Origin and Abundance of Steller Sea Lions (Eumetopias jubatus) in Winter Haulout at Benten-Jima Rock Off Cape Soya, Hokkaido, Japan between 2012–2017

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Original paper

Origin and abundance of Steller sea lions (*Eumetopias jubatus*) in winter haulout at Benten-Jima Rock off Cape Soya, Hokkaido, Japan between 2012–2017

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Abstract. Benten-Jima Rock, located off Cape Soya, Hokkaido, has been a Steller sea lion (SSL; *Eumetopias jubatus*) winter haulout for decades. The animals usually occupy the site from October to May. Observations have been sporadic, although the population count started to increase in 2005. We have monitored SSL numbers since 2012 using several survey methods, such as observation by direct counting and remote archival cameras. Since these data were not sufficient, owing to blind spots, we started using unmanned aerial vehicle (UAV) surveys in 2016 and corrected the previously collected data. Using these methods, a considerable number of SSLs were observed at Benten-Jima Rock during 2016–2017. The maximum number of SSLs was 3158 on land and 3056 in the water near the site, as counted from UAV images on May 2, 2017. Based on hot brand marks, we found that Benten-Jima Rock hosted SSLs from all ten main rookeries along the Asian coast. The majority (~60%) were from Tuleny Island near the east coast of Sakhalin. The cause of this extraordinary increase in SSL numbers at Benten-Jima Rock remains unclear and requires further monitoring and research.

Key words: branding, population increase, unmanned aerial vehicle (UAV).

The Asian stock of Steller sea lions (SSLs; *Eumetopias jubatus*) breeds only in Russian waters along the Asian coast and migrates to the northern area of the Sea of Japan during winter (Isono et al. 2010). Aerial surveys in 2010–2013 estimated the wintering population of SSLs in Hokkaido at approximately 6237 individuals (Isono et al. 2019). Various haulout sites exist along the coast of Hokkaido (Hoshino et al. 2006; Hattori et al. 2009; Isono et al. 2010). Sightings of SSLs on Benten-Jima Rock (also referred to as "the rock" in this study; 45.5259°N, 141.9193°E; Fig. 1) were rare in the 1970s. However, SSL numbers have increased since 2005 (Wada 2009), and the rock is now one of the main haulout sites in Japan. In the 1970s, the rock provided shelter when stormy weather prevented SSLs from coming ashore at Onishibetsu Todo Rock, located 28 km to the southeast (Itoo et al. 1977). There are no coastal fishery operations or other human activities around Benten-Jima Rock in winter. Therefore, it is likely that this location is a preferred haulout site for SSLs during transit (Wada 2009).

Surveys based on direct counts and interviews conducted in the 1980s reported that a maximum of 50–60 SSL individuals hauled out annually on Benten-Jima Rock (Yamanaka et al. 1986). Since 2005, the number of SSLs has increased, with over 100 individuals recorded in 2005 (Wada 2009). The use of remote archived time-lapse cameras for SSL observations on Benten-Jima Rock began in 2007 with specific individuals identified from branding marks (Wada 2009). However, the data obtained by these cameras were intermittent because of system

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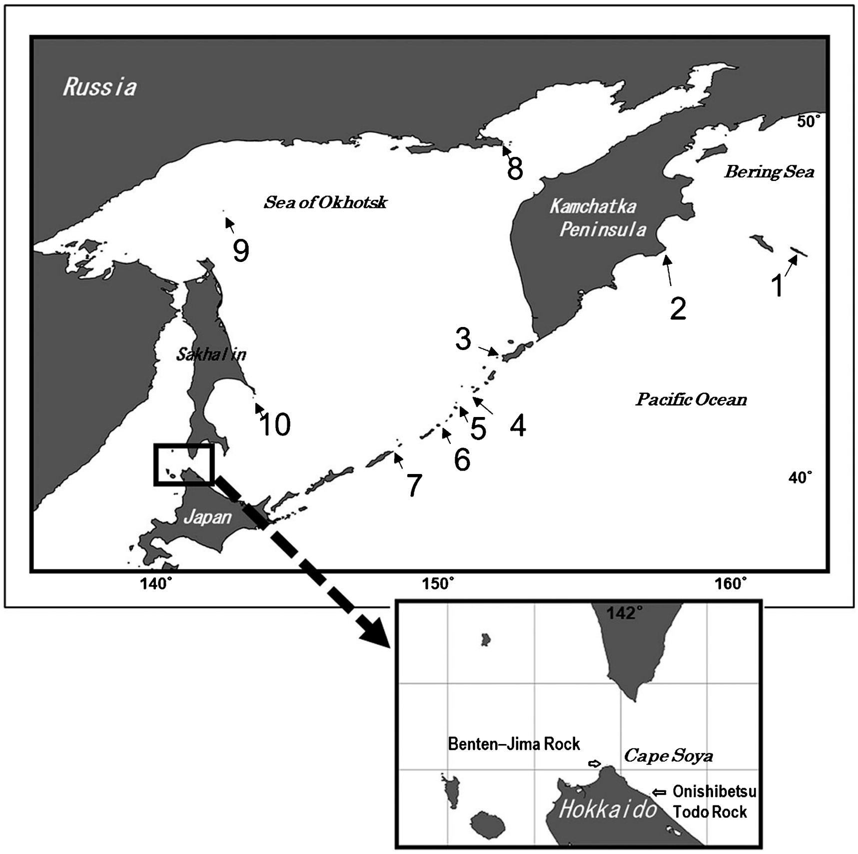

Fig. 1. Study area. Location of the Benten-Jima Rock haulout in Hokkaido, Japan, and major Steller sea lion rookeries along the Asian coast: 1) Medny Island; 2) Kozlova Cape; 3) Antsiferov Island; 4) Lovushki Islands; 5) Raykoke Island; 6) Srednego Islands; 7) Brat Chirpoev Island; 8) Yamsky Islands; 9) Iony Island; 10) Tuleny Island.

failures (for example, flat batteries), removal by waves, or damage by SSLs. Hattori et al. (2021) also reported a recent increase in the number of SSLs observed around Benten-Jima Rock. Since their surveys were conducted by aircraft and only once a year, the results were limited. In other words, it was not clear whether the changes in abundance were temporary or whether they increased year by year. We decided to improve the remote camera systems to obtain more accurate and longer-term data. In addition, we decided to monitor the rock from another location as a countermeasure against destruction by high waves and storms using other remote camera systems. However, our remote camera systems did not cover all the haulout areas of the rock and the surrounding marine area. Therefore, in 2016, we started counting SSLs using high-resolution digital aerial photographs of the entire island and surrounding waters collected by unmanned aerial vehicles (UAVs).

Recently, UAVs have proven to be a valuable tool for studying wildlife (Christie et al. 2016; Korczak-Abshire et al. 2019). For example, Sweeney et al. (2016) used the APH-22 hexacopter, a type of unmanned aircraft system (UAS: defined by the Federal Aviation Administration) for SSL surveys at haulouts and rookeries in the outer Aleutian Islands in Alaska. In addition, many marine mammal habitat studies have been conducted using UAVs (Smith et al. 2016). These devices can access coastal habitats and hard-to-reach research areas more easily than traditional vehicles, such as boats, and are cheaper than aircraft. Moreover, UAVs are noninvasive and minimize animal disturbances. Using UAVs with a telephoto lens, we obtained images of hot-branded SSLs without being detected. These clear images helped us to easily estimate SSL numbers and body sizes.

