Mapping of underwater habitats based on the analysis of backscatter intensity of the return acoustic signal

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ABSTRACT

Mapping of underwater habitats, through a multidisciplinary approach, represents a fundamental prerequisite for adequate representation of physical and biological topologies with the objective of sustainable use and management of marine resources.
Increased demand for diverse geoinformation resulted with the development of modern technologies and the acquisition of new knowledge in the field of underwater acoustics as the basic method of modern hydrographic survey. In addition to 3D modeling of the seabed, modern multibeam sonars allow possibility of processing the propagation and backscatter data of the acoustic signal trough the water column. By integration with the classical methods of underwater habitat mapping, complete coverage of the seabed with reliable high resolution data is effectively achieved. The collected data represents the basis for further advanced interdisciplinary analysis in GIS environment.
The paper is theoretically based and methodologically appropriate representation of hydrographic surveying for the purpose of underwater habitat mapping in part of the southern coast of the Stari Grad bay on the island of Hvar in order to determine the state of underwater habitats of Posidonia seagrass.
The paper describes the theoretical and empirical basis of the acoustic signal backscatter whose specificity is used here as an identifier type of sea bottom that is of underwater habitats. Key steps in the creation of maps of underwater habitats are discussed theoretically and practically presented on the basis of the data collected. Appropriate map of underwater habitats containing three basic classes based on data sampling was made. Conclusions and final observations which were derived through analysis of the results could show very useful in further study of the spatial distribution of underwater habitats.

Keywords:
Mapping, habitats, multidisciplinary approach, underwater acoustics, backscatter

1. Introduction

The Adriatic Sea, with a significant role for the geographical identity of the country, represents one of the most valuable resources of Croatia. Many economic activities are related to the underwater ecosystem, however, at the same time they are creating a real danger for the destruction of the biodiversity. Human impact on the environment of the seabed has reached an unprecedented level. Human impact on the Adriatic through industrial operations, tourism, maritime transport and the practice of fishing is very little, or completely uncontrollable.

Exploitation of undersea resources therefore directly depends on the preservation of long-term stability of the underwater ecosystem whose nature is very dynamic. Access to the data related to sea is vital for the marine industry, decision-making bodies and scientific research.

The rapidly increasing trend on environmental awareness has led to the general public less-known networks of protected habitats at the level of Europe or the world. NATURA 2000 and EMODnet represent the basis of the Europe's proactive approach on the protection of the underwater, and preservation of underwater endangered and native species through the mapping of the underwater habitats. Areas of the sea, covered by these networks in Croatia, are mainly related to the Croatian national parks, because of their biodiversity and fundamental role in the conservation of the species. The initiative for the formation of a network of this type is usually identified with the protected areas where human activities are significantly limited or even excluded in order to preserve biodiversity. This creates a misconception of the importance of these projects that are based on other principles. The objective of the management is sustainability, improving conservation of target species and habitats in a particular area, and in the case of the management of the areas of interest, the well-being of people who live in them is taken into the account. This is possible to achieve without prescribing essential constraints, but through the implementation of precautions by the people who are in touch with the nature and are sharing their living space with the targeted species.

Informatization of society is a global phenomenon. Practically there are no activities where information technology does not play a major role. The same have an enormous impact in the scientific research. Therefore, a society that, in terms of informatization, does not keep pace with the developed countries, and especially with the surrounding regions and countries, lags behind in science. Geodesy and hydrography are also influenced by the development of new technologies, and many new research opportunities open up. The creation of systematically organized database of underwater is a unique goal for establishing the system of protection and control of the underwater. The same can be useful for a variety of scientific fields and is the foundation for the implementation of various activities or research in the area of interest.

Therefore, this paper describes a pilot project of the mapping of the underwater habitats by using the acoustic scattering data collected by remote sensing equipment of the new generation. In order to determine the state of the habitats of the sea grass Posidonia on the southern coast of the Stari Grad bay on the island of Hvar, a hydrographic survey was conducted using the modern multibeam sonar. On the basis of the conducted analysis of the acoustic backscatter signal in the area of the hydrographic survey, an exemplary map of underwater habitats containing three basic classes based on data sampling had been made. By analyzing the results, conclusions and final remarks were made that may be useful in further study of the spatial distribution of underwater habitats.

2. Mapping of the underwater (seabed) habitats

Mapping of the underwater (seabed) habitats is the current process in the world that is gaining more and more interest every day. The term “underwater habitat” is originally associated with the place where underwater animals or algae live (single specie). The original term can be extended by "merging" multiple species in one living community. The use of the term "habitat", in terms of mapping, involves the physical and natural factors that support the living conditions of some of the communities. In this way the algae in the shallow part of the sea with sandy seabed can be differentiated from the algae that are found on rocky reefs.

