A quantitative assessment of the biotic integrity of the Okavango River, Namibia, based on fish

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Abstract

This is the first calculation of an index of biotic integrity (IBI) for the Okavango River to quantitatively assess the biological status of the river. The assessment indicated a definite degradation of the biotic component of the Okavango River. Furthermore isolated problem areas were also identified such as habitat and trophic level degradation, increased pollution and reduced fish stocks at several localities along the river. Several measures were proposed to counteract this trend to ensure a sustainable fisheries component of the Okavango River in future.

Introduction

The northern areas of Namibia, especially the Cuvelai System, the Okavango River and the Zambezi floodplains in the Caprivi have always been important regions for subsistence fishery (Van der Waal, 1976; 1991a; b; Van Zyl, 1992 and Tvedten et al., 1994). A major concern has been the possible depletion of the fish resource in the Okavango and Zambezi Rivers as a result of increased subsistence fishing due to the high population growth. Several other factors may also indirectly influence the fish stock, such as the effects of overgrazing, soil erosion, deforestation, siltation of the rivers, pollution and low floods. Fish are an important protein supplement in the diet of the people along the Okavango River and the perceived "shortage of fish" in the river is therefore of major concern (Tvedten et al., 1994). If historic data are insufficient to serve as a good baseline, it is difficult to determine whether fish abundance is declining, and if so, the reasons for it. For this reason an index of biotic integrity (IBI) was compiled to quantitatively express the present biotic status of the Okavango River.

An IBI based on fish was developed by Karr (1981) to assess the biological status of aquatic systems and is designed to incorporate all relevant information. Parameters used in the index are sensitive to several types of degradation, including sewage effluents, pollution by mining, runoff sediment, nutrients and toxic chemicals from agricultural lands, wood debris removal and habitat destruction (Fausch et al., 1990). Other indices which have been used in the past are:

- indicator taxa or guilds;
- indices of species richness, diversity and evenness; and
- multivariate methods (Fausch et al., 1990).

The disadvantage of using taxa indicators is that few guidelines are present for choosing appropriate taxa. It is, therefore, difficult to determine whether a species is sensitive to degradation solely on the basis of empirical evidence or whether other factors may have influenced it. When using species richness, diversity and evenness indices, the disadvantage is that the information conveys limited information on the fish community. The multivariate method requires a computer for calculation, statistical calculations as well as biological information to interpret.

A useful feature of the IBI is that direct observation is used which limits the possibility for errors. Although several taxonomic groups of organisms had been used for the IBI, such as aquatic macrophytes (Canfield and Jones, 1984), amphibians (Moyle et al., 1986) and macroinvertebrates (Schaeffer et al., 1985), freshwater fish in general is used in North America (Hocutt, 1985 and Karr et al., 1986). Freshwater fish is widely used for the following reasons:

- The taxonomic status and ecological aspects have been sorted out to a large extent.
- Freshwater fish occupies several trophic levels including the top of the food chain, and any disturbance in the system will be reflected by the fish.
- Freshwater fish occupies a variety of habitat and food niches.
- Direct observation can be done in the field.

Using fish as biological monitors, however, is not without problems. Sampling gear is selective and will affect the species richness as would the experience of the field team. The problem of sampling is best minimised by using a wide variety of sampling gear for the collection of data. During an assessment it is assumed that the sample represents the community. Therefore the sampling must be thorough to be representative of the fish community.

According to Herricks and Schaeffer (1985) biomonitoring should satisfy several criteria before it could be classified as valid for the assessment of a system. These criteria are as follows:

- The measure must be biological - The IBI meets this criterion as biological monitoring is done.
- Several trophic levels must be included - The IBI includes four trophic levels.
- The measure must be sensitive to the environmental conditions - The IBI includes the assessment of pollution, river flow and habitat degradation.
- The response range of the measure must be suitable for the intended application - The IBI is sensitive to small changes as well as to a broad range of conditions.

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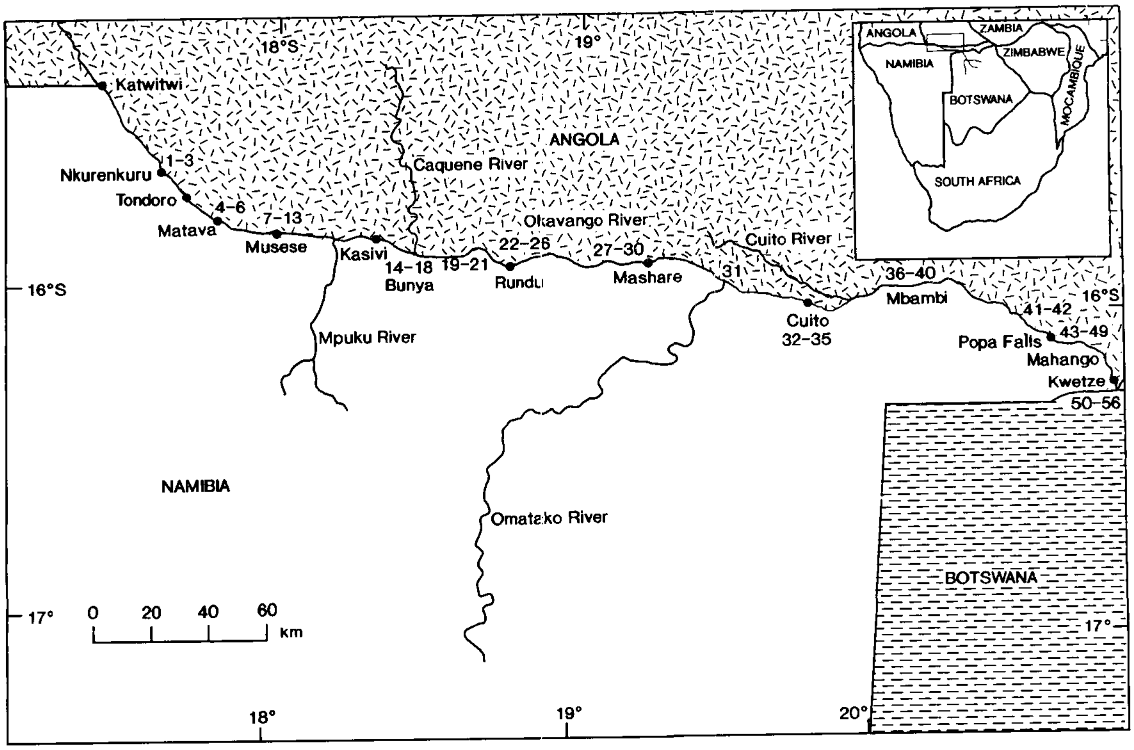

Figure 1
Sampling localities along the Okavango River

- The measure must be reproduced over space and time - It is possible for the IBI to reproduce the data sampled over a time period and space.
- Variability of measure must be low - The IBI also meets this criterion.

The word healthy is a subjective term and must be interpreted correctly. For instance a tropical system will have a high species richness whereas a temperate system will have a low diversity, but both systems can be classified as healthy (Hocutt, 1981).

Four categories, namely species composition, trophic composition, fish abundance and fish condition were used by Karr (1981) in calculating his IBI. Each of these categories were then subdivided into several metrics consisting of levels such as native species, piscivores, benthic species, hybrids, etc. Biological data for each metric are then obtained from the system.

Description of the study area

The Okavango River originates in the central highlands of Angola where the river is known as Rio Cubango (Smit, 1991). The river enters Namibia at Katwitwi and forms the international border between Namibia and Angola. The river section 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. The annual flood peaks between February and June.

The Cuito River is a major tributary that enters the Okavango River from the north. This river is important because the annual runoff below the confluence is nearly double that of the annual runoff at Rundu (Smit, 1991). From Mbambi the river narrows and the rapids increase where the river drops 2.5 m at the Popa Falls (Wilson and Dencer, 1976). The river then enters the Mahango game reserve close to the Botswana border where large floodplains occur.

The Omuramba Omatako enters the Okavango River from the south. The central and north eastern parts of Namibia drain into the Okavango River. Although certain sections of this system sometimes receive water, the water hardly ever reaches the Okavango River.

Materials and methods

A total of 56 localities were sampled between Katwitwi and Kwetze (Fig. 1). Hocutt et al. (1995) subdivided the Okavango River into four zones. Zone one, from Katwitwi to Kasivi, is characterised by shallow waters with sandy and rocky substrates. The floodplains are well developed in zone two, from Kasivi to Mbambi.

Several oxbows and back waters are present. The substrate is sandy with some rocky outcrops. The third zone stretches from Mbambi to the Popa Falls. This zone is characterised by many rapids and large rocky areas with a sandy and gravelly substrate. Zone four stretches downstream from Popa Falls to the Namibia-Botswana border. This section has large floodplain areas and is considered the start of the panhandle of the delta. The localities sampled were chosen so as to represent the four zones identified. A further factor taken into consideration was to include all possible habitat types present in the Okavango River. These sampling localities were also chosen in such a way as to facilitate resampling at each locality during all the surveys.

Localities 1 to 13 are in zone one, localities 14 to 35 in zone two, localities 36 to 49 in zone three and localities 50 to 56 in zone four (Fig. 1). Marginal vegetation is the vegetation on the river bank which extends into the river for approximately one meter. These areas are dominated by *Phragmites* spp. and *Cyprus* spp. Aquatic plant species are mainly *Nymphaea* spp. present in side streams and floodplains, whereas submerged vegetation such as *Echinochloa* spp., *Eragrostis* spp. and *Vassia* spp. are present on the floodplains.

The water flow was measured with a ciclomaster velocity meter. The stream velocity was divided into four categories. Isolated pools and some back waters had no water flow and are indicated as such in Table 3. Stream velocity less than 0.2 m/s is indicated as slow, 0.2 up to 0.7 m/s as medium and higher than 0.7 m/s as a strong current.

Data were collected from Nkurenkuru to the Mahango game reserve at more than 50 fixed sampling localities during all the surveys (Fig. 1). Surveys were done during March 1993 (autumn), June 1993 (winter), October 1993 (spring), April/May 1994 (autumn) and August (winter) 1994. An attempt was made to sample all the different habitats which could be identified in order to obtain a good representative sample of the fish community and to reduce possible gear selectivity and the possible effects of habitat preferences and behaviour of fish. The results of two surveys by Skelton and Merron done in March 1984 and July 1986 (Skelton and Merron, 1984; 1986) in which similar sampling methods were used, are also included to compare with the results from these surveys.

The IBI was calculated for the portion of the river from Nkurenkuru to the Mahango game reserve by combining all the data collected throughout the river. These data were compared with the results obtained by Skelton and Merron (1984; 1986). Hopefully this comparison will reveal changes and trends in this section of the river that have taken place since the 1984 and 1986 surveys. The IBI was furthermore calculated for seven specific localities along the river. It is considered to be more likely to detect changes at a specific locality than when looking at the river as a whole. Seven localities were, therefore, chosen to include all habitat types to give a fair representation of the fish community.

A wide range of sampling gear was used to limit selectivity in order to obtain an unbiased sample of the fish community.

The following equipment was used for sampling to limit selectivity and to prevent the data from being biased:

- Monofilament gill nets with stretched mesh sizes of 35, 45, 57, 73, 93, 118 and 150 mm, each mesh 10 m in length. Nets were surface set.
- Mosquito net (10 m) with a fine mesh size.
- A 30 m seine net with a 12 mm stretched mesh size.
- Rotenone.
- Traps.
- A 2 m cast net.
- D-net with a fine mesh size.

