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**Preliminary findings: Anthropogenic and killer whale (Orcinus orca) scarring on Pacific Coast Feeding Group gray whales (Eschrichtius robustus) in northwest Washington**

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# Preliminary findings: Anthropogenic and killer whale (*Orcinus orca*) scarring on Pacific Coast Feeding Group gray whales (*Eschrichtius robustus*) in northwest Washington

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**Abstract**

Gray whales face many threats to their survival that are multi-faceted and difficult to document. In this study, we evaluate scarring of Pacific Coast Feeding Group gray whales photographed during 2014–2020 off northwest Washington to document the occurrence of scarring from vessel strikes, entanglements, and killer whale attacks. We found that of the 139 PCFG whales evaluated, 11.5% had scarring from entanglements, 5.0% had scarring from vessel strikes, and 21.6% had scarring from killer whale attacks. We found no difference in scarring rates between males and females. Our observed rates of scarring from entanglements were less than previously observed at Sakhalin Island while our scarring rates from vessel strikes were slightly greater, but the differences were not statistically significant. Gray whales observed at Sakhalin Island had a significantly higher frequency of having scars due to killer whale attacks than the PCFG whales assessed in this study. Our estimates of anthropogenic and killer whale scarring are likely biased low because we had poor photographic coverage of the posterior caudal peduncle and tail region where scarring from killer whale attacks and entanglements are most commonly observed. Our methods were similar to past studies at Sakhalin Island, suggesting the studies had similar biases. Our finding of no significant differences in anthropogenic scarring between PCFG whales and Sakhalin Island whales can be used to evaluate if current models of gray whale threats from anthropogenic sources for the two groups are presenting plausible mortality estimates.

## Introduction

Gray whales (*Eschrichtius robustus*), once spanning most of the northern hemisphere, were exploited to extinction in the Atlantic Ocean and near extinction in the Pacific Ocean by unsustainable commercial whaling activities (Anthony, 1921; Rice & Wolman, 1971; Mead & Mitchell, 1984). Following the cessation of commercial whaling, gray whales of the Eastern North Pacific (ENP) rapidly increased in abundance and currently have a population that fluctuates near its carrying capacity (Punt & Wade, 2012; Eguchi, Lang & Weller, 2022). The abundance of gray whales that utilize the Western North Pacific (WNP) were severely depressed by commercial whaling and many thought that the population was extinct (Nishiwaki & Kasuya, 1970; Bowen, 1974). Currently, there is debate about whether the whales that feed in the summer around Sakhalin Island and the Kamchatka Peninsula are an extant population of WNP gray whales or a newly established feeding group of ENP gray whales (International Whaling Commission, 2018). Cooke et al. (2019) show that the small population of whales that feed around Sakhalin Island and the Kamchatka Peninsula is increasing in abundance with an estimated rate of increase of 4.1% per year.

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Although gray whale populations have recovered (ENP), or are showing signs of recovery (WNP), it is still important to understand sources of mortality for these populations to improve current management practices (International Whaling Commission, 2018, 2020). Both the ENP and WNP experience injuries and mortalities from anthropogenic sources, the most notable of which are vessel collisions and entanglements in fishing gear (Oldach et al., 2022). Over the past five years, an average of 14.3 whale mortalities a year occurred due to non-hunting anthropogenic sources (Scordino et al., 2023) and the study likely underreport the total number of whales that die from these anthropogenic sources (Williams et al., 2011; Rockwood et al., 2017; International Whaling Commission, 2020a)). The high occurrence of ship strikes and entanglements in gray whales is likely due to the overlap between gray whale foraging areas and migratory routes with fishing and shipping activities (Saez et al., 2013; Lowry et al., 2018; Silber et al., 2021).

Gray whales also face natural threats. The greatest threat to gray whale abundance and health appears to be environmental factors that affect the distribution and abundance of gray whale prey that may cause large-scale mortality events (Le Boeuf et al., 2000; Moore et al., 2022). A lesser threat, but still of importance, is the role of killer whale (*Orcinus orca*) predation (Goley & Straley, 1994; Barrett-Lennard et al., 2011; Matkin & Durban, 2013; Weller et al., 2018). There are two geographic areas known to be hotspots of killer whale predation on gray whales including Monterey Bay, California (Goley & Straley, 1994) and the False Pass/Unimak Pass region of Alaska (Barrett-Lennard et al., 2011). There are also a number of observations of killer whale predation of gray whales outside of those two hotspots (Andrews, 1914; Burrage, 1964; Morejohn, 1968; Baldridge, 1972; Fauquier et al., 2022). Killer whale predation is a natural source of gray whale injury and mortality, and understanding the magnitude of this threat will better inform our understanding of gray whale population dynamics.

While observing and quantifying environmental threats to gray whales is complex, entanglement, vessel strikes, and killer whale predation each leave distinct scar patterns that can be analyzed for both non-lethal and lethal interactions. Previous studies have documented the frequency and types of scars on gray whales feeding at Sakhalin Island (Bradford et al., 2009; Weller et al., 2018). This paper sought to replicate their methods for another important feeding group of gray whales, the Pacific Coast Feeding Group (PCFG). The PCFG is a group of ENP gray whales that show multiyear fidelity to the Pacific coast of the United States and Canada from 41°N to 52°N during the feeding season of June–November (Calambokidis et al., 2002; International Whaling Commission, 2011). The PCFG range has well established stranding networks that document the cause of gray whale mortalities in addition to having regulations in the US and Canada that require mariners and fishers to report vessel strikes and fishery interactions (Saez et al., 2020; Scordino et al., 2020). In contrast, there is little in the way of stranding response at Sakhalin Island and the Kamchatka Peninsula making it likely that anthropogenic mortality sources are more underreported at these sites than for PCFG whales (Lowry et al., 2018). Comparing the anthropogenic scarring of Sakhalin Island whales and PCFG whales provides a means to evaluate if modeling efforts, such as the International Whaling Commission's Rangewide Review of Gray Whale Stock Structure and Status (International Whaling Commission, 2018), utilize plausible estimates of mortalities due to anthropogenic sources for both Sakhalin Island and PCFG gray whales.

