Spatio-temporal Variability of Otolith Shape of the Red Band Parrotfish (*Sparisoma aurofrenatum*) in Martinique

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ABSTRACT

Otolith is widely used in the study of stocks identification essential for fisheries management. Scaridae are ecologically important in the Caribbean reef fish fauna and are exploited by traditional fisheries. Sagittal otoliths of the red-band parrotfish *Sparisoma aurofrenatum* were examined in order to analyze geographical and temporal variations of populations. Shape indices (roundness, rectangularity) and Fourier descriptors were compared between fishes caught by traps in 2007 in March (dry season) and October (wet season), between fishes from Caribbean and Atlantic sites and between protected and unprotected areas within sites. Temporal and spatial differences both site-specific and level of protection-specific were found. Canonical discriminant analysis based on Fourier descriptors indicated a strong discrimination of *Sparisoma aurofrenatum* populations: 1) between dry and wet seasons, 2) between Atlantic and Caribbean sites and 3) between protected and unprotected areas, with high classification rates. The observed differences in otolith shape may result of environmental effects like stress, type and quality of habitat inducing differences in food quality and quantity. The combination of shape indices and external outline analysis showed that otolith shape is a powerful indicator for population discrimination.

KEY WORDS: Otolith shape, *Sparisoma aurofrenatum*, Martinique

La Variabilidad Espacio-temporal de la Forma del Otolito de *Sparisoma* aurofrenatum en Martinique

El otolito es comúnmente utilizado para la identificación de stocks necesaria para la gestión de las pesquerías. Los Scaridae son importantes ecológicamente en la fauna de los arrecifes del Caribe y son explotados por las pesquerías tradicionales. Los otolitos de *Sparisoma aurofrenatum* fueron examinados par analizar las variaciones temporales y geográficas de las poblaciones. Los índices de forma (redondez, factor de forma, rectangularidad, circularidad y elipticidad) y los descriptores de Fourier fueron comparados entre peces capturados con nasas en 2007en marzo (época seca) y en octubre (época húmeda), entre peces del sitio caribe y del sitio atlántico, y entre áreas protegidas y no protegidas. Diferencias temporales y espaciales (sitio y nivel de protección) fueron encontradas. El análisis de discriminación de los coeficientes de Fourier mostraron una importante separación de las poblaciones de *Sparisoma aurofrenatum*: 1) entre las épocas seca y húmeda, 2) entre los sitios caribe y atlántico, 3) entre las áreas protegidas y no protegidas, con un fuerte índice de clasificación. Estas variaciones fueron relacionadas con diferencias del índice de Fulton. Las diferencias observadas en la forma del otolito podrían explicarse por efectos medioambientales como el estrés y el tipo y la calidad del hábitat que inducen una calidad y une cantidad de dieta distinta. La combinación de los índices de forma y del análisis del contorno externo mostró que la forma del otolito es une índice poderoso para la discriminación de poblaciones.

PALABRAS CLAVES: Otolito, descriptores de Fourier, índices de forma, *Sparisoma aurofrenatum*, Martinique

Variabilité Spatio-temporelle de la Forme de L'otolithe du Perroquet à Bandes Rouges (*Sparisoma* aurofrenatum) a la Martinique

L'otolithe est couramment utilisé pour l'identification des stocks nécessaire à la gestion des pêcheries. Les Scaridae sont une composante importante de la faune récifale de la Caraïbe et sont exploités par les pêcheries traditionnelles. Les otolithes du perroquet à bandes rouges *Sparisoma aurofrenatum* ont été examinés dans le but d'analyser les variations temporelles et géographiques des populations. Les indices de forme (rondeur, facteur de forme, rectangularité, circularité et ellipticité) et les descripteurs de Fourier sont comparés entre des individus capturés par nasses en 2007 en mars (saison sèche) et octobre (saison humide) 2007, entre sites de la côte Caraïbe et Atlantique et entre zones protégées et non protégées pour chaque site. Des variations temporelles et spatiales (site et niveau de protection) ont été trouvées. Les analyses discriminantes canoniques basées sur les descripteurs de Fourier, indiquent une forte discrimination : 1) entre les saisons sèche et humide, 2) entre la côte Caraïbe et la côte Atlantique et 3) entre les zones protégées et non protégées, avec un taux de classification élevé. Ces variations ont été mises en relation avec des différences de coefficient de Fulton. Les différences observées au niveau de la forme de l'otolithe pourraient résulter d'effets environnementaux tels que le stress, le type et la qualité de l'habitat induisant une différence de qualité et quantité alimentaire. La combinaison des indices de forme et de l'analyse du contour externe a montré que la forme de l'otolithe est un outil puissant pour la discrimination des populations.

