Neotropical Ichthyology, 8(2):379-383, 2010

Scientific Note

Reproductive and population parameters of discus fish *Symphysodon aequifasciatus* Pellegrin, 1904 (Perciformes: Cichlidae) from Piagaçu-Purus Sustainable Development Reserve (RDS-PP), lower Purus River, Amazonas, Brazil

Felipe Rossoni[1], Sidinéia Amadio[2], Efrem Ferreira[2] and Jansen Zuanon[2]

The ornamental discus fish *Symphysodon aequifasciatus* Pellegrin, 1904, is a popular endemic cichlid species from the Amazon basin, however scientific information concerning biology and ecology in its natural habitat is scarce despite its importance on the international aquarium trade. In this study we evaluated reproductive parameters of *S. aequifasciatus* in natural habitat in Piagaçu-Purus Sustainable Development Reserve (RDS-PP), lower Purus River, Brazilian Amazon. Males are more frequent in the larger size classes and this might be related to the complex breeding behavior known for *S. aequifasciatus*. Values of L_{50} for both sexes corresponded to more than 60% of the maximum attained length which may indicate that energy allocation for somatic growth takes longer in *S. aequifasciatus* than in other species. Average fecundity for female discus was 1490, ranging from 950 to 1892 oocytes and its correlations with standard length and total weight were very low, probably due to the highly compressed discus´ body shape. Egg size distribution showed four types of patterns, indicating one to four modes besides the reserve oocytes group. Our results indicate that *S. aequifasciatus* shows total spawning, in the beginning of flooding period, with the peculiar capacity of releasing multiple egg batches as a strategy that potentially enhances reproductive success.

O acará-disco (*Symphysodon aequifasciatus* Pellegrin, 1904) é uma espécie popular de ciclídeo endêmico da bacia amazônica, porém são poucas as informações científicas sobre biologia e ecologia em seu habitat natural, apesar de sua importância no comércio internacional de aquário. Neste estudo avaliamos parâmetros reprodutivos de *S. aequifasciatus* em vida livre na Reserva de Desenvolvimento Sustentável Piagaçu-Purus (RDS-PP), baixo rio Purus, Amazonas, Brasil. Os machos são mais frequentes em classes de comprimento maiores, o que provavelmente está relacionado com o complexo comportamento reprodutivo de *S. aequifasciatus*. Os valores de $L_{50,}$ para ambos os sexos, corresponderam a mais de 50% do comprimento total máximo atingido para a espécie, o que pode indicar que a alocação de energia para o crescimento somático é mais prolongada em *S. aequifasciatus* que em outras espécies, visto que o tamanho dos exemplares é essencial para o bom desempenho. A fecundidade média foi de 1490 ovócitos, (950 a 1892) e sua relação com o comprimento padrão e peso total foi baixa, provavelmente devido ao formato comprimido do corpo. Constatou-se quatro padrões na distribuição de tamanho dos ovócitos, incluindo de 1 a 4 modas, além do grupo de reserva. *Symphysodon aequifasciatus* apresenta desova total para o período reprodutivo, com a peculiaridade de liberar mais de um lote de ovócitos quando necessário, como uma estratégia que possivelmente aumenta a probabilidade de sucesso reprodutivo.

Key words: Ornamental fish, Population structure, Breeding strategy.

[1]Programa Integrado de Pós-Graduação em Biologia Tropical e Recursos Naturais (PIPG-BTRN), Programa de Biologia de Água Doce e Pesca Interior – Instituto Nacional de Pesquisas da Amazônia (INPA), Instituto Piagaçu. f_rossoni@yahoo.com.br
[2]Coordenação de Pesquisas em Biologia Aquática (CPBA), Instituto Nacional de Pesquisas da Amazônia. amadio@inpa.gov.br, efrem@inpa.gov.br, zuanon@inpa.gov.br

The discus fish *Symphysodon aequifasciatus* Pellegrin, 1904, an endemic cichlid from the Amazon basin, is one of the most popular ornamental fish species in the world. Despite its historical exploitation for the international aquarium trade there is little information available in the scientific literature concerning biology and ecology of this species in its natural habitat (Hildemann, 1959; Crampton, 1999, 2008; Bleher, 2006; Ready *et al*., 2006).

