ECOLOGY OF THE TIGER-FISH (*HYDROCYNUS VITTATUS*) IN THE INCOMATI RIVER SYSTEM, SOUTH AFRICA

I. G. GAIGHER

Provincial Fisheries Institute, Lydenburg, South Africa

INTRODUCTION

Topography

The Incomati River system drains those parts of Eastern Transvaal, Swaziland and Moçambique lying between the Limpopo River system in the north and the Pongola River system in the south. The area is bounded roughly by parallels of south latitude 24° 15′ and 26° 15′ and meridians of east longitude 29° 45′ and 33° 5′. The main tributaries of the system, namely the Sabie, Crocodile and Komati Rivers rise in the high altitude regions of the plateau, flow down the Drakensberg escarpment and thence through the lowveld regions of the Eastern Transvaal and Swaziland where they join to form the Incomati River which meanders through Moçambique to empty into the Indian Ocean at Villa Luiza.

Climate

West of the Drakensberg escarpment winters are cold with frequent night frosts. Snow, however, is rare. The mountainous area east of the escarpment and the lowveld is hot to warm during the summer and temperate during the winter.

TABLE 1

MEAN DAILY MINIMUM AND MAXIMUM AIR TEMPERATURES IN DEGREES CELSIUS FOR JUNE AND JANUARY AT DIFFERENT LOCALITIES IN THE INCOMATI RIVER SYSTEM DRAINAGE BASIN

	June		*January*	
Locality	*Max.*	*Min.*	*Max.*	*Min.*
Lake Chualo	20·6	17·9	27·7	23·8
Skukuza	25·6	6·1	32·3	19·6
Nelspruit	23·4	7·0	28·8	18·6
Barberton	23·2	6·7	29·1	18·4
Sabie	20·0	3·6	26·5	15·7
Mbabane	19·0	5·5	26·5	15·1
Lydenburg	19·3	3·7	25·7	14·4
Carolina	16·9	1·3	25·2	12·9

The rainy season extends from October to March with heavy downpours occurring from November to February. The rainfall in the area above the escarpment is high and decreases with decreasing altitude but increases again near the coast.

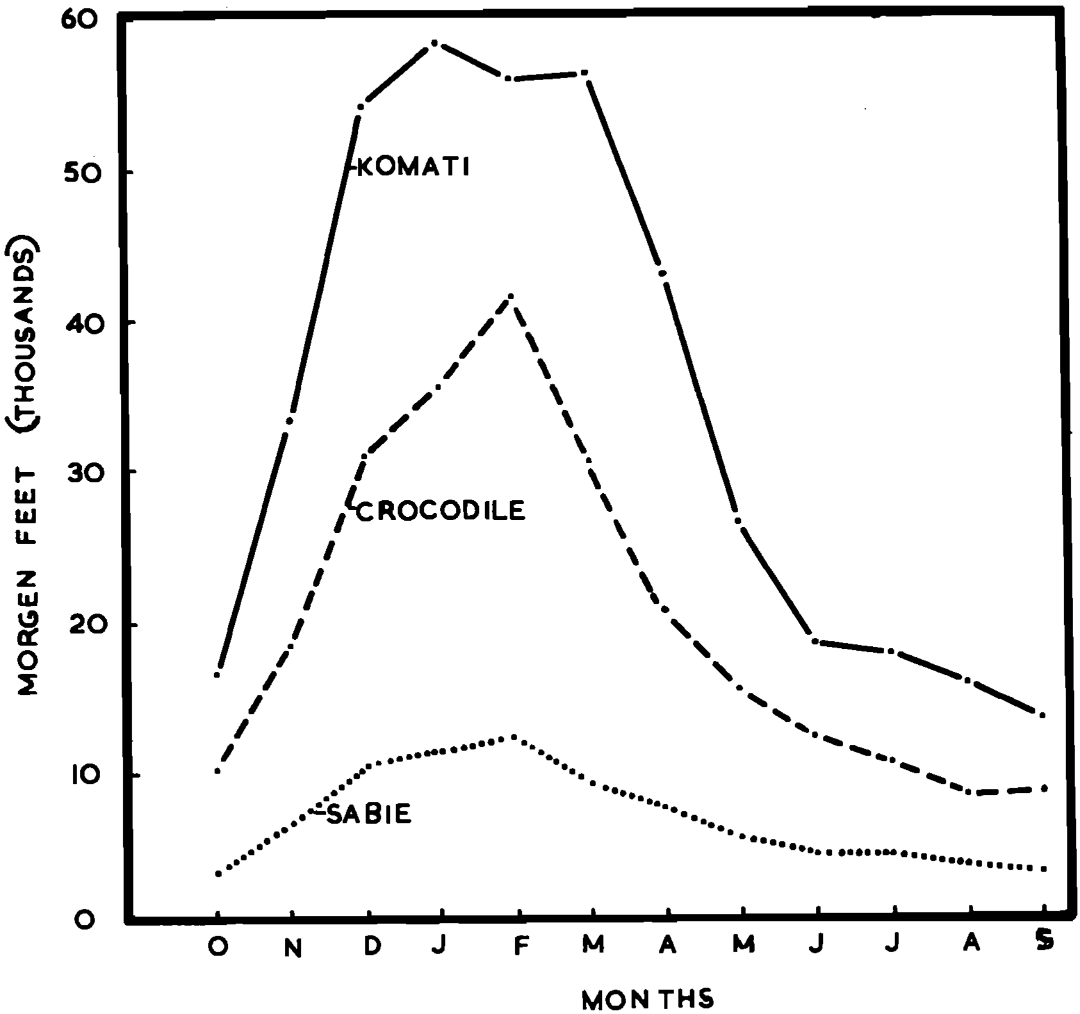

FIGURE 1
Monthly average rates of flow at three stations on the Incomati River system.