In this study, we monitored the trend of observable SSL numbers at Benten-Jima Rock from 2012 to 2017. These data were obtained from land-based observations and the analysis of image data collected from remote archival time-lapse cameras. Additionally, using UAVs, we obtained detailed counts of the increasing number of

Fig. 2. Map showing the location of remote cameras. We also carried out land-based observations at this location (Google Earth map data ©2019 Google). Distance from the Cape Soya camera to Benten-Jima Rock is 1.54 km.

SSLs at Benten-Jima Rock in 2016–2017. The data obtained by UAVs enabled us to correct past camera data, using the correction equation, and clarify the trend of changes in the number of SSLs at this site. We were able to identify branded individuals from these three platforms we used for the observation. From the branding information obtained, we analyzed the group composition of SSLs that migrated to Benten-Jima Rock.

Materials and methods

Benten-Jima Rock is located in the La Pérouse Strait (the Soya Strait in Japanese), 1.2 km north of Cape Soya, and has an area of approximately 8000 m^2 at low tide calculated from three-dimensional ortho data of the rock obtained by a UAV, using Pix4Dmapper software (Pix4D Co. Ltd, Tokyo, Japan). To monitor the hauled-out SSLs on Benten-Jima Rock, we carried out surveys on the number of individuals and its seasonal changes, and individual identification by brand numbers from the beginning to the end of the haulout season.

Land-based observations

We started land-based observations of Benten-Jima Rock using binoculars near Cape Soya (approximately 1.2–1.5 km away) on October 3, 2012. These observations were conducted at irregular intervals, approximately once a week, to check for the presence of SSLs on the rock and surrounding areas. We observed Benten-Jima Rock and the surrounding marine area from along the road and from the remote-setting point near Cape Soya (Fig. 2). When we identified SSLs in the study area, we took photographs using a handheld camera (PowerShot SX50HS or SX60HS, Canon, Tokyo, Japan). From these photographs, we counted the number of SSLs. When a large number of SSLs were identified, counts were performed using the cell counter function in ImageJ (Schneider et al. 2012). In the summer of 2013, weekly observations continued when the SSLs were few or absent. During the following summers, when few or no SSLs were present, observations continued for approximately three weeks. Observations were suspended and restarted in October. The visual survey was suspended once the UAV investigation began in November 2016.

In addition to data collection at a distance, animal counts and brand searches were performed during three visits to the site, which were necessary for remote camera installation and maintenance. Before landing, all individual SSLs were counted from the boat using binoculars, while branded animals were photographed

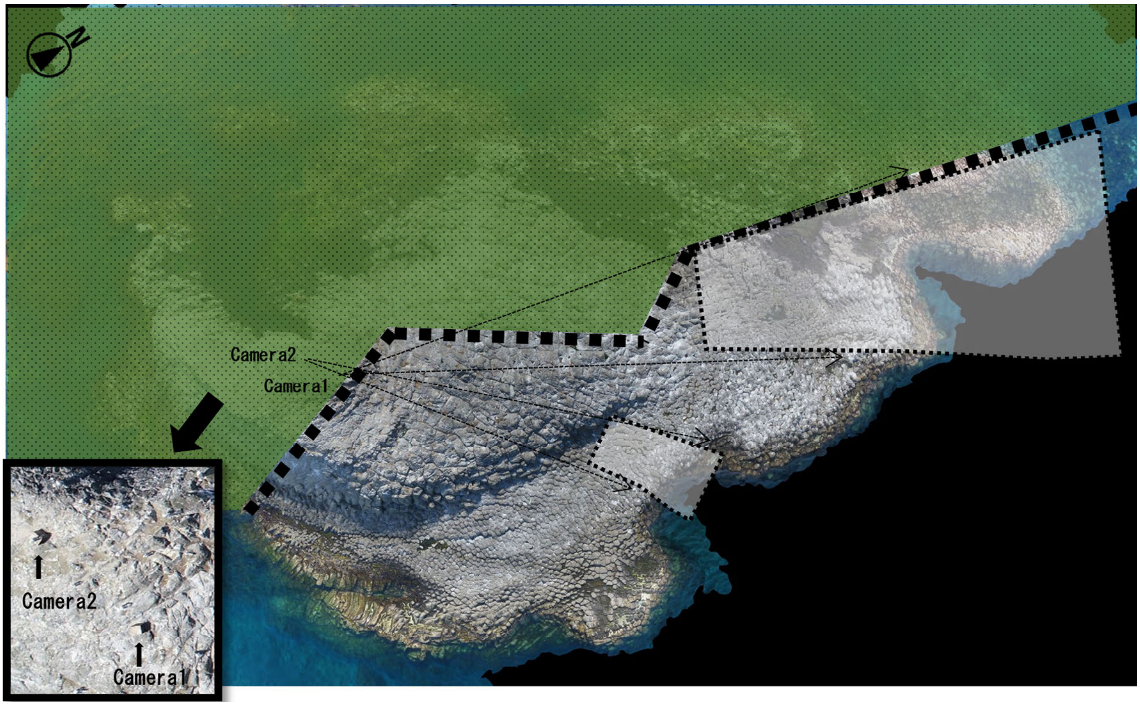

Fig. 3. Photo of an orthoimage taken by an UAV and remote camera fields of vision. The dot pattern background area demarcated by the thick dashed line indicates the approximate blind area for remote cameras near Cape Soya. The thin dashed box indicates the approximate shooting range of remote cameras on the rock.

using a handheld camera (PowerShot SX50HS, Canon). This research was conducted using U.S. and Russian research methods (Gelatt et al. 2007; Jemison et al. 2013).

Automated remote archival time-lapse cameras

On December 4, 2013, four custom-made remote archival cameras (DMC-FH8, Panasonic, Osaka, Japan) controlled by a multi-point precision electronic timer (HRE DT-16TP1D, Hokkaido Remote Engineering, Sapporo, Japan) with originally designed wiring (T. Isono, unpublished data) were set up as a preliminary test to determine the installation point and shooting area. These cameras were equipped with improved energy-saving specifications such as optical sensors and were stouter than previously used cameras, being outfitted with iron housing, which had not been used before (T. Isono, unpublished data). Images were taken automatically every 60 minutes during the daytime and saved to internal SD memory cards as jpeg files. Three of the four cameras were installed halfway up a slope, similar to the cameras used by Wada (2009), and a remaining camera was installed on the top of Benten-Jima Rock. The three halfway cameras were swept away by waves during stormy weather; however, the top camera remained in place and worked. The data from the remaining cameras are presented in Supplementary material 1. Some of the images could not provide accurate counts of SSLs because of snowy or foggy conditions, birds obstructing the camera lens, or any other reason. These situations occurred randomly. Based on these results, the same camera and a new custom-made remote archival camera (EOS-Kiss X7, Canon) controlled by microcomputers (T. Isono, unpublished data) were set up on top of Benten-Jima Rock on November 1, 2014. The new camera's shooting interval was set to ten minutes during the daytime. Both cameras pointed north to obtain an image of the main SSL landing area. These cameras were retrieved on June 17, 2015. The camera used for both survey periods (DMC-FH8) was found to have malfunctioned; therefore, only one camera (EOS-Kiss X7) was operational during the 2014–2015 survey period (Supplementary material 1). We confirmed that the camera at the top of the mountain had worked well, and the battery output was maintained for an extended period. Therefore, in the following autumn, we started the next study period using the same setting points and remote archival camera system. From November 3, 2015, the camera system operated well until removal on April 29, 2017. During this period, batteries and SD cards were occasionally replaced. Camera 1 pointed north to obtain a wide-angle

