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APPLYING COMBINED BIOLOGICAL METHODS WITH REMOTE SENSING TECHNIQUES IN STUDIES OF MARINE BIODIVERSITY, BOTTOM HABITATS AND COMMUNITIES OF FLORA AND FAUNA

Applying remote sensing techniques have become common in contemporary research of the sea bed. They allow precise delineation of bottom habitats, thus limit the number of representative biological sampling sites, the time of expedition and its costs. Remote sensing can be applied to assess the bottom biota resources, e.g., range of occurrence of underwater meadows or mussel beds. The paper presents the results of studies on benthic communities carried out at three locations in the southern Baltic Sea. Remote sensing methods were used in biodiversity studies on the coastal and open-sea stony reefs as well as for elaboration of assessment methods of macrophytes meadows in the Puck Bay. The results proved the efficiency of the method in biodiversity studies; however, selective algorithms for multi-species underwater meadows assessment require further development.

1. INTRODUCTION

In numerous marine environment applications it is crucial to efficiently assess the spatial distribution of the bottom habitats and bottom communities that together form the category of biotope, in order to assess basic parameters, such as range of occurrence, biomass and species composition. This requires applying monitoring techniques that preferably should be cost-effective, i.e., neither time-consuming nor labour-intensive, hence allowing coverage of a large sea bottom area in a possibly short time and similar environmental conditions. Utilization of modern techniques of remote sensing in environment assessment applications is recommended by a number of international agreements, such as EU Water Framework Directive [4], Helsinki Convention [5] and Habitat Directive EU [3].

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The paper shows the utility of the remote sensing methods for biological studies of the three areas in the Polish Exclusive Economic Zone of the southern Baltic proper: (i) stony reefs of the offshore Słupsk Bank, (ii) northern part of the Puck Bay (Gulf of Gdańsk), and (iii) open coast area of Rowy village in the vicinity of the Słowiński National Park (figure 1). The main aim of the projects was to assess the biodiversity and natural values of the stony bottoms – unique along the sandy Polish coast – in order to determine if it is justified to include the areas in the system of HELCOM Baltic Sea Protected Areas and NATURA 2000. Studies of the underwater meadows in the Puck Bay were the basis for elaboration of the monitoring principles of the buoyant, rooted, submersed aquatic vegetation covering plane, sandy bottom by means of hydroacoustic methods.

