ISSN 1063-0740, Russian Journal of Marine Biology, 2022, Vol. 48, No. 2, pp. 101–107. © Pleiades Publishing, Ltd., 2022.
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ORIGINAL PAPERS

Changes in the Breeding Range of Spotted Seals, *Phoca largha* (Pallas, 1811) (Carnivora, Pinnipedia), in the Western Sea of Japan: Causes and Effects

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Received June 8, 2021; revised July 12, 2021; accepted September 17, 2021

Abstract—This article considers the dynamics in the spatial structure of breeding haulouts of spotted seals (*Phoca largha* Pallas, 1811) whose population inhabiting Peter the Great Bay, Sea of Japan, is currently increasing in size. Differences in age structure exist between the reproductive aggregations within the islands or groups (clusters) of islands in the Rimsky-Korsakov Archipelago. On the islands of the western and central clusters, females whelp earlier than on the eastern cluster islands, to which the breeding-population range has recently expanded. The colonization of new islands in the bay, where additional breeding sites have formed, occurs through the immigration of young females that have reached the fertile age. The stimulus to the seals' dispersal over Peter the Great Bay has been the threshold density achieved by the reproductive group at most of the traditional breeding sites, where its further increase was, thereby, restricted.

Keywords: spotted seal, *Phoca largha*, abundance, density, reproduction, age structure, reproductive aggregations

DOI: 10.1134/S1063074022020109

INTRODUCTION

Recent estimates of the size of the spotted seal (*Phoca largha* Pallas, 1811) population inhabiting Peter the Great Bay, western Sea of Japan, differ both in absolute values and in the pattern of variations. According to some data, the spotted-seal population in the bay has been in a state of unstable equilibrium at an "extremely low level", with its size remaining at 2500 individuals over the past 1.5–2 decades [8, 9]. According to other data, it is steadily growing, and its size has reached 3000 to 3200 individuals by the onset of the breeding season [11]. The annual pup production estimates reported by these authors also differ significantly: 400–450 and 750 pups, respectively.

In Peter the Great Bay, spotted seals breed on island shores, which simplifies the collection of information about their breeding biology: this provides an opportunity to obtain sufficiently precise data on the location of reproductive aggregations, the timing of breeding, pup production and its year-to-year variations, and also other parameters that allow the assessment of variations in breeding-related processes. With a stable population size, any serious intrapopulation changes in density and spatial rearrangements of the reproductive core are unlikely to be expected during the breeding season. However, the size of the spotted-seal reproductive group in Peter the Great Bay increases, new breeding sites appear, and, accordingly, the breeding range changes [22]. With these events, the reproductive aggregations of seals at their traditional breeding sites and at the recently colonized ones should manifest a certain age structure and the associated probable differences in the timing of pupping. In this report, I attempt to answer the questions as to how and what causes the breeding range of the population to expand now and what animals are involved in this process. Addressing these questions is the goal of the study.

MATERIALS AND METHODS

The material was the results of visual counts of spotted seal number on the islands of the Rimsky-Korsakov Archipelago, Peter the Great Bay, Sea of Japan (Fig. 1), which is the reproductive center of the local spotted-seal group. The counts were carried out in different breeding seasons from 2002 to 2017. Besides the pup counts for assessing the annual population increase, additional interim counts were also performed at the onset of the breeding season or at the stage of completion of the pupping season, when the number of pups at breeding sites is markedly lower than the maximum values. The purpose of such counts was to determine the timing of breeding in different reproductive aggregations.

