Tracking Kuril harbor seals (*Phoca vitulina stejnegeri*) at Cape Erimo using a new mobile phone telemetry system

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Abstract

We developed a tracking unit that uses the Japanese mobile phone network to transmit data from Kuril harbor seals (*Phoca vitulina stejnegeri*), which are difficult to recapture. The unit senses location by GPS, hauling-out status, depth and temperature. Six wild Kuril harbor seal pups were tracked at Cape Erimo, Japan, in summer. GPS data indicated that the seals hauled out only on insular rocks in a known haul-out site at Cape Erimo. Although the data of hauling-out status were limited in accuracy, they at least indicated the seals often hauled out both at daytime and at nighttime. The depth logs of four of the seals were analyzed. The greatest depth recorded was 131m. Of the depth logs >1 m, 98% were <50 m. The seals may tend to use deep water when nearshore water is rough. Three of four seals tended to have depth logs distributed at about 30 m. The seals tended to spend more time at shallow depths at night than at other times.

Key Words: Kuril harbor seal, *Phoca vitulina stejneger*i, mobile phone telemetry, GPS, diving behavior

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Introduction

In Japan, investigations of hauling-out behavior and population trends of Kuril harbor seals (*Phoca vitulina stejnegeri*) have been limited to daytime visual observation[31)]. Niizuma[29)] identified Kuril harbor seals by their natural markings to analyze social behavior. Chishima[4)] and Kawashima[19)] used the natural markings to establish that the seals migrate between haul-out sites. However, the behavior and movements of seals at sea, in remote areas, and at night remain unknown. The lack of an adequate method for remote long-term study of animals has prevented researchers from gathering even the most basic behavioral information.

It is difficult to determine the movement and behavior of marine animals, because we cannot observe them directly. Systems using very-high-frequency signals[35)], satellite tracking[23)] and more recently global positioning systems (GPS)[13)] have allowed researchers to overcome this problem and to determine the whereabouts of marine animals. GPSs are being increasingly used, including for seal research[32)], because they are cheaper and more accurate than Argos systems[30)]. However, these require that the animals be recaptured for recovery of the GPS. But whereas GPSs can provide information only on a seal's location, bio-logging units allow researchers to reconstruct the behaviors marine animals, including diving activity[26)]. For instance, time-depth recorders (TDRs) have been used substantially over the past 40 years to study the diving behavior of seals[21)]. As is true for GPSs, the TDRs and bio-logging units need to be retrieved to access the data. The recapture of Kuril harbor seals is challenging, because they haul out on insular rocks and are very shy. Automatic drop-off systems, which are sometimes used to recover devices without recapture[3)], run the risk of being released at sea and lost. In a recent study by the Sea Mammal Research Unit of the University of St Andrews (Scotland), McConell *et al.*[24)] remotely collected data from grey seals (*Halichoerus grypus*) via mobile phone network. Upon recapture, they were able to obtain data on the hauling-out status and location of grey seals. The seal location was regarded as that of the Global System for Mobile Communications (GSM) net cell receiving contact, with the coverage area being that within a 35 km radius of the relay antenna.

To monitor the at-sea behavior of Kuril harbor seals, we developed and used a similar tracking unit that communicated via the Japanese mobile phone network.

Materials and Methods

Study area

Cape Erimo (41°55'N, 143°14'E), Hokkaido, Japan (Fig. 1), where we captured the seals, is the southernmost haul-out site for Kuril harbor seals in the western Pacific[16]. The population of Kuril harbor seals in Hokkaido dramatically declined due to hunting and reduction in the number of haul-out sites[16]. The population has been rebounding over the past 20 years, exceeding 900 individuals in 2002[31]. The largest group of the seals is centered around Cape Erimo, with numbers there having increased from about 150 seals in the mid-1980s to about 400 seals at present[15].

Animal capture and tagging

We landed by boat on a reef near Cape Erimo three times between June 25 and 30, 2004, and captured six post-weaning pups (Seals A, B, C, D, E and F) with dip nets (Table 1). Only Seal E was female. The body masses of the seals were measured using a spring balance. One researcher sat astride each seal to restrain the animals[12]. After confirming that the unit was less than 5% of the animal's weight[1, 6], we mounted it at the median dorsal line near the shoulder with adhesive (Loctite 401, Henkel Loctite Corporation, Connecticut, USA). The animals were released from the beach at Cape Erimo. The time from capture to release was 30 to 40 min. To check the condition of animals, the respiration rate and body temperature of the seals were monitored while the seals were restrained. The units were left on the animals until they dropped off in the next moulting season.