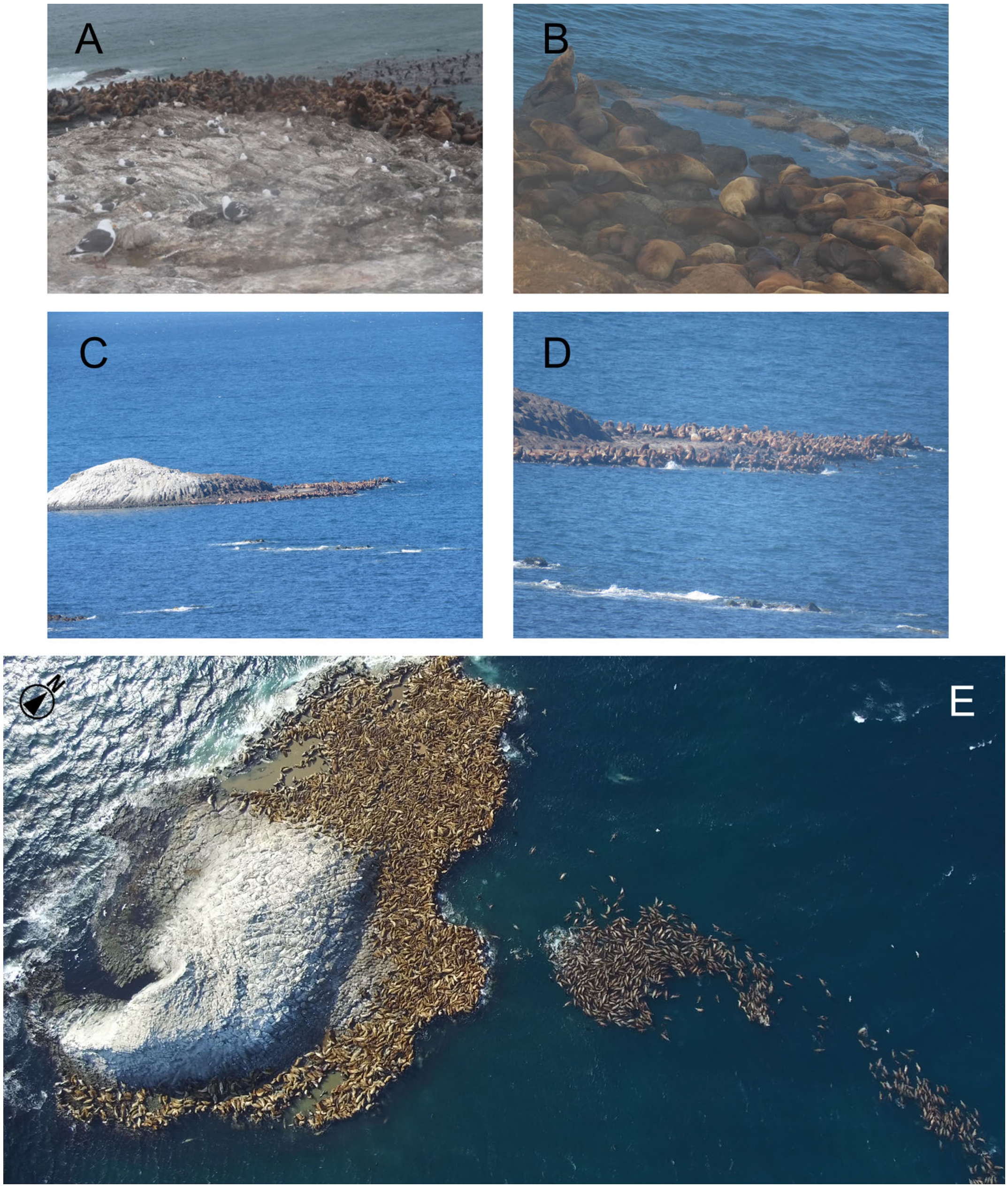

Fig. 4. Examples of images used in this study. Photos from Benten-Jima Rock taken on April 4, 2016 (A) and June 6, 2016 (B). Photos from Cape Soya taken at 12:25 (C) and 12:27 (D) on March 10, 2017. An image taken by an UAV on May 2, 2017 (E).

image appropriate for counting SSLs (Figs. 3 and 4A), and Camera 2 pointed northeast to capture images of branded animals using a telephoto lens (Figs. 3 and 4B). The shooting areas of Cameras 1 and 2 did not overlap (Fig. 3).

Because of the difficulty in accessing Benten-Jima Rock, we installed another system of remote archival cameras on the terrace deck of a commercial building near Cape Soya for ease of access during winter (Fig. 2). The installation point for these cameras was approximately 1.54 km from Benten-Jima Rock. These cameras used digiscoping (camera with a telescope) or superzoom (built into a compact camera; PowerShot SX60HS, Canon); details are provided in Supplementary material 2. The telescope used varied depending on the year of the survey. The digiscoping cameras have a built-in interval imaging function that is used for controlled time-lapse shooting. Every day, most of these cameras automatically took photographs every 60 minutes, including at night. One camera was set to shoot every 30 minutes as a trial and to assess the SSL haulout. We used a maximum of five cameras simultaneously and obtained a complete view of the haulout and enlarged views of several rock sections (Fig. 4D). In the digiscoping camera, it was difficult to adjust the angular field of view, and the obtained images often did not show the rock owing to a suboptimal viewing angle. The number of images from the digiscoping cameras that could be used to count the number of SSLs is provided in Supplementary material 2. After various trials, in November 2015 we started using superzoom cameras to increase the number of countable images (Supplementary material 2). In the superzoom cameras, the controlled time-lapse systems were the same as those in Benten-Jima Rock. A trial in which images were taken every 30 minutes revealed that the movement of SSLs and weather conditions varied over a relatively short time. Therefore, 30 minutes was used as the imaging interval. These cameras were installed on a relatively high hill; however, the back side of the rock was obscured and could not be photographed (Figs. 3 and 4). The total shooting area covered by both cameras fixed on Cape Soya and Benten-Jima Rock was approximately 3095 m^2, which was calculated from three-dimensional ortho data of the rock obtained by UAV, using Pix4Dmapper software (Fig. 3).

By counting SSLs in photographic images collected hourly within the field of view of all cameras, we determined the maximum number of SSLs each day for Benten-Jima Rock and Cape Soya. Although we obtained images every ten or 30–60 minutes, we only used hourly data for each hourly count. To count each SSL, we used the multiple-counter function in ImageJ. In some cases, data from cameras installed at the same point were combined. For example, for the cameras installed on Benten-Jima Rock, when SSLs were confirmed in the shooting area of Camera 2, we added this SSL number to the number of SSLs counted from the image obtained by Camera 1. In contrast, for the Cape Soya cameras, we counted each SSL from the images of the entire rock (Fig. 4C). However, when the images of the entire rock were unclear, or SSLs were congested, we supplemented them with other enlarged partial images (Fig. 4D). Because SSLs were often distributed in areas outside the camera's view, the daily maximum SSL count was lower than the actual number and did not accurately reflect the SSL abundance for any given day. In addition, how SSLs used the areas outside the camera's view was unknown, preventing us from describing the actual seasonal abundance of SSLs at the Benten-Jima Rock haulout.

