TYPES OF INTERACTIONS IN CONSORTIA OF BAIKALIAN SPONGES

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ABSTRACT

The composition of invertebrate communities inhabiting Baikalian sponges was studied. All the sponges examined were inhabited by invertebrates. Their number varied from 80 to 280 individuals per 100 cm^3 of sponge, the biomass was found to be from 200 to 1020 mg per 100 cm^3 of sponge. Twelve taxa: Turbellaria, Hirudinea, Nematoda, Oligochaeta, Polychaeta, Copepoda, Ostracoda, Isopoda, Amphipoda, Trichoptera, Chironomidae, Mollusca were found. There are two distinctive sets of species within the sponge consortia, which we designate as "specific" and "non-specific" ones. The latter differs in sponges sampled in different parts of the lake. The specific set consists of species, which are typical of all the sponge species sampled in different parts of the lake. The interaction between the sponges and the inhabiting invertebrates includes topic and trophic links. For most of sponge-dwelling invertebrates their interaction with the sponge is most likely to be as proto-cooperation (non-obligate co-existence), and for some species like *Brandtia parasitica* and *Acanthocyclops spongicola* as mutualism (obligate co-existence).

KEY WORDS

Lake Baikal, sponge, consortia, invertebrates, type of interactions.

INTRODUCTION

The interaction of marine sponges with other organisms inhabiting them has been rather well studied. About 500 different cases of more or less tight links between sponges and crustaceans have been described which are considered as phenomena of commensalism, symbiosis, and parasitism or as relations of a mixed character. Interactions with consortia of fresh-water sponges have been investigated to a far lesser degree (PRONZATO & MANCONI, 2002). The consortia of Baikalian sponges have been poorly studied. As far back as 1874 DYBOWSKY described two species of amphipods - *Spinacantus parasiticus* and *Eulimnogammarus violaceus*, which, in his opinion, parasitized on the sponge *Lubomirskia baicalensis* (DYBOWSKY, 1874). KOZHOV (1963) also detected the close link of these two species of amphipods with sponges. However, the character of the interrelations between sponge and invertebrate dwelling on it has not been determined completely up to now. The first investigation dedicated to the study of consortium of the Baikalian sponge *L. baicalensis* was carried out in 1990 (KAMALTYNOV *et al.,* 1993). It was observed that *L. baicalensis* acted as a determinant of a specific Baikalian consortium when the sponge became big enough to harbour a significant associated fauna. It was revealed that the representatives of 12 groups of zoobenthos were in the composition of sponge consortium. One of these groups dwelled directly on the sponge surface (epon), the other group swarmed around it (peron). Some dependence between the sponge weight and that of the dwelling zoobenthic organisms was determined. The aim of the present study is to identify the composition of invertebrates inhabiting Baikalian sponges and to elucidate the types of interactions between sponges and their associated biota.

MATERIALS AND METHODS

The majority of material was obtained in Kharin-Irgi Bay (Central Baikal) in August 2001. Besides, the samples obtained in the region of Ushkany Islands and in Bolshie Koty (Southern Baikal) in 2000 were used. The sampling was performed by SCUBA divers with the known procedure (KAMALTYNOV *et al.,* 1993). Under the water the sponge was covered with a sack and brought to the ship together with a stone to which it was attached. Then the invertebrates inhabiting the sponge were collected according to the following scheme: 1) peron (invertebrates swarming round the sponge); 2) epon 1 (invertebrates dwelling on the sponge surface); 3) epon 2 (invertebrates inhabiting the sponge's base); 4) epon 3 (invertebrates dwelling on the stone surface to which the sponge is attached). Several species of sponges (up to 4) often lodged on the same stone. As a rule, one of these sponges is branching, while the others are encrusting. Such small sponge communities have a common population of peron and of the stone. Those invertebrates, which inhabited the sponge surface, were considered to be consorts of that particular sponge species. Seven species of Baikalian sponges (belonging to the family Lubomirskiidae) were surveyed. Among them there were *Lubomirskia baicalensis* (Pallas, 1771) (10 specimens), *Baikalospongia intermedia* (Dybowski, 1880) (7 specimens), *B. bacillifera* (Dybowski, 1880) (2 specimens), and *Swartschewskia papyracea* (Dybowski, 1880) (2 specimen). Three new species were described by Efremova (EFREMOVA, 2001, 2004): *Lubomirskia incrustans* Efremova, 2001 (2 specimens), *Baikalospongia recta* Efremova, 2001 (2 specimens), and *Rezinkovia echinata* Efremova, 2001 (2 specimens). Quantitative data (abundance and biomass) of invertebrates were calculated per sponge volume, defined as the volume of water substituted by the sponge in a measuring flask (technique of Dr. Y. Masuda, Kawasaki Medical School, Japan, pers. comm.). The species content was determined for the following groups of invertebrates: Copepoda, Isopoda, Amphipoda, Trichoptera, and Chironomidae. For the elucidation of trophic interactions between sponges and invertebrates inhabiting them two methods were used - direct (the investigation of the stomach contents) and indirect (analysis of the fatty acids composition). The stomach contents of 30 larvae of Trichoptera were investigated. The composition of fatty acids as methyl ethers from two species of amphipods was analyzed according to the known technique (KATES, 1972; CHRISTIE, 1973) on a gas-liquid chromatographer Shimadzu model GC - 9A.

