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MARINE NATURE PROTECTION

The Distribution of Macrobenthic Epifauna in the Far Eastern Marine Reserve Based on Remote Underwater Video Data

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Abstract—The spatial distribution of epifauna in the Far Eastern Marine Reserve was examined using a remotely operated vehicle. The abundance and distribution patterns of the sea stars *Patiria pectinifera, Distolasterias nipon*, and *Asterias amurensis,* as well as those of brittle stars, the black sea cucumber *Cucumaria japonica,* the sea urchin *Strongylocentrotus intermedius,* the ascidian *Halocynthia aurantium,* hermit crabs, and the Japanese scallop *Mizuhopecten yessoensis* were determined in the South Section of the Reserve. The average biomass of five dominant epifaunal species ranged from 51.0 to 87.4% of the average biomass of the soft-bottom communities.

Keywords: distribution, biotopes, habitat, macrofauna, epibenthos, mapping, Far Eastern Marine Reserve

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INTRODUCTION

Since the 1980s, during undersea research that is beyond the range of SCUBA gear, many problems have been solved using remotely operated vehicles (ROVs). Submersibles provide surveillance to the maximum depths of the oceans [25, 29, 34]. The main factors that restrict ROV use in hydrobiological research are their high cost and very high level of logistical support [33, 36]. In recent years, however, these technologies are increasingly being used at depths that are quite ordinary for SCUBA divers [39, 31].

It should be noted that the standard hydrobiological methods of sampling, viz., dredges, trawls, and grabs, disturb the biodiversity in protected waters; therefore, their use is restricted or prohibited [1, 2, 24]. The obvious alternative is to develop environmental monitoring by methods based on underwater photo and video documenting. This approach not only provides correct assessment of the species composition, distribution patterns, and population densities of benthic organisms [3], but also enables one to receive direct information on habitat parameters.

The objective of this work was to study the distribution of macrobenthos epifauna of the South Section of the Far Eastern Marine Reserve (FEMR) based on analysis of ROV video materials.

MATERIALS AND METHODS

The survey was carried out on board the R/V *Vladimir Kasyanov* in August 2013. The onboard ROV *SUB FIGHTER 3000* was equipped with two cameras (the HD type) with horizontal—vertical pivoting and two 250 w lamps. Two 25 w lasers were set in parallel to the HD camera. Scale laser marks in the center of the frame, with a distance of 7 cm between them, provided accurate measurement of the transect width and the body size [32, 37]. The horizontal speed of the device was 2.8 knots and the vertical speed was 1.5 knots; the working depth was up to 700 m.

While planning works based on the topography, depths, and nature of currents in the survey area, we determined that it is expedient to conduct transects perpendicular to the shoreline on the undersea slopes and to have radial transects on the plains (Fig. 1). The first method optimizes video sampling by maximizing the diversity of habitats for a fixed time unit [23, 26, 28]. The second method is more suitable for areas of low gradients of environmental factors and implicit boundaries between biotopes [33, 35].

The video recording was carried out over 37 transects of the total length of 9873 m at depths from 2 to 36 m. A Garmin GPSMAP 520s chartplotter with 12-channel GPS-receiver was used for positioning of the start and end points of the profiles. The creation and editing of the profiles, as well as the determination of the transect lengths and their parts, was carried out in the MapSource v. 6.16.13 (Garmin, United States) environment.

The technique of video data analysis included several successive steps. Using the determined profile length in coordinates and by knowing the time of its

