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FURTHER READING

Compton, S. G., S. J. Ross, and I. W. B. Thornton. 1994. Pollinator limitation of fig tree reproduction on the island of Anak Krakatau (Indonesia). *Biotropica* 26: 180–186.

Shilton, L. A., J. D. Altringham, S. G. Compton, and R. J. Whittaker. 1999. Old World fruit bats can be long-distance seed dispersers through extended retention of viable seeds in the gut. *Proceedings of the Royal Society, London B* 266: 219–223.

Simkin, T., and R. S. Fiske, eds. 1983. *Krakatau 1883—the volcanic eruption and its effects.* Washington, DC: Smithsonian Institution Press.

Thornton, I. W. B. 1996. *Krakatau: the destruction and reassembly of an island ecosystem*. Cambridge, MA: Harvard University Press.

Whittaker, R. J., M. B. Bush, and K. Richards. 1989. Plant recolonization and vegetation succession on the Krakatau Islands, Indonesia. *Ecological Monographs* 59: 59–123.

Whittaker, R. J., R. Field, & T. Partomihardjo. 2000. How to go extinct: lessons from the lost plants of Krakatau. *Journal of Biogeography* 27: 1049–1064.

Whittaker, R. J., and S. H. Jones. 1994a. The role of frugivorous bats and birds in the rebuilding of a tropical forest ecosystem, Krakatau, Indonesia. *Journal of Biogeography* 21: 245–258.

Whittaker, R. J., and S. H. Jones. 1994b. Structure in re-building insular ecosystems: an empirically derived model. *Oikos* 69: 524–530.

Whittaker, R. J., S. H. Jones, and T. Partomihardjo. 1997. The re-building of an isolated rain forest assemblage: how disharmonic is the flora of Krakatau? *Biodiversity and Conservation* 6: 1671–1696.

KURILE ISLANDS

ALEXANDER BELOUSOV AND MARINA BELOUSOVA

Institute of Volcanology and Seismology, Petropavlovsk, Russia

THOMAS P. MILLER

U.S. Geological Survey

The Kurile (or Kuril) Islands are one of the last blank spots on the world map, and their very remoteness results in a uniquely pristine environment. The biodiversity of the islands is remarkable, ranging from broad-leaved subtropical forests with magnolia, ligneous lianas, and Kurile bamboo in the south to subarctic moss tundra, alder shrubs, and stunted birches in the north. The landscapes are impressive, combining rocky capes, heavy fogs, surrealistic volcanic cones, boiling crater lakes, and almost impenetrable giant grasses. The Kurile Islands have often been compared to the nearby Aleutian Islands, and with good reason in terms of geology, remoteness, and notoriously bad weather. But the critical, though usually ignored, difference in orientation between the 1200-km-long, northeast-trending Kuriles and the 1800-km-long, east-west-trending Aleutians results in major differences in climate and accordingly in flora and fauna.

GEOGRAPHY

General Description

The Kurile Islands are located in the northwestern part of the Pacific Ocean, forming a 1200-km long island arc stretched over 8° of latitude from the Kamchatka Peninsula (Russia) southward to the island of Hokkaido (Japan) (Fig.1). This island arc separates the Sea of Okhotsk from

