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The Onshore Period in the Annual Life Cycle of Ringed Seals (*Pusa hispida*) at the Largest Haulout Site of the Species in the North Pacific

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Abstract

The largest multispecies haulout of true seals at Sakhalin Island (Sea of Okhotsk) is located in the mouth of Piltun Bay. It is comprised of ringed (*Pusa hispida*), spotted (*Phoca largha*), and bearded (*Erignathus barbatus*) seals and can include as many as 2,500 animals at one time. Spotted seals numerically dominate the haulout, but ringed seals can also make a notable contribution into the structure and general dynamics of the entire pinniped aggregation during some periods of the year. The haulout is used by ringed seals throughout the ice-free period from June through October. The pattern of haulout occupancy by seal species was studied from 2014 to 2017. Seasonal variations in the number of ringed seals followed a general pattern: annually, the seasonal maximum in number of seals were recorded from the last 10 days of August to the first 10 days of October. This is the period when numerous species of small- and medium-sized fish become abundant in the mouth of Piltun Bay and in the adjacent waters of the Sea of Okhotsk. These fish species constitute the major portion of ringed seal diet throughout its range. The number of ringed seals in the study area has remained stable over the past two decades.

Key Words: ringed seal, *Pusa hispida*, onshore period, haulout, seal aggregation, Sakhalin Island, Piltun Bay

Introduction

The ringed seal (*Pusa hispida*; Schreber, 1775) has one of the largest populations of the marine mammal fauna in the Arctic. According to the latest information, the current population of ringed seals is estimated at no less than 2.5 million (Kelly et al., 2010). The distribution range of this species extends to the highest latitudes (up to the North Pole) of the Northern Hemisphere and far south of the Arctic Ocean boundaries. In the Pacific sector of the Arctic, ringed seals inhabit the Bering Sea, the Sea of Okhotsk, and the Sea of Japan, where they are found in relatively limited numbers in its northernmost area—Tatar Strait (Ognev, 1935; Geptner et al., 1976; Kelly et al., 2010; Belikov et al., 2017).

This species comprises five subspecies of which two live in the northern Pacific Ocean. *P. h. hispida*, the most widely distributed subspecies in the Arctic, inhabits the Bering Sea, while *P. h. ochotensis* is found in the Sea of Okhotsk and in the Tatar Strait (Sea of Japan) (Rice, 1998). Being different morphologically, *P. h. ochotensis* also has a number of biologically and ecologically distinct traits. In particular, the duration of lactation in *P. h. ochotensis* is almost twice as long as that known for the entire species (6 wks vs approximately 3 wks); this subspecies is also characterized by a more rapid growth rate and earlier maturation (Fedoseev, 1975).

Ringed seals show pronounced pagophily—a significant part of their annual life cycle is associated with zones of fast or pack ice. During the ice-free period, ringed seals are distributed mostly in open waters, often near coasts. In the Pacific sector of the Arctic and eastern Bering Sea during the ice-free season, ringed seals live in pelagic areas and typically do not haul out on shore (McLaren, 1958; Kelly et al., 2010). No reliable reports about ringed seals on the Chukchi Peninsula coast and the Asian coast of the Bering Sea are available to date (Belikov et al., 2017). However, it should be noted that very few observations have been conducted in this region.

In some areas of the Sea of Okhotsk, individuals or small groups of ringed seals may sometimes form haulouts on shore in the summer and fall. Nevertheless, very few such places are known, and all the publications on this issue date back to the early 20th century. During the summer and fall seasons in the Sea of Okhotsk, such

haulouts were formerly found on the islands of the Shantar Archipelago, western Sea of Okhotsk (Ognev, 1935; Nikulin, 1937; Naumov, 1941); on the western coast of the Kamchatka Peninsula, northeastern Sea of Okhotsk (Lun, 1936); and in the Shelikhov Bay, northeastern Sea of Okhotsk (Freiman, 1935; Pikharev, 1940). All of the above-mentioned authors expressed a similar opinion: ringed seals in the Sea of Okhotsk enter the land rarely and, even when they do, they are hauling out in very limited numbers: individually or in small groups. At the same time, knowledge of the coastal (hauling-out) period in ringed seals' annual life cycle has long been limited to fragmentary information. Moreover, some important details remain unknown such as the abundance of ringed seals at haulouts, the period of the year when animals occupy such places, and the dynamics of on-shore aggregations of seals during the ice-free period.

