

Ecological aspects of asexual reproduction of the White Sea Sponge *Polymastia mammillaris* (Demospongiae, Tetractinomorpha) in Kandalaksha Bay

Alexander S. Plotkin & Alexander V. Ereskovsky

Abstract: The results of the several years observations on White Sea sponge *Polymastia mammillaris* (Müller, 1806) (Demospongiae, Tetractinomorpha) asexual reproduction by budding from June to October are presented. Budding intensity decreased in autumn which is probably connected with the sexual reproduction intensification in *P. mammillaris* population this period. Substrate structure and stability appear to be the most substantial exogenous factors influencing budding. Its average individual intensity in sponges living on soft substrate was twice as high than in sponges from hard substrate. Considerable budding intensity decrease was observed while depth rising since 25 m independently on season and substrate type. *P. mammillaris* budding appears to depend on sponge body volume. The highest individual budding intensity (13.9%) was registered in sponges having one oscular papilla and average body volume 5.6 cm³.

Key words: Asexual reproduction, Budding, Ecological factors, *Polymastia mammillaris*, White Sea.

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1. Introduction

Asexual reproduction specific for many marine attached invertebrates is typical to Porifera. This type of reproduction is observed in all sponge classes and realized by fragmentation, gemmulation and budding (Fell, 1974; Simpson, 1984). Obligatory blastogenesis is described for Spongillidae, Potamolepidae, Halicionidae (Haplosclerida, Ceractinomorpha), Suberitiidae and Clionidae (Hadromerida, Tetractinomorpha). Gemmulation is typical for these sponges (Topsent, 1888; Herlant-Meevis, 1948; Hartman, 1958; Brien, 1973; Fell, 1974; Garrone, 1974; Connes, 1977; Connes et al., 1978; Simpson, 1984). Budding is typical for Polymastiidae and Tethyidae (Hadromerida, Tetractinomorpha) (Merejkovsky, 1879a, b; Connes, 1967; Battershill & Bergquist, 1990). Obligatory asexual reproduction in life cycle is peculiar to sponge populations of r-strategy. In this case blastogenesis is a special stages of reproductive cycle and interchange with sexual embryogenesis appropriately (Ereskovsky & Korotkova, 1997).

Budding is rarely found in all sponge taxons independently on their systematic and geographic location. But it is random in them except two families stated above. Adaptive function of budding and its dependence on sponge environment are at the beginnings of their investigations (Ayling, 1980; Battershill & Bergquist, 1990). According to T. Simpson (1980), budding is a constant morphogenesis independent on season. This suggestion is corroborated by A. Ayling data (1980). Battershill & Bergquist (1990) consider budding to be a more preferable reproductive type than sexual embryogenesis at sponges, inhabiting silt-covered or sandy substrate and being influenced with tides and storm waves.

We studied the budding of oviparous sponge *Polymastia mammillaris* (Müller, 1806) (Tetractinomorpha, Hadromerida). For the first time budding of this sponge inhalant papillae was described by K. S. Merejkovsky (1879 a,b) exactly at White Sea populations. But he didn't pay attentions on the ecological aspect of this process. A. Arnesen (1917) described the Barents Sea *P. mammillaris* budding. The main detailed description of the asexual reproductive ecology and of its adaptive function at sponges *Polymastia* sp. and *P. granulosa* inhabiting the North Shoals of New Zealand have been made by Battershill & Bergquist (1990).

Many problems, connected with *Polymastia* budding are unclear. In particular dependence of its budding on depth, where sponge live, on substrate type, and on seasons was not studied. There are also no available data on budding intensity relation to the sponge size, to the number of oscular papillae and to the sexual reproductive period. In this connection we studied the influence of the foregoing exogenous and endogenic factors on *P. mammillaris* budding.

2. Material and methods

We studied the budding of *P. mammillaris* populations from Kandalaksha Bay of the White Sea. This sponge has a disk-like body. Its diameter reaches 13 cm and its height is about 2 cm. Body surface is usually looks like covered with needles or density setaceous and has numerous papillae mounting to 1.5 cm in high. Inhalant papillae have ostia. Few oscular papillae (usually 1-4 ones per sponge) are located at the body surface center. As a rule they are higher and thicker than inhalant papillae (Koltun, 1966). *P. mammillaris* is a wide spread

subtropic-arctic species found at depth range 1.5 - 400 m (Ereskovsky, 1994, 1995).

