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Marine species mortality in derelict fishing nets in Puget Sound, WA and the cost/benefits of derelict net removal

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ABSTRACT

Derelict fishing gear persists for decades and impacts marine species and underwater habitats. Agencies and organizations are removing significant amounts of derelict gear from marine waters in the United States. Using data collected from repeated survey dives on derelict gillnets in Puget Sound, Washington, we estimated the daily catch rate of a given derelict gillnet, and developed a model to predict expected total mortality caused by a given net based on entanglement data collected upon its removal. We also generated a cost:benefit ratio for derelict gear removal utilizing known true costs compared to known market values of the resources benefiting from derelict gear removal. For one study net, we calculated 4368 crab entangled during the impact lifetime of the net, at a loss of $19,656 of Dungeness crab to the commercial fishery, compared to $1358 in costs to remove a given gillnet, yielding a cost:benefit ratio of 1:14.5.

1. Introduction

Derelict fishing gear is accidentally lost or intentionally discarded or abandoned fishing lines, nets, pots, traps, or other gear associated with commercial or recreational fishing. Much of this equipment is made of synthetic materials that do not degrade in the ocean environment and has been found to persist for decades. Derelict gear damages the marine ecosystem in different ways, directly and indirectly (Dayton et al., 1995). It also causes damage to vessels and vessel equipment. Derelict nets artificially modify seafloor and rocky reefs, altering the natural rugosity and/or hardness of a reef, obstructing crevices, enshrouding ledges, causing abnormal scouring of the seabed, and entrapping fine sediment that suffocates plants and animals thereby affecting the complexity of microhabitats available for the diversity of animal, plant and algal communities living on the seafloor. Boat propellers catch ropes attached to lost traps and pots or discarded monofilament line, and abandoned gear clutters fishing grounds, impeding fishermen's ability to safely and efficiently deploy their own gear and in some cases causing more gear loss.

Hundreds of marine species have been reported to be affected by fishing gear entanglement and ingestion (Laist, 1996), which has been identified as a major cause of morbidity and mortality in some populations (Fowler, 1987; Stewart and Yochem, 1987; Nakajima, 1990; Page et al., 2004). Fishing line and hooks, ropes, or net fragments entangle and wound animals, restricting movement or foraging ability (Laist, 1987; Arnould and Croxall, 1995; Goldstein et al., 1999; Hanni and Pyle, 2000; Tasker et al., 2000; Zabka et al., 2006). In the Northwest Hawaiian Islands, an estimated 52 tons of derelict fishing gear accumulate annually (Dameron et al., 2007) and derelict gear is thought to be the largest anthropogenic threat to the endangered Hawaiian monk seal (Boland and Donohue, 2003): indeed, annual rates of entanglement in fishing gear ranged from 4% to 78% of the total estimated population of 1300 in recent surveys (Donohue and Foley, 2007). In California, nearly 10% of brown pelicans and gull species treated at marine wildlife rehabilitation centers are admitted due to fishing gear entanglement or ingestion injuries (Dau et al., 2009). Reports of derelict fishing gear impacts on marine resources are not limited to mammals and birds: Tanner crabs (Stevens et al., 2000), corals in the Northwestern Hawaiian Islands (Donohue et al., 2001), sponges, corals and other colonial sessile organisms in the Florida keys (Chiappone et al., 2002), and octopus in Japan (Matsuoka et al., 2005) have been shown to suffer significant mortality due

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to entrapment or entanglement in derelict fishing gear. Several studies have been conducted to quantify the impact of derelict fishing gear on marine resources around the world, and models have been developed for predicting total impacts of derelict gear on select resources (Matsuoka et al., 2005).

In order to reduce the threat that derelict fishing gear poses to marine life and underwater habitats, federal and state agencies and organizations are removing significant amounts of derelict fishing gear from marine waters in the United States. In the Northwestern Hawaiian Islands), 579 metric tons of derelict gear have been removed since 1998 through the combined efforts of state and federal agencies. In California, more than 14 tons of fishing gear have been removed since May 2006, including over 1 million feet of fishing line recovered from public fishing piers. And in Washington State over 85 tons of derelict gear, primarily crab pots and gill nets, have been removed from Puget Sound since 2002.

A significant outlay of funds is required for surveys, removal operations, disposal, and reporting of derelict gear. Costs are justified by the direct fiscal benefits of derelict fishing gear removal, which can be conservatively estimated by measuring the value of commercially valuable resources that would otherwise be lost to the fishery due to entanglement or entrapment in derelict fishing gear. Such estimates must take into account the rate of loss of such species in derelict gear, the effective impact lifespan of the gear, and the market value of the species impacted by the gear. Other benefits that are more difficult to measure directly include reducing hazards to non-commercial species, such as protected species, which can be grossly estimated by assigning a contingent valuation based on the comparative cost of benefitting that species via another mitigation method for ameliorating damage to marine wildlife (e.g., oiled wildlife rehabilitation).

