Short Communication

Trophic relationships revealed by dart tags found in the stomachs of large pelagic fishes in the Atlantic Ocean

Guelson Batista Silva[a], Lisa Elma Ailloud[b], Justin Monin Amandé[c], Rafael Ferreira Muniz[d], Fabio Hissa Vieira Hazin[d], Doug Beare[e].

a Departamento de Ciências Animais, Universidade Federal Rural do Semiárido, Mossoró, RN, 59625-900, Brazil.

b Southeast Fisheries Science Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, FL 33149, USA.

c Centre de Recherches Océanologiques, 29 rue de pecheurs, BP V 18, Abidjan, Ivory Coast.

d Departamento de Pesca e Aquicultura, Universidade Federal Rural de Pernambuco, Recife, PE, 52171-011, Brazil.

e International Commission for the Conservation of Atlantic Tunas, ICCAT/AOTTP – Calle Corazón de Maria, 8, 28002 Madrid, Spain.

*corresponding author: guelson@ufersa.edu.br

Abstract

Plastic dart tags are the main type of tag used in all major fish tagging projects but their potential for studying trophic relationships has never been addressed. The occurrence of dart tags in the stomach contents of large pelagic fishes and direct observations onboard tagging vessels reveal novel information on predation and cannibalism by tropical tunas in the Atlantic Ocean. The observations were all made during the Atlantic Ocean Tropical Tuna Tagging Programme (AOTTP), which targeted bigeye tuna (*Thunnus obesus*), yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwomis pelamis*), wahoo (*Acanthocybium solandri*), and little tunny (*Euthynnus alletteratus*). During the programme (so far) 5 conventionally tagged fish have been reported in stomach contents from captures made in Brazil, São Tome and Principe, and Ivory Coast: including one yellowfin tuna and two skipjack tunas in a yellowfin tuna, one yellowfin tuna in a blue marlin (*Makaira nigricans*), and one yellowfin tuna in a non-identified shark. We use these observations to illustrate the potential role that dart tags could play in helping describe trophic interactions among marine pelagic fish species.

Keywords: tag-recapture; dart tags; predation; cannibalism; trophic interaction

1. Introduction

Tagging studies are typically used in fisheries stock assessment and management to estimate population size, mortality, movement (spatial stock structure) and growth. The overall objective is to establish an "experimental" sub-population of individuals marked with uniquely numbered tags that can be monitored and modelled over time through recaptures by the fishery. The main type of tag used in all major tuna tagging projects has been the external plastic tipped dart tag with a nylon barb (Fonteneau and Hallier, 2015; Leroy et al., 2015). The potential use of dart tags as a tool to study trophic relationships has, however, never been addressed.

The Atlantic Ocean Tropical tuna Tagging Program (AOTTP) is working with the International Commission for the Conservation of Atlantic Tunas (ICCAT) to provide evidence-based, scientific advice to Atlantic coastal states in support of more effective conservation and management measures for tuna fisheries; mainly via improvements in the estimation of key parameters used in stock assessment analyses, e.g. growth, mortality, migratory activities, such as horizontal movement, and stock structure (Beare et al., 2019).

Here, we report novel observations on the occurrence of plastic dart tags in the stomach contents of large pelagic fishes in the Atlantic Ocean with a case of cannibalism by yellowfin tuna and tuna predation by shark, yellowfin tuna, and blue marlin.

2. Material and methods

The AOTTP, which started in June 2016 and is scheduled to end in early 2021, had an overall target to tag and release 120,000 tuna fish. The main target species were the bigeye tuna (*Thunnus obesus*), yellowfin tuna (*T. albacares*), skipjack tuna (*Katsuwonus pelamis*), wahoo (*Acanthocybium solandri*), and little tunny (*Euthynnus alletteratus*). The AOTTP used different kinds of tags: (i) conventional dart tags inserted into the second dorsal fin of the tagged fish; (ii) chemical 'tags', by injection of oxytetracycline (OTC); and (iii) electronic tags, consisting of internal archival and pop-up satellite tags. All fish tagged with either a chemical or electronic tag were marked with a conventional red dart tag, while all others were marked with yellow ones. The dart tags used were 15cm long by 2mm in diameter and weighed 0.58 g (Fig.1). All tunas were measured by straight fork length (FL) and tagged in a cradle. The predators were also measured by FL when captured during the tagging campaign or reported to recovery office.

