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Contribution to the Knowledge of Cetacean Strandings in Chile between 2015 and 2020

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Abstract: Strandings caused by anthropogenic factors are one of the most worrying threats in relation to the conservation of cetacean species, and in the case of Chile, due to its geography and large extension of the coastline, monitoring and access to these events is difficult, making their study more complex. Chile has a shortage of specialized scientific forensic research facilities for cetaceans; however, for this study, it was able to collect data recorded from official institutions and sporadic scientific biological sampling oriented to investigate the causes of death or stranding. According to the Chilean government official database, we described that the main causes of unusual mortality events (UME) and mass strandings from 2015 and 2016 were acute poisoning by biotoxins and strandings by multiple possible causes, respectively, while individual strandings would have their causes in anthropogenic activities, such as entanglements in fishing and aquaculture gears and collisions with vessels. The predominant species in mass strandings was the sei whale (*Balaenoptera borealis*). The geographical area of greatest prominence in mass strandings was the Aysén Region in the Central Patagonia of Chile, while the species mostly involved in individual strandings along the south-central, central, and northern coasts of Chile was the small porpoise (*Phocoena spinipinnis*). The most common gross pathological findings were advance decay of the carcasses and non-specific wounds of different natures.

Keywords: cetaceans; misticeti; odontoceti; strandings; pathology; Chile

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1. Introduction

Interest in researching cetaceans as conservation targets has increased markedly due to their particular features and charisma [1], their fundamental role in the context of oceanic food chains as top predators and fertilizers of the sea [2], as providers of ecosystem services [3], as bio-indicators of the ocean's health due to their great longevity, and the relevance of their population abundance as a biological tool in carbon sequestration to face climate change [4]. Strandings are undoubtedly one of the best sources to generate data for forensic studies of marine animals [5]. However, years of investigation of these events have led to a broader and more detailed understanding that includes animals found dead on shore, cetaceans found alive on shore, pinnipeds found sick or injured on shore, and animals that are "out of habitat". In some cases, marine mammals found entangled in fishing gear or debris and carcasses found floating in the sea are also considered strandings [6]. There are basically four types of stranding events: According to the number of individuals involved: (1) individual stranding (of a single individual or a mother with a calf, alive or dead), (2) mass stranding (more than one individual, alive or dead), (3) mass mortality and unusual mortality events (UMEs), and (4) out-of-habitat situations [7]. And according to the nature of the event, all four types can fit into two categories: (a) natural strandings (old age, malnutrition, abandonment of offspring, diseases of various etiologies, poisoning by biotoxins, and scape from predators), environmental causes (tides, volcanic eruptions, and earthquakes), and geographical causes (coast with low slope and local anomalies of the earth's magnetic field), and (b) anthropogenic strandings (noise pollution, plastic pollution, hydrocarbon spills, climate change, entanglements in fishing and aquaculture gear, and collisions with boats) [8]. With increasing stress and anthropogenic pressures on the marine environment, the impacts on marine mammals are growing. The sustained expansion in the number of annual cases, whether entangled in fishing gear or victims of collisions with large vessels because of intense maritime traffic [9], added to the inherent difficulties for the implementation of mitigation measures in highly migratory populations, making it imperative to quantify and understand the mechanisms by which these interactions occur. The objective, systematic, and coherent examination of stranded specimens, dead or alive, offers the only and opportune instance to carry out different studies; however, a combination of medical–forensic training and field experience is necessary to reliably evaluate the specimens and search for signs that guide the diagnosis towards its causality [10]. Added to the above, in the Chilean case, due to the geography and great extension of its coastline, monitoring and access to these events is even more complex, hindering the timely arrival of scientific research that helps to clarify the possible causes that generate these events [11]. In Chile, the diversity of cetacean species is abundant; a total of 8 species of mysticetes and 32 species of toothed whales have been recorded [12] (Table 1), reaching 43% of the global number of species described [13]. All cetacean species were declared a natural monument by Chilean regulation (Decree 230/2008); apart from that, the maritime areas of national sovereignty and jurisdiction have been declared a free zone for cetacean hunting (Law 20.293). Despite all the regulations and instruments designed to protect this group of species, there are still threats that affect them (MERI Foundation, undated).

Table 1. Habitual cetacean species recorded in the Chilean Sea [12].

Species per Family	Common Name
Balaenopteridae	
Balaenoptera musculus	Blue whale
Balaenoptera physalus	Fin whale
Megaptera novaeangliae	Humpback whale
Balaenoptera bonaerensis	Minke whale
Balaenoptera borealis	Sei whale
Balaenoptera edeni	Bryde's whale
Balaenidae	
Eubalaena australis	Eastern Pacific southern right whale
Neobalanidae	
Caperea marginata	Pygmy right whale
Delphinidae	
Globicephala macrorhynchus	Short-finned pilot whale
Globicephala melas	Long-finned pilot whale
Lagenorhynchus australis	Peales' dolphin
Cephalorhynchus eutropia	Chilean dolphin
Cephalorhynchus commersonii	Commersonii dolphin
Delphinus delphis	Short-beaked common dolphin
Delphinus capensis	Long-beaked common dolphin
Lagenorhynchus cruciger	Hourglass dolphin
Steno bredanensis	Rough-toothed common dolphin
Stenella coeruloalba	Striped dolphin

Table 1. *Cont.*

Species per Family	Common Name
Grampus griseus	Risso's dolphin
Lissodelphis peronii	Southern right whale dolphin
Tursiopstruncates	Bottlenose dolphin
Lagenorhynchus obscurus	Dusky dolphin
Pseudorca crassidens	False killer whale
Orcinus orca	Killer whale
Feressaattenuate	Pygmy killer whale
Phocoenidae	
Phocoena spinipinnis	Burmeister's porpoise
Australophocoena dioptrica	Spectacle porpoise
Ziphidae	
Ziphius cavirostris	Cuvier's beaked whale
Mesoplodon grayi	Gray's beaked whale
Mesoplodon layardii	Layard's beaked whale
Mesoplodon densirostris	Blainville's beaked whale
Mesoplodon hectori	Hector's beaked whale
Mesoplodon bahamondi	Bahamondi's beaked whale
Mesoplodon peruvianus	Peruvian beaked whale
Berardius arnouxii	Amoux's beaked whale
Hiperoodon planifrons	southern bottle-nosed whale
Tasmacetus shepherdi	Shepherd's beaked whale
Physeteridae	
Physeter macrocephalus	Sperm whale
Kogidae	
Kogia sima	Dwarf sperm whale
Kogia braviceps	Pygmy sperm whale

In the case of cetaceans, low adult survival or massive mortality events can have negative consequences for their population abundance. Cetacean mass strandings cause the deaths of up to hundreds of individuals in a single event. They occur in species of mysticetes and odontocetes; however, mass strandings of odontocetes occur more often than those of mysticetes, in part because of pod sizes and social interactions of odontocetes [14]. Recent research suggests that environmental factors, such as seasonal fluctuations or geographic location, would influence the increase in mass strandings. Despite this, while there have been numerous advanced theories, a few are backed by concrete evidence. There is no single conclusive explanation for all individual and mass strandings around the world [15]. According to a study of 50 years of cetacean strandings in Chile, which used the spatiotemporal permutation model using the space–time scan statistic for the cetacean strandings between January 1968 and August 2018, in Chile, the occurrence of these events is estimated to be 80% more than the global average [16]. Some authors point out that there is a trend towards an increase in these events since 2015 on the country's coasts, plus the difficulty in collecting data in Chile and the dispersion of the information obtained. Various agencies, both state and private institutions, that have registered strandings [16] provide the appropriate context for the generation of improvement initiatives in the collection and review of data and information, as well as the need to develop histopathological diagnostic techniques that will help to clarify the causes responsible for the current state of the strandings in Chile.

