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Preliminary Study of the Spatial Distribution of Non-marine Molluscs in the Kamchatka Peninsula

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Abstract The spatial distribution of terrestrial and freshwater molluscs was measured in the central and southern parts of the Kamchatka Peninsula (52°42′N–56°30′N, 156°05′E–161°59′E) in July 1996. Seventeen observations at five localities showed that the density of terrestrial molluscs was higher in meadows along rivers than in *Betula* forests. No terrestrial molluscs were found in seashore grasslands. *Zoogenetes harpa* and *Euconulus* aff. *fulvus* inhabited various types of vegetation. *Discus paupar* was the only species using rotten logs. Twenty-eight observations at 17 localities showed that the density and diversity of freshwater molluscs were lower in ponds inhabited by fish than in those without fish.

Key words: terrestrial molluscs, freshwater molluscs, Kamchatka Peninsula, spatial distribution, rotten logs.

Dall (1905) and Prozorova and Foster (1996 a, 1996b) studied non-marine molluscs of the Kamchatka Peninsula. Twenty-five terrestrial and 32 freshwater species of molluscs (gastropods and bivalves) are known from the peninsula. However, the spatial distribution of these molluscs in this region is poorly understood. I present the results of field observations of terrestrial and freshwater molluscs in the central and southern parts of the Kamchatka Peninsula and compare these with previous reports from the regions around Kamchatka.

Study Sites and Methods

The study sites were in the central and southern parts of the Kamchatka Peninsula, from Petropavlovsk-Kamchatskiy to Azhabach'ye Lake (Fig. 1).

As time was limited, I did not use intensive quadrat sampling for estimating absolute density. For terrestrial molluscs, I estimated relative densities by collecting specimens at five stations (eight sites, 17 times in total). At one station, both living and dead shells were collected in a 10-minute survey by one person within a plot of 10×10 m (forest) or 2×2 m (meadow and grassland). As terrestrial molluscs are known to aggregate in particular microhabitats, special attention was paid

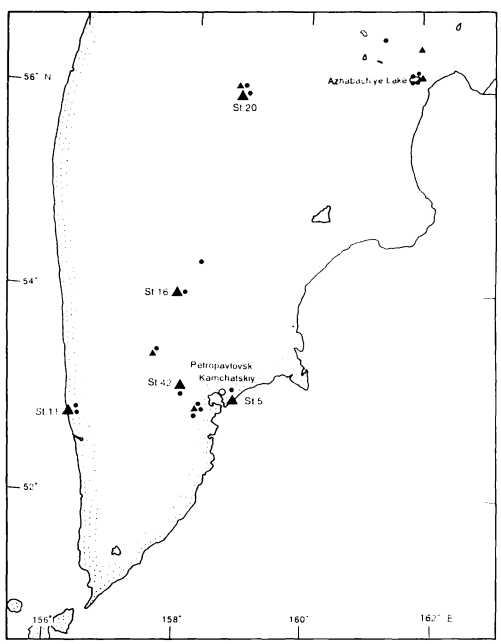

Fig. 1. Sites for sampling of non-marine molluscs in the Kamchatka Peninsula. Large triangles: stations for survey of relative density (see "Study Sites and Methods") of terrestrial species; small triangles: stations for survey of terrestrial species on rotten fallen trees; and small dots: sites for observation of freshwater species.