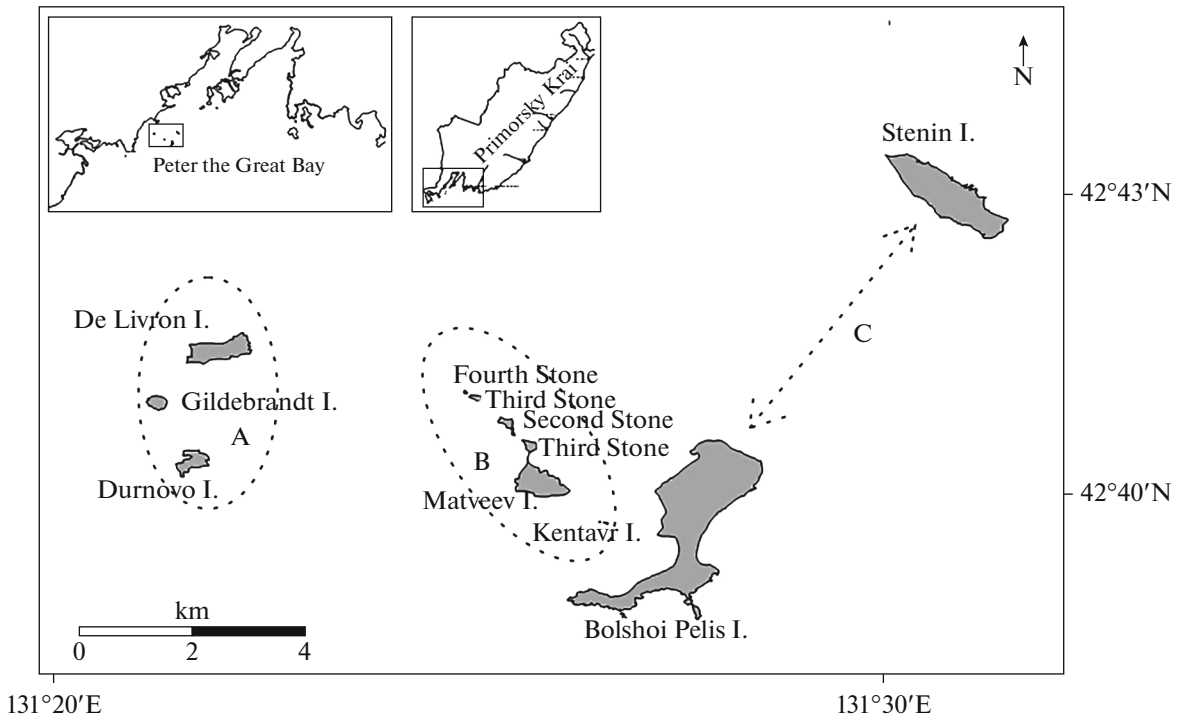

Fig. 1. Study area: Rimsky-Korsakov Archipelago, Peter the Great Bay, Sea of Japan. Clusters of islands are as follows: (A) western, (B) central, and (C) eastern.

All counts were carried out by a single technique with the participation of myself and their results served as a basis for the present study. Seals were counted from a motor boat by two or three observers without landing. The observers on the boat went around each island at a distance of 5–30 m from the shore, making stops for a more thorough examination of the shoreline if necessary. The condition of the pelage was visually evaluated in all the registered pups of the year. Depending on this feature, all recorded pups were divided into three age groups: *belyok* (white-coat, i.e., pups with the lanugo pelage and having no visible signs of postembryonic molt), *khokhlusha* (molting pups with differently sized areas devoid of the natal lanugo pelage that has been shed on the body, head, or limbs), and *serka* (adult-type pelage, i.e., completely molted pups without remnants of lanugo pelage). It should be noted that the juvenile molt lasting for 4–5 days usually coincides in time with the completion of lactation, which lasts for up to four weeks; by about five weeks of age, all pups of the year molt into the *serka* stage (pups with adult pelage) [10]. The approximate age of pups can be estimated on the basis of these time periods.

Spotted seals breed on all islands of the archipelago. To analyze the spatial and temporal characteristics of the reproductive process in the population, the islands were provisionally grouped into three clusters: western (De Livron, Gildebrandt, and Durnovo islands), central (Kentavr Island, Matveev Island, and first–fourth Stones), and eastern (Bolshoi Pelis and Stenin islands) (Fig. 1). This division was based on the geographical isolation of certain groups of islands (western and central clusters), and also on the time when the spotted-seal reproductive aggregations began colonizing the islands (eastern cluster).

RESULTS

Of all the counts carried out in 2002–2017, the present analysis includes only those that covered all the islands of the archipelago, with the number of pups counted differentially for all three age groups (white-coat, molting pups, and pups with adult pelage) (Table 1). To assess possible year-to-year variations in the timing of pupping between different clusters, the values obtained in similar time periods of 2002, 2016, and 2017 were compared on the basis of the condition of pup pelage (Fig. 2). In 2002, only six pups were recorded from the eastern cluster islands and, therefore, they were not included in the general analysis. The age structures of pups born in 2002 in the western and central clusters were almost identical (Fig. 2a), which indicates that the pupping processes in 2002 were synchronous in both clusters and coincided in time. After 15 years, the pattern has changed radically (Figs. 2b, 2c).

