Monitoring species in artificial reefs using acoustic communications

David Sarriá[1], Erik Molino[1], Antoni Mànuel[1], Albert García[1],
Guiomar Rotllant[2], Enric Gisbert[2], Francesc Sardà[3], Jacopo Aguzzi[3], Valerio Sbragaglia[3]

[1]SARTI Research Group. Electronics Dept. Universitat Politècnica de Catalunya (UPC). Rambla Exposició 24, 08800, Vilanova i la Geltrú. Barcelona. Spain.
[2]Institut de Rercerca i Tecnologia Agroalimentàries (IRTA)
[3]Institut de Ciències del Mar (CMIMA-CSIC)

Abstract- The purpose of this work is to study and evaluate the limitations of using acoustic communications in the vicinity of artificial reefs. By placing hydrophones and transmitters in different strategic locations we have studied the performance of this technology in confined spaces. The ultimate goal of this work is to provide information for the proper design of acoustic communication systems to monitor species in artificial reefs.

Keywords - hydrophones, acoustic communications, monitoring species, species tracking

I. INTRODUCTION

Nowadays, 76 per cent of global fisheries stocks are currently over-exploited or exhausted, and with risk of extinction if they are not managed correctly. An adequate fishery management is imperative; therefore there is the need to increase the actual knowledge of the habits of the exploited species [1].

Actually, advances in wireless communications systems and the increasing possibility of finding miniaturized sensors have motivated the deployment of new generation of distributed smart sensor networks, spatially or geographically disseminated in the environment. In underwater acoustic sensor networks, expensive and big equipments are replaced by relatively small and less expensive underwater sensor nodes.

There are different techniques to transmit data through the water, however, acoustic signals propagate better than radio or optical signals; therefore, they are preferred for underwater communications. On the other hand, underwater communications present more challenges than air communications. The most important factor is the strong attenuation of the signals and the multi-path signal propagation and time variability of the medium.

This paper is a contribution to previous works [2-4] where infrared, radio-frequency identification and vision technologies were used to monitor the behavior of species. These systems were developed to study the behavior of species in laboratories or small aquariums but present many drawbacks when are used in the field.

To get an idea, infrared is a simple noninvasive technology that can be used to detect the passage of the species in certain areas; however, it is not possible to identify the species, so is limited to study the behavior of isolate individuals.

On the other hand, with a camera is possible to monitor species in a simple and inexpensive way; but to identify individuals requires to mark the species and to develop complex recognition algorithms [5]. The image quality, and therefore, the algorithm performance will be strongly affected by environmental conditions e.g. biofouling, turbidity, light and so on.

Another method, also previously studied, consists on using radio-frequency identification (RFID). With this technology we can solve some issues or difficulties found in vision systems. Passive transponders, which are powered-up by the antenna's electric field, are a great advantage due to the unlimited autonomy of operation, weight, size and price. However, the high attenuation of signals in the aquatic environment does not allow much range of detection; for this reason this technology is limited to monitor species that move along the ground near the antennas.

The strength of acoustic communications technology with respect to the previously mentioned technologies is the viability of deployment in the field (lakes, rivers, and the see) and the cost and maintenance of the system versus the detection area covered, as shown in Table 1.

Table 1. Comparison of different technologies to monitor species

Features	IR	RFID	Vision	Acoustic comm.
Transponder or Tag	No	Yes	Yes	Yes
Cost Vs detection covered area	Medium	Very High	Medium/High	Low
Maintenance	High	High	Medium/Low	Very Low
Multiple detection	No	Yes	Yes	Yes
Transponder battery	-	Unlimited	-	Limited
Detection highly affected by the environment	Yes	No	Yes	No

II. Objectives

The objectives of this study are to assess the performance and limitations of acoustic communications as a technology to monitor marine species, particularly in the vicinity of artificial reefs, which are places of great interest for biologists, and experiments can be set-up easily.

Also, it is interesting to observe good practices on the deployment of acoustic communication system in artificial reefs, in order to maintain the quality of data.