RESULTS

Among sponges studied, one species (*Lubomirskia baicalensis*) had a branching shape, two species (*Baikalospongia baicalensis, B. recta*) have globular form, and all the rest are encrusting sponges. Associated invertebrates were identified on all the sponge species, their abundance varied within the range of 60 - 280 specimens per 100 cm^3 of sponge, biomass fluctuated from 200 to 1020 mg per 100 cm^3 of sponge. Twelve taxa: Turbellaria, Hirudinea, Nematoda, Oligochaeta, Polychaeta, Copepoda, Ostracoda, Isopoda, Amphipoda, Trichoptera, Chironomidae, Mollusca were found (Tab. I). Because of the small number of samples, the quantitative data can be considered to be representative only for two species of sponges - *L. baicalensis* and *Baikalospongia intermedia*, and therefore, we shall conduct further analysis of the composition of consortia only of these two species.

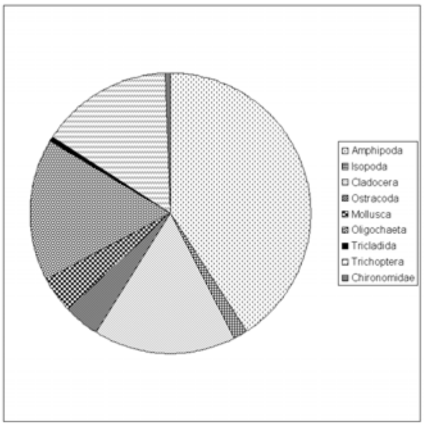

Fig. 1. Correlation between volume of sponges, cm^3 (V), quantity of invertebrates, ind/cm^3 (N) and biomass of invertebrates, mg/cm^3

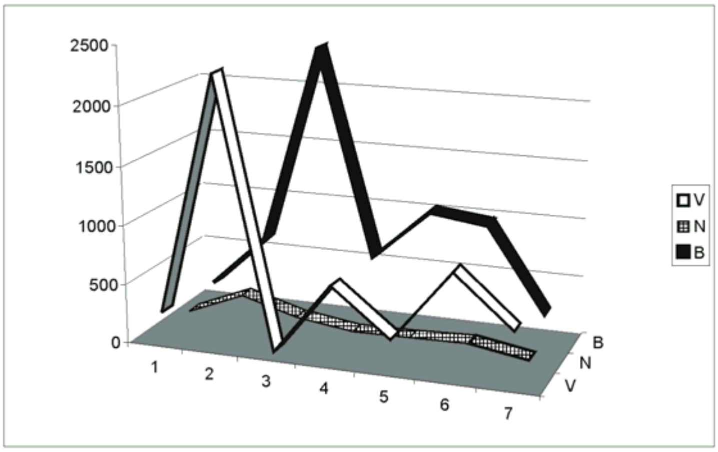

Fig. 2. Ratio of different groups of invertebrate inhabiting sponge *Lubomirskia baicalensis*.

Tab. II. Fatty acid composition (percentage in total fatty acid) of two species of Baikalian amphipods; samples from Kharin-Irgi Bay, deep 10 m, August 2001.