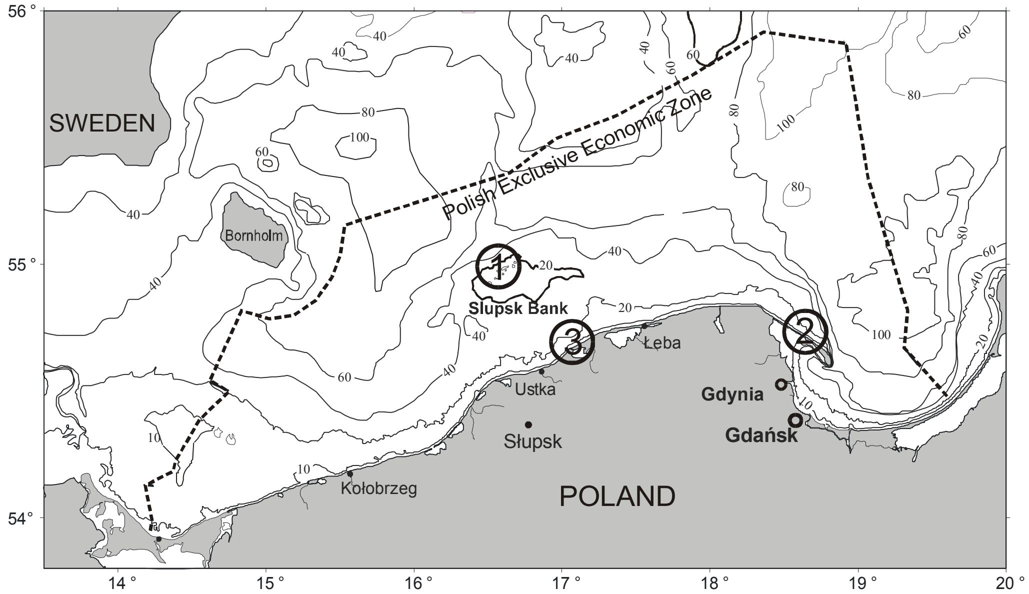

Fig. 1. Location of the hydroacoustic and biodiversity study areas
in the Polish Exclusive Economic Zone (1 – Słupsk Bank, 2 – Puck Bay, 3 – Rowy)

2. MATERIALS AND METHODS

Direct and indirect methods can be applied in studies of bottom biocenoses and habitats. The direct method consists in either sampling performed by a scuba diver or by using sampling devices (drags and grabs) lowered from the research ship, whereas the indirect one utilizes the video documentation as well as hydroacoustic record of the echosounder and/or side scan sonar. Precise positioning information is combined with hydroacoustic data and then processed by computer software to a form of linear/surface plots in the case of echosounder or three-dimensional plots in the case of side scan sonar.

The paper demonstrates the method applying combined hydroacoustic measurements of the echosounder and side scan sonar profiling with traditional method of biological qualitative and quantitative sampling by modified Kautsky gear [1] operated by a scuba diver in the process of identification of bottom biocenoses and habitats (table 1).

Table 1

Scope of the research carried out at the Słupsk Bank, Puck Bay and Rowy ([6] and [1])

Area	Słupsk Bank	Puck Bay	Rowy
Period	June 1999	September 2002	June, August 2005
Sediment type	boulders, gravel	fine sand	boulders, gravel
Depth [m]	8.5–13; 16.5–18	2	5–10
Hydroacoustic research	GPS Magellan NAV 1200; DGPS Magellan DBR; Multi-beam echosounder Koden CVS-106; NMEA/RS232 BST IKS-2TV; Computer system BST proSTATION/II-300; Integrated navigation system BST Navigator SARP	Dual-beam echosounder Biosonic; side scan sonar DF-1000 EdgeTech; DGPS Trimble SE4000	DESO 15 echosounder (210 kHz); SEABAT 9106 multi-beam echosounder; DF-1000 EdgeTech sidescan sonar; ORETECH 3010-S subbottom profiler; Integrated navigation system HYDRO; DGPS; RTK OTF Site Surveyor 4400; TRACKPOINT II underwater navigation system
Biological research	Modified Kautsky sampler [1], [2] Bottom flora: species composition; dry weight; depth range Fauna: species composition; abundance; dry weight	Modified Kautsky sampler [1], [2] Flora: species composition; dry & wet weight of macroalgae and Angiosperms; height of the canopy; plant inclination angle	Modified Kautsky sampler[1], [2], core sampler Flora & epiphytic diatoms: species composition; dry weight; depth range Meio- & macrofauna: species composition; abundance; wet weight
Underwater documentation	Towed camera (Fishers MFG INC TOV-1); video-camera (Sony Hi-8);	digital camera SONY DCR-TRV 900E	digital camera SONY DCR-TRV 900E

2.1. SITE SELECTION

Słupsk Bank. Studies were performed in 1999 at stony reefs in the north-western part of the bank located in the central part of the southern Baltic, approximately 25 km north off the Polish coast (figure 1). The area was selected for the biodiversity studies due to its uniqueness. The reefs can be regarded as 'island of diversity' within the surrounding dynamic, sandy bottom (ANDRULEWICZ et al. [1]). Stony reefs provide suitable substratum for macroalgae and mussels, spawning grounds and shelter for juvenile fish and food resources for wintering birds.

