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Doctor of Biological Sciences

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# REPORT

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**Overview of published and archive materials on Steller sea lion distribution, abundance and feeding habits in the Sea of Okhotsk during its yearly life cycle**

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## Introduction

Any human activity should be aimed at conservation of biological diversity as a priority (text of the Convention on Biological Diversity, June 05, 1992). The agreement on biological diversity was signed by more than 145 countries. Russian Federation joined it in 1995 (No. 16-FZ of February 17, 1995). More intensive anthropogenic activities and global climate changes in the second decade of the 21st century highlight importance of this international document. The Russian pollock fishery in the Sea of Okhotsk (SOO), one of the world's largest fisheries, was certified for compliance with sustainable fishing standards on September 24, 2013 (Russian Sea of Okhotsk Mid-water Trawl.....2013). The certification report places special emphasis on observance of international environmental standards applicable to fisheries and on conservation of biodiversity of marine ecosystems.

Special attention in sustainable fishery management practices should be given to vulnerable ecosystem elements – species which are understudied and feature low abundance. Even minor fishery impacts on them may lead to their extinction, in whole or partly (in part of their range). Therefore, study and protection of such fauna species is very important for prevention of ecological tragedies in the future.

One of such species is the northern sea lion or the Steller sea lion (Eumetopias jubatus). The Steller sea lion is endemic to the North Pacific. It is widely distributed all over the Russian Far East (Fig. 1). Its abundance drastically dropped at the end of the past century. And the causes of this catastrophic reduction have not been identified in full till presently. The Steller sea lion is currently listed on the Red Book of Russia (2001) and on the IUCN Red List of Near Threatened Species (Gelatt, Lowry 2012).

A whole series of scientific studies was performed in the late 1990s – early 2000s to find out causes of this decrease of Steller sea lion abundance, mostly in the American part of its range. By the beginning of the 20th century, the total number of articles on Steller sea lion studies was estimated at more than 600 (Hunter, Trites 2001). To date, this number has exceeded one thousand but no clear and unambiguous answer about reasons of the catastrophic decrease of Steller sea lion abundance at the end of the 20th century has been received (Pascual, Adkinson 1994; Loughlin 1998; Rea et al., 1998; Fay, Punt 2006 and many others). The current level of knowledge about the Steller sea lion biology is not sufficient to assess human impact on this animal's population. The most dangerous factor for this species is commercial fishery. This issue is very topical in SOO as it is an area of active fishing for a whole number of aquatic organisms and, at the same time, one of Steller sea lion

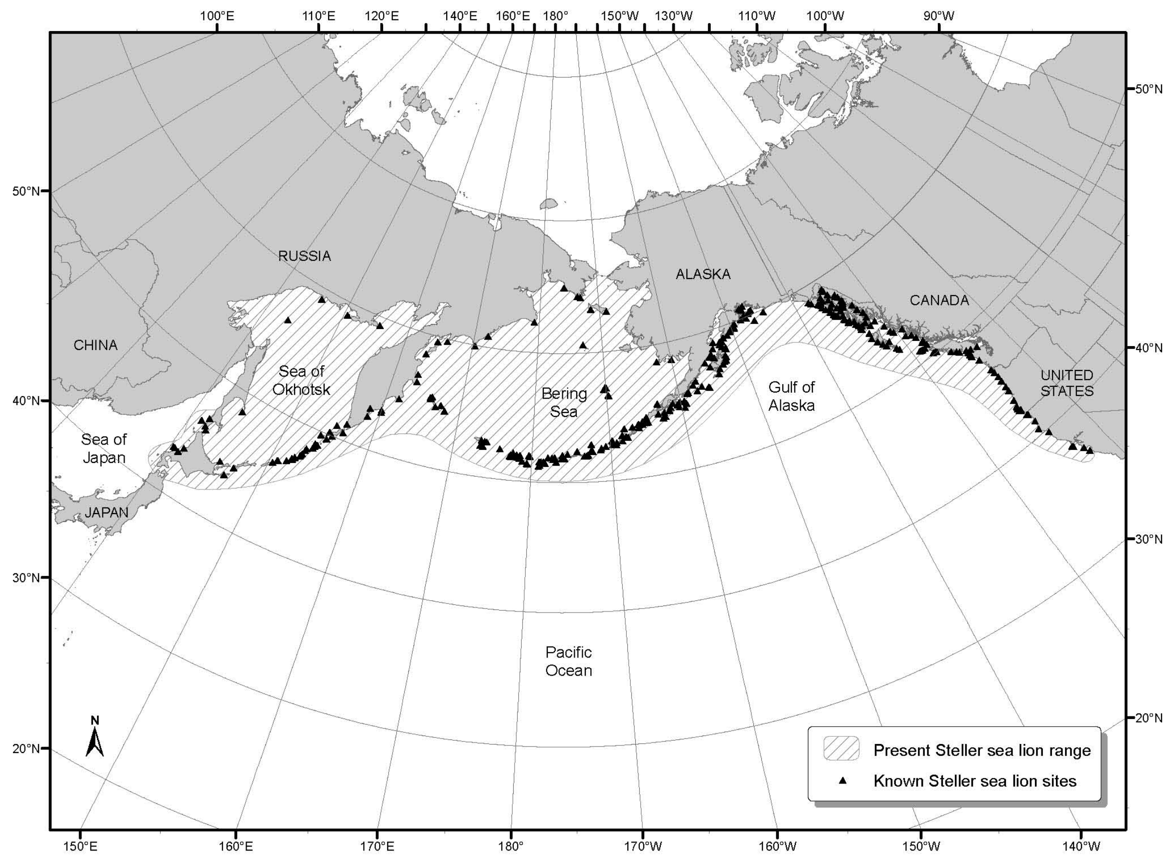


Figure 1. Current range of Steller sea lion (from Burkanov and Loughlin, 2005)

key habitats near the Asian coast. Such biological issues as feeding behavior and distribution are of special interest with regard to the relation between commercial fisheries and Steller sea lion. However, these elements of its biology are very little studied in SOO. The need to get answers to these questions was also stressed in the SOO pollock fishery certification report (Russian Sea of Okhotsk Mid-water Trawl.....2013).

This report presents an overview of materials, published and accessible to authors through archives, on two above said aspects of the Steller sea lion biology and suggests recommendations on organization of studies on these two aspects of its biology in SOO.

**Material and methodology**

This report presents an overview of literature sources on Steller sea lion feeding behavior and distribution in SOO during its yearly life cycle based on published and archival materials accessible to the authors. It also reviews and presents a whole number of papers on the general biology and physiology of Steller sea lion relating to adaptation of this species to an aquatic way of life and diving, as this information is directly related to its feeding behavior and use of the study area – water basin of SOO. The authors admit that this overview fails to cover all published data on Steller sea lion nutrition and feeding behavior, particularly in the eastern part of its range (western coast of North America and Aleutian Islands). The authors place their primary focus on study of above issues off the Asian coast and mostly in SOO.

The main purpose of this overview is to summarize available information on Steller sea lion abundance, seasonal distribution, feeding and use of SOO water basin during a yearly life cycle. The paper highlights aspects which are of primary importance for assessment of the SOO pollock trawl fishery impact on Steller sea lion as an element of the SOO ecosystem. It suggests recommendations on priorities in study of those aspects of the Steller sea lion biology which are currently understudied or completely unexplored. The authors have tried to present such information which is most applicable to SOO; however, it was impossible to do so in some cases due to complete absence of any data. In these cases, information from other areas of the Steller sea lion range was used with proper reference to such approximation.

This overview consists of 2 sections and includes 68 pages. It contains 12 illustrations, 6 tables and 2 attachments. The list of references includes 178 publications in Russian and English languages. No statistical methods are used in this paper. Graphic illustrations were produced either in Excel or R-environment (R Development Core Team 2013).

# 1. Results

## 1.1 Sea of Okhotsk as Steller sea lion habitat. Historical background.

Steller sea lions in the Sea of Okhotsk were first mentioned by Steller (1751) and Krasheninnikov (1755). Later on, many Russian discoverers and researchers traveled across the northern part of the Sea of Okhotsk in the late 18th – 19th century. They are likely to have left some reports on encounters with Steller sea lions but their reports and publications are not always accessible today (Sarychev, 1802; Krusenstern, 1806; Shemelin, 1816; Rimsky-Korsakov, 1858; Middendorf, 1869; Nevelskoy, 1878; and others). The first description of the Steller sea lion in the northern part of the Sea of Okhotsk was made by N.V. Slyunin (1900). Dukul et al. (1929) mention that Steller sea lions live and can be hunted for in this area. Ognev (1935) made a detailed summary of available information about Steller sea lion presence and condition in the Sea of Okhotsk as of the beginning of the 20th century. P.G. Nikulin (1937) and G.A. Pikharev (1938, 1941) who took part in several expeditions on sea animal research and hunting in the Sea of Okhotsk published first detailed data about Steller sea lions of Iona Island and Yamsky Islands. Some data about the Steller sea lion of the Sea of Okhotsk are contained in reports by S.Yu. Freyman (1931, 1935) and by S.S. Lun (1932). We have been able to find little data on the Steller sea lion condition in the northern part of the Sea of Okhotsk during 1940–1980 which confirms that no Steller sea lion studies were performed in the Sea of Okhotsk in that period. There are only separate reports about condition of some rookeries and encounters during works not relating to Steller sea lion studies or data obtained through interviews with local fishermen and hunters (Gurvich, Kuzakov, 1960; Lisitsyna, 1975; Perlov, 1977; Kosygin et al., 1984; Zadalsky, 1997). More detailed data are available on variations of Steller sea lion abundance in this area from mid-1980s till presently (Zadalsky, 1997, 2000, 2001; Zadalsky, Pavlov, 2001; Burkanov et al., 2002; Burkanov and Loughlin, 2005).

First data on Steller sea lion distribution and abundance off the Sea of Okhotsk coast of Sakhalin in the 19th century were published by A.M. Nikolsky (1889). Some data on Steller sea lion off Sakahlin coast in the end of the 19th century and in the first half of the 20th century are contained in writings by Rosset (1888), Slyunin (1895), Snow (1910), Dukul et al. (1929), Nikulin (1935), Sleptsov (1950) and others. Data on Steller sea lion abundance in this area in the latter half of the 20th century are as scarce as such data for the northern part of the Sea of Okhotsk. The greater portion of publications address the Steller sea lion grouping of Tuleniy Island (particularly in 1990-2000) and, in much smaller degree, other areas of Sakhalin (Voronov, 1974; Lagerev, 1988; Kuzin, 1996, 2001; Kuzin, Naberezhnykh, 1991; Kuzin, Kurmazov, 2000; Kuzin, Pavlov, 2000, 2001; Kuzin et al., 2002; Perlov, 1996; Perlov and Chupakhina, 1991). Valuable data on the condition of the Steller sea lion grouping of Tuleniy Island in the autumn-winter period of 1977-1985 and summer season of 1986-1988 are contained in Sakhalinrybvod's annual reports on marine mammal protection (Report on protection…, 1983, 1985, 1986, 1987, 1988).

Steller sea lion abundance and distribution in the Sea of Okhotsk off Kuril Islands have been studied much better. First data on Steller sea lion on Kuril Islands were obtained during Captain Spanberg's voyage from Kamchatka to Japan in 1738-1739 (Divin, 1971). S.P. Krasheninnikov (1755) described Steller sea lion distribution near North Kuril Islands (Atlasov Island) in 1738-1741. Further history of Steller sea lion on Kuril Islands during more than one hundred years is completely unknown. Only in the late 19th century (1873-1890), Captain Snow (1902) provided detailed data on locations of its largest rookeries on Kuril Islands and made an approximate estimate of its total abundance in this area.

S.A. Tikhenko (1914) provides general data on rookery locations on Kuril Islands in early 20th century based on the publication "Kuril Islands and Tuleniy Island" published in Japanese by the Departments of Sea Industries under Japan's Ministry of Agriculture and Trade in 1913. As seen from the style of this narration, much information in this publication was borrowed from the book written by Snow (1902), with some new data obtained in 1904-1913 added.

No later data on Steller sea lion on Kuril Islands when these islands stayed in Japan's jurisdiction (1904-1945) have been found.

The first enumeration of Steller sea lions on Kuril Islands was performed in 1955-1956 (Klumov, 1955 a, b). In the late 1960s – early 1980s, TINRO undertook a whole series of investigations of Steller sea lion rookeries on Kuril Islands, and several estimates of this species' abundance were performed (Belkin, 1966; Voronov, 1974; Nikolayev, 1965; Belkin, 1966; Perlov, 1970, Kuzin et al., 1977, 1984; Merrcik et al., 1990; Maminov et al., 1991; Trukhin, 2000; Kornev et al., 2001; Burkanov et al., 2000, 2002, 2004, 2008, and others). All published literature and archival data on Steller sea lion in all SOO areas were thoroughly analyzed and presented in the form of summary tables in a large paper by Burkanov and Loughlin (2005). Our review relies primarily on data from this publication.

## 1.2. Locations and classification of Steller sea lion rookeries in the Sea of Okhotsk

The Steller sea lion lives in the Sea of Okhotsk round the year. As was said above, this animal cannot live without land. Hauling out on the shore for breeding and rest it forms rookeries. We understand “rookery” as a limited piece of land used by animals for rest and/or breeding. Animals staying on the shore (or ice) form a haul-out. Haul-outs are normally segregated by a certain criterion – sex, age, social status. By saying “haul-out” we mean animals staying at a rookery (e.g., mixed haul-out, male or female haul-out, young animal haul-out, breeding haul-out, etc.).

As of today, at least 59 Steller sea lion rookeries are known and described on the SOO coast including Kuril Islands and Sakhalin Island (Fig. 2). (Burkanov and Loughlin, 2005). Most Steller sea lion rookeries exist in same places during many decades. Many of them were reported back in the late 19th – early 20th century (Rosset, 1888; Slyunin, 1895; Snow, 1902; Dukul et al., 1929; Ognev, 1935; Klumov, 1957, and others). The reasons why Steller sea lions stick to rookery locations remain unclear. It is believed that one of the main factors for a rookery’s existence in a particular area is nearby ample and permanent aggregations of prey items – herring, pollock, greenling, cephalopod mollusks and other aquatic organisms on which Steller sea lions feed.

