Ecology of *Synodontis nigromaculatus* (Pisces: Mochokidae) from the Okavango River, Namibia

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This is the first detailed study on the biology of *S. nigromaculatus* in the section studied of the Okavango River that forms the international border between Namibia and Angola. It was found to be abundant especially in the floodplain habitats in the eastern section of the river. The minimum length at which this species matures in the Okavango River correlates with the population from the Okavango Delta. Furthermore, the annual flood was found to be the main stimulant for reproduction. The status of *S. nigromaculatus* in the Okavango River is not threatened, but future monitoring is essential. Changes in the annual flood and degradation of the floodplains may prove to be detrimental to this species.

Écologie de Synodontis nigromaculatus *(Pisces: Mochokidae) de l'Okavango en Namibie.* —C'est la première étude détaillée de la biologie de *S. nigromaculatus* dans la section étudiée de l'Okavango qui forme la frontière internationale entre la Namibie et l'Angola. Elle y a été trouvée en abondance en particulier dans la plaine inondable, dans la section orientale du fleuve. La longueur minimale à laquelle l'espèce atteint la maturité concorde avec celle des populations du delta. Par ailleurs, la crue annuelle semble le stimulant principal à la reproduction. L'espèce ne semble pas menacée actuellement, mais à l'avenir, son suivi semble essentiel. Des modifications des crues annuelles et la dégradation de la plaine innondable peuvent se révéler néfastes pour l'espèce.

Key words: Growth, mortality, reproduction, habitat.

INTRODUCTION

Synodontis nigromaculatus belongs to the family Mochokidae, the largest African catfish family with 10 genera of which two occur in the Okavango River (Skelton, 1993). Of these two, the *Synodontis* is the most common in the Okavango River with seven species present. In southern Africa, *S. nigromaculatus* has a distribution in the Okavango/Upper Zambezi System, Zambian/Zaire System, the Kasai River and in Lake Tanganyika (Skelton, 1993). Despite its abundance and wide distribution in the Okavango River, not much is known about the biology of *S. nigromaculatus*, especially about their reproduction. Large numbers were sampled by Skelton & Merron (1984) in the Okavango River near Rundu as well as in the Okavango Delta in Botswana (Merron & Bruton, 1988). Van der Waal (1986) succeeded in the artificial propagation of this species.

The Okavango River originates in the central highlands of Angola at the Bié plateau 1900 m above sea level where the river is known as Rio Cubango (Smit, 1991). The river flows south east until it enters Namibia at Katwitwi from where it forms the international border between Namibia and Angola. Several tributaries that enter the Rio Cubango in Angola originate in the Angolan highlands. The steepest gradient is in the upper reaches of the system. The river from Katwitwi to Tondoro is narrow and includes several rapids (Fig. 1). As the gradient declines, the river expands to give rise to large floodplains with sandy substrates, rocky outcrops and an abundance of aquatic vegetation. Welcomme (1979) defined the Okavango floodplain as a fringing floodplain lying between river valley walls. The Okavango region has a subtropical climate with an annual rainfall of 596 mm (Smit, 1991). The rainy season starts during October/November and has its peak during January/February. The peak flooding period is February to June when the floodplains can extend over 2km.

The Cuito River, the major tributary, enters the Okavango River from the north, 260 km east of Nkurenkuru (Fig. 1). Its inflow nearly doubles the annual run-off of the Okavango River from 5 600x106 m^3 at Rundu to a 10 500x10^6 m^3 discharge at Mukwe (Smit, 1991). From Mbambi the river narrows and the rapids increase where the river drops 2.5 m at the Popa Falls (Wilson & Dencer, 1976). From the Popa Falls, the river enters the Mahango game reserve which is the start of the panhandle before it terminates in the delta in Botswana.

The aim of this study was to obtain biological data for *S. nigromaculatus* from the south-western portion of its range.

MATERIALS AND METHODS

Sampling

Sampling was done at 56 localities along the river (Fig. 1). The following equipment was used in order to limit selectivity:

1. Monofiliment gill nets with stretched mesh sizes of 35, 45, 57, 73, 93, 118 and 150 mm and each panel with a length of 10 m. Gill nets were used in the main stream and large open back waters.
2. Mosquito net (10 m x 1 m) with a fine mesh size. Shallow floodplains and back waters were sampled.
3. A seine net (30 m x 1 m) with a 12 mm stretched mesh size. Similar habitats were sampled with this gear than with the mosquito net.
4. Rotenone. Rocky and densely vegetated areas were sampled.
5. Traps, 45cm x 41cm x 18cm, covered with a 12 mm mesh size net, with four inlets. Habitats sampled included the main stream, back waters, side streams and rapids.