We had two objectives in this study. Our first objective was to characterize the frequency and types of anthropogenic threats to PCFG gray whales and document the frequency of killer whale attacks by evaluating the scarring on live whales observed in northwest Washington. Male and female gray whales have differences in migratory pathways and timing (Rice & Wolman, 1971; Herzing & Mate, 1984) which may lead to differences in exposure to anthropogenic activities. Likewise, killer whales are reported to target cow-calf pairs (Matkin & Durban, 2013) which may result in females being attacked more often than males. To help improve our understanding of these threats to PCFG whales and potential effects on population dynamics, we tested if males and females have differences in scarring rates due to killer whale attacks and anthropogenic sources. Our second objective was to compare the rates of anthropogenic and killer whale scarring of PCFG gray whales to previously published results of scar assessments from gray whales at Sakhalin Island (Bradford et al., 2009; Weller et al., 2018). We hypothesize that we will observe more anthropogenic scarring of PCFG whales due to a large number of fisheries in the PCFG range and due to the presence of many busy ports. We also hypothesize that PCFG whales will have less killer whale scarring because the PCFG whales pass fewer locations with known high rates of killer whales hunting gray whales than do Sakhalin whales, which complete a much longer migration. Addressing the two objectives for this study will contribute to the overall goal to provide a better understanding of the threats to PCFG gray whales and inform modeling efforts for both Sakhalin Island and PCFG gray whales.

**Methods**

Small vessel surveys were conducted within the Makah Tribe's usual and accustomed (U&A) fishing grounds and adjacent waters to photograph gray whales (*Eschrichtius robustus*) and document their distribution and abundance. The research area lies at the northwest tip of Washington State, USA, which is bordered by the Strait of Juan de Fuca to the north and the Pacific Ocean to the west (Fig. 1). Survey efforts for the entire region were divided into two geographic areas. One survey area occurred within the Strait of Juan de Fuca from Neah Bay east to Sekiu Point. The second survey area follows the shoreline of the Strait of Juan de Fuca west to Cape Flattery and then south along the Pacific Ocean coast to Sea Lion Rock (Scordino et al., 2017). Surveys are generally conducted within 1 to 2 kilometers of shore during the gray whale feeding season.

Using SLR digital cameras with high powered lenses, photos were taken of as much of the full side of each whale as possible during each surfacing event with an emphasis on photographing the dorsal hump region for photo-identification. Photos were submitted to Cascadia Research Collective for comparison to their catalog of gray whales following methods previously described (see Calambokidis et al., 2002). Whale catalog numbers were provided by Cascadia Research Collective and used to create a catalog of PCFG whales photographed in the study region during the summer and fall (June–November) during 2014–2020.

Following the methods of Bradford et al. (2009) and Weller et al. (2018) for scar analyses on gray whales photographed off Sakhalin Island, Russia, this study used photo analysis to determine the body region and source of anthropogenic and killer whale scars for PCFG whales. Assigned body regions spanning the entire whale were based on those used in Bradford et al. (2009) with additional regions separating the posterior caudal peduncle into left and right sides (Fig. 2) as this is a common area for entanglements for large whales and is a focal region for other scar analyses (Robbins & Mattila, 2001; Robbins & Mattila, 2004). A gray whale sighting was defined as at least one photograph of an individual whale during a survey, with sufficient quality to identify the given whale and assess any scarring present. For each gray whale sighting, the visibility and sources of scars were recorded for each of the 23 designated body regions (Fig. 2). The visibility classifications were categorized as full visibility, partial visibility, and no visibility/poor quality. To be categorized as visible, a body region (full or partial) had to be captured in photographs of sufficient quality to detect and identify a potential scar. Scars were identified and assigned to the following source categories: entanglement, vessel strike, tagging scar, killer whale rake, and unknown (example photos Fig. 3). Note that scar sources were analyzed for their presence or absence rather than their frequency in each body region. However, multiple scar sources could be assigned to the same body region. Scar classifications were based on similar studies that assessed anthropogenic and natural scar sources for other marine mammals (Robbins & Mattila, 2004; Rommel et al., 2007; Norman et al., 2017; Basran et al., 2019; Silber et al., 2021). A subset of scars classified as 'unknown' were assigned to one of the source categories with low confidence by the evaluators. While these photos are not included in the present analysis, they are currently being shared with expert collaborators for further evaluation. Scarring was analyzed independently by three evaluators. After scoring independently, the team met together and formed consensus on scar determinations. These evaluations of scar sources were then used to analyze the proportion of whales with scars from each source and the affected body regions, differences in scarring by sex, and scar rates between the PCFG and Sakhalin Island gray whales.

*Data Analysis*

Scar and visibility assessments for the 23 body regions from each gray whale sighting were compiled into a composite score for each whale. This composite encompassed the presence or absence of each scar source from all sightings of the whale as well as the greatest visibility assignment for each body region during the study period. This analysis represented each whale (n=139) for evaluating PCFG scarring dynamics.