The IBI as applied to the Okavango River was slightly modified from the one described by Karr (1981) to include additional categories and metrics. The reason is that the Okavango River is a subtropical river which has a much higher species richness than the rivers studied by Karr (1981). Furthermore, the Okavango River, compared to rivers in first-world countries, is much less affected by urbanisation, industrialisation, agriculture and densely populated areas. For these reasons several metrics were included although some of these represent pristine conditions in the

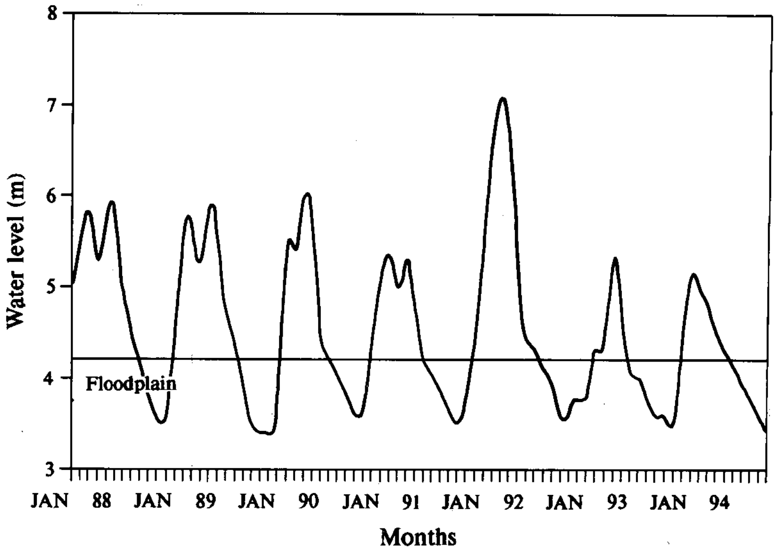

Figure 2
Water levels of the Okavango River at Rundu

Okavango River. The IBI developed for the Okavango River contains six categories, namely species richness, pollution levels, habitat condition, trophic structure, fish abundance and fish condition. The species richness category is separated from the habitat assessment whereas Karr (1981) combined both categories as species richness and composition. Another added parameter is pollution levels which is assessed on the basis of orthophosphate concentration. A number rating is assigned to each metric to assess whether that specific metric deviates strongly from what is expected, deviates somewhat or whether it is similar to the situation expected for that metric for the specific system. These ratings are either 1 (indicating degradation for that metric), 3 (for an average rate) or 5 (for a near perfect condition). The ratings of all the metrics are then added to get a total score for the system. This score can then be compared to values of future assessments in order to reflect possible changes in the system.

Flood cycle

The water level readings of the Okavango River was received from the Department of Water Affairs in Rundu. These water levels were measured at Rundu at weekly intervals (Fig. 2).

Water analysis

Water was sampled at Kakuru, Matava, Musese, Bunya, Rundu, Cuito, Mbambi, Popa Falls and at Kwetze in the afternoon and sent to the Department of Water Affairs in Windhoek for chemical analysis. Nitrate, nitrite and soluble orthophosphate were measured at the locality with a Hach DR/EL 4 spectrophotometer whereas the oxygen levels were measured with an HI 8043 oxygen meter. The air and water temperatures were measured with a standard mercury thermometer. The minimum temperatures were measured between 06:00 and 07:00 and the maximum temperatures between 16:00 and 17:00. The localities for the water analysis were chosen in such a way as to be representative of each zone and each habitat type. These localities also included areas where possible pollution and urbanisation could have influenced the water quality.

TABLE 1
THE PROPOSED IBI FOR THE OKAVANGO RIVER, NAMIBIA

Category	Metric	Scoring criteria 1	3	5
Species richness	Total number of native species (Nkurenkuru-Mahango)	< 40		> 53
	Total number of native species (separate localities)	< 12		> 25
Pollution	mg/ℓ soluble orthophosphate	> 2		< 1
Habitat condition	Percentage individuals rheophilic species	< 12%		> 17%
	Percentage individuals preferring vegetated areas	< 35%		> 50%
	Percentage individuals benthic species	< 10%		> 20%
Trophic structure	Percentage individuals piscivores	< 3%		> 8%
	Percentage individuals invertivores	< 25%		> 50%
	Percentage individuals herbivores	< 10%		> 30%
	Percentage individuals omnivores	> 45%		< 15%
Fish abundance	Aver. number of fish sampled in the 35 mm mesh (10 m)	< 13		> 31
	Aver. number of fish sampled in the 45 mm mesh (10 m)	< 12		> 27
	Aver. number of fish sampled in the 57 mm mesh (10 m)	< 5		> 15
	Aver. number of fish sampled in the 73 mm mesh (10 m)	< 2		> 6
	Aver. number of fish sampled in the 93 mm mesh (10 m)	< 1		> 3
	Aver. number of fish sampled in the 118 mm mesh (10 m)	< 0.7		> 2
	Aver. number of fish sampled in the 150 mm mesh (10 m)	< 0.2		> 0.7
	Combined values	< 12		> 20
Fish condition	Percentage individual hybrids	> 1%		<0.2%
	Percentage individuals with diseases, anomalies, parasites, etc.	> 3%		< 1%

The guidelines for the evaluation of drinking water for human consumption with regard to chemical and bacteriological quality were used to evaluate the water quality results (Department of Water Affairs, 1988). Water and soil samples were taken along the Okavango River for pesticide residue analysis. This was sampled for the Department of Water Affairs in Windhoek. The analysis was done by the CSIR in South Africa. These analyses included aldrin, pp-DDE, dieldrin, endosulfan, pp-DDT, pp-DDD and Br-P-methyl.

The scoring criteria were selected on the following basis:

Species richness: Data from all the different sampling gear were used for the calculation of this category. The results of the 1993 and 1994 surveys of the Okavango River were used as the baseline to determine the scoring criteria for the species richness. It is accepted that the degradation of a system may be reflected in a decline in the number of native species present which may open up opportunities for replacement by alien species.

Pollution: Orthophosphate was determined with a HACH DR-EL/4 spectrophotometer. The accepted South African standard of 1 mg/ℓ soluble orthophosphate concentration as being the upper limit for waste water that is allowed to be returned to a river system was used as a baseline to decide on the scoring that is used (Murray, 1987). Pollution according to Hocutt (1981) is any human alteration of the environment by increasing or decreasing the productivity of a system. The orthophosphate concentration is related to anthropogenic activities as the origin is likely to be sewage runoff, fertilisers, cattle and goat manure.

Habitat condition: Data from all the sampling gear were used for the calculation of this category. The information from the 1993 and 1994 surveys done during this study were used as the baseline values to decide on the scoring criteria for each metric in this category. Rheophilic species are used as an indicator of the open water in the system such as flowing water habitats. Species preferring vegetated habitats will reflect whether floodplains or the aquatic vegetation have been damaged most likely due to agricultural activities, overgrazing, deforestation and soil erosion. Soil erosion will result in siltation of the system and is likely to be reflected by the benthic species.

Trophic level: Data obtained by using all the gear were used for the calculation of this category. The 1993 and 1994 surveys conducted in the Okavango River were used as the baseline. A high number of piscivores indicate a healthy trophic composition. Variability in the invertebrates will affect the abundance of invertivores which in turn reflect changes in the water quality or energy resources (Karr et al., 1986). The use of pesticides will also affect this group. The invertivores will assess the secondary productivity of the system, whereas the herbivores will assess the primary productivity of the system. The omnivores will increase in abundance as specific food needed by specialised feeders becomes less. Omnivores have the ability to change their feeding habit when the food chain is under pressure.

Fish abundance: Fish abundance was based only on gill net catches due to a constant catch per unit effort which can be obtained by this method. The mesh sizes 35 mm, 45 mm, 57 mm, 73 mm, 93 mm, 118 mm and 150 mm stretched mesh each with a length of 10 m were used. The survey done in the Okavango River in the winter of 1990 was used as the baseline (Van Zyl, 1992). The scores of all the mesh sizes were added for the calculation of the score for this category (see Table 1 for combined values). This was done to avoid a skewing of the results of the IBI score because too much emphasis would have been placed on this category. The rationale for this category is that a poorer locality is likely to yield a lower abundance which will be reflected in the gill net catches.

Fish condition: At present the fish is still in a pristine condition, therefore low percentages were allocated for the scoring criteria for the two metrics in this category. According to Karr et al. (1986) environmental degradation can lead to habitat degradation which

TABLE 2
DIET AND HABITAT PREFERENCES OF SPECIES FROM THE OKAVANGO RIVER

Species	Trophic level	Habitat preferences
Hippopotamyrus discorhynchus	I	W
Marcusenius macrolepidotus	I	V
Mormyrus lacerda	I	W
Pollimyrus castelnaui	I	V
Petrocephalus catostoma	I	V
Brycinus lateralis	O	W
Hydrocynus vittatus	P	R
Micralestes acutidens	O	R
Rabdalestes maunensis	I	V
Hepsetus odoe	P	W
Hemigrammocharax machadoi	I	V
H. multifasciatus	I	V
Barbus kerstenii	I	V
B. barnardi	I	V
B. barotseensis	I	V
B. bifrenatus	I	V
B. codringtonii	I	R
B. eutaenia	I	R
B. cf. eutaenia	I	W
B. fasciolatus	I	V
B. haasianus	I	V
B. multilineatus	I	V
B. paludinosus	I	W
B. radiatus	I	V
B. thamalakanensis	I	W
B. poechii	I	W
B. unitaeniatus	I	V
Coptostomabarbus wittei	I	V
Labeo cylindricus	H	B
L. lunatus	H	B
Mesobola brevianalis	I	V
Opsaridium zambezense	I	R
Leptoglanis cf. dorae	I	B
Parauchenoglanis ngamensis	O	B
Schilbe intermedius	O	V
Clariallabes platyprosopos	P	W
Clarias gariepinus	I	W
C. liocephalus	O	W
C. ngamensis	O	W
C. stappersii	I	W
C. theodorae	I	V
Chiloglanis fasciatus	I	B
Amphilius uranoscopus	I	B
Synodontis leopardinus	O	B
S. vanderwaali	O	B
S. thamalakanensis	O	B
S. macrostoma	O	B
S. woosnami	O	B
S. nigromaculatus	O	B
S. macrostigma	O	B
Aplocheilichthys johnstoni	I	V
A. katangae	I	V
A. moeruensis	I	V
Hemichromis elongatus	I	U
Pharyngochromis acuticeps	I	V
Pseudocrenilabrus philander	I	V
Serranochromis altus	P	R
S. angusticeps	P	R
S. macrocephalus	P	R
S. robustus jallae	P	R
S. thumbergi	P	R
Sargochromis carlottae	I	V
S. codringtonii	I	V
S. giardi	I	V
Tilapia rendalli	H	V
T. ruweti	H	V
T. sparrmanii	H	V
Oreochromis andersonii	H	W
O. macrochir	H	W
Ctenopoma intermedium	I	V
C. multispine	I	V
Aethiomastacembelus frenatus	I	V
A. vanderwaali	I	B

I = invertivores
O = omnivores
P = piscivores
H = herbivores/detritivores
W = wide habitat tolerance
V = vegetation
R = rheophilic
B = benthic

in turn may lead to reduced segregation of breeding fish and therefore hybridisation will increase. Poor conditions in the river will enhance diseases, parasites and anomalies in freshwater fish.

The inclusion of species at their specific trophic level and habitat preference was done according to the data sampled during the surveys (Table 2).

The student t-test was used to determine which category (species richness, trophic level, etc.) had the most influence on the total IBI score (Zar, 1984). Furthermore this test was also used to determine whether there was any correlation between the different metrics of the habitat assessment and trophic level categories. This was done against a 95% significance level. Regression values were calculated for each correlation done. The null hypothesis is $H_0 : P = 0$ and if not rejected it will indicate that there is no correlation between the two specific variables. Regressions were calculated to determine whether there is a correlation between the total score with time (Table 4).

Results and discussion

Habitat description

The habitat descriptions are listed in Table 3 and encompass the entire section studied. All habitat types identified in the Okavango River were covered during this study.

