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Historical Perspectives

Nobuyuki Miyazaki

(born 4 August 1946)

Nobuyuki Miyazaki began his career as a research associate at the University of Ryukyus, Japan, obtaining his Ph.D. in 1975 under Professor Nishiwaki. He established a Japanese research team focused on marine pollution and hazardous chemicals using marine mammals as an indicator species. Dr. Miyazaki organized the research project "Coastal Marine Environment" that was conducted by United Nations University, Ocean Research Institute of The University of Tokyo, and Iwate Prefecture. He worked as general coordinator of the Japanese Society for Promotion of Science's Multilateral Core University Program "Coastal Marine Science" with other distinguished scientists from five Asian countries. In collaboration with Dr. Y. Naito, he developed an advanced data logger and camera logger, and he also established the "Bio-Logging Science" program at the University of Tokyo. Since 1990, he has conducted international ecological research of Lake Baikal in cooperation with colleagues from Russia, the United Kingdom, Belgium, Switzerland, and the United States. Dr. Miyazaki has published more than 270 English and 13 Japanese peer-reviewed papers, nine English and 51 Japanese books, and seven English and 109 Japanese reports. He also has given 316 presentations at national and international conferences.

Nobuyuki Miyazaki (Photo courtesy of John Anderson)

Seal Survey in Eurasian Waters in Collaboration with Russian Scientists

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I. Personal History and Interest in Wild Animal Investigation

I was born in Tokyo on 4 August 1946, the year following the end of World War II. The Japanese people had begun to reconstruct their cities. When I was in elementary school and the Japanese economic situation had improved slightly, my parents sometimes brought me to the coastal area of Enoshima, which was close to Tokyo, to enjoy the ocean and sea life and to collect marine animals such as fishes, sea stars, and clams along the coast. This was the first time I became interested in sea life and it was my first collection of specimens as a summer holiday task. At that time, I never expected that I would eventually examine a hybrid dolphin named "Kuri-chan" who was a cross between *Tursiops truncatus* and *Grampus griseus* that was kept in captivity at the Enoshima Aquarium for nine years. Nor did I imagine then that I would publish a scientific paper about these animals with the late Dr. Hideo Ohmura, Director of the Whales Research Institute, Japan (Miyazaki et al., 1992).

When I was an undergraduate student (1966 to 1970), I studied general marine biology at Kyoto University under Professors Tamotsu Iwai and Eigi Harada. After that, I studied marine mammals at the Ocean Research Institute, the University of Tokyo, and obtained my Ph.D. entitled *School Structure of the Striped Dolphin off the Pacific Coast of Japan* under the supervision of Professor Masaharu Nishiwaki in March 1975 (Miyazaki, 1977a, 1977b; Miyazaki & Nishiwaki, 1978). Before beginning my Ph.D. program, I believed that striped dolphins (*Stenella coeruleoalba*) might have a sophisticated social structure because the dolphin has a large brain with complex furrows and an intricate, functional nervous system. During the course of my doctoral studies, I analyzed biological information of striped dolphin school members that had been collected by the drive fishery. From my analysis of the growth and sexual maturity of these dolphins, I expected that striped dolphins would have a significantly fluid school structure with individuals readily moving between schools (groups) according to their growth stage and sexual maturity. Still, I did not expect individuals to remain within the same groups for their entire lives. The social structure of striped dolphins seems to be fundamentally composed of a juvenile school and two types of mature schools—(1) a breeding school and (2) a nursery school. (The terms *school* and *group* are used interchangeably here.) Individual dolphins remained in their mother's school for two or three years after birth and then moved from the mother's group to a juvenile school at one or two years after weaning (mean weaning period: 1.5 years). Striped dolphins attained sexual maturity at 9 years old in both sexes; and once sexually mature, dolphins moved from the juvenile school to the mature group. It is noted that the male striped dolphin attained social maturity at approximately 16 years old based on histological observations of the testes and analysis of schools that included many estrous females. The socially mature males moved to the breeding-mature school to mate with estrous females. In the nursery school, lactating females mainly nursed their calves.

I worked as a Research Associate at the University of Ryukyus from 1976 to 1978; as a curator; as a senior curator of marine mammals at the National Science Museum in Tokyo from 1978 to 1985 and 1985 to 1993, respectively; and as a professor of the Ocean Research Institute at the University of Tokyo from 1993 to 2010. As curator of marine mammals at the National Science Museum, I spent much effort in establishing and arranging management of a marine mammal specimen collection, in publishing a catalogue of marine mammals (Miyazaki, 1986), and in creating an electronic database of these collections for access by users, including scientists and members of the general public. I also organized a marine pollution study using marine mammals as indicators of the health of the marine environment with cooperation from Professors Ryo Tatsukawa and Shinsuke Tanabe, both from Ehime University, Japan. Professors Tatsukawa and Tanabe made a great contribution to monitoring environmental conditions and resolving environmental issues of wild animals, especially of seals in Eurasian waters (Tatsukawa et al., 1994).

As a professor at the University of Tokyo, I gave lectures to graduate students about the meaning and importance of field surveys when studying wild animals. I encouraged graduate students and young scientists who had a great interest in biological and ecological studies of marine mammals and marine pollution, and I recommended that these students should conduct their work with their own original ideas. In cooperation with the United Nations University, the Japanese Society for Promotion of Science (JSPS), and other groups (e.g., Miyazaki & Wattayakorn, 2004, 2008; Miyazaki et al., 2005; Miyazaki & Tsukamoto, 2006; Nishida et al., 2011), I organized 21 international symposia and workshops concerning aspects of the marine environment. To understand better the underwater behavior of aquatic animals and their environments, I established a five-year project in 2008, "Bio-Logging Science, The University of Tokyo (UTBLS)" (http://cicplan.ori.u-tokyo.ac.jp/UTBLS/Home.html), using advanced technology developed by distinguished scientists and engineers in Japan. This project is going well and includes cooperation of both intra- and internationally distinguished scientists. Professor Yasuhiko Naito of the Polar Research Institute of Japan made a significant contribution to improving scientific activity using biologging systems in Japan, and he organized the first International Symposium on Bio-Logging Science (Naito, 2004, 2010). This bio-logging system has provided previously unattainable scientific evidence on the underwater behavior of Baikal seals (*Pusa sibirica*). In most of my lectures, I mention that "Advanced Technology creates New Science."

After I retired from the University of Tokyo, the title "Professor Emeritus" was conferred on me, in June 2010. At present, as a senior fellow, I intend to disseminate useful and meaningful knowledge about marine mammals not only to young scientists but also to members of the general public through the Ocean Policy Research Foundation.

