Filatova Olga (Orcid ID: 0000-0003-1533-4807)
Burdin Alexander (Orcid ID: 0000-0001-5701-1008)

Important Areas for Cetaceans in Russian Far East Waters

Olga A. Filatova[1,2], Erich Hoyt[3,4], Alexander M. Burdin[5], Vladimir N. Burkanov[5,6], Ivan D. Fedutin[1], Ekaterina N. Ovsyanikova[7], Olga V. Shpak[8], Tatiana S. Shulezhko[5], Olga V. Titova[8]

[1]Faculty of Biology, Lomonosov Moscow State University, Moscow, Russia

[2]Beringia National Park, Providenya, Chukotka, Russia

[3]Whale and Dolphin Conservation, Bridport, UK

[4]IUCN SSC-WCPA Marine Mammal Protected Areas Task Force, Gland, Switzerland

[5]Kamchatka Branch of the Pacific Institute of Geography, Petropavlovsk-Kamchatsky, Russia

[6]Marine Mammal Laboratory, National Oceanic and Atmospheric Administration, Seattle, USA

[7]The University of Queensland, Gatton, Queensland, Australia

[8]Severtsov Institute of Ecology and Evolution, Moscow, Russia

Abstract

1. Cetacean species are highly mobile, most of them regularly travelling over long distances, thereby presenting complex obstacles to their conservation. Identification of their critical habitats, specifically those parts of a cetacean's range that are essential for day-to-day survival and for maintaining a healthy population growth rate, is essential for their effective protection.
2. This study presents a summary of the data on cetacean sightings during surveys that covered substantial parts of the Russian Far East coastal waters from the Okhotsk Sea to Chukotka in order to determine important areas for particular cetacean species. Sixteen cetacean species were registered during the surveys, and for 12 of them with sufficient numbers of sightings, zones with maximum sighting rates were identified.
3. Only 13% of all cetacean sightings and 22% of sightings of protected species occurred within marine protected areas (MPAs). The highest sighting rates for protected species were concentrated off North-eastern Sakhalin Island, in the Shantar Area, in Anadyr Gulf, in Kresta Bay and in the waters off eastern Chukotka. The analysis of the distribution patterns of various cetacean species in Russian Far East seas provides a solid base for future conservation planning. Lack of specific MPAs for protection of cetaceans and associated biodiversity hinders marine conservation in Russian Far East seas.
4. The study highlights the specific zones important for various cetacean species, suggests the extension of some existing MPAs and the creation of new MPAs for future spatial habitat protection measures.

Keywords

whales, dolphins, marine protected areas, important marine mammal areas, critical habitat, biodiversity

Introduction

Cetacean species are highly mobile, most of them regularly travelling over long distances, thereby presenting complex obstacles to their conservation. Spatial protection of the entire home range of foraging toothed whales, much less migrating baleen whales, is impractical. There are, however, strategies to address this problem. The starting point is the identification of critical habitats, specifically those parts of a cetacean's range that are essential for day-to day survival during specific seasons, as well as for maintaining a healthy population growth rate (Hoyt, 2011). Various criteria have been proposed for defining critical habitats for cetaceans, such as their importance for feeding, calving, socializing and other vital activities, as well as sufficient habitat size, species diversity and ecosystem integrity (e.g. Ross et al., 2011; Hoyt & Notarbartolo di Sciara, 2014). More recently, these criteria have been incorporated into the concept of 'important marine mammal areas', or IMMAs (IUCN Marine Mammal Protected Areas Task Force, 2018; Notarbartolo di Sciara & Hoyt, 2020). Important marine mammal areas utilize a set of criteria closely matched to other systems for identifying biodiversity, including Convention on Biological Diversity (CBD), ecologically or biologically significant areas (EBSAs), IUCN key biodiversity areas (KBAs) and BirdLife International's important bird and biodiversity areas (IBAs) (Corrigan et al., 2014; Hoyt & Notarbartolo di Sciara, 2014; Notarbartolo di Sciara et al., 2016). Important marine mammal areas, as well as EBSAs, KBAs and IBAs, are not marine protected areas (MPAs) but may be used to design new MPAs, or expand, zone or inform reviews of existing MPAs, as well as functioning as layers for marine spatial planning (Notarbartolo di Sciara & Hoyt, 2020). For now, while IMMAs await identification in Russian Far East waters, researchers have been gathering cetacean data contributing to assessments of cetacean conservation needs leading to potential spatial protection measures such as MPAs.

Russia has many terrestrial protected areas, but few MPAs with cetacean habitat (Hoyt, 2011). Many cetacean species inhabit Russian Far East waters including the western North Pacific and adjacent Arctic waters, which is a hotspot of marine mammal species at risk of extinction (Davidson et al., 2012). Effective conservation of cetaceans requires knowledge of species biology, population structure and distribution as well as threats to cetaceans; however, little is known about many cetacean species in Russian waters. Large whales were severely depleted in the years of commercial whaling; since that time, some species have begun to recover (e.g. humpback whale, Barlow et al., 2011), but others remain rare (e.g. blue whale, North Pacific right whale). Government fisheries institutions in Russia receive little funding for cetacean monitoring, and therefore have no means to obtain the data for decision-making by government bodies. This is of critical concern in light of mounting threats: developing oil exploration and drilling, high fisheries pressure on ecosystems and direct impacts on cetaceans, underwater noise from shipping (especially, along the growing Northern Sea Route) and industrial activities, and climate change.

Oil and gas development has occurred for many years on the shelf east of Sakhalin Island (south-western Okhotsk Sea) but has now spread to other parts of the Okhotsk Sea (Fadeev, Ilyinsky & Ilyin, 2020). Drilling was launched off the west coast of Kamchatka Peninsula (eastern Okhotsk Sea), and there are plans for drilling to begin near Magadan (North-western Okhotsk Sea). The Arctic continental shelf is also viewed as a potential oil and gas source for future development (Kontorovich et al., 2010). In total, significant areas of Russian Arctic seas (up to 40% of the current exclusive economic zone [EEZ]) are already covered by oil and gas contracts (pers. comm. Boris Solovyev, WWF Russia).