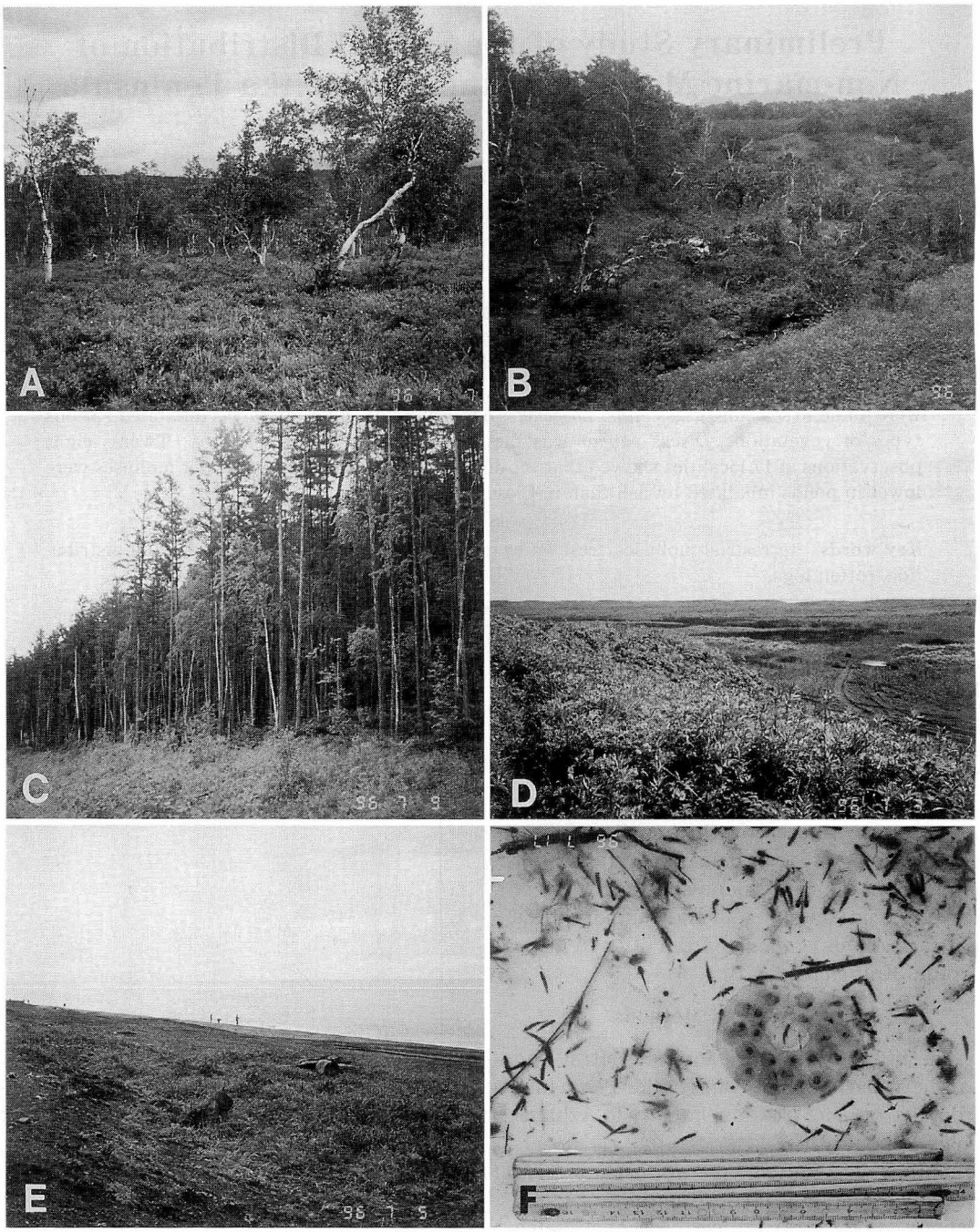

Fig. 2. Vegetations where terrestrial molluscs were surveyed (A-E), and egg masses and juveniles of salamanders (F). A, *Pinus pumila* scrub with *Betula*, relatively high stands with whitish trunks (St. 16); B, *Betula* forest in upper part of slope and meadow in lower part of slope (St. 42); C, a young *Larix* forest, diameter at breast height (DBH) ca. 15 cm (St. 20); D, grassland of *Rosa rugosa* on Pacific coast (St. 5); E, grassland along coast of Sea of Okhotsk (St. 11); F, Mt. Vachkazhets, basin of Plotnikova.

to bases of trees, undersides of stones, and sites where leaf litter accumulated. Rotten fallen tree trunks were also examined, and their diameter and species names were recorded. Hultén (1972) described the categories of vegetation in the southern Kamchatka Peninsula.

Detailed information of the stations are given below.

