A PILOT STUDY ON MOVEMENT PATTERNS OF BRAZILIAN REEF FISH USING ACOUSTIC TELEMETRY

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ABSTRACT

The application of acoustic telemetry caused profound changes in the study of ecology, including in the marine environment. This technique allowed the development of research investigating the movement patterns of fish and other organisms, for both ecological and management purposes. In this study we analyse the living area and the movement patterns of a reef fish within and around a strictly protected area, aiming, among others, to evaluate its effectiveness for the conservation of fishing resources. The study was developed in the Marine Biodiversity Protection Zone of Tamandaré (ZPVMT), an exclusion area (resource extraction and visitation) located on the southern coast of the state of Pernambuco, within the limits of the Marine Protected Area APA Costa dos Corais. In particular this report presents the results obtained during range tests carried out near the Ilha da Barra reef, covering the four moon phases in order to evaluate the influence of tidal variations on the detection range of the VR2W receivers. Results of this experiment, coupled with observations of fish movement using underwater visual census were the basis for the design of a telemetry receiver array deployed on the reef site.

The continuation and expansion of this work, with tagging of fish and analysis of results, will serve as a basis to evaluate the effectiveness of ZPVMT to increase biomass in the surrounding open areas, to plan new exclusion zones within the APA Coral Coast, and to contribute to the design of other marine protected areas.

Keywords: marine protected area; acoustic telemetry; movement pattern; fish behaviour.

CONTEXT

This technical report resumes a pilot study on acoustic telemetry conducted under the Reef ECOlogy and design of Marine PRotected Areas (RECOMPRA) exchange project with the advisement and participation of V.M. Giacalone during the two-month period of his stay in Tamandaré (state of Pernambuco, northeastern Brazil) together with the Federal University of Pernambuco staff. The activities fall within the scope of the project (Annex 1): “Review and synthesize tagging and acoustic tracking studies […], as well as complete own mobility studies on selected species in South Western Atlantic and Western Mediterranean".

Moreover this study is the pilot part of local Brazilian projects related to "Projeto Meros do Brazil (funded by Petrobras Ambiental) and "Project Recifes Costeiros (funded by SOS Mata Atlântica and the Toyota Foundation), under the component for monitoring of biodiversity and evaluation of the effectiveness of a protected area by biomass ranging study, spillover effect and distribution patterns and movement of reef species in a no-take no-entry zone inside the marine protected area APA Costa dos Corais".

INTRODUCTION

Biotelemetry, defined as the "instrumental technique used to obtain and transmit information of a living organism and its environment to a remote observer" (Slater, 1965), has revolutionized the study of ecology (Adams, 1965), including in the marine environment (Baldwin, 1965). Based on data transmission mode and frequency of operation, biotelemetry can be divided into two basic categories, radio and acoustic. Most of the radio systems currently used transmits at very high frequencies, between 30 and 300 MHz, while most of the acoustic system transmits at low frequencies, between 30 and 300 kHz (Adams *et al.*, 2012).

The technology on which modern acoustic telemetry systems are based was developed for military purposes, mainly related to the use of submarines, and commercial purposes, such as offshore oil and gas exploration. These strategic needs have enabled to overcome the limitations imposed by the marine environment (e.g., high absorption of acoustic energy of high-frequency) and achieve the high data transmission rates required (Baggeroer, 1984). Recent advances, including the increase in data storage capacity, the development of sensors and miniaturization of transmitters, allowed the broad application of acoustic telemetry technology in scientific research on wild animals, providing data for population analysis, as well as ecological studies and behavioural studies (Nielsen *et al.*, 2009)(Nielsen et al., 2009). The use of acoustic transmitters in biotelemetry studies have a wide range of applications in the ocean, with pelagic fish being actively followed for a few days and a few hundred kilometres (Bertrand *et al.*, 1999; Brill *et al.*, 1999) and more sedentary fish being passively monitored for long periods at finer spatial scales (Eristhee &

