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Reducing marine mammal bycatch in global fisheries: An economics approach

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ABSTRACT

The broader ecosystem impacts of fishing continue to present a challenge to scientists and resource managers around the world. Bycatch is of greatest concern for marine mammals, for which fishery bycatch and entanglement is the number one cause of direct mortality. Climate change will only add to the challenge, as marine species and fishing practices adapt to a changing environment, creating a dynamic pattern of overlap between fishing and species (both target and bycatch). Economists suggest policy instruments for reducing bycatch that move away from top-down, command-and-control measures (e.g. effort reduction, time/area closures, gear restrictions, bycatch quotas) towards an approach that creates incentives to reduce bycatch (e.g. transferable bycatch allowances, taxes, and other measures). The advantages of this flexible, incentive-oriented approach are even greater in a changing and increasingly variable environment, as regulatory measures would have to be adapted constantly to keep up with climate change. Unlike the regulatory process, individual operators in the fishery sector can make adjustments to their harvesting practices as soon as the incentives for such changes are apparent and inputs or operations can be modified. This paper explores policy measures that create economic incentives not only to reduce marine mammal bycatch, but also to increase compliance and induce technological advances by fishery operators. Economists also suggest exploration of direct economic incentives as have been used in other conservation programs, such as payments for ecosystem services, in an approach that addresses marine mammal bycatch as part of a larger conservation strategy. Expanding the portfolio of mandatory and potentially, voluntary, measures to include novel approaches will provide a broader array of opportunities for successful stewardship of the marine environment.

1. Introduction – bycatch of marine mammals in fisheries; what do economists have to offer

Bycatch (including entanglement in discarded or lost fishing gear[1]) is the greatest direct threat to marine mammals, with estimates of annual mortality in excess of 650,000 marine mammals globally (Read et al., 2006). In some cases, bycatch in fishing gear is driving species to extinction, such as the vaquita, the world's smallest and most endangered porpoise endemic to the upper Gulf of California, which is caught incidentally in gillnets (CIRVA, 2016). Bycatch affects not only marine mammal populations, it can also have broad-ranging impacts on the entire marine ecosystem and its components (including target species) through the reduction of nutrients that are provided by marine mammals (Lavery et al., 2014; Roman et al., 2014). While there has been some progress in reducing marine mammal bycatch in U.S. fisheries (Geijer and Read, 2013), some fisheries still lack adequate measures to meet bycatch reduction goals (Van Der Hoop et al., 2013). The challenge of monitoring and mitigating marine mammal bycatch will only intensify with climate change and increasing climate variability, as the distribution of marine mammal stocks and fishing fleets adapt to shifts in water temperatures, prey availability, and anthropogenic activities (Thomas et al., 2015; Evans and Bjørge, 2013; Moore and Gulland, 2014; Last et al., 2011).

For marine economists, bycatch is identified as an unpriced or underpriced negative externality, which in this case is an unintended adverse impact of fishing (Lent, 2015). The “costs” of bycatch in terms of impacts on the marine ecosystem and on marine mammals are not factored into the costs of fishing – i.e. the externality has not been internalized as part of the individual operator's decision-making.[2] Seafood from fisheries with marine mammal bycatch is therefore

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[1] The term “bycatch” includes interactions that cause injuries to marine mammals that have temporary, long-term, or lethal impacts.

[2] An anonymous referee notes that the costs of bycatch are not centralized but spread over all of society, making them more difficult to reconcile.

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overproduced and underpriced. Economists underscore the need to include regulatory measures that require operators to incorporate these higher costs of fishing that incentivize changes in producer and consumer behavior, and over the longer term create "dynamic" incentives for induced technological change to reduce marine mammal bycatch. The standard instruments of environmental policy—including quantity, price, and technology regulations—seek to correct market failures or externalities by mandating changes or creating incentives to encourage more efficient outcomes. The extent to which they do depends critically on how the fee is structured. For example, fixed fees that are designed to generate revenue but are not tied to bycatch reduction in any way do not provide incentives to improve performance. Conversely, performance-based fees create incentives to reduce bycatch by altering production techniques and/or locations, and over the longer term to induce technological change that would lower the bycatch per unit of target catch.

There are other advantages to incentive-based policies and policy instruments besides the creation of incentives. It allows operators flexibility to adjust to shifts and variability in marine mammal interactions due to changes in climate, markets, and the environment in general. Incentive-based policy also increases the likelihood of compliance, and the development of new cost-effective fishing technology. Without internalizing such costs, society as a whole is subject to the environmental impacts of bycatch of marine mammals in the marine ecosystem. Additional incentives to decrease marine mammal bycatch increasingly arise from: (1) consumer markets and firms in the supply chain through eco-labeling, certification and standards as well as changing consumer tastes and preferences and (2) through voluntary actions by civil society, reflecting changes in social values and perceptions of the role of governments, over time.

The objective of this article is to review and compare "traditional" marine mammal bycatch measures that have been applied to fisheries around the world with more innovative and incentivizing approaches to bycatch that have been suggested by economists. Examples are used to assess and discern the factors that influence the effectiveness of these two approaches in reducing marine mammal bycatch, while considering other impacts of the measures. The discussion includes consideration of how such incentivizing measures might be incorporated into an ecosystem-based fishery management system that is adaptable to increasingly variable ocean conditions.

The balance of the article is organized as follows. Section 2 discusses the shortcomings to traditional bycatch management and the advantages of an economic incentive-based approach. Section 3 discusses the economically optimal level of bycatch, and why this level is not necessarily zero. Section 4 discusses incentivizing approaches, first discussing in Section 4.1 the importance of placing a price and market value upon bycatch. The following sub-sections present a number of potential incentivizing policy instruments, including biodiversity offsets in Section 4.2, placing a reward upon bycatch such as through tournaments and prizes or subsidies in Section 4.3, cap-and-trade systems through transferable bycatch rights and credits in Section 4.4, insurance or risk pools in Section 4.5, market measures such as ecolabeling certification, information programs, market access, and trade measures in Section 4.6, and other approaches in Section 4.7. Section 5 concludes by returning to incentivizing bycatch reduction.

2. Traditional bycatch management – shortcomings and the advantages of an incentivizing approach

Until relatively recently, bycatch measures have been primarily what economists would characterize as "command-and-control" or "top-down" approaches to fishery management. These types of bycatch measures include gear modifications (type and deployment, called technology standards), time/area closures, non-lethal deterrents such as pingers (technology standard), and overall bycatch quotas (called performance standards). Specific examples in the United States include the time/area closures in the New England lobster fishery for protection of North Atlantic right whales, pingers on gillnets in the New England groundfish fishery for harbor seal avoidance, and depth restrictions on gear deployed in the California driftnet fishery to minimize sea lion bycatch.[3]

While some command-and-control measures have proven effective, considerable limitations arise (Grafton et al., 2006; Dutton and Squires, 2008; Gjertsen et al., 2010; Dutton et al., 2010; Pascoe et al., 2010; Segerson, 2011; Squires and Garcia, 2014, in prep). One downside is that vessels' incentives are not harnessed to fully utilize their own skills to reduce bycatch in their own manner. Command-and-control regulations raise average costs, but do not put a price on bycatch and thereby alter the marginal cost of bycatch, which in turn alters vessel behavior at the margin. Vessels do not receive incentives to alter the mix of target and bycatch species nor to alter the scale of production of both species to the optimal level. Instead, the relatively imprecise and ineffective use of direct regulation only incentivizes lower effort and thus lowering both target and bycatch species catches. However, because the vessel's remaining (residual) bycatch is not given a price and cost, the scale of production does not decline to the optimum.