The knowledge about species biology and ecology, especially regarding breeding, is essential to promote its exploitation in a sustainable way, avoiding depletion of stocks. Information about fecundity, type and time of spawning, sex-ratio and size at sexual maturity are extremely important to support political decisions on activities related to sustainable exploitation of natural resources.

Chellappa *et al*. (2005) studied the ovarian development of *S. discus* in semi-natural conditions and characterized it as a multiple-spawner fish species. Crampton (2008), studying *S. aequifasciatus* (identified as *S. haraldi* in his study) also found the species to be a multiple-spawner. Câmara (2004) doing a behavior assessment of *S. discus* in semi-natural conditions verified that during the breeding season adult males showed aggressive behavior, established territories and defended the area against another males. The author also found that females show preference for larger bodied males with established territories, and was selective about the type of substrate for spawning.

In this study we evaluated reproductive parameters of *S. aequifasciatus* in natural habitat during dry/rising water season (September to November) of 2006 and 2007. Samples were obtained in Ayapuá Lake, Piagaçu-Purus Sustainable Development Reserve (RDS-PP), lower Purus River, in the Brazilian Amazon (04º53'S; 62º59'W). Fish were captured by netting artificial fish attractors (tree branches structures, measuring approximately 2 x 2 x 2m) and natural submerged tree crowns ("galhadas") and were sacrificed with a lethal dose (varying from 2 to 5 drops per liter) of Eugenol. Fish for fecundity determination were captured in November 2006, during ten days interval.

Standard length (Ls, mm) and total weight (Wt, g) were taken from each specimen. Sex and gonadal maturity stages were identified considering texture, consistency, coloration, size and surface vascularization of gonads (Vazzoler, 1996), through direct macroscopic observation in the field (Table 1).

The population structure of the species was analyzed concerning sex- ratio, which was calculated using the absolute frequency of males and females. Biases from 1:1 sex ratio were tested by G test (Zar, 1999).

Mean length at sexual maturity (L_{50}) for both sexes was determined from the relative frequency distribution of young males and females (stage 1) and adults (stages 2, 3 and 4) by standard length classes (10 mm). The L_{50} value was determined by a logistic function using the expression $v_2=1/(1+\exp(-b_1*(v_1-b_2)))$, where: v_1= size class; v_2= percentage of adults in the size class; $b_2= L_{50}$. Males captured during 2006 were not included in the analysis due to the initial difficulty on identifying of males gonadal stages development.

Table 1. Macroscopic description of gonadal development stages of females (F) and males (M) of *Symphysodon aequifasciatus*, based on scale suggested by Vazzoler (1996).

Stage	Characteristics
Immature (F1/M1)	Ovaries are thin, small, and translucent without vascularization. It is not possible to observe oocytes. Testes are thin and translucent.
Maturing (F2/M2)	Ovaries are large and intensively vascularized with opaque eggs inside. Oviduct is tubular, transparent and empty. Testes are in lobular shape and white.
Pre-spawning (F3/M3)	Ovaries are enlarged with many orange oocytes, occupying much of the abdominal cavity and part of the oviduct. Testes are swollen and white.
Spent (F4/M4)	Ovaries are flaccid, small, with scattered eggs with hemorrhagic appearance. Testes are flaccid with hemorrhagic appearance.

Female fecundity was estimated as the total number of vitelogenic oocytes produced during the reproductive period. Ovaries of pre-spawning females (F3) were removed, immersed in Gilson solution (Simpson, 1951) for the complete detachment of ovarian membranes, washed and preserved in 70% alcohol. The type of spawning was determined by the frequency distribution of the oocyte diameter classes (0.1 mm intervals) taken randomly from 300 oocytes of each female (N = 23) (Vazzoler, 1996). Relationship between fecundity and standard length or total weight for *S. aequifasciatus* was analyzed using simple linear regression. Mean fish size and mean fecundity for each spawning type found were tested using ANOVA.