Tracking unit

The tracking unit used in this study measured 105 × 70 × 40 mm and weighed about 500 g. The unit was coated in epoxy resin covered with smoothly curved rubber. The unit contained the following components.

1. A DoCoMo Packet (DoPa) mobile phone system of the Nippon Telegraph and Telephone digital phone network, which covers most of coastal Japan. DoPa communication is possible only when the unit is out of the water, and the maximum communication rate is 9600 bps. The DoPa system is extremely flexible, allowing the sensor parameters and data logging to be changed.

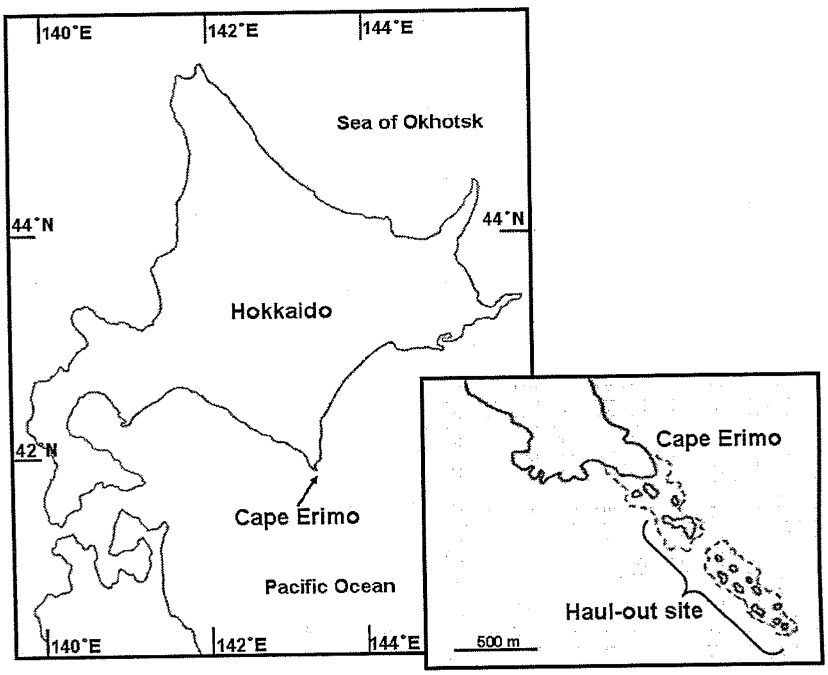

Fig. 1. Study area (Cape Erimo, Hokkaido, Japan)
The seals were captured on haul-out site near Cape Erimo.
The broken line indicates area of reef. The dimension of the haul-out site depends on the tide level.
All the locations obtained from the seals with GPS were on usual haul-out site of Cape Erimo.

2. A packet communication module (HC9-010100, Hitachi Kokusai Electric, Japan) that enables data collection via DoPa network. This module can store 128 kB of data. Data packages are cleared automatically after transmission via DoPa.

3. A lithium battery (3B30, Wilson Greatbatch Technologies, New York, USA) that operates at 3.9V for 7Ah (about 3 months of lifespan).

4. A GPS module (GH-79L, Furuno Electric, Japan) designed to save power by shutting down 4 min after losing contact with the satellite and 5 min after being unable to position. The module measured latitude and longitude with a precision of 1/10000 min. We tested the accuracy of GPS locating at a triangulation station (43°4'34.4119"N, 141°22'39.7999"E). Thirty-eight of 45 locating attempts at the triangulation station succeeded, and average of deviation from the true point was approximately 6 m (standard deviation was 19.9 m). Furuno Electric, which manufactures of the GPS module, states that 95% locating points will be within a 15 m radius of the true point[11].

5. A dry/wet sensor that detects electric current between two exposed terminals in the water and measures conductivity on a scale of 0 for non-conductance (completely dry) to 255 for full conductance (completely submerged). The seal was considered to be hauled out at readings of 128 or less. That value was determined experimentally in laboratory by immersing the sensor repeatedly in salt water. To increase battery life, the GPS operated only when the dry/wet sensor indicated that the unit was on land.