There are other limitations to direct regulation. In a command-and-control straightjacket, vessels cannot flexibly respond to changes in markets, environment, resource conditions, and climate. Because technology standards effectively "freeze" bycatch-reducing technology, such measures may limit vessel innovation. Overall bycatch quotas or limits (performance standards) create perverse "race-to-fish" incentives to catch target species, and thereby generate bycatch, before the cap binds, and also to circumvent bycatch regulations (Boyce, 1996; Abbott and Wilen, 2009; Sugihara et al., 2009; Gjertsen et al., 2010; Pascoe et al., 2010; Segerson, 2011). The result is similar to that of a global targeted catch limit – the race to fish causes higher production costs, safety concerns, and no additional benefit to bycatch reduction, while imposing unnecessary costs and restricting flexibility, thereby curbing incentives for vessel to comply. Direct regulation of inputs (outputs) can lead to substitution of unregulated inputs (outputs) for regulated inputs (outputs), as vessels attempt to circumvent regulations and catch more fish (Squires, 1987). In the process, fishing pressures can shift to other stocks, species, times, and areas. The vessel, supply chain, and consumers pay only for bycatch control, not for the remaining bycatch that still occurs even after the direct controls are in place and enforced (Goulder and Parry, 1998; Squires and Garcia, 2014, in prep).

Direct regulation can potentially hinder vessel reductions in bycatch under conditions in which climate change impacts target or bycatch species. Climate change is expected to alter the distribution, species compositions, and abundances of marine mammals. Quotas limiting bycatch may then no longer match bycatch abundances. Time-and-area closures may no longer align with species distribution and abundance. Spatial zoning restrictions may unduly hinder vessels from shifting where they fish as they try to reduce marine mammal interactions. Gear restrictions may limit vessels' adaptation to changing species composition in vessels' current areas of fishing.

Direct regulation leads to economic inefficiencies, because vessels are not left to address bycatch reduction in their own way (Dutton and Squires, 2008). Moreover, the incentives for noncompliance create economic waste and in some instances require additional regulatory resources for enforcement. Another hidden cost is the foregone opportunities for conservation elsewhere due to the lost economic surplus from the economic inefficiency. Direct regulation does not lead to least-cost bycatch reduction, since the same bycatch control is imposed upon each vessel despite considerable vessel heterogeneity

[3] See http://www.nmfs.noaa.gov/pr/interactions/trt/teams.html for further information about the NMFS (marine mammal) Take Reduction Teams and Plans.

in its costs and ability to reduce bycatch. Such an approach lessens potential bycatch reduction under limited budgets, since there is less conservation per dollar of budget. Traditional approaches, in many circumstances, are also likely to be ineffective with transboundary species, such as many marine mammals, since the transnational externality remains unaddressed (Dutton and Squires, 2008; Dutton et al., 2010; Gjertsen et al., 2010; Squires and Garcia, in prep). Multilateral cooperation or coordination among nations is required, and unilateral conservation is costly and ineffective. For example, while U.S. fleets discontinued the use of dolphin sets for harvesting yellowfin tuna with purse seiners in the eastern tropical Pacific Ocean, other fleets continued the practice. Through the negotiation of the multilateral Agreement on the International Dolphin Conservation Program (AIDCP), significant reductions in observed dolphin mortality have been achieved. Interestingly, this program assigns individual dolphin mortality limits (DMLs) to each purse seiner (in addition to multiple other measures) providing an incentive to minimize dolphin mortality in order to keep fishing throughout the season. DMLs are a limit that cannot be traded or carried across seasons, not a right or credit.

Under some circumstances, traditional, command-and-control approaches can be effective in a multilateral setting. In some instances, technology standards, even though not cost-effective, are more readily observed, monitored, and accepted by vessels than incentive-based approaches. Such standards can limit technological advances, but they can also force more effective bycatch reduction practices.

Overall, marine mammal bycatch management in U.S. fisheries has had positive, although variable, results (Geijer and Read, 2013) in terms of reducing marine mammal bycatch. As noted in O'Keefe et al. (2014), bycatch mitigation can be more effective when a mix of mitigation measures is used, including programs that incentivize fishery operators to reduce bycatch. In some cases, this incentive to reduce bycatch can stem from strict, traditional fishery measures that are either implemented or under consideration. One example is the three-year research program that was conducted by scientists from the U.S. government's National Marine Fisheries Service (NMFS) and engineers. This collaborative approach included commercial pelagic longliners as scientific platforms in an effort to design sea turtle bycatch reduction fishing techniques (Graves and Kerstetter, 2006) following a regulatory closure of the Grand Banks to the swordfish fleet.

A number of promising incentivizing measures are discussed below. In evaluating the various alternative regulatory and negotiated measures for mitigating marine mammal bycatch, economists include not just the costs to fishery operations, but also estimates of the benefits, to the ecosystem and to the public, of reductions in marine mammal mortality.

3. What in fact is an optimal level of bycatch? Why economists would say it is not *necessarily* zero – and thereby more efficiently use scarce resources for conservation measures

The U.S. Marine Mammal Protection Act (MMPA) mandates the process (Take Reduction Teams (TRTs) that prepare Take Reduction Plans), as well as specific targets for reductions in marine mammal bycatch in U.S. fishing fleets. The targets for "strategic" stocks are set at Potential Biological Removal (PBR) – to be achieved within six months of the start of the TRT, and Zero Mortality Rate Goal (ZMRG) to be achieved within a year of the formation of the TRT. Kirby and Ward (2014) suggest setting standards for managing fisheries bycatch, including the development of specific goals, for both domestic and multilateral fishery management. A recent final rule from NMFS would require foreign fisheries to implement bycatch reduction programs that are "comparable" to U.S. standards if these fisheries' seafood products are to be exported to the U.S. market.

Economists argue that the optimal level of bycatch is not necessarily zero (or PBR or ZMRG), but rather the level at which the cost of the last unit of bycatch reduction equals the marginal benefit of the bycatch measures implemented. While this may generate an outcry that economists want money to "trump" wildlife conservation, it is critical to recall that economists include *all* market and non-market costs and benefits in making such decisions-costs and benefits to society as a whole. Thus, the calculation of benefits of marine mammal conservation from reductions in bycatch mortality would include the value of the ecosystem services[4] provided by large whales (Roman et al., 2014; Lavery et al., 2014) and the non-market value of the recovery of the protected species (Wallmo and Lew, 2012). Other benefits include non-consumptive uses of marine mammals, such as whale watching, as well as existence value (Blomquist and Whitehead, 1995).