Unmanned aerial vehicles

A preliminary investigation of SSLs on Benten-Jima Rock using UAVs was conducted on June 5 and June 23, 2016, to confirm the suitability of this method. The test results were better than expected, prompting the use of UAVs from November 2016 to take high-resolution digital images of the entire Benten-Jima Rock and the waters surrounding the haulouts, counting SSLs and searching for branded animals. Three types of DJI (Shenzhen, China) drones were used: Phantom 4, Mavic Pro, and Inspire 1 Pro. The first two drones had built-in cameras, while the latter was equipped with a Zenmuse Z3 camera (DJI). Supplementary data recorded by a local fisher were also used to analyze the number of SSL individuals. Additional videos were recorded throughout the entire haulout area. A total of 96 flights over 67 days were performed between November 3, 2016 and May 22, 2017 (Supplementary material 3). Depending on weather conditions, we conducted a morning and afternoon survey each day. Before each flight, we checked the mean wind speed using a hand anemometer (Windtronic2, Kaindl, Frankfurt, Germany). We conducted flight surveys when weather conditions were not snowy or rainy and when mean wind speeds were less than 8 m/s. Each flight lasted for approximately 20 minutes. Depending on the number and distribution of SSLs on the rock, one to three flight surveys were performed with short intervals for battery replacement. We also recorded SSLs in the surrounding water when they were visible. Images and videos were recorded manually by a UAV operator at an altitude of 15–80 m. During the first flight, we kept the UAV at 40 m to count all the hauled-out SSLs. For additional flights, depending on the situation, we flew at an altitude of approximately 15 m to capture the brand marks. If SSLs noticed the UAV and showed signs of movement, we increased the altitude to approximately 80 m.

Counting and searching for branded SSLs from raw MOV files were conducted in the laboratory using the screen-capture function of Microsoft Windows 7. Using the multiple-counters function in ImageJ, the SSL numbers for each size category (large, medium, and small) were counted by visual inspection of the images (Hoshino et al. 2006). We assumed that large individuals were larger subadult males and adult bulls, medium were younger males and adult females, and small were juveniles and pups of both sexes. These size classes were in accordance with the growth stages determined by the branding information, which will be described later. Because of the distinct sexual dimorphism of SSLs

(NOAA Fisheries 2012), it was easy to distinguish between adult and subadult males and others. The maximum length of adult males is approximately 3.3 m, while the maximum length of adult females is approximately 2.5 m (Gelatt and Sweeney 2016). Furthermore, adult and subadult males have distinctive manes (King 1983) with larger and more muscular chests and necks than females (NOAA Fisheries 2012). Juveniles and pups are smaller than older individuals; the standard length of SSLs under three years old is predicted to be less than 2.0 m in both sexes (Winship et al. 2001). These characteristic features were clearly discernible in the UAV images. However, in many cases, it was not possible to accurately evaluate the size of the animals in water; therefore, these individuals were counted without relation to size. We occasionally needed to divide the captured images into several segments when numerous SSLs were hauled out at Benten-Jima Rock. The images were divided based on the characteristics of the SSLs (e.g., brands or colors) or characteristic rock shapes. We carefully counted all hauled-out SSLs to avoid double counting. The images were counted by one person and checked again. The UAVs occasionally disturbed the SSLs, and in these cases, the SSL count data used were those from before the disturbance. When we had data from two investigation flights in a day, we used the data with the largest number of hauled-out SSLs.

To compare the SSL numbers from the remote cameras with those from the UAVs, regression lines were determined. The values used in these analyses were obtained at or near the same time on the same day. After retrieving Cape Soya cameras (in late April 2017), the values used for this comparison were obtained using a handheld camera (PowerShot SX60HS, Canon) with photographs taken from the remote camera installation point. Analyses were performed using Microsoft Excel software. In these equations, the intercepts were set to zero for the following reasons. From the results of land-based observation and remote cameras, it was assumed that when there was no SSL haulout, the rock was often covered by waves due to stormy weather, and it was impossible to haul out in most cases. In fact, the mean wind speed (Japan Meteorological Agency, http://www.data.jma.go.jp/obd/stats/etrn/index, Accessed 20 October 2020) was significantly higher on days when no SSLs were observed by the remote cameras than on days when groups of ten or more SSLs were hauled out (Supplementary material 4). Wada (2009) also reported that when it was windy (over 10 m/s), SSLs tended to leave the rock or move to a higher area of the rock. If the SSLs moved to a higher area of the rock, they could be recognized using photo images from remote cameras. Therefore, we assumed that in most cases where there was no SSL haulout in the remote camera images, there was no haulout in areas without oversight. Using the obtained regression equation, we attempted to estimate the number of SSLs in the blind spots of the remote cameras.

There were several instances of artificial disturbance events during the survey period. First, visiting the site to maintain remote cameras created a disturbance that caused all SSLs to enter the water. In addition, local fishers and hunters caused six expulsions of SSLs from haulouts during May–June 2017. All expulsions were instigated and recorded by the fisheries cooperative. They used a shotgun to kill and scare animals to protect local fisheries, a legal act under current Japanese legislation. All SSL count data immediately following human disturbances were excluded from the dataset.

Brand-resight data collection

Using all the images collected by remote cameras installed on the rock and UAVs, and obtained at the visits to the rock, we were able to find and review branded SSLs. This review process is usually performed by two people to minimize errors. Once a brand was found, it was compared to a digital imagery database of branded SSLs developed by Russian researchers to precisely identify branded individuals (Altukhov and Burkanov 2008; Burkanov 2009; Altukhov et al. 2015). Based on reported cases of birth dates in major SSL breeding rookeries in Russia (Kuzin 1996; Sychenko et al. 2008), July 1 was defined as their birthday. Because no branding surveys were conducted in 2012 (except in Medny Island and Kozlova Cape) and 2013, no branded individuals born in these years were observed. For example, there were no three- and four-year-old branded SSL individuals in 2016/2017 season.

Results

Number of Steller sea lions on Benten-Jima Rock

Land-based observations: From October 2012 to November 2014, no more than 100 hauled-out SSLs were confirmed by land-based observations (Fig. 5). Subsequently, over 100 hauled-out SSLs were identified on occasion, including on November 26, 2014, when 102 SSLs were observed on the rock. During the 2012 study period, SSLs were not observed until mid-November,

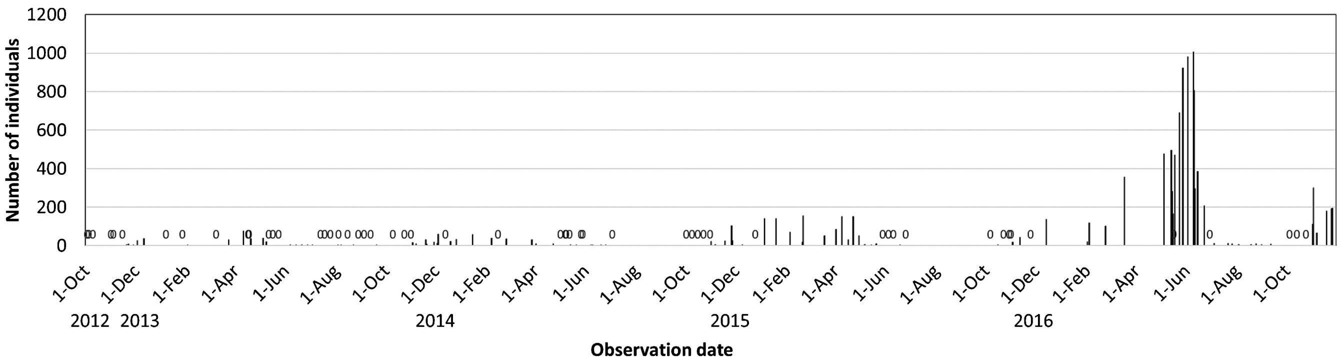

Fig. 5. Number of Steller sea lions (SSLs) hauled out on Benten-Jima Rock, Cape Soya, October 2012 to November 2016. Count data for SSLs were obtained from land-based observations and handheld camera photographs captured from the opposite shore in Benten-Jima Rock. "0" means no SSLs hauled out.

with several dozen hauled-out individuals confirmed after mid-December. During the summer of 2013 (late May–October), although we continued to observe the rock approximately once a week, SSLs were mostly absent. Every year until 2016, SSLs appeared in this area in early November and left during mid-May. Although regular observations throughout the fall only occurred in 2013, few SSLs were identified each year from mid-May to November until the summer of 2016 (Fig. 5).

