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SCHOOLS OF LARGE YELLOWFIN (*Thunnus albacares*) CONCENTRATED BY FORAGING ON A MONOSPECIFIC LAYER OF *Cubiceps pauciradiatus*, OBSERVED IN THE EASTERN TROPICAL ATLANTIC

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SUMMARY

Observations on stomach content of large yellowfin tuna were carried out aboard a purse seiner operating in EasternTtropical Atlantic during early 2001.A monospecific concentration odf large yellowfin was observed during several days. These large fish were feeding on a monospecific concentration of Cubiceps pauciradiatus. These small fish were juveniles agregated in a thick layerat moderate depth and stable by day and night, feeding on zooplancton. This simple food web induce a concentration of large yellowfin tuna in the Equatorial area,and it seems that such situation occur rather frequently. However the relation of this feeding behaviour with spawning activity whichis known to occur in the same time area strata has still to be explored.

Many thanks to Bernard SERET for precise zoological determination of Cubiceps pauciradiatus based on specimens collected in stomach contents of yellowfin. Many thanks as well to the crew of the purse seiner VIA HARMATTAN .

RESUME

Une campagne d'observation sur un senneur en Atlantique tropical oriental, a permis d'observer une concentration monospécifque de bancs de gros albacores qui se nourissaient activement sur une couche de Cubiceps pauciradiatus. Ces petits poissons mesopélagiques étaient agrégés en une couche profonde stable de jour comme de nuit, apparement stabilisée par l'abondance de zooplancton qu'ils consommaient. Cette chaine alimentaire simple détermine donc une concentration des bancs d'albacore en zone équatoriale. Il est possible que ce type de chaîne alimentaire soit fréquente dans cette même zone equtoriale de l'Atlantique oriental ; mais la possibilité d'une connexion avec des activités de reproduction reste à explorer.

Tous nos remerciements à Bernard SERET pour la détermination zoologique précise de Cubiceps pauciradiatus sur des specimens issus des estomacs d'albacore. Tous nos remerciements également à l'équipage du VIA HARMATTAN.

RESUMEN

Se han realizado observaciones del contenido estomacal de listados grandes a bordo de un cerquero que operó en el Atlántico tropical este a principios de 2001. Durante varios días se pudo observar una concentración monoespecífica de rabiles grandes. Estos peces grandes se alimentaban en una concentración monoespecífica de Cupiceps pauciradiatus. Estos peces pequeños eran juveniles concentrados en una gruesa capa situada a una profundidad moderada donde mantuvieron estables tanto de día como de noche, alimentándose de zooplancton. Esta cadena alimentaria simple determina una concentración de rabil grande en la zona ecuatorial, situación que parece roducirse con bastante frecuencia. Sin embargo, la relación entre su conducta alimentaria y su actividad reproductora, que se sabe que se produce en el mismo estrato espacio-temporal, todavía no ha sido objeto de estudio.

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KEYWORD

Thunnus albacares, feeding behaviour, Cubiceps pauciradiatus.

1-INTRODUCTION

Since 1981 (ICCAT, 1982) the quantities of large yellowfin (*Thunnus albacares*)captured in surface by the large purse seiners operating far offshore in the Eastern Tropical Atlantic increased considerably, Diouf (1991). During the 90's decade the catches of such large fish amount to a third or half of the total catches of yellowfin in Atlantic ocean.. Remarkably the feeding ecology of these large fish has not been studied intensively extensively, whereas it was the case for similar sizes of yellowfin captured, along with other large tunas, by longline in the Central Atlantic. (Zavala Camin 1991, Valle et al. 1979). On an other hand early studies on feeding ecology of tropical tunas were carried out from scientific cruises, Dragovich (1970), Dragovich and Potthof (1972), and for yellowfin on relatively small fish captured in the inner part of the Gulf of Guinea.

The fishery of large yellowfin by purse seiners exhibit two clear features. It is very seasonal, extending from November to April, (Figure 1), and purse seiners fish on discrete concentrations of schools along the Equator (Fonteneau,1986, 1992) As these fish are adults, the main determinism of such agregation seems to be a spawning concentration. But it could be not exclusive as the duration of this large fish season, November-April, is longer than the spawning season centered on first quarter (Bard et Capisano, 1991)

Such clear spatio-temporal distribution of large fish raise some questions : What is the finality of such concentrations ? Concentrations of mature fish could be driven by the search of planctonic conditions suitable for future optimal larvae survival. On an other hand, these large yellowfin could be actively feeding prior to spawning, accumulating metabolites for final maturation of gonads. And if so what are the preys, ? Does it exist preferential preys items or is feeding purely opportunistic. ? Eventually, are these two hypothesis exclusive ?