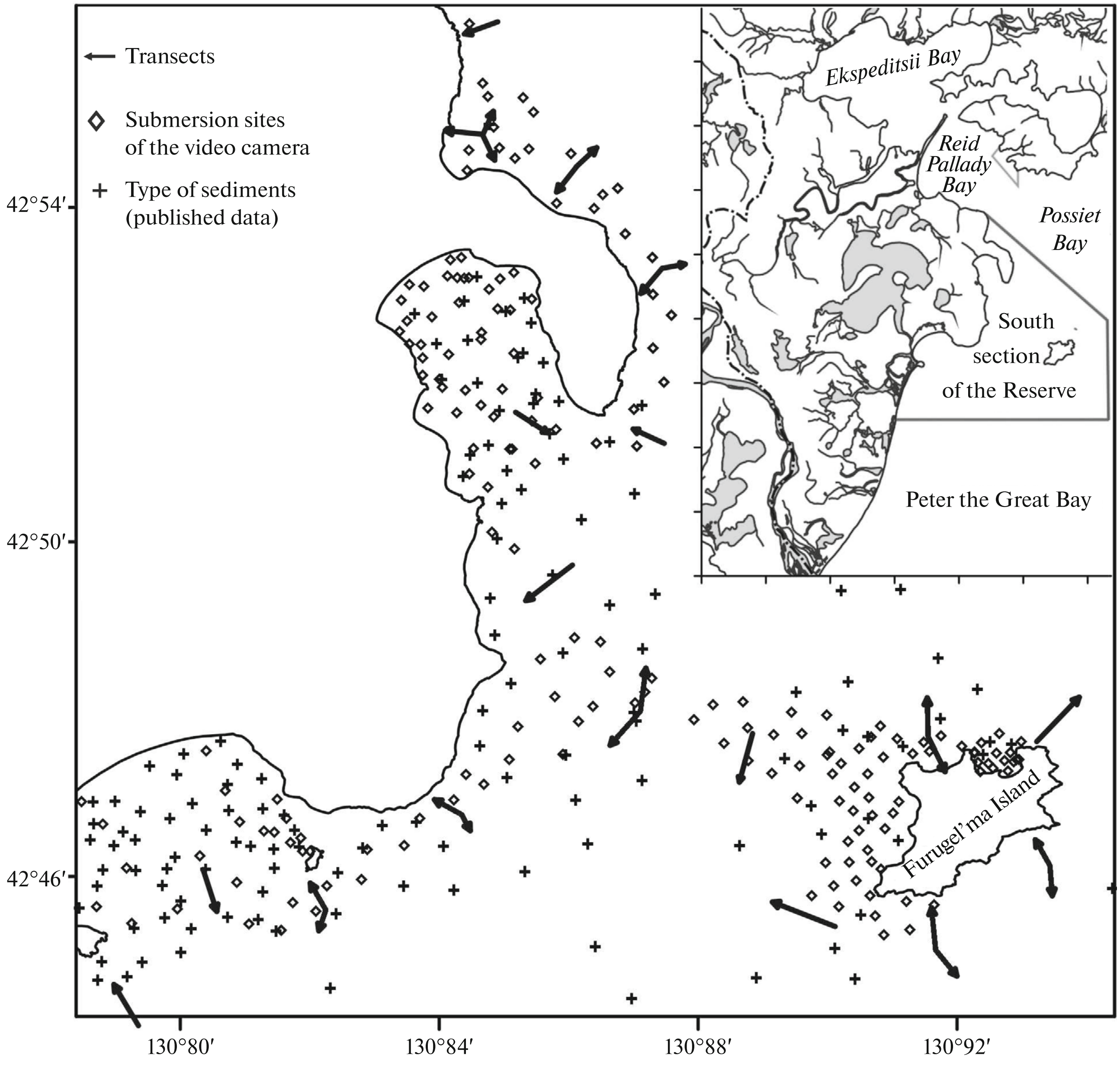

Fig. 1. Map of the material sampling.

passage we estimated the average speed of the device (0.28 ± 0.01 m/s). The video sections were then cut into segments of 20 m in length, each of which was further treated as an individual video sample [22, 27]. The width of the counted band (W) in meters was determined by the equation:

$$W = 0.07 W_m / W_l,$$

where W_m is the width of the monitor, W_l is the distance between the laser marks, as measured at the display, and 0.07 m is the fixed distance between the lasers [33]. The distance W_l was measured every 10 s; the area of each 20-meter segment was then calculated. According to the obtained values, the average area of video samples was determined as 15.30 ± 0.22 m^2. In total, 455 video samples were examined.

In the samples, the numbers of the starfish species *Patiria pectinifera, Distolasterias nipon, Asterias amurensis*, of brittle stars, of the holothurian *Cucumaria japonica,* the sea urchin *Strongylocentrotus intermedius,* the ascidians *Halocynthia aurantium,* hermit crabs, and the scallop *Mizuhopecten yessoensis* were counted. The number of each species in video sample was estimated for a 1 m^2 area and the obtained values were used to determine the average population densities of the animals. The dimensions of hydrobionts at the display were measured to an accuracy of 1 mm and

