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Short Note

Pilot Study of Underwater Observations of Interactions Between Harbor Seals, California Sea Lions, and Cormorants with Halibut Trawl Fisheries in Southern California

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In California, growing California sea lion (*Zalophus californianus*) and harbor seal (*Phoca vitulina)* populations (Carretta et al., 2011) contribute to a conflict with fisheries, posing a problem from conservation and management perspectives (Fletcher, 2008; Scordino, 2010; Keledjian & Mesnick, 2013). This conflict affects both fisheries and pinniped welfare. Pinniped depredation incurs direct costs on fisheries from lost fish, time, and resources when gear is broken and pinnipeds have to be untangled from nets (Moore et al., 2009; Scordino, 2010). Depredation also results in pinniped mortality from ingestion of gear, entanglement with fishing lines or nets, and retaliatory actions from fishermen (Read et al., 2005; Moore et al., 2009).

In southern California, the California halibut (*Paralichthys californicus*) fishery occurs in the State-designated California Halibut Trawl Grounds (CHTG) from Point Arguello to Point Mugu (see Figure 1) 16 June through 14 March, and year-round in federal waters (i.e., outside of 3 nmi) (Frimodig et al., 2008). California halibut fisheries in the Santa Barbara area alone landed 42.6 kg in 2013, with a total value of U.S. $491,320 (California Department of Fish and Wildlife [CDFW], 2014).

California sea lions and harbor seals interact with halibut trawl vessels by removing fish from the net, resulting in reduced catches (Bell & Tanaka, 2008). Fishermen report that pinnipeds follow vessels and surround towed nets, and observe a subsequent reduction in the quality and quantity of halibut caught (Bell & Tanaka, 2008). Currently, quantifying depredation relies on onboard observers to document the number of fish damaged by pinnipeds and the presence of entangled pinnipeds. Observer coverage of the California halibut fishery is provided through the West Coast Groundfish Observer Program (National Oceanic and Atmospheric Administration [NOAA], 2012). Given that this fishery is managed by the State of California and is not a high priority for the federal observer program, the observer coverage rate for California halibut trawl vessels in southern California is typically less than 10% (Jannot et al., 2011). Observer data provide some insight into the existence and extent of depredation, but there is little understanding of the underwater behavior of pinnipeds or other species interacting with California trawl fisheries. A more robust understanding of pinniped depredation would assist managers in determining the true catch numbers of California halibut and managing their populations accordingly.

Most studies on marine mammal depredation rely on surface observations rather than viewing the animals underwater (Creamer, 2013). Understanding how pinnipeds locate and interact with trawl nets could help mitigation strategies such as gear changes or deterrents, and could determine whether surface observers are adequately documenting depredation. Herein, we describe a pilot study using underwater video cameras to examine interactions between pinnipeds, coromorants, and halibut trawl nets. These observations represent the first analyzed underwater videos of pinniped interactions with California trawl fishing and provide novel insights into pinniped behavior and depredation.

Study Site and Trawl Nets

Observations were conducted from the *F/V Cecilia*, a 15.2 m trawler. The vessel fished in

Figure 1. A map of the California Halibut Trawl Grounds (CHTG), spanning from Point Arguello to Point Mugu; the location of major harbor seal (*Phoca vitulina*) and California sea lion (*Zalophus californianus*) haulouts are also shown. Haul-out location data are from the National Marine Fisheries Service, *California Pinniped Map* (*ArcGIS*).

various locations between Santa Barbara and Ventura, California, approximately 1.7 to 3.5 nmi offshore. The depth of fishing ranged from 10 to 33 fathoms. Trawling typically occurred from 0800 to 1400 h.

The trawl net had a headrope of 24.3 m and a footrope of 27.4 m (Figure 2). The average speed of trawling was about 2 kts for a 60-min tow. This is a relatively slow trawling speed compared to most bottom trawling fisheries; the purpose of this fishery is to catch live California halibut with the least amount of damage or injury to the fish and a higher survival of bycatch species (Frimodig et al., 2008).