The aim of the mapping of the underwater habitats is to develop a complete and detailed view of the underwater world through a multidisciplinary approach where hydrographers make a bathymetric map and analyze the acoustic characteristics of the bottom, geologists show lithology and sedimentology, while biologists observe underwater wildlife. In this way, the collected data is then combined into appropriately structured database that forms the basis for further interdisciplinary analysis. Based on the difference of perception in a certain period of time, it is possible to come up with many conclusions about the dynamics of the underwater environment. Accordingly, it allows the tracking of changes caused by human activities such as industry, pollution, increased traffic or certain methods of fishing, but also the impact of nature through waves, wind or ocean currents.

It is important to emphasize that the maps of the underwater habitats are in fact the best estimate of the spatial distribution of habitats, at some point, which was formed on the basis of currently available knowledge and skills at the disposal of experts. Therefore, this kind of mapping is still relatively limited by the process of improvement of the human knowledge on the underwater environment. Namely, there is no end point in the process of mapping the undersea habitats, since the maps created in such a way are a prediction, and need to be tested trough use. In a narrow sense, the mapping of the underwater habitats is the application of mapping the spatial distribution and extent of the habitat in the form of complete coverage of the sea floor (continuous surface) with indicative boundaries between adjacent habitats (Foster-Smith et al., 2007). Perhaps the most important consequence of the process of mapping underwater habitats is the fact that the maps that occurred in this way are not just a result of observation data, but the result of polemics about the distribution of habitats based on the best available information and opinions of experienced professionals.

This type of research is an extremely complex process and is different in each individual case. But nevertheless, we can identify the key and indispensable process steps:

- Optimal selection of location and sample density (sampling)
- Selection of the most appropriate method of observation (remote sensing)
- Integration and modeling
- Designing a map with respect to purpose (cartography)

When mapping the underwater habitat, data obtained by sampling and the data of continuous surface, containing physical characteristics of the habitat which are important for the clear separation between the classes of habitat, are combined. The latter can be determined directly from some form of remote sensing (e.g., acoustic techniques) or can be derived from the physical model. Ideally, the information should be derived from the developed models that directly link the physical characteristics of the habitat with biological data (Van Lancker and Foster-Smith, 2007). Because of the imperfections of mentioned models, experts often have to rely on their experience. The process of drawing conclusions about the spatial distribution of habitats is most often called, for lack of a better term, "modeling". The objective of the integration of data obtained by different methods, or sensors, is that the required information of a demanding quality is determined with the maximum efficiency at minimum cost. The basic steps in the process of habitat mapping are shown in Figure 1.

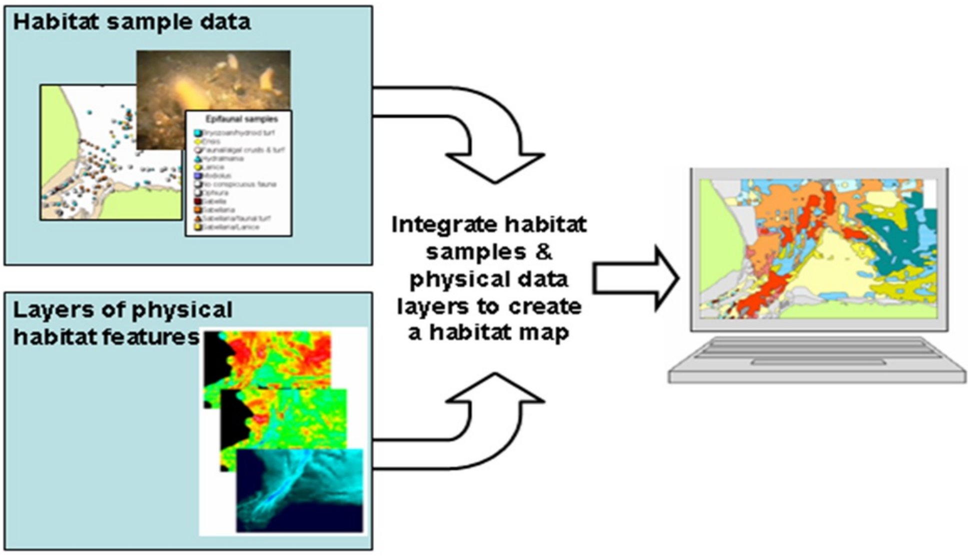

Figure 1: Basic steps in the process of habitat mapping (Foster-Smith et al., 2007)

Different methods of data collection for the purpose of mapping underwater habitats differ in quality, efficiency and economy. The term "data" generally refers to the numbers, however, one can use different types of written information, photos, videos, and physical samples (White and Fitzpatrick, 2007). The previous (classic) mapping methods were mainly based only on sampling and interpolation, whose resolution and efficiency cannot meet the needs of modern scientific management of underwater projects that require a full understanding of the dynamics of the underwater ecosystem. Furthermore, it should be noted that the observations are conducted under water, which makes the process of surveying more complicated than for terrestrial surveying, so the whole process is gaining importance as it is necessary to show the objects that are invisible to the human eye. In such conditions, the choice of remote sensors usually falls on the acoustic sensing technique because of the exceptional properties of the transmission of acoustic waves with water, as opposed to other properties (electromagnetic).

