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DIET COMPOSITION OF PELAGIC FISH IN THE SOUTHWESTERN ATLANTIC, BRAZIL: AN ISOTOPIC MIXTURES APPROACH

Composição da dieta de peixes pelágicos no atlântico sudoeste: uma abordagem com misturas isotópicas

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ABSTRACT

The purpose of this study is to characterize, through isotopic mixture models (13C and 15N), the diet of pelagic top predators of the Southwestern Atlantic Ocean. Thus, samples of muscular tissue were collected from individuals of the species: Xiphias gladius, Thunnus obesus, Thunnus alalunga, Thunnus albacares, Prionace glauca, Alopias superciliosus *and* Isurus oxyrinchus. *Results indicate the diet of* X. gladius *is primarily composed by cephalopods (Ommastrephidae squids). A similar pattern is presented by* T. alalunga*, whose food is also mainly composed by Ommastrephidae squids.* T. obesus *and* T. albacares *present similar compositions, but smaller pelagic fish species are important to their diet compositions. A. superciliosus feeds mainly on Scombridae species (*T. albacares *and* T. alalunga*). A. superciliosus diet is composed mainly by Scombridae species, differing from that one from* P. glauca*, whose diet consists of smaller pelagic fish. The use of information in a conjugated way of the predators' stomach contents as well as the isotopic tissue analyses may be a important step towards a more complete understanding of pelagic food web composition in Southwestern Atlantic Ocean.*

Key words*: top predators; stable isotopes; mixture models.*

RESUMO

A proposta do presente trabalho é caracterizar, através de modelos de mistura isotópica (^{13}C e ^{15}N), a dieta de predadores de topo pelágicos do Oceano Atlântico Sudoeste. Para isso, amostras de tecido muscular foram coletadas dos seguintes peixes: *Xiphias*

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gladius, *Thunnus obesus*, *Thunnus alalunga*, *Thunnus albacares*, *Prionace glauca*, *Alopias superciliosus* e *Isurus oxyrinchus*. Os resultados indicam que a dieta de *X. gladius* é composta primariamente de cefalópodes (lulas Ommastrephidae). Um padrão similar é apresentado por *T. alalunga*, cuja dieta é também composta principalmente por lulas Ommastrephidae. *T. albacares* e *T. obesus* apresentam padrões similares de composição da dieta, ambas as espécies alimentam-se primariamente de pequenos peixes pelágicos. *A. superciliosus* compõe sua dieta principalmente de espécies de Scombridae (*T. albacares* e *T. alalunga*), diferentemente de *P. glauca*, cuja dieta é composta primariamente de peixes pelágicos de menor porte. O uso, de forma conjunta, das informações extraídas tanto do conteúdo estomacal dos predadores, quanto das análises isotópicas de seus tecidos, apresenta-se como um importante passo em direção ao completo entendimento da rede trófica pelágica do Oceano Atlântico Sudoeste.

Palavras-chave: predadores de topo, isótopos estáveis, modelos de mistura.

INTRODUCTION

A trophic web consists in representation of the feeding relationships among predators and their prey in an ecologic community. The interactions may indicate the energetic flow within the referred ecosystem (Pimm, 1982). By meaning as direct interactions inside the trophic web, competition and predation may be assessed using traditional approaches (stomach contents analysis, fecal composition), but they may also be analysed using relatively recent techniques, including stable isotopes (Caut *et al.*, 2006). As observed by Hildebrand *et al.* (1996), the studies based only on stomach contents may present some limitations. As the digestion rates may interfere, estimations about the consumed bulk may become more problematic and even more difficult to estimate what is assimilated by the predator. In this situation the use of stable isotopes (mainly ^{13}C, ^{15}N and ^{34}S) should be an important, though complementary but useful tool to reconstruct the consumer's diet, as such data may provide a continuous measurement about the trophic position of the components in the community. They also help to integrate the energy assimilation through the mass flow at distinct compartments until they reach the individual in the community (Peterson & Fry, 1987; Post, 2002).

According to Phillips (2001), the isotopic signature of a consumer may be interpreted as pondered mixture, which reflects the relative contribution distinct items represent to the diet of the consumer. Its proportion may be determined by means of mathematic mixture models. These models consist of a series of lineal equations, which maintain the mass balance to estimate the potential contribution the sources furnish to the system (details in Phillips, 2001.; Phillips & Gregg, 2003). The literature registers studies, which succeeded by using models of isotopic mixtures to describe the predators` diet composition as is the case of researches conducted by Ben-David *et al.* (1997a, b), Melville and Connolly (2003) and Caut *et al.* (2006).

The purpose of this study was to characterize, by using isotopic mixture models, the diet composition of species which represent top predators living at the pelagic environment of the Southwestern Atlantic Ocean, as well as to visualize, the trophic web in which these species are inserted.

