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EXECUTIVE SUMMARY

1. A 12-month field characterization study of the fisheries and fish biodiversity of the Kavango and Caprivi Provinces, Namibia was initiated in January 1992 by the University of Maryland Eastern Shore (UMES) in cooperation with the University of Namibia (UNAM) and the Namibia Ministry of Fisheries and Marine Resources (NMFMR) under the USAID-funded Historically Black Colleges and Universities (HBCU) Research Grant Program (DAN-5053-G-00-1048-00).

2. The primary objective of the investigation was to categorize aspects of the fish resources of the Kavango and Caprivi Provinces. Sub-objectives were to (a) initiate a formal collaborative research effort under an institutional linkage agreement between the University of Maryland System (UMS) and UNAM; (b) assist in the capacity building of environmental science programs at UNAM and UMES; and (c) nurture the developing relationship between UNAM, UMES and NMFMR, to facilitate future cooperative programs to address the research and management needs on Namibia's inland waters. All of these objectives and sub-objectives were achieved.

3. Eighty fish collections were taken from the Kavango River, Namibia in 1992 yielding 62 species of 33 genera in 14 families. This investigation was the first to address seasonality in the fish biodiversity of the Kavango River, and provides a strong baseline for continued studies by the NMFMR. The cichlid group ("tilapia") dominated total relative abundance, comprising nearly half of all specimens collected for the entire study. Relative abundance data per sampling period for three zones along the Kavango River are interpreted by season, and distribution maps for 62 species are presented. The first key to the fish species of Namibia resulted from the project. Recommendations are made concerning future research needs, particularly emphasizing syn- and aut- ecological relationships of the fish community to the annual flooding cycle, which is recognized as the primary driver of productivity in the floodplain system.

4. Two exotic fish species are reported from a permanent fontein located in the Omuramba Omatako sub-drainage of the Kavango River. Astyanax orthodus is a characin native to Columbia, South America, while Trichogaster trichopterus is a belontid from southeast Asia; this is the first report of either species in African waters. A key is provided to distinguish these species from related species indigenous to Namibia. Recommendations are given for the establishment of a National protocol for (a) imported fishes to Namibia, including prospective aquaculture species, and (b) for the standardization of definitions concerning exotic and transplanted fishes.

5. The fish fauna biodiversity information obtained for the Kavango River on a seasonal and temporal scale is used to develop the conceptual basis of an Index of Biological Integrity (IBI),

representing the first employment of this methodology in African waters. Instream biological criteria are a routine component of water quality monitoring programs in developed countries, but have been seldom utilized in less developed countries. The IBI method has received favorable use over the past 10 years in North America. The IBI relies on the structural and functional components of the fish community as a reflection of overall aquatic system "health". A rationale is presented for the metrics proposed, and limitations of the IBI procedure are recognized.

6. Preliminary estimates of asymptotic length (L_{∞}), the growth coefficient (K) and total mortality (Z) are presented for two species targeted in the Kavango River fishery. These estimates were determined using the length-frequency based software package ELEFAN. Limitations of the procedure and future data needs are recognized.

7. The first-ever attempt to evaluate the nutritional value of the Kavango River fishery is presented. Specimens of 15 representative species of the subsistence fishery were analyzed for gross energy content (MJ/kg), percent protein (%) and percent ether-soluble fats (%). These data are preliminary and not statistically robust, although unique. Procedures for future nutritional studies are recommended, which are aimed toward a sound management philosophy to ensure the sustainment of the subsistence fishery.

8. An additional 19 collections were made at 16 localities in the Eastern Caprivi Province, concentrating on biodiversity. These collections yielded 59 species and 3494 specimens. Several recommendations were presented, the foremost being the establishment of an international "center" for floodplain studies at Katima Mulilo, near the common border of Namibia, Botswana, Zambia and Zimbabwe at the Zambezi/Chobe river confluence.

9. The prospects of aquaculture in Namibia are reviewed. A low technology demonstration project aimed toward supplementing subsistence catch on a seasonal basis is recommended. The project should also have a function of training UNAM students, and be operated in cooperation with the NMFMR.

10. It was recognized from the study that a priority need of the region is to characterize the socio-cultural components of individual fisheries. All the ethnic groups of the Kavango and Caprivi Provinces are historically linked to the regional fisheries. However, virtually no data are available on the socio-cultural heritage of the fisheries, and the traditional vs. contemporary roles of women in the fishery.

11. A severe need is capacity building at the University of Namibia in the marine and environmental sciences, including fisheries. The Republic has been recognized by the 10-member Southern African Development Community (SADC) as the lead country

for training and research in the fisheries sector, with UNAM

recognized as the principle institution for advanced tertiary training. However, UNAM's physical plant is lacking, equipment is minimal and there is a void of persons specifically trained in fisheries and the marine sciences, which represents a key pillar to the Republic's economy.

12. As at UNAM, there is a similar need for capacity building in the Freshwater Fisheries Institute of the NMFMR. The facility has two dedicated permanent staff, but is located 800-1500 km away from regional fisheries, thus prohibiting routine data gathering efforts and management. The addition of one staff person in the Eastern Caprivi appears mandatory, while other staff should be reviewed for the Kavango, Owambo, and Kunene provinces. Specific needs at the FFI include a limnologist (specializing in primary productivity and water quality analyses), benthic ecologist and reservoir biologist.

13. The study resulted in one UMES student receiving a M.S. degree, and UNAM personnel receiving advanced training.

14. Five manuscripts for publication have been identified as potentially arising from the project, including: (1) Seasonal relationships of the fishes of the Kavango River to the flooding cycle; (2) Development of the conceptual basis of an index of Biotic Integrity (IBI) for the Kavango River; (3) A preliminary key to the fishes of Namibia; (4) A description of new exotic fishes from Namibia, with recommendations for the establishment of a National protocol for introduced aquatic organisms; and (5) Gear influence on the estimate of population parameters using ELEFAN.

CHAPTER I. INTRODUCTION

Namibia is Africa's newest nation, having gained its independence from South Africa on 21 March 1990. The Republic has often been referred to as the "Gem of Africa" since it has abundant natural resources including diamonds, gold, uranium and oil (Miller 1990). Namibia shares its boundaries with Angola, Botswana, South Africa, Zambia and Zimbabwe. The Republic has one of the lowest population densities (1.8 persons/km^2) in the world with 1.5 million inhabitants and a surface area of 823,144 km^2 (Anonymous 1992a). Namibia's size is larger than Texas, with a 1,600-km long shoreline along the southeast Atlantic Ocean.

Namibia, situated along the Tropic of Capricorn, is an arid country with an average annual rainfall varying from <10 cm in the south to about 65 cm in the northeast; however, these figures can be misleading since climatic conditions may result in no rainfall from year to year in a significant portion of the country. Over 80% of the Republic's population of 1.5 million people live in the more water rich areas of the north, bordering Angola, Zambia and Botswana (Adams et al. 1990).

The gross domestic product (GDP) of about $2,000 million, with an average per capita income of approximately US $1,300 per annum makes Namibia one of the richest countries in sub-Saharan Africa; however, the distribution of income is uneven, being biased for the urban populations. The majority of the population averages US $750 per annum, and those dependent upon subsistence agriculture US $85

(World Bank 1989). Approximately 85% of the population of the Kavango and Caprivi provinces in north-eastern Namibia, which this proposal addresses, lives at the subsistence level. Thus, it is recognized that the regional fresh waters of the north represent an important means of supplementing income and protein requirements (Sandlund & Tvedten 1992). The Namibian Department of Economic Affairs (NDEA 1990) estimated that the fishery resources of the Kavango and Chobe provinces have a potential exploitation level over 28,000 tons per year; present exploitation is estimated at <10% of potential catch. Thus, upgrading the fishery will have immediate local and regional benefits.

Fisheries research and management activities within the Republic fall under the administration of the Ministry of Fisheries and Marine Resources (NMFMR). However, the ministry's line functions are dominated by the vast marine resources, which have an estimated value of US $1 billion annually (World Bank 1989). The Freshwater Fisheries Institute has two scientists, plus a modest support staff, that has the responsibility for all freshwater fisheries research and management activities in the country. These individuals are located over 800 km away from the Kavango River, and 1,200 km away from the Eastern Caprivi Province. The Ministry of Wildlife, Conservation and Tourism and the Ministry of Agriculture, Water and Rural Development each have sub-programs that consider freshwater aquatic resources and wetlands, but have no responsibility for fishery resource assessment and management.

Namibia became the tenth member of the regional Southern

African Development Community (SADC) with independence. Other members include Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia and Zimbabwe. SADC countries are all "front line" nations, striving for economic reform and independence from the Republic of South Africa. Importantly, SADC agreed by unanimous decision in 1992 that Namibia would be the lead country in developing research and training initiatives in the marine environmental sciences for the community, led by NMFMR. It was also agreed that the University of Namibia (UNAM) will serve as the principle institution for tertiary education and research. This has resulted thus far in two important missions to Namibia in 1992-93: (1) the Norwegian Agency for Development Cooperation (NORAD) intends to fund a 5-year post-graduate training program at UNAM for SADC fisheries administrators commencing in 1994, and (2) UNESCO has sponsored a fact-finding mission to Namibia to discuss the development of research and educational opportunities in the marine environmental sciences. In each case, freshwater fisheries was specifically tabled as a sub-discipline for inclusion.

The field component of this research effort was initiated in January 1992 with the intention of describing the fisheries of the Kavango and Caprivi provinces. The objectives of this investigation were directly responsive to the concerns voiced in the **WORLD CONSERVATION STRATEGY** (Anonymous 1980), a joint publication by the International Union for Conservation of Nature and Natural Resources (IUCN), United Nations Environment Programme (UNEP) and World Wildlife Fund (WWF), which stressed the critical

need to balance the protection of the natural environment with the equally vital need to raise the standard of living of the world's poor. The aim of the WORLD CONSERVATION STRATEGY was to help advance the achievement of sustainable development through the conservation of living resources via (1) maintenance of essential ecological processes and life-support systems; (2) preservation of genetic diversity; and (3) insured sustainable use of species and ecosystems.

Importantly, the **WORLD CONSERVATION STRATEGY** recognized that conservation of resources and development are not incompatible, but indeed they are mutually dependent. The **WORLD CONSERVATION STRATEGY** noted that unless development is guided by ecological, as well as by social, cultural and ethical considerations, it will continue to fail to meet or sustain its desired economic objectives.

This report is structured into 10 chapters, entitled: **CHAPTER I.** INTRODUCTION (above); **CHAPTER II.** BIODIVERSITY OF THE KAVANGO RIVER; **CHAPTER III.** DESCRIPTION OF NEW EXOTIC FISHES FROM NAMIBIA; **CHAPTER IV.** DEVELOPMENT OF THE CONCEPTUAL BASIS OF AN INDEX OF BIOTIC INTEGRITY (IBI) FOR THE KAVANGO RIVER; **CHAPTER V.** DESCRIPTION OF THE KAVANGO RIVER FISHERY; **CHAPTER VI.** BIODIVERSITY AND FISHERY OF THE CAPRIVI PROVINCE; **CHAPTER VII.** AQUACULTURE; **CHAPTER VIII.** SUMMARY AND RECOMMENDATIONS; **CHAPTER IX.** ACKNOWLEDGEMENTS; and **CHAPTER X** is a consolidated REFERENCES section. Recommendations regarding specific aspects of the fishery are made at the end of each chapter.

CHAPTER II. BIODIVERSITY OF THE KAVANGO RIVER

INTRODUCTION

The Kavango River remains a rather pristine catchment (Fig. 1) in a western world context, with minor human impact in Namibia other than through organic enrichment and riparian zone mismanagement. Watershed development has thus far been retarded; however, with political normalization of the region, various water resource utilization schemes are being considered for the Kavango catchment by Namibia, Angola and Botswana to utilize its vast water resources, averaging $10,500 \times 10^6$ m^3 per year at the Botswana border (Baldwin 1991).

The region is a focus for drought relief aid, being within the Kalahari Desert biome (Fig. 2) with an average annual rainfall of <20 cm. Over 85% of the 150,000 Kavango people are considered subsistence wage earners, and live within 10 km of the river (Sandlund & Tvedten 1992). The Kavango people are dependent upon the river as a protein source (the fishery), for potable water supplies, bathing and livestock watering (which is viewed as "banked" wealth, not to be slaughtered except under duress). Thus, development activities which are likely to alter the productivity of the system will have a profound impact on the local populace.

Knowledge of the seasonal structure and functioning of the floodplain fishery is largely anecdotal, despite the dedicated efforts of the two NMFMR freshwater scientists, Dr. B.J. van Zyl

and C. Hay. As the NMFMR seeks solutions to manage the fishery in light of increasing demand (the population is expected to double over the next decade), it is critical to understand how seasonal flooding drives productivity in the littoral zones of the river.

Given the shifting sand substrate of the river bed, annual productivity is related to the flooding cycle. The floodplain might extend 2+ km away from the stream bed during peak flooding conditions as annual floods wax and wain. It is the temporary littoral zone which is identified by high macrophyte growth and secondary productivity. The littoral zone vegetation serves as nesting areas, feeding zones and refugia for most fish species. It appears that the reproductive strategies of some fishes are in advance of flooding (e.g., cichlids) while other species (e.g., many cyprinids) are in sync with flooding and the stimulation of littoral zone plant growth. The vegetation itself acts as a mineral and nutrient sink, with Kavango water having minimal levels of conductivity (e.g., <40 umhos) and nutrients during flooding conditions.

Considering the above, knowledge of the status of the ichthyofauna and its seasonal variability is an exceptionally important baseline data requirement. This is especially so (Breen et al. 1984) given the current regional planning to change or interrupt the natural processes of this important floodplain river system. This chapter addresses that need.

Historical aspects

The fishes of the Kavango River have been studied by a number of investigators, dating back to pioneering work by Castelnau, who in 1861 described the first specimens from the Okavango Swamp region of Lake Ngami collected by Daviaud (Jubb and Gaigher 1971). Woosnam lead the next expedition to the watercourses of Ngamiland (Botswana) in 1909, collecting from all the Okavango Delta lakes and tributaries he encountered (Ogilvie-Grant 1912), while the specimens he obtained were described and documented by Boulenger (1911). Fowler (1931, 1935) described the specimens collected during the following 20 years by the Kirkham and Stigand, de Schauensee, and Vernay-Lang expeditions into the Okavango basin.

The first account of the upper Kavango River (Cubango R. in Angola) fish fauna was given by Pellegrin (1936), and three years later the first collection of fishes from the Kavango River in South West Africa (Namibia) was obtained by Eedes (Jubb and Gaigher 1971). The specimens from this latter collection were examined and described by Barnard (1948), who drew attention to taxonomic anomalies of the fishes of this region (Jubb and Gaigher 1971).

It was 1963 before rigorous collecting was carried out in the Okavango region when Maar sampled extensively throughout northern Botswana, defining type localities of previously obtained specimens and detailing the state of fisheries in Ngamiland. Prompted by unsolved taxonomic problems, Gaigher set out in 1969 to collect the Lower Okavango drainage, revisiting the sites of the early expeditions. Synthesis of Gaigher's collections and a

comprehensive study of Maar's specimens by Jubb culminated in the first checklist of the fishes of Botswana, with a key to the species (Jubb and Gaigher 1971). Although not mentioned in Jubb and Gaigher's (1971) review of early Okavango drainage fish collections, Jubb's (1967) general account of freshwater fishes of southern Africa and Poll's (1967) tome of the freshwater fishes of Angola were also important contributions (Skelton et al. 1985).

The works of Bell-Cross (1968, 1972, 1976) and Bowmaker et al. (1978) were central to the Upper Zambezi River system, but their checklists of fishes were inclusive of Okavango drainage species. Skelton et al. (1985) reported that several collecting expeditions to the Okavango system took place from 1957-73, but the findings were either never published (e.g., Skelton et al. 1983), or were distributed as investigational reports (e.g., Merron & Bruton 1985). Skelton and Merron (1984, 1985, 1987) collected the Kavango River in Namibia, investigating potential impacts of the proposed Eastern National Water Carrier (ENWC) system, while Minshull (1985) considered the ecology of Okavango Delta-dwelling fish. Skelton et al. (1985) presented an annotated checklist of the fishes from the Okavango drainage in Angola, Namibia and Botswana, inclusive of a thorough taxonomic review of the species. Van der Waal (1987, 1991) surveyed the Kavango River in Namibia, described the traditional fishery and emphasized the exploitation of the fishery resources. Van Zyl (1992) and van Zyl and Hay (unpublished) have monitored the fishery on annual basis since 1987 (pers. comm.). P.H. Skelton (<u>in press</u>) will soon publish a tome on the freshwater

fishes of southern Africa, including Namibia.

The ichthyofauna of the Namibia and Botswana portion of the Kavango drainage is well documented (Skelton et al. 1985), however the Angolan portion of the catchment is only modestly known, primarily through the works of Poll (1967). Gabie (1965), Bell-Cross (1965) and Hay and van Zyl (in press) theorized that the freshwater fishes of southern Africa are stemmed from ancestry that occupied the central tropical regions of the continent, dispersing to the subcontinent in a series of invasions. Bell-Cross (1967) suggested that during the late Tertiary, the Okavango or Greater Ngami basin drained all the rivers of western and central southern Africa, with the entire basin deriving its fish faunas from the Congo basin. Support of this is evidenced in the closely allied representatives of the southern Congo River system and the Okavango drainage complex (Poll 1967). However, intra-continental biogeographical perspectives involving the historical fish faunas of southern Africa are regarded as suspect (Greenwood 1983), as disjunct distribution patterns and sketchy phylogenetic relationships between species make it difficult to trace their initial entrance and consequent dispersion into the river systems of the sub-continent (Gaigher and Pott 1973).

Former drainage connections between river systems facilitated the invasions in southern Africa (Skelton 1985); particular processes involved were perhaps river capture, river diversion, watershed exchange, reversal of flow due to continental tilting and connections between different systems in flood during pluvial

periods (Gaigher and Pott 1973). The earliest invasions may have occurred in the mid-Pliocene, providing the ancestral stock for the fishes now found in southern Cape rivers of South Africa (Jubb 1964; Jubb and Farquharson 1965). These first invaders penetrated when the Orange River was linked to the Kavango River (Jubb and Farquharson 1965), with subsequent invasions resulting in competitive displacement of the existing species from earlier invasions (Skelton 1985). This latter point is well-taken considering the poor representation of the Kavango fauna in the Orange and South Cape Rivers (Gaigher and Pott 1973).

Explanation of present day discontinuous or disjunct species distributions may be the presence of obstacles or barriers during periods of former drainage connections (Gaigher and Pott 1973), with such barriers being either physical (Crass 1962), ecological (Jackson 1962) or behavioral (Bell-Cross 1965) in nature. Gaigher and Pott (1973) list other possible causes of discontinuity; retreat due to competition, extermination by predation and catastrophic destruction of fish-life in intermediate areas. Historic climate change yielding adverse conditions (low temperatures, and aridity) is also considered to provide explanation for distribution gaps and isolation of species in southern Africa (Skelton 1985). A reduction of mean annual temperature of 4 to 7.2° C over Africa is suggested, perhaps paralleling the last glaciation in the northern hemisphere (Stuckenburg 1969). The consequences of this temperature reduction would hinder the distribution of tropical species while extending

the ranges of temperate species (Gaigher and Pott 1973).

Study area

The Kavango River originates in the highlands of Central Angola where it is known as the Cubango before it becomes the border between Namibia and Angola for 415 km. The river generally flows in a southeasterly direction through Namibia for another 35 km before it reaches the Botswana border where it eventually terminates into the 15,000 km^2 Okavango Delta and its swamps (Fig. 1). The Kavango River floods seasonally, normally from December to June, with a general maximum in February to April. Approximately 375 km of the middle portion of the Kavango River in Namibia is unique in that it has the lowest gradient in the drainage (Fig. 3), with extensive floodplains occurring north into Angola.

From the northern border within Namibia, the Kavango River can be divided into four zones based on the occurrence of extended floodplain and associated habitats (Fig. 4). Zone 1, from Katwitwi to Kasivi, is characterized by very little floodplain development and mostly shallow water environments with sand and or rock substrates. Small rapids are scattered throughout, with prevalent submergent vegetation and aquatic weed beds in a rather well defined river bed. In Zone 2, from Kasivi to Mbambi, the floodplain becomes well developed, extending at times to over 5 km in breadth (Sandlund and Tvedten 1992). The main river is wider here, seasonally broadening into innumerable inferior channels, back bays and oxbow ponds (Fig. 5). The substrate in the main

river is predominantly sand with the occasional occurrence of rock outcroppings. The back bays and oxbow ponds occur as a rule over submerged pasture-land. Zone 3, from Mbambi to Popa Falls, finds the floodplain diminished, with wooded islands encircled by narrower channels. Large boulder and gravel substrate associated with rapids are common in this area, which is rather analogous to the Fall Line between the Piedmont and Coastal Plain physiographic provinces of the eastern United States (see Hocutt & Wiley 1986). Zone 4 below Popa Falls, including the Mahango Game Reserve, is characterized by well established reed and papyrus beds that are permanently inundated and considered as the uppermost "panhandle" portion of the Okavango Delta proper (van der Waal 1987).

METHODS AND MATERIALS

Fish community samples were taken from 80 localities during five collecting periods along the Kavango River in 1992. A high but increasing flood stage was observed in February which peaked before May and receded until December, 1992 when the river began rising again. Sampling localities were initially chosen based on accessibility, with emphasis given to re-sampling the sites within each collecting period (see Table 1 for a list of collecting stations and Figure 6 for a distribution map of sampling localities). However, this proved at times to be impossible given that the character of the river and its floodplain varied throughout the year. Exact locations of longitude and latitude were triangulated with a Magellan 1000-Plus Global Positioning

Satellite (GPS) hand-held unit.

Fish sample collections were obtained using a variety of gears, dependent upon water levels and habitats encountered. The primary objective was to obtain a representative sample (Hocutt 1978) of the fish communities within the localized habitats, with each collection terminating only after no new species were found with continued use of gear(s) employed.

In backwater areas, with slow to stagnant flow conditions and dense aquatic vegetation, the ichthyocide rotenone was the primary collecting tool. The technique normally involved mixing powdered rotenone with water and a small amount of dish soap to enhance the solubility of the powder. The mixture was then broadcasted into the habitats, and after a few moments the stunned fish would be netted after they began to surface. During minimal flow conditions and if deemed appropriate, a seine net would sometimes be placed at a defined point to collect any fishes drifting with the current.

In shallow water flowing habitats, especially with gravel and sand substrates, a 3 x 1.5 m seine net with 5-mm mesh was the collecting gear of choice. The seine would be dragged along the substrate, vigorously poked into weed beds, or plunged and swept over fish visible through the clear water. In the case of shallow flowing waters with gravel and submerged aquatic vegetation, the "cast and kick" seining method was used. Dubbed the "Yankee-doodle dance" by an amused and spectating P. H. Skelton, this technique calls for casting the net in a downstream direction, anchoring it in the substrate, and thoroughly disturbing the gravel and plant

material by kicking and churning up the bottom. Often times if called for, seining was done to supplement a rotenone collection, and vice versa.

Attempts were made to use a Coffelt 12-v gas-powered backpack, a Smith-Root model VII 24-v battery-charged backpack, and a Coffelt 700-watt boat/shore-mounted electrofishing units to sample fishes. All these units were found to be ineffective due to the low conductivity encountered, with exceptions being in higher flow, rocky habitats. The normal protocol with the backpack unit was to shock in an upstream direction probing the substrate and aquatic vegetation with the meshed end of the anode pole, with the dip netter following close behind collecting stunted fish.

Other fish collecting methods also were used occasionally such as wire-mesh minnow traps employed at camp site collecting localities. In the evening, four traps would be baited with bread, tethered to shoreline vegetation, casted out and retrieved the following morning. An experimental gill net with four different mesh sizes was used sparingly to collect larger rheophilic fish; it was set either overnight or for several hours before retrieval. A 30 x 1.5 m bag seine with 70-mm mesh was occasionally used in turbid backwaters. Some collections were supplemented by using a large beach seine (5 x 25′ with 5 x 5′ bag of .25" mesh), while simple dip netting was employed under other occasions. Angling, the remaining sampling method used, was selective for the more predacious species, such as tigerfish (Hydrocynus vittatus). Light to medium weight spin-casting rigs or fresh-cut bait were used

either from boat or shore.

Fishes were preserved in 10% formalin immediately after collecting and stored at least ten days for proper hardening. The samples were then rinsed with freshwater for several days before transfer to 70% ethyl alcohol. All specimens were donated to the State Museum of Windhoek for cataloguing and permanent storage.

Seasonal data interpretations presented below are based exclusively on relative abundance, i.e., numbers of each taxa collected. Data are presented in an annotated fashion, with parallel discussion of relevant literature emphasizing the works of Bell-Cross and Minshull (1988) and van der Waal and Skelton (1987). Species are ranked on the basis of their relative abundance; however it is understood that fish collecting is a qualitative and gear-selective procedure that might mask the conclusions presented. The basis of the ranking criteria used to describe the commonness of species collected is presented at the bottom of Table 2.

Appendix A is a tabulation of common and scientific names of species collected; Appendix B lists gear used and number of individuals collected per site; and Appendix C is an atlas of distributional maps for each species collected. Fish were identified using a variety of regional keys (e.g., Jubb & Gaigher 1971; Jubb 1967; Poll 1967; Skelton et al. 1985; Bell-Cross & Minshull 1988); these references in addition to personal observations were employed to draft the first preliminary key of the freshwater fishes of Namibia (Appendix D).

RESULTS

A total of 80 fish community samples were taken along the Kavango River, from Katwitwi downstream to the Mahango Game Reserve at the border of Botswana. Sampling was conducted on a seasonal basis with 5 sampling periods throughout 1992. A total of 14 families, 33 genera and 62 species were collected. Table 2 lists percent occurrence and percent of total catch for all fish species collected during the study. Table 3 shows percent of total catch per zone (upper, floodplain, lower) for each family or group of fishes, and Table 4 presents numbers of individuals collected per zone for each sampling period. The following discussion is structured such that each family of fishes (or group) is addressed in descending order of total relative abundance.

Annotated discussion of indigenous species

Cichlidae.- As a family the cichlids dominated the habitats surveyed, comprising almost 50% of total numbers sampled in 1992. The shallow and secure conditions of the floodplain refugia were shown to harbor an abundance of these fishes, as members of this family made up over half of the total numbers collected in zone 2. The upstream areas of the Kavango also harbored large numbers of cichlids, but further downstream when the river narrowed and as their seemingly preferred habitats became scarce, the cichlids dwindled in both occurrence and abundance. Seasonally, this group was most abundant during the February (as juveniles) and November

(as young of year) sampling periods (67.2% and 50.5% of total, respectively). Since many cichlids are known to migrate to and utilize floodplains for either spawning, nursery, refugia or ranging movements (Bell-Cross and Minshull 1988), it is not surprising to find such a preponderance of these fish during relatively high flood periods. Conversely, the highest seasonal abundance on the lower Kavango River occurred during the June sampling period (31.8%), when water levels were commencing to recede.

