Herbivorous Reef Fish Movement Ability Estimation in Marine Protected Areas of Martinique (FWI)

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ABSTRACT

Marine protected areas (MPA) are valuable tools for biodiversity conservation and fisheries management. Their effectiveness is highly dependent on fish's spillover through unprotected areas. Nowadays, many studies focus on predictive modeling to determine MPA optimal size. In this paper, we proposed an empirical study in Martinique to evaluate the efficacy of one MPA in function of different species.

Two complementary methods were selected: 1) Mark-recapture technique aiming at defining insular movements, 2) Acoustic telemetry aiming at determining the movement capacity of coral fish and their local movement patterns. Two families of fish were selected according to their mobility abilities: Surgeonfishes, (*Acanthurus chirurgus*) and Parrotfishes (*Sparisoma chrysopterum et viride*).

Areas home range of the two species were determined both by tracking mobile techniques. Different responses were observed according to the species and the technique used. Areas home range were found to be 3220 m² for *S. viride* (terminal phase) and 7341 m² for *A. chirurgus*. *A. chirurgus* had covered 4 km, only one individual *S. viride* was fished at 3.7 km.

These preliminary results give a good insight about these species mobility and more research is currently being conducted to gather knowledge on coral reef fish local movement patterns in no-take zones to improve the effectiveness of fisheries management.

KEY WORDS: Home range, Marine Protected Area, herbivorous fish, Martinique

Estimación Capacidades de los Desplazamientos de los Peces Herbívoros Coralinos en las Áreas Marinas Protegidas (AMP) en Martinique

Las áreas marinas protegidas (AMP) son herramientas muy eficaces para la conservación de la biodiversidad y la gestión de la pesca artesanal. Su eficacia depende mayoritariamente de la tasa de exportación de los peces hacia las zonas no protegidas. Los trabajos actuales están principalmente orientados hacia la modelización de las redes de las AMP y tienen como objetivo identificar su talla óptima. En este trabajo nos proponemos realizar trabajos empíricos en la isla de Martinica con el fin de evaluar la eficacia de una AMP.

Dos métodos complementarios han sido seleccionados: 1) la técnica de captura - recapture que pretende definir los desplazamientos insulares 2) la telemetría acústica que permite determinar las capacidades de movimiento de los peces coralinos y los patrones de desplazamiento local. Dos especies de peces pertenecientes a dos familias distintas fueron escogidas con arreglo a sus diferentes capacidades de desplazamientos: Acanthuridae, (*Acanthurus chirurgus*) y Scaridae (*Sparisoma chrysopterum y viride*). Un total de treinta individuos fueron marcados por especie.

Observamos respuestas diferentes según la especie considerada. A través de la utilización del tracking móvil pudimos estimar las superficies de los territorios de las dos especies: 3220 m ² para *S. viride* (fase terminal) y 7341 m ² para *A. Chirurgus. A. chirurgus* recorrió de media 4 km y un solo individuo *S. viride* pescadó a 3.7 km.

Estos resultados preliminares nos dan una idea buena sobre la movilidad de estas especies de peces y más investigaciones estan siendo llevadas a cabo por nuestro equipo para conocer mejor los diferentes patrones de comportamiento de las especies en las AMP y así poder evaluar y mejorar su eficacia en la conservación y la gestión de los recursos marinos.

PALABRAS CLAVE: Territorio, Áreas Marinas Protegidas, peces herbívoros, Martinique

Evaluation des Capacités de Déplacements de Poissons Coralliens Herbivores dans les Aires Marines Protégées (AMP) en Martinique

Les aires marines protégées sont des outils efficaces pour la conservation de la biodiversité et la gestion des pêcheries artisanales. Leur efficacité dépend majoritairement du taux d'exportation des poissons vers l'extérieur de l'AMP. Néanmoins, les travaux actuels sont principalement axés sur la modélisation des réseaux d'AMP ayant pour objectif d'identifier les tailles et les distances optimales entre réserves. Dans ce papier, nous proposons des travaux empiriques en Martinique afin d'évaluer l'efficacité d'une AMP en fonction de différentes espèces.

Deux approches complémentaires ont été sélectionnées : 1) Technique de capture-recapture visant à définir les mouvements insulaires, 2) Marquage acoustique visant à déterminer les capacités de déplacements des poissons coralliens et leurs patterns de déplacements locaux. Deux familles de poissons ont été choisies en fonction de leurs différentes capacités de déplacements : les Acanthuridae (*Acanthurus chirurgus*) et les Scaridae (*Sparisoma chrysopterum* et *viride*).

