Killer whale (*Orcinus orca*) occurrence and interactions with marine mammals off Peru

By Juan Pablo Testino, Andrea Petit, Belén Acorta, Aldo S. Pacheco, Sebastian Silva, Joanna Alfaro-Shigueto, David Sarmiento, Javier Quiñones, Alberto More Eche, Eduardo Motta, Sara Fernandez, Elizabeth Campbell, Geyby Carrillo, Maurice Epstein, Miguel Llapapasca, Adriana González-Pestana*

**Abstract**

Killer whales (*Orcinus orca*) are widely distributed in all ocean basins however, their occurrence, distribution and ecology in the southeast Pacific, including Peru, is poorly defined. This study aims to describe the occurrence of killer whales in Peruvian waters, with additional description of predatory behaviors. Between 2003 and 2018 there were 29 reports of killer whales in Peruvian waters in which at least 110 individuals were observed, with pod sizes ranging between 1 and 15 individuals. Most sightings occurred in waters within the continental shelf or in close proximity to the shelf break. During eight of the sightings, killer whales displayed predatory behavior towards other marine mammals, including cetaceans (*Megaptera novaeangliae* and *Balaenoptera musculus*), and pinnipeds (*Otaria flavescens* and *Arctocephalus australis*). In addition, we present the first photo-analysis of the incidence of killer whale tooth rake marks on humpback whale flukes off northern Peru. Between 2009 and 2017, 897 unique individual humpback whales were photo-identified off northern Peru, of which 19.6% (n= 172) displayed rake marks in their flukes, suggesting that humpback whales in the southeast Pacific are exposed to the attack of killer whales. Our findings suggest that the occurrence of killer whales in Peruvian waters are more common than previously documented and that killer whales are preying marine mammals in this region. Further understanding killer whale distribution, foraging habitats and movement patterns within Peruvian waters will be essential in promoting their conservation.

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**Introduction**

Killer whales (*Orcinus orca*) are the most widely distributed marine mammal in the world’s oceans, commonly associated with areas of high primary productivity in coastal, temperate waters (Forney and Wade 2006). However, information on this species distribution and foraging habits in tropical waters remains limited (Kinzey et al. 1999, Jackson et al. 2008). In the southeastern Pacific, killer whales have been poorly studied, although notable exceptions are the Galapagos islands (Merlen 1999) and Chilean Patagonia (Häussermann et al. 2013). In Peru, some records exist (Bini 1951, Grimwood 1969, Dahlheim et al. 1982, Van Waerebeek et al. 1988, Majluf and Reyes 1989, García-Godos 2004), but information regarding their ecology is limited. García-Godos (2004) presents the most comprehensive and updated information on killer whales in Peruvian waters with 20 sightings recorded between 1995 and 2003, including reports of predation on the South American sea lion (*Otaria flavescens*) and South American fur seal (*Arctocephalus australis*) in southern Peru (Van Waerebeek et al. 1988, Majluf and Reyes 1989), where significant rockeries are located (Majluf and Trillmich 1981). Since 2003, no further observations of killer whales have been reported in Peruvian waters (García-Godos 2004).

Killer whales are top predators in marine ecosystems, and different pods can exhibit foraging specializations, denoted as specific ecotypes (Heimlich-Boran 1988, Baird et al. 1992, Heise 2003, Mehta et al. 2007). In the northeastern Pacific, three ecotypes have been identified: fish-feeding residents, mammal-hunting transients, and a fish-feeding offshore ecotype (Ford et al. 1998, Ford and Ellis 2006). Reports of killer whales attacking or harassing cetaceans are widely documented (Jefferson et al. 1991, Baird et al. 2006, Branch and Williams 2006, Pitman et al. 2007). Yet, these predatory interactions might be more common than currently thought, as
humpback whales (*Megaptera novaeangliae*) among others cetaceans, are often found with killer whale tooth-rake marks on their flukes (Mehta et al. 2007, Pitman et al. 2015). In the southeastern Pacific, the existence of individual ecotypes remains unclear (Olson and Gerrodette 2008), and reports of killer whales preying on large whales (e.g. sperm whales, baleen whales) has been elusive to document with some exceptions (Arnbom et al. 1987, Flórez-González et al. 1994, Brennan and Rodriguez 1994, Scheidat et al. 2000, Ford and Reeves 2008, Goddall et al. 2007, Alava et al. 2013, Häussermann et al. 2013). In Peru, a single report exists of recently wounded sperm whales (*Physeter macrocephalus*), which were likely attacked by killer whales (Dufault and Whitehead 1995). Furthermore, only two records of killer whales attacking common bottlenose dolphin (*Tursiops truncatus*) and short-finned pilot whale (*Globicephala macrorhynchus*), exist for Peruvian waters (García-Godos 2004)