During the rainy season the lower Incomati frequently overflows its banks, forming a number of lakes adjacent to the main stream. The most important of these is Lake Chualo near Cutane in Moçambique, with a surface area of 2,800 hectares when full. During October, 1966, however, all that remained of the lake was a mud-pool without any fish. The period of high flow lasts from November to April with the maximum flow in January and February, and minimum in August and September (Fig. 1).

Angling

The tiger-fish is one of the most sought-after sport fishes on the African continent. The southern limit of its distribution is the Pongola River. The Incomati River system used to provide some very fine fishing for this species in the lower reaches. However, rapid agricultural development in the past few years has necessitated the withdrawal of large quantities of water from the streams and the construction of new weirs; this has created unfavourable stream conditions during the dry season and in recent years anglers' reports indicated that the tiger-fish has disappeared from some of its earlier haunts. It was, therefore, deemed necessary to survey the fishery resources of the Incomati River system before further deterioration of the river habitat takes place. This paper reports on the data collected on tiger-fish. The tiger-fish has been studied in river systems further north (Bowmaker 1960; Jackson 1960, 1961a, 1961b; Badenhuizen 1965, 1966; Munro 1967) but in the Transvaal virtually nothing is known of its ecology.

METHODS

Field sampling

Thirty-nine collecting sites were chosen with due regard to factors like altitude, gradient, accessibility and suitability for operating sampling gear (Fig. 2). Population samples were collected during April, July, August-September, October, and December, 1966, and during January, 1967.

At each site water and air temperatures, pH, conductivity, alkalinity and turbidity of the water were determined. Flow data were supplied by the Department of Water Affairs, while meteorological data were extracted from the records and publications of the Weather Bureau, Department of Transport. Fishes were collected with seine nets, gill nets and an electrofishing apparatus. They were measured, weighed and sexed, while gonad weights were recorded, and stomach contents and scale samples collected.

Condition index

To allow an evaluation of the relative physical condition of a fish to be made, it was necessary to establish a norm more useful and more accurate than the commonly used cube formula. An adaptation of the method used by Le Cren (1951) was used in which a condition index was given by

$$K_n = \frac{W}{\hat{W}}$$

where W = Observed weight of fish
$\hat{W}$ = Calculated weight

$\hat{W}$ was calculated by averaging all the data of a particular length group for any one season or survey (usually coincident) and then averaging all figures for the five separate visits. To this set of averages a length-weight regression was fitted by least squares and the resultant formula used for calculation of $\hat{W}$.