2.1 The principles of the underwater acoustics

Acoustics can be defined as the creation, transfer and reception of energy in the form of vibrating waves in matter (Pribičević, 2005). As such, today it is widely applied in systems whose task is underwater observation, since the water is compressible medium and allows the propagation of sound through it. Common acoustic phenomena are longitudinal acoustic waves. Passing along the media, the media particles vibrate and cause fluctuations in the density and pressure (acoustic pressure) along the path of motion of the wave, thus, there is a movement of particles and changes in their distance due to the acoustic pressure.

The characteristic acoustic resistance is defined as the ratio of the acoustic pressure and particle velocity. The measure for the force that is transmitted through the acoustic wave is intensity I (W/m^2) (Pribičević, 2005). Accordingly, the intensity is the amount of energy that in one second flows through surface $1m^2$ in size, and is perpendicular to the direction of sound propagation. Acoustic intensities are usually in the range of 10^{-12} to 10^1 W/m^2, thus a logarithmic scale of numbers is introduced to make it easier to express this range. Then we talk about the scale that represents the sound intensity (*IL*). The most commonly used is the scale of decibels (*dB*).

The largest number of systematic errors in the measurement of acoustic sonars applies to the determination of the exact speed of sound in different layers of water, since the velocity of propagation of acoustic waves depends on the characteristics of the media in which the wave spreads. In water, it depends on the two physical parameters (density and compressibility) that are functions of temperature, pressure (depth), and salinity, and it ranges from 1460 to 1560 *m/s*. Therefore, the speed of sound in water can be expressed as a function of three variables. There are several empirical formulas for determining the speed of sound in water from which it is clear that the speed of sound rises with the increase of any of the three variables. However, it should be noted that the greatest impact on the speed of sound in water has the temperature, so it is necessary to pay particular attention to the measurement of the speed of sound in the water column during the summer months in closed areas because of the pronounced warming of the surface layer of seawater.

The main factors that influence the spread of acoustic waves in water are: refraction, attenuation and reflection. Horizontal layering of the speed of sound in water, whereby the temperature decreases, and the pressure increases with depth, hinders the propagation of the acoustic signal so as to limit the observation of the seabed under the high vertical incident angles due to the occurrence of refraction. The refraction comes on the border between layers of different speed of sound and the acoustic wave is refracted toward a layer with higher-refractive index, that is the area with lower speed of sound. The second factor that affects the spread of acoustic waves is acoustic attenuation which can be divided into two key processes: absorption and scattering. Both processes lead to weakening of the acoustic signal. The superiority of acoustic signals under water in relation to electromagnetic is reflected in the depth of penetration of the signal into the water, but that does not mean that the absorption of acoustic signals in water is negligible. It is associated with physical and chemical properties of water and is one of the key factors in the perception of the seabed for the purposes of mapping of the underwater habitats. The second process of attenuation, scattering, occurs with multiple reflections of acoustic signals due to different inhomogeneity that encounter on the path of the acoustic signal. The third factor, reflection, occurs upon arrival of the acoustic wave on the boundary surface between two different media or sea layers. The characteristics of the reflected signal depends on the incidence angle and the properties of the media that are provided as the characteristic acoustic impedance, which is the product of medium density and sound velocity in the same (Hansen, 2013):

$$Z_0 = \rho \times c \tag{2.1}$$

where c is the speed of sound in the medium, and ρ the density of the same.

Based on this, with underwater acoustic signals, just the opposite of complicated effects of electromagnetic waves, is easy to determine the differences between the various objects on the seabed and the water that surrounds them, as shown in Figure 2. Even slight changes in acoustic impedance within the sediment can be demonstrated in the measured data, which ensures successful implementation of the classification process.

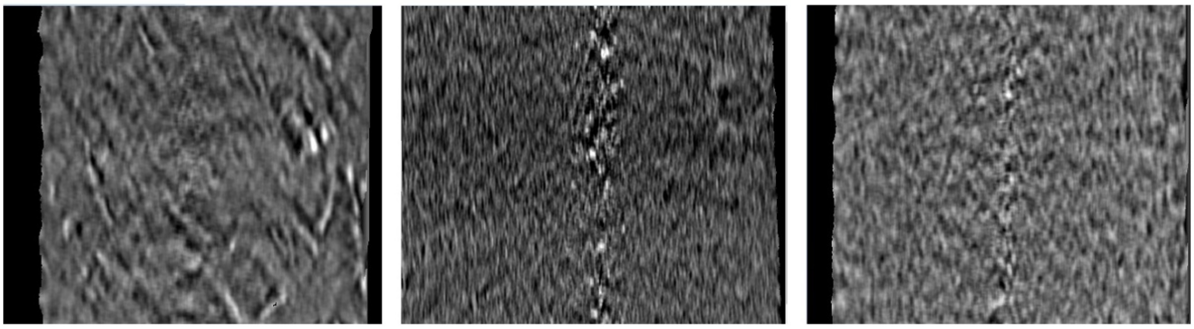

Figure 2: The samples of pseudo side-scan images (rocks, Posidonia beds, sand)

