THE REPRODUCTION OF *BARBUS CF. KIMBERLEYENSIS* (PISCES, CYPRINIDAE) IN THE HARDAP DAM, SOUTH WEST AFRICA

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ABSTRACT

Only one large yellowfish species occurs in the Hardap Dam, apparently closely related to *Barbus kimberleyensis*. Though smaller than this species in the Vaal River, it is nevertheless a valuable and abundant angling fish. After maturity, reached in females at 26 cm and in males at 18 cm fork length, females outnumber males by 9 : 1 beyond 30 cm. Main spawnings occur between February and April, some four months later than in the Vaal River, being correlated with peak seasonal rains in both cases. A minor spawning later in the year is usual, with improved fry survival due to warmer weather conditions reducing the winter mortality of the earlier spawned young. Breeding sites are probably in lentic gravelly-bottomed areas within the dam. Egg production increases from 5–6 000 in 30 cm fish to *ca* 47 000 in 60 cm females, with strong relationship between cube of fish length and fecundity.

INTRODUCTION

The yellowfishes, namely, *Barbus kimberleyensis* G. & T., 1913, and *B. holubi* Steind., 1894, are the most important angling fishes in the Orange River system because they are attractive, grow to a large size and are excellent game fish. *B. holubi* is abundant and is successfully reared and distributed by the Department of Nature Conservation of the Transvaal (Mulder & Franke 1973). *B. kimberleyensis*, however, has been the cause of concern to anglers and conservationists for several years because its numbers are declining and attempts to rear it have been unsuccessful.

The upper reaches of the Fish River, a northern tributary of the Orange River below the Aughrabies Falls, is geographically isolated from the rest of the Orange River system by a waterfall. Although its fish fauna is basically similar to that of the Orange River it contains only one species of yellowfish. In appearance and angling characteristics this fish resembles *B. kimberleyensis*, but in some morphological characters it is intermediate between *B. kimberleyensis* and *B. holubi*. Until the systematic status of the Hardap yellowfish has been clarified it will be referred to as *B. cf. kimberleyensis*. The fish taxonomist of the Albany Museum is investigating its systematic status.

The Hardap Dam is situated in the Fish River near Marienthal at an altitude of 1 135 m. It is the largest dam in South West Africa with a surface area of 25 km^2 and a capacity of 310 million m^3. Although the Fish River is annual in flow it carries heavy floods during the rainy season and the dam is filled every year.

This paper describes part of the results of a survey on the growth and reproduction of the angling fishes of Hardap Dam carried out from September 1974 to June 1975. The dam has

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a great potential as a recreation resort as well as for commercial fish production and for this reason a full-time fisheries biologist was appointed there in 1970. Studies that have been done to date were concerned with the growth rates of *Labeo capensis* and *Sarotherodon mossambicus* and length-mass relationships and condition of the larger species, including *B. cf. kimberleyensis* (Bloemhoff 1974). Nothing else was known of the ecology of *B. cf. kimberleyensis*. Several studies have been done on the reproduction of *B. holubi*, but the only data available on the ecology of *B. kimberleyensis* are those of Mulder (1971; 1973a) and Hamman (1974).

METHODS

The fork length, mass, sex, gonad mass and gonad developmental stage of each yellowfish collected were recorded. Ovaries containing visible eggs were preserved in modified Gilson's fluid (Bagenal & Braum 1968).

Juvenile fish were collected from shallows with the aid of a mosquito net and preserved in 10 per cent formalin for subsequent measurement.

Maturity coefficients were calculated from the following formula:

$$MC = \frac{\text{gonad mass (grams)}}{\text{cube of fish length}} \times 10^4$$

Cubic length was used in the above formula because Bloemhoff (1974) found that there is an approximate cubic exponential relationship between the length and mass of *B. cf. kimberleyensis*. Bagenal & Braum (1968) have stated that fecundity is, typically, approximately proportionate to the cube of length.

Preserved eggs were separated by vigorous shaking and ovarian tissue removed by repeated filling and decanting with water. Gilson's fluid proved to be unsuitable for ovaries with minute eggs, and such eggs had to be separated manually. After being separated the eggs were stirred in water and subsampled with a glass tube. The subsample was spread evenly over a perspex slide which had parallel lines on it. Excess water was carefully dried up with blotting paper. Fifty to one hundred eggs in the subsample were then measured to the nearest 0,036 mm with the aid of an eyepiece micrometer. In order to obtain an objective indication of the relative abundance of eggs of various sizes in each ovary only those touched by the parallel lines on the perspex slide were measured. This method does not give a true indication of the absolute number of eggs of different sizes in the subsample because larger eggs with greater surface area have a better chance of being counted than smaller ones. Only those ovaries with at least 3 per cent eggs over 1,5 mm in diameter were used for fecundity studies. The eggs were spread out on blotting paper trays and allowed to dry for several days at room temperature. When thoroughly dry all the eggs of a particular specimen were weighed to the nearest 0,0001 gm. A random subsample of 250 was then counted and weighed and the fecundity calculated from these figures.

RESULTS

Sex ratio

It was only possible to sex fishes over 16 cm in length macroscopically. Table 1 shows that the sex ratio is approximately 1:1 in fishes under 26 cm in length but in larger fish the percentage males in relation to females greatly decreases to reach a ratio of about one male to nine females in fishes over 30 cm in length. All fish over 52 cm in length were females.