Despite the high marine productivity and potential for foraging areas for higher trophic-level consumers in Peruvian waters (Chavez and Messie 2009, Pompa et al. 2011), little is known regarding the distribution, occurrence and predation habits of killer whales. Moreover, no direct observation of a predatory interaction exists between a killer whale and large whales, even though the neritic waters of northern Peru are breeding areas for humpback whales (Pacheco et al. 2009, Guidino et al. 2014). In this study we present new sightings of killer whales in Peruvian waters from 2003 to 2018, with associated observations of predatory behavior. We also present a photo-analysis of humpback whale flukes from northern Peru, as an indication of the prevalence of killer whale attacks.
MATERIALS AND METHODS

Killer whale sightings

Sightings of killer whales in Peruvian waters between 2003 and 2018 were gathered from opportunistic and research-based observations. For each sighting, the date, location, group size, and behavior were recorded. Sources included: pelagic surveys conducted by the National Institute of the Peruvian Sea (IMARPE, Spanish acronym) during 2008 and 2014, commercial tourism vessels (including whale-watching vessels where trained researchers were on-board for data collection), and opportunistic observation by trained researchers. Given the limited amount of research conducted on killer whale in Peru, additional occurrence records were compiled from local news reports, and social media channels (filtering posts for the words “orcas” and “Peru”). Information from the National Oceanic and Atmospheric Administration (NOAA) was also included from their surveys in the Eastern Tropical Pacific Ocean (Jackson et al. 2008).

During 35 days, 154 pelagic transects- perpendicular to the coast with a separation of 28 km- were conducted along the majority of the Peruvian coast by IMARPE between 5 November and 24 December 2008 (05°00´S-17°40´S; 1.8 to 555 km offshore) (IMARPE, 2008), and between 24 February and 11 April 2014 (03°23´S-18°20´S; 1.8 to 148 km offshore) (IMARPE, 2014). One to three observers sighted cetaceans from the vessel deck at 15 m above the sea level during daylight hours (06:00-18:00 h) (Garcia-Godos 2004).

Marine-based tourism vessels (i.e. North shore expeditions, Pacifico Adventures and Las Cherelas) operate in northern Peru (Piura and Tumbes) during the morning (06:00-11:00 h) between five to seven days per week during the whale-watching or humpback whale breeding season (July-October), and between three to five days during the rest of the year. The number of
observers (i.e. land and boat based) are between two to three. The years surveyed varied according to the tourism operators: North shore expeditions (2012-2018), Pacifico Adventures (2009-2018) and Las Cherelas (2016-2018).

**Humpback whale fluke analysis**

To evaluate the prevalence of rake marks on flukes of humpback whales, photo catalogues were recorded along the coast of Piura and Tumbes during the humpback whale breeding season yearly between July to October (2009-2017) by marine-based tourism vessels (i.e. North shore expeditions, Pacifico Adventures and Las Cherelas). Photographs of individual whales were examined for predatory tooth rake marks. Rake shaped scars result from attacks by killer whales and are not created by some other source (e.g. false killer whales). This assumption is supported by work conducted by Schevchenko (1975), and more recently by Mehta (2004).