We used Chi-squared tests of independence to compare the frequency of males and female PCFG whales having scars due to entanglement and killer whale predation. We used a Fisher's exact test to compare the frequency that males and females have scars due to vessel strikes. We also used Chi-squared tests of independence to compare the frequency that PCFG whales had scars due to entanglements and killer whale attacks as compared to scarring rates of Sakhalin Island whales published by Bradford et al. (2009) and Weller et al. (2018). We used a Fisher's exact test to compare the frequency of vessel strike scarring for PCFG and Sakhalin Island whales.

## Results

*Scar Assessment of PCFG whales*

During this seven-year study period, 197 gray whale surveys were conducted, resulting in photo identification of 139 individual PCFG gray whales from 774 total sightings. Each gray whale was photographed during a median of 3 sightings (range 1–28). Of the 139 whales, 52 were female, 42 were male, and 45 were of unknown sex based on past studies of gray whale genetics (Lang et al., 2014; Scordino, Jacobsen & Lang, 2019).

Photographic coverage and visibility of each of the 23 outlined body regions (BR) (Fig. 2) varied, with the areas used for photo identification (BR5, BR6, BR7L, BR7R, BR8, and BR9) observed and documented most frequently (Fig. 4). These body regions were most commonly assigned partial visibility, with the ventral portion of body regions 5, 6, 8, and 9 exposed only in the rare occurrences of breaches. Body regions 3 and 4 were least visible, with each region fully or partially visible in 5.0% (n=7) of the PCFG whales photographed in this study.

During 2014–2020, 23 (16.6%; 6 males, 10 females, and 7 unknown sex) PCFG gray whales had evidence of anthropogenic scarring from either a vessel strike or an entanglement out of the 139 whales in this study. Of these, 16 whales (11.5%; 3 males, 7 females, and 6 unknown sex) had evidence of entanglement wounds and seven whales (5.0%; 3 males, 3 females, and 1 unknown sex) had evidence of a vessel strike. Scarring from killer whale attacks was observed in 30 whales (21.6%; 7 males, 12 females, and 11 unknown). Five whales (3.6%; 2 males, 2 females, and 1 unknown sex) had evidence of scars from both entanglements and killer whale attacks (Fig. 5). Chi-squared tests of independence and Fisher's exact tests showed no significant differences in the number of individuals scarred between males and females for entanglements, vessel strikes, and killer whale predation.

Our ability to detect the presence of scars within a certain body region for each whale was influenced by the visibility of that region. Table 1 and Figure 6 present the frequency that whales were scarred in each body region. For entanglements, BR10 (21.1%, n = 12) and BR11 (16.9%, n = 10) — the caudal peduncle region — were the regions where entanglement scars were observed on the greatest proportion of whales. Vessel strikes were most often documented in the thoracic region, within BR5 (2.2%, n = 3) and BR6 (3.6%, n = 5). Evidence of killer whale scars was most often observed on the corners of the fluke in BR12 (33.8%, n = 22) and BR14 (16.9%, n = 11).

Anthropogenic scarring was also present from past research activities. Satellite tagging scars were only identified in the thoracic region and were more commonly observed on the right side of the whales in BR6 (5.8%, n = 8) than the left side in BR5 (0.7%, n = 1) (Table 1).

*Comparison of scarring rates of PCFG and Sakhalin Island whales*

We compared the anthropogenic and killer whale scar occurrences in PCFG gray whales off northwest Washington to gray whales studied at Sakhalin Island. Comparing the scar rates of PCFG and Sakhalin gray whales based on the results of Bradford et al. (2009) and Weller et al. (2018) showed that Sakhalin gray whales had scar-based evidence of entanglement and killer whale interactions more frequently than PCFG gray whales, but less frequently for vessel strikes. Chi-squared tests of independence and Fisher's exact tests showed that there were no significant differences between the presence of either entanglement or vessel strike scars for PCFG and Sakhalin gray whales. There was, however, a significant difference for the frequency of killer whale scars between PCFG and Sakhalin gray whales, ($X^2$ = 15.8, df = 1, p < .001), with Sakhalin gray whales being 2.8 times as likely to have killer whale scars.

## Discussion

*Scar Assessment of PCFG whales*

During this study we found that a large portion of PCFG whales observed in northwest Washington have scars from anthropogenic sources. This finding is important because past research has shown that injuries due to anthropogenic sources can reduce whale survivorship and potentially fecundity, especially if the injury is severe (Knowlton et al., 2022). We were not surprised to observe anthropogenic scarring because gray whales overlap spatially and temporally with many different fisheries on the West Coast during their migration, and much of that migration takes them through coastal waters that are easily accessible to a range of human activity (Saez et al., 2013). Most of the whales observed with anthropogenic scarring had evidence of a past entanglement and only a small proportion had scars due to vessel strikes. Many of the entanglement scars we observed created very narrow scars that may have been due to entanglement in recreational fishing gear (Fig. 3). Gray whales in northwest Washington are typically observed between 5 and 15 m of water near kelp beds (Scordino et al., 2017), which is an area also frequently used by recreational anglers fishing for rockfish (*Sebastes sp.)* and lingcod (*Ophiodon elongatus*) (Beaudreau & Whitney, 2016).

We examined our data for differences in anthropogenic scarring by sex and did not find any significant differences. Despite not being significant, females were observed with scars from entanglements more often than males. This observation could be due to differences in migration patterns between independent whales whose typical northbound migration is further from shore than it is for females with calves, who typically migrate closer to shore (Herzing & Mate, 1984).

We observed killer whale scarring on 22.0% of the PCFG whales. A priori, we hypothesized that we would see more scarring on females than males because killer whales are known to target mother-calf pairs (Matkin & Durban, 2013). As a result, we would expect males to accumulate scars mostly from interactions while a calf and that females would accumulate scars both while a calf and as an adult while trying to protect their young during interactions with killer whales. Although we observed a larger proportion of PCFG females with evidence of killer whale attacks, the difference was not significant.