To identify the timing of pupping in different clusters during one breading season, three consecutive counts were performed in 2015 (Fig. 3). Within the first 2–3 weeks since the birth of the first pups (from

Table 1. Results of spotted seal pup counts in the Rimsky-Korsakov Archipelago

Island	Count dates					
	Feb. 24–25, 2002	Feb. 6–7, 2015	March 5–6, 2015	March 14–16, 2015	March 4 and 6, 2016	March 1, 2017
De Livron	35-8-5*	51-0-0	33-22-68	15-4-50	45-22-37	49-19-58
Gildebrandt	2-0-2	11-0-0	20-5-12	3-3-19	20-6-13	15-5-20
Durnovo	32-4-2	31-0-0	48-16-29	11-5-15	31-14-40	56-17-32
Matveev	25-0-1	17-0-0	64-14-30	26-14-44	76-30-22	84-12-18
First Stone	5-0-0	3-0-0	18-2-7	6-5-5	20-5-1	11-4-2
Second Stone	11-10-4	17-0-0	58-21-18	14-20-26	60-11-7	69-7-9
Third Stone	3-0-1	2-0-0	12-2-2	4-4-5	10-1-2	12-0-2
Fourth Stone	1-0-0	2-0-0	10-2-2	3-2-10	13-1-2	12-3-3
Kentavr	9-0-1	1-0-0	10-1-1	3-1-3	8-0-1	8-2-1
Bolshoi Pelis	3-3-0	4-0-0	89-13-6	32-16-41	139-18-13	123-21-11
Stenin	Not counted	1-0-0	22-4-6	7-2-27	14-7-3	44-5-5

* The first number is for *belyok* (white-coat pups); the second, for *khokhlusha* (molting pups); the third, for *serka* (pups with adult pelage).

the second ten-day period of January to February 6–7), females whelped most actively on the western cluster islands: 66.4% of the total number of pups registered all over the archipelago. It was noted that white-coat pups in the western cluster had, on average, larger body sizes than those at the haulout sites of the central cluster. In the eastern cluster, pupping had just begun in this time period (Fig. 3). A month later, when the culmination of pupping in the population had already passed, the pattern looked different: most pups were recorded from the haulout sites of the central and eastern clusters, and by the end of the breeding season (mid-March), the proportion of pups of the year increased to a maximum at the haulout sites of the eastern cluster. Due to the earlier completion of the pupping season on the western cluster islands, the pups of the year born here made the transition to independent living earlier, and their mass emigration from natal haulout sites began at a time when pupping and nursing were still observed on the islands of the central and eastern clusters.

The results of the counts carried out after the completion of mass pupping (the first week of March) during the seasons 2015–2017 showed that the numbers of pups on each of the islands of the western and central clusters remained quite stable and did not vary significantly, unlike those on Bolshoi Pelis and Stenin islands of the eastern cluster (Fig. 4).

DISCUSSION

The first pups are born at coastal haulout sites of the archipelago, as a rule, in the second ten days of January; by March, the period of active reproduction ends, although some females whelp until the end of this month. With such a long breeding season, newborn pups and pups of the year that have completed postembryonic molt and made the transition to independent living are simultaneously present at haulouts. The pelage condition in pups of the year allows estimation of their age and assessment of pupping dynamics on a particular island.

According to information on the age structure of pups obtained in 2002 and in 2016–2017, there are pronounced differences between the clusters of the archipelago (Fig. 2). Thus, the pup age structure in the central cluster did not change in general, whereas in the western cluster, the relative number of white-coat pups noticeably reduced with a simultaneous increase in the proportion of molted pups with adult pelage. This indicated the onset of the breeding of females in the western cluster on earlier dates. At the same time, on the eastern cluster islands, where spotted-seal reproduction had acquired a mass character by 2017, the pup-age structure was similar to that in the central cluster.

Based on the results of consecutive pup counts in 2015, performed during different stages of a single reproductive cycle, the chronology of spotted-seal pupping in the archipelago can be interpreted as follows. At the onset of the breeding season, pups are more frequently born at the haulout sites of the western cluster. Then the pupping process gradually spreads to sites located in the central cluster. Seal pups in the eastern cluster are born noticeably later than on the first two groups of islands (Fig. 3). The end of the reproduction process in the eastern cluster is also shifted by a corresponding time delay. It is evident that such spatial-temporal dynamics of pupping is characteristic of the current period of existence of the spotted-seal population in Peter the Great Bay, and it can