TABLE 1

The sex ratios of different length groups of *B. cf. kimberleyensis* from the Hardap Dam.

Length group (cm)	*Sample size*	*% males*
16–20	215	44
21–25	258	50
26–30	321	30
31–35	306	10
36–40	108	12
41+	153	12
Total	1361	28

Mulder (1973a) found a ratio of 1,8 female to 1 male in both yellowfish species of the Vaal River for all length groups combined. Hamman (1974) reported a ratio of 1,9:1 for *B. holubi* and 3:1 for *B. kimberleyensis* in the Verwoerd Dam. Both authors also found that females grow larger than males.

The percentage length-frequency of male and female *B. cf. kimberleyensis* over 16 cm in length collected with different gear is shown in Figure 1. The largest male collected was 52 cm in length while females up to 64 cm in length were found. It is interesting to note that females become markedly more abundant than males in fishes over 26 cm in length, i.e. the length at which females reach sexual maturity. Because large females produce more eggs than smaller ones it is beneficial to the population natality if females grow to a larger size. Fewer males in relation to females in fishes over 26 cm in length results in less intraspecific competition thus providing a better chance for females to survive and reach a large size.

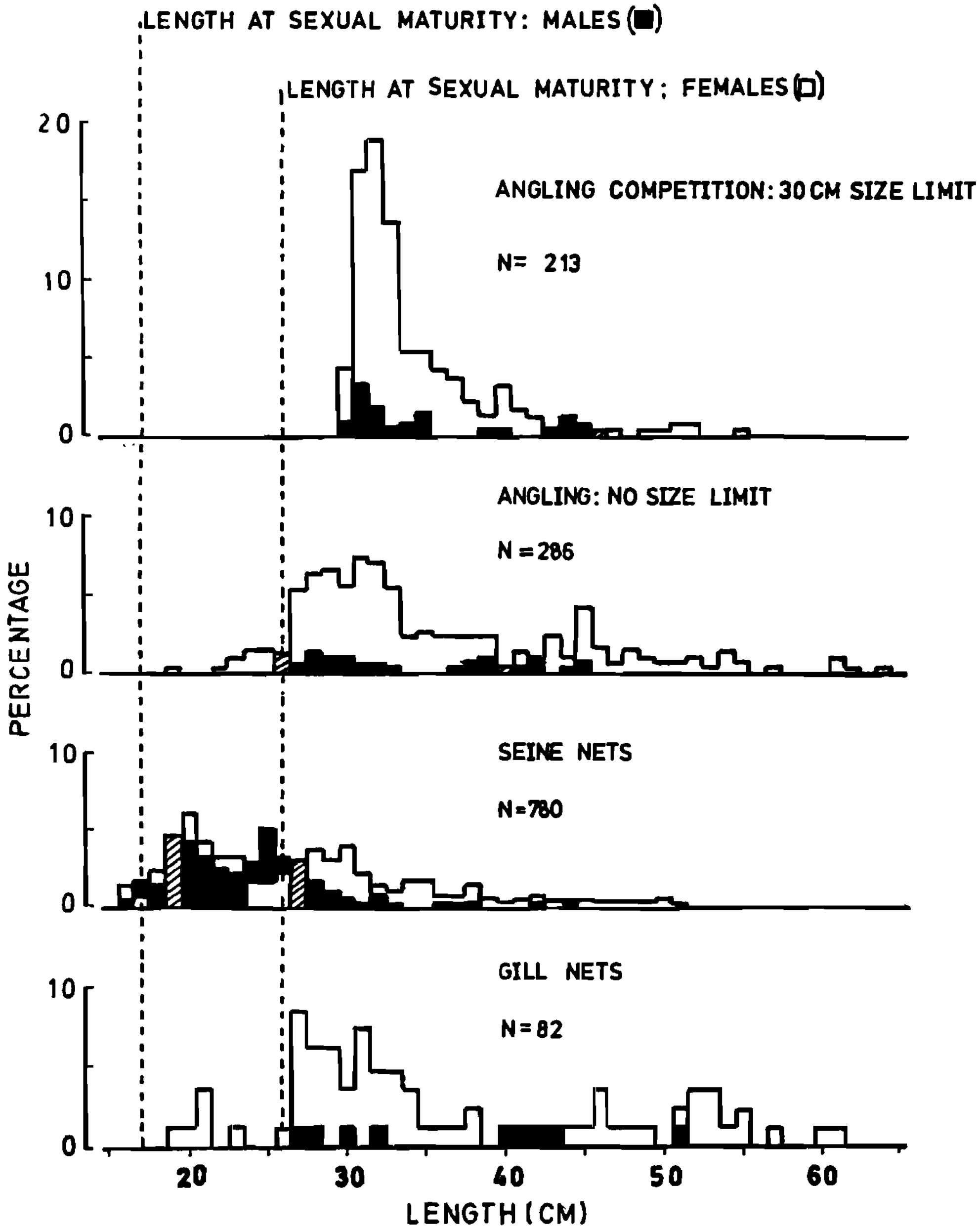


FIGURE 1

The length-frequencies of male and female *B. cf. kimberleyensis*, collected with different types of gear from the Hardap Dam, September 1974 to June 1975.

