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Bycatch of Shrimp Fishery in the West Coast of Madagascar: Case of *Otolithes argenteus* (Cuvier, 1830)

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Abstract: An increasing interest of the economic operators on the bycatch of shrimp fishery endangers bycatch species to over-exploitation risks. This study provides a better knowledge regarding to the current status of one major component of the bycatches: *Otolithes argenteus* (*O. argenteus*) caught in the shrimp fishery area along the West coast of Madagascar using the morphometric analysis. Individual body weight and body measurement were carried out on 565 specimens collected from the sale's society of seafood (SOPROMER) in the Capital city. Results show a high proportion of small fishes like as immature young individuals. A "negative allometry" growth type within the juveniles to become "isometric allometry" for the adult, large size was observed. Marine environment is favorable to the development for the whole population of the *O. argenteus* species. The morphometry approach helped to better understanding of the characteristics and the operating status of the *O. argenteus* population thus constitute as a tool in establishing a sustainable fisheries management strategy in Madagascar.

Key words: *Otolith argenteus*, morphometry, bycatch, West coast of Madagascar.

1. Introduction

The fisheries sector represents a key sector for economic development in Madagascar [1, 2]. Marine fisheries are a predominant, a major export commodity for Madagascar and important source of foreign currency income of around 7% in value for the year 2010 [3]. Despite the development of the tuna fishing industry in the past decade, Penaeid shrimp remains the largest export fishery product with 65.81% of the total export earnings in 2010 [4, 5]. The capital city is the second most important destination of fishing products originating from 13 regions in Madagascar with 35.34% of total shipments [3, 4]. These fishing products are dominated by auxiliary products of the shrimp fishery termed "bycatch" [6]. Bycatches have long times been considered as waste for their low market values compared to that of shrimp. Faced with nutritional problems, Madagascar's fishing authority, implemented a mandatory landing of at least 0.5 kg of fish to 1 kg of shrimp since 1998 [7] to supply the local market. Due to progressive increase in energy prices since 2001, considered as the main reason in decrease of shrimp fishing profitability, operators had to develop bycatch products [8, 9]. The effort to increase bycatch landing quantity resulted in a decrease in discard accompanied by a price increase and subsequently exposed bycatch species to over-exploitation risks. *O. argenteus* belongs to the family Sciaenidae, commonly called "croakers" is one of the major component of the bycatches (contribute more than 16%) in the shrimp fishery along the West coast of Madagascar [7]. This specie is one of high commercial value and highly sought on the local market [6] but remains little known. Genome analysis and external examination of fishes are the foundation studies in biology of populations. Thus, this study aims to assess the current status of *O. argenteus* in its production and commercial context through integrated morphometric approach to biometrics [10, 11] in order

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to establish a strategy for sustainable management for Malagasy fish stocks.

2. Material and Methods

2.1 Materials

In this study, *O. argenteus* caught on the Western coastal fishing area of Madagascar was the target specie. A total of 565 specimens were collected for the morphometries data (body weight and body measurement) during the period of January to March in 2014.

These measurements were effected with: (1) electronic kitchen scale with a 3 kg maximum range and a precision of 1 g for body weight; (2) artisanal ictiometer constituted a platform on which is affixed a metric tape with a 65 cm range and a precision of 1 mm and (3) electronic caliper with a 50 cm range and a precision of 0.02 mm for external measurements. SAS JMP 5.0.1 software was used for data analysis.

2.2 Methods

The intact body shape without deformations and no more than 50% defects from the head to the caudal fin were the only individual inclusion criterion.

Individual weight (P) and eight external body measurements were taken for each fish including two lengths measurements such as the total body length (LT) and the standard length (LS); maximum body height (HC), width at the maximum body height (+E), peduncle height (HPC), cephalic length (Lte), head height (Hte) and eye diameter (DO) (Fig. 1).

All body measurements were carried out to the nearest 0.5 cm except for ocular diameter (nearest 0.5 mm) [12, 13].

Standard statistical analysis, including range, mean, standard error and coefficient of variance were used for a qualitative and comparative analysis of the morphometric performances of the species [14, 15].

Some growth and ecological biometrics index were calculated and used for individual categorization as well as to evaluate the influence of ecology on the species:

(1) Index profile (IP) was used for individual classification regarding to the external conformation [16, 17] by Eq. (1):

$$IP = \frac{Standanrd\ Length}{Maximum\ body\ height} \quad (1)$$

(2) Index sction (IS) in order to distinguish the variety and to characterize the muscular efficiency of fish [16, 18] by Eq. (2):

$$IS = \frac{Maximum\ body\ height}{Width\ at\ the\ maximum\ body\ height} \quad (2)$$

(3) Allometric model (Length-weight relationships) is important in fisheries biology; it is often used for estimating the weight corresponding to a given length,

