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Review Article

Investigating the sustainability, utilisation, consumption and conservation of sea mammals – A systematic review

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ABSTRACT

Almost 80 % of the oceans, especially the Arctic and Subarctic are primarily inhabited by marine mammals. Marine species depend mostly on sea ice for food, raising their young ones and safeguarding themselves from predators. Consumption of marine mammals has always been recommended as healthy, but the truth is that it can be detrimental for human health because of sea water pollution from trash and chemicals. This systematic review provides an in-depth examination of sea mammals, their complex relationship with humans, and their sustainability in the face of various threats such as overexploitation and climate change. Through analysis of various aspects regarding human-sea mammal interactions - including consumption, cultural and religious beliefs, use in traditional medicine, and negative impacts from, e.g. by-catch and overfishing - the significant pressures exerted on these species are highlighted in this systematic review. Despite conservation efforts, certain sea mammal populations continue to decline, necessitating more robust research and policy action. The need for further research into the sustainable utilisation of sea mammals, considering health, ecological, economic, ethical and cultural aspects, as well as the accumulation of pollutants in sea mammals, is underscored. Additionally, a comprehensive list of knowledge gaps and future research directions are provided to enhance our understanding and conservation of these unique marine creatures.

1. Introduction

Diverse groups of mammals, including sea mammals, have evolved to live in aquatic environments. These mammals have high resistance to cold, pressure and could extend their breath to a long duration. The members of this family are the following: *sirenians* (manatees and dugongs), *mustelidae* (sea otters), *ursidae* (polar bears) and *cetaceans* (Reeves, 2018). Humans have utilised sea mammals for various purposes over a extended period of time, i.e. as sources of food, traditional medicine, ornaments and clothing. For instance, narwhal tusks are traded as ornaments, while polar bear hides are valued for their aesthetic appeal. Additionally, *spermaceti* and *ambergris* are extracted from the sperm of whales to make perfumes and cosmetics, while *baleen* is used to produce clothing items such as umbrella ribs, women's skirts and corsets. Previously, seals were killed for their fur, blubber and flesh, whereas whales were targeted for their blubber which was used as soap, lubrication and lamp oil. In traditional medicine, seal penises are used as aphrodisiacs (Brennecke and Siebert, 2020; Reeves, 2018). The

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sustainability of sea mammal populations has raised concerns about their exploitation practices, leading to restrictions on these activities. However, some nations continue to consume and capture sea mammals for various purposes.

Ocean pollution, global warming, ocean acidification and sea ice melting has contributed to a decrease in the population of different sea mammal species (Castro-Muñoz, 2023). Annually, over 6,50,000 deaths of sea mammals are caused by over-fishing, which play a crucial role in reducing sea mammal populations (Davidson et al., 2012). Hunting and accidentally catching sea mammals remain significant factors contributing to the decline in their population. According to estimates for various sea mammal populations in the Northeast Atlantic, as reported by ICES (2019), D. M. Leonard and Øien (2020a) and Biuw et al. (2022), certain species have shown a decline in numbers, including hooded seals, harp seals, northern bottlenose whales and humpback whales.

The population growth of marine mammals can also be influenced by various factors such as environmental conditions, food availability, successful reproduction and protection from threats, i.e. hunting and accidental entanglement in fishing gear. Conservation efforts have also played a role in the increase of some sea mammal populations. Specifically, small *cetaceans* have decreased in numbers due to lack of environmental management as well as other factors such as habitat loss and pollution.

Cultural attitudes towards the utilisation of marine mammals have had a significant role in determining their use. Traditional Chinese medicine uses twenty parts of marine mammals, and dugong tears are utilised as a love potion in Malaysia and Cambodia. Consumption, traditional medicinal needs and hunting marine mammals occur in Asia, including species such as the Minke Whale, Sei Whale, Sperm Whale, Killer Whale, Common Dolphin, Bottlenose Dolphin and Harp Seal. In some countries, marine mammal hunting is still prevalent with Japan being a significant consumer of Sei and Minke whales (IWC, 2021; Porter and Lai, 2017). However, the over-exploitation and hunting of marine mammals have led to some species becoming endangered. International agreements and laws such as the International Whaling Commission or the Marine Mammal Protection Act have been established to defend marine mammal populations and ensure their sustainability, aimed at preventing further exploitation and protecting these animals for future generations.

Investigating sea mammal utilisation has considerable importance due to its ability to illuminate human practices related to these animals. This investigation plays a critical role in safeguarding biodiversity, maintaining ecological balance and protecting public health. Given the urgent threats such as climate change and biodiversity loss, this topic demands greater attention. Finding balance between human consumption and the utilisation of sea mammals, as well as their conservation, presents a complex challenge. In this comprehensive review, an endeavour is made to examine the broad impact of human-sea mammal interactions. This includes examination of sea mammals as sources of food, components of traditional medicine and materials for clothing, along with the wider ecological implications of these practices.

In this review, all available publications are quantified, including peer-reviewed articles and technical reports on the conservation of sea mammal research in different regions of the world from 2012 to 2023. The publications have been categorised into different thematic areas - 1) characteristics and distribution; 2) meat consumption ratio; and 3) sustainability. Using a bibliographic approach, the relationship of research has been modelled with various parameters to identify areas that can facilitate more research attention. This review offers insights into major research trends in relation to sea mammals and allows to identify conservation and knowledge gaps that can be used to outline priorities for future studies on mammals. In this review, the priority was to gather knowledge on: (1) the availability and characterisation of different marine mammals all over the world; (2) the reason for the consumption and high demand of sea mammal meat and what could be the nutritive status of the meat; (3) the discussion regarding how conservation measures are taken, but still, there remains a drawback in its sustainability; and (4) outlining the application of research and monitoring techniques.

The data was collected by complying available published materials, including peer-reviewed articles and technical reports containing relevant datasets on marine mammals. A bibliographic search of SCOPUS-indexed publications (Elsevier) and Google Scholar were also performed to complement the above. The following keyword search combination was used: (1) characteristics of sea mammals; (2) current population in the entire world; (3) nutritional quality of meat from sea mammals; and (4) sustainability and conservation of the animals. The materials were categorised according to type, year of publication and research focus. Data was also acquired from peer-reviewed literature and readily-available secondary sources (i.e. online databases and field guides) to collect data on life history characteristics and conservation-based assessments. Additionally the materials were obtained from the authors' self-archived works in Research Gate, university libraries, laboratory websites, and personal communications with researchers working on marine mammals (di Sciara et al., 2016; Nelms et al., 2021; Pompa et al., 2011; Tiongson et al., 2021).

The results included articles consistently written in English and published after being peer-reviewed. Following careful evaluation, a raw dataset that reported sustainability studies focused on sea mammals and presence of nutritive constituents in the meat of sea mammals was constructed and extracted. The articles were carefully chosen and selected in accordance with the guidelines of Preferred Reporting Items for Systematic Reviews (PRISMA). Published articles were submitted to the Mendeley reference manager. Initially, 450 results were achieved through the Science Direct database. From these, 165 articles were excluded due to not being related to the sustainability and conservation of sea mammals. Further, 125 articles were selected with full paper details. Finally, 95 articles remained for detailed review in the study of characterisation, sustainability and conservation of sea mammals (Fig. 1). The algorithm search key for the entire paper was set from 2012 to 2022, using the MESH terms ("marine mammals") AND ("population") AND ("conservation" OR "sustainability").

2. Characterisation of sea mammals

All across the world, marine habitats are home to sea mammals. They undergo aquatic adaptations and depend on the ocean to sustain a balanced, liveable existence. These mammals are primarily found in the world's major oceans, from tropical regions near the equator to the northern and southern hemispheres in the Arctic and Antarctic oceans (K. H. Andersen et al., 2017). They possess unique physical adaptations allowing them to thrive in marine environments with extreme temperatures, depths, pressure and darkness. Sea mammals are classified into four different taxonomic groups:

- *Cetaceans* (whales, dolphins, and porpoises): they live totally underwater and have a variety of adaptation mechanisms at their disposal. The cetacean family contains >70 different species.
- *Pinnipeds* (seals, sea lions, and walruses): these carnivorous mammals with fins on their feet move both on land and in water by using flippers. They spend most of their time swimming and eating, and only come ashore or to ice floes to give birth, rest or moult.
- *Sirenians*, which include manatees and dugongs, are the only species of marine mammals that are fully herbivorous and live entirely in water. They have massive bones and a big, fusiform body.
- *Fissipeds* include polar bears and sea otters. They are classified as sea mammals but spend the most of their time on land and only a small amount of time in the water, primarily to forage for food (Aguilar et al., 2014).

Sea mammals represent a variety of ecological roles including herbivores (manatees), filter feeders (baleen whales) and top predators

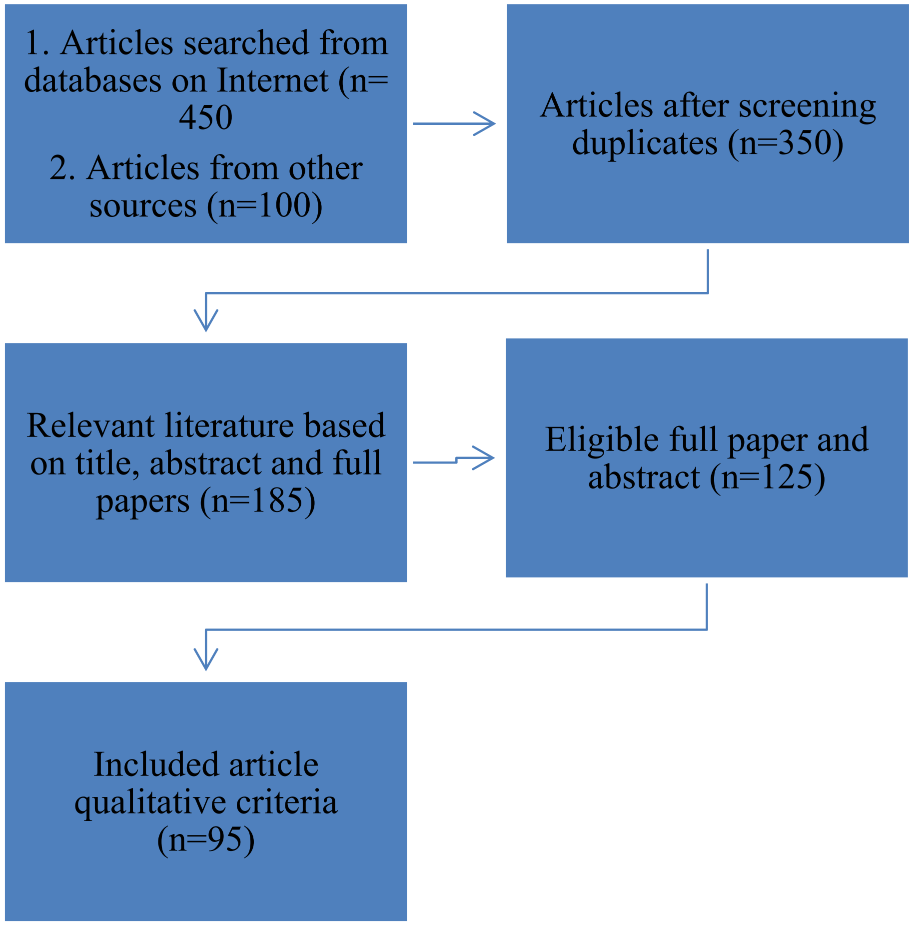


Fig. 1. Flow chart showing methodology used in screening articles used for writing manuscript.