St. 5 (Fig. 2D), near Petropavlovsk-Kamchatskiy, near Ozero Khalaktyrka, river mouth of Krutoberezovy river, seaside of Pacific Ocean (52°58.1′N; 158°50.0′E), 2 m alt., seashore grassland, *Rosa rugosa,* 4 July 1996:

St. 11 (Fig. 2E), near Bol'sheretskiy, seaside of Sea of Okhotsk (52°47′N; 156°05′E), 1 m alt., seashore grassland, 6 July 1996:

St. 16 (Fig. 2A), ca. 23 km south to Pushchino, river side of upper part of Bystraya river (54°01.3′N; 157°51.3′E), 542 m alt., *Pinus pumila* scrub with *Betula* and meadow at river side, 7 July 1996:

St. 20 (Fig. 2C), near Esso, 17 km southeast to Anavgay, basin of Bystraya river (55°58.3′N; 159°09.6′E), 294 m alt., young *Larix* forest, DBH (diameter at breast height) ca. 15 cm, 9 July 1996:

St. 42 (Fig. 2B), ca. 25 km southwest to Koryaki, northwest edge of Mt. Vachkazhets Volcano (53°07.3′N; 157°54.5′E), 350 m alt., *Pinus pumila* scrub with *Betula, Betula* forest on upper part of slope and meadow on lower part of slope, 17 July 1996.

Freshwater molluscs were collected in springs, ponds, rivers, and lakes (Fig. 3). Benthic organisms including molluscs were randomly sampled by 2-mm mesh net. Fish species were also recorded. Each survey was done by one person for 5–20 minutes. Mollusc abundance per survey is indicated as follows: 'abundant'=10 or more than 10 individuals; 'common'=4−9; 'uncommon'=2−3; 'rare'=1.

All specimens are deposited in the Natural History Museum and Institute, Chiba.

Results and Discussion

Terrestrial molluscs

I recorded 13 species of terrestrial molluscs: *Cochlicopa lubrica* (Müller), *Vertigo* sp., *Columella* aff. *edentula* (Draparnaud), *Vallonia cyclophorella kamtschatica* Likharev, *Zoogenetes harpa* (Say), *Punctum* sp., *Discus paupar* (Gould), *Oxyloma* sp., *Euconulus* aff. *fulvus* (Müller), *Pristiloma* sp., *Zonitoides nitidus* (Müller), *Vitrina pellucida* (Müller), and *Deroceras*? sp. (Table 1). This is 52% of the number recorded by Prozorova and Foster (1996a). All 13 species are small (shell length <10 mm, except *Oxyloma* sp. which attains 12 mm).

1. Density at each station

Table 2 summarizes the relative density, indicated by the number of individuals found during the 10-minute survey. The five rare species, *C.* aff. *edentula, V. c. kamtschatica, P.* sp., *O.* sp., and *D.*? sp., are not included in Table 2, because they were collected from only a single location. The highest density (31.5 ind. per 10-min survey) was recorded in the meadow along the river at St. 16. The second and third highest densities (ca. 25) were recorded in *Pinus pumila* scrub on the ridge and in the meadow of the lower part of the slope at St. 42. At the other stations, the densities were low: ca. nine in *Betula* forest at the upper part of the slope at St. 42; and less than five in *Pinus pumila* scrub at St. 16 and in *Larix* forest at St. 20. The results suggest that the density in meadows is relatively high, but the density in *Pinus pumila* scrub is variable.

From the forests of central Japan, we have previously reported relative densities (ind./10 min.) of 0–11.0 (Kurozumi *et al.,* 1993), 0–12.2 (Kurozumi and Okamoto, 1994), and 4.0–5.4 (Aoki *et al.,* 1996). Densities in grassland (27.0; Kurozumi and Okamoto, 1994) and in forest damaged by deer (10.3; Aoki *et al.,* 1996) were higher than in forest without deer in the same area. Densities of 2.8–37.7 were recorded on different soil types in British Columbia, Canada (Cameron, 1986; data for 1-h survey converted to 10-min values). The relative density in meadows in Kamchatka is higher than in forests without intensive disturbance in central Japan and in forests with 'mor-type' soils in British Columbia, and is close to the densities in grasslands and disturbed forests in central Japan and in forests with 'mull-type' soils in British Columbia.

I collected no terrestrial molluscs in the

Table 1. Terrestrial molluscs collected at each station in the central and southern part of Kamchatka Peninsula.