To date, a quantitative assessment of the direct impact of derelict fishing gear on marine resources has not been conducted in Puget Sound, WA. Such data, as well as a predictive model that would allow for estimating total mortality of marine life due to derelict gear in Puget Sound, is critical for continuing to garner industry, governmental and public support for derelict fishing gear removal. As well, an assessment of the costs of gear removal relative to the direct fiscal benefits resulting from the removal of hazards to harvestable resources could strengthen the basis for selection of derelict fishing gear removal as a mitigation strategy from among other available mitigation measures.

The objectives of this study were to use data collected from repeated survey dives on derelict nets slated for removal to estimate the daily catch rate of a given derelict gillnet in Puget Sound, and then to develop a model that enables prediction of expected total mortality caused by a given derelict net based on entanglement data collected from the net upon its removal. We also aimed to generate a cost:benefit ratio for derelict gear removal utilizing known true costs compared to known market values of the resources benefiting from removal of the hazard.

2. Methods

2.1. Data collection

Four nets were selected non-randomly from the Washington Department of Fish and Wildlife's derelict fishing gear database (Table 1). Each net had been previously located by sidescan sonar at a depth accessible by standard surface supplied air diving but had not yet been surveyed by divers, and was located in the Northwest Straits region of Puget Sound, for ease of access from our port of embarkation in Anacortes, WA. All four nets were caught on rocky reef or sand/boulder seafloor habitat. To take advantage of optimal ocean conditions for diving, all nets were surveyed in late spring through late summer. One net (#3969) was surveyed five times at 3–14 day intervals over the course of 4 weeks in May–June 2007; two nets (#3957 and 3971) were surveyed three times at 3–4 day intervals over a 1-week period in August 2007; and a fourth net (#4564) was surveyed three times at 3–5 day intervals over a 1-week period in September 2007.

On each survey, two surface supplied air divers, equipped with underwater two-way radios that allowed for communications with project personnel on deck, surveyed each net for 20–45 min, depending upon the size of the net. The same two divers conducted all dive surveys. On the initial dive, divers attached a stainless-steel clip with an individually-numbered plastic tag (13.5 cm disk™, Floy Tag & Mfg Inc., Seattle, WA) to the net next to each entangled animal observed. The diver reported via radio to deck-based personnel the tag number, common name of the entangled animal, and a description of its condition as either FL (fresh live), FD (fresh dead), rotten/partially decomposed (R/PD), bones or shell parts (B/SP) or completely gone (CG) (the latter descriptor used on dives subsequent to the initial). To determine entanglements and decomposition rates for each net, on each subsequent dive the divers followed these same procedures, recording the condition of any previously observed entanglements and marking and describing any new entanglements that had occurred since the previous dive. The presence of predators at or near the entangled animal (e.g., sunflower stars (*Pycnopodia helianthoides*)) was noted. All nets were removed immediately after the final surveys by the divers, who detached the net from the substrate using hand-held cutting instruments, sectioned the net into manageable bundles, and attached lift bags to the bundled sections to raise them to the surface. Removed nets were surveyed again on deck by project personnel, who recorded all entangled species and carcass conditions, noting each identifier number according to the clipped tag.

2.2. Data analysis

Entanglement rates (# of entangled animals/day/net) were calculated by taxa (invertebrates, fish, or birds) by counting the number of animals newly entangled between surveys and dividing by the number of days between observations. Entangled animals

Table 1
Study nets. Locations in Puget Sound, type and dimensions of nets, survey dates, and survey intervals (days since previous dive), SI.

Net identifier	Net #3969	Net #3957	Net #3971	Net #4564
Location (lat/long)	Lopez Island 48°25.00 N 122°50.54 W	San Juan Island 48°27.45 N 123°02.16 W	San Juan Island 48°26.97 N 123°00.28 W	Point Roberts 48°57.53 N 122°58.75 W
Habitat type	Rocky reef	Rocky reef	Boulders/sand	Boulders/sand
Dimension: $L \times W$ (ft)	1000 × 60	300 × 50	1000 × 80	150 × 3
Minimum depth (ft)	52	57	41	33
Initial survey (date)	5/24/07	8/15/07	8/15/07	9/5/07
2nd survey date (SI)	6/8/07 (15.0)	8/18/07 (3)	8/18/07 (3)	9/7/07 (2.2)
3rd survey date (SI)	6/11/07 (3.2)	8/23/07 (5.0)	8/23/07 (5)	9/12/07 (4.8)
4th survey date (SI)	6/15/07 (3.8)	n/a	n/a	n/a
5th survey date (SI)	6/21/07 (6.0)	n/a	n/a	n/a