TABLE 3
HABITAT DESCRIPTION OF THE SAMPLING LOCALITIES IN THE OKAVANGO RIVER

Ref. no. Fig. 1	Locality	Substratum	Vegetation	Flow	Mean depth (m)	Sampling methods
1	Kakuru Back waters	Clay	Marginal	None	1.0	D-net; 30 m Seine
2	Kakuru Isolated Pool	Clay	Aquatic	None	1.0	30 m Seine
3	Kahenge Main Stream	Sand	Marginal	Medium	0.5	Mosquito net
4	Matava Floodplain	Clay	Marginal	None	1.0	Gill-net series
5	Matava Floodplain	Clay	Aquatic	None	1.0	30m Seine; D-net; Rotenone; Traps
6	Main Stream	Sand & Rock	None	Medium	1.5	Cast; Mosquito
7	Musese Back Waters	Clay	Aquatic	None	0.5	Rotenone
8	Musese Back Waters	Sand	Aquatic	None	0.7	Gill-net series
9	Musese Floodplain	Mud & Clay	Aquatic	None	0.5	30 m Seine
10	Musese Floodplain	Mud & Clay	Submerged	None	0.5	Mosquito
11	Musese Main Stream	Sand	Marginal	Medium	1.5	Gill-net series
12	Musese Isolated Pool	Sand	None	None	1.5	30 m Seine, D-net
13	Musese Side stream	Rock	None	Slow	0.5	30 m Seine
14	Bunya Rocks	Sand & Rock	Marginal	Medium	0.3	Rotenone
	Bunya Rocks	Sand & Rock	Aquatic	Medium	0.3	Rotenone
15	Bunya Main Stream	Sand & Clay	None	Medium	2.0	Gill-net series
16	Bunya Main Stream	Sand & Clay	Aquatic	Medium	1.5	Gill-net series
17	Bunya Back Waters	Clay	Aquatic	None	1.0	Gill-net series
18	Bunya Back Waters	Sand	Aquatic	None	1.0	Gill-net series
19	Mupini Floodplain	Clay	Aquatic	None	1.0	Rotenone, D-net
20	Mupini Floodplain	Sand	Submerged	None	0.5	Mosquito
21	Mupini Main Stream	Sand	None	Medium	0.5	Mosquito, Rotenone
22	Rundu Floodplain	Clay	Submerged	Slow	1.0	Rotenone
23	Rundu Floodplain	Clay	Submerged	Slow	1.0	Mosquito
24	Rundu Main Stream	Sand	Marginal	Medium	1.5	Gill-net series
25	Rundu Main Stream	Sand	Marginal	Slow	1.0	Rotenone
26	Vungu-Vungu	Sand	Marginal	Slow	1.0	Mosquito
27	Mashare Side Stream	Sand & Rock	None	Strong	0.5	Rotenone
28	Mashare Side Stream	Clay	Aquatic	Slow	0.1	Rotenone
29	Mashare Main Stream	Sand	None	Medium	2.5	Cast
30	Mashare Main Stream	Rock	None	Medium	0.3	Rotenone
31	Omatako Confluence	Sand	Submerged	None	1.0	Mosquito
32	Cuito Back Waters	Clay	Aquatic	None	1.0	Gill-net series
33	Cuito Main Stream	Sand	Marginal	Strong	2.0	Gill-net series
34	Cuito Floodplain	Clay	Aquatic	None	0.3	Rotenone
35	Cuito Floodplain	Sand	Submerged	Slow	0.3	Rotenone, D-net
36	Mbambi Floodplain	Clay	Aquatic	None	0.5	Rotenone
37	Mbambi Isolated Pool	Clay	Submerged	None	1.5	30 m Seine net
38	Mbambi Main Stream	Sand	Marginal	Medium	1.5	Gill-net series
39	Mbambi Rocks	Sand & Rock	None	Medium	0.5	Rotenone
40	Mbambi Back Waters	Clay	Submerged	None	0.5	Rotenone
41	Andara Main Stream	Sand	None	Medium	0.5	Mosquito; Cast
42	Andara Back Waters	Clay	Aquatic	None	1.0	Rotenone
43	1km West of Popa					
44	Main Stream	Gravel	None	Medium	0.3	Mosquito net
45	Main Stream	Rock	None	Strong	0.3	Rotenone
46	Popa Side Stream	Sand	Marginal	Strong	0.5	D-net
47	Popa Rapids	Rock	None	Strong	0.2	Rotenone
48	Bagani Floodplain	Sand	Aquatic	Slow	0.2	Rotenone
49	Bagani Floodplain	Sand	Aquatic	Slow	0.2	Rotenone
50	Kwetze Back Waters	Clay	Marginal	Slow	2.0	Gill-net series
51	Kwetze Back Waters	Clay	Aquatic	None	2.0	Gill-net series
52	Kwetze Back Waters	Clay	Marginal	Slow	2.0	Gill-net series
53	Kwetze Main Stream	Sand	Marginal	Medium	1.5	Gill-net series
54	Kwetze Main Stream	Sand	Marginal	Medium	3.0	Gill-net series
55	Kwetze Floodplain	Clay	Aquatic	None	1.0	Rotenone
56	Kwetze Floodplain	Sand	Aquatic	None	0.5	Rotenone

Flood cycle

The floods of 1988 to 1991 had two peaks, one during January to March and then a second in May/June for 1988 and 1989 and April for 1990 and 1991 (Fig. 2). The 1992 and 1994 floods only had one peak during January to March and during April in 1993.

Rundu and Musese had the highest concentrations during the study period (Table 4). These values ranged between 0.01 and 0.10 mg/ℓ in the main stream and 0.02 to 0.32 in the back waters during 1984 (Bethune, 1991).

IBI for the entire river

The autumn 1984 survey done by Skelton and Merron had the highest total score followed by their winter 1986 survey (Table 5). The overall diversity was excellent with minimum pollution detected throughout the system. The habitat assessment was the highest during the 1986 survey followed by the autumn 1984, 1993 and 1994 surveys. Low values were calculated for the winter 1993, spring 1993 and winter 1994 surveys. The abundance indicated a definite decrease in the gill net catches. No variation was detected in the fish condition during all the surveys. When comparing the time of each survey with its specific total score, a negative correlation index was calculated. This was also the situation when the winter and then the autumn surveys were compared with their specific total score. These negative correlations indicate a decline in the IBI total score with time.

The following regressions were calculated:

Autumn surveys

Formula $Y = A \times X^B$

$A = 49.99764$

$B = -0.034646$

$r = -0.9997$

$r^2 = 0.999$

Winter surveys

Formula $Y = A \times X^B$

$A = 58.25317$

$B = -0.0815803$

$r = -0.92$

$r^2 = 0.84$

All the surveys

Formula $Y = A + (B \times X)$

$A = 49.92588$

$B = -0.1657998$

$r = -0.94$

$r^2 = 0.88$

$t_{0.05(2),5} = 2.571 \quad t = 6.068$

Therefore reject H_0. $P < 0.05$.

This indicates that at a significance level of 95% the total IBI score with time will decrease if the status quo of the Okavango River is maintained.

According to Table 6 the rheophilic species influenced the habitat score for the entire river. Furthermore the rheophilic species decreased since the 1984 survey whereas the species preferring vegetated areas also declined slightly. The benthic species however remained stable with a slight increase during the spring 1993 and winter 1994 surveys (Table 6). That the total score, however, decreased since the early eighties is the result of a decrease in the numbers of the rheophilic species and to a lesser extent the

TABLE 4
ORTHO-PHOSPHATE CONCENTRATION (mg/ℓ) AT THE DIFFERENT LOCALITIES FOR THE DIFFERENT SURVEYS

Survey	Musese	Matava	Bunya	Rundu	Mbambi	Cuito	Kwetze
Aut 1993	0.08	0.23	0.08	0.20	0.10	0.05	0.06
Win 1993	0.08	0.06	0.05	1.38	0.10	0.04	0.30
Spr 1993	1.23	0.09	0.58	0.17	0.22	0.25	0.30
Aut 1994	0.13	0.20	0.07	0.09	0.20	0.08	0.08
Win 1994	0.19	0.03	0.03	0.04	0.02	0.07	0.06

TABLE 5
TOTAL SCORE, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR THE ENTIRE STUDY AREA

Survey	Richness	Pollution	Habitat	Trophic	Abundance	Condition	Total score
Aut 1984	5	5	11	14	5	10	50
Win 1986	5	5	13	12	3	10	48
Aut 1993	3	5	11	14	1	10	44
Win 1993	5	5	9	12	1	10	42
Spr 1993	5	5	7	12	3	10	42
Aut 1994	5	5	11	12	1	10	44
Win 1994	5	5	9	14	1	10	44

Correlation	Regression values					Students T-test	Significance level	H_0
	a	b	n	r	r^2			
Richness vs. total score	42.50	0.50	7	0.13	0.02	0.294	$p \geq 0.05$	Accept
Pollution vs. total score	Values constant						$p \geq 0.05$	Accept
Habitat vs. total score	33.70	1.10	7	0.71	0.50	2.245	$p \geq 0.05$	Accept
Trophic vs. total score	32.00	1.00	7	0.35	0.12	0.834	$p \geq 0.05$	Accept
Abundance vs. total score	41.81	1.42	7	0.74	0.55	2.467	$p \geq 0.05$	Accept
Condition vs. total score	Values constant						$p \geq 0.05$	Accept

floraphylic species (Table 6). Seventy-six per cent of the deviation of the habitat assessment score was influenced by the rheophilic species (Table 6). There was also a negative correlation between the species preferring vegetated areas and the benthic species (Table 6) reflecting the replacement of the one group by the other during certain periods of the year. The former group is more abundant during periods of high water levels when vegetated areas are covered with water whereas the latter increased in numbers during periods of low water levels e.g. in spring.

According to the trophic level assessment very little deviation occurred over the past ten years (Table 7). All the metrics contributed equally to this category (Table 7). The herbivores were inversely correlated with the piscivores (Table 7) at a 99% significance level. The invertivores increased in numbers as the piscivore numbers declined during different periods of the year. The herbivores, however, increased as the piscivores increased. It is furthermore of interest to note that the invertivore numbers declined from 1984 to autumn 1993 after which the numbers steadily increased up to the last survey. The overall assessment of the invertivores indicated a slight degradation.

Table 8 indicates that a definite decrease in fish abundance had taken place since the first survey. It must be taken into account that the two surveys by Skelton and Merron (1984 and 1986) included no gill net collections at Kwetze where gill net catches are usually much higher than the rest of the river which may have increased the catch per unit effort (CPUE) during 1984 and 1986. The surveys during 1993 and 1994 had a relatively high score for the small mesh sizes whereas high scores were recorded for the larger mesh sizes during the surveys done by Skelton and Merron (1984; 1986).

The condition of the fish remained excellent over the years with

TABLE 6
HABITAT ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR THE ENTIRE RIVER

Survey	Rheophilic % score	Vegetation % score	Benthic % score	Total score
Aut 1984	18.1 (5)	53.6 (5)	3.6 (1)	11
Win 1986	17.0 (5)	52.8 (5)	15.2 (3)	13
Aut 1993	12.3 (3)	39.3 (3)	23.5 (3)	11
Win 1993	10.1 (1)	57.0 (5)	12.7 (1)	9
Spr 1993	10.3 (1)	26.5 (1)	32.6 (5)	7
Aut 1994	12.3 (3)	56.1 (5)	12.6 (1)	11
Win 1994	4.8 (1)	57.8 (5)	18.5 (3)	9

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Rheophilic vs. habitat score	7.59	0.94	7	0.87	0.76	3.971	$p \leq 0.05$	Reject
Vegetation vs. habitat score	7.12	0.73	7	0.59	0.35	1.636	$p \geq 0.05$	Accept
Benthic vs. habitat score	10.34	0.00	7	-0.26	0.07	0.603	$p \geq 0.05$	Accept
Rheophilic vs. vegetation	48.42	0.05	7	0.02	-	0.045	$p \geq 0.05$	Accept
Rheophilic vs. benthic	28.95	-0.99	7	-0.48	0.23	1.223	$p \geq 0.05$	Accept
Vegetation vs. benthic	48.63	-0.65	7	-0.82	0.67	3.192	$p \leq 0.05$	Reject

TABLE 7
TROPHIC LEVEL ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR THE ENTIRE RIVER

Survey	Piscivores % score	Invertivores % score	Herbivores % score	Omnivores % score	Total score
Aut 1984	3.4 (3)	58.4 (5)	16.4 (3)	20.2 (3)	14
Win 1986	1.7 (1)	53.7 (5)	10.2 (3)	33.1 (3)	12
Aut 1993	10.8 (5)	26.3 (3)	26.5 (3)	36.3 (3)	14
Win 1993	5.5 (3)	36.9 (3)	22.1 (3)	29.7 (3)	12
Spr 1993	3.1 (3)	43.9 (3)	13.4 (3)	35.0 (3)	12
Aut 1994	6.3 (3)	46.7 (3)	16.3 (3)	28.7 (3)	12
Win 1994	3.5 (3)	51.7 (5)	20.0 (3)	23.4 (3)	14

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Piscivores vs. trophic score	11.36	0.50	7	0.54	0.29	1.433	$p \geq 0.05$	Accept
Invertivores vs. trophic score	11.25	0.42	7	0.42	0.18	1.037	$p \geq 0.05$	Accept
Herbivores vs. trophic score	Values constant						$p \geq 0.05$	Accept
Omnivores vs. trophic score	Values constant						$p \geq 0.05$	Accept
Piscivores vs. invertivores	60.40	-3.07	7	-0.85	0.72	3.592	$p \leq 0.01$	Reject
Piscivores vs. herbivores	10.42	1.52	7	0.84	0.71	3.488	$p \leq 0.01$	Reject
Piscivores vs. omnivores	25.89	0.73	7	0.37	0.14	0.892	$p \geq 0.05$	Accept
Invertivores vs. herbivores	34.59	-0.37	7	-0.74	0.55	2.467	$p \geq 0.05$	Accept
Invertivores vs. omnivores	46.55	-0.38	7	-0.69	0.48	2.140	$p \geq 0.05$	Accept
Herbivores vs. omnivores	28.57	0.05	7	0.05	-	0.112	$p \geq 0.05$	Accept

no hybrids and a very low percentage of anomalies recorded during the study. This was also the situation during 1984 and 1986 (Table 9).