Our observed rates of scarring due to vessel strikes, entanglements, and killer whale attacks were likely biased lower than the true rates due to the limitations associated with photography from a small vessel. Previous studies have found that entanglement scars are best documented in photographs of the posterior region of the peduncle and on the leading edge of the tail (Robbins & Mattila, 2001; Neilson et al., 2009; Basran et al., 2019). PCFG gray whales in northwest Washington feed in shallow water (Scordino et al., 2017) and do not fluke often, resulting infrequent documentation of the posterior caudal peduncle (our BR10 and BR11). Ramp et al. (2021) compared drone imagery to boat based assessment of scarring and found that boat based surveys under report scarring especially for species like gray whales that rarely lift their fluke above the water while diving. If we restricted our analysis of entanglements to just the caudal peduncle region, as done in other studies (Robbins & Mattila, 2001; Neilson et al., 2009; Basran et al., 2019), we would have reported a much higher rate of entanglement scarring of around 20%. Likewise, scars from killer whale attacks are most frequently observed on the fluke and less often on the pectoral fins (Rice & Wolman, 1971) and these regions were infrequently observed during our study. Corsi et al. (2022) evaluated killer whale scarring of gray whales and only included gray whales in their analysis if they had photographs of the whale's tail and reported that 42% of PCFG whales had scarring from killer whale attacks. Interestingly, despite not having full visual coverage of the gray whales we assessed, our finding of 22% of the whales being scarred by killer whales was greater than the 18% Rice and Wolman (1971) reported for gray whales they examined on board whaling vessels during scientific whaling in the 1960s while they could examine the full body of each whale.

Curiously, we found that eight of the nine satellite tag scars on gray whales were observed on the whale's right side. No preference was given during tagging on which side to approach to tag during the Lagerquist et al. (2019) study (Irvine and Lagerquist pers. comm.) suggesting that approaches on the right side were more successful. Makah whalers used to prefer approaching gray whales from the right side of their body (Waterman, 1920). It is possible that if gray whales typically feed on their right side (Kasuya & Rice, 1970) that they may damage the sensory organs (i.e., the eye) on that side of their head, making it easier for researchers or hunters to approach the whale from its right side. Alternatively, the observed success of tagging on the right side of the body and ethnographic record on whaling (Waterman, 1920) may be due to the swimming pattern of gray whales making their right side more vulnerable (i.e., if a whale more frequently turns counter-clockwise when turning at the surface).

*Comparison of scarring rates of PCFG and Sakhalin Island whales*

An objective of this study was to compare scarring rates of PCFG whales with whales observed at Sakhalin Island. Sakhalin Island whales more frequently bore scars due to entanglement than did PCFG whales, but the difference was statistically insignificant. Sakhalin Island gray whales had a significantly higher rate of scarring from killer whales than did PCFG whales. Some, if not all, of the whales feeding at Sakhalin Island migrate to and from wintering grounds in Baja California past known hot spots for killer whales hunting gray whales at Monterrey Bay, California (Goley & Straley, 1994) and around Unimak Island, Alaska (Barrett-Lennard et al., 2011) whereas PCFG whales are likely to only migrate past the Monterrey Bay hotspot. Andrews (1914) documented many occurrences of killer whales attacking gray whales during his studies in Korea suggesting that gray whales migrating south from Sakhalin Island may also encounter high interaction rates with killer whales.

The IWC conducted a Rangewide Review of Stock Structure and Status of Gray Whales from 2014–2018 (International Whaling Commission, 2018). The structure of the model from this review was subsequently used for the *Implementation Review* of aboriginal subsistence whaling on gray whales (International Whaling Commission, 2018, 2020). The model incorporated all known sources of anthropogenic mortality based on stranding records and self-reports of fishers and mariners (Scordino et al., 2020). The model was affected by the collection of data on anthropogenic mortality by area with the best reporting along the US and Canadian west coasts where stranding networks are well funded. If we assume that mortalities of gray whales due to entanglements and vessel strikes are proportional to the frequency that whales receive visible scars from anthropogenic sources, then we can make important inferences about mortality rates from anthropogenic sources for Sakhalin Island whales. We found no statistical difference in the proportion of PCFG gray whales with anthropogenic scarring from gray whales at Sakhalin Island after implementing similar methods between the two study regions for analyzing scars based on body region and source. Thus, results from this study can be used to defend using observed rates of mortalities of PCFG whales due to vessel strikes and entanglements as a best estimate for anthropogenic mortality rates of Sakhalin Island whales.

*Next steps*

Over the next couple of months, our photographs of whale scars will be reviewed by three experts on whale injury and scarring: Dr. Amanda Bradford, Dr. Raphaela Stimmelmayr, and Dr. Stephanie Norman. The experts will review our determinations of scars that originated from an entanglement, vessel strike, or killer whale attack. The experts will also review scars that we classified as unknown initially, but have flagged for them as potentially due to entanglement, ship strike, or killer whale attack. This will assist in evaluating if the photographs show enough evidence to include them as known sources in our final analysis. We plan to analyze the remaining unknown scars to inform current understandings of gray whale behavior. Additional plans include analyses on the differences in scarring of individuals by age and to evaluate the inter-annual scar accrual rate for PCFG gray whales photographed off northwest Washington.