1.1. Probable Causes of Strandings in Chile

1.1.1. Anthropogenic Factors

(a) Fishing and aquaculture activities. There are mainly two types of interactions with marine mammals associated with fishing and aquaculture activities. On the one hand, those of the direct type (also known as operational or technical) in which the animals usually come into physical contact with the fishing gear or fish-capturing devices generate negative effects for both cetaceans and the targeted species of the fishery. On the other hand, indirect interactions (also known as biological or ecological) are those in which both marine mammals and the fishing industry compete for fish species [17] (Obusan et al., 2016). In Chile, bycatch of dolphins, killer whales, and sperm whales has been reported. Due to these rooted habits, these species currently suffer a deplorable reputation in most fisheries, and in response, they generate very drastic solutions or measures to repel mammals, threatening their survival, not only with those species that interact with fishing activity but also with those that do not, generally due to ignorance [18] (Arata and Hucke-Gaete, 2005). The most common form of anthropogenic trauma for small cetaceans is death by submersion due to bycatch. According to a study through pathological findings at necropsy carried out in 2020, most small and medium-sized cetacean species were affected by drowning when interacting with fishing activity [11] (Alvarado-Rybak et al., 2020a). Diagnosis of this condition is difficult in carcasses with moderate or advanced autolysis; therefore, the real magnitude of this problem is difficult to assess when access to fresh-stranded carcasses is limited. However, another in situ study carried out in south-central and southern Chile highlighted that the most common species affected by bycatch are Commerson's dolphin (*Cephalorhynchus commersonii*), Chilean dolphin (*Cephalorhynchus eutropia*), bottlenose dolphin (*Tursiops truncatus*), and Burmeister's porpoise (*Phocoena spinipinnis*) [16] (Alvarado-Rybak et al., 2019). On the other hand, based on an offshore stranding investigation by the Fisheries Development Institute (IFOP), during 2018 and 2019, small cetaceans of the Delphinidae family were incidentally caught (killer whale, bottlenose dolphin, dusky dolphin, common dolphin, and an unidentified dolphin). The total number of small cetaceans captured was 102, and 39 of them were killed. The species with the highest capture was the common dolphin, with 56 individuals, while the dusky dolphin was the species with the highest mortality, registering 19 dead individuals (IFOP, 2020). Regarding aquaculture, the interaction of marine mammals with this activity is usually negative; animals are affected by the loss of habitat and by the application of erratic mitigation measures, such as nets and acoustic artifacts that prevent the approach but cause the abandonment of the areas or even the death of the animals. Although there are no empirical data on whether the presence of salmon cages directly influences or alters movement patterns or habitat use by dolphins, Chilean dolphins have been observed avoiding salmon farms in fjords [19] (Hucke-Gaete, 2006).

(b) Whale-watching tourism. Whale watching can provide many socioeconomic benefits and could also aid conservation. However, this has many direct and indirect impacts on this group of species [20] (Parsons, 2012). In the short term, drastic changes in immersion times, group cohesion, or changes in speed and direction of movement can be observed in mysticetes [21] (Christiansen et al., 2013). Various behavioral changes were observed in humpback whales in Peru. While groups with calves avoid boats by increasing immersion time, course changes, and decreasing their number of breaths, groups without calves increase travel speed, time on the surface, and the number of breaths [22] (Garcia-Cegarra et al., 2020)

Chile has not been immune to this phenomenon either, due to the great diversity of species that visit the Chilean Sea. Although there are "General Regulations for the Observation of Hydrobiological Mammals, Reptiles, and Birds and the Cetacean Watching Registry" (D.S. No 38-2011), this is little known by tourists and the public. According to an investigation in the Isla Chañaral Marine Reserve, by observing whales through a theodolite, an alteration in the behavior of the fin whale was observed during tourist activity, particularly in reorientation (greater during post-tourism) and linearity (lower with and post-tourism), and in resting behavior (higher during post-tourism). These changes would be related to an evasive response in the presence of tourist boats; however, it is important to note that the intensity of tourism in the study area is moderate, since most of the observations had between one and two boats of tourism and, in a smaller proportion, more than three boats, with a maximum of five [23] (Sepulveda et al., 2017). Despite the latter, there is no record that proves any stranding event in Chile due to this cause.

(c) Collisions. Ship collisions with cetaceans are a major concern in the context of the conservation of these groups of species, whose incidence has increased rapidly due to the increase in global maritime traffic, speed, and fleet size.

This is particularly serious in populations of mysticetes since the groups facing the greatest risk of collisions were the most hunted during the last century, specifically during the whaling season, due to which several of them still have not been recovered [24] (Jackson et al., 2016). Ship collisions can cause acute trauma, with severe cuts to the skin, often compromising subcutaneous tissue and skeletal musculature, as well as limb amputation and/or evisceration. However, it is difficult to determine the pre- or post-mortem nature of these findings without further histopathological studies.

Regarding marine transit in Chile, according to what was observed in the Mejillones Bay, northern region of Tarapaca, Chile, one of the main whale aggregation areas is very close (less than 1000 m) to one of the main routes used by large cargo ships [25] (Pacheco et al., 2015), and, added to this, the navigation routes of fishing vessels coincide with the distribution of small cetaceans. Another issue in addition to the above is the speed of merchant ships, which usually exceeds the maximum limit [22] (Garcia-Cegarra et al., 2020). In Chile, there are published records of three possible collisions between ships and whales. During 2009, the first confirmed collision of a large whale was reported in Chile, which was identified as a female sei whale [8] (Brownell et al., 2009). The second collision report corresponds to the stranding of a blue whale during the year 2014 in the bay of Puerto Montt, region of Los Lagos, which would have arrived dead or dying a few meters from the waterfront of that city; the specimen had an exposed fracture in its right pectoral fin, which could probably be attributed to a collision with a large vessel [26] (CCC, 2014). Later in 2019, a complaint was registered for a collision of a blue whale specimen in the Tarapacá region through the hot line of the Chilean Fisheries and Aquaculture Service (SERNAPESCA) [27] (SERNAPESCA database 2009–2022). In addition to the three previously described vessel strikes, the review of the pathological findings of strandings between 2010 and 2020 revealed two more likely vessel strikes [11] (Alvarado-Rybak et al., 2020a). These animals were found near two ports with high maritime traffic, which could have increased the chances of collision with a ship [11] (Alvarado-Rybak et al., 2020a).

(d) Contamination. Another anthropogenic threat for these mammals is the exposure to high levels of pollutants, both acoustic and due to pollution from industrial activities or fishing operations [28] (Avila et al., 2018). For cetaceans, the threats posed by marine debris are manifold and range from direct impacts on health and mortality to possible secondary effects because of habitat degradation, the transference of chemical pollutants, and effects on prey populations [29] (Baulch and Perry, 2014). Eighty percent (80%) of marine pollution by plastics derives from terrestrial sources. Even in the case of countries like Chile, far from the large centers of production and consumption, there is evidence of incipient contamination by plastic [30] (Elías, 2015).

