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False killer whales and fisheries interactions in Hawaiian waters: Evidence for sex bias and variation among populations and social groups

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ABSTRACT

We assessed scarring patterns as evidence of fisheries interactions for three populations of false killer whales in Hawai‘i. Bycatch of the pelagic population in the tuna longline fishery exceeds their Potential Biological Removal level. Scarring was assessed by seven evaluators as consistent, possibly consistent, or not consistent with fisheries interactions, and average scores computed. Scores were highest for scarred main Hawaiian Island (MHI) false killer whales, followed by pelagic and Northwestern Hawaiian Island (NWHI) individuals. Considering only whales for which the majority of evaluators scored scarring as consistent revealed significant differences among populations in the percentage of individuals scarred; MHI: 7.5%, pelagic: 0%, NWHI: 0%. Assessment by social cluster for the MHI population showed that 4.2% of Cluster 1, 7.1% of Cluster 2, and 12.8% of Cluster 3 individuals had such scarring, although differences between clusters were not statistically significant. There was a significant sex bias; all sexed individuals ($n = 7$) with injuries consistent with fisheries interactions were female. The higher proportion of MHI individuals with fisheries-related scarring suggests that fisheries interactions are occurring at a higher rate in this population. The bias towards females suggests that fisheries-related mortality has a disproportionate impact on population dynamics.

Key words: bycatch, injuries, fisheries interactions, fisheries, sex bias, false killer whales, Hawai‘i.

Three discrete populations of false killer whales (*Pseudorca crassidens*) have been designated in Hawaiian waters, a main Hawaiian Islands (MHI) insular population, a Northwestern Hawaiian Islands (NWHI) insular population, and a pelagic population (Chivers *et al*. 2007, 2010; Baird *et al*. 2008, 2010, 2013; Martien *et al*. 2014). For the pelagic population, estimates of mortality and serious injury from interac-

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tions with the Hawaiʻi-based tuna longline fishery exceed the population's Potential Biological Removal (PBR) level (Carretta *et al*. 2014), defined under the U.S. Marine Mammal Protection Act (MMPA) as the maximum number of animals that can be removed from a population while allowing that population to reach or maintain its optimum sustainable population size (Taylor *et al*. 2000). Because of the high levels of bycatch relative to PBR, under the MMPA a Take Reduction Team[2] was established in 2010, and a Take Reduction Plan (TRP), to try to reduce bycatch, was put into place in 2013. The scope of the TRP includes the tuna and swordfish longline fisheries and all three recognized populations of false killer whales in Hawaiian waters.

Presumably bycatch occurs as false killer whales attempt to take the catch or bait off lines, occasionally getting hooked as a result. Observer coverage in the Hawaiʻi-based tuna (~20%) and swordfish (100%) longline fisheries has provided the only information on false killer whale bycatch rates in fisheries in Hawaiian waters (Forney and Kobayashi 2007, Bradford and Forney 2014). These longline fisheries are excluded from operating in near-shore waters around the Hawaiian Islands, and the number of longline vessel licenses is limited. Individuals from the NWHI false killer whale population likely have relatively limited interactions with fisheries. The majority of the range of that population is within waters of the Papahānoumokuākea Marine National Monument (Baird *et al*. 2013), an area where commercial and most recreational fishing activity has been banned since 2009, and prior to that was limited, at least in comparison to the main Hawaiian Islands.[3]