2.2 Basic principles of the backscatter theory

The sea bottom, unlike water, is highly resistant to the spread of the acoustic waves and does not allow relatively unobstructed propagation, as shown in Figure 3. The reason for this is the high density of the particles of the seabed, which disables free movements of the same. By the laws of physics, the total energy should be conserved. Obstructed part of the energy is reflected back into the water. Observed area reacts as a secondary source of acoustic waves. Scattered acoustic energy that is returned in the direction of the sonar is called the backscatter. Modern acoustic systems are able to register that energy, respectively the intensity of the backscatter, on which is possible to define features of the seabed. The echo level (*EL*) depends on the source level (*SL*), transmission loss (*TL*) and target strength (*TS*). This relation is given by the sonar equation (Lurton, 2010):

$$EL = SL - 2TL + TS\ , \qquad (2.2)$$

Transmission loss is included twice for a double signal path, of the transducer to the seabed and back. This effect is caused by a circular spread of the acoustic signal.

Target strength (in dB) is defined as the ratio of the backscattered intensity (I_{bs}), and the incident intensity (I_i):

$$TS = 10log\frac{I_{bs}}{I_i}. \qquad (2.3)$$

However, the target strength is the logarithmic expression for the backscattering and can be decomposed into two parts: the backscattering strength for a unit of surface (*BS)* in dB/m^2 and the actual ensonified area at the seafloor (backscattering area, *BA*) (Lurton, 2010):

$$TS = BS + 10log(BA). \qquad (2.4)$$

The backscatter strength for a unit of surface represents the bottom reflectivity. It is often referred to as backscatter coefficient and can be expressed as (Jackson et al., 1986):

$$BS = \frac{R^2 I_s}{I_i A}, \qquad (2.5)$$

Where *A* is the actual ensonified area, *R* is the slant-range, I_S is the scattered intensity and I_i the incident intensity. *BS* is dimensionless and therefore independent of the employed unit system.

The backscatter strength is usually defined as the *dB*-value of the backscatter strength for a unit of surface and does not reference to a unit of length (Jackson et al., 1986):

$$\text{Backscatter strength} = 10logBS, \tag{2.6}$$

The backscatter strength varies in dependence of the seafloor characteristics and the incidence angle. The returned energy is inversely proportional to the incidence angle. So the backscatter strength will be high at small, and low at large incident angles (Lurton, 2010):

$$BS = BS_0 + 10logcos\theta, \tag{2.7}$$

where BS_0 represent the mean backscatter coefficient (mean unit backscatter strength) whose upper limit can be defined as around -5 dB/m^2 (Lurton, 2010). In practice, observed values for BS_0 are usually in the range of -10 to -40 dB/m^2, of course, depending on the terrain characteristics and sonar settings.