A method for investigating the latter question question is to analyse the stomach content of large yellowfin caught by purse seiners in such concentration. An earlier attempt was made by Bard and Pezennec (1992) observing the stomach content of yellowfin butchered in Abidjan canning plants. However this study was not designed to aim specifically at fish caught during this concentration but rather to investigate the feasability of observing stomaches in canneries. It proved that the original time-area strata of the fish butchered was not easy to ascertain. And moreover the conservation of preys items observed in thawed fish was poor.

Consequently the observation of stomaches contents on freshly captured yellowfin was decided and the senior author of this document boarded the French purse seiner *VIA HARMATTAN* during February 15 th to March 2 th, 2001. He carried out observations on large yellowfin eviscerated during 15 sets. The results of these observations are described here. They show that a concentration of schools of large yellowfin was induced by active foraging on a thick layer of juveniles of *Cubiceps pauciradiatus*, inducing a particular vulnerability of the tunas to purse seiners.

2-MATERIAL AND METHODS

A concentration of large albacore was discovered by the supply ship *Amaryllis* on February 24th. The purse seiner *Harmattan* and some ships of the same company took immediatly advantage of this information, and fishing began by 1.18°N and 9°18 W. Fishing by others European purse seiners continued in the following days till March 3th . Catch was composed only of large yellowfin, averaging 65 kg . The total catch by European purse seiners amounted to 2 500 Mt. All, except one of the 15 net sets observed aboard *Harmattan* took place in the morning.

Selected fish during brailing aboard *Harmattan* were eviscerated, stomach and gonads removed. Stomach content was observed, prey species identified and counted and a coefficient of state of digestion as defined by Bard, (2001), assigned to each item. Then the stomach content was frozen for ulterior check in laboratory at CRO in Abidjan. Gonad were observed, then frozen for weighting in laboratory. Due to the loss caused by evisceration on fish of high economic value, only 18 large yellowfin were eviscerated. But observation of the preys regurgitated on the deck , which is a common fact during purse seining, (Olson and Boggs, 1986,Batalayants, 1992) showed clearly that all the yellowfin tunas captured were feeding on a unique species of fish.

3- RESULTS

3.1 Identity of the prey

This fish was identified by Dr Séret on the best preserved specimens. A confirmation came from comparison of otoliths extracted from prey with the otolith atlas of Rivaton et Bourret, 1999. These prey fish are juveniles of *Cubiceps pauciradiatus* (Nomeidae) dubbed « Cigarfish » .At laboratory the sizes of fish were measured in standard length, due to common digestion of caudal fin rays, enabling to establish a distribution of sizes, Figure 2. A conversion to fork length was done (*1.09) based on the best preserved specimen. Live weight of the fish were computed using the equation :

W= 1.73266 E-5 * Fl **2.9264

established by the senior author on *Cubiceps pauciradiatus* fished with pelagic trawl in the Pacific during ECOTAP (Abbes et Bard, 1999) program. The average weight of *Cubiceps* in stomaches of yellowfin was then computed as 4.25 grams. Based on this average weight the number of *Cubiceps* counted in each stomach was converted in an estimation in weight of the stomach content (Table 1, Figure3). It appeared that some yellowfin had engulfed a considerable quantity of *Cubiceps* before beeing captured in the morning. Some others had apparently the stomach less filled, but regurgitation during agony of the fish could have occured.

3.2 Acoustic observations

Echosounder of Harmattan was observed regularly during days and night from 24/02/2001 to 28/02/2001, noting the geographical position of the ship. It showed that *Cubiceps* were apparently concentrated in a constant layer of 20 to 40 m thick, evoluting between –40 m to –80 m. This layer did not disappear at night. The spatial distribution of this layer was continuous, and apparently streched as an ellipsoidal shape with major axis from at least 1.18N, 9.18W to 1.50N, 8°13W, ie 66 NM, and minor axis about 20 NM.

Schools of large yellowfin were detected using « bird radar », but final approach by purse seine were conducted by spotting directely the fish, forming so called « boilers ». Such boilers were apparently caused by an vigorous activity of feeding on *Cubiceps* driven to the surface by the chase, and then becoming vulnerable to birds which consequently were associated to yellowfin school.

It appeared possible to observe the stomach contents of *Cubiceps* themselves, as stomacal mucus protected it against digestion by tunas. A quick analysis showed that *Cubiceps* were feeding on zooplancton, with a majority of Copepods and Chaetognats. 15 taxa were identified . Group of Copepods was the most diversified,and the rest of zooplancton is distributed among 5 groups.