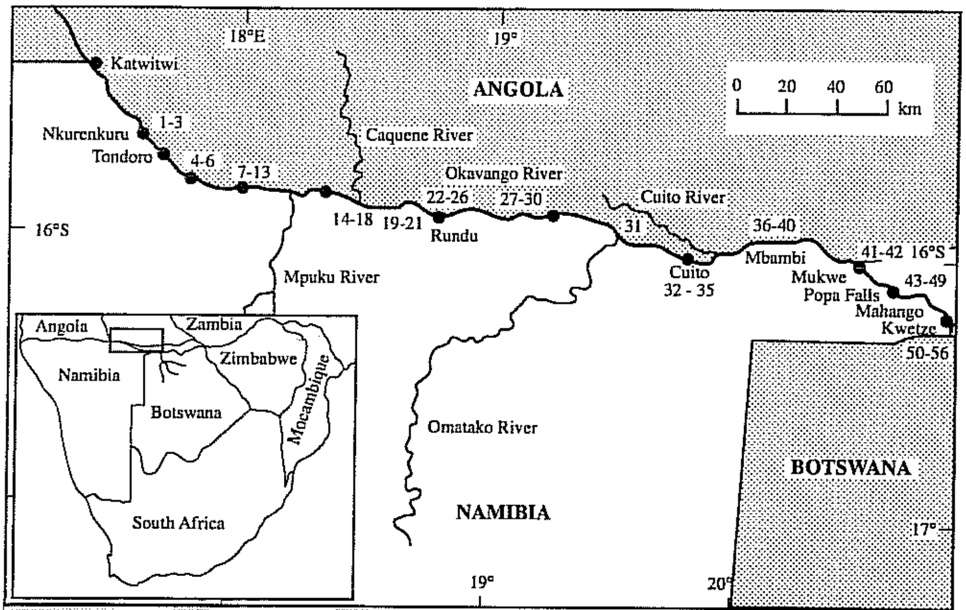

Fig. 1. — Map of the study site.

6. Two meter cast net. Back water habitats were sampled.
7. D-net with a fine mesh size. Shallow sandy areas in side streams and the main stream were sampled.

Growth and mortality

Six surveys were conducted: autumn 1993, winter 1993, spring 1993, summer 1994, autumn 1994 and winter 1994. Each survey was approximately 14 days.

Fork length was measured to the nearest millimeter and mass to the nearest gram (Mettler PE16). The Von Bertalanffy formula was then calculated.

$$L(t) = L_{\infty}(1 - e^{-k(t - t_0)})$$

Lt = length of species during sampling
L_{∞} = asymptotic length
k = a measure of the rate at which the growth curve according to the growth formula approaches the asymptotic length.
t_0 = time when the fish would have had zero length if growth had taken place according to the formula.
t = time in years.

Growth was calculated by using length frequency. The VONBER program in the Length-based Fish stock Assessment (LFSA) software was used to calculate the von Bertalanffy growth parameters. The following methods were applied for the calculation of the growth parameters by using length frequencies (Sparre *et al.*, 1989):

- Bhattacharya method to separate cohorts.
- Modified Wetherall method for calculation of the asymptotic length.
- Forced Gulland & Holt method to determine the growth parameters (k and L_{∞}).

Munro's phi-prime was used to compare the different growth rates.

$$\varnothing = \ln k + 2 \ln L_{\infty}$$

Only total mortality was calculated as the fishing mortality was unknown. This was done by using the catch curve method (Sparre *et al.*, 1989).

Reproduction

Sex ratio

The chi-square (χ^2) test was used to test the deviation from an expected 1:1 sex ratio (Zar, 1984):

$$\chi^2 = \Sigma \ (|f1 - f2|)^2 / f2$$

where
$f1$ = total individuals collected per sex
$f2$ = total expected individuals collected per sex.

Length at sexual maturity

The length/mass relationship was determined with the ONEVREG program from the statpak software which also gives the calculated mass. The condition of a species (K) was calculated as follows:
K = empirical mass/ calculated mass.

Gonad maturation index

The gonads were visually classified as follows according to Nikolskii (1969).
1 = Sexually immature or resting - Testis small and colourless. Ovaries with no visible eggs.
2 = Developing - Testis white and slightly enlarged. Ovaries with a few eggs visible. Individuals were classified as mature during this stage.
3 = Fully mature gonads.
4 = Individuals with spent gonads.

