

## Short Note

# Entanglements and Mortality of Endemic Chilean Dolphins (*Cephalorhynchus eutropia*) in Salmon Farms in Southern Chile

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Bycatch in mobile and static fishing gear is the most important direct threat to marine mammals (Read, 2008). Small cetaceans are frequently bycaught in gillnets or trawl nets (Read, 2008), but their entanglement in fish farm cage netting is less well documented (Kemper & Gibbs, 2001; Díaz López & Shirai, 2007). Chile is the second largest producer of farmed salmonids in the world, with an annual production of over 600,000 MT and an export value exceeding US \$4.3 billion in 2014 (León-Muñoz et al., 2018). Salmonids are farmed using circular or square net-pens (usually 10 to 30 m across and 10 to 15 m deep) surrounded by an outer anti-predator net made with 25-cm knot-to-knot mesh size. Anti-predator nets are designed to protect the cages from depredation by South American sea lions (*Otaria byronia*) while also reducing the risk of accidental entanglement of sea lions in accordance with Chile's Environmental Regulation for Aquaculture (RAMA in its Spanish acronym). Salmon farms are concentrated in southern Chile in the regions of Los Lagos, Aysén, and Magallanes (41 to 54° S; Figure 1) with hundreds of additional concessions in preparation in remote areas where oversight and monitoring of fish farming activities are severely limited (Niklitschek et al., 2013). These regions are also home to the poorly known Chilean dolphin (*Cephalorhynchus eutropia*), the only cetacean species endemic to Chile (Goodall et al., 1988). Chilean dolphins have a strictly coastal distribution with strong preference for sheltered bays and channels (Goodall et al., 1988; Viddi et al., 2015; Heinrich et al., 2019). Range-wide abundance estimates are not available, but the species is suspected to number only in the low thousands (Dawson, 2018). Chilean dolphins

are listed as “Near Threatened” on the IUCN *Red List of Threatened Species* (Heinrich & Reeves, 2017) and as “Vulnerable” under the Chilean species classification system (Ministerio del Medio Ambiente, 2011).

In Chile, all marine mammal species are protected by law from intentional killing. It is a legal requirement to report accidental mortality in fishing operations to the Chilean fisheries authorities (National Fisheries and Aquaculture Service of Chile [SERNAPESCA] Law No. 20.293, 2008). Reporting and assessing marine mammal mortality in fisheries have increased in importance due to the recent changes in seafood import restrictions in the United States that require countries exporting fisheries products to the U.S. to comply with the U.S. Marine Mammal Protection Act (Williams et al., 2016). Farmed salmon is an important export product for Chile, including supplying markets in Japan, China, and the U.S. (Dresdner et al., 2016). Published records on the interactions of marine mammals with salmon farms in Chile are limited to South American sea lions (Sepúlveda & Oliva, 2005; Vilata et al., 2010), but unpublished information might be available in grey literature, via social media, or through personal observations by those involved in the salmon farming industry.