Oxenford, 2001; Szedlmayer & Schroepfer, 2005). Telemetry studies with marine fishes are focused on determine the home range of the species in order to evaluate the efficiency and/or establish parameters to properly design marine protected areas (Afonso *et al.*, 2008; Chateau & Wantiez, 2009; Afonso *et al.*, 2011; Green & Starr, 2011; Bryars *et al.*, 2012; Di Lorenzo *et al.*, 2014; Garcia *et al.*, 2014; Abecasis *et al.*, 2015), assess the connectivity between habitats (Bégout Anras *et al.*, 1999; Curry *et al.*, 2006; Abecasis *et al.*, 2009; Crook *et al.*, 2010; Abecasis *et al.*, 2013) or study ecological aspects (Fox & Bellwood, 2011; Alos *et al.*, 2012; Ilestad *et al.*, 2012; Fox & Bellwood, 2014; Jewell *et al.*, 2014) and movement patterns (D'Anna *et al.*, 2011; Hitt *et al.*, 2011; Topping & Szedlmayer, 2011; Jacoby *et al.*, 2012; Reubens *et al.*, 2013). Generally, studies were conducted on species of commercial importance (Cote *et al.*, 2003; Cote *et al.*, 2004; Espeland *et al.*, 2007; Zemeckis *et al.*, 2014) but sometimes it includes little-known species, as coelacanths (Hissmann *et al.*, 2000).

The establishment of marine protected areas (MPAs) has been used for decades as conservation measure and fisheries management tool (Agardy, 1994; Prates & Blanc, 2007). Protected areas can contribute to enhance fish population in the surrounding areas open to fishing, by the dispersal of larvae and adults, a phenomenon known as spillover (Francini-Filho & Moura, 2008; Harmelin-Vivien *et al.*, 2008; Stobart *et al.*, 2009; Sale *et al.*, 2010). While the exportation of larvae from marine protected areas is supported by indirect evidence (e.g., genetics), several examples of migration of mature fish from areas closed to fishing have been obtained by the use of acoustic telemetry (Afonso *et al.*, 2008; Chateau & Wantiez, 2009; Afonso *et al.*, 2011; La Mesa *et al.*, 2012; Abecasis *et al.*, 2015). However, the powerfulness of this technique relies on the accuracy of data analysis and, above all, on the range tests performed prior to tagging fishes and releasing them at sea.

As it is well known, some oceanographic features such as thermocline, tides, sea current and turbidity, among others, can strongly affect the ultrasonic signal propagation and underwater detection, thus modifying the detection range of automated receivers (Giacalone *et al.*, 2005; Heupel *et al.*, 2006; Cagua *et al.*, 2013; Kessel *et al.*, 2014). Range tests are a crucial part of any telemetry study, especially in shallow waters and/or where tides can increase water turbulence and/or turbidity.

The APA Costa dos Corais is the largest MPA in Brazil, extending over 135 km of coastline, from the municipality of Tamandaré (state of Pernambuco) to the municipality of Maceió (state of Alagoas), in the north-eastern part of the country. Within this MPA, an exclusion area of 4,000 m^2, the Marine Biodiversity Protection Zone of Tamandaré (ZPVMT in Portuguese), was implemented in 1999 in Tamandaré. In addition, the management plan for the MPA provides that new exclusion areas should be implemented along its length. Therefore, knowing the size of the living area (home range) of target fish species and measuring their movement patterns is essential to determine the potential biomass exportation from enclosed areas and hence their impact on fish activity on neighbouring areas. In this context, this project is one of the first initiatives to study the living area of reef fish based on acoustic telemetry in Brazil and aims to analyse the effectiveness of a strictly protected area and to provide subsidies to set the future design of marine protected areas.

The first step to implement the telemetry study was to determine the range of reception and establish the receiver array. Factors such as presence of obstacles (reefs), depth and tide were considered and tested prior to the installation of the experiment.