Steller sea lion rookeries differ in numbers and composition of animals staying on them and nature of their use. Some rookeries are used round the year and some are used for short time and in a particular season only (summer, autumn or winter). Steller sea lions use some rookeries for many decades and even centuries while at some rookeries they were registered only a few times; in some places they give birth to pups and feed them every year and in other places pups are born very rarely. A.N. Belkin (1966) grouped Steller sea lion rookeries into two categories (major and secondary) and several sub-categories. He believed that a characteristic feature of major rookeries is “available convenient places for haul-out and permanent presence of a significant number of animals – normally 400 head.” Steller sea lion presence at secondary rookery sites is less permanent and their number “often depends on such factors as weather condition, seasonal aggregation of prey items in its vicinity, etc.” He singled out harem (breeding) and non-harem (non-breeding) rookeries in the major rookery category. Non-breeding rookeries were further subdivided into two categories

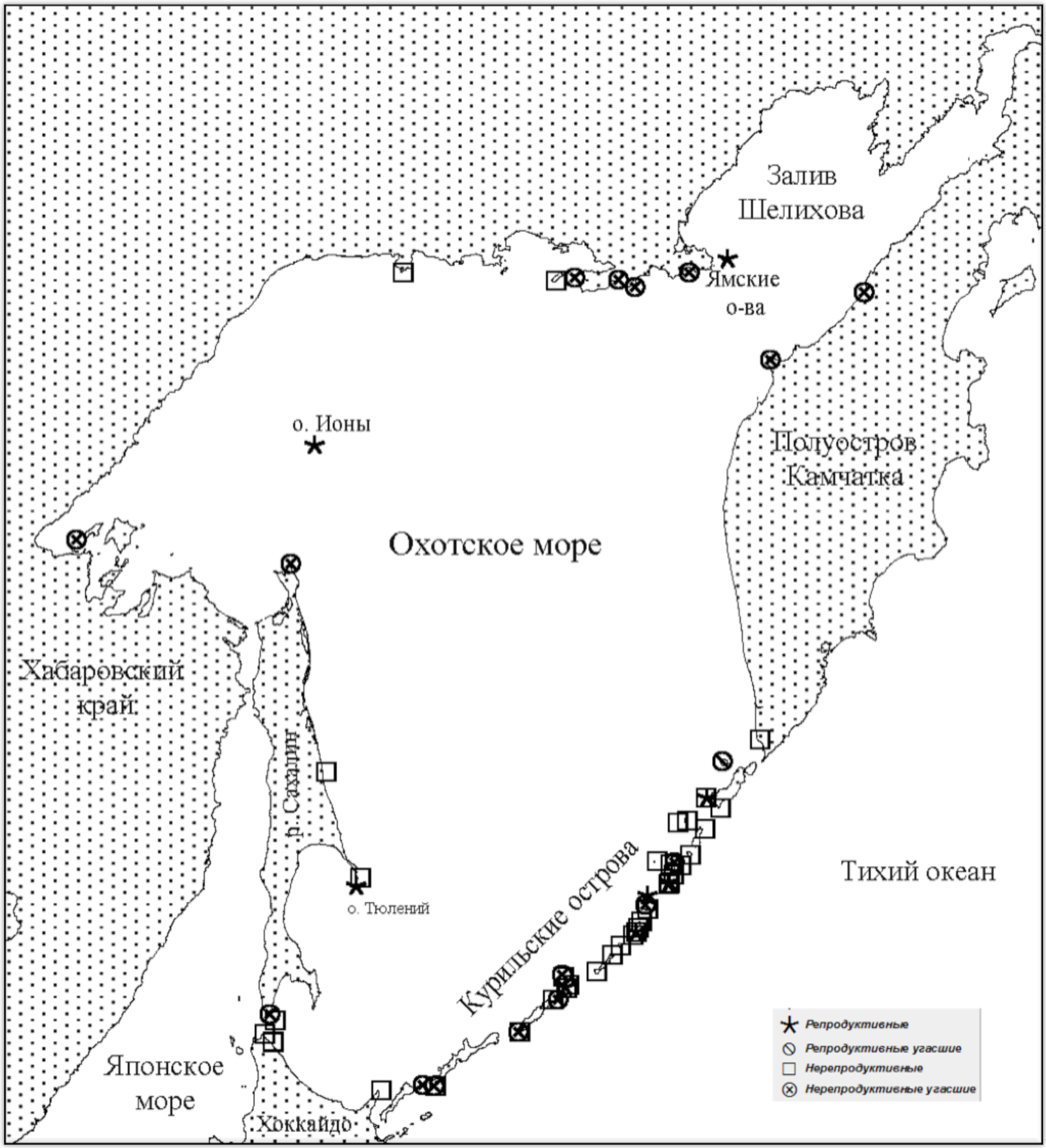


Figure 2. Locations of Steller sea rookeries on the Sea of Okhotsk coast

| | |
|---|---|
| Залив Шелихова | Shelikhov Bay |
| Ямские острова | Yamsky Islands |
| Остров Ионы | Iona Island |
| Охотское море | Sea of Okhotsk |
| Полуостров Камчатка | Kamchatka Peninsula |

| | |
|---|---|
| Хабаровский край | Khabarovsk region |
| о. Тюлений | Tuleniy Island |
| о. Сахалин | Sakhalin Island |
| Японское море | Sea of Japan |
| Хоккайдо | Hokkaido |
| Курильские острова | Kuril Islands |
| Тихий океан | Pacific Ocean |
| Репродуктивные | Breeding |
| Репродуктивные угасшие | Breeding extinct |
| Нерепродуктивные | Non-breeding |
| Нерепродуктивные угасшие | Non-breeding extinct |

by sex and age – bachelor rookery sites (attended mostly by males) and juvenile rookery sites (attended mostly by young animals, both males and females). In general, this approach seems rather logical. However, Belkin (1966) himself pointed out that such sub-divisions are fairly tentative because a rookery site may be of the breeding type in summer and of the bachelor type in winter or of the bachelor type in summer and of the juvenile type in autumn and winter. Furthermore, both bulls and mature females (quite many in some cases) who continue nourishing yearling pups are normally present at juvenile rookeries as well. Mating of animals and typical "harem" behavior of adult bulls is also observed at such rookeries.

Later on, Perlov (1980) singled out only three rookery types by the sex and age composition of animals (harem, juvenile and bachelor types). However, he also indicated that such division is rather tentative.

Also, significant changes occur at rookery sites in the course of time: they turn from breeding ones to non-breeding ones and vice versa. Some rookeries degrade with time and Steller sea lions stop hauling out at them, while new rookeries emerge in new places and are actively used by animals (Perlov, 1980; our observations). Such transformations occur at a particularly fast pace in recent 30 years due to significant reductions of Steller sea lion numbers in the greater portion of its range. With consideration for these circumstances, we use only two criteria, suggested by Belkin but somewhat modified by us, for Steller sea lion rookery classification in this paper. The first one is presence or absence of newborn pups at the rookery; the second one is permanence or duration of its use by Steller sea lions. In accordance with these criteria, we classify all rookeries as follows:

**Breeding (reproductive) rookeries** – all rookeries where newborn pups (>= 10 pups/year) were regularly registered in the breeding period during a long period of time (>=5 years);

**Non-breeding (non-reproductive) rookeries** – all rookeries where no newborn pups are registered in the breeding period or are registered not regularly (<5 years) and in small numbers (<10 pups/year);

**Permanent rookeries** – Steller sea lions haul out on a regular basis during a long period of time (<=10 years), round the year or during a particular season only but every year;

**Temporary rookeries** – Steller sea lions haul out not regularly (not every year) or were registered only several times during a long period of time;

According to this classification, all breeding rookeries are permanent and all temporary rookeries are non-breeding.

We also single out **Extinct (vanished)** rookeries. These are rookeries at which Steller sea lions used to haul out in the past but which they don't use at the present time (were not registered at them during last 5-10 years).

Fig. 2 shows all Steller sea lion haul-out sites on the Sea of Okhotsk coast known during last 200-250 years. There are 8 breeding rookeries in the Sea of Okhotsk – 5 ones in Kuril Islands, one on Tuleniy Island near the eastern coast of Sakhalin, one in the middle of SOO on Iona Island and one in the NW part of SOO on Matykil Island, the largest one among Yamsky Islands located at the mouth of Shelikhov Bay.

As clearly seen on Fig. 2, Steller sea lion rookeries are very unevenly distributed in SOO. As this sea lion tends to stay close to rookeries during its entire yearly cycle, its distribution in SOO will be uneven as well. In the breeding period, major Steller sea lion aggregations are observed in Kuril Islands area and near the SOO northern coast between Shelikhov Bay and Lisyanskogo Peninsula. Steller sea lions permanently live off the eastern coast of Sakhalin Island where they form a large breeding rookery on Tuleniy Island. However, there are virtually no Steller sea lions in vicinity of Shantar Islands and off the greater portion of the West Kamchatka coast (Fig. 2).

It should be specially noted that the vast majority of Steller sea lion rookery investigations in SOO were performed in the summer season and characterize this animal distribution and rookery usage only in the summer season of its yearly life cycle. The nature and phenology of usage by Steller sea lions of most rookeries in SOO in the autumn, winter and spring seasons are not studied at all. It is well known only that the character of Steller sea lion distribution and abundance is subject to broad seasonal variations in this area.

**1.3. The nature of use by Steller sea lion of the Sea of Okhotsk basin during its yearly life cycle and the structure of its spatial distribution in this area.**

The Steller sea lion lives in SOO round the year (Ognev, 1935; Geptner, 1976; Burkanov and Loughlin, 2005). However, its seasonal distribution over the SOO basin widely varies from season to season. During harsh winters, the whole northern and southern part of the Sea of Okhotsk including South Kuril Islands is covered with heavy ice for several months. It was believed earlier that as air temperatures go down and ice appears in this area Steller sea lions leave their rookeries and do not occur off the greater portion of the coast till next spring or summer (Chapsky, 1964). The timing of their departure is likely to depend on the timing of winter beginning. On Yamsky Islands, Iona Island and Tuleniy Island, Steller sea lions were observed on the shore in December (Kosygin et al., 1984; Report…, 1985). We were unable to find any subsequent data on Steller sea lion rookery investigations in SOO in winter time; therefore, any exact data on the use of these rookeries by Steller sea lions in the winter are also lacking. Also, there is no information in literature sources on the timing of Steller sea lion return to rookeries in the spring.

The winter period of Steller sea lion life off the Asian coast remains heavily understudied as yet. Nikulin (1935) believed that these animals do not stay in SOO in the winter and leave for Kuril Islands and Japanese coast. It was found later that Steller sea lions do not avoid discontinuous ice and often haul out on ice for rest (Pikharev, 1940; Freyman, 1935; Tikhomirov, 1959). As fisheries and ice hunting for true seals (which enabled to expand seasonality and coverage of Steller sea lion observations) developed, data on permanent stay of Steller sea lions at the ice edge line in the Bering Sea appeared in early 1960s (Tikhomirov, 1959, 1964; Popov, 1982; Mymrin, 1999; Semenov, 1990). In mid-1980s, we observed from aircraft Steller sea lion aggregations on ice counting up to several hundreds of head in Karaginsky Bay and Olyutorsky Bay. Kosygin et al. (1984) observed from aircraft a haul-out of Steller sea lions on ice counting 20 head in Shelikhov Bay on February 19, 1982. These data are also confirmed by fishermen's information about large groups of wintering Steller sea lions in the Sea of Okhotsk off West Kamchatka. These animals are also observed during winter far from shore at the ice edge line in fishery operating areas in Kuril-Kamchatka, North Sea of Okhotsk and East Sakhalin fishing sub-zones. According to some data, it is mostly males that haul out on ice – bulls and half-bulls (Tikhomirov, 1959; Popov, 1982; Perlov, 1983; Calkins, 1999). Our observations also confirm these data. The issue of locations where females and juveniles stay during the winter season in SOO remains completely unexplored.

We can only suggest that the majority of juveniles and females winter south of the ice edge line. In early 1980s, the number of Steller sea lions at many seasonal rookeries in the southern part of the East Kamchatka coast noticeably grew in autumn and winter and reduced in summer and mid-winter (Burkanov, 1986). It looked as if these changes were associated with seasonal migrations of Steller sea lions along the East Kamchatka coast. Encounters with Steller sea lions migrating in the spring in the southern part of SOO were reported by Nikulin (1937), Freyman (1945) and Sleptsov (1950).

According to reports by some Japanese researchers, Steller sea lions occur off Hokkaido Island only in winter and extremely rarely in summer (Nishivaki and Nagasaki 1960; Itoo et al., 1977; Ishinazaka T., Suzuki N., Hoshino H., pers. comm.). Significant seasonal variations of Steller sea lion abundance at Peshchernaya Rock rookery off South Kurils and near Nevelsk port on Sakhalin are another confirmation of its seasonal migrations in SOO. Based on his own observations and reports from local residents, Belkin (1966) pointed at a marked seasonal character of rookeries functioning on the Smaller Kuril Archipelago and believed that Steller sea lions come here from northerly Kuril Islands, while Nikulin (1937) believed that they migrate to this area from Iona Island. At the same time, Belkin (1966) believed that “a significant” portion of Steller sea lions spend winter in vicinity of summer rookeries and at temporary winter haul-out sites. However, all these assumptions are based on indirect data. On the whole, it can be positively stated that the winter distribution pattern of Steller sea lions in the greater portion of Russian Far East seas remains unexplored till presently.

We studied Steller sea lion migrations in SOO by observing encounters with marked animals. About 9,000 newborn pups were marked by hot branding method (Merrick et al., 1996) in all breeding rookeries in the Russian Far East during 1989-2011. Upon analysis of repeated encounters with marked Steller sea lions, it was found that the vast majority of adult animals involved in breeding activities return to natal rookeries during the breeding period (Burkanov and Calkins, 2008; Burkanov, 2009). Young and mature Steller sea lions not involved in breeding activities are widely spread over the Asian mainland coast and can be encountered in any area of the Far East (Fig. 3). There are significant movements and exchange of animals between rookeries of the northern part of SOO and Sakhalin (Yamsky Islands – Iona Island – Tuleniy Island – Moneron Island). In Kuril Islands, Steller sea lions move mostly between rookeries of this area but can be

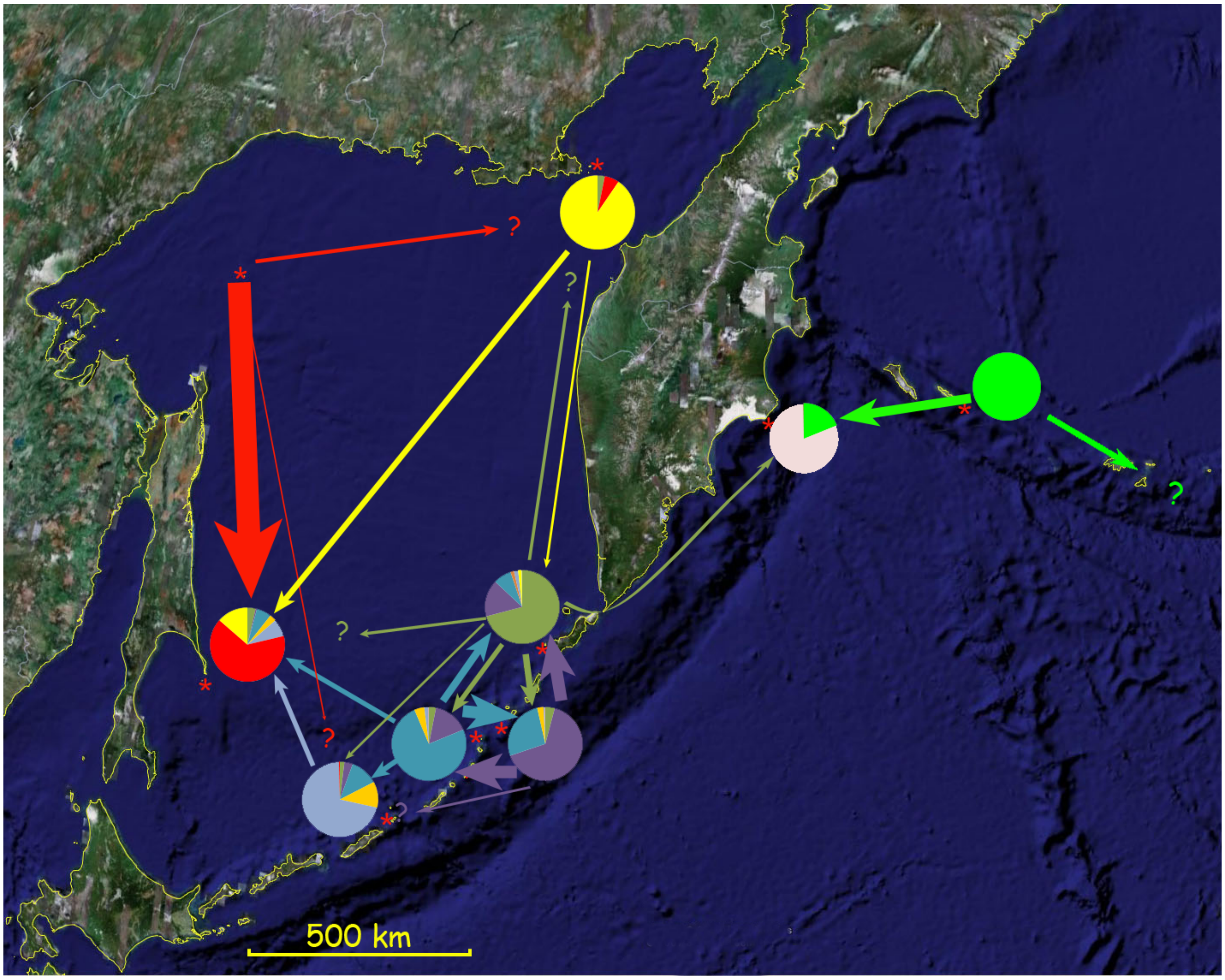


Figure 3. Migrations of marked Steller sea lions between major breeding rookeries of the Far East during breeding period (source: Burkanov, 2009)

observed both off the northern coast and off Sakhalin Island and even in La Perouse Strait and in the Sea of Japan (our data).