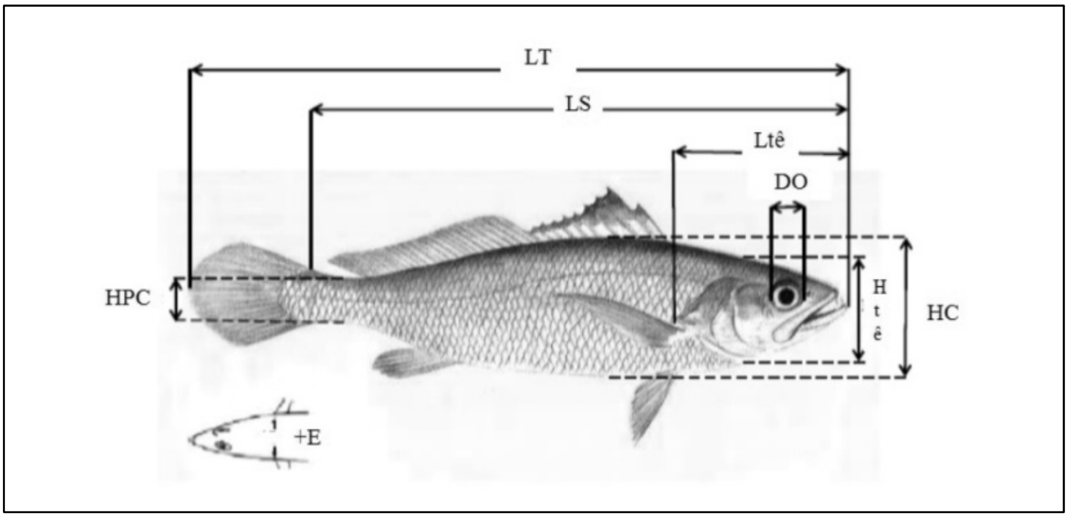

Fig. 1 External morphometric characters measured from the *O. argenteus*.

for predicting growth, corpulence and variations during the growth and may be also used to determine possible differences between separate unit stocks of the same species [19-36] using Eq. (3):

$$P = a\,(LT)^b \tag{3}$$

with P: Weight (g) and LT: Total body length (cm). which was transformed to linear form as Eq. (4):

$$LogP = Loga + bLog(LT) \tag{4}$$

(4) Condition coefficient (K) provides information on the variation of fish physiological status, and used as indicators to the characteristics of fish, such as health, “well-being” and growth, but also the characteristics of the ecological condition, such as habitat quality, water quality, feeding activity of a species, and tropic resources availability and it is still one of the most commonly used conditions today [23-25, 37-44].

In this study, Fulton’s condition factor (K) was used Eq. (5):

$$K = \frac{P}{(LT)^3} X\,100 \tag{5}$$

with P: Weight (g) and LT: Total body length (cm).

3. Results and Discussion

3.1 Analysis of Population Structure

A very high frequency of low weight fishes between 25 g and 100 g was observed (n = 328 or 58% of the total population) (Fig. 2a). In addition, the total length distribution showed a modal group between 16 and 17 cm (n = 53 or 9.4% of the whole population) (Fig. 2b).

Therefore, it can be inferred that the population of *O. argenteus* has high heterogeneity. For the bycatch in shrimp trawl fishery, small size fishes including individuals of *O. argenteus* represent the main fraction of catch, even if the sizes of the target specie in this study varied considerably from young to adult stages. This high variability of the population is due to the presence of individuals of various physiological stages [45-47].

Moreover, the high frequency of small size fishes observed in catches and sales of bycatch species, including *O. argenteus* indicates a low selectivity of the fishing gear used, but also a low discard rate in shrimp trawl fishery. Hence, it can be suggested that more than half of the catch are individuals of very small size that are probably still immature. Indeed, the total length is considered as an adequate predictor of the physiological state of a fish [48]. The *O. argenteus* mature size in African waters is 23 cm, size at which it is estimated that more than half of individuals have reached their sexual maturity [49]. This indicates that the rate of immature fish in the catch of shrimp trawl fishery in Madagascar is very high (80% of the population of *O. argenteus* in the present study). This is due to increased production costs and sought after revenue of the bycatch as a key component in the profitability of shrimp fishery, requiring operators in the sector to adopt a strategy of lower discard rate which was around 15% in 2005 [7]. In addition, *O. argenteus* is a popular species among local consumers [6]. The frequency of low weights and short lengths appearance of *O. argenteus* sold in local markets in Antananarivo contribute to the conclusion of the preponderance of individuals of very small size in the population. However, the profusion of small size fishes in the catch may indicate an overexploitation state of fish stocks [50].

3.2 Population Characteristics

Four morphometries groups (group A, B, C and D) significantly different (p < 1‰) were distinguished by analyzing *O. argenteus* population (Table 1).

The most abundant sampled (n = 364; i.e. 65% of the total population) were composed of very small size (group A) *O. argenteus*. This group was characterized by a mean weight of 56.44 ± 23.33 g; a total length of 15.45 ± 2.38 cm and a standard length of 13.80 ± 2.22 cm. In contrast to the group D, composed of very large size were in the minority in this *O. argenteus* population, representing by 23 individuals (4% of whole population) and characterized with a mean

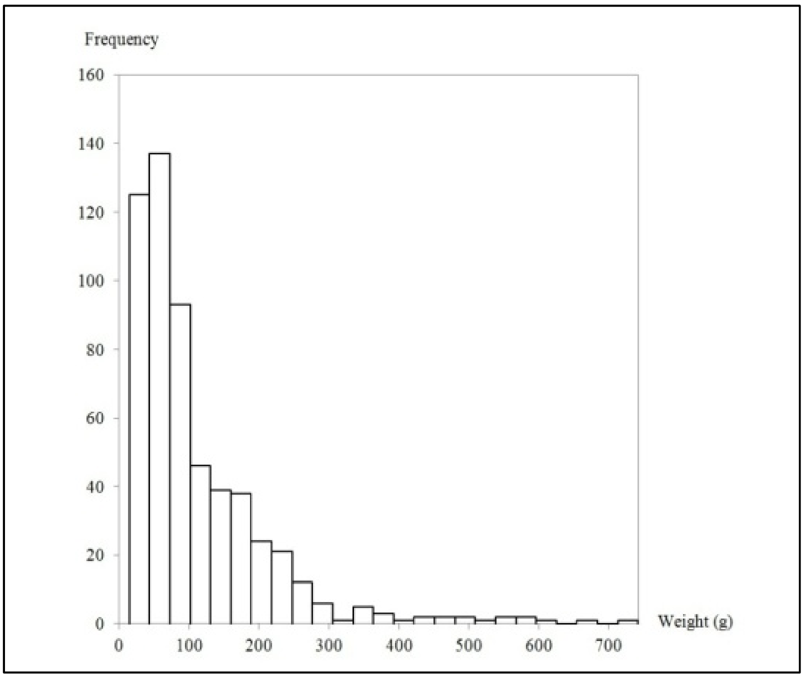

Fig. 2a Ponderal distribution of the *O. argenteus*.