	St. 2	St. 15	St. 16	St. 18	St. 19	St. 20	St. 23	St. 25	St. 30	St. 36	St. 42
Class Gastropoda											
Order Pulmonata											
Suborder Stylommatophora											
Infraorder Orthurethra											
Family Cionellidae											
Cochlicopa lubrica					+				+		+
Family Pupillidae											
Vertigo sp.			+		+						
Columella aff. *edentula*										+	
Family Valloniidae											
Vallonia cyclophorella kamtschatica				+							
Zoogenetes harpa			+	+		+					+
Infraorder Sigmurethra											
Family Punctidae											
Punctum sp.									+		
Family Discidae											
Discus paupar	+		+		+			+		+	+
Family Succineidae											
Oxyloma sp.		+									
Family Helicarionidae											
Euconulus aff. *fulvus*	+		+	+					+		+
Family Zonitidae											
Pristiloma sp.											+
Zonitoides nitidus						+				+	+
Vitrina pellucida	+		+								+
Family Limacidae											
Deroceras? sp.							+				

St. 2, 5 km west to Mt. Vilyuchinsky; St. 15, 70 km north to Malka; St. 18, 63 km north to Malka; St. 19, near Esso;
St. 23, 25 km west to Klyuchi; St. 25, 42 km northwest to Ust Kamchatsk; St. 30 and St. 36, near Azhabach'ye Lake. Other stations see text.

Table 2. Relative densities (no. individuals/10 min. survey) of terrestrial molluscs in the Kamchatka Peninsula.

	St. 16		St. 42			St. 20	St. 5	St. 11
	Site A	Site B	Site A	Site B	Site C			
Topography	platform	river side	ridge	upper part of slope	lower part of slope	platform	dunes (Pacific coast)	dunes (Okhotsk side)
Vegetation	*Pinus pumila*	meadow	*Pinus pumila*	*Betula*	meadow	young *Larix*	grassland *Rosa rugosa*	grassland
	n=2	n=2	n=1	n=3	n=2	n=3	n=2	n=2
Zoogenetes harpa	2.50		19.00	1.33	4.50	0.33		
Euconulus aff. *fulvus*	1.00	11.50	4.00	2.00	6.50			
Discus paupar		1.66		5.00	4.00			
Vertigo sp.		3.00						
Cochlicopa lubrica			1.00	0.67	1.50			
Pristiloma sp.			1.00					
Zonitoides nitidus				0.33	5.00	0.67		
Vitrina pellucida		16.00			4.00			
Relative density	3.50	31.50	25.00	9.33	25.50	1.00		
No. species	2	4	4	5	6	2		

n: number of repeats for sampling.

vegetation of the seashore areas (Table 2). In Japan, the density and number of species of terrestrial molluscs in coastal areas are higher in the subtropical Ryukyu and Ogasawara islands than in the warm-temperate regions, and low or zero in cool-temperate areas (Habe, 1958; Kurozumi, 1985, 1988, pers. obs.). The fact that terrestrial molluscs were not found in the coastal areas of Kamchatka is consistent with the geographical gradient from subtropical to arctic suggested from these previous observations.

2. Number of species at each site

I collected 13 species (Table 1), but the number of species was different from site to site (Table 2). The highest number, six, was recorded in the meadow at St. 42. Only two species were collected in *Pinus pumila* scrub at St. 16 and *Larix* forest at St. 20. Except for the *Betula* forest at St. 42, the number of species tended to be higher where the relative density was higher.

From central Japan, we have found species numbers of 0–7.0 per 10 min (Kurozumi *et al.*, 1993) and 0–4.5 per 10 min. (Kurozumi and Okamoto, 1994). Cameron (1973) reported seven to 23 species from southern England. Cameron (1986) found five to nine species on 'mull-type' soils and 11–17 species on 'mor-type' soils in British Columbia. The number of species collected in Kamchatka Peninsula was lower in general than in other regions.

3. Distributional pattern of each species

The results suggest that habitat preference differs with species: *Zoogenetes harpa* was collected from five sites; *Euconulus* aff. *fulvus* from four sites; *Discus paupar, Cochlicopa lubrica,* and *Zonitoides nitidus* from three sites with different patterns of occurrence; *Vitrina pellucida* from two sites; and *Vertigo* sp. from one site (Table 2).