Camera Systems

Two camera systems were used. The first was a Multi-SeaCam 1050 low-light camera (Deep Sea Power and Light) connected to a Micro DVR digital hard drive for video storage. This camera was powered by a 13.2 V 4Ah nickel-metal hydride (NiMH) rechargeable battery pack. The power source and video recording were contained in a titanium metal tube, cabled to the camera which was attached to an aluminum bracket sewn into the webbing of the net or attached with cable ties. This system allowed for an entire day of video data to be collected without the need to change the power supply or video storage device. The camera was always mounted in the primary camera position to face backward from an area in front of the codend. The total cost of this system was U.S. $6,700.

The second camera system used was two GoPro Hero 2 cameras mounted in a TrollPro housing either sewn or cable-tied to the webbing of the net. The primary camera was positioned just behind the place where the codend attaches to the net, facing the end of the net. The secondary camera was attached approximately 7.6 to 9.1 m forward of the primary camera position on the net, always looking forward toward the mouth of the net. Figure 1 shows a diagram of the positions of the camera systems on the net. Six trips were recorded with the Multi-SeaCam, and four trips were recorded with the two GoPros. The camera systems were never used simultaneously. The GoPro cameras only lasted for one tow before the batteries needed to be switched out, and the total cost of the system was U.S. $500. Although the camera systems were different, most notably in the much cheaper cost of the GoPro system, the quality of footage was not different for the purposes of this study.

Analysis of Videos

Each of the 10 fishing trips were composed of two to four separate tows. Footage from the tows was first sorted by amount of light. Footage with enough light to see animals approach the camera was considered "usable footage" and was analyzed

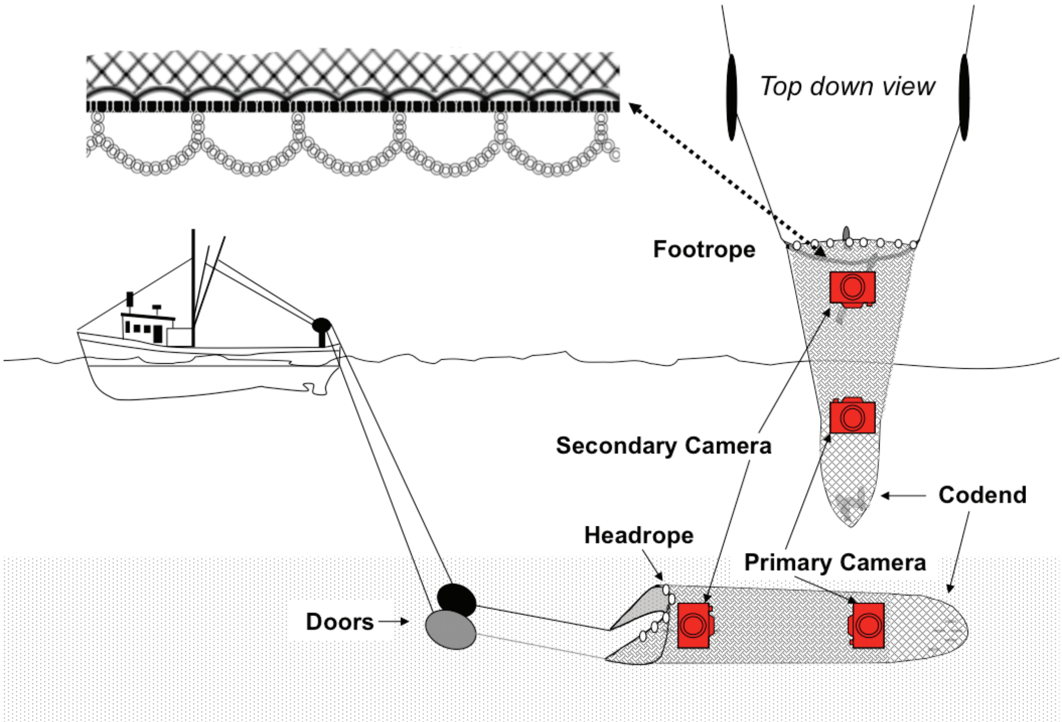

Figure 2. A diagram of camera positions on the southern California halibut (*Paralichthys californicus*) fishery trawl net