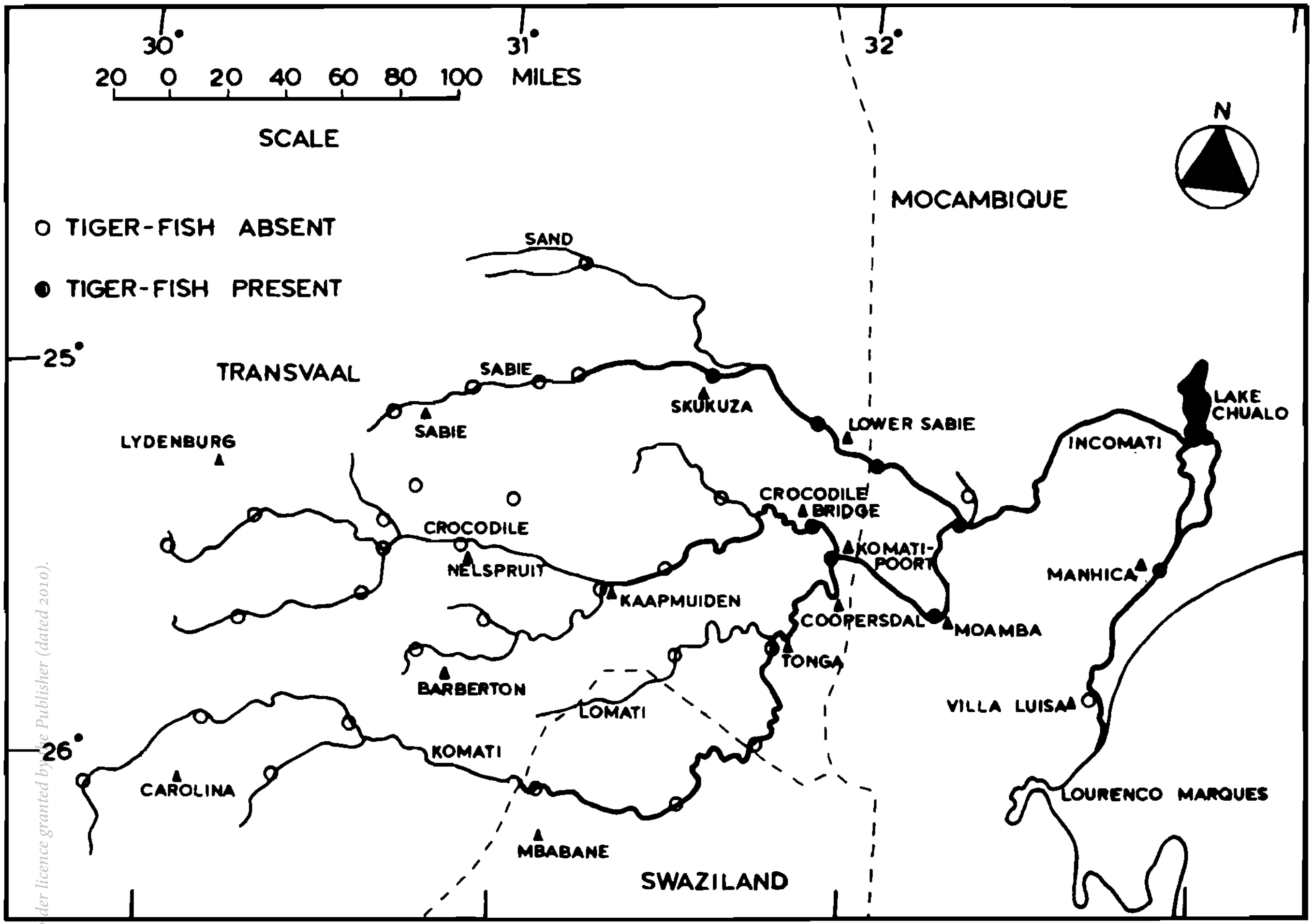

FIGURE 2
Map of the Incomati River system showing the location of collecting sites.

Age determination

Age was determined by the analysis of length data as well as the examination of scales. Five scales of every fish were examined at a magnification of 41 diameters. In order to validate age determination it was necessary to identify the annuli and determine their time of formation.

Growth rate

The relation between fish length and scale radius was determined and used to calculate the lengths of individual fish at earlier ages by using the formula

$$L_n = C + \frac{S_n(L_t - C)}{S_t}$$

Where L_n = Length of fish at the time of formation of n^{th} annulus
L_t = Length of fish at time of capture
s_n = Distance from focus of scale to n^{th} annulus
s_t = Radius of scale to anterior margin
C = The X-axis intercept of the function which describes the fish length- scale radius relationship (Schaefer 1965)

Averages of the lengths so computed, as well as of the lengths actually observed, were used to fit a Von Bertalanffy growth in length equation (Ricker 1958).

Maturity coefficient

In order to determine the length at first spawning and the breeding season, use was made of a calculated coefficient of maturity (Nakai and Usami 1962), according to the formula

$$\text{Maturity coefficient} = \frac{G}{L^3} \times 10^4$$

where G = Gonad weight in grams
L = Fork length in centimeters

Food habits

The frequency of occurrence of various food items as well as the composition of stomach contents by volume were determined. Fish larger than 70 mm were examined in the field and only the stomach contents preserved. Smaller fish were dissected in the laboratory and the finely divided contents analysed using the fullness-index method of Le Roux (1956). Volumes of the stomach contents of larger specimens were determined by water displacement.

RESULTS

Distribution

H. vittatus has a remarkable distribution in Africa extending from the Nile and Congo Rivers to rivers of West Africa through to the Zambezi, Okovango and Limpopo to the Pongolo River in the south (Jubb 1967). In the Incomati River system tiger-fish only occur

TABLE 2

ABUNDANCE OF TIGER-FISH AT KOMATIPOORT DURING 1966 AND 1967

Date		Mean number caught per 70 m netting effort
April	1966	11·5
July	1966	44·6
August	1966	42·7
October	1966	4·1
January	1967	0·1
April	1967	3·0
July	1967	11·0

in the warm water areas of the Lowveld. During this survey they were common in the Incomati River up to Komatipoort and in the Sabie River up to the eastern border of the Kruger National Park. They were very scarce higher up in the system. None was collected in the Komati River above a weir at Coopersdal 423 JU. None was found in the Lomati and only a few in the Crocodile River at Crocodile Bridge and in the Sabie River at Lower Sabie and Skukuza. The species was also absent from the Sand River.

Previous records indicate that in the past tiger-fish were much more abundant in the higher reaches of the Komati and Crocodile Rivers. They were previously collected by the staff of the Provincial Fisheries Institute at Lomatimond 445 JU and at Tonga Weir (Van der Merwe, personal communication). These records are supported by earlier reports of anglers' catches in the Crocodile River at Kaapmuiden, in the Lomati River and in the Komati River in Swaziland.

