FISHERIES IN THE SAINT PETER AND SAINT PAUL ARCHIPELAGO: 13 YEARS OF MONITORING

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ABSTRACT

The objective of the present study was to verify the temporal variation of the specific composition of the pelagic fishes caught by commercial fishing boats and the catch-per-unit-effort (CPUE) of the main caught species in the Saint Peter and Saint Paul Archipelago (SPSPA). Data from six fishing boats based in Natal - RN (Brazil) that operated in the SPSPA were monitored between 1998 and 2010, with a total of 290 landings. The yellowfin tuna (*Thunnus albacares*) was the main species caught, showing a relatively stable CPUE throughout the years. Monthly yellowfin tuna CPUE values has shown a large increase between November and March indicating a greater abundance of this species during this period. Wahoo (*Acanthocybium solandri*) CPUE was also rather stable over the years and monthly CPUE indicated an increase between July and September. The rainbow runner (*Elagatis bipinnulata*) CPUE also remained stable over the years and grew in the summer, between October and December. Flying fish (*Cheilopogon cyanopterus*) CPUE showed a decline in the last years of monitoring and monthly CPUE had low values from June to November and high values in the remaining months, with peaks in December and April. Observed CPUE variations of the monitored species are discussed throughout the text.

Keywords: *Acanthocybium solandri;* catch-per-unit-effort; *Cheilopogon cyanopterus; Elagatis bipinnulata; Thunnus albacares*

PESCA NO ARQUIPÉLAGO DE SÃO PEDRO E SÃO PAULO: 13 ANOS DE MONITORAMENTO

RESUMO

O objetivo do presente trabalho foi verificar a variação temporal da composição específica dos peixes pelágicos capturados pela frota comercial e a captura-por-unidade-de-esforço (CPUE) das principais espécies capturadas no Arquipélago de São Pedro e São Paulo (ASPSP). Dados de seis barcos baseados em Natal – RN, que operaram no ASPSP entre 1998 e 2010, foram monitorados, com um total de 290 desembarques. A albacora-laje (*Thunnus albacares*) foi a principal espécie capturada, com a CPUE permanecendo relativamente estável durante os anos. A variação mensal da CPUE da albacora-laje mostrou um grande aumento do seu valor entre os meses de novembro e março, indicando uma maior abundância desta espécie durante este período. A cavala-impigem (*Acanthocybium solandri*) também apresentou uma CPUE estável ao longo dos anos, com aumento do seu valor entre os meses de julho e setembro. A CPUE do peixe-rei (*Elagatis bipinnulata*) também permaneceu estável ao longo dos anos, apresentando um aumento no verão, entre outubro e dezembro. A CPUE do voador-holandês apresentou um declínio durante os últimos anos de monitoramento e a CPUE mensal teve valores baixos de junho a novembro e valores elevados nos meses restantes, com picos em dezembro e abril. As variações da CPUE observadas nas espécies monitoradas são discutidas ao longo do texto.

Palavras chave: *Acanthocybium solandri;* captura-por-unidade-de-esforço; *Cheilopogon cyanopterus; Elagatis bipinnulata*; *Thunnus albacares*

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INTRODUCTION

The Saint Peter and Saint Paul Archipelago (SPSPA) is a small group of rocky islands located in the middle of the Atlantic Ocean, 510 miles off the Brazilian coast and 985 miles from Guinea-Bissau, in the African coast (00º55'02"N, 29º20'42"W) (Figure 1). It is located within 50 miles from the equator and has an emerged area of about 7,500 m^2 distributed in three main islands. Because of its strategic location, it is an important feeding and reproduction ground for several migratory pelagic species (VASKE-JR *et al.*, 2003; LESSA *et al.*, 1999). Due to its long distance from the coast, the SPSPA presents a high level of endemism, making it an area of high relevance for the conservation of biodiversity (LUBBOCK and EDWARDS, 1981; VASKE-JR *et al.*, 2005; VIANA *et al.*, 2010).