Coastal waters off eastern Sakhalin Island (Sea of Okhotsk, Russia) are one of the main feeding grounds used by true seals in the Sea of Okhotsk during the ice-free period. Three decades ago, the total number of true seals (almost exclusively spotted seals [*Phoca largha*; Pallas, 1811]) that hauled out on the eastern coast of the island in summer and fall was estimated at approximately 10,000 animals (Kosygin et al., 1986). However, there were no reports of ringed seals hauling out on Sakhalin Island at that time.

In the recent past, the ringed seal was the most abundant species among ice-bound seals in the Sea of Okhotsk. One of its densest reproductive aggregations was associated with the shelf of eastern Sakhalin Island in spring (Fedoseev, 2000). Information on the use of the coast of Sakhalin Island by ringed seals during its ice-free period was unavailable until the late 20th century when a multispecies haulout of true seals in the mouth of Piltun Bay was first described (Trukhin, 2000). The haulout was shared by three species: (1) the bearded seal (*Erignathus barbatus*; Erxleben, 1777), which is the least abundant species in the local pinniped aggregation (Trukhin & Blokhin, 2003), (2) the ringed seal, and (3) the spotted seal. The latter was the most numerous of the three. The numbers of these three species in the local aggregation varied; however, it can be seen as one bearded seal to ten ringed seals to 100 spotted seals. To date, this aggregation is the largest haulout of true seals in Sakhalin Island (Trukhin & Permyakov, 2019).

The goal of this study was to elucidate the pattern of occupancy of the haulout in the mouth of Piltun Bay by ringed seals and to assess the seasonal and annual variations in the number of individuals of this species at the haulout.

Methods

Study Area

The study was conducted from 2014 to 2017 in the mouth of Piltun Bay on the northeastern coast of Sakhalin Island, Russia (Figure 1). Piltun Bay is a lagoon-type body of water. This is the largest bay on the eastern coast of Sakhalin Island. It extends for 71 km from north to south, with a maximum width of 12 km and a total water surface area of 435 km^2. Piltun Bay is classified as a semi-enclosed lagoon given its geomorphological characteristics and degree of its isolation from the sea, which have an effect on the dynamic processes within the bay (Brovko, 1990). The bay is separated from the Sea of Okhotsk by two long, narrow sandy spits and is connected to the sea via a relatively narrow (300 m wide) strait, referred to as the "mouth," in the southern part. Due to tidal processes, this strait provides an active water exchange between the sea and the bay. Large shallow areas of sandy/silty bottom in the mouth of the bay are exposed during low tide, forming extensive sandbars. The irregular semidiurnal tides in Piltun Bay, which reach maximum amplitude of 2.1 m, cause strong currents in the mouth (Putov & Shevchenko, 1998).

The bay is predominantly shallow, with depths no greater than 1 to 2 m, thus facilitating deep warming of the water in the summer months. Due to a regular inflow of water masses from the Sea of Okhotsk, the water of the bay is characterized by abrupt variations in average temperature and salinity, especially in the mouth of the bay (Kafanov et al., 2003). Several rivers flow into the bay—the Sabo, Kydylan'y, Mukhto, Paromay, Piltun, and others—significantly freshening the water in the lagoon. River discharge is one of the factors that determines the main hydrochemical parameters in the bay such as water salinity, temperature, and gas saturation.

Piltun Bay is a unique ecosystem partially isolated from the adjacent sea waters. This ecosystem is enriched in nutrients due to significant amounts of organic matter discharged into the bay via the rivers. This circumstance, along with significant warming of the shallow water during the summer season, causes intensive proliferation of autotrophs that constitute the initial links of food chains (Tabunkov et al., 1988). This eventually results in the relatively high levels of bioproduction in the mouth of the bay, which provides a rich feeding ground for three species of true seals in summer and fall (Trukhin & Permyakov, 2019).