Six genera and 14 species of cichlids were collected from the Kavango River, one of which proved to be the most common and most abundant species of the entire biota. The southern mouthbrooder, Pseudocrenilabrus philander, accounted for over 12% of total yearly catch. This small ubiquitous cichlid was found during each sampling period per zone, and it represented over 14% of total catch in zones 1 and 2. Pseudocrenilabrus philander, an extremely common species in the rivers of Zimbabwe (Bell-Cross and Minshull 1988), certainly thrives in the flooded habitats of the Kavango River as well. With a relatively lower percent abundance from zone 3 (7%), this fish decidedly prefers calmer, vegetated shallow-water environments. The redbreast tilapia (Tilapia rendalli) and the banded tilapia (T. sparrmanii) were the next two most abundant species. In combination with P. philander, these 3 cichlids comprised almost 30% of all individuals collected for the entire year. Numerous and abundant in the river systems of Zimbabwe (Bell-Cross and Minshull 1988), T. rendalli and T. sparrmanii were

found in 80% of the samples, and were represented during all sampling periods in each zone. Like the southern mouthbrooder, these species were found in fewer numbers along zone 3, revealing their preference for slower moving water and aquatic vegetation. Although abundant in zones 1 and 2, the fewest individuals of redbreast tilapia were taken during the June and September sampling periods. This seems logical given that as floods recede and their habitats of choice are less available, T. rendalli become scarce and less abundant perhaps either due to predation or subsistence fishing. However, with T. sparrmanii, the reverse becomes apparent, with more individuals found during the June and September periods relative to the rest of the year (exception being the May sample in zone 2). Perhaps these fishes undergo seasonal habitat partitioning, with the latter out-competing the former for the limited, slow water areas. As suggested by Yamaoka (1991), cichlid species that have been regarded as sharing the same trophic requirements show slight but distinct inter-specific differences in feeding behavior, feeding sites and habitat in African Great Lakes. Little is known however, of the interrelationships between these species, as ecological studies have been scant up to date concerning African floodplain fisheries (Welcomme 1979).

Another species, the Okavango tilapia (T. ruweti) was collected and found to be much less common and more restricted in its distribution than the other two, representing less than 2.5% of total yearly catch. Tilapia ruweti was most abundant in zone 2. Bell-Cross and Minshull's (1988) observed that the Okavango tilapia

is locally or seasonally common, but is generally rare.

The Zambezi happy, Pharyngochromis acuticeps, is another common and abundant cichlid in the Kavango River. This species was a relatively significant member of the fish community, occurring in 75% of all samples and making up over 5% of total yearly catch. Although collected during all sample periods for each zone, P. acuticeps was most abundant in zones 1 and 2 like the cichlids discussed above. Much like T. rendalli, the Zambezi happy was most abundant during the higher flow periods of February and November. Known to be one of the most plentiful species in Zimbabwe (Bell-Cross and Minshull 1988), this cichlid seems to be slightly less common in the Kavango River, where it is ranked fifth in percent occurrence and sixth in total abundance from the collections in this study.

The genus Oreochromis is represented by two species in the Kavango River, Namibia: the threespot tilapia (O. andersonii) and the greenhead tilapia (O. macrochir). Of the two, O. andersonii was more common and more abundant, while O. macrochir was found to be quite scarce with only 6 individuals collected from 4 sites. Interestingly, Bell-Cross and Minshull (1988) found both species to be abundant in the Upper Zambezi system, with the latter an extremely important commercial species, second only to the tigerfish. Knowing this, the relative paucity of O. andersonii and the genuine scarcity of O. macrochir from the 1992 collections seems unusual since the Zambezi and Kavango Rivers share so many faunal attributes (Bell-Cross and Minshull 1988). The Oreochromis

species appear to be replaced in importance in the Kavango River by Tilapia species. Perhaps the planktonic/algal diet preference is less successful than in the Zambezi system. In the case of the greenhead tilapia, a very specialized feeder of a single algal group (Bell-Cross and Minshull 1988), perhaps their food of choice is simply not available. Ecologically-based research is needed to gain further understanding of the species and community level processes that regulate fish community dynamics (Welcomme 1979; Yamaoka 1991).

Six cichlid species of the genus Serranochromis were collected, with two of them somewhat prominent roles in the fish community: the nembwe (Serranochromis (S.) robustus jallae) and the purpleface largemouth (S. (S.) macrocephalus). Both of these species occurred in over half of the samples and comprised over 1% of the total yearly catch; the nembwe was represented during each sampling period from all zones. Zone 2 harbored the most individuals of the two species, with S. (S.) macrocephalus making up almost 3% of the total catch for that floodplain region of the Kavango. Bell-Cross and Minshull (1988) found these fish to be plentiful and fairly common in the Zambezi, and important to the commercial gill net fishery. Another cichlid, similar to those just mentioned, but found to be uncommon in the Kavango River, is the thinface largemouth (S. (S.) angusticeps). Most of the individuals of this species were collected during the June sampling period in zones 1 and 2, while only a single specimen was taken from zone 3. Of sporadic occurrence and few numbers, the thinface

largemouth probably does not figure prominently in Kavango River fish communities. This species, although encountered frequently in the Upper Zambezi River, is thought not to be abundant (Bell-Cross and Minshull 1988).

The remaining three Serranochromis species collected in 1992 are all of the subgenus Sargochromis: the rainbow happy (S. carlottae), the green happy (S. codringtonii) and the pink happy (S. giardi). With the exception of the uncommon green happy, these species were found so infrequently that they can be considered rare in the habitats sampled, and not one of these species were found in zone 3. S. carlottae is represented in the collections by a single individual. Despite their near absence from the Kavango River samples, Bell-Cross and Minshull (1988) state that all three are important to the commercial gill net fishery in the Upper Zambezi system. Van Zyl and Hay (pers. comm.) have collected them with gill nets, thus our efforts might have been biased by gear.

The last member of the cichlid family encountered along the Kavango is the banded jewelfish (Hemichromis elongatus). Similar as in the Upper Zambezi (Bell-Cross and Minshull 1988), H. elongatus seems to be uncommon in the Kavango with sporadic occurrences and few numbers. In contrast to most of the other cichlids, the banded jewelfish seems to prefers rocky habitats, evidenced by its presence during all sampling periods in zone 3 and its absence altogether in zone 2.

There are 3 additional species from the cichlid genus Serranochromis known from the Kavango River, Namibia but not found

in this study; S. (Sargochromis) greenwoodi, S. (Serranochromis) altus , and S. (Serranochromis) thumbergi (Skelton et al. 1985; Skelton and Merron 1987; Bell-Cross and Minshull 1988; van der Wall 1991). In the case of S. altus, it is a newly found species in the Kavango River (P.H. Skelton: pers. comm.), having been recently in the Upper Zambezi River by Winemiller & Kelso-Winemiller (1991).

Cyprinidae.- The Cyprinidae was the most speciose family (19 species) found in the study, and comprised 27.8% of total yearly catch (by numbers). The family dominated the fauna collected in zone 3. The June sample yielded the highest proportion (37.6%), coinciding with the period when cichlids were found in fewest numbers. Seemingly, there is a spatial and temporal relationship between these two most common and abundant families.

Four genera of cyprinids were collected during the study, the genus Barbus representing a large proportion of the family with 15 species. The dashtail barb (B. poechii) was the most commonly occurring and abundant member, found in over half the samples and making up over 6% of total yearly catch. The data revealed nothing regarding seasonal variability in numbers for this fish, other than it being represented in all sampling periods for each zone except the November sample in zone 1. This species is perhaps more widely distributed in the Kavango River than the Upper Zambezi, where it is considered only fairly common (Bell-Cross and Minshull 1988). The Thamalakane barb (B. thamalakanensis) is another common cyprinid, second only to B. poechii in percent occurrence among this group. Other members of this genus found to be fairly common

and thus considered to play relatively prominent roles in the fish communities include the hyphen barb (B. bifrenatus), orangefin barb (B. eutaenia), straightfin barb (B. paludinosus), and the Beira barb (B. radiatus). The hyphen barb was the most abundant cyprinid in zone 1 where it comprised over 4% of total catch, confirming its preferred habitat of clear water, bank vegetation and sandy substrate. Almost 8% of total catch within zone 3 was B. eutaenia, a fast water, rocky-substrate dweller. The straightfin barb is the most widely distributed and abundant fish in Zimbabwe (Bell-Cross and Minshull 1988), and was found in highest numbers in zone 2, and may be considered locally very common. The Beira barb was also most prominent in zone 2, due mostly to a single collection in May.

The spottail barb (B. afrovernayi), blackback barb (B. barnardi) and red barb (B. fasciolatus) were found to be uncommon in the habitats sampled. Although collected from each zone, the blackback barb was best represented in zone 1 where a single collection yielded 109 individuals. Collections exhibited sporadic occurrence and low relative numbers for the other two species. Bell-Cross and Minshull (1988) found the red barb to be fairly evenly distributed but uncommon in Zimbabwe, the spottail barb plentiful in suitable habitats and the blackback barb common in a few selected habitats.

Three Barbus species were collected infrequently and in such low numbers that they can be considered scarce within the habitats sampled; the Barotse barb (B. barotseensis), linespotted barb (B. lineomaculatus) and longbeard barb (B. unitaeniatus). The

longbeard barb was present in all zones, whereas the linespotted occurred from zones 1 and 2. Barbus barotseensis, the least abundant of the three, was collected exclusively from zone 2. Bell-Cross and Minshull (1988) found B. lineomaculatus to be one of the three most common fish species in Zimbabwean waters. As for B. unitaeniatus and B. barotseensis, Bell-Cross and Minshull (1988) classified them to be fairly common and not very common, respectively, in Zimbabwe.

The remaining barbs were represented by only three samples each, giving them a rare status: the broadstriped barb (B. annectens), sicklefin barb (B. haasianus) and the copperstripe barb (B. multilineatus). The sicklefin barb was found in all zones, the broadstriped barb in zones 2 and 3, and the copperstripe barb was present in only the fourth zone. Bell-Cross and Minshull (1988) found B. annectens to be a common species in most environments, B. haasianus not common, and B. multilineatus fairly common in suitable habitats of Zimbabwe.

Four other cyprinid species representing three genera were found in the Kavango River: the upjaw barb (Coptostomabarbus wittei), redeye labeo (Labeo cylindricus), Upper Zambezi labeo (L. lunatus) and barred minnow (Opsaridium zambezense). The barred minnow and redeye labeo were each found to be fairly common. Both of these cyprinids are present in all zones and each is most abundant in the rocky, swift moving waters of zone 3 (the barred minnow occupies pelagic areas and the redeye labeo is found in substrate crevices) where they comprise a sizeable amount of total

catch. Within the zones, O. zambezense was found in highest numbers during the February sampling periods. The data reveal no apparent seasonal changes in abundance for L. cylindricus, but interesting to note is that the May sampling period was the only time this species was not represented within each zone. This was the period of highest flooding, resulting in difficulties collecting these species. Bell-Cross and Minshull (1988) list these species as two of the more common ones in the flowing waters of Zimbabwe. The Upper Zambezi labeo, on the other hand, is considered relatively uncommon in Zimbabwe, taken only sparingly in the commercial fisheries (Bell-Cross and Minshull 1988). Perhaps the same can be said of this fish in the Kavango, as it was represented by only four specimens from three locations. Only a single specimen of the upjaw barb was captured in this survey, and it is thought not to be common in Zimbabwe (Bell-Cross and Minshull 1988).

An additional four species of cyprinids are known from the Kavango River, but not collected during this study: Upper Zambezi yellowfish (Barbus codringtonii), largescale yellowfish (B. mareguensis), redspot barb (B. tangandensis) and river sardine (Mesobola brevianalis) (Skelton et al. 1985; Bell-Cross and Minshull 1988; van der Waal 1991). However, a single specimen of B. codringtonii was collected by van Zyl and Hay in 1992 from zone 2 by gill net (pers. obs.).

Characidae.- Four species, each representing monotypic genera, constitute the characin family in the Kavango River: the

striped robber (Brycinus lateralis), tigerfish (Hydrocynus vittatus), silver robber (Micralestes acutidens) and slender robber (Rhabdalestes maunensis). As a group these fishes comprised over 8% of total yearly catch by numbers, and over 16% of total catch within zone 1. Seasonally, the characins peaked in May, representing 12% of the entire catch for that sampling period. The most common species of the family was M. acutidens, which was also the most abundant non-cichlid overall. Zone 1 harbored higher numbers of this fish than any other species. Bell-Cross and Minshull (1988) maintain the silver robber to be probably the most common species anywhere it occurs in Zimbabwe. This species is considered locally abundant in the Kavango River. Also found to be a fairly common species, B. lateralis was represented primarily in zone 2. This fish is extremely common in the waters of Zimbabwe (Bell-Cross and Minshull 1988). Rhabdalestes maunensis, the remaining small characin, was found from three localities where nine specimens total were collected. Generally uncommon in Zimbabwe (Bell-Cross and Minshull 1988), the slender robber is perhaps rare in the Kavango.

Tigerfish, open-water swift carnivores were assuredly more common than the samples indicate. Hydrocynus vittatus, found in greatest numbers in zone 2 primarily due to two collections, were ubiquitous in their distribution, but difficult to collect with the dominant gear used. For instance, several adults were collected in May over a 2-3 day period using rod and reel, but this technique is selective for the species and time consuming. A sample in November

within zone 2 yielded 25 juvenile tigerfish (< 15 cm TL), all taken from a small flooded inlet and constituting the only substantial collection of non-adult individuals of this species. However, in several instances, juvenile tigerfish were observed preying on stunted fishes following a rotenone application, but were sufficiently swift to move out of the treated area and avoid the toxicants and/or seining. Bell-Cross and Minshull (1988) state that the "water dog" is one of the most common of the larger species in any river system in Zimbabwe.

Cyprinodontidae.- Ranked fourth as a group in relative abundance with over 7% of total yearly catch, this family is currently represented by three species from the genus Aplocheilichthys: the meshscaled topminnow (A. hutereaui), Johnston's topminnow (A. johnstoni) and striped topminnow (A. katangae). The family, however, is under taxonomic review (Skelton, pers. comm.) and other species are likely to be recognized in the future.

Of these cyprinodonts, A. johnstoni was most ubiquitous and abundant, ranking sixth in total relative abundance of all species collected and occurring at over 80% of all collecting localities making it the second most commonly found species in the study. Johnston's topminnow was collected in highest numbers within zone 2, and comprised almost 8% of the entire catch within zone 1. Seasonally, in zones 1 and 2 where this fish was most abundant, the May sampling period yielded the most individuals. Where it is present in Zimbabwe, A. johnstoni is one of the most numerous

species in any river system (Bell-Cross and Minshull 1988). Aplocheilichthys hutereaui and A. katangae were found to be fairly common and scarce, respectively, in the habitats sampled, while the former species was most abundant in zone 2. The striped topminnow was not collected from zone 1, and was represented primarily in zone 4 by a sample harboring 17 specimens. Interestingly, that same collection also had relatively high numbers of A. johnstoni (73), and A. hutereaui (13). Nothing is known regarding abundance of the meshscaled topminnow in Zimbabwe, but A. katangae is thought to be numerous in favored habitats (Bell-Cross and Minshull 1988).

Siluriformes.- There are five families of catfish in the Kavango River, three of which are represented by several species (Bagridae, Clariidae, Mochokidae) and two that are monotypic (Amphiliidae, Schilbeidae). The most common and abundant catfishes are the mochokids, primarily of the genus Synodontis. As the taxonomy of the synodontids is extremely difficult and currently under revision (Skelton pers. comm.), for the purposes of this study all fishes of this group were lumped as Synodontis spp. Presumably, there are seven species of this genus present in the Kavango River: leopard squeaker (S. leopardinus), largespot squeaker (S. macrostigma), largemouth squeaker (S. macrostoma), spotted squeaker (S. nigromaculatus), S. thamalakanensis, S. vanderwaali, and the Upper Zambezi squeaker (S. woosnami) (Skelton & White 1990). Collectively, Synodontis spp. occurred at over half of all sample localities, and were collected during all sampling periods from each zone. The highest numbers for this group were

found in zone 1, and seasonally these fishes peaked in abundance during the November sample. Baited fish traps set overnight were a very effective means of collecting synodontids, as was rotenone. Bell-Cross and Minshull (1988) found the various Synodontis spp. to be numerous and plentiful in Zimbabwean waters. The final member of the Mochokidae family collected during the study was Chiloglanis fasciatus, found uncommon in each zone. A large majority of C. fasciatus specimens (80%) were taken from zone 1, showing a decided preference for sand and rock substrates and running water.

The lone member of its family, the silver catfish (Schilbe intermedius) proved to be common and fairly evenly distributed both spatially and seasonally, being absent only in the February samples of zone 1. The highest relative abundance for the silver catfish was in zone 3, where it comprised over 4% of total catch. Bell-Cross and Minshull (1988) found that in Zimbabwe, this species is extremely abundant in some areas and not very common in others, suggesting predation pressure may dictate its relative abundance.

The Clariidae family was represented in the samples by three species of the genus Clarias: the sharptooth catfish (C. gariepinus), blunttooth catfish (C. ngamensis) and snake catfish (C. theodorae). Collectively, most clarid specimens were taken from zone 2 during the May sampling period, with the blunttooth catfish showing the widest seasonal distribution giving it a fairly common status in the habitats sampled. The other two clarids were collected less frequently; however, as C. gariepinus and C. ngamensis are probably more common in the Kavango River than the

numbers suggest, and were simply not well represented in this survey due to gear selectivity. Bell-Cross and Minshull (1988) found both species to be numerous in Zimbabwe, with C. gariepinus the more common of the two. The snake catfish occurred sporadically, with few individuals collected. In Zimbabwe, C. theodorae is known to be numerous in selected habitats (Bell-Cross and Minshull 1988).

The family Bagridae is known from the Kavango River by three species in two genera: the Chobe sand catlet (Leptoglanis dorae), spotted sand catlet (L. rotundiceps) and the Zambezi grunter (Parauchenoglanis ngamensis). This last species, the more common and abundant member of the family, was found in highest numbers in zone 1 and was represented in each zone. It's infrequent occurrence in this study suggests it is scarce in the Kavango River. Bell-Cross and Minshull (1988) could distinguish no habitat preference for P. ngamensis, and consider it to be a non-rare species in Zimbabwe. The other bagrids were found to be rare in occurrence, with L. dorae collected from three localities, and L. rotundiceps represented by a single specimen taken from zone 2. In Zimbabwe the Chobe sand catlet is plentiful in suitable habitats, while the spotted variety is considered common though not often seen (Bell-Cross and Minshull 1988).

The remaining siluriform collected during this study is the stargazer mountain catfish, Amphilius uranoscopus. This fish was taken most abundantly in the first zone at a single locality where 11 individuals were collected over a gravel bar using the "cast and

kick" technique. Occurring in a total of five samples, this fish can be termed scarce, but probably locally common in suitable habitat. Bell-Cross and Minshull's (1988) observed that the stargazer can be exceedingly numerous in favorable habitats.

According to Skelton et al. (1985) and Bell-Cross and Minshull (1988), three additional catfish species (not collected in this study) are known from the Kavango River in Namibia, all of the Clariidae family: the broadhead catfish (Clariallabes platyprosopos), the Okavango catfish (Clarias dumerilii) and the blotched catfish (C. stappersii). In the case of the Okavango catfish, confirmation of the identity of specimens collected in 1936 by Pellegrin is required to verify its presence (Skelton et al. 1985).

Mormyridae.- In the Kavango River, the mormyrid family is represented by six species in five genera: the slender stonebasher (Hippopotomyrus ansorgii), Zambezi parrotfish (H. discorhynchus), bulldog (Marcusenius macrolepidotus), western bottlenose (Mormyrus lacerda), churchill (Petrocephalus catostoma) and the dwarf stonebasher (Pollimyrus castelnaui). The mormyrids comprised over 3% of total individuals collected and peaked in zone three where members of this group made up over 7% of total catch. Seasonally, the mormyrids were most abundant during the September sampling period where they represented almost 9% of all fishes collected. Pollimyrus castelnaui occurred the most frequently and P. catostoma was the most abundant fish in this group for all of 1992. These two species, along with the bulldog, were found to be fairly common

within the habitats sampled. The churchill was found in highest numbers in zone 3 where it made up over 5% of total catch, and peaked seasonally during the June sampling period in each zone. Bell-Cross and Minshull (1988) found this species can be exceedingly numerous in Zimbabwe, and is considered the same in the Kavango. Pollimyrus castelnaui on the other hand is usually found in low numbers in Zimbabwe (Bell-Cross and Minshull 1988), but our data, especially from zone 1, suggests it may be more prolific in the Kavango. Marcusenius macrolepidotus was collected in highest numbers in zone 2, primarily due to a single sample yielding 36 specimens. This species is thought to be one of the more numerous ones in Zimbabwe (Bell-Cross and Minshull 1988).

The remaining three mormyrids occurred infrequently and in low numbers, suggesting they are all uncommon within the habitats sampled. Both Hippopotomyrus species were found to be more abundant in zone 3, seemingly preferring rocky substrates and fast water. Throughout Zimbabwe, the slender stonebasher is regarded as rare, while the Upper Zambezi parrotfish is considered common nowhere (Bell-Cross and Minshull 1988). Mormyrus lacerda is thought to be generally uncommon in Zimbabwe (Bell-Cross and Minshull 1988), as well as the Kavango, based on the infrequency of occurrence found in this study.

Distichodontidae.- The citharins in the Kavango River are represented by three species of two genera: the dwarf citharine (Hemigrammocharax machadoi), multibar citharine (H. multifasciatus) and broadbarred citharine (Nannocharax macropterus). Of the three,

the multibar citharine occurred in highest numbers and most frequently, giving it a fairly common status within the habitats sampled, concurring with Bell-Cross and Minshull's (1988) findings in Zimbabwe. Hemigrammocharax multifasciatus was most abundant in zone 2, and seasonally the most individuals were collected during the June sampling period. This species is locally abundant in the Kavango River. Hemigrammocharax machadoi, found in low numbers and absent in zone 1, is considered uncommon in the habitats sampled, although Bell-Cross and Minshull (1988) found this species as numerous as the multibar citharine, and fairly well distributed where swampy conditions prevail in Zimbabwean river systems. Nannocharax macropterus, thought to be uncommon in Zimbabwe (Bell-Cross and Minshull 1988), was rare in the Kavango River; it is known in this study from a single individual collected during May in zone 2.

Anabantidae.- The manyspined climbing perch (Ctenopoma multispinis), was the only member of this family collected during the survey. Ctenopoma multispinis was scarce in the habitats sampled, was not found in zone 1, and was most prevalent in zone 2 during May. Bell-Cross and Minshull (1988) found this fish nowhere common but fairly widely distributed in suitable habitats in Zimbabwe. A second species in this family (blackspot climbing perch, C. intermedium) is known from the Kavango (Skelton et al. 1985; Skelton 1988), but not collected in this study.

Mastacembelidae.- The spiny eels are known from the Kavango River by two species in the genus Aethiomastacembelus: the

shorttail spiny eel (A. frenatus) and ocellated spiny eel (A. vanderwaali). The former was absent from zone 2, and is considered rare based on infrequency of occurrence. The latter was represented in each zone but is considered to be uncommon. The ocellated spiny eel was most abundant in zone 1. Nothing is known of the abundance of A. vanderwaali in Zimbabwe, but A. frenatus is probably uncommon (Bell-Cross and Minshull 1988).

Hepsetidae.- The single member of this family, the Kafue pike (Hepsetus odoe) was found to be scarce as it was known from only eight specimens in four samples. This may be a reflection of sampling effort, however, based on its increased occurrence in zone 2 in recreational angling efforts by P. and L. Kibble in August (pers. comm.). During this survey, the only adult specimens (3) were taken from a gill net sample during February in zone 1, with the remaining individuals all being young of the year. Bell-Cross and Minshull (1988) found H. odoe to be uncommon in Zimbabwe when coexisting with tigerfish, but extremely numerous in areas devoid of H. vittatus.

CONCLUSIONS

The results of the biodiversity and spatial/seasonal abundance study for the Kavango River is most relevant in regards to the general trends that they reveal. However, given the qualitative nature and gear selective biases of fish collecting methodology, rigorous conclusions involving fish community dynamics cannot be proposed based on a single year of investigation. Regardless,

these confounding factors should not be allowed to minimize the general utility of the data set.

A major trend disclosed by this investigation involves the overall dominance of the cichlid and cyprinid families and their seemingly spatial and seasonal displacement of one another. The seasonal sampling protocol allows for basic indications of how this relationship is synchronized to flood stage. For instance, cichlids represented by young of the year tended to dominate low flow conditions in November/December 1992, while juveniles were common during flooding conditions. Cyprinids peaked in numbers during flooded stages, presumably using the littoral vegetation growth as spawning/nursery areas and as cover to escape predation. These relative abundance data stimulate the desire to look closer at the relationship between these family groups, initializing ecologically-based research.

In general terms, this study has shown the degree of prominence each species plays in the Kavango River fish community on the whole (e.g., P. philander and T. rendalli on the significant side, with other species such as R. maunensis and C. wittei being rare). Zonal comparisons allow for basic characterization of the dominant habitats, and in many instances species' habitat preferences were unveiled that have direct relevance to the establishment of an environmental assessment protocol for the basin (see Chapter IV).

From a management perspective, relative abundance data from 80 collections along the Kavango River give a reasonable indication of

the status of the fishery resource on a seasonal basis. Some of the collecting techniques used are considered to parallel the traditional methodologies, thus having inference on seasonal catch by the subsistence fishery.

RECOMMENDATIONS

This investigation is the first to address seasonality in the fish biodiversity of the Kavango River. This information in addition to that of Skelton et al. (1985), van der Waal (1991), van Zyl (1992), other historical references and the current activities of NMFMR scientist C. Hay, provides a good baseline on the structural components of the Kavango River ichthyofauna. The taxonomy of the Kavango River fishes in Namibia is well known, based on the work of Jubb (1967), Poll (1967), Bell-Cross & Minshull (1988) and Skelton (in press), and while future changes may occur, they will be relatively minor.

From an ecological and fish biology perspective, several different research themes are recommended. However, the key to future studies is to understand the role of seasonal flooding on the functional component of the fishery, given that the floods drive the system and impact both primary and secondary productivity. Recommendations: Specific research priorities that have been identified include (a) a major ecosystem study (5 years at least) to understand fish productivity in relation to the annual flooding cycle and primary productivity, ultimately to serve as a predictor of what theoretically represents maximum sustainable

yield (MSY); (b) basic studies on the biology, ecology and life history of targeted fish species in relation to the flooding regime; and (c) behavior studies incorporating radiotelemetry to monitor fish movements and migrations in relation to the annual flooding regime.

CHAPTER III. DESCRIPTION OF NEW EXOTIC FISHES FROM NAMIBIA, WITH RECOMMENDATIONS FOR THE ESTABLISHMENT OF A NATIONAL PROTOCOL FOR INTRODUCED AQUATIC ORGANISMS

INTRODUCTION

Exotic fishes have been known from the waters of southern Africa since 1857 when the goldfish, Carassius auratus, was recorded from the Cape (Jubb 1967), but they have been held in captivity since at least 1726 (Raidt 1971). de Moor & Bruton (1988a) recognized at least 108 aquatic animal species which have become established (i.e., reproductively viable populations) in southern Africa, including 24 alien and 64 translocated species of bony fish. Schrader (1985) listed only four fishes in his account of invasive species in Namibia, but recognized (a) the real prospect of translocation occurring on a wide scale, and (b) the threat of truly foreign species.