The system under study consists on a set of hydrophones and acoustic transmitters, which are placed in strategic locations to evaluate their behavior in confined spaces. The study and tests have been performed on artificial reefs close to the OBSEA observatory [6], near the coast of Vilanova i la Geltrú, Spain, at a depth of 20m. The artificial reefs are concrete cubes of 2.5 x 2.5 x 2.5 m with an open on the top (Fig. 1).

One of the problems faced on this project is the interference that arises from the echoes of acoustic signals when reflected on surfaces, and when transmitters and receptors are close [7]. This paper focuses on this problem and describes a test to evaluate them. The data collected is analyzed to give the best places for locating the hydrophones in order to improve their reception inside these reefs.

III. System description

The monitoring system is composed by three transmitters and four hydrophones located inside and outside two artificial reefs. The location of the transmitters and hydrophones in the different experiments is important in order to study the performance and limitations of the system. With a good location of elements only two experiments are needed to extract most of the important information.

The underwater system is based on Vemco's commercial equipments. The transmitter is the model "V6", which operates at 180 KHz. This frequency operates well in both fresh and salt water, in a range of up to 200m [8]. The most interesting features of these kinds of transmitters are their size and weight (6mm of diameter and a weight of 0.5 grams in water), in addition to the possibility to program the latency of the emitting signal, which can be from some seconds to minutes. This feature allows extending the battery life of the transmitter when the experiment requires long periods of time (up to one year sending pings every several minutes).

The hydrophones are the autonomous Vemco VR2W-180 KHz, which have a battery life of 8 months and can operate at a maximum depth of 500m.

The transmitters send their ID data through acoustic waves automatically, every few seconds, which are then detected and decoded by the receivers (hydrophones), which store the ID with a time-stamp (arrival time of the signal). A lower transmission rate means a greater lifetime of the transmitter. In our case, transmitters have autonomy of 64 days, sending data every 30 seconds.

Fig. 1. Artificial reef close to OBSEA observatory

All transmitters send data in the same way, so if two or more transmitters are working together there may be some collisions or false detections. However, after each transmission, the transmitters wait a random time until the next transmission, greatly reducing potential false detections.

If the transmitter is in the reception area of the hydrophone, the ID of the transmitter is stored along with a time-stamp and the serial number of the hydrophone. Later, crossing the data between hydrophones allows checking the range of transmitters or evaluating the interferences of the reef's walls.

IV. Experiments and results

The system described has a maximum detection range of 200 m. Nevertheless, because the system is not working in an open area and taking into account the signal reflections on the artificial reefs, seafloor and surface, the maximum range will be strongly affected.

In order to test the system performance, a set of three transmitters and four hydrophones have been placed inside and outside the artificial reefs in two experiments, each with a particular purpose.

Experiment 1

In the first experiment is evaluated the detection range of transponder 2 by the hydrophones C and D (Fig. 2). This set-up shows the high interferences caused by the artificial reef.

In this case, C is able to detect sometimes the tag 2, meanwhile D is out of range (very low detections, less than 5% of pings). In this configuration, the mission of tag 3 is to check if hydrophones A, C and D are working well because all of them are inside the range. The location of tag 3 also permits to contrast the performance of detections considering the interferences by the reef (tag 2 – hydrophone C Vs. tag 2 – hydrophone D Vs. tag 3 –

hydrophone B). In this test, tag 3 – hydrophone B has the best performance and doesn't lose detections.

With these results, a hydrophone located inside the reef can detect transmitters -or species- correctly between 20 and 40 meters around.

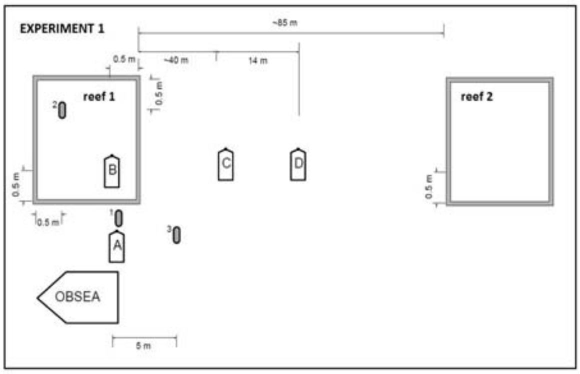

Fig. 2. Set-up experiment one

Experiment 2

This set-up was prepared after experiment 1, and hydrophones were deployed inside each reef, as shown in (Fig. 3), considering the possibility to detect the transmission of the opposite reef. Hydrophone C is located at 40 m of tag 1, but in this case we want to analyze the influence of the walls of the reef (the acoustic signal has to cross two walls).

