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ECONOMIC IMPACTS ON THE MANAGEMENT OF *ARAPAIMA GIGAS* (PIRARUCUS) IN PROTECTED AREAS IN THE CENTRAL AMAZON OF BRAZIL

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ABSTRACT

Objective: to analyze basic aspects of the management of Arapaima gigas (pirarucus) in seven Protected Areas and to evaluate the impact of the change in the legislation of the minimum capture size on the gross revenue of the Management Units in the State of Amazonas, Brazil. **Material and Methods**: the study was carried out in nine Pirarucu Management Units (UMP), linked to seven Protected Areas in the State of Amazonas, four of them Sustainable Development Reserves (RDS), Extractive Reserve (RESEX), Indigenous Land (TI) and a fisheries agreement (AP). Data collection occurred in the catches of Arapaima gigas, in the period corresponding to 4 years, and their respective weights were measured, by size classes. **Results**: The sum of Arapaima gigas (pirarucus) totaled 29,245 specimens. Of this total, the majority (49%) were captured in the third year of the survey. The quantities collected in the first year (22%) and in the second year (28%) were similar. The weight totaled 1,572.96 tons, with 50% of this total collected in the third year of the survey. The tonnages produced in the first and second surveys were also similar. The gross revenue resulting from the sale of Arapaima gigas, in the period of 4 years, was R$ 8,651,302.00 (eight million six hundred and fifty-one thousand three hundred and two reais), 91% of which came from four UMP, located in the Middle Rio Solimões region. **Conclusions**: the results of this study can contribute to the improvement of participatory regulatory frameworks, which strengthen the control instruments over the management of Arapaima gigas (pirarucu) and the management of protected areas in the State of Amazonas, Brazil.

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INTRODUCTION

Throughout the history of environmental protection, the conservation of tropical forests has been one of the greatest challenges for societies on the planet, due to the delicate balance between market demands, the need to generate goods and services and the state of need for human populations that reside inside and exploit their natural resources. In addition, they are complex and fragile ecosystems with different capacities for adaptation and resilience to climate change [Bodmer, 1994]. The Central Amazon is an example of this fragility, exposing the difficulties of reconciling the protection of its great biological diversity, which exhibits a high level of endemism, with the elementary needs of human life. The preservation of the Amazon has received attention from traditional populations in the implementation of instruments for the sustainable use of their forest, wildlife and fishing resources [Redford, 1987]. The sustainable management of natural resources in the Amazon is quite complex and faces

obstacles regarding the prevention and control system, which has not safeguarded the necessary effectiveness on the performance of the monitoring and inspection service, thus contributing to the reduction of the abundance of some species, like the *Arapaima gigas* (pirarucu) [Browder, 1992]. However, traditional populations living on the banks of lakes and rivers have been developing adaptive and participative management strategies since the 1980s, aiming at the sustainable use of their forest, wildlife and fishing resources [Redford, 1987]. In the state of Amazonas, the economic management of *Arapaima gigas* represents an important strategy for environmental conservation and income generation, becoming an alternative for the sustainable use of this fishing resource, in the aquatic environments of this State. The political decision to implement the *Arapaima gigas* management regime in Protected Areas in the State of Amazonas represents a strategic and promising conservation initiative [Bessa, 2010]. The administration of management in Conservation Units (UC) tends to be more complex, mainly in the socio-environmental scenario of the Amazon, due to the involvement of biological, social, economic and political dimensions [Da Silveira, 2006].
As a general rule, the management regime implemented in Protected Areas, in the State of Amazonas, is characterized as an adaptive and participatory process, based on the precautionary principle in relation to stocks. However, the relevance of the social, ecological, biological, political and economic dimensions must be considered as determinants for the improvement of regulatory frameworks that take into account regional conditions [Araripe, 2013]. In this logic, community participation requires greater integration from the manager in the implementation of the management steps, which must interact with the social, economic, ecological and biological dimensions. Community-based participatory management has generated significant contributions to conservation. Among these contributions, we identify the advances in the ordering of species fishing under the management regime. Community participation has also registered advances in participatory zoning, *Arapaima gigas* counting for quota authorization and, mainly, in community surveillance, an essential tool for the prevention and control of management [Castello, 2004]; [Figueiredo, 2013]. It is evident that the formulation of legal norms for the management of *Arapaima gigas*, considering the current management model, requires management bodies to allow the management of the activity based on knowledge of the biological, economic and social dimensions, through elaboration, execution and monitoring of the adoption of criteria for the use of fishing resources, according to the Amazonas State Center for Conservation Units - CEUC. The establishment of rules ensures not only the receptivity of the community, but above all the adoption of good practices by the user public, so that management on management is efficient and does not threaten the stocks to be exploited and the biological diversity of ecosystems [Da Silveira, 2012].

Initiatives to formulate regulatory frameworks for the conservation of *Arapaima gigas* occurred initially in 1975, with the inclusion of *Arapaima gigas* (pirarucu) in the list of protected species. In 1989, the minimum size was regulated, and in 1991 the reproductive defenses were standardized [10]. However, such measures have shown low effectiveness at the level of control, making researchers, managers, technicians, NGOs and fishing communities increasingly critical of the future of conservation and expressing concerns about reducing the abundance of *Arapaima gigas* in the Amazon, promoted by illegal fishing [Castello et al., 2009; Castello, 2010]. And in this context of analysis, the management of *Arapaima gigas*, developed in Amazonas, shows weaknesses in the implementation of important management instruments, as the inspection has rarely been effective, allowing uncontrolled illegal fishing. This low effectiveness is directly linked to the reduction of budgetary and human resources [Castello et al., 2011b]. On the other hand, the low level of integration in the stages of implementation, analysis and evaluation of monitoring data and other control instruments, has enabled most of the collections of *Arapaima gigas* to be violating the efficient management policy, leading to populations wild *Arapaima gigas* to become over-exploited and declining in much of the Amazon basin [Castello, 2011a]. This fact has contributed to the fact that formulators, managers and managers have limited access to the information necessary for the adoption of prevention, remediation and control. This limitation also interferes with services for the dissemination of good practices among fishermen. Most populations, in the wild, are now limited to community-based management areas [Castello et al., 2011a]. The deficiency in the integration of prevention and control actions, among managers, at the three levels of government, has hampered the conduct of *Arapaima gigas* management units and has weakened the administration of Protected Areas, and mainly, has hampered the maximization of efforts by co-managers on the management of *Arapaima gigas*.