During June, 1964, a hailstorm in the catchment areas of the Komati and Crocodile Rivers killed hundreds of tiger-fish. This appears to have eliminated the tiger-fish which occurred above certain weirs in these streams as no reports of tiger-fish catches have since been received from these areas. Although great numbers of tiger-fish were present below the Coopersdal weir during March, 1966, when young *Labeo cylindricus* moved upstream, none was found above this weir, which thus appears to be an effective barrier to upstream movement of tiger-fish.

Migration

In the Incomati River system tiger-fish spawn in Moçambique and evidence for a downstream movement during the spawning season was found in the change in abundance of tiger-fish at Komatipoort, situated nearly 40 miles upstream of the nearest spawning grounds. Numbers increased from April to August and decreased again from October to January (Table 2).

As no tiger-fish were found higher up in the Komati River during any of the surveys, a downstream migration must have taken place from October, 1966, to January, 1967, and an upstream migration after the spawning season.

TABLE 3

SEASONAL VARIATION IN RELATIVE CONDITION OF *H. vittatus* FROM THE INCOMATI RIVER SYSTEM DURING 1966 (100 TO 350 MM FORK LENGTH)

KN	*Percentage of frequency*			
	April	*July*	*Aug.-Sep.*	*October*
0·7000–0·7499			2	
0·7500–0·7999		2	10	
0·8000–0·8499		10	20	9
0·8500–0·8999	2	15	23	13
0·9000–0·9499	5	20	22	31
0·9500–0·9999	16	19	10	21
1·0000–1·0499	22	20	8	19
1·0500–1·0999	20	9	2	4
1·1000–1·1499	21	4	2	1
1·1500–1·1999	9			3
1·2000–1·2499	4	1	1	
No. of Fish	147	357	125	78
Mean KN	1·0649	0·9578	0·8948	0·9533
Standard deviation	0·0837	0·0843	0·0953	0·0775

Upstream movement of tiger-fish may be caused by the upstream migration of small prey fishes or the existence of unsuitable living conditions in the lower reaches of the river. It is known that towards the end of summer large numbers of young *Labeo cylindricus* move upstream from the spawning grounds in Moçambique and it is thought that the tiger-fish follow this source of food.

Physical condition

The length-weight relationship for the calculation of relative condition is described by the equation

$$W = 0{\cdot}007328\ L^{3{\cdot}2323}$$

where W = Weight in grams

and L = Length in centimeters

Fish collected in April were in the best condition with a mean relative condition of 1·0649, but suffered a loss of condition during the winter months (Table 3). This can be correlated with poor environmental conditions such as lack of food, low water level and lower water temperatures. Increase in water temperature, river flow and available food caused an improvement in condition from October onwards.

Differences between mean relative condition at various seasons were significant between April and July ($Z = 13 \cdot 0610$), between July and August ($Z = 6 \cdot 5625$), and between August and October ($Z = 4 \cdot 7794$), but not between July and October ($Z = 0 \cdot 4592$). The increase in relative condition during October was not caused by gonad development. Relative condition was not calculated for January because of a lack of specimens over 100 mm in length.

Growth rate

Tiger-fish in the Incomati River system are subject to adverse conditions during the winter months as a result of the low water level and food shortage. Very little or no growth probably takes place from April to September. New growth recommences after the first rains in October. Most of the scales collected during this time showed annulus formation on the anterior margin. The new rings were complete and tended to cut across the ends of the incomplete rings laid down during the slow growing period (Fig. 3).

The annulus is a reliable yearmark, as lengths calculated from scale measurements agreed reasonably well with actual lengths of fish of corresponding ages as well as with length-frequency graphs. Fork length and anterior scale radius plotted on a scatter diagram showed an inflection point corresponding to a body length of about 120 mm. Two straight line regressions were fitted to the data by the method of least squares with the resulting equations $Y = -6 \cdot 8801 + 0 \cdot 5031X$ ($R = 0 \cdot 99$) for fish under 120 mm in length and $Y = -38 \cdot 8710 + 0 \cdot 7740X$ ($R = 0 \cdot 99$) for fish over 120 mm in length. The inflection point corresponded to an anterior scale radius (x 41) of 54 mm. Length-frequencies of young tiger-fish collected during April, July, August, September and October showed that no growth occurred from April to the end of August. It was thus assumed that fish caught during April, July and August-September had completed their year's growth.

Table 4 shows the length-frequencies by age groups of *H. vittatus* determined both by back calculation and actual lengths at corresponding ages. The wide range in length at each age indicates a high degree of individual variation in growth rate.

In Table 5 only back-calculated lengths for each age group of 466 tiger-fish are shown. Calculated lengths were consistent for different age groups except for the 1965-66 year class. The Incomati River system was subject to a severe drought at the end of 1965 with the result that spawning probably started later than usual.

The mean fork length at the end of each year of life was determined from all the data combined. The Von Bertalanffy growth-in-length equation fitted to these data is described by the equation $L_t = 471\ (1 - e^{-0.25\ (t-\ 0.12)})$.

Growth (Table 6) is slow compared to that of Zambezi tiger-fish which reach an average length of 140 to 180 mm at the end of their first and 250 mm at the end of their second year of life (Jackson 1961a).