False killer whales also take fish from other commercial and recreational fisheries in Hawaiʻi (Shallenberger 1981, Nitta and Henderson 1993, Oleson *et al*. 2010), most of which operate closer to the main Hawaiian Islands in areas where longline fishing is prohibited. However, there is currently no observer coverage in other fisheries in Hawaiian waters, and historical observer coverage has been limited to some bottomfish fisheries in the Northwestern Hawaiian Islands. Information on movements of satellite tagged individuals from the MHI insular population suggests that, at least for two of the three social groups identified, movements into areas where these individuals could interact with the longline fisheries are infrequent (Baird *et al*. 2010, 2012). However, the range of this population does overlap with waters used by other commercial and recreational fisheries around the main Hawaiian Islands (Oleson *et al*. 2010). The MHI insular population of false killer whale was listed as endangered under the U.S. Endangered Species Act (ESA) in 2012. In the ESA status review for this population, interactions with fisheries was ranked as one of the most important current and future threats for this population, while recognizing that the level of certainty regarding these threats was low (Oleson *et al*. 2010). Fisheries operating around the MHI include troll and handline fisheries, as well as short-line and kaka-line fisheries. These latter two fisheries use similar gear to longlines, but are restricted to mainlines less than one nautical mile in length, with kaka-lines set on or near the bottom or in midwater, while short-lines are set near the surface (Carretta *et al*. 2014).

In Hawaiʻi a State Commercial Marine License (CML), also known as a commercial fishing license,[4] is required for selling catch from fisheries. From 2010 through 2013, the number of CMLs issued each year ranged from 3,711 to 3,916 for participation in

[2]http://www.nmfs.noaa.gov/pr/interactions/trt/falsekillerwhale.htm.

[3]http://coralreef.noaa.gov/education/educators/resourcecd/brochures/resources/nwhi_fisheries_b.pdf.

[4]http://state.hi.us/dlnr/dar/licenses_permits.html.

fisheries in Hawaiian waters.[5] Some of these CMLs are for longline fishing, with 129 vessels actively fishing in the longline fleet in 2012.[6] Assuming that the captain and four crew members all hold CMLs, less than 20% of the total CMLs are issued for longline fishing. Thus, no fewer than 3,000–3,200 CMLs are issued each year for other fisheries in Hawai'i, including the troll, handline, short-line, and kaka-line fisheries. With no observer coverage in these other fisheries, there is a limited basis for assessing their interactions with false killer whales around the main Hawaiian Islands.

In the absence of observer data, the number of live false killer whales with scarring that can be attributed to fisheries interactions may be used as an indicator of the relative frequency of nonfatal fishery interactions for particular species or populations. This approach has been used with a number of species of cetaceans to assess the relative frequency and outcome of fisheries interactions (*e.g.*, Philo *et al.* 1992, Robbins and Mattila 2004, Kiszka *et al.* 2008, Bradford *et al.* 2009). False killer whales hooked on longlines have been observed struggling against the taut line, and Baird and Gorgone (2005) suggested that injuries to the dorsal fin or other appendages may occur as the animals struggle. Such injuries were documented on a dwarf or pygmy sperm whale (*Kogia* sp.) recently hooked in the longline fishery (National Marine Fisheries Service [NMFS] Pacific Islands Regional Office, unpublished data). Baird and Gorgone (2005) assessed photographs taken of false killer whales from the MHI population from 2000 through 2004 for evidence of line injuries on the dorsal fin likely originating from fisheries interactions. These authors found that four individual false killer whales out of a catalog of 80 individuals had scarring consistent with fisheries interactions, and the rate of major dorsal fin disfigurements was more than four times higher than for any of the 13 other populations (of eight different species) evaluated.

Two recent events prompted a reexamination of dorsal fin injuries on false killer whales as an indicator of fisheries interactions in Hawaiian waters. First, under the ESA, NMFS is tasked with developing and implementing recovery plans for threatened or endangered species, and on 2 October 2013, NMFS announced their intent to prepare a recovery plan for the MHI false killer whale population (U.S. Federal Register 2013). An assessment of dorsal fin injuries as an indicator of fisheries interactions may have relevance for recovery planning. Second, on 6 October 2013, a necropsy was undertaken on a false killer whale from the MHI population that had stranded and died at Ka Lae, Hawai'i Island. Although there was no external evidence of interactions with fisheries, upon examination of the stomach contents five fish hooks were recovered, including three J-hooks (two different sizes), a circle hook, and a hook resembling a Japanese tuna hook.[7] Varying states of degradation of the hooks indicate they were likely ingested over a number of months, and hook types and sizes suggest that at least three of the five hooks did not originate from the longline fishery.[7] While histopathology results did not implicate hook ingestion as a cause of death,[7] the number and type of hooks indicate the animal repeatedly interacted with more than one type of fishery, and injury or death during future fishery interactions was plausible given that ingested gear typically leads to mortality (Wells *et al.* 2008).