Puck Bay. The selected area was previously investigated in 1999 [8]. Not only rich taxonomic composition of the bottom flora, but also considerable biomass of angiosperms forming underwater meadows was found there. Over 98% of the total phytobenthos biomass of the entire Puck Bay coastal zone (depth 0.4–10 m) occurred in this part of the Puck Bay in 1999, *Angiospermae* constituting 72%.

Rowy. The stony reef of Rowy is located in the middle coast of Poland (figure 1, table 1). It was explored for the first time in 1997 during the research carried out in waters adjacent to the Słowiński National Park [9]. Within a limited bottom area several types of habitats were identified. Despite the relative proximity (1.4 km) to the coastline and the Łupawa River mouth with a small fishery river port, the reef is not subjected to strong anthropogenic impact.

2.2. SYSTEM DESCRIPTION AND DATA COLLECTION

Słupsk Bank. The shallowest parts of the bank were selected using navigational charts. The acoustic profiler with DGPS and the computer were used to record the profile parameters and to identify the stony sites (table 1).

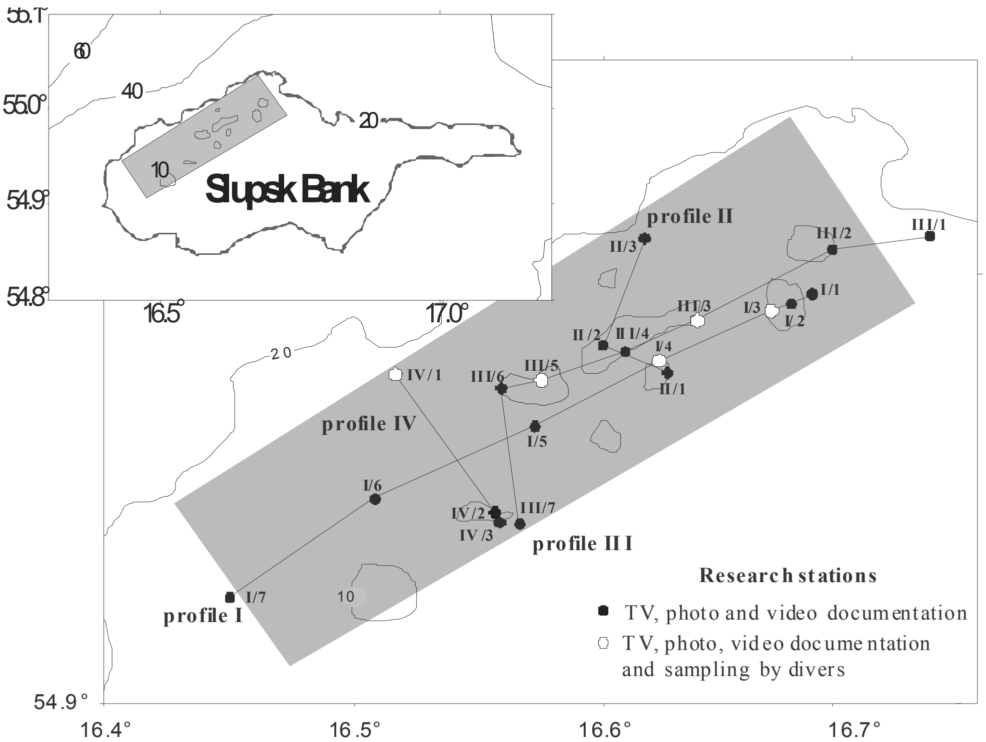

Fig. 2. Location of sampling stations in the Słupsk Bank stony reefs in 1999

Preliminary screening at selected stony sites was performed at low speeds using the acoustic recorder and close-circuit TV. Following this, it was decided whether or not to use scuba divers for sampling. Altogether 20 stations were documented on video and 36 samples of macroalgae and associated fauna were collected by the divers (figure 2), [1].