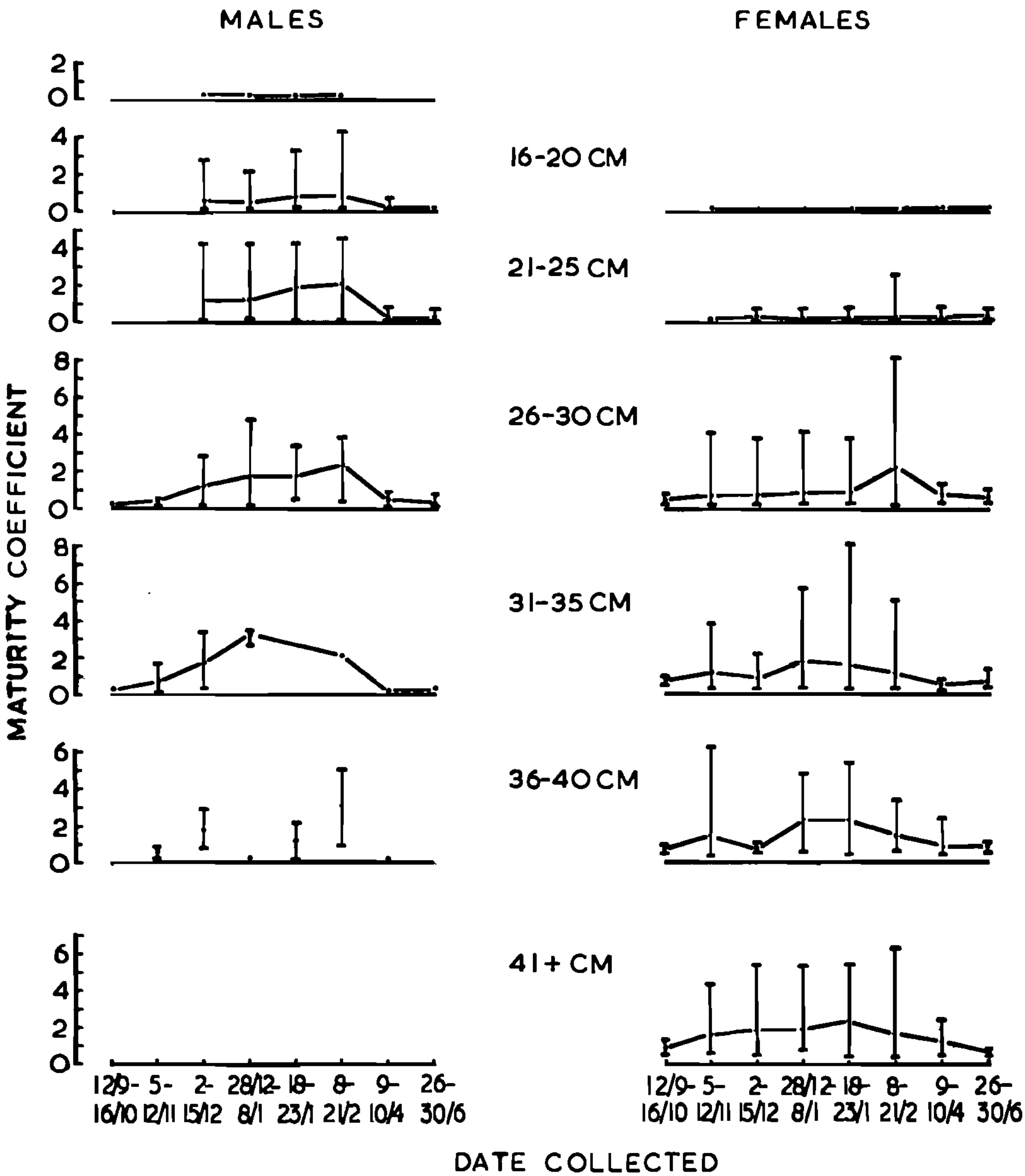


Figure 2

Changes in maturity coefficients (average and range) in different length groups of *B. cf. kimberleyensis* from the Hardap Dam, September 1974 to June 1975.

Length at sexual maturity

Male specimens of *B. cf. kimberleyensis* reach sexual maturity at a length of about 18 cm and females at a length of about 26 cm. The length of the smallest mature male and female collected was 17 cm and 25 cm respectively. Mulder (1973a) found that *B. kimberleyensis* males only reach sexual maturity at a length of 35 cm and females at a length of 46 cm in the Vaal River. The same author found that male and female *B. holubi* reach sexual maturity at lengths of 28 cm and 34 cm respectively. However, the length at maturity seems to vary according to environmental conditions because both Groenewald (1957) and Göldner (1967) found that *B. holubi* from populations in the Vaal River and Baberspan reach sexual maturity at lengths of 20 cm (males) and 24–25 cm (females).