Hydrophones B and D, monitor the presence of transponders inside each reef. With this configuration and distances, every hydrophone store the ID of the transponders that are around - in a real scenario, detect the individuals, species under study - inside or close to the reef.

Hydrophone C stores the ID from transponder 1, but also looses data, very similar to results obtained with tag 2 – hydrophone C.

Results of the different experiments confirm the position of hydrophones inside closed areas is critical, and in order to improve the reception performance it is advisable to place them as far as possible of the reef walls, and a minimum distance of 1 meter from transponders.

Nowadays, with this criteria some biological experiments are been performed with this equipments in the reefs. The specie under study is the Mediterranean spider crabs, *Maja Squinado*, shown in (Fig. 4) and the configuration used is similar to the second experiment.

The biological goal is to study the activity of the specie: movements of individuals (male-female) between reefs, adaption to the environment and survival of transponder to the carapace shedding.

ACKNOWLEDGMENTS

We want to acknowledge the financial support of the Ministerio de Ciencia y Educación of Spain, through the project TRA2009_0294 "Redes de sensores submarinos acústicos aplicados al seguimiento de especies de interés commercial".

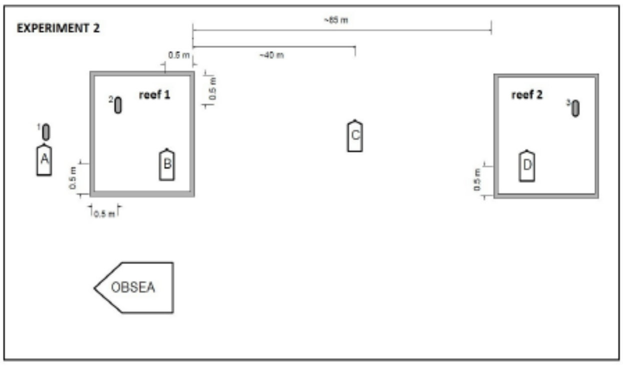

Fig. 3. Set-up experiment two

Fig. 4. Biological experiment with crabs

REFERENCES

[1] J. Csirke, "Global production and state of marine fishery resources" In: FAO Marine Resources Service, Fishery Resources Division. Review of the state of world marine fishery resources. FAO Fisheries Technical Paper. No.457. 2005, Rome: FAO.

[2] D. Sarriá, J. del Río, A. Mànuel, J. Aguzzi, J.A. García, F. Sardà. Infrared and Imaging Application to measure emergence activity rhythms on Nephrops norvegicus (L.) population Assessment. IEEE Sensors Applications Symposium 2008. Atlanta, USA

[3] D. Sarriá, J. del Río, A. Mànuel, X. Roset, J. Aguzzi, F, Sardà. A new tracking system to study the behaviour of species. XIX IMEKO World Congress, 2009. Lisbon, Portugal

[4] D. Sarriá, J. del Río, A. Mànuel, J. Aguzzi, F. Sardà, J. A. García. Studying the behaviour of Norway lobster using RFID and Infrared tracking technologies. Oceans'09 IEEE Bremen. Bremen, Germany

[5] J. Aguzzi, C. Costa, Y. Fujiwara, R. Iwase, E. Ramírez-Llordà, P. Menesati. A Novel Morphometry-based protocol of automated video-image analysis for species recognition and activity rhythms monitoring in deep-sea fauna. Sensors 2009. ISSN 1424-8220

[6] http://www.obsea.es

[7] C. Sherman; J. L. Butler, "Transducers and Arrays for Underwater Sound", Springer, 2007

[8] D. Webber, "Acoustic Telemetry new User Guide", Vemco Education. Vemco 2009