In the length-frequency analysis the first two age groups could be distinguished clearly. Because of individual variation in growth rate, older age groups could not be separated by length-frequencies alone.

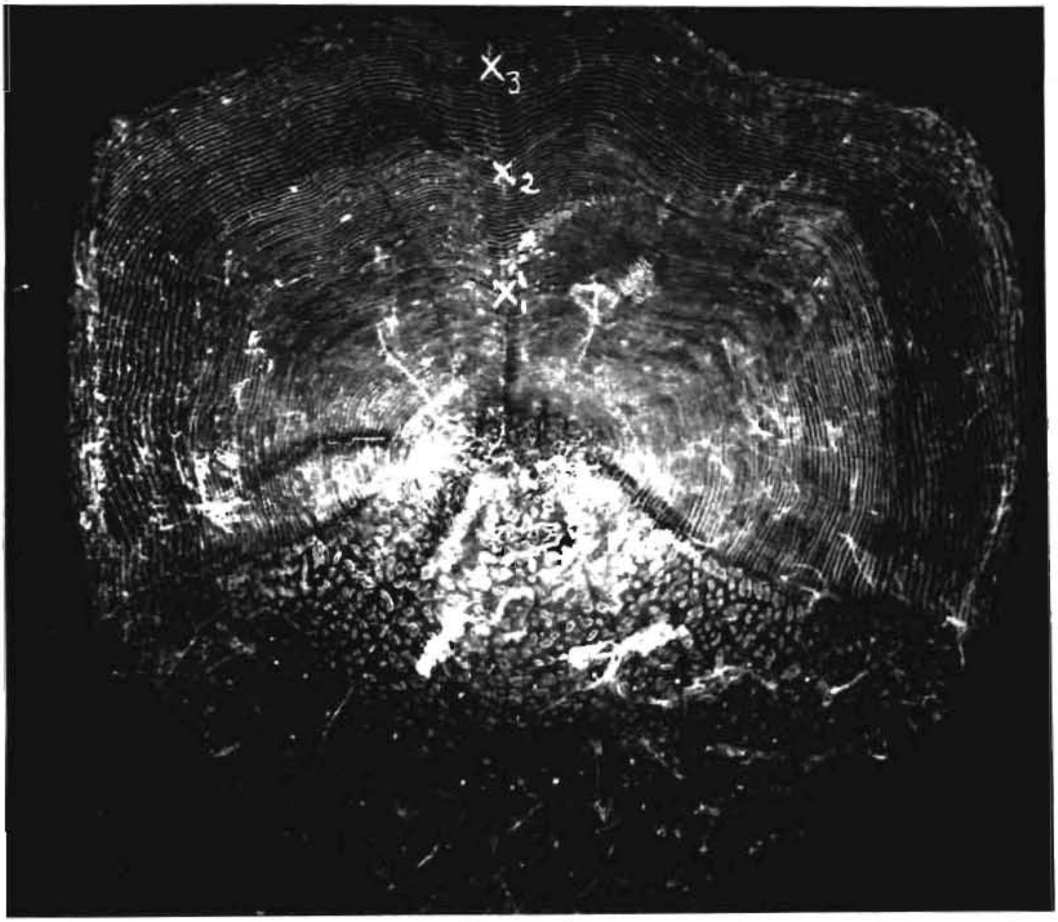

FIGURE 3
Scale image of a three-year-old *H. vittatus* from the Incomati River system, December, 1966. Annuli are indicated by crosses.

Reproduction

Of the 266 tiger-fish that could be sexed by gross examination in the field, 35·7% were males and 64·3% females. Females were distinctly larger than males. The largest male was 390 mm while females up to 580 mm in length were found. Females grow faster than males (Table 7). Only the average lengths of the V + age group did not differ significantly, probably because the sample was too small. Males also appear to have a shorter life span than females as there is a progressive decrease in the proportion of males with advancing age.

The gonads of fish under 150 mm in length were undeveloped during all seasons. Males reach sexual maturity at a length of 200 mm in their third year of life. Because so few mature

TABLE 4

LENGTH-FREQUENCIES BY AGE GROUPS OF *H. vittatus* FROM THE INCOMATI RIVER SYSTEM

Fork length	Age						
(*mm*)	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*
50 – 59	2						
60 – 69	4						
70 – 79	61						
80 – 89	151						
90 – 99	163	2					
100 – 109	67	3					
110 – 119	16	3					
120 – 129	3	5					
130 – 139	1	7					
140 – 149	..	50					
150 – 159	..	150					
160 – 169	..	161					
170 – 179	..	112	1				
180 – 189	..	57					
190 – 199	..	19					
200 – 209	..	16	7				
210 – 219	..	3	14				
220 – 229	..	3	17				
230 – 239	..	..	11				
240 – 249	..	..	17	3			
250 – 259	..	..	20	2			
260 – 269	..	..	11	6			
270 – 279	..	..	17	7			
280 – 289	..	..	7	10	2		
290 – 299	..	..	1	11	1		
300 – 309	..	..	1	6	4		
310 – 319	..	..	2	7	3	1	
320 – 329	..	..	1	3	4		
330 – 339	..	..	1	1	5	1	
340 – 349	..	..		5	3	1	
350 – 359	..	..	1	1			
360 – 369	..	..	..	..	5	1	
370 – 379	..	..	..	..	1	1	1
380 – 389	..	..	..	..	1	3	
390 – 399	..	..	..	..		1	
400 – 409	..	..	..	..	1		
430 – 439	..	..	..	..	..	..	1
Total	468	591	129	62	30	9	2