Data Collection

Data collection was conducted each summer-fall (field) season from 2014 to 2017. The dataset was

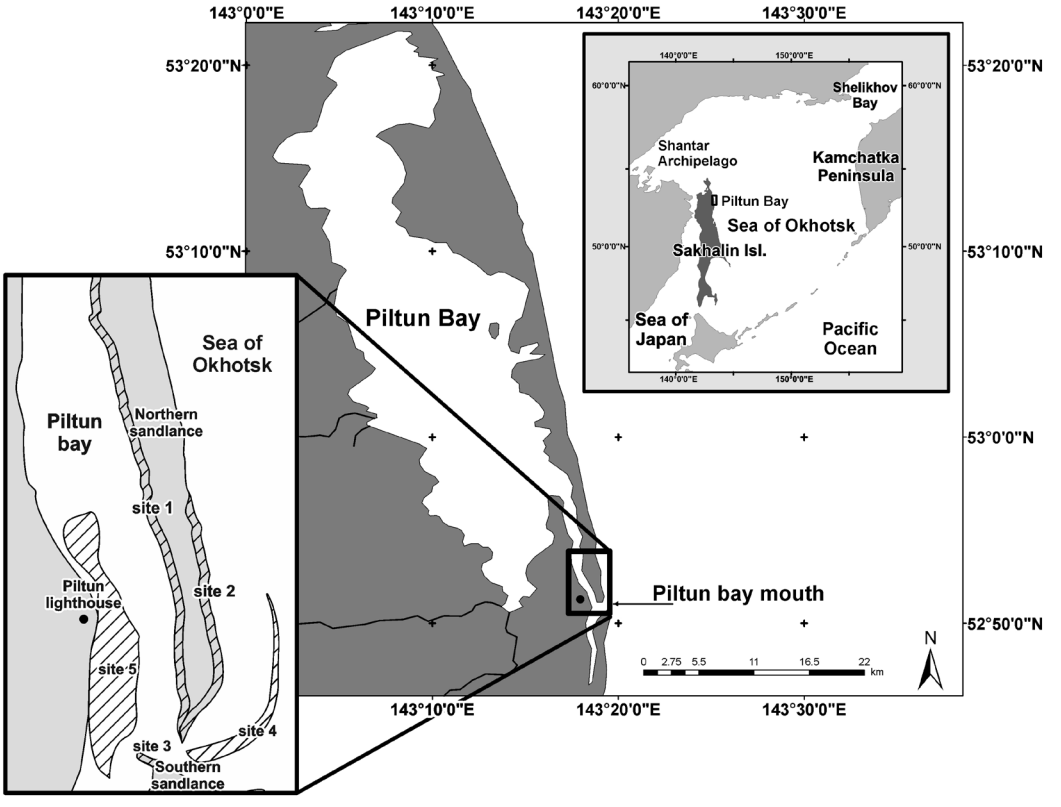

Figure 1. Study area on Sakhalin Island and the spatial structure of the pinniped haulout in the mouth of Piltun Bay (sites 1 through 5)

supplemented by data collected by us in 1999 at the same haulout following the same research protocol. Work began after the water in the nearshore zone of the mouth became free of ice (usually from late May to early June) and was terminated in late October when the first fast ice appeared near the shore, preventing seals from hauling out on land. The pinniped studies in the Piltun Bay had several objectives, including systematic counts of the number of animals at the haulout.

The main methodological approach for collecting data was visual observations of the haulout and animals on it. The lighthouse tower (52° 51' 0" N, 143° 18' 6" E) situated opposite the mouth of the bay was used as an observation point (OP) for the study. Due to the lowland terrain in the area, the position on the top of the lighthouse (with an elevation of approximately 40 m) provided a perfect view. It is important to note that the haulouts consist of distinct sites that are spread over a big territory (Figure 1). Nevertheless, from the OP, researchers were able to observe the entire area of the mouth, including both the internal water area of the bay and the adjacent sea waters. The observation deck of the lighthouse was shielded by a glass screen from all sides that protected observers from weather conditions and accidents.

Observations were conducted continuously during daylight hours. Three observers were consecutively rotated through the day so that the OP was always manned by at least one observer; each shift lasted from 2 to 4 h. Seals were counted once in a 2-h period. The number of counts during the day depended on the length of daylight hours and varied from six to nine counts. We delineated five sites at the haulout territory (Figure 1). The sites were separated from each other by natural barriers (water flows, wide open areas of a flat sandy ground). Seals were counted at each site separately. Each count consisted of three recounts; the arithmetic mean was rounded up to the nearest integer and taken for assessment of seals' immediate number. The accounted abundance of true seals was subdivided by species of true seals.