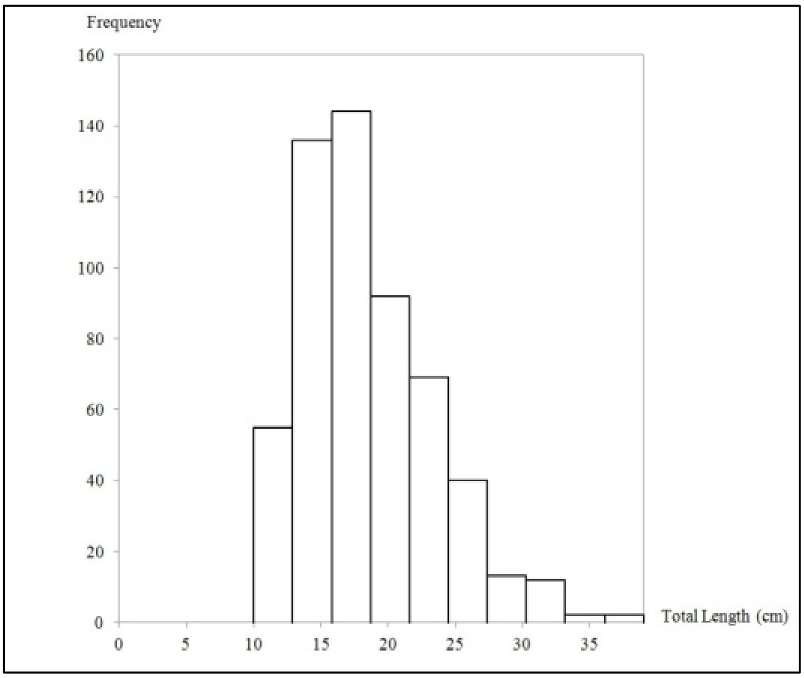

Fig. 2b Size distribution of the *O. argenteus*.

weight of 472.83 g ± 114.60 g, a total length of 31.63 cm ± 2.85 cm and a standard length of 28.96 cm ± 2.27 cm. In addition, two more intermediate group (group B and group C) were also categorized; the group B (n = 125; or 22% of the total population) was composed of small size fish; this group was characterized a mean weight of 149.74 g ± 27.48 g; a total length of 21.56 cm ± 1.84 cm and a standard length of 19.39 cm ± 1.49 cm. The group C (n = 53 or 9% of the total population) was composed of a moderate size fish (mean weight of 241.74 g ± 28.46 g; a total length of 25.23 ± 1.58 cm and a standard length of 22.41 ± 1.08 cm).

Table 1 Morphometric parameters of *O. argenteus* in the West coast fishing area of Madagascar.

Morphometric characters	Weight (g)	LT (cm)	LS (cm)	Ltê (cm)	Htê (cm)	DO (cm)	HC (cm)	HPC (cm)	+E (cm)
Pooling data (n=565)	111.42±101.50	18.38±4.93	16.46±4.49	4.99±1.42	1.02±0.20	3.41±0.89	4.64±1.32	1.54±0.50	2.81±0.85
Group A (n=364)	56.44±23.33	15.45±2.38	13.80±2.22	4.18±0.81	2.91±0.49	0.93±0.15	3.84±0.63	1.27±0.36	2.33±0.49
Group B (n=125)	149.74±27.48	21.56±1.84	19.39±1.49	5.89±0.66	3.92±0.48	1.12±0.16	5.49±0.49	1.84±0.19	3.34±0.38
Group C (n=53)	241.74±28.46	25.23±1.58	22.41±1.08	6.93±0.59	4.78±0.39	1.28±0.11	6.58±0.33	2.14±0.09	3.97±0.30
Group D (n=32)	472.83±114.60	31.63±2.85	28.96±2.27	8.46±0.76	5.38±0.64	1.38±0.14	8.12±0.62	2.67±0.27	4.90±0.50

There was high significant relationship ($r > 0.82$; $p < 1‰$) between the body weights and other mentioned morphometric parameters of *O. argenteus*; it was revealed that the individual length and body width increase at the same rate. The highly significant relationships between the body weight and standard lengths ($r = 0.937$; $p < 1‰$) indicated that the body weight of the *O. argenteus* could be estimated with a fairly high degree of accuracy ($p < 1‰$) from known standard lengths compared to the total length. Whereas the lowest correlation ($r = 0.729$; $p < 1‰$) were obtained between the eye diameter to the other morphometric parameters. However, the eye diameter does not present a major influence not only in the ponderal growth but also in its growth in weights and lengths ($r = 0.729$; $p < 1‰$).

So, it was found that relationship between individual body length to the body weight and the other morphometric parameters showed positive proportionate relationship for each group. This indicated a spatiotemporally harmonious development of the individual in his habitat.