Heavy metals and non-essential metals, such as mercury, cadmium, and lead, are very toxic, even in small concentrations. Chronic or subchronic exposure to concentrations lower than those producing toxic effects can alter the composition and/or functionality of the immune system [31] (Cámara et al., 2003). According to studies carried out in Chile, the concentrations of both trace elements and persistent organic pollutants measured in pilot whales stranded on the Chilean coast are lower than those reported for the same species from Australia or New Zealand [22] (García, 2020). However, the presence of thallium ion (Tl+), a residue from the metallurgical industry that can produce toxic effects in mammals due to its competition with potassium ion (K+) in metabolic processes, was detected. Given their characteristic longevity and their quality as predators at the highest levels of the food chain in the marine environment, the order Odontoceti is most exposed, and although we are aware of the toxic effects that this trace element can cause, their effects on marine mammals are unknown. However, the fact that it was found in remote ecosystems may indicate its persistence in the environment [22] (Garcia-Cegarra et al., 2020), which opens the spectrum of factors to be considered when analyzing the causative agents that influence mass strandings and/or mortality events in Chile.

Noise pollution, or anthropogenic underwater noise, is currently recognized as a global problem, and studies have shown a wide range of negative effects on a variety of taxa [32](Williams et al., 2015). It can be generated by a variety of activities, such as commercial transportation, oil and its subsea exploration, pipeline development and construction, naval operations (e.g., military sonars), fishing (e.g., acoustic deterrents and harassment devices), research using air guns, icebreakers, and recreational boating [9] (Colpaert et al., 2016). Although there is no confirmed evidence of these activities causing mortalities or mass strandings in Chile, they could all perfectly be part of the "multiple causality of strandings" in Chile. Further studies should necessarily be implemented to confirm it.

1.1.2. Natural Factors

(a) Biological agents that can lead to death and/or stranding can be viral, fungal, parasitic, and bacterial infections [33] (Starrantino, 2018). It is also important to include stranding events associated with biotoxin poisoning, as occurred in the mass stranding of Golfo de Penas, Chile, during the summer of 2015 [34]. Although in live specimens the assessment of the health status of wild cetaceans is difficult to carry out without handling and capture, the observation of skin lesions allows the identification of diseases such as lobomycosis caused by *Lacazia loboi*, dermatitis caused by herpesviruses, and rhomboid lesions caused by *Erysipelothrix rhusiopathiae*, a disease potentially lethal [35] (Powell et al., 2018). Even the lesions observed in carcasses could also be a source of data for population extrapolation [5] (Geraci and Lounsbury, 2005). In the case of Chile, around the year 2006, the presence of wounds on the skin of Chilean dolphins (*Cephalorhynchus eutropia*) and bottlenose dolphins (*Tursiops truncatus*) was detected for the first time, which could have been related to environmental degradation as an effect of pollution or exotic diseases probably associated with aquaculture. However, more research is needed to test this hypothesis [19] (Hucke-Gaete, 2006). Regarding parasitic infections, according to necropsies carried out on 15 specimens stranded between 2010 and 2019, parasitism and diseases derived from these agents were observed in some toothed whales, including verminous pneumonia and vasculitis due to *Pseudalius inflexus* in Burmeister's porpoises. This nematode is a parasite that can cause direct mortality or cause secondary bacterial pneumonia with fatal consequences. In the case of respiratory and periotic sinus nematodes within the genus Stenurus, it has been suggested that they can potentially affect hearing and echolocation, and although lesions observed in the study were significant, there is no evidence that they have complicated the escape from entanglements or increased the risk of stranding due to echolocation failures, since to assess the real impact of parasites of Stenurus spp. in Burmeister's porpoises, a histopathologic examination is needed [36] (Alvarado-Rybak, et al., 2020b).

(b) Climatic and seasonal factors, such as El Niño and Harmful Algal Blooms (HABs), can result in domoic acid (DA) production, a neurotoxin that can cause amnesic shellfish poisoning in humans, with symptoms such as vomiting, seizures, memory loss, and disorientation. In the case of marine mammals, such as sea lions and seals, they have shown neurological dysfunction due to brain lesions, especially in the hippocampus, which could lead to maladaptive navigation behavior and consequent mortality in the wild [37]

(Bengston, 2016). Although biotoxin poisoning is a biological agent, the reason why it was decided to address in this item is due to its possible relationship with climate change. During 2015 in Golfo de Penas, Chile, an unusual mass mortality episode (UME) was reported, producing by far the largest ever recorded unusual mortality event of baleen whales at one time and place, with the death of 369 individuals in the span of a few weeks, and most probably the number of individuals killed in that event probably exceeded 400 individuals, since those that die offshore tend to sink and not refloat [38] (Smith et al., 2015). In five of the specimens analyzed by necropsy, no signs of human interaction were determined in the deaths of these animals. Also, due to the position of the whales on shore (skull resting on their dorsal part), it was postulated that the animals apparently died while they were still in the water, and the sea currents and winds dragged them to shore; therefore, some authors referred to this event as mass mortality rather than multiple stranding. Traces of toxin were found in the vectors, *Sprattus fuegensis* and *Munida* spp., and in the stomach contents of two necropsied specimens. Additionally, the remains of *Pseudonitzschia* spp. cells in their intestinal content were also found. This is supported by the higher presence of Pseudonitzschia during February and March 2015, measured at the stations of the Chilean Red Tide Monitoring Program [34]. Due to this and to rule out other natural or anthropogenic causes, the most solid and probable hypothesis was that of poisoning by biotoxins from harmful algae blooms (HABs), and although this would have been possibly related to the phenomenon of El Niño [34] (Häussermann et al., 2017), it is relevant to stress the increase in HABs, whether associated with climatic phenomena or the contribution of nitrogen or other nutrients to the sea, and its impact as a possible cause of mass strandings.

(c) Geographic factors: the hypothesis on coastal morphology indicates that shallow, closed bays with wide intertidal differences act as traps for pelagic cetaceans [4] (Perrin & Geraci, 2009). On the other hand, there is evidence that geomagnetic anomalies of the earth are directly related to stranding zones [39] (Mazzariol et al., 2011), in which animals tend to get disoriented, become stressed, and escape to strand on nearby coasts. Although this factor could perfectly be a common natural cause of live stranding events, so far there is no registered evidence of this phenomenon causing the stranding of cetaceans in Chile.

2. Materials and Methods

The material used for this study came from the official database of SERNAPESCA from 2009 to 2022 (http://www.sernapesca.cl/informacion-utilidad/registro-de-varamientos, accessed on 1 January 2022), a database Excel spreadsheet that was carefully revised case by case for possible duplications or inconsistencies, the latter complemented with personal communications from the stranding team of the same institution and from published scientific studies. Species belonging to the cetacean order, odontoceti, and misticeti suborders, identified in this database were used as the animal unit. The criteria used to select each case of stranding were based on the definition of strandings [7] (Würsig et al., 2018). The aim of this article was to describe and analyze strandings that occurred in Chile between 2015 and 2020, considering: (a) category (mass or individual events), (b) species, sex, and age of animals; (c) geographic location of events; (d) vital status of the specimen(s); (e) most common pathological findings; (f) most probable causes of stranding and/or death; and (g) seasonality.

3. Results

According to the data obtained in Chile, mass strandings had their origin in an acute natural cause such as poisoning by biotoxins like domoic acid and saxitoxin [34] (Häussermann et al., 2017) and possibly brevetoxin (Perez et al., In Press) present in the food source, together with stranding due to multiple possible causes of anthropogenic and/or natural origin [16] (Alvarado-Rybak et al., 2019). On the other hand, the greatest number of individual events of stranding were possibly caused by entanglement in fishing gear and collisions with vessels, both of anthropogenic origin [18] (Arata and Hucke-Gaete, 2005). Despite the above, in most cases originally registered in this database, the causes of stranding were undetermined. However, through the careful classification of gross pathological features and injuries, it was possible to generate hypotheses on both causes of entanglements and collisions and achieve fairly accurate diagnoses on the possible causes of strandings, interestingly reaffirming the usefulness of a data set lacking further histopathological studies.