Breeding season

Figure 2 shows that the maturity coefficients of both sexes increased from September onwards to reach a peak in January or February, after which spawning apparently took place, as illustrated by a sharp decline in the coefficients. The figure also indicates a great individual variation in gonadal development of all size groups and even during January and February a certain percentage had totally undeveloped gonads. Mulder (1971) found the same phenomenon in *B. holubi* but not in *B. kimberleyensis.*

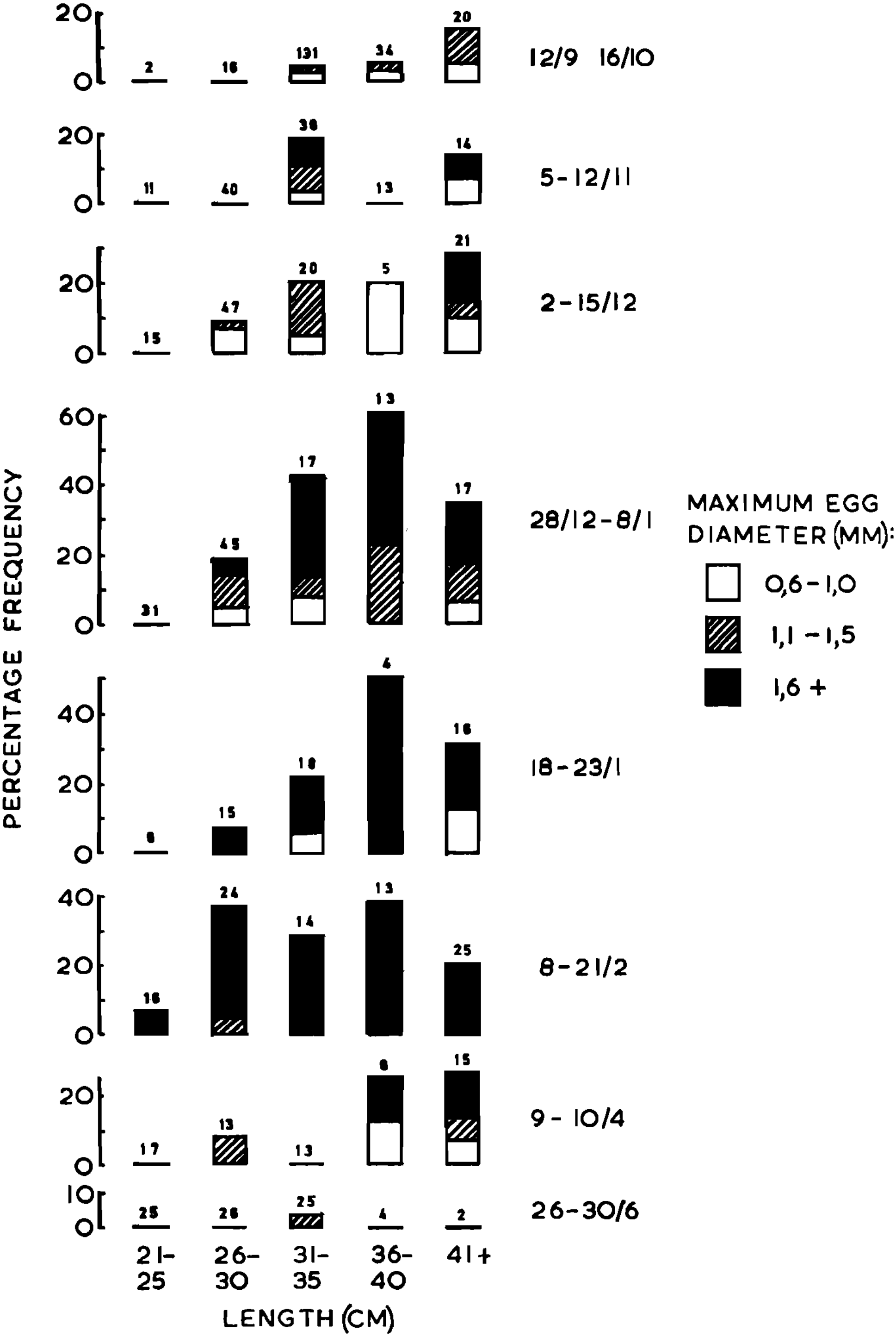
Figure 3, based on maximum egg sizes, also shows that the ovaries reached their peak of development during February and that spawning took place between February and April. From the figure it is also apparent that the ovaries of large fish mature before those of smaller specimens.

Mulder (1973a) found that both Vaal River yellowfish species spawn mainly from October to December. His findings are substantiated by the observations of Groenewald (1951) and le Roux (1968). According to Groenewald *B. holubi* spawns after the water has reached a temperature of 18°C. Because the Fish River is annual in flow, rainfall is of great importance for reproduction. There is a correlation between the peak rainy season and the peak spawning period of all the indigenous fishes in the Hardap Dam. In the upper reaches of the Fish River maximum rainfall occurs during February and March, which coincides with the peak spawning period of *B. cf. kimberleyensis*. In the upper reaches of the Vaal River maximum rainfall occurs earlier, namely during the months of November, December and January, explaining why Vaal River yellowfishes spawn earlier than those in the upper Fish River.

Examination of the ovaries and egg counts of some larger specimens collected during February and April showed that these fishes were partly spent and this indicated that *B. cf. kimberleyensis* possibly spawns more than once per season. This is substantiated by the mosquito net catches and egg diameters. According to Bagenal & Braum (1971) and Nikolskii (1969)

FIGURE 3

Percentage frequency of occurrence of female *B. cf. kimberleyensis* with eggs over 0,5 mm in diameter from the Hardap Dam, September 1974 to June 1975. The numbers above each column represent the sample size in the length group.