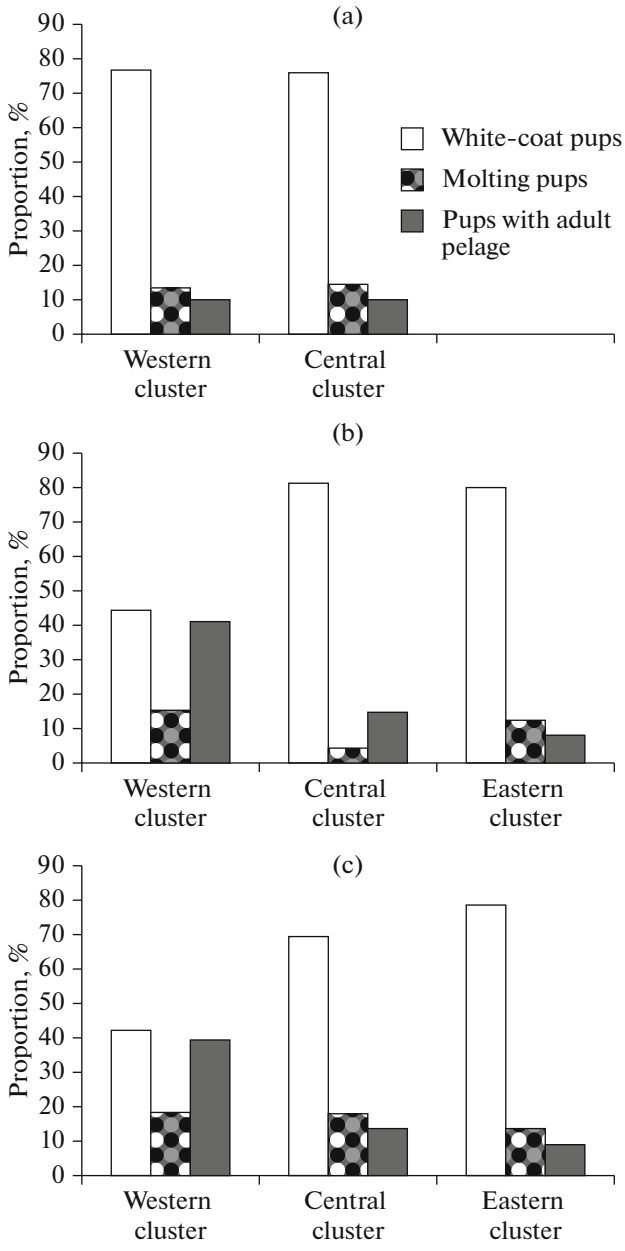

Fig. 2. Changes in the age structure of pups of the year (in % of the total number) that occurred in the Rimsky-Korsakov Archipelago from 2002 to 2017: (a) February 24–25, 2002; (b) March 4 and 6, 2016; (c) March 1, 2017.

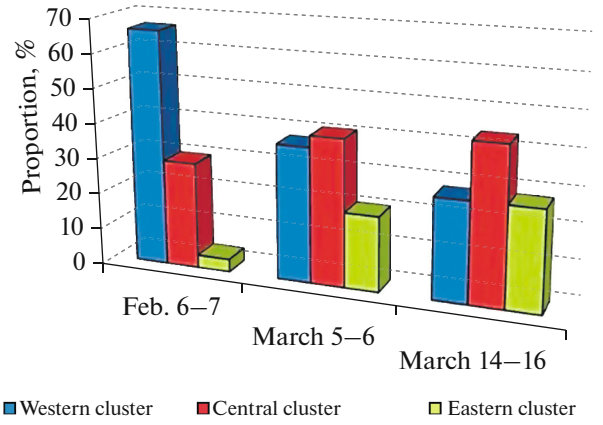

Fig. 3. Proportions of pups of the year from different clusters (%) in total spotted-seal pup production in the Rimsky-Korsakov Archipelago during the breeding season of 2015.

(and, undoubtedly, will) radically change depending on the stage of population development.

The results of pup counts at the breeding haulout sites of the eastern cluster during the seasons 2015–2017 have revealed pronounced year-to-year variations in the number of pups within the three-year period under consideration with quite stable values of parameters characterizing the size of pup production in the western and central clusters (Fig. 4). This can probably be explained by the still ongoing colonization of the eastern cluster islands by new females recruited to the breeding process. However, it seems that there was no increase in the number of whelping females on the islands of the western and central clusters in 2015–2017. Obviously, a certain limit to the density of reproductive aggregations of females exists, at which a further density increase becomes impossible or it decreases to a minimum.