3.1. Strandings by Category (Mass or Individual Events)

The total number of stranding events has remained relatively stable (Figure 1), showing a gradual increase between the years 2015 and 2019, counting 36, 37, 42, 45, and 46 stranding events for each year, respectively. However, during the year 2020, there was a slight drop (43 registered events), and there may be a bias in the number of records associated with less vigilance due to movement restrictions during the COVID-19 pandemic. On the other hand, the number of stranded animals were by far higher than the number of events, being the largest number recorded in the summer of year 2015, counting 402 specimens of sei whale (*Balaenoptera borealis*), given the contribution of the mass unusual mortality event (UME) of mysticetes that occurred in Golfo de Penas, Aysén Region, in the central Patagonia of Chile (Ulloa et al., 2016). On the other hand, most of the individual events occurred on the south-central, central, and northern coasts of Chile and involved small cetaceans such as Burmeister's porpoise, dusky and Chilean dolphins, and large whales like fin and sperm whales (Table 2).

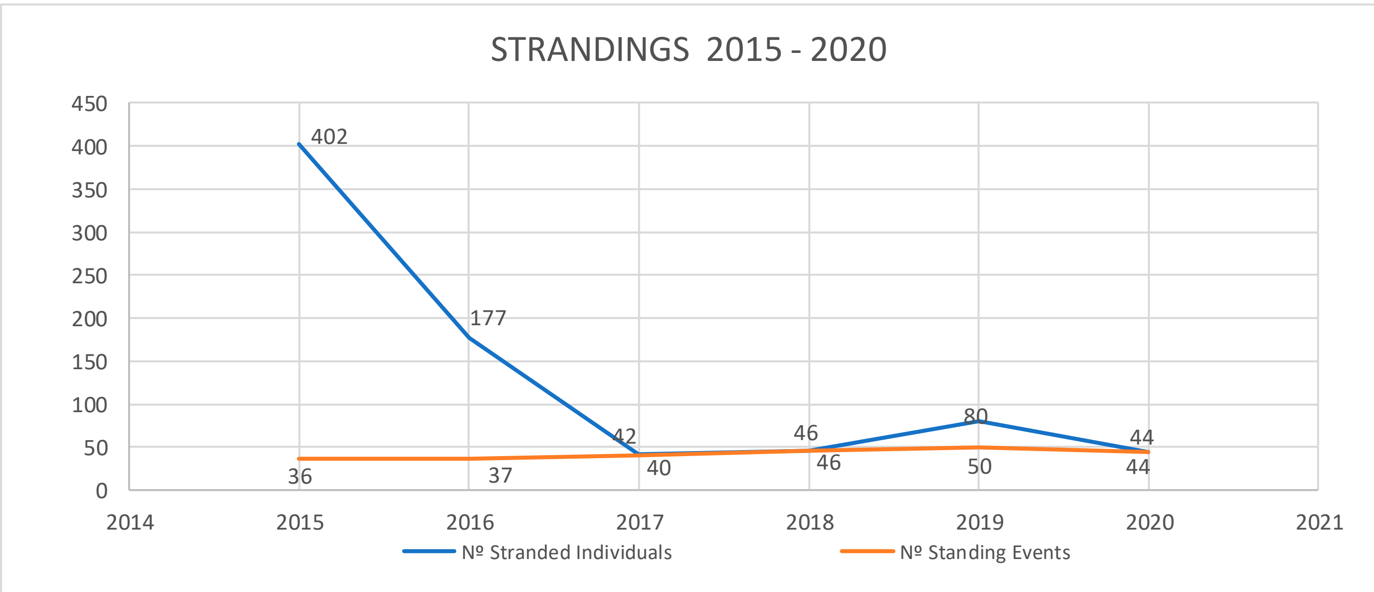

Figure 1. Stranding events in contrast to stranded individuals 2015–2020.

3.2. Strandings by Species of Animals

Out of 791 stranded animals (Table 2), the species with the largest number of individuals recorded, ordered from highest to lowest, corresponded to: sei whale (426 individuals), long-finned pilot whale (129 individuals), and Burmeister's porpoise (53 individuals). The first two most affected species are related to mass strandings in 2015 (sei whales) and 2016 (pilot whales). In the case of Burmeister's porpoise, they mostly correspond to individual strandings, with the later registering the highest number of stranding events in the period.

3.3. Strandings by Sex of Animals

Eighty-nine animals (11.3%) corresponded to males, 79 individuals (10%) to females, and 623 individuals (78.7%) were indeterminate in terms of sex. Table 2. The literature indicates that the generic structure of cetaceans favors females [40] (Ottensmeyer and

Whitehead, 2003). Although these partial results show a slight preference for males, the number of indeterminate individuals is too large to support this difference.

Table 2. Cetacean species recorded in strandings in Chile by taxonomic family, sex, and age group 2015–2020.

		Sex			Age Class				Total	
Species per Family	**Common Name**	**Female**	**Male**	**Undetermined**	**Calve/ Juvenile**	**Subadult**	**Adult**	**Undetermined**	**No Individuals**	**%**
Balaenopteridae (60.9 %)										
Balaenoptera musculus	Blue whale	4	1	2	2	1	4		7	0.9
Balaenoptera physalus	Fin whale	6	8	9	6	8	9		23	2.9
Megaptera novaeangliae	Humpback whale	3	3	10	6	3	7		16	2.0
Balaenoptera acutorostrata	Minke whale	1		2	1		2		3	0.4
Balaenoptera borealis	Sei whale	16	11	399	3	8	6	409	426	53.9
Balaenoptera brydei	Bryde´s whale			1		1			1	0.1
Unidentified whale				6		2		4	6	0.8
Balaenidae (0.3%)										
Eubalaena australis	Eastern Pacific southern right whale		1	1		1	1		2	0.3
Delphinidae (27.1%)										0.0
Globicephala macrorhynchus	Short finned pilot whale	2	1	1	1		3		4	0.5
Globicephala melas	Long finned pilot whale	10	20	99	38	12	23	56	129	16.3
Lagenorhynchus australis	Peales´ dolphin	2	1	2	2		3		5	0.6
Cephalorhynchus eutropia	Chilean dolphin	2	1	8	4	2	5		11	1.4
Delphinus delphis	Short-beaked common dolphin	1	4	2	1	2	4		7	0.9
Lagenorhynchus cruciger	Hourglass dolphin			1			1		1	0.3
Steno bredanensis	Rough-toothed common dolphin		1	1		2			2	0.3
Grampus griseus	Risso´s dolphin	1	4	4	1	5	3		9	1.1
Lissodelphis peronii	Southern right whale dolphin			2			2		2	0.3
Tursiops truncatus	Bottlenose dolphin		1	7	3		5		8	1.0
Lagenorhynchus obscurus	Dusky dolphin	3	5	14	2	3	15		22	2.8
Pseudorca crassidens	False killer whale	2	1	2	2		2		4	0.5
Orcinus orca	Killer whale	1	1	5	2		5		7	0.9
Unidentified Dolphin			1	2	1		2		3	0.4
Phocoenidae (6.7%)										0.0
Phocoena spinipinnis	Burmeister´s porpoise	15	12	26	18	14	21		53	6.7
Ziphidae (0.8%)										0.0
Ziphius cavirostris	Cuvier´s beaked whale	1		3		1	3		4	0.5
Mesoplodon grayi	Gray´s beaked whale	1			1				1	0.1
Mesoplodon layardii	Layard´s beaked whale		1				1		1	0.1
Physeteridae (2.8%)										0.0
Physeter macrocephalus	Sperm whale	6	8	8	5	7	10		22	2.8
Kogidae (1.5 %)										0.0
Kogia sima	Dwarf sperm whale	2	3	7		4	8		12	1.5
TOTAL		79	89	623	99	76	145	469	791	100.0
%		10.0	11.3	78.8	12.5	9.6	18.3	59.3		

3.4. Strandings by Age of Animals

Registration of animals' ages was possible only in a small proportion (33.1%) of the total stranded individuals. Within this figure, out of 262 individuals classified by age, the largest number corresponds to 123 adults, followed by 65 juveniles and calves, 53 subadults, and 21 indeterminate (Table 2). There is no information on age estimation for the remaining 529 individuals, which comes mainly from two mass strandings that occurred in the southern Aysén region in 2015 and 2016. The method used for estimation of age was the size of the specimens.