The weight and the relative body measurements are useful in order to establish the commercial shape of a fish [51]. The observed differences between *O. argenteus* caught from the West coast of Madagascar to other studies can be due to differences in sampling, fishing ground characteristics, fishing gear, food availability and fishing season [43].

In Madagascar, large size *O. argenteus* were caught into the fishery during the beginning of shrimp fishing season (March-May), which was April in India. In the other hand, large size bycatch are rarely caught, and the small one are retained and landed during the end of shrimp fishing season, i.e. from September to November [7, 52]. Indeed, the sample of this study were obtained from fishing activities around the end of shrimp fishing season (stock of SOPROMER from January to March 2014) source of abundance of the small size individuals in the population.

The findings regarding body weight (in the range from 107 g to 202 g, mean weight of 149.74 ± 27.48 g ; n = 125) and mean total length (21.56 ± 1.84 cm) of the group B in the present study correspond well with the previous findings (mean weight of 108 g and a mean total length of 21 cm) [7].

In otherwise, observed extreme (minimal and maximal) values distribution shows an important difference between the two studies.

In this study, the total length ranged from 10 cm to 39 cm, value comprised in the range of 5.5 cm to 46 cm [7].

This range would be a fishing methods and fishing gear used by the industrial shrimp fisheries indicators which didn't retain very small size individuals. So, large size specimens became rare at the end of the fishing season.

Small-scale trawler use a lower selectivity fishing gear (they will capture individuals into the range of a total length of 5.5 cm), instead of the industrial one with bigger specimens (able to capture individuals into the range of a total length of 46 cm), especially at the beginning of the shrimp fishing season [7]. Also, industrial fishery is operated in large shore (deeper as 40 m) which is the predilection area of the adult, compares to the artisanal fishery which is more coastal and in shallow water (until 30 m); there are place for the juveniles and non-matures individuals [7, 45, 53].

Smaller individual captured fish varied according to fishing area. In Madagascar, the smaller sizes corresponding to a total length of 5.5 cm are retained as bycatch of the shrimp fishery [7]. The maximum value of this smaller size was observed in Percic Golf (a total length of 29.6 cm) [36]. As the same time, the maximum size of captured fish was varied between fisheries. The smaller value of the maximum total length (32 cm) was recorded in Mozambique [54-56] against a longest *O. argenteus* (59 cm) observed in the South of Iran [57]. In this study, a population of small size *O. argenteus* was noted (total length varied at 10 cm to 39 cm) compared to that captured in Yemen (21.8 cm to 42.5 cm) [36] and in Kuwait (14.5 cm to 45.5 cm) [38] as well as in India (11.2 cm to 42.5 cm) [52].

Indeed, the physical characteristics of the population are the resultants of their adaptations to the environmental conditions. Variations can be noted according to the level of the anthropic stage, food availability, physicochemical conditions of the fishing area and the fishing season. These variations influence spatiotemporally the genetic print of the species. This variation affects the genetic fingerprint of the species in time and space [58]. In addition, the abundance of very small sizes fishes (group A = 64%) consolidates the assumption concerning an overexploitation [50].

The correlation degree between the morphometric parameters is specific, however it can present a small variations from one population to another [10, 59]. This relationship is very important, in order to choose the morphometric parameters used to estimate the weight. For *O. argenteus* in this study, the standard length (r = 0.937) was selected and used to model the Le Cren [20] equation in order to establish the length-weight relationship in biometrics of fish [44].

3.3 Growth Studies

In Western part of Madagascar shrimps fishing area, mensural characters of the population of *O. argenteus* shows a «negative allometry » growth type (Table 2).

Modelling the regression equation between the size and the weight is a key factor in fish biology as well as in aquatic resources management [36, 60]. This equation allowed to estimate a weight of one individual from its size, and is mainly used in fish biometry [52, 61]. However, any variations could be observed through the season's year, although those variations are less effective within the tropical species, where climatic factors are less variable [23, 24].

In addition to the fact that a high correlation was observed between the weight and the standard length (r = 0.937), the use of the standard length to estimate weight of fishes, especially in frozen conserved population, was most obvious [36]. However, obtained results are close to those who were analyzed using the total length parameters or the fork length.

Allometry rate «b» value is characteristic for one species. However, this value can be influenced by some environmental factors, and then the growth type shows a variation according to trophic and environmental factors of fish's habitat.

O. argenteus species shows mostly an isometric growth type, as in India (b = 3.040; R^2 = 0.9901) [41], also in Kuwait (b = 2.916) and in the Persian Gulf (b = 2.890; R^2 = 0.9461) [36], as in the west coast of

Table 2 Growth type.

	Allometric equations	R^2	Standard deviation	*p*	n	Growth type
Pooling data	$LogP = -1.55 + 2.88Log(LS)$	0.9657	0.008	< 1‰	565	Negative allomety
Group A	$LogP_A = -1.26 + 2.62Log(LS_A)$	0.9011	0.046	< 1‰	364	Negative allometry
Group B	$LogP_B = -0.31 + 1.93Log(LS_B)$	0.6447	0.130	< 1‰	125	Negative allometry
Group C	$LogP_C = 0.17 + 1.64Log(LS_C)$	0.4848	0.240	< 1‰	53	Negative allometry
Group D	$LogP_D = -1.58 + 2.91Log(LS_D)$	0.8646	0.260	< 1‰	23	Isometric growth

Madagascar with the group D of this study (b_D = 2.910; R^2 = 0.8646; n = 23).