Thus, the objectives of this study were 1) to test the detection range of acoustic receivers in different sea conditions and 2) to set up the receiver array based on the obtained results.

MATERIAL AND METHODS

STUDY AREA

This work is being carried within the APA Costa dos Corais and, in particular, within the ZPVMT, a fully protected area of 4,000 m^2 (Fig. 1).

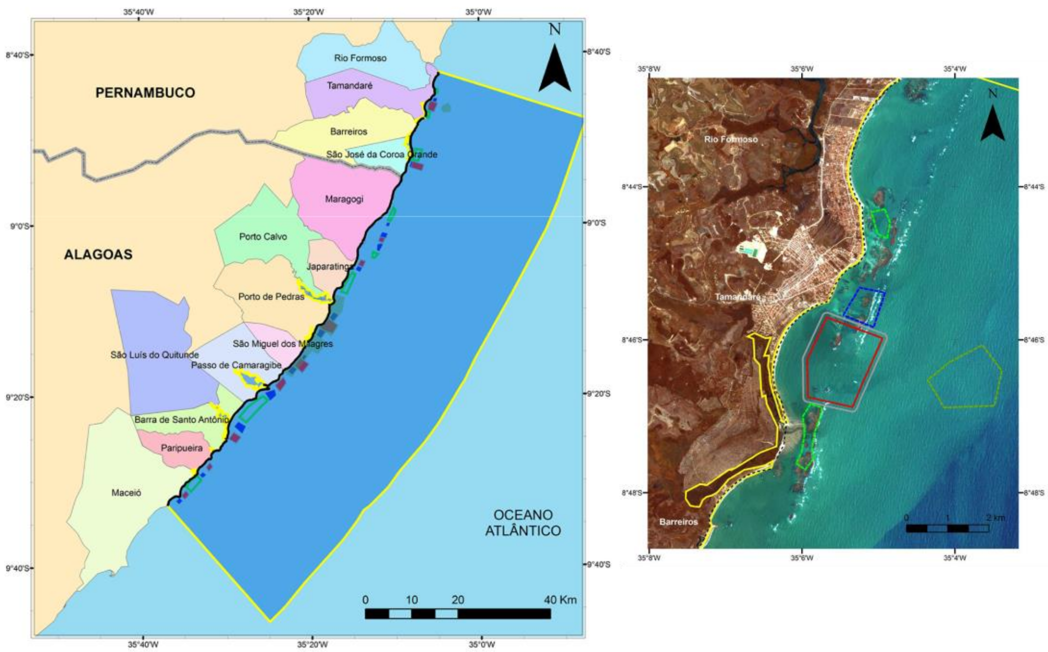


Figure 1: Map of the study area on the southern coast of the state of Pernambuco (right), highlighting the location and extent of MPA APA Costa dos Corais (left). The location of the "Marine Biodiversity Protection Zone of Tamandaré" is indicated in red.

RANGE TESTS

Range tests are important because detection may vary depending on local conditions. This is particularly the case of coral reefs, where the reef framework represents an obstacle to detection that needs to be assessed (Welsh et al.; 2012). The effect of obstacles, and thus detection range, are also expected to vary with other factors, such as depth and wave movement. The study area is under a semi-diurnal tidal regime, with two low and two high tides in every 24 hour period. On full and new moon tidal range may reach 2.0 to 2.5 meters, during which the reef barrier is surpassed by incoming waves causing higher turbulence in inner lagoon.

