Bulletin
of
the Natural History Museum in Belgrade

Natural History Museum Belgrade, 2008
Volume 1

ISSN 1820-9521

Biology

Bulletin of the Natural History Museum, 2008, 1: 149-160.

UDC: 593.9(497.16)

SPATIAL AND SEASONAL DISTRIBUTION OF ECHINODERMS IN THE BOKA KOTORSKA BAY

Slavica Kašćelan

Institute for Marine Biology,
Dobrota bb, Kotor, Montenegro,
E-mail: skascelan@yahoo.com

This paper presents the results of an investigation into the diversity of echinoderms inside the Boka kotorska Bay, as well as their spatial and seasonal distribution. This area is characterized by a specific complex of physical-chemical parameters of the sea water and sediments, which make it a particular biotope. Regarding the biology of echinoderms as sessile and slow-moving animals, the environment has an important role in their distribution and abundance. Obtained results show the presence of 32 species, distributed over diverse kinds of sea bottoms and different depths. Statistical analyses of samples show very low seasonal differences. According to the bottom type, the highest average similarity is recorded from samples taken from *Posidonia oceanica* meadows and rocky bottoms.

Key words: Echinoderms, Boka Kotorska Bay, substrate, statistical analysis

INTRODUCTION

Echinoderms are mostly slow-moving and some of them are sessile organisms and because of this lifestyle they are directly impacted by the environment. Feeding upon sediments and sea water they ingest all dissolved noxious substances. Some of them are tolerant of the polluted environment (Tortonese 1965), while others respond negatively (Buznikov 1984) and leave the area. For this reason, investigation of the echinoderms species and their abundance is a very important indicator of the sea water pollution (Zavodnik *et al.* 1989; Cunha *et al.* 2005).

According to the literature this area is populated by 39 species of echinoderms (Karaman & Gamulin-Brida 1970; Stjepčević & Parenzan 1980; Milojević 1979). In the period since the last investigation almost 20 years ago, the anthropogenic impact has increased greatly. The

Map 1. - Map of Boka Kotorska Bay with indications of the sampling points.

arrival of a significant number of new inhabitants in the coastal zone and a sewage system not yet regulated have caused serious damage to the marine ecosystem. Once a large area previously covered by the sea grasses *Posidonia oceanica* and *Cymodocea nodosa*, now they have greatly diminished (Mačić & Boža 2001).

The aim of this paper is to define the present qualitative and quantitative composition of the echinoderms fauna in the Boka kotorska Bay where urban impact has occurred, and evaluate their response to environmental stress.

MATERIALS AND METHODS

THE STUDY AREA

Boka kotorska Bay is situated on the northern part of the Montenegrin coast (Map 1 to the right) from Rt Oštro to Rt Mirište. This area is, both geographically and oceanographically, a semi-closed basin. According to the geomorphologic and physical-chemical characteristics, it is mostly diverse from the open sea. In this region the sea penetrates deep into the mainland and creates a coast of about 105.5 km. On the basis of its geographical-hydrographical characteristics the Bay could be divided into 3 parts: Kotor-Risan Bay (inner part), Tivat Bay (central part) and Herceg-Novi Bay (outer part). The sea bed is complex. In each bay the profundity increases towards the central part, except Kotor Bay where the maximal depth is near the northern coast (Dražin vrt). The average depth of the Boka kotorska Bay is 27.6 m, and its maximum profundity is 60m (Herceg-Novi Bay).

SAMPLINGS

Material collection was done by SCUBA diving (up to 40 m in depth). Field work was conducted from May to November 2007. Sampling was done on a transect line, 100 m long and ordinated perpendicularly to the coastal line. According to the relief, transects reached to 40 m in depth. Material was collected every 10 m along the transect line, 1 meter to the left and right of the line. In total, 6 transects were done on the researched area (Tab. 1). Sampling was done seasonally (spring, summer and autumn), but due to bad weather conditions it was not done in winter. Thus sampling for statistical analyses contains 10 stations in each transect per 6 localities-a total of 60 positions during one season. Apart from the transect sampling, material was collected from 5 localities randomly chosen (Tab. 2). The material was immediately anaesthetized with a saturated solution of menthol in sea water and later preserved in 70% alcohol. Determination was done according to Tortonese (1965) and Koehler (1924) and corrected by ERMS (Hansson 2001).

Tab. 1. - Localities where is collected materials for quantitative analysis (transects).