In certain cases, the growth type of the species is the «negative allometry» type, as in South Africa (b = 2.790) and Yemen (b = 2.334) [36], also in the coast of Thoothukudi in India (b = 2.835; R^2 = 0.8851) [52] and in the west coast of Madagascar for the present study: for the group A (b_A = 2.620); R^2 = 0.9011; n = 364), for the group B(b_B = 1.930; R^2 = 0.6447; n = 125) and the group C (b_C = 1.640; R^2 = 0.4848; n = 53), or on the whole population (b = 2.884; R^2 = 0.9657; n = 565).

In contrary, this growth type is rarely the «positive allometry» type, as in Mannar Gulf in India (b = 3.243; R^2 = 0.9781) [62].

Adding to this issue, the determination coefficient value (R^2 = 0.9657; p < 1‰) reflects an important part of the standard length, in the topic to be able to explain the individual weight variation.

Thus, the observed «negative allometry» growth type could be assessed that within the *O. argenteus* species, the growth in length is more obvious than the weighting one [23, 24, 63].

The individual grows more in length before the corporal musculature mass structuration. In other hand, «negative allometry» growth type was confirmed for the three first morphometric group (A, B and C), when the group D testify an «isométric» growth type.

Indeed, it can be deduced that those different growth type reflect three distinct periods according to the physiological stage of the individual, according to the following succession:

(1) One period of weight growth within the juveniles, for the very small size individual group (A);

(2) One period of strong length growth instead of the weight (young), observed through the intermediate size individual (B and C group);

(3) One period of slowing down the length growth, when the muscular mass is more structured (adult), corroborated by the fact that weight growth is more obvious within the large size group (D).

Thus, a «negative allometry» is for the small size individual in strict stage of growth, when «isométric» and «positive allometry» reflects a strong proportion of big size individual at their final stage in commercial fish.

3.4 Habitat State

About the environmental adaptation and for the whole population of the *O. argenteus* species (K_{min} = 0.832; K_{max} = 2.395; p < 1‰; n = 565), an average value of the condition coefficient «K» about 1.478 ± 0.229 was calculated. This result means that the population of *O. argenteus* from the shrimps fishing area of the west of Madagascar is under influence of the same environmental condition and shows one homogeny adaptation to the environmental condition.

This kind of adaptation supposes one environment which is favorable to the development of the species, independently of their physiological stage and the non-existence of food competition (p > 0.21 between the morphometric groups).

Probably, younger individual of *O. argenteus* are more oriented to the zooplankton as food resources, when the adult check shrimps and fish. Thus, the bigger specimen faces more difficulty to feed themselves instead of the juvenile [64]. Then, the bigger specimen can be characterized by a lower condition coefficient. However, in this study, values of «K» are not significantly different independently of the group of size.

In addition, water area in western part of Madagascar owns three of the four shrimp's stock area of the island, providing an abundant food sources to the adult *O. argenteus*. Geographically, the western part of Madagascar shows a multitude of waterway, which bound to the Mozambique Channel with a large surface of mangroves as a nursery for the younger *O. argenteus*. Whatever the physiological stage, those elements show one good habitat for the development of the *O. argenteus*.

Then, feeding status couldn't be considered as a limitation factor, in term of growth, for the *O. argenteus* in the western part of Madagascar [7].

3.5 Biometric Index

Profile and section indications calculation shows homogeneity of the *O. argenteus* population, with a variation of coefficient respectively about by 7.8% and by 14.5%.

Concerning the profile indication of the population, lower amplitude was observed with a minimum of 2.83 and a maximum of 4.81. In addition, no significant difference was observed between the morphometric groups ($p > 0.05$). Thus, it was proved that the population of *O. argenteus* in this study shows rapidly a length growth instead of a height growth ($IP_{moyen} = 3.57 \pm 0.28$).

For the section indication, the observed amplitude for the whole population was lower with a minimum of 0.92 and a maximum of 3.80. In addition, no significant difference was observed between the morphometric groups ($p > 0.05$). Thus, it can be assessed that the population of *O. argenteus* has a good muscular proportion rates ($IS_{moyen} = 1.68 \pm 0.24$).

The general form of the body is similar for the whole individuals of the *O. argenteus* population. For the section and profile indications, the homogeneity of the individuals allowed us to determine that there is no genetic variability within this population, corroborating a considerable trophic richness which induces homogeneity of the growth and an acceptable muscular result in time and space.

Within one same species, biometrical indications are under the influence of severe population variations, according to the food resources availability, which is so determinant in new characters apparition, and those characters should be transmissible through the time and space [17].

Then, an abundance of food induces rapidly a muscular development instead of the skeletal growth, providing short and stocky individuals. In contrary, if there is a food stress, the body became thin and decrease in height and thickness, to finally develop a thin length body [65].

Also, waters areas in western part of Madagascar are rich and permit an acceptable development of the *O. argenteus* population. Thus, biometrical index found in this study are low value (profile indication = 3.57 ± 0.28; section indication = 1.68 ± 0.24; n = 565), and the *O. argenteus* population shows a certain homogeneity. It can be deduced that this homogeneity reflects the fact of no food competition, and then this population is characterized by a height and thickness of the body instead of the length [65].

4. Conclusion

The authors can conclude that, by the fact that there is more juveniles found in the market, this study tends to shows an over-exploitation of the stock of *O. argenteus*. However, the species is resistant to this situation. It is not only result from the excellent trophic and environmental factors, but also related to the prolificacy and precocity of the species.