The AOTTP has 12 recovery offices in the Atlantic coastal countries and islands with the responsibility to collect tags and pay the rewards, distribute incentives, and send the recovery data back to ICCAT. Some reports of dart tags in the stomach contents of large pelagic fishes came directly from AOTTP tagging teams, and others from staff, via fishers, at the recovery offices. All the detailed information used in this report was acquired from the official ICCAT-AOTTP databases.

3. Results and Discussion

The AOTTP, at the time of writing, had tagged and released (database version February 2020) 118,154 fish, of which 20,943 were double tagged. From that, we found 5 occurrences of tagged fish in the stomach contents of other large pelagic fishes: yellowfin tuna, blue marlin (*Makaira nigricans*), and a non-identified shark (Table 1). These cases were reported from both sides of the Atlantic: Brazil, São Tome and Principe, and Côte d'Ivoire. They all occurred in the areas with higher concentration of tagging activities (>1,000 releases) (Fig. 2). The probability that a fish that has eaten a tagged fish, is noticed and reported is very low; especially since stomachs themselves are not usually opened in the evisceration process. We suspect, therefore, that this sort of predation is actually a relatively common occurrence.

So far five tags have been reported from the stomach contents of fish tagged during AOTTP, in chronological order: a) in case 1, the Brazilian recovery team was notified of a double tagged skipjack tuna that had been eaten by a yellowfin tuna. Only the tags were found in its stomach 16 days after tagging and 74.2 nautical miles (NM) away from the tagging site; b) in case 2, the recovery team of São Tomé and Principe received a tag from a skipjack tuna that had been eaten by a shark (unfortunately the species was not identified) 110 days later and 75.9 NM from where it was tagged; c) in case 3, the Ivorian recovery team received a tagged yellowfin tuna that was found in an advanced stage of digestion in the stomach of a large blue marlin (Fig. 3a) one day after tagging; but unfortunately, the recovery position was not reported; d) in case 4, a skipjack tuna was found almost intact in the stomach of a yellowfin tuna (Fig. 3b), about eleven hours and 17.7 NM away from its release; e) finally, in case 5, the tagging team recovered

1 tag, that was deployed in skipjack tuna, which was completely digested, and 2 tagged fish (1 skipjack tunas and 1 yellowfin tuna) partially digested from the stomach contents of a single large yellowfin tuna (Fig. 3c). They were recovered 48, 21, and 12 hours later, at distances of 41.7, 12.6, and 20.2 NM, from each tagging site, respectively. In the case of Brazil, the tunas were tagged using the boat as the own aggregator, in a technique called as 'associated schools', using handlines, in São Tomé and Principe the tunas were tagged from natural aggregations, using trolling lines, and in Cotê d'Ivoire the tunas were tagged mainly around moored Fish Aggregation Devices (FADs).

Several tagging cruises were made on aggregated schools and the occurrence of 3 fish in the stomach of a large yellowfin tuna, which were tagged in 3 consequent days, gives us evidence that these predators probably follow the boat during tagging, taking advantage of more vulnerable prey. Indeed, those fish tagged and released almost certainly get confused for a short period after being hooked, caught and then deprived of oxygen. It is also common that they are released with some bleeding, which will attract top predators, such as sharks, billfishes, and tunas.

This is the first report about the occurrence of dart tags in the stomach of top predators, however, there are some previous reports of the predation by sharks on tunas equipped with pop-up satellite archival tag (Hoolihan et al., 2014; Cosgrove et al., 2015) and also on marlins and opah (Kerstetter et al., 2004), which could be evidence that such tags may attract predators in the post release, decreasing the retention rates.

A deeper examination in the trophic linkages within the top predator guild reveals the potential occurrence of complex interactions among and within species in the form of intra-guild predation and cannibalism, where large-bodied marlins commonly consume skipjack and yellowfin tuna. Pelagic sharks are widely viewed as opportunistic top predators, and skipjack, yellowfin, and bigeye tunas all cannibalize juveniles with some regularity (Essington et al., 2009).

There are only few reports of yellowfin tuna in the stomach contents of blue marlin (Brock, 1984; Shimose et al., 2006), and both of these were reported from the Pacific Ocean. Note that there is another observation but only to genus (*Thunnus* sp.) in the literature made by Vaske Jr et al (2011) since the species could not be identifiable.