Fisheries contribute to anthropogenic pressure on cetaceans in several ways: entanglement of whales and dolphins in fishing gear (including bycatch), depletion and dispersal of food resources, and, together with other industries, noise pollution. Entanglement in fishing gear is one of the most commonly observed causes of human-caused marine mammal mortality (Baulch & Perry, 2012). Gillnets targeting demersal species were suggested to pose the greatest potential risk to cetaceans (Brown, Reid & Rogan, 2013), but other types of fisheries, including the pelagic drift net fishery (Artukhin, Burkanov & Nikulin, 2010), coastal salmon set net fishery (Lowry et al., 2018), trawls (Dans et al., 2003) and longlines (Forney, 2004) also often cause lethal entanglements of cetaceans. Bycatch in drift nets was an important factor of mortality in Russian Far East seas (more than 2,000 cetaceans killed over the period of 1992-2001, Artukhin, Burkanov & Nikulin, 2010); this type of fishing gear was finally prohibited in Russian waters in 2016.

Overfishing is a global problem (Jackson et al., 2001), and extends into Russian Far East seas. Many fish species in Russian waters are depleted due to unsustainable fishing. For example, the Korf-Karaginsky herring population – the important food source for the local humpback whale population – was abundant until the late 1950s, but has since been significantly depleted (Naumenko, 2010). Atka mackerel was an important prey for killer whales (*Orcinus orca*) in Avacha Gulf of Kamchatka, but uncontrolled fishing led to the collapse of important spawning grounds and forced the whales to rely more on salmon (Nagaylik et al., 2010).

Underwater noise pollution also threatens cetaceans, with shipping being the most widespread and chronic noise source (McDonald, Hildebrand & Wiggins, 2006). Increased global shipping has led to a rise in ocean ambient noise levels by 0.5 dB re 1 μPa per year (Ross, 2005). Since the 1950s, noise levels at the lower frequencies have increased by an average of 3-4 dB per decade based mainly on studies in the north-eastern Pacific (Ross, 1993; Andrew et al., 2002; McDonald, Hildebrand & Wiggins, 2006). Thus, the sound intensity of this background noise has increased substantially over a period of time roughly comparable to the lifetime of a whale. Persistent noise exposure negatively affects cetaceans in different ways: it decreases the detection range of their own and their conspecifics' signals due to acoustic masking and shifts in hearing thresholds, potentially reducing their ability to hunt and find mates; this effectively degrades and reduces their usable habitat, and it can also compromise health (Richardson et al., 1995). In addition, acute noise impacts from oil and gas seismic work and Navy sonar have led to individual as well as mass stranding events (Weilgart, 2007).

All types of activities with vessel traffic present the risk of vessel strike to cetaceans (Laist et al., 2001; Silber et al., 2021). The Bering and the Chukchi Seas are listed among the high risk areas where collisions between ships and whales can occur (Silber et al., 2021). Vessel strikes have been shown to cause injuries and significant levels of mortality in some cetacean species (Mullen, Peterson & Todd, 2013; van der Hoop et al., 2015).

In addition to direct anthropogenic impacts, Russian Far East seas are experiencing signs of climate change. Rapid increases in annual temperatures lead to changes in ocean circulation and ice cover, which severely affect regional ecosystems (Wassmann et al., 2011). Rising temperatures are having a dramatic effect on the local biodiversity, such as a decrease in range and abundance of some cold-water and/or ice-dependent species (Laidre et al., 2015; Laidre & Regehr, 2017; Silber et al., 2017), dispersal of boreal species to the higher latitudes (Fossheim et al., 2015; Hunt et al., 2016), biological invasions (Spiridonov & Zalota, 2017) and sea-ice habitat loss (Amstrup, Marcot & Douglas, 2008; Moore & Huntington, 2008).

Cetaceans have weak protection in Russia. By law, they are considered 'aquatic biological resources', i.e. they have the same legal status as fish. There is no special law considering cetaceans or marine mammals as a distinct group requiring a specific approach for conservation and management. The forms of zonal protection of aquatic biological resources provided by the Fisheries Law are not adapted for cetaceans. Moreover, in July 2020 a package of laws was adopted to support entrepreneurial activity in the Russian Arctic. The lenient tax, administrative, insurance and other provisions established by these laws were designed to promote economic activity in Arctic waters. In view of this legislation and the lack of specialized measures for cetacean protection, there exists a high risk of the degradation of cetacean habitats with the consequent reduction in population numbers. At present, the only legal recourse would apply to species listed in the Russian Red Book (http://publication.pravo.gov.ru/Document/View/0001202004020020) of endangered species (Table 1). This gives those few species some legal protection, but the Red Book offers few practical actions to ensure conservation other than prohibiting and prosecuting direct takes. Therefore, in absence of other legal mechanisms for cetacean conservation, a pragmatic approach may be to adapt existing Russian legislation to protect more of their marine habitat.

Russia's system of nature protected areas developed during the Soviet period includes strictly protected natural reserves, or zapovedniks (IUCN Protected Area Category Ia), national parks (IUCN Category II), preserves (IUCN Category IV/VI), natural monuments (IUCN Category III) and regional protected areas (IUCN Category Ib). However, most of these areas were designed to protect terrestrial ecosystems. Russia currently has no MPAs without a terrestrial component: by common practice, the officials expect that a protected area should include land first and sea as an addition. Coastal waters of terrestrial reserves are considered an integral part of protected areas, though less important (PAME, 2015). MPAs comprise only about 3% of Russia's exclusive economic zone (WWF, 2020). The largest marine protected area (MPA) in Russia is the Commander State Nature Biosphere Reserve which has a 30 nm zone around the islands, totalling 34,633 km^2. This area has a high abundance and diversity of cetacean species. Most other MPAs comprise only 1-6 nm wide waters adjacent to the coasts of terrestrial reserves. As they are relatively small, few of them overlap with cetacean hotspots, and indeed cetaceans were not considered at all when these zones were established. Until recently, Russian waters also included special Marine Mammal Protection Zones that were created in 1986 to protect pinniped rookeries and sea otter habitat (Order of the Ministry of Fisheries of the USSR from 30 June 1986 No. 349); however, these zones were invalidated in 2020 (Resolution of the Government of the Russian Federation from June 13, 2020 No. 857).