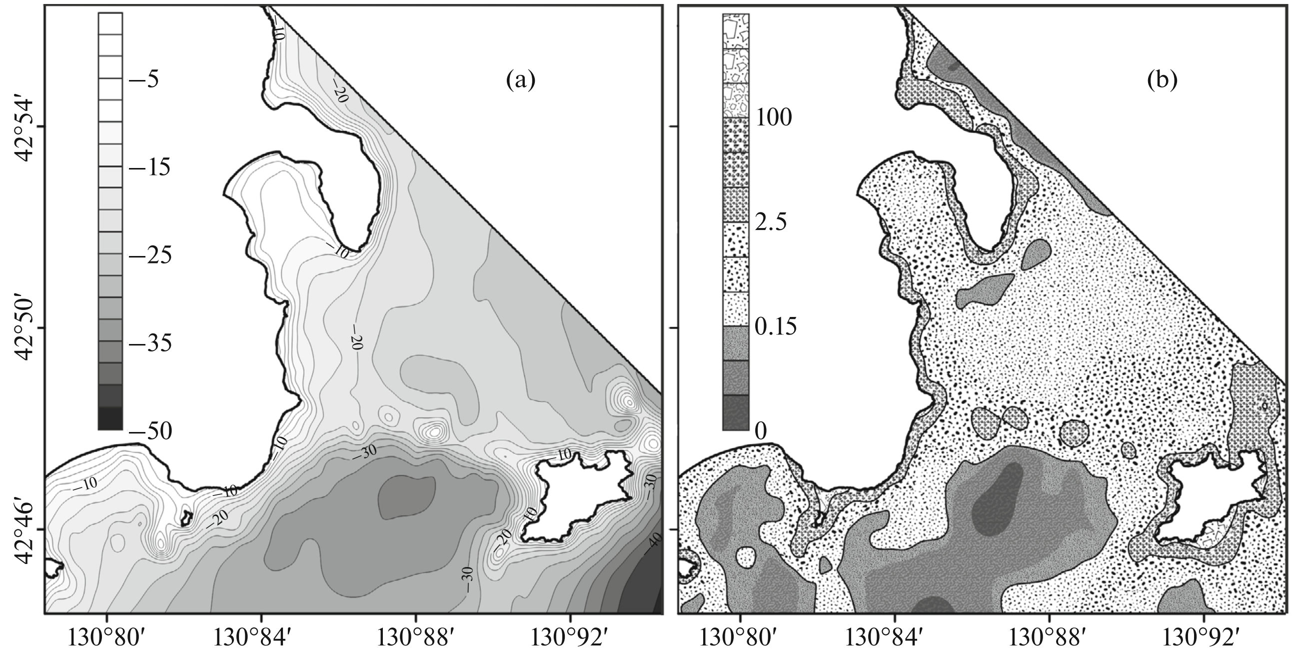

Fig. 2. The distribution in the South Section area of the Far East Marine Reserve: (a) depths (scale, depth, m) and (b) substrates (scale, estimated size of fraction, mm).

scaled according to laser marks in the frame. We measured the height of the scallop shell, and of the sea urchin test, as well as the maximum distance between the ends of arms in starfish. The average weight of an individual was calculated according to the size–weight ratio that was given in [9]. Data on the average weight of the starfish *D. nipon* was taken from [6].

The dominant fractions of the bottom grounds (silt, sand, gravel, boulders, etc.) was visually determined for each video sample; its size was evaluated using the grain-size scale [4, 13]. This data was used with information obtained at dive points of the CR110-7A BestWill cable camcorder (Fig. 1). To map substrate distribution charts in addition to videos (Fig. 2b), we used landscape descriptions of SCUBA diver transects that were performed previously [15], and data from the navigation and topographic maps, as well as the literature data [8, 12]. While mapping the chart the data converted to the logarithmic scale; after calculating and smoothing the grid they were brought to the initial display by potentiation.

The biotopical associations of the organisms were assessed according to the ratio of the number of occurrences of taxon in a specific biotope to the total number of occurrences of this type of biotope, and the specific frequency of occurrence. The values obtained for this parameter and statistical errors of the ratios [18] are given in Table 1. All field work was accompanied by echo sounding. The bathymetric diagram of the area was built according to these data and materials from previous research of the South Section of the Reserve [15], (Fig. 2a).

The maps in this paper were built using Surfer v. 10 (Golden Software), which provides a wide range of methods to create grid surfaces and operate them and the most appropriate solutions for our tasks [19, 20].

RESULTS AND DISCUSSION

In our previous research we determined the area occupied by hard and mixed bottom biotopes in the South Section of the FEMR [15]. These included the areas of distribution of all fractions greater than sand, i.e., greater than 1 mm in diameter [4]. Analysis of cable camcorder records and literature data almost did not influence the previous assessment: the estimated areas of such biotopes occupied 12.3% of the bottom area in the survey region.

The ground parameters are traditionally used when typifying biotopes, while the issue of the particle size of fractional units is still open [21], but is distinct for hard and soft bottoms. The former are referred to as hydrodynamically immobile substrates that are used by the organisms as a surface for permanent habitation, the second are movable substrates where hydrobionts inhabit both the surface and the body of the sediments [10]. According to our observations, ripples (traces of wave action and currents) in the study area were often composed of small gravel and pebbles. We took this fraction (2.5 mm) as the upper limit of the moving substrate. Further analysis of the video data enabled us to define four types of biotopes with characteristic combinations of substrates: silt–sand (particle size up to 0.15 mm), sand–gravel (0.15–2.5 mm),

Table 1. The specific frequency of occurrence, %, of epifauna in various biotopes