Nikon optical instruments (8 × 40 field binoculars and a telescope with a magnification power of 20-60×) were used for observations. Before each count, the haulout sites were photographed using a

Nikon D610 camera equipped with a Tamron 150-600 mm lens. If during the counting the number of hauling-out seals underwent sharp changes (e.g., due to mass escapes of animals into the water), the analysis of photographs allowed for a precise estimation of the number of animals and identification of the species present at the site.

Statistical Analysis

For data processing, daily maxima of the total number of seals (all three species) were recorded on each observation day. The data on seasonal dynamics in the seal aggregation were smoothed by the 5-d moving average procedure (Hyndman, 2011). The 95% confidence intervals (CIs) for assessment of a moving average were calculated using the standard procedure (Zar, 2010). The data arrays did not fit a normal distribution (Shapiro-Wilk test, $p < 0.05$). For this reason, we used the median as a central tendency for assessment of a seasonal abundance of seals. The 95% CIs for assessments of medians were calculated using the percentile bootstrap procedure (Bootstrap Confidence Interval [BCI]: $R = 1{,}000$; Efron & Tibshirani, 1993). Moving blocks bootstrap (MBB; block length = 5 d; $R = 1{,}000$) was used to test for between-group differences. The test statistic Θ was constructed as a gap between seasonal medians of maximum daily abundances. The data for the 2014-2017 seasons were pooled ($\Theta = Me_{1999}–Me_{2014\text{-}2017}$). The difference between groups was significant at $p < 0.05$ when 95% BCI for bootstrapped Θ^* did not contain a zero.

Statistical data processing was performed using the *GraphPad Prism* and *Microsoft Excel* package with the 'Real Statistics' plug-in (Zaiontz, 2019).

Results

For the entire period of field observations in 2014 to 2017, a total of 2,742 seal counts (from 487 to 801 counts per season) were performed during 492 working days (from 114 to 128 d per season). Additionally, 619 seal counts were performed during 136 working days in 1999 (Table 1). The data have demonstrated a common pattern in seasonal dynamics of a number of ringed seals as well as for the whole aggregation of true seals.

In 1999 and 2014 to 2017, the total number of seals in aggregation tended to reach its highest value from the last 10 d of August to the first 10 d of October of each year. Also, that period was marked by registration of a seasonal peak of ringed seals' abundance. The highest counts of ringed seals occurred in late August and September (Table 2).

Table 1. Efforts on observations of true seals at the haulout site in the mouth of Piltun Bay

	Season					
	1999	2014	2015	2016	2017	Total
Beginning of observations date	20 May	3 July	18 June	7 June	6 June	
End of observations date	12 Nov.	30 Oct.	26 Oct.	25 Oct.	26 Oct.	
Number of observation days	136	114	124	128	126	628
Number of counts	619	487	728	726	801	3,361

Table 2. Intraseasonal chronology of true seals forming a haulout in the mouth of Piltun Bay

	Season				
	1999	2014	2015	2016	2017
Date of first registration of spotted seal	2 July	Not documented	19 June	7 June	8 June
Date of first registration of bearded seal	8 July	8 July	21 June	21 June	16 June
Date of first registration of ringed seal	Not documented	8 July	19 June	21 June	11 June
Maximum abundance of ringed seals, individuals	612	561	683	682	573
Date of registration of maximum abundance of ringed seals	11 Oct.	17 Sept.	26 Sept.	25 Sept.	24 Aug.

The number of all three species at the Piltun Bay haulout changed significantly between 1999 and 2014-2017 (MBB: n_1999 = 136 counts, n_2014-2017 = 492 counts; BCI: Me_{1999}–$Me_{2014\text{-}2017}$ = 154 to 403 individuals). In 1999, the median count of all animals was estimated at 172 individuals (Trukhin & Permyakov, 2019); it was assessed at 502 to 650 in 2014-2017 (Figure 2). The total number of ringed seals did not change significantly from 1999 to 2014-2017 (MBB: n_1999 = 41 counts, n_2014-2017 = 422 counts; BCI: Me_{1999}–$Me_{2014\text{-}2017}$ = 0 to 18 individuals). In 1999 and 2014-2017, the median number of ringed seals in both time periods ranged between 22.5 and 62 individuals (Figure 2).