During my life and career as a scientist, I have focused on three kinds of research: (1) the biology of marine mammals, (2) understanding marine pollution using marine mammals, and (3) bio-logging science. I have conducted my research in these areas with the cooperation of my colleagues in Japan and overseas. I have published 283 scientific papers (270 in English and 13 in Japanese), 60 books (9 in English and 51 in Japanese), and 116 monographs and other publications (7 in English and 109 in Japanese) over 41 years from 1970 to 2010 (Miyazaki, 2010).

II. Background Information on Seals in Eurasian Waters

From 1970 through 2010, during my research work on marine mammals, I covered the biology and ecology of various marine mammals and their environmental condition, studying species distributed not only in Japanese waters but also in the Bering Sea, tropical waters, and the Antarctic Ocean. In 1988, Dr. Micheal Gurachev, Director of the Limnological Institute of the Russian Academy, Irkutsk, Russia, proposed his original research plan for the establishment of the Baikal International Center for Ecological Research (BICER) with the cooperation of distinguished scientists from around the world. His proposal was accepted by the Academy of Science in the USSR in May 1990. In December 1991, the BICER was established with the cooperation of distinguished scientists from six countries (Belgium, Japan, Russia, Switzerland, UK, and the U.S.) under an agreement with the old USSR—Scientific Academy. Japanese scientists as a group also established a division of BICER in Japan (President: Professor Setsuo Tokuda) in 1991. I was one of the original members and participated in research activities of the BICER of Japan. During two periods—from 1994/1995-1996/1997 and 1996/1997-1998/1999—as project leader, I obtained overseas research funding from the Ministry of Education, Culture, Sport, Science and Technology in Japan and conducted two Japan-Russia cooperative studies. The first cooperative study was on "Animal Community, Environment and Phylogeny in Lake Baikal," during the first period, while the "Biodiversity, Phylogeny and Environment in Lake Baikal" study took place during the latter period. These types of research studies were considered important and essential for co-existence between wild animals and humans on Earth.

Lake Baikal (51° 28'-55° 56' N, 103° 40'-110° 05' E), which was formed 25 to 30 mya, is annually growing 2 cm in width and 6 mm in depth. The lake is the most famous of ancient lakes in the world because of its volume of 2.3 million km^3. Lake Baikal is 639 km long, 80 km in maximum width, 1,643 m in maximum depth, and 46,000 km^2 in area; it contains 1,017 species from 285 genera, excluding protozoa that were recognized, with 70% of them considered endemic species (Morino & Miyazaki, 1994). The Baikal seal is the only mammal species and is a top predator in the ecosystem of Lake Baikal (Figure 1).

Through a series of these research projects, I extended my research target from Baikal seals in Lake Baikal to Caspian seals (*Pusa caspica*) in the Caspian Sea and ringed seals (*P. hispida*) in the Arctic Ocean in order to compare biological and ecological details about each of the three species of their genus, *Pusa,* and to understand their environmental situation that might have been affected by manmade chemicals. Additional research funding aided these studies. During our Japan-Russia collaboration, I visited many places in Russia and enjoyed Russian culture and life under the kind support and warm hearts of many local Russian people. I learned a lot of useful information on the biology and ecology of seals and their environmental condition(s), as well as a greater understanding of Russian culture and the life of the local people. In this essay, I would like to share what I learned as background

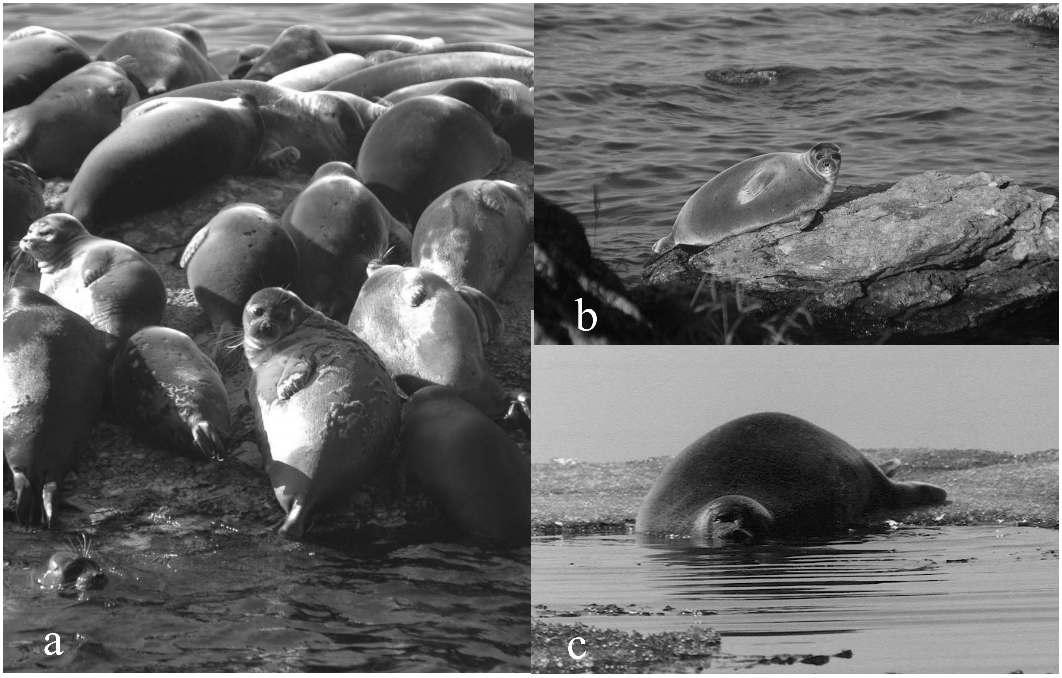

Figure 1. a: An aggregation of Baikal seals (Photo by Dr. Yuuki Watanabe); b: a slender Baikal seal (Photo by Dr. Yuuki Watanabe), and c: a fatty Baikal seal (Photo by Dr. Shinsuke Tanabe)

information from the Japan-Russia cooperative study to enrich the understanding of the three species of the genus *Pusa*.

III. What Is the Relationship Among the Three Species of the Genus *Pusa*?

In order to understand the relationship among the three species of genus *Pusa*, we studied their morphological characteristics and phylogenic relationships in terms of skull morphology and mitochondrial DNA analysis.