To test for lunar and tidal variation, range tests were performed between 6 and 30 November 2014, covering the four lunar phases (new, first quarter, full and third quarter). In each test, five receivers were placed in a sandy bottom near Ilha da Barra reef (within the ZPVMT) at distances of 75 m from each other (300 m between the extremes) using moorings of concrete and PVC (Fig. 2). The receivers were positioned along a depth gradient (RT0, RT75, RT150, RT225 and RT300, from smallest to largest depth) ranging between ~2 and ~8 m (Fig. 3), and maintained in situ for cycles of 24 hours or 48 hours. At each opposite end (RT0 and RT300) were installed two transmitters, differing in their acoustic power (Low - L - or High - H) and average time beeping (60 or 120 s), just above the receivers. The “data” are the number of detections recorded per hour (NDh) by each receiver. As the maximum NDh was recorded by RT0 and the RT300 in the two ways (up-down and down-up), respectively, results are presented in terms of percentage of recordings, which can be read in terms of probability in detect a pinger over distance.

Figure 2: Positioning of the receivers near Ilha da Barra reef during the range tests (left) and mooring used to place the receivers (right), with two transmitters over it.

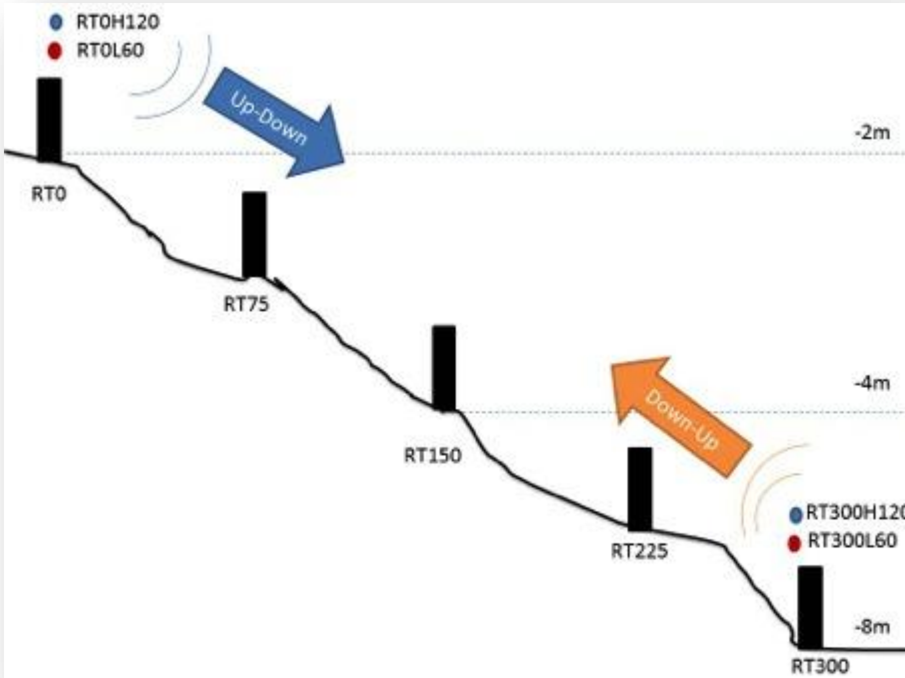


Figure 3: Positioning of receivers along the depth gradient.

Observations on Target species and Training for TAGGING PROCEDURES

Underwater visual census (UVC) monitoring revealed that fish aggregate in some preferred areas, among which a cave located at the entrance of the lagoon of the Ilha da Barra reef (B. P. Ferreira, pers. obs.). Several species, which are targeted by the artisanal fisheries in the region occur in the cave and may be used as model species for the continuity of the study.

In order to train the research team for tagging (implanting of transmitters in the coelomic cavity) trials were conducted using dead fishes, in order to evaluate the minimum fish size suitable for transmitter implantation, and to define the surgical protocol to be used in live specimens. The transmitters to be used were Vemco “V9”, that weight about 4.6 g. The model species used for the trial was the Brazilian snapper, a small sized lutjanid that performs ontogenetic movements from estuaries to coastal reefs (Aschenbrenner & Ferreira, 2015) and is abundant within the ZPVMT and along with the other species of Lutjanidae, forms the main target of artisanal fishery in the region (Aschenbrenner & Ferreira, 2015).

