MITIGATING PROBLEMATIC BYCATCH IN SMALL SCALE MARINE CAPTURE FISHERIES

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Introduction

Responsible fisheries conduct requires the effective governance of all sources of fishing mortality, including from retained target catch, retained and discarded bycatch, and unobserved mortalities. An integral component of implementing the ecosystem approach to fisheries, this is necessary to contribute to maintaining marine biodiversity, marine ecosystem functioning and ecosystem services, including sustainable fishery resources, and is necessary to avoid negative socioeconomic consequences for fishing communities (Hall et al., 2000; Worm et al., 2006).

While used inconsistently, the term bycatch can be defined as being comprised of: (i) retained catch of non-targeted but commercially valuable species, referred to as 'incidental catch'; (ii) discarded catch, whether the reason for non-retention is economic or regulatory; plus (iii) unobserved mortalities (Alverson et al., 1994; Hall et al., 2000; Kelleher, 2005). Discarded catch might be dead, released alive but die as a result of injuries, or released alive and survive the interaction. Sources of unobserved fishing mortality include catch that is depredated or falls from the gear before retrieval, and ghost fishing from lost or abandoned gear. Regardless of the definition of bycatch employed, reporting and regulating all sources of fishing mortality is critical for effective fisheries governance.

Bycatch contains species of marine megafauna and lower trophic-levels critical for the maintenance of the structure and functioning of marine ecosystems and the continued provision of marine ecosystem services. Sensitive species groups subject to bycatch include seabirds, sea turtles, marine mammals, elasmobranchs (sharks and their relatives) and other fish species, which are particularly vulnerable to overexploitation of older age classes, can decline over short temporal scales (decades and shorter), and are slow to recover from large population declines due to their K-selected life-history strategy. Unsustainable levels of bycatch also have concomitant negative socioeconomic consequences for fishing communities, as bycatch is an important income source and contribution to food supply in some fisheries and countries. Overexploitation of commercially important non-target bycatch species, including bycatch of juvenile and undersized individuals of a commercial species, can adversely affect future catch levels, and can result in allocation issues between fisheries (Hall et al., 2000; Gilman and Lundin, 2010).

Ensuring levels of retained and discarded bycatch in small scale marine capture fisheries are sustainable is a substantial governance deficit. This is due to inadequate monitoring, data collection protocols, management, enforcement, and performance assessment. There are a range of methods to mitigate (avoid, minimize and offset) problematic bycatch, including gear technology approaches, involving changes in the design of fishing gear and methods; input and output controls; compensatory mitigation; time/area restrictions; fleet communication; market-based mechanisms, where eco-labeling and other certification programs for marine capture fisheries, and employment of sustainable seafood sourcing policies by grocery retailers through to their suppliers, can provide large incentives for fisheries to meet sustainability criteria, including mitigating problematic bycatch; and rights-based mechanisms (Gilman, In Press). Here we identify key considerations in mitigating bycatch via gear technology approaches, review bycatch problems in small scale pelagic longline, purse seine, and passive net and trap fisheries, and identify best practice gear technology bycatch solutions.

Gear Technology Principles and Approaches

Several principles and approaches require consideration when identifying gear technology bycatch mitigation measures appropriate for an individual fishery.

- Some bycatch solutions are fishery-specific, and therefore fishery-specific assessment is warranted.
- Fishers have a large repository of knowledge, which can be tapped to contribute to finding effective and practical bycatch solutions, and can result in industry developing a sense of ownership for mitigation methods.
- Ideal bycatch mitigation methods:
    i. Are effective at mitigating unwanted bycatch to nominal rates and levels, through methods that, prioritized in the following order, avoid, minimize, and offset bycatch;
    ii. Are commercially viable, including: (a) practical, (b) safe, and (c) economically viable, or better yet, provide operational and economic benefits;
    iii. Require a minimal amount of alteration to traditional fishing gear and practices;
    iv. Require acceptable cost for uptake and continued employment;
    v. Are effective regardless of crew behavior;
    vi. Facilitate enforcement and lend themselves to measurable performance standards without requiring observer data;
    vii. Are commercially available; and
    viii. Do not cause increased bycatch of other unwanted bycatch species/sizes, or better yet, effectively mitigates multiple problematic bycatch species.
- It is critical to identify conflicts and benefits amongst species groups from bycatch mitigation strategies. For example, use of wider circle hooks in place of narrower J and tuna hooks to reduce turtle bycatch rates and mortality in pelagic longline fisheries has also been found to reduce seabird bycatch rates by about 80%, while use of fish instead of squid for bait to reduce turtle catch rates also significantly reduces shark catch rates by about 30% (Gilman and Lundin, 2010). However, for instance, in some regions, setting longlines at night to protect albatrosses and other diurnal foraging seabirds has led to higher bycatch of nocturnal-foraging seabirds.