The non-synchronous timing of spotted seal pupping in different clusters and the variation in the number of whelping females in them result from an increase in the values of quantitative parameters of the local population, whose size in 2017 was estimated at 3200–3600 individuals without pups taken into account [22], due to the natural changes in the age structure that occur in it, and also due to the differentiated distribution of whelping females of various ages within the archipelago boundaries. The reproductive aggregations of females breeding within the western cluster are currently represented by seals of predominantly older ages, which are characterized by an earlier timing of pupping. The existence of a relationship between the age of breeding females and the timing of their pupping has not been described for spotted seals to date, despite such a relationship being found in other pinniped species. In particular, in the gray seal *Halichoerus grypus* (Fabricius, 1791), earlier entry into reproduction (pupping with subsequent mating) is characteristic of older females, while young females, often breeding for the first time, whelp and mate later [13, 16, 17]. A similar relationship was reported for the northern elephant seal *Mirounga angustirostris* (Gill, 1866) [21]. More detailed information on the timing of pupping for females of different ages has been published on the Antarctic fur seal *Arctocephalus gazella* (Peters, 1875) [18, 20] and the northern fur seal *Callorhinus ursinus* (Linnaeus, 1758) [1, 3, 5, 14, 15, 19]. In these species, the first females to haul out at breeding sites and whelp are older aged females.

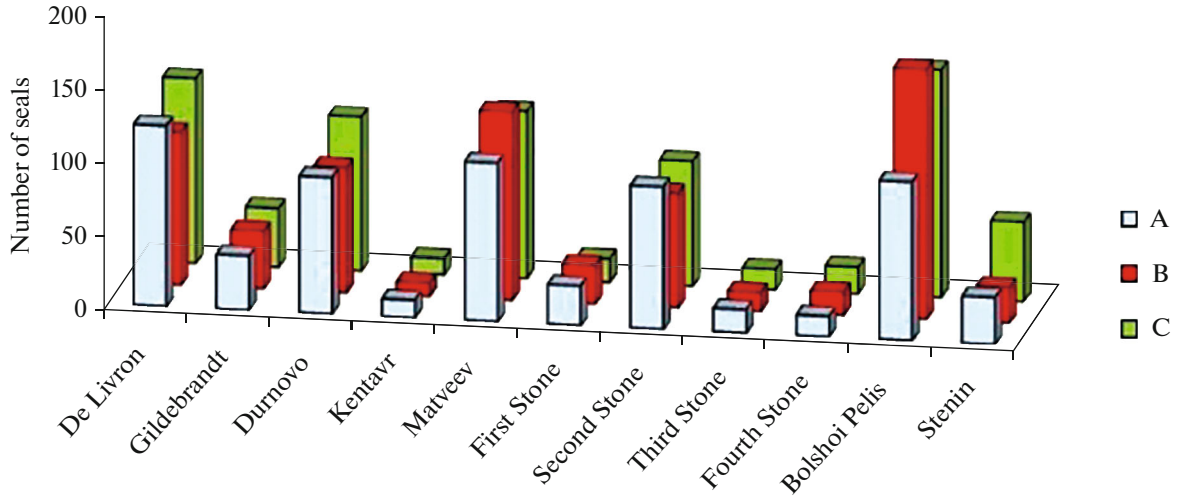

Fig. 4. Absolute number of spotted seal pups in the Rimsky-Korsakov Archipelago according to the results of counts conducted in 2015–2017: (A) March 5 and 6, 2015; (B) March 4 and 6, 2016; (C) March 1, 2017.

There is no doubt that the same relationship is characteristic of spotted seals. The earlier timing of spotted-seal breeding at the haulout sites of the western cluster may indicate a general increase in the average age of females that breed within this cluster. Due to the philopatry typically exhibited by spotted seals, the cluster core is formed by the same seals from year to year, despite a slight decrease due to the natural mortality of resident senile females and the proportionally moderate recruitment of young females to the cluster. Apparently, female spotted seals that have reached the fertile age manifest conservatism in selecting a site for pupping to a great extent. Thus, one female pup of the year, tagged by myself with a blue plastic tag in 1998 [10], was subsequently observed three times with her pups at the same haulout site on Gildebrandt Island (western cluster) during the breeding seasons of 2010–2013 [9]. Another tagged female spotted seal gave birth to pups for at least four seasons on the same beach of Utashud Island located off the western coast of Kamchatka Peninsula [2].