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**Tables and Figures**

**Table 1.** Number of whales scarred out of those with visibility for a particular body region, expressed as a percent for each scar source, reported by body region for PCFG gray whales photographed off northwest Washington during 2014–2020 (n=139).

| Body Region | Entanglement | Vessel Strike | Killer Whale | Unknown | Tag |
|---|---|---|---|---|---|
| 1 | 1.7% | 0.8% | 0.0% | 10.9% | 0.0% |
| 2 | 0.9% | 0.0% | 0.0% | 12.9% | 0.0% |
| 3 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 4 | 0.0% | 0.0% | 0.0% | 28.6% | 0.0% |
| 5 | 0.0% | 2.2% | 3.0% | 31.3% | 0.7% |
| 6 | 1.4% | 3.6% | 2.2% | 38.4% | 5.8% |
| 7L | 1.5% | 0.7% | 4.5% | 13.4% | 0.0% |
| 7R | 0.7% | 0.7% | 5.1% | 9.5% | 0.0% |
| 8 | 0.0% | 1.5% | 0.7% | 7.5% | 0.0% |
| 9 | 0.0% | 1.5% | 0.7% | 7.4% | 0.0% |
| 10 | 21.1% | 0.0% | 0.0% | 5.3% | 0.0% |
| 11 | 16.9% | 0.0% | 0.0% | 11.9% | 0.0% |
| 12 | 0.0% | 0.0% | 33.8% | 12.3% | 0.0% |
| 13 | 1.7% | 0.0% | 0.0% | 1.7% | 0.0% |
| 14 | 0.0% | 0.0% | 16.9% | 7.7% | 0.0% |
| 15 | 9.0% | 0.0% | 1.5% | 7.5% | 0.0% |
| 16 | 4.6% | 0.0% | 4.6% | 10.8% | 0.0% |
| 17 | 0.0% | 0.0% | 18.8% | 9.4% | 0.0% |
| 18 | 0.0% | 0.0% | 14.3% | 7.9% | 0.0% |
| 19 | 1.6% | 0.0% | 0.0% | 8.2% | 0.0% |
| 20 | 1.8% | 0.0% | 9.1% | 10.9% | 0.0% |
| 21 | 3.3% | 0.0% | 3.3% | 21.7% | 0.0% |
| 22 | 3.7% | 0.0% | 5.6% | 25.9% | 0.0% |

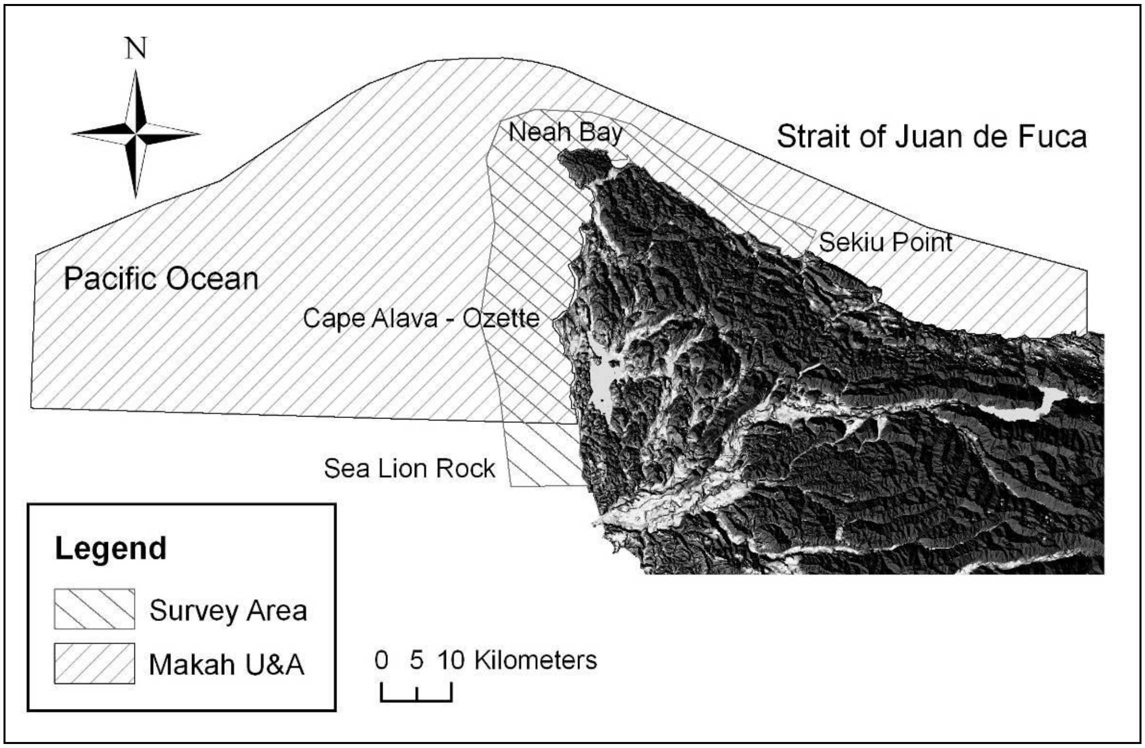


**Figure 1.** Map of the survey area of northwest Washington overlaid with the adjudicated usual and accustomed (U&A) fishing area of the Makah Tribe.