Photographs were selected using three criteria: i) proportion of the fluke that was visible (more than 50% of the fluke), ii) fluke angle (visibility of the ventral side), iii) photograph quality (appropriate focus, lighting and exposure). Photographs that did not meet these criteria were excluded from the analysis. The five categories established by Steiger et al. (2008) were used for the analysis (Table 1), in which a rake mark is defined by a set of three or more parallel lines or marks in close proximity. The prevalence of rake marks on flukes of humpback whales off the northern coast of Peru was estimated from the total number of photo-identified humpback whales between the years 2009 and 2017. Then this percentage was extrapolated to the southeastern Pacific humpback whale stock (Breeding Stock G) to calculate the number of individuals that are exposed to killer whale attacks. For this analysis, the latest estimation of their stock size was used which is 6,504 individuals (95% CI: 4,270–9,907) (Félix et al. 2011).
RESULTS

Killer whale sightings

Between 2003 and 2018, killer whale sightings were recorded on 29 separate occasions off the coast of Peru (Figure 1, Table 2). The total number of individuals sighted was at least 110, with an average group size of 4 individuals (range: 1-15 individuals). In these sightings, each individual was not uniquely identified; thus, it cannot be determined that the 110 individuals sighted were unique or resighted individuals. Killer whales were sighted at an average distance of 55 km (range: 0-148 km) from the coast. Sightings (n=14 groups) were most frequently within the continental shelf or in close proximity to the shelf break -where the seafloor transitions to the continental slope- in which these 14 sightings occurred at an average distance of 9 km (range: 0-30 km) from the continental shelf break. Sightings were registered year-around, with the exceptions of April and May.

Behavioral observations

During eight sightings, killer whales displayed predatory interactions with cetaceans, such as blue whale (*Balaenoptera musculus*), humpback whale and common dolphins (*Delphinus* sp.), and pinnipeds, such as South American sea lions and South American fur seals. Two observations were first time records of killer whales preying on pinnipeds in the northern Peru region (i.e. Lobos de Tierra and Lobos de Afuera islands; Figure 1).

Predatory interactions with cetaceans

On November 27, 2008, seven killer whales were observed chasing a group of approx. 3000 common dolphins off northern Peru. On August 3, 2016, two killer whales were seen harassing an unidentified species of whale by swimming very close (less than a meter) and following the
whale. Furthermore, this interaction was registered close to an artisanal boat off southern Peru. On November 3, 2016, ten killer whales were observed flanking a blue whale very closely (less than a meter) off southern Peru.

On September 7, 2016 at 06:30 am a single male killer whale (Figure 2) followed along the seaward side of a mother and calf pair of humpback whale off Punta Sal (Tumbes, Peru; -3.9777, -80.9768) traveling southwards at approximate speed of 7-9 km/h. and approximately 30 m from shore. The calf was positioned close to the shoreline with the adult whale seaward. The killer whale swam approximately 4-5 m away from the humpback whales. Then the killer whale changed position and launched three attacks at the calf, striking with its caudal fin. There were 3-5 minutes between each attack. It could not be confirmed whether the killer whale attacked with mouth open or closed, therefore it could not be determined whether the killer whale was biting or ramming. The killer whale remained 4-5 m away from the humpback whales on the seaward side, and at times approached within 1 m of the whales. When this happened the adult humpback whale raised its caudal fin towards the killer whale. The humpback whales were constantly breaching to breath, possibly due to exhaustion. The killer whale’s breathing was less frequent. When the humpback whales came within 20 m of a purse seine they changed direction to south-west; the killer whale continued to follow them but from a greater distance (approximately 20m). The last record of the killer whale following the humpback whales was at 08:12 am (-4.0005527, -81.0004194), and no further information was recorded. The observers observed the event for a total time of 102 minutes. Video footage of the attack is available in supplemental material https://www.instagram.com/p/BWJfsqCAJSs/?taken-by=northshoreperu

Predatory interactions with pinnipeds
Off northern Peru, two sightings were reported of killer whales chasing South American sea lions close to their rockeries: on December 1, 2015, one killer whale was observed chasing a sea lion on Lobos de Tierra island, and on November 1, 2016, two killer whales were observed chasing a group of sea lions on Lobos Afuera island. In both sightings, sea lions were seen jumping out of the water close to the mouth of killer whales. Off southern Peru, two sightings were made of killer whales chasing pinnipeds close to their rockeries: on January 1, 2003, two killer whales were seen chasing South American fur seals on San Juan de Marcona, and on December 1, 2016, three killer whales were observed chasing a group of South American sea lions on Punta Coles.