Par l'utilisation de la technique de tracking mobile, les superficies des territoires des certaines espèces ont été estimées à 3320 m² pour *S. viride* (Phase terminale) et 7341 m² pour *A. chirurgus*. Cependant, certains individus recapturés ont parcouru 4 km en moyenne (*A. chirurgus*) et 3.7 km pour un seul *S. viride*. Les résultats préliminaires donnent une estimation intéressante sur les capacités de déplacements de certaines espèces. Des études supplémentaires sont en cours afin de mieux appréhender les déplacements locaux au sein des aires marines protégées et ainsi d'évaluer et d'améliorer leur efficacité de conservation et de gestion des ressources marines.

MOTS CLÉS: Territoire, aires marines protégées, poissons herbivores, Martinique

INTRODUCTION

Marine Protected Areas (MPAs) or No-take marine reserves are defined as "areas of the marine environment fully protected from fishing or all other types of exploitation" (Francini-Filho and Moura 2008). MPAs are one of the tool the most used in order to preserve marine resources and habitats (Thresher 1980, Fishelson et al. 1987, Rocha et al. 2002, Sale et al. 2005, Baskett et al. 2007, Afonso et al. 2008). Numerous management methods of local fisheries are possible but marine reserve is the only one that allow for habitat protection. Variety of habitats type and reserve size are decisive factors for MPA efficiency (Halpern 2003, Shanks et al. 2003, Barrett et al. 2007, Mason and Lowe 2010). MPA efficacy is partly dependent on emigrant larvae and fish adult displacement abilities. In the adult phase, marine reserve is particularly efficient for species with small home ranges and strongly attached to sites (Kramer and Chapman 1999, Russ 2002, Afonso et al. 2008). Many studies demonstrated that reef fishes have small home range around 1 m² (Low 1971, Luckhurst and Luckhurst 1978). Their displacements are restrained inside the marine reserve and optimal protection can be possible. Nevertheless, species with large home ranges are more susceptible to leaving MPAs for feeding and reproduction if all the areas are not contained within the reserve boundaries. These species are more susceptible to participate in spillover effect. This effect which can benefit the local fisheries but requires connectivity between different habitats (Afonso et al. 2008).

The surgeonfishes (Acanthuridae) and parrotfishes (Scaridae) are widely distributed in the West Atlantic. These families represent an important part of common herbivorous biomass on coral reef ecosystems. *Acanthurus chirurgus* and *Sparisoma viride* compose inshore Antillean fisheries (Munro 1983, 2000, Randall 2002).

This study, aimed at:

i) Evaluating the movement ability and
ii) Characterizing the site fidelity of three coral fish species *A. chirurgus, S. chrysopterum* and *S. viride* inside one MPA.

MATERIALS AND METHODS

Study Area

This study takes place in Martinique, French West Indies where eight coastal MPA have been implemented over the last 10 years. The present work focused on one MPA, in the Robert's Bay on the Atlantic side of the island. It was created in 2000 and has an area of 10 km² (Figure 1).

Active tracking

Ultrasonic telemetry is an effective tool to study the ecology and physiology of marine animals in the natural environment without the requirement of direct observation (Winter 1996). Thus, active acoustic tracking was performed in this MPA to follow fish displacement. Fish were caught with Antillean traps. All the individuals tagged measured at least 16 centimeters. Fish were anesthetized with clove oil at 0.02 ml/L, and ultrasonic transmitters Vemco V7-4L were implanted in their peritoneal cavity. Fish were maintained in captivity for one week following capture and finally released at their capture point. From March to august 2010, fish were tracked using Vemco™ VR100 receiver mobile once a week. Omnidirectional hydrophone and coded transmitters are used in this study.

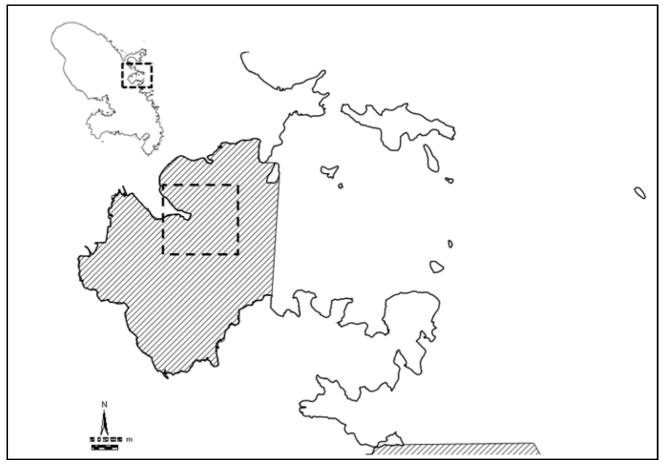

Figure 1. Location of Robert's MPA (black line) in Martinique.