PERCENTAGE FREQUENCY
12/9 16/10
5-12/11
2-15/12
28/12-8/1
18-23/1
8-21/2
9-10/4
26-30/6
MAXIMUM EGG DIAMETER (MM):
0,6-1,0
1,1-1,5
1,6+
21-25
26-30
31-35
36-40
41+
LENGTH (CM)

multiple spawners exhibit different modes in the size-frequency distribution of ova. Figure 4 shows that this is the case with the ova of *B. cf. kimberleyensis*. The eggs of mature ovaries vary in size, and in the ovaries of fishes of all length groups three modes in the size-frequency distribution of eggs can be identified, namely:

(a) Small ova or oocytes with diameters less than 0,25 mm. (These probably constitute the stock from which the spawn of the next season will be derived.)
(b) An intermediate group of ova varying in size but with mode between 0,76 and 1 mm in diameter.
(c) Mature ova with a mode between 1,26 and 1,5 mm in diameter.

The two groups of larger eggs indicate that *B. cf. kimberleyensis* spawns twice every season, in other words as soon as the mature ova are spawned, the intermediate sized ones develop to maturity and are then spawned. This is substantiated by the graph of the egg-size distribution of partly spent ova in Figure 4, where these ovaries have less intermediate-sized ova in relation to mature ovaries. Figure 3 shows that the ovaries of several females collected during April still contained intermediate-sized or mature ova, but in June only a few ovaries with intermediate-sized ova and none with mature ova were found. The sample size of large fish was too small to reach any conclusions in this regard but sufficient specimens under 35 cm in length were analysed to indicate that most of the smaller females had spawned all their eggs before June.

The mosquito net catches (Figure 5) show that a successful 'second spawn' took place in August or September 1974 indicating that some fishes retained part of their eggs over winter of that year. The smallest fry collected at the end of September 1974 varied in length from 1,5 to 3,4 cm with a mode at 2,3 cm. Le Roux (1968) found that young *B. holubi* reach a length of 1 cm two to three days after hatching and 7–10 cm after four to six months. Assuming a similar growth rate the small yellowfish collected from Hardap Dam therefore could not have been older than a few weeks.

A second size group collected in September 1974, which was less abundant, varied in length from about 3,5 to 6 cm. This length group probably represents fishes that hatched during February or March 1974. Although February/March is obviously the peak spawning season, fishes hatched after the winter seem to have a better survival rate due to conditions in the dam. During the survey it was found that fry occur in the shallow water, where they are protected from predaceous fish, when the water temperature is high. However, during the June survey, when the water temperature was low, few small fish were found in shallow water. Shallow bays and isolated pools, which during warmer periods swarmed with small fish of different kinds, were devoid of yellowfish. They probably avoid the shallow water during the coldest months because of unsuitable water temperatures. No higher aquatic plants occur in the Hardap Dam so that fry are highly vulnerable to predaceous fish in the deeper water. This probably explains why so few of the February/March 1974 spawn survived the winter. Permanent pools in the Fish River itself characteristically have abundant aquatic vegetation which provides protection for fry during the winter months.

Figure 5 also shows that fry of the February/March 1975 spawn were collected during June 1975. The mode of this length group coincides with the mode of the smallest length group collected during September 1974.