It would be expected that initial and immediate direct costs of reducing bycatch will be relatively low, while initial benefits to reducing bycatch of the most critically endangered species will be relatively high. As additional measures are taken in a step-wise fashion, marginal costs would be expected to increase while marginal benefits will decline. Once these two are equal, it is more efficient to allocate marginal funding from scarce budgets to other bycatch challenges, and in the end, achieve greater overall conservation. This approach also incentivizes compliance, since vessels enjoy larger profits and do not waste economic resources as they face diminishing returns to each level of additional bycatch reduction. Climate change is expected to increase the costs of information, the frequency of adjustment, and the level of uncertainty, thereby raising marginal costs of bycatch reduction. In turn, the optimal level of bycatch should correspondingly alter.

While the initial and immediate direct costs of bycatch reduction may be low, relatively high and largely fixed regulatory costs can in some instances accompany such adjustments. For example, the institutional and infrastructure costs to implement, monitor, and enforce some bycatch programs may be comparatively high. The total cost of bycatch reduction also includes the costs associated with any costs of direct or command-and-control regulation. Bycatch reduction costs might also differ between direct bycatch reduction with actively deployed nets, such as dolphins caught in tropical tuna purse seine nets used to harvest large yellowfin tunas in the Eastern Pacific Ocean versus reducing entanglement for more passive gear, such as great whales entangled in gill nets. The latter may require replacing gear altogether or instituting spatial or temporal closures, such lobster fishers reducing North Atlantic Right Whale entanglement in the Northeast United States. Again, climate change should increase information and adjustment costs and costs associated with uncertainty, at least in the short and intermediate terms.

While it is not always possible to exactly quantify the marginal cost and marginal benefit of a bycatch reduction measure, economists argue that at the very least, a given bycatch target (e.g. PBR or ZMRG) should be attained at the lowest possible cost – again, including all costs (direct and indirect or opportunity costs).

Also, taking the concept of economic efficiency of bycatch measures a step further, economists recommend "least-cost conservation across all steps in the mitigation hierarchy" (see ten Kate et al., 2015 for the mitigation hierarchy), in which the marginal cost of bycatch reduction is equated across each step in the mitigation hierarchy (see Squires and Garcia, 2014, in prep for the full development of this concept). In practice, average costs tend to be equalized across all four steps of the mitigation hierarchy (adjusted for risk). Such a least-cost approach within the mitigation hierarchy framework places bycatch into a broader biodiversity framework and achieves the greatest amount of bycatch reduction when facing limited bycatch reduction budgets, by minimizing the otherwise diminishing returns that arise within each step when sequentially following the mitigation hierarchy, and helps incentivize vessel compliance. For example, a holistic (ecosystem-level) bycatch mitigation program would examine the broadest possible range of opportunities to reduce the impacts

[4] The inclusion of ecosystem services in federal decision making was recently championed by the U.S. White House environmental leadership (see https://www.whitehouse.gov/sites/default/files/omb/memoranda/2016/m-16-01.pdf).

of bycatch. Examples include conservatory and compensatory offsets that address partial compensation and reduced net loss or the residual and no net loss (Bellagio, 2004; Quigley and Harper, 2006; Wilcox and Donlan, 2007; Dutton and Squires, 2008; Dutton et al., 2010; Gjertsen et al., 2010; Janisse et al., 2010; Gjertsen et al., 2014) and "payments for ecosystem services" (Dutton and Squires, 2008; Gjertsen et al., 2010; Gjertsen and Stevenson, 2011; Bladon et al., 2014), inspired by terrestrial use, and further explained and with concrete examples in the sections below.

4. Approaches that incentivize

4.1. Putting a price on bycatch

Economists view bycatch as a cost that is not accounted for by markets and market prices (i.e. an externality), which in most cases is treated as a market failure that might be addressed through appropriate pricing. Implementing a market-based policy instrument on bycatch (or some form of benefit for avoiding bycatch) means that the bycatch now has a "cost", which increases the costs to fishery producers and consumers. That is, the bycatch price, created by the market-based policy instrument, will be incorporated into the price of the target species, and thereby become part of the target species cost (Goulder and Parry, 2008; Pascoe et al., 2010; Dutton et al., 2010; Squires and Garcia, 2014, in prep). Everything else being equal, the seafood product that is the target catch becomes more expensive (and less plentiful on the market) and consumers would have to pay more for their seafood. Then, in principle, every firm in the supply chain, every vessel, and every consumer has an incentive to utilize all of its bycatch reduction opportunities until *each* economic actor's marginal cost of bycatch reduction equals the common price of bycatch that they all face. This bycatch price will add to the unit cost of the target species by the ratio that bycatch is related to the target species catch. In principle, each consumer, supply chain firm, and vessel has a unique and different marginal cost of bycatch reduction, which they set equal to the common bycatch price.

A price on bycatch may not capture all of the non-market costs of marine mammal bycatch (Gjertsen et al., 2010; Squires and Garcia, 2014, in prep). Marine mammals are what are called impure public goods (both private uses with market benefits and direct use values, and public uses with non-market economic values) (Kuronoma and Tisdell, 1993; Haraden et al., 2004). Hence, the price should ideally capture all of the non-market costs of foregone existence and option values and the economic value of foregone ecosystem services (such as contributions to the food web). If the price fails to capture all of these nonmarket benefits, then some remaining cost not captured by market prices remains (the external costs are not fully internalized). The market failure then persists to some extent, i.e. there is excessive marine mammal bycatch.

There are a number of options for putting a price on bycatch. As with carbon credits, an initial amount of bycatch quota could be offered for sale to the fleet, perhaps through an auction. Vessels would be allowed to fish only if a minimum amount of bycatch quota has been purchased prior to each trip. Another approach would tax landings based on the observed level of bycatch on each fishing trip, or on representative trips in this time and area (Boyce, 1996; Dutton and Squires, 2008; Pascoe et al., 2010; Gjertsen et al., 2010; Dutton et al., 2010; Segerson, 2011; Squires and Garcia, 2014, in prep). A bycatch tax in Namibia may be the only example (Pascoe et al., 2010). The proceeds from such a tax can be used to offset costs for programs that support marine mammal bycatch monitoring and mitigation. Such an approach is called "double-dividend taxation." Both tradable bycatch credits and bycatch rights also price bycatch.[5] Still other ways to price bycatch include offset or conservation easement credits traded in biodiversity markets (biomarkets), payments for ecosystem services, and environmental bonds (all discussed below). Economists would note that an initial allocation of transferable bycatch limits means that bycatch is no longer "free", since vessels could sell their allocation. The critical point is to impose a cost (including an opportunity cost) of incurring marine mammal bycatch.