Sing	Locality	N	E	Bottom type	Maximal depth
T1	Dobrota	42°26.247′	18°45.711′	Sandy-mud	18m
T2	Dražin vrt	42°29.034′	18°43.508′	Sandy-mud	30m
T3	Verige	42°28.664′	18°41.443′	Stone-mud	38m
T4	Uvala Ku-koljina	42°24.536′	18°42.020′	Mud	9m
T5	Herceg Novi	42°26.890′	18°32.259′	Rocky-sand	10m
T6	Žanjice	42°23.765′	18°34.534′	Sandy-mud	25m

Table 2. - Localities where is collected materials for qualitative analysis.

Sign	locality	N	E	Bottom type	Depth range (m)
A1	Sveti Stasije	42°28.046′	18°44.995′	Sandy-mud	0-15
A2	Perast	42°29.015′	18°42.442′	mud	0-20
A3	Kostanjica	42°29.164′	18°40.472′	Sandy-mud	0-26
A4	Verige (tjesnac)	42°28.664′	18°41.442′	stone	0-26
A5	Rt Arza	42°23.764′	18°34.532′	Rocky-stone	0-30

DATA PROCESSING

Data collected by transects are used for qualitative and quantitative estimation of the echinoderms on the area. For statistical purposes Microsoft Excel 2000 and PRIMER 5 are applied.

Available data provided the spatial distribution of echinoderms according to depth and substrate type. A matrix of the average abundance of the echinoderms species per station was compiled using a square root transformation. To analyze similarities between localities, the Bray-Curtis similarity coefficient (Bray & Curtis 1957) was performed. Ordination of the sampling stations according to the type of substrate, season and depth was performed by means of non-parametric multidimensional scaling (nMDS) based on Bray-Curtis similarity using PRIMER 5 software (Clarke & Warwick 2001). Analysis of similarities (ANOSIM) was applied to test the differences between the groups of the species-station. A pair wise test was carried out to evaluate the differences between levels. An individual species contribution (up to about 90%) to average the similarity within each group was identified by the SIMPER procedure (Clarke & Warwick 2001).

RESULTS AND DISCUSSION

Obtained results show the presence of 32 species of echinoderms in the investigated area (Table 3). A determination of the taxonomic groupings revealed a high percentage (31%) of the *Holothuroidea* and *Echinoidea* classes. The *Asteroidea* class has 22% of the total species, 13% belong to the *Ophiuroidea* class, and there is one species of *Crinoidea* (3%) (Fig. 1). The number of noted species is lower than that in the literature data. Regarding the species previously mentioned by authors, this research discovered eight species recorded in the Bay for the first time. On the other hand, new investigation shows an absence of 15 species noted in the literature. Considering the high anthropogenic impact inside Boka kotorska Bay, the absence of some species is expected. Also, previous investigations were done by grab, dredge or trawl beam while this one is based on SCUBA diving, a possible reason for the many differences between the sampled animals.

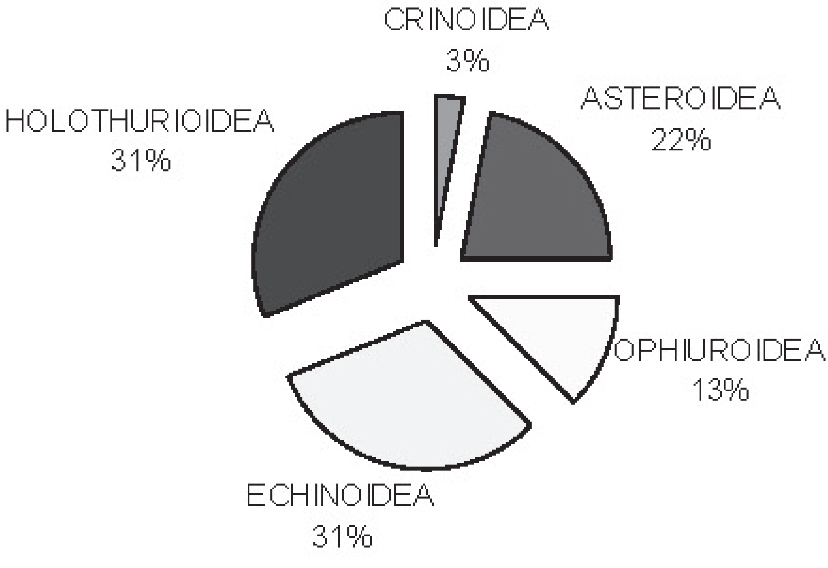

Fig. 1. - Percentage contribution of the classes of echinoderms in total sample.