To develop an effective network of MPAs and appropriate protection zones for cetaceans and the biodiversity their habitats contain, a first step is to determine which particular areas are used with higher frequency, and for what purpose (breeding, feeding, resting, socializing). A useful reference point is the Convention on Biological Diversity EBSA workshop process which in 2013 identified EBSAs in the North Pacific, including the Russian Far East, as well as in the adjacent Arctic region, some of which were identified on the basis of cetacean habitat, although the EBSAs did not use the various data presented in this paper. In the waters of the Russian Far East, no consistent large-scale assessment of cetacean distribution has yet been published. Cetacean surveys have been either small-scale or opportunistic (e.g. Istomin et al., 2013; Shulezhko & Burkanov, 2013; Belonovich & Gutovsky, 2017; Myasnikov et al., 2017), and no effort has been made to analyse the presence of various cetacean species on a large scale. This study presents a comprehensive summary of the data on cetacean sightings during surveys from several research teams covering substantial parts of Russian Far East coastal waters in order to determine important areas for particular cetacean species.

Methods

Data sources

The data used for this study were obtained through dedicated cetacean surveys as well as opportunistically during pinniped surveys and tourist cruises in the summer seasons (May-September) of 2003-2018, spanning more than 4,000 km from the western Okhotsk Sea to Wrangel Island in the Chukchi Sea (Figure 1).

The vessels used for the data collection varied from 10-15 m yachts to cruise ships up to 72 m in length. During the dedicated surveys, two observers scanned the area with the naked eye and binoculars on two-hour shifts, weather permitting. During the opportunistic observations, the number of observers and duration of observation shifts varied. When cetaceans were detected, the observers recorded the GPS position, species and number of individuals. During the dedicated surveys, the bearing and distance to the cetaceans were also recorded, but these data were not used for this study because no comparable bearing and distance data were collected during the opportunistic surveys.

Local shore-based or small boat-based surveys were not included in this study.

Effort calculations

For all dedicated cetacean surveys and Steller sea lion surveys, the GPS tracks were recorded along with detailed weather conditions. For this study, the observations were assumed to be on-effort if the following conditions were met: visibility > 1.5 km, swell < 2 m, wind speed on Beaufort scale < 5. Off-effort observations were excluded from the analysis. To calculate the effort for each zone, the Sum Line Lengths tool in QGIS was used (QGIS Development Team, 2020).

Besides marine mammal surveys, some data on the opportunistic sightings of cetaceans from cruise ships were used for this study. These data were recorded by cruise guides or experienced whale watching tourists (the tourists' competence was assessed by the guides). No systematic effort data were available for observations from cruise ships. The effort for these observations was calculated based on the information from the cruise guides about their normal observation routine. The calculations were based on the marine mammal (cetacean, pinniped or sea otter) sighting records because, according to the guides, the observations were usually conducted in situations when there was a high probability of marine mammal encounters (good weather and visibility and/or location known for marine mammal presence). If the time lag between two consecutive sighting records was one hour or less, then the observational effort was assumed to be continuous between these points. In this case, the points were joined into a track line that was treated in the further analysis similarly to on-effort track lines of dedicated surveys. For the single records that had no consecutive sightings one hour or less before and after, the observation effort was assumed to last for one hour. Therefore, to calculate the observation track length corresponding to each single marine mammal sighting record, the average vessel cruising speed (19 km/h) was multiplied by one hour. This value was added to the effort track length in the corresponding zone, but these tracks were not shown on the map because in many cases the direction of vessel movement was not obvious from the data.

Calculation of encounter rates

The study area was divided into 33 zones according to oceanographic features and natural borders, such as capes (Figure 1). Boundaries between the coastal and oceanic (pelagic) areas were drawn following the shelf slope where feasible. Coastal areas received finer division because more effort was concentrated there. A zone around the Commander Islands followed the 30 nm protected zone of the

Commander Reserve. The encounter rate for each zone was calculated as a ratio of the number of encountered individuals of each species in the particular zone to the length of track lines in that zone. The number of individuals of each species in the particular zone was calculated using the 'Count points in polygon' plug-in in QGIS, and the length of track lines in each zone using the 'Sum line length' plug-in in QGIS. Only species with at least five sightings were used to calculate the encounter rate per zone.

To identify zones that are especially important to protected species, the sighting rates were summed only for the species listed in the Russian Red Book (Table 1), weighted by their protection status. There are six categories in the Russian Red Book: 0 – Probably extinct, 1 – Endangered, 2 – Decreasing numbers or range, 3 – Rare, 4 – Uncertain status, 5 – Recovered or recovering. To calculate the weighted sighting rate, the sighting rate of a species in a particular zone was divided by its protection status. Therefore, the weighting factor varied from 1 for endangered species to 0.2 for recovering species. Then, the weighted sighting rates for each zone were summed to get the combined weighted sighting rate for protected species. IUCN Red List ratings for each species in Table 1 were not used in the analysis and provided for information only.

Environmental correlates of species presence

The depth values for the study area were obtained with 4-minute resolution using the *getNOAA.bathy* function from the *marmap* package (Pante & Simon-Bouhet, 2013) in R (R Core Team, 2020). From these values, the respective depth value was calculated for each cetacean sighting using the function *get.depth*. The distance from each sighting position to the shore and to the shelf slope (140 m isobath) was also calculated using the *dist2isobath* function.