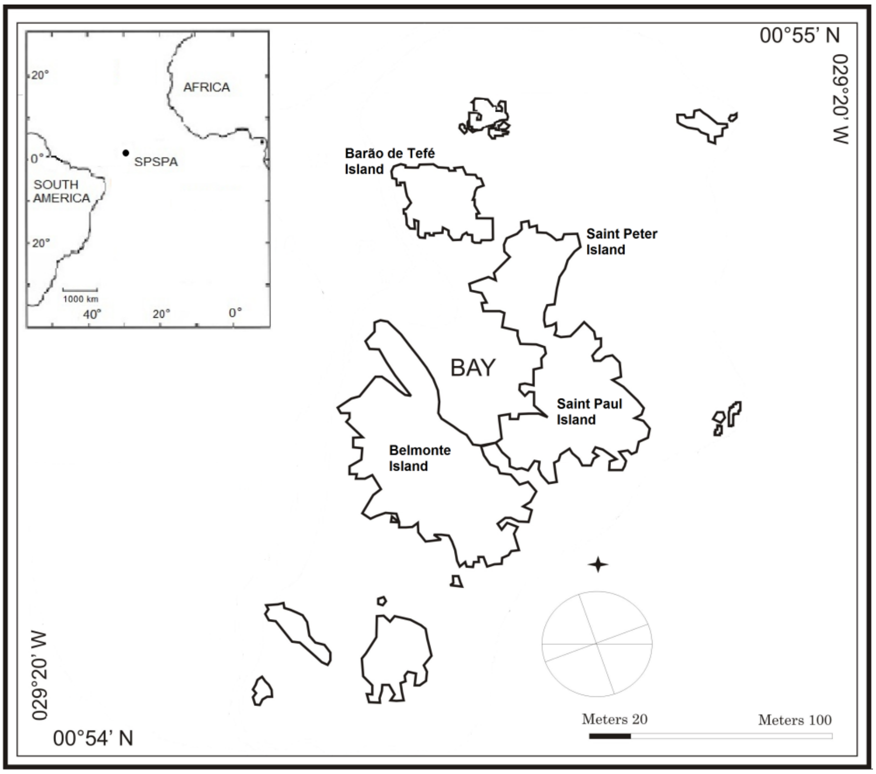

Figure 1. Saint Peter and Saint Paul Archipelago, Brazil, and its islands.

Commercial fishing activities in the vicinity of SPSPA were probably first carried out by Japanese tuna longliners in the late 50's (WISE, 1968). Brazilian vessels started fishing in the area in the mid 1970's from the Natal port (PAIVA and GALL, 1975), in the Rio Grande do Norte state, targeting yellowfin tuna (*Thunnus albacares,* Bonnaterre, 1788), wahoo (*Acanthocybium solandri,* Cuvier, 1832), flying fish (*Cheilopogon cyanopterus,* Valenciennes, 1847), and rainbow runner (*Elagatis bipinnulata,* Quoy and Gaimard, 1825), but due to the long distance from the coast, these activities were very sporadic and scattered along time. It was only from the mid 1980's onwards that Brazilian fishing boats started to fish regularly in SPSPA, particularly during the fourth and first quarters of the year, targeting yellowfin tuna, abundant in that area during that particular period of the year (OLIVEIRA *et al.*, 1997), and the other three species mentioned above, in a more opportunistic manner. According to VASKE-JR. *et al.* (2010), catches of those four species sum up to 85% of the total catch in SPSPA.