MOTS CLÉS: Otolithe, descripteurs de Fourier, indices de forme, *Sparisoma aurofrenatum*, Martinique

INTRODUCTION

Parrotfishes (family Scaridae) are very important in coral reef ecosystems in ecological and economical point of view. Scaridae represent one of the two families of herbivorous species in the Caribbean. They play an important role in the transfer of energy from primary producers to the higher trophic levels (Bruggemann *et al.* 1994) and take part in coral reefs conservation through the grazing activities. The red band parrotfish *Sparisoma aurofrenatum* is widely distributed in Caribbean coral reefs ecosystems and is a significant component of traps catches in Martinique. According to (Gobert 1990), traps produce around 60% of benthic catches and Scaridae represent around 14% of total benthic catches in Martinique. Despite the ecological and economical importance of Scaridae, few biological and ecological data on Caribbean parrotfishes are available while informations on population structure and stock discrimination are essential for fishery management.

Otolith analysis is an important tool to study fish populations and recent studies used with success shape analysis of otolith to distinguish groups of fish (DeVries *et al.* 2002, Petursdottir *et al.* 2006, Pothin *et al.* 2006, Tracey *et al.* 2006, Burke *et al.* 2008). Otoliths, small calcified structures located in fish ear, are natural "black box" that record information in their microstructure and chemistry (Campana 1999). This information, including growth, feeding, habitat, can be used at the population level in terms of ecology, demography and life history of species essential in fisheries management and species protection (Popper *et al*. 2005). Otolith shape is species specific (L'Abée-Lund 1988) and often varies geographically within species in relation to environmental factors. Variation in otolith shape is widely considered as a useful descriptor to identify and discriminate fish stocks (Campana and Casselman 1993, Katayama and Isshiki 2007, Stansky *et al*. 2007).

This study investigates if *Sparisoma aurufrenatum* captured at different sites and season around Martinique can be distinguished on the basis of otolith shape.

MATERIAL AND METHOD

Fish Sampling

Martinique is located in Lesser Antilles in South of the Caribbean island arc. This is a volcanic island characterized by mountainous relief and narrow shelves. Unbaited double funnel Antillean-Z traps were used for experimental fishing: 2 x 0.6 x 0.3 m with a mesh size of 31 mm. Trap fishing was conducting in March (dry season) and October (wet season) 2007 and sites were selected on Caribbean and Atlantic coast both in unprotected (FZ) and protected areas (NTZ) (Figure 1).

Figure 1. Location of sampling sites

Laboratory Procedures

Following sampling, each fish was measured (total and standard length in cm) and weighed (total weight in g). Pairs of sagittae were removed, cleaned with distilled water, dried and stored in tubes. Each otolith was weighed to the nearest 10^{-2} mg. Otolith size variables, length (L_o), width (l_o), perimeter (P_o) and area (A_o) were obtained by an image analysis software (Visilog v.5 Noesis).

Otolith Shape Indices

Shape indices result from different combinations of size variables (Tuset *et al*. 2003) (Table 1.). In this study, we focused on roundness and rectangularity. Roundness give information on the similarity of various features to a perfect circle and rectangularity describes the variations of length and width with respect to the area.

Otolith Shape Analysis

The method of elliptic Fourier descriptors was used in accordance with the procedures suggested by (Kuhl and Giardina 1982). Fourier descriptors have been successfully used for the characterization of closed contours. Normalized elliptic Fourier descriptors were calculated with Shape software (Iwata and Ukai 2002). The Fourier analysis indicated that *Sparisoma aurofrenatum* otolith shape could be summarized by 20 harmonics.