This *Short Communication* makes the first report of cannibalism by yellowfin tuna in the juvenile phase, which are exceptionally scarce and the few observations that have been made were for the larval stages only (Reglero et al., 2011; Uriarte et al., 2019). Skipjack, however, have been regularly reported from stomach contents of yellowfin tuna in the Atlantic Ocean (Dragovich and Potthoff, 1972; Vaske Jr and Castello, 1998; Ménard et al., 2000; Vaske Jr et al., 2003; Silva et al., 2019). Otherwise, in an extensive work in the western and south Pacific, Conand and Argue (1980) reported cannibalism from skipjack tunas and also the occurrence in the stomach contents of another pelagic predators like yellowfin tuna.

With very short-term recaptures, there is a possibility that the predatory behaviors observed may not accurately reflect the "natural order". Confusion and excitement created around a tagging vessel (AOTTP used baitboats to tag the majority of its fish) could either artificially inflate the rate of predation by conspecifics or cause predators to consume species they would not otherwise target. However, predation events over longer-term recaptures are much less likely to have been impacted by the tagging activity itself and could be good indicators of trophic interactions in the wild.

Surely the high digestion rate by top predators maybe a factor limiting this kind of study. According to Olson and Boggs (1986), based on captive studies, yellowfin tuna spent almost 14 hours to digest a mackerel, corroborating with our findings recovering just a tag after 48 hours of the releasing, while the other tunas released between 21 and 12 hours were partially digested, indicating they were eaten almost simultaneously. On the other hand, the almost intact skipjack tuna may have been consumed just a few hours ago.

Our findings occurred at random, with tagged fishes founded occasionally in the moment of evisceration of top predators by the fishers, but they do indicate that with proper planning it might be possible to use dart tags as a tool for studying trophic relationships, in both captive and natural environments for a better understanding of processes such as gastric evacuation and digestion rate, as well as prey-predator interactions.

5. Declarations of interest

None

6. Author contributions

GBS: collected data in the field, compiled the information from the database, analyzed stomach contents, and wrote the manuscript. LEA: former AOTTP assistant coordinator, organized the database, and reviewed the manuscript; JMA: collected data in the field, analyzed the stomach contents, and reviewed the manuscript; RFM: collected data in the field, analyzed the stomach contents, and reviewed the manuscript; FH: regional coordinator of AOTTP and reviewed the manuscript; DB: coordinator of the AOTTP and reviewed the manuscript.

7. Funding

The AOTTP Program is funded by the European Union (DCI-FOOD/2015/361-161), ICCAT CPCs, and Contributors.

8. Acknowledgements

We would like to thank everyone involved in the AOTTP project. In particular, we thank the skippers and crew members of all the tagging boats for their hard work finding and catching fish, as well as the tag recovery teams who worked tirelessly to find tagged fish, distribute rewards and send the metadata back to ICCAT.

9. Tables and figures

Table 1.

Predator	FL (cm)	Prey(s)	Prey FL (cm)	Dispersion (nautical miles)	Location	Reporting Source
Yellowfin	130	1 SKJ	51	74.2	WA	RT
Shark (n.i)	UND	1 SKJ	40	75.9	EA	RT
Blue marlin	UND	1 YFT	60	UND	EA	RT
Yellowfin	150	1 SKJ	46	17.7	WA	TT
Yellowfin	166	2 SKJ; 1 YFT	46;54;40	41.7; 12.6; 20.2	WA	TT

Figure 1.

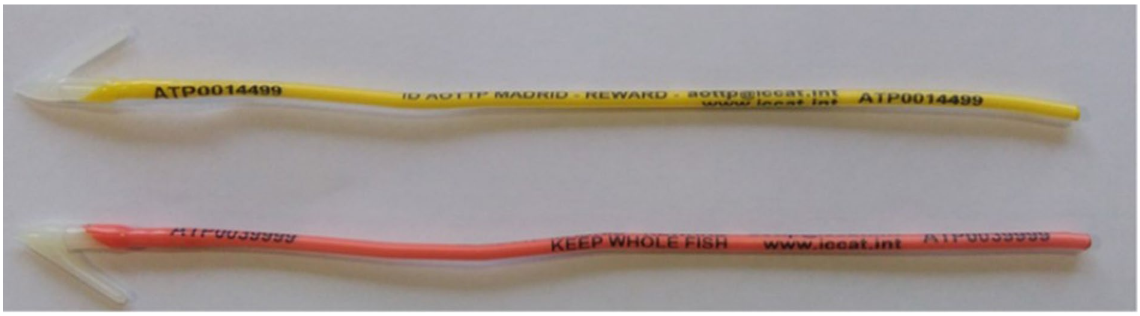


Figure 2.