Size distribution (Table 2) shows that small sized organisms (< 1mm) are nearly absent in these stomachs. Reversely , the middle sized ones (1-4 mm)are slighly abundant . Chaetognats are the most abundant group among large sized (> 5 mm) group. Chaetognats are predators of smaller zooplanctonic organisms. The most common species encountered are, by increesing rank, , *Euchaeta sp., Candacia sp., Oncaea sp., Euphausiids and Chaetognaths.*

3.3- Maturity of the yellowfin observed

Gonado somatic index of the female yellowfin eviscerated averaged 27, slightly less than the value commonly accepted for full maturity of tunas (Cayré and al, 1988). No sign of « spent » tuna nor spontaneaous emission of hydrated ova by female on the deck was observed. Consequently, the aera observed was not apparently an area of direct spawning activity.

4- DISCUSSION

4.1 A feeding ground

Juveniles of *Cubiceps pauciradiatus* have been already observed as an notable item in the diet of large (>90 cm) yellowfin captured in free swimming schools, non associated with FADs, in the Eastern Tropical Atlantic by Ménard and al. , (2000). On another hand, Olson and Boggs(1986) refer to Nomeidae as a notable item in the diet of yellowfin fished in the Eastern Pacific. Remarkably they observed that importance of the Nomeidae in the stomaches of yellowfin increases strongly from age 1 (0%) to age 4 (21.7%).

The massive foraging of large yellowfin (65 kg)on a layer of fish small (4 g), but abundant is an interesting biological feature. In spite of regurgitation effect, 11 of the 18 tunas had engulfed enough preys to fill up their stomach. For these « filled » fish, the ratio of reconstructed stomach content to body weight is comparable with the maximum of 4 % determined for large tunas (Bard, 2001). The size of the elliptic « patch » of forage fish is notable, 66 NM on an axis and 20NM on the other, suggesting an area of about 1200 Km² or more of continuous presence of prey. The food web constituted by the trophic levels, zooplancton, Cubiceps, tunas is remarkably short compared to the size of the apex predator ., i.e. large yellowfin ranging from 30 to 100 Kg.

Another important feature is the fact that large yellowfin foraged on concentration of preys which did not migrate vertically at daytime. This situation is similar to the one observed in the so- called PICOLO area, which was intensively studied by IRD during 1995-2000. (Menard at alii, 1998). A concentration of *Vinciguerria nimbaria* , a mesopelagic fish which did not exhibited diel vertical migration (Marchal and Lebourges, 1996), constituted a considerable source of forage for tunas. However the tunas concentrating in PICOLO area are much smaller, as they are a majority of skipjack (*K. pelamis*) mixed with juveniles of Yellowfin and Bigeye (*T. obesus*).

Bard et Pézennec (1991) in the study of large yellowfin stomaches carried out at Abidjan canneries observed frequently huge numbers of a small fish , 5 to 10 cm (Standard length), unfortunately misdentified at this time as *Neoscopelus*. This error was corrected later and identification using, otoliths, by P. Bourret proved that it was in fact *Cubiceps pauciradiatus*. The spatial origin of the stomach containing *Cubiceps* was from both side of the Equator. *Cubiceps* was present in 18 out of 36 samples of stomaches issued from large yellowfin captured in Equatorial zone. (5°N-5°S), mainly from October 1989 to May 1990.

Consequently it seems that *Cubiceps* is a major component of large yellowfin diet in the Eastern Equatorial waters in Atlantic. Such vulnerability of the *Cubiceps* to yellowfin might be linked to the fact that juvenile of *Cubiceps* do not perform vertical migrations and remain in the 30 to 90 m stratum in this area (Salekhov, 1990). This stability of vertical distribution could be linked to a particular feeding on a strong abundance of zooplancton as suggested by their own stomacal content.

On an other hand huge biomasses of small pelagic fish have been previously observed in the same Eastern Equatorial waters using echo –integration. They followed the classical day-night vertically migrating behavior, (Gerlotto, 1975). The species, observed only by echo-sounding, could not be determined. An hypothesis is that it could be adults *Cubiceps,* which at the reverse of juvenile, perform vertical migration at day time. (Salekhov op.cit.)