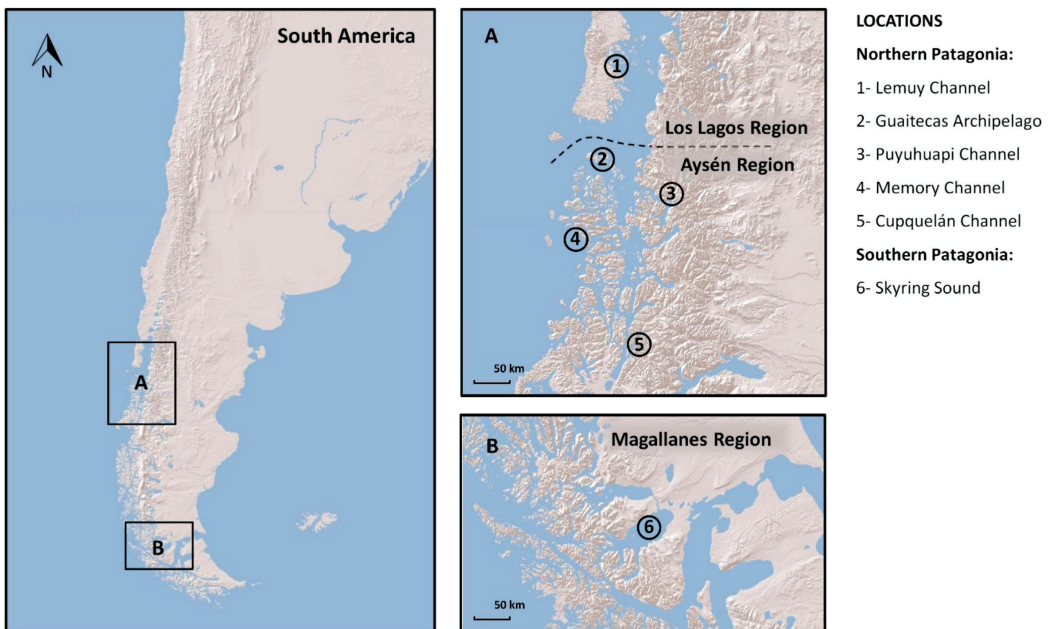
Herein, we present results of a systematic review of available information on the occurrence of entanglement events of cetaceans in Chilean salmon farms and their reported outcomes. Although we were particularly interested in Chilean dolphins, we documented all cases we found to help put the records for Chilean dolphins into some broader perspective. We compiled information from three

sources consisting of official government records, published and grey literature (including Web-based resources), and eyewitness reports. To evaluate potential discrepancies, we compared published and witnessed reports to those documented in the official government records. We only included data where the source could be verified and sufficient detail on the entanglement case could be obtained to allow species identification. We limited the review to the period from 2007 to 2017 as this time frame corresponded with the national legislation requiring the reporting of marine mammal mortality to the Chilean Fisheries Authorities (Decree No. 320; Undersecretariat of Fisheries and Aquaculture of Chile [SUBPESCA], 2001).

We accessed official reports using a freedom of information request to the Chilean National Fisheries Service to obtain information on all records of cetaceans entangled at salmon farms in the Los Lagos, Aysén, and Magallanes administrative regions of southern Chile (Figure 1). Information provided included the species, number of animals, released alive or recovered dead, sex, size, date, location, exact position using Global Positioning System (GPS), type of fishing net, and reporter information. We conducted Web-based searches covering peer-reviewed and grey literature, news articles, and key social media sites (e.g., Facebook) using relevant key words in English and Spanish. Our team also conducted annual field surveys in different parts of

the three regions as part of other research activities (Acevedo et al., 2017) and for long-term studies of Chilean dolphins (Heinrich et al., 2019; SH & CE, unpub. data). We were also active in Chile's stranding networks (CE and OB) and conducted regular outreach activities in local communities (BC, CE, and MF). Our efforts to acquire bycatch information were opportunistic and not spatially or temporally representative for the regions or fishing effort. Therefore, the results provided herein represent a minimum record of entanglements. Information that originated from residents is reported anonymously to protect the informer from potential repercussions. Each record was classified as either "confirmed" when there was photographic evidence or other formal documentation or as "probable" when credible and corroborated information was provided orally about the entanglement.

We found eight reports of cetacean entanglements at salmon farms in southern Chile from 2007 to 2017 (Table 1). Six of these reports (4 confirmed, 2 probable) involved Chilean dolphins (Table 1; Figure 1). All six had fatal outcomes and involved both males and females. Moreover, two entanglement records (confirmed) involved one adult humpback whale (*Megaptera novaeangliae*), which was released alive, and one humpback whale calf that was found dead and entangled in a salmon farm net (Table 1). All dolphin and whale entanglements occurred in the large-mesh anti-predator nets that



**Figure 1.** Map of the study area where entanglements of cetaceans were identified: (A) shows the locations in northeast Patagonia and (B) shows the location in southeast Patagonia. For details on the events, see Table 1.

**Table 1.** Entanglement records of six Chilean dolphins (*Cephalorhynchus eutropia*) and two humpback whales (*Megaptera novaeangliae*) in salmon farms in the Los Lagos, Aysén, and Magallanes regions. Records are classed as confirmed or probable (see text for definitions), and the sex of the individuals was classified as male (M), female (F), or unknown (U).