Fatty acid	*Brandtia parasitica*	*Brandtia latissima*
14:0	5.6	9.2
15:0	0.2	0.1
16:0	6.0	12.2
17:0	1.1	0.5
18:0	2.4	0.8
19:0	0.2	-
20:0	0.4	-
i - 15:0	0.1	-
ai - 15:0	0.2	-
i - 16:0	0.5	-
ai - 16:0	0.4	-
i - 17:0	0.4	-
ai - 17:0	0.2	-
i - 18:0	0.6	0.2
ai - 18:0	0.3	0.7
16:1 n-7	1.8	27.3
16:1 n-5	0.2	-
17:1 n-8	0.4	3.0
18:1 n-9	3,3	15.8
18:1 n-7	2.6	4.6
19:1	0.3	-
20:1 n-9	0.2	-
20:1 n-7	0.1	-
16:2 n-4	1.1	2.0
18:2 n-6	0.1	-
18:3 n-6	0.2	0.3
18:3 n-3	0.3	1.2
18:4 n-3	4.1	2.6
20:3 n-3	0.3	0.2
22:1 n-9	0.2	-
20:4 n-3	1.1	0.4
20:5 n-3	9.2	8.8
22:6 n-3	0.4	0.3
24:1 n-9	0.1	-

All the quantitative characteristics of benthos tend to increase with the increase of the total sponge volume (Fig. 1). The dominant groups in abundance among invertebrates are Amphipoda (41 %), followed by Oligochaeta (17 %), Cladocera (16 %) and Trichoptera (15 %) (Fig. 2). The rest groups make up from 1 to 4 % of the invertebrates total. Amphipods and cladocerans inhabit mainly the sponge surface, while Oligochaeta and caddisflies dwell on the sponge base. The cases of caddisflies emptied after pupae's hatching and filled up with living Oligochaeta, Turbellaria and their cocoons, as well as the cases of caddisflies with dead pupae inside are found under the base of sponges.

For the evaluation of trophic links of invertebrates we investigated the contents of stomach of caddisflies *Baicalina bellicosa*, and *B. reducta.* Diatomaceous algae (predominantly benthic), scraps of filamentous algae and separate sponge spicules were detected in the contents of alimentary canal of Trichoptera. The fatty acid composition of amphipods *Brandtia parasitica* and *B. latissima* was analyzed (Tab. II).

DISCUSSION AND CONCLUSIONS

Two sets of invertebrate animals were isolated in the consortia of sponges: specific and non-specific ones. Non-specific set is represented by invertebrates of peron and epon. As a rule, it consists of plankton (*Cyclops colensis, Epishura baikalensis*) and benthic invertebrates widespread on the shallow water platform at the definite place of sponge habitation. The non-specific set differs in sponges sampled at different parts of the lake. The specific one is formed by the definite set of species (exceptionally by epon invertebrates). This set is represented by amphipods: *Brandtia parasitica, B. latissima* and cyclops: *Acanthocyclops incolotaenia*, *A. intermedius*. The specific set is typical of all the specimens of sponge species sampled from different parts of the lake. Besides, two more crustacean species (cyclops *Acanthocyclops spongicola*, amphipod *Eulimnogammarus violaceus*) of this array occur on the ramified sponge *Lubomirskia baicalensis*. Last species of crustacean also occur on the globular sponge *B. bacillifera*. All crustaceans of the specific set (except *Eulimnogammarus violaceus* which lives in holes gnawed in sponges bodies) have spines on the body and appendages that allow them to stick to the sponge surface and use it efficiently as a substrate.

Benthic invertebrates belonging to the non-specific set have no pronounced morphological adaptation to dwelling on the sponge – they are more eurytopic. The animals of this array mainly inhabit the sponge base or the stone surface to which a sponge attaches. Along with this, they also settle on stones without sponges. In the event of free space limitation, these animals (caddisflies in particular) can compete with the sponges for substrate. The finding of three cases of Trichoptera *Baicalinella foliata* with dead pupae inside coated by the sponge *Baikalospongia intermedia* can serve as verification for this competition. Caddisflies in the pupation and pupa stages stay in the attached case for about a year – during this period a sponge can settle on a case and deprive the pupa of the possibility of getting out to the surface.