(killer whales) (Bailey et al., 2010; Baines et al., 2017; Cade et al., 2020) (Table 1). Each taxonomic sea mammal group evolved from a different group of land mammals, whose ancestors separated and ventured back into the ocean environment (Blanchet et al., 2020; Das et al., 2017). Their cylindrical body shape with small appendages reducing body projections help them swim. Thee streamlined body shape reduces surface area to a volume ratio of the body which further reduces heat loss (Das et al., 2017). Other animals, such as polar bears, have bulky bodies which help them stay warm and disperse their body heat. Their thick, curved claws are used for grabbing prey and predators, sharp teeth and powerful jaws for tearing apart prey, and strong muscles for attacking and fighting. Seals have massive amounts of blubber and fat to stay warm (J. M. Andersen et al., 2013; Bamford et al., 2020).

Coastal indigenous people used to kill sea animals for food and other resources. Only regional hunting operations on a modest scale are affected by them. Emerging trends in the exploitation of sea mammals led to extinct of the Caribbean monk seal and Steller's sea cow (Bannister, 2009). Today, populations of species that were historically hunted, such as blue whales and the North Pacific right whale, are much lower compared to pre-exploited levels because of their low reproductive output. Areas of Norway continue to engage in commercial whale killing, which is followed by Iceland, killing about 150 fin whales annually. Under the pretence of conducting scientific research, Japan also kills hundreds of whales in the North Pacific and Antarctic (Kleinertz et al., 2014; Hamilton et al., 2018; Jourdain et al., 2020).

Sea mammals are widely distributed throughout the globe, but their distribution is patchy and coincides with the productivity of the oceans (Rossman et al., 2016; Løviknes et al., 2021) (Fig. 2.A). At a latitude of approximately 40°, primarily in and around North and South America, Africa, Asia, and Australia, the number of species in these areas peaks compared to other regions. Most marine animals typically inhabit areas that are equal to or smaller than one-fifth of the Indian Ocean (Gjøsaeter et al., 2002; Lydersen et al., 2020). The variation observed in range size is the result of different ecological requirements regarding each species and their ability to cope with a broad range of environmental conditions (Fig. 2B). The majority of marine mammals, such as seals and sea otters, live around the coast. Most seals live on land, lounge on sandy beaches, rocky coasts, mud flats, tide pools and marine caves in temperate and tropical regions, as described by Hamilton et al. (2018) and Hansen et al. (2019). In their writings, Dalpadado et al. (2014) also noted that some species also rest on man-made objects, including oil platforms, jetties, piers and buoys. Seals can move further inland, rest on vegetation and sand dunes, or even scale cliffs.

Most *cetaceans* live in the open ocean and species such as the sperm whale may dive to depths from −1000 to −2500 ft (−300 to −760 m) in search of food (Corkeron, 2009; Pike et al., 2019, 2020). *Sirenians* typically live 30 ft (9.1 m) below sea level, in shallow coastal waters. Sea otters may lay in drift ice or in sandy, muddy or silty environments, although they prefer protective areas, such as rocky shorelines (Nowacek et al., 2016; Smith et al., 2015).

According to the studies by Bogstad et al. (2015) and Hansen et al. (2019), seals depend on the weather conditions for their movement. While traveling, seals rely on geomagnetic fields, water, wind currents, the position of the sun and moon as well as the taste and temperature of the water to get to their chosen destination. Seals may also migrate in response to other environmental changes, such as El Nino. Each summer, the ice in Hudson Bay, James Bay or other places, melts entirely, causing polar bears to come ashore and wait for the freeze-up. Polar bears relocate to the frozen ice further north in the Chukchi and Beaufort seas each summer, as reported by Jewell et al. (2012) and Hansson et al.

Table 1
Sea mammals consumed by different nations.

No.	Sea mammals	Country	Amount of catch per year	Seafood waste	Reference
1	Grey seal (*Halichoerus grypus*)	Finland, Sweden and Estonia	1240-2860	Bone, liver, heart and other internal organs	(Anderson et al., 2020; Vanhatalo et al., 2014)
		Norway	133		(NAMMCO, 2019, 2022)
2	Harp seal (*Pagophilus groenlandicus*)	Greenland	29,680	Bone, liver, heart and other internal organs	(Anderson et al., 2020; NAMMCO, 2022)
	Bearded seal (*Erignathus barbatus*)	Greenland	924		(NAMMCO, 2022)
3	Ringed seal (*Pusa hispida*)	Greenland	24,711		(NAMMCO, 2022)
4	Beluga whale (*Delphinapterus leucas*)	Greenland	233		(NAMMCO, 2022)
5	Long-finned pilot whale (*Globicephala melas*)	Faroe Islands	528	Skin, liver, heart and other internal organs	(NAMMCO, 2022)
6	Killer whale (*Orcinus orca*)	Greenland	23	Skin, bone, heart and other internal organs	(NAMMCO, 2022)
7	Atlantic walrus (*Odobenus rosmarus*)	(Nunavik) Canada	–	Heart, intestines, liver, head and flippers (less consumed)	(Martinez-Levasseur et al., 2020)
		Greenland	124		(NAMMCO, 2022)
8	Bowhead whale (*Balaena mysticetus*)	Greenland	1	Meat, bone, liver, heart and other internal organs	(NAMMCO, 2022)
		Canada	2		(IWC, 2021)
		Alaska, USA	70		(IWC, 2021)
9	Minke whale (*Balaenoptera acutorostrata*)	Korea	12	Bone, liver, heart and other internal organs	(IWC, 2021)
		Japan	91		(IWC, 2021)
		Norway	557		(IWC, 2021)
		Iceland	1		(IWC, 2021)
		Greenland, Denmark	198		(IWC, 2021)
10	Sei whale (*Balaenoptera borealis*)	Japan	25	Bone, liver, heart and other internal organs	(IWC, 2021)
11	Sperm whale (*Physeter macrocephalus*)	Indonesia	18	Bone, liver, heart and other internal organs	(IWC, 2021)

(2018). Baleen whales travel very far to reach tropical waters where they give birth and rear their young in order to avoid being eaten by killer whales, as reported by Kaschner et al. (2012) and Linnebjerg et al. (2016). The grey whale has the longest recorded migration of any mammal, with one traveling 14,000 miles (23,000 km) from the Sea of Okhotsk to the Baja Peninsula (Kohlbach et al., 2018; D. Leonard and Øien, 2020b). During winter, manatees living at the northern end of its range migrate to warmer waters.

Based on estimates for several sea mammal populations in the Northeast Atlantic, it has been observed that certain species such as the dolphin genus *Lagenorhynchus* harbor porpoises, killer whales, fin whales and sperm whales experienced an increase in numbers between 2002 and 2018, whereas hooded seals, harp seals, northern bottlenose whales and humpback whales experienced a decline in numbers (Biuw et al., 2022; ICES, 2019; D. M. Leonard and Øien, 2020a) (Fig. 3).

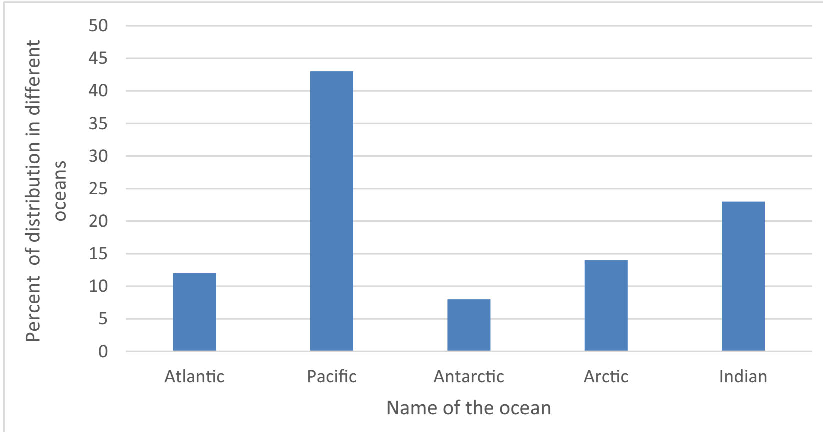
Various factors can influence the population growth of marine mammals, i.e. favourable environmental conditions, adequate food supply, successful reproduction and protection from threats such as hunting and accidental entanglement in fishing gear. It is also possible that conservation efforts may have played a role in the increase of some sea mammal populations. Magera et al. (2013) reported that 42 % of marine mammal populations showed significant increases, while 10 % significantly decreased, 28 % remained relatively stable, and 20 % were unknown. Specifically, about half of pinniped and coastal cetacean (bowhead, grey and humpback whales) populations have been observed to be significantly increasing. The faster life history characteristics of pinnipeds may have facilitated their recovery, while management and conservation efforts to limit exploitation, by-catch and habitat loss may have also contributed to the population growth in some species. Conversely, small cetaceans were observed to be decreasing in numbers, possibly due to their exploitation after the depletion of more easily accessible coastal species, lack of direct management and other factors such as habitat loss and pollution.

In China and Vietnam, sea mammal bones are used for placement in temples according to beliefs. Although it is now banned, a province in China called Fujian used to consume dolphin meat. Traditional Chinese medicine uses 20 parts of marine mammals, while dugong tears are utilised as a love potion in Malaysia and Cambodia. Consumption, traditional medicinal needs and hunting marine mammals occur in Asia, including species such as the minke whale, sei whale, sperm whale, killer whale, common dolphin, bottlenose dolphin and harp seal (Porter and Lai, 2017). Finless porpoises (*Neophocaena phocaenoides*) and Indo-Pacific humpback dolphins (*Sousa chinensis*) are frequently caught in Paloh, while spinner dolphins (*Stenella longirostris*) and bottlenose dolphins (*Tursiops* sp.) are accidentally caught in Adonara, according to the research conducted by Mustika et al. (2014) in Indonesia. Japan permits regulated hunts within national waters and is a significant consumer of sei and minke whales (IWC, 2021; Porter and Lai, 2017). Several countries across the world hunt marine mammals for food and ornaments, especially the Inuit (Eskimos) and residents living in the Arctic, such as Greenland, Nunavik and others. The people living in Nunavik and Canada eat all parts of the walrus. The skin, blubber and meat of walrus are aged as *igunaq*, while the meat, fat, intestines and cheeks are boiled. The heart and liver, on the other hand, are occasionally eaten fresh (Martinez-Levasseur et al., 2020). The eastern Canadian Arctic is also home to marine mammal hunting, which started when the bowhead whale population started to fall (Stewart et al., 2014). Harp seal and other marine mammal meat are sold commercially in Canada. Furthermore, harp seal pelts and fur are highly prized in the seal hunting industry (Butterworth and Richardson, 2013).