The deficiency in the integration of prevention and control actions, among managers, at the three levels of government, has hampered the management of *Arapaima gigas* management units and has weakened the management of Protected Areas, and mainly, has hampered the maximization of efforts by co-managers, on the management of *Arapaima gigas*. The low effectiveness in complying with the rules of minimum size and reproductive closure has made fishing an unsustainable practice, negatively impacting *Arapaima gigas* populations in most of the Amazon [Bayley, 1989; Castello, 2013]. The evidence that all stages fulfill a certain function in relation to the dimensions that involve management, in the same way that compliance with the instruments for their management is essential for their sustainability. On the other hand, noncompliance with these basic rules has caused a reduction in the density of *Arapaima gigas*, in lakes in the Amazon, from being the dominant fish in fisheries, a century ago, to be an increasingly rare fish [Castello, 2011a; Bayley, 1989]. Despite this dynamic, the *Arapaima gigas* remains a symbol fish of the Amazon. Although many other fish are important, few stand out in their importance as the *Arapaima gigas*, being the fish of most interest to the riverside populations [Crampton, 2004]. The available information indicates that the lack of management is the main cause of the unsustainability of *Arapaima gigas* fishing. The development of the new *Arapaima gigas* management model in the Mamirauá Sustainable Development Reserve (RDSM), based on the *Arapaima gigas* counts, carried out by the fishermen themselves, represents an important advance towards the conservation of the species. But, in isolation, it is not enough to guarantee the desired sustainability status for the exercise of the management regime in Protected Areas in the Amazon [Castello, 2011b]. The general objective of the study was to analyze basic aspects of the management of *Arapaima spp*. (pirarucus) in seven Protected Areas and to evaluate the impact of the change in the legislation of the minimum capture size on the gross income of the Management Units in the State of

Amazonas, Brazil, and as specific objectives to verify how it varied, between years and Management Units, the number of specimens caught, the mass sold and the gross income obtained from the sale and how the size structure of the captured *Arapaima gigas* varied between Management Units. The study was carried out in seven Protected Areas in the State of Amazonas, with four Sustainable Development Reserves (RDS), an Extractive Reserve (RESEX), an Indigenous Land (TI) and a Fisheries Agreement (AP). The Fisheries Agreement of this study is a territory regulated by legal norms of the State of Amazonas, being then considered a protected area in which the management regime is allowed.

KEY ASPECTS OF *ARAPAIMA GIGAS* (PIRARUCU)

Arapaima gigas mainly inhabit floodplains, including forests, rivers, lakes and canals. Its geographical distribution is generally determined by barriers, such as waterfalls with strong currents that impede its passage. Environments with weak or no current, such as lakes, are preferred by *Arapaima gigas*, which perform lateral migrations in the lake system, following the flood pulse [Castello, 2008a; Lowe-Mcconnell, 1964]. The *Arapaima gigas* is a top predator of the trophic chain, being primarily a piscivore, generally preying on small fish, especially detritivores or omnivores [Sánchez, 1969; Queiroz, 2000]. However, a recent study, using nitrogen isotopes, indicated a tendency to omnivory. *Arapaima gigas* grows fast and reproduces relatively early [Arantes et al., 2010]. In environments where there is no fishing or where the minimum catch size is respected, the *Arapaima gigas* grows up to 88 cm in length in its first year of life, 123 cm in the second year, 154 cm in the third year, 174 in the fourth year, and 188 in its fifth year of life [Arantes et al., 2010]. In the Solimões River, the female of the *Arapaima gigas* reaches sexual maturity from 157 cm in total length and at the age of three [Arantes et al., 2010]. In the Tocantins River, the first maturation of the *Arapaima gigas* is reached in the range of 145–154 cm and 115–124 cm of female and male CT, respectively [Godinho et al., 2005]. However, Arantes et al [Arantes et al., 2010] showed that the selectivity of fishing with harpoon and mesh net tends to decrease the speed of growth of the *Arapaima gigas* population, due to the removal of larger individuals that grew faster, among those of the same cohort. Thus, the growth of *Arapaima gigas* is also affected by fishing practices and equipment. During the dry season, *Arapaima gigas* form couples, and when the level of rivers rises, couples build nests on the banks of the flooded forest that surrounds the environments of the channel lakes [Castello, 2008a; Castello, 2008b]. The *Arapaima gigas* couple deposits, fertilizes, and takes care of the eggs until they hatch. There are indications that the genus can make multiple spawning in the same year [Luling, 1964; Neves, 1995]. The male takes care of his offspring, and migrates to the flooded forests that offer an environment rich in food. Insects and small shrimp are preferred food for young *Arapaima gigas* [Sánchez, 1969; Queiroz, 2000]. The *Arapaima gigas* population can recover quickly from overexploitation largely due to parental care, rapid sexual growth and maturation. Studies carried out on five *Arapaima gigas* populations that were overexploited and started to be fished under management indicated increases in abundance at an average rate of 25% per year [Arantes, 2006]. The empirical model developed by Castelo et al. [2004] on population dynamics estimated that well-managed populations of *Arapaima gigas* can yield about 1.5 kg/ha of whole fish caught annually. However, this estimate is five times greater than the 0.3 kg / ha floodplain estimate, which was obtained based on the observation of historical series of production data. This indicates the need to better understand the productive capacity of the *Arapaima gigas* populations, as they may vary in different parts of the Amazon basin [Sánchez, 1969]. Using genetics tools, Hrbek et al. [2005] estimated that the population of *Arapaima gigas* in an area of approximately 100,000 km2 in the Amazon basin would be 300,000 individuals. Population census carried out in the Mamirauá Reserve showed the existence of at least 50,000 individuals in an area of approximately 1,000 km², where the *Arapaima gigas* populations are being well managed [Arantes et al., 2006]. On the other hand, Castello et al. [2011a], proposed a classification of the density of *Arapaima gigas*, by type of management, and estimated that, currently, the population in the floodplain ecosystem is around 800,000 individuals over 1 m of TC. However, it is difficult to extrapolate data from existing population censuses to large areas because the densities of *Arapaima gigas*, can vary widely (0 to 200 individuals / ha), depending on management.