In last 3-4 years, KB PIG FEB RAS specialists developed a self-sustained automatic photographic recorder based on a Canon T3 standard digital camera with matrix resolution of 12 megapixels capable of automatic shooting of animals staying on a haul-out site every day, fixing presence of Steller sea lions on the shore and registering marked animals at a rookery during a year (Altukhov and Burkanov, 2001, 2003). These photo recorders were used in a number of rookeries in Russia and Alaska in 2012-2013 and showed high reliability and good performance (Burkanov et al., 2014). Use of self-sustained automatic photo recorders is a new method in study of Steller sea lion seasonal distribution and migrations. It will enable to obtain detailed and accurate data on the nature of rookery use by Steller sea lions and, therefore, use by them of the whole basin of the Sea of Okhotsk during their yearly life cycle and new data on seasonal migrations between rookeries, areas and regions.

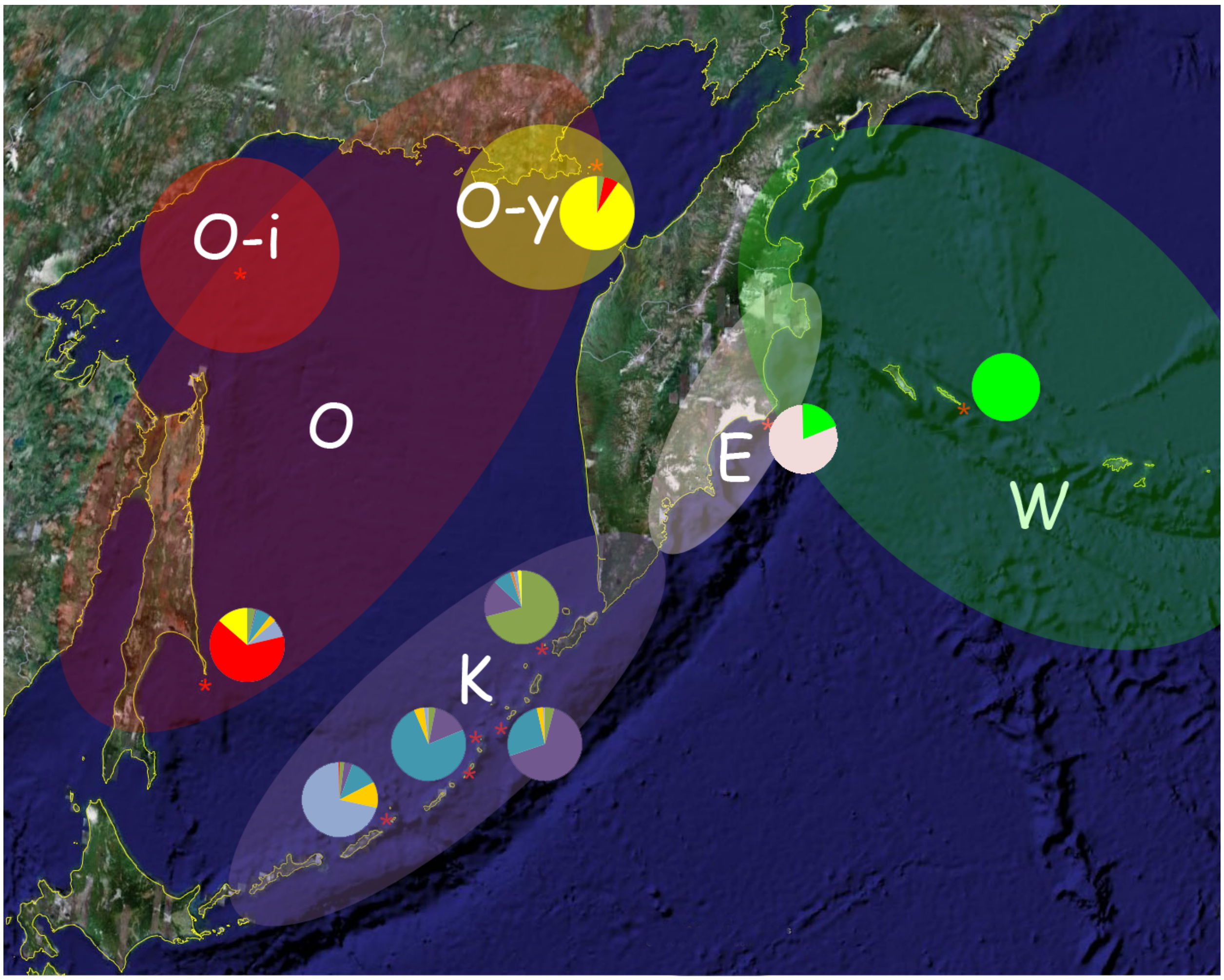


Figure 4. Spatial structure of Steller sea lion in the waters of the Russian Far East.

*Letters designate breeding groupings of Steller sea lion: W – Western; E – East Kamchatka; K – Kuril; O – Okhotsk-Sakhalin; Oi – Iona Island; Oy – Yamsky Islands. (source: Burkanov, 2009)*

There are several publications about population and spatial structure of the Steller sea lion off the Asian coast including SOO (Bickham et al., 1998; Zasypkin et al., 2002, 2003; Baker et al., 2005; Burkanov and Calkins; 2008; Burkanov 2009). Three Steller sea lion populations have been identified using mitochondrial DNA analysis method: eastern population living off the western coast of North America; western population living west of 144º W along the Aleutian Islands including Commander Islands; and Asian population encompassing coastal waters of Kamchatka and the whole Sea of Okhotsk till the western boundary of the Steller sea lion range (Baker et al., 2005). It was noted that the Asian population is not homogeneous. Upon analysis of materials on marked Steller sea lion encounters at breeding rookeries of the Far East, at least four groupings, largely isolated during the breeding period, were singled out off the Asian coast – Commander grouping which is part of the western population; Kamchatka grouping living and breeding solely near the eastern coast of Kamchatka; Kuril grouping consisting of five large breeding rookeries; and Okhotsk-Sakhalin grouping encompassing the waters of the northern part of SOO from Shelikhov Bay to East and South Sakhalin (Fig. 4) (Burkanov and Calkins, 2008; Burkanov, 2009).

These features of the spatial structure of Steller sea lion should be taken into consideration for effective management and protection of Steller sea lion populations near the Asian coast.

**1.4. Multi-year dynamic of Steller sea lion abundance in the Sea of Okhotsk**

All enumeration surveys of Steller sea lion in SOO were performed in the breeding period only (Nikulin, 1937; Klumov, 1957; Belkin, 1966; Perlov, 1970; Kuzin et al., 1984; Maminov et al., 1991; Zadalsky, 2000, 2001; Burkanov et al., 2002, 2004, 2006; and others).

First of all, it should be noted that no simultaneous and full enumeration survey of Steller sea lions at SOO rookeries has been ever performed (Burkanov and Loughlin, 2005). Separate segments or areas of the SOO coast were investigated in different years and at different intervals. The most complete data are available for Kuril Islands (Klumov, 1957; Belkin, 1966; Perlov, 1970; Kuzin et al., 1984; Maminov et al., 1991; Burkanov et al., 2002, 2004, 2006; and others). Enumeration surveys were less regular and less complete off the northern coast (Nikulin, 1937; Zadalsky, 2000, 2001; and others) and even less regular and less complete off Sakhalin coast (Kuzin, 1996, 2001, 2002, 2006; Burkanov et al., 2008). That's why researchers had to consolidate area-specific data for different years and estimate data for rookeries not investigated during the period being considered in order to obtain total abundance data (Burkanov and Loughlin, 2005).

**Number of newborn pups**: Fig. 5 shows data of Steller sea lion pup enumeration surveys at SOO rookeries during 1960s till presently. In early 1960s, pups were born in two areas only – on Kuril Islands and in the northern part of the Sea of Okhotsk. There were no breeding rookeries on Sakahlin before early 1990s. Total number of pups in 1960s was estimated at 4,300 individuals of which nearly 90% were born in Kuril Islands. Their number in SOO was declining till 1990s and reached a minimum of 2,200 individuals in early 1990s – mid-1990s (Fig. 5).

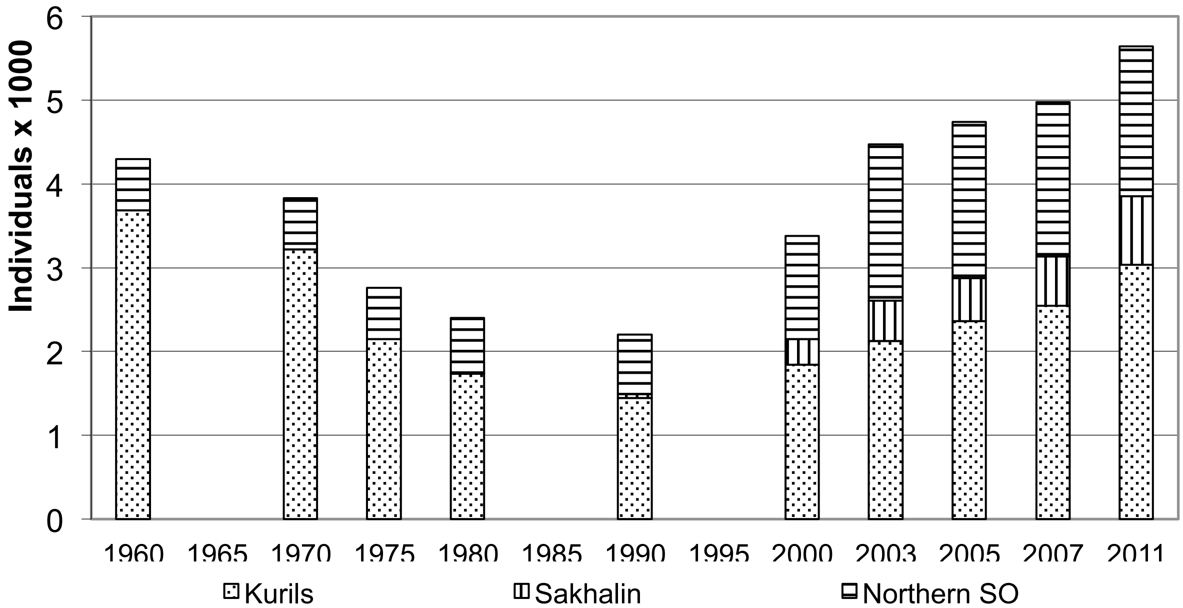


Figure 5. Numbers of Steller sea lion pups at rookeries in the Sea of Okhotsk, 1960-2011 (source: Burkanov and Loughlin, 2005; our data)

Offspring numbers were declining primarily because of reductions in Kuril Islands (Fig. 5). As Steller sea lions began regularly breeding on Tuleniy Island and off Sakhalin coast in early 1990s, their number was increasing and reached thousands of heads by 2013 (Fig. 5). The number of Steller sea lion offspring in the Sea of Okhotsk is currently estimated at 5,600 individuals of which only about half are born in Kuril Islands. Offspring numbers grew due to growth at the rookery of Tuleniy Island and two rookeries in the northern part of the Sea of Okhotsk (Iona Island and Yamsky Islands). It should be emphasized that offspring numbers in Kuril Islands have recovered only to 80% of the number registered in early 1960s.

**Number of adult and juvenile Steller sea lions:** A multi-year dynamic of this category is shown in Fig. 6. According to estimates, there were up to 16,000 adult and young Steller sea lions at rookeries in 1960s. The vast majority of them (over 90%) were hauling out at rookeries in Kuril Islands. From 1960s to early 1990s – mid-1990s, Steller sea lion numbers were declining in Kuril Islands reaching a minimum of 4,800 heads and, at the same time, were gradually growing off

Sakhalin coast and in the northern part of the SOO (Fig. 6). The fastest growth rate was observed near the coast of Sakhalin Island where a new breeding rookery came into existence by early 1990s. At the present time, at least 12,000 Steller sea lions (less newborn pups) haul out for rest and breeding at Sea of Okhotsk rookeries.

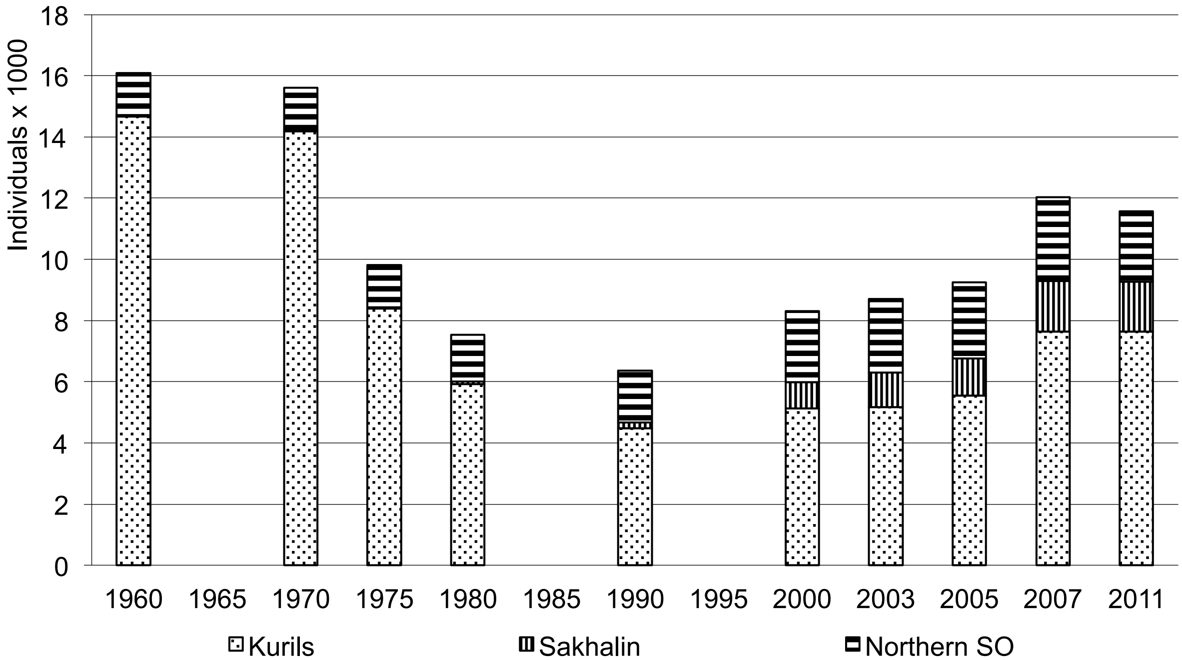


Figure 6. Numbers of juvenile and adult Steller sea lion pups at rookeries in the Sea of Okhotsk, 1960-2011 (source: Burkanov and Loughlin, 2005; our data)

In comparison with survey data for early 1960s, young and adult animals have recovered their numbers by approx. 70% only, with largest growth observed primarily in the coastal waters of Sakhalin and in the northern part of SOO. Their numbers in Kuril Islands have roughly halved since early 1960s (Burkanov and Loughlin, 2005).

When addressing Steller sea lion abundance in this report, we use only data of direct enumeration surveys of animals staying at rookeries. It is well known that not all animals living in vicinity of a particular rookery stay on the shore at the time of survey. Part of them (sometimes quite many animals) stay in the sea and are not seen by observers. In this report, we did not use any correction factors for this part of the population or estimated data when analyzing total Steller sea lion abundance in SOO.