King (1964) reported that the genus *Pusa* is represented by three species, *Pusa sibirica, P. caspica*, and *P. hispida*, which have common features such as small size, a delicate skull, and an affinity for ice. Baikal seals, which do not have distinct spots, are uniformly dark silver gray dorsally and light yellowish gray ventrally. Caspian seals are irregularly spotted with brown or black against a light grayish yellow background. The spots are light-colored rings. On the ringed seal, gray-white rings are found on the generally gray backs, and the belly is usually silver and lacking dark spots. The rings are separate or somewhat fused together. The pups of these three species are born with a white woolly natal lanugo. This lanugo is considerably finer and longer than that of the two other northern phocids—the spotted seal (*Phoca largha*) and the ribbon seal (*Histriophoca fasciata*) (Frost & Lowry, 1981). The ringed seal is a species of the circumpolar Arctic coasts with a broad geographic distribution; it is found wherever there is open water in fast ice, even as far as the North Pole, and in fjords and bays, but rarely in the open sea or on floating pack ices (King, 1964). Although numerous populations or subspecies have been reported for the ringed seal, at present, five distinct subspecies are usually recognized: *P. h. hispida* from the Arctic Ocean and the confluent Bering Sea, *P. h. ochotensis* from the Sea of Okhotsk, *P. h. saimensis* from Lake Saimaa, *P. h. ladogensis* from Lake Ladoga, and *P. h. botnica* from the Baltic Sea (King, 1964).

Baikal seals have larger relative growth coefficients for width of snout and nares in comparison to skull length. A large zygomatic width, greater length of the jugal, and smaller orbital width are evidence of the large orbit of this species (Amano et al., 2000). Phenograms indicated a slightly closer morphological affinity between Baikal and ringed seals than between Baikal and Caspian seals. This relationship coincides well with the genetic relationship among the three species by analysis of mtDNA.

According to Sasaki et al. (2003), through their analysis of mtDNA haplotypes, Caspian seals were derived from the common ancient type of *Pusa* at 60 mya and were enclosed in the Caspian Sea. Baikal seals were derived from the ringed seal-like ancestor in the Arctic Ocean and were enclosed in Lake Baikal 40 mya. Based on Russian geographical information on the Eurasian continent, as the Earth was warmer around 40 mya, the southernmost end of the Arctic Ocean was shifted closer to Lake Baikal. This seemed to be one of the reasons why Baikal seals adapted to Lake Baikal; they entered Lake Baikal and adapted to fresh water. After that period, the southernmost end of the Arctic Ocean gradually moved northward as Earth became cooler, and the distance between the Arctic Ocean and Lake Baikal became wider, up to several thousand kilometers.

In addition to the above, it is noted that Baikal seals possess enlarged eyes that enable them to find prey in water as deep and clear as Lake Baikal (Endo et al., 1998a, 1998b, 1999). The Caspian seal has a well-developed masseter muscle. The skull of the Caspian seal possesses the same thin frontal bone and dorso-ventrally developed zygomatic arch found in Baikal seals that are required to hold an enlarged eyeball in the orbit (Endo et al., 2002).

IV. How Do the Seals Live in Eurasian Waters?

In order to understand the lives of Baikal seals, we examined the growth of the species with age, reproductive characteristics, feeding behavior via stomach analysis and stable isotope analysis, and underwater behavior using a bio-logging system. In this section, the life history parameters of these three species of *Pusa* are summarized in order to better understand their adaptation to nature.

Growth

I used an age determination method for these seals by using a canine tooth, which was ground to 20 µm in thickness while keeping the center of the tooth and staining it with hematoxiline solution after decalcification. Age was estimated by reading annual growth layers, having one pair of stained-unstained layers (Miyazaki, 1980). The maximum known age in both sexes in Baikal seals is 56 years old for females and 52 years old for males (Pastukhov, 1993). According to Amano et al. (2000), the oldest age of Baikal seals in the samples (N = 73) collected in 1992 was 24.5 years old for females and 35.5 years old for males. In Caspian seals collected from Pearl Island in the western North Caspian Sea (N = 118), the oldest age of seals examined was estimated to be 43.5 years old for females and 33.5 years old for males.

The body length growth of Baikal seals appears to cease around the age of 15 years old (Amano et al., 2000). The seals may continue to grow for 8 to 9 years after the age of sexual maturity (6 years old for females and 7 years old for males). Asymptotic body length is 140 cm in males and 130 cm in females. In Caspian seals, body length growth appears to cease around the age of 10 years, which is the age of sexual maturity in both sexes. Asymptotic body length is 118 cm in males and 111 cm in females. McLaren (1958) reported that the growth of ringed seals continues throughout the first 8 to 10 years of life. About 86% of final body length is attained by sexual maturity at 6 to 8 years old. Average adult lengths for the ringed seal vary from 121 cm in the Chukchi Sea to 128.5 cm in the Bering Sea (Fedoseev, 1975) and 135 cm in the Canadian Arctic (McLaren, 1958).

Reproduction

Most Baikal seals breed by 6 years old for females and 7 years old for males (Thomas, 1982). Pups are 65 cm in body length and 4.1 kg in body weight on average. A rather high rate of twinning (4% of annual births) is exhibited compared to other seals (Pastukhov, 1968). Mating may occur under water in March at about the time mothers wean their pups. Mothers nurse their pups in a birthing lair. The lactation period is estimated at 2 to 3 months. The mating system is assumed to be polygamous with little or no pair bonding. In winter, when Lake Baikal is covered with ice averaging 80 to 90 cm in thickness with a maximum of 1.5 m, seals are sighted throughout the lake and adjacent to breathing holes in the ice. In Baikal seals of 7 years old or more, 84% of the females give birth to pups yearly (Patstukhov, 1993). Caspian seal pups are born on the ice from the middle of January to the end of February and are about 60 cm in body length. Mating takes place between the end of February and the middle of March. Sexual maturity is attained at 4 to 6 years in females and 6 years old in males (Ognev, 1935; Fedoseev, 1975). The pregnancy rate of Caspian seals over 9 years of age was 31.3% (n = 16) in 1993 and 20% (n = 30) in 1997 and 1998. Ringed seal pups, which are born between the middle of March and the middle of April, are on average 65 cm in body length and about 4.5 kg in body weight. They are always born on shore-fast ice, either in a lair under the snow, excavated by the mother, or in a natural hollow in the ice. Ringed seals attain sexual maturity at 6 to 7 years old in both sexes with wide geographic variation from 3 to 5 years old for *P. h. botnica* to 6 to 10 years old for *P. h. hispida* (Frost & Lowry, 1981).