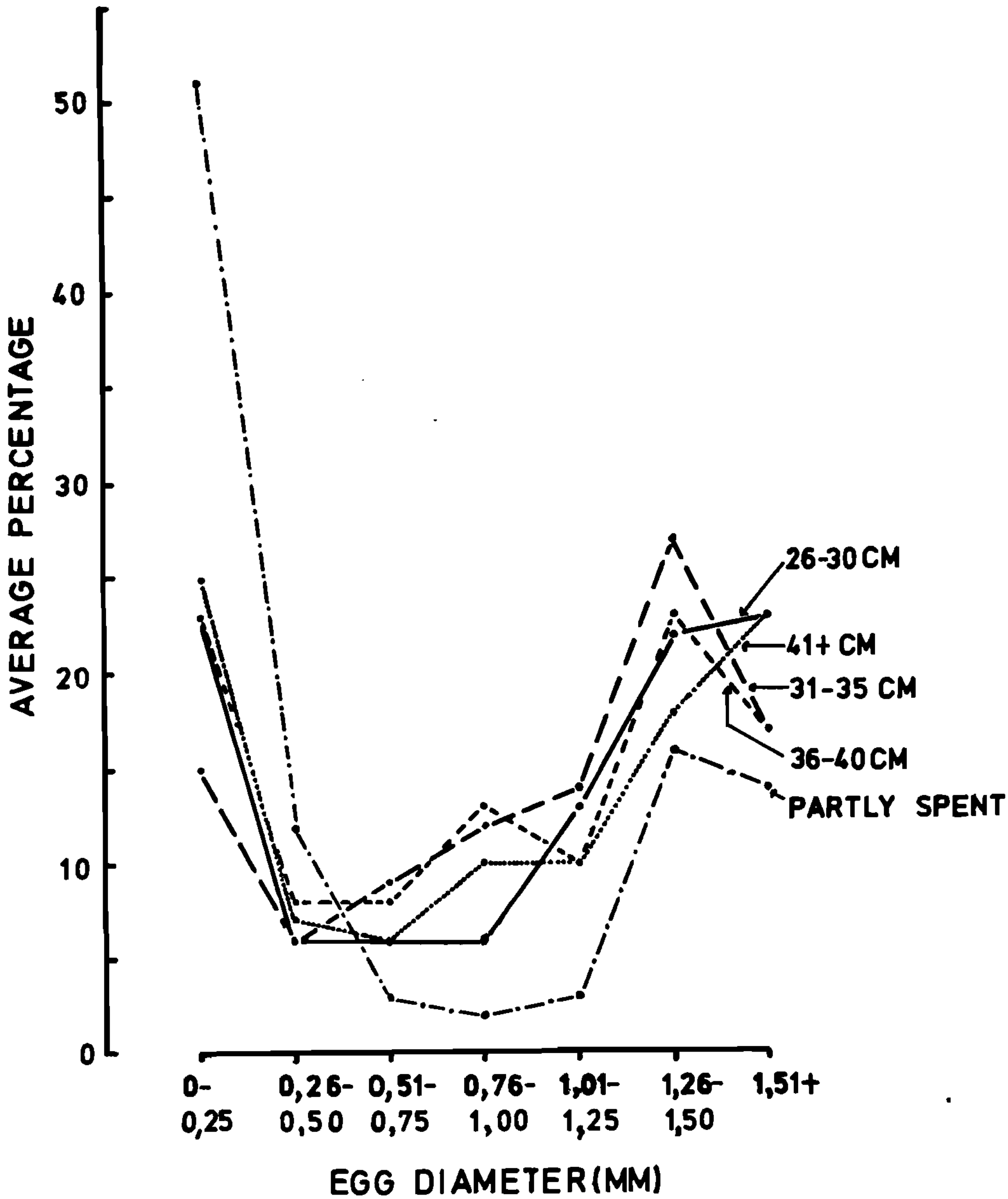


FIGURE 4

Average percentage relative frequency of occurrence of eggs of various diameters in mature ovaries of different length groups of female *B. cf. kimberleyensis* in the Hardap Dam.

More than one spawning per season has also been observed in Vaal River yellowfishes. Groenewald (1951) found that *B. holubi*, kept in ponds at the Provincial Fisheries Institute, Lydenburg, spawned at least twice in 1949, namely in October and again in November or December. Mulder (1973a) found evidence that both *B. holubi* and *B. kimberleyensis* spawn twice per season in the Vaal River. The first major spawning occurs during the period October to December and the second in January. Twenty per cent of the females he collected in January 1970 and 1971 had partly spent gonads, and his findings were substantiated by the length intervals of fry collected in the river, as well as observations at the Provincial Fisheries Institute. According to this author one spawning seems to be the natural event although disturbance could result in several spawnings within a certain time interval.

Spawning site

Actual spawning of yellowfish has never been observed in the Hardap Dam. At the end of September 1974 fry of 2 cm length were found at all sites sampled with the mosquito net. They were most abundant in shallow bays where they occurred in schools, having probably moved into these areas for protection and feeding. It is doubtful whether a fish of 2 cm length could have covered a long distance since hatching and it therefore seems as if spawning takes place at several sites distributed over the whole dam. The same applies to juveniles collected during June 1975. There was no indication of spawning migrations or concentrations of fish in the bays or in the upper reaches of the dam as was the case with certain other species of fish. All this evidence indicates that *B. cf. kimberleyensis* probably spawns in the dam and that it is not dependent on running water for spawning. No water entered the dam between 24 April 1974 and 5 March 1975.

Groenewald (1951) found that *B. holubi* also spawns successfully in standing water of small ponds. He observed that the breeding fish make hollows in gravel with their snouts and tail fins, into which the eggs are deposited. According to le Roux (1968) there is apparently no paired mating in this species and the parents do not guard the nest. Mulder (1973a) never observed the spawning of *B. kimberlensis*, but according to him the occurrence of larvae and fry indicates that spawning probably also takes place on gravel.

Gravel is abundant along the shores of Hardap Dam, and although no definite evidence was collected in this regard, one can assume that *B. cf. kimberleyensis* spawns on gravel too.

Fecundity

Figure 6 shows that the fecundity of *B. cf. kimberleyensis* increases with increase in length from about 5 000 to 6 000 in fishes of 30 cm length to about 47 000 in fishes of 60 cm length. There is great individual variation in fecundity. A straight line regression fitted to the data collected before February is described by the equation:

$$\text{Fecundity} = -495{,}2 + 0{,}2219\ L^3.$$

The correlation coefficient for this line is 0,8704, showing that there is a strong linear relationship between the cube of fish length and fecundity. The fecundity data of fishes collected after January was not included for the calculation of the regression line because it was apparent that some specimens collected from February onwards were partly spent. The fecundity figures of