Table 3. - List of echinoderms recorded in the Bay of Boka Kotorska (literature and personal data).

Species	Literature data	Personal data
Class: CRINOIDEA		
Antedon mediterranea Lamarck, 1816	x	x
Class:ASTEROIDEA		
Marthasterias glacialis (Linnaeus, 1758)	x	x
Astropecten aranciacus (Linnaeus, 1758)	x	x
Astropecten spinulosus (Philippi, 1837)	x	
Astropecten irregularis pentacanthus (Delle Chiaje, 1825)	x	x
Astropecten jonstoni (Delle Chiaje, 1825)	x	
Astropecten platyacanthus (Philippi, 1837)	x	
Luidia ciliaris (Philippi, 1837)	x	
Anseropoda placenta (Pennant, 1777)	x	
Echinaster sepositus (Retzius, 1783)	x	x
Hacelia attenuata (Gray, 1840)		x
Ophidiaster ophidianus(Lamarck, 1816)		x
Coscinasterias tenuispina (Lamarck, 1816)	x	x
Class: OPHIUROIDEA		
Ophiomyxa pentagona (Lamarck, 1816)	x	
Ophiotrix fragilis (Abildgaard, 1789)	x	x
Amphiura chiajei Forbes, 1843	x	
Amphiura mediterranea Lyman, 1882	x	
Amphiura filiformis (O. F. Muller, 1776)	x	
Amphipholis squamata (Delle Chiaje, 1828)	x	
Ophioderma longicauda (Retzius, 1805)	x	x
Ophiura ophiura (Linnaeus, 1816)	x	x
Ophiura albida Forbes, 1839	x	x
Class: ECHINOIDEA		
Arbacia lixula (Linneo, 1758)		x
Sphaerechinus granularis (Lamarck, 1816)	x	x
Psammechinus microtuberculatus (Blainville, 1825)	x	
Paracentrotus lividus (Lamarck, 1816)	x	x
Echinocyamus pusillus (O. F. Muller, 1776)	x	
Spatangus purpureus (O. F..Muller, 1776)	x	x
Echinocardium fenauxi Pйq, 1963		x
Echinocardium cordatum (Pennant, 1777)	x	x
Brissus unicolor (Leske, 1778)	x	x
Cidaris cidaris (Linnaeus, 1758)		x

Species	Literature data	Personal data
Schizaster canaliferus (Lamarck, 1816)		x
Brissopsis lyrifera (Forbes, 1841)	x	x
Class:HOLOTHURIOIDEA		
Holothuria tubulosa Gmelin,1788	x	x
Holothuria polii Delle Chiaje, 1823	x	x
Holothuria forskali Delle Chiaje, 1823	x	x
Holothuria mammata Grube, 1840		x
Holothuria impatiens (Forskal, 1775.)	x	
Mesothuria intestinalis (Ascanius-Rathke, 1867)		x
Stichopus regalis (Cuvier, 1817)	x	x
Ocnus planci (Brandt, 1835)	x	x
Pseudocnus syracusanus (Panning, 1962)	x	x
Trachythyone elongata (Duben-Koren, 1844)	x	x
Trachythyone tergestina (M. Sars, 1857)	x	x
Thyone fusus (O. F. Muller, 1788)	x	
Labidoplax digitata (Montagu, 1815)	x	

Statistical data processing (MDS) shows very few differences between samples by season (Fig. 2). This group of marine organisms is mostly slow-moving and some of them sessile animals (Krunić 1989; Matonickin 1981), and during the seasons there are no significant changes. The nMDS carried out for the samples collected on different