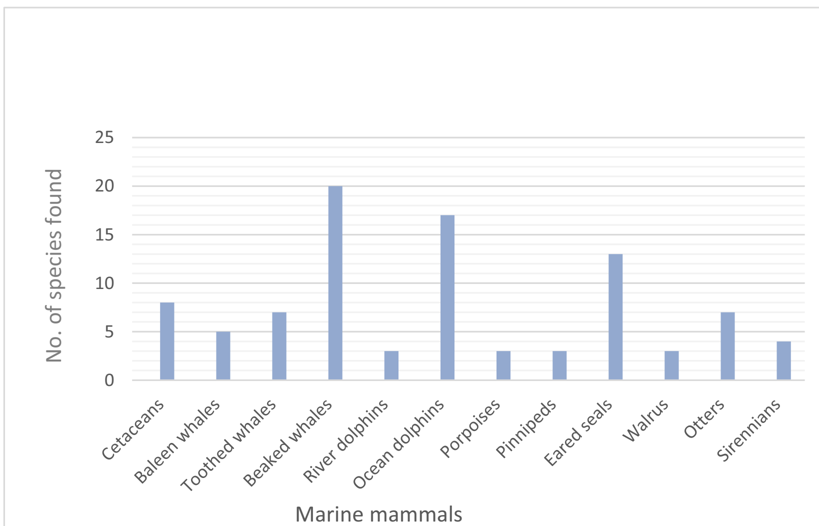
Additionally, it is worth mentioning that the hunting and exploitation of marine mammals have caused some species to become endangered. Several international agreements and laws, such as the International Whaling Commission and the Marine Mammal Protection Act, have been established to defend marine mammal populations and ensure their sustainability. These regulations aim to prevent further exploitation and protect marine mammal populations for future generations.

3. Consumer meat consumption reduction incentives in relation to sea mammal meat consumption

In recent studies, the production and consumption of meat has been repeatedly linked with adverse effects on the environment, human health and animal welfare. However, many people have a well-established eating habit of consuming meat (Newsome et al., 2012). Since meat is a staple food in many cultures, it may be difficult to change eating habits. However, there is a subset of customers who have cut back on their dietary meat intake. Future communal reductions in meat consumption can be encouraged by having a better understanding of the



(A). Distribution of marine mammals in different oceans (Rossman et al., 2016; Loviknes et al., 2021).



(B). Number of species found in different marine mammals (Tittensor et al., 2010).

Fig. 2. (A). Distribution of marine mammals in different oceans (Rossman et al., 2016; Løviknes et al., 2021).
(B). Number of species found in different marine mammals (Tittensor et al., 2010).

facilitators and barriers that affect these behavioural changes in various cultures and circumstances.

The killing and consumption of marine mammals create tense global struggles between advocates of sustainable use and those of completely protecting these animals. However, reporting on the extent and nature of marine mammal consumption by people is uneven and often anecdotal. Human consumption of marine mammals is geographically widespread, taxonomically diverse, and often of uncertain sustainability. Since 1990, people in at least 114 countries have consumed one or more of at least 87 marine mammal species. While some regions are experiencing a decrease in the killing and consumption of marine mammals due to shifting social, ecological or political circumstances, other regions are experiencing an increase in these activities due to new technologies and prevailing socioeconomic conditions, especially with regard to small cetaceans. Eating marine mammals is seen as an important part of cultural and food security in many areas, and it offers some economic (including monetary) advantages to people in at least 54 countries. Scholars reveal a rise in the fishing of tiny cetaceans higher up on the food chain that have been captured in connection with fishing operations since 1970 (Porter and Lai, 2017; Martinez-Levasseur et al., 2020).

Researchers Aguilar et al. (2014) and Chavarie et al. (2020) reported that there were usually intentional killing of marine mammals for human consumption. 'By-catch,' or accidental marine mammal catches in fishing gear present potential for food procurement. The possibility of transforming by-catch into direct food acquisition is perhaps indicative of the hundreds of thousands of small cetaceans that perish in fishing gear every year throughout the world. Although fishermen and women seeking new livelihood strategies that promote nutritional or economic security may have logically adapted to intentional capture or kill marine mammals accidentally caught in fishing gear. This practice has contributed to a "looming crisis" in marine mammal conservation.

3.1. Nutritional quality and potential hazards of sea mammal consumption

According to Blanchet et al. (2019) and MacKenzie et al. (2022), sea mammal flesh is a good source of protein, amino acids and minerals such iodine, potassium, selenium, magnesium, zinc, phosphorus and calcium (Table 2). Products made from marine mammals may have health benefits because of their distinct fatty acid makeup and high quantities of omega-3 fatty acids (Castro-Muñoz et al., 2022; Garza-Cadena et al.,

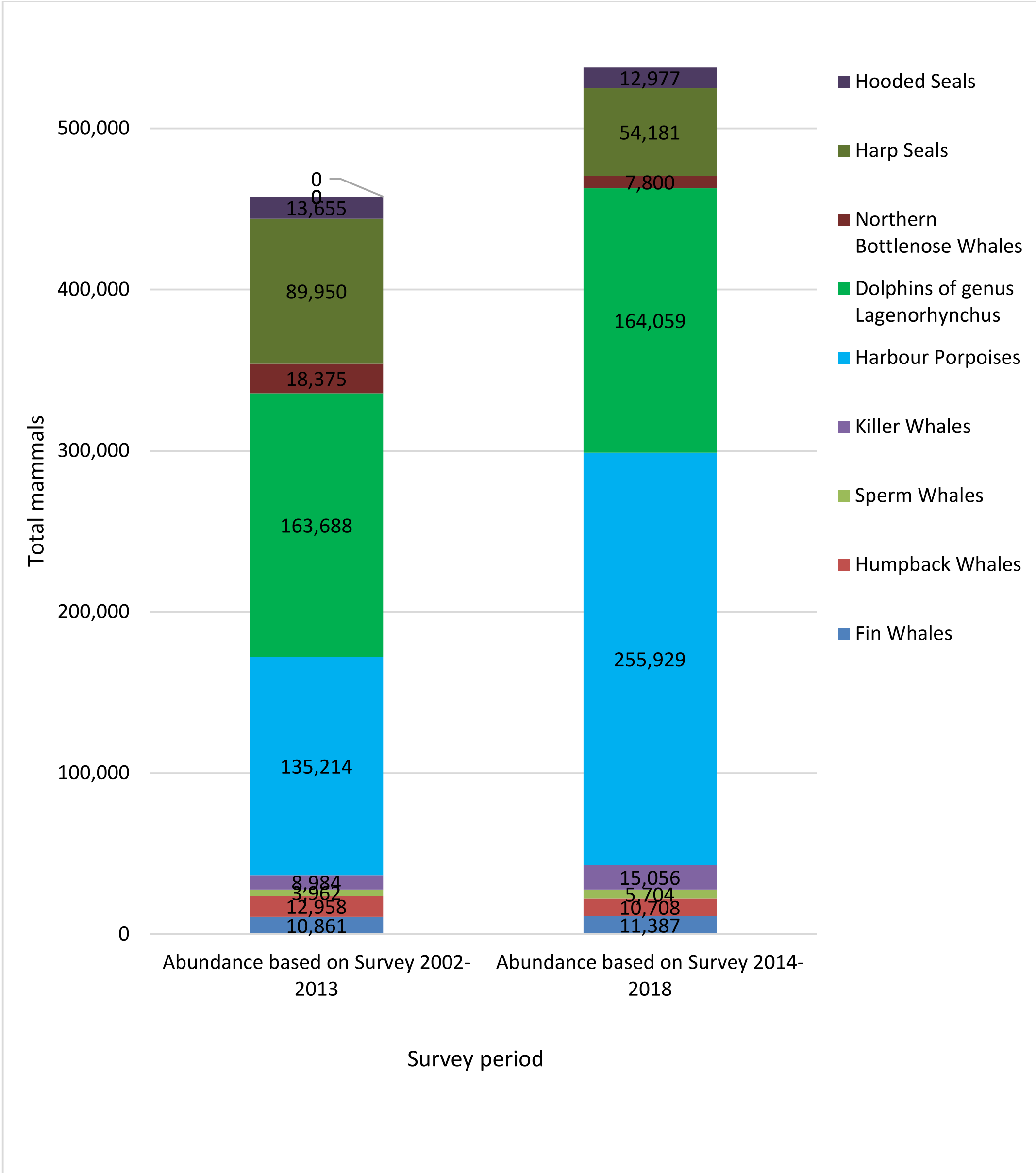


Fig. 3. Estimation of sea mammal abundance according survey from 2002 to 2018 in Northeast Atlantic (Biuw et al., 2022; ICES, 2019; D. M. Leonard and Øien, 2020a).

2023). Antioxidants and other compounds present in the oils from whales and seals may potentially be relevant (Benoı̌t et al., 2011; Bortolotto et al., 2016; Pagano et al., 2018). The skin is rich in vitamins A and C, thiamine, riboflavin, and niacin, while blubber has a high amount of antioxidants and is a significant source of vitamin C (Aguilar et al., 2014; Chavarie et al., 2020; McMahon et al., 2021). Marine mammal oils possess significant health benefits for a variety of ailments, including pain relief, lowering hypersensitivity, enhancing blood cell activity and regulating coagulation factors (Chavarie et al., 2016; Loseto et al., 2018; Matthews et al., 2020).

In contrast, sea mammals are also highly exposed to toxic agents present in the ocean waters. Many studies have been conducted on the flow of methyl mercury, a toxic global pollutant (Aniceto et al., 2018; Choy et al., 2020; Iverson et al., 2004). Under certain conditions and climate change scenarios, methyl mercury increased in the ecosystem, translating into increased human exposure over time. Methyl mercury bioaccumulates and biomagnifies at all tropic levels in the food web, and can have severe toxicologic effects (Cretton et al., 2022; Meier et al., 2016). Marine mammals are contaminated from the water with a wide range of toxic chemicals and other dangerous substances (Table 3). These include PCBs (polychlorinated biphenyls) and dioxin, which harm the foetus, liver and the nervous system. According to Cañavate (2019) and Hansen et al. (2019), these environmental toxins tend to build up in the bodies of sperm whales, orcas, pilot whales and false killer whales. Many nations consume whale meat and blubber for gastronomic or commercial reasons. The present contaminants harm the human nerves, reproductive and developmental systems as well as the immunological system, the liver, skin and the endocrine system. These exposures are associated with certain cancer risks (Bengtson Nash et al., 2013; Bengtsson et al., 2020; Haug et al., 2017).