A total of 1592 specimens of *S. aequifasciatus* were captured, from which 241 were dissected and sexed (128 females and 113 males). The sex-ratio was of 1:1 (G = 0.704), similar to that found by Crampton (2008). However, the sex-ratio analysis by size class showed significant differences with more females in the 135-145 mm class and more males in the 155-165 mm class (Table 2). A higher frequency of males in the larger size classes was also observed by Crampton (2008), indicating that males attained larger sizes than females.

Several factors of fish's life history may affect sex-ratios differently, and there may be variations over time. Differential mortality and growth of males and females may influence sex-ratio structure, resulting in the predominance of one sex or the other throughout development stages. In many cases

Table 2. G test for sex-ratio of *Symphysodon aequifasciatus* from Ayapuá Lake captured between September and November 2006 and 2007, by standard length (Ls) classes. (N = number of specimens; % = percentage;* significant for G > 3.841).

Ls (mm)	Absolute Frequency (N)		Relative Frequency (%)		G
	Females	Males	Females	Males	
85\95	4	1	80.00	20.00	0.82
95\105	14	7	66.66	33.34	1.73
105\115	12	13	48.00	52.00	0.04
115\125	22	12	64.70	35.30	2.41
125\135	15	15	50.00	50.00	0.03
135\145	30	13	69.76	30.24	6.09*
145\155	28	35	44.44	55.56	1.01
155\165	3	14	17.64	82.36	9.36*
165\175	0	3	0.00	100.0	-

overall sex-ratio is 1:1, however, females can be more frequent in larger sizes classes due to their faster growth rates (Vazzoler, 1996). Amadio & Bittencourt (2005) suggest that the predominance of females in fishes in flooded areas in Central Amazon may be explained by different growth and mortality rates. Lowe-McConnell (1999), discussing differences in size of males and females as a function of parental behavior suggests that in egg-keeping fish species, the individual keeper (usually the male) tend to be larger than females, and this pattern is shown by many cichlid species. Apparently this is not the case of the discus since this species exhibit biparental care. Neverthess Lowe-McConnell (1999) also suggests that in species where breeding is very frequent, size differences tends to be more pronounced due to bioenergetic reasons. Greater weight loss occurs during egg production as opposed to sperm production, delaying female's growth in comparison to males.

Our results showed a significantly higher proportion of males in the larger size classes. Although the number of individuals in those classes is small, this pattern may indicate differences in growth and/or mortality rate for males and females. Nevertheless, mortality and growth rates for the species were not the focus of this study and indications on this matter have to be taken cautiously.

Cichlid species have, in general, a complex and wide range of reproductive behavior, such as: territoriality, competition between males, and spawning site selection. Chellappa *et al*. (1999a, 1999b) and Cacho *et al*. (2006) suggest that male size, aggressiveness and ability to choose and defend the territory, are crucial factors for breeding success. Câmara (2004) shows that female discus prefer males of larger size. These results corroborate our findings of males being more frequent in the larger size classes and this might be related to the complex male breeding behavior known for *S. aequifasciatus*.

Relationship between standard length and total weight of all captured specimens was highly significant (Regression equation: Wt = -4.5545 + 3.1668 Ls, $r^2 = 0.91$, n = 1590 (Fig. 1). These parameters are important to predict weight from length and vice versa, to infer the growth of the species as well as determine the physical condition of the specimens.

Estimated L_{50} for female discus was 98.4 mm (SD ±0.38), corresponding to 63.9% of the maximum attained length for females (154 mm) in this study. A value of 95.8 mm (SD ±0.86) for males was found, which corresponds to 61.8% of the maximum attained length for males (155 mm).

According to Agostinho *et al*. (1991), tropical fish species seem to reach sexual maturation around 40 to 50% of their maximum attained length. The results found here contrast with this generalization, showing values higher than 60% for both sexes. This fact may indicate that energy allocation for somatic growth takes longer than average in *S. aequifasciatus*.