for pinniped interactions. Tows had a mixture of usable and unusable footage depending on the depth of the trawl net and whether or not it was contacting the bottom, which decreases visibility by stirring up sediment. An interaction was defined as the presence of a harbor seal or California sea lion in the frame of the video. The presence of cormorants and dolphins was also noted. In addition, the number of individuals present in the frame at any given time was recorded.

Observer Data

National Marine Fisheries Service (NMFS) West Coast Region staff biologists ("observers") were present during trawling to document catch, discards, and bycatch. They recorded the presence or absence of damaged halibut. Observer data were compared to the underwater video data to determine how well the datasets agreed.

Video Coverage

The recording device was used on 10 total fishing trips consisting of 28 individual tows. The total footage retrieved was roughly 16 h with 5.5 h of usable footage.

Interactions

The interaction rate was calculated as the number of tows with interactions divided by the total number of tows. The presence or absence of an interaction in a given tow was considered, not the amount of time over which the interaction took place. Interaction percentages for each species as well as definitions of behavioral categories (depredation, contact, and swimming by) are detailed in Table 1. Notably, the number of depredations is low over all species. Harbor seals and cormorants are responsible for all observed depredation. California sea lions and dolphins were never observed depredating despite the high number of swim-bys for California sea lions. (Representative examples of each harbor seal interaction [contact with net, swimming by, and depredation] are shown in Figure 3.)

Cormorant species were difficult to identify from the footage but were most likely either Brandt's cormorants (*Phalacrocorax penicillatus*) or double-crested cormorants (*Phalacrocorax auritus*) as both species were previously found in California halibut fishing nets (Carretta & Enriquez, 2012). Figure 4 shows an example of a cormorant depredating.

Table 1. Summary of harbor seal (*Phoca vitulina*), California sea lion (*Zalophus californianus*), cormorant, and dolphin interactions with a southern California halibut fishery trawl net (n = instances); the three behaviors observed are swimming by (animal present but not touching net), contact with net (animal touching net with flipper or nose), and depredation (animal removing fish or part of fish from net).

	% of tows observed in	Total interactions	Swimming by (%)	Contact with net (%)	Depredation (%)	Length of interaction (min) (mean ± SD)	# of individuals per interaction (mean ± SD)
Harbor seal	60.7 (n = 17)	135	63.7 (n = 86) in 17 tows	30.4 (n = 41) in 14 tows	5.9 (n = 8) in 5 tows	1.17 ± 0.70, max. of 5	1.08 ± 0.37, range of 1 to 4
California sea lion	14.3 (n = 4)	68	98.5 (n = 67) in 4 tows	1.5 (n = 1) in 1 tow	n = 0	0.86 ± 0.32, max. of 1	1.07 ± 0.30, range of 1 to 3
Cormorant	28.6 (n = 8)	58	81.0 (n = 47) in 8 tows	10.3 (n = 6) in 4 tows	8.6 (n = 5) in 3 tows	0.23 ± 0.18, max. of 0.78	2.00 ± 1.20, range of 1 to 6
Dolphin	3.6 (n = 1)	1	100 (n = 1) in 1 tow	n = 0	n = 0	1.35	6

Dolphin species were also unknown, but they were most likely long-beaked common dolphins (*Delphinus capensis*) as these were the only bycatch species found in California halibut fishing nets (Carretta & Enriquez, 2012). A single pass by a group of six dolphins was observed; they swam past the net without touching it.

NMFS Observer Data

Observer data were recorded for seven out of 10 total trips during which video data were collected. Of those seven trips, damaged halibut due to depredation were observed on five of 27 tows (18.5%). Evidence of damaged halibut is shown in Figure 5.