IBI for the locality Musese

Musese had the lowest total score of all the localities calculated. The species richness was constant throughout the study period (Table 10). The area showed very little pollution with only a slightly higher orthophosphate concentration detected during the spring 1993 survey. The habitat condition value remained constant throughout the study period. The lowest total score was recorded during the spring 1993 survey (Table 10). The trophic level was the main contributor in influencing the total score at a 99.5% significance level (Table 10).

High numbers of floraphylic species were collected at Musese whereas rheophilic and benthic individuals were present in low numbers (Table 11). The overall habitat score is low at Musese which is attributed to the rheophilic and benthic species. From this it is inferred that the habitat at Musese showed signs of degradation.

The herbivores were the least abundant metric at Musese especially during the winter 1993 and autumn 1994 surveys (Table 12). The piscivores were abundant especially during the autumn 1993, winter 1993 and autumn 1994 surveys. A low percentage of omnivores was also present during the autumn 1993 and winter 1994 surveys (Table 12). The omnivores were the major factor in affecting the trophic score (Table 12). A negative correlation was present between the herbivores and omnivores tested against a

TABLE 8
FISH ABUNDANCE FOR THE ENTIRE RIVER

Survey	35 mm ave. score	45 mm ave. score	57 mm ave. score	73 mm ave. score	93 mm ave. score	118 mm ave. score	150 mm ave. score	Total score
Aut 1984	12.4 (1)	12.9 (3)	5.7 (3)	2.0 (3)	2.1 (3)	1.5 (3)	1.0 (5)	5
Win 1986	27.7 (3)	3.8 (1)	3.1 (1)	0.4 (1)	5.6 (5)	0.0 (1)	0.0 (1)	3
Aut 1993	14.5 (3)	8.2 (1)	1.9 (1)	0.5 (1)	0.5 (1)	0.1 (1)	0.2 (3)	1
Win 1993	18.7 (3)	7.1 (1)	3.7 (1)	1.2 (1)	0.6 (1)	0.2 (1)	0.2 (3)	1
Spr 1993	14.6 (3)	13.0 (3)	2.0 (1)	1.4 (1)	0.6 (1)	1.1 (3)	0.2 (3)	3
Aut 1994	6.1 (1)	9.3 (1)	1.8 (1)	1.3 (1)	0.3 (1)	0.2 (1)	0.1 (1)	1
Win 1994	10.1 (1)	1.7 (1)	1.3 (1)	0.3 (1)	0.1 (1)	0.0 (1)	0.0 (1)	1

TABLE 9
FISH CONDITION FOR THE ENTIRE RIVER

Survey	Hybrids % score	Anomalies % score	Total score
Aut 1984	0.0 (5)	0.2 (5)	10
Win 1986	0.0 (5)	0.0 (5)	10
Aut 1993	0.0 (5)	0.0 (5)	10
Win 1993	0.0 (5)	0.0 (5)	10
Spr 1993	0.0 (5)	0.0 (5)	10
Aut 1994	0.0 (5)	0.3 (5)	10
Win 1994	0.0 (5)	0.1 (5)	10

TABLE 10
TOTAL SCORE, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR MUSESE

Survey	Richness	Pollution	Habitat	Trophic	Abundance	Condition	Total score
Aut 1993	3	5	7	16	1	10	42
Win 1993	3	5	7	12	1	10	38
Spr 1993	3	3	7	10	1	10	34
Aut 1994	3	5	7	10	1	10	36
Win 1994	3	5	7	16	1	10	42
Average score	3	4.6	7	12.8	1	10	38.4

Correlation	Regression values a b n r r^2	Students T-test	Significance level	Ho
Richness vs. total score	Values constant		$p \geq 0.05$	Accept
Pollution vs. total score	25.75 2.75 5 0.69 0.48	1.657	$p \geq 0.05$	Accept
Habitat vs. total score	Values constant		$p \geq 0.05$	Accept
Trophic vs. total score	25.65 1.50 5 0.98 0.96	8.487	$p \leq 0.005$	Reject
Abundance vs. total score	Values constant		$p \geq 0.05$	Accept
Condition vs. total score	Values constant		$p \geq 0.05$	Accept

98% significance level indicating the replacement of herbivores with omnivores and vice versa during certain periods of the year (Table 12).

Fish abundance was very low at Musese. This was the case for catches with all mesh sizes, but this trend is especially of great concern for the larger mesh sizes (Table 13).

The condition of the fish was generally good and ectocysts and ectoparasites were rarely found (Table 14).

IBI for the locality Matava

The overall total score at Matava was higher than at Musese (Table 15). The pollution, habitat and trophic values were higher than that

TABLE 11
HABITAT ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR MUSESE

Survey	Rheophilic % score	Vegetation % score	Benthic % score	Total score
Aut 1993	8.3 (1)	73.1 (5)	2.8 (1)	7
Win 1993	9.4 (1)	44.6 (3)	14.7 (1)	5
Spr 1993	0.7 (1)	50.3 (3)	6.6 (1)	5
Aut 1994	7.7 (1)	55.0 (3)	1.9 (1)	5
Win 1994	4.7 (1)	83.2 (5)	0.7 (1)	7
Average score	(1)	(3.8)	(1)	5.8

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Rheophilic vs. habitat score	Values constant						p ≥ 0.05	Accept
Vegetation vs. habitat score	Values constant						p ≥ 0.05	Accept
Benthic vs. habitat score	Values constant						p ≥ 0.05	Accept
Rheophilic vs. vegetation	62.55	-0.21	5	-0.05	0.00	0.087	p ≥ 0.05	Accept
Rheophilic vs. benthic	2.91	0.39	5	0.24	0.06	0.429	p ≥ 0.05	Accept
Vegetation vs. benthic	21.55	-0.26	5	-0.76	0.58	2.031	p ≥ 0.05	Accept

TABLE 12
TROPHIC LEVEL ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR MUSESE

Survey	Piscivores % score	Invertivores % score	Herbivores % score	Omnivores % score	Total score
Aut 1993	9.3 (5)	48.1 (3)	27.8 (3)	14.8 (5)	16
Win 1993	11.5 (5)	37.8 (3)	3.6 (1)	38.8 (3)	12
Spr 1993	0.3 (1)	47.2 (3)	12.9 (3)	38.5 (3)	10
Aut 1994	9.2 (5)	30.4 (3)	4.2 (1)	48.8 (1)	10
Win 1994	6.0 (3)	57.0 (5)	24.8 (3)	12.0 (5)	16
Average score	(3.8)	(3.4)	(2.2)	(3.4)	12.8

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Piscivores vs. trophic score	11.38	0.38	5	0.22	0.05	0.391	p ≥ 0.05	Accept
Invertivores vs. trophic score	6.00	2.00	5	0.59	0.35	1.268	p ≥ 0.05	Accept
Herbivores vs. trophic score	9.50	1.50	5	0.54	0.29	1.110	p ≥ 0.05	Accept
Omnivores vs. trophic score	7.21	1.64	5	0.91	0.83	3.823	p ≤ 0.05	Reject
Piscivores vs. invertivores	52.03	-1.09	5	-0.46	0.21	0.896	p ≥ 0.05	Accept
Piscivores vs. herbivores	18.57	-0.54	5	-0.21	0.04	0.371	p ≥ 0.05	Accept
Piscivores vs. omnivores	29.98	0.08	5	0.02	0.00	0.035	p ≥ 0.05	Accept
Invertivores vs. herbivores	-26.44	0.93	5	0.84	0.71	2.702	p ≥ 0.05	Accept
Invertivores vs. omnivores	91.53	-1.38	5	-0.87	0.76	3.076	p ≥ 0.05	Accept
Herbivores vs. omnivores	50.44	-1.35	5	-0.94	0.88	4.700	p ≤ 0.02	Reject

TABLE 13
FISH ABUNDANCE AT MUSESE

Survey	35 mm ave. score	45 mm ave. score	57 mm ave. score	73 mm ave. score	93 mm ave. score	118 mm ave. score	150 mm ave. score	Total score
Aut 1993	2.9 (1)	1.2 (1)	0.5 (1)	0.2 (1)	0.2 (1)	0.2 (1)	0.0 (1)	1
Win 1993	10.8 (1)	2.8 (1)	1.3 (1)	0.3 (1)	0.2 (1)	0.0 (1)	0.3 (3)	1
Spr 1993	5.0 (1)	1.7 (1)	0.0 (1)	0.0 (1)	0.7 (1)	0.0 (1)	0.0 (1)	1
Aut 1994	2.7 (1)	5.7 (1)	1.2 (1)	0.2 (1)	0.2 (1)	0.0 (1)	0.0 (1)	1
Win 1994	7.0 (1)	0.0 (1)	0.0 (1)	0.0 (1)	0.0 (1)	0.0 (1)	0.0 (1)	1
Average score	(1)	(1)	(1)	(1)	(1)	(1)	(1)	1

of Musese. A relatively high species richness was present with no pollution detected at Matava. The autumn 1994 survey results yielded the highest total score with the habitat and trophic levels being the main contributors to this. Low values were calculated from the data recorded during the autumn 1993 and winter 1994 surveys. Four of the six categories were constant with some variation in habitat condition and trophic level (Table 15).

The habitat assessment at Matava had a high total score except for the winter 1994 survey (Table 16). This sampling locality is in a side stream that is heavily fished. Fishing activities may disturb the substrate to the detriment of the benthic species. A large variety of aquatic plants are present that attract large numbers of floraphylic species. The high numbers of rheophilic species during the two autumn surveys are due to high numbers of *H. vittatus* moving onto the floodplains during this time of the year. The benthic species were low in number, with the floraphylic species the most abundant (Table 16). A positive correlation was found between the floraphylic species and the benthic species (Table 16).