Taxon	Biotope			
	silt–sand	sand–gravel	gravel–pebble	rock–boulder
Patiria pectinifera	89.24 ± 4.89	99.06 ± 1.31	98.04 ± 3.94	100
Distolasterias nipon	40.51 ± 7.74	66.98 ± 6.38	76.47 ± 12.05	76.00 ± 17.95
Strongylocentrotus intermedius	26.58 ± 6.97	51.89 ± 6.78	72.55 ± 12.68	84.00 ± 15.41
Brittle stars	59.84 ± 8.63	16.57 ± 5.56	4.26 ± 5.98	4.00 ± 4.69
Asterias amurensis	48.10 ± 7.88	29.25 ± 6.18	27.45 ± 12.68	60.00 ± 11.72
Hermit crabs	51.27 ± 7.88	30.19 ± 6.23	11.76 ± 9.15	4.00 ± 8.24
Mizuhopecten yessoensis	29.75 ± 7.21	31.13 ± 6.29	11.76 ± 9.15	0
Halocynthia aurantium	18.35 ± 6.10	13.21 ± 4.60	21.57 ± 11.68	8.00 ± 11.40
Cucumaria japonica	8.23 ± 4.33	3.77 ± 2.59	5.88 ± 6.68	4.00 ± 8.24

gravel–pebble (2.5–100 mm), and rock–boulder biotopes (more than 100 mm). Biotopes of prevailing sand and gravel substrates occupy 63.5% of the bottom area of the South Section of the Reserve, silt–sand, 28.2%, gravel–pebble and rock–boulder substrates, 7.65 and 0.65%, respectively.

The space distribution of habitats (Figs. 2a and 2b) correlated with basic undersea geomorphological structures of the survey area. The bottom of the South Section of the Reserve's area (Fig. 2a) has complex concave areas, with sloping decreasing from the shore. Its surface is formed by coastal slopes, stacks, accumulative plains, and depressions. A well-defined elevation between the Khalezova Cape and Furugelm Isl. separates two hollows. The north hollow between the Furugelm Isl. and Kalevala Bay is relatively shallow (22–24 m). The other hollow, with depths of up to 35 m, extends to the south, in the direction of Sivuchya Bay (Fig. 2a). The first hollow is dominated by sand and gravel biotopes, while the second is dominated by silt–sand ones. Rock–boulder and gravel–pebble substrates are characteristic to biotopes of the upper portions of the underwater coastal slope and of the elevation that connects Furugelm Isl. and the mainland (Fig. 2b).

We found sea anemones, ascidians, decapods, isopods and amphipods, bivalves, holothurians, sea urchins, starfish, brittle stars, polychaetes, nemerteans, echiuroids, and fish in the videos approximately 30 faunal taxa were observed in total. The video footage did not always provide definitive identification of the taxonomic status of animals. Confident identification and quantitative calculation were possible for few taxa.

The echinoderms led according to the frequency of occurrence in the epifauna, taking the first five places according to this parameter among the studied animals. The ratio of their occurrence in the samples ranged from 95.29 ± 1.18% for *P. pectinifera,* to 37.44 ± 2.69% for *A. amurensis,* while it was only 5.61 ± 1.28% for *C. japonica* (Table 1). The specific occurrence of *P. pectinifera* was close to 100% in all of the biotopes, except the silt–sand type, while even there it was slightly under 90%. Similar values of this parameter (84.3 and 100%) were observed in the subtidal zone of the Vostok Bay and Nakhodka Bay in [6], which also provided data on the occurrence of *D. nipon* (37.5 and 25.2% respectively) and *A. amurensis* (54.3 and 77%). For *D. nipon* it was comparable to our data that were obtained for silt–sand biotopes; this species occurred 2–3 times more frequently on gravel and pebble bottoms. The occurrence of *A. amurensis* in the surveyed area was 1.5 times lower than in Vostok Bay and Nakhodka Bay, but it increased to a comparable value on rock–boulder bottoms.

Strongylocentrotus intermedius is a euryedaphic species [11]; in the survey area it was recorded in all of the biotopes. The maximum specific occurrence on hard bottoms indicated its lithophility. On silt–sand substrates, the occurrence of *S. intermedius* was at a minimum, but exceeded 25%, which does not allow considering it as an incident species in this biotope. In total, the occurrence of *S. intermedius* was higher than that of *Strongylocentrotus nudus.* The sea urchin *S. nudus* was recorded in all the samples that belong to the rock-boulder bottoms; in silt–sand biotopes it occurred much more rarely. This distribution corresponds to the most stenoedaphic and lithophilic species of the genus *Strongylocentrotus* [11].

The occurrence of brittle stars, hermit crabs and holothurians was the highest on silt–sand bottoms, while that of scallops was highest on sand, silt–sand, and gravel bottoms. Ascidians *H. aurantium* preferred biotopes with combinations of silt–sand and gravel–pebble bottoms. The maximum population density on silt–sand bottoms in the survey area was recorded for brittle stars, *A. amurensis, H. aurantium, C. japonica*, and hermit crabs (Table 2), while on sand and gravel substrates it was found only for *M. yessoensis.* The average population densities of *P. pectinifera, D. nipon* and *S. intermedius* were at a maximum on gravel–pebble bottoms.