Thus, three months closing in annual fishing season seems yet enough to regenerate the stock. However, the intensification of the exploitation provokes an obvious reduction in size of *O. argenteus* captured. For sure, this situation will not affect their economic value because this species should be calibrated before trading takes place, and their unite price (in kilogram) is closely related to their calibration.

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References

[1] Andrianaivojaona, Ch., Kasprzyk Z.W., and Dasylva, G. 1992. *Fisheries and Aquaculture in Madagascar: Diagnostic Assessment.* Food and Agriculture Organization–Ministry of Animal Production (Livestock and Fisheries) and Forestry, Fisheries and Aquaculture. report.

[2] Andriantsoa, M. H., Randriamiarisoa. 2013. *Characterization of Marine Fisheries in Madagascar, Statistical Systems of the Ministry of Fishing and Fishery Resources and Designing Activities for the New System to Monitor Catches (Industrial, Artisanal and Traditional fishery) in Madagascar.* report.

[3] Anon. 2012a. *Instead of Study on the Market of Fish Products in the City of Antananarivo–Analysis of Shipping Seafood Data. Economic Observatory of the Shrimp Industry and Statistical Service of the Ministry of Fishing and Fishery Resources in Madagascar.* report.

[4] Anon. 2012b. *Overview of Trade in Seafood through Fish Markets: Case of the City of Antananarivo. Economic Observatory of the Shrimp Industry and Statistical Service of the Ministry of Fishing and Fishery Resources in Madagascar.* Preliminary report.

[5] Raboanarijaona, H. Z. 2013. *Ongoing of Fishing Communities for Francophone Countries of West and Central Africa to Japan: Case of Madagascar. Ministry of Animal Production (Livestock and Fisheries) and Forestry, Fisheries and Aquaculture.* report.

[6] Anon. 2012. ‘‘Overview of Trade in Marine Products Through Fish Shop: Case of the Urban City of Antananarivo, Madagascar.’’ Economic Observatory of Fishing and Aquaculture in Madagascar. First report.

[7] Randriarilala, F., Rafalimanana, T., and Caverivière, A. 2008. “Bycatch in Industrial and Artisanal Shrimp.” In Caverivière A., Chaboud C., Rafalimanana T., 2008. ‘‘The Coastal Shrimp of Madagascar: Biology, Exploitation and Management.’’ Research Institute for Development (IRD) Editions.

[8] Anon. 2011. ‘‘Madagascar Economic Scoreboard.’’ Executive Economic Analysis of the National Institute of Statistics 3rd report.

[9] Anon. 2012. ‘‘Diagnostic of the Energy Sector in Madagascar.’’ Aides Office Consultant report.

[10] Kraiem, M. M. 1994. ‘‘Analysis of Morphometric and Meristic Variability of the Barbus Callensis Valenciennes (Fish, Ciprinids) of Tunisia.’’ *French Bulletin of Fisheries and Aquaculture* 334: 201-212.

[11] Chlaida, M. 2009. “Allozyme Variability Associated with Migratory Flow of Populations of *Sardina Pilchardus* along the African Northwest Coast.” Ph.D. thesis, Mohammed V University, Morocco.

[12] Holden, M. J., and Raitt, D. F. S. 1974. “Manual of Fisheries Science, part 2: Methods of Resource Investigation and their Application.” *Fisheries Technical paper* 115 (1): 1-215.

[13] Badts, V., and Bertrand, J. 2009. ‘‘Guide of the Measurement of Fishes, Mollusks, Shellfishes and Marine Mammals in Halieutic.” 1st vol. Accessed March 17, 2009. http://www.archimer.ifremer.fr/doc/2009/rapport/id=6237.pdf.

[14] Dagnelie, P. 1986. *Theories and Statistical Methods: Agronomics Applications*. Vol. 2. Belgium: Agronomic of Gembloux Press.

[15] Vessereau, A. 1988. *Statistical Methods in Biology and Agronomy*. France: Technique & Documentation Lavoisier Edition.

[16] De Drouin De Bouville, M. 1931. ‘‘The Carp Format.’’ *French Bulletin of Fish* 33: 267-271.

[17] Charpy, M. R. 1943. ‘‘Index Determination in Carp Farming.’’ *French Bulletin of Fish* 129: 125- 131.

[18] Unger, E. 1930. ‘‘Carp Hungarian Elite.’’ *French Bulletin of Fisheries and Aquaculture* 24: 277-284.

[19] Hile, R. 1936. “Age and Growth of *Leucichthys Artedii* (Le Sueur) of the Lakes in the Northeastern Highlands, Wisconsin.” *Bureau of Fisheries Bulletin* 48 (19): 211-317.

[20] Le Cren, E. D. 1951. “The Length Weight Relationship and Seasonal Cycle in Gonad Weight and Condition in the Perch (*Perca fluviatilis*).” *Journal of Animal Ecology* 20 (2): 201-209.

[21] Hureau, J. C. 1970. ‘‘Biology Comparative of Some Antarctic Fish (Nototheniidae).’’ *Oceanographic Institute Bulletin of Monaco* 68 (1391): 1-224.

[22] Kartas, F. 1971. ‘‘The triglidae of the Catalan Sea: Distribution, Growth and Reproduction. Gender Lepidotrigla, Trigloporus lastoviza, Eutrigla gurnadus.’’ Ph.D. thesis, Paris University, France.

[23] Ricker, W. E. 1958. Handbook of Computation and Interpretation of Biological Statistics of Fish Populations. Ricker W. E. and Carter N. M. Editors, Ottawa, Canada.