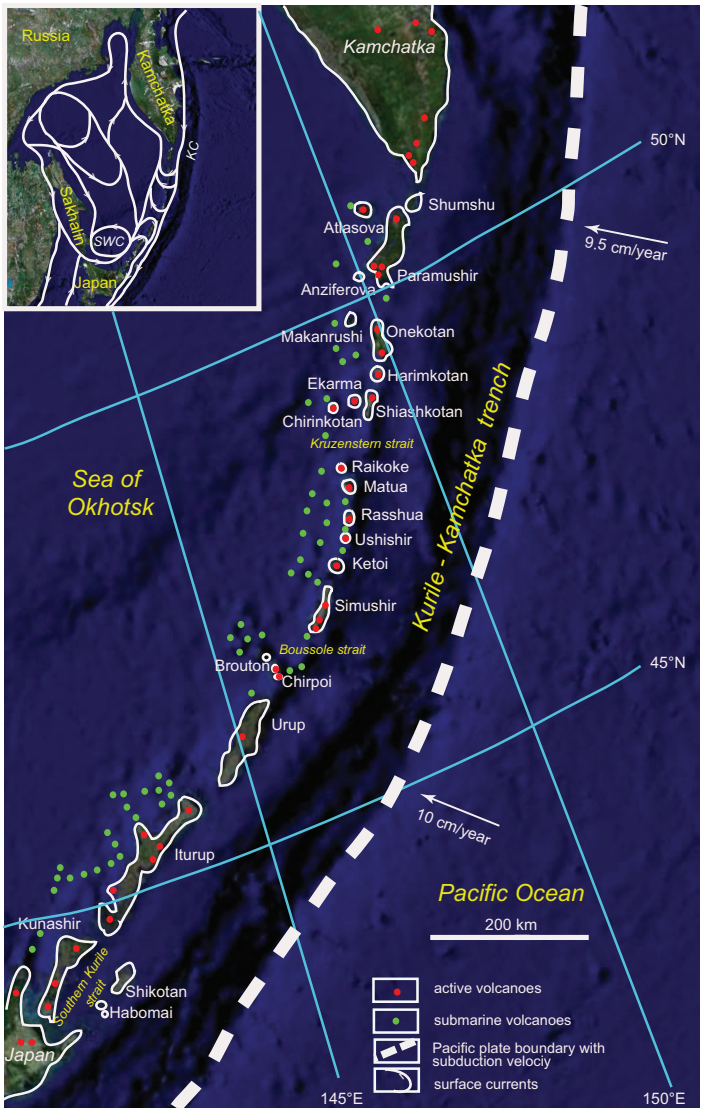

FIGURE 1 Schematic map showing the location of the Kurile Islands with inset showing their location in the Northwest Pacific. In the inset, the surface currents are shown with directions of circulation. SWC: Soya warm current; KC: Kamchatka Current.

the Pacific Ocean and represents an important geographical and geological boundary. The arc consists of 22 main islands and 30 smaller islets with a total area of 15,600 km^2. The largest islands—Iturup (3200 km^2), Paramushir (2000 km^2), Kunashir (1500 km^2), and Urup (1450 km^2)—are very narrow across the arc and extended along the arc, in contrast to the smaller islands, which tend to be oval or irregularly shaped.

The Kuriles are subdivided longitudinally into two approximately parallel island chains: the Greater Kuriles and the much shorter Lesser Kuriles, located in the southern part of the arc. The chains are separated by the 50-km-wide and 130-m-deep Southern Kurile Strait. The Lesser Kuriles consist of Shikotan Island and six small islands (the Habomai group). The Greater Kuriles include all of the remaining Kurile Islands, from Shumshu southward to Kunashir. Both island chains represent emerged summits of approximately parallel undersea ridges: the Greater Kurile Ridge, which connects to the Shiretoko Peninsula of Hokkaido, and the Lesser Kurile Ridge or Vityaz Ridge, which connects to the Nemuro Peninsula of Hokkaido. The oceanic slope of the Vityaz Ridge descends into the deep (10,542 m) Kurile-Kamchatka Trench, which lies along the entire length of the archipelago and represents the surface expression of subduction of the Pacific Plate under the Okhotsk Plate (formerly considered part of the North American Plate).

The island arc is subdivided transversely into three groups of islands separated by deep and wide straits. The Northern Kurile Islands (Shumshu to Shiashkotan) are separated from the Central Kurile Islands (Matua to Simushir) by the Kruzenstern Strait (1900 m deep and 80 km wide). The Central Kurile Islands are, in turn, separated from the Southern Kurile Islands (Chirpoy to Kunashir) by the Boussole Strait (2300 m deep and 67 km wide). Most of the Kurile Islands have mountainous relief punctuated by tall volcanoes, many of which are active. The highest volcanoes are Alaid (2339 m, Atlasova Island), Tyatya (1819 m, Kunashir Island), and Chikurachki (1816 m, Paramushir Island). Tyatya is considered one of the most beautiful volcanic cones in the world (Fig. 2). Shumshu Island and islands of the Lesser Kuriles have no volcanoes and a low flat relief.