Fecundity

Fully developed ovaries were collected and preserved in Gillson's solution for approximately one month (Ricker, 1968). After rinsing the tissue in water the eggs were dried in an oven for 30 hours at 50°C and cooled in a desiccator. A subsample of 300 eggs was then counted and weighed. The fecundity was then calculated as follows (Bagenal & Braum, 1971):

Fecundity = mass of all the eggs/ mass of the subsample x 300

RESULTS

Relative density

Synodontis nigromaculatus was found to be relatively common in the Okavango River with totals of 425, 32, 293, 175, 83 and 17 sampled during autumn 1993, winter 1993, spring 1993, summer 1994, autumn 1994 and winter 1994, respectively.

Growth and mortality

The minimum and maximum lengths recorded were four and 24cm, respectively (Figs 2 & 3). Some recruitment cohorts were present, especially during the autumn, winter and spring 1993 surveys (Table 1). The 1994 surveys indicated poor recruitment. The third cohort had the highest number of individuals. Only one cohort was present during the winter 1994.

The asymptotic lengths calculated by using the Gulland & Holt (24.9cm; r = 0.74) and the Wetherall methods (28.9cm; a = 3.51; b = -0.12; r = 0.84) are considered realistic when comparing it with the maximum length sampled (Table 2). The phi-prime value calculated was 5.19 whereas the total mortality was 1.692. The survival of this species after the first year is 18.4%.

Reproduction

Sex ratio

The males dominated the sex ratio during the autumn and winter 1993

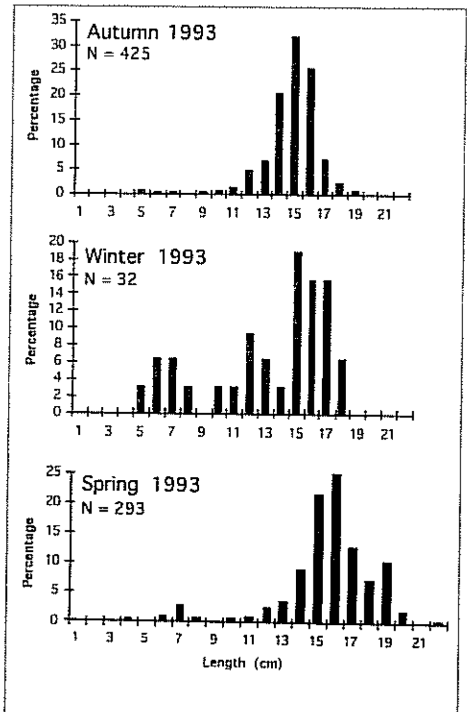

Fig. 2. — Length frequencies of *Synodontis nigromaculatus* for the surveys autumn, winter and spring 1993.

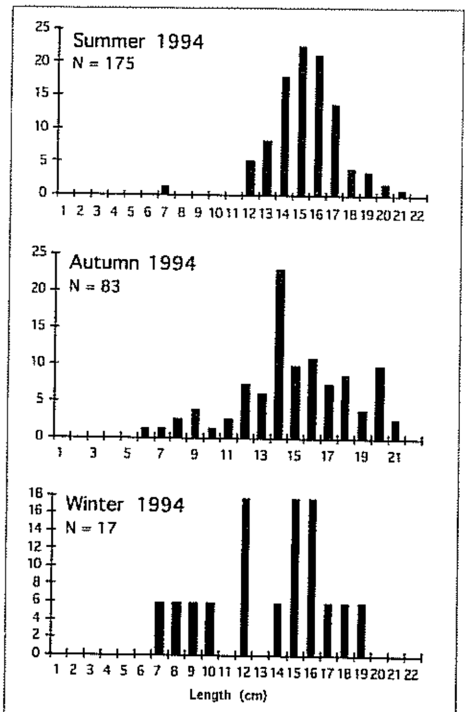

Fig. 3. — Length frequencies of *Synodontis nigromaculatus* for the surveys summer, autumn and winter 1994.

Table 1. — Separation of length frequencies of *Synodontis nigromaculatus* into cohorts.