Feeding Behavior

Baikal seals feed mainly on four fish species: the greater golomyanka (*Comephorus baicalensis*), the lesser golomyanka (*C. dybowskii*), the Baikal yellowfin sculpin (*Cottocomephorus grewingki*), and the longfin sculpin (*C. comephoroides*), all of which are not of commercial value. In captivity, an adult Baikal seal consumes up to 5.6 kg of fish per day (Pastukhov, 1969). Caspian seals in the northern Caspian Sea feed on *Clupeonella engrauliformis, C. grimmi, C. delicata* *caspia,* Gobiidae, *Rutilus rutilus caspicus, Atherina mochon pontica, Lucioperca lucioperca,* other fish species, and crustaceans (Khuraskin & Pochtoyeva, 1997). It is estimated that an adult Caspian seal appears to consume 2 to 3 kg fish per day or approximately 1 ton of fish per year. Ringed seals feed on small fish and also on a wide variety of small pelagic amphipods, euphausids, and other crustaceans. Seventy-two food species were identified in the stomachs of seals from the eastern Canadian Arctic. In shallow, inshore waters, the seals feed near the bottom, chiefly on polar cod (*Boreogadus saida*) and on the small crustacean *Mysis*; whereas those in the deeper offshore waters catch the planktonic amphipod *Themisto libellula* (King, 1964). According to Yoshii et al. (1999), stable isotope analyses of muscles of Baikal seals indicated that seals seemed to consume fishes of pelagic sculpins (54% of total food examined) and *Macrohectopus branickii* (gammarid crustaceans) (46%). This result showed a big difference from the results of stomach content analysis, indicating that it might be due to a difference of digestion speed between fishes and crustaceans.

Advanced technology such as a bio-logging system has been used to confirm the foraging behavior of this seal. Information from the data logger (UWE 1000-PD2GT), together with a camera logger (DSL DTV), also showed behavior of Baikal seals chasing fish prey and their different diving behavior between day and night (Watanabe et al., 2004) (Figure 2). The mean (maximum) dive depths and durations of Baikal seals were 68.9 m (245 m) and 6.0 min (13.5 min), respectively. The DSL image showed that Baikal seals appeared to choose a pelagic sculpin (*Comephorus* sp.) at 54 m depth with swimming speeds of more than 2 m/s, and the seal recognized the fish as silhouette against the surface water with a body angle of 45°. These experiments also showed the utility of the automatic releasing system with a timer. Baikal seals showed significantly different underwater behavior between day and night time, indicating that the seals mostly swam in the shallow zone (0 to 50 m depth) at an average speed of 1 to 5 m/s in the daytime; while in the nighttime, the seals were in a slightly deeper zone (0 to 150 m) at an average speed of 5 m/s. During the daytime, we confirmed the catching performance of the seal which recognized the sculpin as a silhouette

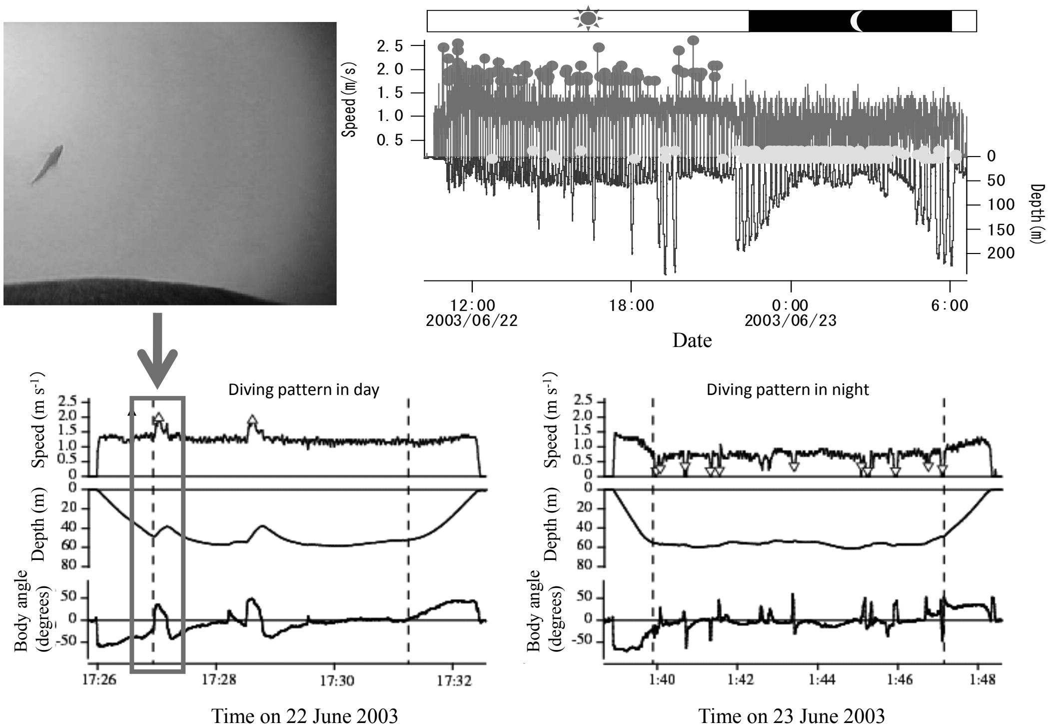

Figure 2. Underwater diving profile of Baikal seals (Watanabe et al., 2004); photo (upper left) was taken by a camera logger mounted on a Baikal seal, indicating the seal recognizing fish as silhouette against surface water. Acceleration and body angle were recorded by the data logger (lower left) with a comparison of swimming speed and depth between day and night time (upper right). Arrow indicates the acceleration and body angle when photo was taken (Watanabe et al., 2004).

and chased fish from the bottom to the surface. On the other hand, Baikal seals showed characteristic downward behavior for capturing *M. branickii* with similar vertical patterns of the species in the nighttime: descend 200 m depth in the evening and ascend to surface at midnight and descend again to 200 m in the early morning. Although we did not directly confirm the feeding behavior of Baikal seals by the camera logger at night, it appeared that Baikal seals behaved in a manner corresponding to the vertical behavior of *M. branickii* at night. This kind of diving behavior by Baikal seals seems to support the results of stable isotope analysis (Yoshii et al., 1999).

Buoyancy Control Mechanism

Watanabe et al. (2006) conducted experimental research of Baikal seals in terms of stroke-and-glide swimming patterns using lead weight. From the speed and pitch of the seal when swimming, they indicated that body density of the seal was estimated at 1,027 to 1,046 kg/m^3, which corresponds to a 32 to 41% lipid content, for the weighted condition, and 1,014 to 1,022 kg/m^3, with a 43 to 47% lipid content, for the unweighted condition. This result suggested the Baikal seals had a characteristic buoyancy control mechanism: slender seals having a density of more than one were able to easily move toward bottom in the descend stage without stroking; while in the ascend stage, the individuals had to use strong stroking (Phillips, 2006) (see Figure 3). On the other hand, fatty seals having a density of less than one had to use strong stroking in the descend stage; while in the ascend stage, the individuals were able to move to the surface without stroking.