[24] Ricker, W. E. 1973. “Linear Regression in Fishery Research.” *Journal of Fisheries Research Board of Canada* 30 (3): 409-434.

[25] Freon, P. 1979. ‘‘Relation Size-weight, Condition Factors and Indices of Sexual Maturity: Bibliographical Reminders, Interpretation, Remarks and Applications.’’ *Scientific Paper Oceanographic Research Center* 68: 143-171.

[26] Coulibaly, N. D. 2003. ‘‘Lenght-weight Relationship for 11 Fish Spieces of Burkina Faso.’’ In Palomares M. L. D., Samb B., Diouf T., Vakily J. M. and Pauly D. ACP-EU Fisheries Research report.

[27] Coulibaly, N. D. 2008. ‘‘Lenght-weight Relationship for 4 Fish Spieces in Souruo River of Burkina Faso.’’ *International Journal of Biological and Chemical Sciences* 2 (3): 331-338.

[28] Hattour, A. 2003. ‘‘Lenght-weight Relationship of the Bluefin Tuna Catches (*Thunnus thynnus*) in Tunisi.” *International Commission for Conservation of Atlantic Tuna* 55 (1): 217-233.

[29] Yahyaoui, A., Freyhof, J., and Steinmann, I. 2004. ‘‘Ichthyological and Biological Diversity of *Anguilla Anguilla L*., 1958 (Actinopterygii, Anguillidae) in the Middle Rhine.” *Zoologica Baetica* 15: 39-60.

[30] Djemali, I. 2005. ‘‘Evaluation of the Fish Biomass in the Plans of Tunisian Freshwaters: Analytical Approaches and Acoustics.’’ Ph.D. thesis, National Agronomic Institute, Tunisia.

[31] Benmessaoud, F. 2007. ‘‘Physicochemical Quality, Metal and Bacteriological of the Estuary Waters of Bouregreg and Impact on the Biology and Demography of *Venerupis decussata* (Linne, 1758) and *Cardium edul* (Linne, 1967).” Ph.D. thesis, Mohammed V University, Morocco.

[32] Khemiri, S., and Gaamour, A. 2009. ‘‘Relationship of Size-mass, Condition and Sexual Cycle of Anchovies and Sardines in the Tunisian Coasts.’’ *Bulletin of the National Institute of Science and Technology of the Sea of Salammbô* 36: 46-57.

[33] Kada, O., Abdellaoui, S., Najih, M., and Nachite, D. 2010. ‘‘Growth Estimate of *Sardina pilchardus* (Walb, 1792) of the Central-eastern Region of the Moroccan Mediterranean with the Study of Otoliths.’’ *Bulletin of the Scientific Institute, Life Science Section* 31 (1):13-15.

[34] Chu, W. S., Wang, J. P., Hou, Y. Y., Ueng, Y. Ts., and Chu, P. Hs. 2011.“Length-weight Relationships for Fishes off the Southwestern Coast of Taiwan.” *African Journal of Biotechnology* 10 (19): 3945-3950.

[35] Forghani, Sh. 2011. “Age and Morphometric Specifications Silver Pomfret Fish (*Pampus argenteus*) in the Persian Gulf.” *World Journal of Fish and Marine Sciences* 3 (5): 357-360.

[36] Raeisi, H., Paighambari, S. Y., Davoodi, R., Bibak, M., Hoseini, S. A., and Shabni, M. J. 2011. “Length-weights Relationships and Relative Weights of Some Demersal Fish Species from the Persian Gulf, Iran.” *African Journal of Agricultural Research* 7 (5): 741-746.

[37] Fulton, T. 1911. “The Sovereignty of the Sea. Edinburgh and London. In Lenght-weight Relationship, Condition Factors and Indices of Maturity Sexual: Bibliographical Reminders, Interpretations, Remarks and Applications.” *Scientific Paper Oceanographic Research Center* 68: 143-171.

[38] Tesch, F.W. 1971. Age and Growth. In “Methods for Assessment of Fish production in Freshwaters.” 2nd Edition. Ricker, W.E. Edition, Oxford & Edinburgh, United Kingdom.

[39] Bagenal, T. B. and Tesch, F. W. 1978. Age and Growth. In: “Methods for Assessment of Fish Production in Freshwaters”. Handbook 3, 3rd Edition. Bagenal, T. B. Edition, Oxford, United Kingdom.

[40] Ricker, W. E. 1975. ”Computation and Interpretation of Biological Statistics of Fish Populations.” *Bulletin of the Fisheries Research Board of Canada* 191: 1-382.

[41] Nimbalkar, V. D. 1991. “Biostatistical Evaluation and Management of Sciaenid Fishery with Particular Reference to *Otolithes ruber* (Schneider, 1801) and *Johnieops sina* (Cuvier, 1830) of Konkan Coast.” Ph.D. thesis, Conchin University, India.

[42] Chaoui, L., Derbal, F., Kara, M., and Quignard, P. 2005. ‘‘Food and Condition of Sparus Aurata (Teleostei: Sparidae) in the lagoon Mellat in the Northeast Algeria.’’ *Cahier de Biologie Marine* 46: 221-225.

[43] Froese, R. 2006. “Cub Law, Condition Factor and Weight-length Relationship: History, Metaanalysis and Recommendations.” *Journal of Applied Ichtyology* 22: 241-253.

[44] Abba, E., Belghyti, D., Benabid, M., and Ibaoui, H. E. 2010. ‘‘Length-weight Relationship and Condition Factor of *Salmo trutta macrostigma* (Dumeril, 1958) in Oued Sidi Rachid (Middle Atlas) Morocco.’’ *Africa Science* 6 (2): 60-70.