Although rivers and lakes are common on the larger Kurile Islands, several small islands have no sources of drinking water. Island rivers are commonly short and rapid (whitewater rivers) with many waterfalls. The 140-m high Ilia Murometz waterfall on Iturup is one of the highest in Russia. Many of the lakes are located in volcanic craters and calderas. The deepest (>264 m) and most beautiful is Kol'tsevoye (Circular) Lake (Fig. 3), which is located inside the Tao-Rusyr caldera at Onekotan Island. Some lakes and rivers located in

FIGURE 2 Tyatya volcano, Kunashir Island. View from the southeast from the Pacific coast. Photograph by A. Belousov.

hydrothermal areas have acid thermal waters, where special thermophilic microorganisms and algae flourish (e.g., Kipyasheye Lake on Kunashir, with a pH of 2.8, and Yur'eva river on Paramushir, with a pH of 1.6).

Climate

The Kuriles, in general, have a maritime monsoon climate influenced by sea currents (both cold and warm, Fig. 1) of the Pacific Ocean and the Sea of Okhotsk, as well as by air masses coming from eastern Asia or the Bering Sea region. The southern part of the Sea of Okhotsk is under the influence of the warm Soya sea current, whereas the cold Kamchatka current travels south along the Pacific coast. As a result, the climate of the western slopes of the largest southernmost islands, warmed by the Soya current and protected by high ridges from the cold Pacific, is close to subtropical. The climate of the eastern slopes is notably colder, resulting in strikingly different vegetation. The northernmost islands

FIGURE 3 Kol'tsevoye lake located in Tao-Rusyr caldera. Since the caldera formed 7500 years ago, Krenitzin Peak stratovolcano has formed in the central part of the caldera. The 1952 crater and the lava dome are visible on the slope and at the foot of the volcano. Photograph by A. Belousov.

and the small islands of the Central Kuriles are surrounded by the cold sea and have a subarctic climate.

Precipitation is high throughout the year, from 700 to 1000 mm on the northern islands and 1000 to 1100 mm on the southern islands. Thus, the climate is rather humid, and the islands are almost continuously shrouded by cloud and fog; extended rain (drizzle) is common. In winter the precipitation occurs in the form of heavy snowfalls; snowstorms are frequent. By the end of winter, the Sea of Okhotsk is extensively choked by ice fields that can block the western coasts of the islands.

Population

Similar artifacts (pottery, stone tools, etc.) dated 14,000–11,000 years ago have been found in Japan, southern Kamchatka, and southern Alaska, indicating that in the past the Kurile Islands formed a migration route between Japan and Kamchatka that could have been involved in maritime migrations in and out of the North American continent.

Ancient settlements have been discovered on almost all the Kurile Islands. During the last 7000 years, the Kurile Islands were inhabited by several ethnically different groups of people that replaced one another. First known settlers were people of the Jomon (7000–2000 years ago), Epi-Jomon (2000–1300 years ago), and Okhotsk I and II (1300–700 years ago) cultures. Ainu people inhabited the islands after 700 years ago but were gradually displaced by Japanese and Russians in the eighteenth century.

Since the end of World War II in 1945, all the islands politically belong to the Sakhalinskaya oblast' (Sakhalin District) of Russia, although Japan claims the southernmost islands (Iturup, Kunashir, and the Lesser Kuriles). Only the largest islands (Paramushir, Iturup, Kunashir, and Shikotan) are presently inhabited, and the population of about 20,000, mostly Russian fishermen and coast guard personnel, is concentrated in several small towns.

GEOLOGY

Tectonic Setting

The Kurile Islands were formed by geological processes associated with subduction of the Pacific Plate under the Okhotsk Plate. The rate of subduction of the Pacific Plate is estimated at 95 mm/yr in the north (where the plate motion is normal to the Kurile Trench) and 100 mm/yr south of Boussole Strait (where the arc makes a sharp 22–23° turn to the west and plate subduction becomes oblique). Boussole Strait is considered to be a graben formed by northeast-southwest tension, caused by westward motion of the southern part of the arc due to oblique subduction of the Pacific plate since the Late Miocene (6–7 million years ago). The dip angle of the subduction plane is 48–55° in the northern part and 38–46° in the southern part of the arc. Crustal thickness is 25–36 km below the Northern Kuriles, 26–32 km below the Central Kuriles, and 25–44 km below the Southern Kuriles.