Pelagic Longline Fisheries

There is problematic bycatch of seabirds, sea turtles, sharks, marine mammals and juvenile/undersized swordfish in some small scale pelagic longline tuna fisheries (Gilman, In Press). Gear technology methods to mitigate problematic bycatch in small scale pelagic longline fisheries include:

- **Seabirds**: A large and growing number of effective seabird bycatch avoidance methods exist, including measures to: (i) avoid peak periods of seabird foraging via night setting; (ii) reduce seabirds' detection of baited books through blue-dyed bait, shielded deck lights, underwater setting devices, retention of offal and other discards, and artificial bait; (iii) limit bird access to baited hooks through underwater setting devices, side setting, increased weighting near hooks, thawed bait, bait casting machine, and setting terminal tackle and mainlines outside of propeller turbulence; and (iv) deter birds from taking baited hooks through bird scaring 'tori' lines, towed objects, water cannons, and acoustic deterrents. Effective employment of combinations of these methods has been observed to nearly eliminate problematic seabird bycatch.
- **Sea turtles**: Using a wider circle hook in combination with large whole fish bait in place of narrower J-shaped hooks with squid bait significantly reduces sea turtle catch rates by 55-90% and significantly reduces the proportion of caught turtles that swallow hooks versus being hooked in the mouth or body or entangled, hypothesized to increase the likelihood of survival. While no significant difference has been found on turtle catch rates or the location of hooking between 10 degree offset and non-offset (with the point in the same plane as the shaft) circle hooks, presumably there is a threshold offset angle above which the gape would be sufficiently large to cause it to hook catch similarly to J-shaped hooks. Deploying hooks below 100 m holds promise. Other promising approaches include restricting use of lightsticks, single-hooking fish bait, reducing gear soak time and retrieval during daytime, and fishing in waters with a sea surface temperature $< 20^{o}$c.
- **Sharks**: Using fish instead of squid for bait causes a significant, ca. 35%, decrease in shark CPUE. Deeper setting reduces catches of pelagic sharks, but likely increases catches of deeper-dwelling shark species. Significantly lower shark catch rates occur with monofilament leaders vs. leaders of more durable material (wire, multifilament nylon). There is a need to invest in continued research and development of shark deterrents, which could be incorporated into terminal tackle.
- **Marine Mammals**: Best practice methods to mitigate cetacean depredation and bycatch include: (i) Avoiding hotspots; (ii) conducting fleet communication; (iii) moving when interactions occur; (iv) using circle hooks in place of J and tuna hooks, to reduce both cetacean catch rates and the proportion of those caught that are deeply hooked; and (v) using 'weak' hooks, designed so that when cetaceans (but not commercially important finfish) are hooked, they straighten the hooks and escape. Designs for hydrophones, to detect the presence of species of echolocating cetaceans that depredate from longline gear, are in development. Encapsulation of caught fish, and adding hardware to physically protect baited hooks, have potential.

- **Juvenile and undersized billfish**: Avoiding grounds with high densities of small swordfish and other billfish, such as shallow seamounts, using circle hooks to increase the prospects of discarded billfish of surviving the interaction, employing gear designed to set baited hooks below 100m, and restricting the use of lightsticks, are best practices for mitigating unwanted bycatch of juvenile and undersized swordfish and other billfish.