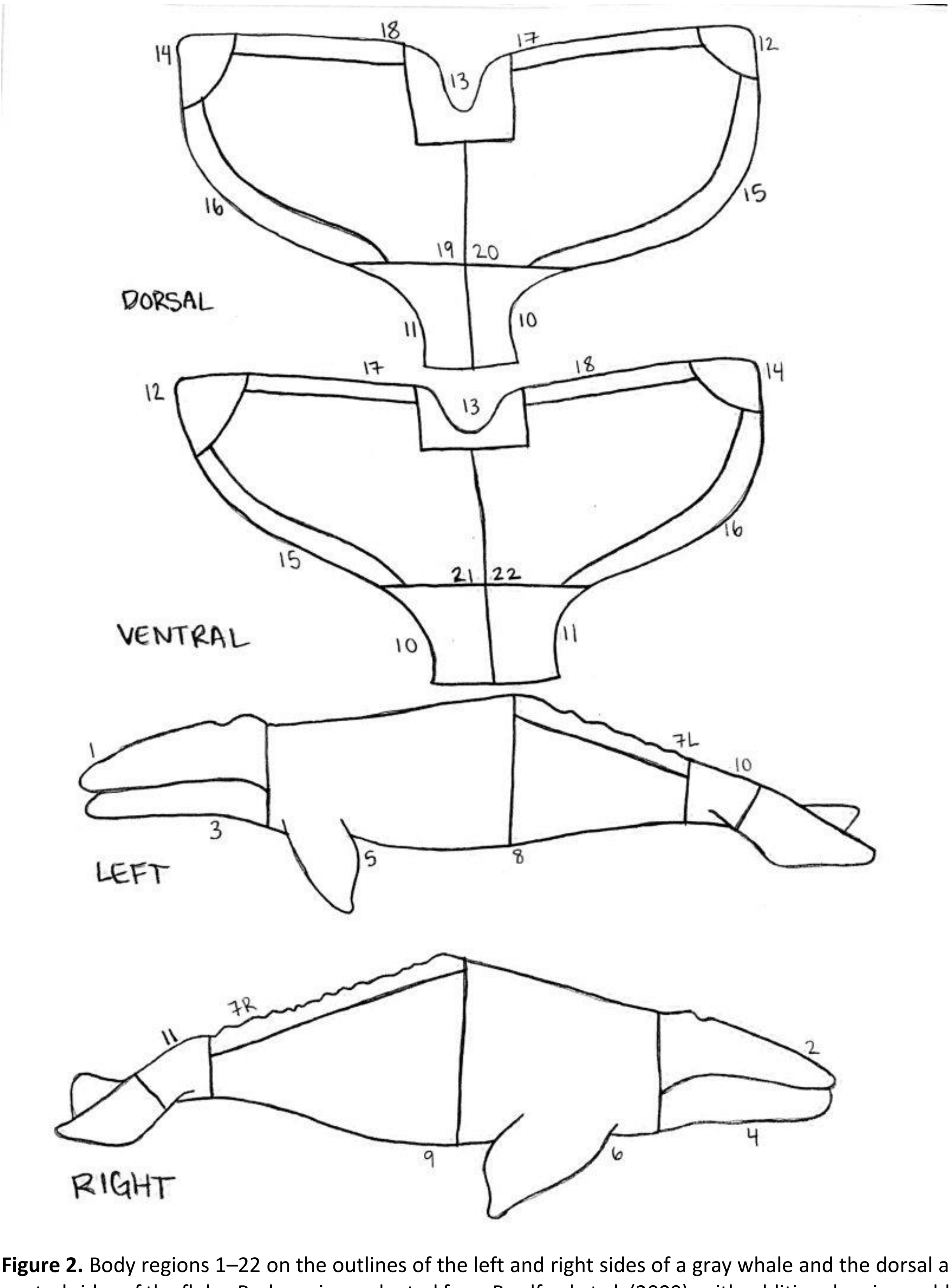


**Figure 2.** Body regions 1–22 on the outlines of the left and right sides of a gray whale and the dorsal and ventral sides of the fluke. Body regions adapted from Bradford et al. (2009), with additional regions added for the posterior left and right caudal peduncle (body regions 10 and 11).