Results

The dataset included 3,861 sighting records of 17,848 individuals from 16 species in the period of 2003-2018 (Table 1). Cetacean species encountered during the surveys included Dall's porpoise *Phocoenoides dalli*, harbour porpoise *Phocoena phocoena*, beluga whale *Delphinapterus leucas*, sperm whale *Physeter macrocephalus*, Baird's beaked whale *Berardius bairdii*, Cuvier's beaked whale *Ziphius cavirostris*, killer whale *Orcinus orca*, Pacific white-sided dolphin *Lagenorhynchus obliquidens*, common bottlenose dolphin *Tursiops truncatus*, humpback whale *Megaptera novaeangliae*, fin whale *Balaenoptera physalus*, common minke whale *Balaenoptera acutorostrata*, blue whale *Balaenoptera musculus*, gray whale *Eschrichtius robustus*, bowhead whale *Balaena mysticetus*, and North Pacific right whale *Eubalaena japonica*. Dall's porpoise was the most frequently observed species over the study period. Humpback whale and killer whale were the next most frequently observed taxa. Five species were sighted only a few times: blue whale, common bottlenose dolphin, Cuvier's beaked whale, Pacific white-sided dolphin and North Pacific right whale.

Twelve species with at least five sightings were included in the analysis of the sighting rate per zone (Table S1): Dall's porpoise, harbour porpoise, beluga whale, sperm whale, Baird's beaked whale, killer whale, humpback whale, fin whale, common minke whale, gray whale, bowhead whale, and North Pacific right whale.

Zones important for each species

The sighting rates of six odontocete (Figure 2) and six mysticete (Figure 3) species were analysed in the various zones of the study area.

Dall's porpoises were frequently sighted in most zones except the waters of Chukotka and some coastal regions of the Okhotsk Sea: Penzhinsky Gulf, Middle and North-eastern Sakhalin, Sakhalin Gulf and Shantar Area.

Harbour porpoises were recorded with high sighting rates in Gizhiginsky Gulf, in the Northern Kuril Islands, off North-eastern Sakhalin, in Karaginsky Gulf, Olutorsky Gulf and in the pelagic zones of the Okhotsk Sea.

Beluga whales formed stable summer aggregations in the coastal waters of the Okhotsk Sea, Chukotka and adjacent areas. In the Okhotsk Sea, belugas were most frequently observed in the Sakhalin Gulf, Gizhiginsky Gulf and Shantar Area, and less frequently in the waters of North-eastern Sakhalin, Penzhinsky Gulf and Western Kamchatka. In Chukotka, belugas regularly occurred only in the Anadyr Estuary, and some encounters were also registered in Kresta Bay and off the Koryak Coast. In other areas of Chukotka, belugas were observed infrequently.

Sperm whales were mostly found off the shelf slope and in deep-water pelagic areas. The highest sighting rate of sperm whales was in the Middle Kuril Islands. High sighting rates were also recorded in the Northern and Southern Kuril Islands, in the Southern Pelagic Okhotsk Sea off the Kuril Islands, in the Commander Islands, in the pelagic Pacific Ocean and in Kronotsky Gulf. Some sightings were also registered in Avacha Gulf and in the pelagic Bering Sea.

Baird's beaked whales were mostly found near the shelf slope in coastal areas off eastern Kamchatka and in the Commander and Kuril Islands, as well as in the deep water of the Southern Pelagic Okhotsk Sea and in the Pacific zone off the Commander Islands.

Killer whales were mostly encountered in coastal waters. The highest sighting rate was in the Middle Kuril Islands. High sighting rates were also recorded in the Northern and Southern Kurils, as well as off the eastern Kamchatka coast and off the Commander Islands, in the coastal western Okhotsk Sea, in Anadyr Gulf and eastern Chukotka.

Humpback whales form feeding aggregations in particular areas of the Russian Far East that have been stable for years. The highest sighting rate was in Kresta Bay in Chukotka. Other areas with high sighting rates were off the Chukotka coast north of Cape Navarin and in the Chukchi Sea, the Commander Islands and Karaginsky Gulf in Kamchatka. Humpback whales were also regularly observed in other areas off eastern Kamchatka, including the offshore area between Kamchatka and the Commander Islands. This species was rarely observed or completely absent in most zones of the Okhotsk Sea, except for a small feeding aggregation in the northern Kuril Islands.

Fin whales had the highest sighting rate in the offshore Bering Sea. High sighting rates were also observed in the offshore Southern Pelagic Okhotsk Sea and Pacific Ocean as well as in coastal areas: off the eastern and south-eastern coast of Sakhalin Island, in Ozernoy Gulf and Karaginsky Gulf off eastern Kamchatka, and in the waters of Anadyr Gulf and eastern and northern Chukotka Peninsula.

Common minke whales were observed both in coastal and offshore areas, but the highest sighting rates were found in shallow coastal areas of northern and western Okhotsk Sea in the Shelikhov Gulf, the Shantar Area and off the North-eastern Sakhalin coast.

Gray whales occurred in clustered feeding aggregations found in the same areas from year to year. The highest sighting rates were off eastern Chukotka in the Senyavin Strait area and north to the Bering Strait, and also off North-eastern Sakhalin. This species was also regularly sighted in other coastal areas of Chukotka from Olutorsky Cape to Chukchi Sea and in the Kronotsky Gulf of eastern Kamchatka.

Bowhead whales were observed in two distinct areas: in coastal western and northern Okhotsk Sea and in the Chukchi Sea. The highest sighting rate was found in the Shantar Area in the western Okhotsk Sea.

North Pacific right whales were observed only in the waters of the Northern Kuril Islands and South-eastern Kamchatka. There were only five sightings of this species in the dataset, which were made in three different years (2009, 2013 and 2014) and in different surveys, suggesting that this area is indeed a summer feeding ground for this species.

Zones with highest sighting rates of all and protected species

The highest sighting rates of all species were found in Sakhalin Gulf, Anadyr Estuary, Gizhiginsky Gulf and the Shantar Area because of the large beluga whale summer aggregations in these zones (Figure 4). The next highest sighting rates were in Kresta Bay, Senyavin Strait and Mechigmensky Gulf because of the regular presence of summering aggregations of humpback and gray whales. The Middle Kuril Islands also had high sighting rates because of the high density of Dall's porpoises, killer whales and sperm whales. The lowest sighting rates were found in the Middle Sakhalin zone, in South-eastern Kamchatka south to Povorotny Cape, as well as in the northern Okhotsk Sea – in the Magadan zone, in Penzhinsky Gulf and in Shelikhov Gulf.