We used the collection of *P. mammillaris* from Zoological Institute of Russian Academy of Sciences made since 1905-1991 as well as our own collections in 1994-1995. We have studied 200 specimens in total, collected at the period from June, 1 to November, 1 and from the depth range 5-40 m. The number of osculars, inhalant budding and unbudding papillae as well as the number of buds were counted at each sponge. In order to measure body volume we dipped the sponges into a graduate with water. Body volume was assumed to be equal to the displaced water volume.

We selected two parameters for budding quantitative estimations - group budding intensity (GBI) and individual budding intensity (IBI). GBI is the per cent of budding specimens in a group of sponges expressed by the formula:

$$(1) \quad P = \frac{N_0}{N} * 100\%,$$

where N - general number of specimens in a group, N_0 - number of budding specimens.

In order to calculate confidence intervals GBI values underwent Fisher φ - transformation for portions expressed by the formula:

$$(2) \quad \varphi = 2 \arcsin \sqrt{\frac{P}{100\%}}.$$

Standard error for transformed portion were expressed by a formula:

$$(3) \quad S_\varphi = \frac{1}{\sqrt{N}}.$$

High and low confidence intervals for the portions were calculated using the standard Student coefficient for N and for confidence level 95%:

$$(4) \quad \varphi_{up} = \varphi + t_{st} * S_\varphi,$$

$$(5) \quad \varphi_{down} = \varphi - t_{st} * S_\varphi.$$

Then the interval values were retransformed to normal percent.

IBI is the percent of budding papillae among all inhalant papillae of a sponge expressed by the formula:

$$(6) \quad p = \frac{n_0}{n} * 100\%,$$

where n_0 - number of budding papillae of a specimen, n - general number of inhalant papillae of a specimen.

At first IBI we calculated for each specimen. Finally, general GBI and average IBI were separately calculated for specimens collected during each month for following depth ranges: 0 - 10 m, 10 - 15 m, 15 - 20 m, 20 - 25 m, 25 - 30 m, 30 - 40 m, and from different substrates. We selected two substrate types. The sediments containing much silt or sand were considered soft substrate. Rocks, boulders and huge stones were assumed to be hard one. Average IBI was also

calculated separately for monooscular and for multioscular specimens. Besides that we studied the dependence of IBI on body volume. All data were divided into five equal groups of increasing volume meanings. Average IBI was calculated in each group.

In order to calculate average IBI in a group of sponges every IBI meaning underwent Fisher φ - transformation (formula 2). Average transformed portion was calculated in each group by the formula:

$$(7) \quad \bar{\varphi} = \frac{\sum_{i=1}^k \varphi_i}{k},$$

where φ_i - transformed portion (IBI) of, i - number specimens, k - number of sponges in a group.

Standard error of the average portion was expressed by the formula:

$$(8) \quad S_\varphi = \frac{\sqrt{\sum_{i=1}^k (\varphi_i - \bar{\varphi})^2}}{(k-1)^k}.$$

Confidence intervals of the portion were calculated by the formula (4). Then their meanings as well as the portion meanings were retransformed to normal percent.

Average body volume and average number of oscular papillae were separately calculated for specimens collected from hard and from soft substrate. Average number of oscular papillae was also calculated for five groups of increasing volume meaning stated above. All statistical calculations were made according to the biometrical handbook by G. F. Lakin (1990).

3. Results

Budding intensity didn't vary greatly from June to August. Group budding intensity averaged about 61% and individual budding intensity averaged 7.6% at that period. But budding intensity appears to decrease in October. GBI about 40.5% and IBI about 1.8% were observed at that time. This value averaged 62% at the foregoing depth range and decreased from 20 m to 10% at the depth 32 m. Low IBI was observed in sponges living in extreme depth ranges studied (about 2.6% at depth range 0 - 10 m and about 0.1% at the range 30 - 40 m). IBI peak appears to fall on the depth range 15 - 20 m. It averaged 12.7%. The majority (90%) of sponges collected from the soft substrate had one oscular papilla per specimen. Their volume averaged 5.3 cm³ (fig. 3 c, d). Their GBI was 55% and average IBI totaled 60% (fig. 3 b). Most of sponges living on hard substrate (77%) appears to have several oscular papillae (averaging 3). Their volume averaged 36.8 cm³ (fig. 3 c, d). Their GBI accounted for 67% and IBI averaged 31% (fig. 3 a).