Bruton & Merron (1985) summarized Taylor et al. (1984), noting that it was generally considered that invasive fishes potentially had various harmful effects, including (a) the prospect of habitat alteration; (b) introduction of parasites and diseases, (c) trophic alterations in the ecosystem, (d) hybridization, and (e) spatial alterations. They concluded that little was known about the harmful effects of introduced fishes on indigenous fishes, but there were "implications" that the introduction of trout (Salmonidae) and bass (Centrarchidae) into southern African waters had resulted in reductions or extinctions of certain indigenous

species.

The manuscript of Laurenson, Hocutt and Hecht (1989) was one of the first of its kind, i.e., they attempted to quantify the impact of fishes introduced through the Orange River Tunnel on indigenous species of the Great Fish River, but could discern no impact. Regardless, it is generally thought that introduced species alter the natural biotic integrity (Karr 1981; Karr et al. 1986) of a system, thus inferring environmental degradation.

This chapter presents information on two exotic fish species recorded for the first time in Namibia and southern Africa. Both species occur in the same isolated fontein in the Omuramba Omatako sub-drainage of the Kavango River, in the proximity of the Waterberg Plateau Park. Additional information is provided on other species translocated to the fontein.

RESULTS

The research team first visited the fontein of Wabi Lodge, Otjahewita Farm (20°20′00" S x 17°29′21" E) on 10 June 1992, based on information that an unusual fish "...with whiskers" and another "...colourful fish" inhabited it "...three years ago" (P. Kibble: pers. comm.). The authors had just completed a seasonal biodiversity survey of the Kavango River proper, and were returning to Windhoek, having stored their principle collecting gear in Rundu. Thus, they were not prepared for the dimensions of the fontein pool when they first attempted to collect it with dip nets.

The fontein is considered permanent: it seeps out of bedrock,

and fills a pool ca. 150 m^2 in size with a depth of 1 m which contains abundant aquatic macrophytes. The pool was excavated in about 1907 (W. Delfs: pers. comm.), and is maintained. Water is piped from the pool to a trough in a nearby camp to supply game and livestock, but no overflow occurred during either of our two visits.

The June collection effort yielded specimens of the southern mouthbrooder, Pseudocrenilabrus philander, and banded tilapia, Tilapia sparrmanii, both of which are native to other fonteins and karst areas in the region, and might be native here as well. Three voucher specimens of P. philander and 10 of T. sparrmanii were taken for cataloguing into the State Museum, Windhoek.

Additionally on 10 June 1992, a single specimen of the threespot gourami, Trichogaster trichopterus (Belontiidae), was collected. The individual measured 75.2 mm total length (TL), and represented the first such specimen taken from southern Africa. The threespot gourami is native to southeast Asia, a member of the Anabantiformes and is commonly cultured by tropical aquarists. The pelvic fins of gouramis are diagnostic, being located anterior to the pectoral fins and forming elongated filaments resembling "whiskers".

The farm was revisited on 5 September 1992, and collections were made using a 1,5 x 3-m seine and a backpack electrofishing unit (the latter proving ineffective due to low conductivity). The effort resulted in several additional species being collected, including voucher specimens of the three-spot tilapia, Oreochromis

andersonii (2 specimens); Zambezi happy, Pharyngochromis acuticeps (3); pink happy, Serranochromis giardi (1); and other T. sparrmanii (2). The three-spot tilapia and pink happy are distinctive in that they are indigenous to regional waters, but are not expected to occur in a fontein habitat; thus, they are considered to be translocated species. The presence of P. acuticeps also probably represents a translocated species.

In the September collection, two additional T. trichopterus were collected (69 and 79 mm TL). However, the most exciting specimens were 31 individuals of Astyanax orthodus, a member of the family Characidae. At least two or three age classes were present based on the range in total lengths (33.8 to 48.5 mm TL; mean = 39.6 mm TL). The latter species is also another common aquarium fish, native to Columbia. Astyanax orthodus is distinctive in having bright red dorsal, caudal and anal fins, and a dark lateral spot posterior to the operculum.

DISCUSSION

This chapter reports on two exotic fishes new to Namibian and southern African waters: T. trichopterus and A. orthodus. The family Anabantidae, which is closely related to Belontiidae, are represented locally by the genus Ctenopoma, and regionally by Sandelia (Jubb 1967). Ctenopoma intermedium and C. multispinus are native to the Kavango River system (Skelton 1988), while S. bainsii and S. capensis are isolated in the southern coastal streams of South Africa . Local characins include four species indigenous to

Namibia: the striped robber, Brycinus lateralis; tiger fish, Hydrocynus vittatus; silver robber, Micralestes acutidens; and slender robber, Rhabdalestes maunensis. Other anabantids have been introduced to African waters (Moreau et al. 1988), and characins are often translocated (de Moor & Bruton 1988a).

A key is presented in Table 5 to separate A. orthodus and T. trichopterus from species of characins and anabantids native to Namibia. A complete key to the fishes of the Republic, including these and other exctics, is included in Appendix D.

There is evidence that both exotic species are established within the Otjahewita Farm fontein, based on the presence of several age classes of A. orthodus and the continued presence of T. trichopterus over a several-year period. Other age classes of the gourami might be present, but difficult to collect due to intense aquatic vegetation and undercut banks. Based on discussions with the previous owner of the farm, he introduced these fish into the fontein about 15 years ago, as well as guppies and swordtails which we did not record (W. Delfs: pers. comm.).

Multiple translocations of cichlids into the fontein has occurred, based on discussions with W. Delfs and P. Kibble. Additionally, W. Delfs confirmed that he had introduced two Nile crocodile, Crocodylus niloticus, at the same fontein nearly 20 years ago. One of these animals has now apparently died, and the other (ca. 2 m TL) has moved to a temporary water hole where it is occasionally fed (R. Walter: pers. comm.).

Schrader (1985) indicated concern that carp (Cyprinus carpio),

largemouth bass (Micropterus salmoides), and Mozambique tilapia (Tilapia mossamibicus), each widely distributed in the Omuramba Omatako, could establish themselves in the Kavango River given appropriate rainfall conditions. Similarly, A. orthodus and T. trichopterus have the potential for dispersing naturally into the Kavango River; however, the Otjahewita Farm fontein is located some 500 km south (upstream) within the Omuramba Omatako sub-drainage. The ability of these two species to tolerate a wide range of climatic conditions, and to be reproductively successful within the Kavango River should they succeed in reaching it, is not questioned. Both have tolerated the weather extremes associated with the Waterberg region. Additionally, T. trichopterus is an air breathing fish with a suprabranchial organ and capable of surviving in low dissolved oxygen conditions.

The Otjahewita Farm exotics raise a philosophical question regarding their control. In principle, the establishment of exotic biota should be discouraged, and there should be legal recourse against offenders on state-controlled land which is set aside as a part of the natural heritage of Namibians. On the other hand, the two exotic fishes in question occur on private land and seemingly pose little threat for invasion to the main stream Kavango River, thus having only the "potential" for contact with indigenous biota. The natural conduit for transfer, the Omuramba Omatako via the Klein Omatako, flows only sporadically, decreasing the likelihood of a successful invasion of the Kavango River, some 500 km to the north. However, the Eastern National Water Carrier (ENWC) system

represents a more real possibility of dispersion of the two exotics, particularly as it flows through the farm and discharges into the Omatako Dam about 90 km southwest (Anonymous 1992b). The establishment of these species in the Omatako Dam would significantly increase the likelihood of their spread throughout Namibia, both through irrigation and overflow channels as well as transfer by aquarists. Thus, care should be taken to prevent these species from entering either the Eastern National Water Carrier system or the Klein Omatako sub-drainage.

RECOMMENDATIONS

Recommendation 1.- As a corollary to the main objectives of this chapter, we wish to recommend that the jargon relative to exotic, and alien, fish species be standardized by Namibian fishery scientists. For instance Laurenson & Hocutt (1986) recognized that the definitions re: introduced fishes are varied, and terms such as alien, exotic, foreign, introduced and translocated have sometimes been used interchangeably by authors. The very valuable work edited by Brown et al. (1985) focused on Namibia, but provided no guidance on this resulting in the term "alien" being used differently by some chapter authors. Standardization of terms is more than semantics, rather a sense of orderliness is brought to the issue.

The need for standardized terminology amongst fish biologists is stated simply, but requires careful consideration. Definitions have sometimes been based on political considerations or

geographical boundaries for the sake of convenience (Bruton and Merron 1985; de Moor & Bruton 1988a,b). However, Laurenson (1984), Laurenson & Hocutt (1986), and Hocutt (1984, 1985a) argued that biological criteria be used to establish definitions, given the likelihood of loss of genetic integrity through hybridization of allopatric sibling species brought into contact with one another through translocation. They considered the latter mode of introduction as of special concern where recreational anglers might use live bait, or in the aquaculture industry where higher growth rates are often achieved through "hybrid vigor". Bruton & Safriel (1985) concurred with the latter view. Additionally, developmental activities such as the Orange/Great Fish River tunnel of South Africa (Laurenson & Hocutt 1986) and the Kunene/Cuvelai canal system in Namibia (Schrader 1985; Van der Waal 1990) are extreme examples for the mass translocation of sibling species, potentially resulting in species intergrades and breakdown of genetical isolating mechanisms.

It is our recommendation that the following definitions be adapted by Namibian fish biologists: **(1) exotic** or **introduced species:** any species deliberately or inadvertently introduced to a location outside its natural (extant) range by man (after Hubbs 1977; Laurenson & Hocutt 1986); **(2) alien** or **foreign species:** a species from a different biogeographical region (sensu stricto Pielou 1979), continent or subcontinent; **(3) translocated species:** a species occurring naturally within southern Africa, but which has been deliberately or inadvertently moved by man from one

environment to another outside its natural (extant) range (Laurenson & Hocutt 1986; de Moor & Bruton 1988a); **(4) endemic species:** a species that is restricted in its distribution, be it in reference to a particular spring, lake, drainage system or biogeographic region (Laurenson & Hocutt 1986); **(5) indigenous species:** a native species, but (as compared to an endemic) not necessarily restricted in its distribution to a particular spring, lake, drainage system or biogeographic province (Laurenson & Hocutt 1986); **(6) established species:** a reproductively successful species (Laurenson & Hocutt 1986); and **(7) invasive species:** species expanding their ranges either as a consequence of natural phenomenon, e.g., stream capture (Laurenson & Hocutt 1986), or as a result of man's deliberate or inadvertent action (Laurenson & Hocutt 1986; de Moor & Bruton 1988a). These definitions provide guidance for the discussion of exotic fishes in Namibia, and are founded upon biological and zoogeographical criteria.

Recommendation 2.- A particularly useful regional document is that of de Moor & Bruton (1988b), and its collection of papers on the management of "invasive" aquatic fauna in southern Africa. The manuscripts by Walmsley & Pike (1988) and de Moor (1988) have particular relevance to the legislation concerning exotic aquatic biota, and are paraphrased here in part. A similar synthesis for Namibia would be beneficial to the law enforcement and academic community. In general, there are three approaches for the control of alien or exotic species: (1) an **approved-listing** of species which are permitted for importation; (2) a **prohibited (or**

restricted) listing of species either not allowed for importation, or restricted for importation based on certain conditions; and (3) a **protocol approach**, which requires the development of a data base to ascertain the probable impact of a candidate species. The first two categories are generally aimed toward the aquarium trade, and aquaculture industry. The protocol procedure has been recommended by the International Union for Conservation of Nature and Natural Resources (IUCN), and has been adopted by the Committee for Inland Fisheries of Africa (CIFA) (de Moor 1988). Regardless of the approach, it is essential that the legislation be enforceable. It is recommended that Namibia adopt an "approved/prohibited listing" procedure such as mentioned above concerning the importation of alien species.

Recommendation 3.- Relative to the proposals put forward above concerning introduced or exotic species, there have been several independent assessments of the prospects for the development of freshwater aquaculture in Namibia, both in terms of commercialization and subsistence ventures (Remedio & Regadera 1991; Sandlund & Tvedten 1992; Yaron et al. 1992; and Wilton, undated). The need to use indigenous fishes in these operations can not be over emphasized. The effects of "biological pollution" from aquaculture includes a plethora of potential problems (Weston 1990), including the introduction of non-indigenous species into the wild; hybridization and the breakdown of isolating mechanisms of closely related species; competition for preferred food resources and breeding sites; alteration of the structural and

functional integrity of the ecosystem; and the introduction of new disease and parasite vectors. For these reasons, it is recommended that the developing industry be regulated from the start, with the objective of mitigating any potential physical, chemical or biological impacts. Lists of approved/prohibited species for importation and culture should be developed.

Recommendation 4.- The aquarium industry is more difficult to regulate than aquaculture; however, there should be an active education program aimed toward tropical fish hobbyists, aquaculturists and the public in general, e.g., through environmental education services.

CHAPTER IV. DEVELOPMENT OF THE CONCEPTUAL BASIS OF AN INDEX OF BIOTIC INTEGRITY (IBI) FOR THE KAVANGO RIVER

INTRODUCTION

The Kavango River rises in the southern sloping highlands of central Angola as the Cubango River, flows in a southeast direction along the Namibia/Angola border for ca. 450 km to the Botswana border, and continues another 50 km as the primary source of the Okavango Delta. As mentioned in Chapter I, the Delta is considered one of the few truly pristine natural wonders of the world, however this does not preclude various regional plans in Angola, Botswana and Namibia for water resource development, such as Namibia's Eastern National Water Carrier (ENWC) system (Anonymous 1992b). However, at least in the case of Botswana, such plans might be canceled or altered once independent environmental assessments are performed (e.g., IUCN 1992). Presumably, the cumulative effect of developmental projects will significantly impact the seasonally fluctuating flood-driven processes of the Kavango River, with subsequent adverse effects on the quality and quantity of the catchment's water resources.

The Kavango River/Okavango Delta system presents a unique situation with regards to influence of flood stage. The river experiences peak flooding February through April, filling extensive floodplains along the Namibian/Angolan border, where the gradient is minimal. Flooding in the lower Okavango Delta lags river flooding by up to 6 months.

Given the likelihood of implementation of some or all of the various water diversion/utilization schemes proposed for the future in the drainage, it is prudent to commence the conceptual development of a methodology to assess their probable long-term synergistic impact. This observation has special relevance given (a) the forecast of a doubling of the population base living adjacent to the river in Namibia over the next decade (although data are lacking, a similar increase can be projected for Angola and Botswana); (b) the prospects of land reform policy (Adams et al. 1990), which will alter land use patterns and potentially lead to increased overgrazing and desertification; and (c) continued chronic regional drought.

Knowledge of pre-developmental aquatic system conditions is crucial if long-term resource utilization is an objective (Breen et al. 1984), as historical results of watershed developmental programs in Africa have in general been devastating. Common impacts have included destruction of biodiversity, forests and traditional farms; social disruption, including separation of traditional family or ethnic groups, resettlement into unacceptable areas, land reallocation, and inundation of culturally-important sites; destruction of traditional fisheries; desertification; salinization; alterations in water quality and quantity, including downstream impacts; accumulation of agro-chemicals; and health and disease (Graham 1984; Mounier 1984; Webb 1984; Timberlake 1985).

Developed countries spawned the industrial revolution, but even today it remains unfeasible or impractical to completely

control the respective environmental impacts in many instances. In the process of Neo-colonialism, third world countries have often acquired technological development, but they have also inherited the associated problems, the effect of which can be magnified due to lack of experience or financial resources (Hocutt et al. 1992).

It is becoming increasingly clear that development within a LDC must not be at the sake of sustaining natural heritage (Hocutt et al. 1992). Particularly for LDCs, environmental policies that attempt to anticipate or predict significant economic, social and ecological impacts rather than react to them, are becoming increasingly necessary for the achievement of certain important goals: the satisfaction of basic needs, such as foods, clothing, sanitation and shelter; the development of a high quality environment; the optimum use of available resources; and the control of pollution and other forms of environmental degradation. Such anticipatory environmental policies involve actions to ensure that conservation and other environmental considerations are taken fully into account at the earliest possible stage of any decision that is likely to effect the environment (Hocutt et al. 1992).

Current aquatic resource concerns in southern Africa

Gaigher et al. (1980), in regards to threatened fish species in South Africa's Cape Province, listed four major threats: (1) farming and short-sighted land use practices, (2) introduction of exotic fish species, (3) human settlement, mining and industrial development and (4) dam and weir construction. Skelton (1983)

emphasized that the destruction of habitat is clearly the most significant threat to southern African aquatic environments and their respective organisms by stating that... "It is not only realistic but true to say that habitat destruction is becoming more and more evident in southern Africa as the human population grows". Ten years have passed since that statement, and undoubtedly conditions have not improved.

Presently, the Kavango River is relatively free of perturbations related to development projects and modern industrialization. The current state of the Kavango may be deemed (via qualitative observations) fairly pristine in areas of sparse human population (e.g. upstream where the river initially forms the Angolan/Namibian border near Katwitwi; downstream near the Botswana border in the region of the Mahango Game Reserve) and modestly degraded in areas near the river's population centers (e.g. Rundu, Bagani). Factors directly contributing to aquatic habitat degradation in the Kavango River include the effects of livestock grazing (erosion, organic enrichment, increased turbidity, demolished aquatic and terrestrial vegetation beds), flow modifications and chemical disturbances.

Especially in highly populated areas, herds of livestock along the river's edge can be observed grazing the banks and floodplain habitats, and tromping through backwater pools. Van der Waal (1991) reported signs of habitat degradation due to uncontrolled livestock over-grazing and consequent problems of erosion in certain regions of the Kavango Province. Increased suspended

particulate loads would be expected in these areas of over-grazing, resulting in turbid conditions that may disrupt photosynthesis and destroy benthic habitats. The destruction of riparian vegetation from both cattle grazing and the artisanal method of trampling weed beds for fish harvesting certainly contribute largely to the visibly unstable river banks. Not only do these practices deprive riverine fish communities of their primary energy resource, they also negate the riparian vegetative zones ability to stabilize river bank structure, allowing the normal effects of flooding to become disastrous (Appleton et al. 1986). Van der Wall (1991) suggested that large-scale soil erosion in the densely populated areas may cause the deeper oxbows and side channels to fill with sediment, thus minimizing the available refugia habitats.

Present flow modification schemes such as small-scale irrigation systems and construction of canals for livestock watering pose no real problems currently due to their minimal nature. However, in the event of larger-scale implementation of water diversion projects and impoundment construction, the effects of such practices can be considered far reaching, as downstream users are impinged, the physical stability of the watercourse is altered and the biota is disrupted (Appleton et al. 1986). The balance between submergence and exposure in floodplain areas is altered both spatially and temporally in instances where the natural hydrologic regime is deviated (Breen et al. 1984), resulting in loss of habitat when floodplains are deprived of flood waters. Less well known are the secondary, often synergistic

effects on the biotic components, water quality and channel morphology, which perhaps operate on relatively long time scales (O'Keefe et al. 1989). In the case of the Great Fish River in southern Namibia, modified flow regime resulted in the alteration of invertebrate community structure and the translocation of fish species (Cambray and Jubb 1977; O'Keefe and de Moor 1988).

Chemical pollution, although currently not a major threat to the aquatic fauna of the Kavango River, can be considered a prominent factor in the destruction of southern African waterway habitats and the consequential deleterious effects on fish communities (Skelton 1983). The decimation of entire fish populations have been attributed to chemical pollutants, e.g., cattle dip in the Hluhluwe River drainage of South Africa (Brooks and Gardiner 1980) and the adverse effects of endolfan insecticide application has been reported for both fish and fish eating birds in the Okavango Delta (Douthwaite 1982; Matthiessen & Roberts 1982).

The introduction of non-native species is another major threat to the freshwater of fishes of southern Africa, as noted in Chapter IV. Skelton (1983) stated that endemic species with restricted distributions are especially vulnerable to predation by angling species such as trout (Salmo spp.) and blackbass (Micropterus spp.), which have been introduced throughout South Africa. Presently, there are no known exotic species in the Kavango River proper, but do occur in the Omatako subdrainage (Chapter IV).

Biological monitoring

Biologists have used aquatic biota to monitor water quality since the pioneering efforts of Kolkwitz & Marsson (1908, 1909) and Forbes (1928). Since that early work, the concept of biological monitoring has been greatly refined with a general trend away from the indicator species concept towards an integrated, community-based approach (Patrick 1949; Cairns 1974; Hocutt 1975). Water resource managers have abandoned the simple indices that examine fragments of the biotic systems, and in recent years began implementing more holistic, community level assessments. One such integrated methodology currently in vogue in North America to quantify the empirical relationships between land use and stream health via fish communities is the Index of Biotic Integrity (IBI), first formulated by Karr (1981).

Various taxonomic groups of organisms have proven useful in monitoring water resource quality, as demonstrated by the following examples. Siegfried (1988) analyzed lake acidification problems in relation to planktonic community structures. Aquatic macrophytes assisted in classifying and determining trophic status in lakes (Canfield et al. 1984). An amphibian diversity component aided in assessing coastal streams in northern California (Moyle et al. 1986). Macroinvertebrate community groups are commonly used as cursory indicators of lotic system quality (Howmiller & Scott 1977; Schaeffer et al. 1985; Rosenburg et al. 1986), and a protocol has been recently developed, stressing benthic community composition and function (Plafkin et al. 1989). However, Cummins (1991) points

out that this latter approach is seriously limited because taxonomic definition of freshwater inverts is unclear, with all groups remaining incompletely described.

The use of fish communities to biologically assess stream condition and health, i.e., biotic integrity, is now in common practice in North America and Europe (e.g., Hocutt 1985b, 1988; Hocutt & Stauffer 1980; Karr et al. 1986; Angermeier and Schlosser 1987; Steedman 1988; Fausch et al. 1984, 1990; Oberdorff & Hughes 1992). A substantial literature base exists for various anthropogenic effects, including aquatic resource degradation through stormwater runoff, stream burial, channelization, thermal pollution, land use practices, mining activities, siltation, organic and inorganic pollution. Guild-based approaches have allowed for insight into structural and functional community-level fluctuations as well as indications of the extent of degradation in aquatic systems (Karr 1987).

The rationale for use of fish communities in biological monitoring programs is strongly stated, including: (1) The taxonomy, ecological requirements and life history aspects of fishes are generally better known than for other phyletic groups; (2) Through their ontogenetic development, fish occupy a variety of trophic levels and habitats; (3) Different components of the fish community, and their life stages, are sensitive to a number of different sources of environmental degradation, including both the direct and indirect effects of stress; (4) In general, fish are at the top of the aquatic foodchain, and thus are integraters of

temporal and spatial alterations in ambient environmental conditions; and (5) importantly, the fish community has both economic and aesthetic values which can be assigned to it, thus it commands attention from both the public and government agencies responsible for the sustainable utilization of the aquatic resources of the (particular) catchment. All of these reasons have particular relevance in a developing country context, where other aquatic communities (e.g., macroinvertebrates) are poorly documented and where persons living at the subsistence level are dependent upon the local water resources to meet their daily living needs, including the fishery as a protein resource.

Herricks & Schaeffer (1985) defined six criteria that must be met to validate instream biomonitoring programs: (1) the unit of measurement must be biological; (2) the unit must be interpretable at several different trophic levels, either directly or indirectly through the food chain; (3) the unit must be sensitive to environmental alterations; (4) the unit must have a wide degree of sensitivity to changing conditions; (5) the unit of measurement must be well defined and reproducible over space and time; and (6) the variability of the unit of measurement must be low. Karr et al. (1986) presents evidence that the IBI meets all these conditions, and with regards to the last criterion, note that variation may either be a consequence of sampling bias, a natural phenomenon or anthropogenic affect. As they quote Herricks and Schaeffer (1985), "The concern is not that a measure be variable, but that the nature of the variability be well understood".

Karr's (1981) original Index of Biotic Integrity (IBI) was constructed for Midwestern USA streams, and integrated 12 attributes of fish assemblages to determine biotic integrity or "health" of the system (Table 6). Categories of attributes (metrics) included species richness and composition, trophic structure, and fish abundance and health. Each metric reflected the quality of a different portion of the fish community that responds to a different aspect of the aquatic system (Fausch et al. 1984). The combination of metrics was subsequently refined to reflect insights from individual, population, community, ecosystem, and zoogeographic perspectives (Miller et al. 1988). The primary underlying assumptions of the IBI concept are presented in Table 7.

The conceptual basis of the IBI has been constantly revised since its introduction (e.g., Karr et al. 1986; Miller et al. 1988; Fausch et al. 1990), and now is a standard for the National instream water quality monitoring program of the USA Environmental Protection Agency (USEPA 1990). The application of the principles of the IBI have also been introduced to Canada (Steedman 1988) and Europe (Oberdoff & Hughes 1992). The IBI concept is not without its limitations (Hocutt 1981; Karr et al. 1986; Fausch et al. 1990; Hocutt 1990). However, the beauty of the IBI concept is that it incorporates the principles of community structure and function into an index measurement of stream health. Additionally, the tenets of the IBI can be modified to meet individual catchment or regional needs.

With the expected technological and economic constraints of

developing countries, freshwater resource monitoring and assessment strategies in southern Africa are not highly prioritized and in most cases are nonexistent. In South Africa, however, there have been studies regarding aquatic resource monitoring, dating back to Chutter (1972) who used benthic macroinvertebrate faunal diversity to assess the degree of organic pollution in river systems. Cambray et al. (1988) listed all the long-term data sets regarding aquatic resources of southern African water-bodies to date, remarking that very few have been synthesized or analyzed for long-term trends related to either natural climatic fluctuations or anthropogenic effects.

As far as known, this is the first attempt to use structural and functional components of an aquatic community to develop biological criteria for southern African waterways, especially a floodplain system like the Kavango River. The conceptual development of a biological monitoring program is based on the data presented in Chapter II.

METHODS AND MATERIALS

As stated in Chapter II, the Kavango River in Namibia can be sub-divided into four longitudinal zones based on the substrate, extent of floodplain, water depth and characteristic riparian vegetation (Smith 1976; Bethune 1990) (Chapter II; Figs. 2 & 4): Zone 1, from Katwitwi to Kasivi, is characterized by very little floodplain development, well-developed banks, sand and or rock substrates, and small rapids scattered throughout; in Zone 2 from

Kasivi to Mbambi, the floodplain is well developed, seasonally extending at times to over 5 km in normal breadth covering submerged pasture land, and including innumerable inferior channels, back bays and oxbow ponds with a predominant sand substrate with occasional rock outcroppings; Zone 3, from Mbambi to Popa Falls, finds the floodplain diminished with wooded islands encircled by narrower channels; rubble, large boulder and bedrock substrate associated with rapids are reminiscent of the Fall Line of the eastern United States; and Zone 4, below Popa Falls through the Mahango Game Reserve, is characterized by well established reed and papyrus beds of the permanently inundated upper Okavango Delta.

Fish community samples were taken from 80 localities during five collecting periods along the Kavango River in 1992 (Chapter II). For the purposes of comparing spatial and seasonal fish assemblage variability as it is reflected with the proposed biological criteria, the focus is concerned with Zones 1, 2 and 3. Tables 10 and 11 show general range values for the proposed metrics on zonal and temporal scales, respectively. A high but increasing flood stage was observed in February which peaked in May and receded from June through December 1992. Sampling localities (Fig. 6) were initially chosen based on accessibility, with emphasis given to re-sampling the sites within each collecting period. However, this proved to be impossible given that the character of the river and its floodplain varied throughout the year; thus for the purpose of creating a monitoring protocol, locations that were in close proximity (± 1.5 km) to one another were lumped as a

single location.