In the 19th and early 20th centuries, the *Arapaima gigas* (pirarucu) was responsible for the most important fishing in the Amazon [Veríssimo, 1895]. *Arapaima gigas* populations are believed to be following a general downward trend in the Amazon Basin. Since the 1950s, the catch and the size of the individuals caught began to decrease [Issac, 1993]. Catch data are available and analyzed for very few regions and all data showed a predominance of juveniles, a common sign of over-fishing [Castello, 2010]. The most complete and long-term data series is for dry and salted *Arapaima gigas* landed in Manaus, Amazonas State, Brazil [Castello, 2010]. However, most *Arapaima gigas* catches are not recorded [Castello et al., 2009]; [Lowe-Mcconnell, 1964]; [Viana et al., 2007] due to the lack of monitoring efforts and the decentralized nature of fishing in the Amazon. The only existing analysis of the population trend of *Arapaima gigas* was carried out by researchers Queiroz and Sardinha in 1999, and the results suggested a population decline. Exceptions to this trend of population decline exist in areas where communities practice management and conservation efforts. Several riverside communities are currently developing *Arapaima gigas* conservation initiatives [Castello et al., 2009]; [Castello, 2011b]; [Mcgrath et al., 1993]. *Arapaima gigas* has different conservation status, and from 1975 it became part of the list of protected species of the Convention on International Trade in Species of Wild Fauna and Flora in Danger of Extinction – CITES [Viana et al., 2007]. Also on the IUCN Red List of species threatened with biological extinction - World Conservation Monitoring Center. In this study, fishing was analyzed in nine management units located in seven Protected Areas in the State of Amazonas. The regulation of the minimum capture size of 150 cm in force since 1989 was also evaluated [Viana et al., 2007] and the recent researches that are guiding a proposal by IDSM researchers to increase this size regarding the change in specific legislation.

MATERIAL AND METHODS

The study was carried out in nine Pirarucu Management Units (UMP), linked to seven Protected Areas in the State of Amazonas, of these, four are Sustainable Development Reserves (RDS), an Extractive Reserve (RESEX), an Indigenous Land (TI) and a Fisheries Agreement (AP).

The Fisheries Agreement of this study is a territory regulated by legal norms of the State of Amazonas, being then considered a protected area in which the management regime is allowed. Namely, the protected areas were as follows: RDS Amanã, RDS Mamirauá, RDS Piagaçu-Purus, RDS Uacari, RESEX Médio Juruá, TI Acapurí and Ilha da Paciência Fishing Agreement. The UMP's: Maraã, Fonte Boa and Focal Area, are part of the Mamirauá Reserve. The management units evaluated in this study were distributed over the Solimões, Juruá, Japurá and Purus rivers (Table 1). Data collection occurred in the catches of *Arapaima gigas*, in the period corresponding to 4 years and their respective weights, by size classes.

RESULTS AND DISCUSSION

The sum of all *Arapaima spp*. (pirarucus) evaluated in this study totaled 29,245 specimens. Of this total, the majority (49%) were captured in the third year of the survey. The quantities collected in the first year (22%) and in the second year (28%) were similar. The data for the 460 specimens of *Arapaima gigas*, collected in 2014, came only from the regions of Alto Solimões (Indigenous Land Acapurí) and Ilha da Paciência. Most of the specimens (32%) were captured at the *Arapaima gigas* (Pirarucu) Management Unit (UMP) in Maraã, followed by Fonte Boa (25%), Mamirauá Sustainable Development Reserve (RDS) (21%) and Amanã RDS (14%). In the other UMP's, the amount of *Arapaima gigas* collected was ≤ 3.2% of the total. The total weight of all *Arapaima gigas* totaled 1,572.96 tons, with 50% of this total collected in the third year of the survey. The tonnages produced in the first and second of the survey were also similar. In the fourth year of the survey, 1.4 tons came from the Acapurí de Cima / Kokama Fishing Agreement, on the Ilha da Paciência, in Alto Solimões.