Table 2. Population density, ind./m^2, of epifauna in various biotopes

Taxon	Distribution depth, m	Biotope			
		silt–sand	sand–gravel	gravel–pebble	rock–boulder
Patiria pectinifera	2.6–30.8	1.958 ± 0.202 13.533	3.619 ± 0.225 19.574	4.857 ± 0.673 25.000	3.202 ± 0.374 8.542
Distolasterias nipon	6.5–30.4	0.164 ± 0.038 3.333	0.243 ± 0.023 1.983	0.363 ± 0.049 1.339	0.142 ± 0.033 0.733
Strongylocentrotus intermedius	3.5–30.9	0.068 ± 0.015 1.136	0.554 ± 0.083 6.545	0.918 ± 0.174 5.089	0.235 ± 0.048 0.776
Brittle stars	9.4–31.0	47.752 ± 7.602 398.400	15.659 ± 4.701 458.000	1.446 ± 1.440 67.700	0.004 ± 0.004 0.100
Asterias amurensis	3.5–31.0	0.126 ± 0.017 1.356	0.051 ± 0.008 1.000	0.033 ± 0.010 0.417	0.067 ± 0.019 0.380
Hermit crabs	6.7–29.9	0.142 ± 0.019 1.149	0.084 ± 0.021 2.963	0.007 ± 0.003 0.112	0.002 ± 0.002 0.050
Mizuhopecten yessoensis	8.4–28.9	0.049 ± 0.008 0.662	0.060 ± 0.011 1.489	0.016 ± 0.008 0.313	0
Halocynthia aurantium	13.3–30.9	0.049 ± 0.013 1.196	0.023 ± 0.006 0.758	0.036 ± 0.012 0.381	0.006 ± 0.004 0.086
Cucumaria japonica	8.5–29.8	0.010 ± 0.003 0.455	0.003 ± 0.001 0.179	0.006 ± 0.003 0.150	0.002 ± 0.002 0.043

Above the line, the average density ± SEM, values below the line, the maximum density.

The starfish *P. pectinifera* was observed throughout the South Section area, except for the Sivuchya Bay and southern hollow; its main aggregations of population density up to 7 ind./m^2 were confined to gravel–pebble substrates (Fig. 3a). With the average density of *P. pectinifera* of 3.149 ± 0.158 ind./m^2, in the surveyed bottom area, the maximum density of this species reached 25 ind./m^2. The clusters of *D. nipon* of population density of 2.5 ind./m^2 were concentrated in the northeast of the South Section area and were absent to the south from the elevation between Mys Khalezova cape and Furugelm Isl. They were confined to the sand–gravel and gravel–pebble bottoms (Figs. 2b and 3b). With the average population density of *D. nipon* of 0.223 ± 0.018 ind./m^2, its maximum value reached 3.33 ind./m^2. *S. intermedius* mostly inhabited the elevation between Khalezova Cape and Furugelm Isl. (Fig. 3b). Its clusters were confined to gravel–pebble substrates; the average population density was 0.406 ± 0.046 ind./m^2. Northeast of Furugelm Isl. the population density of this species reached the maximum for the surveyed area, exceeding 6.5 ind./m^2. The main aggregations of the starfish *A. amurensis* (Fig. 3d) with a population density of 0.8 ind./m^2, were located to the south of this elevation in silt–sand biotopes. The average population density of *A. amurensis* was 0.076 ± 0.008 ind./m^2, i.e., one order lower than in the clusters. The concentration of this species in the south of the surveyed area was caused by the fact that it's number increased with an increase in organic pollution [6] and organic matter that accumulated in the area due to increased coastal runoff into the Sivuchya Bay and from the Tumannaya River [7, 16].

Subtidal biotopes with combinations of loose substrates occupied most of the FEMR bottom area. Animals were less exposed there to extreme factors (storms, typhoons, and pollution discharges) as compared to the littoral population. Therefore, the structural changes in these communities can be considered as human impacts and the effects of climate change. Three dominant soft-bottom communities, *Ophiura sarsi* + *Maldane sarsi, Maldane sarsi*, and *Echinocardium cordatum,* were described earlier in the South Section area [17]. The locations of brittle star clusters (Fig. 3g) coincided with the location of the first community as defined by the data of benthic surveys of the 1980s. The population density of brittle stars in the clusters was 260–320 ind./m^2, which is comparable to their average density, 534 ± 197ind./m^2, in the *Ophiura sarsi* + *Maldane sarsi* community as determined according to the results of dredge sampling [17]. According to this data, the *Maldane sarsi* community dominated in the areas that are adjacent to Sivuchya Bay. In the direction from the bay to the deep-water hollow at Furugelm Isl., the number of brittle stars