Target Species Selection

A. *chirurgus* and *S. chrysopterum* species were selected according to their trophic group. Thirty *A. chirurgus* (herbivorous species) were tagged. For this species, the distance between anal fin and anus was too small to implant a transmitter. It was thus inserted 0.5 cm above the fish anus.

Number of detections obtained with the 21 *S. chysopterum* individuals tagged was not enough to allow for data analyses. The second group of species (*S. viride*) was chosen, because they belonged to the same family and trophic group. Fourteen *S. viride* were tagged in this study.

Data Analyses

Movement data were obtained using Animal Movement Extension (Hooge and Eichenlaub 1997) for ArcView 3.2 (ESRI, Redlands, CA, USA). Home range sizes were calculated from active tracking positions using kernel utilization distributions (KUD) and minimum convex polygon (MCP) areas (Kernohan et al. 2001). KUD is a probabilistic method that calculates the area of probability of finding a fish based on position data; we used 50% KUD to represent fish core enters of activity and 95% KUD to calculate the animals' home range. MCP estimate the maximum area covered by each fish (Worton

1989, Seaman and Powell 1996). Null hypothesis, that displacements of each detected fish were random was tested using site fidelity test (Wetherbee et al. 2004). This test compares observed data with 100 simulated data by a Monte Carlo simulation (Okubo 1980, Spencer et al. 1990, Hooge and Eichenlaub 1997, Wetherbee et al. 2004). Mean squared distances from the center activity (MSD) and Linearity Index (LI = (linear distance between detection first point and last point /cover distance) were generated by simulations.

Mark-recapture Study

The second method used to evaluate ability displacement of this species was the "mark-recapture" technique. In this study, 1,400 individuals belonging to three different fish species were tagged: 700 *A. chirurgus*, 220 *S. viride* and 500 *S. chrysopterum*. Fish were trapped with Antillean traps, tagged, and released at their point of capture.

RESULTS

Minimum Convex Polygon and Kernel Analyses

Habitat Robert's bay is made up of silt (83.3 %) and rocky substrate (coral reef zone) (16.7%) (Legrand et al. In press). Active tracking was realized preferentially on coral reef, a vital zone. Nevertheless, the silt area was also investigated but less frequently (one time every 15 days).

Kernel analyses were only possible for two *A. chirurgus* which were detected enough times. Each fish presented important differences in home range surfaces. Indeed, MCP varied between 5 238 m² and 9 444 m². The same observation can be made for KUD 95% which varied from 24 108 to 31 863 m^2 and KUD 50% from 3 406 to 5 913 m^2 (Table 1, Figure 2).

Three male *S. viride* were detected enough times to permit an analysis. The three individuals presented very different MCP and KUD 95%. MCP of individual number 158 was eighteen times larger than for individual number 153. We observed that the smallest individual had the largest home range (Table 1, Figure 3).

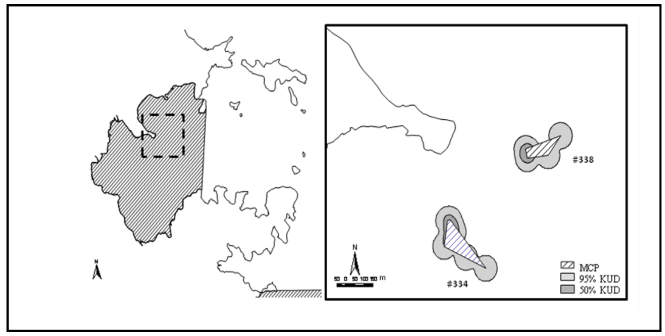

Figure 2. Patterns of two *A. chirurgus* home range: MPC, 50% KUD and 95% KUD.

