SPATIAL AND SEASONAL VARIATION OF PEACOCK BASS (Cichla spp.) FISHERY: AN ANALYSIS OF CATCHES LANDED IN MANAUS, AMAZONAS STATE, BRAZIL*

ABSTRACT
This study analysed the commercial fishing for peacock bass (Cichla spp.) and its variation according to the river regime and the fishing environments, based on landing data in Manaus. The landing data were provided by the Z-12 Fishermen’s Association and the monthly quotas (m) of Rio Negro by the National Water Agency, corresponding to the years 2012 and 2013. The Catch per Unit of Effort (CPUE) was obtained by dividing the total catch and the number of boats. A Generalized Linear Model was used to analyse the relationship between CPUE and the river level. Through the Analysis of Variance we compared the averages of capture between the fishing areas and Fisher’s LSD test revealed which environments had different capture averages. Student’s t-test was used to compare the mean of capture between white and black water environments. The largest catches and CPUEs occurred during receding water, and the relationship between CPUE and river level was inverse. Black water environments obtained the highest CPUEs, as well as the highest capture averages. There were differences in the average catches between fishing areas, but not between water types. This study shows how peacock bass exploitation occurs and can assist in management measures for this species.

Keywords: fishing production; river regime; CPUE; freshwater fishery.

INTRODUCTION
The Amazon basin encompasses a huge and complex ecosystem, including several aquatic habitats and sub-basins, which are limnologically distinct and broadly classified by the color of the water: black, clear and whitewater (Val et al., 2010). The hydrological cycle is another source of complexity. The intra-annual oscillation, with effects clearly...
defined in the flood pulse concept (Junk et al., 1989), promotes substantial changes in the environment, connecting and isolating habitats by the alternating seasons of high and low water (Bittencourt and Amadio, 2007; Hurd et al., 2016). Inter-annual climate events, such as El Niño and La Niña, could exacerbate the annual seasonality effects and cause critical impacts on the environment and its biota (Marengo and Oliveira, 1998; Freitas et al., 2012).

The Amazonian environment hosts one of the most important commercial freshwater fisheries on Earth, and the exploitation of abundant fish stocks, which are the main source of animal protein for riverine populations, generates income for small-scale fishers (Santos and Santos, 2005; Cardoso and Freitas, 2007). The peacock bass (Cichla spp.) is a genus of large cichlids, regionally known as tucunaré and, in commercial and recreational fisheries, has a high value (Batista and Petrere Júnior, 2003; Santos and Santos, 2005). It is a sedentary and piscivorous species, which preferentially inhabits lentic habitats, such as lakes and stretches of rivers with slow currents. It is a parental care fish, breeding predominantly during the receding water season (Andrade et al., 2001; Nascimento et al., 2001; Rabelo and Araújo-Lima, 2002; Gandra, 2010; Campos et al., 2015; Souza et al., 2015).

Although the peacock bass (Cichla spp.) has a high value in the regional markets and, as a consequence, is important to the commercial fisheries in the Amazon, there are few studies that analyze its catch sizes. This study describes the seasonal and spatial patterns of peacock bass fishery, based on catch data for fish landed in Manaus, the main urban center in the central portion of the Amazon basin. For this, we tested the following hypotheses: 1) The catches of the peacock bass vary according to the fishing environment; 2) The catches of the peacock bass vary according to the water type.

MATERIAL AND METHODS

Study Area

The catches landed at the Panair port in Manaus are caught all over the Amazonas state, thus the whole state was defined as the study area (Figure 1). Data regarding fish captures and fishing effort were collected at the Panair port, the main fish-landing site in Manaus and the capital of the Amazonas state. Manaus is a city with more than 2 million inhabitants, of which about 120 thousand are directly linked to fishing activity (Gandra, 2010), with most of the fish caught in the Amazon River basin being landed in the city.

Data Collection

Interviewers belonging to the Z-12 Fishers Association collected the catch data for 2012 and 2013, as well as information regarding the fishing fleet. Data were collected daily at the Panair port, though interviews with the fishers during fish landings. Hydrological data measured at the fluvial station in Manaus, where the water levels of the Negro River have been measured since 1901, were obtained from the Brazilian National Water Agency (Agência Nacional de Águas). The year 2012 was marked by the historic flood recorded on May 29 when the Rio Negro reached the 29.97 m level (Satyamurty et al., 2013). Several studies were consulted in order to correctly classify the rivers and lakes by

Figure 1. The Amazonas state, including its main rivers and the city of Manaus, where the Panair port is located.
their type of water (Guarim, 1979; Santos and Ribeiro, 1988; Cravo et al., 2002; Barthem and Goulding, 2007; Lages, 2010; Horbe et al., 2013; Silva, 2013).