[5]Personal communication from R. M. Kokubun, Department of Land and Natural Resources, 1151 Punchbowl Street, Honolulu, HI, 7 March 2014.

[6]http://www.pifsc.noaa.gov/library/pubs/DR-13-004.pdf (accessed 9 June 2014).

[7]Personal communication from K. L. West, College of Natural and Computational Sciences, Hawai'i Pacific University, 45-045 Kamehameha Hwy, Kaneohe, HI, 5 March 2014.

Since the Baird and Gorgone (2005) study, the photo-identification catalog of false killer whales from Hawaiian waters has grown to include individuals from all three different populations found in Hawaiian waters (Baird *et al.* 2008, 2013). The availability of photographs from each of these populations allowed us to compare dorsal fin injury rates and thus a measure of fisheries interactions among populations. In addition to comparisons among the three different populations, we assessed differences in evidence for fishery interactions among three distinct social units, termed "clusters," within the MHI insular population (Baird *et al.* 2012). These clusters represent individuals that preferentially associate over long periods of time (Baird *et al.* 2008), and based on genetic analyses represent extended groups of related individuals (Martien *et al.* 2014). Satellite tagging data from two of the three social clusters (Clusters 1 and 3) indicate that, while their ranges largely overlap, each cluster has different high density areas (Baird *et al.* 2012), thus they likely overlap with fisheries to different degrees. In addition, foraging behavior of many species of whales and dolphins is a learned behavior, passed on from mothers to offspring and/or learned within social groups (Sargeant and Mann 2009, Allen *et al.* 2013), thus it is likely that different social clusters may interact with fisheries to varying degrees. Lastly, assuming that the evidence of fisheries interactions from scarring of live animals reflects underlying rates of fisheries interactions for the social groups and populations, we examined evidence for sex-bias in fisheries interactions. A sex bias in fisheries interaction rate may have important implications for the impacts of fisheries-related mortality on population dynamics.

Methods

Photo-identification Catalogs and Association Analyses

Photographs of false killer whales were obtained throughout Hawaiian waters from a variety of sources (Baird *et al.* 2008, 2013). Although photos of individually recognizable false killer whales in Hawai'i are available starting in the mid-1980s, directed photo-identification where efforts were made to photograph all individuals in each encountered group began in 2000 (Baird *et al.* 2008). Photos obtained from 2000 through the end of 2013 were used in our analyses. Photos within encounters were sorted by individual, and each individual was assigned a distinctiveness rating: (1) not distinctive, (2) slightly distinctive, (3) distinctive, (4) very distinctive. Assessment of potential origin of scarring was restricted to distinctive and very distinctive individuals (hereafter referred to as distinctive). The best photo for each individual from each encounter was also graded for quality (see Baird *et al.* 2008). Analyses were undertaken both using photos of all qualities and restricted to those individuals with good or excellent quality photos (hereafter referred to as good quality). Individuals were compared between encounters to generate sighting histories. Population identity (*i.e.*, MHI insular, NWHI insular, pelagic) was assessed on a per group basis, using a variety of types of information. These include sighting history of individuals, mitochondrial haplotypes from genetic samples obtained from some groups (Martien *et al.* 2014), the location where photographs were obtained, the proportion of individuals within an encounter that were already in the catalog, and satellite tag data (Baird *et al.* 2012, 2013). For the MHI insular population, individuals were assigned to a social cluster following the methods outlined in Baird *et al.* (2012). Individuals not assigned to one of the three main social clusters were categorized into one of the three clusters based on proximity within the social network, as network distance between individuals indicates relative association strength.