Puck Bay. The data were collected in a 500 m × 500 m area covered by patchy underwater vegetation. A small survey boat with precise navigational instrumentation was used (table 1, figure 3). The acoustical data were collected from a vegetated and bare sea floor along fifty transects parallel to the shoreline with a fixed distance between them in order to assess the range of occurrence of *Zostera marina*. The data were used to verify the algorithm for detecting the type of bottom as well as measuring the height of the vegetation canopy and its biomass. Additionally, detailed visual inspection and video documentation together with DGPS localizations of the vegetated areas were carried out along some of the hydroacoustic transects. The observations were helpful in evaluating the differences between the relevant parameters for the vegetated and bare sea floor [7], [16].

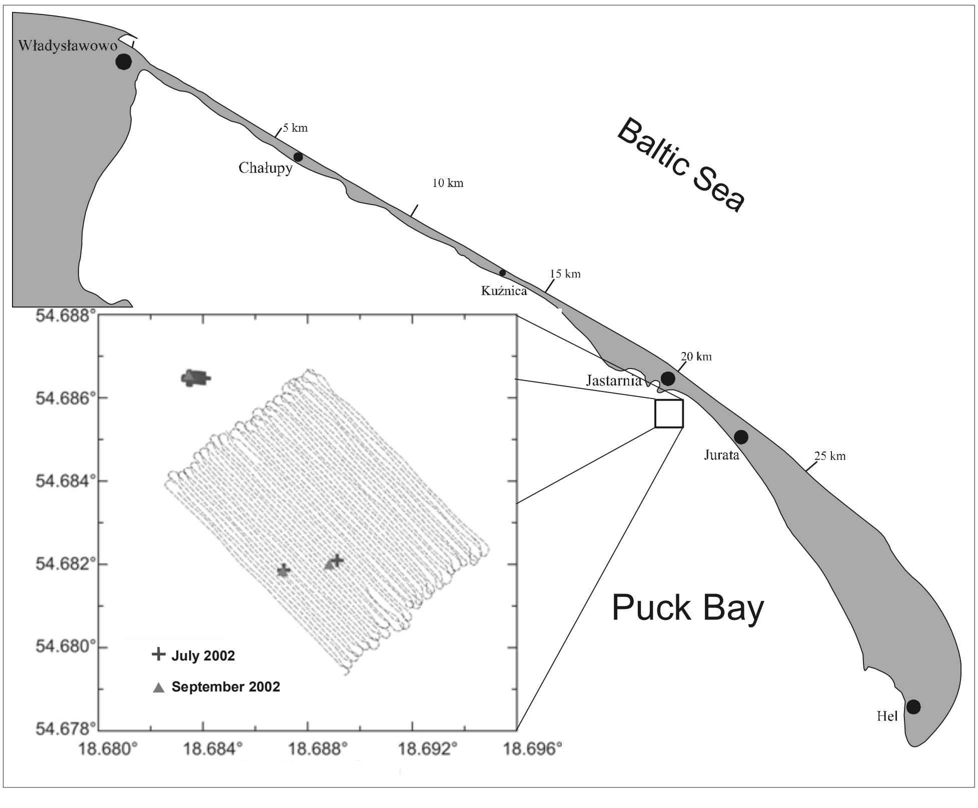

Fig. 3. The Puck Bay – the area of hydroacoustic and biological studies of the underwater meadows of *Zostera marina* in 2002