The haulout of pinnipeds in the mouth of Piltun Bay has a complex spatial structure, consisting of five locations (sites 1 through 5) geographically isolated by natural borders (Figure 1). Site 1—the shore of the northern spit facing the lagoon—was a location regularly occupied by ringed seals during the season. At the other sites, ringed seals occurred very rarely and in small numbers. In the local pinniped aggregation, ringed seals seemed to avoid a proximity to spotted seals. If both species were occupying the same site, they were almost always spatially separated. In contrast, ringed seals often hauled out next to bearded seals. At these joint sites, animals of both species were frequently observed lying close to each other.

Discussion

Our research reports the first case of season-long observations of true seals hauling out on the coast of the Sea of Okhotsk during the ice-free period of their annual life cycle. Each year, pinnipeds begin to occupy the shores of Piltun Bay after its internal surface and the adjacent marine coastal zone clears of ice and animals obtain access to land. In some years, the animals begin to haul out as soon as the ice disappears; while in other years, the haulout forms later. In 1999, as well as during the 2014-2017 study period, the first species to arrive at the site was the spotted seal. The ringed and bearded seals typically appear at the haulout 3 wks behind the spotted seals (Table 2; Figure 3).

The overall aggregation of seals (formed mostly of spotted seals) begins to use the haulout daily at this time, with the number of animals on the shore increasing steadily from day to day. When ringed seals appear at the haulout during the early phase of the ice-free period (Figure 3), only individual animals can be observed or they may even be missing completely from the haulout for several successive days.

The arrival of the first ringed seals in nearshore waters and their first regular (short-term) haulouts in June coincide in time with spawning migrations of herring (*Clupea pallasii*; Valenciennes, 1847),

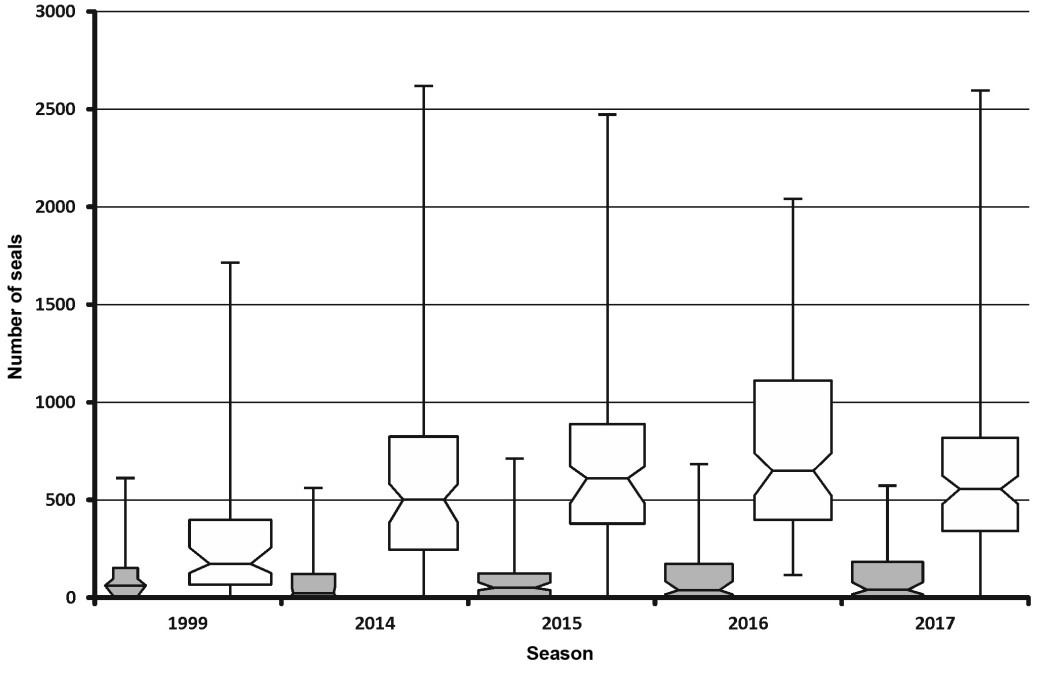

Figure 2. Notched box plot for the median of the number of pinnipeds at the Piltun Bay haulout site. Grey box plot for ringed seal (*Pusa hispida*); and white box plot for the entire pinniped aggregation (according to Trukhin & Permyakov, 2019).