Assessment of Scarring Patterns

The two primary catalog curators (AMG, SDM) independently chose photos from the catalog for further evaluation if individuals had linear cuts on the dorsal fin or other major disfigurements of the dorsal fin (*e.g.*, missing the fin, bent fin) or the area(s) immediately behind or in front of the fin. For each individual whale chosen by either reviewer, the best left and/or right side photos available were identified for evaluation. If available, photos taken from in front or behind the animal that would allow for assessment of injuries were also included. To account for the uncertainty associated with evaluating the original source of injuries on animals long after the injuries have occurred, seven different individuals independently evaluated the set of photographs. Individual evaluators had particular expertise or experience related to false killer whales, bycatch, and/or fisheries interaction assessments and injury assessments of live and/or dead cetaceans. Evaluators were asked to classify dorsal fin injuries as consistent, possibly consistent, or not consistent with line injuries from fisheries interactions. Individuals undertaking evaluations were: RWB, AMG, and SDM (Cascadia Research Collective), ALB and EMO (Pacific Islands Fisheries Science Center), E. Lyman (Hawaiian Islands Humpback Whale National Marine Sanctuary), and A. J. Read (Duke University). Each of the ratings was converted to a numerical score: 3 (consistent), 2 (possibly consistent), 1 (not consistent). The average score for each individual whale was calculated using all seven numerical scores. The average score of selected individuals by population was compared using a Kruskal-Wallis one-way ANOVA. To assess differences in the proportion of individuals with scarring consistent with fisheries interactions among populations, we considered individual whales with an average score >2.5 to have injuries consistent with fisheries interactions. Individual whales could pass the 2.5 threshold either by having four scores of consistent and three scores of possibly consistent (mean = 2.57), or by having five scores of consistent, one score of possibly consistent, and one score of not consistent (mean = 2.57). Individual whales with scores >2.5 are hereafter referred to as having injuries consistent with fisheries interactions. To evaluate the influence of our choice of >2.5 as a cutoff on our conclusions, we also assessed a cut off of >2.7, equivalent to five of the seven scores of consistent and two scores of possibly consistent. We used the Freeman-Halton extension of the Fisher's exact test (two-tailed) to compare proportions of individuals with fisheries-related scarring among populations, and among social clusters in the MHI population. When possible, we identified the sex of individuals with such scarring through genetic analysis of biopsy samples (Chivers *et al.* 2010) or based on the presence of neonates or small calves in close attendance. Evidence for a sex bias in individuals with scarring consistent with fisheries interactions was assessed with a two-tailed Sign test. Significance levels for all analyses were set at 0.05.