The highest sighting rates for combined protected species were concentrated off North-eastern Sakhalin Island (western gray whales), in the Shantar Area (Okhotsk Sea bowhead whales, mammal-eating killer whales), in Anadyr Gulf (gray, humpback and fin whales), in Kresta Bay (gray and humpback whales) and in the waters off eastern Chukotka (gray and humpback whales) (Figure 4).

Species distribution related to the existing MPAs

The total area of the federal MPAs in the study region is currently 66,365 km^2 (Gulbina, 2020). The majority of this area belongs to the Commander State Nature Biosphere Reserve (34,633 km^2) and Wrangel Island Reserve (14,300 km^2) (Figure 4). Only 13% of all cetacean sightings and 22% of sightings of protected species occurred within the MPAs. Endangered (category 1 in the Russian Red Book) species and populations also appeared to be poorly protected by the existing area-based conservation measures: only three out of 95 sightings of the Okhotsk Sea bowhead whale population were within the marine protected zone of the Shantar Islands National Park. For gray whale, the sightings of the western (category 1) and the eastern (category 5) populations could not be distinguished because they overlap in the Okhotsk Sea, where they mostly feed off North-eastern Sakhalin in unprotected waters (Brüniche-Olsen et al., 2018), and in eastern Kamchatka, where they commonly occur within the protected marine zone of the Kronotsky Reserve. All sightings of the endangered North Pacific right whale and endangered blue whale occurred outside MPAs.

Environmental correlates of species presence

The depth, distance to shore and distance to the shelf slope were compared to the species presence of the various cetaceans (Figure 5). Some species showed distinct patterns in habitat preferences that were reflected in the combination of these three factors. Bowhead whales, beluga whales and gray whales comprised a group of seasonal shallow-water coastal species that occurred in the areas with depths up to 60 m (rarely up to 100 m) close to the shore (commonly up to 50 km, sometimes up to 100 km) but showed no association with shelf slope. By contrast, Baird's beaked whales and sperm whales were normally found close to the shelf slope at depths > 500 m but did not demonstrate any specific preferences for being close to shore. Killer whales also showed more consistency in their association with shelf slope than with shore, but it was less pronounced than in sperm whales and Baird's beaked whales. Rorquals (fin, common minke and humpback whales) and both species of porpoises had a wider range of habitat preferences, occurring both in coastal and pelagic waters, at different depths and distances to the shelf slope. The presence of humpback whales related to the shelf slope and of fin whales related to depth showed a distinctive bi-modal distribution, indicating that these species can demonstrate preferences to different environmental factors.

Discussion

Cetaceans are especially vulnerable to human impacts due to their life history parameters: slow growth and reproduction rates, high metabolic requirements and extremely large home ranges. This paper presents a comprehensive overview of the distribution patterns of various cetacean species in Russian Far East seas, providing a starting point for future conservation measures. In this study, the effort was mostly concentrated in coastal waters which are more vulnerable to anthropogenic impacts. The impacts on coastal ecosystems and the cetaceans living there are associated with various human activities, including fisheries, oil and gas development, and pollution from mainland runoffs, among other anthropogenic factors (Read, Drinker & Northridge, 2006; Crain et al., 2009).

Patterns of species distribution

The distribution of particular species often had obvious environmental correlates. Two Arctic species and one Arctic seasonal resident – bowhead whale and beluga whale, and gray whale respectively – mostly occurred in shallow coastal waters and showed no association with shelf slope. For gray whales, these results agree with the data from other areas (Moore, DeMaster & Dayton, 2000); however, bowhead and beluga whales often showed different preferences from other studies. For example, Moore, DeMaster & Dayton (2000) found that in the Beaufort Sea, bowhead whales selected continental slope waters in summer and preferred inner shelf waters in autumn; beluga whales inhabited slope and open basin waters in summer and outer shelf and slope in autumn. In a later study of the same area, bowhead sighting rates were highest in the outer shelf habitat in July and the inner shelf-shallow habitat in August-October; beluga whales were associated with continental slope habitat in all months (Clarke et al., 2018). This difference is likely related to local conditions. In contrast to the narrow shelf and steep continental slope of the Beaufort Sea, the Chukchi and Okhotsk seas have a wide shelf often spanning several hundred kilometres from the shore, and the shelf slope is gradual. Besides, in the Okhotsk Sea, ice is normally absent in July-October, which makes beluga whales and young bowhead whales vulnerable to killer whale predation. A combination of these factors drives the habitat preferences of these species in Russian Far East waters. In the Okhotsk Sea, both beluga and bowhead whales concentrate in the inner parts of shallow coastal bays (Figure 2,3).

For beluga whales, habitat selection is highly dependent on prey species. In subarctic and temperate regions, where salmon runs are abundant, they usually concentrate in river estuaries (Lowry et al., 2008; Solovyev et al., 2015). In Arctic seas, estuarine waters play a lesser role in beluga summer distribution. In these areas beluga whales are thought to follow the concentrations of their principal prey, Arctic cod (*Boreogadus saida*) (Richard et al., 2001; Hornby et al., 2017).

There are several populations of beluga whales in the Russian Far East. In the Okhotsk Sea, two populations are currently recognized: western Okhotsk Sea and north-eastern Okhotsk Sea (Meschersky et al., 2013). The western Okhotsk Sea belugas comprise four summer 'nursery' aggregations, usually recognized as different stocks. There is no data on stock differentiation of the north-eastern Okhotsk Sea beluga population. The only stock that summers in the coastal waters of the Russian Far East outside the Okhotsk Sea is the Anadyr stock. This stock spends summer months in the Anadyr River estuary (Litovka et al., 2002). In other areas of Chukotka, encounters of migratory belugas were only rarely registered during the ice-free season. Beluga whales mostly occur in the shallow inner parts of the bays and in river estuaries both in our surveys and in previous studies (Solovyev et al., 2015). Beluga whales demonstrate extreme site-fidelity (O'Corry-Crowe, 2009), which makes this species especially suitable for area-based conservation measures.