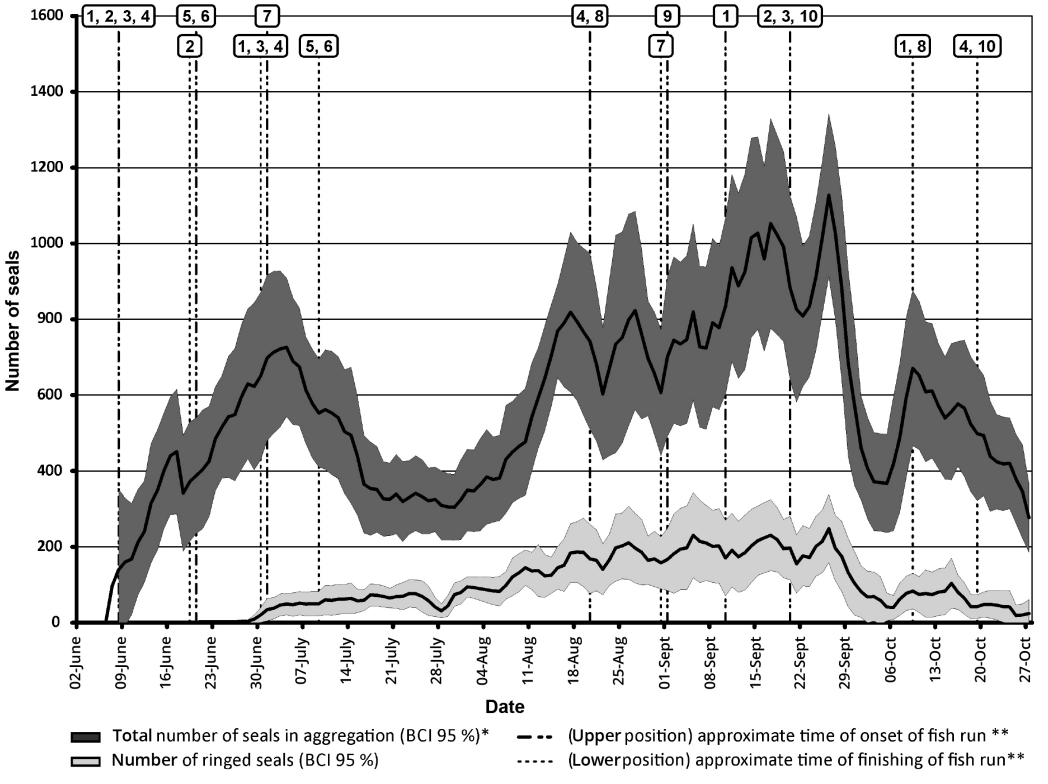

Figure 3. Seasonal variations in the number of ringed seals and of the entire pinniped aggregation at the haulout in Piltun Bay, 2014 to 2017 (5-d moving average; BCI 95%). * = abundance of entire pinniped aggregation by Trukhin & Permyakov (2019); and ** = feeding and feeding/spawning fish migrants running through the area: (1) Pacific herring, (2) pond smelt, (3) big-scaled redfin, (4) whitespotted char, (5) capelin, (6) three-spined stickleback, (7) pink salmon, (8) chum salmon, (9) coho salmon, and (10) rainbow smelt (see Gritsenko, 2002; Zemnukhov, 2008; Trukhin & Permyakov, unpub. data, 2014-2017).

pond smelt (*Hypomesus olidus*; Pallas, 1814), big-scaled redfin (*Tribolodon hakonensis*; Sauvage, 1883), capelin (*Mallotus villosus*; Müller, 1776), three-spined stickleback (*Gasterosteus aculeatus*; Linnaeus, 1758), and some other fish species in the bay mouth (Gritsenko, 2002; Zemnukhov, 2008; Trukhin & Permyakov, unpub. data, 2014-2017; Figure 3). These mostly marine fishes are usual food items in the diet of ringed seals in the northern Pacific Ocean and adjacent waters of the Arctic (Pikharev, 1946; Fedoseev, 1965; Bukhtiyarov, 1990; Kelly et al., 2010; Trukhin & Permyakov, unpub. data, 2014-2017; Boveng, 2016).