Results

Assessment of Fisheries Related Scarring

The numbers of distinctive individuals in the catalog from 2000 to 2013 by population were: pelagic, 76; NWHI insular, 51; MHI insular, 168. Restricted to only those with good quality photos, the numbers were: pelagic, 53; NWHI insular, 39; MHI insular, 160. For the MHI insular population, the numbers of distinctive individuals by social clusters were: Cluster 1, 76; Cluster 2, 43; Cluster 3, 49, using all photo qualities, or: Cluster 1, 71; Cluster 2, 42; Cluster 3, 47, using only good quality photos. From the total of 295 distinctive individual false killer whales, 19 (6.4%) individuals were chosen by one or both reviewers for evaluation, four from the pelagic population, two from the NWHI insular population, and 13 from the MHI insular population. Good quality photos were only available for one of the four individuals from the pelagic population, neither of the two from the NWHI population, and all 13 from the MHI population. For the 19 individuals chosen, average scores varied by population (Kruskal-Wallis one-way ANOVA, $P = 0.007$), with highest scores for MHI individuals (median = 2.71), followed by pelagic (median = 2.29) and NWHI individuals (median = 2.21). As there was only a single pelagic individual with good quality photos it was not possible to test for differences by population, although the score for the pelagic individual was 2.14, while the lowest score for an individual from the MHI population was 2.43. Of the 19 individuals selected for evaluation, 13 individuals (4.4% of the 295 individuals) had scores >2.5 (mean scores of these 13 ranged from 2.57 to 3.0). The 13 individuals with scores >2.5 included the four individuals noted by Baird and Gorgone (2005), one missing the dorsal fin entirely, two with linear cuts at the leading edge base of the fins with the fins bent completely over, and one with evidence of a leading edge cut on the fin and the fin partially bent over. Of the additional nine individuals, one was missing approximately the top two-thirds of the dorsal fin, and the remaining eight all had leading edge cuts on the dorsal fin, four of which were partially bent over. Examples of individuals with injuries consistent with fisheries interactions are shown in Figure 1.

Using those with an average score of >2.5, the number of individuals with injuries consistent with fisheries interactions by population were: pelagic, 1 (1.3% of the distinctive pelagic individuals); MHI, 12 (7.1% of the distinctive MHI individuals); NWHI, 0 (0% of the distinctive NWHI individuals). Good quality photos were available for 12 of the 13 individuals with average scores >2.5; all 12 were from the MHI population. Considering only individuals with good quality photos, 7.5% (12 of 160) of the distinctive MHI individuals had scores >2.5. The proportion of individuals with injuries consistent with fisheries interactions varied significantly by population, whether considering all distinctive individuals (Fisher's exact test, $P = 0.032$) or restricted only to those with good and excellent quality photos (Fisher's exact test, $P = 0.023$). Eight individuals passed a cut-off of 2.7; all were from the MHI population. Using the 2.7 cut-off, the difference by population was not significant when considering all distinctive individuals (Fisher's exact test, $P = 0.161$) or restricted to those with good and excellent quality photos (Fisher's exact test, $P = 0.053$). Using those with an average score of >2.5 and restricted to individuals with good quality photos, the breakdown by MHI social cluster was: Cluster 1, 3 (4.2%); Cluster 2, 3 (7.1%); Cluster 3, 6 (12.8%). Proportions of individuals with injuries consistent with fisheries interactions did not differ significantly between clusters either using all distinctive individuals (Fisher's exact test, $P = 0.215$) or restricted to those with good and excellent quality photos (Fisher's exact test, $P = 0.236$). Sex was known (based on genetics) for 6 of the 12 MHI insular individuals, and inferred (based on presence of a small calf next to one individual) for a seventh individual. All seven individuals were females and this sex bias was significant, whether considering all seven individuals (Sign test, $P = 0.016$) or only the six where sex was confirmed based on genetics (Sign test, $P = 0.031$). One female from Cluster 2 acquired injuries in two different events. When first documented in 2006, this individual had a linear cut on the leading edge of the fin at the base of the fin. When next documented in