V. How Do the Seals Handle Severe Environmental Conditions?

Hazardous chemicals (e.g., heavy metals, organochlorine compounds, organotin compounds, radionuclides, etc.) were highly accumulated in Baikal and Caspian seals, which are top predators in the ecosystem and have long lives—more than 40 years at maximum. Hazardous chemicals are considered to be one factor for lowering the immune system of wild animals. In this section, I briefly review the reported concentrations of these chemicals accumulated in seals in Eurasian waters.

Heavy Metals

The mean concentration of heavy metals in the liver, muscle, and kidney of 60 Baikal seals collected in 1992 was 940, 290, and 160 μg/g in wet weight for Fe, respectively; 42, 20, and 34 μg/g for Zn, respectively; 3.8, 1.1, and 5.5 μg/g for Cu, respectively; 2.3, 0.25, and 1.8 μg/g for Hg, respectively; 2.1, 0.12, and 0.84 μg/g for Mn, respectively; and 0.28, 0.003, and 2.0 μg/g for Cd, respectively (Watanabe et al., 1998). Higher levels of Zn, Hg, and Mn were observed in the liver, while higher concentrations of Cu and Cd was found in the kidneys. The level of both Hg and

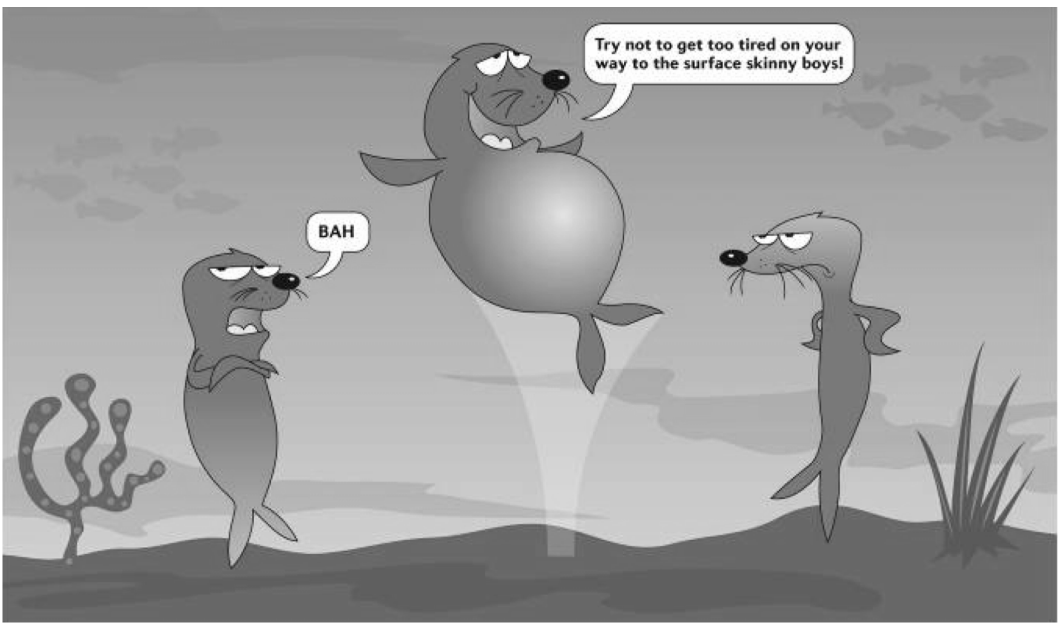

Figure 3. Schematic relationship of fatty and slender Baikal seals related with buoyancy. Reprinted with permission from Phillips (2006).

Cd in Baikal seals is lower than that of other seals collected from polluted areas such as the Bering Sea (Dietz et al., 1990; Frank et al., 1992; Ikemoto et al., 2004) and off the UK coast (Law et al., 1991, 1992). The mean concentration of Hg in fur was 3.5 µg/g. The annual excretions of Hg from the liver of adult females and males were estimated at 0.78 and 0.65 mg/y, respectively (Watanabe et al., 1998).

Organochlorine Compounds

Levels of DDTs and PCBs in the blubber of Baikal seals, of which the fat content was 87%, ranged from 4.9 to 160 µg/g and 3.5 to 64 µg/g on a lipid weight basis, respectively (Nakata et al., 1995). Concentration of CHLs (0.22 to 1.9 µg/g) and HCHs (0.028 to 0.14 µg/g) were approximately one to three orders of magnitude lower than those of DDTs and PCBs. Female Baikal seals appeared to transfer about 20% of their total DDTs and 14% of their total PCBs to a pup during the reproductive process such as parturition and lactation. In Caspian seals, DDTs were dominant chemicals in the blubber samples of 23 individuals collected in 1993 (ranging 5.6 to 88 µg/g wet weight), followed by PCBs (2.2 to 2.3 µg/g), HCHs (0.13 to 2.0 µg/g), CHLs (63 to 500 ng/g), and HCB (2.4 to 77 ng/g) (Watanabe et al., 1999) (Figure 4). In adult Caspian seals, there was less sexual difference in organochlorine contamination levels than for Baikal seals. The mean concentration in prey fish such as *Rutilus* sp. was 0.033 µg/g by wet weight for PCBs, 0.018 µg/g for DDTs, 0.055 µg/g for HCHs, 0.001 µg/g for CHLs, and 0.0008 µg/g for HCB. These chemicals in Caspian seals were accumulated at about 10 to 1,000 times higher than the levels found in their prey fish. Baikal seals are highly polluted by PCBs and DDTs but less contaminated by HCHs than are Caspian seals. According to Kajiwara et al. (2002), some dead Caspian seals collected after a mass die-off that occurred in 2000 showed a higher accumulation than healthy individuals.

Professor Iwata's laboratory at Ehime University, Japan, has studied the biological impact in Baikal seals of aryl hydrocarbon receptor (AHR) and AHR nuclear translocator (ARNT) expression; potential sensing biomarkers of persistent organic pollutants (POPs); and molecular characterization of cytochrom P450 1A1, 1A2, and 1B1, and polychlorinated dibenzo-p-dioxin, dibenzofuran, and biphenyl congeners on their hepatic expression in Baikal seals (Sakai et al., 2006; Hirakawa et al., 2007). It is noted that the results gleaned from this research could make significant contributions to a better understanding of the environmental issues affecting all three species of *Pusa*: Caspian, ringed, and Baikal seals (Kim et al., 2005; Sakai et al., 2006; Hirakawa et al., 2007).