Biological criteria based on fish community assemblages were developed for assessing the Kavango River. Table 8 summarizes diet, habitat preferences and ecological requirements for all species known from the Kavango River in Namibia. The information gathered in Table 8 is based on a synthesis of regional ichthyological literature (Jubb 1967; Poll 1967; Van der Waal and Skelton 1984; Bell-Cross and Minshull 1988) and personal observation, and is the cornerstone for developing the biological criteria for a Kavango River IBI.

RESULTS

Fish community samples from the Kavango River were used to formulate the preliminary measurements (or metrics) based on faunal attributes regarding species richness and composition, trophic structure and abundance and condition. Table 9 lists the proposed metrics to be used to characterize the status of the Kavango River fish assemblage. Tables 10 and 11 summarize the values of each proposed metric on both zonal and temporal scales.

Proposed metrics for IBI

Species richness and composition.- Faunal composition and species richness were assessed using four metrics designed to monitor overall biodiversity and habitat-specific fish assemblages.

Metric 1: Total number of native fish species.- This was included as a general indication of relative biodiversity, with the

rationale being that species richness will decrease with increased environmental degradation. Karr (1981) proposed this metric for midwestern U.S. stream fish assemblages; others retained it (see Miller et al. 1988) in various regional North American applications, and Oberdoff and Hughes (1992) included it in their characterization of the Seine River basin in France. While this metric has shown wide applicability in temperate waterways, there is no reason why its basic premise would not hold true in tropical systems.

Metric 2: Total number of benthic specialist species.- This replaces the number of darter species metric of Karr (1981) while retaining its original intent of assessing benthic habitat conditions. Such substrate habitats are known to be degraded by the effects of siltation (Karr et al. 1986), which is a major concern regarding southern African lotic water resources (Gaigher et al. 1980; Skelton 1983). The fish to be included in this metric are defined as those with specific biological requirements adapted for benthic habitats. When assessing southern African fauna, the following groups should be included in this metric; Labeo spp. (small, benthic dwelling species of this cyprinid genus), Amphiliidae (mountain catfish), Bagridae (grunter catfish), Chiloglanis spp. (members of this Mochokidae catfish genus specifically adapted for rocky habitats) and Mastacembelidae (spiny eels). Benthic specialists of the Kavango River included in the calculation of this metric are the following species: Labeo cylindricus, Amphilius uranoscopus, Leptoglanis dorae, L.

rotundiceps, Parauchenoglanis ngamensis, Chiloglanis fasciatus, Aethiomastacembelus frenatus, and A. vanderwaali.

Metric 3: Total number of cichlid species.- This metric replaces the number of sunfish species metric of Karr (1981) keeping its intent of measuring the degree of degradation of submerged vegetation, which members of the cichlid family generally inhabit. There are 17 cichlid species known from the Kavango River in Namibia (see Table 2), all of which should be included when tallying this metric.

Metric 4: Total number of pelagic rheophilic species.- This new metric is designed to assess open-water flowing areas by monitoring the number of species inhabiting such habitats. Degradation of open-water flowing habitats should be reflected by a decrease in pelagic rheophiles. Species to be examined in calculation of this metric include the majority of the characins (Brycinus lateralis, Hydrocynus vittatus, and Micralestes acutidens) and the cyprinid Opsaridium zambezense.

Trophic Structure.- Alterations in habitat and water quality due to land use practices often result in food resource fluctuations in aquatic systems, which are reflected in the structural changes in trophic composition (Karr et al. 1986). Four metrics were developed to monitor these fluctuations in tropical floodplain rivers.

Metric 5: Proportion of individuals as principal herbivores/detritivores.- This new metric is used to assess the

quality of the aquatic system food base at the primary level. Fishes to be included in this group are defined as those with diets known to comprise primarily plant material, plankton, detritus and algae. Members of this dietary assemblage found in the Kavango River include: Labeo cylindricus, L. lunatus, Oreochromis andersonii, O. macrochir, Tilapia rendalli, T. ruweti, and T. sparrmanii.

Metric 6: Proportion of individuals as principal invertivores.- Designed to assess the secondary or invertebrate food base, this is similar to those modified from Karr's (1981) original metric proportion of insectivorous cyprinids (see Miller et al. 1988). Principal invertivores are defined as those fish with diets primarily consisting of aquatic larvae, insects, crustaceans and mollusks. With the absence of stomach analysis data for most of the tropical fish fauna in southern Africa, species with unknown feeding preferences having mouth and lip morphology suggesting invertebrate diets were included in this group. Invertivorous fish dominate the Kavango River fauna (see Table 8 for a list of designated invertivores used in calculating this metric).

Metric 7: Proportion of individuals as opportunistic scavengers.- This is similar to Karr's (1981) percent omnivore metric in that the proportion of opportunists is thought to increase as degradation disrupts the food web by limiting or decreasing available food base components. Members of this group are fishes known to show catholic feeding behavior or feeding

plasticity. The following Kavango River species are designated as opportunistic scavengers: Clariallabes platyprosopos, Clarias dumerilii, C. gariepinus, C. ngamensis, C. stappersii, Parauchenoglanis ngamensis, Schilbe intermedius, and all Synodontis spp.

Metric 8: Proportion of individuals as piscivores.- This original metric of Karr's (1981) is retained to assess trophic diversity at the top of the food chain. Fishes are deemed piscivores if as adults their diet is comprised primarily of fish, while as juveniles invertebrates may be their food items of choice. The following list includes all fishes of the Kavango River used in the calculation of this metric: Hydrocynus vittatus, Hepsetus cdoe, Serranochromis altus, S. angusticeps, S. macrocephalus, S. robustus and S. thumbergi.

Abundance and condition.- Relative abundance and fish health of populations are evaluated using the following three metrics, all of which are based on those proposed by Karr (1981).

Metric 9: Number of individuals in a sample.- This metric evaluates sample abundance as it relates to catch per unit of sampling effort. The logic behind this is that with similar sampling methods and effort, degraded sites are expected to harbor fewer individuals than sites with higher quality conditions (Karr et al. 1986).

Metric 10: Proportion of individuals as introduced or invasive species.- This is similar to metrics modified to replace

Karr's (1981) original percent hybrids (Miller et al. 1988), but is unique in that it includes native invasive species. The rationale behind this is that since the Kavango River proper is absent of both exotic and regionally-invasive species (Skelton et al. 1985; van der Waal 1991), the initial effects of exotics on the native fish assemblage structure can be monitored and documented, e.g., if indeed T. trichopterus and A. orthodus are successful in colonizing the river proper (Chapter IV). The obvious assumption here is that the integrity of native fish communities is compromised when foreign species have invaded or are introduced.

Metric 11: Proportion of individuals with visible anomalies.- This metric is a direct evaluation of fish health, and is retained from Karr (1981). Any individuals observed to have disease, deformities, lesions and tumors are included in the calculation of this metric.

Seasonal and spatial trends

Species richness and composition.- Metric 1: Total number of native fish species.- On a longitudinal basis, this metric yielded higher values in the non-floodplain zones, with the greatest median and average relative species richness in Zone 3. Seasonally, species richness was found to be lowest in the February, May and November sampling periods, while on the average the June effort yielded the most species per collecting site. It was during this period when the most diverse collections were obtained, with two samples of 30 species each, from Zones 1 and 2, respectively. The

least diverse collection was obtained during May in Zone 2, harboring only two species.

Metric 2: Total number of benthic specialist species.- As to be expected, these species occurred most frequently in the non-floodplain zones, with Zone 3 showing the highest frequency of appearance (over half of all samples) . Benthic specialists were rarely found in Zone 2, as over 75% of all collections within that zone were absent of these species. Almost 50% of the Zone 1 samples contained members of this group. The September collecting period found the highest incidence of occurrence of these species, with 70% of all samples having benthic specialists. The most species of this group (5) collected at any one site occurred in Zone 1 during June.

Metric 3: Total number of pelagic rheophilic species.- Zone 1 found the highest relative species occurrence of this group, with 2 species collected per site on the average and over 80% of all samples containing at least one pelagic rheophile. Zone 2 had the lowest relative frequency of occurrence, with just over 50% of all collections having a member of this group. The pelagic rheophilic group peaked in relative frequency during the February and November sampling periods, with 2 species obtained per collection on the average. The May sampling effort yielded the lowest relative incidence regarding this group, with over half the collections absent of any pelagic rheophiles. The maximum possible number of pelagic rheophilic species (4) was obtained in all three zones exclusively during the February sampling period.

Metric 4: Total number of cichlid species.- On a longitudinal basis, this metric showed no trends as relative occurrence of cichlid species was quite similar from zone to zone on the average. Basically, the same can be said regarding seasonal comparisons, as averages and medians barely fluctuate from period to period. The May sampling effort, however, indicates a slight decrease in the median value. A single collection was absent of any cichlids, obtained during May in Zone 2. The maximum number of cichlids collected in any one sample (9) were taken from zone 1 (twice in June) and Zone 2 (once in both June and November).

Trophic structure.- Metric 5: Proportion of individuals as principal herbivores and detritivores.- The medians and averages for this trophic group are roughly constrained within the 20 to 30% range for the three zones, with Zone 3 showing slightly higher relative values than the other two. Temporally, herbivore and detritivore proportions show two distinct modal groupings: (1) February, September and November, and (2) May and June. The former sampling periods portray a consistency in their medians, which are confined to the 25 to 30% range, while the latter are markedly lower, approximating the 15 percentile. Furthermore, these latter sampling periods each contain a single sample completely lacking any members of this dietary assemblage, both of which occurred within Zone 2. The maximum relative proportion of herbivore/detritivore feeders was found in Zone 2 during the February effort, comprising over 90% of the entire sample.

Metric 6: Proportion of individuals as principal invertivores.- The median and average range over all three zones for this trophic group is roughly between 60 and 75%, with Zones 1 and 3 slightly higher relative to Zone 2. Seasonally, an interesting trend is revealed when comparing the proportion of invertivores to the proportion of herbivores/detritivores (Fig. 7). The May and June efforts, which harbored the lowest proportion of the latter, yield the highest proportion of the former relative to the other sampling periods. The invertivore assemblage during May and June ranged between 70 and 78% based on medians and averages, while the remaining periods ranged from roughly 50 to 67%, with the November effort yielding the lowest relative proportion for this group. February of Zone 2 harbored the only collection absent of principal invertivores, while the maximum proportion obtained was during May within Zone 1 where this dietary assemblage comprised over 95% of a single collection.

Metric 7: Proportion of individuals as opportunistic scavengers.- Based on both medians and averages, the proportion of this group peaked in Zone 3, while Zones 1 and 2 were fairly similar and slightly lower. Throughout the year, on average the proportion of this group per sample ranged from a low in February (1.3%) to highs in June and September (over 8%). Collections lacking opportunistic scavengers were obtained most frequently in February, while all samples in June and September contained some members of this group. The highest proportion of this feeding group from a single collection was found in a November sample from

Zone 1, where this opportunist assemblage comprised over 40% of all individuals.

Metric 8: Proportion of individuals as piscivores.- Zone 2 was found to harbor the highest relative proportions of piscivorous fishes based on both median (3.0%) and average (6.1%), while the other zones ranged between 1.5 to 2% for these parameters. Seasonally, fish eaters were most prevalent during the November sampling period where two collections yielded piscivore proportions over 20%, and one sample was comprised of 67%; these three samples were all obtained within zone 2. Each zone and each sampling period found collections absent of this group, with Zone 2 and the May sampling effort having higher relative incidence of this result.

Abundance and condition.- Metric 9: Number of individuals in sample.- The range of average values along the Kavango River for this metric spanned from 160 in Zone 3 to 214 in Zone 2. On a seasonal basis, the average number of individuals peaked during the May effort and bottomed out during the September sampling period. The smallest and largest number of individuals collected from any single site (8 and 769 specimens, respectively) were both obtained from Zone 2 in June. The results of this metric are simply general indications of relative abundance and nothing more, as they are not calculated as a function of catch per unit of sampling effort.

Metric 10: Proportion of individuals as introduced or invasive species.- No foreign species are known from the Kavango

River proper at the present time.

Metric 11: Proportion of individuals with visible anomalies.- After examining over 14,000 individuals, only a single specimen (juvenile Oreochromis andersonii) collected in November within Zone 2 was found with a visible anomaly (ectoparasite).

DISCUSSION

Inherent within fluctuating systems such as seasonal rain driven, tropical floodplain rivers, there are difficulties regarding assessment and characterization. As opposed to lotic systems in temperate climates with characteristic steadfast processes, relatively speaking (see Vannote et al. 1980), tropical floodplain rivers are much less stable and unpredictable (Lowe-McConnell 1987), perhaps tending towards community states without structure (O'Keefe 1986). Cambray et al. (1988) perceived that aquatic organisms adapted to very constant and predictable conditions may become recognizably different within a year or two of a minor change, while those of a highly fluctuating system might not react perceptibly over many generations.

As data sets regarding fluctuations in natural tropical systems (i.e. water quality) are either nonexistent or un-synthesized (Cambray et al. 1988), monitoring the impacts of natural variability and catastrophic events is impossible since knowledge of baseline conditions has not been achieved. Cambray et al. (1988) theorized that the effects of anthropogenic interferences on the long term cycles of inland aquatic ecosystem

biota are often obscured by non-foreseen natural processes (i.e. unpredictable and inequitable distribution of rainfall). This emphasizes the point that natural disturbances and those of anthropogenic origin must be discernible in order to properly understand cause and effect relationships relating to degradation and biotic response. It has been generalized that in the case of southern African systems, changes due to anthropogenic disturbances exceeds those due to normal annual events, while natural abnormal catastrophic events can alter the aquatic environment to a similar degree (Cambray et al. 1988).

Evidenced by the seasonality of the results discussed above regarding the proposed biological criteria to characterize the Kavango River fish fauna (Tables 10 and 11), the metrics are highly variable spatially and temporally. To summarize: (a) <u>of the four species richness metrics</u>, (1) the average number of species was highest in Zone 3, and highest in June. (2) The number of benthic species peaked in September, 70% of all samples, with highest numbers generally occurring in Zone 3. These species were absent in 75% of the Zone 2 collections. (3) The pelagic species numbered highest in Zone 1, lowest in Zone 2, and seasonally were found in greatest numbers in February and lowest in May. (4) The number of cichlid species showed the same basic trends seasonally and longitudinally; (b) <u>amongst the trophic metrics</u>, (5) the percentage of herbivores and detritivores were generally the highest in February, September and November samples (20-30% of the total), and lowest in May and June (±15%). (6) The number of

invertivores varied inversely with the herbivores and detritivores, with the highest relative numbers (70-78%) in May and June. They were reasonably well distributed across all three zones (60-75%). (7) The opportunistic scavengers peaked in Zone 3. They were present in lowest numbers in February, and highest in June and September (8%). (8) Piscivores, especially tigerfish, were probably under-sampled, but seemingly occurred in highest percentages in Zone 2, and in November; and (c) <u>of the abundance and condition metrics</u>, (9) numbers of specimens, peaked in May, but were distributed evenly longitudinally. Metrics (10) numbers of introduced and invasive individuals and (11) those fish with anomalies, each were considered representative of a near-perfect state with only one specimen of fish observed with an anomaly. Such variability contrasts considerably to Steedman's (1988) excellent employment of the IBI concept for Ontario streams, where he reported low variation of IBI scores within and between years.

The variability discussed above is compounded by three distinct zones of different physiographic features of the stream bed, the channel, substrate and littoral zone formation, all influencing fish structure and function as well as sampling bias. Thus, it is premature to finalize criteria based on a single year's effort; however, this data base is extremely useful for refining such a monitoring protocol after continued sampling.

Hocutt (1981) first drew attention to the limitations of the IBI concept, and recommended that the inherent difficulties of obtaining a representative sample should not be minimized,

especially in a developing country context. Factors which influence this concern are (a) the qualitative nature of sampling, (b) gear selectivity, and (c) experience, training and motivation of the personnel involved. Additionally, it should be recognized that biota are seasonally abundant or scarce dependent upon ecological and life history requirements, including (a) migratory habits, (b) reproductive strategies, (c) habitat preferences, (d) behavior, e.g., some species might be nocturnal, (e) longitudinal zonation, and (f) zoogeographic considerations. The taxonomy of many species is under review, and often difficult. Importantly, most species pass through different trophic levels as they develop, and this must be a long-term consideration in refining an IBI model.

It is apparent that sampling efforts should be coupled with certain flow characteristics or flood stage over a period of many years to ascertain the status and condition of faunal assemblages, and whether a somewhat fixed community structure exists (O'Keefe 1986). Emphasis should also be given to sampling in coincidence with biotic processes such as growth stage and reproductive intervals (Cambray et al. 1988), so as to track environmental conditions as related to fish community life histories. Furthermore, the development of standardized quantitative sampling methodology should be undertaken to give more meaning to faunal comparisons on both intra and inter-drainage scales.

The biological criteria for aquatic resource assessment proposed in this investigation for the Kavango River should be

regarded by no means as definitive, and by all means preliminary. As the first attempt to characterize a floodplain river system by the structure, function and condition of its resident fish community assemblages, this work is considered as a baseline model to build on in the face of continuing environmental degradation and resource disparagement. As biologists become more familiar with ecological requirements and tolerance responses, those species which prove to be indicative of particular disturbances will be revealed, and the biocriteria model can be shaped and evolved into a more effective monitoring tool.

The development of a biological monitoring protocol in Namibia should not be viewed as an academic exercise. All the rivers of the region have modified flow regimes or land use-associated impacts. Notably, the expansion of the Eastern National Water Carrier (ENWC) system could have significant deleterious consequences for the Kavango River, and its ability to sustain a subsistence fishery, dependent upon the location of the pumping stations and the volume of water pumped relative to natural flows. We agree completely with the views of Cashman et al. (1986) and van der Waal (1991) that extraction points of the ENWC should be downstream of the Cuito River confluence to mitigate impact.

RECOMMENDATIONS

Recommendation 1.- The Kavango River catchment is unique, and remains relatively pristine in a developed country context. The headwaters are little explored, the middle basin has an extensive

seasonal floodplain fishery, and the lower part of the catchment is endorheic, terminating in the Okavango Delta, Botswana. Given the likelihood of increased water resource utilization, stream alterations, development activities, population expansion, riparian zone modifications, and so forth, it is prudent to establish a long term water quality surveillance program for the catchment. Firstly, it is recommended that Namibia play a lead regional role in the establishment of a basin-wide surveillance protocol for the Kavango River involving both Angola and Botswana. This central position of managing the system should blend the resources of both the NMFMR and the Multi-Disciplinary Research Centre of UNAM.

Recommendation 2.- Relative to the proposed long-term monitoring program, an initial effort should be made to establish routine sampling stations in Namibian waters to develop a physico-chemical and biological data base in order to delineate between natural and man-related alterations in the system. As a first step, seasonal sampling efforts should be conducted in at least each of the three zones identified above, inclusive of flooding, peak flooding, post flooding and low flow conditions. This effort, and subsequent data analysis, should be conducted for at least two years (preferably five) as a screening procedure to define the magnitude of variability of parameters to be measured, and identify the most appropriate stations and times of the year for sampling.

Recommendation 3.- Effort, gear, laboratory methodologies and preferably field crew must be standardized.

Recommendation 4.- Chapter III has emphasized the development

of the IBI procedure as a monitoring tool for the Kavango River. Relative to Chapter II, it is recommended that the functional aspects of the fish community be further investigated in order to refine the IBI procedure and its metrics. As a corollary to this recommendation, it is important to recognize that the IBI procedure, as contemporarily practiced in North America and Europe, might be limited as a long-term monitoring procedure in a tropical flocdplain environment. Thus, alternate techniques of data interpretation require simultaneously investigation (e.g., see Fausch et al. 1990) to determine which procedure (or set of procedures) best serves as a predictor of environmental alterations.

CHAPTER V. DESCRIPTION OF THE KAVANGO RIVER FISHERY

INTRODUCTION

The Kavango River fishery was recently addressed by van der Waal (1991) and van Zyl (1992). These works included a discussion of fishing methods and their selectivity, intensity of fishing activities, and estimates of total production. Their data and our observations indicate that the complete fish biodiversity of the Kavango River comprises the subsistence fishery. Clear signs of over-exploitation are not evident, but lower frequencies of larger individuals in experimental and commercial catches may indicate otherwise (Skelton and Merron 1984, 1985, 1987; van der Waal 1991; van Zyl pers. comm.). Table 12 is a list of the colloquial names applied to the fishes of the Kavango and Caprivi provinces by the indigenous people.

We have identified two components of the subsistence fishery of the Kavango River: the traditional and the contemporary. The traditional fishery is that component which relies upon hand-made traps and weirs (Table 13) from natural material to capture fishes; normally, these appear to be consumed by the family. As the fishery can be divided into traditional and contemporary gear components, this also has inference for partitioning the fishery by gender participation and economic value.

The traditional fishery is dominated by women and their children, usually daughters. The catch is primarily those smaller

short-lived species with high annual turnover, or juveniles of larger species which have longer life spans and require longer periods to achieve sexual maturity. While catch certainly represents fishing mortality, in many respects it could be viewed as that portion of total mortality which would be lost naturally on an annual basis due to the limiting factors associated with floodplain systems (Lowe-McConnell 1987). The additional pressure of contemporary gear such as drag nets and gill nets, however, presents a severe strain on the fishery as it tends to harvest (a) a higher catch per unit effort (CPUE), and (b) the larger, most reproductively viable individuals of the longer-lived species. While the gill net fishery is related to subsistence living standards, it is also very commercialized with catch openly sold or traded; it is a male-oriented component of the fishery.

Namibia is currently developing a "white paper" fisheries management plan for the Republic's inland waters. Key concerns are the establishment of gear (e.g., traditional baskets vs. contemporary seines/gill nets), size, and season restrictions. Also, thought is being given to the establishment of "no fishing" zones to act as epicenters for fish production and dispersion. Yaron et al. (1992) addressed the fishery in a limited way, but estimated that households along the Kavango River consume between 3 and 5 kg of fish a week, with a large percentage (60%) of consumption representing fishes caught by the household. This reflects an importance of the fishery greater than its role in household income.

The objective of this chapter is to provide baseline information on (a) life history aspects of certain fish species targeted in the subsistence fishery using Electronic Length Frequency Analysis software (ELEFAN), and (b) nutritional values of representative Kavango fishes.

LIFE HISTORY ANALYSES

Introduction

With the continuing problems related to accelerated population growth and limited food resources in Third World countries, tropical fishery assessment has become a major focus in the development of impoverished nations (Csirke et al. 1987). Fish have been regarded as the protein that will nourish the world, whether from subsistence riverine fisheries, intensive aquaculture facilities, or exhaustive sustainable yield marine fisheries. Consequently, cost-effective means of assessment are needed to analyze fishery data, allowing for proper long-term management decision making.

Fundamental to the long-term objectives of sustainable fishery utilization is knowledge of age and growth rates of stocks in question. In temperate zone fisheries, ages of individual fish can easily be determined by examining skeletal structures such as scales, bones, and otoliths, which leave 'marks' as evidence of winter checks in growth. In tropical zone fisheries however, where seasonal growth is not so apparent, the methods of inspecting bony structures to infer fish age are inadequate. For this reason,

Pauly and Gaschutz (1979) and in particular Pauly (1983) turned to length frequency analysis to estimate growth parameters for tropical fish stocks.

The Electronic LEngth Frequency ANalysis (ELEFAN) computer software package was developed to aid research scientists and fishery resource managers in assessing the dynamics of tropical fish stocks, using length frequency data as the singular primary input. Created and refined within the last 10 years by Pauly (1985, 1986a,b, 1987) and Guyanilo et al. (1989), ELEFAN has shown wide applicability and utility for a diverse array of fishery resources. The use of ELEFAN for fishery assessment spans from molluscan fisheries off the Bahamas (Berg and Atalo 1984) and Kuwait (Almatar et al. 1984); crustacean fisheries near the Galapagos Islands (Reck 1983), India (Silas et al. 1984) and Spain (Pauly 1987); and fin-fish resources in the areas of the North Sea (Rohde 1982), South Pacific (Sua 1990), Philippines (White 1982), India (Birador 1989), Kuwait (Morgan 1985) and Mozambique (Gjosaeter and Sousa 1983). This work presents an attempt of extracting growth parameters from length frequency data for two species of freshwater fishes from the Kavango River, Namibia, using the ELEFAN software package.

Methods and Materials

Biological Sampling

Specimens used for the preliminary assessment were collected during a biodiversity and distribution study of the Kavango River,

Namibia in 1992. Fish community samples (N = 80) were obtained with a variety of gears during five sampling periods in 1992 (see Chapter II for sampling methodology details). Each specimen was preserved immediately after collection and measured in the laboratory.

Growth Parameter Estimation

The growth model, proposed by Pauly and Gaschutz (1979) and used in the ELEFAN program is a seasonally oscillating version of the generalized von Bertalanffy Growth Formula (VBGF) (Bertalanffy 1938), which has the form:

$$L_t = L_{\infty} \left(1-e^{-KD(t-t_0) + (CKD/2\pi)\sin 2\pi (t-t_s)}\right)^{1/D}$$

where

L_t is the predicted length at age t;

L_{∞} is the asymptotic length, or mean length the fish of a given stock would reach if they were to grow forever;

K is a growth constant ("stress factor" in Pauly 1981);

D is another growth constant ("surface factor" in Pauly 1981);

C is a factor which expresses the amplitude of the growth oscillations;

t_0 is the age the fish would have at zero length if they had always grown in the manner predicted by the equation; and

t_s sets the beginning of sinusoidal growth oscillations with respect to $t = 0$.

ELEFAN replaces two of the original parameters of the VBGF by designating;

(1) the Winter Point (WP), the period of the year as when growth is the slowest, takes the place of t_s. WP is expressed as a fraction of a year, and is related to t_s through $t_s + 0.5 = WP$; and (2) the VBGF parameter t_0 by the term T0, which is used internally to fulfill the role of positioning the growth curve along the time axis, correcting for erroneous length-at-age output (Pauly 1987).

The ELEFAN program identifies peaks and troughs in length frequency histograms by using a high-pass filter calculation. A running average leads to definition of peaks as those parts of a length frequency distribution that are above the corresponding running average, with troughs separating the peaks. Growth curves are then fitted to the restructured data through a series of prompts asked of the user (see Pauly 1987).

Once best estimates of the critical parameters are obtained, ELEFAN allows for the user to extract related fishery resource outputs from several separate ELEFAN subroutines. Inferences regarding total, natural, and fishing mortalities, length converted catch curves, gear selection curves, and seasonal recruitment patterns can be drawn through the use of ELEFAN given that the proper inputs are known and all assumptions are satisfied (Pauly

1983).

It cannot be overemphasized that the valid utility of ELEFAN (as with any other simulation software) is directly related to the quality of data and whether the assumptions inherent within the programs model are met (Gulland 1987; Shepherd et al. 1987). The reliability of this software is suspect in some opinions, as ELEFAN relies on the optimization of a goodness of fit criterion of assumed growth parameters and the data, which is based on coincidences of expected and observed modes (Shephard et al. 1987). It has been shown to both over and underestimate growth parameters when fishing is size selective (Hampton and Majkowski 1987), while the observed modes may be gear selective modes and need not indicate age class (Alagaraja 1989). Additionally, the software user should be adept at examining length frequency data with the ability to discern what the data suggests before turning to the computer for the answer, as analysis of length frequency relationships is a developed and honed skill (Sparre 1989). For these above-mentioned reasons, all fishery assessment information extracted from my data sets should be considered strictly preliminary.