The invertivores had the lowest score, especially during the autumn 1993 and winter 1994 surveys (Table 17). The high concentration of algae usually present attracts large numbers of algavore *Oreochromis andersonii* and *O. macrochir*. This was the

TABLE 14
FISH CONDITION AT MUSESE

Survey	Hybrids %	Hybrids score	Anomalies %	Anomalies score	Total score
Aut 1993	0.0	(5)	0.0	(5)	10
Win 1993	0.0	(5)	0.0	(5)	10
Spr 1993	0.0	(5)	0.0	(5)	10
Aut 1994	0.0	(5)	0.4	(5)	10
Win 1994	0.0	(5)	0.0	(5)	10
Average score		(5)		(5)	10

TABLE 15
TOTAL SCORE, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR MATAVA

Survey	Richness	Pollution	Habitat	Trophic	Abundance	Condition	Total score
Aut 1993	3	5	9	10	1	10	38
Win 1993	3	5	7	16	1	10	42
Aut 1994	3	5	11	14	1	10	44
Win 1994	3	5	5	12	1	10	36
Average score	3	5	8	13	1	10	40

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Richness vs. total score	Values constant						$p \geq 0.05$	Accept
Pollution vs. total score	Values constant						$p \geq 0.05$	Accept
Habitat vs. total score	32.00	1.00	4	0.71	0.50	1.420	$p \geq 0.05$	Accept
Trophic level vs. total score	27.00	1.00	4	0.71	0.50	1.420	$p \geq 0.05$	Accept
Abundance vs. total score	Values constant						$p \geq 0.05$	Accept
Condition vs. total score	Values constant						$p \geq 0.05$	Accept

TABLE 16
HABITAT ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR MATAVA

Survey	Rheophilic %	Rheophilic score	Vegetation %	Vegetation score	Benthic %	Benthic score	Total score
Aut 1993	19.7	(5)	49.0	(3)	0.7	(1)	9
Win 1993	11.2	(1)	63.1	(5)	6.1	(1)	7
Aut 1994	17.8	(5)	60.9	(5)	3.9	(1)	11
Win 1994	2.3	(1)	45.7	(3)	0.3	(1)	5
Average score		(3)		(4)		(1)	8

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Rheophilic vs. habitat score	5.00	1.00	4	0.89	0.79	2.747	$p \geq 0.05$	Accept
Vegetation vs. habitat score	4.00	1.00	4	0.45	0.20	0.712	$p \geq 0.05$	Accept
Benthic vs. habitat score	Values constant						$p \geq 0.05$	Accept
Rheophilic vs. vegetation	49.67	0.39	4	0.36	0.13	0.546	$p \geq 0.05$	Accept
Rheophilic vs. benthic	1.93	0.06	4	0.18	0.03	0.258	$p \geq 0.05$	Accept
Vegetation vs. benthic	-14.21	0.31	4	0.97	0.94	5.600	$p \leq 0.05$	Reject

case during the winter 1994 survey (Table 17). Piscivores were found in high numbers during autumn 1993 and 1994. The trophic level assessment score was the lowest during the autumn 1993 survey when low numbers of invertivores and high numbers of omnivores were present. The omnivores were the only metric that had some influence on the trophic score at Matava.

Fish abundance at Matava was generally low but relatively high numbers were sampled during the autumn and winter 1993 surveys with the 35 mm mesh gill nets. Large individuals caught in the 150 mm mesh gill net were only sampled during autumn 1993 (Table 18).

The condition of fish was generally good. Some ectocysts were, however, collected during the autumn 1994 survey (Table 19).

IBI for the locality Bunya

Bunya had a high species richness especially during the last two surveys (Table 20). No pollution at Bunya had been detected. Habitat assessment indicated low values during the two winter surveys whereas the trophic levels were the lowest during the last two surveys. The lowest total score was recorded during the winter 1993 and 1994 surveys. Fish abundance was low at this locality. The habitat assessment had the greatest effect on the total score whereas the other categories showed little deviation during the surveys (Table 20).

In contrast with the previous two localities the benthic species had higher values than the rheophilic species and species preferring vegetated areas (Table 21). This can be explained by the fact that rocky habitats are present which are ideal for benthic species such

TABLE 17
TROPHIC LEVEL ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR MATAVA

Survey	Piscivores %	Piscivores score	Invertivores %	Invertivores score	Herbivores %	Herbivores score	Omnivores %	Omnivores score	Total score
Aut 1993	16.3	(5)	21.4	(1)	10.5	(3)	47.3	(1)	10
Win 1993	11.2	(5)	46.7	(3)	27.6	(3)	14.5	(5)	16
Aut 1994	18.8	(5)	37.5	(3)	19.4	(3)	24.3	(3)	14
Win 1994	4.9	(3)	20.2	(1)	42.2	(5)	32.7	(3)	12
Average score		(4.5)		(2)		(3.5)		(3)	13

Correlation	a	b	n	r	r^2	Students T-test	Significance level	Ho
Piscivores vs. trophic score	10.00	0.67	4	0.26	0.07	0.381	$p \geq 0.05$	Accept
Invertivores vs. trophic score	9.00	2.00	4	0.89	0.79	2.747	$p \geq 0.05$	Accept
Herbivores vs. trophic score	15.20	-0.67	4	-0.26	0.07	0.381	$p \geq 0.05$	Accept
Omnivores vs. trophic score	8.50	1.50	4	0.95	0.90	4.249	$p \geq 0.05$	Accept
Piscivores vs. invertivores	24.03	0.58	4	0.28	0.08	0.413	$p \geq 0.05$	Accept
Piscivores vs. herbivores	50.29	-1.98	4	-0.90	0.81	2.919	$p \geq 0.05$	Accept
Piscivores vs. omnivores	26.33	0.26	4	0.12	0.01	0.171	$p \geq 0.05$	Accept
Invertivores vs. herbivores	27.58	-0.08	4	-0.08	0.01	0.114	$p \geq 0.05$	Accept
Invertivores vs. omnivores	59.78	-0.96	4	-0.89	0.79	2.747	$p \geq 0.05$	Accept
Herbivores vs. omnivores	39.45	-0.39	4	-0.38	0.14	0.579	$p \geq 0.05$	Accept

TABLE 18
FISH ABUNDANCE AT MATAVA

Survey	35 mm ave.	35 mm score	45 mm ave.	45 mm score	57 mm ave.	57 mm score	73 mm ave.	73 mm score	93 mm ave.	93 mm score	118 mm ave.	118 mm score	150 mm ave.	150 mm Score	Total score
Aut 1993	20.0	(3)	3.7	(1)	0.3	(1)	0.0	(1)	0.3	(1)	0.0	(1)	0.3	(3)	1
Win 1993	23.7	(3)	5.7	(1)	0.7	(1)	1.0	(1)	0.0	(1)	0.0	(1)	0.0	(1)	1
Aut 1994	5.7	(1)	21.3	(3)	1.7	(1)	1.0	(1)	0.3	(1)	0.3	(1)	0.0	(1)	1
Win 1994	4.0	(1)	0.0	(1)	3.0	(1)	0.0	(1)	0.0	(1)	0.0	(1)	0.0	(1)	1
Average score		(1)		(1)		(1)		(1)		(1)		(1)		(1)	1

TABLE 19
FISH CONDITION AT MATAVA

Survey	Hybrids %	Hybrids score	Anomalies %	Anomalies score	Total score
Aut 93	0.0	(5)	0.0	(5)	10
Win 93	0.0	(5)	0.0	(5)	10
Aut 94	0.0	(5)	0.7	(5)	10
Win 94	0.0	(5)	0.0	(5)	10
Average score		(5)		(5)	10

as *L. cylindricus*. The benthic species were low in numbers during the winter 1993 survey. The rheophilic species were also less than expected when considering the large open water habitats which are present. Species preferring vegetation was at a low during the last survey. The rheophilic species were the metric that affected the habitat score at a 99.9% significance level (Table 21). None of the metrics correlated with each other at a 95% percent level, although the species preferring aquatic vegetation and the benthic species had a negative correlation when tested against a 90% significance level.

The piscivores maintained a relatively high percentage, except during the last two surveys when lower percentages were recorded (Table 22). A low percentage of omnivores was recorded during the winter 1993 and autumn 1994 surveys that were inversely correlated with the invertivores (Table 22). The invertivores and herbivores were slightly degraded when comparing the scores of both food niches. None of the metrics affected the trophic score.

Fish abundance was low despite the fact that fish was sampled with the larger mesh sizes during the autumn and winter surveys (Table 23).

No anomalies or hybrids were sampled at this locality (Table 24).

IBI for the locality Rundu

The species richness was relatively high with a slightly higher orthophosphate concentration (1.38 mg/ℓ) detected during the 1993 winter survey (Table 4). The higher phosphate concentration could be attributed to the higher concentration of people in comparison to the rural areas. The trophic level scores were high especially during the autumn and winter 1993 surveys. Furthermore the habitat assessment score during autumn 1993 was much higher than the other surveys. Fish abundance, as with the other localities, remained very low (Table 25). The habitat category had an important influence on the total score (Table 25).

The vegetation at Rundu appears to have been in a pristine condition because a large number of species preferring vegetated areas were present at this locality (Table 26). Very few rheophilic and benthic species were sampled according to Table 26. A high percentage rheophilic species, however, was sampled during the autumn 1993 survey. Disturbances of the substrate could be a reason for the lower numbers collected of the former two groups of species. The rheophilic species affected the habitat score tested against a 99.9% significance level (Table 26).

The trophic level had a generally high score (Table 27). A fact worth mentioning is the low number of omnivores sampled at

TABLE 20
TOTAL SCORE, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR BUNYA

Survey	Richness	Pollution	Habitat	Trophic	Abundance	Condition	Total score
Aut 1993	3	5	11	12	1	10	42
Win 1993	3	5	7	12	1	10	38
Aut 1994	5	5	11	10	1	10	42
Win 1994	5	5	7	10	1	10	38
Average score	4	5	9	11	1	10	40

Comparison	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Richness vs. total score	40.00	0.00	4	0.00	0.00		$p \geq 0.05$	Accept
Pollution vs. total score	Values constant						$p \geq 0.05$	Accept
Habitat vs. total score	31.00	1.00	4	1.00	1.00		$p \leq 0.001$	Reject
Tropic level vs. total score	40.00	0.00	4	0.00	0.00		$p \geq 0.05$	Accept
Abundance vs. total score	Values constant						$p \geq 0.05$	Accept
Condition vs. total score	Values constant						$p \geq 0.05$	Accept

TABLE 21
HABITAT ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR BUNYA

Survey	Rheophilic %	Rheophilic score	Vegetation %	Vegetation score	Benthic %	Benthic score	Total score
Aut 1993	15.6	(3)	35.2	(3)	28.7	(5)	11
Win 1993	8.0	(1)	59.2	(5)	8.8	(1)	7
Aut 1994	16.7	(3)	46.4	(3)	24.5	(5)	11
Win 1994	4.9	(1)	25.8	(1)	66.4	(5)	7
Average score		(2)		(3)		(4)	9

Comparison	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Rheophilic vs. habitat score	5.00	2.00	4	1.00	1.00		$p \leq 0.001$	Reject
Vegetation vs. habitat score	9.00	0.00	4	0.00	0.00		$p \geq 0.05$	Accept
Benthic vs. habitat score	6.33	0.67	4	0.58	0.34	1.010	$p \geq 0.05$	Accept
Rheophilic vs. vegetation	36.94	0.42	4	0.17	0.0.	0.244	$p \geq 0.05$	Accept
Rheophilic vs. benthic	54.62	-1.99	4	-0.47	0.22	0.753	$p \geq 0.05$	Accept
Vegetation vs. benthic	96.69	-1.55	4	-0.92	0.85	3.359	$p \geq 0.05$	Accept

TABLE 22
TROPHIC LEVEL ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR BUNYA

Survey	Piscivores %	score	Invertivores %	score	Herbivores %	score	Omnivores %	score	Total score
Aut 1993	15.6	(5)	19.7	(1)	21.3	(3)	44.3	(3)	12
Win 1993	7.6	(3)	38.2	(3)	29.0	(3)	25.2	(3)	12
Aut 1994	4.2	(3)	46.1	(3)	12.1	(1)	24.8	(3)	10
Win 1994	4.9	(3)	24.0	(1)	24.5	(3)	44.9	(3)	10
Average score		(3.5)		(2)		(2.5)		(3)	11

Comparison	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Piscivores vs. trophic score	8.67	0.67	4	0.58	0.34	1.010	p ≥ 0.05	Accept
Invertivores vs. trophic score	11.00	0.00	4	0.00	0.00		p ≥ 0.05	Accept
Herbivores vs. trophic score	9.33	0.67	4	0.58	0.34	1.010	p ≥ 0.05	Accept
Omnivores vs. trophic score	Values constant						p ≥ 0.05	Accept
Piscivores vs. invertivores	44.29	-1.52	4	-0.65	0.42	1.207	p ≥ 0.05	Accept
Piscivores vs. herbivores	19.57	0.27	4	0.19	0.04	0.274	P ≥ 0.05	Accept
Piscivores vs. omnivores	26.65	1.01	4	0.47	0.22	0.753	p ≥ 0.05	Accept
Invertivores vs. herbivores	29.33	-0.24	4	-0.41	0.17	0.636	p ≥ 0.05	Accept
Invertivores vs. omnivores	62.96	-0.88	4	-0.95	0.90	4.249	p ≤ 0.05	Reject
Herbivores vs. omnivores	27.66	0.33	4	0.21	0.04	0.303	p ≥ 0.05	Accept