Overall, the Kurile Arc is seismically and volcanically much more active than the Izu-Bonin–Mariana and Ryukyu Arcs to the south, but less active than Kamchatka to the north. Six earthquakes with magnitude >8 were recorded in the twentieth century. Seismicity in the subducting slab occurs to the depth up to 650 km. The most intense seismicity is recorded in the southern sector of the Kurile Arc.

Some earthquakes and volcanic eruptions have generated tsunamis. The most deadly historic tsunami, up to 20 m high, occurred in 1952 in the northern part of the arc, when the town Severo-Kurilsk (Paramushir Island) along with multiple fishing settlements of the Pacific coast of the islands were demolished, with an estimated death toll of 5000. About 50 small to moderate-scale tsunamis have been recorded since 1952, and studies of paleotsunami deposits revealed multiple strong tsunamis throughout the Holocene in the Kuriles. Great earthquakes on November 16, 2006, and January 13, 2007, with magnitudes of 8.3 and 8.1, generated tsunamis more than 20 m high that affected unpopulated shores of the Central Kuriles.

At the present time, the Kurile Islands experience slow ground deformation between major local earthquakes and more rapid deformation (commonly in a reverse direction) during earthquakes. Long-term tide gauge data show that the west coast of Shikotan Island was uplifting at a rate of 12.6 mm/yr until the October 5, 1994, earthquake, when it experienced a 50-cm drop. Recent GPS measurements have shown horizontal motion of the south of Urup Island, with a rate of 18 mm/year in a direction coinciding with the direction of subduction. During the period of the winter 2006–2007 earthquakes, Ketoy Island experienced horizontal motion exceeding 60 cm in a direction opposite to the subduction direction.

Stratigraphy

The Kuriles are built of predominantly volcanic rocks (both volcaniclastic and effusive), and chemical and biochemical sedimentary rocks are rare. The geology of the Lesser and Greater Kuriles is notably different. The Lesser Kuriles are built of Late Cretaceous–Paleogene mafic volcaniclastic rocks intercalated with basalt and basaltic andesite lava flows. The lower part of the sequence (K/Ar ages 105–62.5 million years ago) was deposited in submarine conditions, while the upper (K/Ar ages 61–59 million years ago) formed subaerial shield volcanoes. No Neogene or younger rocks occur in the Lesser Kuriles.

The Greater Kuriles are built of a much wider spectrum of volcanic rocks of Late Miocene age and younger (<12 million years ago). Rock compositions range from basalt to rhyolite (basalts 20%; andesite 64%; dacite 13%, and rhyolite 3%), and the rocks were formed by diverse volcanic processes common for volcanic island arcs. The oldest rock sequence is commonly exposed along the lowermost part of an island sea cliff. It is represented by sub-aquatic tuff and breccia that formed when the islands emerged from the ocean. In the Northern and Central Kuriles, the sequence consists of predominantly basic-composition rocks (commonly palagonitized). In the Southern Kuriles, the sequence is represented by more evolved rocks. The uppermost, predominantly andesitic sequence comprises the volcanic formation processes of Quaternary age.

The Kurile Islands have a blocky structure: geologic formations are disrupted by multiple faults, forming horsts and grabens. Folds are rare and mostly associated with large faults. Intrusive bodies of various types and compositions are widespread.

Geologic History

Formation of the Kurile Archipelago began in the Late Cretaceous (approximately 100 million years ago) when subduction along the Siberian continent was blocked by a large terrain. A new subduction zone appeared in the ocean far southeast from the previous position, where the Kurile-Kamchatka Trench was formed and volcanism started above the subducting slab. The Lesser Kurile Ridge (Vityaz Ridge) was formed during Late Cretaceous. Volcanic activity and uplift in the region intensified during the Paleocene and Eocene (35–60 million years ago), when the islands of the Lesser Kuriles emerged from the sea. Then a late Eocene–Middle Miocene volcanic hiatus followed.