ELEFAN application method

The ELEFAN program was applied to select Kavango River species through the following steps to estimate growth and mortality:

(1) Length frequency data from were entered into the ELEFAN 0 routine of the Compleat ELEFAN software

package of Guyanilo et al. (1988);

(2) Attempted to extract preliminary estimate of Loo using the subroutine estimation of Loo and Z/K within the ELEFAN II routine;

(3) To check for any modal progressions over the restructured length frequency data, the curve fitting by eye subroutine of ELEFAN I was used;

(4) To refine the Loo parameter estimate obtained in (2), and to estimate a corresponding value of K, the response surface analysis subroutine within ELEFAN I was used;

(5) To further hone in best estimates for the above mentioned parameters, the automatic search routine of ELEFAN I was employed;

(6) To obtain estimates of mortality parameters, the catch curve routine of ELEFAN II was used.

Target species

Five species of fish were initially chosen to be analyzed using the ELEFAN program: a cyprinid (*Barbus poechii*), a catfish (*Schilbe intermedius*) and three cichlids (*Pseudocrenilabrus philander*, *Tilapia rendalli*, *T. sparrmanii*). Justification behind the target species was that each species was commonly represented in our catches (Table 2), as well as the traditional fishery (van der Waal 1987, 1991; van Zyl, pers. comm.; pers. observ.). Only two of the species (*B. poechii* and *P. philander*) were analyzed with ELEFAN, as the data sets for the remaining three proved to be

inadequate although length frequency histograms were determined.

Van der Waal (1991) found B. poechii to comprise 13% of total catch by fishing lines and P. philander to comprise over 25% of all fishes caught with funnels in the Kavango. Barbus poechii, a fairly small cyprinid (maximum size 11 cm TL), is a shoaling species known to undertake spawning migrations during the rainy months (Bell-Cross and Minshull 1988). Pseudocrenilabrus philander, a small cichlid (maximum size 9 cm TL), is a quiet water species, but may be found in almost any aquatic riverine habitat (Bell-Cross and Minshull 1988). These two species were found to be very common and numerous on both spatial and temporal scales during this study (see Chapter II). These species were treated in detail because all presumable age classes were well represented in the data.

Results

Barbus poechii

Figure 8 is a length frequency plot for all B. poechii collected in 1992 with various gears. Using the length frequency data from Table 14, a range of best parameter combinations along a response surface plateau with a goodness-of-fit of Rn = .273 was obtained via ELEFAN for B. poechii (L_{∞} = 117.4 - 122.3 mm and K = 1.116 - 1.011/yr). The restructured length distributions are presented in Figure 9 together with a fitted growth curve using L_{∞} = 122.3 mm, and K = 1.011. Using these same values, a catch curve analysis was done to estimate total mortality, yielding a Z value

of 3.46/yr.

Pseudocrenilabrus philander

Figure 10 is a length frequency relationship for P. philander for all individuals collected during 1992 with various gears. Using the length composition data from Table 15, a best parameter combination range of L_{∞} = 101.8 - 108.2 mm, and K = .64 - .56/yr (goodness-of-fit of Rn = .351) was obtained via ELEFAN.

The restructured length frequency data for P. philander is shown in Figure 11, with a superimposed growth curve fitted to the peaks and troughs. The equation behind the curve uses a L_{∞} value of 101.8 mm, and a K value of .64/yr. Using these same parameter values, a catch curve analysis was done to estimate a total mortality value of 4.18 for this small cichlid.

Remaining species

Length frequency data for S. intermedius, T. rendalli and T. sparrmanii collected during both this seasonal study and the annual Kavango River fishery investigation conducted by the NMFMR (van Zyl et al.) are presented in Tables 17, 18 and 19, respectively. Figures 12, 13 and 14 are histograms illustrating the length distributions of these three species, respectively.

Discussion

Barbus poechii

Upon examination of the length distribution numbers per season

for this species (Table 14), it becomes evident that an age class can be traced through the consecutive sampling periods. Starting in February, the size classes comprising most of the catch for the sampling period consisted of those towards the low end of the size spectrum, an indication of a dominant juvenile life stage. The following sampling periods of May and June show consistently higher numbers in larger length classes, the presumable advancement of the year class into the sub-adult life stage. Although September yielded fewer individuals, the trend of increasingly larger fish observed with each consecutive sampling period is still apparent. This trend is validated in November, with highest relative numbers occurring towards the upper end of the size spectrum, indicating the cohort in question is attaining the adult life stage. The length frequency relationship shown in Figure 8 portrays a bimodal distribution, an apparent correspondence to two separate cohorts. The steep descending right arm of the plot may suggest a preliminary indication of high mortality rates towards the upper end of the size range (Gulland 1987b).

The range for asymptotic length (117.4 - 122.3 mm) generated using the ELEFAN package is close to the observed maximum length for this species (110 mm), thus deeming these estimates plausible. Whether the derived best estimate range of the K coefficient (1.116 - 1.011/yr) has credibity or not is difficult to address given the paucity of available information regarding cyprinid growth in tropical floodplain systems. The total mortality estimate of 3.46/yr seems rather high, indicating that second year (relative

age) fish are selected for at an exceedingly high rate. However, given the natural annual oscillations of the system and high (subsistence) fishing mortality, this estimate may be reasonable. Also, the high total mortality estimate concurs with the observation regarding the steep descending right arm of the length frequency plot (Figure 8) suggesting higher mortality rates of larger-sized fish.

Pseudocrenilabrus philander

The length frequency distributions per season (Table 15) for this species indicate a consistently broad range of sizes captured, with several size increments comprising comparable numbers of individuals. Within each sampling period, the length frequency relationship can be thought to resemble a relatively normal, unimodal curve (excepting the November sample) with no particular cohort visibly advancing through the fishery as in the case of B. poechii. This uniformity of size class distribution on a seasonal basis suggests multiple broods per year, a life history strategy characteristic of some members of the cichlid family (Lowe-McConnell 1982; Bell-Cross and Minshull 1988). The length frequency histogram for P. philander (Figure 10) portrays a bell-shaped normal distribution, with perhaps two apparent modes. As with B. poechii, the steep descending right arm of the plot may suggest relatively higher mortality rates regarding the larger older individuals. While this needs confirmation through age and growth studies, the data are reasonable. Tropical floodplain

fishes often follow a "boom or bust" life history strategy characteristic of r-selected species (lowe-McConnell 1987; Laurenson & Hocutt 1986).

As the range of L_∞ values (101.8 - 108.2 mm) generated via ELEFAN approximates the observed maximum for the species on the low end, this spectrum of values can be considered decent estimates. The K value range estimated for P. philander (.64 - .56/yr) is within the ranges estimated for other members of the cichlid family (Table 16), but is well towards the upper end of the spectrum. As the goodness-of-fit indicator is relatively high (Rn=.351) for the estimated range of growth parameter combinations, these estimates can be perceived as believable. As with B. poechii, the high estimate of total mortality (4.18/yr) for this small cichlid indicates a very high mortality rate in the second year (relative age).

Schilbe intermedius

As shown in Table 17, the length frequency distribution data for S. intermedius collected seasonally reveal very little due to the relatively low numbers of individuals found during each sampling period. When shown collectively with data from van Zyl et al. (Figure 12), there appears to be three distinct modes among the size class distributions, implying three separate age classes of this species in the fishery.

Also apparent in this plot is an obvious gear size-selectivity relationship. The length frequency histogram shown illustrates the

effect collecting gear can have on the size distributions sampled. The fishes sampled during this study were collected primarily with small seines, rotenone and backpack electrofishing units (see Chapter II for detailed description of collecting methodology). The methods employed by van Zyl et al. during their annual fishery survey in June consisted primarily of gill nets (mesh size up to 14 cm) and beach seines (mesh sizes up to 8 cm). Thus, the relationship portrayed in Figure 12 implies that the gear used in this study selects for and is more effective in the collection of smaller, younger S. intermedius than the methods used by van Zyl et al. The converse is also apparently true in that seining and rotenone are ineffective in the capture of larger, older individuals, as adults of this species seem to be vulnerable only to nets with large mesh sizes.

Tilapia rendalli

The seasonal length frequency data for T. rendalli (Table 18) reveal no advancement of a particular age class through the seasons, much like that observed for P. philander. Plotting the data along with those of van Zyl et al. (Figure 13), a unimodal distribution is presented showing a steep descending right arm of the curve. As T. rendalli is known to attain considerably larger sizes than observed during this study (Bell-Cross and Minshull 1988), size-selectivity bias should be investigated before suggesting higher mortality rates among larger individuals (Gulland 1987). Comparing our data with those of van Zyl et al., the

collecting methods employed in this study seem to be more effective at capturing juvenile and sub-adult individuals of this species.

Tilapia sparrmanii

Length frequency data on a seasonal basis for *T. sparrmanii* are shown in Table 19, and much like the cichlids discussed above, no trends regarding age classes moving through the fishery are apparent. Like *P. philander*, the relative uniformity of age distribution for each sampling period suggests a likelihood of multiple broods per year. A length frequency histogram of our data coupled with those of van Zyl et al. for this species (Figure 14) implies a slight suggestion of a bimodal distribution, perhaps indicating the presence of two separate age classes. From the standpoint of gear size-selection, again our methods seem to be more effective for capturing the smaller individuals, whereas van Zyl et al.'s collection techniques select for slightly larger individuals.

NUTRITIONAL VALUES

Introduction

Van der Waal (1990, 1991) and van Zyl (1992), particularly, have evaluated aspects of the subsistence fishery in the Kavango and Caprivi provinces, including gear types, species taken and catch per unit effort. Yaron et al. (1992) estimated that Kavango households ate 3-5 kg of fish per week, with 60% of this

consumption taken from local waters; this latter figure, an expression of dependence on the local fisheries, might well be an under-estimation given the subsistence livelihood of the majority of the indigenous people.

The nutritional role of fish in the diet of local communities has been examined only in a cursory manner, primarily from the view of catch statistics (e.g., van der Waal 1991). It was beyond the scope of the present study to provide a detailed analysis of the socio-cultural relationships of villagers to the fish community; however, a modest data base was obtained on the relative nutritional values for a few of the Kavango River fish species with the intention of extrapolating "backwards" as to how many people the fishery can support by meeting the daily nutritional requirements of villagers. The live weight of fish usually consists of approximately 70-80% water, 20-30% protein and 2-12% fats (Love 1980); however, the precise values vary considerably within and by species, being dependent upon their specific diets, sex, season, activity and so forth (Weatherley & Gill 1987).

Methods and Materials

The Ministry of Agriculture, Water and Rural Development kindly made available its analytical laboratory facilities to analyze the gross energy (MJ/kg), percent (%) total crude protein and percent (%) of fat concentrations (fats, oils, etc.) soluble through ether extraction. Some 15 species were examined (Table 20), all taken during March 1992 near Rundu. The sample size

varied by species. All the fish were homogenized in tact, excluding that the alimentary canals were removed, which is similar to how fish are prepared for eating by the Kavango people.

Gross energy was determined using an adiabatic bomb calorimeter from Digital Data Systems (CP500) calibrated prior to sample analysis. Approximately 0.5 gm of homogenized sample was combusted under high oxygen pressure (3000 KPa) in each sample. Measurement were made in joules (J), the current international standard unit of energy (1 kJ = 0.239 kilocalories [kcal], so 1 kcal = 4.184 kJ or 0.004 megajoule (MJ)), and represents the heat of combustion of the different energy substrates such as proteins, lipids and carbohydrates (Busacker et al. 1990). A single gram (1 g) of either protein or carbohydrates produce 4 kcal (16.7 kJ) of energy, while 1 gram of fat produces 9 kcal (37.6 kJ) (Whitney and Hamilton 1987), excluding urinary loss.

Crude protein was calculated as nitrogen X 6.25, according to the traditional Kjeldahl digestion procedure (Busacker et al. 1990). A 0.5-gm sample was digested using a Buchi 430 block digester unit, until the solution was translucent. After digestion, the sample was cooled to room temperature, and 250 ml of distilled water added. Twenty milliliters of this sample was mixed with 80 ml of distilled water and 2 ml of alkaline reagent (10 M sodium hydroxide and 2 M sodium iodide), and mixed by a magnetic stirrer prior to reading. Ammonia nitrogen was measured with a Model 9510 Orion ammonium ion selective electrode and a Model 701 Orion specific ion meter, both calibrated.

Fats are readily extractable from proteins and carbohydrates due to their solubility in non-polar solvents such as ether (Busacker et al. 1990). Fat content was determined using the Soxhlet extraction procedure using a Buchi 810 Soxhlet Extraction Unit. A 0.5-gm sample was placed into cellulose thimbles and sealed with cotton. The cellulose thimbles and pre-weighed Buchi beakers with petroleum ether were placed in the extraction unit for two hours. Extracted fat was subsequently dried in the beakers for 30 minutes at 100°, cooled and weighed. The percentage ether extract was calculated using traditional formulae.

Results

The results of the study are presented in Table 20. Gross energy content (MJ/kg) varied from 15.54 to 20.47 MJ/kg for the fifteen species examined, with the highest reading occurring in the tigerfish (*H. vittatus*) and the lowest in the southern mouthbrooder (*P. philander*).

Adequate samples were available to measure the percentage crude protein in only 10 of the fifteen species. For those species examined, crude protein varied from 52.4% in *Oreochromis macrochir* to 76% in *Serranochromis robustus*. The percentage fats by ether extraction was measured in 13 species, with the lowest being 2.4% in *Marcusenius macrolepidotus* to 15% in *Shilbe intermedius*.

Discussion

These data on the nutritional value of Kavango River fish are very preliminary. The sample sizes used and the lack of replications do not permit a statistically rigorous interpretation of the results. However, no similar data are known to exist on freshwater fishes of southern Africa, and we have successfully demonstrated that this procedure if expanded in the future can lead to a fuller appreciation of the value of the fishery. Once the NMFMR gains an understanding of the population dynamics of the system, including yield, this type of data will be important in establishing management strategies. That is, a reliable estimate can be made of the value of the fishery to support persons living at the subsistence level.

The fifteen species examined, when combined, can be construed to represent a typical catch by traditional gear, i.e., all the species examined and their respective size ranges are normally encountered in the catch by villagers. If the data are averaged for all samples combined, mean values for gross energy (18.6MJ/kg), crude protein (64%) and soluble fats (7.8%) are obtained. Davis & Warren (1968) presented information on the mean caloric values of eight fish species as determined by bomb calorimetry; values ranged from 4.215 to 5.633 kcal/g, with a mean of 5.034 kcal/g. The latter figure translates to 20.1 MJ/kg, which compares well with our mean value of 18.6 MJ/kg.

Van der Waal (1991) indicated that Kavango people using traditional gear catch about 0.6 kg of fish per daily effort, and

this will be used to feed the family. The RDA energy allowance for adult North American males 19-50 years old varies by age category, but averages 11.34 MJ/day; women of the same age average 9.2 MJ/day dependent upon whether they are pregnant or lactating (Kreutler and Czaka-Narins 1987). If our average figure of 18.6 MJ/kg of energy obtained from a mixed assortment of fish species is realistic, and if we use the RDA's established for the USA, only 11 MJ/kg is available in a daily catch of 0.6 kg, which is just adequate to feed one adult daily, i.e., an average male would have to consume about 0.6 kg and an average female 0.5 kg of fish per day to meet the RDA, if fish alone were the source of all energy demand. Juvenile (4-10 years of age) RDA average demand is about 8 Mj/day (0.43 kg). However, fish is supplemented by other protein sources such as processed fish and meat which are either purchased or bartered (van Zyl 1992). The principle crop (and staple) is millet, which accounts for 74% of crop production, followed by maize (13%), sorghum (7%), beans (3%) and other vegetables (3%) (Yaron et al. 1992).

Based on a population estimate of the Kavango people at 150,000 persons, divided between a ratio of 40:60% adults to juveniles with an average RDA protein requirement of 58g and 40g, respectively, the total RDA for the population is 2.58 kg x 10^6 per annum. Sandlund and Tvedten (1992) indicated that the Kavango River yields from 840 to 3,000 metric tons (0.84 to 3 kg x 10^6) of fish annually. At an intermediate level of 2,000 metric tons, this implies about 1.2 metric tons (1.2 kg x 10^6) of crude protein is

available to the population based on about 60% crude protein composition in our preliminary laboratory analyses. This infers that the river can meet only about 50% of the current protein demand of the Kavango people, if the fishery alone represented the only source of protein.

These calculations are entirely preliminary, but provide thought provoking insight into the prospect of the river not being able to meet the demands of an expanded subsistence fishery given the combined scenarios of increased water diversion schemes, expanding populations and continued drought. The calculated figures for total RDA crude protein demand are far less than the maximum sustainable yield estimates provided by Sandlund and Tvedten (1992). If these crude nutrition estimates held up under critical hypothesis testing, it would call for substantial relief aid within the next decade and/or alternate means of protein supplementation such as through subsistence aquaculture ventures. However, all persons may not be involved in the fishery (van der Waal 1991; van Zyl 1992), and as mentioned above, fish is supplemented in the diet by other foods.

As expressed by Busacker et al. *(1990), all these indices can* be affected by age, size, sex, reproductive state, season, acclimation temperature, diet and other variables, and their synergistic effects on growth. Similarly, many variables influence the RDA for humans; the Food and Agricultural organization of the United Nations has established an independent set of RDA goals for persons living in less developed countries. Thus, data of this

nature should in the long-term be gathered in a well disciplined manner with clear objectives and adequate sample sizes.

SUMMARY AND RECOMMENDATIONS

To reiterate, the growth and mortality estimates for the two species discussed above should be considered strictly preliminary. Conclusive remarks regarding these matters cannot be made until actual age can be validated and both ELEFAN related limitations and sampling biases can be accounted for. However, despite the nature of the fishery assessment information reported here, there were certain advances reached by the exercise. The basic population structures of two important traditional fishery species were speculated upon using a series of length frequency based assessment programs. The use of the ELEFAN software package for tropical floodplain fishery assessment is a new approach, and like any untested methodology, initial application results should be viewed as precursory information.

The effect of collecting gear size-selection was addressed by comparing the size distributions sampled using different means of collecting. In general, the juvenile and sub-adult life stages of the species in question were selected for using the techniques employed in this study (small seine net, rotenone), whereas larger, adult individuals were more vulnerable to the beach seines and gill nets. This trend should be viewed with caution however, as our data are seasonal in nature while those of van Zyl et al. were collected during a single sampling period. A thorough

investigation of the effects of gear size-selectivity in seasonal floodplain fisheries should include intensive sampling throughout all seasons and flood stages. Only then will fishery assessment studies of such dynamic systems like the Kavango River result in credible growth and mortality inferences.

Recommendation: In spite of the efforts of van der Waal (1991) and van Zyl (1992), a reliable estimate of maximum sustainable yield (MSY) in the Kavango River is lacking. Sandlund & Tvedten (1992) indicated that estimates of MSY in the Namibian portion of the drainage ranged from 840 to 3,000 tons (per annum), but provided no supporting documentation. This remains a critical need if the fishery is to be managed successfully. Data such as provided above using ELEFAN, and the similar studies of van Zyl (1992), require adequate samples taken in a time series if they are to provide reliable estimates of population dynamics.

Recommendation: Virtually all species are targeted by the subsistence fishery, thus deserve detailed investigation. However, it is recognized that such an effort will be both time consuming and labor intensive. For this reason, representative species of each family, or perhaps each trophic category (e.g., Chapter IV), should be monitored temporally and spatially to determine if drastic changes in population characters occur.

Recommendation: The nutritional data obtained in this study are a modest baseline, but provide another indicator of the capacity of the fishery to meet the protein demands of the subsistence-based

Kavango people. This study requires expansion to discern seasonal, longitudinal and annual differences to serve as a predictor of the river's capacity to meet increasing demands. Such an investigation should also consider such biological parameters as size, sex and seasonal differences in condition. This appears to be a priority area of research, given that the initial results indicate that the fishery may not be able to meet expanding demand; such an investigation would have to include a nutritional evaluation of all the dominant food types.

Recommendation: Namibia must initiate cross-border talks with Angola, especially, and Botswana to establish a common means of monitoring and regulating the freshwater fishery, duplicating similar discussions concerning the marine fishery. Size, seasonal and gear limitations, as well as management strategies, must be established which are supported by Angolan authorities. This is particularly relevant given the lack of any reliable measure of fishing pressure on the Angolan side of the river, and the number of Angolan refugees which have fled to the Kavango border as the war has escalated.

Recommendation: The socio-cultural value and tradition of the Kavango fishery are unknown, with the work of van der Waal (1991), Yaron (1992) and van Zyl (1992) providing only modest insight to this data need. Given that the five ethnic groups of the Kavango people practice a matrilineal society, the role of women requires further inquiry.

Recommendation: The recreational fishery of the Kavango River is

not understood; at this time it is neither monitored nor regulated. The fishery by its very nature targets the larger slower growing species, which require a longer time to reach sexual maturity. Guidelines for tournaments need to be established, and enforced. This does not mean that recreational angling should be discouraged, rather the regulation of recreational angling is viewed as a part of the overall need to manage the fishery. For instance, all-day tournament participants should be encouraged to install live wells in their boats and release their catch alive after weigh-in.

Recommendation: Similar to the recreational fishery, the subsistence fishery requires regulation. A moratorium of 3-5 years on the use of gill nets needs to be initiated, and reinstated (when deemed appropriate) with mesh, length, number and seasonal restrictions. Nets require identification to owner, and those without appropriate markings or left unattended must be confiscated. Drag nets or seines need to be banned altogether. However, traditional gear made of natural materials might well be left as a daily unregulated practice.

CHAPTER VI. BIODIVERSITY AND FISHERY OF THE CAPRIVI PROVINCE

INTRODUCTION

"Caprivi is a finger-like extension to the north-eastern corner of South West Africa/Namibia and represents a territorial relict of the great aspirations of the German Empire to provide an east-west bridge between German East Africa (now Tanzania) and German West Africa. Caprivi was occupied for the first time in 1908 and named by Von Streitwolf in honor of the Chancellor, Count Von Caprivi. The strategic value of this relatively small area (11 655 km^2) to Namibia lies in the rich supply of fresh water, of which there is a general shortage elsewhere in the territory" (van der Waal & Skelton 1984).

The Caprivi Province is considered to be that portion of Namibia lying to the east of the Kavango River. The region is inhabited by about 100,000 persons from a number of different ethnic groups having fishing traditions. The main community in the Caprivi is Katima Mulilo, located 1,200 road kilometers from Windhoek. At this date, the closest freshwater fishery scientists within the Ministry of Fisheries and Marine Resources are stationed at Hardap Dam, 250 km south of Windhoek! However, the Ministry of Wildlife, Conservation and Tourism maintains an office in Katima, with one researcher conducting seasonal fisheries investigations.

The Caprivi lies within the Kalahari Desert biome (Fig. 2), an

area dominated by the Kalahari sands that stretch for hundreds of kilometers through southern Africa (Ross 1987). Water is confined in the Caprivi to the channels of the major rivers without any visible surface waters except after seasonal rains. The province is sub-divided geographically into the Western Caprivi, lying between the Kavango and Kwando rivers, and the Eastern Caprivi, occurring from the Kwando eastward to the confluence of the Zambezi and Chobe river systems (Fig. 15). The Western Caprivi lacks surface water and is considered unimportant in this discussion, while the Eastern Caprivi is generally considered to be bordered by the dominant riverine systems (Schlettwein et al. 1991).

The major rivers are the Kwando-Linyanti-Chobe system and the Zambezi River, all of which are interconnected during high floods (see section on drainage history). The Kwando River (Cuando) flows south out of Angola through Namibia for ca. 35 km. before forming a border with Botswana for another 75 km. It then turns 90° to the east, and through a myriad of swamps and channels forms the 100-km long Linyanti River which drains through Lake Liambezi to become the Chobe River. The Chobe subsequently has a confluence with the Zambezi River about another 100 km away. The Linyanti-Chobe system has a general southwest to northeast alignment, but may flow in either direction dependent upon the flood stage of the Kwando and Zambezi rivers, the latter being seasonally dominant with flooding typically 5 to 6 m above normal stages, but occasionally reaching up to 8-10 m. This complex drainage inclusive from the Kwando River to the Zambezi in the Eastern Caprivi covers an area of ca.

11,600 km^2 (Schlettwein et al. 1991), of which 10% is covered by swamps, marsh land or open water with up to about 30-35% comprising the normal floodplain (Curson 1947; van der Waal 1974). All of these systems covered a combined area of 4680 km^2 (40%) of wetlands in 1985 (Sandlund & Tvedten 1992).

Lake Liambezi had a surface area of 200 km^2 in 1985 (Sandlund & Tvedten 1992), but has subsequently dried up as a consequence of regional chronic drought conditions. Based on the historical account provided in van der Waal (1974), this cyclical drying and flooding condition is normal. For instance, van der Waal (op. cit.) noted that the famous scout and explorer C. Selous located a large lake in the vicinity of Liambezi during the 1870s. During the period from 1916 to 1933, the area was primarily a swamp, but flooding occurred again in the late 1940s, 1950s and mid-1960s.

The Zambezi River basin is immense, being the fourth largest on the African continent and draining over 1.3 x 10^6 km^2. It arises in the Central African Plateau and flows southeast for 3,000 km to enter the Indian Ocean (UNEP 1986). It is a typical "sand-bank" river (Jackson 1961) with a sandy substratum. At an elevation of about 1,000 meters above sea level, it enters a 100-km series of rapids extending from Ngonye (Siona) Falls, Zambia, to the rapids at Katima Mulilo. From Katima downstream to its confluence with the Chobe River at Kazengula, a distance of about 130 km, the Zambezi forms the border between Namibia and Zambia. The confluence of the Zambezi and Chobe rivers at Kazengula at an altitude about 900 m above sea level, forms a common international

boundary between Botswana, Namibia, Zambia and Zimbabwe. Downstream from this point, the Zambezi reaches its greatest width of ca. 1350 m, before plunging over Victoria Falls some 50 km downstream.

Fishery Aspects

Van der Waal and Skelton (1984) provided a thorough summary of previous ichthyofaunal collections in the Caprivi, and that is paraphrased here. The Vernay-Lang Kalahari Expedition of 1930 (Fowler 1935), and the first and second Bernard Carp Expeditions of 1949 and 1952, respectively, added important data on the fish biodiversity of the Caprivi (Van der Berg 1956; Jubb 1958). The Queen Victoria Museum conducted an expedition to the Caprivi in 1961 (Guy 1962), with subsequent collections made in following years. Van der Waal's own collections commenced in 1973 (van der Waal & Skelton 1984).

From a fisheries perspective, the Caprivi region is the least documented system in Namibia. With up to 35% of the eastern province seasonally or perennially covered with water, fish are considered an important alternate source of subsistence and income; however no reliable estimate exists for the total number of fishermen involved (Sandlund & Tvedten 1992). Within the Caprivi, the fishery (e.g., van der Waal 1974, 1976, 1980, 1983, 1985, 1990; Grobler 1987) and water quality (Seaman et al. 1978) of Lake Liambezi has been studied better than elsewhere. The Lake offers a great potential for fisheries development; it supported a

fisheries cooperative during the 1960's producing up to 800 tons per annum of fresh/iced fish for sale into Zambia and Zimbabwe. However, with the war for independence in Zimbabwe and the imposition of currency control in Zambia, the cooperative collapsed in the early 1970s.