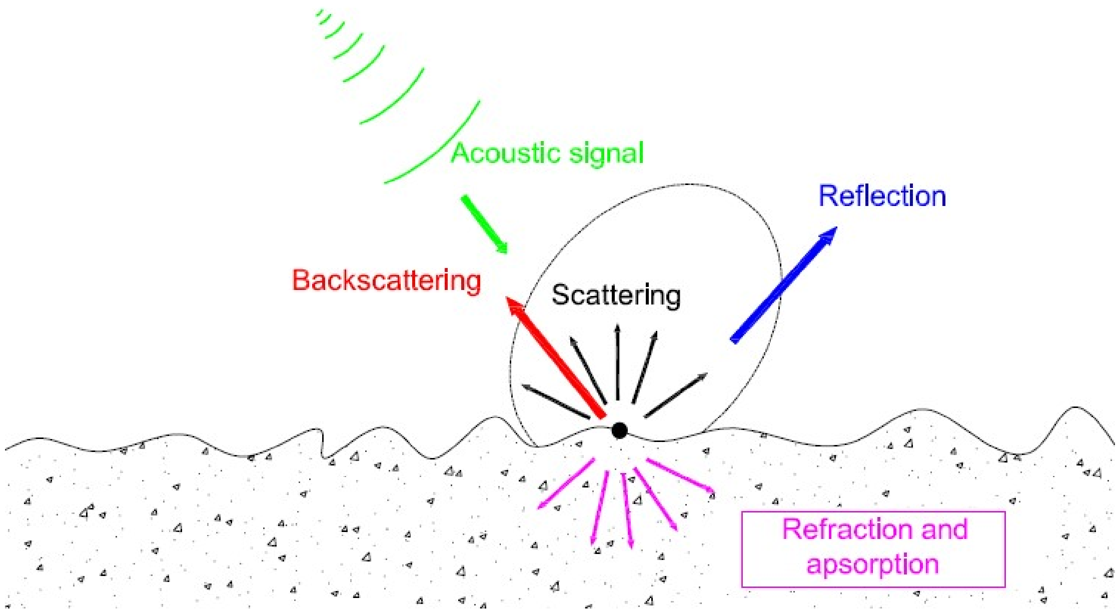

Figure 3: Acoustic signal backscattering

The intensity of the backscatter depends on the characteristics of the transmitted acoustic signal (incident angle, frequency), the distance from the target, the physical nature of the seabed (material, geometry, roughness) and its inner structure, as shown in Figure 4. Based on this it is possible to distinguish four types of backscatter. Interlaced backscatter is scattering due to differences between the characteristic acoustic impedance of the seabed and the water that surrounds it, and is a major component of the total backscatter. Volume backscatter depends on the heterogeneity of the seabed structure. Part of the energy that penetrates the sea floor (depending on the frequency and impedance contrast) is hampered by the heterogeneity of the sediments causing an increase in backscatter. As the incident angle is increasing, heterogeneity of the seabed has the greater impact in the total backscatter. The impedance of the seabed, among other things, depends on the grain size of the sediment. Therefore, the impedance is correlated to the roughness of the bottom sediment whose impact is defined as a Kirchhoff's backscatter. The larger the grains of sediment are, and surface roughness is higher, the impedance is increasing. Here we refer to the irregularities of the seabed whose dimensions are comparable to the wavelength of the acoustic waves. Finally, the intensity of the backscatter increases with the impedance contrast between water and sediment. By mapping the underwater habitats, commonly observed value of the backscatter is total backscatter which is the sum of all the above mentioned types of acoustic backscatter signal.

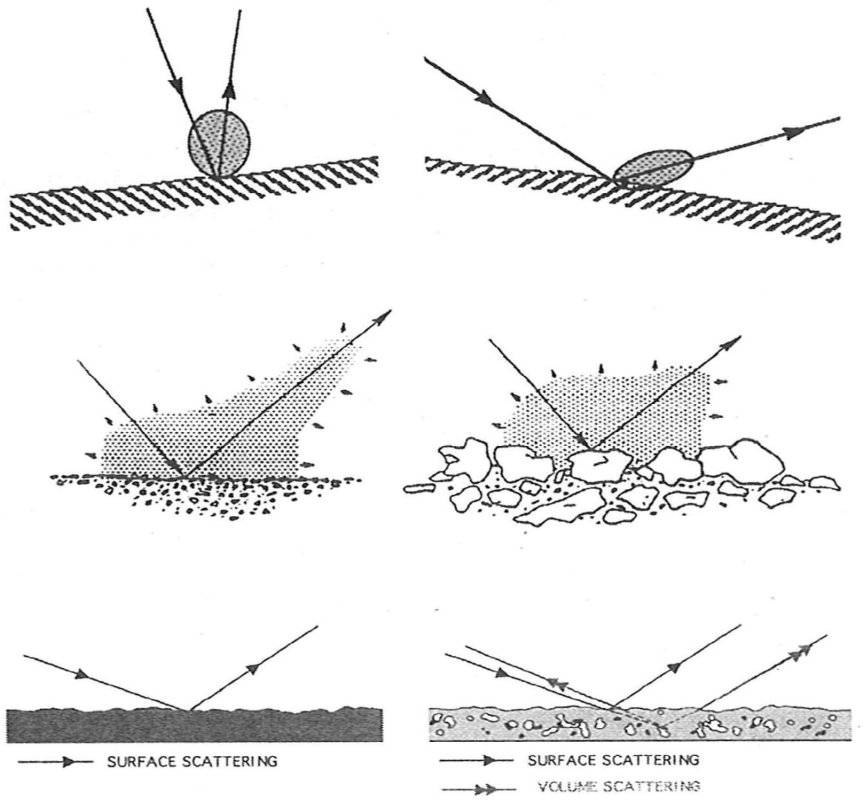

Figure 4: Types of backscatter due to a different sea bottom characteristics (Blondel and Murton, 1997)

In order to conduct classification of the seabed on the basis of the backscatter intensity, measurements should be first corrected for many different geometric and radiometric factors, and then can be compared with the model. This process is also called the Angular Range Analysis (*ARA*). Selected model should directly link the features of the seabed with the measured intensity (such as models by Jackson). Three main parameters which are modeling the curve on the basis of which classification is done are: acoustic impedance contrast, roughness and heterogeneity of the seabed.

2.3 Multibeam echosounders

Recent developments of the acoustic measurement techniques, especially of the multibeam echosounders (*MBES*), changed the way in which we can present and understand the ecosystems of the seabed. By using the MBES it becomes economical to observe really large areas of the seabed. Such studies provide basic data from which, integrated with data collected at the bottom of the sea, thematic maps of the seabed environment can be performed and interpreted. Multibeam echosounders are an expansion of singlebeam echosounders (*SBES*) which are transmitting only one vertical beam and the depth is determined based on the time measurements of double signal path. MBES simultaneously transmit several hundred beams down to the seabed. They can be divided into two groups: sweep and swath systems. Sweep systems consist of a row of closely placed SBES, mounted on the hull perpendicular to the vessel.