IBI of the smallest sponges (body volume not more than 1 cm³) appears to be the lowest (1.1% for body volume 0.2 cm³). The highest IBI (13.1%) was

observed in sponges which body volume averaged 5.6 cm³. (fig. 4 a). All foregoing sponges as a rule had one oscular papillae (fig. 4 b). Budding intensity of large sponges (average body volume not less than 16.4 cm³) appear to have several oscular papillae (fig. 4 b). More or less constant individual budding intensity (averaging 3.5%) was observed in them. Individual budding intensity averaged 4.6% in monooscular specimens and 3.6% in multioscular sponges. However the difference was not valid.

4. Discussion

Asexual reproduction in Metazoa is known to depend on the certain population environment (Ivanova-Kazas, 1977). Sponge asexual reproduction depends on ecological conditions too and that is why our results testify to the great correlation of *P. mammillaris* budding to the external factors. The influence of the environment on *P. mammillaris* budding as well as on Spongillidae gemmulation are mediated by the internal integrative mechanisms of sponges (Simpson & Fell, 1974; Korotkova, 1988; Pronzato et al., 1993). Correlative variability of sexual and somatic morphogeneses (gametogenesis, embryogenesis, blastogenesis etc.) at sponge life cycle appears to be such a mechanism (Ereskovsky & Korotkova, 1996). In particular, gemmulation starts not earlier than vitellogenesis finished inside the same specimen in case of active gametogenesis proceeding evidently, it is due to the fact, that gemmulation and vitellogenesis have the same cell source - nucleolar amoebocytes (archoocytes) (Brien & Meewis, 1941; Simpson, 1984; Weissenfels, 1989).

Probably budding intensity season variations in *P. mammillaris* population can be accounted by the foregoing data. Nucleolar amoebocytes are known to be the main cell source while for Tetractinomorpha sponges budding. It has been established for *Tethya lyncurium* (Connes, 1966; 1967) and *Axinella damicornis* (Boury-Esnault, 1970). According to our preliminary data nucleolar amoebocytes also dominate other cell types inside *P. mammillaris* buds. Autumn budding intensity decrease in studied *P. mammillaris* population is apparently due to the activation of its gametogenesis, being finished with gamete release in October. According to B. Zheleznov data (Zheleznov, 1980, unpubl.) nucleolar amoebocytes concentration in *P. mammillaris* mesohyl is the highest in October. Such an explanation agrees with G. P. Korotkova (1979, 1984, 1988 a,b) suggestion about incompatibility of sexual and somatic morphogeneses which require the functioning of the same organism structures.

Substrate structure and stability as well as hydrodynamic conditions in sponge habitats appears to be the most substantial exogenous factors influencing budding intensity. In particular, according to Bergquist et al. (1970) and Battershill & Bergquist (1990) budding is in preference to sexual reproduction while continual sediment shifting at soft substrate. Our data about the comparatively higher budding intensity in sponges living on soft substrate

corroborate the foregoing suggestion. *P. mammillaris* as well as other Tetractinomorpha is oviparous sponge. Sediment shifting at the bottom appears to form stress conditions for fertilization, for larval development and metamorphosis. A bud contains nearly all definitive cells and needs no hard substrate (stones, gravel) for settling and adult development in contrast to a larva. The accomplishment of such a reproductive tactics is the mechanism providing the protection of subpopulation living under the conditions stress for sexual reproduction. Small sediment fractions shifting at the hard substrate (mainly at rocks, stones, boulders) exert no considerable influence on an egg or a larva. Evidently it accounts for comparatively low individual budding intensity in sponges living on hard substrate. Budding intensity decreases at large depth (since 25 m) independently on season and substrate type which it is apparently due to the great stabilization of hydrological, physical and chemical factors such as temperature, salinity and substrate mobility at these conditions. Adaptive role of budding decreases at large depths.