MATERIAL AND METHODS

Data collection

Samples were obtained in collaboration from the Santos (SP, Brazil) tuna fishery fleet. Such vessel operations occur at the Southwestern Atlantic Ocean in an area comprised by 17 - 35° S and 27 - 52° W out of the continental shelf (as observed by Amorim *et al.,* 1998) (Figure 1).

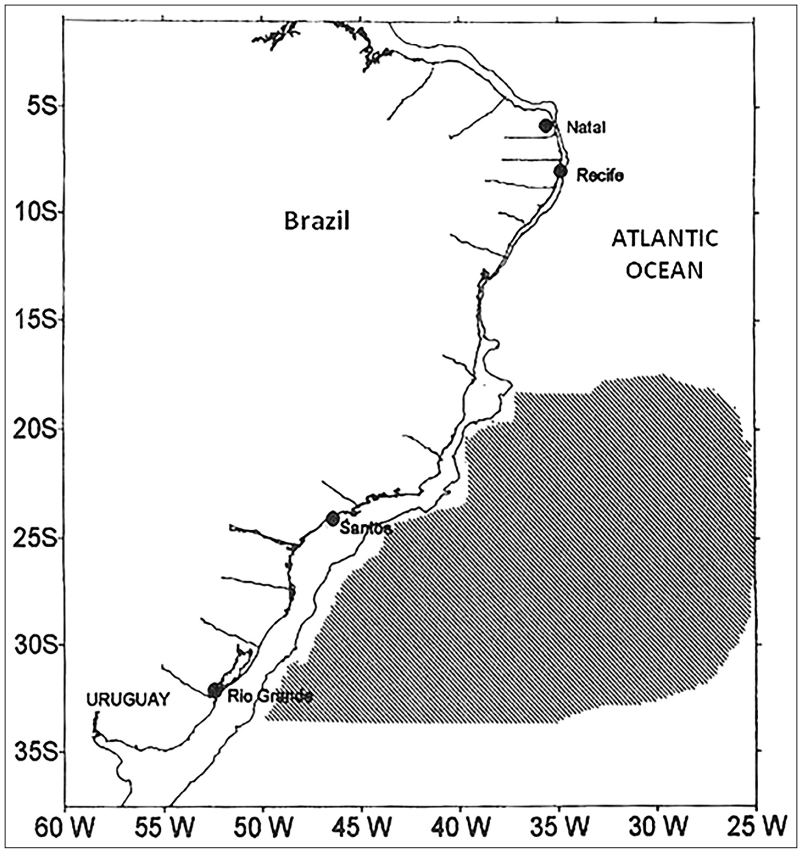

Figure 1 - Santos longliners fishing area (adapted from Amorim *et al.*, 1998).

Muscular tissue samples from *Xiphias gladius* Linnaeus 1758 (N = 5), *Thunnus obesus* (Lowe 1839) (N = 2), *Thunnus alalunga* (Bonnaterre 1788) (N = 3), *Thunnus albacares* (Bonnaterre 1788) (N = 1), *Prionace glauca* (Linnaeus 1758) (N = 2), *Alopias superciliosus* Lowe 1841 (N = 2) and *Isurus oxyrinchus* Rafinesque 1810 (N = 4) were collected from February to October 2009, during fish landed at the Santos fishing terminal (SFT). Based on stomach contents observations, samples of the most representative prey were collected in order to complement the analyses. They were represented by: Ommastrephidae squids, pelagic fishes (*Gempylus serpens*, *Trichiurus lepturus*, *Brama brama*, *Cubiceps* sp.), and Decapoda crustaceans (infraorder Caridea). Such samples were directly collected from the stomach contents of the fish species under study, and identified using taxonomic criteria based on Figueiredo & Menezes (1980; 2000), Menezes & Figueiredo (1980; 1985), Clarke (1986), Nesis (1987), and Figueiredo *et al.* (2002).

Diet characterization

The isotopic signature ($^{13}C/^{12}C$ and $^{15}N/^{14}N$) of each sampled species was then used to determine the diet characterization. The potential contribution of the sources to each consumer was estimated by means of the resolution expressed by the equations seen below:

$$f_a\delta_a + f_b\delta_b + f_c\delta_c + \cdots\cdots f_m\delta_m = \delta_m$$
$$f_a + f_b + f_c + \cdots\cdots f_m = 1 \quad (1)$$

Where f_a and f_m represent the proportions each potential *m* food item contributes to the consumer`s diet. The isotopic traces from each source are represented by δ_a, δ_b, δ_c, and δ_m; and δ corresponds to the isotopic signature (mixture) of the consumer. The calculations were made using the software IsoSource (Phillips & Gregg, 2003), following the methods of aggregation indicated by Phillips *et al.* (2005).