Average fecundity for female discus was 1490 oocytes (n = 23, SD ±304) ranging from 950 to 1892 oocytes, with diameters ranging from 0.1 to 1.4 mm. Discus size ranged from 118 to 145 mm Ls (mean 134.59, SD ±7.48) and from 90 to 185 g

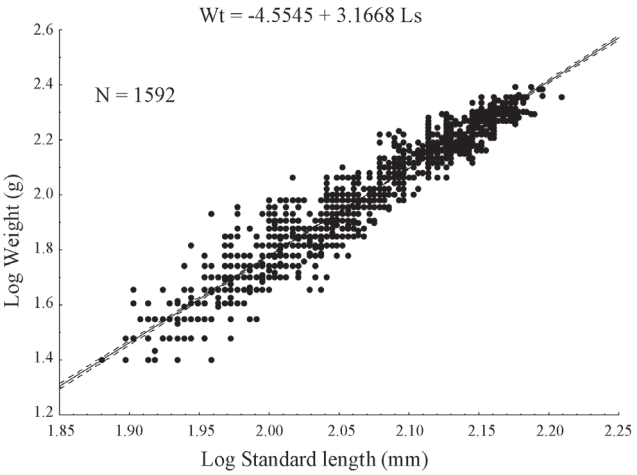

Fig. 1. Length x weight plots for specimens of *Symphysodon aequifasciatus* captured in Ayapuá Lake during September-November 2006 and 2007.

of total weight (mean 141.22, SD ±24.26). Egg size distribution showed four types of patterns, indicating one to four modes besides the reserve oocytes group (under 0.4 mm). It was possible to observe a progression of modes indicating the release of the most developed egg group from type 4 to type 1 (Fig. 2). Most females showed egg size distribution of type 3 (52%) followed by type 2 (22%) and type 4 and 1 (13%). All types were composed by females of similar sizes (F = 0.4824, p = 0.698) and fecundities (F = 0.0929, p = 0.963) (Table 3).

Câmara (2004) defines *S. discus* as a multiple spawner for captivity breeding individuals. Under these conditions we assume that the individuals were not exposed to a wide range of possible environmental factors occurring in nature, such as the floodplain pulse regime in the Amazon. Besides, Câmara (2004) defines the type of spawning considering females in four different stages of gonadal development while in the present study the type of spawning was defined based on pre-spawning female discus only, impairing a reliable comparison between the two studies.

Crampton (2008) observed a tri-modal egg size distribution for *S. haraldi*, and considered it a typical partial-spawning fish. However, his analysis was based on a single pre-spawning female fish with 1271 oocytes in the ovary. Foucher & Beamish (1980) described the occurrence of a multiple modal egg size distribution for *Merluccius productus* (Merlucciidae), but with total spawning. According to the authors, only the most developed oocyte group is released and the remaining ones are absorbed. Similarly, Andrianov & Lisovenko (1983) described for *Merluccius gayi peruanus*, a process where

Table 3. Standard length (Ls), total weight (Wt), number (N) and fecundity range for each type of egg size distribution of pre-spawning female of *Symphysodon aequifasciatus*.

Type of egg size distribution	N	Ls (mm)	Wt (g)	Fecundity
1	3	126-136	107-160	1427-1807
2	5	126-145	125-165	1034-1892
3	12	118-142	90-185	950-1861
4	3	134-138	135-170	1155-1881