This pilot study represents one of the few underwater assessments of pinniped–fishery interactions (Shaughnessy & Davenport, 1996; Lyle & Willcox, 2008). Harbor seals interacted with the nets during more than half of the tows (135 interactions in 17/27 tows), with depredation observed in a comparatively small portion of those tows (8 interactions). When interacting with the net, harbor seals were most often observed to be swimming by (86 interactions), most likely searching for easily available prey in the nets. When removal of fish did occur, the harbor seals appeared to remove fish that had some portion of their body sticking out of the net. This suggests that rather than risk putting their head in the net, which may lead to entanglement or entrapment, seals may pursue a strategy that involves swimming around the net until trapped fish slip out of the net or become exposed. This implies that a physical barrier around the net would be effective in reducing harbor seal depredation.

Harbor seals were the most common pinnipeds interacting with the trawl net (66.5% of pinniped interactions), likely because of the fishing grounds' proximity to harbor seal haulouts (Becker et al., 2011). Major haul-out locations include beaches adjacent to the waters fished by the California halibut fishery (National Marine Fisheries Service [NMFS], 2008). Interestingly, no depredations by California sea lions were observed, despite high depredation rates in other fisheries in southern California (Hanan, 1989; Scordino, 2010). Halibut were not observed in studies of California sea lion diet (Lowry, 2011) and are not likely a preferred item, which may explain the low depredation rates. Cormorants accounted for a good proportion of observed depredation (38.5% of interactions). This means that fishermen and observers may attribute too much depredation to pinnipeds when birds are active depredators as well. Unlike harbor seals, cormorants appeared to remove fish from inside the net by placing their head and necks through the mesh. Cormorant depredation on fisheries has not been studied extensively in California (e.g., Trapp et al., 1998). The observed impact of cormorants suggests that the mesh size of physical boundary deterrents must be small enough to prevent cormorant depredation.

Comparison with NMFS Observers

On-board observers recorded damaged California halibut in five of 27 observed tows for which catch data were available. In 14.8% of the total observed tows (n = 4), observers documented damaged halibut, but no depredation was documented by the underwater camera. In four other