Data Analysis

Capture data were clustered as catches (kg) per boat, catches (kg) per river. Afterwards, the rivers were classified by their type of water, in sensu Sioli (1968), as black and whitewater, and the data also was stored as catches (kg) per type of water. The Catch per Unit of Effort (CPUE) is an estimate of the abundance of fish stock (Sparre, 1997) and was estimated using the equation:

\[
CPUE = \frac{P}{E}
\]

where, \( P \) is the monthly landed catch and \( E \) is the fishing effort, assumed as the number of boats.

A generalized linear model using the log-transformed CPUE monthly estimate as the response variable, and a quadratic function of the monthly average of the water level as the explanatory variable, was employed to evaluate the influence of the hydrological cycle on the peacock bass fishing yield. Akaike Information Criterion (AIC) was used as criteria to evaluate the model’s fit. Packages \textit{car} (Fox and Weisberg, 2019), \textit{ggplot2} (Wickham, 2016) and \textit{MASS} (Venables and Ripley, 2002) from the Software R (R Core Team, 2019) were employed for modeling.

An analysis of variance (ANOVA) was performed to test the null hypothesis that the fishing yield is the same for all rivers. As this hypothesis was rejected, a paired Fisher test (LSD) was performed. This post hoc test is more appropriate, since the quantity of data per fishing ground is different. A Student’s t test was performed to test the hypothesis that the fishing yield is the same for each type of water: black and whitewater. The ANOVA, Fisher test and t test were done using the software STATISTICA (Weiß, 2007).

RESULTS

The total landings of peacock bass (\textit{Cichla} spp.) were 548,190 kg and 430,010 kg in 2012 and 2013, respectively (Figure 2). The largest catches for both years were observed at the end of the period of receding water (October), with 133,630 kg in 2012 and 82,650 kg in 2013. In contrast, the period of rising water showed the smallest catches; April 2012 registered catches of 1,900 kg, and May 2013, 1,650 kg. There was a historic flood of the Negro River in 2012 (Satyamurty et al., 2013) and no peacock bass were landed in May of this year.

In total, 208 and 252 fishing boats were responsible for the catches of 2012 and 2013, respectively. The total CPUE estimated for 2012 was 10,170.00 ± 423.92 (kg/number of boats) and, for 2013, total estimated CPUE was 9,648.60 ± 368.67 (kg/number of boats). For both years, the smallest CPUEs were in May and June, during the high-water season. And the greatest CPUEs for both years were reached in October, during the period of receding water (Figure 3).

The GLMs indicate the negative relationship between the CPUE and the water level for both years. Nevertheless, the explained deviance of the model for 2012 (\( p<0.001 \)) accounted for 68.29% (Figure 4) and was substantially higher than in 2013 (\( p = 0.0359 \)), when it accounted for only 36.98% (Figure 5).

In 2012, the catches of peacock bass occurred in 27 fishing grounds (rivers and lakes). However, in 2013, just 23 fishing grounds were exploited. The Manaquiri River, which is a blackwater environment, achieved the greatest CPUE (4,600 kg/number of boats) in 2012 (Figure 6). While the Coari River, also a blackwater system, showed the highest CPUE (2,344.83 kg/number of boats) in 2013 (Figure 6). Nevertheless, the location that most contributed to the total catches, taking the two years together, was the Purus River (336,450 kg), which is a whitewater environment. This river was...
also the most exploited area, with 95 and 130 boats fishing them in 2012 and 2013, respectively.

There are differences in fishing yields among the fishing grounds for 2012 (df = 26, F = 6.037, p<0.001) and 2013 (df = 22, F = 1.80, p = 0.0145). The LSD test shows that there were just two groups of fishing grounds per fishing yield, both for 2012 and 2013 (Table 1). On the other hand, the fishing yield was the same according to type of water, both in 2012 (df = 574, t = -0.743, p = 0.452) and 2013 (df = 495, t = -1.31, p = 0.189).

**DISCUSSION**

The largest fishing yield of peacock bass, observed during receding water season, corroborated the pattern observed, which indicated that this season presents better conditions for fisheries of lake species (Rabelo and Araújo-Lima, 2002; Muñoz, 2006; Alves and Barthem, 2008). In the receding water season, when the habitat of the flooded forest becomes smaller, the peacock bass moves toward open water where it is easier to catch. This
synchronic movement of the peacock bass with the water level is also related to greater prey availability near the banks of the rivers and lakes during this season (Rabelo and Araújo-Lima, 2002; Aguiar-SANTOS et al., 2018). Other studies also indicated the variability of landings according to river regime (Isaac et al., 2015; Sousa et al. 2017; Lopes and Freitas, 2018). The peacock bass is among the main species landed, not only in the present study area (Faria Junior and Batista, 2019), but also in other regions (Silva et al., 2017) and in reservoirs where it was introduced (Agostinho et al. 2007; Novaes et al., 2015).