4.2. Offsets

Inspired by their use in addressing challenges in the terrestrial environment, "offsets" for fishery bycatch are increasingly considered to address the adverse biodiversity impact of bycatch.[6] From an economics perspective, offsets can be considered as the voluntary provision of a public good[7] that is motivated, in part, to compensate for activities that diminish the pure public good (Kotchen, 2009) or an impure public good (Vicary, 2000). The "polluter pays" principle holds for offsets. The party producing biodiversity loss (the externality) is responsible for paying or otherwise compensating for damage to the recipient of biodiversity loss. Willingness to pay (WTP) holds for the inflicting party and willingness to accept (WTA) for the inflicted party. WTP and WTA bound the size of economically rational payments/compensation for any (Coasian) bargaining with conservatory offsets but not for mandated no net loss with compensatory offsets. This range impacts economically efficient application and incentivizing of the mitigation hierarchy.

Compensatory offsets can be used as a "last resort" to address the residual from the first three steps of the mitigation hierarchy for no net loss or even a net gain in the reduction of bycatch of the same species and stock (cf. (BBOP, 2012; Bull et al., 2013; ten Kate and Crowe, 2014). Compensatory offsets for marine mammals could protect key calving or reproductive grounds. They create additional and/or comparable biodiversity gains off-site, and complement, but not substitute for, the first three steps.

Conservatory offsets are called "offsets" because they are obtained off-site, away, and sometimes far from the impact area (migrating marine mammals, sources that supply sinks in meta-populations, etc.) (Squires and Garcia, 2014, in prep). They are called "conservatory" because they are applied within the first three steps in the mitigation hierarchy. They are applied within the impacted species life cycle, and aim to restore the impacted populations. In contrast, compensatory offsets are mandatory, accept the damage as a last-resort residual, and pay for it "in-kind". Conservatory offsets can be used in the second or third step (minimization, restoration/remediation) as a voluntary addition, or alternative. They can potentially reduce the first step, avoidance. They yield a range of benefits, ranging from partial recovery to over-recovery (above the baseline) of the stock or habitat, depending

[5] Transferable bycatch rights price residual bycatch, i.e. price the remaining bycatch, within the property and use rights system (Helfand, 1991; Nentjes and Woerdman, 2012; Squires and Garcia, 2014, in prep). The vessel places a cost upon the bycatch that remains within the overall bycatch cap established by the regulatory body because the vessel owns the right to the remaining bycatch. The cost of residual bycatch is added to the other costs of producing target catch and raising the target catch's price and cost to

(*footnote continued*)
buyers, supply chain producers and consumers behavior. In contrast, bycatch credit systems do not price, and therefore place a cost upon, residual bycatch. This non-priced and non-coasted residual bycatch is called an implicit output subsidy in the pollution literature.

[6] Ten Kate and Crowe (2014, p. i) define biodiversity offsets as,"... measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development after appropriate prevention and mitigation measures have been taken. The goal of biodiversity offsets is to achieve no net loss and preferably a net gain of biodiversity on the ground with respect to species composition, habitat structure, ecosystem function and people's use and cultural values associated with biodiversity."

[7] A pure public good is one that cannot be diminished through use (non-rivalry) and for which consumers or producers cannot be excluded from using (non-exclusion) (Samuelson, 1954). An impure public good has characteristics of a pure public good and a private good (can be diminished through use – rivalry – and for which consumers or producers can be excluded from use (exclusion). Biodiversity offsets are generally considered a pure public good, but can conceivably be an impure pubic good if there is a mixture of protection and usage (e.g. partial protection of marine mammals but some limited exploitation).

upon the scheme and context. Conservatory offsets can begin earlier in the mitigation process than compensatory offsets to achieve faster and least-cost conservation. They can either substitute for or complement on-site minimization and restoration efforts. Their utility ends when restoration ends and compensation of the residual impact begins, either according to least-cost criteria or to mitigation to the maximum extent practicable.

Both compensatory and conservatory offsets include nesting beach protection for sea turtles (Bellagio, 2004). While there are no known uses for marine mammal bycatch, biodiversity offsets can be cost-effective and ecologically effective conservation expenditure (Bellagio, 2004; Wilcox and Donlan, 2007; Dutton and Squires, 2008; Dutton et al., 2010; Gjertsen et al., 2010, 2014). Offsets can be part of cost-effective conservation across each of the first three steps of the mitigation hierarchy (adjusting each step for risk to obtain equivalent expected risk across steps): avoiding bycatch (such as avoiding bycatch "hotspots"), minimizing bycatch when it cannot be avoided (such as using appropriate gear), and restoring or rehabilitating when it cannot be minimized (such as releasing bycatch alive) (Squires and Garcia, 2014, in prep).

Conservatory offsets, in contrast to compensatory offsets, might be considered earlier in the mitigation process (before step four, the residual), together with other incentive-based and even selective command-and-control instruments, in a voluntary and integrated least-cost bycatch reduction package (Squires and Garcia, 2014, in prep). That is, conservatory offsets can be used from the onset of the impacting fishery in order to achieve the aimed conservation objectives at least cost (Bellagio, 2004; Wilcox and Donlan, 2007; Dutton and Squires, 2008; Janisse et al., 2010; Dutton et al., 2010; Gjertsen et al., 2010; Gjertsen et al., 2014; ten Kate et al., 2015; Squires and Garcia, 2014, in prep). Offsets reflect the "Polluter Pays Principle".

The Federation of Independent Seafood Harvesters initiated a conservatory offset in 2004 for Pacific Leatherback sea turtles by voluntarily self-taxing and funding nesting site protection in Baja California (Janisse et al., 2010). Through adopting the holistic approach to conservation and species that interact with more than one fishery, fishers in one fishery can finance improved gear in another fishery that might otherwise not have the financial resources to adopt the bycatch-reducing technology, such as pingers for artisanal drift gillnet fisheries. Since 2006, and as a direct implementation of the offset option in Bellagio (2004), the International Seafood Sustainability Foundation initiated a voluntary self-taxation of long-line-caught tuna to fund nesting site and artisanal fishery conservation, implementing a piece of least-conservation of global sea turtles (ISSF, 2012). Such sea turtle conservatory offset programs can provide a template for marine mammal offsets, and in principle offsets price bycatch.

Studies demonstrate that in some cases, more conservation at a lower cost can be achieved elsewhere in the geographic range or life cycle of a species than through direct bycatch reduction – i.e., the marginal cost is far below the marginal benefit at a different life stage of the protected species. Gjertsen et al. (2014) demonstrate that the costs of ensuring the survival of one additional adult Pacific leatherback sea turtle through extensive avoidance (first step) is over $200,000 for the California drift gillnet fishery and over $28,000 in the Hawaii pelagic logline fishery – in sharp contrast with the cost of $1588 for the same conservation of one adult leatherback on a nesting beach through conservatory offsetting that provides partial compensation of the population. Pascoe et al. (2011) similarly showed substantial cost savings for rat eradication on seabird rookeries compared to at-sea conservation through avoidance. In both instances, minimization (step two) is implemented through technology standards (prescribed gear and operating conditions) and sea turtle quotas for the California and Hawaii fisheries. Offsets are currently used in Canadian salmon habitat programs (Quigley and Harper, 2006) and for sea turtles on a voluntary basis as discussed above, and have been proposed for seabirds (Wilcox and Donlan, 2007). While there are no current examples of the use of offsets in addressing marine mammal bycatch, the protection of rookery, mating, calving, or key feeding area habitat or transfer of bycatch reducing technology to other fisheries would be the "marine mammal analogy."