**Humpback whale tooth rake marks: prevalence of killer whale attacks**

A total of 897 photo-identified humpback whales were registered between 2009 and 2017 off the north coast of Peru, and 871 were found appropriate for rake mark analysis. From the 871 humpback whale flukes analyzed, 19.6% (n=172 individuals) showed tooth-rake marks. From this group 2% (18 ind.) showed damage on their flukes with missing pieces associated with the rake mark (Category 1, Figure 3), 2% (18 ind.) showed severe scarring with three or more sets of rake marks (Category 2, Figure 3), and 15.6% (136 ind.) had at least one set of rake marks (Category 3, Figure 3). Many whales presented scars (41.6%, 363 ind.), but these did not meet the definition of rake marks (Category 4, Figure 3), and 38.5% (336 ind.) had no visible rake marks or scars on their flukes (Category 5, Figure 3). When extrapolating the percentage of rake marks found in humpback whales in the coast of northern Peru (19.6%) to the southeastern Pacific humpback whale stock (6,504 individuals; 95% CI: 4,270–9,907; Félix et al. 2011), at least approximately 1,275 (95% CI: 837–1,942) (19.6%) individuals of the southeastern Pacific stock presented tooth-rake marks on their flukes.
DISCUSSION

Our study presents the most complete and up-to-date information regarding killer whales in Peru. This study documents a further 29 sightings of killer whales in Peruvian waters, in which eight sightings showed predatory interaction with another marine mammal. This study reports the first direct observation of a killer whale attacking baleen whales in Peru, and notably, 19.6% of humpback whales examined presented an indication of a killer whale attack. This study also represents the first observation of a killer whale hunting pinnipeds off northern Peru. These findings indicate that in Peruvian waters killer whales are preying on marine mammals.

Distribution of killer whales off Peru

Within the southeastern Pacific, the presence of killer whales has been documented primarily in the Galapagos islands and the waters of Chilean Patagonia (Merlen 1999, Häussermann et al. 2013). Yet, in other areas within the region (i.e. continental Ecuador and Colombia), their presence has been poorly documented (Flórez-González et al. 1994, Scheidat et al. 2000). In Peru, most of the sightings reported by García-Godos (2004) were oceanic; whereas in this study, most sightings were associated with the continental shelf or the shelf break (Figure 1). Coastal areas within the continental shelf are known for their high marine productivity and high concentrations of marine mammals (Ryther 1969, Pompa et al. 2011). Furthermore, irregularities of the sea floor can alter water flow above them, enhance mixing, and promote upwelling of nutrient-rich waters (Springer et al. 1996, Connolly 2012). As a result, areas above or in close proximity to the shelf break are foraging areas for higher trophic-level consumers, including species predated upon by killer whales, such as pinnipeds and other cetaceans (Payne and Heinemann 1993, Springer et al. 1996, Cañadas et al. 2002, Roberts et al. 2016). In addition,
breeding areas of humpback whales are located in neritic waters. Therefore, the area above or in close proximity to the shelf break off Peru might be a suitable area of prey availability for killer whales.

**Predation interactions on marine mammals**

In Chilean Patagonia killer whales are regularly observed harassing and predating upon pinnipeds (i.e. *Otaria flavescens, Arctocephalus australis*) (Capella et al. 1999, Hückstadt and Antezana 2004, Häussermann et al. 2013). In Peru, this predatory behavior appears uncommon however, occurrences have been observed at significant rockeries of pinnipeds in southern Peru (i.e. San Fernando and San Juan) (Majluf and Trillmich 1981, Van Waerebeek et al. 1988, Majluf and Reyes 1989, García-Godos 2004). This study represents the first record of a killer whale preying on South American sea lions and South American fur seals off northern Peru which is located within an area of exceptional primary productivity (7–8°S; Moron 2000, Chavez and Messie 2009). This in turn supports the abundance of higher-trophic level organisms that are potential prey for killer whales, such as pinnipeds. Since northern Peru represents two of the most important rockeries of pinnipeds (i.e. Lobos de Tierra and Lobos de Afuera; Majluf and Trillmich, 1981), this area may represent an area of prey availability for killer whales.