ACOUSTIC TELEMETRY ARRAY

Based on the results from the range tests and UVC observations, automated receivers "VR2W" (Vemco Inc.) were placed within the APA Costa dos Corais, around Ilha da Barra reef, according to the design showed in figure 4. This design was based on the range-test results and, above all, was adopted in order to track fish movement from the cave in the inner part of the island, where fishes are observed daily, to the external boundaries of the reef.

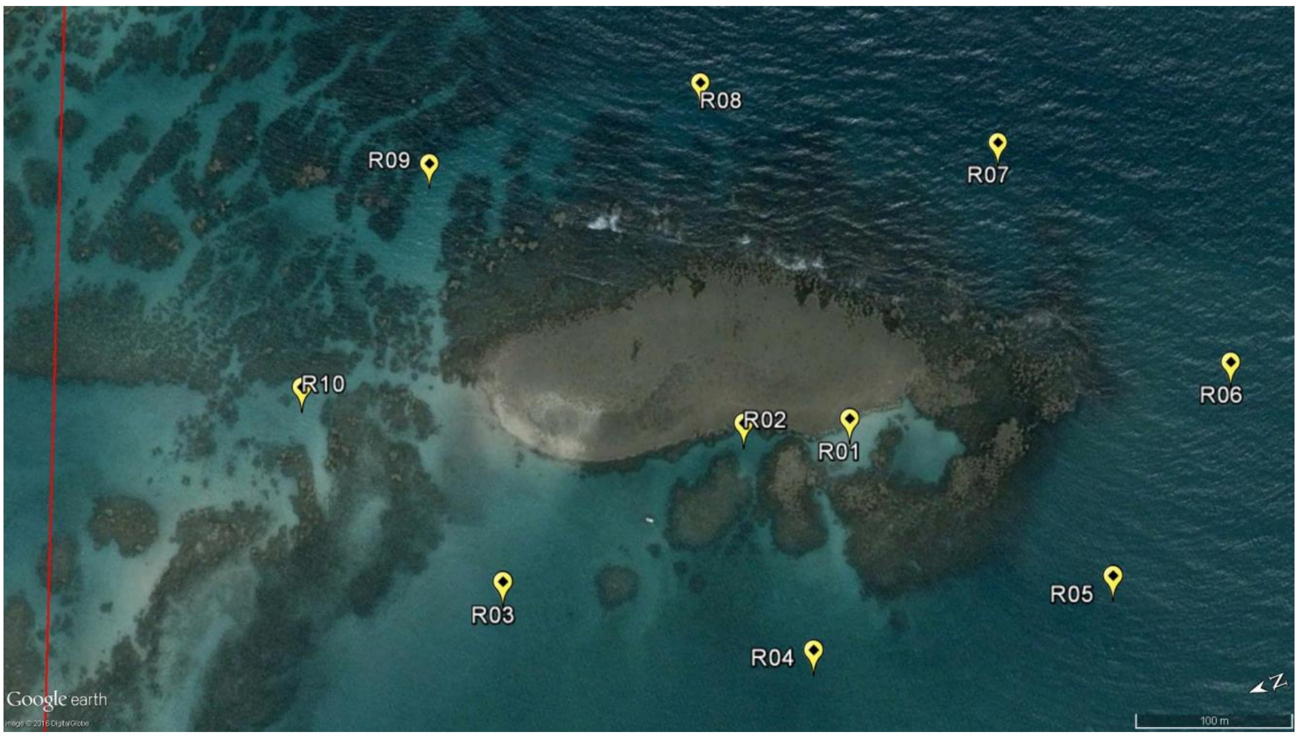


Figure 4. Positioning design of VR2W receivers around the Ilha da Barra, Tamandaré. The red line on left side of the map indicates the northern boundary of ZPVMT.