The gross revenue resulting from the sale of *Arapaima gigas*, in the period of 4 years, was R$ 8,651,302.00 (eight million six hundred and fifty-one thousand three hundred and two reais), 91% of which came from four UMP, located in the Middle Rio Solimões region. The sample of 29,245 specimens of *Arapaima gigas* evaluated in this research did not include all *Arapaima gigas* legally collected in the 22 Pirarucu Management Units (UMP) in Amazonas, between the first and the third year of research. However, it is believed that the conclusions emerging from the results of this study will also be directly applicable in the other UMP in the state of Amazonas. Mainly because the UMP's that were evaluated are distributed over basically all the major rivers in the state where *Arapaima gigas* management occurs, including the Solimões, Juruá, Japurá and Purus rivers. In particular, data were obtained from Alto, Médio and Baixo Rio Solimões. It is worth mentioning, even though the data evaluated in 2014, came exclusively from the UMP Terra Indígena Apucarí / Alto Solimões and from Ilha da Paciência / Baixo Solimões.

And, although the total of *Arapaima gigas* collected in these two units represent only 1.4% of the total of analyzed specimens, it was decided to include these UMP very much for their value and strategic symbolism, because it is an Indigenous Land (TI) and the Fisheries Agreement for the management of *Arapaima gigas*, closer to the capital Manaus. Fisheries of *Arapaima gigas* in these two UMPs is also biologically important, since the fourth year of the research was the first year of obtaining an extraction quota in these areas. As for the other seven UMP evaluated, it is also worth noting that they represent the areas with the longest management time, the highest relative production and the best community social organization, including the strong contribution of civil society entities, which in practice, act as co-manager. Fishery statistics are important sources of data for assessing the conservation status of populations of target species, or of the stock available for sale. In the specific case of this study, information about the sizes of the collected *Arapaima gigas* included only individuals of TC ≥ 150 cm. Therefore, these statistics are suitable primarily for the assessment of stocks.

Structure of the Sizes of Arapaima spp. (pirarucus) Collected: The number of *Arapaima gigas* collected in the Middle Solimões Region, comprising three UMP located in the RDS Mamirauá, was 22,741 specimens, corresponding to 78% of the total number of individuals we analyzed in this study. The highest frequency of individuals (N = 14,850) occurred in the range of total length classes (CCT) from 164 to 189 cm, corresponding to 65% of the specimens evaluated in this region. In this same region, the relative frequency of occurrence (RF) was ≥ 10% in four CCTs, ranging from 169 to 184 cm. In Baixo Japurá (RDS Amanã), RR was ≥ 10% only in CCTs 159, 164 and 174 cm. In turn, in the Middle Juruá (RDS Uacari, RESEX Médio Juruá), the RR of each CCT was always ≤ 8%. On the Lower Purus River (RDS Piagaçu-Purus), the RR was ≥ 10% in six classes of TC, within which the average was 12.1 ± 1.2. In Alto Solimões (TI Acapurí), RR was ≥ 13% in only three categories and ≤ 10% in the other TCCs. Finally, in Baixo Solimões (Ilha da Paciência - Fisheries Agreement), the RR was ≥ 10% in four CCT, of which in two of them the value was 21%. In the other TCCs in this region, RR was ≤ 8%. Evaluating only the collection of *Arapaima gigas* from CT ≥ 200 cm (CCT ≥ 204 cm), the highest RF (32%) was captured in the Middle Juruá, while in the regions of Baixo Japurá and the Middle Solimões the RF of these larger specimens was much lower, with 12 and 11%, respectively. In turn, the FR of these larger *Arapaima gigas* was 10% in Alto Solimões, 6% in Baixo Solimões and only 4% in Baixo Purus. Number of *Arapaima spp*. (pirarucus) (N), and the respective percentage (% N), total weight sold in tonnage (T), and the respective percentage (% T), collected per Management Unit. Gross amount, in reais (R$), obtained from annual sales. RDS = Sustainable Development Reserve. RESEX = Extractive Reserve. TI = Indigenous Land. AP = Fisheries Agreement.

Minimum Capture Size: According to Decree nº 1534 IBAMA / DF of 12/20/1989 the current minimum total capture length (MTC) is 150 cm. In the consensus among the participants of several technical meetings held mainly in 2014 in Manaus and Tefé, within the scope of the Pirarucu Management Committee linked to the State Fisheries Council (CONEPA), changing the CTM to 155 cm would be easy to approve for the purpose of formulation new regulatory framework. In turn, the suggestion with the greatest potential for negative impact on the management economy was proposed by Lopes and Queiroz. These authors, based on a gonad study, recommended increasing the minimum total collection size for males to 174 cm and for females to 165 cm.