Data Analysis

First otolith morphometric variables of left and right otoliths were compared pair-wise using t-test. No difference was found, therefore analysis were performed on otolith from the two sides. All variables were examined for normality (Kolmogorov-Smirnov's test) and homogeneity (Bartlett's test) of variances. Total length of fishes was compared between March and October (temporal level) and between unprotected and protected areas both for Atlantic and Caribbean side (spatial level) for Initial phase (IP) and Terminal phase (TP) using Mann-Whitney non parametric test. Shape indices were compared to determine differences between season and sites. Canonical discriminant analysis (CDA) were performed on Fourier coefficients defining the 20 harmonics to determine spatial (site and protection) and temporal (season) variation of otolith shape. Previously, we have verified that there is no discrimination between IP and TP based on otoltith shape.

Table 1. Otolith shape indices used in this study

Size variables	Shape indices
Length (L_0)	
Width (l_0)	Roundness = $4A_0/\Pi L_0^2$
Perimeter (P_0)	Rectangularity = $A_0/(L_0 l_0)$
Area (A_0)	

RESULTS

Population Structure

In March and October IP catches dominated (Figure 2). Length of IP showed different distribution between seasons (Figures 3 and 4), there was not difference of length distribution between season in the case of TP (Figures 5 and 6). Length of IP was significantly higher in March ($p = 0.003$), but TP length was not different between season ($p > 0.005$). On Caribbean coast, IP catches were higher both in NTZ and FZ (Figure 7). Length of both phases showed a different distribution between NTZ and FZ (Figures 8, 9, 10 and 11) and was significantly higher in NTZ than in FZ ($p < 0.001$). On the opposite, in case of Atlantic coast, TP catches were higher in NTZ and equal to IP catches in FZ (Figure 12). Length distribution of both phases was similar between protected and unprotected areas (Figure 13, 14, 15 and 16), and length was not different between areas with different level of protection ($p > 0.005$).

Otolith Shape Indices

Roundness and rectangularity of different season, sites and level of protection are summarized in Table 2. Roundness was similar between seasons but was higher for FZ than for NTZ both for Caribbean and Atlantic coast. Rectangularity was equal between seasons, sites and level of protection.

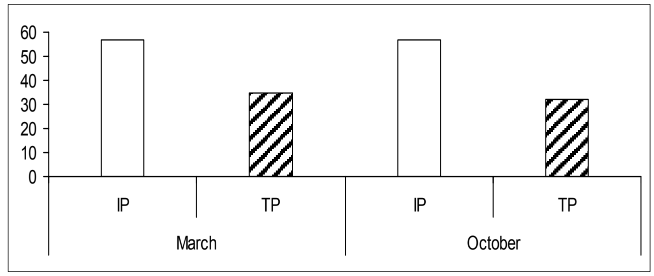

Figure 2. Number of fish of initial phase (IP) and terminal phase (TP) in March and October.

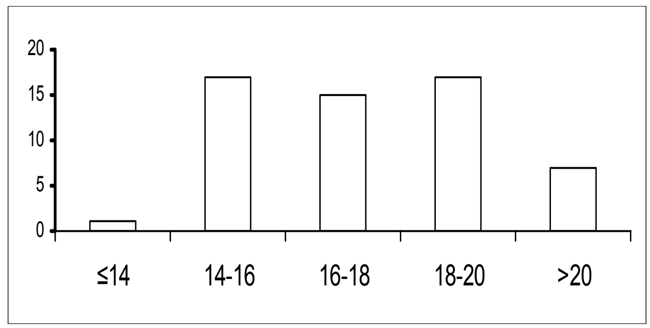

Figure 3. IP length frequency distribution in March.

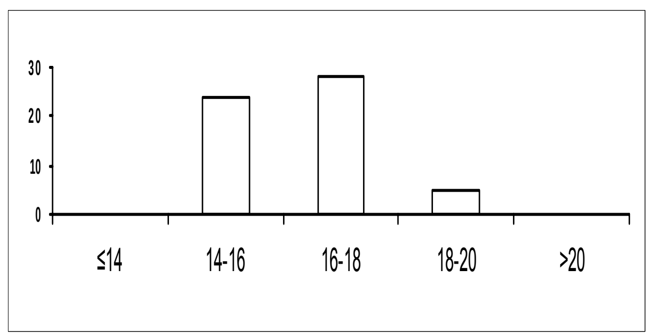

Figure 4. IP length frequency distribution in October.