RESULTS

The prey proportions for the diets of *X. gladius*, *A. superciliosus*, *P. glauca*, *T. albacares*, *T. obesus* and *T. alalunga* are shown in Table I. The equations system resolution corresponding to *I. oxyrinchus* did not get a viable solution. In consequence, it was impossible to obtain an access to the potential food sources to this species. At Figure 2, presents the pelagic trophic web diagram from Southwestern Atlantic Ocean.

Table I - Mean and standard deviations of the prey proportions to the diets of *Xiphias gladius, Alopias superciliosus, Prionace glauca, Thunnus albacares, T. obesus* and *T. alalunga* inferred by the use of models of isotopic mixture ($\delta^{13}C$ and $\delta^{15}N$).

Predator	Prey - mean (SD)				
	T. alalunga	***T. albacares***	**Ommast**	**Decap**	**Pelagf**
Xiphias gladius	0.01 (0.01)	0.14 (0.02)	0.81 (0.02)	0.00 (0.01)	0.04 (0.03)
Thunnus obesus	0	0	0.28 (0.16)	0.07 (0.02)	0.65 (0.19)
Thunnus alalunga	0	0	0.83 (0.05)	0.08 (0.04)	0.09 (0.02)
Thunnus albacares	0	0	0.04 (0.03)	0.21 (0.06)	0.74 (0.07)
Prionace glauca	0	0.19 (0.01)	0.26 (0.05)	0.01 (0.01)	0.53 (0.06)
Alopias superciliosus	0.25 (0.03)	0.68 (0.02)	0.05 (0.03)	0	0.02 (0.02)
Isurus oxirinchus	-	-	-	-	-

Note: **Ommast**: Ommastrephidae squids; Decap: Decapoda crustaceans; **Pelagf**: small pelagic fish; **SD**: standard deviation.

The calculations indicate that the *X. gladius* diet may be primarily composed by cephalopods (Ommastrephidae squids), followed by scombrid fishes (mainly *T. albacares*) and other smaller pelagic fish. Among the analyzed sharks, *A. superciliosus* may compose its diet with scombrid species mainly; (*T. albacares* and *T. alalunga*) in a distinct way when compared to *P. glauca*, whose diet is primarily composed by smaller pelagic fish, followed by Ommastrephidae squids.

The *T. albacares* and *T. obesus* present similar food compositions for their diets. Both species feed on small pelagic fish, and other kinds of prey are secondary to their diets. It may be important to emphasize that Decapoda crustaceans play an important role to the

diet of *T. albacares*, in which they perform approximately 20% of the total assimilated food. The *T. alalunga*, on the other hand, composes its diet with Ommastrephidae squids in first place. Fish and crustaceans play a secondary role to its diet.

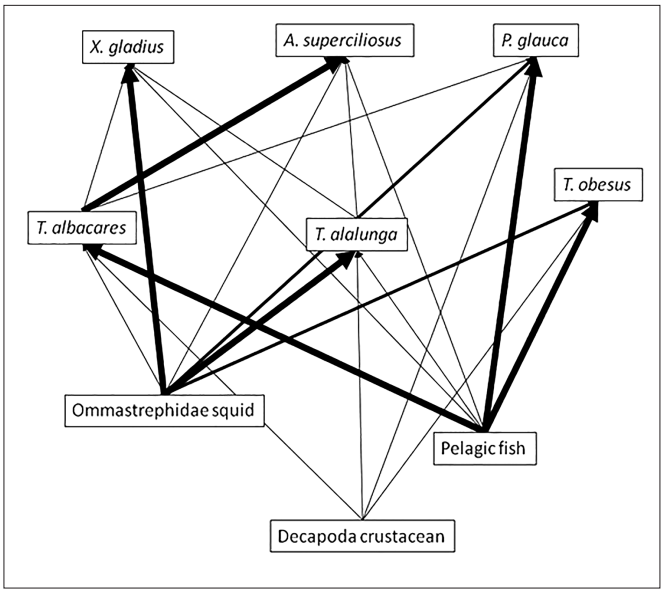

Figure 2 - Pelagic trophic web diagram from Southwestern Atlantic Ocean. Thinner lines represents contribution of less than 25% in food source; medium thickness lines indicate the contribution of 25 to 50% of the diet, and thicker lines represent more than 50% of the diet.