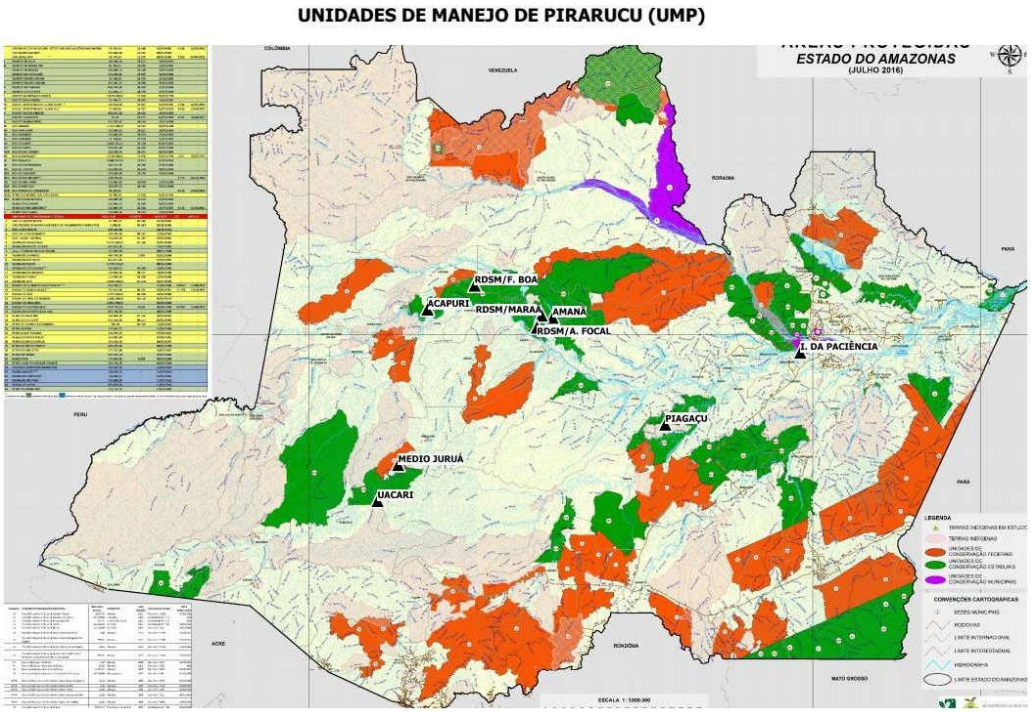

Table 1: Catch and weight data of Arapaima spp. (pirarucus), in the management units analyzed

Region	Management Unit	N	% N	T	%T	R$
Médio Solimões	Maraã (RDS Mamirauá)	9250	31,7	503,848	32,0	2.771.164,00
	Fonte Boa (RDS Mamirauá)	7243	24,7	390,275	24,8	2.146.512,50
	Área Focal (RDS Mamirauá)	6248	21,5	331,755	21,1	1.824.652,50
Baixo Japurá	RDS Amanã	4053	13,8	203,329	12,9	1.118.309,50
Baixo Purus	RDS Piagaçu-Purus	897	3,2	48,395	3,1	266.172,50
Médio Juruá	RDS Uacari	532	1,8	36,005	2,3	198.027,50
	RESEX Médio Juruá	513	1,7	34,401	2,2	189.205,50
Alto Solimões	TI Acapuri	399	1,2	19,161	1,2	105.385,50
Baixo Solimões	Ilha da Paciência – AP	110	0,4	5,795	0,4	3.1872,50
	TOTAL	29.245	100	1.572,964	100	8.651.302,00

Number of *Arapaima spp*. (pirarucus) (N), and the respective percentage (% N), total weight sold in tonnage (T), and the respective percentage (% T), collected per Management Unit. Gross amount, in reais (R$), obtained from annual sales. RDS = Sustainable Development Reserve. RESEX = Extractive Reserve. TI = Indigenous Land. AP = Fisheries Agreement.

Table 2: Arapaima spp. (pirarucus), catch data, per year, and their respective total weight and gross value

Year	N	%N	T	%T	R$
1st year	6440	22,0	338,323	21,5	1.860.776,50
2nd year	8144	27,8	428,348	27,2	2.355.914,00
3rd year	14201	48,6	783,956	49,8	4.311.758,00
4th year	460	1,6	22,337	1,4	122853,50
Total	29.245	100	1.572,964	100	8.651.302,00

Table 2. The number of *Arapaima spp.* (pirarucus), (N), and the respective percentage (% N), total weight in tonnage (T), and the respective percentage (% T), collected in nine Management Units in the State of Amazonas. Gross amount, in reais (R$), obtained from annual sales.

However, as the external sexual dimorphism of *Arapaima gigas* is not as evident as previously predicted [Lopes, 2009], the approximate average value of 170 cm would be the most feasible in terms of legislation. However, according to the partial consensus among the participants of technical meetings held in 2014 in Manaus and Tefé, within the Pirarucu Management Committee linked to the State Fisheries Council (CONEPA), the 160 to 174 cm CTM would be difficult to approve due to the negative impact on the income of the Management Units. In the option of lesser impact, referring to changing the minimum total length (TC) of collection from the current 150 cm to 155 cm, it would imply the exclusion of 1,636 specimens and the failure to obtain R$ 298.642,64 by the communities managing the nine UMP that were evaluated. In this possibility, the financial loss of the UMP would have varied from 2.3 to 9.8% (average = 5,97, SD = 2,75.

However, if the value of 170 cm is used, representing the average of the minimum reproductive CT values recently released for females (165 cm) and males (174 cm) by IDSM, 13,517 specimens of *Arapaima gigas* (pirarucus) and loss of amount of R$ 3,539,494.05. In this case, the loss between the UMP would vary from 28.2 to 67.3% (average = 49,33, SD = 12,27.

Conclusion

It is concluded that, despite mainly including data from only three years of management, it showed that production can vary greatly between years, with 49% of *Arapaima gigas* being collected only in the third year of the research. While the production of 1st and 2nd year of research was similar. The interpretation of the factors that may have generated the concentration of production in the 3rd year of research is

complex, as it may reflect management on the actions dispensed in the various stages of management or of an environmental nature. In terms of actions, one can highlight the consistency of interinstitutional action or better community organization. Environmentally speaking, one of the factors that directly affect the production of *Arapaima gigas* would be the flood pulse, as the water level in rivers can consistently affect the accessibility of Arapaima gigas meters to different habitats, influencing the quota to be authorized, as it represents up to 30% of the total *Arapaima gigas* with TC ≥ 150 cm counted. However, what was observed in the research is that the greatest influence of the flood pulse occurs during the capture of *Arapaima gigas*, because in years of initial floods it is common for UMP to fail to execute the authorized quota. Evaluating the production in spatial terms, it was found that 78% of *Arapaima gigas* were collected in only three UMP located in the Mamirauá Sustainable Development Reserve. This high production of *Arapaima gigas* can be explained by the fact that RDS Mamirauá is a pioneer in the management practice of *Arapaima gigas*, having produced most of the research on management in management. Among the UMP located in the Mamirauá Reserve, the UMP Maraã stood out, where 32% of these *Arapaima gigas* were collected. However, the largest production of *Arapaima gigas* in Maraã was in the 2nd year of research (54%), and not in the 3rd year.