6. A pressure sensor (40PC250G1A, Honeywell, New Jersey, USA) logs water or air pressure with a precision of 1/1000 MPa. The readout of pressure sensor when the dry/wet sensor indicates that the seal has hauled out was regarded as the pressure at the water depth of zero. The water depth was calculated based on that, with an increase of 1 m in depth for every increase of 1/100 MPa in pressure. Honeywell, which manufactures the pressure sensor, indicated that the sensor has an accuracy of ±0.2% at 25 ℃, and ±2.0% in the range from -18 to 63 ℃[14]. The unit of Seal A did not contain a pressure sensor.

7. A temperature sensor (S-8100B, Seiko, Japan) measures the temperature with a precision of 1/10 ℃. Before the unit was used for field study, the sensor was tested and calibrated in laboratory using a high-precision thermometer (Super EX sensor, Empex, Japan). The difference in readout between the temperature sensor and the high-precision thermometer was ±0.5 ℃.

Collected Data

The tracking unit logged data of hauling-out status, depth, temperature and battery voltage every 30 min (on the hour and half-hour). GPS positioning was attempted every 60 min (on the hour). These data were transmitted to the mobile phone network every 30 min (on the hour and half-hour). After testing the communication via DoPa, we changed the interval for communication to 60 min (on the hour) from 30 min to extend the battery life. The low sampling frequency used in this study did not allow us to conduct a detailed analysis of the diving behavior of the seals, but analysis of the frequency of the recorded depths did provide some novel information on Kuril harbor seals.

The communication rate was calculated by dividing the number of successful communications via DoPa by the number of tracking days. The locating success rate was calculated as successful locations a share of locating attempts.

Depth log analysis was limited to logs of >1 m in depth. Statistical calculations were carried out using SPSS・11.0J for Windows Base System (SPSS Japan Inc., Japan).

Results

Efficiency of the unit

Seal A, C, E and F were tracked continuously for more than two months (Table 1). The battery

Table 1. Tracking period, Communication rate and Locating success rate of each Kuril harbor seal pups

	Sex	Body mass (kg)	Start of tracking	Tracking period (day)	Communication rate	Locating success rate
Seal A	M	34	30 June	79	1.1 (88/79)	85.6% (184/215)
Seal B	M	35	27 June	2	3.0 (6/2)	0.0% (0/6)
Seal C	M	31	27 June	82	0.6 (51/82)	—
Seal D	M	30	27 June	35	0.7 (24/35)	70.1% (89/127)
Seal E	F	28	25 June	74	2.0 (149/74)	76.3% (306/401)
Seal F	M	33	25 June	88	1.3 (111/88)	86.7% (299/345)

The communication rate was calculated by dividing the number of successful communications via DoPa by the number of tracking days.
The locating success rate was calculated as successful locations a share of locating attempts.

voltage of the unit on Seal B decreased abnormally 20 h after release, and the communication stopped completely 2 days after release. The communication rates of Seal A, B, E and F exceeded 1.0, which means that the units could communicate everyday, on average (Table 1). The locating success rates exceeded 70%, except for Seal B (Table 1). The locating success rate of Seal C was not calculated, because the GPS of Seal C operated while the animal was under water due to the malfunction of dry/wet sensor (see below). Temperature and pressure were sensed and logged every 30 min without gaps in the data. Although the dry/wet sensor also operated every 30 min, there were problems with its sensing accuracy. When the dry/wet sensor indicated that the animal was swimming, the temperature sensor sometimes continued to indicate values over 37 ℃, which is clearly higher than the water temperature measured by the First Region Coast Guard Headquarters[7]. Temperatures over 37 ℃ are even higher than the air temperature[18]. These high values probably resulted from heat accumulating in the device when the seals hauled out in the sun. In some instances, the tracking unit was able to communicate while the dry/wet sensor indicated that the seal was underwater. This problem was observed on 5 of the 6 units. Conversely, the dry/wet sensor of Seal C indicated that the animal was hauled out while the pressure sensor indicated it was under water. With either problem, the accuracy of the dry/wet sensor decreased over time. The dry/wet sensor of Seal C eventually indicated that the seal was continuously hauled out. The dry/wet sensor of Seal E, which was recaptured (see below), worked again normally after being rinsed with fresh water.