Zoogenetes harpa was collected in *Pinus pumila* scrub at St. 42 and *Larix* forest at St. 20, where other species were scarce. At the two sites of *Pinus pumila* scrub, only *Zoogenetes harpa* and *Euconulus* aff. *fulvus,* encountered frequently during the survey, were collected. These two species showed a wide range of preference for vegetation. *Discus paupar* and *Zonitoides nitidus* were not collected in *Pinus pumila* scrub; these species might not prefer this kind of vegetation. *Vitrina pellucida* was found in meadow by a river side and by the base of a slope, and *Vertigo* sp. was found exclusively in river meadow. These observations suggest that these two species prefer a moist environment.

Cameron (1973, 1986) discussed distributional patterns of terrestrial species in relation to environmental conditions. *Discus cronkhitei, Cochlicopa lubrica,* and *Vitrina alaskana* occurred only on 'mull-type' soil, and *Vertigo columbiana, Euconulus fulvus,* and *Zonitoides arboreus* occurred frequently on 'mull-type' soil in British Columbia. *Cochlicopa lubrica* occurred on alkaline soil at scarp sites rather than on acidic soil, and *Euconulus fulvus* occurred frequently on acidic soil in southern England (Cameron, 1973). Cameron's observations are consistent with our results: *Euconulus* aff. *fulvus* showed a wider habitat preference than *Cochlicopa lubrica;* and *Vitrina pellucida* was limited to river meadows.

4. Species composition: Kamchatka and other regions

In a survey of soil animals in southern Sakhalin, Russia, Molodova (1976) measured absolute densities of some terrestrial molluscs in relation to vegetation. Low densities (ca. $1/m^2$) of *Deroceras agrestis* were recorded, and medium to large species, *Succinea lauta* and *Bradybaena weyrichii,* increased in autumn in *Salix-Alnus* forest in flood-lowland. *Cochlicopa lubrica* had a high density ($10/m^2$) and *Discus pauper* had a low density ($1.8/m^2$) in lowland *Calamagrostis* meadow. *Columella edentula, Vallonia costata, Pristiloma arcticum, Euconulus fulvus,* and *Deroceras laevis* were scarce (all $< 1/m^2$) in *Abies* and *Betula platyphylla* forests and in *Betula ermanii* and *Sasa* forest at 300–500 m altitude. No species were collected in *Pinus pumila* scrub at 800–1000 m altitude.

Comparison between the result from Sakhalin (Molodova, 1976) and this and previous studies in Kamchatka reveals the following points: species composition in southern Sakhalin is similar to that reported previous-

Table 3. Occurrence of benthic animals with presence or absence of fish species in the Kamchatka Peninsula.

	width >2 m			River	width <1 m			Lake	Pond		Swamp at river side	Spring
	O:+, S:+	O:+, S:−	O:−, S:−	O:+, S:+	O:+, S:−	O:−, S:+	O:−, S:−	O:−, S:+	O:−, S:+	O:−, S:−	O:−, S:−	O:−, S:−*
	n=1	n=1	n=3	n=1	n=3	n=2	n=2	n=3	n=3	n=4	n=4	n=1**
Molluscs												
Hydrobiidae gen., sp. (Gastropoda)										+		
Cincinna sp. (Gastropoda)												
Lymnaea sp. (Gastropoda)								−		+		
Anisus? sp. (Gastropoda)									−			
Pisidium spp. (Bivalvia)						−			=	++	=	
Amphipods										++	−	
Water beetle (larvae)										+		
Salamander (juvenile)										+		

++: Abundant, +: Common, −: Uncommon, =: Rare. *O: blue-back salmon, *Onchorynchus nerka,* S: sticklebacks, *Gasterosteus* sp. and/or *Pungitius* sp.. +: presence, −: absence. **n: no. sites for sampling.