The presence of ringed seals at the site remains irregular until the middle of summer. Ringed seals begin to occupy the haulout regularly only by mid-July. Even then, the number of individuals on shore remains relatively low. The frequency of their attendance and the number of individuals on shore increases from summer to fall, reaching its peak in September. During this period, some fish species (e.g., smelt, herring; Figure 3) rise in abundance, improving the availability of nutrients for ringed seals. But even during this period, the number of animals fluctuates between days. In October, ringed seals haul out mainly in small numbers (Figure 3).

The high total number of pinnipeds at the site, the prolonged occupancy of the site (5 mo a year), and the multispecies structure of a local pinniped aggregation (three species) indicate that the main environmental conditions in the mouth of Piltun Bay are favorable for pinnipeds to reside throughout their annual feeding season. Most essential of these conditions are the availability of an ample food supply at the mouth and in adjacent waters and the topography of the haulout—sites are separated from the mainland by wide water flows; while on shore, resting seals have unobscured lines of sight in most directions that provide the animals with a high degree of safety from predators (Trukhin & Permyakov, 2019).

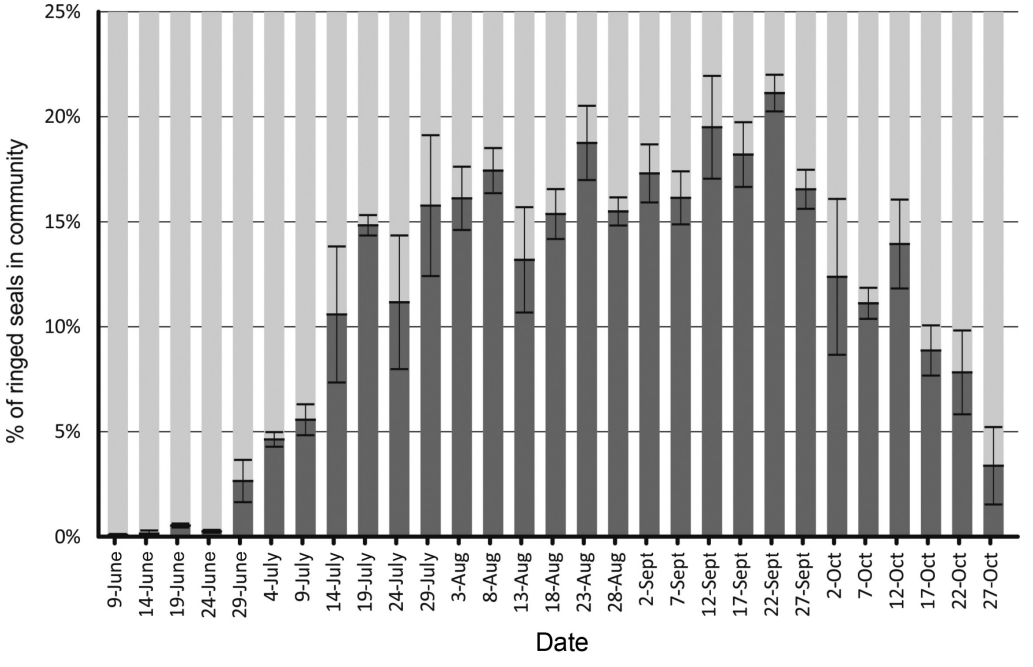

Figure 4. Proportion of ringed seals in the aggregation of true seals at the Piltun Bay haulout, 2014 to 2017. Bars are the value averaged over a 5-d period. "Whiskers" are the 95% CI for assessing the 5-d moving average.