Effect of the tracking unit on the animal

Seal E was caught dead in a fixed salmon net near Hyakunin Beach, approximately 10 km northeast of Cape Erimo, on 6 September. Body mass, body length (nose to tip of tail), girth at axilla, and blubber thickness near xiphisternum were measured (Table 2). These morphometric measurements indicated that the seal had gained body mass and body length while equipped with the tracking unit.

Hauling-out status

Although the data of hauling-out status were of limited accuracy, they at least indicated that the seals hauled out both at daytime and at nighttime.

Depth data

As these were very few depth data logged for Seal B, this individual was removed from the analysis of diving behavior. Of the >1 m depth logs, 98.0% (6417/6547) were <50 m. The greatest depth record, 131 m, was logged by Seal F at 5:00 on 9 September, when the Muroran Coast Guard Office observed 6 m waves near Cape Erimo (3.3 km offshore)[25]. Of the all depth logs, ten were deeper than 100 m and 7 of the >100 m depth logs were logged while ≧6 m waves were observed. When waves were 6 m or higher (6 to 8 m), 17.1% (22/129) of depth logs were >50 m. When waves were lower than 6 m, 1.7% (108/6418) of depth logs were >50 m. The depth logs when the waves were ≧6 m were statistically different from the logs when the waves were <6 m (Mann-Whitney, $P<0.05$). A depth histogram was plotted for each seal (Fig. 2). The depth distribution was clearly bimodal for Seals C, E, and F, with a first mode around 1 to 5 m and a second mode around 28 to 32m. In contrast, the depth distribution for Seal D showed a predominant peak around 1 to 5 m and no clear trend for the depths >5 m. The average depth logs for each of the seals are shown for the four time period: morning (3:00–8:30), midday (9:00–14:30), evening (15:00–20:30), and night (21:00–2:30) after Frost *et al.*[9] (Fig. 3). For all these seals, the night depths are shallower than other time periods (Kruskal-Wallis, $P<0.05$; Mann-Whitney, $P<0.0125$).

Table 2. Constitution of Seal E

	Body mass (kg)	Body length (cm)	Girth of axilla (cm)	Blubber thickness (cm)
25 June	28	95	78	—
6 September	32	107	76	2

Seal E was by-caught in a fixed salmon net during tracking period.
Weight, length (from rostrum to end of tail), girth of axilla and blubber thickness near xiphisternum of the seal were measured on 25 June (tagged) and on 6 September (caught dead).