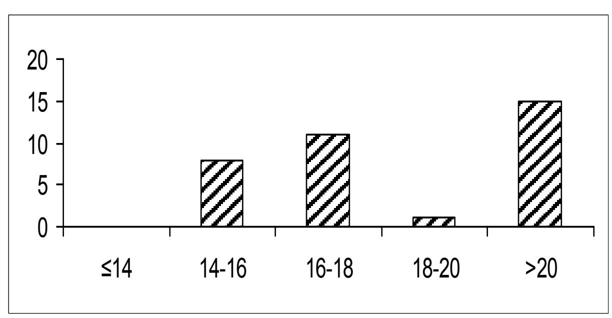

Figure 5. TP length frequency distribution in March

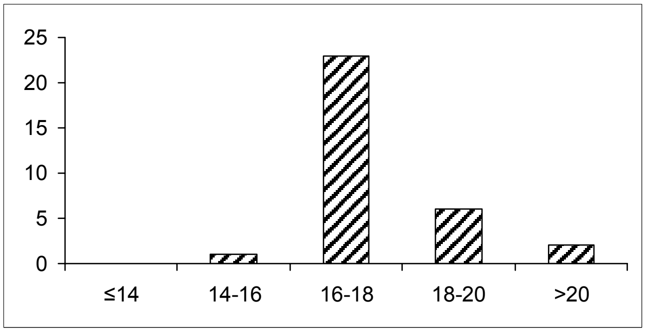

Figure 6. TP length frequency distribution in October

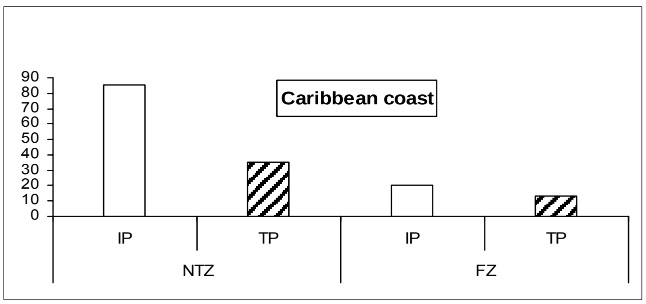

Figure 7. Number of fish of initial phase (IP) and terminal phase (TP) in no-take zone (NTZ) and fishing zone (FZ)