Okhotsk Sea bowhead whales mostly concentrate in the mainland bays, which is consistent with previous studies (Shpak & Paramonov, 2018). It would be useful to extend protection efforts for these two species, especially the endangered Okhotsk Sea bowhead whale population, by expanding the protected zone of the Shantar Islands National Park to include the mainland bays.

No MPA covers the distribution of gray whales off North-eastern Sakhalin Island. This feeding aggregation contains whales from both the recovered eastern and endangered western populations (Brüniche-Olsen et al., 2018). Intensive oil drilling can be a significant threat to the whales in this area, which is considered the main feeding ground for the few remaining western gray whales (Villegas-Amtmann et al., 2017). Designation of an MPA is long overdue for this area.

In Chukotka, gray whales are frequently found all along the coast from Chukchi Sea south to the Koryak coast, but bowhead whales in the summer are found almost exclusively in the Chukchi Sea. Neither of these populations is considered endangered: these gray whales are part of the recovered eastern population wintering in Baja California (Durban et al., 2015), and the bowhead whales belong to the recovering Bering-Chukchi-Beaufort Sea (BCB) population (Givens et al., 2013). The BCB population in early summer feeds mostly in the Beaufort Sea, but in late summer and autumn they migrate to the Chukchi Sea and form aggregations near Wrangel Island and off the northern Chukotka coast on their way south to the Bering Sea, where they spend the winter (Quakenbush et al., 2010; Citta et al., 2015; Citta et al., 2021). Despite these populations not being endangered, they are still listed in the Russian Red Book under category 5 ('recovered or recovering'). The high sighting rates of these species, as well as the humpback whales in coastal Chukotka waters, suggest that these waters represent an important summer feeding area. The waters around Wrangel Island are protected as part of the Wrangel Island Nature Reserve, and some areas along the Chukotka mainland coast belong to Beringia National Park. However, most of the protected waters include only the inland bays where whales rarely or never occur (the notable exception is Senyavin Strait area where large aggregations of gray and humpback whales are found). The expansion of the terrestrial clusters of Beringia National Park into adjacent coastal waters could help to protect important habitat for cetaceans in Chukotka.

In contrast to beluga, bowhead and gray whales, Baird's beaked whales and sperm whales were normally found close to the shelf slope at substantial depths, without any demonstrated preference for nearshore closeness. These species feed on deep-water squid and demersal fish and normally occur in deep waters near steep slopes and underwater trenches (MacLeod, 2018; Whitehead, 2018). The highest sighting rates of these species were found in the waters of the Commander Reserve as well as around the Kuril Islands and off eastern Kamchatka.

Killer whales also showed more consistency in association with the shelf slope than with the nearshore. Two forms, or ecotypes, of killer whales occur in Russian waters: fish-eating R-type and mammal-eating T-type (traditionally also called 'resident' and 'transient' respectively) (Filatova et al., 2015). R-type killer whales are common in areas where the shelf slope is situated close to shore, namely off eastern Kamchatka, the Kuril and Commander Islands; the T-type killer whales, which have a protection status in the Russian Red Book, are more common in the wide shallows of the western and northern Okhotsk Sea, western Kamchatka and in Chukotka (Filatova et al., 2019b). In many of the sighting records, however, it was impossible to determine the ecotype, because no photos were taken or they were of insufficient quality. Therefore, the distribution of the killer whale in our study is shown as the combined habitat preferences of both ecotypes.

The rorquals and porpoises showed a wide range of habitat preferences, occurring both in coastal and pelagic waters, at different depths and distances to the shelf slope. Harbour porpoise was absent from the pelagic Pacific and Bering Sea, but relatively common in the pelagic Okhotsk Sea. Among rorquals, the fin whale and common minke whale had wide and relatively uniform distribution, occurring in most zones, while humpback whale distribution was more clustered. This species was rarely recorded in the Okhotsk Sea, but formed dense aggregations off eastern Kamchatka, the Commander Islands and Chukotka. It is unclear why this species is rare in the Okhotsk Sea despite the abundant feeding opportunities utilized by other rorquals. The humpback whale is beginning to recover from the commercial whaling in the 20th century (Barlow et al., 2011) and appears to be gradually recolonizing its former range in Russian waters as well (Titova et al., 2020).

The humpback whale is listed in the Russian Red Book under category 5 ('recovered or recovering'), and fin whale – under category 4 ('undetermined status'). The clustered structure of humpback whale distribution makes the species a good candidate for area-based protection measures, more so than the fin whale. One of the largest summering aggregations of the humpback whale is already protected within the marine zone of the Commander Reserve, while the summering aggregation in Senyavin Strait, eastern Chukotka, is protected within the marine zone of Beringia National Park. In both areas, commercial fishing and any industrial activities are prohibited. However, the large aggregation in Karaginsky Gulf has no protection and is subject to threats from the intensive fisheries in this area (for example, a young humpback whale died due to entanglement in fishing nets in summer 2018, https://ria.ru/20180702/1523745000.html [in Russian]). Humpback whales feeding near the northern Chukotka coast are currently less impacted by anthropogenic activity, but the planned intensification of traffic on the Northern Sea Route could threaten this species in the future. Another potential threat is the expansion of long-line and crab pot fisheries northward and walleye pollock fisheries into the Chukchi Sea.

North Pacific right whales in the waters of the Russian Far East are presumed to belong to a single western North Pacific population numbering fewer than 1,000 individuals (Kenney, 2018). The species is listed as 'Endangered' (category 1) in the Russian Red Book. One of the main threats for right whales is entanglement in fishing gear due to its specific 'skimming' feeding technique (Knowlton, 2012). An MPA and/or local restrictions on fisheries (such as a full ban of gillnets, seasonal restriction of long-line and crab fisheries and immediate implementation of the government marine mammal bycatch programme) in the Northern Kuril Islands and South-eastern Kamchatka would help to ensure the survival of this species. Besides the Northern Kuril Islands, Ovsyanikova et al. (2015) reported several encounters near the Commander Islands, but in our study no sightings were registered in this area. In 2018, a North Pacific right whale was encountered in eastern Chukotka, but this individual is thought to belong to the eastern Pacific population (Filatova et al., 2019a). Critical habitat for North Pacific right whales has been identified with protection measures under the U.S. Endangered Species Act in the Gulf of Alaska and Bering Sea but, in Russian waters, currently only the Commander Reserve could offer protection for this endangered species.