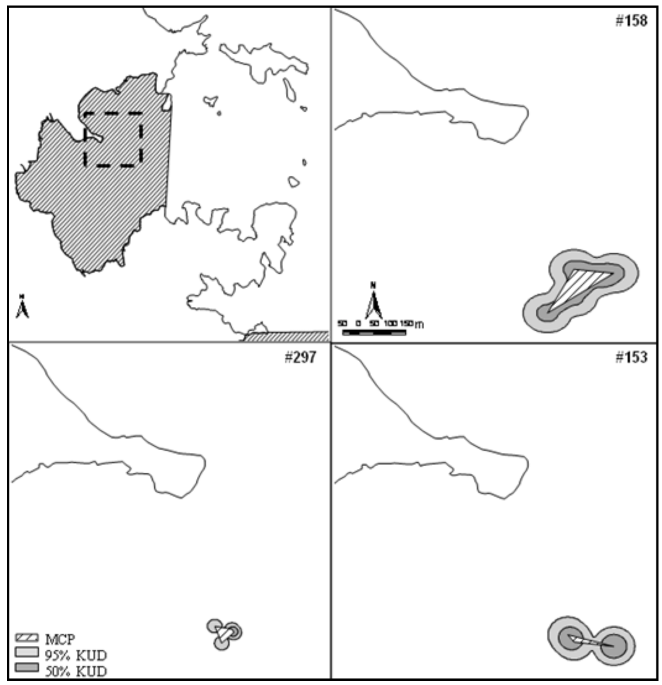

Figure 3. Patterns of three *S. viride* (terminal phase) home range: MPC, 50% KUD and 95% KUD.

Table 1. Home range characteristics of each individual for *A. chirurgus* and *S. viride.* $KUD_{95\%}$: Animal home range with kernel utilization distribution, $KUD_{50\%}$: Core area, MSD: Mean Squared Distances, SD: Standard deviation.

Species	Fish ID	L_F (cm)	Mass (kg)	Home range			MSD		Site fidelity (p)
				MCP (m^2)	$KUD_{95\%}$ (m^2)	$KUD_{50\%}$ (m^2)	Mean	SD	
Acanthurus chirurgus	338	16	100	5 238	24 108	3 406	14433	± 707	0.001*
	334	15.5	80	9 444	31 863	5 913	25 534	± 1151	0.001*
Sparisoma viride	153	24	230	924	19 826	6 588	5264	± 9.1	0.001*
	158	17.5	100	7 548	44 015	17 737	4700	± 194	0.89
	297	22.5	160	1 189	537	3 845	2108	± 88	0.001*

Site Fidelity Test

Null hypothesis was rejected for all fish except individual 158. The observed movements were more constrained than random movements' paths. All other fish seemed to have a site fidelity on the rocky substrate composed of coral and algae or on the seagrass beds at depths between 0.5 and 3 meters (Legrand et al. In press).

Mark-Recapture

Six *A. chirurgus* traveled outside the MPA and were fished at different distances of the point of release. Each individual was caught by fisherman with Antillean traps deployed next to rocky reef habitat. On average, *A. chirurgus* covered 4 km. No *S. chrysopterum* were caught, and only one *S. viride* was fished at 3.7 km (Figure 4, Table 2).

DISCUSSION

Kernel home range and test site fidelity results indicated that *A. chirurgus* and *S. viride* were highly sedentary and had small home ranges. Active acoustic tracking has not permitted to detect every fish each week suggesting they could have travelled outside the MPA. However, another study (G.J, Unpubl. data) using a double fixed receptor barrier, implanted at the MPA boundary, confirmed the permanent presence of fish inside the reserve as no detection were acquired for six months tracking. These results tend to show that we have identified site fidelity of these individual. MPA size appears to be optimal for protection of some fish species.

Our estimate of *A. chirurgus* home range was around 4 660 m² which is larger than results found in the literature. Caribbean fish home range sizes are poorly documented. *A. bahianus* and *A. coeruleus* have a territory of about 100 m (Chapman and Kramer 2000). But, Foster (1985) and Lawson et al. (1999) described that *A. bahianus* executed large foraging schools. In the present study, all fish were