3.5. Strandings by Geographic Location

The largest number of stranded individuals was recorded in southern Chile, in the Aysén region, central Patagonia, followed by the Valparaíso and Coquimbo regions in the central and northern areas of the country, respectively. The highest number of stranded specimens recorded in the Aysén region is not related to the low number of recorded events, which is easily explained by the occurrence of two mass mortality and stranding events of sei whales and long-finned pilot whales in that region. In the case of Valparaíso and Coquimbo central and northern regions, respectively, there is equivalence between the number of events and the number of stranded specimens, regions that account for the greater number of individual events. On the other hand, if we only refer to the number of events, the highest numbers were registered in the regions of Coquimbo (33) and Valparaíso (33) (Figure 2).

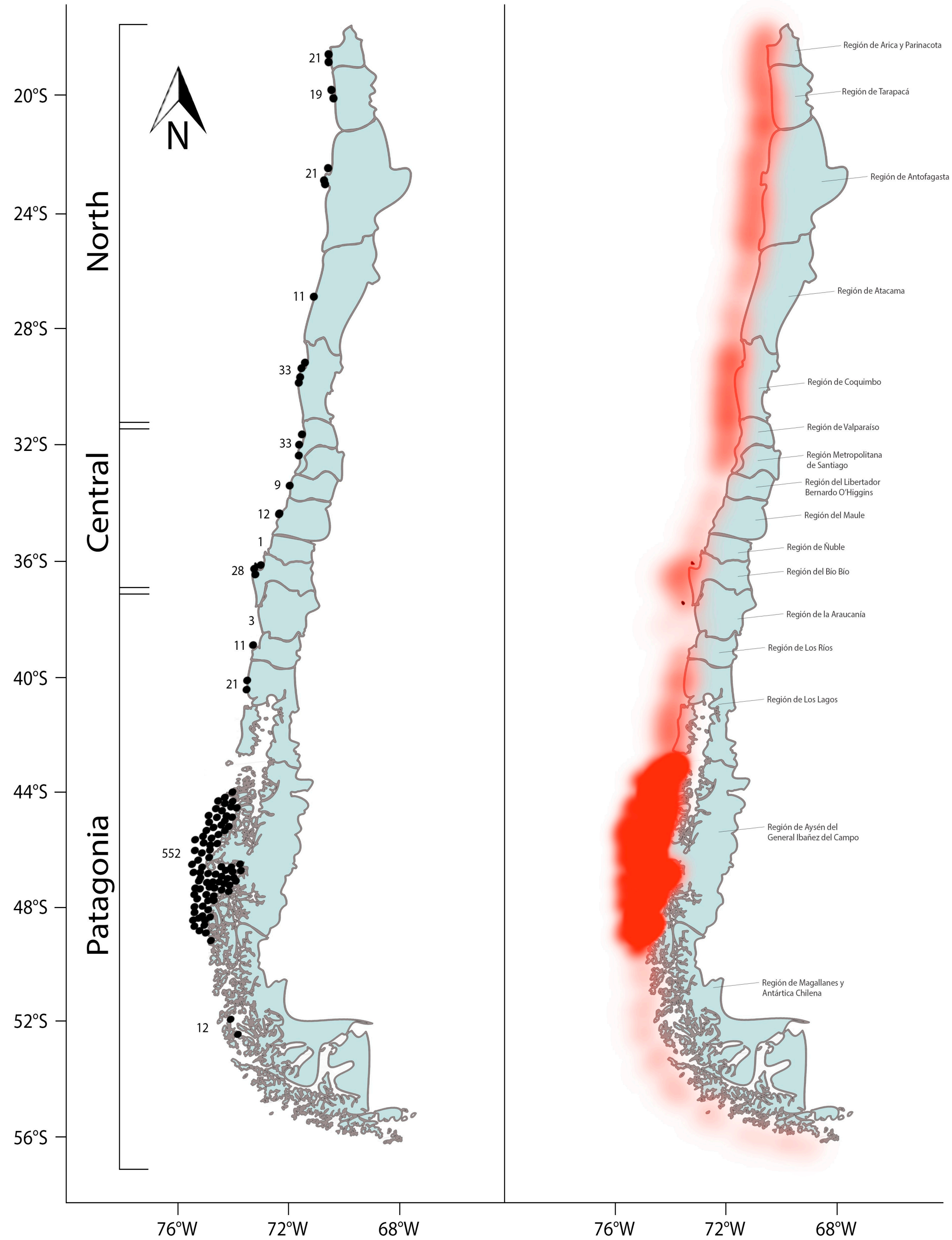

Figure 2. Map of Chile and its 15 coastal regions, highlighting the occurrence of strandings.

3.6. Strandings According to Vital Status

According to the initial or vital state of the stranded animals, 5.3 percent (42 individuals) in 35 events were reported alive, while the other 94.7% (749 individuals) in 218 events were reported dead. Of the 42 live animals, 7 were refloated and released with human intervention, and one of them refloated spontaneously and was reinserted into the sea by its own means when the tide rose again. The rest of the animals stranded alive died shortly after beaching.

3.7. Strandings According to the Most Common Pathological Findings

According to the records of necropsies performed, only in 17.4% (44) of the total number of events (253), a necropsy or biological sampling was performed on one or more animals, while in 82.6% (209), it was not due to factors such as the advanced state of decay of the carcasses, difficulties in accessing the site due to geography, a lack of appropriate logistics, and also a lack of expertise to carry out a proper necropsy procedure.

The advanced state of decay was recorded in 57 events, and other findings associated with this natural process include exposed bones (2), loss of skin coloration (1), absence of the eyeballs (8), deep holes (1), destroyed carcass (1), and the presence of skeletons (2). In the case of superficial lesions, 34 cases of lesions in the epidermis, 2 lacerations, and 5 skin detachments were found.

Putting aside findings associated with the advanced state of decay, gathering superficial lesions in a single item, and performing the same action in relation to internal organs, 19% of the events recorded wounds without a specific affected area or depth. Fifteen percent (15%) of the lesions were superficial, and in 13% of the records, no marks or wounds were observed. However, injuries such as severed muscle cuts (6%) or fin cuts (9%) are relevant in terms of human attacks or post-mortem slaughter, and evisceration (2%) and dismemberment are also included as signs of anthropogenic intervention (Figure 3).