Van der Waal (1990) estimated that the Caprivi yielded 1,500 metric tons of fish per annum, with Lake Liambezi contributing over one half of that prior to its drying up since 1985. Van der Waal (1983) canvased 700 fishermen, with more than 520 (74%) belonging to the Basubia tribe living along the Eastern floodplain; gill nets were being intensively fished collectively with traditional fishing techniques. Van der Waal (1980) thought that catch was selective for the larger species.

There is now concern that traditional techniques (see Table 13) have been replaced by newer gears, resulting in depletion of some stocks (B. van der Waal, in litt. 1993). For instance, of 43 species identified from Lake Liambezi (van der Waal 1985), 27 are large enough to be captured in the gill net fishery. When the Lake is dry, the fishermen simply move their operations, primarily to the Zambezi and Chobe rivers, thereby increasing fishing pressure on these systems.

The effect of recreational fishing in the Zambezi/Chobe rivers is not well understood, but there is concern that angling tournaments may be decimating the breeding stocks of certain target species such as various tilapia and tigerfish (M. Grobler: pers. commun.). Very little is known about the behaviour of these

species relative to migration to preferred spawning areas and subsequent dispersal. However, as described above, this region of inter-related waterways forms a rather discrete research area from Ngonye Falls to the rapids above Victoria Falls, including the Chobe River upstream to the bed of Lake Liambezi. For this reason, there has been keen interest expressed by the NMFMR in having radiotelemetry studies conducted on select target species.

The exact number of species known from the Eastern Caprivi is uncertain. Bethune & Roberts (1991) listed 72 species, while Sandlund & Tvedten (1992) considered that 81 species occur. Skelton et al. (1985) stated that of 80 species occurring in the Okavango drainage, 77 are in the Upper Zambezi; they also list another 10 species from the upper Zambezi (including headwater tributaries) not found in the Okavango drainage, thus inferring the possibility of more than 87 species occurring in Namibian waters. Bell-Cross and Minshull (1988) thought 84 species exist in the Zambezi drainage above Victoria Falls, 74 within Zimbabwean waters. Merron (1989) provided information on the Kwando/Lake Liambezi/ Chobe River sub-system.

METHODS AND MATERIALS

Methods used were the same as described in the Kavango River section. All collections were made either with a 3 x 10 ft seine with 3/16" mesh, or by rotenone. Electrofishing was ineffective due to low conductivity (<50 umhos). Setting of nets by boat was impractical given the lack of access roads. For these and other reasons cited above, a decision was reached by mid-year (1992) that an in-depth seasonal investigation of the Caprivi region such as we were conducting along the Kavango River simply was not practical. Thus, it was a strategic decision to concentrate on biodiversity, particularly in the lower Kwando/Linyanti river where chronic drought had reduced the side channels to a series of interrupted pools and relatively shallow rivulets. Additionally, this region had historically been avoided due (a) to its remoteness, and (b) its geographic location mid-way between the Kavango and Zambezi rivers, which were more attractive, ichthyofaunally-speaking.

The main-channels of each the Kwando and Linyanti rivers were usually over 2 m in depth. There were few wadeable backwaters due to the drought, with water usually confined within the (usually steep) banks. Several of our collections (Table 21; Fig. 15) were made in the interrupted side channels of the Kwando River within the Mamili Game Reserve, which under rainy conditions would prohibit entry. Many of these channels had standing water only in pools, with no surface movement, and were routinely used by wildlife as water holes. The water levels in all rivers were seasonally low, with Lake Liambezi being dry.

RESULTS AND DISCUSSION

A total of 3,494 specimens representing at least 59 species were collected during the survey of the Eastern Caprivi (Table 22). The total number of catfish species collected belonging to the genus Synodontis is uncertain, given the difficulty of their taxonomy. Species collected in the Eastern Caprivi, but missing from our Kavango River collections included Barbus marequensis and Clariallabes platyprosopos, even though they are reported from the latter system (Skelton et al. 1985). A few species were collected from the Zambezi River proper, but not the Kwando/Linyanti survey area, and vice versa; however, this is a reflection of the amount of effort and available habitats for sampling.

Van der Waal & Skelton (1984), based on 39 collections over a 4-year period from 1973-1977, recorded 76 species from the Caprivi. They listed several species from the Zambezi River not found in the Kwando/ Linyanti system, 10 of which they considered rheophilic thus explaining their absence in the Kwando/Linyanti (Table 23). We did not collect any of these species as well.

SUMMARY AND RECOMMENDATIONS

Recommendation 1.- Our survey of the Caprivi region was limited. However, the experience gained in 1992 conclusively demonstrated the need for permanent staff, or donor agency consultants, to be stationed full-time in Katima Mulilo to conduct extensive, and intensive investigations of the fishery. The NMFMR has extended permission to Rand Afrikaans University to conduct

research in the Caprivi; however, their geographic location in Johannesburg, South Africa presents the same logistical difficulties as working from Windhoek.

Recommendation 2.- Despite the historical efforts of Prof. B.C.W. van der Waal and H.J.W. Grobler, the fishery largely remains un-characterized. Studies which are recommended to be undertaken include (a) the socio-cultural relationship of the indigenous ethnic groups to the fishery, including seasonal trends (estimated 2-year effort); (b) an interdisciplinary structural and functional characterization of the Eastern Caprivi floodplain at the confluence of the Zambezi and Chobe rivers (minimum 4-year effort); (c) migratory behaviour (radiotelemetry) and reproductive requirements of certain species targeted in the fishery (3 years); (d) life history aspects of all species, since all are represented in the combined traditional and contemporary fishing effort; and (e) evaluation of the impact of recreational fishing. Additionally, baseline research on Lake Liambezi in its current dried-up condition should commence immediately to document its evolution into a temporary, highly productive floodplain lake.

Recommendation 3.- The research activities recommended above should be carried out in a collaborative program between the Ministry of Fisheries and Marine Resources and the Multi-disciplinary Research Centre of the University of Namibia (UNAM). Additionally, it is recommended that cooperative arrangements be negotiated with Botswana, Zambia and Zimbabwe, with consideration given to the establishment of a truly international research

station for floodplain studies in or near Katima Mulilo. The rationale for this is as follows: Namibia was formally designated in 1992 by the Southern Africa Development Community (SADC) to be the lead country for training and research in fisheries, and UNAM was recognized as the host institution for tertiary training. Given this regional mandate, the Caprivi's central geographic location, and the need for understanding Africa's floodplain rivers (Junk et al. 1983), this proposal is worthy of consideration. Africa's floodplain rivers account for nearly one-half of the continent's total freshwater fisheries production (Welcomme 1979).

Recommendation 4.- Lastly, there is no concrete information at this time which addresses whether the Eastern Caprivi's fish stocks are under- or over-exploited. Relative to concerns discussed under the Kavango River section of this report, consideration needs to be given to gear, size and daily/seasonal limits to assure sustainable utilization of these resources. Van der Waal recommended some years ago that gill nets be licensed, and this in turn will permit control of numbers fished, their length and mesh size. Drag nets should be banned. Licenses should be required for recreational angling, and tournaments need to be regulated and monitored.

CHAPTER VII. AQUACULTURE

INTRODUCTION

An evaluation of the prospects of aquaculture in Namibia was originally justified in the USAID/HBCU research program for several reasons. These included (1) the increasing worldwide demand for fishery products, coupled with decreasing wild fish stocks, (2) the need to increase local living standards in the Kavango/Caprivi region, which is subjected to an average annual income of $ 85 for most persons, (3) the availability within the Kavango/Caprivi region of the dominant surface water resources in the Republic, (4) available manpower, (5) a long growing season, and (6) a central location to potential markets in Zambia, Angola, Botswana, Zimbabwe and South Africa.

From a commercial perspective, however, the above views were very short sighted. Based on our in-country experience, it is doubted whether aquaculture would ever achieve a favorable profit ratio, nor is there incentive for private capitalization for freshwater aquaculture ventures. These opinions are also shared by three independent evaluations (Remedio & Regadera 1991; Sandlund & Tvedten 1992; Wilton, undated), as well as expressed within a draft White Paper on inland fisheries management by the Namibia Ministry of Fisheries and Marine Resources (NMFMR). This is primarily a consequence of Namibia's vast marine fisheries. However, the Freshwater Fish Institute of the NMFMR is currently considering the use of a geographic information system (GIS) procedure to identify

prospective areas for the commercialization of aquaculture, following the methods of Kapetsky et al. (1987; 1991).

Huisman (1990) summarized that the total international assistance to the fisheries sector in developing countries during the years 1978-1984 amounted to 2.5 billion USA dollars. Of this total, nearly $370 million were spent for aquaculture projects which tended to emphasize "research and development". The level of this investment itself argues strongly that aquaculture should be self sustaining. However, as Pullin (1991) pointed out, the term "aquaculture" has been defined various ways, hampering the compilation of meaningful statistics.

The role of aquaculture in less developed countries has been viewed many ways, including a means to supplement capture/demand from wild fish stocks, the provision of an inexpensive source of protein, development of a foreign currency exchange (FOREX) market, employment objectives, and so forth. Amongst African countries, the per capita fish consumption per annum is about 10.5 kg, with wild fish stock capture and aquaculture production contributing about 99.7 and 0.3%, respectively. However, as Huisman (1990) emphasizes, the initiation of aquaculture research should be the culmination of a national policy decision as to whether or not more fish is required and for what reason. If the answer is in the affirmative, then the decision should be made as how to best proceed, i.e., capture fisheries or aquaculture. This latter point needs to be touched on in greater detail.

The sea off the 1600-km Namibian coastline has exceptionally

valuable fishery resources occurring both inshore and offshore, including pilchard, anchovy, marsbunker, snoek, kingklip, sole, squid, deep sea crab and rock lobster. The region is the center of the world's largest hake fishing grounds; this species alone accounted for over 375,000 metric tons of catch and earned over twice the annual budget of Namibia in 1986 when foreign catch is taken into consideration (UNDP 1989). The fishing industry, more than any other sector, has a tremendous potential for expansion of foreign exchange (FOREX) earnings; it has an estimated value in excess of USA $1 billion per annum. The profound impact of the marine fisheries sector does not stop at the fish processing plant. Frozen marine fish can be purchased anywhere in Namibia at USA $ .42 per pound (R 3 per kg). The NMFMR forecast in 1992 that 12,000 new positions will be created in the Namibian fisheries sector in the next decade, with virtually all of these positions targeted for the marine fishing industry, not freshwater.

There has been limited entry into aquaculture by the Ministry of Agriculture, Water Resources and Rural Development, which sponsors a fry/fingerling production facility at Ongwediva and Mahenene. The Freshwater Fish Institute (FFI) at Hardap, financed by the Ministry of Fisheries and Marine Resources (NMFMR), also maintains culture facilities; thoughts to privatize these culture capabilities have been postponed indefinitely (B. van Zyl, pers. commun.). Costs are minimized in that the facility is government owned and operated. Additionally, the facility produces its own food (pellets), which is a mixture of camel thorn seed pods and

seal meal. The cost of this food is about $150 per ton (R450/ton), as opposed to $666 per ton (R2,000/ton) for imported trout pellets. B. van Zyl (pers. commun.) will soon commence a study to determine an inexpensive, protein-enriched food mixture for use on the local market.

One private cage culture farming operation of Oreochromis mossambicus exists at Hardap. No other private freshwater aquaculture ventures are known to currently exist in the Republic although at least two attempts near Rundu failed in the late 1980s. The cage culture operation purchases about 10,000 fry from the FFI annually for R500, which grow from 2 to 150 grams each, yielding about 1.5 tons/year. Based on a conversion ratio of 2:1, 3 tons of food are required (total cost R2,400). Other costs include overhead (R150), repairs (R300) and miscellaneous items (R600), for a total production cost of R3,950 per 1.5 tons, which equals R2.63/kg, virtually the same price as frozen marine fish (R3/kg). If the bream are filleted for the market, processing costs increase the price per kg to R6.57, and if they must be frozen and packaged, an additional R1.25± is added onto product costs. These fillets are sold for R10/kg; thus, the market is very selective.

Logically, therefore, it appears more cost effective for the Republic to base its regional (and international) trade agreements on shipping low priced marine fishes to adjacent countries rather than to consider a commercial freshwater aquaculture scheme with questionable prospects for success. Similarly, there is a strong rationalization to basing a food aid program on the marine

fisheries sector rather than heavily subsidizing freshwater aquaculture in the northern, subsistence-based portion of the Republic. While a complete analysis has not been performed, it might be cost effective for a donor to operate a fleet of distribution trucks for a period of time and give fish to those in need, which are purchased on contract directly from a marine fish processor (at a price reduced from the $ .41 per pound), rather than to develop wholesale aquaculture facilities with the view of "upgrading subsistence living standards" in northern Namibia.

Aquaculture aid projects have had a dismal rate of failure worldwide (Huisman 1985,1990). In theory, most such projects have had their objectives dressed in terms like "increased living standards", "FOREX development", and "rural development". However, in practice aquaculture aid projects have not lived up to expectations. There are several reasons for this, but a major factor has been the replacement of traditional farming techniques with new methodologies or concepts. It is our view that a fundamental flaw in developmental aid for subsistence aquaculture has been the tendency to measure success by western world standards, e.g., the desire to grow fish to marketable size. In reality, there has been a move away from simply providing protein supplements to the daily diet of persons living at the subsistence level. Aquaculture should not be thought of as a formula for achieving instant affluence and literacy; such ventures are virtually doomed for failure unless there is a strong profit motivation, which is defined as including an adequate capital

outlay for appropriate infrastructure, equipment and skilled labor.

RECOMMENDATIONS

Having made such strong statements as above, however, it is important to consider the opinions of the indigenous people. In a 1992 survey, B. van Zyl (van Zyl 1992) of the NMFMR canvased >3,000 persons in the Kavango region concerning the prospects of fish farming (Table 24). Over 99% indicated that fish were an important part of their daily living requirements; 98% of the persons surveyed indicated a desire to participate in fish culture projects, even though 96% lacked familiarity with fish farming practices. Thus, there is a very positive community bias toward self sufficiency and upgrading of living standards. Additionally, despite the valuable marine fishery, these resources in the near term will have little more than a trickle down effect on the majority of Namibians living in the north; the rivers represent a basic source of survival. Lastly, despite a consensus among most independent consultancies on aquaculture in Namibia (Remedio & Regadera 1991; Sandlund & Tvedten 1992; Wilton, undated), Yaron et al. (1992) in their evaluation of the potential for economic development in the Kavango province were positive about the prospects of aquaculture.

Recommendation 1. For the above reasons, it is recommended that a cooperative aquaculture demonstration project between the University of Namibia (UNAM) and the NMFMR be established in the north. The project should have the dual function of "training the

trainers" and teaching villagers how to supplement their protein resources when the seasonal fishery resources dwindle away. The project should offer the opportunity for low technology transfer with minimal finance and time investments for the recipients or by the donor agency. Additionally, as B. van Zyl recognizes (pers. commun.), the demonstration project should attempt to reach as many people as possible. This argues in favor of a centrally located program in northern Namibia; the Kavango drainage is strategically positioned between the Owambo and Caprivi population bases. However, Yaron et al. (1992) recommended the upgrading of the facilities at Ongwediva.

Recommendation 2. It is recommended that the primary objective of an aquaculture demonstration project in northern Namibia be to rear fishes such as certain cichlid species to a consumable size. This means harvesting tilapia, or bream, at a juvenile stage of approximately 70-100 mm TL, which is a size acceptable to the populace and commonly caught in traditional gear. Under maintained conditions, bream can yield 4 tons/ha of fingerlings (Yaron et al. 1992). Additionally, the practice of juvenile harvesting minimizes the impact of natural mortality, reduces the requirements for advanced feeding (diet) technology, and significantly reduces the space requirements for growing fish to larger sizes. Since bream can breed several times a year, this means a rather continuous supply of cultured fish for **local** consumption. Euroconsult (1985), Hecht & Brits (1990), Huisman (1985), and Jackson (1988) can be consulted for additional details

on aquaculture in Africa.

Recommendation 3. With respect to the above recommendations, a thorough cost analysis is required. The prime consideration will be for NMFMR's FFI and UNAM to jointly define the main objectives of the demonstration project, including anticipated achievements. This in turn will influence the prospects of cost sharing between a potential donor, UNAM and NMFMR; the size and location(s) of the project; cost of pond construction; physical plant requirements if needed (e.g., office, dormitory, kitchen requirements, etc.); equipment needs; requirements for trained personnel and unskilled labor on the permanent staff; and numbers of students to receive undergraduate and post-graduate training, as well as other issues. A minimum of a five-year commitment will be required from the donor agency (perhaps longer), with the long-term objective that the program will become self sustaining.

A suitable venue for the demonstration project in the Kavango region might be near Mupini/Sikondo just to the west of Rundu where (a) extensive floodplains occur, and (b) Rundu itself could provide a convenient source of supplies and housing. Alternate choices might be in affiliation with established agricultural programs, e.g., at Musese where some physical plant infrastructure already exists.

Recommendation 4. The need to use indigenous fishes in aquaculture operations in Namibia can not be over emphasized (Bruton & Safriel 1985). The physical, chemical and biological effects of aquaculture (Weston 1990; Pillay 1992) include a

plethora of potential problems, including the introduction of non-indigenous species into the wild; hybridization and the breakdown of isolating mechanisms of closely related species; competition for preferred food resources and breeding sites; alteration of the structural and functional integrity of the ecosystem; and the introduction of new disease and parasite vectors. For these reasons, the industry should be regulated from the start, with the objective of mitigating any potential physical, chemical or biological impacts.

CANDIDATE SPECIES

Two families of fishes are discussed below: the Cichlidae (colloquially "bream" or tilapia) and the Clariidae ("barbel" or catfish). Members of each family have been cultured extensively, and intensively, throughout Africa, and generally occur rather low in the aquatic food web. The attributes of cichlids, termed "aquatic chickens" by the International Center for Living Aquatic Resources Management (ICLARM), and clariids are discussed by Pullin and Lowe-McConnell (1982), Pullin (1991) and Hecht (in press).

Bream

Tilapia rendalli, the redbreast tilapia, and Oreochromis macrochir, the greenhead tilapia, are the prime candidates for culture. Each is a herbivore utilizing algae as a food source; T. rendalli graduates to a macrophyte diet as it matures. Thus, these species requires little or no supplemental feeding. Both species

are indigenous to northern Namibia, reproduce readily with minimal care and can be harvested at juvenile stages, 70-100 mm TL, within weeks. Each species is an accepted food fish within the traditional fishery. The growth characteristics for each of these species, and others, are provided in de Merona et al. (1988) and Pullin (1991). Bell-Cross and Minshull (1988) report that T. rendalli spawned up to eight times a year under control conditions in Zimbabwe.

Oreochromis andersonii, the threespot tilapia, is another herbaceous species that has been extensively used in aquaculture in Africa, and is recommended for consideration as a candidate species (B. van Zyl, pers. comm.). Its diet as an adult is more complex than those species above, since it also utilizes insects and smaller crustacea. However, much is known about its breeding and feeding biology. A polyculture approach using O. andersonii with T. rendalli has been extensively used in Central Africa (Mortimer 1960), since the two species appear to be complimentary feeders (Bell-Cross & Minshull 1988).

In time, a polyculture approach might be considered utilizing the rainbow happy (Serranochromis carlottae), green happy (S. codringtonii), pink happy (S. giardi), purpleface bream, (S. macrocephalus), or the olive bream (S. robustus) in combination with T. rendalli. The former three species are primarily molluscivores and insectivores, while the latter two species are more carnivorous. Each of these species cultured in concert with T. rendalli would initially require an experimental approach to

discern the appropriate pond design and stocking ratios. Also, care would have to taken that S. macrocephalus and S. robustus did not reach maturity within a pond system; however, their juvenile stages consume zooplankton and benthic organisms. The experimental aspects could be treated by postgraduate students at UNAM.

Van Zyl (1988) compared the growth rates of populations of O. andersonii, O. macrochir, and T. rendalli from the Kunene and/or the Kavango river, where they were indigenous, with O. mossambicus from the Orange River drainage at Hardap Dam. He found that O. macrochir and T. rendalli from the Kavango River showed the best length/mass ratio at specific age intervals for all species, regardless of river source. This would imply that a demonstration project in the Kavango drainage might be preferable over other locations.

The Mozambique bream (Oreochromis mossambicus) is a species often associated with aquaculture in Africa and elsewhere. However, this species is not native to the northern rivers of Namibia, and there is concern that escapees from a culture facility might either hybridize with the threespot bream (O. andersonii), a phylogenetically closely-related species, or otherwise alter the natural faunal composition (Schrader 1985).

Barbel (catfish)

Much attention has been focused in southern Africa on the use of various catfish (barbel) species of the genus Clarias in aquaculture programs. These species indeed have great potential

for culture in a profit-oriented commercial setting; however, a high degree of technology is required to assure success. For these and other reasons, clariids are not recommended in a subsistence aquaculture setting (T. Hecht, *in press*).

CHAPTER VIII. SUMMARY AND RECOMMENDATIONS

Namibia, Africa's newest nation, shares its northern and eastern borders with Angola, Botswana, Zambia and Zimbabwe. This is also the area which harbors the dominant perineal rivers of the Republic, including in a east to west direction the Zambezi/ Chobe/Kwando anastomosed complex of inter-connected waterways, the Kavango River, Cuvelai River and the Kunene River. Namibia is an arid country with an average annual rainfall varying from <10 cm in the south to about 65 cm in the northeast. As a consequence, over 80% of the Republic's population of 1.5 million people live in the more water rich areas along the northern and eastern borders. Most (ca.85%) of the indigenous population lives at a subsistence level earning less than $85 per annum per person. The region encompassed by this study includes the Kavango and Caprivi provinces, bounded by the Kavango River in the west and the Zambezi in the east.

Fisheries research and management activities within the Republic fall under the administration of the Ministry of Fisheries and Marine Resources (NMFMR). However, the ministry's line functions are dominated by the vast marine resources, with only two scientists located at its Freshwater Fisheries Institute at the Hardap Recreational Park. This facility is located over 800 km away from the Kavango River, and 1,200 km away from the Eastern Caprivi Province, which this study addressed.

The field portion of this research effort was conducted over a 1-year period, commencing in January 1992 in affiliation with the

University of Namibia's (UNAM) Multi-disciplinary Research Centre (MRC) and the NMFMR. The primary objective of the investigation was to characterize aspects of the fish resources of the Kavango and Caprivi Provinces. Sub-objectives were to (a) initiate a formal collaborative research effort under an institutional linkage agreement between the University of Maryland System (UMS) and UNAM; (b) assist in the capacity building of environmental science programs at UNAM and the University of Maryland Eastern Shore (UMES); and (c) nurture the developing relationship between UNAM, UMES and NMFMR, to facilitate cooperative programs to address the research and management needs on Namibia's inland waters. All of these objectives and sub-objectives were achieved. Additionally, one of the authors (a UMES graduate student) will receive a M.S. degree based on his research on the investigation, while training was provided to UNAM students.

This study has allowed for insight regarding several aspects of fish science: (1) biology, ecology, species distribution and identification, (2) structural and functional community level assessment, and (3) preliminary fishery evaluations. This investigation was the first to address seasonality in the fish biodiversity of the Kavango River, and provides a strong baseline for continued studies by Dr. B. van Zyl and C. Hay of the NMFMR. Similarly, our attempt to develop guidelines for a biological monitoring protocol using the contemporary Index of Biotic Integrity (IBI) is the first such effort on the continent. Further, our studies discovered two new established populations of

exotic fish species in Namibia, one being from Southeast Asia and the other from South America; neither had been previously reported from Africa. Distributional maps were prepared for 62 species along the 450-km section of the Kavango River in Namibia, and the biodiversity studies have led to the first preliminary key to the fishes of Namibia. Our investigations on the life history aspects of certain fish species targeted by the subsistence fishery well compliments the activities of Namibia's freshwater fishery scientists; the development of an ELEFAN data base is at an infantile stage in Namibia, while no previous studies have been conducted on the energy content of species representative of the subsistence fishery. Our efforts complimented those of the NMFMR and other international consultancies in terms of providing an overview on the prospects of aquaculture development in Namibia.

Five publishable manuscripts have been identified as potentially arising from the project, including: (1) Seasonal relationships of the fishes of the Kavango River to the flooding cycle; (2) Development of the conceptual basis of an index of Biotic Integrity (IBI) for the Kavango River; (3) A preliminary key to the fishes of Namibia; (4) A description of new exotic fishes from Namibia, with recommendations for the establishment of a National protocol for introduced aquatic organisms; and (5) Gear influence on the estimate of population parameters using ELEFAN.

The Kavango and Zambezi/Chobe/Kwando river complex are floodplain systems, with their productivity being driven by the annual flooding cycle. Our biodiversity studies in combination

with historical accounts provide a reasonable overview of the structure of the fish community. However, the functioning of each system, and the fish community, is poorly understood and borders on the anecdotal. Recommendation: It is vital to the sustainable management of these rivers to gather knowledge on how the flooding cycle drives their seasonal processes, and to define the natural variations in community structure and function. Similarly, it is equally important to development a data base on the life history aspects of representative fish species targeted by both the subsistence/ artisanal fishery and the recreational fishery. These needs include studies on home range requirements, migratory behavior, habitat preferences and limiting factors, reproductive strategies, age and growth studies, and community ecology including food web analyses. Detailed information on floodplain systems is lacking (Welcomme 1979; Lowe-McConnell 1987), especially on the African continent.

From the aut- and syn- ecological investigations proposed, it will become clearer as to the role of the annual flooding cycle on the respective fisheries, and consequently how the "development-related" alterations of the natural regimes will impact the health of indigenous persons who are dependent upon the aquatic systems for their daily living requirements. In-depth investigations will also permit insight into the natural variability of the functioning of the systems, which is crucial to establishing long-term monitoring and surveillance procedures.

We are of the opinion that the fishery of the two provinces

has not been over exploited at this time, but may be at a pivotal position. Namibia is currently developing a "white paper" fisheries management plan for the Republic's inland waters. The current management philosophy is to establish "no fishing" zones in the Kavango and Zambezi systems to act as epicenters for fish production and dispersion. Also, thought is being given to the establishment of gear, size, and seasonal restrictions. Recommendation: Based on our evaluation, and professional judgement, we recommend that (1) gill nets and drag nets be completely banned for at least a three year period, and possibly longer, but that the traditional fishery be allowed to continue as practiced; (2) recreational fishermen be licensed; (3) recreational species taken by non-traditional gear have daily bag limits placed on them (and conceivably, size and seasonal limits); and (4) every effort be made to solicit cross border cooperation with neighboring countries to set the same limits to avoid a "tragedy of the commons" (Hardin 1968; Gulland 1980; Panayotou 1982; and Berkes 1985, among others).

It should be recalled that the summary of the socio-cultural synthesis group of the International Large River Symposium (Malvestuto 1989) recognized the need to factor in biosocioeconomic issues (social accounts) into traditional fisheries management approaches, especially in emerging nations. Data sets which were deemed as important to be included in fishery management protocols to achieve optimum yield (OY) were ecosystem health, human nutrition, socio-cultural values and economic values. The first

data set has been addressed in this study in detail, while preliminary information has been presented on the second data set. Recommendation: Hardly any information exists on the economic and socio-cultural values of the region's freshwater fisheries, thus these seem of paramount interest as management and catchment development plans are put forth and evaluated.