Survey	Cohort no	Mean length (cm)	Standard deviation	Number in cohort (n)	Separation index
Autumn 1993	1	5.0	0.95	4	-
	2	13.3	0.95	74	8.72
	3	15.7	1.00	342	2.51
	4	18.0	1.10	7	2.15
Winter 1993	1	7.0	1.20	6	-
	2	12.7	0.82	7	5.69
	3	15.9	0.66	12	4.34
Spring 1993	1	7.4	0.65	14	-
	2	13.7	1.43	37	6.08
	3	16.3	1.03	191	2.07
	4	19.3	0.65	49	3.63
Summer 1994	1	15.7	1.46	161	-
	2	20.33	0.69	12	4.25
Autumn 1994	1	9.0	1.06	8	-
	2	12.9	0.85	14	4.06
	3	16.2	1.37	44	3.03
	4	20.5	0.63	4	4.23
Winter 1994	1	16.0	0.95	15	-

Table 2. — Growth parameters of *Synodontis nigromaculatus* from the Okavango River.

Method	k	L_∞	Munro's phi prime
Gulland & Holt	0.35	24.9	5.38
Modified Wetheral		28.9	

surveys, after which the sex ratio was 1:1 (Table 3).

Length at sexual maturity

The minimum lengths recorded at which this species reached sexual maturity were 12.0 and 11.8 cm for the males and females respectively (Table 4). The length at which 50% matured were 14 cm for the males and 12 cm for the females.

Table 3. — Sex ratio of *Synodontis nigromaculatus* from the Okavango River.

Survey	Sex ratio ♂	Sex ratio ♀	Chi-square	Significance level
Autumn1993	249	166	8.30	$P \leq 0.05$
Winter1993	17	7	4.17	$P \leq 0.05$
Spring1993	106	115	0.37	$P \geq 0.05$
Summer1994	83	90	0.28	$P \geq 0.05$
Autumn1994	27	41	2.88	$P \geq 0.05$
Winter1994	6	5	0.09	$P \geq 0.05$

Table 4. — Minimum and 50% maturity length for *Synodontis nigromaculatus* from the Okavango River.

Survey	Sex	Minimum length	50% maturity
Autumn 1993	♂	12.0	14.0
	♀	11.8	15.0
Winter 1993	♂	-	-
	♀	-	-
Spring 1993	♂	-	-
	♀	-	-
Summer 1994	♂	12.4	14.0
	♀	11.9	12.0
Autumn1994	♂	-	-
	♀	-	-
Winter1994	♂	-	-
	♀	-	-

Gonad maturation index

This species matured after the onset of the annual flood. The breeding season commenced during December and continued through April (Table 5). Gonad development of the males was slightly earlier than that of the females. A higher percentage of sexually ripe female gonads was observed during March, whereas during the same period male gonads were degenerating.

Fecundity

The fecundity/length relationship was linear, whereas the best fit for the fecundity/mass relationship was a logarithmic formula (Table 6). The best fit was for the fecundity/length

Table 5. — Gonad maturation index of *Synodontis nigromaculatus* from the Okavango River.

Survey	Sex	Gonad maturation index 3	2	1
Autumn 1993	♂	38	189	22
	♀	49	16	101
Winter 1993	♂	-	-	17
	♀	-	-	7
Spring1993	♂	-	-	115
	♀	-	-	106
Summer 1994	♂	4	30	49
	♀	64	5	21
Autumn1994	♂	-	-	27
	♀	-	-	41
Winter1994	♂	-	-	6
	♀	-	-	5

Table 6. — Fecundity versus length and mass of *Synodontis nigromaculatus* from the Okavango River.

Parameter	Fecundity/length	Fecundity/mass
A	-13511.34	-2216.86
B	997.87	1105.88
r	0.59	0.50
r^2	0.35	0.25
n	29	29

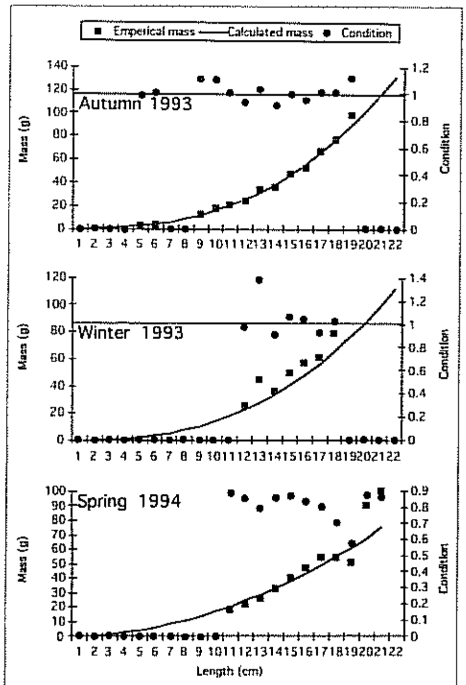

Fig. 4. —Length/mass relationship and condition of *Synodontis nigromaculatus* for the surveys autumn, winter and spring 1993.