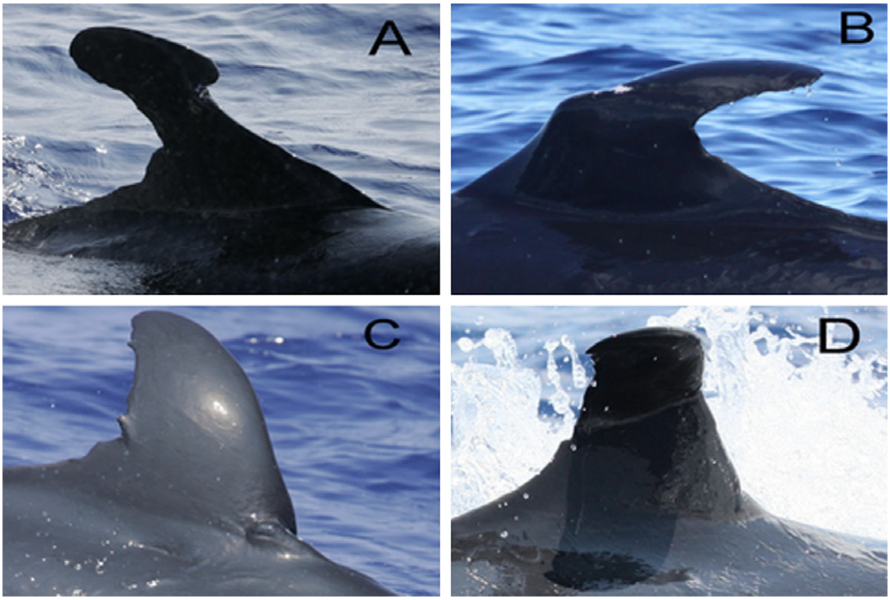

Figure 1. Example photographs of four false killer whales from the main Hawaiian Islands population categorized with fisheries-related injuries. A. HIPc230, an adult female from Cluster 2. B. HIPc299, of unknown sex from Cluster 3. This individual is the same as that shown in figure 7 of Baird (2009). C. HIPc316, an adult female from Cluster 1. D. HIPc398, an adult female from Cluster 2. This individual has two independently-acquired injuries, a cut on the leading edge base of the fin present when the individual was first documented in 2006, and a cut part way through the fin about mid-way up the fin on the leading edge, resulting in partial fin collapse. This injury was present when the individual was next documented in 2010.

2010, this individual had an additional leading edge cut approximately half way up the fin, with the fin partially bent over (Fig. 1). Of the remaining 11 MHI individuals categorized with injuries consistent with fisheries interactions, the first year individuals were documented (in all cases already with scarring) were: pre-2000 (two individuals), 2000 (one individual), 2003 (three individuals), 2004 (two individuals), 2005 (one individual), and 2008 (two individuals).

Discussion

Individual whales can acquire injuries to the dorsal fin from a variety of sources, including inter- and intraspecific interactions, as well as encounters with humans or human activities in contexts other than fisheries, such as vessel strikes. Each source of injury tends to leave specific types of scars, and the scarring patterns observed in our study consistent with injuries from fisheries interactions, *i.e.*, typically single linear injuries on the leading edge of the dorsal fin, often at the base of the fin and parallel to the body axis, are very different than the types of injuries that are well-known to occur from vessel strikes, shark bites, or intraspecific interactions (*e.g.*, McSweeney *et al.* 2007, Kiszka *et al.* 2008, Wells *et al.* 2008, Luksenburg 2014). Our results, combined with the evidence from the stranded false killer whale with five hooks in the stomach,[7] suggest that false killer whales from the MHI insular population are regularly interacting with fisheries. While two of the individuals with scarring consistent with fisheries interactions were first documented prior to 2000, and four others were first documented in the early years of our photo-identification efforts (2000–2003), individuals with such scarring continue to be documented. It should be noted that the false killer whale with five hooks in the stomach had no external evidence of fisheries interactions, thus the scarring documented here should be taken as an indicator of such interactions, rather than representing the absolute proportion of individuals within the population (or social cluster) that survive interactions with fisheries. Our results also indicate the individual rate of interactions, as evident by the proportion of individuals in the population with such injuries, may be greater for individuals from the MHI population (7.1% of distinctive individuals or 7.5% with good quality photos) than for individuals from the pelagic (1.3% of distinctive individuals or 0% with good quality photos) or NWHI (0%) populations. As noted previously, the estimated number of individuals from the pelagic population that are seriously injured or killed exceeds the Potential Biological Removal level for that population (Carretta *et al.* 2014). If the likelihood of serious injury or mortality were similar for different gear types for each interaction when false killer whales depredate catch or bait, the more than five-fold difference in proportion of individuals with such scarring is cause for concern for the MHI insular population. It is possible that the rate of mortality or serious injury is higher from hooking on longline gear than on other gear types, perhaps a reflection of the relatively heavier longline gear. A higher per interaction rate of mortality and serious injury may therefore apply to the pelagic false killer whale population, given the majority of their range overlaps with the offshore longline fishing grounds. Of those false killer whales known to be hooked or entangled in the tuna longline fishery between 2007 and 2011, 83% (20 of 24) were either killed or considered to have serious injuries (Bradford and Forney 2014). The per interaction rate of mortality or serious injury may be less for MHI false killer whales primarily interacting with other fishery types.