TABLE 5

AVERAGE CALCULATED FORK LENGTHS IN MM FOR 466 *H. vittatus* REPRESENTING 7 YEAR CLASSES COLLECTED FROM THE INCOMATI RIVER SYSTEM APRIL, 1966 TO JANUARY, 1967

Year class	*No. of Fish*	Average calculated fork length in mm at indicated year of life* 1	2	3	4	5	6	7
1959–1960	2	84	156	217	269	317	362	385
1960–1961	7	101	160	216	276	328	360	
1961–1962	17	92	167	233	295	338		
1962–1963	13	98	175	244	292			
1963–1964	35	95	177	238				
1964–1965	311	93	165					
1965–1966	81	78						

* Average for the last year in each year class based on fish that had completed growth for the current year.

TABLE 6

ACTUAL AND EXPECTED GROWTH OF *H. vittatus* FROM THE INCOMATI RIVER SYSTEM

Age (years)	*Mean length (mm)*	*S.E. of mean*	*Expected length (mm)*	*% of max. expected length*	*Yearly Growth Increment (mm)*
I	90·4	0·5	93·0	19·8	93·0
II	164·4	0·7	176·6	37·5	83·6
III	248·3	2·5	241·7	51·3	65·1
IV	293·9	3·3	292·4	62·1	50·7
V	333·2	5·3	332·0	70·4	39·6
VI	367·3	11·2	362·7	77·0	30·7
VII	384·5	—	386·2	82·0	23·5

TABLE 7

AVERAGE FORK LENGTH AND SEX RATIO FOR EACH AGE GROUP OF *H. vittatus*, SEXED BY GROSS EXAMINATION

	Males				Females				
Age group	*No. of Fish*	*% of sample*	*Average length (mm)*	*Standard deviation*	*No. of Fish*	*% of sample*	*Average length (mm)*	*Standard deviation*	$t(p=0 \cdot 05)$
II-III	41	43·6	251	22·8	53	56·4	267	32·0	2·7114
III-IV	10	29·4	278	35·1	24	70·6	311	26·4	3·0111
IV-V	3	20·0	300	20·6	12	80·0	350	33·2	2·4506
V-VI	4	36·4	346	26·1	7	63·6	382	70·2	0·9692*

* Not significant at 5% level.

females were collected, a clear picture of length at maturity could not be formed. Jackson (1961b) found that the breeding size is 350 mm in Lake Kariba. Only one female with well developed gonads was collected in the Incomati River system. It had a fork length of 360 mm. Females under 340 mm in length showed no marked increase in maturity coefficient during October to January. It can thus be assumed that female Incomati tiger-fish attain sexual maturity at a length of approximately 360 mm. This corresponds to the fifth or sixth year of life.

Newly hatched fry were collected with a 2·5 mm-mesh net during January, 1967. It was assumed that fry under 20 mm in length were incapable of moving over long distances and their presence would thus indicate the breeding site. Such fry were found on the flooded banks of the Incomati River from Moamba to Manhica, that is, along almost the whole course of the river in Moçambique, and in Lake Chualo, where large numbers occurred. A typical breeding site in Lake Chualo is shown in Fig. 4. All small fry were found in lentic waters with a depth of less than two feet. The bottom consisted of clay or sand and submerged grass or weeds were always present.

Tiger-fish were absent from Lake Chualo at the end of the dry season and, therefore, spawning migrations must have taken place into the lake after the first floods. Ideal conditions for spawning are created by the rising waters of Lake Chualo after the first rains and it is probably the main breeding site of Incomati tiger-fish.

Despite careful search in Transvaal waters of the system, no fry were found, obviously due to the absence of suitable conditions for breeding.

Spawning can probably only take place after flood-plains have been inundated by rising waters. The fry collected from 17th to 19th January, 1967, varied in length from 14 to 60 mm with the mode at 40 mm, indicating that spawning probably took place from October to January with the peak in November or December.

With the breeding sites situated in Moçambique, replenishment of tiger-fish stock in the Transvaal is dependent upon upstream movement after the spawning season. These movements

FIGURE 4
Typical breeding site of *H. vittatus* in Lake Chualo.

are easily halted by the construction of weirs or dams, the main reason for the present-day absence of tiger-fish in areas where they previously occurred. Fish ladders are thus essential to re-establish tiger-fish for anglers in the higher reaches of the system.

Food habits

The analysis of stomach contents of 490 fingerlings collected from Lake Chualo shows that tiger-fish less than 35 mm long fed almost exclusively on Entomostraca, with only occasional insect larvae being recorded. From a length of 55 mm the most important single food item was fish (Fig. 5).