The nutritional quality of sea mammals is relatively scarce due to their classification as protected animals (Fig. 4). However, for six species of analysed sea mammals, high levels were detected of protein and fat, ranging from 19.2 % to 76.9 % and 2.31 % to 41.3 %, respectively (Anderson et al., 2020; Shahidi et al., 2020; U.S. Department of Agriculture, 2019). Furthermore, some species of sea mammals contain high

Table 2
Nutritional content of sea mammals per 100 g.

No.	Sea mammals	Energy (kcal)	Protein (%)	Fat (%)	Omega-3 (DHA + EPA) (%)	Cholesterol (mg)	Vitamin	Mineral	Others	Reference
1	Grey seal (*Halichoerus grypus*)		72.6–76.9	10.1–12	8.3–13.76					(Anderson et al., 2020; Shahidi et al., 2020)
2	Harp seal (*Pagophilus groenlandicus*)	100	55.1–57.1	38.8–41.3	17.3					(Anderson et al., 2020; Brunborg, 2006; Shahidi et al., 2020)
3	Bearded seal (*Erignathus barbatus*)	110	26.7	2.31	15.46	100	Vit. A: 1400 IU; Vit. D_3: < 0.1 μg/100 g; Vit. B3: 5.9 mg	Ca: 10 mg; Fe: 12.9 mg		(Phillips et al., 2018; Shahidi et al., 2020; U.S. Department of Agriculture, 2019)
4	Ringed seal (*Pusa hispida*)	142	28.4	3.2	18.17	90	Vit. A: 385 IU	Ca: 5 mg; Fe: 19.6 mg		(Shahidi et al., 2020; U.S. Department of Agriculture, 2019)
5	Beluga whale (*Delphinapterus leucas*)	111	69.9	8.37	6.2	80	Vit. A: 340 IU; Vit. D_3 2.01 μg/100 g; Vit. B12: 2.59 μg	Ca: 7 mg; Fe: 25.9 mg; Zn: 2.76 mg; K: 283 mg; Se: 36.5 μg	Folic acid: 4 μg	(Phillips et al., 2018; U.S. Department of Agriculture, 2019)
6	Atlantic walrus (*Odobenus rosmarus*)	199	19.2	13.6	0.113	80	Vit. A: 170 IU; Vit. B3: 4.8 mg	Ca: 18 mg; Fe: 19.4 mg; K: 112 mg		(Martinez-Levasseur et al., 2020; U.S. Department of Agriculture, 2019)

levels of omega-3 fatty acids (EPA and DHA), with concentrations reaching up to 18.17 %. This amount is higher than other sources of omega-3, such as caviar (6.54 mg/100 g) and chia seeds (18.04 mg/100 g of ALA) (U.S. Department of Agriculture, 2019). Additionally, marine mammal meat is a rich source of protein and mineral nutrients, including iodine, potassium, selenium, zinc, phosphorus and calcium. It is also a great source of vitamins A, B and D. The blubber and meat of these mammals comprise a high concentration of omega-3 fatty acids, specifically EPA and DHA (Stewart et al., 2014; U.S. Department of Agriculture, 2019). Moreover, fat from the Atlantic walrus is a particularly rich source of total omega-3 fatty acids, containing 113 mg/g, as reported by Martinez-Levasseur et al. (2020).

According to information from FAO Statistics, Iceland consumes the most protein per person at 143.92 g, followed by Hong Kong at 129.45 g and Israel at 126.06 g. The least amount of protein is consumed per person in the Democratic Republic of the Congo, Zimbabwe and Liberia, with amounts of 25.91 g, 38.21 g, and 42.11 g, respectively (FAO, 2023) (Fig. 5A). It is important to note that the FAO numbers do not specifically detail protein consumption per person in Greenland or the Faroe Islands nor do they include information on the production of aquatic mammals or aquaculture (FAO, 2022a, 2022b). The availability of data on the catch numbers of sea mammals is limited. Therefore, the most recent catch data reported for sea mammals by NAMMCO countries are presented. These include the Faroe Islands, Greenland, Iceland and Norway. From 1992 to 2013, the number of sea mammals caught tended to increase annually, with the highest reported catch number of 424,531 individual sea mammals occurring in the year 2000. However, from 2014 to 2022, the trend of catching sea mammals decreased, which could be attributed to a decline in the population of sea mammals, policies that limit the capture of certain species or the provision of quotas for catching sea mammals (NAMMCO, 2022) (Fig. 5.B).

3.2. *Efforts for conservation of sea mammals*

Due to a movement away from resource exploitation and towards animal conservation, sea mammals have benefited the most in the marine kingdom (Magera et al., 2013). Humans have historically exploited and frequently reduced marine populations. However, a significant population loss in the 20th century resulted in a very early and widespread reduction or termination of commercial extraction and the installation of conservation measures (Barton et al., 2018). While some marine mammal populations such as those of sea otters and Eastern North Pacific grey whales have been hailed as major conservation success stories, not all have recovered from earlier exploitation (Miller et al., 2010). However, with data showing positive abundance trend estimations for different populations, there is now a chance to assess threat status, decline and extinction danger, as well as rise and recovery for marine mammals. There are various and evolving threats to marine mammals. Historically, marine mammals have been prized sources of meat, oil, fur, baleen and ivory (Dale and Armitage, 2011). They have also been captured for display in aquariums, culled when declared nuisances, used for bait and indirectly exploited as by-catch (Friedlaender et al., 2015). Many marine mammal species were brought to extremely low abundances by or during the 1900s, and some were even on the verge of extinction, such as Northern elephant seals (*Mirounga angustirostris*) and Guadalupe fur seals (*Arctocephalus townsendi*) (Goldbogen et al., 2019). Few selected species, including the Japanese sea lion (*Zalophus japonicus*), Steller's sea cow (*Hydrodamalis gigas*), sea minks (*Neovison macrodon*), and Caribbean monk seals (*Monachus tropicalis*), have become extinct worldwide. The eastern North Pacific grey whale population, several populations of humpback whales (*Megaptera novaeangliae*), southern right whales (*Eubalaena australis*), sea otters, northern elephant seals, and grey seals (*Halichoerus grypus*) in the UK are a few examples of the survivors that have experienced significant population recoveries in addition to the Northwest Atlantic and several other types of fur seals (Goedegebuure et al., 2017). However, current factors still have impact on sea mammal populations, including disease, predation competition, habitat degradation from coastal development and dams, ship traffic, offshore oil and gas exploration, pollution (chemical, physical, and acoustic) as well as climate change (Friedlaender et al., 2015). According to the Marine Mammal Protection Act, the U.S. National Marine Fisheries Services (NMFS) defines the "optimal sustainable population" level as "a population level between carrying capacity and the population size at maximum net productivity". Depending on the circumstances, other criteria may be significant for evaluating recovery, such as targets for demographic aspects (i.e.as ratios of young to adult or male to female), social dynamics or ecological functions. Recovery can also be measured over a variety of time frames, such as an entire time series of data, a specific time period (such as 50 years or 1950–2000) or with regard to the life cycle of the species, for

Table 3
Toxic elements present in meat and meat products of sea mammals and potential hazards of sea mammal consumption.

No.	Sea mammals	Toxicity	Reference
1	Grey seal (*Halichoerus grypus*)	Accumulated pollutant: total mercury (9.24–29.79 ng/g); Zoonotic parasitic infection: *Trichinella* spp., *Salmonella* spp.	(Grajewska et al., 2019; Tryland et al., 2014)
2	Harp seal (*Pagophilus groenlandicus*)	Zoonotic parasitic infection: *Trichinella* spp., *Salmonella* spp.	(Tryland et al., 2014)
3	Bearded seal (*Erignathus barbatus*)	Zoonotic parasitic infection: *Trichinella* spp.	(Tryland et al., 2014)
4	Hooded seal (*Cystophora cristata*)	Zoonotic parasitic infection: *Toxoplasma gondii, Trichinella* spp.	(Tryland et al., 2014)
5	Ringed seal (*Pusa hispida*)	Zoonotic parasitic infection: *Trichinella* spp.	(Tryland et al., 2014)
6	Beluga whale / white whale (*Delphinapterus leucas*)	Accumulated pollutant: mercury (1–6 μg/g); Zoonotic parasitic infection: *Toxoplasma gondii, Salmonella* spp., *Brucella* spp. (59 % of the white whale sample group was infected)	(Martinez-Levasseur et al., 2020; Nymo et al., 2022; Tryland et al., 2014)
7	Grey whale (*Eschrichtius robustus*)	Accumulated pollutant: ∑PCB (2–3200 ng/g (*w*/w)), ∑DDT (361–1707 ng/g lipid), ∑CHLOR (1–650 ng/g), HCB (1–850 ng/g) ∑HCH (46–3081 ng/g lipid), Dieldrin (2–450 ng/g)	(Chukmasov et al., 2019)
8	Bowhead whale (*Balaena mysticetus*)	Accumulated pollutant: ∑PCB (9.1–410 ng/g (w/w)), ∑DDT (3.7–4680 ng/g), ∑CHLOR (5.4–152 ng/g), HCB (0.6–184 ng/g),∑HCH (9.5–203 ng/g), Dieldrin (3–84 ng/g)	(Chukmasov et al., 2019)
9	Atlantic walrus (*Odobenus rosmarus*)	Accumulated pollutant: mercury (0.07–0.1 μg/g); Zoonotic parasitic infection prevalence: *Trichinella nativa* (2.9 %)	(Martinez-Levasseur et al., 2020)
10	Bottlenose dolphin (*Tursiops aduncus*)	Zoonotic parasitic infection prevalence: *Giardia* spp. (2.13 %), *Cryptosporidium* spp. (3.19 %), *Anisakis typica* (2.13 %), *Diphyllobothrium* spp. (8.51 %)	(Kleinertz et al., 2014)

example, the International Union for Conservation of Nature (IUCN) often uses three generations. Marine mammal management has a significant conservation focus in many places of the world, yet there is a lack of data and a high degree of uncertainty. Many populations do not obtain good catch data that is effort-corrected, and it is notoriously difficult to reliably estimate the abundance of marine mammals. Current population classifications and/or distributions may not correspond to historical data, which makes it problematic to examine long-term trends, raising the possibility that some populations have altered their distributions over time (Jackson et al., 2011). There are not many populations that are or were commercially valuable that have longer time series with historical population estimates. Numerous marine mammal species engage in evasive activities (such as lengthy migrations or deep-diving for extended periods of time), which when combined with their profusion in distant locations, pose significant logistical and financial hurdles for population status monitoring (Iverson et al., 2004; Kolding et al., 2014; Kovacs et al., 2011). With the exception of land-breeding pinnipeds, it can be challenging to accurately estimate abundance trends over very short time periods and abundance time series frequently include erratic survey intervals. The population monitoring and modelling that have been done in conjunction with enhanced management and conservation activities, both domestically and internationally since the 1970s, however, have substantially improved data availability. A quantitative global synthesis of marine animal recoveries has not yet been undertaken on a population level, despite the fact that data on marine mammal abundance are gathered and evaluated by numerous organisations for management and conservation purposes (such as the IUCN, U.S. marine mammal stock assessments). Populations within the same species may show different abundance trends, while population-level abundance monitoring has become increasingly valued (Lowther et al., 2015a; Murphy et al., 2016).