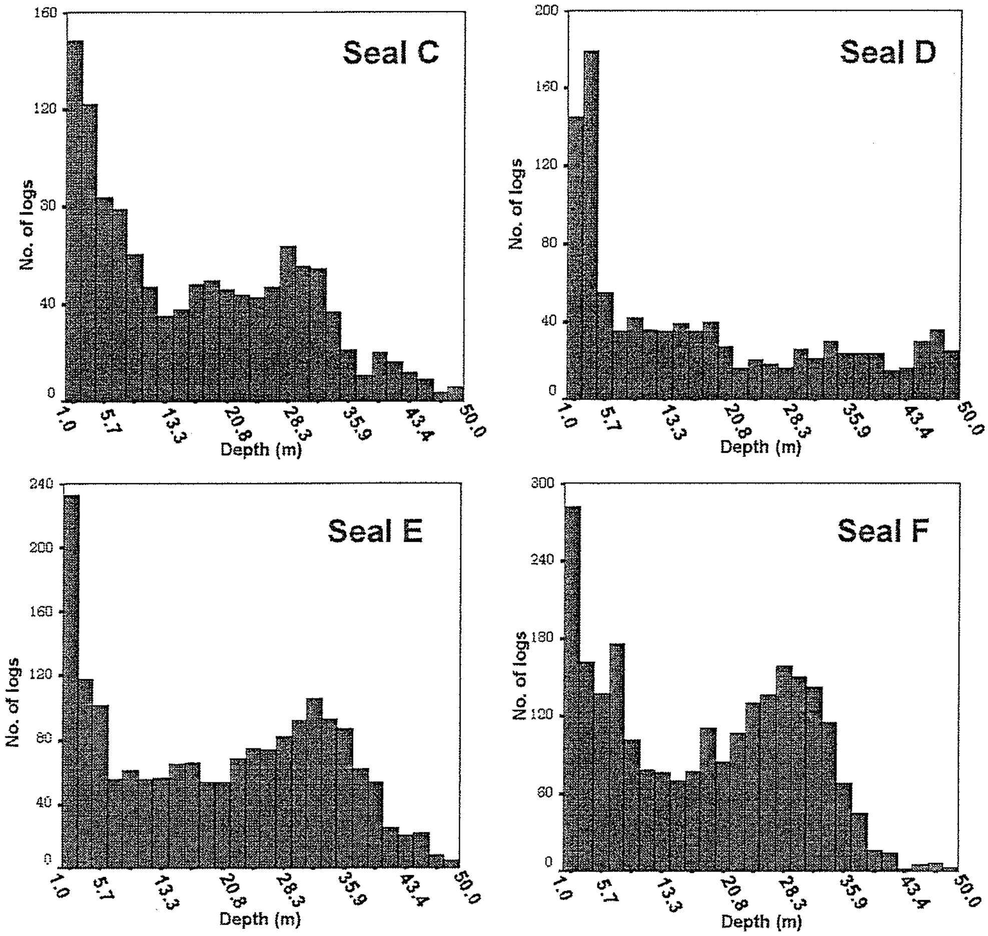

Fig. 2. Depth histograms for each seal
Depth logs 1-50 m were drawn as a histogram for each seal.

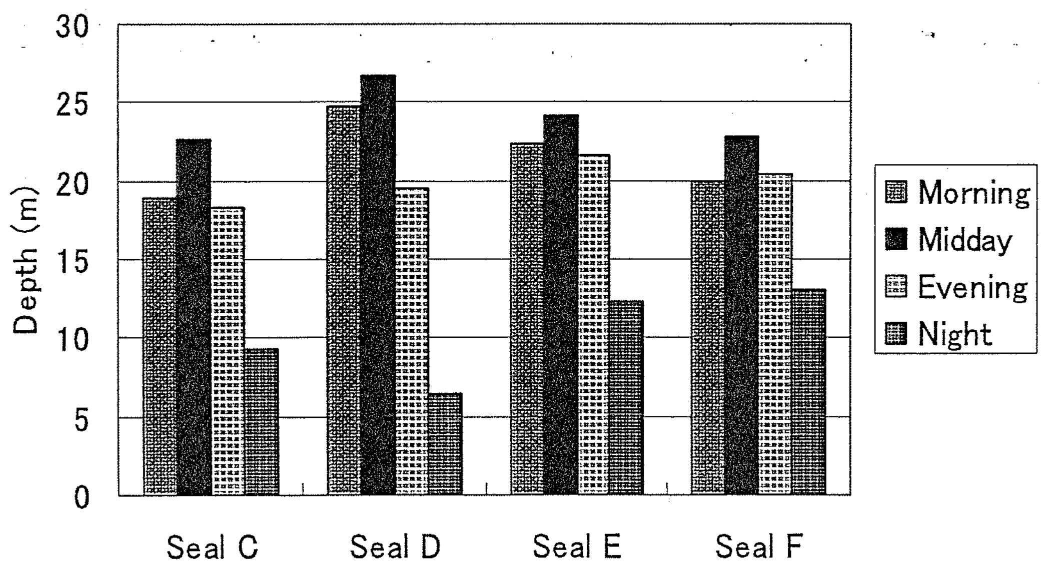

Fig. 3. Average of depth logs
Averages of depth logs for Seals C, D, E, and F were indicated for four time periods: morning (3:00 - 8:30), midday (9:00 - 14:30), evening (15:00 - 20:30) and night (21:00 - 2:30).

Location data

GPS locations were obtained for 5 of the 6 animals (Table 1). All the locations were insular rocks known as a usual haul-out site at Cape Erimo (Fig. 1).