The Form of the system is quite complex because of the performance of the vessel's hull, and therefore the use of this system is largely limited to the port and the narrow channel (Pribičević, 2005). Swath system used in the preparation of this study produces multiple acoustic beams from one system transmitter. These systems allow rapid measurement means for determining the morphology and the nature of the sediments on the sea, river or lake bottom. Multi-element transducer allows many individual measurements of the water depth and power control for each ping. By the extremely large number of side reflected signals, their direction and distance record, and on this basis calculated depth, observation of extremely wide band in just one turn is allowed. Bundles of such systems often reach 8 times the width of the water depth in the area is observed. Thus, the greatest progress in relation to all other acoustic systems is in the efficiency of the system. The MBES measurements ensure sufficient accuracy required integration with additional sensors into a single measurement system. Therefore, the system should be capable of real-time import (import) and process data from other sensors (heading sensor, GNSS, SVP, motion sensor) during data collection. Taking into account all these factors, the vertical accuracy of the MBES in practice is better than 1% of the water depth (Lurton, 2010).

2.4 Pilot project of the seabed habitat mapping by analyzing the MBES backscatter

Practical application of the habitat mapping process, according to the popular methodology of conducting hydrographic survey, is divided into data collection and processing of the intensity of the return of the acoustic scattering and bathymetry. Before setting the test area we contacted Dr.sc. Ante Žuljević (Institute of Oceanography and Fisheries, Laboratory for benthos, Split) in order to advise us with his expert advices and opinions. The test area is located on the southern coast of the Stari Grad bay on the island of Hvar, in the vicinity of the port (Figure 5).

Figure 5: The DOF image of the Stari Grad bay with indication of the "test area" and "calibration area"

This area was chosen because it was the first site of the invasive algae Caulerpa Taxifolia in Croatia, whose unstoppable expansion creates a real danger to the undersea ecosystem around the Adriatic Sea. Eradication was done manually with the aid of a suction pump and by covering the colonies with a black PVC foil with the purpose to prevent further expansion throughout the bay (Žuljević and Antolić, 2001). However, as a result of such proceedings, the seagrass meadows of Posidonia were destroyed (Figure 6). Because of its importance in the underwater ecosystem it is often called "the lungs of the sea". By the sampling frame, it was determined that in the pilot project area, Caulerpa taxifolia's habitat is still present. However, to a much lesser extent than it was before, and usually as a mixed habitat. On the relatively small sample of data the goal was to determine the possibility of mapping the areas that are covered by Posidonia in order to determine the stage of its restoration as a consequence of the process of destroying the other target species. The area in which it was possible to clearly allocate at least three different kinds of habitat is selected as test area.

Figure 6: Samples of Posidonia taken on the site

In order to reliably classify the seabed from the data of the MBES it is necessary to have two groups of high-quality data. The first group is the sampling data collected in two ways. The process of sampling by diving was carried out two weeks before the observations of the study area. It was carried out by one of coauthors of this paper, Nino Pijanović, M.Sc., in cooperation with the “Diving center VIKING” from Hvar, after Dr.sc. Ante Žuljević gave the practical advices and recommended the sampling positions. Insight into the general state of the spatial distribution of underwater habitats within the area was carried out with the help of diving equipment to determine the schedule of sampling points. Sometime later, after finding the state of the monitored area, on randomly selected points, the physical samples of the seabed were collected. However, a more dense arrangement of sampling points was defined by the areas in the immediate vicinity of the indicative boundaries between classes, and at the very specific points in the context of underwater habitats (Figure 5). The above procedure is necessary for the classification of habitats in accordance with the actual spatial distribution of habitats, since the sampling data are compared directly with the data on the intensity of the backscatter, and then for evaluating the end product. Other types of samples are recordings of

pseudo side-scan sonar system, built-in MBES system, collected during the survey (Figure 2). Displayed recordings were used for sampling between the points where the physical samples are collected with the purpose that some key features of the seabed would not remain unnoticed. These data represent an additional source of information, but also a kind of system of sampling quality control.
After proper calibration of the equipment the observation was conducted on the 13. July 2015. The used instruments were mounted on an aluminum speedboat Colnago 20s, as shown in Figure 7. The equipement consisted of: MBES Teledyne Reson SeaBat T20-P, positioning system Applanix POS MV WaveMaster and the sound velocity profiler Valeport miniSVP.