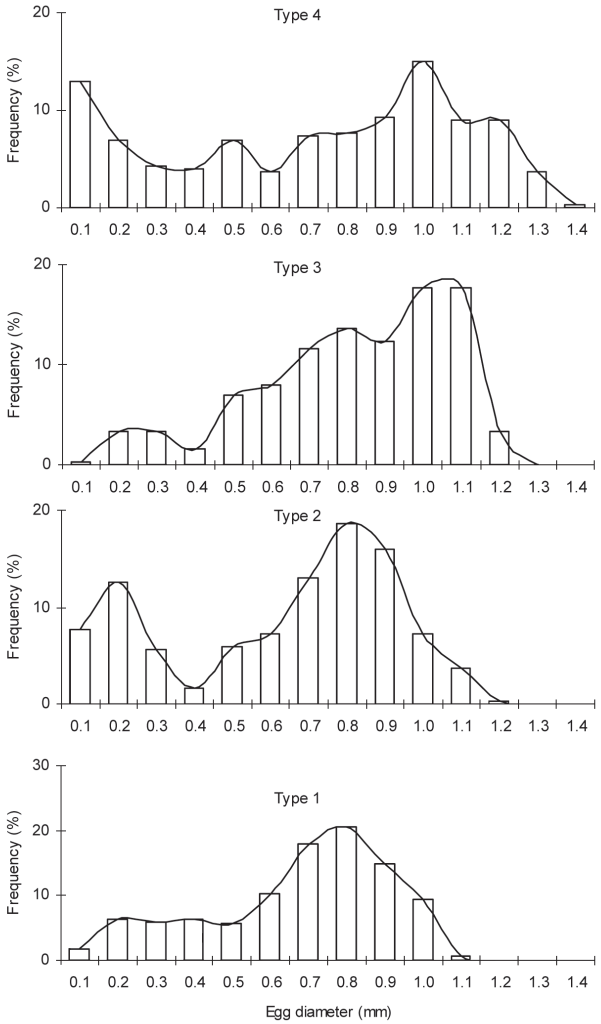

Fig. 2. Oocyte size distribution of pre-spawning female discus *Symphysodon aequifasciatus* captured in November 2006 in Ayapuá Lake (AM) showing four types of egg distribution.

the most developed modal oocyte group is released only after all groups reach full maturity, and are spawned altogether. In both cases what seems to be a partial spawning after detailed analysis proved to be total spawning.

Discus cichlids show complex reproductive behavior and may be influenced by biotic parameters (such as high predation of eggs, larvae, and young adults) and by local and regional environmental dynamics (such as the sudden rise of the river water level, locally known as "repiquetes"). In this sense, it seems plausible that females discus spawn only one egg batch at a time (the most developed one), keeping the rest to be released later if circumstances of high predation on eggs, larvae or fry occur. This would explain the progressive modal shift of egg size (Fig. 2). In that way, female discus would ensure reproductive success through the rapid development of one or more egg batches that are still in the ovary. In the case of reproductive success with the release of one or two egg batches, the remaining ones would be absorbed by the organism.

Data on the reproduction of the cichlid species *Astronotus ocellatus* (Agassiz, 1831) in captivity (Paiva & Nepomuceno, 1989) showed that successive removal of larvae produced by the parents resulted in repeated spawning. Lowe-McConnell (1999) discusses that the number of broods produced depends on environmental conditions, so production in tanks is higher than in the natural environment. The author also highlights the behavioral factor possibly involved, suggesting that the removal of fry from the captivity in the initial phase may change the frequency of spawning, as observed for *A. ocellatus* (Paiva & Nepomuceno, 1989).

Based on what has been presented, we suggest that *S. aequifasciatus* shows total spawning within the breeding season, in the beginning of flooding period, with the peculiar capacity of releasing multiple egg batches as a strategy that potentially enhances reproductive success.

Correlations between fecundity and standard length and total weight for *S. aequifasciatus* were very low (length: $r^2 = 0.306$; weight: $r^2 = 0.189$). There is evidence that fecundity is more related to the length than the weight of the individual, considering it is dependent on the size of the body cavity (Vazzoler, 1996). It is possible that the weak relationship observed in the present study is due to the highly compressed discus´ body shape. In such cases, a correlation between fecundity and body volume, rather than length would prove to be more significant, which remains to be tested.

Acknowledgements

Thanks are due to Rodrigo Neves dos Santos for technical support, RDS-PP fishermen and project members Mário, Assis and Jeremias for field assistance. We are also grateful to Marcelo Rocha and Roselis Mazurek for the English version. This study had financial support from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (MCT/CNPq/SEAP-PR/CT-Infra no; 016/2006, process no. 408805/2006-4 and M.Sc. scholarship), Wildlife Conservation Society (WCS) (Andes Amazon Conservation Program – AACP) and from Piagaçu Institute (IPI). JZ receives a productivity grant from CNPq (process no. 307464/2009-1). FR received a M.Sc. scholarship from CNPq.