Discussion

The units succeeded in logging GPS location, depth and temperature from wild Kuril harbor seals and remotely transmitting the data. The y were expected to track for approximately 3 months. Seals A, C, and F were tracked for more than 2 and a half months. Tracking of Seal E was interrupted when that seal was bycaught; however, the battery was still alive. The short tracking duration of Seal B probably resulted from battery failure. The interruption in the tracking of Seal D may be the result of detachment of the unit, because no battery voltage abnormality was logged. Communication was affected by seal posture and orientation, and tall rocks and spindrift, which obstructed the transmission of radio waves. The communication rate may be influenced by differences in the obstructions and hauling-out frequency of seals. The problem of the dry/wet sensor is serious. The accuracy of Seal E's dry/wet sensor was restored by rinsing with fresh water. This suggests that salt and dirt adhered to the surface of the sensor, preventing it from drying after hauling-out. Conversely, the dry/wet sensor of Seal C continued to indicate that the seal was on land when the other sensors indicated it was underwater. This may have been caused by mis-etching of electric terminals. Such a problem was noted in a previous experiment (unpublished data). In the current study, we tried to overcome this problem by coating the terminals with gold. Seal C's unit may have been imperfectly coated.

Morphometric measurements performed on Seal E suggested that the unit did not affect growth of pups. Seal E had greater body mass and body length at recapture than at release. Harbor seal pups become visibly slimmer the summer after weaning[8], so the decrease in girth at axilla was normal. The body mass, body length, girth at axilla and blubber thickness were similar to those of other Kuril harbor seal pups caught during the tracking period[10]. The stomach contents of Seal E included the beak of a giant Pacific octopus (*Paroctopus dofleini*) and ear stones of arabesque greenling (*Pleurogrammus azonus*) and saffron cod (*Eleginus gracilis*)[27].

Harbor seals generally spend most of their time in shallow, nearshore waters, in which they are thought to feed[23]. Studies in North America[22] and Europe[2] have reported modal dive depths of 60 m or less, although harbor seals are capable of diving to 500 m[20]. These seals are considered to feed at the seafloor[2]. Kuril harbor seals of Nemuro[28] and Cape Erimo[5], Hokkaido, were reported to feed on the finfish, such as cottids and blennies, and cephalopods that inhabit nearshore waters. In this study, Kuril harbor seal pups at Cape Erimo also were found to spent a lot of time at shallow depths (<50 m). The ratio of >50m depth logs when the waves were □6 m was ten times that when the waves were <6 m. The seals may tend to use deep offshore water during the nearshore water is rough. The closest 50 m depth is approximately 5 km offshore of Cape Erimo, and closest 100 m depth is approximately 12 km offshore[17]. Seals C, E, and F abound in depth logs of about 30 m, which is not true for Seals D. It is possible that depth and/or areas used by the seals differ from individual to individual. The tracked seals tended to spend more time at shallow depths at night than at other times, although the details diving depth are unclear. The tendency for nighttime diving depths to be shallow has been reported for harbor seals in other areas[22].

GPS location data showed that the seal pups hauled out only at Cape Erimo. Harbor seals are known for their sedentary behavior[33], but some of harbor seal pups have shown long-distance travel and dispersal[34]. The distance from Cape Erimo to the nearest other haul-out site is about 170 km[31]. Although harbor seal pups are known to be able to travel that distance[34], the Kuril harbor seal pups tracked in this study did not seem to use other haul-out sites. Mitochondrial DNA analysis of Kuril harbor seals confirms that the seals at Cape Erimo show limited movements to other haul-out sites[36].

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携帯電話ネットワークを利用した、襟裳岬における
ゼニガタアザラシのテレメトリー調査

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要　約

携帯電話のネットワークを利用してデータを遠隔的に回収できるテレメトリーシステムを開発し、野生ゼニガタアザラシ（*Phoca vitulina stejnegeri*）の追跡調査を行った。GPS、乾湿センサー、水深センサー、温度センサーを内蔵したテレメトリー機器が、襟裳岬において 6 頭の 0 歳獣に装着され、最長 88 日間の追跡がなされた。追跡期間中、全ての個体は既知の襟裳岬の上陸場のみを利用した。乾湿センサーは精度に問題があったが、少なくとも、昼間にも夜間にも上陸していることが示された。4 頭の水深記録が解析され、最深の記録は 131m であった。水深 1m より深い記録のうち、98%は 50m より浅いものであった。沿岸の波が高いときには、波が低いときよりも、深い水深を利用する傾向がみられた。3 頭では水深 30m 付近に記録が多かったが、残りの 1 頭にはその傾向はみられなかった。全ての個体において、夜間（21:00-2:30）の水深記録は、他の時間帯より有意に浅かった。

キーワード：ゼニガタアザラシ、*Phoca vitulina stejnegeri*、携帯電話テレメトリー、GPS、
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