A variety of anthropogenic effects, including exposure to anthropogenic noise and the possible impact of global climate change, including the potential availability of prey, are experienced by sea mammals (Moore and Reeves, 2018). A lot of these conservation pressures could cause immediate or long-lasting reactions that individuals would notice before population-level effects become obvious. These reactions include increases in stress-related hormones, decreases in reproductive or foraging effectiveness, immune system suppression and deterioration of physical condition. Human societies have come to rely heavily on marine animals as a source of food in many regions of the world. Measures to conserve marine mammals on which people depend should be taken into account alongside measures to ensure the sustainability and fair development of these communities. Sea mammal populations are severely declining or in danger of going extinct in the majority of the oceans as a result of over-fishing, excessive hunting and unintentional by-catch in fishing gear (Morissette et al., 2012a).

Newly discovered methods estimate that Earth is home to 8.7 million species, of which 2.1 million live in oceans (Albouy et al., 2020). Severe depletion in large marine animals over the years and an up to 90 % reduction in the abundance of large, commercially-exploited marine mega-fauna have occurred since the beginning of human impact, along with the reduction of total animal biomass and local extinction of particular species (Avgar et al., 2013). Genetic, ecological and behavioural factors can all contribute to making small populations particularly vulnerable to extinction. One of the most significant challenges for marine mammal conservation is determining demographically independent conservation units, based on acoustic, taxonomic, genetic, geographic, behavioural, social or ecological features.

The advent of widespread and usually indiscriminate commercial fishing methods played a crucial role in the 20th century's dramatic rise in sea animal hunting. Additionally, there was a rise in the demand for aquatic resources as more people moved to coastal areas (Cook and Trijoulet, 2016). According to Christiansen et al. (2014), there has been an upsurge in the food hunting of terrestrial animals. This became a global problem in terms of the amount of consumed meat and factors influencing trade. In studies, questions have been raised regarding the traditional uses of using marine mammals and other aquatic creatures as food and bait. In 2011, a thorough review of existing literature, media reports and local knowledge on the global extent of marine mammal consumption was documented by Forcada et al. (2012). Several key points were highlighted in this review:

i. Sea mammals unintentionally caught in fishing gear had been increasingly utilised for consumption;
ii. Diminished food resources in developing areas had led to both targeted hunting of marine mammals and the deliberate killing of by-caught individuals;
iii. Commercial trade in marine mammal meat is growing.

Native Americans in America often portrayed whales as defenders of the seas. They are regarded as spiritual animals and a representation of wisdom. For the locals, spotting a whale even once brought luck. Sea

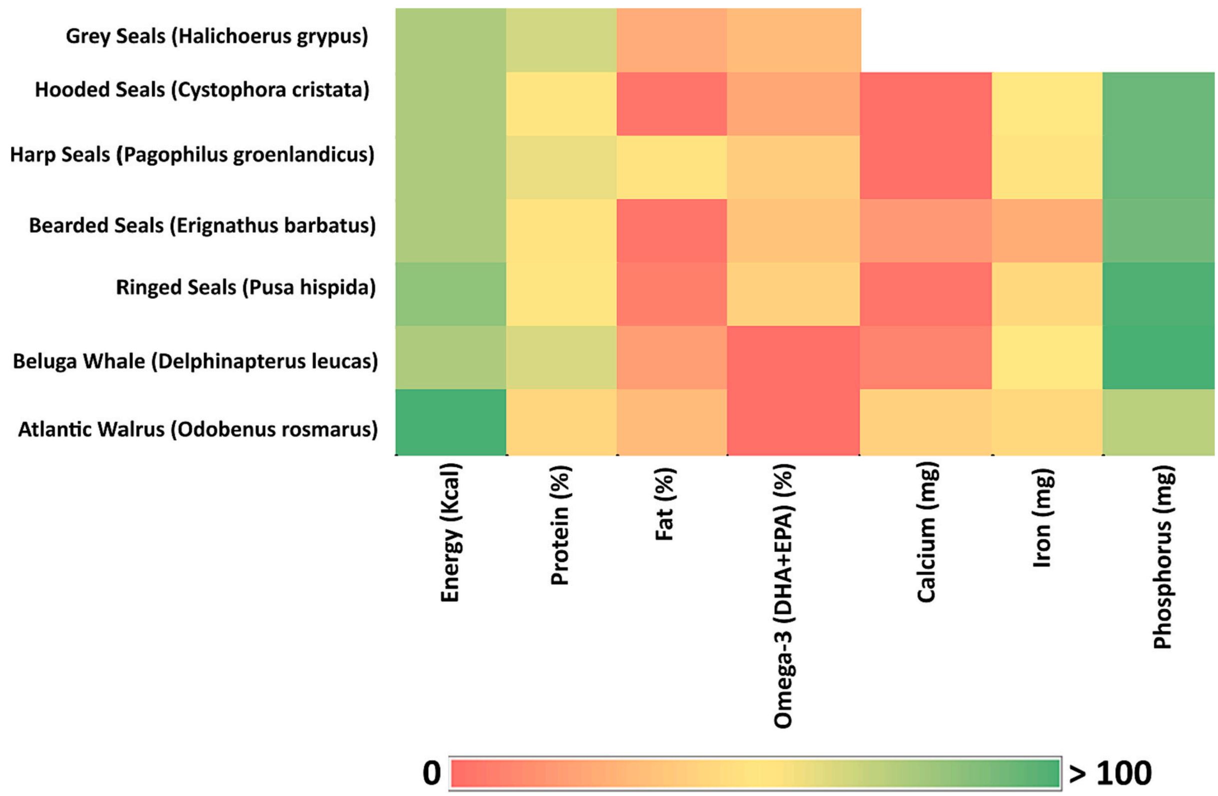


Fig. 4. Nutritional content of meat from sea mammals.

animals are essential to maintaining the harmony of marine environments. These mammals control population growth and provide habitat for other aquatic life. The Marine Mammal Protection Act (MMPA) of the United States protects all species of sea mammals due to the significance of their existence in the ecosystem. The Endangered Species Act (ESA) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) both identify some of them as endangered species (Gilles et al., 2020).

Despite numerous legislative safeguards, these mammals are currently in danger because of a variety of issues, including the merciless fishing practices and habitat destruction. Vaquita, the Hawaiian monk seal, Steller sea lions, Australian sea lions, Hector's dolphins, sea otters, blue whales, sei whales, fin whales and beluga whales are a few of the mammals on the endangered species list (Miller et al., 2010).

3.2.1. Vaquita

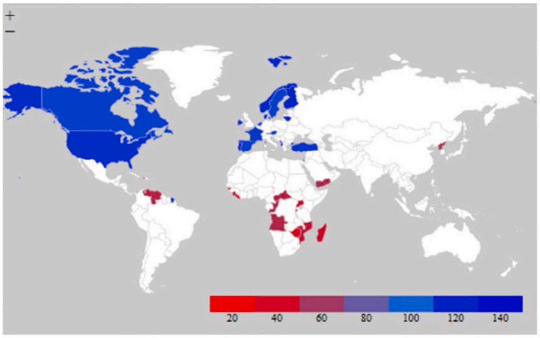
The vaquita is a species of porpoise endemic to the northern end of the Gulf of California in Baja California, Mexico. It is the smallest of all living cetaceans having a maximum body length of 150 cm (4.9 ft) (females) or 140 cm (4.6 ft) (males). It has a small body with an unusually tall, triangular dorsal fin, a rounded head and undistinguished beak. The colour of this species is mostly grey with a darker back and a white ventral field. Their eyes and lips are surrounded by prominent black patches. They are currently listed as Critically Endangered and can be found on the IUCN Red List. The steep decline in abundance is primarily due to by-catch in gillnets from the illegal totoaba fishery. As reported by Fossheim et al. (2015), the first comprehensive vaquita survey throughout their range took place in 1997 and estimated a population of 567 individuals. By 2007, their abundance was estimated to have dropped to 150. The population abundance as of 2018 was estimated at <19 individuals. Given the continued rate of by-catch and low reproductive output from the small population, it is estimated that there are fewer than 10 vaquitas alive as of February 2022. In 2023, it is still estimated that there are as few as 10 in the wild. The Mexican government, international committees, scientists and conservation groups have recommended and implemented plans to help reduce the rate of by-catch, enforce gillnet bans and promote population recovery. The Mexican government has taken major protection efforts to preserve these species.

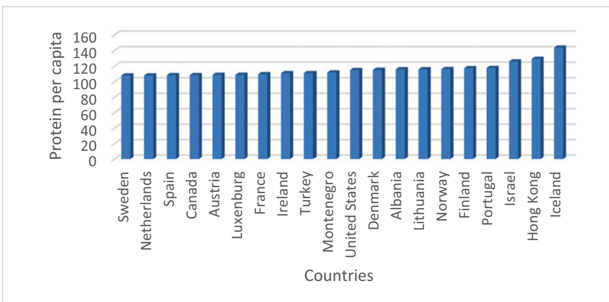
3.2.2. Hawaiian monk seal

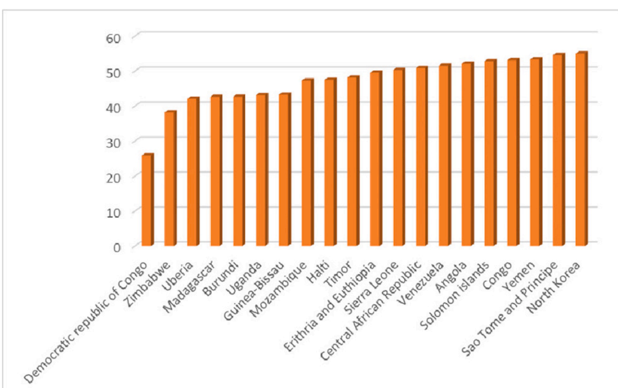
The Hawaiian monk seal (*Neomonachus schauinslandi*) is an endangered species of the Phocidae family, endemic to the Hawaiian Islands. Its grey coat, white belly and slender physique distinguish them from harbor seals (*Phoca vitulina*). The monk seal's physique is ideal for hunting its prey: fish, lobster, octopus and squid in deep water coral beds. When it is not hunting or eating, it generally basks on the sandy beaches and volcanic rocks of the Northwest Hawaiian Islands. These seals spend two-thirds of their life at sea. Monk seals spend much of their time foraging in deeper water outside of shallow lagoon reefs at sub-photic depths of 300 m or more. Hawaiian monk seals breed and haul-out on sand, corals and volcanic rocks; sandy beaches are more commonly used for pupping. They mainly prey on reef dwelling bony fish, but they also prey on cephalopods and crustaceans. Both juveniles and sub-adults prey more on smaller octopus species, nocturnal octopus species and eels, while adult seals mostly feed on larger octopus species. The factors that threaten the Hawaiian monk seal include low juvenile survival rates, reduction of habitat/prey associated with environmental changes, increased male aggression, and subsequent skewed gender ratios. Grebmeier et al. (2006) reported that these are the rarest marine creatures on the planet, and they frequently fall prey to human injustice by being persecuted or caught in fishing nets or other human waste. Since 1983, there has been a steady decline in their population. There were 632 mature animals and 577 young animals in 2005.