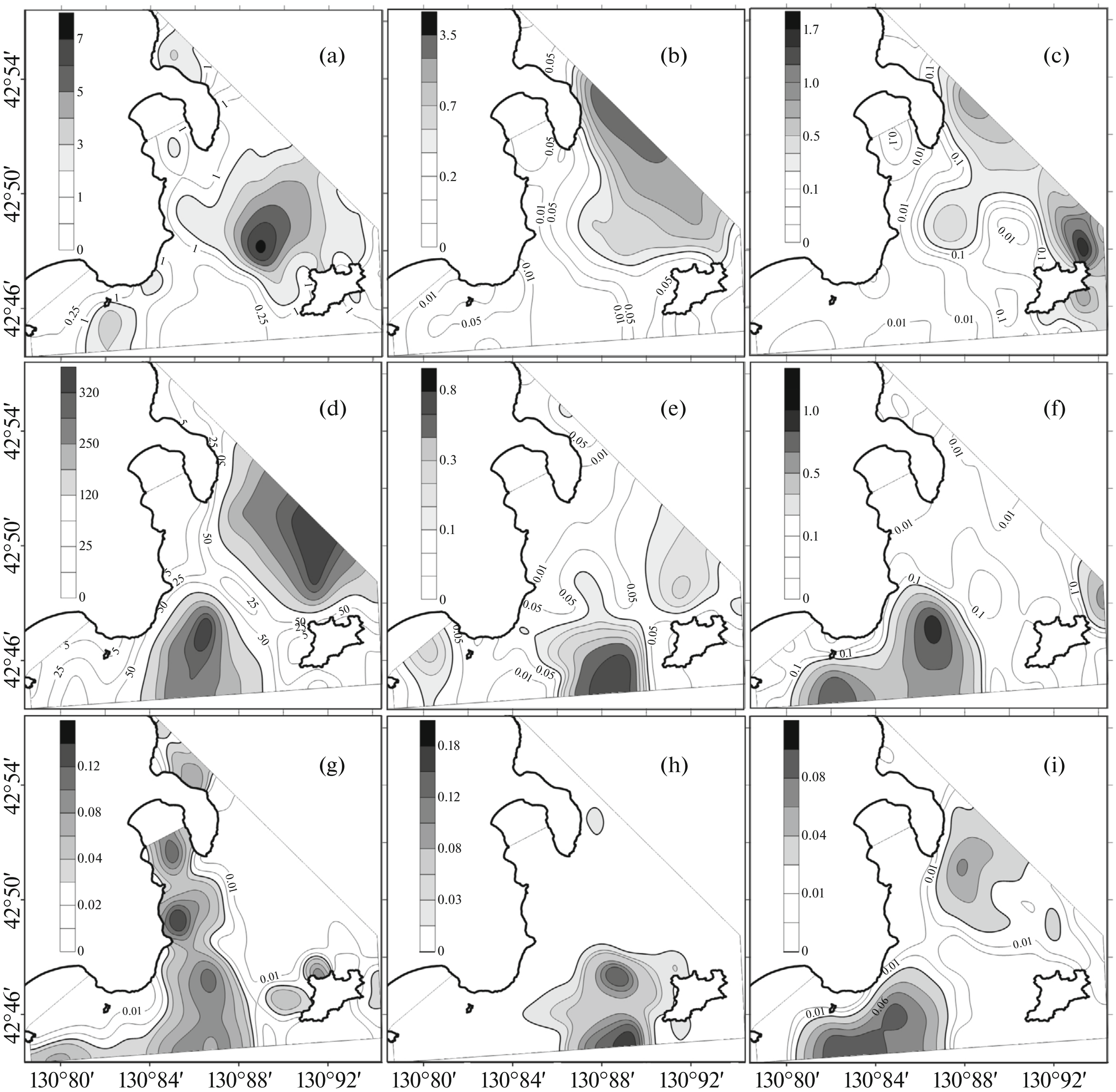

Fig. 3. Distribution of *Patiria pectinifera* (a), *Distolasterias nipon* (b), *Strongylocentrotus intermedius* (c), brittle stars (d), *Asterias amurensis* (e), hermit crabs (f), *Mizuhopecten yessoensis* (g), *Halocynthia aurantium* (h) and *Cucumaria japonica* (i) in the South Section area of the Far East Marine Reserve. Scale, ind./m^2.

increased and the *Maldane sarsi* community was replaced by the *Ophiura sarsi* + *Maldane sarsi* community. The present values of the brittle star population density are quite consistent with the distribution pattern of soft-bottom communities. We may assume that the area occupied by the *Ophiura sarsi* + *Maldane sarsi* community has been virtually unchanged over the past 30 years. We noted that *D. nipon* clusters in the northeast of the South Section and *A. amurensis* to the south from the elevations between Furugelm Isl. and the mainland are adjacent to the distribution area of this community.