Suggestions for future MPA development, management and other protection measures

Cetaceans are indicators of high productivity and biodiversity, as well as of the health of the ocean ecosystem, and protecting areas where they concentrate can serve as a starting point for ecosystem-based management (Hoyt, 2011). As of 2021, IMMAs have been identified in 35% of the world ocean, mostly in the southern hemisphere. In the future, the IUCN Marine Mammal Protected Areas Task Force is planning to convene scientific workshops to identify IMMAs in the western North Pacific and the Arctic, including the Russian Far East, but conservation action, including the identification of MPAs, should not wait for this. Compared to most of the Arctic seas and marine waters of European Russia, the waters of the Russian Far East are especially rich in cetaceans, including rare and endangered species; therefore, the Russian Far East should be considered a priority region for cetacean conservation action in Russia.

Lack of specific MPAs for protection of cetaceans hinders their conservation in Russian Far East seas. Our study highlights the specific zones important for various cetacean species that can be used as potential areas for future IMMAs, EBSAs, and KBAs as a route toward scientific agreement leading to MPAs and other spatial habitat measures. Specifically, the important first step could be the extension of the marine protected zone of some coastal reserves and national parks, such as the Kronotsky Reserve, Shantar Islands National Park and Beringia National Park (Figure 6, areas 1, 4, 7, 10). The coastal area near the Kronotsky Reserve (4 and 7 on Figure 6) is an important feeding area for humpback whales, gray whales, fin whales and Baird's beaked whales, and the extended part of area 4 off southern Kamchatka and Northern Kuril Islands is a hotspot for endangered North Pacific right whales. Coastal bays located close to Shantar Islands National Park (1 on Figure 6) represent summer critical habitat for beluga whales and endangered Okhotsk Sea population of bowhead whales. In this study, only three out of 95 sightings of the Okhotsk Sea bowhead whale population occurred within the marine protected zone of the Shantar Islands National Park; all other sightings occurred in unprotected mainland bays. Beluga whales also concentrated mostly in the mainland bays. The waters of eastern and northern Chukotka adjacent to Beringia National Park (10 on Figure 6) are important feeding areas and migratory corridors for humpback whales, gray whales, bowhead whales, and mammal-eating killer whales.

Additional areas important for cetaceans that should be assigned marine protected area status are: the gray whale feeding area off North-eastern Sakhalin (2 on Figure 6): the mouth of Gizhiga river and the adjacent part of Gizhiginsky Gulf, which is an important feeding area for beluga whales and an area of sightings of gray whales and Okhotsk Sea bowhead whales (3 on Figure 6); the areas around Kekurny and Shipunsky Capes (5 and 6 on Figure 6) which are important for humpback whales and killer whales; Karaginsky Gulf (8 on Figure 6) which is one of the largest humpback whale feeding grounds in Russia, hosting specifically the whales from the threatened Asian subpopulation, and also important for fin whales and killer whales; and Kresta Bay (9 on Figure 6) frequented by humpback whales and gray whales.

To identify IMMAs and cetacean MPAs in Russian Far East waters, the data presented in this paper can serve as a starting point drawing on the recent fieldwork in the region. Substantial additional information on cetacean distribution is available in various published and unpublished sources, and an analysis of these data would assist the development of conservation action plans for all cetaceans in Russian waters.

Bycatch is the most serious global threat for cetaceans (Young & Iudicello, 2007). An important step in cetacean protection in Russia should be the immediate implementation of the Federal marine mammal bycatch monitoring programme. The Russian Far East is data deficient in terms of the overall numbers, locations and specific fisheries implicated in marine mammal bycatch incidents, and this programme could bring valuable data on fisheries-related marine mammal mortality at relatively low cost to help identify problematic areas, including areas that need greater protection or enforcement. The bycatch monitoring programme can thus contribute to the formulation of an action plan with entanglement and bycatch reduction measures. These measures should include gear changes or zoning within MPAs to eliminate fisheries that result in bycatch.

Russia is a party to the Convention on Biological Diversity yet, by 2020, had failed to fulfill Aichi Target 11 to protect 10% of its national (EEZ) waters. To date, MPAs comprise only about 3% of Russia's EEZ (WWF, 2020). Globally, nearly 8% of national waters has been proposed or is already established as MPAs, although only 2.7% is fully protected (https://mpatlas.org). In 2020-21, following the lead of IUCN and other international NGOs, the '30 by 30' initiative was launched, agreed currently by more than 100 countries, and counting, with the objective to protect at least 30% of the global ocean by 2030. We suggest that, in the future, cetacean distribution established through the present study and other available sources, as well as EBSAs and the future IMMA process, be considered as an integral aspect of the assessment of new or expanded MPAs, and be used in other spatial habitat conservation measures such as marine spatial planning in Russian EEZ waters and the adjacent high seas.

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Table 1. Protection status, number of sightings and number of registered individuals of various species over the study period.