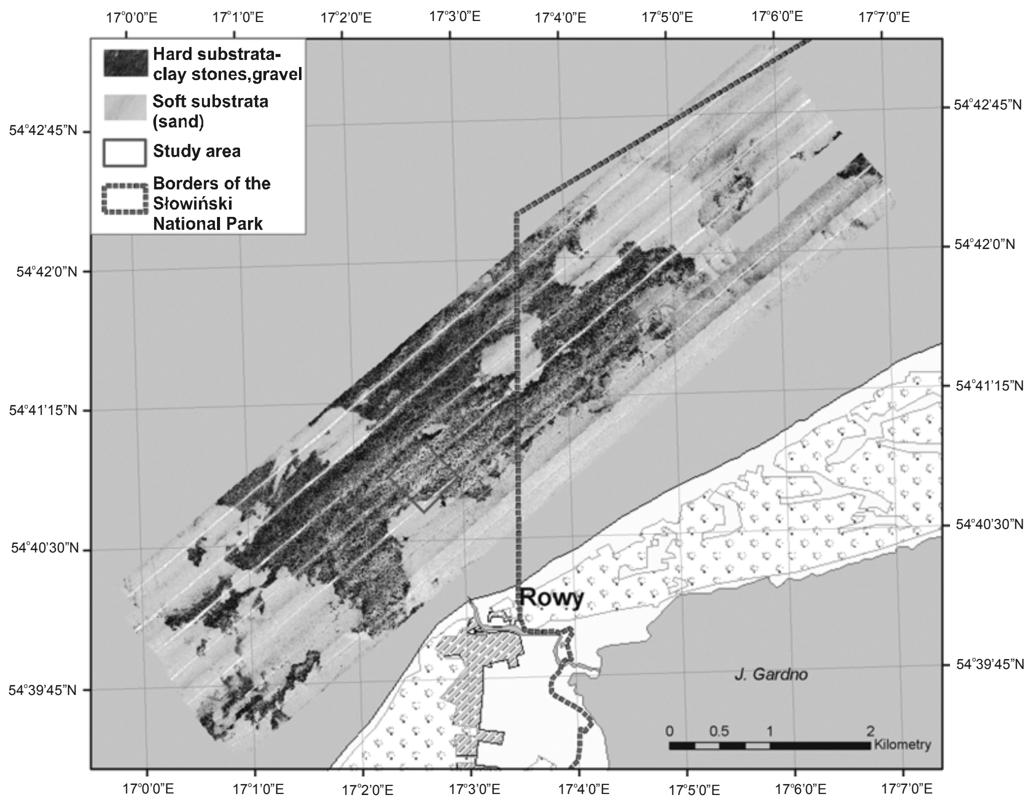

Fig. 4. Preliminary sonar scanning chart 1: 10000
of the Rowy boulder area in 2005

Rowy boulder area. Preliminary sonar scanning preceeded the sampling phase due to limited knowledge of the boulder area boundaries. Sonar scanning was performed within depth range 5–15 m over the area of 28 sq. km. A sonar bottom chart 1:100,000 was plotted (figure 4). Analyses of the bottom image led to delimitation of the study area, 500 m × 500 m, featuring the highest habitat diversity. That area was scanned again in more detail. The large scale bottom chart allowed one to delimit precisely the types and boundaries of the bottom habitats and to select 8 representative sampling stations (figure 5).