Date	Location	Species	Sex	Evidence	Observations	Source
2007	Guaitecas Archipelago, Aysén Region	Chilean dolphin	U	Confirmed (photo)	Chilean dolphin found entangled in an anti-predator net of an active salmon farm. In February. Not reported to SERNAPESCA.	Viddi, 2008
2007	Guaitecas Archipelago, Aysén Region	Humpback whale	U	Confirmed (photo)	Humpback whale calf found dead and entangled in an anti-predator net of a salmon farm. Austral summer. Not reported to SERNAPESCA.	Hucke-Gaete et al., 2013
2011	Lemuy Channel, Los Lagos Region	Chilean dolphin	U	Probable (eyewitness statement)	Small grey dolphin with white belly and round dorsal fin found dead in an anti-predator net of an active salmon farm. Farm worker stated that they had seen small dolphins entangled in anti-predator nets before but did not give sufficient detail to report them here. Not reported to SERNAPESCA.	Salmon farm worker; C. Espinosa-Miranda, pers. comm., 2 February 2012
2015	Cupuelán Channel, Aysén Region	Chilean dolphin	F	Confirmed (photo)	Adult female Chilean dolphin found dead in an anti-predator net of an active salmon farm; pulled aboard the farm support vessel. In March. Not reported to SERNAPESCA.	Photos provided by an anonymous informer to C. Espinosa-Miranda; used with permission
2015	Skyring Sound, Magallanes Region	Chilean dolphin	M	Confirmed (necropsy report)	Healthy, adult male Chilean dolphin drowned in an anti-predator net of a salmon farm. In November. The company notified SERNAPESCA.	Necropsy report (provided by SERNAPESCA)
2016	Skyring Sound, Magallanes Region	Chilean dolphin	F	Confirmed (necropsy report)	Healthy, adult female Chilean dolphin drowned in an anti-predator net of the same salmon farm as in 2015. In April. The company notified SERNAPESCA.	Necropsy report (provided by SERNAPESCA)
2017	Puyuhuapi Channel, Aysén Region	Chilean dolphin	U	Probable (eyewitness statement)	A small dolphin described as grey with a white belly and a round dorsal fin; found dead, entangled in an anti-predator net underneath a salmon farm cage during cage maintenance. Not reported to SERNAPESCA.	Contract salmon farm worker; C. Espinosa-Miranda & S. Heinrich, pers. comm., 3 March 2018
2017	Memory Channel, Aysén Region	Humpback whale	U	Confirmed (photo)	Adult humpback whale became entangled in an anti-predator net that was in the process of being installed at an inactive salmon farm. Whale released by farm workers by lowering the net. In December. The company notified SERNAPESCA.	Information & photos provided by SERNAPESCA

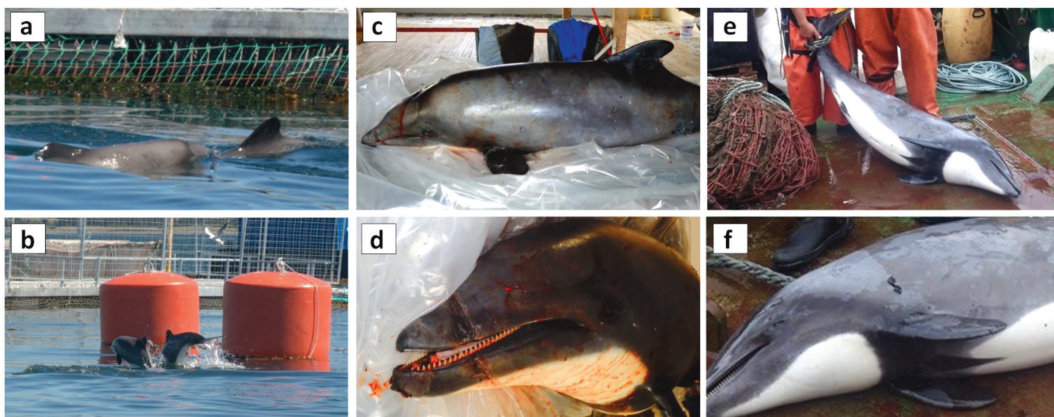
surround the salmon farm cages. Entanglement sites spanned the three administrative regions of southern Chile, but five of the eight reports were from the Aysén region (Table 1; Figure 1).