A marine mammal example of intervention at all life stages can be found in the NMFS Hawaiian Monk Seal Program, which invests considerable funds into saving individual seals that strand on beaches in Hawaii and in protecting juveniles. Harting et al. (2014) estimate that between 17 and 24 percent of all the monk seals currently in the Northwest Hawaiian Islands population were either treated through human intervention or are descendants of monk seals that had received treatment, between 1980 and 2012. While not an offset for fishery interactions, this analysis demonstrates the importance of a holistic approach to conservation of endangered marine mammals.

Climate change can both directly and indirectly impact offsets and in either positive or adverse ways. Current offset effectiveness may increase if climate change positively impacts the offset site, perhaps through more favorable environmental conditions or by shifting exploitative activities that inflict relatively higher rates of injury and mortality upon marine mammals (in the offsetting area) to another area with lower marine mammal interactions. Climate change might lead to shifts in marine mammal distribution in response to warmer ocean temperatures, reduced ice, etc., so that the offset is no longer suitable. Climate change can also alter the size of offset payments and their price. Climate change can alter the "price" of conservatory offsets (through in lieu fees, purchases of offset credits from conservation banks, or amount paid to offset) through altering the WTA of the offsetting party and WTP of the party inflicting marine mammal bycatch. Climate change does not alter the "price" of compensatory offsets that offset mandated residual losses after bycatch avoidance, minimization, and restoration/remediation.

4.3. *Providing a reward for reducing bycatch*

Providing an award for bycatch reduction also incentivizes bycatch reduction; by offering an award for each unit of reduction, the bycatch is no longer "free" due to the income foregone should the bycatch occur. There are no readily available examples of rewards for reducing bycatch of marine mammals, other than the SmartGear prize (discussed in the next paragraph) and price premiums or market access facilitated through eco-labeling and other schemes (see Section 4.4). In an interesting fishery bycatch example, a recent regulatory amendment on bluefin tuna bycatch in the Atlantic pelagic longline fleet rewards vessels whose bycatch levels are lowest during the fishing season with a higher initial individual bycatch quota at the beginning of the following season US Federal Register, 2015). The Scottish Conservation Credit Scheme provides extra fishing days to vessels that reduce cod bycatch (Scottish Government, 2011, 2012).

For a number of years, a coalition of public and private sector funders has provided financial support to the Smart Gear competition organized by the World Wildlife Fund for Nature (WWF). Fishery operators and other interested stakeholders from around the world submit their proposals for reducing bycatch, leading to successful innovations such as specially designed lights to reduce sea turtle bycatch in gillnets and bird scaring devices on tuna longline gear. The Smart Gear program not only awards a prize to the winning submissions, perhaps most importantly, the program provides funding for efforts to disseminate the use of the alternative gear by the fleet. In the 2014 Smart Gear competition, a special award was offered for reduction of marine mammal bycatch in gillnet fisheries, funded by a combination of industry, NGOs, and government agencies.[8] The

[8] While there were several submissions in this category, the marine mammal bycatch award has not yet been issued.

general approach is called tournaments and prizes (Kochin et al., 2008; Gjertsen et al., 2010; Squires and Garcia, 2014, in prep).

Payments for ecosystem services (PES), a direct conservation approach, provide another form of reward that can reduce and directly price bycatch (Dutton and Squires, 2008; Dutton et al., 2010; Gjertsen et al., 2010; Gjertsen and Stevenson, 2011; Bladon et al., 2014). PES are payments from one group to another to conserve, in which the voluntary payments are conditional upon measureable conservation gains (thereby imposing a "condition") that would not otherwise be realized. PES follow the "User/Beneficiary Pays Principle". Governments, civil society, producers can all finance PES. PES have been applied to sea turtle conservation (Gjertsen and Stevenson, 2011) and the *defeso* system for Brazilian artisanal fisheries during periods of fish reproduction and reserves (Begossi et al., 2011).

This PES model can be extended to artisanal fisheries' marine mammal bycatch in important times and/or areas. Along these lines, in 2008 the Mexican government made PES to artisanal fishers in the Upper Gulf of California to stop fishing and/or change gear to protect the vaquita (Barlow et al., 2010; Avila-Forcada et al., 2012). In May 2015, the government of Mexico agreed to compensate these fishermen and other fishery sector workers in the Gulf of California for a complete closure of the gillnet fishery over a two-year period. There are some complications in using PES in fisheries (Dutton and Squires, 2008; Gjertsen et al., 2010; Dutton et al., 2010; Bladon et al., 2014; Squires and Garcia, 2014, in prep), yet they remain a promising policy instrument.

Subsidies that finance innovation, diffusion, and adoption of bycatch reducing technology increase economic and ecological welfare, and provide an example of a "good" (Pigovian) subsidy that helps internalize the external benefit associated with new technology and knowledge in general (Boyce, 1996; Dutton and Squires, 2008; Gjertsen et al., 2010; Dutton et al., 2010; Pascoe et al., 2010; Segerson, 2011; Squires and Garcia, 2014, in prep). Potential and actual examples include development, diffusion, and adoption of pingers, and gill net designs that reduce marine mammal entanglement. Direct bycatch-reduction subsidies, in which a vessel receives a payment or reduction in costs for each unit of bycatch reduced, puts a price on bycatch in the same way that a bycatch tax does, but is less efficient (Goulder and Parry, 2008; Segerson, 2011). Reform of perverse subsidies is also incentive-based.

Climate change can impact PES through altering the adverse impacts upon marine mammals (e.g. marine mammals might migrate away from an area of current damage) or by altering the activities of the parties inflicting mortality or other damage upon the marine mammals. These can change the "downstream" adverse impacts and the activities and opportunity costs of the "upstream" inflictors of marine mammal bycatch. The terms of the agreements and what they cover may have to be renegotiated and the contract rewritten. Moreover, these climate-induced changes alter the "downstream" party's willingness to pay (WTP) to reduce bycatch and the "upstream" party's willingness to accept (WTA) compensation. This, in turn alters the size of the PES, where $WTP \leq PES \leq WTA$ and the "user/beneficiary pays" principle holds.