Late in the Miocene (approximately 12 million years ago), volcanic activity resumed along the Kurile-Kamchatka Trench but was concentrated in a zone parallel to the Vityaz Ridge in the location of what is now the Greater Kurile Ridge. During the past 10 million years, the Greater Kurile Ridge has experienced intense volcanic activity and crustal uplift. Although the oldest rocks in the Greater Kurile Ridge are of Late Miocene age, sediment records indicate that main chain of the Kurile Islands probably did not emerge above the sea surface until the early Pliocene (5 million years ago). Some small islands, such as Atlasova, have been formed by volcanic activity in the Holocene (less than 10,000 years ago). The subduction process that led to the formation of the Kurile Archipelago is still in progress, and the elevation of islands continues to change with new eruptions and crustal movements.

Volcanoes

The Kurile Islands, together with the nearby Kamchatka Peninsula and Hokkaido Island, compose a single volcanic arc, a part of the so-called Pacific Ring of Fire. Because of a high subduction rate, the Kuriles are among the more active volcanic areas in the world. In the islands of the Greater Kuriles, 68 subaerial volcanic centers with a total of 200 Quaternary (less than 2 million years old) volcanoes were identified, and 32 volcanoes have been active in historic time. The list is not complete, since only fragmentary records of volcanic activity exist for the area beginning in 1711, and until the early twentieth century many eruptions, especially small ones, passed undocumented. During the historical period, 17 strong eruptions, with volcanic explosivity index (VEI) greater than 3, were reported. The most active volcanoes (with more than five recorded eruptions) are Alaid, Ebeko, Chikurachki, Severgin, Sarychev Peak, and Goryaschaya Sopka. The highest volcanic activity is observed north of the Boussole Strait, where the plate motion is normal to the Kurile Trench.

In addition to subaerial volcanoes, 96 submarine volcanic edifices were discovered in the course of bathymetric and geophysical surveys. They are situated mostly at the Sea of Okhotsk slope of the Greater Kurile Ridge. Depth to the subducting plate is 110–140 km under land volcanoes and 160–220 km under submarine volcanoes (Fig. 1).

Volcanism of the Kuriles has features typical of convergent plate boundaries of the Mariana type. Volcanic products are characterized by evolved compositions (andesite to rhyolite), whereas basalt is relatively rare. Volcanic eruptions of the Kurile arc are highly explosive and are commonly accompanied by pyroclastic flows and surges that, together with laharic deposits, accumulate in large quantities around volcanoes. Effusive eruptions of evolved, viscous lava, which commonly follow the explosive stage, produce steep-sided lava domes or thick lava flows with blocky surfaces.

Many volcanoes demonstrate complex eruptive history with formation of one or more collapse calderas. During the last 45,000 years, more than 15 such calderas with diameters up to 10 km were formed. Many of the calderas are partly submerged, such as 7 × 9 km Lvinaya Past (Lion's Jaw) caldera, formed 9400 years ago, and five underwater calderas are known in the arc.

The caldera-forming eruptions produced extensive sheets of ignimbrites (both welded and nonwelded), mostly of dacitic to rhyolitic composition. The youngest of the large calderas of the Kurile Islands, the 7-km-wide Tao-Rusyr caldera at Onekotan Island, was formed 7500 years ago (Fig. 3). Its formation was accompanied by deposition of extensive sheets of nonwelded ignimbrites of andesitic composition. The most recent (<2500 years ago) Zavaritsky caldera at Simushir has a diameter of 3 km.

Active volcanism in combination with a high precipitation rate results in strong development of hydrothermal activity in the form of solfataras and hot springs. Steam is extracted from wells at Kunashir and Iturup Islands to produce electricity in geothermal power plants. Wide areas of colorful hydrothermally altered rocks occupy summit areas of most volcanoes of the islands. Alteration weakens volcanic structures and, in combination with triggering effects of eruptions and earthquakes, leads to frequent large-scale flank collapses, the volumes of which reach several cubic kilometers. The collapsed mass transforms into fast-moving debris avalanches that generate tsunamis upon entering into the sea. Collapses also result in formation of broad horseshoe-shaped craters. The most recent collapse (volume 0.4 km^2) associated with strong explosive eruption occurred at Severgin volcano (Harimkotan Island) in 1933, causing a tsunami up to 20 m high that killed two people on nearby Onekotan Island.