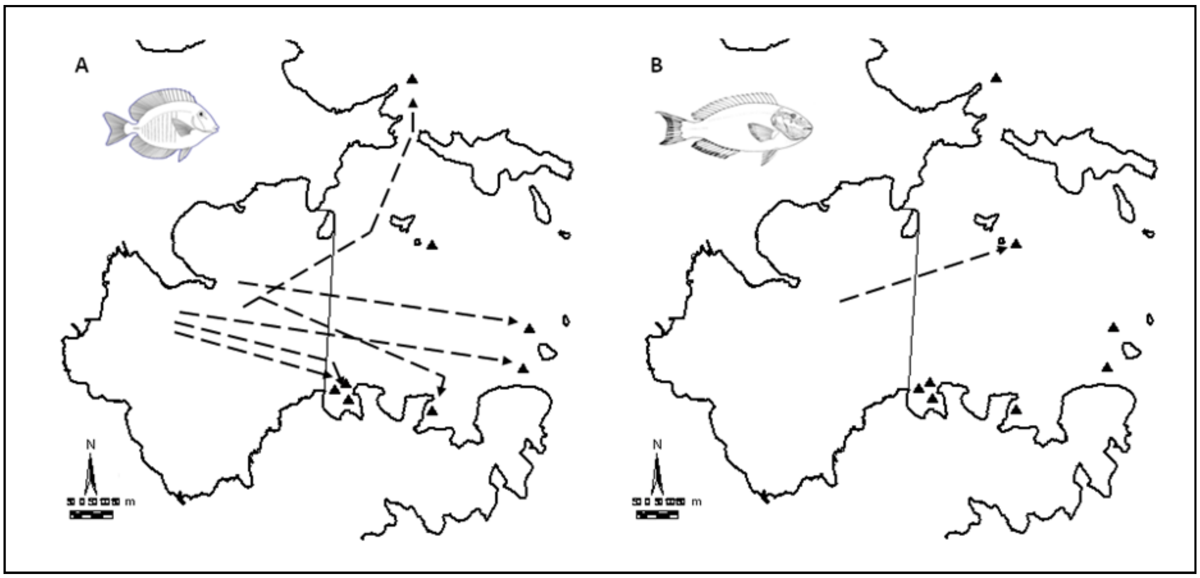

Figure 4. Most direct displacements of two species (A: *A. chirurgus* and B: *S. viride*) between the point of capture (×) and the point of recapture (▲).

Table 2. Longest observed movement of fish between point of capture and point of recapture.

Species	Fish ID code no.	L_F (cm)	Mass (kg)	Longest observed movement(km)
Acanthurus chirurgus	571	17	/	4
	654	16	/	2.4
	975	16	80	4.8
	1371	18,5	120	2.4
	1388	16,5	100	2.4
	1501	16,5	120	4.1
	1728	15	100	2.5
Sparisoma viride	1936	20	140	3.7

recaptured on rocky substrate (algae and corals) and on seagrass beds. Mean territory sizes of *S. viride* in this study (9 390 m²) were larger than in previous works (Chapman and Kramer; 300-529 m², van in Rooiji; 200-800 m²). These evaluations were obtained with different geographic regions and observations techniques.

Eight *S. chrysopterum*. were detected but only at their day of release. Several hypotheses could explain this result:

i) All individuals died within a few days after release, or
ii) All individuals left their fidelity site and travelled outside the MPA.

Fish were captured with Antillean trap which was already demonstrated to cause high mortality rates for *S. chysopterum* (Chapman and Kramer 2000). In our study we managed to keep the fish in good health state for one week in laboratory. However, one *S. chysopterum* was detected five months after release suggesting the first hypothesis not to be accurate. Mumby and Wabnitz (2002) observed that *S. chrysopterum* home range does not depend on the competitor density on the contrary of *S. viride.* This could possibly explain the present results. This predator density dependence could possibly explain the differences observed in *S. viride and S. chrysopterum* detections. *S. chysopterum* home range could be larger than *S. viride* leading to difficulties in acoustic tracking. Other tracking method, using tag with continuous transmitters and directional hydrophone could be employed to better detect site fidelity of *S. chysopterum*.

We noted that the smallest parrotfish individuals had the largest home ranges. However, the number of individuals was not enough to make a safe conclusion. Nevertheless, parrotfish is a protogynous species. Individual 158 (*S. viride*) is a young male and could explore more space than old male.

Nevertheless, we produced different results on recapture using direct tagging. Our external tagging results suggested that Robert's MPA size is smaller than required to obtain optimal protection of species. Indeed, some *A. chirurgus* covered a mean direct distance of about 4 km. Their displacement being probably not straight (linear), they might have travelled longer distances. Chapman and Kramer (2000) suggested that open area constitutes unusable space. Robert's Bay is constituted of small coral reef patches located between 0 and 6 m deep. We assumed that fish used this zone to make their displacements. Thus, estimated distance cover would be more important.

Results obtained with double barrier and thus acoustic tracking we introduce the hypothesis that fish remained in this home range on the site fidelity for long period (< six months). Thus, fish covered a long distance and went out of the MPA for short time. Fish could leave the MPA for different reasons, like reproduction, turbidity, and salinity modifications. The parrotfish group is capable of large movements, especially during the reproductive season (Afonso et al. 2008). Thus, it appears that fish are able to leave their fidelity site, but we have never observed one return to their territory. We suppose that fishing effort, along MPA border, is so high that not much fish could cross the trap barrier.

These two different results demonstrate the limitation of these techniques and their complementarities. The two species used in this study are strongly attached to coral habitat often leading to small home range. Further experiments are currently being carried out to:

i) Better understand home range sizes of semi-pelagic species: *Lutjanus apodus*, and
ii) Better understand the fish displacement processes around MPA areas.

We implanted one double fixed receptor barrier at the MPA boundary and another one outside the MPA but at the external boundary of the bay. This system allowed knowing the time period at which fish execute their displacements outside of the MPA.

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