During the preliminary analysis of the nature of the data, it was decided to exclude information from 1,563 specimens of *Arapaima gigas*. This exclusion was necessary since it detected some discrepancies in terms of size and/or mass information when compared to the total population of data analyzed. Even excluding these hundreds of *Arapaima gigas*, the volume of *Arapaima gigas* meat produced by the nine UMP totaled 1,573 tons, and considering the average value of R$ 5.50 per kilogram of *Arapaima gigas* in the form of a cigar, resulted in a gross revenue of R$ 8,651,302.00 [34]. Dividing this amount by the three-year interval, the resulting amount is R$ 2,884,000.00/year. This amount of resources is significant for the areas assessed. Without considering other species captured in the UMPs and by-products, such as the skin of *Arapaima gigas*. Part of the liquidity resulting from the annual production of *Arapaima gigas* managed contributed to the cost of some management steps, such as zoning, population census, monitoring and surveillance. Contributing significantly to the management of protected areas in Amazonas. The analysis performed on structures the size of *Arapaima gigas*) indicated two basic patterns. In the Middle Solimões there was a higher collection pressure (47%) in only four of the 22 classes of total length (CCT) evaluated. This greater collection effort concentrated in a few CCTs was also seen in Alto and Baixo Solimões. While in the other UMP, the collection effort was diluted in more CCT, especially in the case of Médio Juruá, encompassing RDS Uacari and RESEX Médio Juruá. Despite the relatively smaller number (N = 1045) of *Arapaima gigas* evaluated for the Middle Juruá, the scenario found in this region may be the most promising in the long term, since the collection pressure in the two UMPs is distributed in a all sizes available legally homogeneous and therefore did not focus the economic effort on just a few sizes. Future studies should evaluate this aspect in more detail, considering a larger series of data, in an attempt to indicate trends of which of these management patterns would be more sustainable in the long run. In the bibliographic review, there was no great concern from the authors regarding the protection of larger individuals from *Arapaima gigas*.

The exclusion of these larger individuals could be strategic in protecting the gene pool. Because these older individuals have high longevity, know the habitats better and probably have a greater capacity to not be killed. These genetic and/or behavioral characteristics can ensure the sustainability of management, especially in less productive environments. The most detailed analysis of the Médio Solimões Region showed differences in the size structures between the three UMP that make up this region. These differences occurred despite these three UMP being located within the Mamirauá RDS, and probably sharing the same population of *Arapaima gigas*, or very similar populations, given the spatial proximity between them. This finding reinforces one of the recommendations for the good management of Amazonian fauna, that is, that scientific generalizations from research in a certain area should be carefully extrapolated to other areas, even if these are geographically close and have apparently similar environmental characteristics. The main management instruments that ordered *Arapaima gigas* fishing in the State of Amazonas were the institute with a minimum capture size of 150 cm in total length, reproductive closure and extensive management regulation in Conservation Units for Sustainable Use. More recently, the regulation of Fisheries Agreements has expanded the management of *Arapaima gigas* also to these protected areas, considering the social, environmental, economic and cultural dimensions. Currently, there is also the management of *Arapaima gigas* in indigenous lands in Amazonas, coordinated by FUNAI.

This fact contributed to the protection of the integrity of these areas and the food security of indigenous peoples. In terms of legislation, the management of *Arapaima gigas* sustainable fisheries in Amazonas is based on reproductive defenses, minimum catch sizes, zoning of areas, fishing equipment, quotas and internal regulations. Among these management tools, the minimum capture size proved to be very important for the management of *Arapaima gigas* in the Brazilian Amazon. The study also ratified this importance in economic terms, as it found that even the smallest changes in legislation on the minimum catch size (from 150 cm to 155 cm of TC) would have a significant negative impact on the management economy of most of the nine UMP evaluated. Especially in the case of the Indigenous Land Acapurí, located in Alto Solimões, where the impact of this change would imply the loss of almost 10% of the gross revenue obtained in the management of the 4th year of research. The change of only 5 cm would also affect the management practiced in the UMP Baixo Japurá / RDS Amanã, Fonte Boa and RESEX Médio Juruá, with loss of gross revenue, in the period of 3 years, varying from 8.0 to 8.3%. This approach has shown that any changes in legislation that affect the management of the Amazon community base, must be taken with great caution and responsibility. It is worth mentioning that this change (of 5 cm) was readily accepted when presented in deliberative meetings involving managers, scientists, fishermen, traders and other actors involved at the base of the *Arapaima gigas* management chain in the State of Amazonas. It was found that the minimum capture size of *Arapaima gigas* was established at the federal level 25 years ago as a control instrument. At that time, the lack of robust scientific information led decision makers to regulate that 150 cm of CT would be the minimum size of the first reproduction (maturity) for both sexes of *Arapaima gigas*. However, further research has shown different values for this important parameter of the population dynamics of the species, indicating that the biology and