So, budding is a usual reproductive type of the White Sea *P. mammillaris* living under the stress (changeable) conditions of small depths (5 - 25 m), that is the atlantic highboreal water mass (Babkov, Golikov, 1984). The portion of budding specimens greatly decreases at large depth (under the conditions of the White Sea arctic water mass modification), while abiotic factors becomes more stable. Sexual reproduction prevails under such conditions. A peculiar correlation of *P. mammillaris* body volume and number of oscular papillae with substrate type was observed. Small sponges (average body volume 5.3 cm³) each having one oscular papilla and living on soft substrate mainly, develop from the solitary buds or larvae. Their body is usually hemispherical, its form is regular. Large (average body volume 36.8 cm³) multioscular sponges live mainly on the hard substrate. Irregular dumb-bell- or sole-like body form is typical of them. According to our suggestion *P. mammillaris* colonies are formed by several monooscular specimen fusion exclusively on the hard substrate. Probably, such a fusion proceeds at the stage of developing buds or metamorphosed larvae (Koltun, 1988).

Some number of individual (monooscular) sponges live on hard substrate (about 23% of all specimens from this substrate). Some monooscular specimens may excel junior colonies in size but have the same low budding intensity. That is why average individual budding intensity in monooscular sponges is higher than in multioscular ones independently on substrate type but this difference is not valid. So according to our results, we can conclude that the White Sea *P. mammillaris* inhalant papillae budding depend on complex of exogenous and endogenic factors. The most essential factors are type of substrate and its stability, and the starting period of sexual reproduction as a process alternative to blastogenesis.

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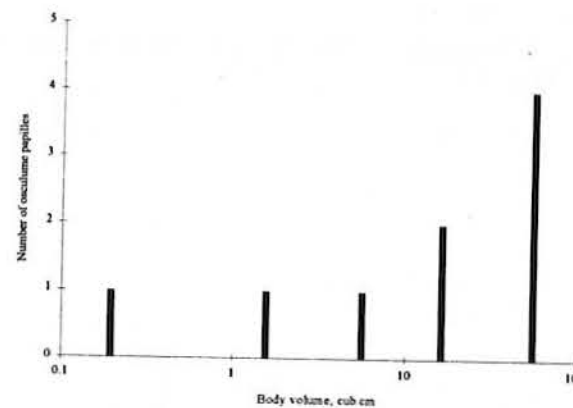
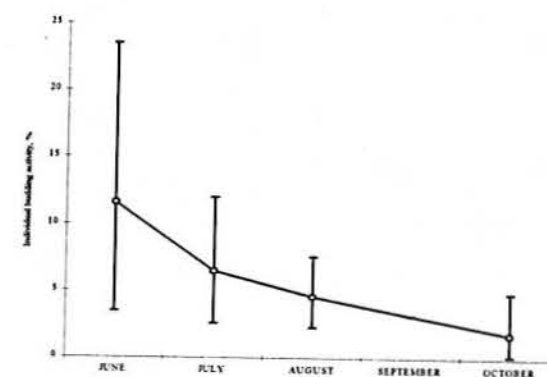
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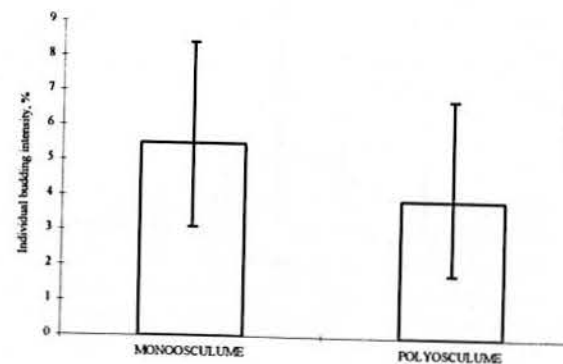
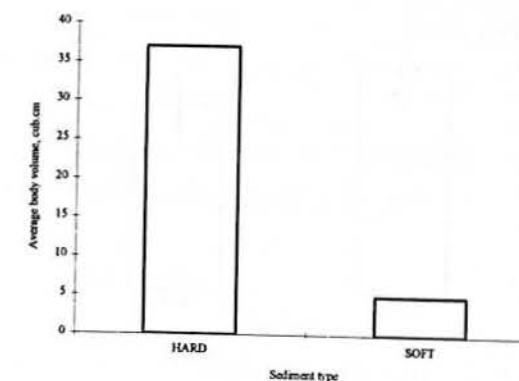
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Budding dependence on season