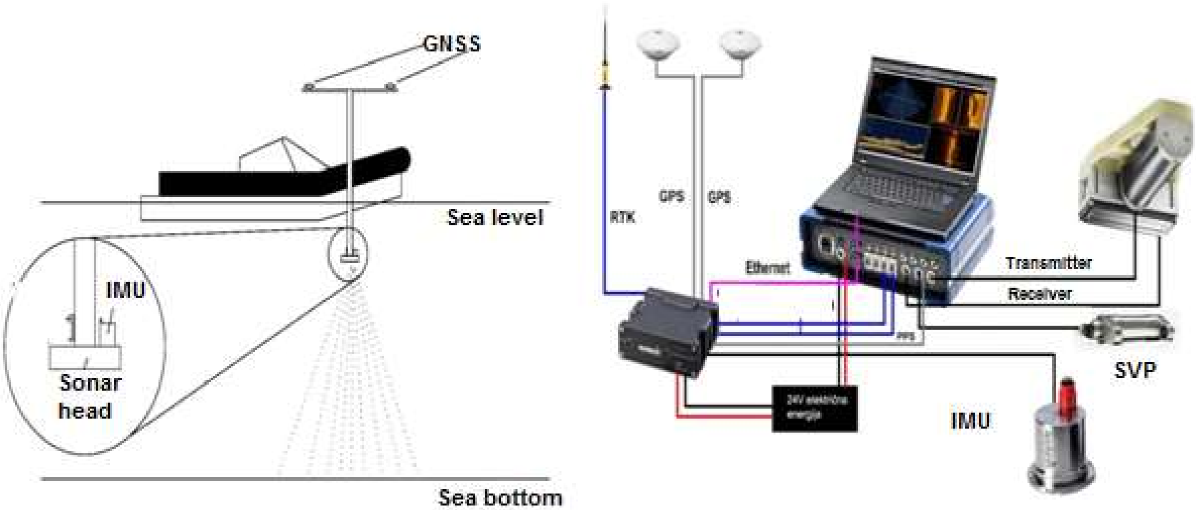

Figure 7: The principle of equipment installation (Tripodij d.o.o., 2015)

3. Results and Discussion

The research results can be divided into three main segments. The first is made of 3D terrain model based on the seabed, which provides the basis of geometric correction data on the intensity of the acoustic backscatter signal. The second segment represents adjusted backscatter data forming a mosaic in the field of research. Once created, backscatter mosaic should be compensated by the set of radiometric and geometric corrections (Time-varying gain correction, slant-range correction, Angular-varying gain correction, etc.) (Figure 8).

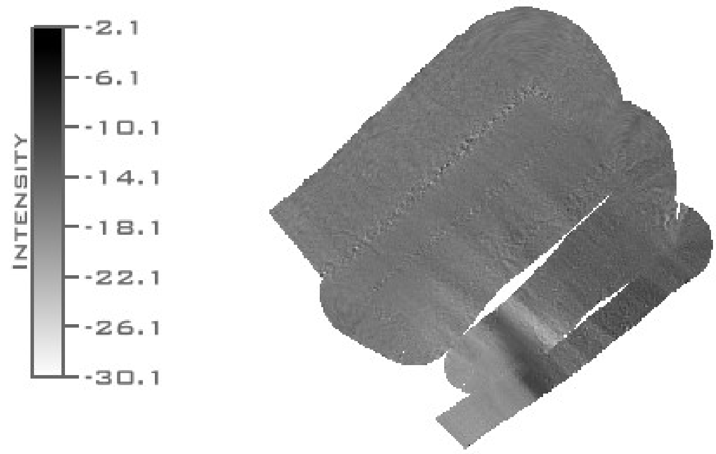

Figure 8: Corrected backscatter mosaic

The analysis of statistical data of the associated values for each point of the mosaic, which are appropriately organized in the histogram, as shown in Figure 9, is determined by the range of values for each class. By the comparison of the data sampling and the previously mentioned statistics, it was decided that the measured data indicates three classes.

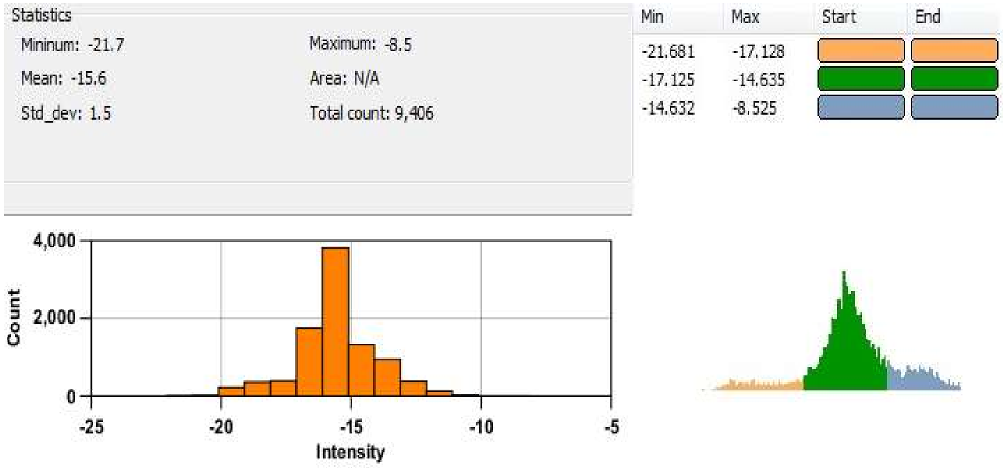

Figure 9: Statistical data of the classification

By the previous action, all conditions for the development of the third segment, thematic map showing the spatial distribution of underwater habitats, were fulfilled. The first class represents the area covered in sand (orange), and is represented by the areas where the intensity of the backscatter was the lowest. Another class is the meadows of the seagrass Posidonia (green), whose backscatter intensity was of medium size. The last class represents areas covered with rocks (blue), where represented areas had the strongest intensity of the acoustic backscatter signal.