Analysis of the stomachs of fish over 90 mm shows that fish was the most important food item from spring to late summer. Insects were more important in winter than during summer (Tables 8 and 9). This was probably a result of the scarcity of the favoured food as the water level dropped and the small fish were consequently decimated.

A clear relationship between the sizes of predator and prey has been indicated by Jackson (1961b) for fish from the Zambesi River and the same relationship has been found to hold for the Incomati River (Fig. 6). Predation is restricted to fish smaller than 100 mm and it is interesting to note that small tiger-fish only start the upstream migration, away from the nursery grounds, at a length of 90 mm, which makes them relatively immune to predation by larger fishes.

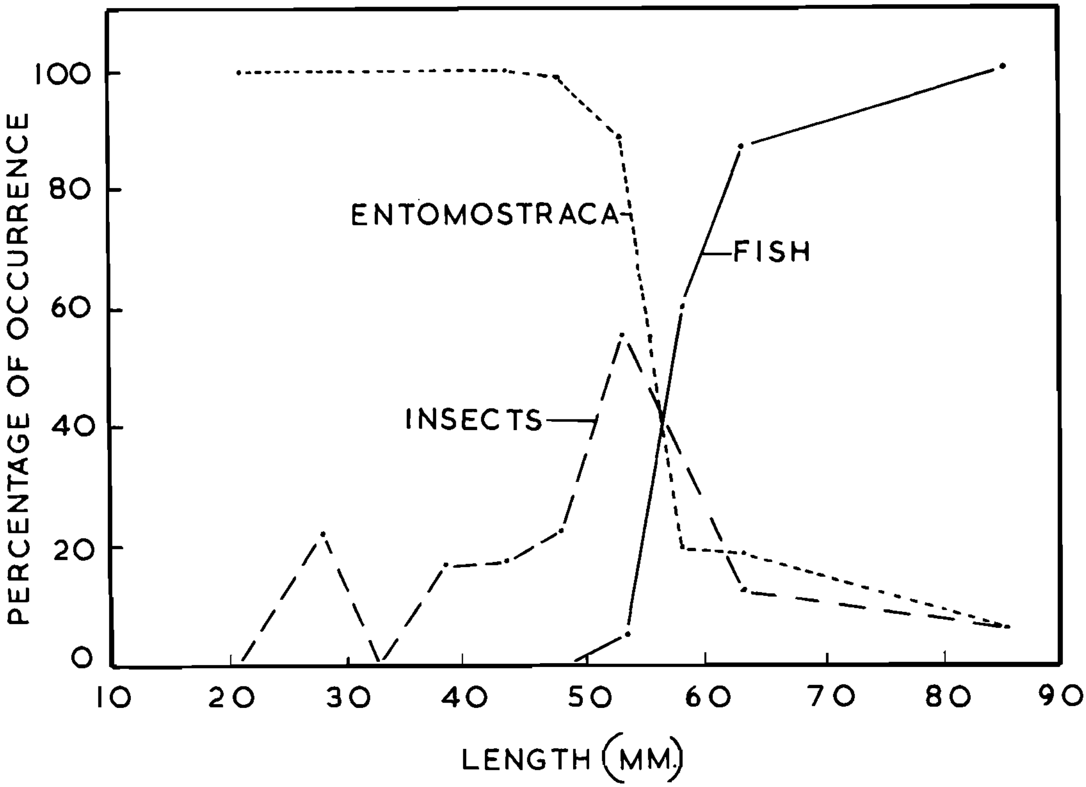

FIGURE 5
Change in food habits with increase in length of *H. vittatus* from Lake Chualo, January 1967.

TABLE 8

PERCENTAGE BY VOLUME OF FOOD ITEMS IN THE STOMACH CONTENTS OF *H. vittatus* OVER 90 MM IN LENGTH FROM THE INCOMATI RIVER SYSTEM, APRIL, 1966, TO JANUARY, 1967

Date	*January*	*April*	*July*	*August*	*October*
No. of stomachs	79	60	71	30	45
Fish	99·2	99·4	97·5	78·4	98·5
Insects	0·3	0·2	2·1	20·6	0·9
Plant material	0·3	0·3	0·4	—	0·1
Sand	—	0·1	trace	—	0·4
Filamentous algae	—	—	0·1	—	—
Cladocera	0·1	—	—	—	—
Copepoda	0·1	—	—	—	—
Nematoda parasite ..	—	—	—	0·9	—

TABLE 9

PERCENTAGE FREQUENCY OF OCCURRENCE OF FOOD ITEMS IN THE STOMACH CONTENTS OF *H. vittatus* OVER 90 MM IN LENGTH FROM THE INCOMATI RIVER SYSTEM, APRIL, 1966, TO JANUARY, 1967

Date	*January*	*April*	*July*	*August*	*October*
No. of stomachs	79	60	71	30	45
Fish	98·7	100·0	64·8	50·0	91·0
Insects	5·1	6·6	60·0	56·7	13·0
Plant material	7·6	6·6	5·6	—	2·0
Sand	—	5·0	1·4	—	9·0
Filamentous algae	—	—	5·6	—	—
Cladocera	3·8	—	—	—	—
Copepoda	3·8	—	—	—	—
Nematoda parasite ..	—	—	—	3·3	—