[45] Pauly, D. 1980. “A Selection of Simple Methods for the Assessment of Tropical Fish Stock.” *Fisheries Circular* 729: 1-54.

[46] Pauly, D., and Mines, A. N. 1982. “Small-scale Fisheries of San Miguel Bay Philippines.” *Biology and Stock Assessment Technical* 7: 38-55.

[47] Pauly, D. 1997. *Methods to Evaluate Fisheries Resources*. France: Cepadues Editions.

[48] Sparre, P. and Venema, S. C. 1996. ‘‘Introduction to the Assessment of Tropical Fish Stocks, Part I: handbook.’’ *Fisheries Technical Paper* 306 (1): 1-364.

[49] Brash, J. M., and Fennessy S. T. 2005. “A Preliminary Investigation of Age and Growth of Otolithes Ruber from KwaZulu-Natal, South Africa.” *Western Indian Ocean Journal of Marine Science* 4 (1): 21-28.

[50] Abou El Ouafa, A., Annala, J., Bonzon, A., Chesson, J., Chong, K. C., Christensen, V., et al. 1999. ‘‘Indicators for Sustainable Development of Marine Capture Fisheries.’’ *FAO Technical Guidelines for Responsible Fisheries* 8: 1-76.

[51] Pineiro, C., Garcia-Vazquez, E., Pendas, A. M., and Moran, P. 1991. ‘‘Pectoral Fin Rays as Appropriateness to Control the Strain Trout.’’ *French Bulletin of Fisheries and Aquaculture* 322: 121-124.

[52] Santhoshkumar, S., Rajagopalsamy, C. B. T., Jawahar, P., and Francis, T. 2013. “Length-weight Relationship of *Otolithes ruber* (Schneider, 1801) in Thoothkudi Coast, Tamil Nadu, India.” *International Journal of Fisheries and Aquatic Studies* 1 (3): 9-11.

[53] Domalain, G., Lhomme, F., and Rasoanandrasana, N. 2000. “The Traditional Shrimp Fishing in Madagascar: Spatial Diversity.” In Gascuel D. Chavanne P. Bez N. Biseau A. Halieumetric Congress “The Halieutic Species.”

Rennes, Paris (France), Research Institute for Development (IRD) Editions 387-412. Accessed February 09, 2011. http://horizon.documentation.ird.fr/exl-doc/pleins_textes/.../id=010024516.pdf.

[54] Brinca, L., Jorge da Silva, A., Sousa, L., and Saetre, R. 1983. A Survey on the Fish Resources at Sofala Bank – Mozambique: Fishery Resources, Exploratory Fishing, Surveys, Saltwater fishes, Prawns and Shrimps. reports.

[55] Brinca, L., Mascarenhas, V., Palha de Sousa, P., Sousa, I. M., Saestra, R. and Timochin, I. 1984. A Survey on the Fish Resources at Sofala Bank Mozambique: Saltwater Fishes, Fishery Resources, Prawns and Shrimps, Geographical Distribution and Biomass. reports.

[56] Saetersdal, G., Bianchi, G., Stromme, T., and Venema, S. C. 1993. "Investigations of Fishery Resources in Developing Regions: History of the Programme and Review of Results." *FAO Fisheries Technical Paper* 391: 1-408.

[57] Mojgan, K., Farbod, E., Gholamhosein, M., and Sepideh, R. 2010. "Estimation of Mortality Coefficients of *Otolithes ruber (*perciformes) in Khoozestan Province of South Iran." *Journal of Environmental Research and Development* 4 (4): 917-922.

[58] Rahim, A. K. P. 2006. "Studies on Food and Feeding of Marine Demersal Finfishes with Special Reference to Trophic Interactions." Ph.D. thesis, Conchin University, India.

[59] Navaluna, N. A., 1982. Morphometrics, Biology and Population Dynamics of the Croaker Fish, *Otolithes ruber*. In Pauly D., Mines A.N. Small-scale Fisheries of San Miguel Bay Philippines: Biology and Stock Assessment. International Center for Living Aquatic Resources Management, Technical report.

[60] Shin, Y. J. 2000. ''Trophic Interactions and Dynamics of the Population in Marine Ecosystems Exploited: Approach by Modeling.'' Ph.D. thesis, Paris 7 University, France.

[61] Almatar, S. 1993. "Comparison of Length-related and Age-related Growth Parameters of Newaiby *Otolithes ruber* in Kuwait Waters." *International Center for Living Aquatic Resources Management*, Fishbyte section: 32-34.

[62] Jayasankar, P. 1990. "Length-weight Relationship and Relative Condition Factor in *Otolithes ruber* (Schneider, 1801) from the Gulf of Mannar and Palk Bay in India." *Indian Journal of Fisheries* 37 (3): 261-263.

[63] Bhuyan, S. K., Jena, J. K., Pillai, B. R., Kumar, P., and Chakraborty, S. K. 2012. "Studies on the Growth of *Otolithes ruber* (Bloch & Schneider, 1801) *Johnius carutta* (Bolch, 1793) and *Pennahia Macrophthalmus* (Bleeker, 1850) from Paradeep Coast, Orissa, India." *Indian Journal of Fisheries* 59 (2): 89-93.

[64] Rao, R. D. 1977. "Biological and Technological Aspects of the Utilization of *Otolithes argenteus* (Doma)." Ph.D. thesis, Bombay University, India.

[65] Fernand, S. 1910. *The carp*. Belguim: Charles Bulens Edition.