Organotin Compounds

Organotin compounds have been used as antifouling paints on ships and set nets. They have caused many deleterious effects on non-target aquatic organisms,

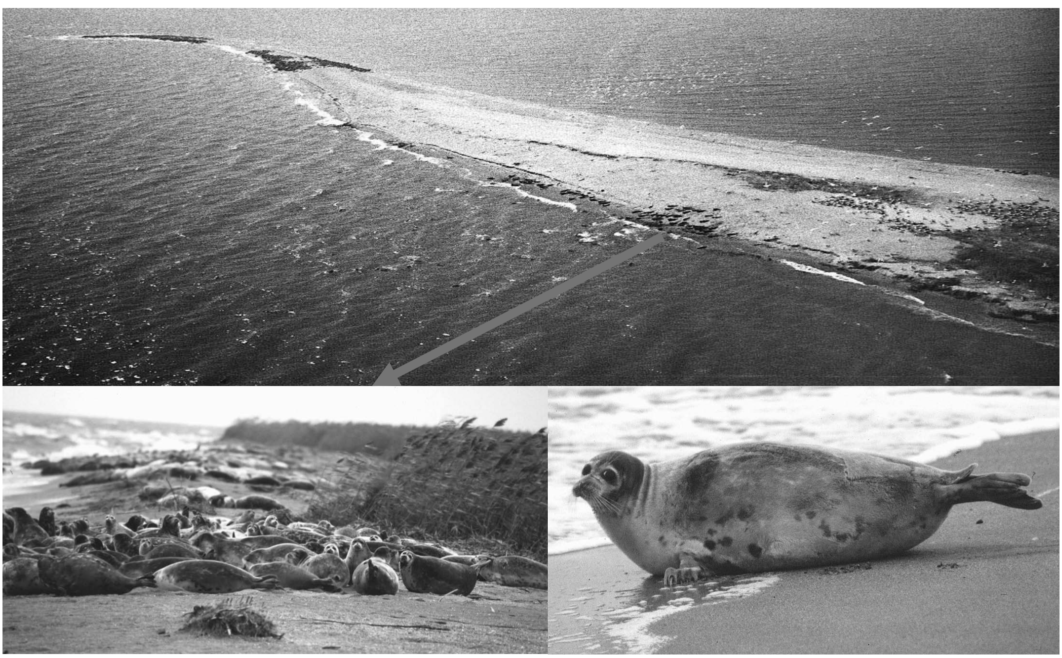

Figure 4. Pearl Island (top) (Photo courtesy of Dr. L. S. Khuraskin), aggregation of Caspian seals (lower left), and a typical Caspian seal on Pear Island (lower right)

including imposex in a gastropod and decrease in the survival rate of caprellid amphipods (Gibbs et al., 1988; Ohji et al., 2002). The concentration of butyltin compounds in the liver of Caspian seals ranged from 0.49 to 17 ng/g on wet weight basis, suggesting less contamination by organotin compounds in Caspian seals (Kajiwara et al., 2002).

Radionuclides

Pollution from anthropogenic radionuclides has occurred in the environment up until the first half of the 1900s. Concentrations of anthropogenic radionuclides such as ^{137}Csijium, ^{148}Plutonium, and ^{90}Strontium have been distributed widely around the world as the result of the fallouts from nuclear tests, accidents at nuclear power plants, and more. From 1954 to 1962, radionuclide contamination on Earth was mainly due to global fallout from past nuclear explosions in the atmosphere. Marine pollution by radionuclides has been influenced by discharge from a reprocessing plant in Sellafield, UK, in 1951 and by the fallout of radionuclides from the nuclear accident at the Chernobyl nuclear power station in 1986. In recent decades, a lot of radionuclide wastes in Russia have been dumped into the Arctic Ocean and Sea of Japan (Yablokov, 2001).

Concentrations of radionuclides are highly accumulated in marine mammals through the food chain in the marine ecosystem. The concentration factor (CF), which is defined as the ratio of the ^{137}Cs concentration in an animal's muscle (mBq/kg wet weight) to seawater's concentration (mBq/L), was 186 for marine mammals, 100 for fish fillets, 30 for crustaceans, and 10 for cephalopods; these levels suggest that CF increases through trophic levels (International Atomic Energy Agency [IAEA], 1985; Yoshitome et al., 2003). The ^{137}Cs level in the muscle of Baikal seals collected in 1992 ranged from 12 to 17 Bq/kg (N = 5; mean: 14 Bq/kg) (Yoshitome et al., 2003). This value for Baikal seals, despite the fact that the ^{137}Cs level in the sediment was low in Lake Baikal (Edgington et al., 1991), was significantly higher than for values in harbor porpoises (*Phocoena phocoena*) of the highly contaminated Black Sea (N = 5, 9.0 Bq/kg) and ringed seals of the Kara Sea (N = 5, 2.0 Bq/kg) contaminated by the dumping of nuclear reactors and radioactive wastes from nuclear weapons facilities (Figure 5). Still, this level for Baikal seals was lower than that found in grey seals (*Halichoerus grypus*) from the UK coast (N = 3, 17.6 Bq/kg); ^{137}Cs levels here were caused by discharges from the nuclear fuel reprocessing plant of Sellafield that started in 1951 and reached a maximum in the mid- to late-1970s (Anderson et al., 1990).

The ^{137}Cs level in the muscle of Caspian seals was relatively low, ranging from 1.5 Bq/kg to 2.8 Bq/kg (N = 5; mean: 2.6 Bq/kg) (Yoshitome et al., 2003). Froehlich et al. (1999) reported that the levels of anthropogenic radionuclides in the Caspian Sea can be explained by global fallout, and signs associated with the dumping of radioactive wastes were not observed.

Yoshitome et al. (2003) reported that the concentration of ^{137}Cs in marine mammals was the highest along the coast of the UK, followed by in Lake Baikal and in the Caspian Sea. Concentrations of ^{137}Cs was highest near Shellafield and decreased with distance from Shellafield in the muscles of harbor seals, grey seals, and harbor porpoises stranded along the UK coast from 1988 to 1995. ^{137}Cs levels in the Black Sea further increased as did the concentration in marine mammals found in that sea, mainly due to the atmospheric fallout after the Chernobyl accident.