Four fishing gears and techniques are predominantly used to catch fish in the SPSPA, according to VASKE-JR. *et al.* (2010): a) portable hand-held scoop net, b) handline, c) trolling, and d) pelagic longline. The scoop net is used to catch flying fish that are attracted by a set of lights during night time. The handline fishery is also done at night, mainly from November to April when the density of flying-fish increases significantly in conjunction to its spawning season (LESSA *et al*., 1999). Live flying-fish caught by scoop nets are then used as bait to catch yellowfin tunas. Although yellowfin tuna is the main target of this fishery, it also catches rainbow runner, sharks and other species. Trolling is used to catch mostly wahoo, with fishing operations occurring in early morning and late afternoon. Five monofilament lines equipped with one hook each are baited with fillet of flying fish (or shark leader cut to look like a small fish) and are then dragged around the SPSPA. Wahoo accounts for more than 99% of the total catch of this fishery. Dolphin fish (*Coryphaena hippurus*), black jack (*Caranx* spp.) and the great barracuda (*Sphyraena barracuda*) are also eventually caught. Pelagic longlines employed in the vicinity of SPSPA usually have 10 km and 180 hooks. Squids (*Ommastrephidae* spp.), mackerel (*Scomber japonicus*) and oilfish (*Ruvettus pretiosus*) are commonly used as bait. Longlines are set in the water after midnight, while the retrieval generally starts soon after sunrise. Dolphin fish, oilfish and several species of billfish, tuna and sharks are caught by longline (VASKE-JR. *et al*., 2010).

Overall, the main species caught by each of these fishing methods are known but the annual trends and seasonal variation of catch composition and of catch-per-unit-effort (CPUE) are not. Such basic information is necessary to make a diagnostic of the status of the fisheries in SPSPA and to guide conservation and management measures. Moreover, intensive fisheries in the SPSPA can cause localized depletions of the stock leading to important economic losses. In this paper, therefore, as an attempt to start filling this gap, fisheries data sampled during 13 years including estimation of CPUE and catch composition of the major fishing activities around SPSPA, were analyzed.

MATERIAL AND METHODS

The present study was based on landings of six fishing boats that operated in the SPSPA from July 1998 to December 2010, with a total of 290 landings (Table 1). Data was collected from the production records of the fishing company TRANSMAR based in Natal – RN. Other boats fish sporadically in the SPSPA, especially from December to March, but data on their landings were not available. The sampled data, therefore, do not include the total fishing effort and catches done in the area, although they do cover the majority of the fishing operations. Total production from all years of monitoring was separated by species for analysis of catch composition and relative participation of the main caught species.

Table 1. Annual and monthly number of the sampled landings of fish carried out by the Brazilian fleet that operated in the surroundings of the SPSPA, Brazil, between July 1998 and December 2010.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Jan	---	2	1	1	2	2	1	3	3	2	2	2	2	21
Feb	---	2	1	2	2	2	2	2	4	2	2	2	2	25
Mar	---	2	1	2	1	3	4	3	2	2	2	2	2	26
Apr	---	2	2	2	2	4	2	3	3	2	2	2	2	28
May	---	2	1	2	2	2	---	---	3	2	2	2	3	21
Jun	---	2	2	2	2	3	---	---	2	2	2	2	1	20
Jul	2	2	2	2	2	2	2	1	2	2	2	1	2	24
Aug	2	2	1	2	1	1	1	3	2	2	1	2	2	22
Sep	2	2	2	2	2	3	1	2	2	1	2	2	2	25
Oct	2	1	2	2	2	1	2	2	2	2	2	2	1	23
Nov	2	2	2	1	1	3	5	2	1	2	2	1	2	26
Dec	2	1	2	2	4	2	3	2	---	2	2	3	2	27
Total	12	22	19	22	23	28	23	23	26	23	23	23	23	290

CPUE was calculated as kilograms of fish by fishing day, since the number of fishing days in the vicinity of SPSPA (15 days) is rather constant for every trip. The days at sea, travelling to and from the area were not considered. Number of fishing hours in one day can vary throughout the year depending on the abundance of target species, but this variation was not accounted for in the present study. For each stratum (year or month), the average CPUE was calculated as the ratio between the sum of catches and the sum of the effort. Such calculation is equivalent to average CPUE weighted by effort (QUINN *et al.*, 1982). Analysis of variance (ANOVA) was applied to the main caught species in order to determine whether there is a difference between monthly and yearly CPUEs. Whenever a difference was found, Tukey's complementary test (TUKEY, 1949) was used to identify which months or years differed significantly (95% significance level). The statistic program R (R CORE TEAM, 2014) was used for the statistical analysis and production of figures.