In the southeastern Pacific few records exist of killer whales attacking or harassing cetaceans. Off Chilean Patagonia three observations indicate killer whales attacking sei whales (*Balaenoptera borealis*) (Ford and Reeves 2008, Goddall et al. 2007, Alava et al. 2013), and in the Galapagos islands, killer whales were recorded attacking sperm whales and Bryde’s whales (*Balaenoptera edeni*) (Arnbom et al. 1987, Brennan and Rodriguez 1994). In Ecuador and Colombia, killer whales have been observed attacking humpback whales (Flórez-González et al. 2014).
1994, Scheidat et al. 2000). In Peru, there are two records of killer whales attacking delphinids (García-Godos 2004) and one presumed attack on sperm whales by killer whales (Dufault and Whitehead 1995). Thus, this study represents the first direct evidence of a killer whale attacking large cetaceans in Peru.

In western Australia, humpback whales have been recorded being attacked by killer whale pods with a median group size of 6 (range 3–11) (Pitman et al. 2015). This contrasts with the attack described in this study, where only one individual was observed attacking a humpback calf. Moreover, killer whales have mainly been observed targeting the calves of humpback whales, during their migration to their feeding or breeding grounds (Clapham 2001, Mehta et al. 2007, Pitman et al. 2015). During this migration mothers and calves maintain a shallow-coastal distribution (Flórez-González 1991, Félix and Haase 2005, Guidino et al. 2014, Oña et al. 2016), which can be a behavioral strategy (Pitman et al. 2015) to reduce potential predation from killer whales (Corkeron and Connor 1999). In this study, the mother and calf were observed very close to shore; this coupled with the mother interposing her body between the killer whale and the calf might have been a behavior to protect the calf from the killer whale (Pitman et al. 2015).

**Humpback whale tooth-rake marks: prevalence of killer whale attacks**

Mehta et al. (2007) reviewed baleen whale photo-identification catalogues from around the world and found that rake-marked humpback whales range from 0 to 40% of the population and are globally widespread with rates varying according to region. In eastern Australia 17% of 1436 humpback whales possessed some form of predatory scarring (Naessig and Lanyon, 2004). In the western North Atlantic rake marks were found in 14% of 3365 humpbacks (Katona et al. 1988). In the North Pacific region, 15% of 3650 humpbacks presented unambiguous, discernable rake
marks (Steiger et al. 2008). Off Gabon, 17.3% of 682 humpback whale flukes showed evidence of killer whale tooth-rake marks (Weir et al. 2010). Rake marks were found in 11.86% of 3042 humpback whales assessed in the south eastern Pacific (i.e. Panama, Colombia, Ecuador, Chile and Antarctic waters) (Capella et al. 2018). The results found in Peruvian waters (19.6%) are within the percentage ranges of tooth-rake marks found in other studies worldwide, including in the south eastern Pacific. These findings in conjunction with Capella et al. (2018) suggest that humpback whales in the southeast Pacific are more exposed to the attack of killer whales than previously recognized. Yet, this estimation should not be used to understand the limiting population growth factors facing this humpback whale stock. Scarring should be considered evidence of either the prey’s ability to escape, or the predator’s inefficiency, or both, rather than as a direct indication of predation rate (Schoener 1979). Yet, attacks can have a successful outcome for killer whales; in Western Australia, killer whales attacked and killed humpback whale calves in 22 events (64% of attack outcomes observed) (Pitman et al. 2015).