On March 18, 2016, 356 SSLs (unprecedented numbers) were counted. After this, SSL daily counts rapidly increased to more than 1000 individuals. Furthermore, the number of SSLs did not decrease after mid-May 2016. On June 11, 2016, we visited the rock for remote camera maintenance. After our visit, the abundance decreased gradually, with approximately 20 SSLs remaining on Benten-Jima Rock in the end of July 2016. The abundance then decreased to less than ten individuals in early August, with a complete absence of SSLs from late August through October (Fig. 5).

Automated remote archival time-lapse cameras: We monitored the hauled-out SSLs on Benten-Jima Rock using cameras installed on both the rock and near Cape Soya. Although the cameras on the rock had a narrower shooting range than the cameras near Cape Soya, the two datasets showed a similar trend (Fig. 6a). This was due to the fact that the cameras on the rock accurately captured the area where the SSLs were usually hauled out. The number of SSLs monitored by cameras at these two sites ranged from 0 to 371 individuals from late November 2012 to February 2016 (Fig. 6a). At this time, the maximum number of SSLs appeared to increase each year. It was not possible to accurately compare SSL counts across the entire study period because the models and performance of the cameras changed. However, we were able to compare the trend of hauled-out SSLs from November 1, 2014 (for cameras installed on the rock) and from November 12, 2015 (cameras installed near Cape Soya) because the remote camera systems used remained the same after these points.

On March 12, 2016, the number of observed SSLs increased rapidly, with almost 1000 recorded by our cameras (Fig. 6a). There were only a few days in early May 2016 when no hauled-out SSLs were observed or when the number of haulouts was low (< 400). On May 13, 2016, more than 1300 SSLs were hauled out in view of remote cameras. In the second half of May 2016, the number of SSLs recorded by the cameras decreased from 1000 to 400. The remote cameras later recorded high (> 400) SSL abundance on the rock until our visit on June 11. Following the visit, SSL abundance gradually decreased; approximately 20 SSLs remained on the rock at the end of July 2016. The numbers decreased to fewer than ten individuals in early August, reaching zero from late August, and remaining at zero until October (Fig. 6a). The numbers increased again on October 30, 2016, with > 20 SSLs observed on the rock; the numbers then increased rapidly after this date. Compared to previous years, there was a more rapid increase in the number of SSLs hauling out on Benten-Jima Rock (Fig. 6a).

High correlation coefficient values between the UAVs and two camera sites were obtained (Benten-Jima Rock, $r^2 = 0.87$, $n = 40$; Cape Soya, $r^2 = 0.84$, $n = 50$; Fig. 7). The regression lines between the UAV and camera data showed that UAV values were approximately 2.5-fold greater than those from the cameras (Fig. 7). The equations used to estimate the total number of hauled-out SSLs (Fig. 6b) are as follows (where Y is the estimated

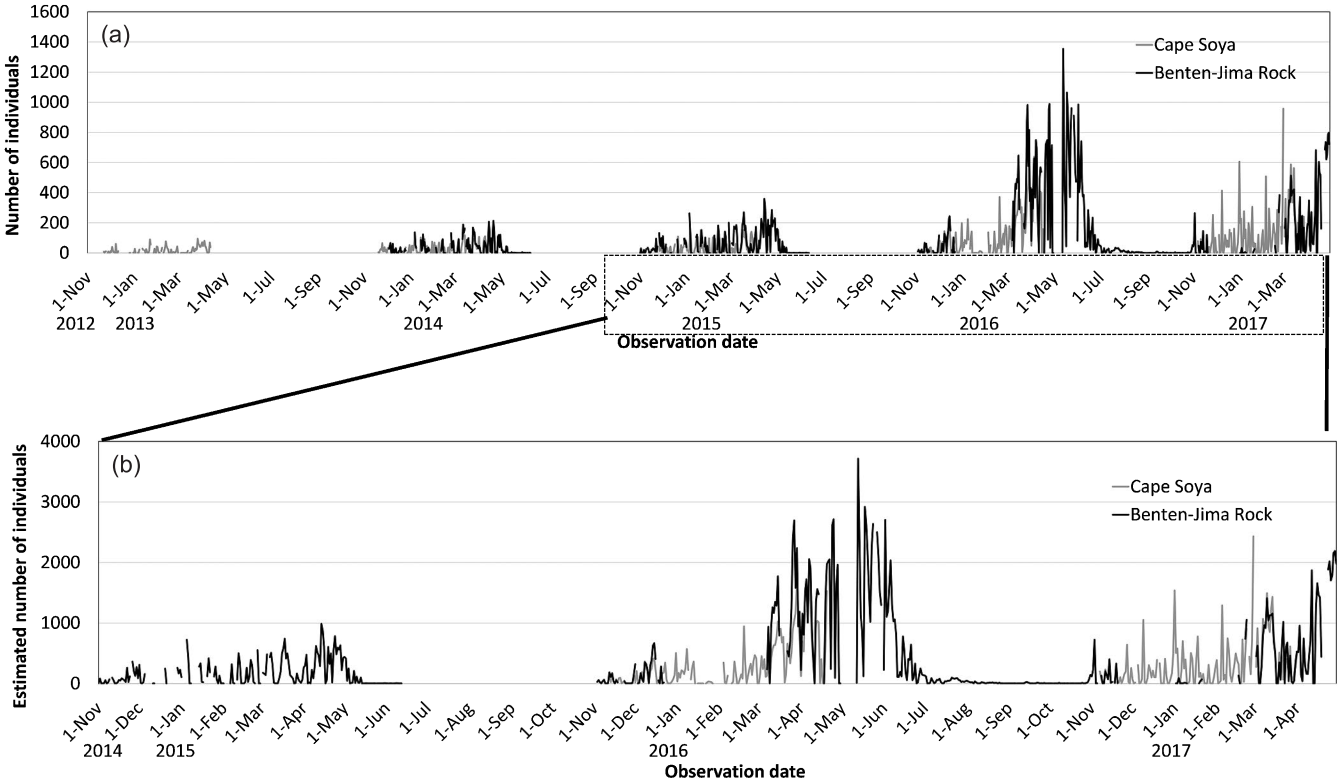

Fig. 6. Actual (a) and estimated (b) maximum daily number of Steller sea lions (SSLs) hauled out on Benten-Jima Rock, from November 2012 to April 2017 and from November 2014 to April 2017, respectively. The data shown in (a) are the actual number of hauled out SSLs counted from the remote camera images. The estimated SSL count data were obtained using the relationships between counts from remote camera and UAV images (see Fig. 7).