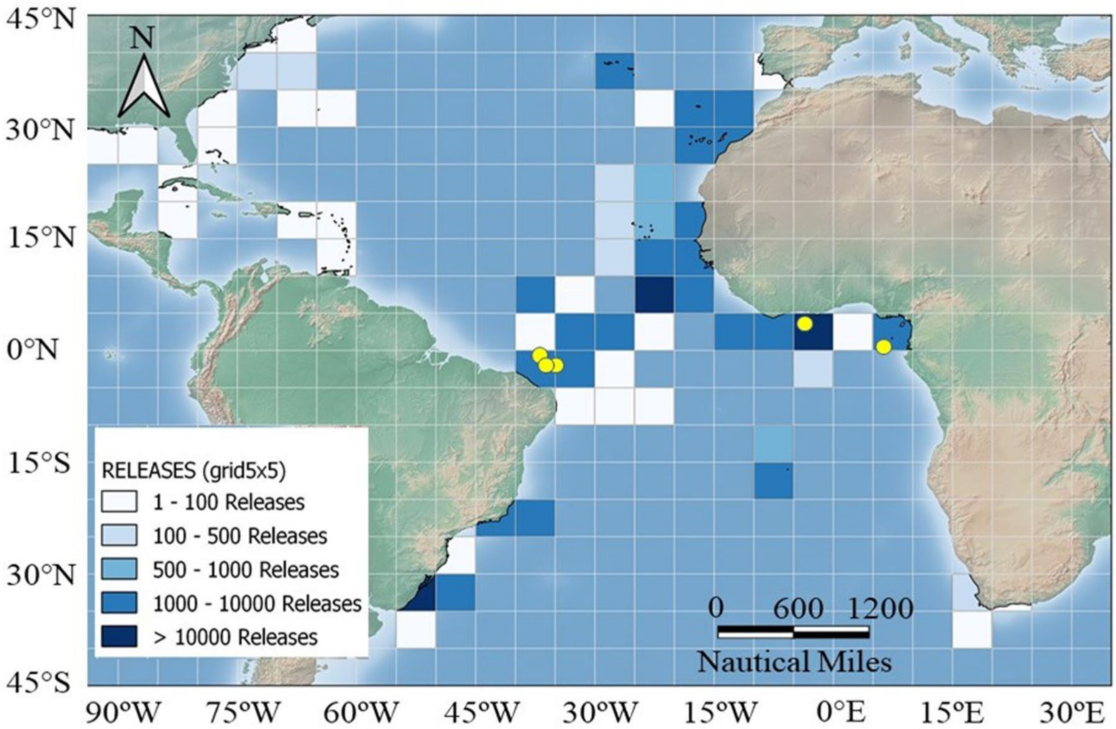
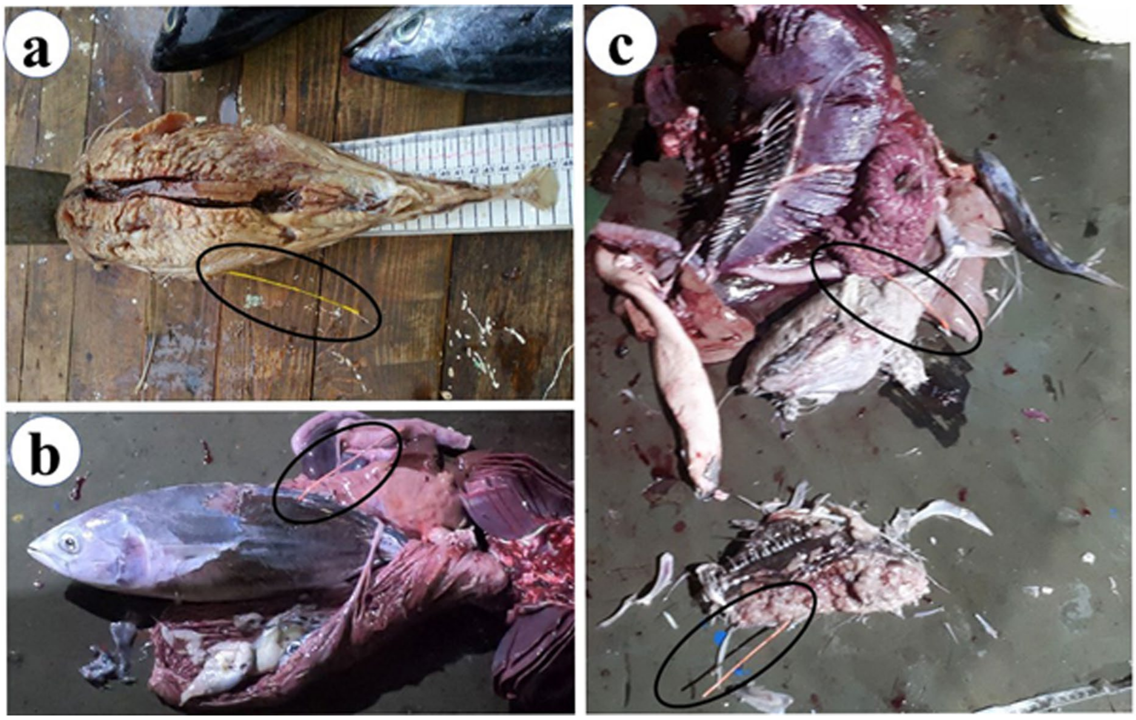