4.4. Cap-and-trade approaches – ITQs or credits

Cap-and-trade approaches are potentially among the most effective incentive-based policies to reduce bycatch. Two important cap-and-trade approaches are vessel-level allocations of tradable bycatch quotas (Boyce, 1996; Haraden et al., 2004; Diamond, 2004; Bisack and Sutinen, 2006; Dutton and Squires, 2008; Dutton et al. 2010; Hannesson, 2010; Pascoe et al., 2010; Gjertsen et al., 2010; Segerson, 2011; Costello et al., 2012; Squires and Garcia, 2014, in prep) and bycatch credits (Sugihara et al., 2009; Pascoe et al., 2010; Segerson, 2011). Trade among operators, either bilaterally or in secondary markets, allows prices to form. Trade allows vessels that are most efficient in reducing bycatch to do most of the fishing, thereby most efficiently reducing impact on marine mammals. Carry-forward provisions that allow unused quota or earned credits to be forwarded to the next year allow higher target species catches than otherwise expected.

Cap-and-trade approaches are not only inspired by terrestrial examples (such as emission cap-and-trade schemes), but also by rights-based management systems for target catch, such as individually transferable quotas (ITQs) for halibut in Alaska and the Alaskan Pollock Salmon Credits. As noted, these cap-and-grade programs price bycatch and can also incentivize dynamic ocean management. A two-part policy instrument is possible, a system of a transferable bycatch quota coupled with a price ceiling and a price floor, an example of which is deemed values. Deemed values attempt to pay fishers their marginal cost of production to discourage at-sea discarding (Squires, 1995). When bycatch is comparatively rare, trades can be limited, matching buyers and sellers can be difficult, information and transactions costs can be high, and this approach is more problematic to apply (Stavins, 1995; Segerson, 2011). Many of the above authors discuss additional limitations. We now turn to specific examples of cap-and-trade programs to illustrate their potential.

Although addressing a finfish bycatch challenge, the Alaska Pollock fishery provides an intriguing example of a voluntary, incentivized co-management agreement by members of an industry group (Pascoe et al., 2010; Mize, 2013; Little et al., 2014; Squires and Garcia, 2014, in prep). The member companies in the At Sea Processors Association implemented their own "Chinook Salmon Incentive Plan and Agreement," a form of bycatch credits that incentivize dynamic ocean management, which includes identification of "rolling hot spots" based on vessel reporting (fleet communications[9]) to a private company, Sea State. Sea State compiles the information in real time and communicates to vessels who avoid high potential bycatch areas. The program features strict provisions and penalties on fishing vessels with low performance in avoiding Chinook bycatch. Vessels are allocated bycatch credits, called Salmon Savings Credits, based upon how well they have avoided salmon bycatch in previous fishing seasons. An additional incentive to reduce bycatch is provided by the provision that allows vessels to sell their unused Salmon Savings Credits to other fishers (subject to a transfer discount) or to carry the credits forward for future use. These tighter performance standards, bycatch credits, transferability, and penalties incentivize bycatch reduction through dynamic ocean management.

The Scottish Conservation Credits Scheme, initiated in February 2008, aims to reduce cod bycatch in the northern North Sea through a two-tiered approach: avoid and reduce effort that in turn reduces total catch (Scottish Government, 2011). The Scheme includes voluntary dynamic ocean management, mandatory technology standards, co-management, and openness to on-going bycatch saving technological change (Scottish Government, 2012). Bycatch credit programs can also be specified as bycatch per unit of target catch. These relative credit programs can be applied when there are no limits on target catch (Helfand, 1991; Nentjes and Woerdman, 2012; Squires and Garcia, 2014, in prep).

Tradable bycatch quotas and credits can also be organized at the level of groups, such as the Alaskan Pollock salmon bycatch credit program (Mize, 2013). Trade then either occurs between groups, creating a bycatch price, or internally within a group, creating an implicit bycatch price. Group-level organization then closely resembles or actually becomes the risk pools or insurance systems discussed below (Mumford, 2009; Holland, 2010; Segerson, 2011). Group approaches may be especially important for stochastic, rare event bycatch (Segerson, 2011). Transactions and information costs can also

[9] Vessels are required to report all salmon interactions to a centralized information hub that is accessible to the whole fleet, serving as a warning to avoid those fishing areas.

be important when deciding whether to organize through markets or through groups (Coase, 1937). Group organization can be important in artisanal and traditional fisheries and when intrinsic motivation for bycatch reduction is important. Group approaches can achieve equivalent economic efficiency with individual quota and credit systems when group management is effective (Baland and Platteau, 1995; Segerson, 2016).

Bisack and Sutinen (2006) use an intra-year bioeconomic model to simulate fishery behavior under two alternative scenarios for managing harbor porpoise bycatch in the New England sink gillnet fishery – time/area closures in contrast with a system of individually transferable quotas (ITQs) for harbor porpoise bycatch. The model predicts higher profits in the fishery sector under the ITQ program (up to 15 percent higher) as opposed to the time/area closures, despite a reduction in the catch of target species. The flexibility afforded to trade quota among fishing vessels (with the most efficient vessels offering higher prices for the bycatch quota) and to modify fishing practices and locations under an ITQ approach increases fleet profitability. Such flexibility can also result in a more even distribution of impacts with fewer fishing ports being closed than with top-down time/area restrictions to the extent bycatch avoidance is not spatially dependent. This modeling also allows an estimate of quota prices, which range from $1395 to $5782 per unit of porpoise quota. In contrast to ITQs, bycatch credits have more appeal to some stakeholders, as they do not provide any "ownership" or "right" to the protected species, even though the incentives are similar to operators who have ownership. Bycatch credits can be viewed as individual bycatch quotas (performance standards) made flexible (Squires and Garcia, 2014, in prep). Haraden et al. (2004) estimated the shadow price and imputed economic value to the US tuna fleet of dolphins lost when setting on dolphins in the harvesting of tuna in the Eastern Pacific Ocean.

There are no known examples of marine mammal bycatch ITQ programs in place at this time. The Eastern Tropical Pacific Dolphin Mortality Limits (DMLs) under the Agreement on the International Dolphin Conservation Program come the closest, but this program is a limit rather than an ITQ or bycatch credit and is not a use right. They do not include a "reward" system to those who have successfully addressed bycatch in the past, and in principle are not transferable or can be carried forward. The design and implementation of a marine mammal bycatch ITQ system would likely be met with considerable challenges, particularly in the United States, where there is a "zero mortality rate goal" for marine mammal bycatch. (See Smith et al., 2014 for further discussion of limits to property rights with marine mammals.) A credit system might be more in line with U.S. legislation. To meet MMPA requirements, the total amount of bycatch would be some fraction of PBR; this total level may not necessarily be the socially optimal level of bycatch, but it is the level imposed by Congressional mandate. Whether applied to the fleet as a whole or via ITQs or individual credits is irrelevant to the question of a socially optimal level of bycatch. Least-cost bycatch reduction, given the PBR, instead forms the economic goal.

To the extent that the marine mammals of concern are transboundary species, and the bycatch is managed by an international organization (i.e. multilateral cooperation), then two issues arise. First, enforcement becomes more difficult because international organizations are self-enforcing, and negative incentives such as trade and port state measures are required (Barrett, 2003). Second, catch rights in international agreements are more complex because they include two rights: the catch (or effort or capacity) right and an access right (Squires et al., 2013). The access right can be to exclusive economic zones (EEZs) due to individual sovereignty of States or to the areas beyond national jurisdiction under the auspices of the international commission with regulatory responsibilities. The catch right may be bundled with, or separate from, the access right. Rights may have to be first issued to States. If rights are first issued to individuals, then States may well assert their sovereignty as with the Inter-American Tropical Tuna Commission's capacity management program and capacity rights.