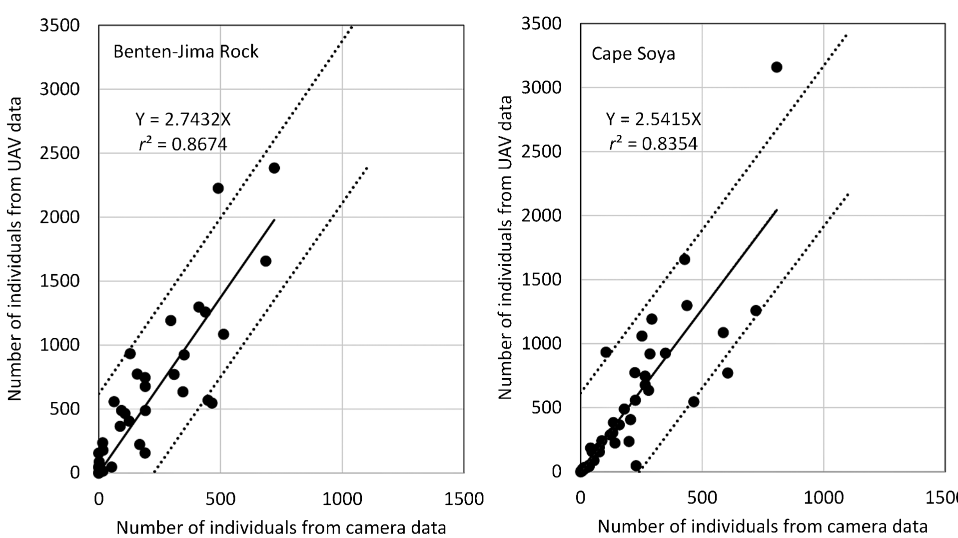

Fig. 7. Relationship between the number of individuals obtained from remote camera (Benten-Jima Rock, left; Cape Soya, right) and UAV images taken simultaneously. Dashed lines indicate 95% confidence intervals.

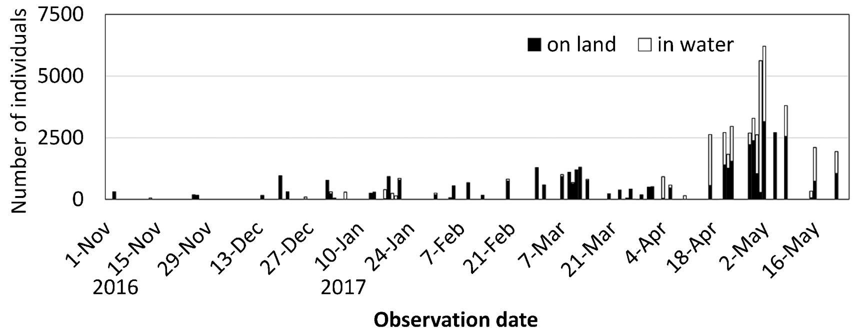

Fig. 8. Maximum daily number of Steller sea lions hauled out on Benten-Jima Rock and in the surrounding water, November 2016 to May 2017. Data were obtained from aerial images collected by UAVs. The assessed area of surrounding water was different for each survey.

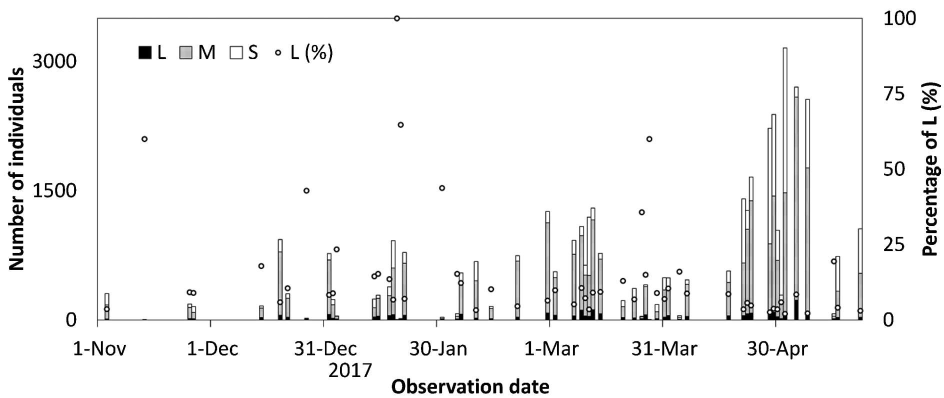

Fig. 9. Number of individuals of each size class and percentage of large individuals of Steller sea lions hauled out at Benten-Jima Rock from November 2016 to May 2017. Data were obtained from UAV surveys. Animal size was determined by visual inspection. L: large (apparent adult male, over five years old), M: medium (apparent subadult male or adult female), and S: small (apparent juvenile or pup of either sex).

number of SSLs and X is the SSL count from remote cameras):

Benten-Jima Rock: Y = 2.7432X
Cape Soya: Y = 2.5415X

The estimates of the total number of SSLs since 2014 could be validated by the relationship between the remote camera and UAV data, making it possible to compare changes in SSL numbers. Our results indicate that more SSLs hauled out on Benten-Jima Rock in 2016 than in 2015.

Unmanned aerial vehicles: A single UAV test flight conducted on June 5, 2016, resulted in a count of 2253 SSLs on Benten-Jima Rock, over two-fold more than any single remote camera count. Maximum daily number of SSLs counted from the remote cameras on the same day was 589. Our two UAV test flights in June 2016 were able to record the entire island without causing significant disturbance to the SSLs. Therefore, observation by UAV was an effective alternative to remote cameras and human observation when a large number of SSLs were present on the rock and in the surrounding water. On December 19, 2016, a single UAV flight photographed 934 individuals on land (Fig. 8). The SSL population showed a sharp increase after April 18, 2017. We observed 3158 SSLs on land and 3056 SSLs in the water on May 2, 2017 (Fig. 8). These were the highest SSL counts recorded in the present study. Six SSL expulsion events were triggered by local fishers after May 13, 2017, with SSL numbers decreasing rapidly afterward. No SSLs were observed after June 7, 2017, until our observations ended on July 4.

The SSL haulout data obtained from UAV photographs suggest that large bulls made up only a small proportion of SSLs at Benten-Jima Rock; the population mainly consisted of medium- and small-sized individuals (Fig. 9). However, when the haulout number was minimal, the percentage of large bulls usually increased (for example, on November 13, 2016, or January 19, 2017;

Table 1. Origin and sex composition of branded Steller sea lion individuals resighted on Benten-Jima Rock, 2014–2017 by each observation season

#	Rookery of origin	2014/15		2015/16		2016/17		Total*		
		Females	Males	Females	Males	Females	Males	Females	Males	%
1	Medny Island	0	0	1	0	0	0	1	0	0.27
2	Kozlova Cape	0	0	1	0	1	0	1	0	0.27
3	Antsiferov Island	0	0	0	0	1	0	1	0	0.27
4	Lovushki Islands	1	0	4	0	8	2	11	2	3.46
5	Raykoke Island	2	0	3	0	3	0	6	0	1.60
6	Srednego Islands	1	1	4	4	5	2	9	4	3.46
7	Brat Chirpoyev Island	2	7	7	8	15	7	17	16	8.78
8	Yamsky Islands	0	0	4	1	10	1	12	2	3.72
9	Iony Island	8	1	30	3	50	7	64	9	19.41
10	Tuleny Island	10	8	65	57	88	70	122	99	58.78
	TOTAL	24	17	119	73	181	89	244	132	100

The number of each rookery is the same as the number shown in Fig. 1.
Data for each individual were determined according to the branding database of Russian survey teams (Altukhov and Burkanov 2008; Burkanov 2009; Altukhov et al. 2015).
* : The total number of branded SSL individuals observed over three years.