Figure 3.



10. Table and figure captions

Table 1. Detailed information from the tags recovered in the stomach content of large pelagic fishes in the Atlantic Ocean. (FL: fork length; SKJ: skipjack; YFT: yellowfin tuna; n.i: not identified; UND: undefined; WA: western Atlantic; EA: eastern Atlantic; RT: recovery team; TT: tagging team).

Figure 1. Plastic dart tags deployed by the Atlantic Ocean Tropical Tunas Tagging Programme (AOTTP). Source: https://www.iccat.int/aottp/en/aottp-tagging.html

Figure 2. Map of the Atlantic with the distributions of releases and the points where the dart tags were recovered inside the stomach of large pelagic fishes (yellow circles).

Figure 3. Some dart tags (black circles) from the AOTTP Program found in the stomach contents of large pelagic fishes in the Atlantic Ocean: a) yellowfin tuna (60 cm) found in the stomach of a black marlin (Photo by: Justin Amandé/AOTTP Abidjan); b) skipjack (46 cm) found in the stomach content of a 150 cm yellowfin tuna (Photo by: Guelson Silva/AOTTP Brazil); c) stomach content of a 166 cm yellowfin tuna (Photo by: Guelson Silva/AOTTP Brazil).

11. References

Beare, D., Ailloud, L., Garcia, J., Kebe, S., 2019. AOTTP tag-recapture data for yellowfin tuna : an update. Collect. Vol. Sci. Pap. ICCAT 76, 108-125.

Brock, R.E., 1984. A contribution to the trophic biology of the blue marlin (*Makaira nigricans* Lacepede, 1802) in Hawaii. Pacific Sci. 38, 141–149.

Conand, F., Argue, A. W., 1980. Preliminary observations on juvenile skipjack from the stomachs of adult skipjack caught by pole-and-line gear. SPC Twelfth Regional Technical Meeting on Fisheries, 21 p. https://core.ac.uk/download/pdf/39877375.pdf (Acessed 12 october 2021).

Cosgrove, R., Arregui, I., Arrizabalaga, H., Goni, N., and Neilson, J. D. 2015. Predation of pop-up satellite archival tagged albacore (*Thunnus alalunga*). Fisheries Research, 162: 48–52. https://doi.org/10.1016/j.fishres.2014.09.003

Dragovich, A., Potthoff, T., 1972. Comparative study of food of skipjack and yellowfin tunas off the coast of west Africa. Fish. Bull. 70, 1087–1110.

Essington, T., Hunsicker, M., Olson, R., 2009. Predation, Cannibalism, and the Dynamics of Tuna Populations. Pelagic Fisheries Research Program 14, 1–20.