As U.S. fisheries have evolved from open access to limited access and then rights-based management such as ITQs and group rights (sector allocations), there has been an ongoing interest in how these measures might impact bycatch. Open-access, derby-style fisheries often are characterized as a "race to fish" with little regard to how the gear is operated, avoiding "hot spots" for protected species interactions, and carefully handling bycatch of protected species when this occurs (Boyce, 1996; Dutton and Squires, 2008; Abbott and Wilen, 2009; Gjertsen et al., 2010; Pascoe et al., 2010; Segerson, 2011). It would thus be expected that bycatch would be reduced under "rationalized management." However, at least one study demonstrates that the longer fishing season that resulted from the Alaskan ITQ fishery for halibut and sablefish has increased the opportunities for whale depredation/interaction with the fleet (Peterson and Carothers, 2014).

Other types of programs when trade is allowed closely resemble cap-and-trade programs. Offset and conservation easement programs can be extended to conservation banking, a type of tradable credit program, in which a party that holds the offset or easement receives credits granted by a regulatory body (Heal, 2000; Gjertsen et al., 2010; Squires and Garcia, 2014, in prep). Such an owner may use, sell, or otherwise transfer the credits within a pre-designated service area to address mitigation required by the regulator. Conservation brokers can arise to facilitate trade. Through trade, a bycatch price is formed. Issues of adverse selection (additionality) arise, in which investments are made that would have been made otherwise, and ecological equivalence.

More recently, the explicit use of fleet communications (O'Keefe et al., 2013) and dynamic ocean management[10] (Maxwell et al., 2015) have been championed as complementary tools to rights-based or pooled bycatch allocation.

4.5. Insurance or risk pools

Bycatch insurance schemes or risk pools share bycatch risk among a group of vessels (Mumford et al., 2009; Holland, 2010; Gjertsen et al., 2010; Segerson, 2011). Sharing bycatch quota through risk pools among vessels can help reduce financial risk when bycatch is highly uncertain. Such risk pools often entail co-management between the regulator and the group of vessels and may be voluntary on the part of vessels. Bycatch insurance schemes are especially useful for rare or highly uncertain species. Examples include sea turtles and sperm whales. Risk pools or insurance schemes help address cases in which bycatch is rare and highly variable, particularly when individual bycatch quotas are low (Sugihara et al., 2009; Mumford et al., 2009; Holland, 2010; Segerson, 2011). One vessel could have a rare, but unfortunate "disaster set" in which an unusual number of protected species are caught – and the low allocation of bycatch per vessel can't possibly cover such an outcome. Insurance schemes may be well adapted to cope with climate change, since collective risk is pooled and the scheme can be structured to be quite adaptive and flexible.

As with all insurance schemes, both *moral hazard* and *adverse selection* issues arise. Moral hazard arises if insurance members have less incentive to avoid bycatch, especially when avoidance is costly, and less incentive to mitigate, Insurance can prescribe best practices for bycatch avoidance and/or impose deductibles (Holland and Jannot, 2012). Adverse selection arises when individuals with higher bycatch risk or a smaller quota to contribute are more likely to join than low risk individuals or those with larger bycatch quotas. By weakening

[10] Maxwell et al. define dynamic ocean management as *management that changes rapidly in space and time in response to the shifting nature of the ocean and its users based on the integration of new biological, oceanographic, social or economic data in near real-time*. Dynamic ocean management is sometimes called real-time spatial management (Little et al., 2014).

individual incentives to avoid bycatch, the risk increases that the aggregate bycatch of the insurance group will exceed the group's pooled quota.

The mothership cooperative in the U.S. Pacific whiting fishery, faced with unpredictable bycatch of four species of rockfish and Chinook salmon that make individual bycatch quotas or credits problematic, established a risk pool and co-management agreement to jointly manage Pacific whiting and bycatch (Holland, 2010). (The catcher vessels harvest whiting and deliver to a mothership for processing into surimi.) The risk pool also employs dynamic ocean management through a private company, Sea State. After the implementation of ITQs in the U.S. groundfish fishery in 2011, several coastal communities recognized that many of the species, especially bycatch species, are stochastic and relatively rare events. One response is for vessels to pool their quotas to share the risks of constraining species whose quota allocations are extremely small and unevenly distributed (see Mumford et al., 2009; Holland, 2010; Segerson, 2011).

4.6. Market measures – ecolabeling, certification, information programs, market access, and trade measures

Ecolabeling for seafood can be conducted by governments, nongovernmental organizations, private firms, multilateral organizations, and other institutions (Ward and Phillips, 2010). Ecolabeling addresses the market failure from incomplete or asymmetric information, i.e. the information externality (Kotchen, 2013). This information can be incomplete or of lower quality or asymmetrically held so that vessels hold more information on bycatch than do firms in the supply chain and consumers. Consumers, and even firms in the supply chain, are generally unaware or are unable to observe how their consumption choices impact the biodiversity impact of bycatch. Markets cannot efficiently function with incomplete information. These types of programs, because they address the information externality, should be quite adaptable and flexible to adjust to climate change.

There is a wide variety of private sector ecolabels, including the Marine Stewardship Council (MSC) and the Monterey Bay Aquarium seafood labeling programs. The MSC's Principle #2 requires that the fishery management system "maintain the structure, productivity, function and diversity of the ecosystem." Examples from the U.S. government include the Fish Watch program, the "dolphin safe" label for canned tuna from the Eastern Tropical Pacific, and the regulatory proposal that would subject seafood imports into the United States to a "comparability finding" process (see discussion above). Given asymmetric information in the world's fishing and seafood sector, ecolabels can serve as a useful source of information for consumers who want to ensure that their seafood purchases are not harmful to marine stocks or ecosystems.

There is scant evidence to date that ecolabels lead to higher prices for seafood at the ex-vessel level (Stemle et al., 2016; Golden, 2010). While some products exhibit price premiums at the retail level, Stemle et al. (2016) found that there was "improved market position" only for a subset of the MSC-certified product analyzed. Nevertheless, fishing fleets may have an incentive to obtain these labels if only to ensure that they will continue to have market access to wholesalers and retailers whose clientele demands seafood products that ensure sustainability of the marine ecosystem. To the extent that this market access and other potential benefits incentivize the fishing sector, ecolabels can serve as an additional incentive to reduce marine mammal bycatch in fisheries. Initially, ecolabels help with market access, but over the long run, any price premium or market access may fade as an advantage when ecolabels become the industry norm.

Certification, a bycatch reduction approach related to ecolabeling in that it addresses the information externality, involves a third party auditor that certifies the environmental soundness of a resource operator and the products (Ward and Phillips, 2010). The logic of supply chain standards (sometimes referred to as private standards) is that corporations that control a large enough share of the market dictate terms that their suppliers must follow.