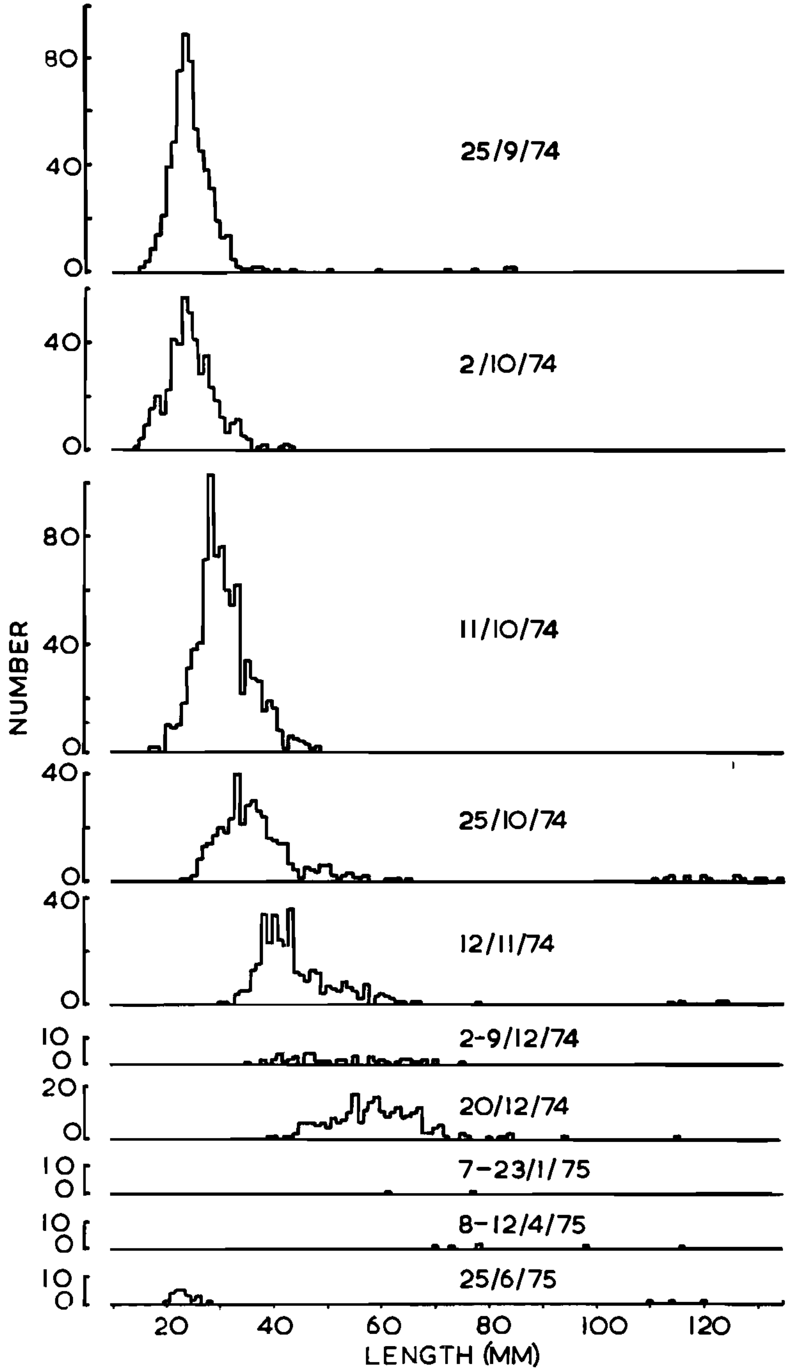


FIGURE 5

Length-frequency of young *B. cf. kimberleyensis* collected with the aid of a small seine net from the Hardap Dam, September 1974 to June 1975.

some fishes collected during February and April fall below the 95 per cent confidence limits for individual observations, showing that these fishes were definitely partly spent (Figure 6).

Mulder (1971) only determined the fecundity of a few yellowfish specimens. His results, plotted on Figure 6, show that the fecundity of both species also varies greatly. Half of his fecundity figures for *B. holubi* fall within, and half fall above, the 95 per cent confidence limits of the *B. cf. kimberleyensis* data, but *B. kimberleyensis* seems to have a lower fecundity because all except one figure falls below the 95 per cent confidence limits. According to Nikolskii (1969) fecundity can show great intraspecific variation depending on environmental factors such as availability of food, and these data are therefore not directly comparable.

All these yellowfishes have low fecundities in comparison with the Orange River labeos which produce about eight or more times as many eggs per female of the same length (Mulder 1973b; Gaigher *et al.* 1975).

DISCUSSION

The results of this study, which is the first of its kind on the reproduction of *B. cf. kimberleyensis*, fit in well with the general picture of what is known of the reproduction of Orange River yellowfishes. In all these fishes mature females are more abundant than mature males, and reach a larger size. Males reach sexual maturity at a smaller size than females, they may spawn more than once in a short period and they have a relatively low fecundity in comparison with other indigenous cyprinids. *B. cf. kimberleyensis* can spawn in standing water, as is the case with *B. holubi*.

However, there are important differences between these results and the known data on the reproduction of Orange River yellowfishes. Both sexes of *B. cf. kimberleyensis* become mature at a shorter length than those of the other two species. Age studies will show whether they mature at a different age too. The Hardap Dam yellowfish spawn mainly in February and March while spawning commences as early as October in the Vaal River. These differences are due to adaptations to different peak rainy seasons. Lastly, the fecundity of *B. cf. kimberleyensis* differs from that of *B. kimberleyensis* in the Vaal River, but this is a variable factor too and could be caused by environmental differences.

The lack of aquatic plants for protection during the colder winter months probably results in a high mortality rate of the major spawn due to predation. At present the dam has a healthy yellowfish population and is one of the best yellowfish angling waters in South Africa (Gaigher 1975). However, if the dam is cropped commercially it might become necessary to establish rooted aquatic plants for the protection of fry during winter months.