### 1.5. Seasonal dynamic of Steller sea lion abundance in the Sea of Okhotsk

The number of Steller sea lions at rookeries of different types or in any particular region is subject to significant variation even during one season. Mostly bulls and a few females are present at most breeding rookeries in the beginning of the breeding period. Later on, the number of females noticeably grows and they dominate the sex and age structure of animals at breeding rookeries (Altukhov and Burkanov, 2004; Permyakov and Burkanov, 2004, 2005; Savenko et al., 2008; and others). At the end of the breeding season, Steller sea lion numbers in breeding areas reduce and animals become widely spread all over the Far East traveling hundreds and even thousands of kilometers away from breeding locations (Fig. 7).

The numbers of Steller sea lions in breeding locations reduce when autumn comes. This was clearly demonstrated on the example of Commander Islands (Burkanov et al., 2004; Vertyankin et al., 2004; Burkanov et al., 2010, 2011; Ryazanov et al., 2012; Burkanov, 2013). Unfortunately, the seasonal dynamic of Steller sea lion abundance at rookeries of the Sea of Okhotsk is completely unexplored. The vast majority of specialist studies of Steller sea lions in the Sea of Okhotsk were performed in summer. Rare and fragmentary data or reports on the number Steller sea lions at some rookeries in autumn or winter indicate that significant seasonal variations of its abundance occur at Sea of Okhotsk rookeries same as in vicinity of Commander Islands. An obvious conclusion is that Steller sea lions widely migrate over the Sea of Okhotsk during their yearly life cycle and travel far away from this sea (Fig. 7). However, the nature of these migrations (or nomadic migrations), the degree of their year-to-year permanence, quantitative and qualitative parameters remain unexplored. There is absolutely no information about quantitative estimates of Steller sea lion abundance in the Sea of Okhotsk in seasons other than the breeding season.

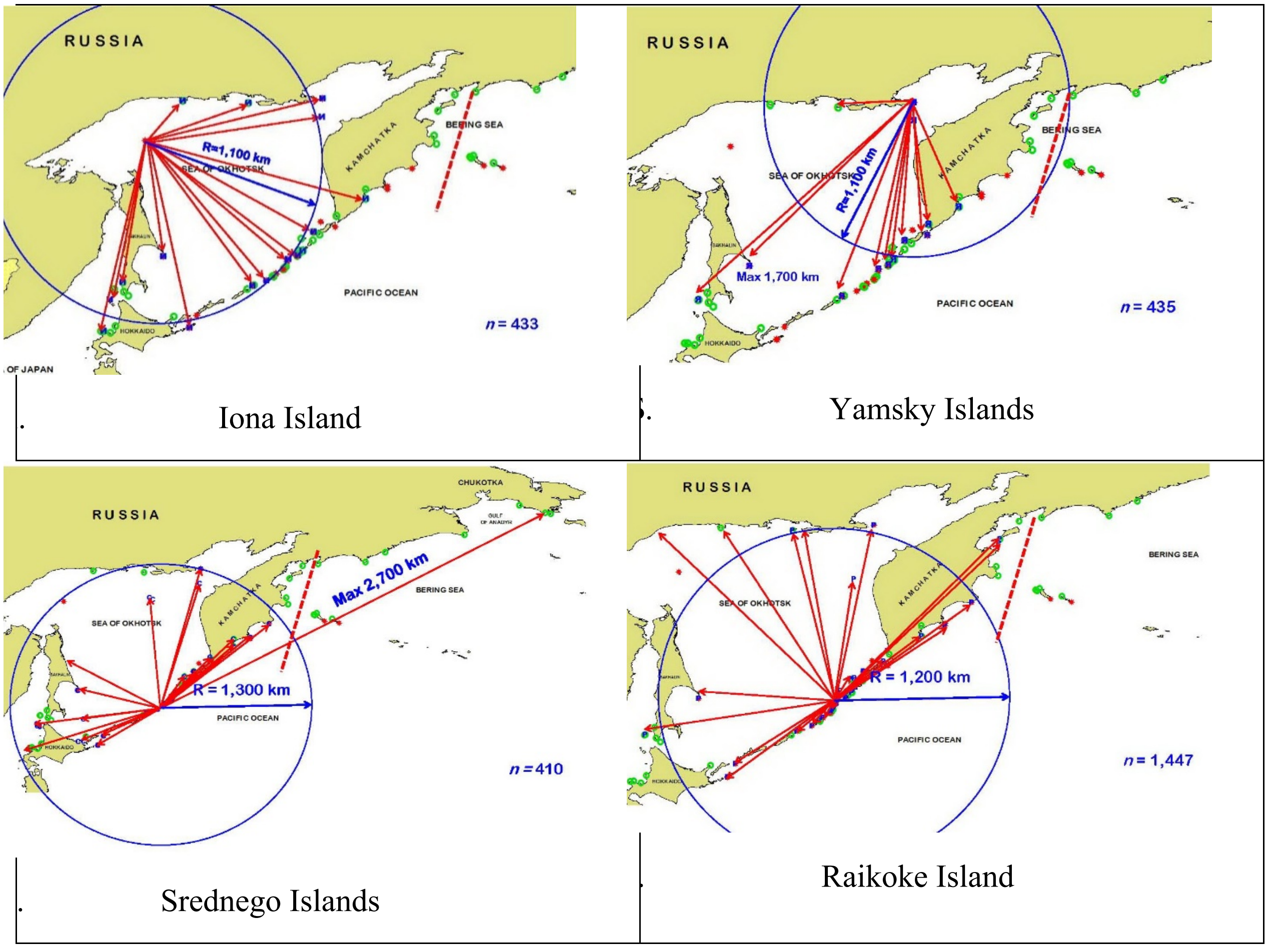


Figure 7. Encounters with marked Steller sea lions from rookeries of Iona Island (A), Yamsky Islands (B), Srednego Islands (C) and Raikoke Island (D) (source: our data).

Therefore, issues of the seasonal use by Steller sea lion of the SOO waters, variation of its abundance in this area during its yearly life cycle, seasonal variation of its sex and age composition in SOO should be addressed in the first place to obtain basic indicators for assessment of the pollock trawl fishery impact on the Steller sea lion population in SOO.

## 2. Steller sea lion feeding habits in the Sea of Okhotsk.

### 2.1. Steller sea lion adaptation to its aquatic habitat.

The Steller sea lion has undergone a number of morphological and physiological changes during its evolution from terrestrial mammal animals. This applies first of all to its limbs and their transformation to flippers which allow it move easily and freely in a 3-D aquatic environment but restrict its movements on land.

Due to some changes of the thermal regulation functions of its blubber and hair, this species became able to live in the cold waters of the North Pacific round the year. Its hair became thinner (Berta et al., 2006) and lost thermal regulation properties while its blubber became thicker but not that much (Nikulin, 1937) as is typical of true seals (Phocidae). Thus, it was demonstrated that Steller sea lion loses more body weight when starving in winter than in summer (1.24% and 1% respectively) (Svärd et al., 2009). External temperature may be an important factor for this animal in winter in case of lack of food resources (Svärd et al., 2009; Jeanniard et al., 2009). Unlike true seals, Steller sea lion has thin blubber, cannot haul out on ice for a long time and tries to avoid continuous ice. In this connection, marked aggregating behavior of these animals in rest locations may serve as a mechanism for heat loss reduction in the cold season (Rosen, Trites, 1999). Therefore, although Steller sea lion lives in the cold waters of the Pacific Ocean and makes no marked seasonal southward migrations as its close relative – Northern fur seal (Callorhinus ursinus) – does, its adaptation to living in a cold climate is rather limited.

The most important physiological feature of Steller sea lion adaptation to an aquatic environment is that its capabilities to live a pelagic life are rather limited. It is likely to have little ability to sleep on the water. We have been unable to find any detailed information about sleep studies of Steller sea lions but the above conclusion can be made based on data on duration of their continuous stay in the water. It is normally within 200 hours or somewhat more (Merrick, Loughlin 1997; Loughlin et al., 1998; Loughlin et al., 2003; Pitcher et al., 2005; Fadely et al., 2005; Rehberg 2005; Briggs et al., 2004). This specific feature of Steller sea lion adaptation to an aquatic environment has significant impact on its spatial distribution. It is probably due to this reason that it, unlike Northern fur seal, makes no long-distance migrations to south living in the same regions in winter and summer and making only short nomadic migrations between rookeries (Geptner et al., 1976; Kuzin, 2002; Burkanov, Loughlin 2005; Burkanov, Calkins, 2008; Ryazanov 2013; and others).

Need for underwater foraging and breath holding for a long time resulted in change of the chemical composition of Steller sea lion blood and muscles. The evolution of lengthy underwater stay proceeded through reduction of oxygen consumption during diving (Hastie et al., 2007; Fahlman et al., 2008) and increased oxygen supply in blood and body muscles (Richmond et al., 2004, 2006). A unique feature of Steller sea lion diving behavior is a long period required to develop a physiological potential for deep diving which becomes fully formed as late as 2 or 3 years of age (Richmond et al., 2004, 2006).

### 2.1.1. Sex and age differences in potential for living in an aquatic habitat

Steller sea lion is characterized by marked sexual dimorphism (Ognev, 1035; Geptner et al., 1976; Loughlin et al., 1987; Pitcher, Calkins 1981; Winship 2000; and others). Males are 2-3 times larger than females and have a thicker layer of fat than females and juveniles. Males and females exhibit different breeding strategies and different consumption of energy for breeding (Winship 2000). Taken together with a lengthy period required to develop a physiological potential for deep diving ((Richmond et al., 2004, 2006), all these conditions result in sex and age differences between males, females and immature individuals in their ability to live in severe conditions of the North Pacific aquatic environment. Most of these differences are theoretical and not covered in specialist studies but are of extreme practical importance in this species' life and will undoubtedly become a focus of intensive studies in the nearest future. The main differences are as follows:

- Due to thicker blubber and larger body size (Pitcher, Calkins 2000; Olesiuk, Bigg 1990), adult males are probably more adapted to lengthy stay in cold water and lengthy rest on ice than females and juveniles;
- Adult males are capable of accumulating more oxygen in their muscles and blood due to their comparatively larger body weight and can dive to larger depths;
- Due to their comparatively larger supply of fat (Pitcher, Calkins 2000), adult males can survive without food for a longer time;
- Young individuals having virtually no blubber (Pitcher, Calkins 2000) are likely to be less than adults capable of hauling out on ice and staying in cold water for a long time;
- Young individuals having small supply of fat cannot starve for a long time and need permanent nutrition – maternal milk or fish (Pitcher, Calkins 2000);

- Due to their limited diving capability, young individuals are limited in search for prey and foraging (Merrick, Loughlin 1997; Loughlin et al., 1998; Loughlin et al., 2003; Pitcher et al., 2005; Fadely et al., 2005; Rehberg 2005);
- Adult females occupy an intermediate position between young individuals and adult males in their deep diving potential, blubber thickness and capability of surviving without food.

All these physiological features of different age and sex groups result in different compositions of Steller sea lion diet and differences in use of their habitat in each particular area of their range during a yearly life cycle. Thus, for instance, mostly males are present during winter in Avacha Bay (Nikulin, Vertyankin, 2008). Before 1980s, males regularly migrated to Commander Islands for wintering while females occurred occasionally (Barabash-Nikifirov, 1935; Marakov, 1964; Pryanishnikov, Pinigin, 1972). Also, males only were observed in winter at the ice edge line in the Bering Sea (Popov, 1982).

### 2.1.2. Diving depth and duration

As was said above, physiological diving adaptations develop in Steller sea lions during first three years of their life (Richmond et al., 2004, 2006). Use of satellite tagging technologies and telemetric data showed that Steller sea lion diving depth is limited in most cases to 20 meters although some individuals dive to depths more than 250 m (Table 1).

The greatest efforts to investigate Steller sea diving habits were undertaken on the western coast of North America and in Aleutian Islands. Published literature sources contain information about two satellite tagging studies on the Asian coast (Loughlin et al., 1998; Olivier et al., 2011). Interestingly enough, it was in Kuril Islands that the largest mean diving depths were registered for Steller sea lion females (over 55 meters). For the Steller sea lion range as a whole, mean diving depth was 38.3 m for adult females, 21.2 m for young females of 1–3 years of age and 9.83 m for young individuals under 1 year of age. Mean diving duration was 2.5 minutes for females, 1.5 minutes for young animals older than 1 year and only 1.1 minutes for young animals under 1 year of age. We have not found any information in published literature sources about satellite tagging of adult males. Their data are likely to be somewhat higher than the data registered for young animals and females.

### 2.1.3. Distance and duration of feeding migrations

The Steller sea lion spends roughly half of its life in the sea (Rehberg 2005; Call et al., 2007) but has to haul out on land for sleep and rest at regular intervals. While in the sea, it moves in search for food, dives for hunting or travels between rookeries. The duration and range of foraging trips is different depending on age and sex, season and region (Table 2). The longest foraging trips are typical of adult females (67 hours on average). Young individuals (0–3 years) make foraging trips more than 5 times shorter – 12 hours on average, and their range is 6.5 km only. No information for adult males has been found in published sources.

**Feeding migrations in summer:** In the summer period, the majority of Steller sea lions aggregate in vicinity of breeding rookeries. Adult males occupying a patch in a breeding rookery don't feed during the whole duration of their breeding activities. This period lasts 2–3 months on average – from mid-May to the latter half of July (Gentry 1970; Gisiner 1985; Mamayev, 1999). After the end of the breeding period, males turn to a migrating style of life and live and feed in vicinity of their native rookery or other rookeries (Mamayev, 1999; Zagrebin, Litovka, 2004; Vazhenina, 2004; Nikulin, Vertyankin, 2008).

Table 1. Data on Steller sea lion diving depth and duration according to published data

| Source | Sex and age group | Number of individuals | Capture location | Season | Type of tag | Mean diving depth | Mean maximum diving depth | Maximum diving depth | Mean diving duration | Maximum diving duration |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| Merric, Loughlin (1997) | F | 4 | Alaska | Summer | SLTDR | 21.0 (med) | | 150-250 | | |
| | F | 5 | Alaska | Winter | SLTDR | 24 | | >250 | | |
| | YOY | 5 | Alaska | Winter | SLTDR | 9 | | 72 | | |
| Loughlin et al. (1998) | F | 8 | Kuril Islands | Summer | SLTDR | 53 | | 250 | 1.9 | 8 |
| Loughlin et al. (2003) | YOY | 13 | CAI, EAI, EGOA, CGOA | All seasons | SLTDR/SDR | 7.7 ± 1.7 | 25.7 ± 16.9 | 252 | 0.8 ± 0.1 | |
| | J | 5 | EAI, EGOA, CGOA | All seasons | SLTDR/SDR | 16.6 ± 10.9 | 63.4 ± 37.7 | 288 | 1.1 ± 0.4 | |
| | J | 7 | WA | All seasons | SLTDR/SDR | 39.4 ± 14.9 | 144.5 ± 32.6 | 328 | 1.8 ± 0.6 | |
| Pitcher et al. (2005) | YOY | 75 | Alaska | All seasons | SDR | 87% of dives < 10 | | 252 | 82% of dives < 2 | >12 |
| | J | 36 | Alaska | All seasons | SDR | | | 452 | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| Fadely et al. (2005) | YOY | 26 | CAI, EAI, GOA | Spring, summer, winter | SDR | 10.3 | | | | |
| | J | 4 | CAI, EAI, GOA | Spring, summer, winter | SDR | 13 | | | | |
| Rehberg (2005) | YOY | 11 | CAI, GOA | Spring, winter | SRDL | 12.4 (11.0-14.0) CI | | | 0.87 (0.7-1.0) CI | |
| | J | 12 | CAI, GOA | Spring, winter | SRDL | 22.9 (20.0-28.0) | | | 1.71 (1.5-2.0) | |
| Briggs (2005) | J | 4 | PWS | Winter, spring | SDR | 13.9 | | 264 | 1.2 | |
| | YOY | 11 | PWS | Winter, spring | SDR | 9.6 | | 167 | 0.9 | |
| Rehberg et al. (2009) | F | 11 | SEA | Summer | SDR | 29.5 | | 190.5 | 1.8 | |
| Olivier et al. (2011) | F | 5 | Kuril Islands | | SDR | 55 | | | 3.1 | |
| Call et al. 2007 | | | CAI, EAI, CGOA, PWS, SEAK | All | SDR, ST | | | | | |
| Mean value for all | | | | | | 21.2 | 77.8 | 252 | 1.5 | 10 |

YOY - young individual under one year, J – juvenile individual 1 to 3 years old, F- F, SDR - relaying satellite tag, SLTDR – recording satellite tag, CAI – central part of Aleutian Islands, EAI - eastern part of Aleutian Islands, GOA – Gulf of Alaska, EGOA – eastern part of Gulf of Alaska, CGOA – central part of Gulf of Alaska, WA – State of Washington, PWS – Prince William Sound, SEA – Southeast Alaska.