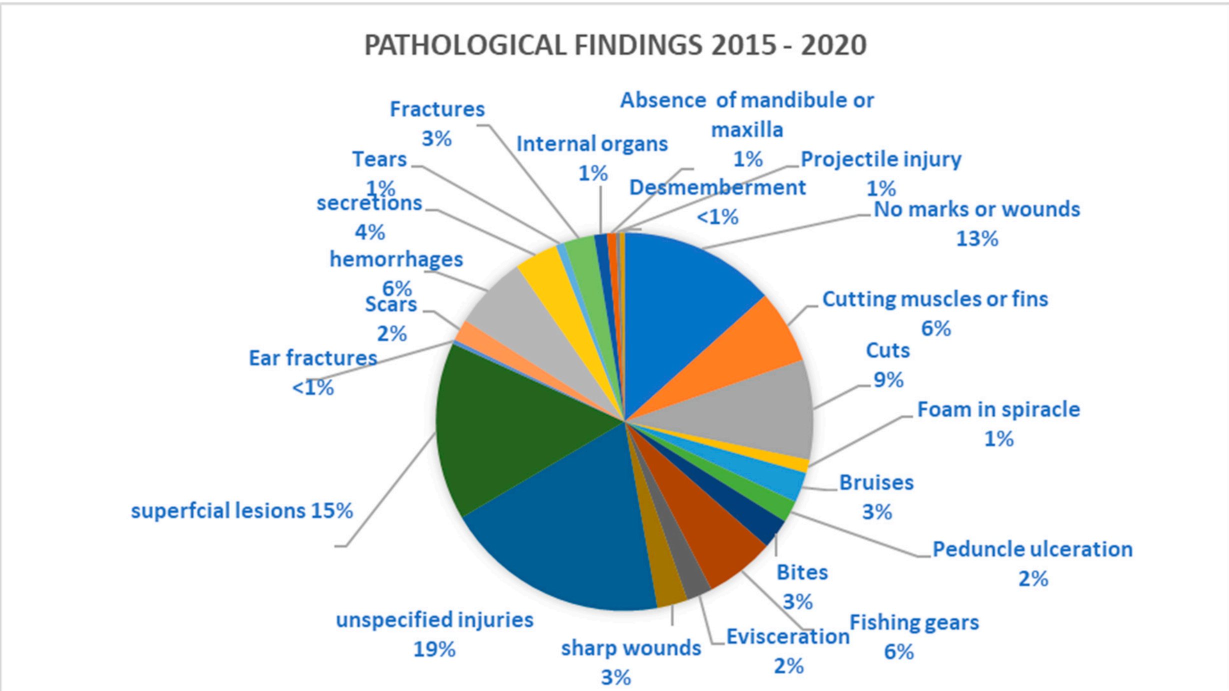

Figure 3. Pathological findings 2015–2020 without considering advance decay.

Findings of fishing gear and/or ulcerations on the tail caused by entanglement in nets or debris reach up to 8%. Other types of findings, such as fractures or dislocation of the mandible or fins (3%), absence of the mandible or maxilla (1%), evisceration (2%), tears (1%), and bruises or contusions (3%), are relevant when determining whether the stranding was caused by a collision with a boat. Regarding suffocation by submersion, the presence of foam in the blowhole or trachea was the external criteria considered for this class (asphyxia by submersion, 1%). Predation as a cause of injuries was associated with sharks or other cetaceans, such as killer whales; two of five records of this item are described as a cause of stranding or death. In terms of slaughter (killing and cutting a live stranded specimen and using the meat for other purposes), all correspond to toothed cetaceans: Burmeister's porpoise (9), dwarf sperm whale (3), sperm whale (1), Chilean dolphin (1), Peale's dolphin (1), and Risso's dolphin (1). More than half of slaughters (56%) corresponded to Burmeister's porpoises. Most superficial lesions observed were related to tidal trawling and scavenger birds, and 153 records could not be associated to any cause.

3.8. Strandings by Main Probable Causes

Species registered in strandings with identification of a possible cause (Table 3).

Table 3. Strandings by main probable causes, species involved, and regions affected.

Main Possible Causes of Stranding, Species, and Regions					
No Animals	**% Animals**	**No Events**	**Possible Stranding Causes**	**Species**	**Region**
388	49.1	3	Biotoxin poisoning	Sei whales	Patagonia
124	15.7	1	Disorientation by multiple possible causes	Pilot whales	Patagonia
40	4.6	35	Possible entanglement	Humpback whale, Chilean dolphin, Burmeister's porpoise, fin whale, sperm whale, sei whale, killer whale	North, Patagonia, central
24	3	24	Possible collision	Fin whale, blue whale, humpback whale, Burmeister's porpoise, sperm whale, unidentified	Patagonia, central, north
16	1.0	16	Possible slaughter	Burmeister's Porpoise, dwarf sperm whale, Chilean dolphin, Paele's dolphin, sperm whale, Risso's dolphin	Central, north
199	26.6	184	Other causes and undetermined	All species	All regions
791		253			

- Asphyxiation by submersion: Burmeister's porpoise (4). Total 4.
- Biotoxin poisoning: sei whale (388). Total 388.
- Disorientation due to multiple possible causes: long-finned pilot whale (124). Total 124.
- Possible collisions: fin whale (5), blue whale (4), and minke whale (1).

Chilean dolphin (1), Burmeister's porpoise (2), humpback whale (2), sperm whale (2), sei whale (1), dusky dolphin (1), short-beaked common dolphin (1), bottlenose dolphin (1), long-finned pilot whale (1), and unidentified whale (2). Total 24

- Possible entanglement: humpback whale (6), fin whale (4), sperm whale (3), southern right whale (2), blue whale (2), sei whale (2), dwarf sperm whale (2), Chilean dolphin (7), short-beaked common dolphin (1), southern right whale dolphin (1), Burmeister's porpoise (5), killer whale (5). Total 40.
- Possible slaughter. Burmeister's porpoise (9), dwarf sperm whale (3), Chilean dolphin (1), Risso's dolphin (1), Peale's dolphin (1), and sperm whale (1). Total 16.
- Predation: sei whale (2) and Burmeister's porpoise (1). Total 3.

Stranding events in which the most probable cause was identified correspond to the mass stranding of sei whales, related to poisoning by biotoxins from harmful algal blooms (HABs) [34] (Häussermann et al., 2017), followed by the stranding of long-finned pilot whales, associated with disorientation due to multiple possible causes [16] (Alvarado-Rybak et al., 2019). The third cause identified was entanglement, either in fishing gear or in debris from this activity. The fourth most common possible cause was collision with vessels, where 54% out of 24 cases corresponded to large whales. Both entanglement and collisions have an anthropic origin; although the number of individuals is lower than in the two previously mentioned causes, the number of events is higher. While poisoning by biotoxins or disorientation due to multiple possible causes represents less than 1% of the stranding events, entanglement corresponds to 13,8%, followed by collisions with 9,5% of the total number of events recorded, all of them being individual stranding cases. With reference to probable causes of death, in cases of collisions and predation, the most probable cause of death is associated with traumatic injuries (multiple fractures, rupture of organs, visceral hemorrhages, anemia by acute hemorrhages, hemothorax, hemoabdomen, and multiple organ failure) [41] (Diaz-Delgado et al., 2018). In the case of entanglement in fishing gear or debris, the most probable cause of death was pulmonary edema, pulmonary emphysema, and organ congestion, which led to suffocation [42] (IJsseldijk et al., 2020). In the case of disorientation caused by multiple possible causes, where it is most probable that the animals were stranded alive, the most probable cause of death should be the stranding syndrome, characterized by internal damage induced by prolonged recumbency and cardiovascular collapse during beaching [43] (Fernández et al., 2005). In cases of intoxication by HABs, the most probable causes of death are paralysis and neurologic clinical signs due to neurotoxic poisoning, gastrointestinal clinical signs leading to dehydration, and respiratory distress due to lung congestion and edema, all of which end in death by submersion [44] (Dierauf and Gulland, 2001).

3.9. Strandings by Seasonality

Regarding the records of seasonality, most events as well as the greatest number of individuals occurred during the spring/summer season. Entanglement and slaughter seem to have equal seasonal presentation throughout the year. On the other hand, collisions have a marked tendency to occur during the spring–summer season (Table 4).