Common name	Latin name	Russian Red Book category	IUCN Red List category	Number of sightings	Number of individuals
Dall's porpoise	*Phocoenoides dalli*	-	LC	1287	5693
Harbour porpoise	*Phocoena phocoena*	4	LC	116	253
Beluga whale	*Delphinapterus leucas*	-	LC	184	2886
Sperm whale	*Physeter macrocephalus*	-	VU	338	454
Baird's beaked whale	*Berardius bairdii*	-	DD	37	285
Cuvier's beaked whale	*Ziphius cavirostris*	2	LC	4	13
Killer whale	*Orcinus orca*	Mammal-eating population - 4	DD	437	3222
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	-	LC	1	4
Common bottlenose dolphin	*Tursiops truncatus*	-	LC	2	4
Humpback whale	*Megaptera novaeangliae*	5	LC	541	2409
Fin whale	*Balaenoptera physalus*	4	VU	107	223
Common minke whale	*Balaenoptera acutorostrata*	-	LC	318	401
Blue whale	*Balaenoptera musculus*	1	EN	2	4
Gray whale	*Eschrichtius robustus*	Eastern -5 Western - 1	Eastern – LC, Western – EN	423	1937
Bowhead whale	*Balaena mysticetus*	Bering-Chukchi-Beaufort – 5; Okhotsk Sea – 1	Bering-Chukchi-Beaufort – LC, Okhotsk Sea – EN	108	170
North Pacific right whale	*Eubalaena japonica*	1	EN	5	5

Figure captions

Figure 1. Effort tracks (red lines) of the surveys used for this study, and the division of the study area into 33 zones. Zone names are shown in black text, and land labels are shown in gray italic text.

Figure 2. Distribution and encounter rates of odontocetes in various zones of the Russian Far East seas. Blue dots represent sighting records.

Figure 3. Distribution and encounter rates of mysticetes in various zones of the Russian Far East seas. Blue dots represent sighting records.

Figure 4. Sighting rates for all species combined (left) and for the protected species combined (right) in the various zones of Russian Far East seas overlapping with existing federal marine protected areas (MPAs) and Convention on Biological Diversity (CBD) ecologically or biologically significant areas (EBSAs).

Figure 5. Environmental correlates of cetacean species presence: depth (top), distance to shore (middle) and distance to shelf slope (bottom). Species abbreviations: BHW – bowhead whale, BLGW – beluga whale, GW – gray whale, MW – common minke whale, HP – harbour porpoise, RW – North Pacific right whale, KW – killer whale, BBW – Baird's beaked whale, SW – sperm whale, DP – Dall's porpoise, HW – humpback whale, FW – fin whale.

Figure 6. Suggested Marine Protected Areas for cetaceans in the Russian Far East seas.

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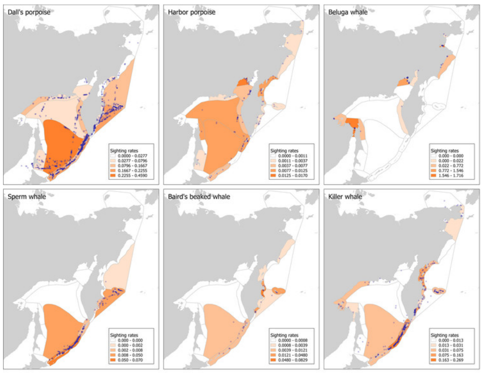

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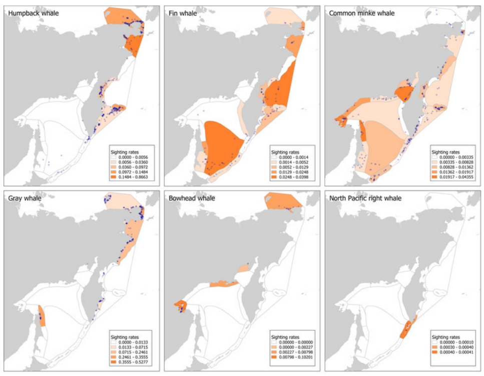

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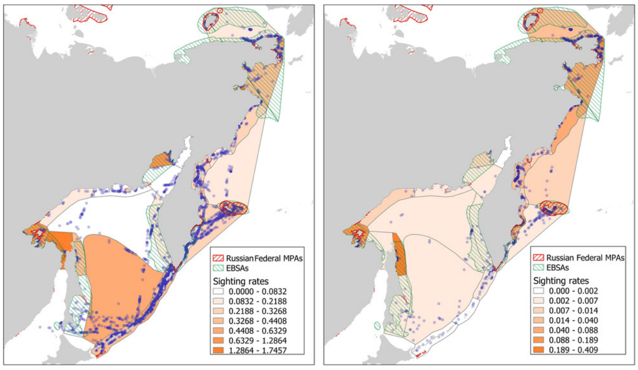

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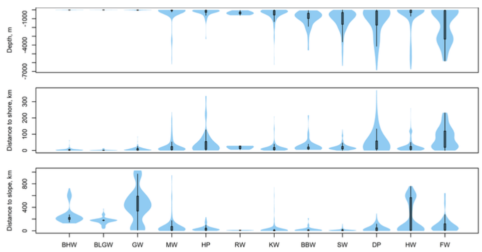

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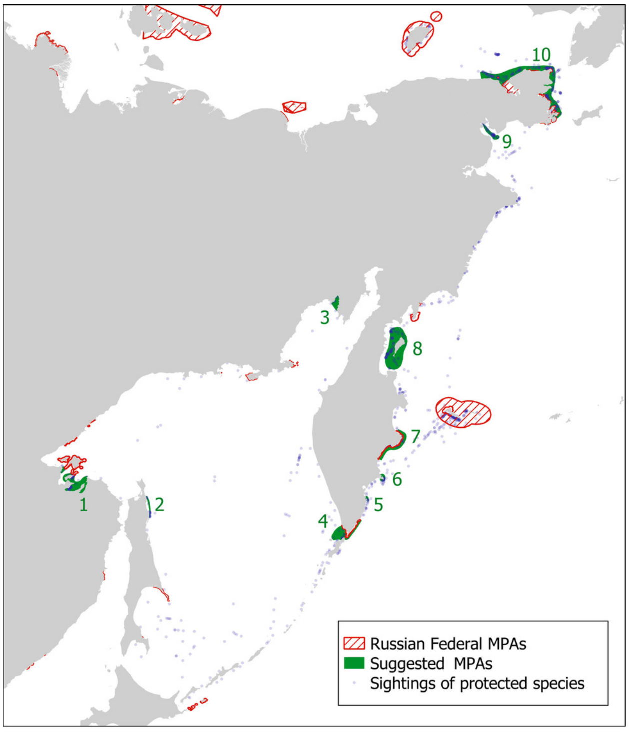

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