It is known that among the animals inhabiting freshwater sponges of the family Spongillidae, there are species closely connected with sponges (for example, feeding on them) and species that have no specific relations, which use the sponge merely as a substrate (REZVOY, 1936). To the first group this author refers Neuroptera larvae of the genus *Sisyra*, caddisflies *Leptocerus senilis*, *Ecnomus tenellus*, *Hydropsyche ornatula*, *Neureclipsis bimaculata* and Chironomidae larvae of the group *Glyptotendipes*. The second group is represented by Oligochaeta, isopods, copepods, as well as by some Trichoptera and Chironomidae. Therefore, in the consortia of freshwater sponges it is possible to distinguish specific and non-specific sets of species. The composition of these sets, however, differs between the cosmopolitan Spongillidae and endemic Baikalian Lubomirskiidae. The specific set of Spongillidae consists mainly of insect larvae, while crustaceans prevail in that of Lubomirskiidae. The prevalence of crustaceans in the specific set of Lubomirskiidae indicates relative similarity of the structural organization of consortia of freshwater sponges with marine ones. In marine sponge-dwelling fauna, there is also a high diversity of crustaceans (COSTELLO & MYERS, 1987; DUFFY, 1992; THIEL, 2000).

The representatives of the specific set in Spongillidae (according to REZVOY, 1936) are connected with sponges by both topic and trophic links. As a rule, they feed on the tissue of sponges. The trophic links between endemic Baikalian sponges and the animal inhabiting them are still unclear.

The type of animal nutrition can be determined from the analysis of the composition of fatty acids of the organism. Besides, specific fatty acids synthesized by any organism can serve as a trophic marker. The sponges synthesize fatty acids of unusual structure (with chain length up to 30 and more of carbonic atoms), which are called "demospongic". Such acids are used as taxonomic (BERGQUIST *et al.,* 1984; THIEL *et al.,* 2002) and trophic (DEMBITSKY *et al.,* 1994) biomarkers.

The composition of fatty acids of two species of amphipods belonging to one genus was analyzed, one species *B. parasitica* being a representative of the specific set of consortium, the other *B. latissima* – of the non-specific set. A high level (48 %) of polyunsaturated fatty acids of linolenic (n-3) series, acids of bacterial and plant origin were found in the composition of fatty acids of amphipods (Tab. II). Demospongic acids were not found in the surveyed amphipods. Judging from the availability of polyunsaturated fatty acid, the bacteria transforming the organic matters of animal and plant origin play a major role in feeding of *B. parasitica.* By scavenging decomposed organic matter from the sponge surface the invertebrates clean the sponge. On the basis of our data, with high degree of probability we can deny the existence of interactions such as parasite-host-relationships within the community of Baikalian sponges and invertebrates inhabiting them. The similar conclusion was made in the study of *B. parasitica* feeding (MEKHANIKOVA, 2001). The author has established that a food clot in specimens of this species contains remains of plant and animal organisms inhabiting the sponge and plankton algae as well.

The animals of non-specific set also feed on algae and plant detritus accumulated on the sponge surface and stones. Sponge spicules detected in the stomachs of caddisflies should not be considered as the remains of sponge skeleton, as they were not coupled in bunches (fascicles) and occurred only in small proportion, and they should rather be considered as sediment particles.

The interaction between animals of non-specific array and sponges may be considered as neutral except the cases of interspecific competition for the substrate. The type of interactions between sponges and the specific set of invertebrates is most likely defined as proto-cooperation (non obligate co-existence) but for some species (like *B. parasitica, A. spongicola*) – as mutualism (obligate co-existence). Nevertheless, we cannot disclaim the availability of more complicated links in the community of sponges and invertebrates, as there have been no special studies of the invertebrate influence on the sponges.

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Tab. I. List of invertebrates of Baikalian sponges consortia. P - peron, E1- epon 1, E2 – epon 2, E3 – epon 3; * - our data; (1) - according KAMALTYNOV *et al.,* 1993.