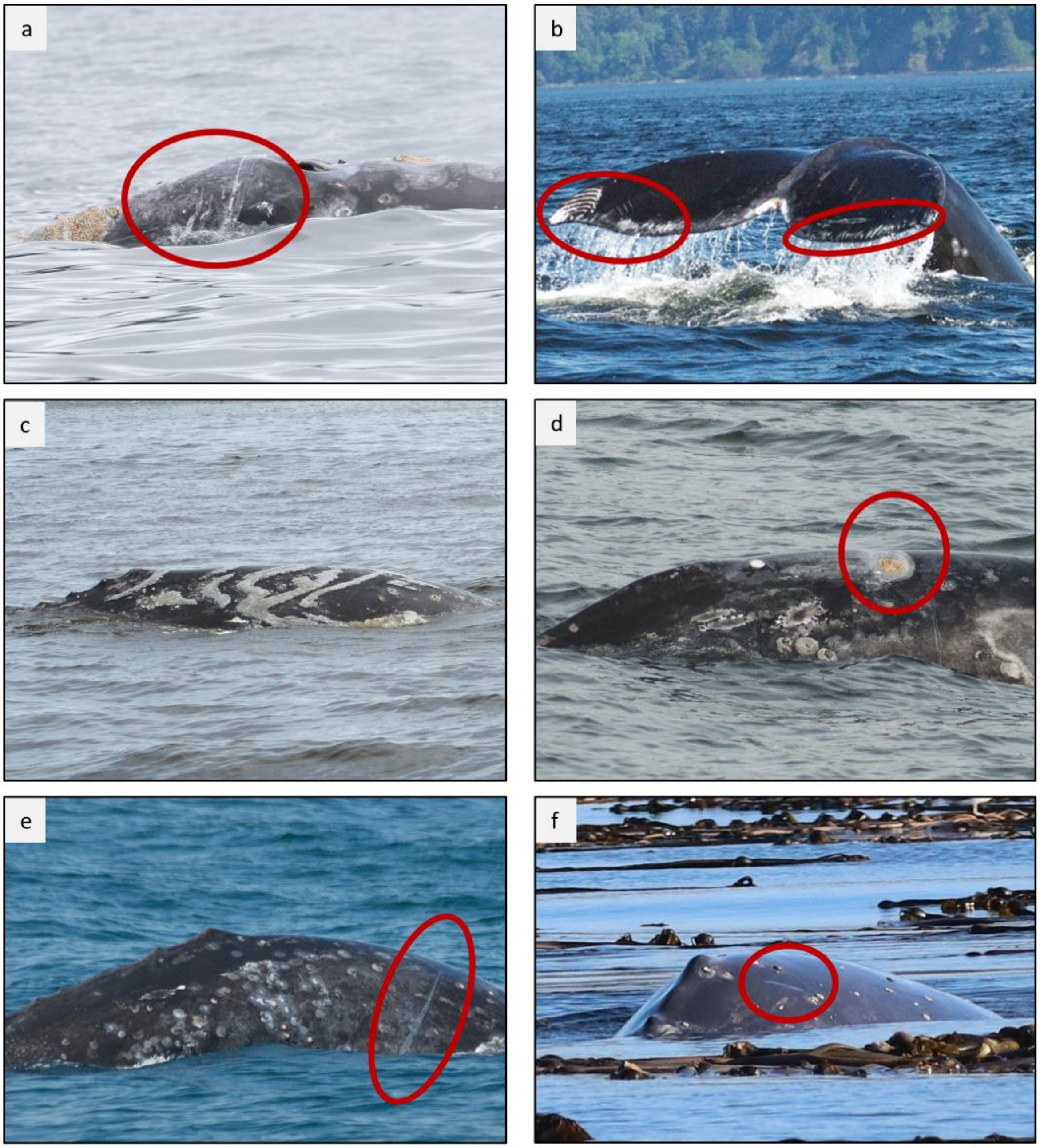


**Figure 3.** Example images of presumed injuries associated with each scar assessment category for PCFG gray whales off northwest Washington from 2014–2020, including a fine line entanglement (a), killer whale rakes (b), vessel strike (c), tag (d), and two examples of unknown scars of different severities (e and f).

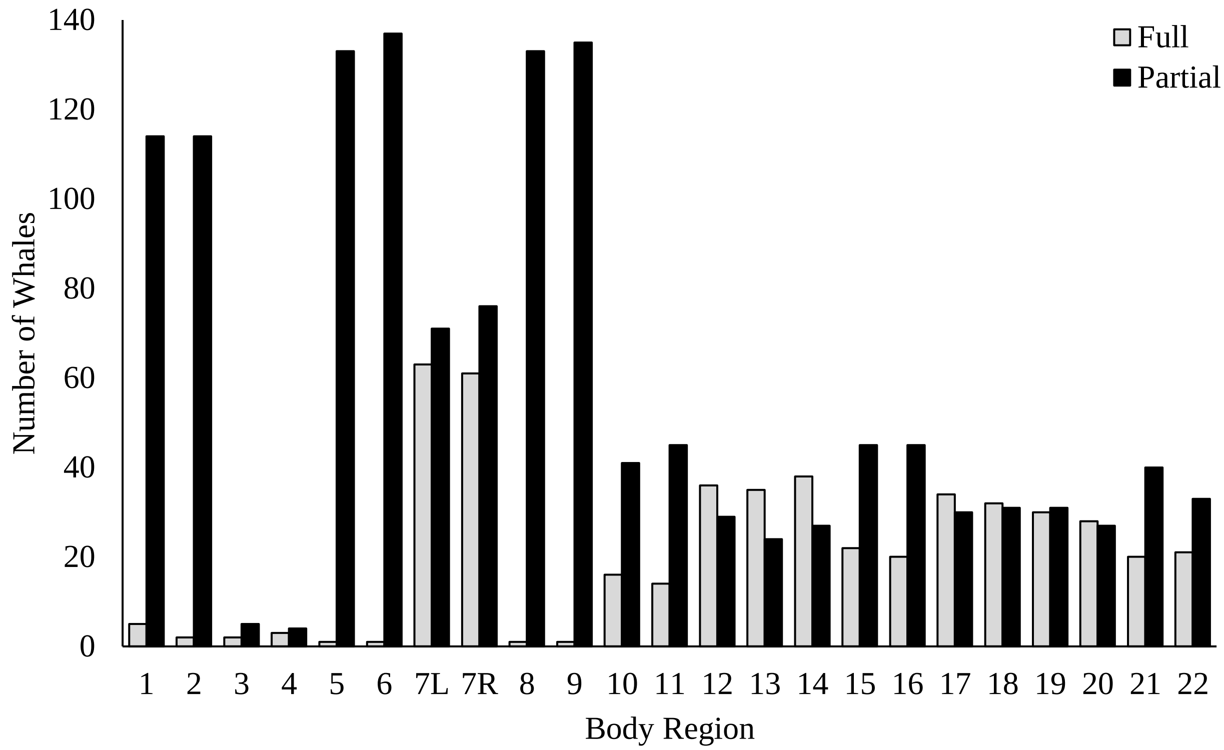


**Figure 4.** Frequency of full and partial visibility for each body region of the PCFG gray whales photographed off northwest Washington during 2014–2020 (n=139).