All adult and young males not involved in breeding activities live and feed in vicinity of breeding (Mamayev, 1999; Altukhov, 2012) or non-breeding rookeries (Belkin, 1966; Lisitsyna, 1976; Altukhov, Burkanov, 2004; Mamayev, 1999; Altukhov, 2012).

Adult breeding females normally appear at a breeding rookery before giving birth to the young. After giving birth, a female stays on the shore together with the pup for 10-12 days (Gentry 1970; Sandegren 1970; Gisiner 1985; Altukhov 2012; Burkanov et al. 2011). Then it regularly goes out to sea for foraging.

Young individuals stay in vicinity of both breeding and non-breeding rookeries during the entire breeding period and make short feeding trips within nearby waters (Merrick, Loughlin 1997; Loughlin et al., 2003; Raum-Suryan et al., 2004; Briggs 2005; Rehberg 2005; Fadely et al., 2005; Rehberg et al., 2009; Lander et al., 2010).

In general, Steller sea lion feeding migrations are shorter in summer than in winter, both in terms of duration and distance (Table 1 and 2). In the first half of summer, the greater portion of the Steller sea lion population feeds in local waters adjacent to breeding rookeries.

**Feeding migrations in winter:** After the end of the breeding period, Steller sea lions gradually leave breeding rookeries and lead a nomadic way of life moving between rookeries (Mamayev, 1999; Altukhov, 2012; Trites et al., 2006; Zagrebin, Litovka, 2004; Vazhenina, 2004; Nikulin, Vertyankin, 2008; Trites, Portes 2002). Some females prefer feeding and living in one place. Others actively move between rookeries (Trites et al. 2006) feeding in passage or in vicinity of rookeries.

Nursing females continue alternating trips to the sea and pup nourishing. In its mother’s absence, the pup makes short local feeding trips near the rookery (Raum-Suryan et al., 2004; Trites et al., 2006) and learns hunting thus complementing its milk diet with fish. The duration of feeding trips made by females grows in winter reaching 200 hours and more (Table 2). The duration of feeding trips made by juveniles remains the same and averages 12 hours both in winter and in summer. Adult males, same as females, lead a nomadic way of life but, probably, feed and live separately from juvenile animals and adult females (Barabash-Nikiforov, 1935; Marakov, 1964; Pryanishnikov, Pinigin, 1972; Nikulin, Vertyankin, 2008).

Table 2. Data on duration and distance of Steller sea lion feeding trips according to published data

| Source | Age group | N | Capture location | Season | Type of tag | Mean duration of stay at sea (hours) | Mean distance of trips (km) | % of time spent at sea |
|---|---|---|---|---|---|---|---|---|
| Merrick and Loughlin (1997) | F | 7 | CGOA | Summer | VHF | 21.0 ± 3.7 (SE) | | 53 |
| | F | 3 | EAI | Summer | VHF | 25.0 ± 3.9 | | 58 |
| | F | 4 | EAI, EGOA, CGOA | Summer | SLTDR | 18.0 ± 3.1 | | 50 |
| | F | 5 | EAI, EGOA, CGOA | Winter | SLTDR | 204.0 ± 104.6 | | 90 |
| | YOY | 5 | EAI, EGOA, CGOA | Winter | SLTDR | 15.0 ± 2.2 | | 38 |
| Loughlin et al. (1998) | F | 8 | Kuril Islands | Summer | SLTDR | max 94 | 94% ≤10 (max.=263) | |
| Loughlin et al. (2003) | YOY | 12 | CAI, EAI, EGOA, CGOA, WA | All | SLTDR/SDR | 7.5 ± 7.5 | 7.0 ± 19.0 | |
| | J | 13 | CAI, EAI, EGOA, CGOA, WA | All | SLTDR/SDR | 18.1 ± 34.2 | 24.6 ± 57.2 | |
| | Все | 25 | CAI, EAI, EGOA, CGOA, WA | All | SLTDR/SDR | 12.1 ± 23.8 | 12.1 ± 23.8 | |
| Raum-Suryan et al. (2004) | YOY (75), J(28) | 103 | | Spring, summer, winter | SDR | 84% ≤20 | 90% ≤15 km | |
| | YOY, J | 29 | EAI, CGOA, EGOA | Spring, summer, winter | SDR | | 6.5 (5.08-8.26) CI | |
| | YOY, J | 74 | North, South | Spring, | SDR | | 4.7 (3.92- | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | and Central part of SE | summer, winter | | | 5.53) | |
| Fadely et al. (2005) | YOY, J | 30 | CAI, EAI, CGOA | Feb. – April | SDR | 8.9 (8.4-9.4) CI | 0.56 (0.56-0.74) CI | |
| | | | | May – July | SDR | 12.5 (11.3-13.9) | 1.30 (0.93-1.49) | |
| | | | | Nov. – January | SDR | 10.1 (8.2-12.5) | 1.11 (0.74-1.67) | |
| Rehberg (2005) | YOY | 11 | CAI, GOA | Spring, winter | SRDL | | | 42 (38-45) CI |
| Rehberg et al. (2009) | F | 11 | SEA | Summer | SDR | 25.8 | 13.5 | |
| | J | 12 | CAI, GOA | Spring, winter | SRDL | | | 51 (49-54) CI |
| Briggs (2005) | J (4) YOY (11) | 15 | PWS | Winter, spring | SDR | | 95%< 6 | |
| Call et al. 2007 | YOY, J | 129 | CAI,EAI, CGOA, PWS,SEAK | All | SDR, ST | 9.2± 12.0 | | |
| Lander et al. (2010) | YOY, J | 21 | WAI, CGA, EAI, CAI, | All | SLTDR | 8.6 ± 14.8 | | |

YOY - young individual under one year, J – juvenile individual 1 to 3 years old, F- F, SDR - relaying satellite tag, SLTDR – recording satellite tag, VHF – very high frequency transmitter, CAI – central part of Aleutian Islands, EAI - eastern part of Aleutian Islands, GOA – Gulf of Alaska, EGOA – eastern part of Gulf of Alaska, CGOA – central part of Gulf of Alaska, WA – State of Washington, SE – Southeast Alaska.

In summary, the home range of Steller sea lion (area with the highest probability of observing the animal born in a particular area) fluctuates during its yearly life cycle. The highest rate of dispersion is observed in winter. In summer, the home range shrinks and encompasses primarily waters adjacent to breeding rookeries. It is important to take this circumstance into consideration when analyzing Steller sea lion feeding behavior in different seasons. Feeding areas are found in immediate vicinity of breeding rookeries in summer and significantly expand and may include both coastal and open waters in winter. This is particularly important for SOO where Steller sea lions can rest on ice far from the shore. It can be assumed that the open waters in SOO at the edge of continuous ice where prey aggregates (pollock, cod, herring, etc.) may play an important role in Steller sea lion nutrition in SOO in winter.

## 2.2. Composition by species and occurrence rate of prey items in Steller sea lion diet

### 2.2.1. General overview

In nutritional terms, Steller sea lion can be classified as a non-selective (opportunistic) predator feeding primarily on prey items that are most accessible to it in terms of abundance and biomass in its particular habitat in a particular season (Sinclair and Zeppelin 2002; Waite, Burkanov 2006; Womble et al., 2009; Burkanov et al., 2011; and others). Prey accessibility and abundance may be one of key factors limiting the number of Steller sea lions in each particular area in seasonal and year-to-year terms (Bredesen et al., 2006; Winter et al., 2009) and influencing demographic parameters of their population (Merrick et al., 1997; NMFS 2008). Therefore, nutritional studies are important for understanding the nature and features of Steller sea lion seasonal distribution over its range (Womble et al., 2009) and information about its nutrition in breeding areas may characterize an overall state of welfare of a particular breeding grouping of Steller sea lion (Merrick et al., 1997; Womble, Sigler 2006).

Steller sea lion nutrition is well studied in the eastern part of its range near the coast of North America, in the Gulf of Alaska and in Aleutian Islands (Fig. 8) (Imler and Sarber 1947; Mathisen et al., 1962; Thorsteinson and Lensink 1962; Calkins, Pitcher 1982; Merrick et al., 1997; McKenzie and Wynne 2008; Sinclair and Zeppelin 2002; Trites and Calkins 2008; Trites et al., 2007; Womble and Sigler 2006, Sinclair et al., 2013).

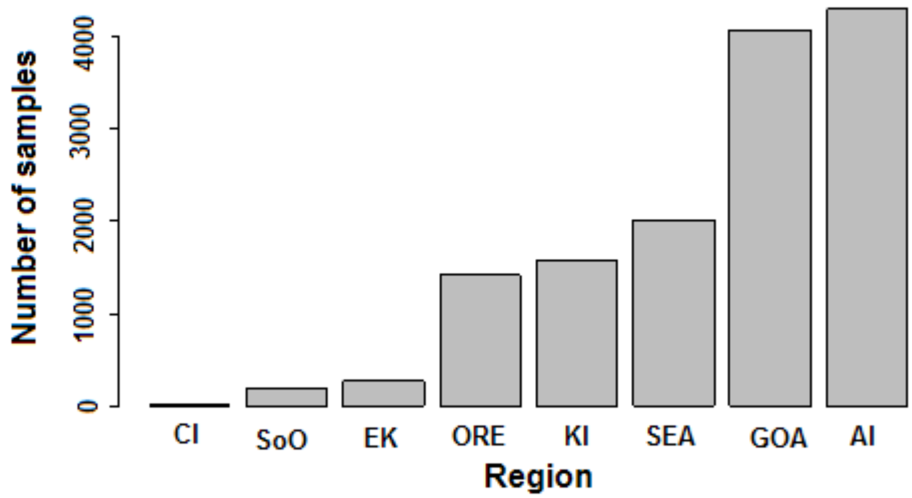


Figure 8. Number of analyzed samples (feces and stomachs) in Steller sea lion dietary studies.

*CI – Commander Islands, NPSO – northern part of the Sea of Okhotsk, EK – East Kamchatka, KI – Kuril Islands, AI – Aleutian Islands, SEA – Southeast Alaska, GOA – Gulf of Alaska, ORE - Oregon.*

In addition to investigation of a simple spectrum of Steller sea lion diet, another reason for studies performed in the middle of the 20th century was an attempt to determine this predator's adverse impact on fisheries and, first of all, consumption and injury of valuable commercial fish species (Imler and Sarber 1947; Mathisen et al., 1962; Thorsteinson and Lensink 1962; Spalding 1964). Once its abundance dramatically decreased in the late 20th century, the main purpose of Steller sea lion nutritional studies was to assess a hypothesis that there was insufficiently food for this animal and its quality had deteriorated (Alaska Sea Grant 1993; DeMaster and Atkinson 2002; Trites et al., 2007).

Steller sea lion nutrition in the Russian Far East waters has been studied very little. There are only a few papers published at long intervals and reflecting only part of species and their percentage in this animal's diet (Nikulin, 1937; Panina, 1966; Perlov, 1975; Waite, Burkanov 2004; Waite, Burkanov 2006; Waite et al., 2012a, 2012b). Steller sea lion nutrition is virtually unexplored in the Sea of Okhotsk and Kamchatka (Nikulin, 1937; Waite, Burkanov 2006). There is only very general understanding of Steller sea lion nutrition in Commander Islands (Barabash-Nikifirov, 1935; Waite, Burkanov 2006).

In total, more than 100 prey items have been identified in Steller sea lion diet over its range (Attachment 1) (Calkins, Pitcher 1982; McKenzie, Wynne 2008; Trites, Calkins 2008; Trites et al., 2007; Sinclair, Zeppelin 2002; Merrick et al., 1997; Waite, Burkanov 2006; Waite et al., 2012a, 20012b; Womble, Sigler 2006; Riemer et al., 2010; and others), of which only 33 prey items have been identified near the Asia coast (Waite, Burkanov 2006; Waite et al., 2012). Possibly, the Steller sea lion diet in this area is represented fragmentarily due to a small number of writings on this issue (Waite, Burkanov 2006; Waite et al., 2012a, 20012b).

The most important prey items found all over the Steller sea lion range (identified in more than 30% of analyzed samples) are Pacific sand lance (Ammodytes hexapterus), arrowtooth halibut (Atheresthes stomias), cephalopod mollusks (Cephalopoda), herring (Clupea pallasii), anchovies (Engraulis sp.), cod (Gadus macrocephalus), capelin (Mallotus villosus), salmons (Oncorhynchus sp.), greenling (Pleurogrammus monopterygius), skates (Raja sp.), rockfish (Sebastes sp.), Northern lampfish (Stenobrachius leucopsarus), Alaska pollock (Theragra chalcogramma), sculpins (Cottidae).

Steller sea lions hunt individually or in groups of 2 to 4 individuals with a maximum up to 12 individuals (Gentry 1970). They leave for hunting mostly in the evening and return in the morning. Hunting takes place in the dark time – in the evening, at night and in the early morning (Merrick, Loughlin 1997; Loughlin et al., 2003). When hunting, Steller sea lions purposefully move to the most likely locations where prey may aggregate (Lander et al., 2010). They hunt actively and, as a rule, non-selectively and don't hide in ambush. Roughly half of encounters with fish ends in its capture (Burkanov et al., 2011; Olivier et al., 2009a, 2009b). Steller sea lions sometimes feed on warm-blooded animals – true seals, fur seals and birds. Still, this is rather exception than a rule (Tikhomirov 1964; Gentry, Johnson 1981; Womble, Conlon 2010). The most important item in Steller sea lion diet is pollock (Merrick, Calkins 1996). Such mass use of pollock for food is probably explained by its domination in shelf ichthyocenoses where its percentage may reach 95-98% in some areas (Shuntov et al., 1993).

### 2.2.2. Steller sea lion diet in the Sea of Okhotsk

**Northern part of the Sea of Okhotsk**: The first data on Steller sea lion diet in the northern part of SOO are contained in a paper by Nikulin (1937). Steller sea lion hunting was organized from ships in Iona Island and Yamsky Islands in 1930s. The composition of its diet was identified visually by cutting open stomachs of captured animals. It was mentioned that pollock remnants were found in these stomachs (Nikulin, 1937). The author provides no quantitative data. The next and last nutritional survey of Steller sea lion in SOO was performed 70 years later – in the early 2000s (Table 4).

Fecal samples were collected in the Sea of Okhotsk at Steller sea lion rookeries on Iona Island (n=156) and Yamsky Islands (n=60) during the breeding period (June – July). In this area and in this season, the Steller sea lion diet was dominated by herring, pollock, salmons, sculpins (Waite, Burkanov 2006). A particular feature of this diet's composition was significant dominance of herring which is rarely found in samples collected at other rookeries on the Asian coast.