TABLE 23
FISH ABUNDANCE AT BUNYA

Survey	35 mm ave.	score	45 mm ave.	score	57 mm ave.	score	73 mm ave.	score	93 mm ave.	score	118 mm ave.	score	150 mm ave.	score	Total score
Aut 1993	10.5	(1)	5.2	(1)	0.0	(1)	0.0	(1)	0.0	(1)	0.2	(1)	0.2	(3)	1
Win 1993	19.0	(3)	2.2	(1)	2.3	(1)	1.2	(1)	0.2	(1)	0.5	(1)	0.2	(3)	1
Aut 1994	3.7	(1)	1.3	(1)	0.0	(1)	0.0	(1)	0.0	(1)	0.0	(1)	0.0	(1)	1
Win 1994	8.3	(1)	2.3	(1)	0.3	(1)	0.3	(1)	0.0	(1)	0.0	(1)	0.0	(1)	1
Average score		(1)		(1)		(1)		(1)		(1)		(1)		(1)	1

TABLE 24
FISH CONDITION AT BUNYA

Survey	Hybrids %	score	Anomalies %	score	Total score
Aut 1993	0.0	(5)	0.0	(5)	10
Win 1993	0.0	(5)	0.0	(5)	10
Aut 1994	0.0	(5)	0.0	(5)	10
Win 1994	0.0	(5)	0.0	(5)	10
Average score		(5)		(5)	10

TABLE 25
TOTAL SCORE, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR RUNDU

Survey	Richness	Pollution	Habitat	Trophic	Abundance	Condition	Total score
Aut 1993	3	5	11	16	1	10	46
Win 1993	3	3	7	16	1	10	40
Spr 1993	3	5	7	12	1	10	38
Aut 1994	3	5	7	14	1	10	40
Win 1994	3	5	7	14	1	10	40
Average score	3	4.6	8.2	14.4	1	10	40.8

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Richness vs. total score	Values constant						p _ 0.05	Accept
Pollution vs. total score	37.50	0.75	5	0.22	0.05	0.391	p ≥ 0.05	Accept
Habitat vs. total score	28.13	1.63	5	0.96	0.92	5.879	p ≤ 0.005	Reject
Trophic level vs. total score	22.29	·1.29	5	0.71	0.50	1.739	p ≥ 0.05	Accept
Abundance vs. total score	Values constant						p ≥ 0.05	Accept
Condition vs. total score	Values constant						p ≥ 0.05	Accept

Rundu with a correspondingly large number of specialised feeders. A high percentage of piscivores was sampled during the autumn 1993 survey (Table 27). All the metrics contributed evenly to the trophic score at Rundu (Table 27).

Fish abundance at Rundu is extremely low especially in the larger mesh sizes where virtually no fish was sampled (Table 28). The smaller meshes did sample some individuals especially the 35 mm during the autumn 1993 and spring 1993 surveys.

Ectocysts were recorded from some fish at Rundu. The overall condition of the fish, however, was good (Table 29).

TABLE 26
HABITAT ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR RUNDU

Survey	Rheophilic % score	Vegetation % score	Benthic % score	Total score
Aut 1993	20.0 (5)	65.0 (5)	9.9 (1)	11
Win 1993	3.5 (1)	63.2 (5)	2.7 (1)	7
Spr 1993	4.1 (1)	56.7 (5)	8.8 (1)	7
Aut 1994	9.5 (1)	67.8 (5)	1.4 (1)	7
Win 94	1.2 (1)	90.8 (5)	0.8 (1)	7
Average score	(1.8)	(5)	(1)	7.8

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Rheophilic vs. habitat score	6.00	1.00	5	1.00	1.00		$p \leq 0.001$	Reject
Vegetation vs. habitat score	Values constant						$p \geq 0.05$	Accept
Benthic vs. habitat score	Values constant						$p \geq 0.05$	Accept
Rheophilic vs. vegetation	72.89	-0.55	5	-0.32	0.10	0.584	$p \geq 0.05$	Accept
Rheophilic vs. benthic	2.10	0.34	5	0.60	0.36	1.299	$p \geq 0.05$	Accept
Vegetation vs. benthic	19.05	-0.21	5	-0.63	0.40	1.409	$p \geq 0.05$	Accept

TABLE 27
TROPHIC LEVEL ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR RUNDU

Survey	Piscivores % score	Invertivores % score	Herbivores % score	Omnivores % score	Total score
Aut 1993	13.5 (5)	23.4 (3)	38.5 (5)	22.6 (3)	16
Win 1993	3.5 (3)	65.1 (5)	18.2 (3)	12.8 (5)	16
Spr 1993	4.1 (3)	49.7 (3)	12.9 (3)	21.1 (3)	12
Aut 1994	4.3 (3)	78.4 (5)	6.3 (1)	11.7 (5)	14
Win 1994	1.2 (1)	65.6 (5)	28.0 (3)	5.2 (5)	14
Average score	(3)	(4.2)	(3)	(4.2)	14.4

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Piscivores vs. trophic score	12.90	0.50	5	0.42	0.18	0.803	$p \geq 0.05$	Accept
Invertivores vs. trophic score	13.00	0.33	5	0.22	0.05	0.391	$p \geq 0.05$	Accept
Herbivores vs. trophic score	12.90	0.50	5	0.42	0.18	0.803	$p \geq 0.05$	Accept
Omnivores vs. trophic score	13.00	0.33	5	0.22	0.05	0.391	$p \geq 0.05$	Accept
Piscivores vs. invertivores	76.48	-3.77	5	-0.85	0.72	2.782	$p \geq 0.05$	Accept
Piscivores vs. herbivores	12.23	1.61	5	0.60	0.36	1.299	$p \geq 0.05$	Accept
Piscivores vs. omnivores	8.60	1.14	5	0.75	0.56	1.958	$p \geq 0.05$	Accept
Invertivores vs. herbivores	46.38	-0.45	5	-0.75	0.56	1.958	$p \geq 0.05$	Accept
Invertivores vs. omnivores	29.71	-0.27	5	-0.78	0.61	2.163	$p \geq 0.05$	Accept
Herbivores vs. omnivores	12.45	0.11	5	0.19	0.04	0.336	$p \geq 0.05$	Accept

TABLE 28
FISH ABUNDANCE AT RUNDU

Survey	35 mm ave. score	45 mm ave. score	57 mm ave. score	73 mm ave. score	93 mm ave. score	118 mm ave. score	150 mm	Total score
Aut 1993	8.3 (1)	3.0 (1)	0.3 (1)	0.0 (1)	0.3 (1)	0.0 (1)	0.0 (1)	1
Win 1993	3.0 (1)	0.3 (1)	0.3 (1)	0.0 (1)	0.0 (1)	0.0 (1)	0.0 (1)	1
Spr 1993	3.7 (1)	1.7 (1)	1.0 (1)	0.0 (1)	0.0 (1)	0.3 (1)	0.0 (1)	1
Aut 1994	0.3 (1)	2.3 (1)	0.0 (1)	1.0 (1)	0.0 (1)	0.0 (1)	0.0 (1)	1
Win 1994	0.5 (1)	0.5 (1)	0.0 (1)	0.5 (1)	0.0 (1)	0.0 (1)	0.0 (1)	1
Average score	(1)	(1)	(1)	(1)	(1)	(1)	(1)	1

IBI for the locality Mbambi

Mbambi had a high species richness during the study period with no pollution detected (Table 30). The total score was stable over the study period. Only the spring 1993 survey had a very low score mainly due to a low trophic value (Table 30). Although no metric influenced the total score tested against a 95% significance level, the trophic level, however, did when tested against a 90% significance level (Table 30).

The species preferring vegetated areas were present in high numbers with only the spring 1993 survey which had a low number when the water level was low (Table 31). The rheophilic species had a surprisingly low number seeing that rocky habitats with a relatively strong current were present which usually benefit these species. The benthic species were high in numbers during the spring 1993 and autumn 1994 (Table 31). A negative correlation was found between the species preferring vegetated areas and the benthic species, even when tested against a 99.8% significance level (Table 31). With a high water level the species preferring vegetation benefited, whereas during the lower water

TABLE 29
FISH CONDITION AT RUNDU

Survey	Hybrids % score	Anomalies % score	Total score
Aut 1993	0.0 (5)	0.0 (5)	10
Win 1993	0.0 (5)	0.0 (5)	10
Spr 1993	0.0 (5)	0.0 (5)	10
Aut 1994	0.0 (5)	0.2 (5)	10
Win 1994	0.0 (5)	0.0 (5)	10
Average score	(5)	(5)	10

TABLE 30
TOTAL SCORE, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR MBAMBI

Survey	Richness	Pollution	Habitat	Trophic	Abundance	Condition	Total score
Aut 1993	3	5	7	16	1	10	42
Win 1993	5	5	9	14	1	10	44
Spr 1993	3	5	7	6	1	10	32
Aut 1994	5	5	11	12	1	10	44
Win 1994	5	5	9	14	1	10	44
Average score	4.2	5	8.6	12.4	1	10	41.2

Comparison	Regression values a b n r r^2	Students T-test	Significance level	Ho
Richness vs. total score	26.50 3.50 5 0.74 0.55	1.911	p ≥ 0.05	Accept
Pollution vs. total score	Values constant		p ≥ 0.05	Accept
Habitat vs. total score	24.00 2.00 5 0.64 0.41	1.443	p ≥ 0.05	Accept
Trophic vs. total score	26.62 1.18 5 0.87 0.76	3.076	p ≥ 0.05	Accept
Abundance vs. total score	Values constant		p ≥ 0.05	Accept
Condition vs. total score	Values constant		p ≥ 0.05	Accept

TABLE 31
HABITAT ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR MBAMBI

Survey	Rheophilic % score	Vegetation % score	Benthic % score	Total score
Aut 1993	6.3 (1)	77.1 (5)	7.3 (1)	7
Win 1993	4.4 (1)	62.2 (5)	18.0 (3)	9
Spr 1993	3.2 (1)	20.0 (1)	62.2 (5)	7
Aut 1994	4.1 (1)	56.6 (5)	26.3 (5)	11
Win 1994	0.7 (1)	75.6 (5)	14.7 (3)	9
Average score	(1.0)	(4.2)	(3.4)	8.6

Comparison	Regression values a b n r r^2	Students T-test	Significance level	Ho
Rheophilic vs. habitat score	Values constant		p ≥ 0.05	Accept
Vegetation vs. habitat score	6.50 0.50 5 0.53 0.28	1.082	p ≥ 0.05	Accept
Benthic vs. habitat score	7.14 0.43 5 0.43 0.18	0.878	p ≥ 0.05	Accept
Rheophilic vs. vegetation	54.22 1.09 5 0.10 0.01	0.174	p ≥ 0.05	Accept
Rheophilic vs. benthic	34.29 -2.30 5 -0.22 0.05	0.391	p ≥ 0.05	Accept
Vegetation vs. benthic	79.30 -0.92 5 -0.99 0.98	12.125	p ≤ 0.002	Reject

periods these were replaced by the benthic species as the availability of aquatic vegetation declined.

The omnivores were the trophic level with the highest value whereas the other metrics maintained average values during the study period. The lowest trophic level score was during the spring 1993 survey, which was due to the invertivores, herbivores and omnivores (Table 32). The metric affecting the trophic level score were the omnivores (Table 32). No correlation was found between the different metrics at the trophic level.

Mbambi had a very low fish abundance in all the mesh sizes (Table 33). The smaller meshes did sample more fish than the larger meshes such as the 35 mm and the 45 mm.

The fish condition at Mbambi was good with no anomalies or hybrids recorded (Table 34).

IBI for the locality Cuito

Cuito had a low total score with the highest during the last survey (Table 35). Low scores were recorded during the two autumn surveys. These low scores were due to low trophic level values. A slightly higher fish abundance was recorded during the two winter surveys. Cuito had a high species richness with low levels of orthophosphate detected (Table 35). None of the categories had a major impact on the total score (Table 35).