Purse Seine Fisheries

There is problematic bycatch of sea turtles, sharks, marine mammals, juvenile/undersized bigeye and yellowfin tunas, and other unmarketable sizes and species of finfish in some small scale purse seine fisheries (Gilman, In Press). Gear technology methods for mitigating bycatch in purse seine fisheries include:

- **Sea turtles**: (i) Restricting setting on anchored and drifting Fish Aggregating Devices (FADs) and other aggregating devices (logs, other floating debris, whales, whale sharks, data buoys); (ii) avoiding encircling turtles; (iii) monitoring FADs and releasing entangled turtles; (iv) recovering FADs when not in use; and (v) deploying crew on boats to spot and release turtles entangled in the net are methods to reduce sea turtle bycatch. There is a need for further research on modified FAD designs.
- **Sharks**: Methods to avoid shark bycatch include: (i) avoiding hotspots; and (ii) restricting setting on FADs and other aggregating devices. There is a need to invest in research on shark repellents with sufficient effective range for deployment on FADs. Employment of a bait station to attract sharks away from a FAD has been suggested as a way to separate sharks from target species. Timing of setting may enable separation of some shark species from aggregations around FADs.
- **Marine Mammals**: Methods to reduce dolphin bycatch include prohibition of night sets, use of a Medina dolphin safety panel, conducting backdown after dolphins are captured, deploying rescuers during backdown, and using safety/rescue equipment. Restricting live whale-associated sets would avoid injury and mortality of whales.
- **Juvenile and Undersized Tunas/Unmarketable Sizes and Species of Fish**: Restricting setting on FADs and other aggregating devices would reduce catches of juvenile and undersized bigeye and yellowfin tunas and unmarketable sizes and species of fish. Other promising approaches include employing sorting grids; using lights in the net to move non-target fish to an escapement device and keep target species away from the area; altering the depth of the appendage beneath a drifting FAD to reduce bigeye abundance; using of acoustic devices to detect the average size of each fish species within aggregations; towing FADs out of the seine during the set; using paired or stacked FADs to separate out bigeye; aerating the water in the net and reducing the constriction of pursing the net to increase the survival of discards; and timing setting to separate skipjack and bigeye tunas.

Coastal Passive Net and Trap Fisheries

There is growing evidence of relatively high sea turtle mortality in coastal passive net and trap fisheries from various regions, and coastal passive net fisheries are now understood to be a large anthropogenic mortality source (Gilman et al., 2009; Peckham *et al*., 2007; FAO, 2010). Promising gear technology approaches to mitigate sea turtle bycatch in gillnets and trammel nets include: increasing gear visibility to turtles through illumination and line materials, but not target species; reducing net vertical height; increasing tiedown length or eliminating tiedowns in demersal gillnets; incorporating shark-shaped silhouettes; and modifying float characteristics, the number of floats or eliminating floats (Gilman et al., 2009). Promising gear technology approaches for pound nets and other trap gear include: replacing mesh with ropes in the upper portion of leaders; incorporating a turtle releasing device into traps; modifying the shape of the trap roof to direct turtles toward the location of an escapement device; using an open trap; and incorporating a device to prevent sea turtle entrance into traps (Gilman et al., 2009). Problematic bycatch of marine mammals, seabirds, and sharks has also been documented in some coastal passive net and trap fisheries, where gear technology and other approaches have demonstrated some mitigation efficacy (Kraus *et al*., 1997; Melvin *et al*., 2001; Alvarez and Wahrlich, 2005).

Open Access Integrated Fishery-Dependent Datasets

Due to the ocean basin-scale distributions of marine magafauna, and because megafauna bycatch occurs in multi-national fleets operating in domestic waters and on the high seas, there is a need for observer data collection over large spatial scales and the ability to access and pool the resulting datasets to support large temporal- and spatial-scale analyses. Improvements are needed, including: (i) Substantial increases in bycatch data collection in small-scale as well as more industrial fisheries; (ii) Standardization of monitoring and data recording methods; (iii) Enabling open access to observer program datasets; and (iv) Cataloguing metadata of fishery-dependent datasets to support discovery and determination of suitability for integration (Gilman, In Press).

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