In addition to this, I have to mention the recent crisis of the Fukushima Daiichi Nuclear Power Station, which was caused by the "Higashi-Nihon Dai-Shinsai" at 14:46 (JST) on 11 March 2011, yielding an earthquake of a magnitude of 9.0 and a tsunami wave of 10 m and more. On 11 March 2012, the Metropolitan Police Department of Japan reported that the number of people dead was 15,854, and 3,155 persons were still missing because of this disaster. This crisis was ranked at a level 7 of the International Atomic Energy Agency (IAEA) criteria, which was a similar level to the Chernobyl Atomic Power Station Accident in 1986. The main reason why this crisis occurred might be due to the stopping of the cooling nuclear generator system of the Fukushima Daiichi Nuclear Power Station. Although the Tokyo Electric Power Company tried to stop the meltdown of a nuclear fuel rod with seawater as the emergency cooling system was broken down by this disaster, it was not successful. On 12 May 2011, the Asahi-shinbun newspaper reported that 520 tons of wastewater containing 4,700 trillion Bq radionuclides flowed out through unknown cracks; this was 200,000 times larger than the legal limit. According to the Japanese Fishery Agency, the concentration of ^{131}I and ^{137}Cs accumulated in the small fish "Konago" (*Ammodytes personatus*), which were collected from the southwest area of the Fukushima Daiichi Nuclear Power Station, was 4,089 Bq/kg and 564 Bq/kg, respectively, indicating that sea waters off Fukushima Daiichi Nuclear Power Station were severely polluted by these radionuclides. As the CF of ^{137}Cs was 100 for fish fillets (IAEA, 1985) and 186 for muscles of marine mammals (Yoshitome et al., 2003), it is noted that radioactive chemicals might be accumulated at a higher level to the predator in the ecosystem through bioaccumulation; this is a crucial environmental problem. Thus, it is very important that international monitoring survey(s) in the Pacific Ocean should be utilized for understanding the movement of radioactive waste and its accumulation in human foods. I strongly recommend a

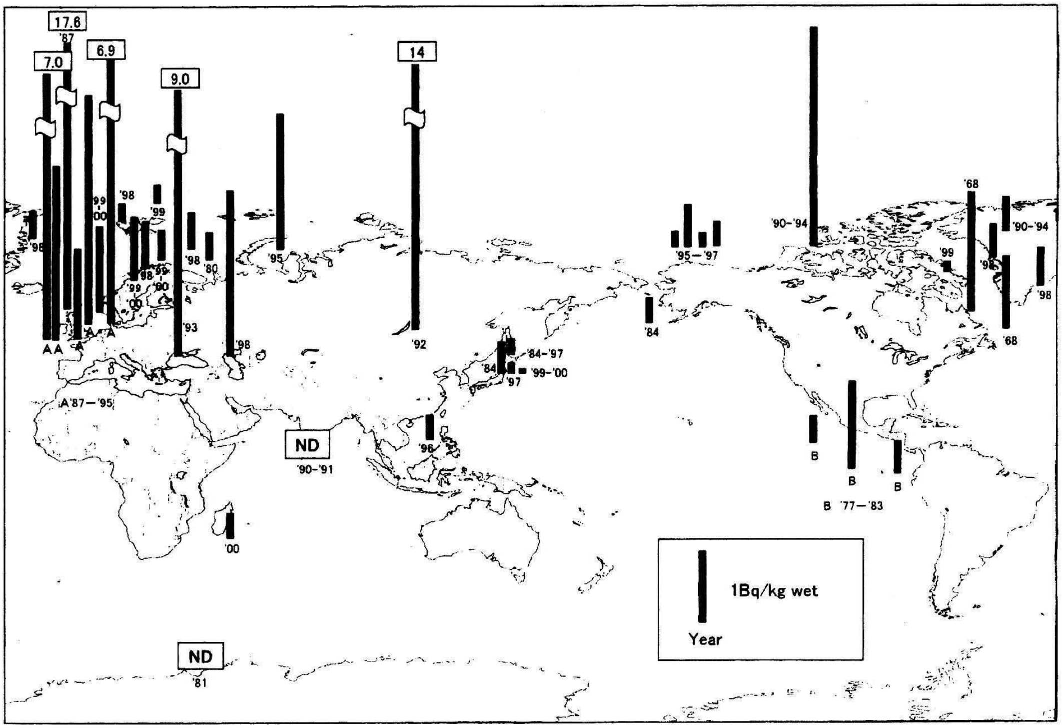

Figure 5. Comparison of ^{137}Cs concentration in the muscles of seals in the world. Reprinted with permission from Yoshitome et al. (2003), *Environmental Science & Technology*, *37*, 4597-4602. Copyright 2003 American Chemical Society.

comprehensive, systematic, and long-term monitoring survey for understanding how radioactive waste accumulates in wild animals through the food chain, and how radionuclides spread from the pollution source, the Fukushima Daiichi Nuclear Power Station, to monitoring sites in the Pacific Ocean.

Dumping Radionuclide Wastes

According to Yablokov (2001), many used facilities (e.g., containers, nuclear surface vessels, nuclear submarine vessels, nuclear ice breaker fleet, nuclear objects) and liquid wastes related to radionuclides were dumped into the Arctic Ocean, the Sea of Okhotsk, and the Sea of Japan. Illesh & Makarov (1992) reported that large explosions at facilities with radionuclides, such as the Chernobyl accident, occurred in Russia several times in the 1950s. Additionally, old facilities which used radionuclides that were established in the 1970s are scattered all over the Russian territory suggesting that residents might face severe health problems related to the half life of ^{90}Sr and ^{137}Cs which have a half life of 29 and 30 years, respectively.

More than several thousand atomic batteries used as an electric resource for lighting along the coast of the Arctic Ocean, where ^{90}Sr (half life: 29 years) is used as an energy source, have been dumped on the coast, and residents live there without precise information on the potentially disastrous effect on human health that can be caused by a used atomic battery (Figure 6). Monitoring studies on radionuclide pollution in these areas should be continued with the cooperation of Russian scientists.

Dr. Yablokov (2001) gave a lecture titled the "Present Situation of Radionuclide Pollution in Russia" at the International Conference "Man and the Ocean," held at the United Nations University in Tokyo in 1998, in which he insisted on the importance of international collaboration for systematic research surveys of radionuclide pollution in Russian territories. The current terrible load of radionuclides is not precisely calculated, and the potential harm to human health has not been made known to the people who would be most affected. A well-coordinated effort for management against the potential for horrible human ailments could be caused by such high loads of radionuclides, even though these levels are not precisely calculated.