Table 4. Strandings by predominant cause and seasonality.

Season	Number of Animals				
	Collisions	Entanglements	Biotoxin	Disorientation	Slaughter
Spring/summer	13	10	388	124	9
Autumn/winter	4	8	n/a	n/a	7

4. Discussion

According to the data obtained, mass strandings in Chile tend to occur preferably during the spring/summer season and in the Patagonia of Chile. An increase in temperature and luminosity provides appropriate conditions for the development of HABs, which favors the presence of biotoxins in the food chain. This was the case of the most numerous mass mortality events of mysticetes (sei whales) registered in the world's history in one single event lasting no more than 4 to 6 weeks in Golfo de Penas, Chile [34] (Hausermann et al., 2017). On the other hand, the mass stranding of pilot whales in 2016 was due to multiple possible causes, such as geomagnetic anomalies; poor knowledge about the topography of coastlines (long, gently sloping beaches) in offshore species; anthropogenic noise like sonars or underwater explosions; and even a psychological factor, like a subconscious longing for land, among others. Although in some cases it is possible to find suggestive lesions of different natures, there is general consensus that in odontocetes, solitary strandings are likely to be related to disease and that mass strandings are largely related to cetacean behavior and biology [45] (Brabyn, 1990) and the possible multicausality of these phenomena [46] (Hunter et al., 2017). Timely access to stranded cetaceans is a critical factor in the success of any scientific research and/or forensic study. However, there are other specific approaches to histopathology to be considered, such as taphonomy (processes affecting remains from the time of death of an organism), which can be quite helpful to orient towards possible causes. This could have been the case of *Globiscephala melas* in 2016, an event discovered between 5 and 6 months after it occurred, where the chaotic arrangement of the individuals in a zone least affected by tides and currents may suggest that there was a stampede of some individuals caused by multiple possible causes, such as underwater noise, among others (Behrensmeyer et al., 2000). Mass mortalities in odontocete species are well known and more frequent than those in mysticete species due to certain characteristics, such as being deep-sea inhabitants and having a strong social organization [47] (Simmonds, 1997). However, the pilot whale (G. melas) itself is one of the odontocetes with the most records of mass strandings in the world [48] (Bravo, C. 2015).

In seventy-one percent (71%) of the stranded individuals, determination of sex was not possible due to mass strandings without access to all carcasses; on the other hand, 29% of animals were sexed; however, according to the data obtained, there was no significant difference in these results compared to proportions of sex globally registered for cetaceans. Recorded age ranges indicated that strandings occurred mainly in adult animals, and it is probable that the greatest mortality of young individuals occurs offshore. It is also inferred that disorientation that leads to mass strandings is much more common in families, even of healthy individuals, that have a high level of cohesion, as was the case with long-finned pilot whales in 2016 [16](Alvarado-Rybak et al., 2019). On the other hand, referring to the low number of necropsies performed and the fact that, in many cases, the procedures only aimed to describe gross signs of alteration or disruption of organs with a focus on biology rather than pathological studies, twenty-six-point five percent (26,5%) of animals had undetermined causes of strandings, while the cause is known in 73.5% of animals. This does not necessarily reflect the actual local scientific capacity to determine causes of stranding but is only due to the occurrence of several mass strandings encompassing more than 90% of this cohort. However, if we analyze the rest of the possible stranding causes classified, we can see certain coherence between the lesions encountered and the possible causes of stranding and or death. For example, possible entanglements have patterns of suggestive evidence, such as the presence of fishing gear, peduncle ulcerations, and compression scars, and possible collisions could be related to sharp wounds, fractures, absence of the mandible/maxilla, evisceration, and hemorrhages mainly. This could support the fact that although no specialized skills in histopathology have been developed in Chile, a gross, detailed, and careful examination can lead to significant accuracy in the diagnosis of causes.

Regarding the geographical location, the greater number of stranded animals was recorded in the southern region of Aysén due to mass strandings of nearly 550 individuals, while the central regions of Coquimbo and Valparaíso recorded the largest number of stranding events. The differences between these two observations (number of events vs. number of specimens) could be related to factors such as geography, climate, and the low number of reports by public observers due to the length of the Chilean coastline and its disproportionately distributed population. Due to these factors, the largest number of events in the central regions of Coquimbo and Valparaíso may be related to better surveillance based on the higher population density, where the Valparaíso region has the highest density of persons per square kilometer (km^2), with a density of 111.27 persons, followed by Coquimbo with 18.67 inhabitants. The Aysén region, on the other hand, has a density of only 0.96 inhabitants [49] (INE, 2017). The greater number of animals recorded in the Aysén and Biobío regions is explained by the greater number of cetacean individuals frequenting the southern coasts, looking for feeding areas [50] (CCC, 2008).

The gross pathological findings analysis recorded a high number of lesions corresponding to signs associated with an advanced state of decay or the action of scavengers. On the other hand, superficial injuries can also be caused by rubbing against rocks or sand when beaching. Tears and bites analysis could be associated with predation; however, analysis of old carcasses has not always led to this interpretation. In contrast, on the slaughter records, the removal of fins or musculature, evisceration, and clean cuts can be associated with direct anthropogenic damage.

Both predation and slaughter as findings to support causes of death require an adequate description and identification of lesions, especially about slaughter, given the large percentage of Burmeister's porpoise individuals with traits of anthropic action, which was reported as a postmortem finding in most cases. Hypotheses could be raised to assign slaughters to a previously possible cause of death by entanglement, which could enlarge figures of the latter.

Histopathology and analysis of the borders of wounds can make the difference between slaughter pre- or postmortem [51] (Stacy et al., 2014). Although both actions are classified as outlaws by Chilean regulation, the clarification of these events may contribute to the investigation of a more precise causality within these groups.

Events causing mortality, such as predation, suffocation, or intoxication with HABs, register a low number of events, and most of the individuals were found in an advanced state of decay. On the other hand, causes such as predation or suffocation have a lower impact on individual populations due to fewer affected animals, versus the numbers of cases of probable intoxication with HABs or stranding due to multiple possible causes, which are larger and thus of great importance in terms of population conservation.

Comparatively speaking, from the perspective of probable causes of stranding, events of an acute and occasional nature, such as intoxication with HABs or disorientation due to multiple possible causes, although they have a small number of occurrences, can lead to the stranding of hundreds of individuals. On the one hand, the monitoring of HABs and their effects on the local fauna is important, and on the other hand, in the case of disorientation due to multiple possible causes (intense noise, among others), there is a need to develop the technical competences to be scientifically able to prove the damage caused by the use of sonars in fisheries, military exercises, archaeology, etc., among others. And in a second stage, it is necessary to develop adequate protocols for the use of these devices in the ocean to avoid or mitigate possible harm to marine animals.

Regarding the registered collisions, 8 out of 9 corresponded to mysticetes; therefore, as previously mentioned, it is confirmed that the group of species with the highest risk of collision is the large whales [24] (Jackson et al., 2016), and among them, the fin whale is the one that registered the highest number of collisions (4/9), which has also been pointed out by other authors as one of the most vulnerable species due to its surface behavior [16] (Alvarado-Rybak et al., 2019). Although these figures are important, they do not reflect the real mortality occurring overseas.

With respect to entanglements, the data obtained showed that species found entangled range from small, toothed cetaceans (21/40) to large, toothed whales and mysticetes (19/40), which makes both figures quite similar; nevertheless, most of the entangled animals die in the open sea and no more than 10% beaches ashore, so this proportion may have an important bias [52] (IWC, 2018).