	Sponges						
Invertebrates	***Lubomirskia baicalensis***	***Lubomirskia incrustans***	***Baikalospongia intermedia***	***Baikalospongia bacillifera***	***Baikalospongia recta***	***Swartschewskia papyracea***	***Rezinkovia echinata***
***Turbellaria** (1)	E2, E3		E2				
***Hirudinea** (1)	E2						
***Nematoda** (1)	E2						E2
***Oligochaeta** (1)	E2, E3		E2, E3	E2			E2
Polychaeta	E2						
Manayunkia baicalensis (Nusbaum, 1901) (1)	E2, E3						
**M. zenkewitshii* Sitnikova, 1997	E2, E3			E2, E3			
Copepoda (1)							
**Cyclops kolensis* Lilljeborg, 1901(1)	P						
**Acanthocyclops galbinus* Mazepova, 1962	E2		E2				
**A. incolotaenia* Mazepova, 1950	E1, E3		E2				
**A. intermedius* Mazepova, 1952	E1						
**A. profundus profundus* Mazepova, 1950	E1						
**A. profundus tomilovi* Mazepova, 1978	E1						
**A. viridis* (Jurine, 1820)	E1						
A. spongicola Mazepova 1962 (1)	infauna						
**Microcyclops rubellus* (Lilljeborg, 1901)	E1, E2		E2				
**Harpacticella inopinata* Sars, 1908	E2, E3		E3				
**Epishura baicalensis* Sars, 1900	P		P				
***Ostracoda** (1)							
Isopoda							
**Baicalasellus baicalensis* (Grube, 1872) (1)	E2, E3						
**B. angarensis* (Dybowski, 1884) (1)	E2, E3	E2	E2				
**Mesoasellus* sp.	E2, E3					E2	
Amphipoda							
**Crypturopus pachytus* (Dybowsky, 1874)	E2						
C. rugosus (Dybowsky, 1874) (1)	E2						
**Micruropus littoralis littoralis* (Dybowsky, 1874)	E1		E2				
**M. minutus* (Sowinsky, 1915)	E3		E2				
**M. brevicauda* Bazikalova, 1945	E3						
**M. macroconus macroconus* (Bazikalova, 1945)	E2						
**Baicalogammarus pullus* (Dybowsky, 1874) (1)	P, E2		E2				
**Echiuropus macronychus macronychus* (Sowinsky, 1915)	E1		E2				
**Brandtia latissima* (Dybowsky, 1874) (1)	E2, E3		E2, E3	E2, E3	E2, E3	E2, E3	
**B. (Spinacanthus) parasitica* (Dybowsky, 1874) (1)	E1, E2, E3	E2	E2, E3	E1, E2	E1	E2, E3	E2
**Hyalellopsis carinata* Sowinsky,1915	E2						
**H. tixtonae* Sowinsky,1915	E2						
**Pallasea cancellus* (Pallas, 1776) (1)	E1, E2						
Hakonboekia strauchii (Dybowsky, 1874) (1)	E1, E2						
**Poekilogammarus erinaceus* Tachteev, 1992 (1)	P, E1						
**Eulimnogammarus cruentus* (Dorogostaisky,1930) (1)	E2, E3						E2
E. czerskii (Dybowsky, 1874) (1)	E2						
**E. grandimanus* Bazikalova, 1945 (1)	E1, E2, E3		E2, E3				E2, E3

**E. lividus* (Dybowsky, 1874)	E2, E3		E2			E2	E2
**E. violaceus* (Dybowsky, 1874) (1)	E1				E1		
E. obsoletus Bazikalova, 1945 (1)	E1, E2						
**E. viridis* (Dybowsky, 1874)	E2, E3						
**Heterogammarus sophianosii* (Dybowsky, 1874)	E2						
H. bifasciatus (Dybowsky, 1874) (1)	E2						
Trichoptera (1)							
**Protobaicalina spinosa* Martynov, 1914			E2				
**Baicalina bellicosa* Martynov, 1914	E2, E3						
**B. reducta* Martynov, 1924	E2, E3						
**B. thamastoides* Martynov, 1914	E2, E3					E2	
**Baicalodes ovalis* Martynov, 1914			E2				
**Baicalinella foliata* Martynov, 1914	E2, E3		E2				
Chironomidae (1)							
**Paratanytarsus baicalensis* (Tshernovskij, 1949)	E2			E2			
**Segentia baicalensis* (Tshernovskij, 1949)	E2						
**Cricotopus* sp.	E1						
**Orthocladius saxosus* (Tokunaga, 1939)			E2				
**Orthocladius* gr. *thienemanni*	E2		E2, E3			E2	E2
***Mollusca**	E2, E3		E2, E3		E2	E2	E2
Megalovalvata baicalensis (Gerstfeldt, 1859) (1)	E2, E3						
Baicalia sp. (1)	E2, E3						