Role: Presenter and Participant.

Dr. Rebecca Lent (rebecca.lent@iwc.int), Executive Director, International Whaling Commission, Cambridge UK. Role: Presenter and Participant.

Dr. Douglas Lipton (douglas.lipton@noaa.gov), Senior Research Scientist for Economics, NOAA Fisheries, Silver Spring MD. Role: Presenter and Participant.

Dr. Jon Lopez (jlopez@iattc.org), Researcher, Stock Assessment Program, Inter-American Tropical Tuna Commission, La Jolla CA. Role: Participant.

Dr. Sabrina Lovell (sabrina.lovell@noaa.gov), Economist, Office of Science and Technology, NOAA Fisheries, Silver Spring MD. Role: Steering Committee Member

Edward Melvin (edmelvin@uw.edu), Affiliate Associate Professor, School of Aquatic and Fishery Sciences, University of Washington, Seattle WA. Role: Case Study Lead.

Dr. Sarah Mesnick (sarah.mesnick@noaa.gov), Ecologist, Marine Mammal and Turtle Division, Southwest Fisheries Science Center, NOAA Fisheries, La Jolla CA. Role: Case Study Lead.

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Charles Villafana (charles.villafana@noaa.gov), Manager, West Coast Region Observer Program, Sustainable Fisheries Division, West Coast Regional Office, NOAA Fisheries, Long Beach CA. Role: Case Study Lead.

Dr. Timothy B. Werner (twerner@neaq.org), Senior Scientist, Anderson Cabot Center for Ocean Life, New England Aquarium, Boston MA. Role: Participant.

Appendix B – Workshop Agenda

Tuesday Oct 29, 2019

8:45 am – 9:00 am – Open workshop, pick up workshop materials

9:00 am – 9:10 am – Welcome from SWFSC Director Kristen Koch

9:10 am – 9:20 am – The Office of Science & Technology and the National Bycatch Reduction Strategy – David Detlor

9:20 am – 9:40 am – The Role of Economics in Bycatch Reduction – Doug Lipton

9:40 am – 10:00 am – Overview of International Whaling Commission's Bycatch Workshop – Rebecca Lent

10:00 am – 10:45 am – Introduction to Bycatch Issues – Dale Squires

11:00 am – 11:45 am – Summary of Previous Workshops and Objectives for this Workshop – Dale Squires

12:45 pm – 2:15 pm – Amendment 80 Sector Bering Sea Non-pollock Groundfish Trawl – John Gauvin

2:30 pm – 4:00 pm – Vaquita Bycatch in the Gulf of California – Sarah Mesnick

4:15 pm – 5:45 pm – Cod Bycatch in the Northeast Recreational Haddock Fishery – Scott Steinback

Wed Oct 30, 2019

8:30 am – 10:00 am – California Large Mesh Drift Gillnet – Charles Villafana

10:15 am – 11:45 am – North Atlantic Right Whales and Lobster Fishery – Kathryn Bisack

12:45 pm – 2:15 pm – Seabird Bycatch in Alaskan Longline Fisheries – Edward Melvin

2:30 pm – 4:00 pm – Gulf of Mexico Red Snapper Fishery – Juan Agar

4:15 pm – 5:45 pm – Hawaii Swordfish Longline Fishery and Sea Turtle Interactions – Minling Pan

Thurs Oct 31, 2019

8:30 am – 10:45 am – Review themes that emerged from case-study examinations. Discuss major messages to be included in the workshop report. Discuss possible outlets for case studies, findings, workshop report, etc. Discuss potential for future collaborative efforts.

10:45 am – 12:00 pm – Discuss practicability of implementing bycatch regulations. This will be an open discussion led by John Gauvin. During the first two days, please think about the practicability of potential solutions offered and send discussion ideas to John (gauvin@seanet.com). In particular, think about how economic-based solutions could help managers understand tradeoffs given that National Standard 9 says to reduce bycatch "to the extent practicable." Close workshop.