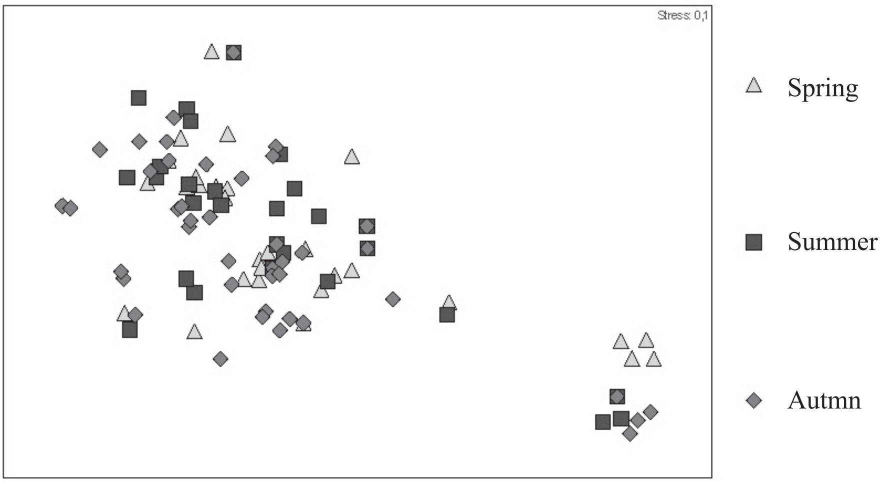

Fig. 2. - Non-parametric Multi-Dimensional Scaling ordination of the echinoderms sampled during 3 seasons.

types of substrate revealed small differences (R=0.179; p=0.001) (Fig. 3). The pair wise test confirmed clear differences between species taken from stony and sandy substrate (R=0.465; p=0.001) as well as from samples collected from *Posidonia oceanica* meadows and stony bottoms (R=0.603; p=0.001). Comparing samples from different depth ranges by nMDS, obtained results show clear differences (R=0.271; p=0.001) (Fig. 4). Pair wise tests revealed differences between species collected from depth ranges of 0-10 m and 21-30 m (R=0.369; p=0.001), while differences between other samples are not statistically significant.

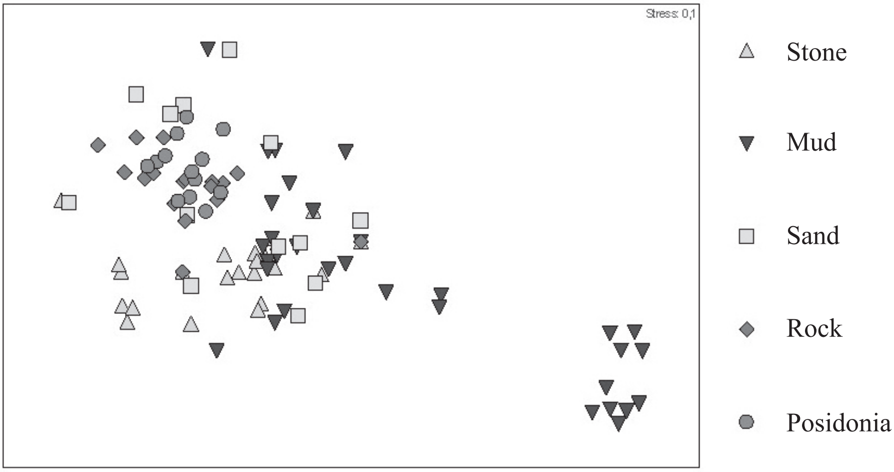

Fig. 3. - Non-parametric Multi-Dimensional Scaling ordination of the echinoderms sampled on different type of substrates.

The SIMPER test samples collected from stony bottoms show an average similarity of 24.31% and were mostly characterized by *Ophiotrix fragilis* (34.17%), *Holothuria tubulosa* (24.67%) and *Holothuria mammata* (22.75%). Within the investigated area, the highest average similarity is recorded between samples from *Posidonia oceanica* meadows (63.22 %). The main constituent was *Paracentrotus lividus* (98.04%). The average similarity between samples from the rocky bad is 38.91% and was characterized mostly by *Paracentrotus lividus* (89.00%) and *Sphaerechinus granularis* (4.62%). Material collected from muddy substrate shows a similarity of 17.89%; the main components were *H. tubulosa* (44.53%) and *Ophiura albida* (21.63%). Species from sandy substrate (14.66%) show a slight similarity.

The SIMPER test carried out by seasons provided the following results: spring samples had an average similarity of 15.33% and were characterized by *Holothuria tubulosa* (35.13%), *Holothuria mammata* (20.73%) and *Paracentrotus lividus* (18.89%); the summer sample-group had an average similarity of 15.00% and the principal constituents were *Holothuria tubulosa* (31.71%), *Holothuria mammata* (27.59%) and *Paracentrotus lividus* (18.59); the autumn cluster showed an average similarity of 11.90% and was characterized chiefly by *Paracentrotus lividus* (26.36%), *Holothuria polii* (26.06%) and *Holothuria tubulosa* (18.62%).