The fishery or fisheries likely responsible for the observed scarring is unknown. However, given the relatively infrequent overlap between individuals from the MHI population and longline fishing areas, at least for Clusters 1 and 3 (Baird *et al.* 2010, 2012), it is likely that other sources, such as interactions with nearshore fisheries, account for some proportion of scarring in this population. This is further supported by the hook types found in the stomach of the false killer whale that stranded in October 2013 (identified as a member of Cluster 3), at least three of which were not longline hooks. Although not significant, the three-fold difference in the proportion of individuals with injuries consistent with fisheries interactions between Cluster 1 (4.2%) and Cluster 3 (12.8%) suggests that different social groups interact with fisheries at different rates. This could reflect differences in where the different social groups spend their time and/or that depredation behavior may be culturally acquired within social groups, as are other types of foraging behaviors (Sargeant and Mann 2009, Krützen *et al.* 2014). Satellite tag data are available from 18 different groups of Cluster 1 individuals, but only six different groups of Cluster 3 individuals and no Cluster 2 individuals (Baird *et al.* 2012; RWB, unpublished data). From tag data available through early 2011, Clusters 1 and 3 appear to differ in their high density areas (Baird *et al.* 2012), suggesting they likely differ in terms of their spatial and temporal overlap with nearshore fisheries. Although the sample size for tagged Cluster 3 individuals is much smaller, one of the tagged Cluster 3 individuals did venture outside the longline exclusion boundary around the main Hawaiian Islands (RWB, unpublished data), suggesting that Cluster 3 individuals might overlap with longline fisheries more frequently than Cluster 1 individuals.

While the catalog sizes for NWHI insular (51 distinctive individuals) and pelagic populations (76 individuals) are relatively small, only a single individual from these combined populations (0.8% of the combined NWHI and pelagic cataloged individuals) was categorized as having a dorsal fin injury consistent with fishery interactions using average scores >2.5, in comparison to 7.1% of the MHI individuals. When restricted to good and excellent quality photos, the difference among populations increases, with 7.5% of MHI individuals having scores >2.5%, compared to 0% of pelagic individuals. The same pattern holds when increasing the threshold to >2.7. Using that threshold none of the pelagic individuals, and eight (4.8%) of the MHI individuals had scarring consistent with fisheries interactions, although this difference was not statistically significant. However, photographic sampling of both the NWHI population and the pelagic population is limited in relation to the estimated abundance of these populations. Thus, the sample of photo-identified individuals in the pelagic and NWHI populations may not be large enough to accurately or representatively reflect the proportion of individuals with injuries consistent with fisheries interactions. Bradford *et al.* (2014) provided abundance estimates for the Hawai'i pelagic population and NWHI insular populations as 1,552 (CV = 0.66) and 552 (CV = 1.09) individuals, respectively, so our existing catalog for these populations, including only good quality photos, represents only approximately 3.4% of the pelagic individuals and 7.1% of the NWHI individuals. Two recent abundance estimates for the MHI insular population, both for the 2006 to 2009 period, were 151 (CV = 0.20) and 170 (CV = 0.21) individuals (Oleson *et al.* 2010). During that period 102 distinctive individuals were documented, all with good quality photos, thus the catalog likely represents from approximately 59% to 67% of the MHI individuals.