Table 3. Frequency of occurrence (FO) of prey items in Steller sea lion feces near the Asian coast, % (source: Waite and Burkanov, 2006).

| Prey item | Northern part of Kamchatka Peninsula | Southern part of Kamchatka Peninsula | North Kurils (non-breeding) | North Kurils (breeding) | South Kurils | Northern part of SOO | Waters of Russian Far East |
|---|---|---|---|---|---|---|---|
| **Ammodytes hexapterus*** | **31.4** | **95.2** | **1.9** | **2.4** | **29.6** | **0.5** | **10.6** |
| Cephalopoda | 6.6 | 4.8 | 8.2 | 20.9 | 21.6 | 14.9 | 14.2 |
| **Clupea pallasii** | **0.9** | **0** | **0.2** | **2.0** | **0.8** | **67.7** | **9.2** |
| **Cottidae** | **53.1** | **92.9** | **8.6** | **10.1** | **76.8** | **25.4** | **25.7** |
| **Engraulis sp.** | **0** | **0** | **0.2** | **0** | **50.4** | **2.0** | **4.2** |
| Eumicrotremus sp. | 1.3 | 2.4 | 2.1 | 3.6 | 0.8 | 0.5 | 2.4 |
| **Gadidae** | **1.3** | **42.9** | **0.4** | **0.2** | **6.4** | **1.0** | **2.1** |
| **Gadus macrocephalus** | **11.5** | **2.4** | **1.3** | **4.4** | **41.6** | **1.5** | **6.9** |
| Gasterosteidae | 17.7 | 14.3 | 0.2 | 1.6 | 0 | 0 | 3.4 |
| Hexagrammidae | 7.5 | 7.1 | 2.9 | 3.8 | 8.8 | 0 | 3.1 |
| Leuroglossus schmidti | 0 | 0 | 1.3 | 20.9 | 0 | 2.0 | 7.1 |
| Liparidae | 7.1 | 11.9 | 9.5 | 2.6 | 8.8 | 4.0 | 7.1 |
| **Mallotus villosus** | **35** | **38.1** | **0** | **2.2** | **0** | **0.5** | **6.6** |
| Myctophidae | 2.2 | 0 | 0.8 | 2.8 | 0 | 1.0 | 1.6 |
| **Oncorhynchus sp.** | **14.6** | **0** | **10.7** | **60.4** | **5.6** | **41.8** | **29.9** |
| Osmerus mordax | 5.3 | 0 | 0 | 0 | 2.4 | 0 | 0.9 |
| Pholididae | 0.4 | 4.8 | 1.7 | 0.2 | 12.8 | 1.5 | 2.1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Pleurogrammus monopterygius** | **69.5** | **4.8** | **98.1** | **58.8** | **27.2** | **0.5** | **65.7** |
| Pleuronectiformes | 11.5 | 16.7 | 0.4 | 1.6 | 5.6 | 2.5 | 3.4 |
| Polychaete | 15.0 | 9.5 | 7.3 | 7.2 | 4.0 | 16.9 | 10.1 |
| Prickleback sp. | 0 | 2.4 | 3.2 | 1.0 | 12.0 | 0.5 | 2.8 |
| Raja sp. | 12.4 | 0 | 0.6 | 1.4 | 6.4 | 1.5 | 3.0 |
| **Theragra chalcogramma** | **62.4** | **23.8** | **6.5** | **38.4** | **14.4** | **65.2** | **32.4** |
| Trichodon trichodon | 8.8 | 2.4 | 1.7 | 0.6 | 0.8 | 0 | 2.2 |

** Prey items with FO > 30% are highlighted in bold; FO – frequency of occurrence*

The second important prey item was pollock. This species was the most frequently registered prey item in other rookeries as well (Table 3). It is interesting that the occurrence of greenling was low although this species together with pollock forms the basis of Steller sea lion diet virtually in all other areas off Asia where Steller sea lions live. A high percentage of herring in Steller sea lion diet during the breeding period may favorably influence successful breeding of animals and survival of young individuals in its population.

**Kuril Islands.** Kuril Islands are a boundary separating SOO from the Pacific Ocean. Nearly all Steller sea lion rookeries in this area face the SOO side or straits between islands (Belkin, 1966). There are several rookeries with few Steller sea lions on the ocean side (Burkanov, Loughlin 2005).

There are two small publications on Steller sea lion nutrition in Kuril Islands in 1960s (Panina, 1966; Perlov, 1975). 149 Steller sea lions were captured in 1963 – 1969 at different rookeries or in the waters adjacent to islands. Their diet was identified visually by examination of non-digested contents of their stomachs. Frequency of occurrence was estimated by the ratio of the number of stomachs containing a particular prey item to the number of all examined stomachs (Table 4).

A small number of species in the diet is explained by inadequate dietary research methods used in those times. The composition of prey items by species was identified visually and only if the food in the stomach was not digested yet. Still, it can be generally stated that the most important prey items in 1960s were pollock and cephalopod mollusks, with sand lance, greenling family representatives and rockfish registered less frequently.

Table 4. Composition of Steller sea lion diet at rookeries of Kuril Islands in 1963–1969 (n=149) (Panina 1966; Perlov 1975)

| Prey item | Frequency of occurrence, % |
|---|---|
| Ammodytes hexapterus | 9.1 |
| Cephalopoda | 31.0 |
| Gonatus magister | 14.4 |
| Gonatus_fabricii | 5.9 |
| Hexagrammidae | 13.7 |
| Ommatostrephes | 7.8 |
| Pleurogrammus monopterygius | 9.1 |
| Sebastes sp. | 9.1 |
| Theragra chalcogramma | 50.6 |

No nutritional studies of Steller sea lion have been performed in the Sea of Okhotsk waters adjacent to Kuril Islands during the next more than 30 years. Several publications were issued already the beginning of the 21st century (Waite, Burkanov 2004; Waite, Burkanov 2006, Waite et al., 2012a, 20012b). The Steller sea lion diet was presented by regions (South and North Kurils) and by rookery importance (breeding and non-breeding). In general, the most important prey items in Kuril Islands were sand lance, sculpins, Japanese anchovy, cod, salmons, greenling and pollock (Table 4). The diet at non-breeding rookeries of North Kurils was markedly dominated by greenling. Other prey items did not play any significant role in the diet. The composition of diets at non-breeding rookeries of North Kurils and South Kurils was different and it differed between breeding rookeries as well. This was reflected in increased importance of some prey items and reduced importance of other prey items. The Steller sea lion diet at breeding rookeries of North Kurils consisted primarily of salmons, greenling, pollock and, in a lesser degree, sculpins, cod, sand lance and Japanese anchovy. The diet in South Kurils was dominated by prey items which were less important in North Kurils, namely: sculpins, Japanese anchovy, cod and sand lance (Fig. 9).

Figure 9. Steller sea lion diet at rookeries of Kuril Islands (shown are O > 30%) (Waite, Burkanov 2006)

**A**-North Kurils, non-breeding rookeries
**B**-North Kurils, breeding rookeries
**C**-South Kurils

The Steller sea lion diet in vicinity of Kuril breeding rookeries consisted of lower-calorie fish species than at breeding rookeries in the northern part of SOO (Table 4). Upon comparing Steller sea lion diets in 1960s and at the beginning of the 21st century, it can be stated that the role of cephalopod mollusks had reduced and that of greenling increased.

### 2.2.3. Seasonal variations of Steller sea lion diet in the Sea of Okhotsk

The issue of seasonal variance of the Steller sea lion diet off the Asian coast remains one of the least studied ones. Only at one rookery (Cape Kozlov, Kamchatka), 93 Steller sea lion fecal samples were collected in the autumn of 2002 (Waite, Burkanov 2006). Researchers stated that the main prey items at the rookery near Cape Kozlov (Kamchatka) during the breeding period in the summer of 2002 were Atka mackerel, pollock and cephalopods, and the autumnal diet consisted mostly of salmons and Pacific sandfish.

The Steller sea lion diet has been much better studied on the American side of its range (Sinclair, Zeppelin 2002, Womble, Sigler 2006, Trites et al., 2007). Sinclair and Zeppelin (Sinclair, Zeppelin 2002) point out at serious regional and seasonal variations of the diet composition. Dietary importance of all prey items except pollock changes in summer and winter periods. Thus, for instance, cod played an important role in the Steller sea lion diet in Alaska and Aleutian Islands in winter but a minor role in summer.

Womble and Sigler (Womble, Sigler 2006) note that the seasonal character of Steller sea lion presence at the rookery on Benjamin Island (Southeast Alaska) is related to fluctuations of herring abundance near this island. As herring abundance in the waters off the island declines in summer, Steller sea lions leave these waters.

Trites et al. (Trites et al., 2007) note that the Steller sea lion diet off Southeast Alaska was dominated by gadids (mostly pollock) in the non-breeding period. Dietary importance of salmons was declining from summer to autumn, and squids and octopuses were more important in the winter diet. Rockfish (Sebastes sp.) were eaten more frequently in summer and were virtually absent in the Steller sea lion diet in the cold season.

Therefore, it can be said for sure that the composition and ratio of the Steller sea lion diet elements vary from season to season (Waite, Burkanov 2006, McKenzie, Wynne 2008). It can be assumed that this is related to seasonal redistribution of fishes which are prey items for Steller sea lion. The seasonal nature of the Steller sea lion diet in SOO has not been studied yet.

### 2.2.4. Methodological specifics of sample collection and analysis in the study of Steller sea lion diet by coprological examination

Coprological examination is currently the main method for studies of the Steller sea lion diet and for reconstruction estimation of the biomass of eaten food. Estimation of the biomass of diet components by this method involves some methodological difficulties. First of all, each fecal sample represents a single act of defecation which may not fully reflect the structure of the diet in a particular feeding trip because animals defecate several times a day or during their stay on the shore. Quantities and weight of feces and, accordingly, quantities of non-digested food remnants accessible to researcher are subject to broad variation. This variance complicates and even makes completely impossible any estimation of the biomass of food eaten by the animal during a day or one feeding trip. This difficulty is somewhat compensated by a number of collected samples. According to Trites and Joy (Trites an dJoy 2005), a minimum number of samples required for credible comparison of the frequency occurrence of prey items between groups being studied (years, months, rookeries, etc.) is 94 samples.

The Steller sea lion diet includes fish of various sizes ranging from 5-10 cm (capelin, sand lance) to 50 cm and more (adult pollock and cod). Most of prey items in the Steller sea lion diet do not exceed 35 cm in length (Trites, Calkins 2008; Sigler et al. 2009) but some fishes reach 70 cm and more (McKenzie & Wynne 2008). Steller sea lion normally swallows its prey whole. When dealing with large items, it tears them into pieces on the water surface (Mathisen et al., 1962). In this situation when the animal tears large fish it is very likely that it eats only soft tissues and solid remnants of fish skeletons (bones, otoliths) do not get into the digestive tract and, therefore, will not be represented in feces. In this case, it is impossible to estimate the share of large fish in the Steller sea lion diet by coprological examination method. Hence, if its diet is dominated by large fish, their content in the diet will be underestimated which may influence both the total estimated biomass of consumed food and species diversity of the diet as a whole.

Depending on the type of prey item, the rate of its passage through the digestive tract is different. Large remnants which are difficult to digest may stay in the digestive tract for several days while small remnants pass in transit within 2-3 days (Harvey, Antonelis 1994; Tollit 2007).

**Conversion factors for reconstruction of frequency of occurrence of consumed prey items**: There are several studies evaluating correlation between the type and size of prey items and probability of their identification in feces (Tollit et al., 2003; 2004, 2007; Joy et al., 2006; Ferenbaugh et al., 2009), some of which address Steller sea lion (Tollit et al., 2003; Tollit et al., 2007). A whole number of fish species most important in the Steller sea lion diet were studied and conversion factors were obtained for them (Table 5). It is seen in Table 6 that, in general, the frequency of occurrence in feces of such large prey items as herring, salmons, greenling, large and mid-size pollock and squids gives us information close to the real diet composition (NCF=0.72-1.85 by otoliths). However, small fishes such as capelin, sand lance and small pollock are heavily underestimated in the Steller sea lion diet (NCF=2.05-7.87) when standard research methods are used.

Table 5. Conversion factors for reconstruction of frequency of occurrence of consumed fishes in the Steller sea lion diet (source: Tollit et al., 2007)

| Prey item | Number of prey items fed during experiment | Mean linear size of prey item (cm) | Otoliths | | Bones | | Otoliths | | Bones | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | % of reconstructed prey items | SD | % of reconstructed prey items | SD | NCF* | CI | NCF | CI |
| Capelin | 1316 | 14.3--14.8 | 12.7 | 8.4 | 13.8 | 9.8 | 7.87 | 4.98--18.74 | 7.26 | 4..47--19.19 |
| Sand lance | 5593 | 10.3--11.2 | 17.4 | 14.2 | 19.7 | 11 | 5.75 | 3.67--13.23 | 5.09 | 3.66--8.28 |
| Herring | 1268 | 19.6--19.5 | 28.7 | 14.4 | 56.7 | 13.9 | 3.48 | 2.54--5.55 | 1.76 | 1.49--2.16 |
| Salmons | 132 | 28.8--44 | 21.9 | 2.7 | 62.1 | 34.8 | 4.57 | 4.23--4.97 | 1.61 | 1.18--2.54 |
| Coho *Oncorhynchus kisutch* | 85 | 28.8--31.8 | 22.5 | 3.5 | 54.2 | 48.3 | 4.44 | 3.86--5.24 | 1.85 | 0.98--14.56 |
| Salmons | 47 | 39.7--44 | 20.3 | 0.4 | 69.9 | 32.4 | 4.93 | 4.84--5.01 | 1.43 | 1.02--2.41 |
| Greenling | 94 | 33.4--36.9 | 38 | 20.2 | 55 | 23.4 | 2.63 | 1.95--4.03 | 1.82 | 1.42--2.52 |
| Pollock | 460 | 13.4--15.4 | 45.7 | 28.9 | 48.8 | 25.1 | 2.19 | 1.28--7.69 | 2.05 | 1.3--4.9 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pollock | 701 | 26.9--29.6 | 67.5 | 0 | 76.9 | 0 | 1.48 | 1.48--1.48 | 1.3 | 1.3-1.3 |
| Pollock | 53 | 36.3--37 | 93.2 | 9.6 | 138.3 | 9.2 | 1.07 | 0.96--1.21 | 0.72 | 0.67--0.75 |
| Squids | 90 | 36-43 | - | - | 97.8 | 1.9 | - | - | 1.02 | 1-1.05 |

NCF* - conversion factor for FO (Frequency of Occurrence)

### 2.2.5. Seasonal and sex/age differences in Steller sea lion daily food requirement

According to the energetics-based model of the Steller sea lion daily food requirement, an adult male needs about 25-40 kg of fish per day and an adult female needs 10-20 kg (Winship et al., 2002; Winship, Trites 2003). The limit of daily food consumption is found in the range of 16-20% of body weight (Rosen et al., 2006). The range of variation depends on the energy value of prey items and proportion of their content in the diet. Depending on the season, diet composition, age and breeding status of an individual, these data may vary quite broadly (Fig. 10) (Winship 2000).

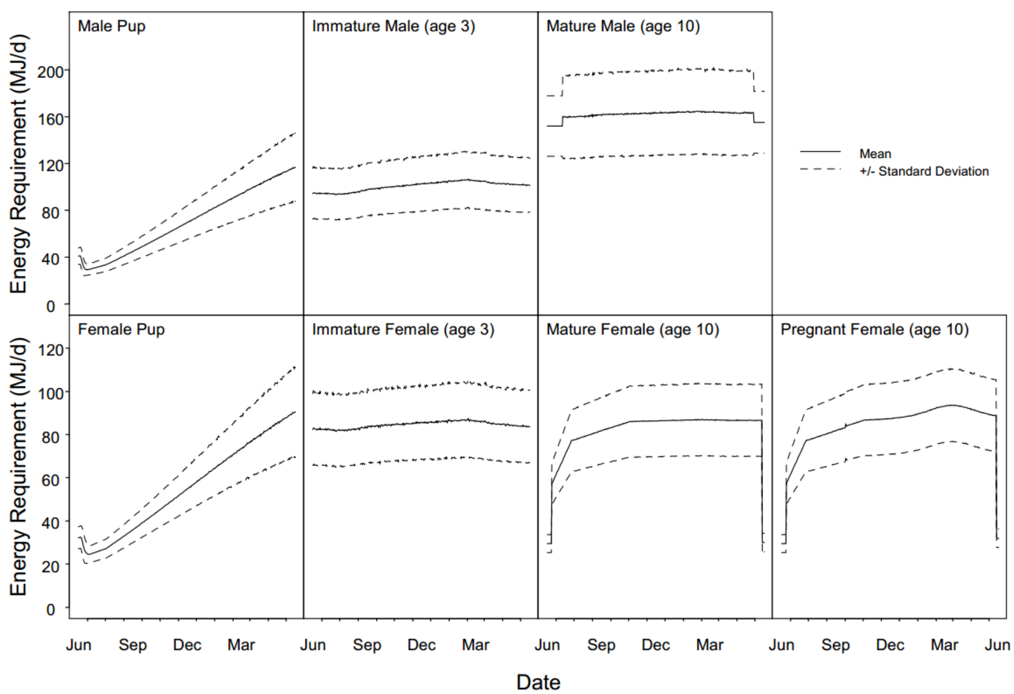


Figure 10. Steller sea lion daily food requirement in different seasons depending on the breeding status and age (Winship 2000).