Piltun Bay is home to a great variety of aquatic invertebrates that are known to constitute a substantial portion in the ringed seal diet in all parts of its range (Fedoseev, 1965; Lowry et al., 1980; Smith, 1987; Bukhtiyarov, 1990; Węsławski et al., 1994; Kelly et al., 2010; Belikov et al., 2017). Freshwater benthic species occupy one-third of its bottom, with the benthos biomass being extremely high in some areas (e.g., more than 6,000 g/m^2 in the strait; Tabunkov et al., 1988; Labai & Pecheneva, 2001; Kafanov et al., 2003). The fish fauna that dominate the diet of ringed seal in the Sea of Okhotsk during the fall season (Fedoseev, 1965) is also very abundant in the area. Only 10% of species, such as saffron cod (*Eleginus gracilis*; Tilesius, 1810) and flounders (Pleuronectidae; Cuvier, 1816), are permanent residents of the bay (Gritsenko, 2002; Zemnukhov, 2008). Most other species are feeding or feeding/spawning migrants. The migrating ichthyofauna in the area is represented by species like herring; pink (*Oncorhynchus gorbuscha*; Walbaum, 1792), chum (*Oncorhynchus keta*; Walbaum, 1792), and coho (*Oncorhynchus kisutch*; Walbaum, 1792) salmons; capelin (*Mallotus villosus*; Müller, 1776); and rainbow smelt (*Osmerus mordax*; Mitchill, 1814) (Gritsenko, 2002; Safronov et al., 2005; Zemnukhov, 2008; Trukhin & Permyakov, unpub. data, 2014-2017).

During the ice-free season, the total numbers of seals in the aggregation show several peaks associated with prespawning migrations of salmon and other anadromous fishes through the mouth of the bay (Figure 3). However, the ringed seal seems to prefer a medium-sized fish with a body length of up to 20 cm (mostly 5 to 10 cm) (Pikharev, 1946; Węsławski et al., 1994), so its numbers tend not to respond to all of the changes in abundance of salmonids and other species of big-sized fish. It is possible that the difference in size-related feeding specialization may explain the fact that the seasonal dynamics of some ringed seals do not entirely match the seasonal dynamics of the whole aggregation of seals. It is worth noting that because of the benthic foraging habits of bearded seals, these seals do not react to fish runs through the area.

In addition to the forage resources, there are other factors that can induce short-term daily and seasonal variations in the abundance of a local aggregation of true seals. Such factors are the weather and tidal conditions (Trukhin & Blokhin, 2003; Bradford & Weller, 2005), as well as anthropogenic disturbance (Permyakov & Trukhin, 2017).

In the local pinniped aggregation, the ringed seal is the second most abundant species. The number of ringed seals is considerably lower than

that of spotted seals, but it is also much larger than that of bearded seals (Trukhin & Blokhin, 2003). The lack of information from 2000 to 2013 does not allow a conclusion as to whether the number of ringed seals at the Piltun Bay haulout varied over the last 1.5 to 2 decades and, if so, by how much. The available data show that in the 2014 to 2017 study period, the number of ringed seals was relatively the same as it was in 1999 (Trukhin & Blokhin, 2003). This, together with the fact that the number of bearded seals at the haulout was always very small, makes it safe to conclude that the observed growth of abundance of the local pinniped aggregation occurred due to an increase in the number of the most abundant species, the spotted seal (Trukhin & Permyakov, 2019). The seasonal maxima of the number of ringed seals and of the whole pinniped aggregation approximately coincided. The proportion of ringed seals in the total number of seals at the haulout varied during the season. It was at minimum levels at the beginning (June and July) and at the end (October) of the haulout season (Figure 4).

Currently, the haulout of true seals in the mouth of Piltun Bay is the largest on Sakhalin Island (Trukhin & Permyakov, 2019). As stated earlier, Piltun Bay is probably not the only ringed seal haulout on the island (Trukhin, 2000), but there is no recent evidence in this regard. There are several lagoon-type bays on the eastern coast of Sakhalin Island that are morphologically similar to Piltun Bay, and the probability of ringed seals hauling out on their shores in the ice-free season is high. However, the eastern part of the Sakhalin Island coast is still poorly studied from this point of view. Future research might address potential seal populations in the most likely sites on the eastern Sakhalin coast where ringed seal haulouts can be found, including Chayvo, Nyisky, Nabilsky, and Lunsky Bays.

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