Table 2. Information on multiple observations of the same individual on Benten-Jima Rock

		2014/15	2015/16	2016/17
Number of individuals observed for three consecutive years			9	
Number of individuals observed for two consecutive years	2014/15, 2015/16	8		
	2015/16, 2016/17		98	
Number of individuals observed for two non-consecutive years	2014/15, 2016/17		3	
Number of individuals observed for more than two times		21	100	128
Mean number of days between first and last observation		36.1	47.8	38.1
Minimum number of days		2	2	2
Maximum number of days		155	190	181

Fig. 9). From March to mid-April, medium-sized SSLs accounted for a large proportion of the total number of SSLs. During late April and early May, when the total number of SSLs increased rapidly, small- and medium-sized SSLs dominated. After the total number of SSLs decreased in mid-May, the medium-sized SSLs decreased drastically, while the number of small-sized SSLs did not decrease significantly.

Branded Steller sea lion age, sex, and origins

A total of 376 uniquely branded SSLs aged 0–20 years were observed on or near the rock during our study, with 258 individuals recorded in a single year, 109 seen in two winter seasons, and nine seen in three wintering seasons (2014/2015, 2015/2016, and 2016/2017) (Tables 1 and 2). The branded SSL dataset represented 132 males and 244 females from all ten major Asian coast SSL rookeries where pup branding was performed (Table 1). The majority of branded SSLs originated from Tuleny Island (58.8%), followed by Iony Island (19.4%), and Brat Chirpoev Island (8.8%). All other rookeries represented only 13.0% of the total population of branded SSLs visiting Benten-Jima Rock during winter (Table 1). Females aged over five years accounted for a high percentage of the total population, around 50% in most months, especially in May 2017 (Fig. 10). In June 2016, the number of females aged over five years decreased, with most SSLs comprised of age less than four years for both sexes that were considered juveniles. The sex ratio was almost even in June of 2016.

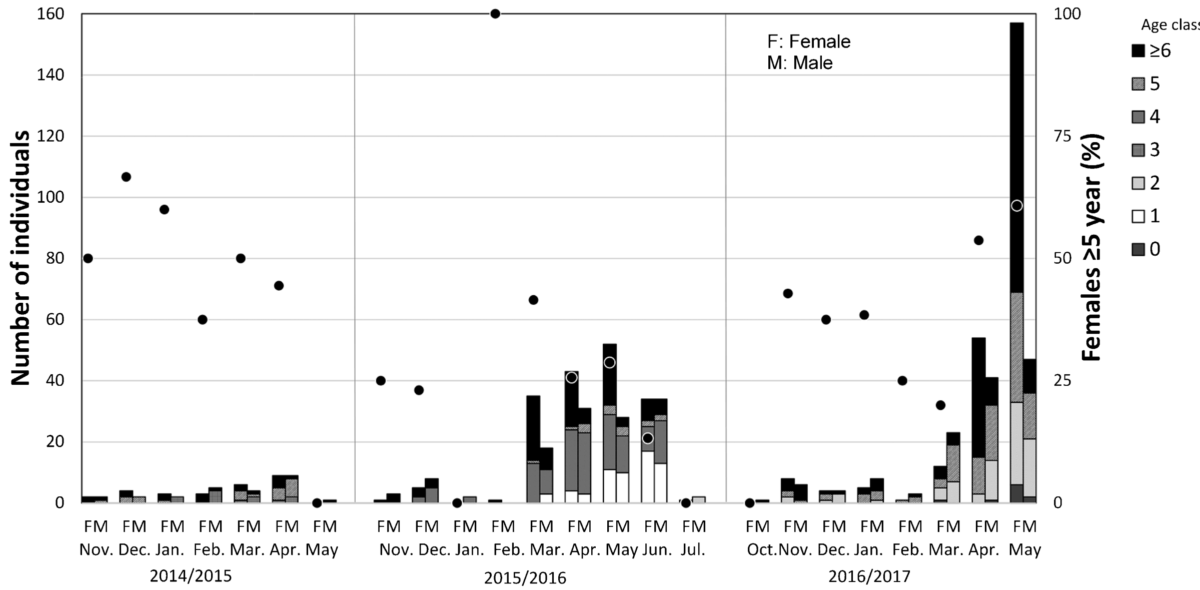

Fig. 10. Number of branded Steller sea lions (SSLs) hauled out on or in the water surrounding Benten-Jima Rock from November 2014 to May 2017, by sex and age class. Dots show the percentage of females over five years old. Sex and age were determined based on the branded SSL database (Altukhov and Burkanov 2008; Burkanov 2009; Altukhov et al. 2015).

Table 3. Information on individuals observed both at Benten-Jima Rock and Todo-Iwa Rock in the same season

Branded ID	Birth Year	Branded Site	Sex	Observation site and date						
				2015–2016			2016–2017			
				Benten-Jima Rock	Todo-Iwa Rock	Benten-Jima Rock	Todo-Iwa Rock	Benten-Jima Rock	Todo-Iwa Rock	Benten-Jima Rock
				First		Last		First		Last
Г49	2009	Tuleny	Male	Nov. 30, 2015	Feb. 26, 2016	Apr. 24, 2016		May 8, 2017		May 16, 2017
Г376	2011	Tuleny	Male	Dec. 9, 2015		Jun. 11, 2016	Feb. 4, 2017	Apr. 21, 2017		Apr. 28, 2017
Г338	2011	Tuleny	Female		Feb. 13, and 28, 2016				Feb. 4, 2017	Apr. 30, 2017
Л844	2008	Lovushki	Male		Feb. 26, 2016			Nov.16, 2016		Feb. 16, 2017
И877	2011	Iony	Female		Feb. 13, 2016	Apr. 4, 2016				
Б164	2011	Brat Chirpoev	Male		Feb. 6, 2016			Mar. 24, 2017		Apr. 1, 2017
Б94	2009	Brat Chirpoev	Male						Feb. 13, 2017	May 22, 2017
Г293	2011	Tuleny	Male	Apr. 21, 2016					Feb. 4, 2017	Mar. 11, 2017
Г270	2011	Tuleny	Male	Apr. 28, 2016			Feb. 4, 2017	Mar. 11, 2017		May 2, 2017
Г99	2009	Tuleny	Male	Mar. 27, 2016		Jun. 23, 2016	Feb. 4, 2017	Apr. 15, 2017		May 22, 2017
Г45	2009	Tuleny	Male	Jun. 11, 2016		Jun. 29, 2016		Nov. 13, 2016	Feb. 19, 2017	May 2, 2017

Data for Todo-Iwa Rock was cited from website of Sea Lions Club Tokyo (2020).