The location and timing of these predation events remains to be revealed. It is possible that at least some of this scarring occurred in the humpback whales’ Antarctic feeding grounds (Pitman and Ensor, 2003); yet, in the Magellan Strait, southern Chile, no attacks on humpback whales have been observed (Capella et al. 2014). Most killer whale attacks occur on young animals, primary calves, in breeding sites or during their first migration to feeding areas (Mehta et al. 2007, Capella et al. 2018). Furthermore, in the south eastern Pacific, the highest overlap between the distribution of humpback whales and killer whales occurs off Peru, southern Ecuador and the Galapagos islands (Capella et al. 2018). Therefore, in this area the highest number of predation events is expected. In this study, direct evidence indicates that these attacks can happen in humpback whale breeding areas. The percentage of humpbacks with tooth-rake marks for the
southeastern Pacific stock might be an underestimation of attack rates since this result does not include the unknown number of calves that are presumably killed.

This study suggests that killer whales occurring in Peruvian waters are preying on marine mammals (i.e. pinnipeds and cetaceans); yet, further research is needed to determine if killer whales in Peruvian waters present a specialized ecotype. Future research efforts should include the recording of photographs to develop a killer whale photo-identification catalogue for Peruvian waters which can clarify their behavioral and movement patterns. Understanding the presence, distribution, abundance and habitat use of cetaceans is essential for their conservation, especially since Peru has been identified as a hotspot for marine mammals (Pompa et al. 2011, Kaschner et al. 2011).

Acknowledgments
We thank the Oficina de Investigaciones de Depredadores Superiores of IMARPE for the data collected between 2004-2017. Phil Jones, Michael Mcmaster, Robert Pitman and an anonymous reviewer are thanked for their suggestions and comments on the manuscript. The humpback whale photo ID catalog is available upon request to A.S.P. Pacifico Adventures thanks their crew for the effort in collecting humpback whale photographs every year.


Tables and Figures

Table 1. Rake mark scarring categories by Steiger et al. (2008).

<table>
<thead>
<tr>
<th>Category</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rake mark injuries damage the integrity of the fluke.</td>
</tr>
<tr>
<td>2</td>
<td>Severe scarring, showing three or more sets of rake marks.</td>
</tr>
<tr>
<td>3</td>
<td>One to three sets of rake marks</td>
</tr>
<tr>
<td>4</td>
<td>Scratches or scars, not in close proximity, not forming three parallel lines.</td>
</tr>
<tr>
<td>5</td>
<td>No rake marks present.</td>
</tr>
</tbody>
</table>
Table 2. Killer whale (*Orcinus orca*) sightings off Peru, 2003–2018. nd= not detailed