The long, complex history of many volcanoes of the Kurile Islands resulted in an equally complex morphology of their edifices. Steep-sided composite cones, frequently complicated by horseshoe-shaped craters and summit and/or flank lava domes, represent dominant type of volcanic structures in the Kuriles. In many cases, such cones are merged into volcanic ridges. Large calderas partly filled with younger cones are also common. Less common are symmetric stratovolcano cones, which belong to the youngest and most active volcanoes erupting basic magmas.

Minor gold deposits in hydrothermally altered volcanic rocks have been discovered at Kunashir and Iturup Islands. Sulfur was mined from many volcanic craters during Japanese times, but these deposits are now considered economically insignificant.

Sea Level and Glaciations

The presence of four sea terraces on the islands is evidence of sea transgressions in the past. Sea terraces with the following elevations and ages were distinguished: 3–7 m (climatic optimum of Holocene, ca. 6000 years ago); 20–40 m (Riss-Wurm interglacial, Late Pleistocene 67,000–128,000 years ago); 80–120 m (Middle Pleistocene 180,000–230,000 years ago); 200–250 m (Early Pleistocene 300,000–330,000 years ago).

During the Late Pleistocene (10,000–30,000 years ago), at least two significant sea-level regressions occurred, caused by global glaciations. Sea level dropped on the order of 100 m and possibly 200 to 300 m below the present elevations. The last of these major sea-level regressions occurred 18,000 yBP, when a broad underwater terrace with depths 120–140 m formed around many of the islands. During these periods, shallow straits separating Kunashir and the Lesser Kurile islands from Hokkaido became dry land. Similarly, the Shumshu and Paramushir islands became connected to the Kamchatka Peninsula. Thus, islands of the northern and southern tips of the archipelago have not been isolated from mainland for long time

During the Pleistocene glaciations, glaciers covered the northern and central islands of the Kuriles. Glaciations probably did not extend any further south than central Iturup Island, as there are no signs of glaciation on Kunashir or on the Lesser Kurile islands.

BIOTIC LIFE

The flora and fauna of the Kuriles are not completely studied. Taxonomic diversity of biota of Kurile Islands is comparatively high; for example, among vascular plants 1194 species, 4550 genera, and 135 families were described. Endemic species compose less than 2% of all vascular plants; most of them are so-called neo-endemics (the differences from species of nearby lands are not significant, and not all botanists agree that they represent separate species). Among 300 known species of birds (either living on the islands or migrating), only one species (*Cepphus columba snowi*) is confirmed as endemic, indicating no prolonged isolation of the islands.

Flora

The flora of the Kurile Islands changes notably from north to south as well as with altitude. The main botanical boundary passes through the Boussole Strait between the islands Simushir and Chirpoy. The flora of the northern Kuriles is similar to that of the Kamchatka Peninsula: cedar and alder shrubs surrounded by tundra and meadow vegetation are widespread. From north to south along the arc the vegetation becomes more luxuriant and taller as the climate becomes milder. In the middle part of the Kurile Island Arc (Rasshua to north of Iturup), small-leaved forests (birch, alder, and poplar) dominate. Flora of two southern islands (Kunashir and southern Iturup)

is similar to that of Hokkaido and Sakhalin Island: broad-leaved and coniferous forests are widespread, and dense shrubs (less than 3 m tall) of Kurile bamboo (*Sasa kurilensis*) are common (Ketoy Island is the northernmost limit of the bamboo distribution).

The total area covered by forest is estimated at about 80% at Iturup, 60% at Kunashir, and 20% at Shikotan. Some islands (Raikoke, Ushishir, and Brouton) have no forest at all. Grass vegetation is very rich on all the islands, and grass commonly grows unusually tall (up to 3 m). This phenomenon is so pronounced that has a special name: "Far East gigantism." Dense vegetation of the islands, mountainous relief, and absence of roads make the internal parts of many islands very difficult to access by foot.