SUMMARY

A general description of the Incomati River system refers to topography, climate and physical condition of the water. The range of *Hydrocynus vittatus* was considerably reduced after the construction of weirs which prevented successful upstream movement. There is a downstream movement into Moçambique after the first floods and an upstream movement after prey at the end of the rainy season. The condition of tiger-fish changed markedly during the course of a year. Scale studies indicate that the annulus is a reliable yearmark. A Von Bertalanffy growth-in-length equation fitted to the data is described by the equation $L_t = (1 - e^{-0.25(t-0.12)})$. Males reach sexual maturity at a length of 200 and females at a length of approximately 360 mm. Spawning takes place among aquatic vegetation on flooded river banks and in lakes in Moçambique after the first heavy floods. As the fish grows, its food changes from Entomostraca to insects and finally to fish. The food habits of fish over 90 mm in length showed a seasonal variation dependent on the availability of fish prey. A tiger-fish is unable to swallow fish larger than half its own length.

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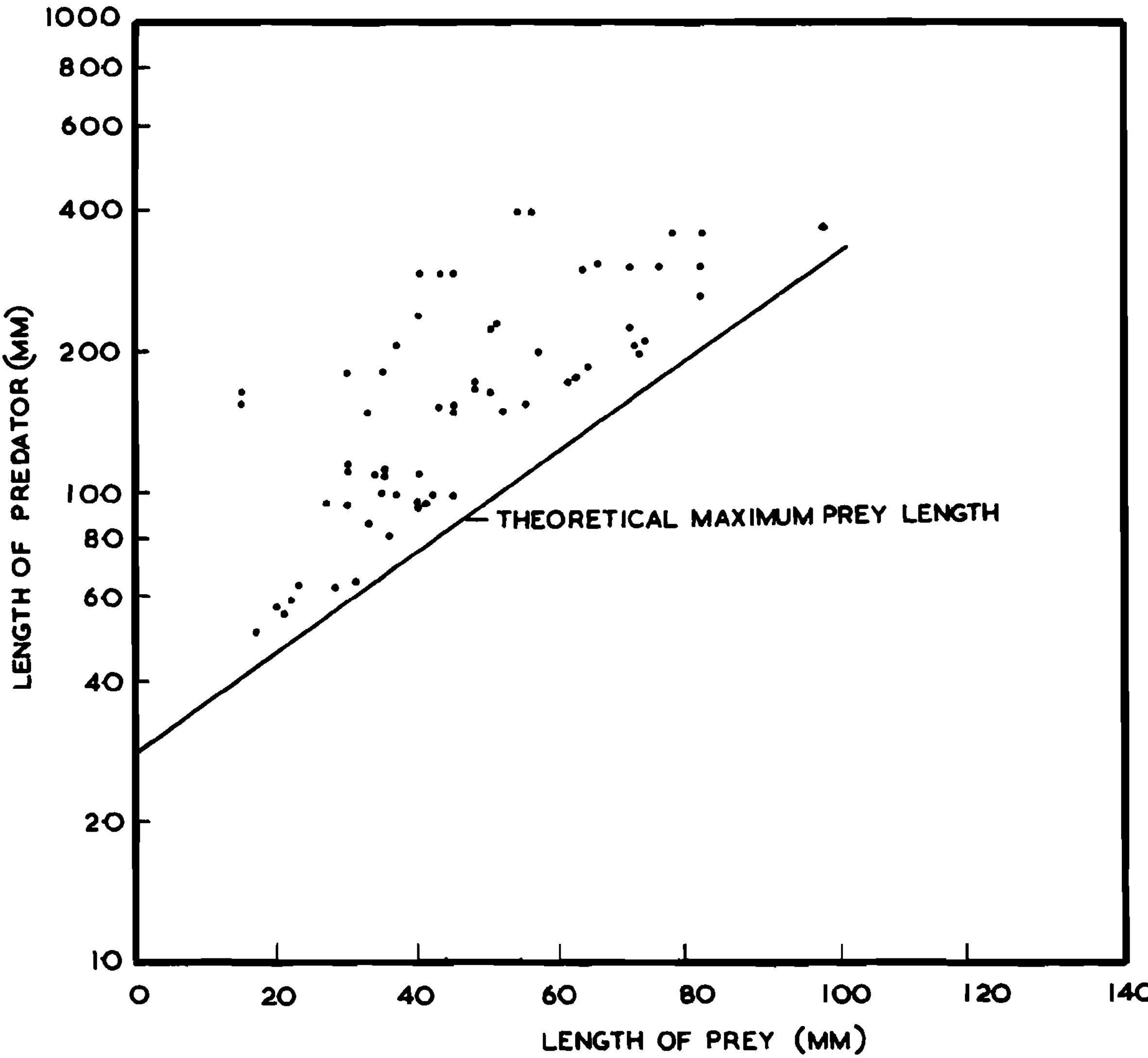

FIGURE 6
Length of prey species in relation to the length of *H. vittatus* in the Incomati River system, April, 1966 to January, 1967.

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