VI. Looking for a Future Direction to Coexistence Between Humans and Wild Animals

A mass-die off of thousands of Baikal seals in Lake Baikal occurred in 1987-1988; the virus isolated

Figure 6. Dumping the used atomic battery of an electric resource for lighting along the coast of the Arctic Ocean

from dead Baikal seals was identified as canine distemper virus. This seal population had been closed genetically and antigenically to the canine distemper viruses isolated from a dog and a ferret (Grachev et al., 1989; Osterhaus et al., 1989; Mamaev et al., 1995, 1996). According to Ohashi et al. (2001), the virus neutralizing test and ELISA (enzyme-linked immunosorbent assay) clearly suggested that the distemper virus epidemic was caused in Caspian seals before the spring of 1997 and that the canine distemper virus infection continued to occur in Lake Baikal in recent years. The genome of the canine distemper virus was found in one of the dead Caspian seals, and the sequence of P gene in that animal was distinct from that of the Baikal seal virus, laboratory strains, and field isolates from terrestrial animals in other areas (Forsyth et al., 1998). According to Kennedy et al. (2000), the mass die-off of Caspian seals also was caused by canine distemper virus.

Antibodies to influenza A virus in Baikal and Caspian seals were examined by my colleagues using ELISA in the sera. In Caspian seals, antibodies to human-related A/Bangkok/1/79H3N2 were detected in 37% of the total (N = 77) of Caspian seals sampled (Ohishi et al., 2002, 2003). These results indicate that the human A/Bangkok/1/79H3N2-like virus was transmitted to Caspian seals probably in the early 1980s and circulated in the population. ELISA-positive sera from one of seven Baikal seals reacted to A/Bangkok/1/79(H3N2) and A/Aichi/2/68(H3N2) strains, respectively (Ohishi et al., 2004). The antibodies to influenza B virus to B/Lee/40 as antigens were detected from four out of 42 Caspian seals collected in 2000 (Ohishi et al., 2003) (Figure 7).

This influenza virus infection occurred through the wall between human and bird species and between human and seal species. In an interview with the editor of *Lancet* on 6 January 2004, I mentioned that epidemics often occur when viruses evolve into more virulent strains as they move from animals to people. Type A viruses have been responsible for worldwide pandemics, including the 1968-1969 "Hong Kong Flu" that killed more than 1 million people (http:en.wikipedia.org/wiki/Influenza_A_virus_, subtype_H3N2) and the 1918 "Spanish Flu" that killed between 50 and 100 million (http:en.wikipedia.org/wiki/1918_flu_pandemic). In an interview with the Associated Press, I stressed that Type A strains are dangerous because they tend to jump from species to species and also mutate quickly. It might be possible for people to catch the virus from birds or seals and be defenseless if the body's immune system lacks the right antibodies to fight it. Citing the SARS (severe acute respiratory syndrome) outbreak, I recommended that health authorities be more vigilant against animal diseases. The SARS virus is believed to have jumped from the masked palm civet (*Paguma larvata*) to humans, killing 774 people worldwide and sickening 8,000 last year (www.who.int/csr/don/2004_01_05/en). Based on these findings, I strongly recommend that an international research system should be established in Eurasian waters to monitor environmental contamination by hazardous chemicals (e.g., heavy metals, organochlorine compounds, organotin compounds, radionuclides, etc.), to monitor for viral infections in wild animals and humans, and to draft a comprehensive defensive system against viral infection to humans. I also recommend that conservation of our ecosystem(s) and protection of wild animals should be established as an internationally collaborative endeavor.

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I appreciate my Russian and Japanese colleagues for their kind help and assistance during the field research of Baikal seals, Caspian seals, and ringed seals of the Arctic Ocean environment in Eurasian waters (Figure 8). I also thank my wife, Noriko, and my family for their understanding of my own ideas and plans for the research, and for supporting my work with warm hearts. Without their great contribution, I could not study these animals and research topics successfully.

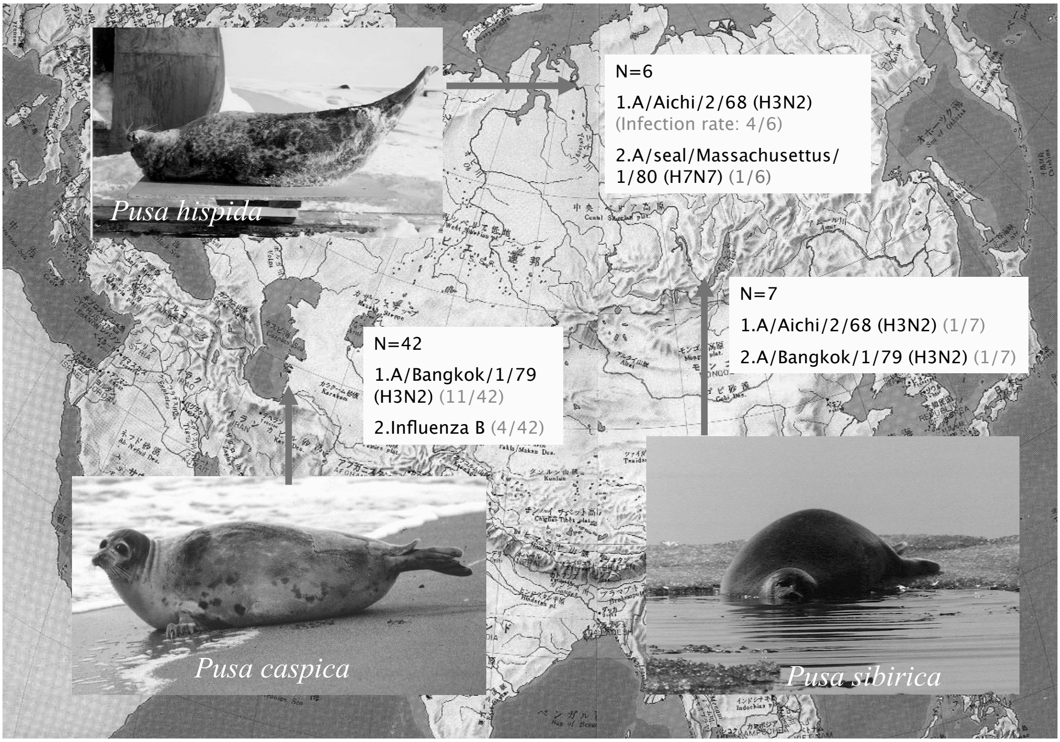

Figure 7. Infection rate of Influenza A and B viruses in the three species of the genus *Pusa* (Ohishi et al., 2002, 2003, 2004)

Figure 8. A group photo of the research team in the Caspian Sea

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