B. cf. kimberleyensis is an excellent angling fish, it becomes sexually mature at a small size, breeds in standing water and is adapted to the extreme temperatures of the Fish River. It therefore has all the potentialities of a suitable stocking fish in certain waters in the Republic of South Africa in preference to exotics which often have a detrimental effect on our indigenous fish.

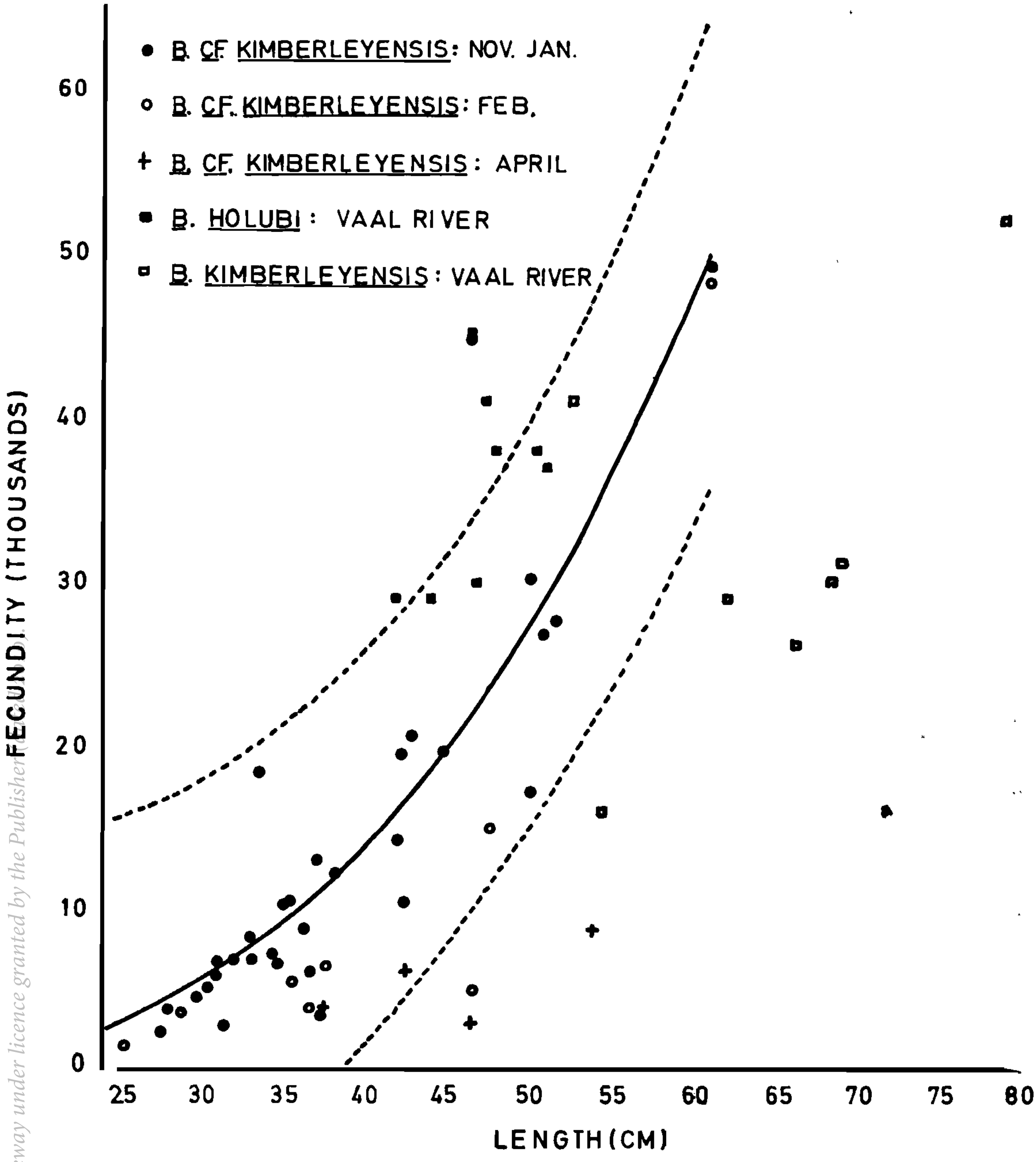


FIGURE 6

The relationship between fish length and fecundity in *B. cf. kimberleyensis* from the Hardap Dam. The regression line was fitted to data collected before February. The dotted lines represent the 95 per cent confidence limits for individual observations. Fecundity data of *B. kimberleyensis* and *B. holubi* as determined by Mulder (1971) are plotted as well.

ACKNOWLEDGEMENTS

I am greatly indebted to the following:

The Council of the University of Fort Hare for permission to do the survey during my study leave. The Director of Nature Conservation of the South West African Administration that provided all the facilities for the surveys. Mr. H. J. Bloemhoff, the Senior Professional Officer at the Hardap Dam, and his labourers for their help with the collection and analysis of fish. My wife for her help with the collection of fish and recording of data. Mr. P. Skelton of the Albany Museum for help with the April survey and for correcting the manuscript. Professor G. Viljoen, Head of the Department of Statistics at Fort Hare University, for guidance with the statistical analysis. Mr. D. P. Baird who helped me with the April survey.

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