Changes in the demographic parameters of the spotted-seal population in Peter the Great Bay resulted in a transformation of its spatial structure during the breeding season. By the early 2000s, the size of the population was estimated at approximately 1000 individuals [10], and its breeding range in the Rimsky-Korsakov Archipelago included the islands of the western and central clusters, while pupping on the eastern cluster islands was episodic. For example, throughout the breeding season 1998, only one pup was born on Stenin Island, and none on Bolshoi Pelis Island [12]. By 2015, the spotted-seal pupping on these islands acquired a mass character, with an expected further increase in the number of females whelping here and a probability of new breeding haulouts to be formed beyond the archipelago [11]. In subsequent years, the values of the quantitative parameters characterizing annual pup production, indeed, increased (with more than 800 newborns), and the number of seals aged 1+ yr reached 3200–3600 individuals [22]. As predicted, the list of islands with breeding haulouts was extended to include those where spotted seals had never whelped previously and then began doing this. In June 2015, Yu. V. Shibaev (pers. commun.) found the mummified carcass of a white-coat spotted-seal pup on Unkovsky Island, located in the northern part of Peter the Great Bay. On March 19, 2021, I found three white-coat pups, of which two were lying near two adult spotted seals each, on Karamzin Island located north of the Rimsky-Korsakov Archipelago. Besides these seals, about 20 more pups of the year that had completed the juvenile molt (with adult pelage) were also present on the island; it can be assumed that some of them were born here.

The growth of the number of seals in Peter the Great Bay and the expansion of their breeding range is also confirmed by the results of stationary observations conducted each year in the waters of the Lazovsky Nature Reserve, which is located a few dozen kilometers east of Peter the Great Bay. There spotted seals have been born annually on Opasny Island since 2011 and on Beltsov Island since 2015, with the number of newborns increasing, although slightly but steadily, year on year [4].

As is well known [7], dispersal is more characteristic of young animals than adults. Pinnipeds are no exception, which can be exemplified by information about the northern fur-seal population on Tyuleniy Island, Sea of Okhotsk. In the early 1960s, during the period when the size of the population reached the highest values, a reproductive community began to form on the southern cape of the island previously occupied only by bachelor males. In 1969, this "col-

lective harem", which had increased in number, was completely harvested by sealing. Its age structure (a sample of 914 seals) was as follows: females aged 4–7 yr made up 64.1%; 8–10 yr, 23.9%; older than 10 yr, only 7.9% [6]. This means that, with a female northern fur-seal life span of up to 35 years, the community core was represented by females of younger ages.

A similar pattern is currently observed in the Rimsky-Korsakov Archipelago, where the eastern cluster islands were (and are still) colonized by young seals, whose timing of pupping is shifted to later dates (Figs. 2, 3). The certain threshold values of abundance and density, achieved by the local group of spotted seals on most of the islands of the archipelago, has become a trigger to their ongoing dispersal over Peter the Great Bay and colonization of new breeding sites.

The results that we have obtained show that each reproductive aggregation of females breeding within the boundaries of different clusters in the Rimsky-Korsakov Archipelago has its own age structure. In the current period, females breeding at the haulout sites of the eastern cluster are represented mainly by young seals that have immigrated here from traditional breeding sites after an optimum density was achieved in the western and, partially, central clusters.

It is now difficult to answer the question as to how long the number of spotted seals in Peter the Great Bay will grow with the accompanying territorial expansion. We can assume that any significant increase in the number of seals of reproductive aggregations in the central and, especially, western clusters of the Rimsky-Korsakov Archipelago is unlikely to occur in the near future. In the current conditions, the density of spotted seals during the breeding season on most islands here apparently has reached the level of biological optimum at which the rate of increase in the density of reproductive aggregations has significantly slowed down at many haulout sites. At some of the sites, this process has ceased completely despite the apparent availability of space necessary for successful breeding and the tolerant interactions between whelped females in reproductive aggregations. A further increase in the Peter-the-Great-Bay spotted-seal population is still possible due to both the continuing colonization of haulout sites of the eastern cluster by females and the emergence of new reproductive aggregations on the islands beyond the Rimsky-Korsakov Archipelago in case conditions favor breeding success.

ACKNOWLEDGMENTS

I am grateful to all colleagues who provided a variety of support in conducting field studies.

FUNDING

The study was carried out at the Il'ichev Pacific Oceanological Institute, Far Eastern Branch, Russian Academy of Sciences, within the framework of the State assignment topic no. 0211-2021-0014 "Ecological and biogeochemical processes in marine ecosystems: The role of natural and anthropogenic factors".

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. I declare that I have no conflict of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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Translated by E. Shvetsov