3.2.3. Steller sea lion

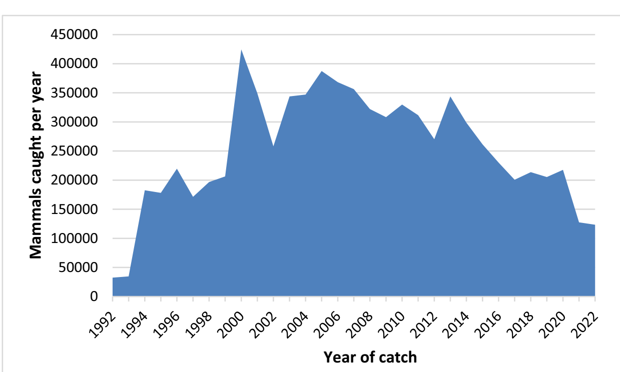
The Steller sea lion is a large, almost threatened species, predominantly found in the coastal marine habitats of the northeast Pacific



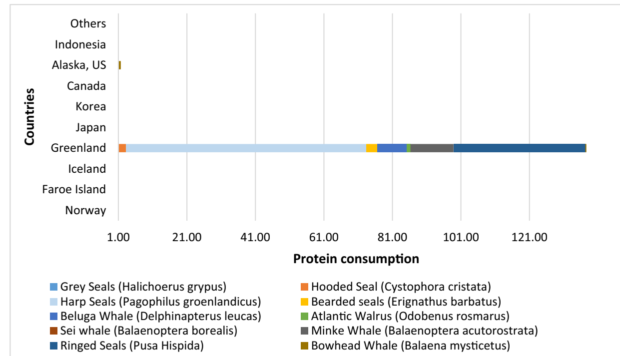


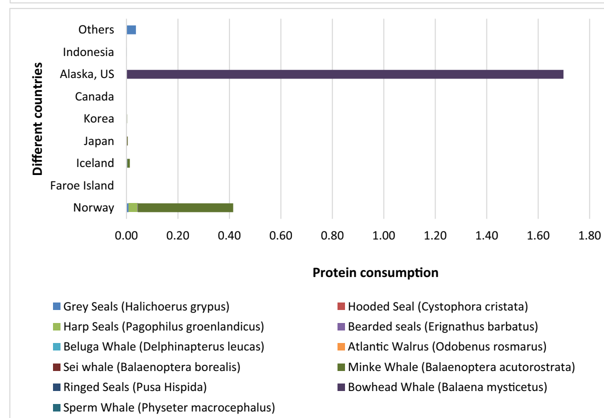


A. Top countries consuming the most and the least protein per capita (FAO,2023).

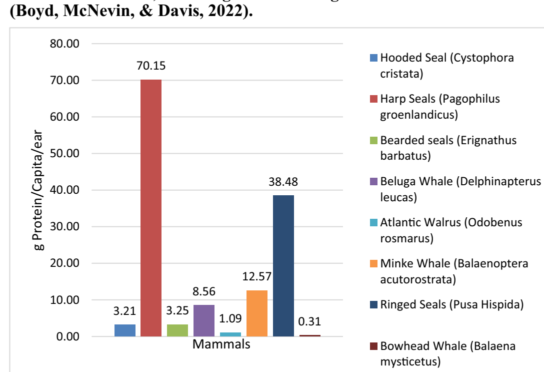


B. Total catch of sea mammals per year in different parts of the world (NAMMCO, 2022).





C. Annual, estimated per capita consumption of protein from sea mammals by humans worldwide, including and excluding Greenland (Boyd, McNevin, & Davis, 2022).



D. Estimated per capita consumption of protein from sea mammals in Greenland (Boyd, McNevin, & Davis, 2022).

Fig. 5. Consumption and total catch of sea mammals worldwide.
A. Top countries consuming the most and the least protein per capita (FAO, 2023).
B. Total catch of sea mammals per year in different parts of the world (NAMMCO, 2022).
C. Annual, estimated per capita consumption of protein from sea mammals by humans worldwide, including and excluding Greenland (Boyd, McNevin, & Davis, 2022).
D. Estimated per capita consumption of protein from sea mammals in Greenland (Boyd, McNevin, & Davis, 2022).

Ocean and the Pacific Northwest regions of North America, from north-central California to Oregon, Washington and British Columbia to Alaska. The range of the Steller sea lion extends from the north shore of Honshu in Japan to the Gulf of Alaska in the north. Steller sea lions tend to live in the coastal waters of the subarctic because of the cooler temperate climate in the area. Steller sea lions are amphibious. These mammals spend their time in the water feeding but come onto land to reproduce, raise their pups, moult and rest. They generally prefer isolated islands as an ideal terrestrial habitat to avoid terrestrial predators. They are skilled and opportunistic predators, feeding on a wide range of fish and cephalopod species. They seem to prefer schooling fish and forage primarily between intertidal zones and continental shelves. Steller sea lions were hunted by human communities for meat and other commodities. A subsistence harvest on the order of 300 animals or less continues to this day in some Alaskan native communities. While the populations of the eastern and Asian stocks appear stable, the population of the western stock, chiefly along the Aleutian Islands, was estimated to have fallen by 70–80 % since the 1970s. On the coasts of Canada and Alaska, deliberate culling between 1997 and 2017 led to a population reduction by almost 80 %. The IUCN reduced the status of sea lions from endangered to nearly threatened in 2012 due to the fact that the likelihood of their extinction within the next 100 years is <10 %. For the reason that sea lion culling has been minimised, the sea lion population has benefited (Moore and Reeves, 2018).

3.2.4. *Australian sea lion*

For thousands of years, Australian aboriginals have used this type of sea lion, native to Australia, as a source of food. The Australian sea lion (*Neophoca cinerea*) is a species that is the only endemic pinniped in Australia. They are sparsely distributed across their range, from the Houtman Abrolhos Islands in Western Australia, along the southern Australian coast to The Pages Islands in South Australia. With a population estimated at 14,730 animals, the Wildlife Conservation Act of Western Australia (1950) has listed them as "in need of special protection". These mammals use their flippers to propel themselves in water and can walk on land with their flippers. These include short fur, short flippers and a bulky body. These pinnipeds are specifically known for their abnormal breeding cycles, which vary between a five-month and a 17–18-month breeding cycle, compared to other pinnipeds which fit into a 12-month reproductive cycle. Females are either silver or fawn with a cream underbelly and males are dark brown with a yellow mane. The wide variety of prey in the diet of the Australian sea lion includes teleost fish, squid, cuttlefish, octopus, sharks, rock lobster, other small crustaceans and little penguins. According to Lowther et al. (2015a, 2015b), in 2010, an estimated number of 14,730 Australian sea lions existed. Currently, there are about 6500 people living there, but the population is still declining with each passing generation. Australian sea lions defecate nutrient-rich faeces which may be an important nutrient source for coastal ecosystems. In a metagenomic analysis of the bacterial consortia found in the faeces of Australian sea lions, very high levels of nutrient cycling and transport genes were found, which may break down the nutrients defecated by sea lions into a bioavailable form for incorporation into marine food webs.

3.2.5. *Hector's dolphin*

This is the smallest marine mammal in the world found in the waters close to northern New Zealand. The most distinctive feature is the rounded dorsal fin, with a convex trailing edge and undercut rear margin. Hector's dolphins display a seasonal inshore-offshore movement, favouring shallow coastal waters during spring and summer, and moving offshore into deeper waters during autumn and winter. Due to human threats, these dolphins are in peril and frequently perish after becoming entangled in fishing nets. Due to their geographic distribution near the coast, it is unlikely that their exposure to them can ever be completely eliminated. These sensitive animals are frightened out by boat interactions and suffer from pollution in addition to being caught as by-catch (Morissette et al., 2012b).

3.2.6. *Sea otter*

Sea otters used to be a common species, inhabiting the whole North Pacific rim. The sea otter inhabits near-shore environments, where it dives to the sea floor to forage. It preys mostly on marine invertebrates such as sea urchins, various mollusks and crustaceans, and some species of fish. Unlike most marine mammals, the sea otter has no blubber and relies on its exceptionally thick fur to keep warm. The fur consists of long, waterproof guard hairs and short underfur. The guard hairs keep the dense underfur layer dry. There is an air compartment between the thick fur and the skin where air is trapped and heated by the body The sea otter is a diurnal mammal. It has a period of foraging and eating in the morning, starting about an hour before sunrise, then it rests or sleeps during the mid-day. Sea otters, whose numbers were once estimated at 150,000-300,000, were hunted extensively for their fur between 1741 and 1911, and the world population fell to 1000–2000 individuals living in a fraction of their historic range. A subsequent international ban on hunting, sea otter conservation efforts and reintroduction programmes into previously populated areas have contributed to numbers rebounding, and the species occupies about two-thirds of its former range. The recovery of the sea otter is considered an important success in marine conservation. However, the IUCN still lists the sea otter as an endangered species, and describes the significant threats to sea otters as oil pollution, predation by orcas and conflicts with fisheries – sea otters can drown if entangled in fishing gear (Kiełpińska and Kowalski, 2021).

3.2.7. *Blue whale*

The blue whale (*Balaenoptera musculus*) is a marine mammal and a baleen whale. The blue whale's long and slender body can be of various greyish-blue shades dorsally and somewhat lighter underneath. Blue whale populations migrate between their summer feeding areas near the poles and their winter breeding grounds near the tropics. There is also evidence of year-round residencies, and partial or age/sex-based migration. Blue whales are filter feeders, their diet consists almost exclusively of krill. The blue whale is usually solitary, but can be found in pairs. Populations may go on long migrations, traveling to their summer feeding grounds towards the poles and then heading to their winter breeding grounds in more equatorial waters. As a result of its extensive migratory patterns, this species of whale can be found in oceans all around the world. The largest animal in the planet, it is threatened by a long history of commercial hunting. Populations appear to be growing as a result of the stoppage of commercial hunting. However, Miller et al. (2010) reported that incidents of ship hits, entanglements in fishing gear or health problems from the overabundance of plastic debris in the ocean continue to pose serious hazards. With climate change harming their native environment, some scientists are also concerned about the blue whales' long-term survival.