Only the two Chilean dolphin entanglement cases at one salmon farm in Magallanes and one humpback whale entanglement in Aysén were reported to SERNAPESCA and feature in the officially held records (Table 1). For the five cases where there is no official record, one was sourced from published material (Hucke-Gaete et al., 2013) and one from grey literature available online (Viddi, 2008). Three further cases were reported to us by local farm workers, one including photographic evidence that allowed confirmation of species, sex, and evidence of entanglement (Figure 2e & f). Two oral records included unsolicited but detailed descriptions of the specimen and the entanglement event. Both eyewitnesses described the entangled dolphin (or *tonina* in local language) as small and grey, with a white belly and a round dorsal fin. The Chilean dolphin is the only species in southern Chile matching this description.

Necropsy reports available for two Chilean dolphins from Magallanes confirmed that the dolphins died from drowning after becoming entangled in anti-predator nets surrounding the fish cages (Table 1). Both animals had net markings and lacerations on their skin, mainly around their heads, as well as blood and foam in their respiratory tract indicative of asphyxia (Figure 2d). In the other four cases, the dead Chilean dolphins either showed net markings on their body (Figure 2f) and/or were reportedly found attached to anti-predator netting at the salmon farm (Table 1).

While entanglement records of six Chilean dolphins and two humpback whales over a 10-y period might not seem to be an obvious cause for concern, we stress that these records represent a minimum number. Actual cetacean mortality in passive fish farming gear is likely underrepresented. Although the number of entanglements detected was low, our observations spanned a decade and an extensive geographic range (Figure 1). There was one report of Chilean dolphin bycatch in the Chiloé archipelago (Table 1) where the preferred shallow-water habitat of Chilean dolphins overlaps extensively with shellfish farms but less so with salmon farms (Heinrich et al., 2019). In the deep fjords and channels of the Aysén and Magallanes regions, where five of the six entanglements occurred, depth increases sharply from the shoreline leaving only a narrow corridor of shallow water nearshore. In these areas, the salmon farms are usually situated close to shore which might bring Chilean dolphins into closer proximity to them (Figure 2a & b).

The diet of Chilean dolphins has not been investigated, but anecdotal evidence suggests that they feed on small schooling and bottom dwelling fish (Goodall et al., 1988; CE & SH, pers. obs., 3 March 2018). There are no observations to suggest that Chilean dolphins (or any other dolphin species in southern Chile) feed on farmed salmonids, which are far larger than any of their suspected prey. Thus, we hypothesize that if Chilean dolphins deliberately approach salmon farm cages, they might be targeting wild fish attracted to the cages to feed on the food spoils of farmed fish (as suggested by Kemper et al., 2003).



**Figure 2.** Interactions of Chilean dolphins (*Cephalorhynchus eutropia*) with salmon farms: (a) dolphins foraging next to a salmon farm (2015); (b) dolphins leaping near a salmon farm (2016); (c) dead dolphin entangled at a salmon farm in Skyring Sound (2016); (d) zoom of net marks on the dolphin's rostrum (same individual as in photo c); (e) dead dolphin entangled in salmon farm in Cupquellán Channel (2015); and (f) dolphin showing skin abrasion caused by net (same individual as in photo e). (Photo credits: Cayetano Espinosa-Miranda [a & b], Olivia Blank [c & d], and an anonymous informer [e & f]).

To characterize the frequency of occurrence of dolphins and their potential behaviour near fish farms, we propose the use of static passive acoustic monitoring (PAM) around fish cages—for example, using echolocation buzzes as an indication of foraging behaviour (Schaffeld et al., 2016).

