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Vulnerability of oceanic sharks as pelagic longline bycatch

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ABSTRACT

Bycatch (the unintentional catch of non-target species or sizes) is consistently ranked as one of the greatest threats to marine fish populations; yet species-specific rates of bycatch survival are rarely considered in risk assessments. Regulations often require that bycatch of threatened species be released; but, if animals are already dead, their release serves no conservation purpose. We examined the survival of 12 shark species caught as bycatch in the US Atlantic pelagic longline fishery. Shark survival was evaluated in relation to fishery target (swordfish versus tuna) and four operational, environmental, and biological variables to evaluate the underlying mechanisms affecting mortality. Survival estimates ranged from 33% (night shark) to 97% (tiger shark) with seven of the 12 species being significantly affected by at least one variable. We placed our survival results within a framework that assessed each species' relative vulnerability by integrating survival estimates with reproductive potential and found that the bigeye thresher, dusky, night, and scalloped hammerhead shark exhibited the highest vulnerabilities to bycatch. We suggest that considering ecological and biological traits of species shows promise for designing effective conservation measures, whereas techniques that reduce fisheries interactions in the first place may be the best strategy for highly vulnerable species.

1. Introduction

Overfishing represents the greatest threat to marine fish stocks globally (Hutchings and Reynolds, 2004; Jackson et al., 2001; Pauly et al., 2002) and substantial research has focused on better understanding the vulnerabilities and resilience of marine species to sustained fishing (Dulvy et al., 2008; Worm and Branch, 2012). Modeling and ranking the vulnerabilities of dissimilar species to fisheries capture can provide insight into how fishery-related stressors affect ecologically/biologically similar (or different) species as well as provide a mechanism for prioritizing species for conservation actions (Astles et al., 2006; Gallagher et al., 2012).

Elasmobranchs are particularly vulnerable to overfishing due to their relatively low reproductive output and low potential for population recovery compared to most teleosts (Myers and Worm, 2005; Stevens et al., 2000). Several elasmobranchs are experiencing drastic population declines across their range (e.g., Baum et al., 2003; Dulvy et al., 2008;

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Ferretti et al., 2010). While many shark species are targeted for the global shark fin trade or otherwise retained for consumption (Clarke et al., 2006; Worm et al., 2013), elasmobranchs are also unintentionally caught as bycatch in many fisheries, and this catch can often exceed that of the actual targeted species (Bonfil, 1994; Molina and Cooke, 2012). Bycatch is often (but not always) discarded regardless of their at-vessel status (live, injured or dead), and is poorly reported in some fishery records making it difficult to assess impacts (Barker and Schluessel, 2005; Bonfil, 1994). Additionally, management regulations often require that bycatch of threatened species be released to promote their conservation (Molina and Cooke, 2012); however, if fishes are dead upon gear retrieval then such practices can be futile for conservation efforts. However, understanding the at-vessel status of individuals caught as bycatch and modeling their survival in light of biological, environmental, and operational variables can provide insights into the underlying mechanisms driving mortality, thus informing which aspects of a fishery might be modified to mitigate lethal effects of capture on a species-specific basis (Serafy et al., 2012).

Longline fishing provides one of the largest sources of fisheries interactions with sharks, and it is well known that species with limited biological productivity are among the most vulnerable to many, if not all forms of fishing mortality, including bycatch (Cortés et al., 2010). Previous studies describing the observational at-vessel survival rates of certain shark species in both pelagic and bottom longline fisheries have documented a wide range of estimated survival rates among species (e.g. Beerkircher et al., 2002; Diaz and Serafy, 2005; Morgan and Burgess, 2007; Morgan and Carlson, 2010). This work has provided a strong foundation to begin asking additional questions about how bycatch affects the survival of shark species; specifically, assessing the potential influences of operational, environmental and biological variables of the fishery under investigation. For example, pelagic longline fisheries often switch between fishery targets (i.e., tuna versus swordfish), thereby altering environmental (time of day) and operational (fishing depth) aspects of the fishery. However, it is unclear if and how these operational differences affect the survival of sharks captured as bycatch. Thus, there is a need to model species-specific survival in light of fishery targets and other potentially significant variables which may affect survival.

To address these gaps, the present study provides an assessment of at-vessel hooking survival for 12 shark species encountered as bycatch in the US Atlantic pelagic tuna and swordfish longline fishery from 1995 to 2012. Study objectives were to: (1) determine the influence of fishery target (tuna or swordfish) as well as various operational (soak time and hook depth), environmental (sea surface temperature) and biological (animal length) variables on shark bycatch survival to evaluate the potential underlying mechanisms driving at-vessel mortality and; (2) determine and rank species-specific hooking survival rates (i.e., proportion alive upon gear retrieval) for the 12 focal shark species after adjusting for these variables. To generate an overall index of relative vulnerability to bycatch, we integrated our results into a framework that incorporated species-specific reproductive potential (age at maturity and fecundity). The novelty in our study resides in the ability to assess the influence of fishery-related variables on survival, as well as by controlling for these variables when generating new survival estimates from nearly two decades of bycatch data. Our findings are discussed in terms of each species' phylogeny, conservation status, reproductive output, physiology, and degree of specialization in selected functional and behavioral traits (Gallagher et al., 2014a).

2. Methods

2.1. Study and data location

The US pelagic longline fishery operates year-round throughout the western Atlantic Ocean and primarily targets swordfish (*Xiphius gladius*), yellowfin tuna (*Thunnus albacares*), and bigeye tuna (*Thunnus obesus*). In the present study, we used shark bycatch data derived from the tuna- and swordfish-directed pelagic longline fishery in the western Atlantic Ocean and Gulf of Mexico from 1995 to 2012. Set-specific data were provided by the US National Marine Fisheries Service (NMFS) Pelagic Observer Program (POP). The POP gathers detailed information on each longline set including: target species, time and location of deployment, hook type, number of hooks, number of light sticks, bait, soak duration, sea surface temperature, and estimated hook depth. Information is also collected on the details of catch, such as the identity (species and/or genus) of captured taxa, their numbers, their size (fork length, FL; visually estimated) and their status (live/dead/damaged) at boat-side when the longline gear is retrieved. Sharks are classified as "dead" if they show no visible movement. If a shark is either dead or alive, but exhibits extensive injuries, the fish is classified as "damaged". Further details of observer protocols are available at http://www.sefsc.noaa.gov/fisheries/observers/forms.htm.

2.2. Species assessed

We focused our analyses on 12 shark species that are readily identifiable (with training) at the species level and commonly captured as bycatch with both tuna- and swordfish-directed pelagic longline gear in the Atlantic Ocean and/or Gulf of Mexico. These shark species included: bigeye thresher (*Alopias superciliosus*), blue (*Prionace glauca*), dusky (*Carcharhinus obscurus*), longfin mako (*Isurus paucus*), night (*Carcharhinus signatus*), oceanic whitetip (*Carcharhinus longimanus*), porbeagle (*Lamna nasus*), sandbar (*Carcharhinus plumbeus*), scalloped hammerhead (*Sphyrna lewini*), shortfin mako (*Isurus oxyrinchus*), silky (*Carcharhinus falciformis*), and tiger (*Galeocerdo cuvier*).