4.2 Relation to Spawning grounds

The most recent identification of time and areas where spawning of yellowfin occur in the Eastern Atlantic, is based on works from Yellowfin Year Program. Gonadal observations by Bard and Capisano (1991) showed occurrence of ripe females in a a zonal area , delimitated roughly by latitude 2°N to 5°S and longitude 5°E to 25°W. The peak spawning season is the first quarter of the year. However observations on larvae distribution could not fully confirm the gonadal evidence as they were carried out during decades 60 and 70. The synthesis by Cayré and al, 1988 show that the Western and Southern parts of the area defined above, have not been fully prospected. But some others observations suggest that the Southern part of this area is the place of most intensive reproductive activity.

(i) The major part of the catches of large adults albacore during first quarter take place in the Southern side of Equator (Fonteneau, 1992) ; (ii) The majority of transatlantic recoveries of large yellowfin tagged of USA, clearly migrating for spawning in Eastern Atlantic were recovered in the Southern side of Equator (Bard and Scott, 1991 ; Jones and al 1999); (iii) Indirect information derived from analysis by Marsac, 1998, of hydroclimatic variables (wind, sea temperature) and anomalies showed possibility of better conditions for larvae survival in this Equatorial area.

The yellowfin described in the present study, although of adult size were not fully ready to spawn . The time of the season was suitable for spawning, but the area in spite of beeing rich in planctonic food is not the best, beeing somewhat too North of the main spawning ground. The concentration of large yellowfin observes seems consequently guided byo intensive feeding, maybe prior to spawning.

Other observations on a nother concentration of large yellowfin South Equator would have been desirable. Unfortunately boarding on a commercial tuna boat does not give much degree of freedom for choice of the route and catches. Moreover it appears that fishing success of purse seiners South of Equator was particularly poor by beginning of 2001.

5-CONCLUSION

An useful conclusion is that a further boarding in 2002 during the spawning season for another set of observations is necessary , hoping that we are lucky enough to reach an active spawning concentration, South of Equator .

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Table 1 : Statistics of reconstructed stomach content

Weight of YFT(Kg)	Number of Cubiceps	Weight of Stomach content (g)	Percentage of body weight
61,7	225	956,25	1,55
60,1	347	1474,75	2,45
39,2	56	238	0,61
56,0	308	1309	2,34
62,2	66	280,5	0,45
50,7	143	607,75	1,20
51,2	61	259,25	0,51
56,0	245	1041,25	1,86
39,6	126	535,5	1,35
92,8	112	476	0,51
54,5	88	374	0,69
47,5	66	280,5	0,59
69,5	270	1147,5	1,65
40,4	159	675,75	1,67
38,4	113	480,25	1,25
59,6	258	1096,5	1,84
37,7	195	828,75	2,20
70,7	111	471,75	0,67

Table 2 : Various groups , size classes and abundance of zooplanctonic items observed in stomach content of Cubiceps.

Size classes	Species	Abundance
< 1 mm	Oncacea sp.	Low
1- 4 mm	Ostracodes	Low
	Calanus sp.	Low
	Calanus minor	Low
	Miracia sp.	Low
	Candacia sp.	Medium
	Undinula sp.	Medium
	Euchierrella sp.	Low
	Euchaeta sp.	Low
	Sapphirina sp.	Medium
> 5 mm	Salpes (Tunicates)	Low
	Amphipods	Low
	Euphausiids	Medium
	Chaetognats	**High**
	Annelids	Low