3.2.8. *Sei whale*

The sei whale is a baleen whale. It is one of ten rorqual species, and the third-largest member after blue and fin whales. It inhabits most oceans and adjoining seas, and prefers deep offshore waters. It avoids polar and tropical as well as semi-enclosed bodies of water. The sei whale migrates annually from cool, subpolar waters in summer to temperate, subtropical waters in winter. They have a lifespan of 70 years. Following large-scale commercial whaling during the late 19th and 20th centuries, when over 255,000 whales were killed, the sei whale is now internationally protected. It is listed as endangered and can be found on the IUCN Red List, despite increasing populations. The origin of *sei* is derived from the Norwegian pollock. This rorqual is a filter feeder, using baleen plates to obtain food by opening its mouth, engulfing or skimming large amounts of the water containing the food, then straining the water out through the baleen. According to Comiso and Hall (2014), commercial hunting of these unfortunate mammals was outlawed in the 1980s. Japan recommenced hunting in the North

Pacific under scientific permission in 2002, allowing for the capture of 100 animals annually. Sei whales have an uncertain exact population size, but estimates indicate that it represents about 20 % of its population level from1937.

3.2.9. Fin whale

The fin whale is the second-largest mammal in the world after the blue whale. It is distinguished by a prominent ridge below its dorsal fin. The fin whale (*Balaenoptera physalus*), also known as the finback whale or common rorqual, is a species of baleen whale. It is the second-longest cetacean on Earth after the blue whale. It is mainly a cosmopolitan species, found in all the world's major oceans and in waters ranging from those polar to tropical. The fin whale is a filter-feeder, feeding on small schooling fish, squid and crustaceans, including copepods and krill. Due to maritime pollution and whale killing, the fin whale is in danger. These whales, which are found all over the world, were thought to be impossible to catch before whale hunting became popular. After a few decades, fin whale hunting became outlawed between 1975 and 1990. As a part of the tradition left by natives, a few whales are permitted to be taken in Greenland each year (Cubaynes et al., 2019).

3.2.10. Beluga whale

The beluga whale is an arctic and sub-arctic cetacean. It is one of two members of the *Monodontidae* family, along with the narwhal, and the only member of the *Delphinapterus* genus. It is also known as the white whale, for it is the only cetacean to regularly having this colour. The beluga is adapted to life in the Arctic, with anatomical and physiological characteristics that differentiate it from other cetaceans. Among these are its all-white colour and the absence of a dorsal fin, which allows it to swim under ice with ease. It possesses a distinctive protuberance at the front of its head which houses an echolocation organ called the melon, which is large and deformable. They are migratory and the majority of groups spend the winter around the Arctic Sea cap. When the sea ice melts in summer, they move to warmer river estuaries and coastal areas. The beluga has a very specialised sense of hearing and its auditory cortex is highly developed. It can hear sounds within a range of 1.2–120 kHz, with the greatest sensitivity between 10 and 75 kHz, where the average hearing range for humans is 0.02 to 20 kHz. Belugas play an important role in the structure and function of marine resources in the Arctic Ocean, as they are the most abundant toothed whales in the region. They are opportunistic feeders. Their feeding habits depend on their locations and the season. For hunters, belugas make for simple prey. This is one of the main causes of the Cook Inlet, Alaska population of Beluga whales declining to just 375 animals in 2004 and the species being classified as critically endangered. There are 150,000 of these creatures in Arctic seas overall, although details on some subpopulations are lacking. The biggest factor contributing to the belugas' endangerment is subsistence hunting in Alaska, Canada and Greenland. Another effect of climate change in the Arctic is thought to have been altered water qualities and pollution seeping into the ocean as reported by (Dale and Armitage, 2011).

Still, many mammals are on the endangered list, such as the Florida manatee, the humpback whale or Fraser's dolphin. They are regularly declining in numbers due to our negligence. The lives of the sea mammals are solely dependent on the maintenance of the ocean and ecosystem together. Sustaining the health of these species is important for preserving the health of the ecosystem and ocean as a whole.

Over-fishing is a further issue related to sustainability. It entails removing more fish out of the water than is sustainable, which causes more sea mammals to be lost than there are births or population increases. This results in a decrease concerning the population of these species, creating problems for ecosystems and jeopardizing the sustainability of the environment. According to research, by the year 2050, marine seafood populations could collapse globally, which would mean a sharp drop in the species that make up our food supply. Now, 3 billion people now primarily get their protein from seafood, and in 2018, there were thought to be 179 million tons of fish caught worldwide. Additionally, it has been noted that the targeted species are quickly diminishing and that at least a third of all analysed fishing operations were conducted in an unsustainable manner (Magera et al., 2013). The prime negative impact on the health of the habitat is the reduction of marine mammals mainly due to increase in fishing. This over-fishing cause depletion of specific species which are frequently targeted on the increase demand of consumers. Reducing the number of sea mammals in the ocean affects the food sources of various marine animals and leads to a decline in their numbers (Lowther et al., 2015b). With trawling fishing techniques, in particular, where the nets grab all animals in the vicinity, over-fishing also leads to a large number of organisms ending up as by-catch. This has significant, negative impact on ecology because numerous marine mammals, including whales, dolphins and porpoises, as well as turtles, sharks and even seabirds, perish in these nets (Kiełpińska and Kowalski, 2021; Øien, 2009). Despite the fact that the business is inadequately supervised and managed, Øien (2009) and Hauksson (2010) discovered that the negative effects of over-fishing are problems with both the environment and the economy.

According to Garcia et al. (2015), the idea of balanced harvest has been put up to lessen the negative effects of fishing on ecosystems, while concurrently improving food production. In order to achieve a balanced harvest, the intensity of fishing should be moderate across the ecosystem. The load must be distributed proportionally to each taxa's production rather than being concentrated on a few, specifically chosen taxa or sizes (Kolding et al., 2014).

Marine mammals are an essential source of energy, fat and protein for people residing in polar regions. Due to their high protein and fat content, they can provide sufficient nutrition for those living in these areas. For instance, the Inuit population in Nunavik traditionally consumes Atlantic walrus meat using a serving technique known as *Igunaq*. In Fig. 5C, as reported by Boyd et al. (2022), the per capita consumption is presented of protein annually derived from sea mammals by the country. Owing to the unavailability of data on the exact quantity of sea mammals consumed by humans, the per capita consumption of protein from sea mammals was estimated by assuming that the reported total catch in each country represents the total consumption. Additionally, 21 % of the total individual weight of sea mammals was considered to be used as meat for human consumption.

In Fig. 5D, it is revealed that Greenland has the highest consumption of sea mammals, with a total consumption of approximately 138 g of protein a year per capita. The consumption is primarily attributed to the total catch of harp and ringed seals, beluga and minke whales in the country. However, the catch data cannot provide an accurate representation of the actual consumption by the population, as the hunting of seals may occur for game or commercial purposes. It is also worth noting that over-fishing can occur, leading to uncertainty at this intersection. Although other regions of the world have reported consuming sea mammals, the data indicate that the usage of sea mammals as a protein source is not as significant as in Greenland. As an illustration, following Greenland, the regions with the highest per capita consumption of protein derived from sea mammals include Alaska (1.69 g protein/capita) and Norway (0.415 g protein/capita). The limited availability of data on certain species in all countries restricts the conclusiveness of this part of the review.

3.3. Ethics of sea mammal catch and slaughter

According to Moore et al. (2019), commercial fishing operations are the main reason why sea mammals suffer from human exploitation and are killed. As reported by Nøttestad et al. (2014), the Marine Mammal Commission promotes sustainable fishing methods that have the least negative effects on marine mammals and their ecosystem. For evaluating and reducing marine mammal by-catch at commercial fisheries, the Marine Mammal Protection Act (MMPA) establishes comprehensive research and management framework (Sanders et al., 2018). This framework's creation is based on the supposition that reduction teams will establish plans to cut back on excessive levels of marine mammal by-catch. Additional scientific and management efforts are required to address the indirect effect of fishing on dynamics for sea mammals (Pyenson and Lindberg, 2011).

Butterworth (2014) and Guilpin et al. (2019) reported that the most thorough safeguard for marine mammals is the Marine Mammal Protection Act (1972). It put an end to the killing, capturing and hunting marine species in US waters. Like other creatures and people, marine animals can sense pain and fear. When sea mammals are caught using hooks or nets, kept at live animal markets, or raised in fish farms, they are subjected to cruelty. As reported by Bowen and Lidgard (2013), government statistics on kills in India note over 6 million metric tons of fish annually. Fishermen/women use huge boats and nets to catch tons of sea animals all at once. They do not make any distinction between target species and animals who are not targeted, but scoop up all animals on their path. The unwanted animals, called “by-catch”, are thrown back into the ocean – dead or dying – after the nets are pulled up and sorted. On some fishing boats, up to 90 % of the animals caught in the nets are by-catch (Chasco et al., 2017; Cubaynes et al., 2019).

According to Essington and Punt (2011), and Haug et al. (2017), sea mammals are reported to routinely remove catch or bait (depredation) from fishermen/women's lines or nets. There are approximately 30 odontocetes species that have been linked to depredation. For instance, several sperm killer, false killer and pilot whale populations all across the world have evolved to remove different fish species from longline hooks. At a variety of fisheries, other toothed whales and dolphins also engage in this activity (Fulton et al., 2011). The main objective of the hunt is to instantly kill the animal or to do it in a way that maximises hunter safety and minimises animal pain. The actual killing method has changed history. Cetaceans, mainly whales and dolphins, are secured properly with a blowhole hook after which the spinal lance is positioned in the midline between the blowhole and the dorsal fin at one hand's breadth behind the blowhole. The spinal cord and the surrounding blood arteries are cut with a single thrust, followed by a sideways motion, which is immediately followed by severing the jugulars and carotids, rendering the whale fully paralyzed and asleep. Rifles with a minimum calibre of 6.5 mm are used to deliberately kill grey seals with hollow-pointed bullets. Marine mammal hunting is opportunistic and seasonal in Greenland. Boats are used to catch whales, primarily minke, fin, humpback and bowhead types. A harpoon loaded with a Norwegian penthrite (whale grenade) is the main armament. Gunners aim for the area around the pectoral fins that contains the heart and lungs.

Unfortunately, depredating marine mammals occasionally make a mistake and are hooked or trapped, resulting in serious injury or death. Other influences include competition for prey and damage or destruction of sensitive sea mammal habitats. Globally, fisheries have significantly reduced the size of many fish stocks and continue to unsustainably exploit them year after year (Garcia et al., 2015; Jourdain et al., 2020). In addition, some types of trawls and dredge fishing have been repeatedly shown to significantly alter the physical and biological structure of sensitive marine habitats, potentially affecting marine mammals that depend on those habitats.