Chilean dolphins are known to become entangled in intertidal and nearshore gillnets (Heinrich & Reeves, 2017). A video of three Chilean dolphins trapped in the same gillnet off Traiguén Island, Aysén region, provides interesting insights into the dolphins' behaviour during net entanglement (<https://www.youtube.com/watch?v=hhDZUOMY3Zs>). During the entanglement, the dolphins remained inactive, floating near the surface, and did not try to break free. The dolphins remained passive even when they were approached by a boat and subsequently handled by divers who came to their rescue and released all three alive. Goodall et al. (1994) reported a similar behaviour for congeneric Commerson's dolphins (*Cephalorhynchus commersonii*) entangled in nearshore gillnets. Such passive behaviour contrasts with that described for net-entangled Peale's dolphins (*Lagenorhynchus australis*) that struggled leading to their escape from the nets (Goodall et al., 1994). Based on these anecdotal reports, we hypothesize that Chilean dolphins and other members of the genus *Cephalorhynchus* could be more prone to death in nets once they have become entangled compared to other sympatric species that might manage to break free. Such behavioural differences might help explain the prevalence of Chilean dolphins in the entanglement records and the apparent absence of other small cetaceans whose habitat also overlaps with salmon farms (e.g., Peale's dolphins). There clearly is a need for systematic investigations of the circumstances and characteristics leading to Chilean dolphin entanglements in salmon farm and other nets.

Molecular studies have shown strong geographic population structure in Chilean dolphins (Pérez-Alvarez et al., 2015). At least in the Los Lagos and Aysén regions, local populations appear to be distributed in small patches of no more than 100 individuals (Heinrich, 2006; SH & CE, unpub. data). Small and spatially structured populations are easily impacted by human-induced mortality events such as bycatch, even if only a few individuals are removed every year (Martien et al., 1999; Taylor et al., 2017).

Bycatch of two healthy adult Chilean dolphins in one salmon farm in Magallanes during a 6-mo period (Table 1) raises concerns over potential population-level effects, but these are difficult to evaluate without the context of local population size. Abundance estimates for Chilean dolphins and a better understanding of their population dynamics, both at local and regional scales,

should be a high priority for conservation and management of this endemic species (Heinrich & Reeves, 2017).

Although the Chilean dolphin was the only small cetacean species reported, this does not mean that entanglements of other cetacean species have not occurred. The two cases of entangled humpback whales indicate that baleen whales are also at risk of negative interactions with salmon farms as has been reported in North America and Scotland (Anon., 2014; Thomas, 2016; Bailey, 2018). Humpback whales and other large whales are recovering from over-exploitation in past commercial whaling and are beginning to recolonise key feeding grounds in southern Chile where salmon farming has been expanding (Hucke-Gaete et al., 2013; Niklitschek et al., 2013; Acevedo et al., 2014). Increasing spatial overlap and abundance of both whales and salmon farms also increases the risk of interactions. Baleen whales are known to be particularly prone to entanglements in static fishing gear that involves ropes, mooring lines, and/or nets (Lebon & Kelly, 2019; Moore, 2019). Humpback whales are still listed as “Vulnerable” under the Chilean species classification system (Ministerio del Medio Ambiente, 2011), and it is not clear if occasional entanglements of individual whales would affect this species' strong recovery in southern Chile. However, it also highlights potential risks to other sympatric baleen whales that are still classed as “Critically endangered” in Chile (Ministerio del Medio Ambiente, 2011) such as the Chile-Peru population of Southern right whales (*Eubalaena australis*) or sei whales (*Balaenoptera borealis*). As this article was about to be published, the first death of a sei whale from entanglement at a salmon farm in the Aysén region was reported in the local media and to the authorities (Anon., 2020). Large whale entanglements tend to attract a lot of public attention (Anon., 2014, 2020; Thomas, 2016; Bailey, 2018) and are more likely to be reported in social and mainstream media than dolphin bycatch.

The current level of official reporting of incidents involving the accidental killing of cetaceans (as required by Chilean law) is neither representative nor comprehensive. The scale and magnitude of the unreported mortality and the species affected remain unknown, but a lack of reporting suggests non-compliance with national legislation. This also hampers meaningful attempts to quantify incidental mortality of cetaceans in Chile's salmon farming industry to meet the requirements stipulated by the new regulations for seafood exports to the U.S. Substantial coordinated efforts from across a broad range of Chilean local, regional, and national government authorities, aquaculture operators, and local stakeholders are urgently needed to identify

and implement systematic monitoring programmes to assess bycatch and, where required, establish appropriate mitigation measures.

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