<table>
<thead>
<tr>
<th>Sighting date</th>
<th>Group size</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Behavior</th>
<th>Source</th>
<th>Observations</th>
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<tr>
<td>1 Jan 2003</td>
<td>2</td>
<td></td>
<td></td>
<td>Predatory interaction with pinnipeds</td>
<td>Marco Cardeña</td>
<td>San Juan de Marcona, Ica (land-based)</td>
</tr>
<tr>
<td>28 Feb 2003</td>
<td>1</td>
<td>−18.322</td>
<td>−70.945</td>
<td></td>
<td>IMARPE (online request)</td>
<td></td>
</tr>
<tr>
<td>Jun-Jul 2006</td>
<td>6</td>
<td>−6.46666667</td>
<td>−80.833333</td>
<td>Probably feeding</td>
<td>Ignacio García Godos</td>
<td></td>
</tr>
<tr>
<td>Oct-Nov 2006</td>
<td>ns</td>
<td>−11</td>
<td>−86</td>
<td>nd</td>
<td>Jackson et al. 2008</td>
<td>Approximate points</td>
</tr>
<tr>
<td>Oct-Nov 2006</td>
<td>ns</td>
<td>−12</td>
<td>−87</td>
<td>nd</td>
<td>Jackson et al. 2008</td>
<td>Approximate points</td>
</tr>
<tr>
<td>Oct-Nov 2006</td>
<td>ns</td>
<td>−13</td>
<td>−91</td>
<td>nd</td>
<td>Jackson et al. 2008</td>
<td>Approximate points</td>
</tr>
<tr>
<td>2 Jul 2008</td>
<td>10</td>
<td>−15.7000526</td>
<td>−76.648882</td>
<td>Swimming</td>
<td>Eduardo Motta</td>
<td></td>
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<tr>
<td>27 Nov 2008</td>
<td>7</td>
<td>−8.298216</td>
<td>−79.60716</td>
<td>Predatory interaction with <em>Delphinus</em> sp.</td>
<td>Ignacio García Godos</td>
<td></td>
</tr>
<tr>
<td>29 Jan 2012</td>
<td>7</td>
<td>−3.76089</td>
<td>−81.80937</td>
<td>Swimming</td>
<td>Eduardo Motta</td>
<td></td>
</tr>
<tr>
<td>19 Aug 2012</td>
<td>2</td>
<td></td>
<td></td>
<td>Swimming</td>
<td>Paul Visscher</td>
<td>5 km north off Ilo port</td>
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<tr>
<td>15 Mar 2013</td>
<td>6-8</td>
<td></td>
<td></td>
<td>Swimming to south close to artisanal fishery</td>
<td>Pacifico Adventures</td>
<td>22 km off Organos</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>boats, an orca was feeding possibly on a devil</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ray (<em>Mobula</em> spp.)</td>
<td>Maurice Epstein</td>
<td>1-2 km off Peña Mala, Vichayito</td>
</tr>
<tr>
<td>10 Sept 2013</td>
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<td>−79.475</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>23 Dec 2013</td>
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<td>−80.22773</td>
<td>Calm,</td>
<td>Ignacio</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Count</td>
<td>Longitude</td>
<td>Latitude</td>
<td>Activity</td>
<td>Author</td>
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<td></td>
</tr>
<tr>
<td>3 Mar 2014</td>
<td>4</td>
<td>−15.415</td>
<td>−75.957</td>
<td>Swimming during seismic prospection</td>
<td>García Godos</td>
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<tr>
<td>1 Dec 2015</td>
<td>1</td>
<td>−6.46929</td>
<td>−80.837459</td>
<td>Predatory interaction with pinnipeds</td>
<td>David Sarmiento</td>
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<tr>
<td>21 Jan 2016</td>
<td>&gt;1</td>
<td>−3.57185</td>
<td>−81.326216</td>
<td>Swimming</td>
<td>Joanna Alfaro</td>
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<td>1 Mar 2016</td>
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<td></td>
<td></td>
<td>Swimming</td>
<td>Andrea Petit Banco de Mancora</td>
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<tr>
<td>3 Aug 2016</td>
<td>2</td>
<td></td>
<td></td>
<td>Predatory interaction with a whale</td>
<td>Clint Cabana South of Pisco</td>
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<tr>
<td>7 Sept 2016</td>
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<td>−3.9777</td>
<td>−80.9768</td>
<td>Predatory interaction with humpback whales</td>
<td>Juan Pablo Testino, Alberto More, Geyby Carrillo, Elizabeth Campbell</td>
<td></td>
</tr>
<tr>
<td>30 Oct 2016</td>
<td>4</td>
<td></td>
<td></td>
<td>Swimming and jumping</td>
<td>Sara Fernández 18 km offshore Punta Sal</td>
<td></td>
</tr>
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<td>1 Nov 2016</td>
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Figure 1. Killer whale (*Orcinus orca*) sighting locations off Peru between 1995 and 2018. Dark grey color represents the continental shelf. Open circles (O) indicate sightings where non-predatory behavior was registered, rectangles (•) indicate sightings were predatory behavior was registered in this study between 2003 and 2018. Crosses (+) indicate sightings from García-Godos (2004) between 1995 and 2003, and closed circles (●) indicate major pinnipeds colonies in Peru (Majluf and Trillmich1981).
Figure 2. Killer whale registered predating humpback whales on September 7, 2016 off Tumbes, Peru.
Figure 3. Rake marks in the flukes of humpback whales off northern Peru. Categories (numbers) determined by Steiger et al. (2008).