RESULTS

Catches

Catch in the SPSPA for all captured species totaled approximately 150 tons per year, with a peak of 250 tons in 2003 and 2004, and minimum of 64 tons in 1998 (Figure 2). Catches of tunas (*T. albacares, Thunnus obesus, Thunnus atlanticus* and *Thunnus alalunga*) increased from 1998 to 2003, followed by a decreasing trend (Figure 3). Catches of wahoo (*A. solandri*) did not show a clear yearly trend, although a drop in catches was noticeable in 2002. This behavior was also observed in the flying fish (*C. cyanopterus*) catches that became very small or even zero after 2005. There is no information about catches in 2006 for species other than tunas and wahoo. Catches of sharks (unclassified) peaked in 2001 and 2005, decreasing considerably after that year. Rainbow runner (*E. bipinnulata*) catches fluctuated along the period, but with no clear trend. High catches for the species were recorded in 1999, 2002 and 2007. Black jack (*Caranx* spp.) had a very high catch in 2004, relative to other years, while oilfish (*R. pretiosus*) catches peaked in 1998 and 2007. Swordfish (*Xiphias gladius*) catches were high in 2001, 2002 and 2009 (Figure 3).

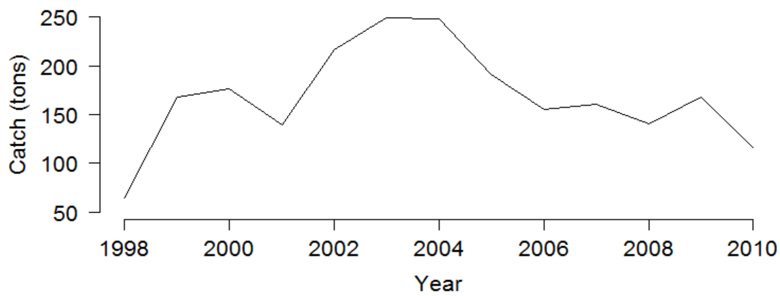

Figure 2. Total production of fish (tons per year) captured in the SPSPA, Brazil, between July 1988 and December 2010.

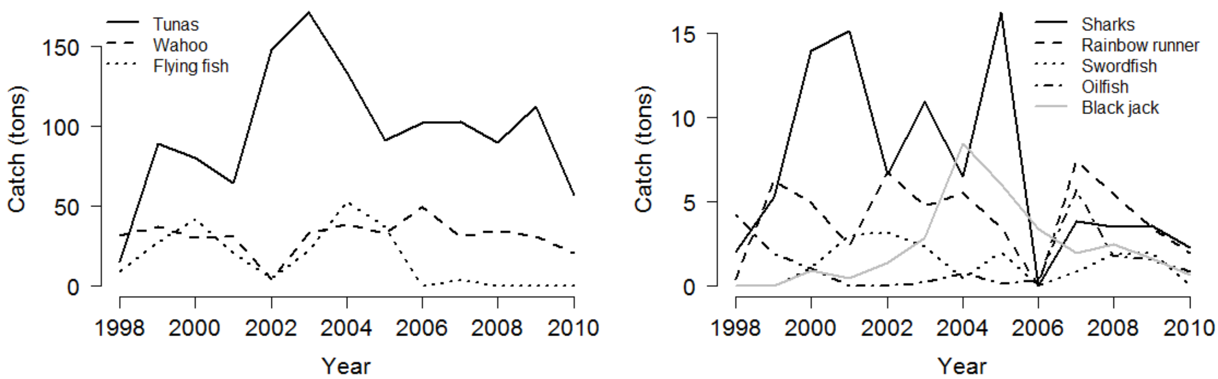

Figure 3. Total production of fish (tons per year) per species captured in the SPSPA, Brazil, between July 1988 and December 2010.