TABLE 32
TROPHIC LEVEL ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR MBAMBI

Survey	Piscivores %	score	Invertivores %	score	Herbivores %	score	Omnivores %	score	Total score
Aut 1993	5.2	(3)	43.4	(3)	41.8	(5)	9.8	(5)	16
Win 1993	4.4	(3)	29.0	(3)	44.9	(5)	21.7	(3)	14
Spr 1993	3.8	(3)	22.7	(1)	2.2	(1)	71.4	(1)	6
Aut 1994	5.6	(3)	46.3	(3)	20.9	(3)	26.3	(3)	12
Win 1994	3.2	(3)	81.8	(5)	7.8	(1)	15.8	(5)	14
Average score		(3)		(3)		(3)		(3.4)	12.4

Comparison	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Piscivores vs. trophic score	Values constant						$p \geq 0.05$	Accept
Invertivores vs. trophic score	3.40	2.00	5	0.49	0.24	0.974	$p \geq 0.05$	Accept
Herbivores vs. trophic score	8.65	1.25	5	0.65	0.42	1.478	$p \geq 0.05$	Accept
Omnivores vs. trophic score	5.36	2.07	5	0.90	0.81	3.576	$p \leq 0.05$	Reject
Piscivores vs. invertivores	79.53	-7.86	5	-0.34	0.12	0.628	$p \geq 0.05$	Accept
Piscivores vs. herbivores	-25.94	11.14	5	0.57	0.32	1.197	$p \geq 0.05$	Accept
Piscivores vs. omnivores	61.34	-7.28	5	-0.29	0.08	0.524	$p \geq 0.05$	Accept
Invertivores vs. herbivores	33.62	-0.23	5	-0.29	0.08	0.524	$p \geq 0.05$	Accept
Invertivores vs. omnivores	56.22	-0.61	5	-0.57	0.32	1.197	$p \geq 0.05$	Accept
Herbivores vs. omnivores	47.76	-0.80	5	-0.63	0.40	1.409	$p \geq 0.05$	Accept

TABLE 33
FISH ABUNDANCE AT MBAMBI

Survey	35 mm ave.	score	45 mm ave.	score	57 mm ave.	score	73 mm ave.	score	93 mm ave.	score	118 mm ave.	score	150 mm ave.	score	Total score
Aut 1993	4.7	(1)	1.7	(1)	0.7	(1)	1.0	(1)	0.0	(1)	0.0	(1)	0.0	(1)	1
Win 1993	5.7	(1)	0.3	(1)	0.7	(1)	0.0	(1)	0.3	(1)	0.0	(1)	0.0	(1)	1
Spr 1993	0.3	(1)	0.7	(1)	0.0	(1)	0.0	(1)	0.0	(1)	0.0	(1)	0.0	(1)	1
Aut 1994	6.0	(1)	2.3	(1)	1.7	(1)	0.3	(1)	0.3	(1)	0.0	(1)	0.0	(1)	1
Win 1994	12.0	(1)	0.0	(1)	10.0	(3)	0.0	(1)	0.0	(1)	0.0	(1)	0.0	(1)	1
Average score		(1)		(1)		(1.4)		(1)		(1)		(1)		(1)	1

TABLE 34
FISH CONDITION AT MBAMBI

Survey	Hybrids %	score	Anomalies %	score	Total score
Aut 93	0.0	(5)	0.0	(5)	10
Win 93	0.0	(5)	0.0	(5)	10
Spr 93	0.0	(5)	0.0	(5)	10
Aut 94	0.0	(5)	0.0	(5)	10
Win 94	0.0	(5)	0.0	(5)	10
Average score		(5)		(5)	10

The habitat assessment indicated little fluctuation with season (Table 36). All the surveys showed a constantly low number of rheophilic species. The number of species preferring vegetated areas were high except during the first survey. Benthic species abundance was relatively high for the study period, except during the last survey (Table 36). This locality is usually fished which may be one reason for the few rheophilic individuals sampled. A negative correlation was found between the rheophilic species and floraphylic species (Table 36).

The trophic levels had low values except for the last survey (Table 37). Piscivores and invertivores were present in large numbers with the herbivores the lowest (Table 37). Both the invertivores and the omnivores affected the total score of the trophic assessment (Table 37). A positive correlation was present between the herbivores and invertivores, but both of these showed a negative correlation to omnivore abundance (Table 37).

Fish abundance was slightly higher than at the previously described localities. A higher abundance was found during the two winter surveys. This higher abundance is attributed to higher catches with the smaller mesh sizes, although catches with some of the larger mesh sizes were also higher (Table 38).

No anomalies or hybrids were recorded at Cuito indicating generally good conditions (Table 39).

IBI for the locality Kwetze

Kwetze had the highest total score for all the localities surveyed. The species richness was very high at Kwetze with no pollution detected at this locality (Table 40). Another important factor is the high abundance of fish. The habitat assessment and trophic level scores were slightly lower than expected. The habitat assessment had a higher score during the two winter surveys and the trophic structure during the autumn 1993 and winter 1994 (Table 40). The habitat category had the greatest affect on the total score (Table 40).

The rheophilic species and species preferring vegetated areas were not abundant while high percentages of benthic individuals were recorded from Kwetze. The habitat assessment was the lowest during the autumn 1994 survey due to the absence of rheophilic species. The vegetation metric had a major influence on the habitat assessment at Kwetze (Table 41).

A relatively high percentage of piscivores and invertivores were present while the weak areas appeared to be a low number of herbivores and a high number of omnivores (Table 42). The score for the trophic level category was very low at Kwetze. The high number of omnivores are due to the *Synodontis* spp. which are usually abundant at Kwetze. The lowest values were during the winter 1993, spring 1993 and autumn 1994 surveys (Table 42). A negative correlation was present between the piscivores and

TABLE 35
TOTAL SCORE, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR CUITO

Survey	Richness	Pollution	Habitat	Trophic	Abundance	Condition	Total score
Aut 1993	3	5	7	8	1	10	34
Win 1993	3	5	9	10	3	10	40
Aut 1994	5	5	9	6	1	10	36
Win 1994	5	5	7	14	3	10	44
Average score	4	5	8	9.5	2	10	38.5

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Richness vs. total score	22.50	1.50	4	0.39	0.15	0.150	$p \geq 0.05$	Accept
Pollution vs. total score	Values constant						$p \geq 0.05$	Accept
Habitat vs. total score	42.50	-0.50	4	-0.13	0.02	0.186	$p \geq 0.05$	Accept
Trophic level vs. total score	27.37	1.17	4	0.90	0.81	2.920	$p \geq 0.05$	Accept
Abundance vs. total score	31.50	3.50	4	0.91	0.83	3.121	$p \geq 0.05$	Accept
Condition vs. total score	Values constant						$p \geq 0.05$	Accept

TABLE 36
HABITAT ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR CUITO

Survey	Rheophilic %	Rheophilic score	Vegetation %	Vegetation score	Benthic %	Benthic score	Total score
Aut 1993	7.2	(1)	30.6	(1)	50.0	(5)	7
Win 1993	2.1	(1)	76.4	(5)	13.0	(3)	9
Aut 1994	5.3	(1)	54.3	(5)	18.1	(3)	9
Win 1994	1.5	(1)	77.1	(5)	3.6	(1)	7
Average score		(1)		(4)		(3)	8

Correlation	Regression values a	b	n	r	r^2	Students T-test	Significance level	Ho
Rheophilic vs. habitat score	Values constant						$p \geq 0.05$	Accept
Vegetation vs. habitat score	6.67	0.33	4	0.58	0.34	1.010	$p \geq 0.05$	Accept
Benthic vs. habitat score	8.00	0.00	4	0.00	0.00		$p \geq 0.05$	Accept
Rheophilic vs. vegetation	92.00	-8.05	4	-0.98	0.96	6.930	$p \leq 0.05$	Reject
Rheophilic vs. benthic	-6.11	6.78	4	0.91	0.83	3.121	$p \geq 0.05$	Accept
Vegetation vs. benthic	72.88	-0.87	4	-0.95	0.90	4.249	$p \geq 0.05$	Accept

TABLE 37
TROPHIC LEVEL ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR CUITO

Survey	Piscivores %	Piscivores score	Invertivores %	Invertivores score	Herbivores %	Herbivores score	Omnivores %	Omnivores score	Total score
Aut 1993	7.2	(3)	27.3	(3)	5.9	(1)	59.5	(1)	8
Win 1993	3.0	(3)	47.8	(3)	9.1	(1)	37.8	(3)	10
Aut 1994	6.8	(3)	22.3	(1)	5.1	(1)	63.2	(1)	6
Win 1994	3.7	(3)	63.0	(5)	11.8	(3)	19.9	(3)	14
Average score		(3)		(3)		(1.5)		(2)	9.5

Correlation	a	b	n	r	r^2	Students T-test	Significance level	Ho
Invertivores vs. trophic score	3.50	2.00	4	0.96	0.92	4.800	$p \leq 0.05$	Reject
Herbivores vs. trophic score	5.00	3.00	4	0.88	0.77	2.595	$p \geq 0.05$	Accept
Omnivores vs. trophic score	4.50	2.50	4	0.85	0.72	2.272	$p \geq 0.05$	Accept
Piscivores vs. invertivores	80.06	-7.72	4	-0.87	0.76	2.511	$p \geq 0.05$	Accept
Piscivores vs. herbivores	14.41	-1.24	4	-0.86	0.74	2.385	$p \geq 0.05$	Accept
Piscivores vs. omnivores	2.77	8.18	4	0.86	0.74	2.385	$p \geq 0.05$	Accept
Invertivores vs. herbivores	1.42	0.16	4	0.99	0.98	9.900	$p \leq 0.02$	Reject
Invertivores vs. omnivores	87.89	-1.07	4	-0.99	0.98	9.900	$p \leq 0.02$	Reject
Herbivores vs. omnivores	97.36	-6.55	4	-0.99	0.98	9.900	$p \leq 0.02$	Reject

TABLE 38
FISH ABUNDANCE AT CUITO

Survey	35 mm ave. score	45 mm ave. score	57 mm ave. score	73 mm ave. score	93 mm ave. score	118 mm ave. score	150 mm ave. score	Total score
Aut 1993	23.3 (3)	2.2 (1)	0.7 (1)	0.0 (1)	0.2 (1)	0.2 (1)	0.2 (3)	1
Win 1993	31.8 (5)	13.7 (3)	3.3 (1)	0.3 (1)	0.2 (1)	0.2 (1)	0.2 (3)	3
Aut 1994	9.7 (1)	17.3 (3)	1.3 (1)	0.7 (1)	0.2 (1)	0.3 (1)	0.0 (1)	1
Win 1994	52.0 (5)	11.0 (1)	0.0 (1)	0.0 (1)	1.0 (3)	0.0 (1)	0.0 (1)	3
Average score	(3.5)	(2)	(1)	(1)	(1.5)	(1)	(2)	2

TABLE 39
FISH CONDITION AT CUITO

Survey	Hybrids %	Hybrids score	Anomalies %	Anomalies score	Total score
Aut 1993	0.0	(5)	0.0	(5)	10
Win 1993	0.0	(5)	0.0	(5)	10
Aut 1994	0.0	(5)	0.0	(5)	10
Win 1994	0.0	(5)	0.0	(5)	10
Average score		(5)		(5)	10

TABLE 40
TOTAL SCORE, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR KWETZE

Survey	Richness	Pollution	Habitat	Trophic	Abundance	Condition	Total score
Aut 1993	3	5	7	10	5	10	40
Win 1993	5	5	11	8	5	10	44
Spr 1993	3	5	7	8	5	10	38
Aut 1994	5	5	5	8	3	10	36
Win 1994	5	5	11	12	5	10	48
Average score	4.2	5	8.2	9.2	4.6	10	41.2

Correlation	a	b	n	r	r^2	Students T-test	Significance level	Ho
Richness vs. total score	33.50	1.83	5	0.42	0.18	0.803	$p \geq 0.05$	Accept
Pollution vs. total score	Values constant						$p \geq 0.05$	Accept
Habitat vs. total score	27.30	1.69	5	0.94	0.88	4.700	$p \leq 0.02$	Reject
Trophic vs. total score	23.38	1.94	5	0.72	0.52	1.800	$p \geq 0.05$	Accept
Abundance vs. total score	26.25	3.25	5	0.60	0.36	1.299	$p \geq 0.05$	Accept
Condition vs. total score	Values constant						$p \geq 0.05$	Accept

herbivores (Table 42).