Fig. 1 a. Group budding intensity: dependence on season

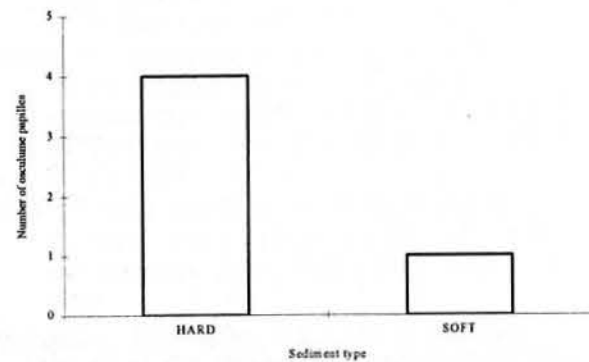
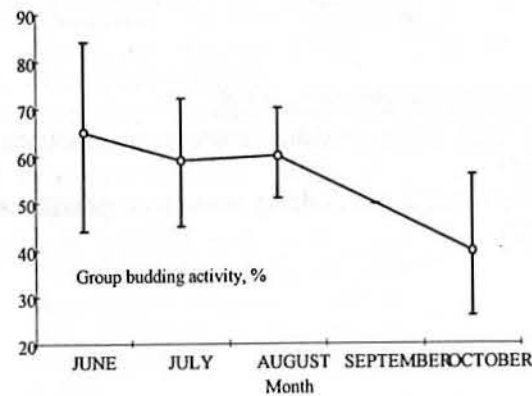
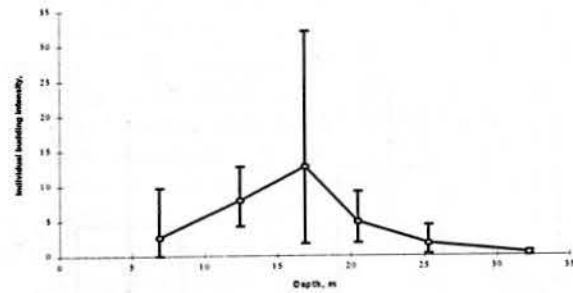
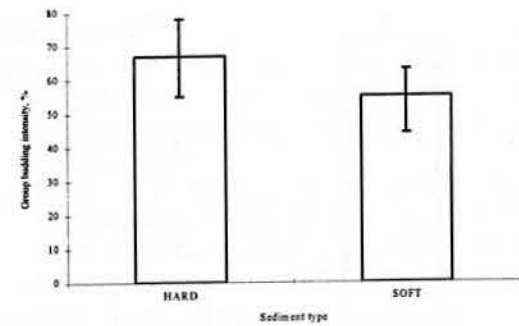
Fig. 1 b. Individual budding intensity: dependence on season



Budding dependence on depth

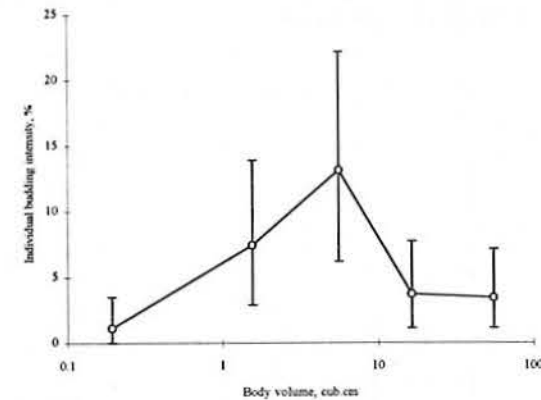
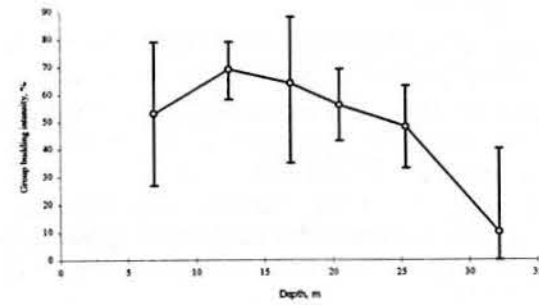
Fig. 2 a. Group budding intensity: dependence on depth