The tunas have accounted for more than half of the total catch for all years, except for 1998 (Figure 4). Although bigeye tuna (*T. obesus*), blackfin tuna (*T. atlanticus*) and albacore (*T. alalunga*) are also caught, the large majority of catches has been of yellowfin tuna (*T. albacares*), even though the data are not broken down by species. Wahoo catch accounted for 20% of landings during the study period, followed by flying fish (10%) and rainbow runner (3%). Together, these four main species accounted for more than 90% of the total catch. Other species caught included: dolphin fish (*C. hippurus*), billfish (*Istiophorus albicans, Makaira nigricans, Kajikia albida*), blue runner (*Caranx crysos*), yellow jack (*Carangoides bartholomaei*), ocean triggerfish (*Canthidermes sufflamen*), black triggerfish (*Melichthys niger*), skipjack tuna (*Katsuwonus pelamis*) and the great barracuda (*S. barracuda*).

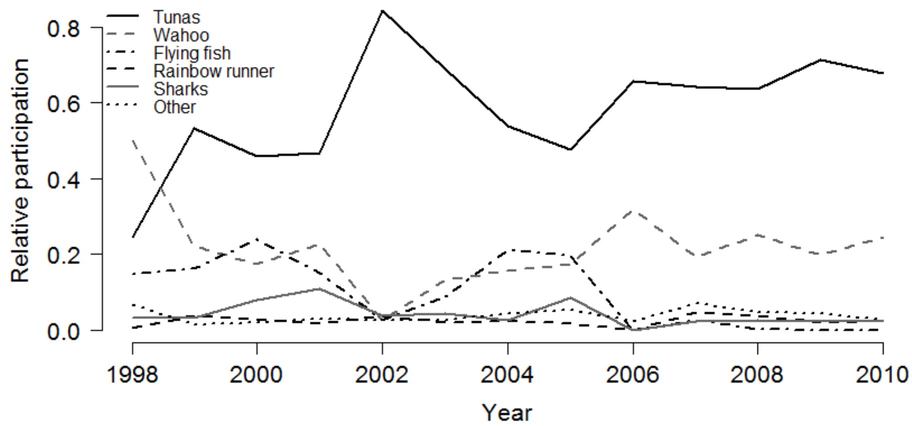

Figure 4. Relative participation per specie captured in the SPSPA, Brazil, between July 1998 and December 2010.

CPUE

Despite a rather large variation, there was no clear trend in the yearly CPUE of tunas over the years of study (Figure 5A), although this species presented statistically significant differences (p<0.05) among years (Table 2). According to the results from the Tukey's complementary test, the year of 1998 had significant lower mean CPUE than 2002 (p = 0.035), 2003 (p = 0.049) and 2004 (p = 0.021). Monthly CPUE values, however, showed a clear seasonal pattern (Figure 5B), with higher values from November to March and lower from July to September. These months showed significantly higher CPUE than the other months, according to the Tukey's complementary test (p<0.05). Variation of wahoo yearly CPUE was moderate (Figure 5C), with no clear time trend and no statistically significant differences among years. The overall seasonal pattern showed by wahoo was, however, different from that showed by tunas, with two clear cycles of high CPUE in January and February, and from July to September (Figure 5D), period in which tuna CPUEs were low. Yearly CPUEs of rainbow runner were not as high as those shown by yellowfin tuna and wahoo (Figure 5E), but its monthly CPUE showed a seasonal pattern which resembled the one exhibited by tunas, with higher values from October to March (Figure 5F). Flying fish yearly CPUE showed a decline in the last years of monitoring, with no reported catch in 2006 and from 2008 to 2010 (Figure 5G). Seasonal pattern is however apparent with low values of CPUE from June to November and high values in the remaining months, with peaks in December and April (Figure 5H). All analyzed species presented a statistically significant difference (p<0.05) of monthly CPUE (Table 3).