Literature Cited

Agostinho, A. A., N. S. Hahn & C. S. Agostinho. 1991. Ciclo reprodutivo e primeira maturação gonadal de fêmeas de *Hypostomus commersonii* (Valenciennes, 1840) (Siluriformes, Loricariidae) no reservatório Capivari-Cachoeira, PR. Revista Brasileira de Biologia, 51(1): 31-37.

Amadio, S. A. & M. M. Bittencourt. 2005. Táticas reprodutivas de peixes em ambientes de várzea na Amazônia Central. Pp. 65-75. In: Renno, J. F., C. García-Dávila, F. Duponchelle & J. Nuñez (Orgs.). Biología de las poblaciones de peces de la Amazonía y piscicultura. Comunicaciones del Primer Coloquio de la Red de Investigación sobre la Ictiofauna Amazónica, Iquitos, Perú.

Bleher, H. 2006. Bleher's discus. Volume I. Pavia, Italy, Aquapress.

Cacho, M. S. R. F., S. Chellappa & M. E. Yamamoto. 2006. Reproductive success and female preference in the amazonian cichlid angel fish, *Pterophyllum scalare* (Lichtenstein, 1823). Neotropical Ichthyology, 4(1): 87-91.

Câmara, M. R. 2004. Biologia reprodutiva do ciclídeo neotropical ornamental acará-disco, *Symphysodon discus* Heckel, 1840 (Osteichthyes: Perciformes: Cichlidae). Unpublished Ph.D. Dissertation, Universidade Federal de São Carlos, São Carlos, 135p.

Chellappa, S., M. R. Câmara & J. R. Verani. 2005. Ovarian development in the amazoniam red discus, *Symphysodon discus*, Heckel (Osteichthyes: Cichlidae). Brazilian Journal of Biology, 65(4): 609-616.

Chellappa, S., M. E. Yamamoto & M. S. R. F. Cacho. 1999a. Reproductive behaviour and ecology of two species of Cichlid fishes. In: Val, A. L. & V. M. F. A. Val (Eds.). Biology of Tropical Fishes. Manaus, INPA, 460p.

Chellappa, S., M. E. Yamamoto, M. S. R. F. Cacho & F. A. Huntingford. 1999b. Prior residence, body size and the dynamics of territorial disputes between male freshwater angelfish. Journal of Fish Biology, 55: 1163-1170.

Crampton, W. G. R. 1999. Plano de manejo para o uso sustentável de peixes ornamentais na Reserva de Desenvolvimento Sustentável Mamirauá. In: Queiroz, H. L. & W. G. R. Crampton (Eds.). Estratégias para Manejo de Recursos Pesqueiros em Mamirauá. Brasília. Sociedade Civil Mamirauá/MCT, CNPq, 208p.

Crampton, W. G. R. 2008. Ecology and life history of Amazon floodplain cichlid: the discus fish *Symphysodon* (Perciformes: Cichlidae). Neotropical Ichthyology, 6(4): 599-612.

Hildemann, W. H. 1959. A cichlid fish *Symphysodon discus* with unique nurture habits. American Naturalist, 93: 27-34.

Lowe-McConnell, R. H. 1999. Estudos ecológicos de comunidades de peixes tropicais. São Paulo, Editora da Universidade de São Paulo, 535p.

Paiva, M. P. & F. H. Nepomuceno. 1989. On the reproduction in captivity of the oscar, *Astronotus ocelatus* (Cuvier), according to the mating methods (Pisces – Cichlidae). Amazoniana, 10(4): 361-377.

Ready, J. S., E. J. G. Ferreira & S. O. Kullander. 2006. Discus fishes: mitocondrial DNA evidence for a phylogeographic barrier in the Amazon genus *Symphysodon* (Teleostei: Cichlidae). Journal of Fish Biology, 69 (Suplement B): 200-211.

Simpson, A. C. 1951. The fecundity of the plaice. Fisheries Investigation. London, series 2, 17(5): 3-27.

Vazzoler, A. E. A. M. 1996. Biologia e reprodução de peixes teleósteos: teoria e prática. Maringá, Eduem, 169p.

Zar, J. H. 1999. Biostatistical analysis. New Jersey, Prentice Hall, 663p.

Accepted May 7, 2010
Published June 25, 2010