Flora of the Kurile Islands exhibits a clear vertical zoning because of the presence of high mountains. In the southern Kuriles (Iturup and Kunashir Islands), the belts of vegetation include (from sea level upward): (1) broad-leaved forests (oak, white elm, maple); (2) dark coniferous forests; (3) birch forests (*Betula ermanii*); (4) cedar and alder shrubs; (5) alpine tundra. At Shikotan an additional belt of juniper shrubs could be distinguished.

Altitude ranges of the belts depend on many factors (e.g., slope exposition, influence of oceanic currents and volcanic activity), and thus the belts are not continuous. From south to north along the archipelago, the lowermost belts gradually disappear, and on Paramushir Island only belts 4 and 5 are present.

Fauna

In total, terrestrial mammals on the Kuriles include six species of chiropterans (bats), nine species of rodents (squirrels, hamsters, and different kinds of rats and mice), nine species of carnivores (foxes, bears, ermines, weasels, minks, and sables), species of insectivores (shrews), and one lagomorph (hare). The largest mammal in the Kuriles is the brown bear, with a total population of about 700. Resident populations of brown bears exist on the largest islands (Kunashir, Iturup, and Paramushir); smaller islands do not support a resident bear population. The most widely distributed species of terrestrial mammals are red and blue arctic foxes, which were introduced on many islands by the Russian-American Trade Company in the nineteenth century. Similarly, American and European mink were introduced by the Japanese in the twentieth century.

Abundant marine mammals live in waters of the Sea of Okhotsk and the Pacific Ocean around the islands: 15 kinds of whales, including blue whales, white whales, sperm whales, and various dolphins. Steller's sea lion, sea otters, spotted seals, and harbor seals are common on rocky shores.

More than 300 species of birds are known in the Kuriles. Cormorants, seagulls, and diving-pigeons form more than 20 giant rookeries.

Seven species of amphibians and reptiles have been discovered in the Kuriles: one species of salamander, one of skink, three of snakes (all of them found only at Kunashir) and two species of frogs (at Kunashir, Shikotan, and at small southern islets). More than 3000 species of insects have been recorded on the islands, but the true number probably is much larger.

Convergence of warm and cold sea currents has made the Kuriles one of the richest fishing zones at the world. Fish from colder water include cod, mackerel, flounder, halibut, and five species of salmon. Subtropical species include saury, sardines, and tuna. Eighteen species of freshwater fishes occur on the islands. Other species, such as crab, shrimp, sea urchin, squid, scallops, and sea cucumbers, are also abundant.

The most significant biogeographical boundary within the Kurile Islands is the Boussole Strait. Of lesser importance are two other straits: the De Vries Strait (between Iturup and Urup Islands) and the Fouth Kurile Strait (between Onekotan and Paramushir Islands).

SEE ALSO THE FOLLOWING ARTICLES

Archaeology / Island Arcs / Japan's Islands, Geology / Pacific Region / Tsunamis

FURTHER READING

Avdeiko, G. P., O. N. Volynets, A. Yu. Antonov, and A. A. Tsvetkov. 1991. Kurile island-arc volcanism: structural and petrological aspects. *Tectonophysics* 199: 271–287.

Gorshkov, G. S. 1958. Kurile Islands, in *Catalog of active volcanoes of the world*. Vol. 7. Rome: IAVCEI, 1–99.

Gorshkov, G. S. 1970. *Volcanism and the upper mantle: investigations in the Kurile island arc*. New York and London: Plenum Press.

International Kuril Island Project (IKIP). http://artedi.fish.washington.edu/okhotskia/ikip/, http://depts.washington.edu/ikip/.

Pietsch, T. W., V. V. Bogatov, K. Amaoka, et al. Biodiversity and biogeography of the islands of the Kuril Archipelago. *Journal of Biogeography* 30: 1297–1310.

[*Vegetation and animals of Kurile Islands* (*materials of Kuril Island Biocomplexity Project*)]. 2002. Vladivostok: Dal'nauka (in Russian).