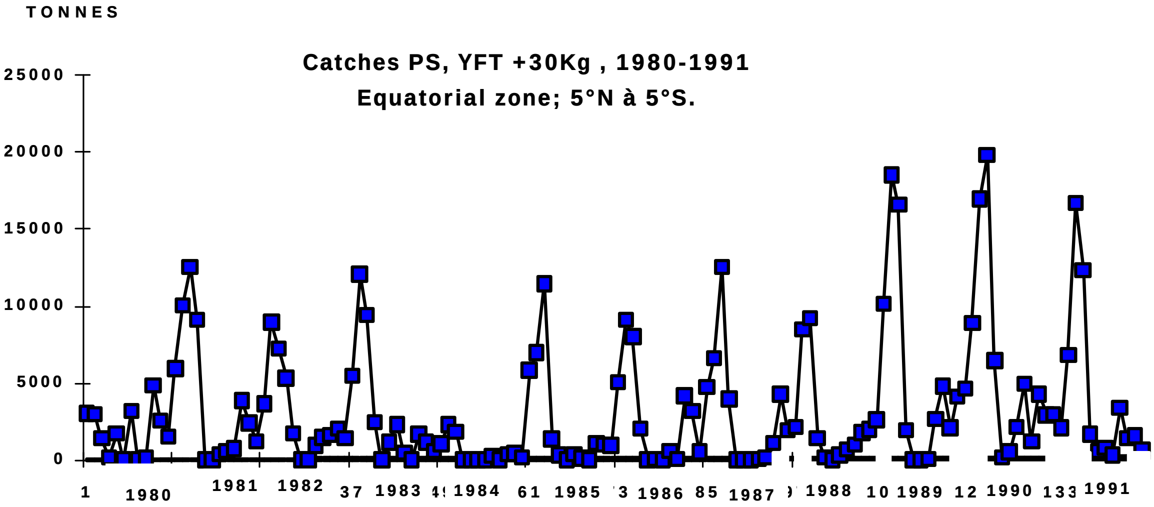

Figure 1 : Monthly catches of large yellowfin(>30 Kg) fished by purse seiner in the Eqautorial zone 5°N to 5°S, years 1980-1991.

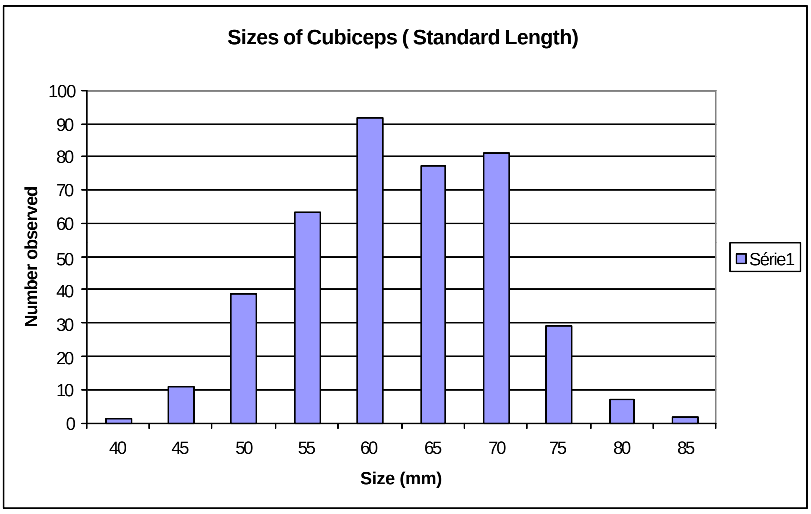

Figure 2 : Sizes expressed in standard length of Cubiceps pauciradiatus observed in stomach of large yellowfin tunas.

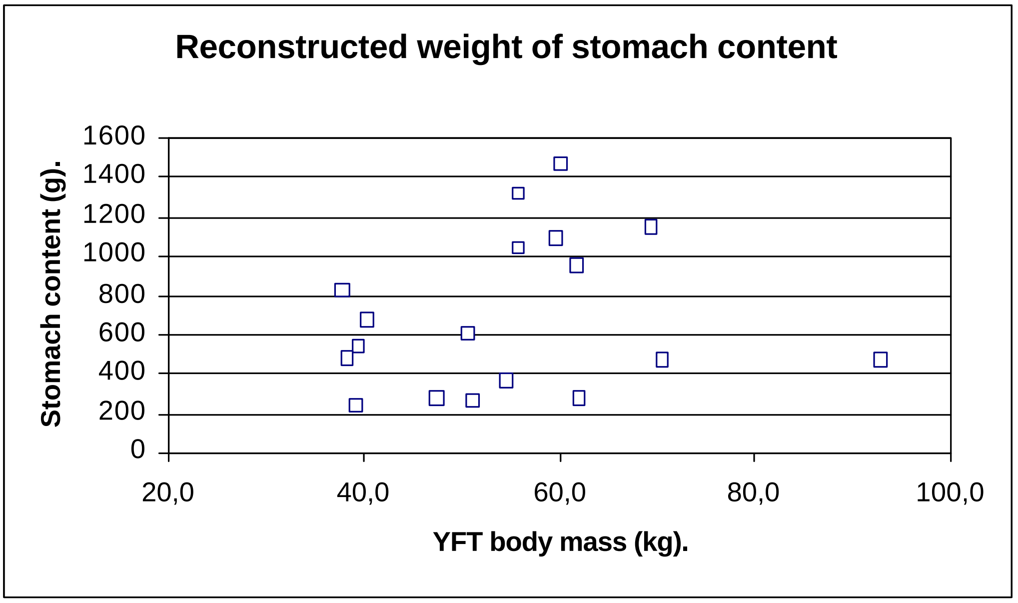

Figure 3 : Reconstructed live weight of stomacal contents of yellowfin, filled with Cubiceps as observed on HARMATTAN.