We obtained more data in 2016/2017 than in 2014/2015 and 2015/2016 by using UAVs (Table 1). Within each survey period, some individuals were observed for more than two days. In addition, the same individuals were sometimes observed more than once after the initial identification, with a maximum interval of 190 days between sightings (Table 2). Some of these individuals were observed at the other haulout site off the coast of the Sea of Japan (Todo-Iwa Rock, Shukutsu, Otaru, Hokkaido, Japan: 43.2421°N, 141.0108°E) between or before the sightings around the rock (Sea Lions Club Tokyo 2020) (Table 3).

Discussion

We used land-based observations, remote cameras, and UAVs to document SSL seasonal abundance on Benten-Jima Rock and in the surrounding waters to make the first composite count of SSL individuals on and near this winter haulout. In particular, we noted that it is possible to obtain a more accurate assessment of the number of SSL around the rock using a UAV survey. In the 2013, 2014, and 2015 survey periods, the number of SSLs increased from early November to early May, while after mid- to late-May, the number of SSLs decreased. In mid-May, before our investigation started in 2012, SSLs were almost completely absent from this area (Wada 2009). With reference to the study by Wada (2009), we considered this to be a normal SSL haulout pattern during the migration season until 2015/2016. Subsequently, in the summer of 2016, we recorded the first observation of an SSL staying on Benten-Jima Rock until June and even later.

Since then, the number of SSLs has increased annually each year after March. Rafts of SSLs were identified in the sea from remote camera images at these times. Bigg (1985) indicated that SSLs rest on the water in a tightly packed group, or raft, where no suitable haulout site is available. However, it was not possible to obtain detailed information from the remote cameras about the number of individuals forming the raft. For example, Fig. 4A shows one of these rafts; however, only part of the raft is visible, and it is very dense, making it uncountable. In the present study, we counted individuals in the water as accurately as possible using UAV data. The number of SSLs in rafts around Benten-Jima Rock was unexpectedly high, suggesting that SSL abundance in this location was underestimated in the previous study years (2012–2015). For a more precise assessment of the number of SSLs in this area, it is necessary to fully understand the distribution and number of individuals in rafts as accurately as possible.

We found that Benten-Jima Rock-hosted SSLs from all ten main rookeries along the Asian coast. The majority of all branded SSLs originated from Tuleny Island, the closest rookery to Benten-Jima Rock (Fig. 1). It seems that almost all SSLs on the Benten-Jima Rock temporarily stayed around the La Pérouse Strait area but moved to different haulout sites during wintering. It is most likely that the branded SSLs did not always stay around the study area during the migration season. For example, one individual was found along the southwestern part of the Hokkaido coast after or before being recognized near Benten-Jima Rock (Sea Lions Club Tokyo 2020). Additionally, some branded SSLs were recognized in the study area in both autumn and spring. This might indicate a specific pattern of migration for these SSLs. In winter, when they approached the Hokkaido coast from several rookeries, they hauled out at Benten-Jima Rock and then moved to the south. When they returned to their rookeries in spring or early summer, they hauled out for a short time on Benten-Jima Rock again. Therefore, it is possible that the Benten-Jima Rock site functions as a stop-off point during migration. Branding identification revealed that a large number of adult females gathered around Benten-Jima Rock in late April. When we visited the rock for maintenance of the remote camera on June 11, 2016, we observed several pregnant females hauled out, identified as such by their distended abdominal appearance. Additionally, SSLs obtained from extermination conducted by local fishers around Cape Soya in May 2018 included pregnant cows (Y. Goto and Fishing Industry/Communities Promotion Organization, unpublished data). The breeding season of SSLs is reported to range from mid-May to mid-July (Pitcher and Calkins 1981). Therefore, it makes sense to believe that the rapid decline in SSL numbers observed after our 2016 camera maintenance visit and after the start of expulsion in 2017 was due to pregnant females returning to their breeding rookeries. In this study, using UAVs, we were able to obtain a large amount of branded SSL data. In the future, by comparing such data with that of other haulout sites in Hokkaido and rookeries in Russia, we will be able to understand in more detail SSL winter migration and haulout patterns.

The maximum SSL count in this study (3158 on land and 3056 in the water) was similar to the estimated population in Hokkaido (6237; Isono et al. 2019), revealing population growth in the study area since 2012. Unfortunately, no clear explanation can be provided for the rapid increase in SSL numbers around Benten-Jima Rock. The SSL population of Tuleny Island has constantly been increasing since the late 1980s (Burkanov and Loughlin 2005), and sea-ice distribution seems to affect the dynamics of this population (Burkanov and Loughlin 2005; Mizuguchi et al. 2020). However, the increase observed on Benten-Jima Rock was comparatively explosive in 2016. In contrast, at Onishibetsu Todo Rocks, where the nearest wintering haulout site to Benten-Jima Rock was previously located, no SSLs were identified by aerial survey in 2002 (Hoshino et al. 2006). Interviews with local commercial fishers revealed that hauled-out SSLs had not been seen in this site in recent years, likely due to the expulsion of SSLs from the rocks.

Wada (2009) reported a relationship between the haulout pattern and weather conditions: i.e., when the wind speed was over 10 m/s, the number of haulouts decreased. Additionally, when the daily average air temperature was colder than –5°C, SSLs were not found on the rock. However, based on maximum daily wind speed and daily average air temperature data (Japan Meteorological Agency, http://www.data.jma.go.jp/obd/stats/etrn/index, Accessed 20 October 2020), we found no significant patterns regarding the number of days with wind speeds of over 10.1 m/s or temperatures lower than –5°C in winter (November to March) 2010–2017 (Cochran–Armitage test; wind speeds: $\chi^2_{(6)} = 6.09$, Cramer's coefficient of association = 0.048; air temperature: $\chi^2_{(6)} = 37.32$, Cramer's coefficient of association = 0.134). It is still possible that environmental and meteorological factors influence SSL migration; however, further studies are required to verify this.

Other reasons may also explain the occasional aggregations of SSLs, for example, the distribution and abundance of prey. Bigg (1985) thought that rafts might move by several miles per year owing to changes in the location of the food supply. Hoshino et al. (2006) assumed that the reason for the expansion of haulout sites on the west coast of Hokkaido in the early 1990s was the change in prey availability. Hattori et al. (2009) also reported that an area of high SSL numbers and the main spawning area of Pacific herring (*Clupea pallasii*, the main prey species of SSLs) overlapped, based on the results of aerial surveys. The La Pérouse Strait is one of the main fishing areas for giant octopus (*Enteroctopus dofleini*; Sano et al. 2015). The giant octopus is the most important SSL prey in Hokkaido (Goto et al. 2017). In this area, the catch of giant octopus has increased since 2014, especially in May and June (Hokkaido Government 2019). It is possible that this change in prey availability affected SSL distribution around Benten-Jima Rock. Scat samples from SSLs remaining on Benten-Jima Rock were obtained in June 2016 for prey analysis. In future studies, it will be possible to discuss the relationship between prey species and the SSL aggregations observed in this study. It will also be necessary to further investigate SSL population dynamics in the region, including those of neighboring rookeries and haulout sites.

Supplementary data

Supplementary data are available at *Mammal Study* online.

Supplementary material 1. Summary of specifications and outputs of automated time-lapse cameras installed on Benten-Jima Rock from 2013 to 2017.

Supplementary material 2. Summary of specifications and outputs of automated time-lapse cameras placed at Cape Soya facility.

Supplementary material 3. Summary of UAV flight survey; flights by the authors and those by a local fisher.

Supplementary material 4. Comparison of daily average wind speed at Cape soya (m/s) between days with no haulouts and those with more than 9 haulouts determined by two remote camera systems.

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