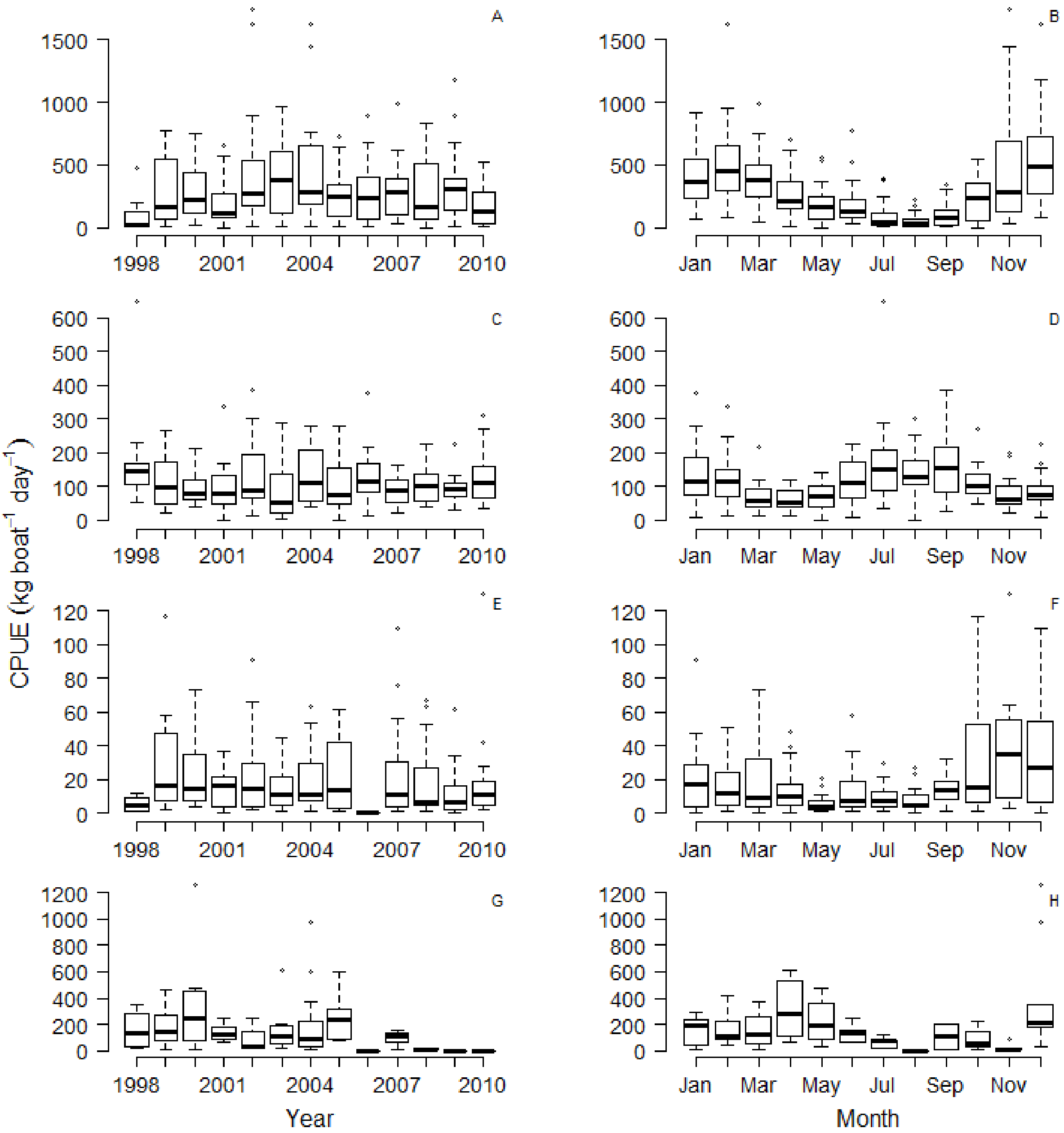

Figure 5. Annual and monthly CPUE (kg boat-1 day-1) of tunas (A and B), wahoo (C and D), rainbow runner (E and F) and flying fish (G and H) caught in the SPSPA, Brazil, between July 1998 and December 2010. Center of the bars represent the medium of annual and monthly CPUE.