Environmental information programs, transparency policies, and openness initiatives provide environmental information to consumers, the supply chain, governments, and nongovernmental organizations and address the information externality (Kotchen, 2013; Squires and Garcia, 2014, in prep). Information programs can be mandatory and externally imposed by governments, NGOs, or the media, and include examples such as hazard warnings for methylmercury in fish and NGO-sponsored performance ratings such as Monterey Bay Aquarium's seafood ratings. With voluntary information disclosure programs, individual entities responsible for environmental outcomes can voluntarily opt in or out of programs. Market access and trade restrictions are other possibilities (Dutton and Squires, 2008; Gjertsen et al., 2010; Pascoe et al., 2010).

4.7. Other approaches

Buybacks of vessels and/or gear can, under certain conditions, contribute to bycatch reduction and conservation in general (Curtis and Squires, 2007; Dutton and Squires, 2008; Gjertsen et al., 2010; Barlow et al., 2010; Squires and Garcia, 2014, in prep). Buybacks of gear with high bycatch and replacement with lower bycatch gear may be the simplest buyback approach. In 2007 and 2008, the Mexican government initiated buybacks for exiting the fishery or switching gear in order to address vaquita bycatch in the gillnet fishery in the upper Gulf of California (Barlow et al. 2010). The program met with mixed success (Avila-Forcada et al., 2012), primarily due to poor design and implementation. Buybacks of vessels and/or gear might be used to remove those that become superfluous or inappropriate due to climate change.

There are still other incentive-based approaches. A conservation easement was implemented in Laguna San Ignacio, Mexico to protect grey whale habitat (Niesten and Gjertsen, 2010).[11] Voluntary programs, sometimes incentivized under credible threats by regulators but other times for market reasons, can also provide bycatch reduction and conservation (Segerson, 2010, 2011). Examples are the voluntary California drift gillnet fleet and ISSF sea turtle conservatory offset programs providing partial compensation for reduced net loss (Janisse et al., 2010; ISSF, 2012). Industry-based approaches, another possibility, can have several advantages, particularly in the presence of uncertainty such as bycatch that is rare and stochastic (Segerson, 2011). Industry-wide limits can also increase incentives for vessels to work collectively to ensure that the bycatch target is met through, for example, information sharing and dynamic ocean management. Bycatch quotas can be combined with shutdown or with penalties and rewards that are either fixed or proportional and at the vessel or group level to create another form of two-part policy instrument (Segerson, 2011). Fines when bycatch is high can be used to finance incentive payments when bycatch is low. Individual habitat quotas for habitat conservation provide an indirect approach to protect marine mammals. Individual habitat quotas utilizing economic incentives to achieve cost-effective habitat conservation goals have been proposed (Holland and Schnier, 2006). Assurance, or performance, bonds are economic instruments commonly used in environmental management (Perrings, 1989; Pascoe et al., 2010). Assurance bonds typically require the resource user – either an individual or group – to guarantee a sum of money equivalent to the potential damage that the activity can have on the environment or more commonly the cost of its remediation. This

[11] A conservation easement is a voluntary, legally binding agreement that limits certain types of uses or prevents development from taking place on a piece of property over some agreed upon time period to protect the property's ecological services. The owner of the property retains use of property that can be for, but not necessarily limited to, commercial purposes, but these purposes are attenuated according to the conservation easement.

process prices bycatch and creates a cost, thereby incentivizing bycatch conservation, and can potentially create dynamic incentives to induce bycatch saving technological change.

Indirect incentive approaches can potentially contribute to marine mammal bycatch reduction, particularly in artisanal fisheries. Indirect incentive approaches to conservation aim at improving conservation performance indirectly, e.g. through an integration of conservation and development concerns, such as in Integrated Conservation and Development Projects (ICDPs) and development of local leadership and stewardship, through Community-Based Conservation (CBC), eco-tourism, and other forms of shared governance between central and local authorities and greater community-based initiatives (Dutton and Squires, 2008; Gjertsen and Stevenson, 2010; Squires and Garcia, 2014, in prep). A community-based sea turtle approach, Proyecto TOMAR in Brazil, is an example that can potentially serve as a template for community-based conservation of some marine mammals. (Marcovaldi, 2011). Another community-based sea turtle example that arose out of Bellagio (2004) and might serve as a template, the ISSF-Ocean Foundation-Eastern Pacific Hawksbill Initiative (ICAPO), conserves Hawksbill sea turtles in the Eastern Pacific Ocean (ISSF, 2012). Protected areas for sea turtles were developed in Jamursba Medi, Indonesia, in exchange for scholarships (Hitipeuw, 2011). These community-based sea turtles approaches can serve as a template for marine mammals, and might best be suited to conserve coastal marine and riverine mammals in well-defined areas and through a holistic approach. This approach will have to adapt to the climatic impacts upon communities, their means of livelihood, bycatch of marine mammals, and the marine mammals themselves.

5. Incentivizing for bycatch reduction; a logical approach, but seldom used in practice – why?

Incentive-based approaches to reducing bycatch are not widely applied, even though they have been shown to work in addressing finfish bycatch for major fisheries such as the Alaskan Pollock fishery and the U.S. West Coast groundfish fishery. Incentive-based management has also been demonstrated to be effective for target species management through rights-based management and credit programs. Terrestrial conservation of wildlife, and managing the comparable problems of pollution, energy use, and carbon also showcase the relative merits of an incentivized approach in addressing environmental challenges (Squires and Garcia, 2014, in prep). There clearly is a lack of knowledge and understanding about the effectiveness of such an approach and the potential to create greater conservation at lower cost and higher rates of compliance. There also may be reluctance to “hand over" control to the fishing industry and to trust decentralized markets.

Change can also be slow, as there is natural resistance to roll back investments in bycatch programs established for traditional “top-down, command-and-control”, and such changes can be costly. In some cases, there may be resistance from the fishing and seafood industry (as with any restrictions on their operations), since there are perceived losers who may resist. Those fishers who are satisfactorily performing under the current bycatch regime may also resist change. However in several cases, as noted above, there is a preference by these industry operators for incentivizing rather than top-down regulatory approaches. Especially with rights-based approaches, these approaches may be resisted by current gainers and not adopted until the situation deteriorates sufficiently that the extent and distribution of gainers and losers becomes clear (Demsetz, 1967; Libecap, 1989). Finally, the considerable uncertainty over the effectiveness of incentive-based bycatch reduction can slow the adoption of the more effective least-cost incentive-based approach to bycatch reduction. Given the critical challenge of marine mammal bycatch around the world and the added uncertainty from climate change impacts on species distribution, there is a growing need to consider the broadest possible range of measures, including those suggested by marine economists and managers charged with terrestrial environmental stewardship.

Disclaimer

The views expressed in this article are those of the authors and do not necessarily reflect the positions or policies of the Marine Mammal Commission or the National Marine Fisheries Service.

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