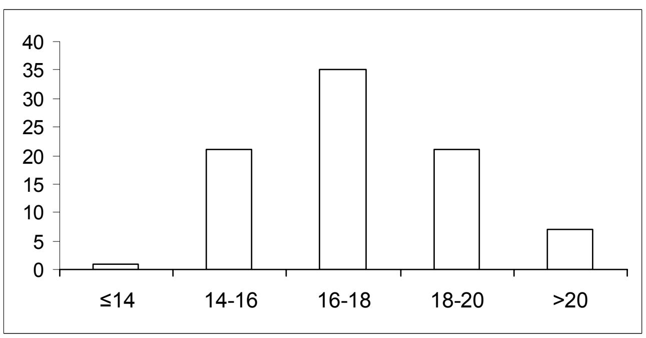

Figure 8. IP length frequency distribution in NTZ of Caribbean coast

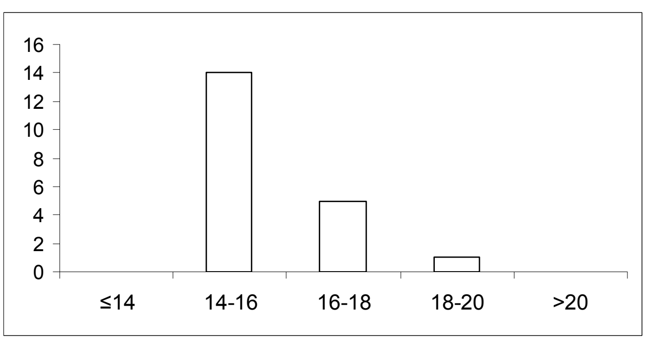

Figure 9. IP length frequency distribution in FZ of Caribbean coast

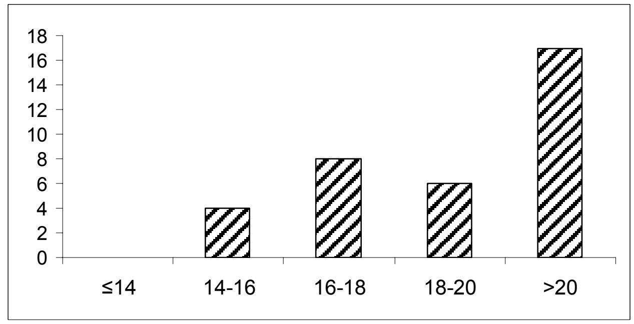

Figure 10. TP length frequency distribution in NTZ of Caribbean coast

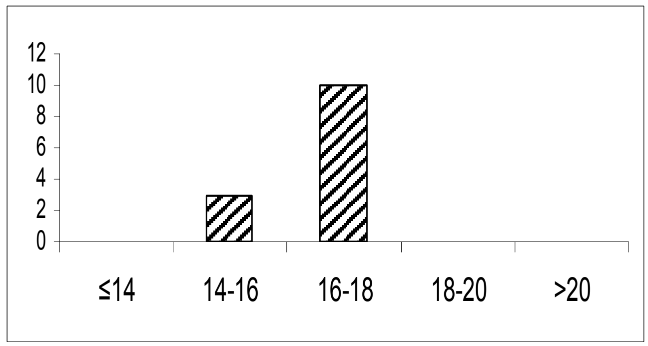

Figure 11. TP length frequency distribution in FZ of Caribbean coast

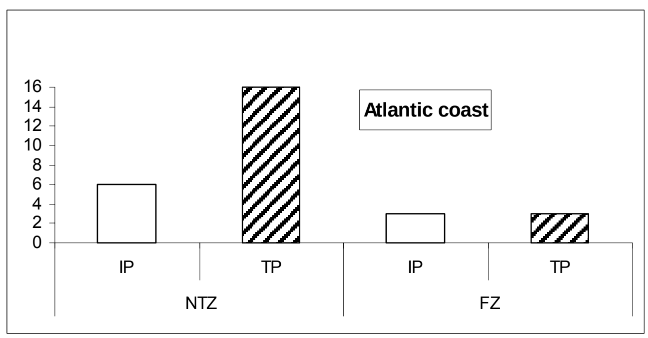

Figure 12. Number of fish of initial phase (IP) and terminal phase (TP) in no-take zone (NTZ) and fishing zone (FZ)