Table 2. ANOVA table for yearly CPUE of analyzed species caught by the Brazilian fleet that operated in the surroundings of the SPSPA, Brazil, between July 1998 and December 2010.

Species	***df***	**Sum of Squares (SS)**	**Mean of Squares (MS)**	**F (ratio)**	***p* (probability)**
Tunas	13	2551490	196268	2.609	0.00193
Wahoo	13	130516	10040	1.72	0.0563
Flying-fish	13	552251	42481	0.959	0.00324
Rainbow runner	13	5698	438.3	0.924	0.53

Table 3. ANOVA table for monthly CPUE of analyzed species caught by the Brazilian fleet that operated in the surroundings of the SPSPA, between July 1998 and December 2010.

Species	*df*	Sum of Squares (SS)	Mean of Squares (MS)	F (ratio)	*p* (probability)
Tunas	11	7554878	686807	12.4	$<2e^{-16}$
Wahoo	11	400939	36449	7.522	$2.34e^{-11}$
Flying-fish	11	1102957	100269	2.841	0.0039
Rainbow runner	12	15734	1311.2	3.113	0.000459

DISCUSSION

Reported fish production of the SPSPA represents around one percent of the Rio Grande do Norte state total catch (MPA, 2011). Although this is a low contribution for fisheries production in the region, it is an important fishing ground for many local boats that fish constantly in the area. Furthermore, although most of the catches are here reported, total catch of the SPSPA is certainly underestimated mainly in the yellowfin tuna season (November to March), since this study does not cover all boats fishing in the area. Although the higher catches in 2002 may be related to higher abundances, it is not possible to ascertain that based only on CPUE values. In 2003, higher catches were probably due to the higher number of boats fishing in the area. The year of 1998 showed a significantly lower catch in comparison with other years mainly because of a lower number of landings.

VASKE-JR. *et al.* (2008) reported wahoo, yellowfin tuna and rainbow runner as the three main species caught in the SPSPA. This result is slightly different from the present work that reported flying-fish with a higher catch than rainbow runner. This is due to the fact that VASKE-JR. *et al.* (2008) did not consider flying-fish catches since it is not a target of the fisheries, being taken only when there is empty storage space in the vessels. Wahoo and yellowfin tuna comprised most of the catches in both studies, but with yellowfin tuna being the main caught species in the present study and wahoo representing most of the catches according to VASKE-JR. *et al.* (2008). To put the yearly total catches of yellowfin tuna done in the SPSPA in perspective, it represented, in 2010, when about 60 tons were landed, around 0.06% of the total catches from the stock, close to 100 thousand tons (ICCAT, 2011).

Regardless of annual oscillations, mean CPUE values for the yellowfin tuna maintained relatively stable throughout the years. CPUE yearly oscillations can be associated with factors inside the SPSPA or throughout all its migration trajectory and cycle around the Atlantic. A reason for such fluctuations can be localized depletions of the Atlantic stock from fisheries through their migration route. According to stock assessments from ICCAT, stock level in early 2000 was one of the lowest in history, while it varies significantly through time (ICCAT, 2011). Other factors can be natural fluctuations of the stock, recruitment, oceanographic features, variation in prey availability and feeding behavior, migratory processes or variation on the number of fishing boats operating in the SPSPA, processes that commonly affect all tuna species in the Atlantic (MAURY *et al.*, 2001; ANDRADE *et al.*, 2005).