Hermit crabs were distributed in three clusters, to the south from Vera Isl., to the northeast from Furugelm Isl., and in the center of the South Section (Fig. 3e). They occupied variously combined sand–silt and sand–gravel biotopes within the boundaries of the *Ophiura sarsi* + *Maldane sarsi* community. At the average value of the population density of 0.076 ± 0.008 ind./m^2, it reached 1 ind./m^2 in the clusters, with a maximum up to 3 ind./m^2. Aggregations of the scallop *M. yessoensis* were mostly confined to sand bottoms (Fig. 3g) and were distributed in the areas dominated by the *Echinocardium cordatum* sea urchin

Table 3. The size parameters of the epifauna

Taxon	Average size, cm	Average body weight, g
Patiria pectinifera	7.8 ± 0.1 (*N* = 201)	48.1
Distolasterias nipon	–	143 [6]
Strongylocentrotus intermedius	7.7 ± 0.1 (*N* = 146)	162.3
Asterias amurensis	18.4 ± 0.4 (*N* = 204)	318.8
Mizuhopecten yessoensis	12.3 ± 0.3 (*N* = 155)	219.3

N, number of individuals.

community [17]. Its average population density was 0.048 ± 0.006 ind./m^2, whereas in the aggregation between the Ded and Khalezova capes it reached 0.15 ind./m^2; the maximum density was 1.5 ind./m^2. The average population density of the ascidian *H. aurantium* was 0.033 ± 0.006 ind./m^2, but in clusters that occupied the gravel–pebble biotope in the ridge area between Furugelm Isl. and Mys Khalezova cape, and on the silt–sand bottom in the hollow to the south of the ridge (Fig. 3h), its maximum density reached 1 ind./m^2. The ascidian clusters were confined to the distribution areas of the *Ophiura sarsi* + *Maldane sarsi* and *Echinocardium cordatum* communities. *C. japonica* of low average population density (0.006 ± 0.001 ind./m^2) was associated with silt–sand and sand substrates and formed two clusters (Fig. 3i) in the *Ophiura sarsi* + *Maldane sarsi* community; the maximum population density of the black sea cucumber reached 0.1 ind./m^2.

The biomass of four dominant epifaunal species, *P. pectinifera, A. amurensis, S. intermedius,* and *M. yessoensis,* was calculated according to the size data we obtained (Table 3). The biomass of *D. nipon* was calculated from its average body weight, as taken from the literature [6]. The maximum total biomass of the species in the north hollow area between Kalevala Bay and Furugelm Isl. reached 500 g/m^2 (Fig. 4). The rapid development of epifauna in the Reserve waters may result from the fact that it was under effect of the flow of organic mater from the Expedition Bay and the Reid Pallady Bay. The average biomass of five species of epifauna on silt–sand and sand–gravel bottoms was 193.9 g/m^2, which exceeded the average biomass of the soft-bottom communities (179.4 g/m^2), as derived from the results of dredge sampling in 1996 [5]. It was 4 times higher than the average biomass of the groups that dominate among the soft-bottom communities in the South Section area of the Reserve, Polychaeta, 49.3 g/m^2, and Echinoidea, 45.9 g/m^2 [5].

The average biomass of the three soft-bottom communities, as defined from the results of 1980 grabber sampling in the South Section area, was 379.9, 221.8, and 258.7 g/m^2, respectively, for the *Echinocardium cordatum, Maldane sarsi*, and *Ophiura sarsi* + *Maldane sarsi* communities [17]. Thus, the average biomass of five epifaunal species that were not taken into account according to bottom grab sampling ranged from 51.0 to 87.4% of the biomass of the soft-bottom communities.

The results of the survey revealed that defining soft-bottom communities according to the dominant species excluding the epifauna does not reflect their real structure. During this work, the number of echiuroids in one of the deepest Reserve areas was counted. While surveying the area we observed the mass death of fauna in the hollow to the south from the elevation between Mys Khalezova cape and Furugelm Isl. (Fig. 2a). Our communication about this phenomenon led to elucidation of its causes; the most likely cause was a lack of oxygen in the bottom water layer. The echiuroids left their holes before dying and were observed on the surface of the ground; their maximum number was 1.61 ind./m^2, while the average was 0.223 ± 0.198 ind./m^2.

Unlike traditional methods of quantifying hydrobionts, the use of an ROV enabled us to observe the behavioral responses of organisms, which affect their quantitative assessment. Thus, via the analysis of videos it was revealed that the black sea cucumber while pumping in water is able to alter its buoyancy almost to zero, reducing contact to the substrate. This observation explains the high mobility of black sea cucumber clusters, which one of the authors observed at the West Kamchatka shelf. There, according to the regular trawl surveys, black sea cucumber fields moved by tens of kilometers annually. Given that strong bottom currents are common in this area, it can be assumed that the aggregations of black sea cucumber are moved in the state of neutral buoyancy.

The advantages of using a ROV were seen in the evaluation of the number of moving epifaunal objects, which are not included in dredging and SCUBA samplings. For the first time we estimated the number of hermit crabs on the soft bottom; previously, it has been identified only in the thickets of sea grasses [14].