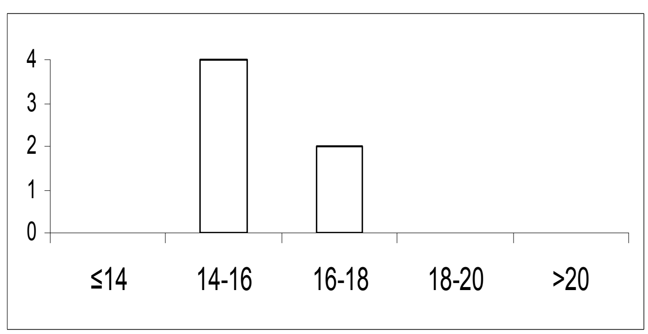

Figure 13. IP length frequency distribution in NTZ of Atlantic coast

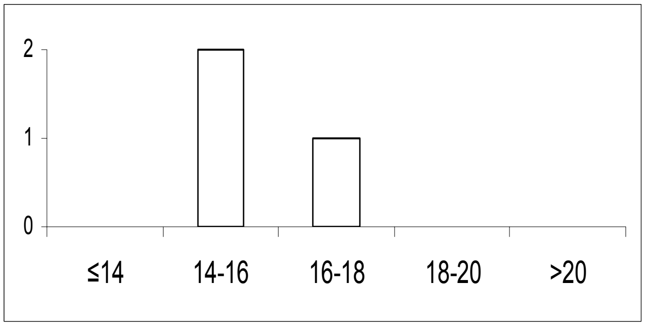

Figure 14. IP length frequency distribution in FZ of Atlantic coast

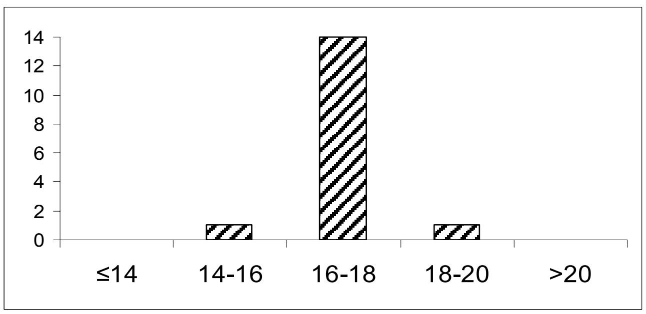

Figure 15. TP length frequency distribution in NTZ of Atlantic coast

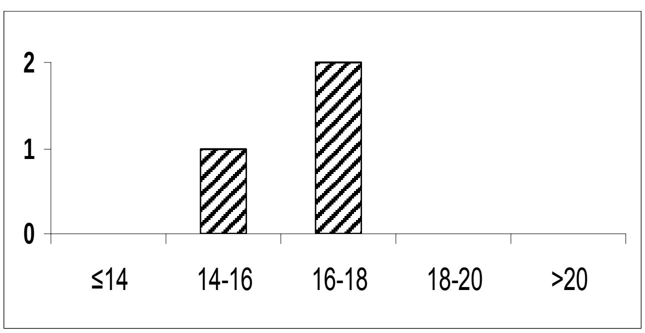

Figure 16. TP length frequency distribution in FZ of Atlantic coast

Fourier Shape Analysis

Figures 17, 18 and 19 show CDAs performed on Fourier descriptors of otolith of *Sparisoma aurofrenatum* from different seasons, sites and level of protection. CDAs gave a classification success of 80% indicating a strong separation between seasons, sites and protected and unprotected areas. The F test associated to Wilk's lambda was highly significant ($p < 0.001$) and 100% of individuals were correctly classified. The estimate of Cohen's kappa confirmed the high rates of classification success.

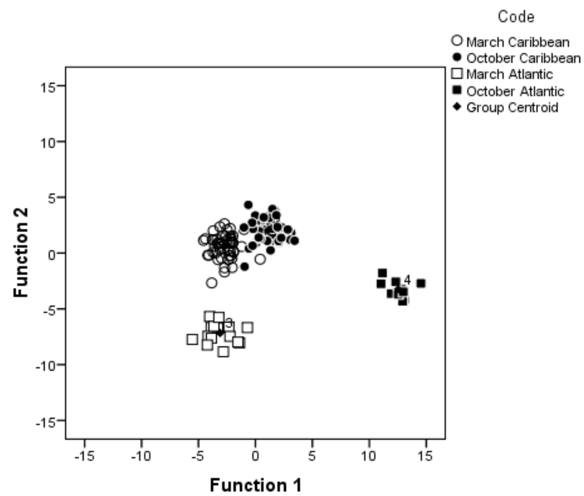

Figure 17. Discriminition between otoliths of *Sparisoma aurofrenatum* from different season and site ($\lambda<0.001$)

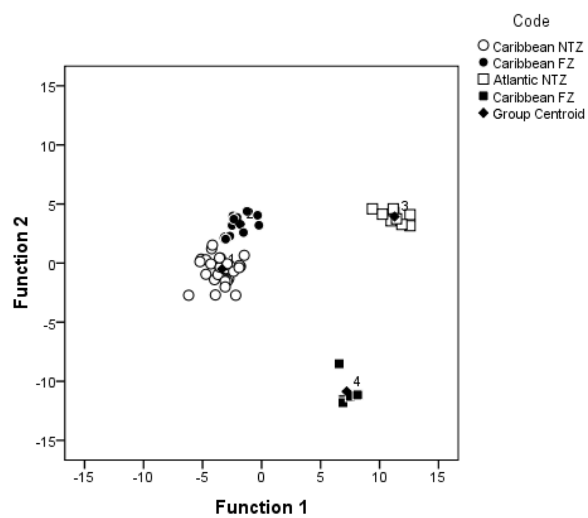

Figure 18. Discrimination between otolith of *Sparisoma aurofrenatum* from protected and unprotected areas of Caribbean and Atlantic sites in March ($\lambda<0.001$)

Table 2. Shape indices for otolith of *Sparisoma aurofrenatum* at different sites and season. Values are mean±SE