DISCUSSION

According to the stable isotopes ^{13}C and ^{15}N data, recorded from the muscular tissues of *X. gladius*, one may infer that its diet may in great part be composed by cephalopods (Ommastrephidae). These cephalopods constitute a common reference to other researches, concerning analyses about stomach contents of such fish species (Gorni *et al.*, 2013). Some authors identify more frequently species, which belong to the genera *Illex*, *Ommastrephes*, *Dosidicus* and *Todarodes* as components of the stomach contents of *X. gladius* (Zavala-Camin, 1981; Stillwell & Kohler, 1985; Simões & Andrade, 2000; Vaske-Júnior, 2000; Ibañez *et al.*, 2004; Castillo *et al.*, 2007; Letelier *et al.*, 2009). The exception cited by Letelier *et al.* (2009) in a mention related to occurrence of fish pieces (*Thunnus*) found in stomach. The detection about the assimilation of mesopelagic prey as some species of Ommastrephidae squids (Nesis, 1987) and epipelagic ones (Figueiredo & Menezes, 2000) may corroborate the attributed daily vertical displacement pattern of *X. gladius* (Carey & Robison, 1981; Takahashi *et al.*, 2003).

The tissue isotopic concentration of *A. superciliosus* revealed a clear dominance of teleosts, in an agreement to the observations made by Polo-Silva (2007) and Preti *et al.* (2008) whose studies were performed at the Pacific Ocean. In more detail, the most representative fish families were Paralepididae, Merluccidae and Sciaenidae. Gorni *et al.* (2013) report great contribution of Teuthida squids and Trichiuridae fishes in *A. superciliosus* stomach content. Meanwhile, in this present study based on isotopic mixture results, there happens to occur a disagreement to those observations, as Scombrid fishes should compose more than 80% of the assimilated prey. So, the lack of research of food composition and isotopic information for *A. superciliosus* at the Southwestern Atlantic may, for now, be considered, at least, a precocious conclusion. The *P. glauca*, in turn, feeds mainly on teleosts, and the squids should only constitute a complementary diet. This pattern confirms results obtained by Bornatowski & Schwingel (2008) and Vaske-Junior *et al.* (2009). Notwithstanding this, a result based on the analyses of 68 stomachs of such sharks caught at oceanic waters off the southern Brazilian coast (Vaske-Junior & Rincón-Filho, 1998) indicate a diet to be mainly based on squids, represented most frequently by the batipelagic *Chiroteuthis veranyi*.

Following the isotopic analysis, *T. albacares* may be considered as food item to all the top predators of the region, as it signalizes to this direction in this study. The tissues of this tuna sustain a signal that this species feeds on smaller teleosts, in accordance to observations

made by Zavala-Camin (1981), Vaske-Júnior (2000), Vaske-Junior *et al.* (2003) and Satoh *et al.* (2004). These fish assimilate mainly specimens of Bramidae and Trichiuridae. These observations reinforce the idea that *T. albacares* uses to prey over monospecific fish concentrations, which come to more superficial layers of the water (Dragovich & Potthoff, 1972; Bard *et al.*, 2002). In a similar way, the isotopic signature indicated *T. obesus* feed primarily on pelagic fish, and cephalopods should only constitute secondary prey. By analyzing 44 stomach contents of *T. obesus*, Vaske-Júnior (2000), registered fish to compose more than 86% of the ingested prey there observed. Liming *et al.* (2005), in an analysis based on 272 stomach contents of *T. obesus*, caught at the Central Atlantic Ocean, also characterize pelagic fish as their most important prey, as they perform almost 50% of the total food within their stomachs. Cephalopod mollusks constitute, therefore, a secondary food item to this species, in which they constitute 30% of the whole food they consume.

The *T. alalunga*, should be, though presenting a differentiated feeding habit, the tuna species to which cephalopods represent the most important food component. More than 80% of the food items are based on cephalopods. This tendency to a teutophagic habit may corroborate the observations made by Zavala-Camin (1981), who, analysing 741 stomachs, registered predominance for mollusks (59.9%), to which fish and crustaceans were secondary food items. In any case, Sabatié *et al.* (2003), Satoh *et al.* (2004) and Gorni *et al.* (2013) show distinct results, in which fish and crustaceans are predominant.

It should be noted that research on the food web of top predators presents a great challenge. Access to large numbers of samples is limited by the high costs involved in capturing these animals on open seas. Therefore, the food patterns recorded in the present study are restricted to the period of this work.

Divergences by comparing results originated from isotopic mixture models and those obtained by stomach contents analyses may be related to particular issues related to each used method. Following Schindler & Lubetkin (2004), the use of stable isotopes may follow the destinies of distinct energy sources and materials through the trophic webs, becoming, therefore, important complementary tools to analyses of food debris. Though more accurate in determining the preyed species, the evaluation of gastric contents may provide a more restrict sight about the feeding habits of the consumers, as such methods limit their analyses to shorter temporal scales (Estrada *et al.*, 2005; Kojadinovic *et al.*, 2008).

Thus, the utilization in a conjugated way of data obtained by investigating food stomach contents and stable isotopes shown in their tissues may be an important way to improve a direction to a better and more complete knowledge about the ecologic relationships presented by the pelagic species at the Southwestern Atlantic Ocean.

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