Another study that considered the strandings between 1970 and 2005 reported through the RAMMC (Chilean Whale Watching Network) that out of the total causes of death, 55% correspond to undetermined causes, 18% to entanglement, 13% to direct capture with a firearm or harpoon, 7% to non-anthropogenic causes, 4% to collision with boats, and 3% to possible noise pollution or loss of habitat [53] (Galletti and Cabrera, 2007). These figures are quite different compared with the official database that started to collect every single event and number of animals in 2009 by SERNAPESCA.

Regarding entanglement events, they equally occur during the summer or winter seasons (10 vs. 8). The predominant species among big whales are humpback (6), followed by fin (3) and sperm (3) whales. About geographical distribution, most of them occur in the northern regions (8) and Patagonia regions (6) (Figure 2). No patterns were observed about seasonality or geography. The species more frequently involved are *Megaptera novaeangliae* among large whales and Burmeister's porpoise among small cetaceans. It is opportune to mention that cetaceans' entanglement events, especially in large whales, are known to be underestimated. Studies suggest that more than 90% of the entanglements in fishing gear occur overseas and less than 10% washes up on the coast; most of them are never registered in official data sets. [52] (IWC, 2018). On the other hand, the highest capture in fishing gear during the fishing operation offshore delivered a quite different outcome compared with strandings on shore, with the common dolphin with 56 individuals and the dusky dolphin with 19 being the species with the highest entanglement rates [54] (IFOP, 2020). Because cetacean populations and fishing activities coincide in the same geographic areas, interactions between the two are inevitable; the removal of fish from the gear during the fishing activity by marine mammals increases the chances of being injured or even killed due to bycatch [55] (Cáceres, 2016).

Although there are capacities built on whale disentanglement along the Chilean coast with 17 teams from the northernmost city to the southernmost city of Chile trained and endowed with tool kits to respond before entanglement on shore or nearby [52] (IWC, 2018), a new and necessary focus should be put on creating capacity building in disentanglement of large whales for the industrial fishing crews to mitigate this issue offshore and simultaneously create consciousness on the importance of cetaceans for the fisheries. The final approach towards this problem must be prevention of entanglements by managing fishing areas according to the foraging seasonality of different species as well as the development of technology directed to create cetacean-friendly fishing gear rather than only focusing on training rescue teams, which may give a false perception that rescuing entangled animals is the solution [56] (IWC, 2011).

About collision events, there is a marked difference between the occurrences of events during spring–summer (13) vs. fall-winter (4). No marked difference is observed according to the geographic area of occurrence (northern 4, central 6, and Patagonia 6). The predominant species involved are fin (5) and blue (4) whales. Interestingly, there may be a strong relationship between foraging seasons (spring–summer) and collisions with vessels since animals normally congregate to feed, ignoring the presence of vessels passing by in the area, making them more susceptible to strikes.

The difficulty in timely attention to stranding events associated with poor accessibility due to geography resulted in a reduced number of necropsies or sampling. In this context, it is important to consider and adopt new ways to detect stranding events in remote areas, especially in southern Chile, where most mass strandings occurred, using remote sensing to detect whale strandings in real time [57] (Fretwell et al., 2019), so that access to carcasses for scientific research is opportune.

The probable causes of strandings are identified that constitute the greater number of events that draw attention to their anthropic origin, and although in most cases they correspond to individual strandings, given their origin, measures should be established for the mitigation of events such as bycatch or collisions. Apart from putting in place speed reductions and route deviations in areas of high cetacean presence to lessen this threat, it is also important to consider and include more precise and reliable definitive histopathological diagnostics for reporting the number of collisions and the incidence of ship-strike fatalities [58] (Sierra et al., 2014). Improvement in the methodology to recognize injuries indicative of boating collisions is urgently required. Several publications have established various criteria for injuries and mortality caused by ship impacts in cetaceans and pinnipeds, of which the following stand out: one or several cuts, verification of bone fractures ante mortem, bruises, and/or hemorrhages [58] (Sierra et al., 2014).

On the other side, the government should necessarily take part in this historic issue by implementing sustained educational programs for fishermen regarding the diversity of marine mammals and their importance to the abundance of species for sustainable fisheries, focusing on the solid involvement and cooperation of this sector in preventing man-made threats [59] (Moreno et al., 2003).

Whale-watching studies carried out in 2007 and 2009 revealed that over 100 animals are found in a feeding area in southern Chile (Golfo de Corcovado), and the high number of large vessels and the high concentration of blue whales became a major concern. As a proof of the risk of collision in this area, in January 2009, a tourist cruise ship arrived in Puerto Montt with a dead sei whale on the bow [60] (CCC, 2009). For the prevention of these events, the CCC had already delivered some recommendations, among which the following stand out: speed reductions of vessels in areas with a high concentration of whales, seasonal changes in navigation routes according to the presence of whales, and a reduction in coastal pollution generated by the intensive salmon farming industry [50] (CCC, 2008).

In November of 2018, the Maritime Government of Castro, Chiloé, Los Lagos region, Chile, issued an official letter recognizing maritime traffic and its consequent risk of collision with cetaceans, as one of the factors that can cause injuries and/or the death of these individuals. In addition, the Chiloé area and the Pacific Ocean coast are important feeding and breeding areas not only for the blue whale but also for other endangered species such as the sei whale and the southern right whale of the eastern South Pacific. It is also recognized that there have already been deaths of cetaceans associated with collisions in the area and that the impact may also pose a risk to the crew, especially at night due to the feeding behavior of this group of species. For this reason, a series of recommendations were delivered to mitigate or prevent collisions in Chile, however, even though these recommendations represent progress, they do not constitute a regulation, and although it is punished by the cetacean law of Chile to kill a specimen, there are no penalties associated with a possible death by collision because it could be categorized as a fortuitous action or a collision post mortem, hence the importance of being able to histopathology determine if the collisions occurred with the living specimen.

Post-mortem examination of dead and live stranded cetaceans for determination of a cause of death provides valuable information for the management, mitigation, and prosecution of unintentional and sometimes malicious human impacts, such as vessel collision, fishing gear entanglement, and gunshot [61] (Moore et al., 2013).

Wild animals can be adversely affected by anthropogenic and natural factors, all of which pose a challenge to be assumed by competent authorities and local scientists in implementing a formal structure with scientific capacities and logistic facilities to study cetacean strandings to achieve a better description of these phenomena with specialized scientific support to make it easy for decision-makers to understand this urgent issue in a country with more than 8.000 km of coast.

5. Recommendations

1. Regarding collisions:
    (a) Studies on the identification of high-risk areas for collisions and cetacean-risk populations must be performed to avoid overlap between whales and ships.
    (b) Mandatory laws on speed limits for vessels entering or departing from areas with a seasonal congregation of large whales should be passed.
2. Regarding entanglements:
    (a) Mandatory laws on the obligatory use of cetacean-friendly fishing gear to reduce entanglement should be passed.
    (b) Disentanglement training for industrial fishing crews should be taken up through the IWC Disentanglement Panel to lessen this threat offshore.
3. Development of histopathological expertise for an adequate description of pathological findings.
4. Development of a national stranding network based on the actual network operated by SERNAPESCA, adding independent scientists, NGOs, research centers, and veterinarians' specialists to cover most of the country's coast appropriately.

5. Adoption of satellite remote sensing to improve surveillance and detection of strandings in remote areas of the country to allow timely access for scientific research.
6. Diffusion of the Supreme Decree No 38-2011 on distances for whale watching to avoid possible disturbance to cetaceans, especially in areas of high public attendance.
7. Improvements in reporting incidents of entanglement and collisions to the IWC will contribute to the enrichment of the global data set of the IWC Ship Strikes and IWC Strandings Panels to get opportune feedback on the treatment of these issues.

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