RESULTS AND DISCUSSION

During the test conducted at the full moon, the decline in the detection rate was linear, especially in the up-down way (Fig. 5). On average, the receivers at 150 m of transmitters captured between 70-80% of the emitted signals. In this test, the performance of the two types of transmitters used was very similar (Fig. 5). Towards down-up, almost 100% of the signals were picked up by the receiver located 75 m away, while in the other direction only 90-94% of the signals were received at that distance. However, the detection rate showed a negative correlation with the tide level (Fig. 6). This effect seems to be more evident when the distance between transmitters and receivers increased (i.e., 150 and 300m). No variation in detection rate related to day/night periods was found (Fig. 6). In general, the rate of reception of receivers located within 75 m of transmitters ranged from 90-100% for most of the time, dramatically dropped to about 50% during the high tide. On receiver located at 150 m the detection rate varied more regularly and negatively correlated with tide. Finally, in the receiver placed 300 m away from transmitters the detection rate was less than 50% most of the time.

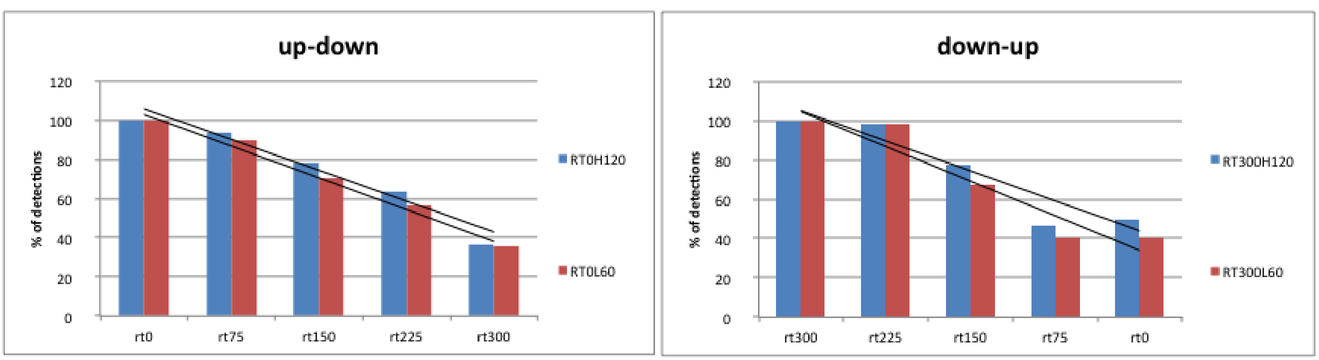
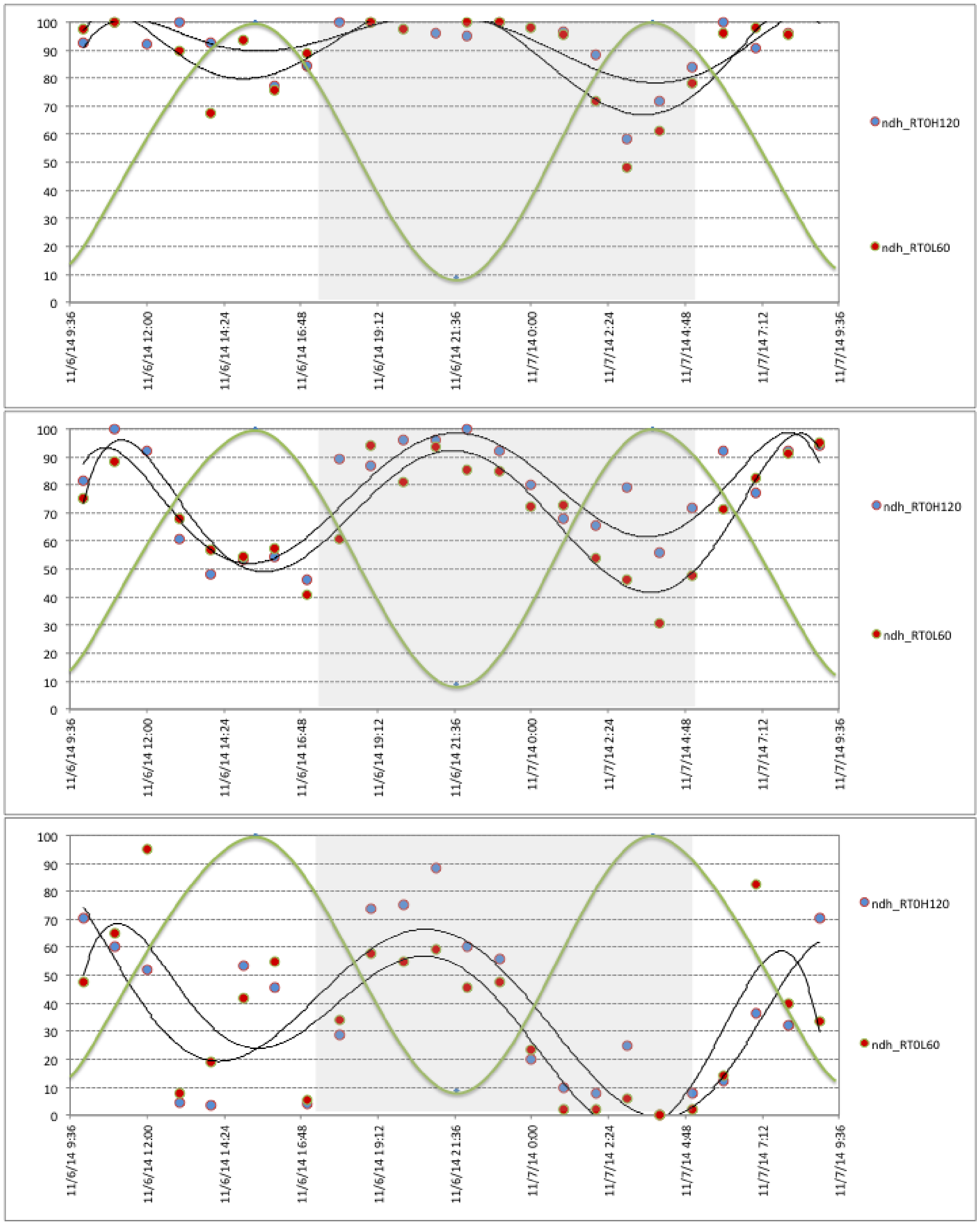