Fig. 3. Sites for observation of freshwater molluscs. A, Rybovoduyi Stream (Azhabach'ye Lake) with blue-back salmons; B, Eshkin Stream (Azhabach'ye Lake) with dead blue-back salmons; C, Azhabach'ye Lake (near river mouth of Lotnaya River); D, pond, near Bol'sheretskiy, on coast of Sea of Okhotsk (St. 11); E, pond near Krutoberezovy River, near Petropavlovsk-Kamchatskiy and Ozero Khalaktyrka; F, pond near Kozyrevka River, about 135 km north to Milkovo.

ly from Kamchatka (Dall, 1905; Prozorova and Foster, 1996a), except that the larger species, such as *Succinea lauta* and *Bradybaena weyrichii*, inhabiting the *Salix-Alnus* forest in flood-lowland in Sakhalin are absent from Kamchatka. *Zoogenetes harpa* and *Vitrina pellucida* had high densities in Kamchatka (>3; Table 2), but were not reported from Sakhalin.

In central Japan, Cyclophoracea, Clausiliidae, Helicarionidae, and Bradybaenidae are dominant in terms of density and number of species (Kurozumi *et al.*, 1993; Kurozumi and Okamoto, 1994; Aoki *et al.*, 1996). The difference in the terrestrial mollusc fauna is obvious between Kamchatka and central Japan.

5. Rotten fallen trees as habitat of terrestrial molluscs

I investigated the species composition and the relative density of each species in rotten logs and stumps 10 times at seven sites. I collected terrestrial molluscs nine times at six sites. The diameters of logs and stumps ranged from 20 to 80 cm. All were identified as *Betula* except for the smallest samples (20 cm). Only two mollusc species were found: *Discus paupar* (9 times) and *Euconulus* aff. *fulvus* (1 time). The average relative density of *Discus paupar* was 4.75 and that of *Euconulus* aff. *fulvus* was 0.38. On northern Kuril Island, Kuroda and Koba (1933) found 'many individuals' of *Discus paupar* in driftwood.

In cool-temperate *Fagus* forests in central Japan, the number of species under rotten logs ranged from 2.6 to 3.8 per 10 min, and the relative density from 3.7 to 5.4 per 10 min; the total number of species collected was 11–27 (Aoki *et al.*, 1996). *Zonitoides nitidus*, which I did not find on rotten logs in Kamchatka, had a high density (10.3 per 10 min) under rotten logs in a *Fagus* forest damaged by deer (Aoki *et al.*, 1996). Thus, judging from the data available at present, species diversity of terrestrial molluscs on rotten logs seems low in Kamchatka compared with that in central Japan.

Freshwater molluscs

I recorded at least five species of freshwater molluscs: Hydrobiidae gen. sp., *Cincinna* sp., *Lymnaea* sp., *Anisus* ? sp., and *Pisidium* spp. Thirty-two species have been reported from Kamchatka (Dall, 1905; Prozorova and Foster, 1996b). The collection represents only 19% of the known local species. This may be due to the limited sampling effort. Most of the collected species were small (shell length <10 mm).

Details of sampling sites are summarized in Table 3. I rarely found molluscs or other animal groups in the rivers. In lakes, swamps alongside rivers, and springs, I found some molluscs and other benthic animals at 'uncommon' or 'rare' levels. On the other hand, several molluscs and other benthic animals were recorded as 'abundant' or 'common' in ponds without fish (Figs. 2F, 3F). This suggests that the blue-back salmon, *Onchorhynchus nerka*, and sticklebacks, *Gasterosteus* sp. and/or *Pungitius* sp., affect the benthic fauna through their feeding and by fouling the water after spawning and dying (Fig. 3A, B). Salmon and sticklebacks are also known to feed on benthic animals, including molluscs, at some stages of their life cycles (Miyadi *et al.*, 1976; Ochiai and Tanaka, 1986).

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カムチャッカ半島における非海産貝類の生態分布に関する予備的観察

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1996年7月に，カムチャッカ半島中南部において，陸産貝類と淡水産貝類の生態分布の簡単な調査を行った．陸産貝類では，川沿いの高茎草本地で密度が高く，ダケカンバ林で低密度で，海岸草地では発見できなかった．マキゾメガイとエゾキビガイ類似種で比較的幅広い生息場所を利用していると考えられた．カムチャッカ半島において，倒木というニッチは，ほとんどパツラマイマイ1種のみが利用していた．淡水産貝類は，密度・種数とも極めて少なかったが，魚類，ベニザケとトゲウオ類，の生息しない池・沼では比較的高密度であった．