The classification is made on the basis of the normal distribution and the resulting mosaic in the Figure 10 has a spatial resolution of 2 meters. Also, a 30 cm resolution mosaic, which provides additional information on the density of each class, was made. Processing of the data was carried out in the comprehensive bathymetric, seafloor imagery and water column data processing software *CARIS HIPS and SIPS 9.0*. It enables simultaneous processing of the multibeam, single beam, sidescan or LiDAR data. The latest technologies on 3D visualization are incorporated very efficiently in the software, processing making, and analysis for the hydrographic, oceanographic or any other marine environment. Implemented software tool *Geocoder,* which was created by Dr. Luciano Fonseca, is used to process the seafloor imagery data and analyze the intensity of the scattering of the acoustic signal (Fonseca and Mayer 2007), (Rzhanov et al. 2011).

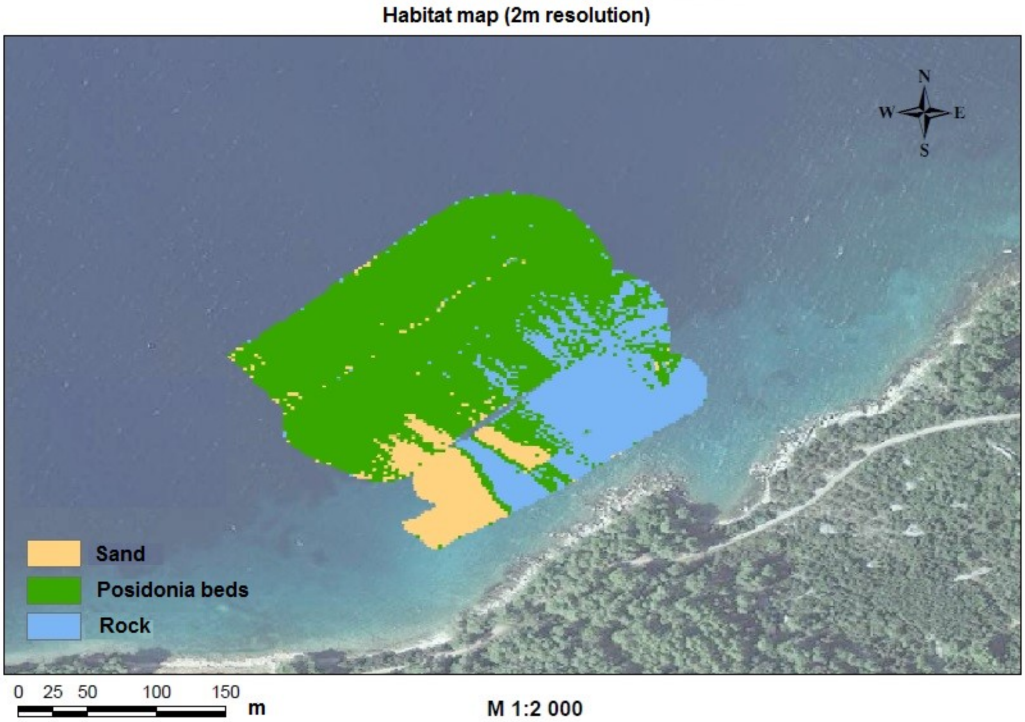

Figure 10: Habitat map crated for the test area

4. Conclusions

Because of the MBES efficiency, the selection of the applied observation method proved to be the best possible option. Observations were carried out in ideal weather conditions, using highly modern and sophisticated instruments. In order to clarify the distribution of underwater habitats the 2m resolution mosaic, which proved to be an acceptable solution with regard to the spatial distribution of the above mentioned classes, was made. The standard deviation of the backscatter intensity is 1.5 dB, what gives the impression of a very reliable data. The lower resolution was the way to reduce the problem of stronger backscatter intensity near nadir. However, the problem of classification occurs at the edges of the area that is covered with rocks. Due to the impact of the volume backscatter and the heterogeneity of the sediment, the edges of rocks covered with sand belonged to the class of seagrass Posidonia which is not in accordance with the real distribution. The sand which was applied to the rock absorbed some of the energy and reduced the intensity of the rock's backscatter what resulted in placing these areas in the medium class which in this case represents Posidonia. Other boundaries between the classes are showing the spatial distribution of underwater habitats quite realistically and in accordance with the sampling. Given that the nature of the seabed is very dynamic, the two meter resolution distribution of habitats should meet the needs of most application. From the produced maps of underwater habitats in this pilot project, we can say with certainty that the damaged habitat of Posidonia, a few years after treatment in order to destroy the invasive algae, are almost fully restored, and that the habitats of Posidonia are very densely populated.
Based on the results it can be concluded that acoustic methods with reliable measurement of depth, certainly provide new opportunities to obtain quality information on the features of the seabed.

Current methods of habitat mapping exclude this type of remote sensing which is presented in the paper. Current methods of habitat mapping also have much lower resolution than this new methodology and need longer period of field work that solely depends on the experience of professionals who plan the sampling. Taking this into account, one can say that a significant progress is achieved in this field of research.

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