reproductive ecology of *Arapaima gigas* are complex and can vary across the Amazon. Recent research, at the gonadal level, has indicated that the minimum maturation size (L50) of *Arapaima gigas* populations can vary according to the management regime (respect or not to the minimum capture size of 150 cm) and population density. The minimum maturation size (regardless of sex) was reached at 157 cm in the managed populations, where the minimum capture size (150 cm) was respected and, therefore, where the population density was relatively higher. It was also demonstrated that, in the absence of respect for the minimum size of the catches (illegal fishing), the maturity of *Arapaima gigas* was only reached at 164 cm in total length and in places of low density. It was also observed that other studies evaluated the sexes separately for the first time, and concluded that the minimum maturation size in *Arapaima gigas* is even greater, reaching 165 cm of TC in females and 174 cm in males, these measures are being proposed and recommended by some researchers. However, this study concluded that, however appropriate it may be to adopt these measures for the future of sustainable management of *Arapaima gigas,* if these recommendations had been legally adopted in recent years, the economic impact on gross management income would have been quite marked. Because the increase in the minimum catch size to 165 cm would result in the loss of gross income of 14 to 35% (average = 25.4%, SD = 7.0) by the assessed UMP. And if this size were 175 cm, the losses would vary from 28 to 67% (average = 49.3, SD = 12.25). In turn, considering the value of 170 cm as the average minimum capture size, as the sexes are indistinguishable at the time of capture, the economic impact on gross income would still be high, having varied from 19 to 51% among the UMP (average = 37.3, SD = 9.9). In this situation, the financial impact would be greater than 34% in seven of the nine UMP that were assessed.

In three of them, the loss in gross income would vary between 45 and 51%. The greatest loss of gross income would have occurred in the production of the 4th year of research in the Indigenous Land Acapurí and Ilha da Paciência. It is worth mentioning that these UMPs deserve special attention, given their peculiarities and conditions of good management, since indigenous lands represent one of the best expectations for the expansion of the *Arapaima gigas* management scale in the State of Amazonas. In turn, the symbolism of Ilha da Paciência represents the fact that it is the closest UMP to the capital Manaus, and therefore subject to the most varied forms of anthropic pressure. Finally, the approach carried out in this study showed some of the weaknesses in the management of community-based *Arapaima gigas*, carried out inside and outside the Conservation Units in the State of Amazonas. Among these peculiarities, it was evident that production was centered in the Médio Solimões region and that the most recent UMP in the activity would be the most affected by the change in the minimum catch size legislation. Highlighting that any changes, in the rule of management of *Arapaima gigas*, even the apparently most trivial ones, need analysis and participatory discussion in the decision-making process and that the contribution of traditional and scientific knowledge must be the reference of the management of *Arapaima gigas* for this to be increasingly sustainable.

REFERENCES

Arantes CC, Castello L, Stewart DJ, Queiroz HL, Cetra M. 2010. Density compensation, growth, and reproduction of Arapaima in floodplains of the Amazon. Ecology of Freshwater Fish, 19(3): 455-465.

Arantes CC, Garcez DS, Castello L. 2006. Population densities of pirarucu (Arapaila gigas, Teleostei Osteoglissidae) in lakes in the sustainable development reserves of Mamirauá and Amanã, Amazonas, Brazil. Uakaro, 2(1): 37-43.

Araripe JL, Rêgo PS, Queiroz HL, Sampaio I, Schneider H. 2013. Dispersal capacity and genetic structure of Arapaima gigas on different geographic scales using microsatellite markers. PloS one, 8(1): e54470.

Bayley PB, Petrere JrM. 1989. Amazon fisheries: Assessment methods, current status and management options. In: Dodge, D.P. (Eds). Proceedings of the International Large River Symposium. Vol. 106. Canadian Special Publication of Fisheries and Aquatic Sciences, Ottawa, Canada. p. 385-398.

Bessa JDO, Lima ÁC. 2010. Manejo de Pesca do Pirarucu (Arapaima Gigas) no Estado do Amazonas: Erros, Acertos e Perspectivas Futuras. In: Anais do I Seminário Internacional de Ciências do Ambiente e Sustentabilidade na Amazônia. Universidade Federal do Amazonas, Manaus, Amazonas. p.2-9.

Bodmer RE, Fang TG, Moya I. 1994. Managing wildlife to conserve amazonian forests: Population biology and economic considerations of game hunting. Biological Conservation, 67(1): 29-35.

Browder JO. 1992. The limits of extractivism: tropical forest strategies beyond extractive reserves. BioScience, 42(3): 174-182.

Castello L, Pinedo-Vasquez M, Viana JP. 2011b. Participatory conservation and local knowledge in the Amazon várzea: the pirarucu management scheme in Mamirauá. In: Pinedo-Vasquez, M.; Ruffino, M.L.; Padoch, C.; Brondízio, E.S. (eds). The Amazon varzea: the decade past and the decade ahead. Springer, New York, U.S.A. p. 261-176.

Castello L, Stewart DJ, Arantes CC. 2011a. Modeling population dynamics and conservation of arapaima in the Amazon. Reviews in Fish Biology and Fisheries, 21(3): 623-640.

Castello L, Stewart DJ, Arantes CC. 2013. O que sabemos e precisamos fazer a respeito da conservação de pirarucu (Arapaima spp.) na Amazônia. In: Figueiredo, E.S.A. (Org.). Biologia, conservação e manejo participativo de pirarucus na Pan-Amazônia. Instituto de Desenvolvimento Sustentável Mamirauá, Tefé, Amazonas, Brasil. p. 17-31.

Castello L, Stewart DJ. 2010. Assessing CITES non-detriment findings procedures for Arapaima in Brazil. Journal of Applicate Ichthyology, 26(1): 49-56.

Castello L, Viana JP, Watkins G, Pinedo-Vasquez M, Luzadis VA. 2009. Lessons from integrating fishers of arapaima in small scale fisheries management at the Mamiraua´ Reserve, Amazon. Environmental Management, 43(2): 197-209.

Castello L. 2004. A method to count pirarucu Arapaima gigas: fishers, assessment, and management. North American Journal of Fisheries Management, 24(2): 379-389.

Castello L. 2008b. Nesting habitat of Arapaima gigas (Schinz) in Amazonian floodplains. Journal of Fish Biology, 72(6): 1520-1528.