Adult females need more food in late winter and in spring (Winship 2000). The embryo grows most intensively in this period as the female continues nourishing the last year's pup with milk. Young individuals may feed both on fish and maternal milk. Young non-breeding females need less food than breeding individuals. In general, it can be assumed that the daily food requirement increases for females from autumn (completion of the latent stage of embryonic development) till spring and early summer (when females give birth to offspring). The peak of consumption for males is likely to occur in winter (the coldest season requiring a maximum of energy to maintain physiological processes) and the minimum of consumption – in summer. However, breeding males that do not feed in the first half of summer are likely to feed intensively after the completion of the harem period.

Thus, we need to have data on the demographic composition of the Steller sea lion population and its variation during a yearly life cycle in order to obtain a credible model for estimation of the biomass being consumed by this animal in SOO. Due to seasonal migrations, the demographic composition of the species in SOO may change greatly during the year.

### 2.2.6. Reconstruction of prey biomass

The issue of food consumption by marine mammal animals has been given much attention (Makhnyr et al., 1984; Burkanov 1989; Härkönen, Heide-Jorgensen 1991; Markussen, Oritsland 1991; Ryg, Oritsland 1991; Olesiuk 1993; Mohn, Bowen 1996; and many others). There are several papers on the estimated rate of food consumption by Steller sea lion on the American coast and in the Aleutians (Winship 2000; Winship et al., 2002; Winship, Trites 2003).

This issue was studied in greatest detail by Winship (Winship (2000) on the example of the Gulf of Alaska and Aleutian Islands. In his dissertation, he presents a multi-component model for evaluation of the biomass of prey items which makes provision for a whole set of conditions affecting consumed biomass of particular diet components. In general, the most important conditions addressed in his estimations are as follows:

- diet composition and structure;
- level of Steller sea lion energy requirement depending on breeding status, age, sex;
- energy value of diet components.

Provision was also made for many other input conditions such as digestion efficiency, metabolism of individuals, reconstruction of the diet structure by various methods, biomass of one-time consumption, proportion of time spent at sea, seasonal variation of the demographic composition of the Steller sea lion population in the study area as well as seasonal variance of above parameters. Brief results of simulations based on this model are presented in Table 7.

Total food consumption by Steller sea lion in the waters of Alaska and Aleutian Islands was estimated at 522,500 tons (Fig. 11). Consumption per 1 individual during the breeding season was estimated at 5,763–6,455 kg.

Table 6. Food consumption by Steller sea lion off the North American coast and in Aleutian Islands in 1990s (source: Winship 2000).

| Region | Food consumption by all individuals (thsd tons) | | | Food consumption per 1 individual during breeding season (kg) | |
|---|---|---|---|---|---|
| | Mean | S.D. | C.V. | Mean | S.D. |
| South Alaska | 157.9 | 29.1 | 0.18 | 5763 | 1061 |
| Gulf of Alaska | 115.0 | 21.0 | 0.18 | 5982 | 1090 |
| Eastern part of Aleutian Islands | 88.0 | 15.9 | 0.18 | 5813 | 1053 |
| Central part of Aleutian Islands 1 | 49.0 | 8.95 | 0.18 | 5843 | 1066 |
| Central part of Aleutian Islands 2 | 70.0 | 13.7 | 0.2 | 6257 | 1229 |
| Central part of Aleutian Islands 3 | 14.8 | 3.1 | 0.21 | 6455 | 1349 |
| Western part of Aleutian Islands | 27.8 | 5.6 | 0.2 | 6310 | 1275 |

On the whole, the Steller sea lion food requirement is at its lowest in summer and at its highest in winter and in spring. The daily food requirement of a female nourishing its pup is 70% higher than for a female having no pup. Differences in food consumption between regions (Fig. 11) are explained by different diet composition, energy value, abundance, breeding and sex-age composition of Steller sea lions in different regions. Steller sea lion nutrition produced insignificant effects on the level of pollock natural mortality but was the main cause of greenling natural mortality.

As all mathematical models, Winship's model represents an abstraction of a real situation and it is rather difficult to apply its results to particular regions or prey items. Be that as it may, there are no alternative competitive methods for evaluation of food consumption by Steller sea lion. This issue is totally unexplored in Russian waters. This is explained first of all by lack of basic information for model development – we don't know Steller sea lion seasonal development and its sex-age composition in different areas of the Russian Far East nor seasonal dynamic of its nutrition.

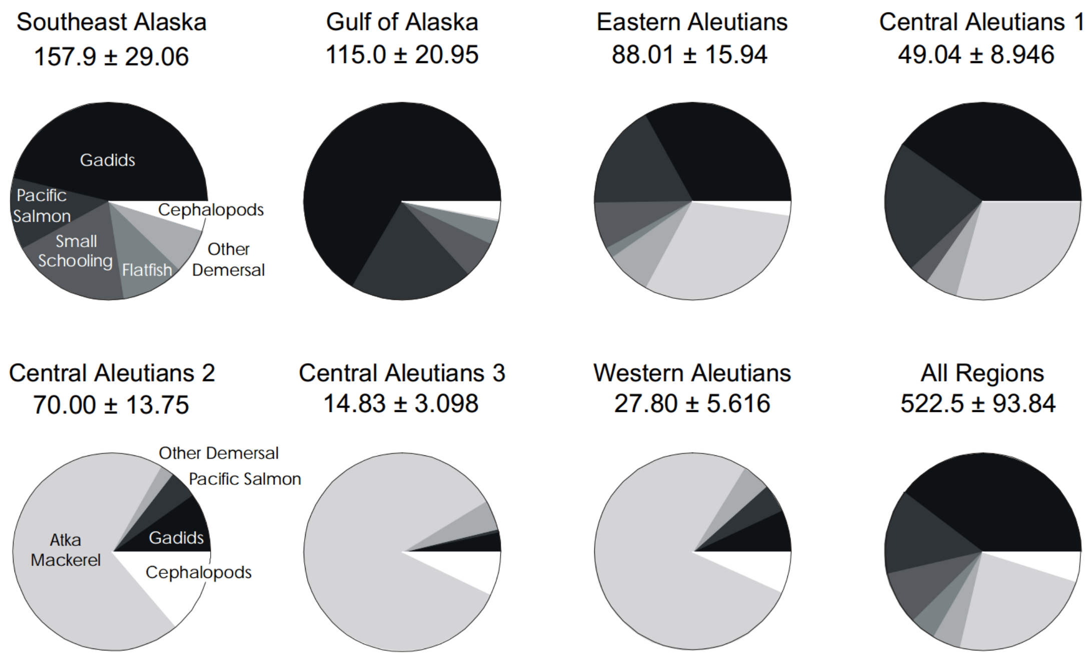


Figure 11. Yearly biomass (mean ± SD, thsd tons) of consumption of various fish species which are prey items for Steller sea lion in the waters of the Gulf of Alaska and Aleutian Islands (Winship 2000)

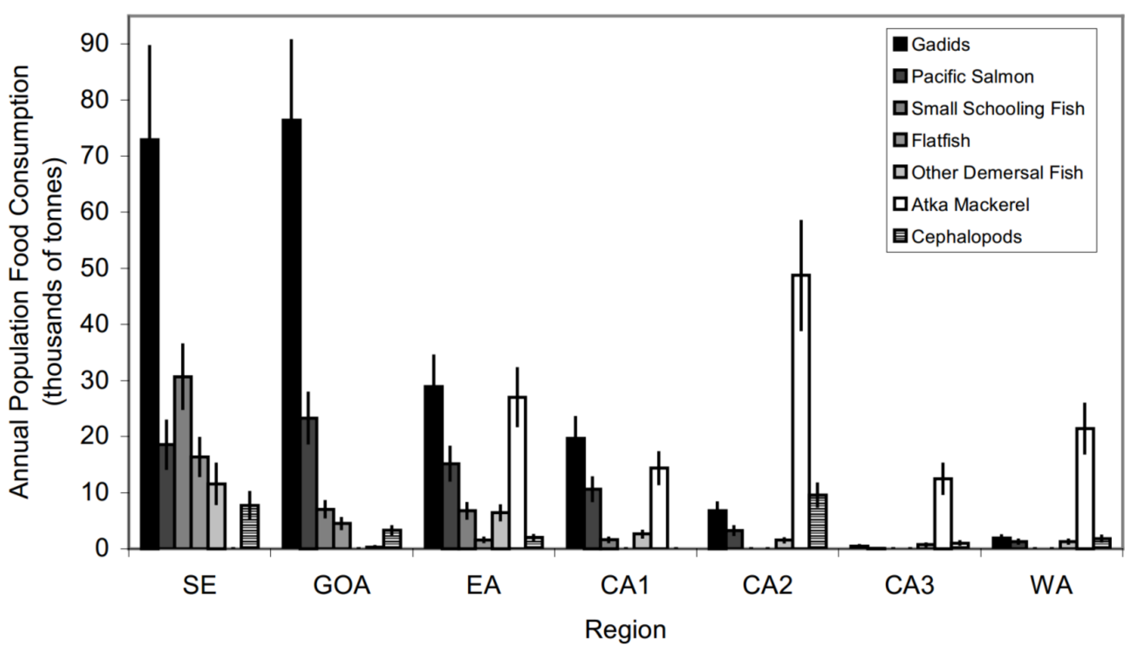

Figure 12. Biomass of food consumption by Steller sea lion in the Gulf of Alaska and Aleutian Islands in 1990s (Winship 2000)

In this connection, it is necessary to undertake studies to obtain basic model parameters for an assessment of food availability in SOO for Steller sea lion and an assessment of pollock trawl fishery impact on its population in SOO.

**Conclusion**

- Steller sea lion lives round the year over the entire SOO basin but its most important habitats are the coastal waters off the northern coast between Lisyanskogo Peninsula and Yamsky Islands (including Shelikhov Bay and the area around Iona Island and Kashevarov Bank), East Sakahlin and Kuril Islands;

- There are 8 large breeding rookeries in SOO located on Tuleniy I., Iona I., Matykil I. (Yamsky Islands), Brat Chirpoyev I., islands in Srednego Strait, Raikoke I., Kamennyie Lovushki Islands and Antsiferova I.;

- There are more than 50 non-breeding rookeries in SOO at which Steller sea lion hauls out for rest during feeding and seasonal migrations and nomadic migrations;

- According to observation data on encounters with marked animals, Steller sea lions concentrate in vicinity of natal breeding rookeries during the breeding season and after its completion widely spread both within and outside the SOO basin traveling over hundreds and even thousands of kilometers; Steller sea lions born and marked at SOO rookeries were found near the Japanese coast, in the Sea of Japan, off East Kamchatka, in Commander Islands and in the western part of the Bering Sea up to the Bering Strait;

- There are 17-18,000 Steller sea lions present at SOO rookeries during the breeding season, of which 6.0-6.5 thousand individuals are newborn pups and 11.5-12.0 thousand are young and adult animals;

- Steller sea lion exhibits a well marked seasonal dynamic of abundance and significant seasonal variance of its age and sex structure at SOO rookeries, and seasonal redistribution of animals between SOO areas; however, this aspect of the Steller sea lion biology remains completely unexplored;

- Steller sea lion of SOO belongs to the Asian population; the intra-population structure of Steller sea lion in SOO is not homogeneous; according to observation data on marked animals, it was found that there are at least two groups largely isolated in the breeding period – Kuril and Okhotsk-Sakhalin groups; there is a hypothesis about a high degree of reproductive isolation of the third grouping in SOO which breeds on Yamsky Islands;

- Studies using advanced methods of mitochondrial and nuclear DNA analysis should be undertaken to obtain full and credible data on the intra-population structure of Steller sea lion in SOO;

- Being a deuteroaquatic animal, Steller sea lion has adapted to life in an aquatic environment less successfully than Northern fur seal, a closely related species; it cannot stay long without a firm substrate used for rest and breeding; it features significant delay in development of diving capabilities (limitations in diving depth and duration) which restrict its ability to live in the high seas; in this connection, its main habitats are coastal waters down to 200 m deep; its distribution in SOO becomes wider in winter due to floating ice used by animals for rest;

- Because of marked sexual dimorphism, different age and sex groups are differently adapted to diving and living in a cold climate; the best adapted are adult males and the least adapted are juvenile animals; females occupy an intermediate position; due to lactation and pregnancy, breeding females have the highest food requirement in winter compared with other age and sex groups;

- As different age and sex groups of Steller sea lion have different physiological capabilities for feeding and different energy consumption during a yearly cycle of life in SOO, it is extremely important to obtain detailed and accurate data on the nature of Steller sea lion its distribution in SOO, its sex and age composition and abundance in different seasons in order to estimate food availability for this animal and assess pollock trawl fishery effects on its population in SOO;

- More than 100 prey items have been identified in the Steller sea lion diet; in nutritional terms, Steller sea lion is a non-selective (opportunistic) predator feeding on small schooling marine animals, mostly fish and cephalopods; birds and marine mammals were also registered in its diet but they are occasional prey items;

- Only 33 prey items have been identified in the Steller sea lion diet near the Asian coast, of which 20 items in SOO; availably dietary data on this animal do not reflect in full even the species composition of its diet in the breeding period; Steller sea lion nutrition in SOO in other seasons is completely unexplored; this is the least studied aspect of its biology and ecology in Russian waters;

- Coprological examination widely used in dietary studies of Steller sea lion has a number of essential limitations in estimation of the biomass of consumed food; in order to obtain more complete data on Steller sea lion nutrition and feeding behavior in SOO, it is important to use also other state-of-the-art methods for nutritional studies of animals such as telemetric sensors recording diving, prey capture, degree and rate of stomach filling with food and direct video registration of animal behavior during prey capturing;

- The most important prey items (identified in more than 30% of analyzed samples) for Steller sea lions are Alaska pollock (Theragra chalcogramma), greenling (Pleurogrammus monopterygius), salmons (Oncorhynchus sp.), herring (Clupea pallasii), Pacific sand lance (Ammodytes hexapterus), arrowtooth halibut (Atheresthes stomias), cephalopod mollusks (Cephalopoda), anchovies (Engraulis sp.), cod (Gadus macrocephalus), capelin (Mallotus villosus), skates (Raja sp.), rockfish (Sebastes sp.), Northern lampfish (Stenobrachius leucopsarus) and sculpins (Cottidae).

- The high frequency of pollock occurrence in the Steller sea lion diet is probably explained by dominance of this species in shelf ichthyocenoses;

- According to energy consumption calculations, the daily food requirement of a Steller sea lion adult male is about 25-40 kg of fish and that of an adult female is 10-20 kg; the limit of daily food consumption is approx. 16-20% of body weight; there is significant seasonal and age-sex variability of the daily food requirement, hence, full data on Steller sea lion abundance, age and sex composition in OM and seasonal variation of these parameters are needed in addition to full data on the structure of its diet in order to perform credible estimations of the biomass of food required for Steller sea lion nutrition in SOO.