	March	October	NTZ Caribbean	FZ Caribbean	NTZ Atlantic	FZ Atlantic
Roundness	0.585±0.003	0.581±0.003	0.576±0.003	0.597±0.006	0.590±0.005	0.610±0.01
Rectangularity	0.74±0.001	0.74±0.001	0.71±0.001	0.71±0.002	0.71±0.002	0.71±0.004

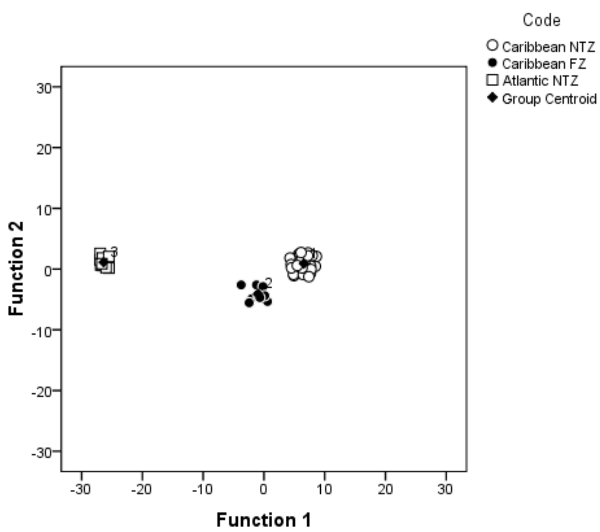

Figure 19. Discrimination between otolith of *Sparisoma aurofrenatum* from protected and unprotected areas of Caribbean and Atlantic sites in October (λ<0.001)

DISCUSSION

Otolith shape analysis was used to distinguish between March and October (temporal scale) fishing *Sparisoma aurofrenatum* from different sites and level of protection (spatial scale). The results of this study showed that a spatio-temporal variability of red-band parrotfish otolith occurred. Several confounding effects must be considered. Indeed sex, age and fish size may influence otolith shape (Campana and Casselman 1993). We have taken both initial and terminal phase but we have previously tested that there is no difference in otolith shape between those phases. In this study, fish length showed different distribution between seasons, site and level of protection but length was not significantly different except between NTZ and FZ for Caribbean coast and between seasons for IP. But according to (Gagliano and McCormick 2004), shape difference could not be attributed to size difference among fish and suggest that shape may reflect fish condition. Differences were observed in roundness at sites and level of protection, but rectangularity was equal between seasons, sites and level of protection. Pothin *et al*. (2006) found differences in all shape indices considered for sites intra-island (Reunion) and sites inter-island (Reunion and Mauritius).

CDA performed on Fourier descriptors indicated a clear discrimination in otolith shape between seasons, sites and level of protection with a rate of accuracy in classification that reached 80%. Different results were found in the literature. Devries *et al*. (2002) obtained about 81.6% accuracy to differentiate stocks of *Scomberonomus cavalla* between the Eastern Gul of Mexico and Atlantic Ocean. (Gonzales-Salas and Lenfant 2007) showed that temporal difference of *Engraulis encrasicolus* occurred between years in the Golf of Biscay with an accuracy > 80. Burke *et al*. (2008) obtained about 84% accuracy for discriminate *Clupea harengus* from Celtic and Irish Seas. Thus, analysis of sagittal shape using Fourier descriptors is a powerful indicator for showing temporal and spatial differences. Campana and Casselman (1993) suggested that environmental factors are generally more influential determinants of otolith shapes than genetic. Differences in otolith shape in this study occurred between groups of fish that are close or very close geographically: island scale (Caribbean and Atlantic coast) and protection scale (NTZ and FZ). It is probable that those differences are driven by environmental factors. Spatial and temporal variations of otolith shape in this study could derived from environmental variations as stress, differences in type and quality of habitat inducing differences in food quality and quantity inducing differences in fish condition and growth rates. Other tools as otolith chemistry, tagging and genetic could be useful in order to follow the dynamic of *Sparisoma aurofrenatum* stocks.

ACKNOWLEDGEMENTS

We thank the Regional Council of Martinique for the financial support and IFREMER and Observatoire du Milieu Marin Martiniquais for the technical support. We are grateful to the fishermen who work with us on the field.

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