According to research, the commercial seal hunt in Atlantic Canada is one of the most extensive and inhumane killings of marine creatures on the planet. Tens of thousands of young seals, some only a few weeks old, are battered, shot and skinned every year for their fur. The annual massacre is brutal, wasteful and unprofitable because it targets populations already affected by climate change (Berta and Lanzetti, 2018; Breen et al., 2016; Link et al., 2015). The majority of the commercial seal hunt takes place in the far northwest Atlantic, in a harsh environment where shooting and clubbing are consistently accurate. Many injured seals flee and suffer a protracted, agonizing death. Others are beaten to death on bloodied boat decks, dragged across the ice and impaled with metal hooks while still awake (Lucifora et al., 2011; O'Boyle and Sinclair, 2012).

4. Knowledge gaps and future research

Currently available data on sea mammals is limited, and several knowledge gaps among the general public exist. This presents potential for further research in the future (Table 4). For instance, Gulland et al. (2022) highlighted surprising explanations about the relationship between climate change and sea mammal populations. Although most people believe that climate change has direct impact on the decline of sea mammal populations, some species of sea mammals can survive climate change. In this study, it is explained that other factors also contribute to this phenomenon. Therefore, it is crucial to identify and study all aspects affecting the decline of sea mammal populations and their relationship with the survival of sea mammals.

Moreover, the data compiled by the Food and Agriculture Organization (FAO) in aquaculture and capture fishery statistics do not include sea mammals as part of production or capture data in their statistics. Additionally, the FAO statistics do not provide specific data on protein consumption per capita in Greenland or the Faroe Islands, nor do they include aquatic mammals or aquaculture production data. However, according to the NAMMCO database, Greenland has the highest number of caught sea mammals (FAO, 2022a, 2022b). The availability of catch data, abundance and the correct amount used as food or non-food ingredients from sea mammals in each country is limited. Only NAMMCO and the International Whaling Commission (IWC) provide sufficient data, nonetheless, it is still limited (IWC, 2021; NAMMCO, 2022). Thus, conducting surveys in each country is necessary to ensure the survival of sea mammals in specific regions.

Furthermore, a conducted survey allowed to indicate that at least 24 aquatic mammals are used in traditional medicine worldwide, with cetaceans, *Carnivora* and *Sirenia* represented by 12, 8, and 4 species, respectively. *Delphinidae*, *Otariidae* and *Phocidae* families have the highest number of species used as remedies. Traditional medicine is strongly associated with religious magical elements, and cultural factors certainly influence the use of aquatic mammals in traditional folk medicine (Alves and Rosa, 2013). However, it is essential to consider the ingredients in sea mammals and their actual relation to health benefits or the cure of certain diseases that have not been confirmed. Only a small number of the reported traditional applications of aquatic animals were also supported by pharmacological research. There is a lack of knowledge regarding the dosage of usage and any potential downsides, such as the spread of zoonoses through intake of these foods. Therefore, it is essential to do thorough toxicological, pharmacological and clinical research in order to learn about potential negative consequences that may be deadly when consumed by humans (Mahomoodally et al., 2021). Finally, data analysing sea mammals indicate that they have high levels of protein and fat, ranging from 19.2 % to 76.9 % and 2.31 % to 41.3 %, respectively. Some species of sea mammals contain high levels of omega-3 fatty acids (EPA and DHA), with concentrations reaching up to 18.17 %. (U.S. Department of Agriculture, 2019). Nevertheless, it is crucial to consider that sea mammals are protected, and some of the species are threatened by their populations. Therefore, studies regarding the sustainability of ecological, economic, ethical, cultural and social variables, as well as toxicity and health research, need to be carried out before choosing to utilise sea mammals over other food sources.

Building on these considerations, several further areas of research could help fill these knowledge gaps. Firstly, cultural acceptance and preference towards sea mammals as a food source warrant detailed exploration. By delving into the underlying attitudes, beliefs and consumption patterns in different regions, valuable insights are gained that could inform of more effective and culturally sensitive strategies for the sustainable use of sea mammals. Next, the influence of legislative frameworks and management policies on sea mammal hunting and consumption also calls for closer scrutiny. A deeper understanding of how quotas, seasonal restrictions and other regulatory measures affect sea mammal utilisation can inform policy adjustments that promote sustainability while considering local economies and traditions. Lastly,

Table 4
Knowledge gaps and future research.

No.	Referenced article	Knowledge gaps	Future research
1	A review of climate change effects on marine mammals in United States waters: Past predictions, observed impacts, current research and conservation imperatives (Gulland et al., 2022)	There have been instances highlighting the influence of climate change on marine mammals; however, their validity remains unconfirmed. This uncertainty can be attributed to the lack of sufficient research and monitoring mechanisms to establish a clear cause-effect relationship (Gulland et al., 2022).	Further investigation is required to examine the direct correlation between climate change and fluctuations in the population of marine mammals.
2	World Food and Agriculture – Statistical Yearbook 2022 (FAO, 2022b), Total Catches (NAMMCO, 2022)and Total Catch (IWC, 2021)	The accessibility of data regarding the catch numbers, abundance and usage of sea mammals as food or non-food ingredients is restricted in each country. The information provided by NAMMCO and IWC is adequate, although still insufficient.	The execution of a survey to determine the abundance of sea mammals in each country is crucial to ensure their continuity and sustainability.
3	Aquatic Mammals Used in Traditional Folk Medicine: A Global Analysis (Alves and Rosa, 2013)	The survey findings reveal that traditional medicine practices across the globe involve the use of a minimum of 24 aquatic mammals, categorised into cetaceans (12 species), *Carnivora* (8 species), and *Sirenia* (4 species). The families of *Delphinidae*, *Otariidae* and *Phocidae* each have 4 species that are commonly used as remedies. It is evident that traditional medicine has close associations with religious and magical beliefs, and cultural factors are instrumental in determining the utilisation of aquatic mammals in traditional folk medicine.	It is imperative to conduct scientific tests to establish the efficacy of utilising specific parts of marine mammals in treating particular ailments.
4	Marine mammals oils (Shahidi et al., 2020)	Omega-3 fatty acid content in sea mammals, specifically DHA and EPA, is typically greater than that found in other sources of omega-3, such as caviar (6.54 mg/100 g) or chia seeds (18.04 mg/100 g of ALA) (U.S. Department of Agriculture, 2019). Additionally, there is a general belief among the public that specific parts of various substances can provide certain health benefits.	The use of endangered and protected marine mammals necessitates an investigation into the sustainability of ecological, economic, ethical, cultural and social factors. Additionally, a toxicity study must be conducted to evaluate the utilisation of these mammals.
5	Beluga Whale (U.S. Department of Agriculture, 2019)	Beluga whale liver contains 22,100 IU of vitamin A.	The stranded carcass of a beluga can potentially yield other valuable, non-food products.
	Entrance and Survival of *Brucella pinnipedialis* Hooded Seal Strain in Human Macrophages and Epithelial Cells (Larsen et al., 2013)	The consumption of sea mammals, including pinnipeds and cetaceans, has the potential to impact human health through the transmission of zoonotic microbes such as *Brucella pinnipedialis* and *Brucellaceti* (Larsen et al., 2013; Waltzek et al., 2012). This can lead to reproductive and neurological disorders, as well as osteomyelitis in sea mammals, while humans may experience symptoms such as headache, lethargy and/or severe sinusitis (Waltzek et al., 2012).	Therefore, it is necessary to conduct further research on the consumption of certain sea mammals by local communities, such as the Inuit, as raw consumption may result in zoonotic diseases that can cause serious illness in humans. Moreover, future studies are required to understand the spread and effects of illnesses caused by zoonotic microbes in sea mammals.

issues of conflict between human activities and sea mammals, particularly those instances leading to retaliatory killings when sea mammals interfere with fishing, require further investigation. By studying these conflict scenarios and developing ways to mitigate them, we could enhance conservation efforts while addressing local community concerns and needs. Addressing these knowledge gaps will facilitate a more informed approach to the conservation and sustainable utilisation of sea mammals, underscoring the need for such research directions.

5. Conclusions

The objective of this review is to understand how cultural, ecological, economic, ethical and health factors shape sea mammal utilisation and to identify potential strategies for sustainability as well as conservation. The most effective tool for addressing threats to marine mammals is to prepare place-based conservation policies. Despite the great strides made by researchers and conservationists towards finding ways to monitor and protect marine mammals as well as their habitats, species and populations continue to be lost. Although humans have utilised sea mammals for various purposes, concerns have been raised about their sustainability due to factors such as hunting, accidental catching, pollution, warming, acidification, melting sea ice and overfishing. Despite efforts to increase conservation, the decline in the population of certain species persists, while others have shown growth due to various factors such as environmental conditions, food availability, successful reproduction and protection from threats. Sea mammals are also rich sources of omega-3 fatty acids, protein and fat, but handling them improperly can pose significant health risks. Cultural attitudes towards the utilisation of marine mammals have also played a significant role in determining their use. Sea mammals are utilised by humans for various purposes, including pelt, fur, meat and certain body parts. Some body parts are also used in traditional medicine, although their efficacy has not been scientifically proven, necessitating further research. The beliefs of the public regarding sea mammals influence their utilisation patterns for food, clothing, medicine, religious and magic purposes. Furthermore, the consumption of sea mammals has the potential to transmit zoonotic diseases from these animals to humans, resulting in adverse health effects if not properly handled and processed. The limited availability of data on catch numbers, abundance and the utilisation of sea mammals for food or non-food ingredients worldwide indicate that not all species of sea mammals can be adequately monitored in each country. The usage of sea mammals necessitates an investigation into the sustainability of health, ecological, economic, ethical, cultural and social factors.

Also, the possible impact of anthropogenic climate disruption on the distribution of these mammals and its repercussions on the establishment of connective corridor systems between protected areas should be considered. Approximately 98 % of marine mammal species are at some level of risk in 56 % of the ocean, mainly in coastal waters. Thus, a few key threats affecting marine mammals around the globe are also mentioned as follows - 1. Climate change; 2. Fishery by-catch; 3. Reduction of prey availability due to over-fishing; 4. Plastic pollution; 5. Use of marine mammals as bait at fisheries; and 6. Pathogen pollution.

CRediT authorship contribution statement

Shahida Anusha Siddiqui: Methodology, Validation, Formal Analysis, Resources, Writing – original draft, Writing – review & editing, Visualization, Data Curation, Project administration, Investigation, Funding Acquisition, Supervision. **Sunayana Baruah:** Writing – original draft. **Yuan Seng Wu:** Validation. **Sunrixon Carmando Yuansah:** Writing – original draft. **Roberto Castro-Muñoz:** Validation. **Andrzej Szymkowiak:** Writing – review & editing. **Piotr Kulawik:** Conceptualization, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare no conflict of interest.

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