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ATTACHMENTS

ATTACHMENT 1. List of Steller sea lion prey items according to published materials

| **Prey items** | **SO** | **NKnB** | **NKB** | **SK** | **SEK** | **WBS** | **FES** |
|---|---|---|---|---|---|---|---|
| **Family Alepisauridae:** | | | | | | | |
| Longnose lancetfish (Alepisaurus ferox) | | | | | | | |
| **Family Anoplopomatidae:** | | | | | | | |
| Sable fish (Anopoploma fimbria) | | | | | | | |
| **Family Engraulidae:** | X | X | | X | | | X |
| Californian anchovy (Engraulis mordax) | | | | | | | |
| **Family Bathymasteridae:** | | | | | | | |
| Blue-eyed searcher (Bathymaster signatus) | | | | | | | |
| Northern ronquil (Ronquilus jordani) | | | | | | | |
| **Family Zoarcidae:** | | | | | | | |
| Marbled eelpout (Lycodes raridens) | | | | | | | |
| **Family Paralichthyidae:** | | | | | | | |
| **Family Hemitripteridae:** | | | | | | | |
| Sea raven (Hemitripterus villosus) | | | | | | | |
| **Family Trichodontidae:** | | | | | | | |
| Pacific sandfish (Trichodon trichodon) | | X | X | X | X | X | X |
| **Family Aulorhynchidae:** | | | | | | | |
| Tube-snout (Aulorhynchus flavidus) | | | | | | | |
| **Family Zaproridae:** | | | | | | | |
| Prowfish (Zaprora silensus) | | | | | | | |
| **Family Anarhichadidae:** | | | | | | | |
| Bering wolffish (Anarhichas orientalis) | | | | | | | |
| Wolf eel (Anarrichthys ocellatus) | | | | | | | |
| **Family Pleuronectiformes:** | X | X | X | X | X | X | X |
| Dover sole (Microstomus pacificus) | | | | | | | |
| Arrowtooth flounder (Atheresthes stomias) | | | | | | | |
| Rock flounder (Lepidopsetta bilineata) | | | | | | | |
| Rex sole (Glyptocephalus zachirus) | | | | | | | |
| Alaska plaice (Pleuronectes quadritubercul) | | | | | | | |
| Yellow-fin sole (Limanda aspera) | | | | | | | |
| Starry flounder (Platichthys stellatus) | | | | | | | |
| Butter sole (Isopsetta isolepis) | | | | | | | |
| English sole (Parophrys vetulus) | | | | | | | |
| Pacific sand sole (Psettichthys melanostictus) | | | | | | | |
| Bering flounder (Hippoglossoides robustus) | | | | | | | |
| Pacific halibut (Hippoglossus stenolepis) | | | | | | | |
| Flathead sole (Hippoglossoides elassodon) | | | | | | | |
| Longhead dab (Limanda proboscidea) | | | | | | | |
| Slender sole (Lyopsetta exilis) | | | | | | | |

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|---|---|---|---|---|---|---|---|
| **Family Gasterosteidae:** | | X | X | | X | X | X |
| Three-spined stickleback (Gasterosteus aculeatus) | | | | | | | |
| **Family Osmeridae:** | | | | | | | |
| Surf smelt (Hypomesus pretiosus) | | | | | | | |
| Pacific capelin (Mallotus villosus) | X | | X | | X | X | X |
| Eulachon (Thaleichthys pacificus) | | | | | | | |
| Rainbow smelt (Osmerus mordax) | | | | X | | X | X |
| **Family Scylinorhinidae:** | | | | | | | |
| **Family Cyclopteridae:** | | | | | | | |
| Lumpsuckers (Eumicrotremus sp.) | X | X | X | X | X | X | X |
| Smooth lumpsucker (Aptocyclus ventricosus) | | | | | | | |
| **Family Liparididae:** | X | X | X | X | X | X | X |
| **Family Agonidae:** | | | | | | | |
| Sturgeon poacher (Podothecus acipenserinus) | | | | | | | |
| **Family Salmonidae:** | | | | | | | |
| Pacific salmons (Oncorhynchus spp.) | X | X | X | X | | X | X |
| **Family Microstomatidae:** | | | | | | | |
| Northern smoothtongue (Leuroglossus schmidti) | X | X | X | | | | X |
| **Family Pholididae:** | X | X | X | X | X | X | X |
| Penpoint gunnel (Apodichthys flavidus) | | | | | | | |
| Crescent gunnel (Pholis laeta) | | | | | | | |
| **Family Myxinidae:** | | | | | | | |
| Pacific hagfish (Eptatretus stoutii) | | | | | | | |
| **Family Petromyzontidae:** | | | | | | | |
| Lampreys (Lampetra spp.) | | | | | | | |
| **Family Moridae:** | | | | | | | |
| **Family Syngnathidae:** | | | | | | | |
| Bay pipefish (Syngnathus leptorhynchus) | | | | | | | |
| **Family Sebastidae:** | | | | | | | |
| Rockfishes (Sebastes sp.) | | | | | | | |
| **Family Gobiesocidae:** | | | | | | | |
| Northern clingfish (Gobiesox maeandricus) | | | | | | | |
| **Family Ophidiidae:** | | | | | | | |
| Spotted cusk-eel (Chilara taylori) | | | | | | | |
| **Family Ammodytidae:** | | | | | | | |
| Pacific sand lance (Ammodytes hexapterus) | X | X | X | X | X | X | X |
| **Family Cottidae:** | X | X | X | X | X | X | X |
| Warty sculpin (Myoxocephalus verrucosus) | | | | | | | |
| Warty sculpin (Myoxocephalus verrucosus) | | | | | | | |
| Crested sculpin (Blepsias bilobus) | | | | | | | |
| Shortmast sculpin (Nautichthys robustus) | | | | | | | |
| Shorthorn sculpin (Myxocephalus scorpius) | | | | | | | |
| Great sculpin (Myoxocephalus polyacanthocepha) | | | | | | | |
| Thread sculpin (Gymnocanthus pistilliger) | | | | | | | |
| Irish lords (Hemilepidotus sp.) | | | | | | | |

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|---|---|---|---|---|---|---|---|
| Tidepool sculpin (Oligocottus maculosus) | | | | | | | |
| Prickly sculpin (Cottus asper) | | | | | | | |
| Northern sculpin (Icelinus borealis) | | | | | | | |
| Blacknose sculpin (Icelus canaliculatus) | | | | | | | |
| **Family Myctophidae:** | X | X | X | | | X | X |
| Bigeye lanternfish (Protomyctophum thompsoni) | | | | | | | |
| Northern lampfish (Stenobrachius leucopsarus) | | | | | | | |
| Lanternfish (Stenobrachius sp.) | | | | | | | |
| **Family Clupeidae:** | | | | | | | |
| Pacific herring (Clupea pallasi) | X | X | X | X | | X | X |
| Pacific sardine (Sardinops sagax) | | | | | | | |
| American shad (Alosa sapidissima) | | | | | | | |
| **Family Scombridae:** | | | | | | | |
| Pacific mackerel (Scomber japonicus) | | | | | | | |
| **Family Carangidae:** | | | | | | | |
| Pacific jack mackerel (Trachurus symmetricus) | | | | | | | |
| **Family Stichaeidae/Cottidae:** | X | X | X | X | X | | X |
| Shortspine thornyhead (Sebastolobus alascanus) | | | | | | | |
| Stone cockscomb (Alectrias alectrolophus) | | | | | | | |
| Slender eelblenny (Lumpenus fabricii) | | | | | | | |
| Decorated warbonnet (Chirolophis decoratus) | | | | | | | |
| High cockscomb (Anoplarchus purpurescens) | | | | | | | |
| Arctic shanny (Stichaeus punctatus) | | | | | | | |
| Black prickleback (Xiphister atropurpures) | | | | | | | |
| Rock prickleback (Xiphister mucosus) | | | | | | | |
| Snake prickleback (Lumpenus sagitta) | | | | | | | |
| **Family Hexagrammidae:** | | | | | | | |
| Kelp greenling (Hexagrammos decagrammus) | | | | | | | |
| Alaska greenling (Hexagrammos octogrammus) | | | | | | | |
| Rock greenling (Hexagrammos lagocephalus) | | | | | | | |
| Lingcod (Ophiodon elongatus) | | | | | | | |
| White-spotted greenling (Hexagrammos stelleri) | | | | | | | |
| Atka mackerel (Pleurogrammus monopterygius) | X | X | X | X | X | X | X |
| **Family Gadidae:** | | | | | | | |
| Pacific cod (Gadus macrocephalus) | X | X | X | X | X | X | X |
| Alaska pollock (Theragra chalcogramma) | X | X | X | X | X | X | X |
| North Pacific hake (Merluccius productus) | | | | | | | |
| Saffron cod (Eleginus gracilis) | | | | | | | |
| Pacific tomcod (Microgadus proximus) | | | | | | | |
| **Class Chondrichthyes:** | | | | | | | |
| Spiny dogfish (Squalus acanthias) | | | | | | | |
| Skates (Raja sp.) | X | X | X | X | | X | X |
| **Family Embiotocidae:** | | | | | | | |
| **Class Cephalopoda:** | X | X | X | X | X | X | X |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Giant Pacific octopus (Enteroctopus dofleini) | | | | | | | |
| Pelagic octopus (Japatella diaphana) | | | | | | | |
| Oceanic squid (Chiroteuthis calyx) | | | | | | | |
| Stubby squid (Rossia pacifica) | | | | | | | |
| Octopuses (Octopus sp.) | | | | | | | |
| Squids (Squid sp.) | | | | | | | |
| **Class Polychaeta:** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **Class Birds/Mammals (Aves/Mammalia):** | | | | | | | **X** |

* SO – Sea of Okhotsk; NKnB – North Kurils, non-breeding rookeries; NKB – North Kurils, breeding rookeries; SK – South Kurils; SEK – Southeast Kamchatka; WBS – northern coast of Kamchatka or West Bering Sea; FES – Far Eastern seas as a whole

ATTACHMENT 2. Biological and ecological features of Steller sea lion with respect to its adaptation to an aquatic way of life (based on published materials)

| **Features** | **Consequence** | **Source of information** |
|---|---|---|
| **1** | **2** | **3** |
| Steller sea lion is unable to rest on water and regularly has to haul out to rookeries or other rest sites (ice, floating navigation aids, buoys, etc.) | Steller sea lions are unevenly distributed over the sea | Merrick, Loughlin 1997; Brandon 2000; Trites, Porter 2002; Milette, Trites 2003; NMFS 2008. |
| | The most important feeding areas are waters near rookeries or other rest sites | Merrick, Loughlin 1997; Brandon 2000; Trites, Porter 2002; Milette, Trites 2003; NMFS 2008; Sinclair, Zeppelin 2002. |
| | Steller sea lion is unable to lead a pelagic life for such a long time as Northern fur seal | Merrick, Loughlin 1997; Loughlin et al. 1998; Loughlin et al. 2003; Raum-Suryan et al. 2004; Fadely et al. 2005; Rehberg 2005; Briggs et al. 2004 |
| Due to physiological limitations, Steller sea lion is unable to make lengthy and deep dives when feeding | Steller sea lion normally feeds at depths 10-50 m and seldom dives down to more than 250 m | Merrick, Loughlin 1997; Loughlin et al. 1998; Loughlin et al. 2003; Pitcher et al. 2005; Fadely et al. 2005; Rehberg 2005; Briggs et al. 2004; Olivier et al. 2011 |
| | Duration of underwater stay is within 2 minutes on average, seldom (less than 10%) exceeds 5-6 minutes | |
| | Large aggregations of prey items play an important role in feeding | Bredesen et al. 2006; Womble, Sigler 2006; Winter et al 2009; Olivier et al. 2011. |
| Steller sea lion uses particular rookeries for breeding during many decades; however, it is less attached to a particular area in winter | During breeding period, a significant portion of its population concentrates and feeds near breeding rookeries | Merrick, Loughlin 1997; Loughlin et al. 1998; Loughlin et al. 2003; Raum-Suryan et al. 2004; Fadely et al. 2005; Rehberg 2005; Merrick et al. 1997 |
| | Steller sea lion distribution significantly expands during non-breeding period of its yearly life cycle | Trites et al. 2006; Zagrebin; Litovka 2004; Vazhenina 2004; Nikulin, Vertyankin 2008; Trites, Porter 2002 |

| 1 | 2 | 3 |
|---|---|---|
| Steller sea lion is a non-selective predator | Its diet consists of mass fish species living in immediate vicinity of its rookeries or other rest sites (ice) | Waite, Burkanov 2006; Burkanov et al. 2011; Calkins, Pitcher 1982; Merrick et al. 1997; McKenzie and Wynne 2008; Sinclair and Zeppelin 2002; Trites and Calkins 2008; Trites et al. 2007; Womble, Sigler 2006; Womble et al 2009. |
| | Normally, only 2 to 5 most mass fish or cephalopod species are its main prey items depending on the region | |
| | Main prey items are subject to seasonal variability | Waite, Burkanov 2006; Sinclair, Zeppelin 2002; Womble, Sigler 2006; Trites et al. 2007; Womble et al 2009. |
| Most mass prey items of Steller sea lion diet on Asian coast in summer migrate to large depths in winter | There is high probability that in winter Steller sea lion may meet difficulty in prey search and capture | Waite, Burkanov 2006; Shuntov, Bocharov 2005; Moyiseyev et al. 2000; Fadeyev 1985; Zolotov 1986; Shuntov et al. 1993; Velikanov 1986; Lapko 1994; Melnikov, Khudya 1998; Naumenko 1990; Tokranov, Orlov 2012; Tokranov 1981; Tokranov 1986; Khudya 1985; and many others |
| Steller sea lion has a prolonged period of physiological development of its diving depth potential which forms in full only by 2-3 years of age | Prolonged period of milk feeding (till 2-3 years of age) which probably may vary depending on food accessibility for young animals | Sandegren 1970; Calkins, Pitcher 1982; Trites et al. 2006; Mamayev, Burkanov 2004; Boness, Bowen 1996. |
| | Young individuals are most susceptible to nutritional stress (food shortage) because of physiological diving limitations | Merrick, Loughlin 1997; Loughlin et al. 1998; Loughlin et al. 2003; Pitcher et al. 2005; Fadely et al. 2005; Rehberg 2005; Richmond et al. 2004, 2006 |
| Clearly marked sexual dimorphism | Males are less susceptible to adverse environmental factors and more adapted to life in severe winter conditions of northern SOO | Pitcher, Calkins 1982; Loughlin et al. 1987; Winship et al., 2000; Trites, Calkins 2008. |
| | Probably, it is much more difficult for pregnant females nourishing yearlings to live in SOO in winter, particularly in late pregnancy period | Calkins, Pitcher, 1982; Boness, Bowen 1996; Pitcher et al. 1998. |
| 1 | 2 | 3 |
| Energy requirement for life support is higher at Steller sea lions in winter than in summer | Steller sea lion requires more food in winter season | Svärd et al. 2009; Jeanniard et al. 2009; Calkins, Pitcher, 1982; Boness, Bowen 1996; Pitcher et al. 1998; Winship 2000; Winship et al. 2002; |

| | | |
|---|---|---|
| | | Winship, Trites 2003 |
| All features taken together | Local aggregations of prey items, ambient air temperature and availability of nearby rest sites (rookeries, marine facilities, floating ice, etc.) may play a significant role in Steller sea lion distribution in winter | Sinclair, Zeppelin 2002; Womble, Sigler 2006; Trites et al. 2007 |
| | In winter, Steller sea lion spends more time at sea, dives deeper and is distributed more widely than in summer | Raum-Suryan et al. 2004; Trites et al. 2006; Merrick, Loughlin 1997; Loughlin et al. 1998; Loughlin et al. 2003; Pitcher et al. 2005; Fadely et al. 2005; Rehberg 2005. |
| | The most vulnerable element of the Steller sea lion population is juvenile individuals | Sandegren 1970; Calkins, Pitcher 1982; Trites et al. 2006; Mamayev, Burkanov 2004; Boness, Bowen 1996; Merrick, Loughlin 1997; Loughlin et al. 1998; Loughlin et al. 2003; Pitcher et al. 2005; Fadely et al. 2005; Rehberg 2005; Pascual, Adkison 1994; York 1994; Richmond et al. 2004, 2006 |