Thus, as a result of the surveys a detailed bathymetric map and a map of the biotope distribution with characteristic combinations of bottoms were plotted. Based on the video recordings the distribution of epifaunal macrobenthos in the South Section of the FEMR was studied and the distribution maps of nine objects of epifauna, viz., the starfish *P. pectinifera,*

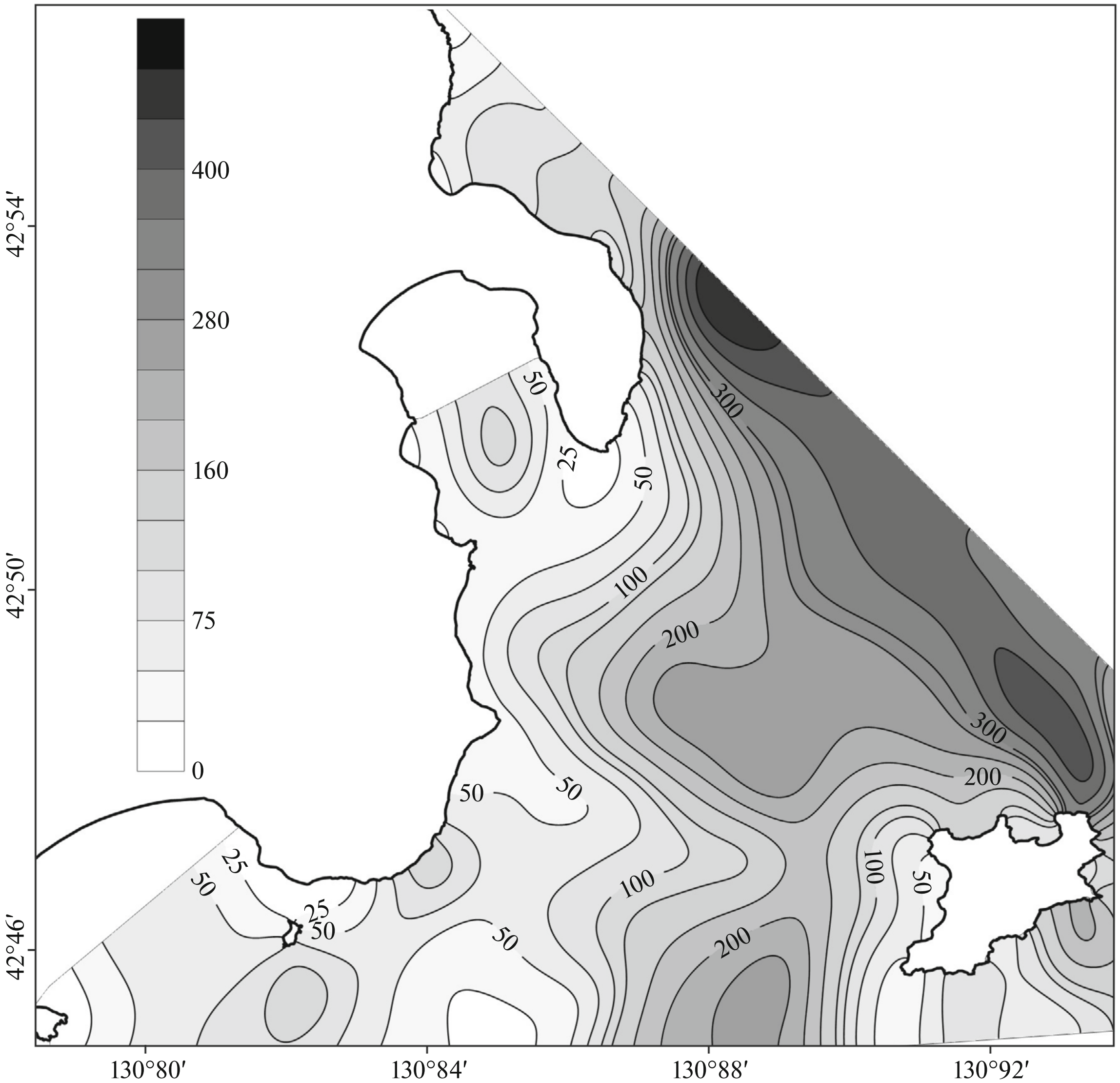

Fig. 4. The total biomass of five dominant species of epifauna in the South Section area of the Far East Marine Reserve. Scale, g/m^2.

D. nipon, and *A. amurensis;* brittle stars; the black sea cucumber *C. japonica;* the sea urchin *S. intermedius;* the ascidian *H. aurantium;* hermit crabs; and the scallop *M. yessoensis,* were plotted. The population density on different types of substrate was determined and a map of the total biomass distribution was built.

It was shown that the values of the average biomass of the five typical species of epifauna, as defined according to video data, are comparable with the values of the average biomass of the soft-bottom communities, as calculated based on the results of dredging surveys. Past work suggests that the area occupied by the *Ophiura sarsi* + *Maldane sarsi* community in the survey has not changed over the past 30 years.

The technical complexity and relatively high cost of ROV use for biodiversity monitoring of protected waters are compensated by the accuracy of the counting of the hydrobionts, the coverage of large areas of the bottom, and the possibility of video recording of underwater research. The use of only traditional dredging and SCUBA methods of sampling without underwater videos and photos does not provide a complete parametric picture of bottom biocenoses. Further studies using submersibles will help to provide a mapping base of long-term video monitoring of the states of communities and ecosystems in the Far Eastern Marine Reserve.

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