The evaluation of gender and family relationships associated with the fishery are of particular relevance in Namibia. For instance, the Kavango people practice a matrilineal society, with women recognized as heads of households; additionally, they (and children) represent the domestic fishing force. However, this does not follow for other ethnic groups, which will be impacted by development and employment opportunities outside their communal areas.

Recommendation: At this time the social structure of the fishery, family ties with fishing, and attitudes affecting fishing behavior are unknown, and the need for such a data base cannot be better stated than within a fisheries White Paper sponsored by the Norwegian Agency for Development Cooperation (NORAD) (Sandlund & Tvedten 1992): "Socio-economic data on inland fisheries in Namibia are scanty; the importance of the inland fisheries sector for employment and subsistence is largely unknown (p. viii).... The socio-political context within which most fishermen find themselves is characterized by the continued importance of traditional kinship relations and the extended family (p.10)....(however), with the current disintegration of the extended family obligations and the

likely increase in the number of female headed households, the role of women in fisheries should be taken into particular consideration (p.11)" (Tapscott 1990; Fosse 1992).

Future socio-cultural investigations should consider whether the persons involved in fishing are male or female, adult or juvenile, and whether a **male** or a de jure (unmarried, divorced or widowed), de facto (desertion, or male migration) or periodical (seasonal male migration household, or polygamous situation) **female** is the head of the house-hold (Sen et al. 1990). Questionnaires developed by the Aquaculture for Local Community Development Programme (ALCOM) of FAO have direct relevance to this recommendation, e.g., the 1990 socioeconomic survey of fish consumption and fishing in neighboring Botswana which itemizes two different census procedures (Sevaly 1990). These quantitative approaches, however, need to be augmented by qualitative anthropological investigative techniques using key informants and focused group discussion participation (I. Tvedten: pers. commun.).

Recommendation: It is recommended that a cooperative aquaculture demonstration project between UNAM and NMFMR be established in the north. The project should (a) have the dual function of "training the trainers" and teaching villagers how to supplement their protein resources when the seasonal fishery resources dwindle away; (b) not be aimed toward commercialization unless adequate capital, personnel and facilities are committed to; (c) offer the opportunity for low technology transfer with minimal financial and time investments; and (d) as B. van Zyl recognized

(pers. commun.), attempt to reach as many people as possible. This argues strongly in favor of a centrally located program in northern Namibia such as in the Kavango drainage, which is strategically positioned between the Owambo and Caprivi population bases.

Recommendation: Recommendations were put forward in the text to establish a protocol for regulating the aquarium trade and aquaculture industry. This is not a small matter and should not be neglected. The deliberate or accidental introduction of non-native biota into the Republic's waterways should be avoided at all costs. Diverse, tropical aquatic ecosystems are now considered to be more fragile than historically thought (Lowe-McConnell 1987), thus there is every prospect that introduced biota can alter the natural structural and functional components of the receiving system. Additionally, the aquaculture industry can impact the physico-chemical structure of surface and ground water supplies.

The natural renewable resources of Namibia are vast, being inclusive of the rich offshore fishing grounds of the South Atlantic Ocean to the unique biotic diversity of the interior. The economic weight of these resources is emphasized by the estimated value of (a) the extensive marine fisheries at over $1 billion per annum, and (b) the tourism industry (becoming more strongly eco-tourism based), currently ranked as the fourth most important sector of the Namibia's economy behind mining, agriculture and fisheries. The Republic is moving forward to insure the sustainable utilization of these resources while simultaneously promoting rural community development projects; such activities are

being directly supported by various international donors, including the USAID-sponsored LIFE Project. Additionally, the need to protect and manage Namibia's resources has culminated in the relatively recent formation of an Environmental Planning Unit within the Ministry of Wildlife, Conservation and Tourism, which has been given a mandate for environmental statement preparation and environmental assessments; related to this development is the rapid expansion of private environmental consulting firms. These sectors employ a large number of persons, many of whom are marginally trained.

Recommendation: In the above context, there is an urgent need for donor support for capacity building in the environmental sciences and fisheries at UNAM, and its research arm, the Multi-disciplinary Research Centre. UNAM has responded to the needs for tertiary training and research in the environmental sciences through an active curriculum evaluation; recruitment of permanent and visiting professional staff; the creation of the MRC; and the fostering of ties with both the NMFMR and the fishing industry. However, much remains to be done to upgrade the faculty and facilities at UNAM. This contention is emphasized by several factors, including (a) the aforementioned valuation of the extensive marine fishery resources at over $1 billion per annum; (b) the projection by the NMFMR that perhaps 10-20,000 new positions will be created in the fishing industry over the next decade (admittedly, most will be unskilled labor, but even if 1% of the posts require advanced training this is a significant input of

students into UNAM); (c) the funding by NORAD for UNAM to serve as the host institution for an annual 3-month Fisheries Planning and Management training course from 1994-1999, aimed toward senior administrative fisheries staff within the 10-country Southern Africa Development Community (SADC) region; (d) the desire of the private fisheries sector to financially support UNAM in the establishment of a research agenda and human health/seafood technology capabilities; and (e) the realization that Namibia's inland fisheries are a vitally important component to the subsistence livelihood of the indigenous communities of northern Namibia.

The Marine and Environmental Sciences disciplines currently fall under the Life Sciences division of UNAM's MRC. However, based on the above considerations, we strongly urge that it be on parity with Life Sciences rather than a sub-division. This is further amplified by a February 1993 UNESCO-sponsored needs assessment team, who recommended that UNAM establish a Graduate School of Marine Science and Fisheries.

Namibia's prominence in the fisheries sector of the SADC region is underscored by the aforementioned nomination of UNAM as the host institution for a NORAD-funded training course in fisheries planning and management. UNAM and NMFMR should be complimented on their common interest of collaborating on training and research needs in the Republic, and use of these opportunities as models for other SADC regional activities. <u>Recommendation</u>: Joint activities between UNAM and the NMFMR should continue to be

encouraged at every level to maximize the benefits of the manpower and facilities each organization has. Recommendation: Additionally, the Republic has much to gain from the fostering of a relationship between the private fishing sector and UNAM. For instance, there is current consideration for the establishment of an industry-sponsored UNAM analytical laboratory service to monitor quality control of seafood processing and products; the UMS would be a collaborative partner in this effort.

This research effort gave a full appreciation of the difficulties encountered by the NMFMR freshwater biologists when conducting field research. The Kavango River presents its share of obstacles and hazards, but is genuinely easy to sample in comparison to the Eastern Caprivi Province where road access to waterways is usually in a state of disrepair, temporary or non-existent. Travel to the Eastern Caprivi and to return is within itself an adventure, never mind sampling elephant watering holes in remote wilderness like Mamili National Park! It was this experience, however, that shaped one of our strongest recommendations.

Recommendation: It is recommended that cooperative arrangements be negotiated with Botswana, Zambia and Zimbabwe, with the intention of establishing an international research station for floodplain studies in or near Katima Mulilo. The rationale for this is as follows: Namibia has been designated by SADC as a lead country for training and research in fisheries, with NMFMR and UNAM being recognized as hosts for training and research. Given this

regional mandate, the Caprivi's central geographic location, the size and importance of the Zambezi floodplain, and the need for understanding Africa's floodplain rivers (Lowe-McConnell 1987), this is a worthy proposal. Africa's floodplain rivers account for nearly one-half of the continent's total freshwater fisheries production (Welcomme 1979). It is expected that such a station would attract strong donor support. Personnel from UMES who conducted this investigation should also be considered as co-participants and collaborators.

Recommendation: It is our recommendation that due attention be given to capacity building within the freshwater fisheries division of the NMFMR. Despite the vast offshore marine fishery and its enormous economic value, these resources have little more than a trickle-down effect on the Republic's citizens living in the north, the majority at subsistence levels. The two permanent scientists at the Freshwater Fisheries Institute (FFI) are to be commended for their dedication. However, the FFI is severely understaffed, under-equipped, and located at an excessive distance from the main surface waters of the Republic, thus prohibiting continuous routine data collecting. As stated above, a permanent staff member in Katima Mulilo appears mandatory, with regional offices in the Kavango, Owambo and Kunene provinces also meriting consideration. Specific staff needs appear to be a limnologist trained in primary productivity (especially vascular plants) and water quality; benthic ecologist; and reservoir biologist.

Other specific recommendations for future studies and capacity

building in freshwater fisheries are summarized in each chapter. In many instances, these recommendations can be considered in a singular context; however, the data needs require an integrated approach to meet the requirements for a sound management agenda. Given the prospect of exponential development and alteration of land use patterns in the Kavango and Caprivi Provinces, the sustainability of the quality and quantity of the region's natural resources is at issue.

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CHAPTER X. REFERENCES

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Table 1. List of fish collecting stations in the Kavango River, 1992. Map site refers to collecting localities plotted on Figure 6.

Coll. No.	Map Site	Latit.	Longit.	Coll. No.	Map Site	Latit.	Longit.
1	1	172452	182628	41	25	175427	200127
2	1	172452	182628	42	25	175427	200127
3	1	172452	182628	43	25	175427	200127
4	2	172806	182826	44	26	175408	200329
5	2	172806	182826	45	27	175432	200803
6	2	172806	182826	46	28	175341	201433
7	2	172807	182828	47	29	175347	202220
8	3	173145	183147	48	29	175347	202230
9	4	173133	183210	49	29	175345	202236
10	4	173133	183210	50	30	175436	202515
11	5	173508	183413	51	31	175843	202740
12	5	173508	183413	52	32	175704	202803
13	5	173508	183413	53	32	175708	202818
14	6	173818	183735	54	32	175704	202823
15	7	173955	183942	55	33	175804	203040
16	8	174421	184440	56	34	180004	203741
17	9	174202	185013	57	35	180039	204226

Table 1. (cont.)

18	10	174719	185030	58	36	180113	204601
19	10	174720	185031	59	37	180143	204910
20	11	174825	185200	60	38	180211	205031
21	12	174917	185526	61	38	180211	205031
22	12	174917	185526	62	38	180211	205031
23	13	175016	190627	63	39	175742	210017
24	13	175016	190627	64	39	175742	210017
25	14	175010	191327	65	39	175743	210020
26	15	175058	192216	66	39	175743	210020
27	16	175156	192717	67	40	175615	211022
28	17	175225	193205	68	41	180400	211700
29	17	175225	193205	69	42	180148	212518
30	17	175225	193205	70	43	180522	213154
31	17	175225	193205	71	43	180522	213154
32	18	175139	193733	72	43	180522	213154
33	19	175111	193832	73	44	180042	213357
34	20	175303	194209	74	45	180719	213458
35	21	175356	194414	75	45	180719	213458
36	22	175340	194520	76	45	180719	213458
37	22	175340	194520	77	46	181016	214300

Table 1. (cont.)

38	22	175340	194520	78	47	181055	214351
39	23	175258	195244	79	48	181148	214419
40	24	175334	195958	80	49	181323	214503

Table 2. Percent (%) occurrence and percent (%) of total catch for each species collected from the Kavango River, 1992. *See below for occurrence ranking.

Genus species	% Occurrence	% Total Catch
Hippopotomyrus ansorgii	0.00%	0.14%
Hippopotomyrus discorhynchus	11.25%	0.18%
Marcusenius macrolepidotus	27.50%	0.63%
Mormyrus lacerda	11.25%	0.12%
Petrocephalus catostoma	33.75%	1.41%
Pollimyrus castelnaui	38.75%	0.92%
Brycinus lateralis	35.00%	1.45%
Hydrocynus vittatus	18.75%	0.63%
Micralestes acutidens	43.75%	6.29%
Rhabdalestes maunensis	3.75%	0.06%
Hepsetus odoe	5.00%	0.05%
Hemigrammocharax machadoi	10.00%	0.18%
Hemigrammocharax multifasciatus	33.75%	1.37%
Nannocharax macropterus	1.25%	0.01%
Barbus afrovernayi	17.50%	0.52%
Barbus annectens	3.75%	0.03%
Barbus barnardi	16.25%	0.91%
Barbus barotseensis	8.75%	0.25%
Barbus bifrenatus	37.50%	2.38%
Barbus eutaenia	30.00%	1.74%
Barbus fasciolatus	15.00%	0.83%
Barbus haasianus	3.75%	0.16%
Barbus lineomaculatus	8.75%	0.35%
Barbus multilineatus	3.75%	0.08%

Table 2. (cont.)		
Barbus paludinosus	27.50%	3.76%
Barbus poechii	62.50%	6.11%
Barbus radiatus	28.75%	3.10%
Barbus thamalakanensis	43.75%	2.78%
Barbus unitaeniatus	8.75%	0.53%
Coptostomabarbus wittei	1.25%	0.01%
Labeo cylindricus	27.50%	1.98%
Labeo lunatus	3.75%	0.03%
Opsaridium zambezense	27.50%	2.21%
Amphilius uranoscopus	6.25%	0.11%
Leptoglanis dorae	3.75%	0.03%
Leptoglanis rotundiceps	1.25%	0.01%
Parauchenoglanis ngamensis	8.75%	0.13%
Clarias gariepinus	18.75%	0.18%
Clarias ngamensis	25.00%	0.25%
Clarias theodorae	12.50%	0.13%
Chiloglanis fasciatus	12.50%	0.20%
Synodontis sp.	53.75%	2.12%
Schilbe intermedius	41.25%	2.03%
Aplocheilichthys hutereaui	25.00%	0.65%
Aplocheilichthys johnstoni	82.50%	6.21%
Aplocheilichthys katangae	7.50%	0.18%
Hemichromis elongatus	11.25%	0.15%
Oreochromis andersonii	43.75%	2.90%

Table 2. (cont.)		
Oreochromis macrochir	5.00%	0.04%
Pharyngochromis acuticeps	75.00%	5.04%
Pseudocrenilabrus philander	86.25%	13.44%
Serranochromis angusticeps	15.00%	0.20%
Serranochromis carlottae	1.25%	0.01%
Serranochromis codringtonii	12.50%	0.21%
Serranochromis giardi	3.75%	0.03%
Serranochromis macrocephalus	51.25%	1.72%
Serranochromis robustus jallae	60.00%	1.05%
Tilapia rendalli	80.00%	10.82%
Tilapia ruweti	18.75%	2.49%
Tilapia sparrmanii	80.00%	8.11%
Ctenopoma multispinis	7.50%	0.24%
Aethiomastacembelus frenatus	5.00%	0.03%
Aethiomastacembelus vanderwaali	10.00%	0.11%

* Commonness ranking in text based on the following criteria:

Rank	Range
very common	> 75.0%
common	40-74.9%
fairly common	25-39.9%
uncommon	10-24.9%
scarce	5- 9.9%
rare	< 5.0%

Table 3. Percent (%) of total catch for each family or group of fishes per Kavango River zone.

Fish Family or Group	Zone 1	Zone 2	Zone 3	Zone 4	Total
Cichlids	44.5	53.3	30.0	15.6	46.2
Cyprinids	19.0	28.7	42.3	30.2	27.8
Characins	16.4	4.8	4.8	6.4	8.4
Cyprinidonts	8.1	6.2	3.7	35.9	7.0
Siluriforms	7.0	4.3	8.8	1.7	5.2
Mormyrids	3.5	2.0	8.1	3.5	3.4
Citharines	0.9	1.7	2.1	3.5	1.6
Anabantids	0.0	0.3	0.2	3.5	0.2
Mastacembelids	0.4	0.04	0.1	0	0.1
Hepsetids	0.1	0.03	0.1	0	0.1

Table 4. Numbers of fishes collected per Kavango River zone for each sampling period.

Zone 1

SPECIES	Feb	May	Jun	Sep	Nov	Total	% Total Zone Catch
Hippopotomyrus ansorgii	0	0	2	0	8	10	0.22%
Hippopotomyrus discorhynchus	2	2	2	0	0	6	0.13%
Marcusenius macrolepidotus	0	4	18	0	0	22	0.48%
Mormyrus lacerda	0	0	0	7	0	7	0.15%
Petrocephalus catostoma	2	10	22	7	4	45	0.97%
Pollimyrus castelnoui	0	20	38	13	2	73	1.58%
Brycinus lateralis	6	7	61	0	6	80	1.73%
Hydrocynus vittatus	4	1	0	0	1	6	0.13%
Micralestes acutidens	157	422	34	7	51	671	14.53%
Rhabdalestes maunensis	0	0	1	0	0	1	0.02%
Hepsetus odoe	3	0	0	0	0	3	0.06%
Hemigrammocharax machadoi	0	0	0	0	0	0	0.00%
Hemigrammocharax multifasciatus	2	12	24	3	2	43	0.93%
Nannocharax macropterus	0	0	0	0	0	0	0.00%
Barbus afrovernayi	0	8	8	8	2	26	0.56%
Barbus annectens	0	0	0	0	0	0	0.00%
Barbus barnardi	1	1	109	5	4	120	2.60%
Barbus barotseensis	0	0	0	0	0	0	0.00%
Barbus bifrenatus	0	119	24	45	27	215	4.65%
Barbus eutaenia	7	0	4	5	1	17	0.37%
Barbus fasciolatus	2	3	7	3	0	15	0.32%
Barbus hanstanus	0	0	1	0	0	1	0.02%
Barbus lineomaculatus	0	0	3	0	0	3	0.06%
Barbus multilineatus	0	0	0	0	0	0	0.00%
Barbus paludinosus	0	8	8	3	25	44	0.95%
Barbus poechii	37	99	13	11	0	160	3.46%
Barbus radiatus	1	9	15	0	0	25	0.54%
Barbus thamalakanensis	2	66	4	2	4	78	1.69%
Barbus unitaeniatus	0	0	0	0	0	0	0.00%
Coptostomabarbus wittei	0	0	0	0	0	0	0.00%
Labeo cylindricus	1	0	9	13	26	49	1.06%
Labeo lunatus	1	0	0	0	2	3	0.06%
Opsaridium zambezense	104	7	3	0	10	124	2.68%
Amphilius uranoscopus	0	0	11	0	1	12	0.26%
Leptoglanis dorae	0	0	0	1	2	3	0.06%
Leptoglanis rotundiceps	0	0	0	0	0	0	0.00%
Parauchenoglanis macrostomus	0	0	1	7	5	13	0.28%
Clarias gariepinus	5	2	0	1	0	8	0.17%
Clarias ngamensis	2	4	6	1	6	19	0.41%
Clarias theodorae	3	0	0	1	1	5	0.11%
Chiloglanis fasciatus	0	0	15	0	9	24	0.52%
Synodontis sp.	12	5	8	14	135	174	3.77%
Schilbe intermedius	0	33	26	7	1	67	1.45%
Aplocheilichthys katangae	0	3	0	1	8	12	0.26%
Aplocheilichthys johnstoni	20	120	52	70	101	363	7.86%
Aplocheilichthys katangae	0	0	0	0	0	0	0.00%
Hemichromis elongatus	1	2	2	0	0	5	0.11%
Oreochromis andersonii	13	2	2	0	141	158	3.42%
Oreochromis macrochir	0	0	2	0	0	2	0.04%
Pharyngochromis acuticeps	118	37	23	17	149	344	7.45%
Pseudocrenilabrus philander	128	196	100	137	109	670	14.51%
Serranochromis angusticeps	1	1	12	0	1	15	0.32%
Serranochromis carlottae	0	0	1	0	0	1	0.02%
Serranochromis codringtonii	0	0	1	1	6	8	0.17%
Serranochromis giardi	0	0	1	0	0	1	0.02%
Serranochromis macrocephalus	2	8	4	2	13	29	0.63%
Serranochromis robustus jallae	6	8	8	3	7	32	0.69%
Tilapia rendalli	64	194	64	15	108	445	9.63%
Tilapia ruweti	1	0	0	0	1	2	0.04%
Tilapia sparrmanii	42	48	117	76	60	343	7.43%
Ctenopoma multispinis	0	0	0	0	0	0	0.00%
Aethomastacembelus frenatus	0	0	3	1	0	4	0.09%
Aethomastacembelus vanderwaali	0	0	1	3	9	13	0.28%
Number of Samples	5	6	4	3	6	24	
Number of Species	31	32	42	32	37		
Number of Specimens	750	1461	870	490	1048	4619	

Table 4. (cont.)

Zone 2

SPECIES	Feb	May	Jun	Sep	Nov	Total	% Total Zone Catch
Hippopotomyrus ansorgi	0	0	0	1	1	2	0.03%
Hippopotomyrus discorhynchus	0	4	0	6	0	10	0.13%
Marcusenius macrolepidotus	0	11	1	38	7	57	0.74%
Mormyrus lacerda	4	0	1	1	0	6	0.08%
Petrocephalus catostoma	0	1	20	11	4	36	0.47%
Pollimyrus castelnaui	0	9	13	16	1	39	0.51%
Bryconaia lateralis	1	12	32	6	75	126	1.64%
Hydrocynus vittatus	9	24	0	6	30	69	0.90%
Micralestes acutidens	14	125	16	2	13	170	2.21%
Rhabdalestes maunensis	0	1	0	0	0	1	0.01%
Hepsetus odoe	1	1	0	0	0	2	0.03%
Hemigrammocharax machadoi	0	3	5	9	0	17	0.22%
Hemigrammocharax multifasciatus	3	76	27	5	1	112	1.46%
Nannocharax macropterus	0	1	0	0	0	1	0.01%
Barbus afrovernayi	1	9	8	13	1	32	0.42%
Barbus annectens	1	0	2	0	0	3	0.04%
Barbus bernardi	1	0	11	2	0	14	0.18%
Barbus barotseensis	17	10	10	0	0	37	0.48%
Barbus bifrenatus	9	28	33	22	0	92	1.20%
Barbus eutaenia	32	0	3	3	0	38	0.50%
Barbus fasciolatus	0	69	6	6	0	81	1.06%
Barbus hanitanus	0	0	0	5	0	5	0.07%
Barbus lineomaculatus	0	11	26	0	0	37	0.48%
Barbus multilineatus	0	0	0	0	0	0	0.00%
Barbus paludinosus	1	449	32	6	23	511	6.66%
Barbus poechii	120	134	104	38	143	539	7.02%
Barbus radiatus	42	111	242	12	3	410	5.34%
Barbus thamalakanensis	82	123	38	1	0	244	3.18%
Barbus unitaeniatus	14	64	1	0	0	79	1.03%
Coptostomabarbus wittei	0	0	0	0	0	0	0.00%
Labeo cylindricus	24	0	2	12	15	53	0.69%
Labeo lunatus	0	0	0	0	0	0	0.00%
Opsaridium zambezense	23	0	0	1	2	26	0.34%
Amphilius uranoscopus	0	0	0	0	0	0	0.00%
Leptoglanis dorae	0	0	0	1	0	1	0.01%
Leptoglanis rotundiceps	0	1	0	0	0	1	0.01%
Parauchenoglanis ngamensis	0	2	0	0	0	2	0.03%
Clarias gariepinus	6	7	0	1	4	18	0.23%
Clarias ngamensis	7	2	3	3	2	17	0.22%
Clarias theodorae	0	5	0	1	3	9	0.12%
Chiloglanis fasciatus	0	0	0	3	0	3	0.04%
Synodontis sp.	4	21	7	19	16	67	0.87%
Schilbe intermedius	8	27	27	8	55	125	1.63%
Aplocheilichthys katangae	6	5	11	0	35	57	0.74%
Aplocheilichthys johnstoni	75	143	92	52	47	409	5.33%
Aplocheilichthys katangae	1	7	0	0	1	9	0.12%
Hemichromis elongatus	0	0	0	0	0	0	0.00%
Oreochromis andersonii	22	186	0	2	32	242	3.15%
Oreochromis macrochir	0	0	0	0	1	1	0.01%
Pharyngochromis acuticeps	111	90	4	11	118	334	4.35%
Pseudocrenilabrus philander	264	574	119	131	59	1147	14.94%
Serranochromis angusticeps	2	1	9	2	0	14	0.18%
Serranochromis carlottae	0	0	0	0	0	0	0.00%
Serranochromis codnagtoni	0	0	1	18	4	23	0.30%
Serranochromis giardi	0	0	2	0	1	3	0.04%
Serranochromis macrocephalus	10	15	23	10	165	223	2.91%
Serranochromis robustus jallae	47	26	10	4	5	92	1.20%
Tilapia rendalli	536	168	39	19	134	896	11.67%
Tilapia rueppelli	92	247	0	0	3	342	4.46%
Tilapia sparrmanii	102	389	151	111	17	770	10.03%
Ctenopoma multispinis	2	17	1	0	0	20	0.26%
Aethiomastacembelus frenatus	0	0	0	0	0	0	0.00%
Aethiomastacembelus vanderwaali	0	0	0	3	0	3	0.04%
Number of Samples	9	11	5	5	8	38	
Number of Species	35	42	36	41	32		
Number of Specimens	1694	3209	1132	621	1021	7677	

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Table 4. (cont.)

Zone 3

SPECIES	Feb	May	Jun	Sep	Nov	Total	% Total Zone Catch
Hippopotomyrus ansorgi	0	0	2	5	2	9	0.40%
Hippopotomyrus discorhynchus	0	0	3	8	0	11	0.49%
Marcusenius macrolepidotus	0	0	5	7	0	12	0.53%
Mormyrus lacerda	0	1	3	0	1	5	0.22%
Petrocephalus catostoma	0	4	72	10	42	128	5.70%
Pollimyrus castelnaui	1	2	5	5	4	17	0.76%
Brycinus lateralis	2	0	1	0	1	4	0.18%
Hydrocynus vittatus	5	0	0	0	5	10	0.45%
Micralestes acutidens	41	37	3	4	8	93	4.14%
Rhabdalestes maunensis	0	0	0	0	0	0	0.00%
Hepsetus odoe	0	3	0	0	0	3	0.13%
Hemigrammocharax machadoi	0	3	0	0	0	3	0.13%
Hemigrammocharax multifasciatus	0	34	10	0	0	44	1.96%
Nannocharax macropterus	0	0	0	0	0	0	0.00%
	0						
Barbus afrovernayi	0	0	3	0	0	3	0.13%
Barbus annectens	1	0	0	0	0	1	0.04%
Barbus barnardi	0	0	0	0	0	0	0.00%
Barbus barotseensis	0	0	0	0	0	0	0.00%
Barbus bifrenatus	1	8	28	3	3	43	1.91%
Barbus eutaenia	1	2	75	85	41	204	9.08%
Barbus fasciolatus	0	0	1	0	2	3	0.13%
Barbus hasianus	0	0	0	0	0	0	0.00%
Barbus lineomaculatus	0	2	10	0	0	12	0.53%
Barbus multilineatus	0	0	1	0	0	1	0.04%
Barbus paludinosus	0	1	1	0	0	2	0.09%
Barbus poechii	5	11	12	29	150	207	9.21%
Barbus radiatus	0	16	2	0	1	19	0.85%
Barbus thamalakanensis	0	16	59	6	1	82	3.65%
Barbus unitaeniatus	0	0	0	0	0	0	0.00%
Coptostomabarbus [illegible]	0	0	2	0	0	2	0.09%
Labeo cylindricus	3	0	38	62	89	192	8.54%
Labeo lunatus	0	0	0	0	1	1	0.04%
Opsaridium zambezense	134	0	13	24	7	178	7.92%
Amphilius uranoscopus	0	0	1	1	2	4	0.18%
Leptoglanis dorae	0	0	0	0	0	0	0.00%
Leptoglanis rotundiceps	0	0	0	0	0	0	0.00%
Parauchenoglanis ngamensis	0	0	3	0	1	4	0.18%
Clarias gariepinus	0	0	1	0	0	1	0.04%
Clarias ngamensis	0	0	0	0	1	1	0.04%
Clarias theodorae	0	2	1	0	2	5	0.22%
Chiloglanis fasciatus	0	0	0	2	1	3	0.13%
Synodontis sp.	1	8	7	42	13	71	3.16%
Schilbe intermedius	1	34	59	3	11	108	4.81%
Aplocheilichthys huterensis	0	2	10	0	0	12	0.53%
Aplocheilichthys johnstoni	1	30	22	6	10	69	3.07%
Aplocheilichthys katangae	0	0	1	0	0	1	0.04%
Hemichromis elongatus	5	2	7	3	1	18	0.80%
Oreochromis andersonii	20	0	2	0	2	24	1.07%
Oreochromis macrochir	0	0	0	0	0	0	0.00%
Pharyngochromis acuticeps	17	2	22	15	14	70	3.12%
Pseudocrenilabrus philander	7	38	91	19	12	167	7.43%
Serranochromis angusticeps	0	0	0	0	0	0	0.00%
Serranochromis carlottae	0	0	0	0	0	0	0.00%
Serranochromis codringtonii	0	0	0	0	0	0	0.00%
Serranochromis giardi	0	0	0	0	0	0	0.00%
Serranochromis macrocephalus	0	0	1	1	1	3	0.13%
Serranochromis robustus jallae	3	3	11	9	4	30	1.[illegible]
Tilapia rendalli	42	7	13	10	182	254	11.30%
Tilapia ruweni	0	3	20	1	2	26	1.16%
Tilapia sparrmanii	7	4	32	31	7	81	3.60%
Ctenopoma multispinis	4	0	0	0	0	4	0.18%
Aethiomastacembelus frenatus	0	0	1	0	0	1	0.04%
Aethiomastacembelus vanderwaali	0	0	0	0	1	1	0.04%
Number of Samples	2	2	4	3	3	14	
Number of Species	21	26	41	5	34		
Number of Specimens	302	275	654	391	625	2247	

Table 4. (cont.)