Castello L., 2008a. Lateral migration of Arapaima gigas in floodplains of the Amazon. Ecology of Freshwater Fish, 17(1): 38-46.

CONAB - Companhia Nacional de Abastecimento. Disponivel em: <http://www.conab.gov.br/>. Acesso: 05 Abri 2019.

Crampton WGR, Castello L, Viana JP. 2004. Fisheries in the Amazon várzea: historical trends, current status, and factors affecting sustainability. In: Silvius, K.; Bodmer, R.; Fragoso, J.M.V. (Eds.). People in nature: wildlife conservation in South and Central America. Columbia University Press, New York, E.U.A. p. 76-95.

Da Silveira R, Arantes CC, Castello L. 2012. Conservação de pirarucus e de crocodilianos no Amazonas: avaliação crítica do histórico de exploração e diretrizes para o manejo econômico na Amazônia brasileira. In: Marcon, J.L.; Menin, M.; Araújo, M.G.P.; Hrbek, T. 1 ed. Biodiversidade Amazônica Caracterização, Ecologia e Conservação. Editora Universidade Federal do Amazonas, Manaus, Amazonas, Brasil. p. 347-366.

Da Silveira R. 2006. Cenários da fauna amazônica sustentável. In: Cavalcanti, F.J.B.; de Paula, A.C.; Vercillo, U.E.; Fischer, W.A. (Orgs.). Política de fauna silvestre na Amazônia. 1 ed. Centro Nacional de Informação, Tecnologias Ambientais e Editoração, IBAMA, Manaus. p. 37-40.

Figueiredo ESA. 2013. Biologia, conservação e manejo participativo de pirarucus na Pan- Amazônia. Instituto de Desenvolvimento Sustentável Mamirauá, Tefé, Amazonas, Brasil. 278pp.

Godinho HP, Santos JP, Formagio PS, Guimarães-Cruz RJ. 2005. Gonadal morphology and reproductive traits of the Amazonian fish Arapaima gigas (Schinz , 1822). Acta Zoologica, 86(4): 289-294.

Hrbek T, Farias IP, Crossa M, Sampaio I, Porto JI, Meyer A. 2005. Population genetic analysis of Arapaima gigas, one of the largest freshwater fishes of the Amazon basin: Implications for its conservation. Animal Conservation, 8(3): 297-308.

Issac VJ, Rocha VLC, Mota S. 1993. Considerações sobre a legislação da "piracema" e outras restrições da pesca da região do Médio Amazonas. In: Furtado, LG.; Leitão, W.; Melo, A.F. (Eds.). Povos das águas, realidade e perspectivas na Amazônia. Ministério de Ciência e Tecnologia, Conselho Nacional de Pesquisa, Museu Paraense Emilio Goeldi, Belém, Pará, Brasil. p.188-211.

Lopes KS, Queiroz HL. 2009. Uma revisão das fases de desenvolvimento gonadal de pirarucus Arapaima gigas (Schinz, 1822) por meio da análise macroscópica como uma proposta para unificação destes conceitos e sua aplicação prática nas reservas Mamirauá e Amanã. Uakari, 5(1): 39-48.

Lowe-Mcconnell RH. 1964. The fishes of the rupununi savanna district of British Guiana, pt. 1. groupings of fish species and effects of the seasonal cycles on the fish. Zoological Journal of the Linnaean Society, 45(304): 103-144.

Luling KH. 1964. Zur biologie und ökologie von Arapaima gigas (pisces: Osteoglossidae). Zeitschrift Für Morphologie Und Ökologie Der Tiere, 54(4): 436-530

Mcgrath DG, Castro F, Futemma C, Amaral BD, Calabria J. 1993. Fisheries and evolution of resource management on the Lower Amazon floodplain. Human Ecology, 21(2): 167- 195.

Neves AMB. 1995. Conhecimento atual sobre o pirarucu, Arapaima gigas (cuvier 1817). Boletim do Museu Paraense Emílio Goeldi, Série Zoologia, 11: 33-56.

Queiroz HL. 2000. Natural History and Conservation of pirarucu, Arapaima gigas, at the Amazonian Várzea: Red Giants in Muddy Waters. Doctorate Thesis, University of St. Andrews, Scotland. 226 pp.

Redford KH, Robinson JG. 1987. The game of choice: patterns of indian and colonist hunting in the neotropics. American Anthropologist, 89(3): 650-667.

Sánchez JR. 1969. El "paiche:" aspectos de su historia natural y aprovechamiento. Revista de Caza y Pesca, 10: 17-61.

Veríssimo J. 1895. A pesca na Amazônia. Livraria Clássica Alves, Rio de Janeiro, Brasil. 206pp.

Viana JP, Castello L, Damasceno JMB, Amaral ESR, Estupiñan GMB, Arantes C, Batista GS, Garcez DS, Pereira SB. 2007. Manejo Comunitário do pirarucu Arapaima gigas na Reserva de Desenvolvimento Sustentável Mamirauá- Amazonas, Brasil. In: Prates, A.P.; Blanc, D. Áreas Aquáticas Protegidas como Instrumento de Gestão Pesqueira. Ministério do Meio Ambiente; IBAMA, Brasília. p. 239-261

Viana JP, Damasceno JMB, Castello L, Crampton WGR. 2004. Economic incentives for sustainable community management of fishery resources in the Mamiraua Sustainable Development Reserve, Amazonas, Brazil. In: Silvius, K.M.; Bodmer, R.E.; Fragoso, J.M.V. 1° ed. People in Nature: Wildlife Conservation in South and Central America. Columbia University Press, New York, U.S.A. p. 139-154.

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