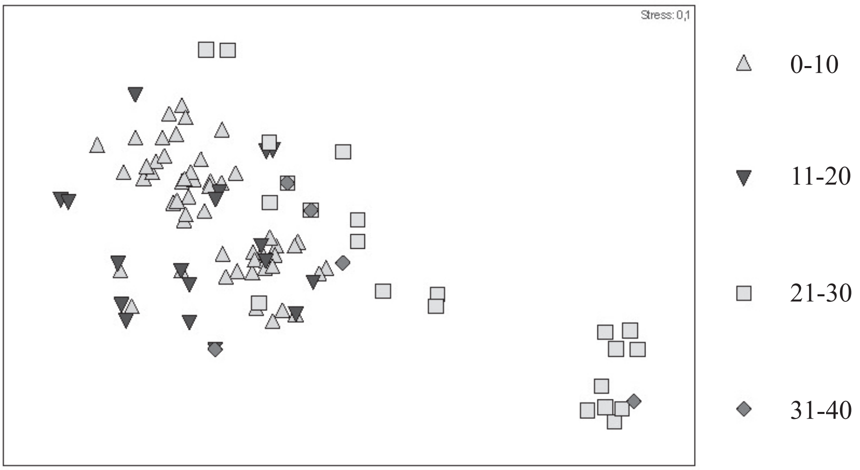

Fig. 4. - Non-parametric Multi-Dimensional Scaling ordination of the echinoderms sampled on different depth range.

The depth range was considered by the SIMPER test. Obtained results show an average similarity in samples taken from 0-10 m of 21.06% with the main constituents of *Paracentrotus lividus* (40.31%), *Holothuria tubulosa* (25.06%) and *Holothuria polii* (18.07). In the depth range of 21-30 m, the average similarity was 19.40% characterized mostly by *Ophiura albida* (76.48%) and *Holothuria mammata* (11.60%). From the inside stratum of 31-40 m depth the average similarity was 18.33% and was characterized by *Marthasterias glacialis* (36.36%) and *Holothuria tubulosa* (36.36%); the similarity of samples from a profundity of 11-20 m was 13.13% and characterized mostly by *Echinaster sepositus*

(42.18%), *Holothuria tubulosa* (17.25%) and *Ophiotrix fragilis* (13.15%).

The substrate features and depths seem to affect the distribution of echinoderms, confirming previous observations in the same and other marine areas (Milojević 1979). Some species, such as *Paracentrotus lividus*, considered to be an indicator of environmental quality (Cunha *et al.* 2005), was found to be abundant on rocky substrate and *Posidonia oceanica* meadows, within the first 10 m of depth. This species inhabits only the outer part of the Boka kotorska Bay where the impact of the open sea is strong. By contrast the *Ophiura albida* was numerous on muddy substrate within stratum of 21-30 m and present mostly inside biocenoses of terigen mud.

CONCLUSIONS

The current study shows the presence of 32 species within the Bay of Boka kotorska. In reference to the literature data, eight new species are recorded for the researched area while 15 species noted by previous authors are not confirmed. Reasons for this apparent discrepancy can be found in the different sampling methods used but also in the strong anthropogenic impact during the period between the two investigations.

Multivariate analysis (non-parametric Multi Dimensional Scaling) indicated small differences between samples by season and clear differences regarding substrate type and depth range.

The SIMPER test carried out by substrate provided the highest average similarity between samples from *Posidonia oceanica* meadows (63.22 %). Regarding the seasons, results were quite similar (spring sample-15.33%; summer sample-15.00%; autumn sample-11.90%). Considering depth range, SIMPER shows the highest average similarity among samples taken from 0-10 m (21.06%).

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ПРОСТОРНА И СЕЗОНСКА РАСПРОСТРАЊЕНОСТ ЕХИНОДЕРМАТА У ЗАЛИВУ БОКЕ КОТОРСКЕ

Славица Кашћелан

Р Е З И М Е

Приказани су резултати истраживања разноврсности бодљокожаца у Бококоторском заливу, као и њихова просторна и сезонска дистрибуција. Истраживано подручје карактерише специфични комплекс физичко-хемијских параметара воде и седимента, што овај Залив чини посебним биотопом. С обзиром да су бодљокожци претежно сесилне и слабо покретљиве животиње, животно окружење игра велику улогу у њиховој дистрибуцији и бројности. На основу добијених резултата, утврђено је присуство представника 32 врсте ехинодермата који насељавају различите врсте подлога и различите дубине. Статистичка анализа показује веома мале промене током годишњих доба. У односу на тип подлоге, највећу (просечну) сличност имају узорци узети са стеновите подлоге и са ливада посидоније.