Greater monthly CPUE values for the yellowfin tuna were observed between November and March. These months differed significantly from the others indicating a possible increase in the species abundance during this period. Expeditions on the research vessel Riobaldo in 1985 and 1986 also reported the seasonality of the yellowfin tuna in the SPSPA, with higher CPUE values in November and December and lower values in June and July (OLIVEIRA *et al.*, 1997), corroborating with the present work. The seasonal increase in abundance is probably due to high concentrations of flying fish in the area, an important prey for tunas. From November to April flying fish aggregates around the SPSPA for reproduction purposes (LESSA *et al.*, 1999). HAZIN (1993) reported that the yellowfin tuna uses the area as a feeding ground, during its returning migration from the western Atlantic to the African coast. VASKE-JR. *et al.* (2003) confirmed the predominance of flying fish in the stomach contents of yellowfin tuna caught in the SPSPA. Biological and fishery data indicate that most of the yellowfin tuna caught in the SPSPA are juveniles, with an average length of 99.6 cm (VASKE-JR *et al.*, 2008) while the maturity length in the Atlantic, for longline-caught specimens, is 140 cm (ALBARET, 1977). This information further supports that tunas are in the area mainly for feeding and not for reproductive purposes. COELHO *et al.* (2014) also found a seasonality of the albacore CPUE in the Reunion Islands, with higher values from November to March, demonstrating that is a common behavior in oceanic islands around the world.

Wahoo CPUE remained relatively constant throughout the years, with no statistically significant difference. OLIVEIRA *et al.* (1997) reported a greater mean CPUE value (264 kg boat^{-1} day^{-1}) than in the present work (115 kg boat^{-1} day^{-1}) during an expedition on the research vessel Diadorim in 1997. These figures, however, are not directly comparable since Diadorim was a research vessel, conducting a scientific expedition, while the present data come from a commercial operation. The increase of wahoo CPUE values in January-February and between July and September probably happen for different reasons. Since this species uses the SPSPA for reproduction (VIANA *et al.*, 2008; VIANA *et al.*, 2013) in the first months of the year, the rise in CPUE during January-February is likely a result of a reproductive migration. The CPUE rise from July to September, on the other hand, is probably also influenced by an increase of fishing hours for the species due to the reduction in catches of yellowfin tuna.

Yearly rainbow runner CPUE presented certain stability during the study period, with no statistically significant difference among years. Increase in CPUE values on the last quarter of the year seems to occur right before its spawning period in the SPSPA, which happens between January and May (PINHEIRO *et al.*, 2011). Increases in food consumption before the spawning period is a common behavior observed in many fishes because of the high energy demanded for gonad maturation (VAZZOLER, 1996). During spawning months, however, CPUE values tend to decrease, suggesting a possible interference of the reproductive activity on the rainbow runner catch.

Flying fish is one of the main sources of food for most predators of the SPSPA and the equatorial part of the Atlantic Ocean (LESSA *et al.*, 1999; VASKE-JR *et al.*, 2003). High concentration of flying fish from November to April in the SPSPA is mainly for reproductive purposes (LESSA *et al.*, 1999), as it depends on the fixation of the eggs on rocks and algae present in the SPSPA (BRÖECKEL and MEYERHÖFER, 1999).

CONCLUSION

Information related with catches in the SPSPA through time is crucial for an adequate understanding of the fishing impacts. Despite the fact that this fishery is relatively small it is economically important for many local boats and information provided by the present work can contribute to a better management of the area. Although the studied species have migratory behaviors and uses the SPSPA mostly for feeding, excessive fishing may cause localized depletions of the stock leading to important ecologic and economic losses. Species that uses the SPSPA for reproduction purposes such as the flying-fish, rainbow runner and wahoo, are particularly vulnerable, since this may affect their recruitment. Through the 13 years of monitoring, CPUE values of the main species caught in the SPSPA, however, have not presented strong oscillations, remaining relatively stable throughout the years, indicating that a localized depletion of the exploited stocks is not yet happening. In order to ensure the sustainability of this fishery, however, monitoring of all fishing vessels operating in the SPSPA is necessary.

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