Fig. 2 b. Individual budding intensity: dependence on depth



Budding dependence on substrate type

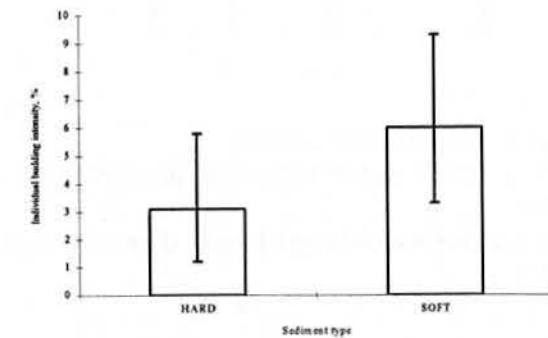
Fig. 3 a. Group budding intensity: dependence on sediment. Fig. 3 b. Individual budding intensity: dependence on sediment. Fig. 3 c. Average body volume: dependence on sediment. Fig. 3 d. Number of osculum papillae: dependence on sediment



Budding dependence on body volume

Fig. 4a. Number of osculum papillae: dependence on body volume

Fig. 4b. Individual budding intensity: dependence on body volume



Budding dependence on number of oscular papillae

Fig. 5. Individual budding intensity: dependence on number of osculum papillae

Symbiosis of the Antarctic sponge genus *lophon* (Porifera) and the ophiuroid genus *Ophiurolepis* (Ophiuroidea, Echinodermata)

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Abstract: Only in the Antarctic sponge *lophon radiatus* settles on two species of brittle stars: *Ophiurolepis gelida* and *O. brevirma*. Changing form of plates sponge and traces of its activity can serve a source of misidentification for species of some brittle stars.

Keywords: Symbiosis, sponge *lophon radiatus*, brittle star *Ophiurolepis*, Antarctic.

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1. Introduction

Owing to abundance in various biocenoses of the Antarctic and Subantarctic, sponges and ophiuroids play an essential role in functioning of communities of cold and temperate waters of the Southern hemisphere (Koltun, 1964; Dearborn et al., 1972; Dearborn, 1977; Smirnov, 1984, 1990 and others).

The special interest presents symbiosis of these animals, which is marked so far only in antarctic waters. The similar parallel things it is possible to find in symbiosis of hydroids of a genus *Hydractinia* and ophiuroids of a family Ophiuridae (Smirnov & Stepanjants, 1980). Attention is drawn to the fact that both hydroid and sponge settle extremely on the representatives of the given family.

2. The basis facts

In our collections specimens are available with putting up on them sponge *lophon radiatus* and with a different degree of overgrowing of the ophiuroid specimens of the genus *Ophiurolepis*, belonging to two species: *O. gelida* and *O. brevirma* (Fig. 1).

3. Results and discussion

The species *O. brevirma* in a greater degree is undergo overgrowing than *O. gelida*. Mortensen (1936) marked it too. Fell (1961), who has made opposite conclusion (we don't know on which basis), has admitted a number of errors at identification brittle stars on underwater photographs, executed in the Ross sea.

Our supervision also show, that the influence of sponge on the ophiuroid tissues and plates can be rather strong thus there are the deformations of skeleton elements. For example, in norm (for not overgrown or weak overgrown specimens of species *Ophiurolepis brevirma*) flat tentacle scales in encirclement of sponge can accept the tubular

form making the channel in spongy mass for tube foot. Probably not rendering of direct effect on ophiuroid plates, as it has a place at influence on substrat of lime in case of drilling sponges, *lophon radiatus* acts on formation of the ophiuroid skeleton by any manner.

This phenomenon has important taxonomic significance and interest with all-biological point of view. And for taxonomists, certainly, account of a degree of epibentic effect on the ophiuroid plates and opportunity of valuation of this influence are important. Changing form of plates sponge and traces of its activity can serve a source of identification errors for separate species of brittle stars.

Acknowledgements

We thank A. V. Ereskovsky for help with photographing. The research described in this publication was made possible in part by Grant on biodiversity from the International Science Foundation.

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Alexander V. Ereskovsky, Helmut Keupp & Rolf Kohring (Eds.)

„Modern Problems of Poriferan Biology“

Proceedings of the first All-Russia meeting of spongiologists
St. Petersburg, February 1996

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"Modern Problems of Poriferan Biology"

Proceedings of the first All-Russia meeting of spongiologists
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Alexander V. Ereskovsky, Helmut Keupp & Rolf Kohring (Eds.)