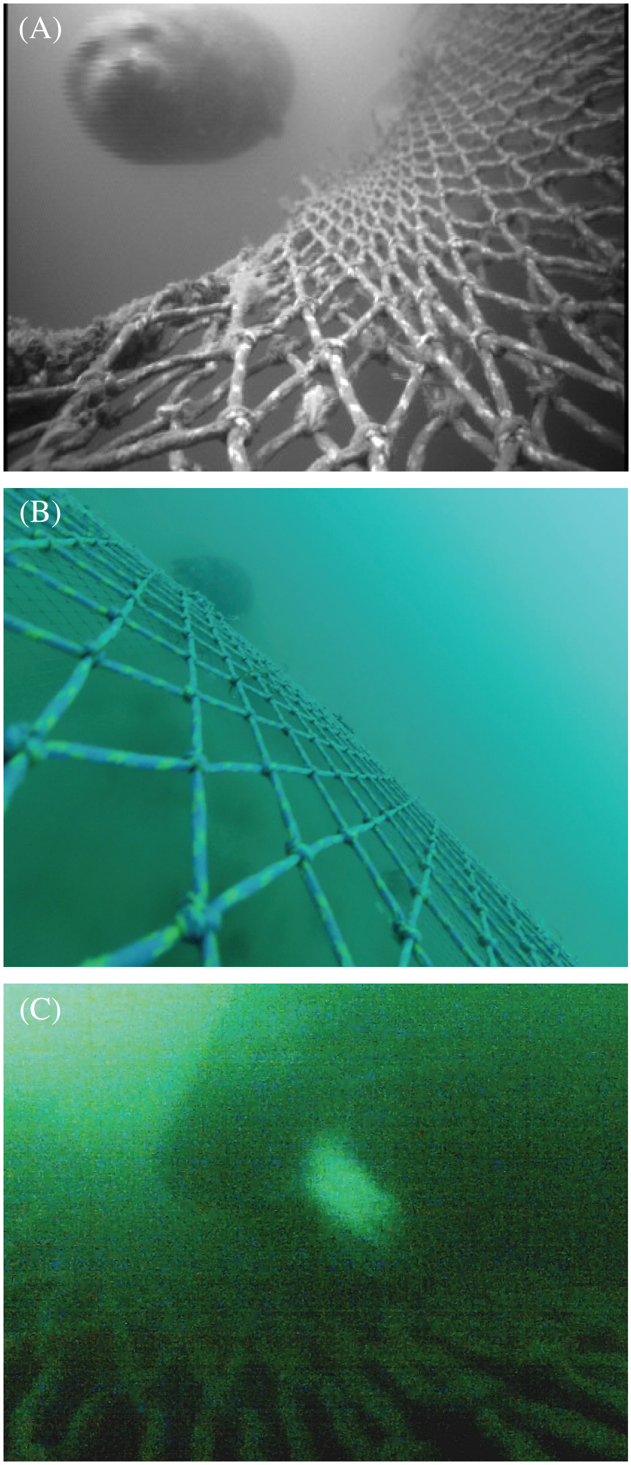

Figure 3. Images of harbor seals during each of the three defined interactions with trawl nets in the southern California halibut trawl fishery: (A) swimming by, (B) contact with net, and (C) depredating (see video link at www.aquaticmammals journal.org/index.php?option=com_content&view=article&id=10&Itemid=147).

Figure 4. A cormorant preparing to depredate out of a trawl net in the southern California halibut trawl fishery (see video link at www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147)

tows, the camera systems captured depredation, but observers did not document it. Depredation may be missed on the video if it occurs outside the field of view or in the unusable footage. Another explanation for the small discrepancy between observers and the camera is that a fish species other than halibut was damaged when depredation was observed. In addition, some depredation involves the complete removal of fish, leaving no damaged fish behind to be counted by observers. On-board recording of damaged halibut appears to be a reasonably reliable source for understanding what kind of depredation is going on under water. Most instances of depredation matched up well with underwater video footage, and the total number of tows with depredation evened out between the underwater video footage and on-board recording.

Limitations

We were unable to identify individual harbor seals and California sea lions. The 135 harbor seal interactions represent sightings, not unique

Figure 5. A damaged California halibut; the gills appear torn, and there is a large gash behind the gills, possibly due to a harbor seal or California sea lion attempting to pull the fish out of a trawl net.

individuals, and many of these are likely resighted individuals. Age or sex class classifications are not possible due to light and distance constraints. At present, there is no reliable way to identify individuals on the underwater camera, so we do not know how many harbor seals or California sea lions are potentially interacting with the trawl fishery. Given the regularity of the observed swimming-by behavior and the slow tow speed, it is likely that some individuals patrolled the net as it was towed and were sighted and resighted many times within a given tow.

The small window of view, even with a two-camera system, is another limitation of underwater filming. The cameras had the best field of view when the net was ascending or descending. Additionally, a majority (65.6%) of the video footage was too dark to see any marine mammal activity. When the net was at the bottom and trawling, the visibility was much lower due to a cloud of sediment created by the net contacting the bottom. This combined with the lack of light at depth means the camera systems almost certainly missed interactions.

Our sample size was small as this was a pilot study, but given the relatively easy application of underwater camera systems to the nets, more extensive studies are underway to evaluate the underwater interactions between pinnipeds and other species with this fishery.

Conclusions

This research offers a new look into pinnipeds' underwater interactions with California trawl nets, which has previously only been observed in dolphins (Broadhurst, 1998; Jaiteh et al., 2013). This footage offers insight into how harbor seals interact with trawl nets. Expansion of underwater videography could help in obtaining baseline information on marine mammal and bird depredation to understand what management efforts should be taken to mitigate loss of catch and reduce bycatch.

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