Kwetze had the highest fish abundance scores. Large specimens were also frequently sampled at this locality (Table 43).

Some ectoparasites were recorded from Kwetze during the last survey, but the overall condition of the fish was good (Table 44). The ectoparasites were recorded during the winter 1994 survey.

Conclusion

The 1988 to 1991 annual floods had two high water peaks, whereas the annual floods of 1992 to 1994 had only one peak. During the last two floods, a 5 m water level was maintained only for one month, whereas for the 1988 to 1991 floods it was maintained for at least three months. With a 5 m water level, large floodplain areas are inundated which promotes fish production (Fig. 2). The longer the period the floodplains are inundated, the higher the survival rate of the juveniles and the higher the fish production. When the floodplains are inundated only for a short period, the breeding as well as the survival of the juveniles are affected. A large water body inundating the floodplains prior to the next flood is also important for fish production. It is during this period that the breeding fish stock needs to be protected so as to maximise the fish production during the oncoming breeding season. The magnitude of the flood has declined since 1989 with the exception of 1992 (Fig. 2). The 4.1 m water level is the height of the river when it enters the floodplains which is the area where the major fish reproduction and the refuge of fry take place. Although 1992 had a very high flood level, the duration was such that fish production was probably much lower than when the duration would have been over a longer period of time.

A definite decline in the IBI total score since 1984 had taken place. This decline was tested against a 95% significance level and the finding was that the null hypothesis was rejected. It can therefore be stated that with a 99.8% certainty the IBI total score

TABLE 41
HABITAT ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR KWETZE

Survey	Rheophilic %	Rheophilic score	Vegetation %	Vegetation score	Benthic %	Benthic score	Total score
Aut 1993	10.3	(1)	17.5	(1)	62.2	(5)	7
Win 1993	1.9	(1)	51.9	(5)	39.5	(5)	11
Spr 1993	7.2	(1)	18.7	(1)	71.0	(5)	7
Aut 1994	1.5	(1)	30.4	(1)	18.5	(3)	5
Win 1994	3.2	(1)	62.7	(5)	21.8	(5)	11
Average score		(1)		(2.6)		(4.6)	8.2

Correlation	a	b	n	r	r^2	Students T-test	Significance level	Ho
Rheophilic vs. habitat score	Values constant						$p \geq 0.05$	Accept
Vegetation vs. habitat score	5.17	1.17	5	0.95	0.90	5.203	$p \leq 0.02$	Reject
Benthic vs. habitat score	-1.00	2.00	5	0.67	0.45	1.565	$p \geq 0.05$	Accept
Rheophilic vs. vegetation	54.04	-3.69	5	-0.69	0.48	1.657	$p \geq 0.05$	Accept
Rheophilic vs. benthic	17.80	5.15	5	0.83	0.69	2.582	$p \geq 0.05$	Accept
Vegetation vs. benthic	71.88	-0.81	5	-0.70	0.49	1.698	$p \geq 0.05$	Accept

TABLE 42
TROPHIC LEVEL ASSESSMENT, CORRELATION, REGRESSION VALUES AND STUDENTS T-TEST FOR KWETZE

Survey	Piscivores %	Piscivores score	Invertivores %	Invertivores score	Herbivores %	Herbivores score	Omnivores %	Omnivores score	Total score
Aut 1993	11.3	(5)	30.9	(3)	0.4	(1)	55.1	(1)	10
Win 1993	4.6	(3)	39.0	(3)	4.0	(1)	64.7	(1)	8
Spr 1993	7.3	(3)	41.3	(3)	1.5	(1)	48.5	(1)	8
Aut 1994	4.6	(3)	40.6	(3)	5.2	(1)	49.3	(1)	8
Win 1994	3.4	(3)	54.7	(5)	4.6	(1)	36.2	(3)	12
Average score		(3.4)		(3.4)		(1)		(1.4)	9.2

Correlation	a	b	n	r	r^2	Students T-test	Significance level	Ho
Piscivores vs. trophic score	7.50	0.50	5	0.25	0.06	0.447	$p \geq 0.05$	Accept
Invertivores vs. trophic score	3.25	1.75	5	0.88	0.77	3.178	$p \geq 0.05$	Accept
Herbivores vs. trophic score	Values constant						$p \geq 0.05$	Accept
Omnivores vs. trophic score	6.75	1.75	5	0.88	0.77	3.178	$p \geq 0.05$	Accept
Piscivores vs. invertivores	54.62	-2.13	5	-0.79	0.62	2.220	$p \geq 0.05$	Accept
Piscivores vs. herbivores	6.95	-0.61	5	-0.93	0.86	4.305	$p \leq 0.05$	Reject
Piscivores vs. omnivores	44.48	1.01	5	0.31	0.10	0.566	$p \geq 0.05$	Accept
Invertivores vs. herbivores	-2.40	0.15	5	0.65	0.42	1.478	$p \geq 0.05$	Accept
Invertivores vs. omnivores	88.93	-0.92	5	-0.76	0.58	1.550	$p \geq 0.05$	Accept
Herbivores vs. omnivores	54.47	-1.18	5	-0.24	0.06	0.429	$p \geq 0.05$	Accept

will decrease with time. This means that the Okavango River (section studied) is without doubt deteriorating with the main areas of change being dwindling fish stocks followed by habitat deterioration, particularly in the open water areas. Furthermore, slight variation in the trophic level was also observed. One possible reason for the decline of the rheophilic species could be that open back waters are heavily fished by the fisherfolk by fencing off such areas with their traditional fences (masasa) made from reeds. Another factor could be that during low water periods, when the subsistence fishery is at its peak, rheophilic species are more accessible and therefore more likely to be heavily exploited. The decrease in the rheophilic species is mainly due to the decline in numbers of *M. acutidens* and *O. zambezense* and to a lesser degree *H. vittatus*. These species are likely to be adversely affected by siltation caused by soil erosion. The erosion could be attributed to the destruction of the riverine vegetation. This is further substantiated by the fact that the floraphylic species showed signs of some degradation. The disturbances of the substrate by fishing leading to increased water turbidity may also have had a similar effect and may have compounded the effect of siltation.

Although the trophic structure remained stable, slight deterioration was detected amongst the invertivores. The orthophosphate concentrations increased since 1984 (Bethune, 1991). Considering the percentages of the invertivores in Table 7, the invertivores decreased, but since the autumn 1993 survey, steadily increased until the last survey. The recent increase in invertivores detected since the 1993 survey may indicate an increase in invertebrates which could be attributed to the increase in the orthophosphate concentration. Although this may seem to be a positive factor, the increase in phosphate could lead to eutrophication. Slightly higher phosphate concentrations at Rundu are associated with the highest trophic score, probably as a result of effluent from the densely populated area. Therefore, although the overall trophic level seemed to be in a good condition, it could actually be an artificial situation where an increase in the orthophosphate concentration could be the reason for the present trophic level condition. If this is the situation, an increase in the phosphate availability is likely to be beneficial only up to the point from where a further increase in phosphate could lead to eutrophication, with catastrophic results on the fish fauna.

Fish abundance, as mentioned, has decreased since 1984. Welcomme and Hagborg (1977) showed that catch and mean biomass decreases over a 4- to 5-year period after a fishery has started and usually stabilizes thereafter at a lower level. Should the decrease continue, the fish may be fished out and disappear. The slight habitat degradation which was detected through the IBI analysis may have influenced the fish abundance, but it is suspected that overfishing by the artisanal fishers is the main reason behind the current perceived lack of fish. As was indicated, the tendency is for the long-lived species to be replaced by the shorter-lived species. This was also found by Christie (1968) in the North American Great Lakes and Turner (1977) for Lake Malawi. Lowe-McConnell (1977) showed that k-selected species are replaced by r-selected species when a population is over-exploited. The biomass therefore may have remained constant although the species composition of catches changed. If however, the biomass also decreases with continued over-exploitation, the fish may be fished out and fish may disappear, especially from the heavily fished parts of the system. The mass per unit effort data of gill nets recorded by Van Zyl (1992) seem to indicate that the biomass has been on the decrease since 1989. As water levels also influence the CPUE and MPUE data, a longer period of time will however be needed to verify this.

From the IBI calculation results for the seven localities, several factors came to light. From the species richness category it is inferred that degradation of the environment has taken place at several localities. A slight increase in orthophosphate concentration at Musese and Rundu is inferred. In general, however, it does not seem to be a serious threat at present. The detection of slight increases in phosphate concentrations at the two localities is an indication that pollution may have to be closely monitored in future.

The abundance of fish at Kwetze, where no fishing is allowed, is in contrast with the situation at the other localities, and may

TABLE 43
FISH ABUNDANCE AT KWETZE

Survey	35 mm ave. score	45 mm ave. score	57 mm ave. score	73 mm ave. score	93 mm ave. score	118 mm ave. score	150 mm ave. score	Total score
Aut 1993	26.3 (3)	33.8 (5)	6.0 (3)	2.2 (1)	3.0 (3)	0.2 (1)	0.8 (5)	5
Win 1993	25.2 (3)	14.7 (3)	14.3 (3)	4.0 (3)	2.5 (3)	0.7 (3)	0.7 (3)	5
Spr 1993	49.3 (5)	12.2 (3)	4.5 (1)	3.3 (3)	1.2 (3)	2.5 (5)	0.5 (3)	5
Aut 1994	14.7 (3)	3.7 (1)	7.7 (3)	6.7 (5)	1.3 (3)	0.3 (1)	0.3 (3)	3
Win 1994	29.3 (3)	31.7 (5)	18.0 (5)	6.0 (3)	4.0 (5)	0.3 (1)	1.3 (5)	5
Average score	(3.4)	(3.4)	(3)	(3)	(3.4)	(2.2)	(3.8)	4.6

TABLE 44
FISH CONDITION AT KWETZE

Survey	Hybrids %	Hybrids score	Anomalies %	Anomalies score	Total score
Aut 1993	0.0	(5)	0.0	(5)	10
Win 1993	0.0	(5)	0.0	(5)	10
Spr 1993	0.0	(5)	0.0	(5)	10
Aut 1994	0.0	(5)	0.0	(5)	10
Win 1994	0.0	(5)	0.2	(5)	10
Average score		(5)		(5)	10

reflect the effect of fishing on the fish resource in the Okavango River. Furthermore the high IBI total score at Kwetze is a further indication of the value of closed and protected areas for the fish resource as well as for the ecosystem as a whole. These protected areas are also important for research purposes as they can be used as control areas for future comparisons with areas which are subject to the subsistence fishery.

It is concluded that although the river is still in a fairly good condition, fish stocks have declined since 1984.

The combination of categories, each with its metrics, was found to be crucial in determining the biological integrity of the Okavango River. The fact that several localities along the river were included in the IBI, ensured unbiased results.

The index applied in this study was found to be suitable to monitor the biological integrity of the Okavango River over the long term. It is, however, possible that this index may be adjusted in future to accommodate new factors arising from this dynamic and complex river system.

Recommendations

To reverse or mitigate the observed negative trends, the following management measures are recommended for implementation:

- Restrictions on the use of non-traditional gear:
  - The gill net mesh sizes should be specified
  - The number and length of the nets must be controlled
  - The use of fish poisons to be forbidden
  - The use of explosives to be forbidden
  - No drag nets should be allowed.
- The erection of any structure over more than half the width of any stream or water body to be forbidden.
- Overgrazing of the water edge or floodplains by livestock to be controlled.
- Subsistence fishery should be kept to a minimum during low water periods as the fish stock during that period is the reproductive potential for the following year. During the high-water periods fishing could be more intense so as to replace the high natural mortality of the juveniles by fishing mortality.
- Closed areas, if practical, should be proclaimed as this was proven to benefit the fish resource (for example Kwetze).
- Negotiations with the Angolan government are important to ensure that these measures are also enforced on the Angolan side.
- Education is probably the best method to implement these measures.

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