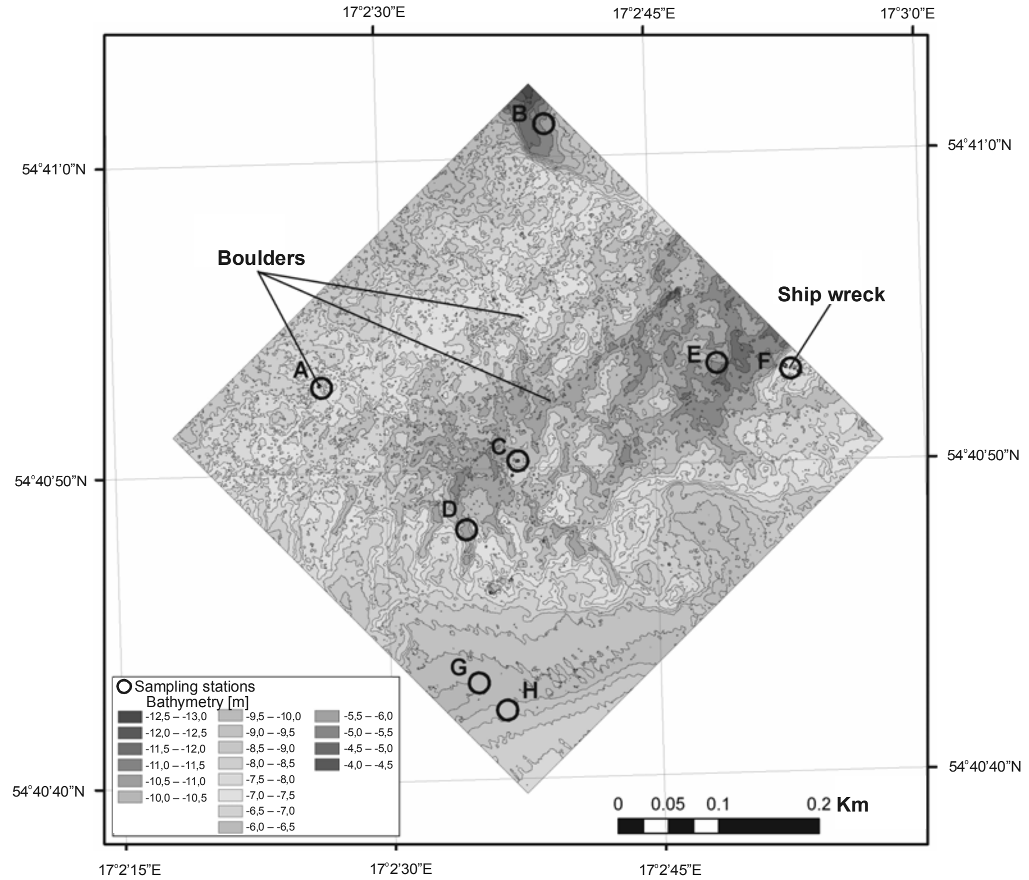

Fig. 5. Detailed chart of the Rowy study area, 500 m × 500 m, with the stations sampled in 2005

3. RESULTS AND DISCUSSION

Słupsk Bank. The results of the three research projects carried out in the Słupsk Bank area by WARZOCHA [16], OKOŁOTOWICZ [12] and OSOWIECKI [13] demonstrate overall taxonomic composition of the bottom fauna; however, the distribution of the bottom communities has not been recognized accurately (table 2). The first two projects covered larger area including mixed and sandy bottoms, whereas the third focused entirely on the stony reefs of the planned marine protected area [2].

Applying in 1999 the remote sensing techniques and the sampling gear for qualitative and quantitative hard bottom benthos sampling allowed precise delineation of the range of occurrence of the macrophytes and associated invertebrate fauna communities within the 100 sq. km area. The taxonomic richness of macrophytes found in 1999 was higher than that found in the 1980s, when the area was sampled with a soft bottom grab at randomly selected sites.

Table 2

Taxonomic composition of macrophytes and bottom fauna of the Słupsk Bank stony reefs investigated with traditional methods in 1978, 1987 and applying hydroacoustic methods in 1999

Taxonomical groups	1978 [17]	1987 [12]	1999 [8], [10]
	Number of sampling stations		
	19	21	12
	Number of taxa		
Macroalgae (total)	–	9	16
Chlorophyceae	–	3	2
Fucophyceae	–	1	4
Bangiophyceae	–	5	10
Bottom fauna (total)	31	21	28
Crustacea	14	11	10
Polychaeta	3	3	4
Gastropoda	2	2	3
Bivalvia	4	2	2
Others	8	3	9

One of the project outcomes was the formal proposal for inclusion of the reefs in the system of the Baltic Protected Areas (HELCOM BSPA), [1], [2]. Another practical effect of the project was the modification of the route of underwater electric power transmission line in order to preserve the natural values of the reefs.

Puck Bay. Heterogenic communities of angiosperms prevailed in the two areas selected for investigation. The borders of the meadows were delineated with DGPS. High correlation was found between the borders in echogram and the underwater observations, however it was concluded that acoustic record of the Angiosperms biomass was influenced by: (i) pelagic and benthic phytophilous animals and epiphytes, (ii) filamentous algae – *Pilayella*, *Ectocarpus, Ceramium* and *Enteromorpha* genera, and (iii) air bubbles on the surface of leaves and stems.