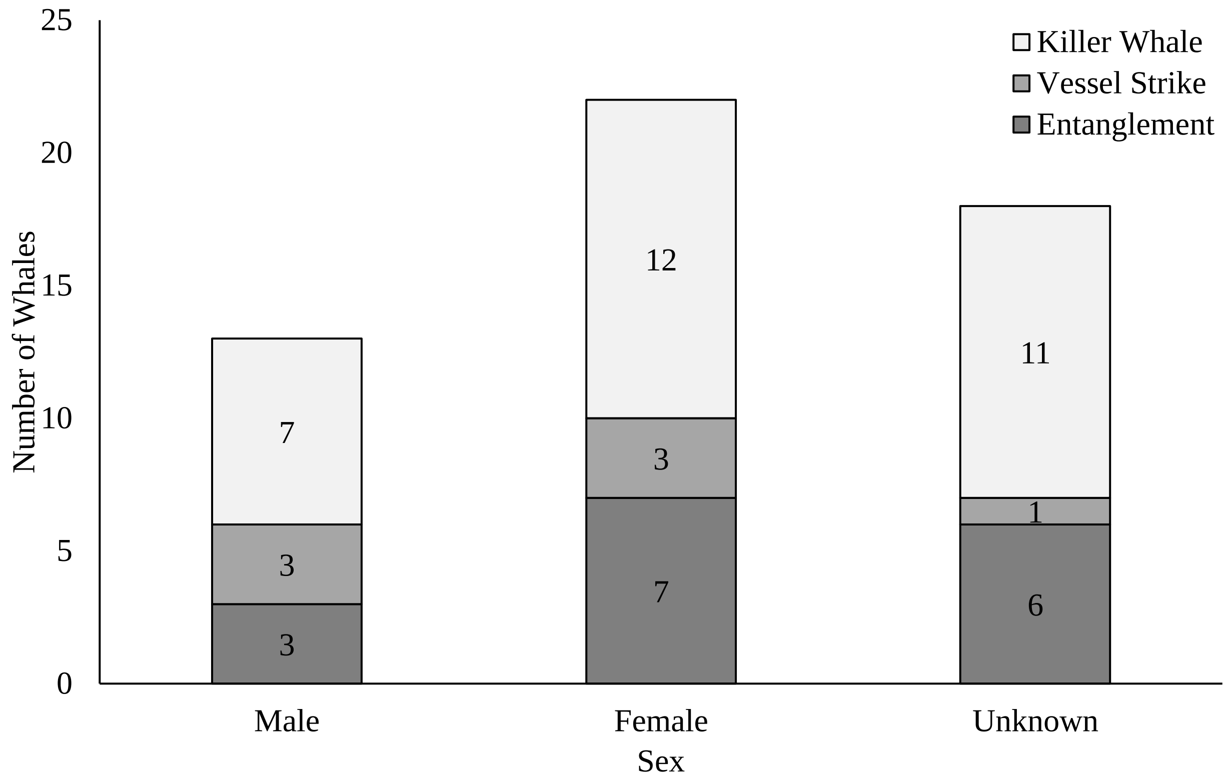


**Figure 5.** Frequency of entanglement, vessel strike, and killer whale scars by sex for the PCFG gray whales photographed off northwest Washington (n=139) during 2014–2020.

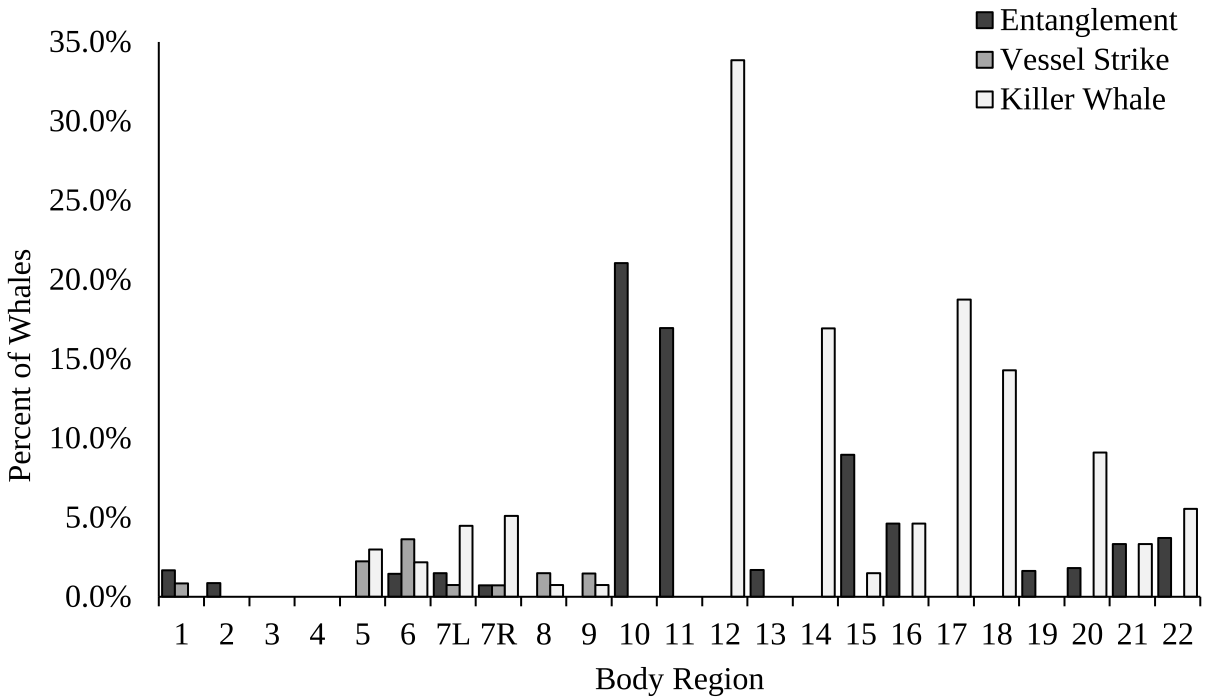


**Figure 6.** Percent of whales observed with scars due to each assessed source by body region for PCFG gray whales photographed off northwest Washington during 2014–2020 (n=139).