Fonteneau, A., Hallier, J.P., 2015. Fifty years of dart tag recoveries for tropical tuna: A global comparison of results for the western Pacific, eastern Pacific, Atlantic, and Indian Oceans. Fish. Res. 163, 7–22. https://doi.org/10.1016/j.fishres.2014.03.022

Hoolihan, J. P., Wells, R. J. D., Luo, J., Falterman, B., Prince, E. D., and Rooker, J. R., 2014. Vertical and horizontal movements of yellowfin tuna in the Gulf of Mexico. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 6: 211–222.

Kerstetter, D. W., Plovina, J. J., and Graves, J. E., 2004. Evidence of shark predation and scavenging on fishes equipped with pop-up satellite archival tags. Fish. Bull. 102, 750–756.

Leroy, B., Nicol, S., Lewis, A., Hampton, J., Kolody, D., Caillot, S., Hoyle, S., 2015. Lessons learned from implementing three, large-scale tuna tagging programmes in the western and central Pacific Ocean. Fish. Res. 163, 23–33. https://doi.org/10.1016/j.fishres.2013.09.001

Ménard, F., Fonteneau, A., Gaertner, D., Nordstrom, V., Marchal, E., 2000. Exploitation of small tunas by a purse-seine fishery with fish aggregating devices and their feeding ecology in an eastern. ICES J. Mar. Sci. 57, 525–530. https://doi.org/10.1006/jmsc.2000.0717

Olson, R. J., and Boggs, C. H., 1986. Apex predation by yellowfin tuna (Thunnus albacares): independent estimates from gastric evacuation and stomach contents, bioenergetics, and cesium concentrations. Canadian Journal of Fisheries and Aquatic Sciences 43, 1760–1775. doi:10.1139/ F86-220

Reglero, P., Urtizberea, A., Torres, A.P., Alemany, F., Fiksen, O., 2011. Cannibalism among size classes of larvae may be a substantial mortality component in tuna. Mar. Ecol. Prog. Ser. 433, 205–219. https://doi.org/10.3354/meps09187

Shimose, T., Shono, H., Yokawa, K., Saito, H., Tachihara, K., 2006. Food and feeding habits of blue marlin, *Makaira nigricans*, around Yonaguni Island, southwestern Japan. Bull. Mar. Sci. 79, 761–775.

Silva, G.B., Hazin, H.G., Hazin, F.H.V., Vaske-Jr, T., 2019. Diet composition of bigeye tuna (Thunnus obesus) and yellowfin tuna (*Thunnus albacares*) caught on aggregated schools in the western equatorial Atlantic Ocean. J. Appl. Ichthyol. 35, 1111–1118. https://doi.org/10.1111/jai.13949

Uriarte, A., Johnstone, C., Laiz-Carrión, R., García, A., Llopiz, J.K., Shiroza, A., Quintanilla, J.M., Lozano-Peral, D., Reglero, P., Alemany, F., 2019. Evidence of density-dependent cannibalism in the diet of wild Atlantic bluefin tuna larvae (*Thunnus thynnus*) of the Balearic Sea (NW-Mediterranean). Fish. Res. 212, 63–71. https://doi.org/10.1016/j.fishres.2018.12.013

Vaske Jr, T., Castello, J.P., 1998. Conteúdo estomacal da albacora-laje, *Thunnus albacares*, durante o inverno e primavera no sul do Brasil. Rev. Bras. Biol. 58, 639–647. https://doi.org/10.1590/s0034-71081998000400011

Vaske Jr, T., Travassos, P.E., Pinheiro, P.B., Hazin, F.H.V., Tolotti, M.T., Barbosa, T.M., 2011. Diet of the blue marlin (*Makaira nigricans*) (PERCIFORMES: ISTIOPHORIDAE) of the southwestern equatorial Atlantic Ocean. Brazilian J. Aquat. Sci. Technol. 15, 65. https://doi.org/10.14210/bjast.v15n1.p65-70

Vaske Jr, T., Vooren, C.M., Lessa, R.P., 2003. Feeding strategy of yellowfin tuna (*Thunnus albacares*) and wahoo (*Acanthocybium solandri*) in the Saint Peter and Saint Paul Archipelago, Brazil. B. Inst. Pesca 29, 173–181.