Based on preliminary results of both the acoustic and biological research a procedure for algorithm verification for Angiosperms biomass assessment was elaborated (figure 6). Hydroacoustic data were calibrated with a set of biological parameters (taxonomic composition, the height and the inclination angle of the plants and their biomass). The scope of further research was specified: (i) delineation of the study profile along the multi-species meadow of varying biomass, the height and the inclination angle of the plants, (ii) acoustic recording of the plant structure along the profile, (iii) analysis of the acoustic record and selection of the biological sampling sites, (iv) assessment of the factors dissipating the acoustic signal such as air bubbles, bottom fauna, suspended matter, etc., (v) photo and video documentation, vi) biological sampling.

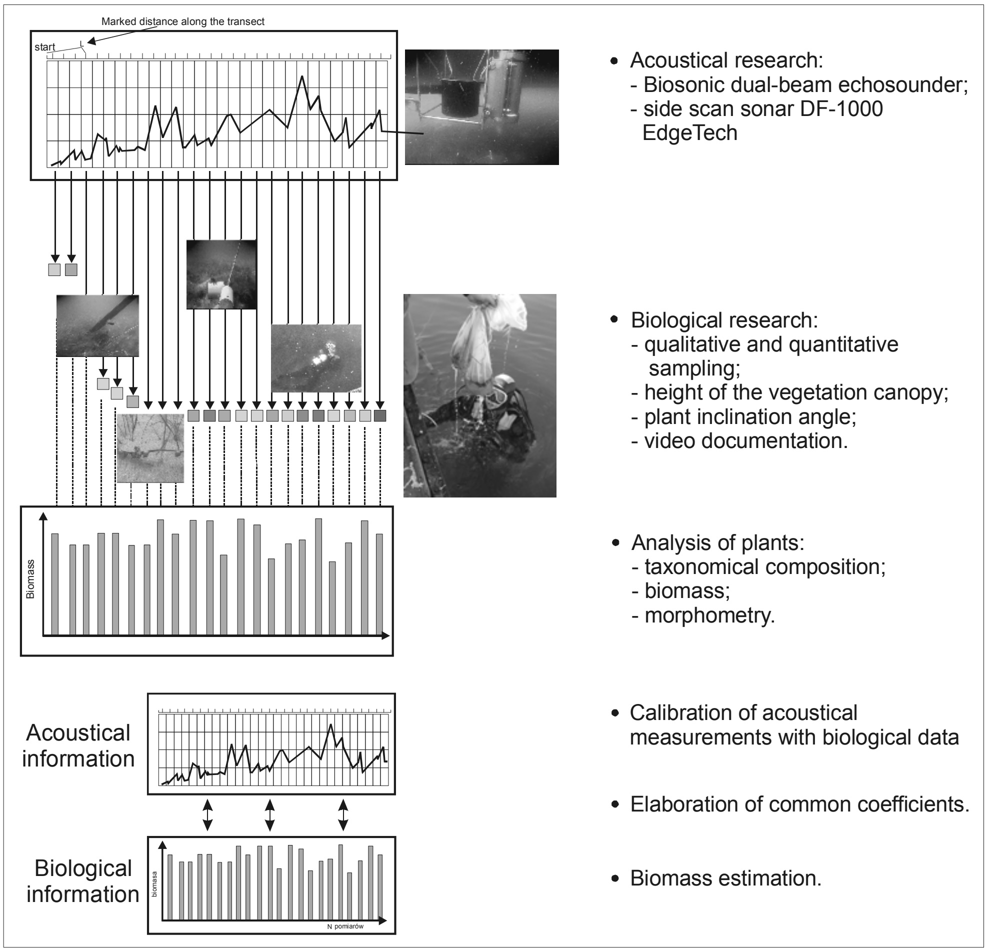

Fig. 6. Diagram representing the procedure of the bottom vegetation studies utilizing remote sensing techniques

Taking advantage of other research results it was positive to elaborate an algorithm for determining the height of the canopy as well as bottom coverage [11], [14], [15].