While we did not find significant differences among MHI social clusters in the proportions of individuals with dorsal fin injuries consistent with fisheries interactions, the proportion of Cluster 3 individuals with such scarring was more than three times higher than for Cluster 1 individuals. We postulate that these types of dorsal fin injuries occur as a secondary process reflecting an individual being hooked in the mouth and struggling against a line. Thus, analysis of injuries visible externally on the mouth line (gape) of individuals may be more powerful for detecting differences among social clusters, since individuals that ingest hooks or are hooked in the mouth or in the lip may be more likely to show evidence of such hooking by injuries on the gape than on the dorsal fin. Such analyses are currently underway, although existing sample sizes of head photographs is limited, and additional field efforts will be needed to increase the sample size of head photographs of all three social clusters. Regardless, the potential for fishery interaction rates to vary among social clusters in the MHI insular population suggests that interaction rates may vary by social group within the pelagic and NWHI populations. However, the current representation of social groups within the pelagic and NWHI populations is insufficient to evaluate this variation.

Powell and Wells (2011) noted that, for common bottlenose dolphins (*Tursiops truncatus*) in Florida, it was primarily adult males that were interacting with recreational fisheries, although for stranded dolphins which were known to have ingested fishing gear, there were similar numbers of males and females (Wells *et al.* 2008). For fish-eating killer whales (*Orcinus orca*) in Alaska involved in longline depredation, Matkin *et al.* (2008) noted that of the 13 individuals of known sex with bullet wounds, 10 of the 13 were females. Our results indicate a significant bias towards females with injuries consistent with fisheries interactions. There are several possible explanations for this bias. Females may be involved in depredation at higher rates than males, reflecting either the higher energy needs of females during lactation and/or the importance of prey sharing among females (see *e.g.*, Ford and Ellis 2006). Conversely, it is possible that male false killer whale interactions with fisheries are more likely to be lethal. Males are, on average, larger and heavier than females (Ferreira *et al*. 2014), and thus might have a greater likelihood of breaking lines when hooked, and trailing gear may impede feeding or locomotion. However, if females are interacting with fisheries at a higher rate, then fisheries-related mortality may have a disproportionate influence on population dynamics, influencing the rate of growth, and thus potential recovery, of the population to a greater extent than if fisheries-related mortality rates were equal for both sexes or were biased towards males. A female-bias in fisheries interactions may influence population dynamics in two ways. If fisheries-related mortality of females is higher than males, this will reduce the potential population growth rate to a greater extent than if fisheries-related mortality was unbiased in relation to sex or biased towards males. In addition, if a female involved in a fatal fisheries interaction has a dependent calf, it is probable the calf will not survive, thus effectively resulting in two deaths.

Combined these results suggest that recovery planning for the MHI population under the U.S. Endangered Species Act should account for the social structure of the population and the potential for impacts from human activities acting disproportionately on certain social groups. Such an approach has been taken with one other population listed under the ESA, southern resident killer whales (National Marine Fisheries Service 2008). Our results also suggest that examining overlap with fisheries as well as estimating abundance and monitoring trends should be undertaken on a cluster-specific basis. Given the relatively high proportion of Cluster 2 individuals with fisheries-related scarring (7.1%), obtaining movement data from satellite tag deployments on individuals from this social cluster is needed to assess whether this group regularly moves far enough offshore to interact with the longline fishery, and determine with what nearshore fisheries it is most likely to interact. Similarly, additional satellite data are needed on groups of Cluster 3 individuals, given the relatively small sample size available for that social group and the high proportion of individuals with injuries consistent with fisheries interactions. Furthermore, our results, combined with the evidence from the stranded individual with a variety of hooks in the stomach, suggest there is a need to broaden the scope of the Take Reduction Plan, which currently focuses only on the longline fisheries, to include nearshore fisheries.

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