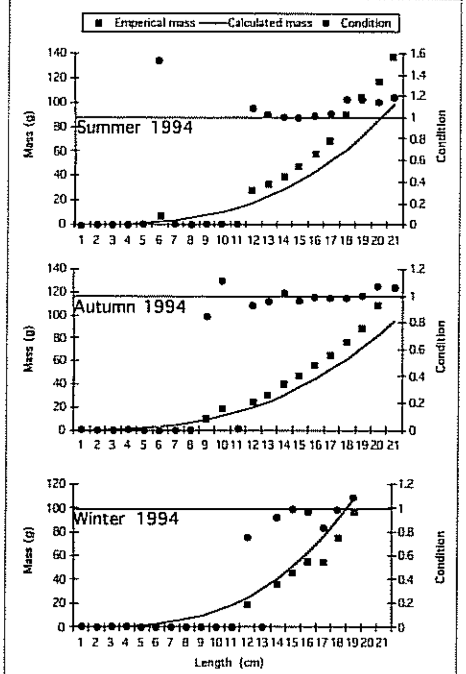

Fig. 5. — Length/mass relationship and condition of *Synodontis nigromaculatus* for the surveys summer, autumn, and winter 1994.

Table 7. — The length/mass relationship of *Synodontis nigromaculatus* from the Okavango River.

Survey	A	B	r	r^2	Number
Autumn 1993	0.03	2.69	0.96	0.91	424
Winter 1993	0.03	2.66	0.94	0.87	25
Spring 1993	0.17	2.00	0.76	0.58	272
Summer 1994	0.01	3.02	0.95	0.89	174
Autumn 1994	0.02	2.78	0.97	0.95	72
Winter 1994	0.01	3.15	0.97	0.94	11

relationship. Fecundity varied from 395 for a 16 cm individual to 9615 for a 19.2cm individual.

Length/mass relationship and condition

The condition of this species increased during the breeding season with a poor condition during the spring (Figs 4 & 5). The autumn 1993 survey was used as the standard. The minimum r^2 value was 0.58 during the spring of 1993 (Table 7).

Habitat preferences

This species prefers floodplain habitats. A few small individuals however were also taken from rocky areas.

DISCUSSION

This species is abundant in the Okavango River which was also the finding of Merron & Bruton (1988) from the Okavango Delta as well as Bell-Cross

& Minshull (1988) from Zimbabwe. A lower number was found during the winter months. Bell-Cross & Minshull (1988) found that predation may dictate the relative abundance of S. *nigromaculatus*. This species formed a small percentage of the gill net catches from Lake Liambezi (van der Waal, 1976). *Synodontis nigromaculatus* was also abundant in gill nets sampled from Kwetze in the back waters (Fig. 1).

The asymptotic length calculated is similar compared to the maximum length recorded. Skelton (1993) reported a maximum length of 30 cm which is similar to our asymptotic length. Maximum lengths reported by several authors are 44 cm (Jackson, 1961) from Zimbabwe, 24 cm from Lake Bangweulu (Bell-Cross & Minshull, 1988), 29 cm from Lake Liambezi (van der Waal, 1976), 30 cm from the Zambezi River (Bell-Cross, 1974) and Okavango River (Barnard, 1948). The growth rate was slower than that calculated for other *Synodontis* spp. (van Zyl, 1992), but the mortality rate was higher.

Overall the sex ratio was 1:1, with more males sampled during the first two surveys. In Lake Liambezi van der Waal (1976) found a sex ratio favouring females. The minimum length at which both sexes matured correlates with the finding of Merron & Bruton (1988) from the Okavango Delta.

The fecundity was lower than for the Lake Liambezi population for which van der Waal (1976) recorded egg counts as high as 62500. Similar counts are reported by Kok (1980) for S. *zambezensis*.

Successful spawning of this species depends on the annual flood with sexually active individuals only sampled after the flood. This was also stated by van der Waal (1985), Bell-Cross & Minshull (1988) and Skelton (1993). Merron & Bruton (1988) indicated a longer breeding period for this species as was found during this study.

The S. *nigromaculatus* population in the Okavango River is not threatened although surveys indicated weak recruitment. Low numbers sampled during the winter surveys may be one of the reasons. As this species is dependent on the flood for successful breeding, any changes in the flood cycle will adversely affect the population.

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