Rowy boulder area. On the basis of the sonar map analysis eight sampling sites representing different sediment types and habitats were selected: sandy slope (H), gravel and sand on the clay (G), sand on the clay (E), pebbles (B), boulders on gravel (D), cobbles with boulders (A, C, D) (figure 5). Epiphytic and associating phytophilous fauna taken in macrophytes samples was identified. Biological studies and hydroacoustic measurements showed that a considerable number of different bottom communities of various taxonomic composition, abundance and biomass inhabited a limited area featuring a variety of habitat types (table 3).

Table 3

Main features of the habitats delimited by hydroacoustic method and the results of biological investigation of the Rowy boulder area in 2005

Sampling site	A	B	C	D	E	F	G	H
Depth [m]	8	10	7	7-8	5	7	10	9
Substrate	cobbles boulders	pebbles	cobbles boulders	boulders	sand, clay	cobbles, ship wreck	clay, gravel, sand	fine sand
N of phytobenthos taxa	6	3	3	5	4	6	0	0
N of macrozoobenthos taxa	20	14	15	17	13	18	1	3
N of associating fauna taxa	14	9	15	16	10	12	–	–

4. SUMMARY

The results obtained in the three research projects showed that: (i) Applying hydroacoustic and biological methods in studies of the large sea bottom areas proved their high applicability for the purposes of the marine environment assessment and nature conservation. (ii) Hydroacoustic reconnaissance carried out prior to traditional biological sampling assures proper and representative selection of the sampling sites. (iii) Elaboration of selective algorithms for biomass assessment of various macrophytes species will allow efficient assessment of the state and the range of occurrence of *Angiospermae* meadows, *Zostera marina* included, according to the HELCOM and WFD recommendations. (iv) Hydroacoustic survey can be regarded as a very useful tool for the monitoring of underwater meadows. Further co-operation between physicists and marine biologists is required to refine the methods.

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TECHNIKI ZDALNEJ DETEKCJI W BADANIACH RÓŻNORODNOŚCI BIOLOGICZNEJ, SIEDLISK DNA MORSKIEGO I OCENY ZASIEDLAJĄCYCH JE ZASOBÓW FLORY I FAUNY

We współcześnie prowadzonych biologicznych badaniach dna morskiego coraz częściej są stosowane techniki zdalnej detekcji. W przypadku, gdy dno morskie nie jest jednorodne, ich zastosowanie gwarantuje pobór prób w miejscach reprezentatywnych. Techniki zdalnej detekcji znajdują też zastosowanie w szacowaniu zasobów dna morskiego, np. zasięgu łąk podwodnych czy ławic małży. Ich zaletą jest

wówczas możliwość zbadania znacznie większych obszarów dna w krótszym czasie i podobnych warunkach środowiskowych niż klasycznymi metodami badań biologicznych przy ograniczeniu kosztów ekspedycji morskiej.

W pracy przedstawiono wyniki trzech projektów badawczych realizowanych przez zespół Samodzielnej Pracowni Ekologii Instytutu Morskiego w Gdańsku, w których wykorzystano techniki zdalnej detekcji do badań nad różnorodnością biologiczną zróżnicowanych siedliskowo rejonów głazowisk dennych polskiego Bałtyku oraz w studiach nad opracowaniem metod szacowania łąk podwodnych makrofitów w Zatoce Puckiej. Uzyskane wyniki potwierdziły efektywność zastosowanych metod w studiach nad różnorodnością biologiczną. Dalszych badań wymaga dopracowanie selektywnych algorytmów w szacowaniu wielogatunkowych łąk podwodnych.