The inverse relationship between peacock bass catches and water level could be exacerbated in years of extreme floods, such as happened in 2012 (Cerdeira et al., 2000; Barthem and Fabré, 2004). Zuanon (2008) explains that extreme flooding events could be favorable to the fish stocks, since strong recruitments one or two years after these events could produce profitable fisheries, due the increase of juvenile survivors as consequence of higher availability of refuges against predators and food. This pattern could describe more accurately what happens with several migratory characins, which explore the floodplain habitats for nursery (Ruffino, 2014).

Figure 6. Peacock bass CPUEs estimated per fishing ground, in 2012 and 2013.
The fishing yield of peacock bass is consistently higher in blackwater environments when compared to those in whitewater ones. Amazonian blackwater rivers host several species of peacock bass, including *Cichla temensis*, which is the largest of all (Holley et al., 2008; Campos et al., 2019) and is the main target species for recreational fishers (Barroco et al., 2018).

Nevertheless, it is important to clarify that some fishing grounds, which are classified as blackwater environments, are rivers and their associated lakes with headwaters in the Amazon sedimentary plain, which are different from the true blackwater systems with headwaters in the Guyana Plateau. The rivers Manaquiri, Coari and Jutaí are typically of the first category, since they are tributaries of the Solimões River, a typical whitewater river (Santos and Ribeiro, 1988; Trevisan and Forsberg, 2007; Barbosa et al., 2016; Moquet et al., 2016). The waters of these tributaries remain black during low water seasons and are greatly influenced by the Solimões River during high-water seasons (Sousa, 2005). The ria lake systems formed near the confluence of these tributaries and the main stem of the Solimões river (Bertani et al., 2015) and seem to be preferential habitats for peacock bass (Sousa, 2005).

The Purus River is a traditional fishing area in the Amazon Basin (Petrere Júnior, 1985; Batista and Petrere Júnior, 2003), and the high levels of exploitation of this basin over the year could explain the reduced CPUE estimates seen in our study. Batista and Petrere Júnior (2003) stated that the greater part of the capture of *k* strategist species, such as peacock bass, landed in Manaus is caught in the floodplain lakes of the Purus River basin. Actually, studies on the total fish production showed that this basin is the most productive followed by the Solimões, Madeira, Amazonas and Juruá Rivers (Sousa, 2005; Corrêa et al., 2018). During the years 2012 and 2013, Corrêa et al. (2018) found that the Purus River fisheries’ contribution to the total capture landed in Manaus was 29.72% and 33.19%, respectively.

The broad distribution of the pool of *Cichla* species in the Amazon basin, with some of them, such as *C. temensis* and...
C. orinocensis, inhabiting blackwater environments and others, such as C. monoculus, C. piquiti, C. melanee, C. thyrous and C. jarina, whitewater environments are all known in the Amazon basin by the same common name “tucunaré”. This fact could explain the absence of differences in catches by water type. Willis et al. (2015) and Sousa et al. (2016) highlight how C. temensis remains in environments with similar characteristics, confirming the species’ low vagility. Since Cichla has non-migratory behavior, it is clear that stock assessment studies and management proposals should be developed per species in specific areas of the basin (Santos et al., 2012). Campos and Freitas (2014) detected an over-fishing status for C. monoculus which is caught in a floodplain area of the lower stretch of the Solimões River.

CONCLUSIONS

The highest captures and CPUE of peacock bass during the receding water indicates this period as the best for capturing this species. The non-landing of this species in an atypical flood year, suggests that this is unfavorable for commercial fishing. During low level water period, with less effort it is possible to make large captures, hence the relationship between the river level and CPUE is inverse, since as the river level decreases, CPUE increases.

The exploitation of commercial fishing occurs mainly in whitewater environments and it is multi specific, which reflected in the peacock bass capture data in this study. Even so, the largest CPUEs in blackwater environments, such as lakes, and rivers with the characteristics of lakes, reveal that in these types of water bodies there is less effort in capturing this species.

Due to the fact that the focus of this study was commercial fishing, in order to gain a better understanding of whether there really is a greater abundance of peacock bass in any of the different types of water (white or black water) or waterbodies (river, lakes), an analysis of experimental fisheries in each aquatic system is necessary. Studies such as the aforementioned can shed light on how the exploitation of the peacock bass occurs and can help manage fisheries of this species.

REFERENCES