Figure 5: Detection rate variation in up-down and down-up ways of communication. Blue bars show the results of the transmitters with high acoustic power and average emission range of 120 s (H120) and red bars show the results of transmitters with low acoustic power and average emission interval of 60 s (L60).



a)

b)

c)

Figure 6: The acoustic signal detection rate (%) over the range-test carried out on the full moon by receivers positioned at 75 m (a), 150 m (b) and 300 m (c) from the transmitters placed in the shallowest mooring. Blue shows the results of the transmitters with high acoustic power and average emission range of 120 s (H120) and red shows the results of transmitters with low acoustic power and average emission interval of 60 s (L60). The green line represents the percentage of sea level relative to the maximum level of the day, the black line represent the trend (polynomial line) of the ndh value, the shaded area represents the night-time.

During the range test performed on the full moon it was observed that at ca. 6m deep there was a stratification of the water column during the high tide, with a warmer and clearer layer on the surface and a cooler and cloudier layer on the bottom. These two factors (temperature and turbidity) together influence the density of water, generating a pycnocline and a thermocline that can prevent or obstruct the passage of sound waves, causing the performance of the propagation of signals to be different in up-down and down-up directions, as noted. To assess this effect, receivers were installed in the water column in RT225 and RT300 moorings in later tests (Fig. 7). In the up-down direction, the average performance of receivers located in the water column (RT225 bis, RT300bis) was about 10%-30% higher than receivers close to the bottom (Fig. 7)

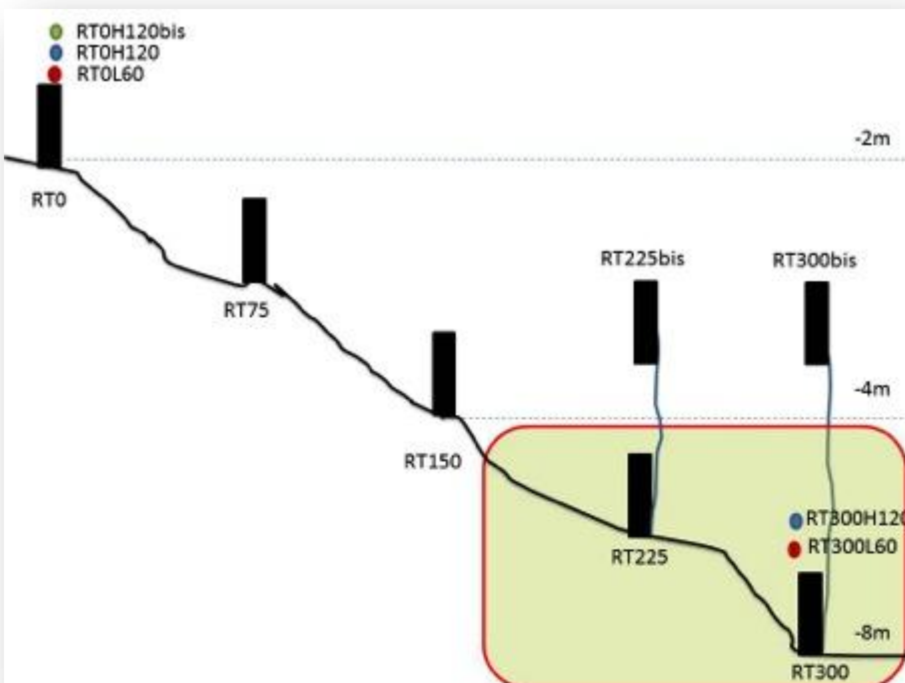


Figure 7: Positioning of receivers along the depth gradient, showing the receivers installed in the water column (RT225bis and RT300bis) after the results of the first range test.

In general, the pattern   abovementioned was observed in the other phases of the moon, despite tidal amplitude differences. From the second test, the receivers and transmitters were kept in operation for two consecutive days allowing the monitoring of the signals for two circadian cycles and four circatidals cycles. The results were very similar between cycles within each test. The results of this study highlight that the tide in this area affects the performance of the acoustic telemetry equipment.. Indeed, it should be taken into account not only to set the positioning receivers but also when analysing the data. Considering a limit of 70% probability of detection, the range of acoustic signals was estimated at 150 m during low tide and 100 m at high tide. Based on these results, , we designed the following deployment plan for 10 VR2W receivers (Fig. 8): eight receivers were arranged around the island, one in front of the cave were fishes concentrate in low tide periods (BPF and MSC pers. Com.) and another one on a lagoon present within the limits of the Island, which is a possible path taken by fishes when they leave the cave during the flood tide (pers. obs.)

Figure 8. VR2W receivers detection limits around the Ilha da Barra, Tamandaré, at low tide (left) and high (right). The red line left side of the map indicates the northern boundary of ZPVMT.

CURRENT AND FUTURE EXPECTATIONS

After the end of V. M. Giacalone visit, the UFPE researchers continued to work in this project, by capturing and tagging of fish, and the results obtained will be reported elsewhere as an original scientific publication. Currently, further range tests are being carried in Ilha da Barra reef, to effectively study the possible interferences of the reef, and noise associated with it, in the detection performance of the designed and installed VR2W array.

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