Zone 4

SPECIES	Feb	Jun	Total	% Total Zone Catch
Hippopotomyrus ansorgii	0	0	0	0.00%
Hippopotomyrus discorhynchus	0	0	0	0.00%
Marcusenius macrolepidotus	0	2	2	0.63%
Mormyrus lacerda	0	0	0	0.00%
Petrocephalus catostoma	0	1	1	0.32%
Pollimyrus castelnaui	0	8	8	2.54%
Bryciana lateralis	0	5	5	1.59%
Hydrocynus vittatus	8	0	8	2.54%
Micralestes acutidens	0	0	0	0.00%
Rhabdalestes maunensis	0	7	7	2.22%
Hepsetus odoe	0	0	0	0.00%
Hemigrammocharax machadoi	0	6	6	1.90%
Hemigrammocharax multifasciatus	0	5	5	1.59%
Nannocharax macropterus	0	0	0	0.00%
Barbus afrovernayi	0	16	16	5.08%
Barbus annectens	0	0	0	0.00%
Barbus barnardi	0	1	1	0.32%
Barbus barotseensis	0	0	0	0.00%
Barbus bifrenatus	0	3	3	0.95%
Barbus eutaenia	0	0	0	0.00%
Barbus fasciolatus	0	25	25	7.94%
Barbus hastianus	0	18	18	5.71%
Barbus lineomaculatus	0	0	0	0.00%
Barbus multilineatus	0	11	11	3.49%
Barbus paludinosus	0	2	2	0.63%
Barbus poechii	0	2	2	0.63%
Barbus radiatus	0	7	7	2.22%
Barbus thamalakanensis	0	9	9	2.86%
Barbus unitaeniatus	0	0	0	0.00%
Coptostomabarbus wittei	0	1	1	0.32%
Labeo cylindricus	0	0	0	0.00%
Labeo lunatus	0	0	0	0.00%
Opsaridium zambezense	0	0	0	0.00%
Amphilius uranoscopus	0	0	0	0.00%
Leptoglanis dorae	0	0	0	0.00%
Leptoglanis rotundiceps	0	0	0	0.00%
Paranchenoglanis zgnmenzis	0	0	0	0.00%
Clarias gariepinus	0	0	0	0.00%
Clarias ngamensis	0	0	0	0.00%
Clarias theodorae	0	1	1	0.32%
Chiloglanis fasciatus	0	0	0	0.00%
Synodontis sp.	0	3	3	0.95%
Schilbe intermedius	0	1	1	0.32%
Aplocheilichthys katangae	0	15	15	4.76%
Aplocheilichthys johnstoni	0	81	81	25.71%
Aplocheilichthys katangae	0	17	17	5.40%
Hemichromis elongatus	0	0	0	0.00%
Oreochromis andersonii	1	6	7	2.22%
Oreochromis macrochir	0	3	3	0.95%
Pharyngochromis acutidens	0	1	1	0.32%
Pseudocrenilabrus philander	0	12	12	3.81%
Serranochromis angusticeps	0	1	1	0.32%
Serranochromis carlottae	0	0	0	0.00%
Serranochromis codringtonii	0	0	0	0.00%
Serranochromis giardi	0	0	0	0.00%
Serranochromis macrocephalus	0	0	0	0.00%
Serranochromis robustus jallae	0	2	2	0.63%
Tilapia rendalli	0	13	13	4.13%
Tilapia rueppelli	0	0	0	0.00%
Tilapia sparrmanii	0	10	10	3.17%
Ctenopoma multispinis	0	11	11	3.49%
Aethiomastacembelus frenatus	0	0	0	0.00%
Aethiomastacembelus vanderwaali	0	0	0	0.00%
Number of Samples	1	3	4	
Number of Species	2	33		
Number of Specimens	9	306	315	

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Table 5. A key to the anabantid and characin fishes known from Namibia.

Characidae

1a. Dorsal, caudal and anal fins bright red; black lateral spot posterior to opercle; not native to Namibia. **Astyanax orthodus**
1b. Fins not bright red; no lateral spot; indigenous.....2

2a. Large exposed canine-like teeth..... **Hydrocynus vittatus**
2b. No large exposed canine-like teeth.....3

3a. Black lateral band extending through to caudal rays **Brycinus lateralis**
3b. Black lateral band not extending to form black spot on caudal rays.....4

4a. Dorsal fin origin above pelvic fin base; dorsal fin often tipped with black and orange; no dark slash of pigment at anal fin base **Micralestes acutidens**
4b. Dorsal fin origin behind pelvic fin base; no color on dorsal fin tip; dark band of pigment along anal fin base **Rhabdalestes maunensis**

Anabantiformes

1a. Pectoral fin rays greatly elongated into filaments longer than total body depth; not native to Namibia..... .....**Trichogaster trichopterus** (Belontiidae)
1b. Pectoral fins not elongated into filaments, being shorter than body depth; native to Namibia.....(Anabantidae)....2

2a. Posterior edge of both dorsal and anal fins pointed; black spot at base of caudal fin, black lines radiating from eye.....**Ctenopoma intermedium**
2b. Posterior edge of both dorsal and anal fins rounded; no black spot at base of caudal fin; no black lines radiating from eye.....**C. multispinus**

Table 6. The original Index of Biotic Integrity (IBI) metrics proposed by Karr (1981).

Category	Metric
Species richness & composition	1. Total number of fish species
	2. Number & identity of darter species
	3. Number & identity of sunfish species
	4. Number & identity of sucker species
	5. Number & identity of intolerant species
	6. Proportion of individuals as green sunfish
Trophic composition	7. Proportion of individuals as omnivores
	8. Proportion of individuals as insectivorous cyprinids
	9. Proportion of individuals as piscivores (top carnivores)
Fish abundance & condition	10. Number of individuals in a sample
	11. Proportion of individuals as hybrids
	12. Proportion of individuals with disease or other anomalies

Table 7. Underlying assumptions of the Index of Biotic Integrity (IBI) concerning how stream fish communities change with environmental degradation (after Fausch et al. 1990).

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(1) The number of all native species and those in specific taxa or habitat guilds declines

(2) The number of intolerant species declines

(3) The proportion of individuals that are members of tolerant species increases

(4) The proportion of trophic specialists such as insectivores and top carnivores declines

(5) The proportion of trophic generalists, especially omnivores, increases

(6) Fish abundance generally declines

(7) The proportion of individuals in reproductive guilds requiring silt-free coarse spawning substrate declines

(8) The incidence of externally-evident disease, parasites and morphological anomalies increases

(9) The proportion of individuals that are members of introduced species increases

(10) The incidence of hybrids may increase

Table 8. Diet and habitat preferences of Kavango River fishes (compiled from a number of sources).

Species	Habitat Preference						Food Preference		Maximum Size	
	Water	Vegetation	Substrate	Floodplain	Spawning	Migration	Diet	Location	TL (cm)	Wt. (kg)
MORMYRIDAE										
Hippopotomyrus ansorgii	R	E	C	U	U	U	I	U	15	
Hippopotomyrus discorhynchus	N	U	N	N	U	W	I	U	31	1.1
Marcusenius macrolepidotus	N	P	N	Y	U	W	I	U	30	0.5
Mormyrus lacerda	S	P	O	N	U	W	I	U	50	2
Petrocephalus catostoma	S	P	O	Y	U	W	I	U	13	
Pollimyrus castelnaui	S	P	O	Y	U	U	I	U	7	
CHARACIDAE										
Brycinus lateralis	U	P	U	U	U	W	I	U	14	
Hydrocynus vittatus	N	E	N	N	U	W	F	A		45.5
Micralestes acutidens	N	E	N	N	U	U	I	U	8	
Rhabdalestes maunensis	S	U	O	Y	U	W	I	U	6	
HEPSETIDAE										
Hepsetus odoe	S	U	U	Y	U	W	F	U	50	2
DISTICHODONTIDAE										
Hemigrammocharax machadoi	S	P	U	Y	U	W	I	U	4	
Hemigrammocharax multifasciatus	S	P	U	Y	U	W	I	U	6	
Nannocharax macropterus	S	P	U	Y	U	W	I	U	6	
CYPRINIDAE										
Barbus afrovernayi	S	P	U	U	U	U	I	U	4.5	
Barbus annectens	N	E	N	Y	U	W	I	U	7.6	
Barbus barnardi	U	P	U	Y	U	W	I	U	7	
Barbus barotseensis	S	P	U	Y	U	W	I	U	5	
Barbus bifrenatus	R	U	D	Y	U	W	I	U	5	
Barbus codringtonii	R	E	C	U	U	U	I	U		3.2
Barbus eutaenia	R	P	C	Y	U	W	I	U	14	
Barbus fasciolatus	S	E	N	Y	U	W	I	U	6	
Barbus hassianus	S	P	U	Y	U	U	I	U	3.2	
Barbus lineomaculatus	N	E	N	Y	U	W	I	U	7.6	
Barbus marequensis	R	E	C	U	U	W	I	U		3.4
Barbus multilineatus	S	P	U	Y	U	W	I	U	4.5	
Barbus paludinosus	N	E	N	Y	U	W	I	U	13	
Barbus poechii	S	P	U	Y	U	W	I	U	11	
Barbus radiatus	N	E	N	U	U	W	I	U	8	
Barbus tangendensis	R	U	C	U	U	U	I	U	6.5	
Barbus thamalakanensis	S	P	U	Y	U	U	I	U	5	
Barbus unitaeniatus	N	E	N	U	U	W	I	U	14	
Coptostomabarbus wittei	S	P	U	Y	U	U	I	U	3	
Labeo cylindricus	R	E	C	U	U	W	V	B	23	
Labeo lunatus	R	E	C	Y	U	U	V	B	40	2.5
Mesobola brevianalis	S	P	U	U	U	U	I	N	7.5	
Opsaridium zambezense	N	E	N	Y	U	U	I	U	15.3	
AMPHILIIDAE										
Amphilius uranoscopus	R	E	C	U	U	U	I	B	17	
BAGRIDAE										
Leptoglanis dorae	R	E	D	U	U	U	I	B	3.7	
Leptoglanis rotundiceps	R	E	D	Y	U	U	I	B	5	
Parauchenoglanis ngamensis	U	U	CD	Y	U	U	T	U	38	

Table 8. (cont.)

Species	Habitat Preference						Food Preference		Maximum Size	
	Water	Vegetation	Substrate	Floodplain	Spawning	Migration	Diet	Location	TL (cm)	Wt. (kg)
CLARIIDAE										
Clariallabes platyprosopos	R	U	R	U	U	U	F	U	30.5	0.128
Clarias dumerilii	U	U	U	U	U	U	T	U		
Clarias gariepinus	S	E	N	Y	U	W	T	N		30.84
Clarias ngamensis	S	P	U	Y	U	W	T	N		3.7
Clarias stappersii	S	P	U	Y	U	U	T	U	30	0.5
Clarias theodorae	S	P	N	Y	U	W	I	U	35	
MOCHOKIDAE										
Chiloglanis fasciatus	U	U	U	U	U	U	I	U		
Synodontis leopardinus	N	E	N	Y	U	U	T	B	22	
Synodontis macrostigma	U	U	U	U	U	U	T	U		
Synodontis macrostoma	U	U	U	U	U	U	T	U		
Synodontis nigromaculatus	S	P	N	Y	U	U	T	U	44	1.8
Synodontis thamalakanensis	U	U	U	U	U	U	T	U		
Synodontis vanderwaali	U	U	U	U	U	U	T	U		
Synodontis woosnami	U	U	U	U	U	U	T	B	19	
SCHILBEIDAE										
Schilbe intermedius	S	P	U	Y	U	U	T	U		0.77
CYPRINIDONTIDAE										
Aplocheilichthys butereaui	S	P	U	Y	U	U	I	A	3	
Aplocheilichthys johnstoni	S	P	U	Y	U	W	I	A	5	
Aplocheilichthys katangae	S	P	U	Y	U	W	I	A	4.5	
CICHLIDAE										
Hemichromis elongatus	N	U	C	Y	U	U	I	U	26.5	
Oreochromis andersonii	S	P	N	Y	G	X	V	U		3.2
Oreochromis macrochir	S	P	D	Y	M	X	V	U		2.6
Pharyngochromis acuticeps	N	E	N	Y	U	X	I	U	22	
Pseudocrenilabrus philander	S	P	N	Y	M	X	I	U	9	
Serranochromis angusticeps	S	P	N	Y	M	X	F	U	2.5	
Serranochromis altus	U	U	U	U	U	U	F	U		
Serranochromis carlottae	S	P	N	U	U	U	I	U	34.6	0.6
Serranochromis codringtonii	S	E	CD	U	M	X	I	U		2.2
Serranochromis giardi	S	E	D	Y	M	X	I	U		2.9
Serranochromis greenwoodi	U	U	U	U	U	U	I	U		
Serranochromis macrocephalus	S	P	N	Y	M	X	F	U		1.5
Serranochromis robustus jallae	N	E	N	Y	M	X	F	U		3.3
Serranochromis thumbergi	N	E	N	U	M	X	F	SN		1.2
Tilapia rendalli	S	P	N	Y	U	W	V	N		1.6
Tilapia ruweti	S	P	U	Y	U	U	V	U	10.3	
Tilapia sparrmanii	S	P	N	Y	U	W	V	U	23.5	
ANABANTIDAE										
Ctenopoma ctenotis	S	P	U	Y	U	U	I	U	6.2	
Ctenopoma multispinis	S	P	U	Y	U	W	I	U	13.5	
MASTACEMBELIDAE										
Aethiomastacembelus frenatus	N	E	C	U	U	U	I	U	33	
Aethiomastacembelus vanderwaali	R	E	C	U	U	U	I	U	17.8	

Table 8. (cont.)

Habitat Preference
- Water:
  - (R) Rapidly moving
  - (S) Slow, swampy
  - (N) No preference
  - (U) Unknown
- Vegetation:
  - (P) Needed, preferred
  - (E) Not necessary, often found in habitats without
  - (U)
- Substrate:
  - (O) Silt, organic matter (assuming for swamp-loving fish)
  - (C) Rock
  - (D) Sand
  - (N) No preference
  - (U)
- Floodplain:
  - (Y) User, during any life stage
  - (Z) Non-user
  - (U)
- Spawning:
  - (M) Multiple
  - (G) Single
  - (U)
- Migrate:
  - (W) Yes, for any purpose
  - (X) No
  - (U)

Diet
- Food preference:
  - (V) Primarily vegetative material, plankton, algae and detritus
  - (I) Primarily aquatic larvae, insects, crusts, and molluscs
  - (F) Primarily fish
  - (T) Opportunist scavengers, anything small enough to be ingested
  - (U)
- Feeding location:
  - (A) Surface
  - (B) Bottom

Table 9. List of proposed biological criteria metrics used to characterize and assess tropical floodplain river systems.

Species Richness and Composition

1) Total number of native fish species

2) Total number of benthic specialist species

3) Total number of cichlid species

4) Total number of pelagic-rheophilic species

Trophic Composition

5) Proportion of individuals as principal herbivores and detritivores

6) Proportion of individuals as principal invertivores

7) Proportion of individuals as opportunistic scavengers

8) Proportion of individuals as piscivores

Fish Abundance and Condition

9) Total number of individuals in a sample

10) Total number of exotic and introduced species

11) Proportion of individuals with visible anomalies

Table 10. Summary values for each proposed metric on a zonal scale.

	Zone 1			
Metric	Min.	Med.	Max.	Avg.
Number of native fish species	8	17	30	17
Number of benthic specialist species	0	0	5	1
Number of pelagic rheophilic species	0	2	4	2
Number of cichlid species	2	6	9	6
Prop. of individuals as princ. herb./detr.	2.20%	20.33%	59.40%	24.97%
Prop. of individuals as princ. invertivores	27.80%	72.47%	95.32%	67.91%
Prop. of individuals as oppor. scavengers	0.00%	2.82%	41.14%	5.16%
Prop. of individuals as piscivores	0.00%	2.12%	5.50%	1.96%
Number of individuals in sample	47	165	555	192
Prop. of inds. as introd. or invasive species	0.00%	0.00%	0.00%	0.00%
Prop. of inds. with visible disease or anomalies	0.00%	0.00%	0.00%	0.00%

Table 10. (cont.)

	Zone 2			
Metric	Min.	Med.	Max.	Avg.
Number of native fish species	2	14	30	14
Number of benthic specialist species	0	0	4	0
Number of pelagic rheophilic species	0	1	4	1
Number of cichlid species	0	6	9	5
Prop. of individuals as princ. herbivores	0.00%	23.50%	90.60%	30.53%
Prop. of individuals as princ. invertivores	0.00%	65.92%	87.20%	59.52%
Prop. of individuals as oppor. scavengers	0.00%	2.03%	25.00%	3.83%
Prop. of individuals as piscivores	0.00%	3.04%	67.00%	6.12%
Number of individuals in sample	8	135	769	214
Prop. of inds. as introd. or invasive species	0.00%	0.00%	0.00%	0.00%
Prop. of inds. with visible disease or anomalies	0.00%	0.00%	0.01%	0.00%

Table 10. (cont.)

	Zone 3			
Metric	Min.	Med.	Max.	Avg.
Number of native fish species	10	18	24	18
Number of benthic specialist species	0	1	4	1
Number of pelagic rheophilic species	0	1	4	1
Number of cichlid species	2	6	8	6
Prop. of individuals as princ. herb./detr.	3.70%	19.36%	88.80%	25.07%
Prop. of individuals as princ. invertivores	7.80%	69.38%	92.00%	63.71%
Prop. of individuals as oppor. scavengers	0.00%	4.09%	36.00%	9.03%
Prop. of individuals as piscivores	0.00%	1.49%	8.40%	2.19%
Number of individuals in sample	61	168	266	160
Prop. of inds. as introd. or invasive species	0.00%	0.00%	0.00%	0.00%
Prop. of inds. with visible disease or anomalies	0.00%	0.00%	0.00%	0.00%

Table 11. Summary values for each proposed metric on a seasonal scale.

	February			
Metric	Min.	Med.	Max.	Avg.
Number of native fish species	5	13	23	13
Number of benthic specialist species	0	0	1	0
Number of pelagic rheophilic species	0	1	4	2
Number of cichlid species	2	7	7	6
Prop. of individuals as princ. herb./detr.	3.89%	30.75%	90.63%	36.98%
Prop. of individuals as princ. invertivores	0.00%	66.44%	91.44%	58.34%
Prop. of individuals as oppor. scavengers	0.00%	0.72%	5.52%	1.28%
Prop. of individuals as piscivores	0.00%	2.79%	9.38%	3.41%
Number of individuals in sample	37	138	561	174
Prop. of inds. as introd. or invasive species	0.00%	0.00%	0.00%	0.00%
Prop. of inds. with visible disease or anomalies	0.00%	0.00%	0.00%	0.00%

Table 11. (cont.)

	May			
Metric	Min.	Med.	Max.	Avg.
Number of native fish species	2	14	26	15
Number of benthic specialist species	0	0	2	0
Number of pelagic rheophilic species	0	0	3	1
Number of cichlid species	0	5	8	5
Prop. of individuals as princ. herb./detr.	0.00%	14.20%	85.51%	24.10%
Prop. of individuals as princ. invertivores	14.49%	77.50%	95.32%	70.43%
Prop. of individuals as oppor. scavengers	0.00%	2.00%	22.34%	3.55%
Prop. of individuals as piscivores	0.00%	1.09%	9.43%	1.94%
Number of individuals in sample	53	181	758	260
Prop. of inds. as introd. or invasive species	0.00%	0.00%	0.00%	0.00%
Prop. of inds. with visible disease or anomalies	0.00%	0.00%	0.00%	0.00%

Table 11. (cont.)

	June			
Metric	Min.	Med.	Max.	Avg.
Number of native fish species	5	21	30	20
Number of benthic specialist species	0	1	5	1
Number of pelagic rheophilic species	0	1	3	1
Number of cichlid species	1	6	9	6
Prop. of individuals as princ. herb./detr.	0.00%	13.24%	59.38%	17.00%
Prop. of individuals as princ. invertivores	37.06%	75.60%	91.84%	72.00%
Prop. of individuals as oppor. scavengers	1.17%	4.08%	35.59%	8.65%
Prop. of individuals as piscivores	0.00%	2.77%	4.24%	2.34%
Number of individuals in sample	8	168	769	221
Prop. of inds. as introd. or invasive species	0.00%	0.00%	0.00%	0.00%
Prop. of inds. with visible disease or anomalies	0.00%	0.00%	0.00%	0.00%

Table 11. (cont.)

	September			
Metric	Min.	Med.	Max.	Avg.
Number of native fish species	11	17	26	18
Number of benthic specialist species	0	2	4	2
Number of pelagic rheophilic species	0	1	2	1
Number of cichlid species	2	6	7	5
Prop. of individuals as princ. herb./detr.	12.58%	25.30%	32.72%	24.04%
Prop. of individuals as princ. invertivores	24.37%	67.42%	79.47%	64.92%
Prop. of individuals as oppor. scavengers	0.69%	4.50%	34.45%	8.58%
Prop. of individuals as piscivores	0.00%	1.74%	8.40%	2.46%
Number of individuals in sample	61	132	285	149
Prop. of inds. as introd. or invasive species	0.00%	0.00%	0.00%	0.00%
Prop. of inds. with visible disease or anomalies	0.00%	0.00%	0.00%	0.00%

Table 11. (cont.)

	November			
Metric	Min.	Med.	Max.	Avg.
Number of native fish species	7	15	24	15
Number of benthic specialist species	0	0	4	1
Number of pelagic rheophilic species	0	2	3	2
Number of cichlid species	2	7	9	6
Prop. of individuals as princ. herb./detr.	1.05%	27.42%	81.01%	32.70%
Prop. of individuals as princ. invertivores	7.77%	52.05%	81.51%	51.73%
Prop. of individuals as oppor. scavengers	0.00%	3.64%	41.14%	6.51%
Prop. of individuals as piscivores	0.00%	2.53%	67.01%	9.06%
Number of individuals in sample	43	153	299	158
Prop. of inds. as introd. or invasive species	0.00%	0.00%	0.00%	0.00%
Prop. of inds. with visible disease or anomalies	0.00%	0.00%	0.00%	0.00%

Table 12. Latin and local names of fish species which potentially occur in the Kavango and Caprivi provinces, Namibia, based on a synthesis of current literature. (AN) Angolan waters, (LZ) Lower Zambezi, (MZ) Middle Zambezi, (UZ) Upper Zambezi, (LK) Lake Kariba, (LI) Limpopo, (PU) Pungwe, (US) Upper Save/Runde, (LS) Lower Save/Runde, (KA) Kavango, (LU) Lundi.

GENUS	SPECIES	LOCAL NAME(S)
Hippopotamyrus	ansorgii	
H.	discorhynchus	Mpatu LZ, MZ, LK; Mançuela LK
Marcusenius	macrolepidotus	Nembele UZ, LK; Mburi, Masija MZ, LK
Mormyrus	lacerda	Ndikusi UZ
Petrocephalus	catostoma	
Pollimyrus	castelnaui	Kaleha AN
Brycinus	lateralis	Mungumba AN; Mbale UZ, LK
Hydrocynus	vittatus	Muka, Musonga, Kasanji, Kasangi AN, Ngweshi UZ; Maluvali, Ilubale, Mcheni LK, MZ; Muvanga LS
Micralestes	acutidens	Muka, Mika, Sese, Lutemba, Mwota, Tshawamba, Lubango AN; Misindi LK, MZ; Chitaka LK
Rhabdalestes	maunensis	Mungumba AN
Hepsetus	odoe	Kasangi, Tusangi, Mukunga AN; Molumezi UZ; Nyeru KA
Hemigrammocharax	machadoi	Namukidji AN
H.	multifasciatus	
Nannocharax	macropterus	Mujiji, Muka, Sese AN
B.	afrovernayi	Senge AN
B.	annectens	
B.	barnardi	Senge, Ngonga, Mukenge AN
B.	barotseensis	
B.	bifrenatus	
B.	codringtonii	Linyonga UZ
B.	eutaenia	
B.	fasciolatus	Chitakala LK
B.	haasianus	
B.	lineomaculatus	Gwinya LK; Msindi LS
B.	manicensis	
B.	marequensis	Kakumbi AN; Mutuba LK, MZ; Kuyu US,LS
B.	multilineatus	Lisangisangi, Senge, Ngonga AN
B.	paludinosus	Ncenga LK; Gwinya LS
B.	poechii	Mungumba AN; Mpifu LK, UZ
B.	radiatus	Msindi LU
B.	tangandensis	

Table 12. (cont.)

B.	thamalakanensis	Senge, Ngonga AN
B.	unitaeniatus	Msindi LK
B.	viviparus	Lisangisangi
Coptostomabarbus	wittei	
Labeo	cylindricus	Mumbu LK, MZ, LZ, US; Nguridzi LK, LS
L.	lunatus	Linyonga LK, UZ
Mesobola	brevianalis	
Opsaridium	zambezense	Lutemba, Sese, Lusese, Lumbungo, Sakunge, Muka, Mika, Mwota AN, Myamkaula
Amphilius	uranoscopus	
Parauchenoglanis	ngamensis	Tshingondola, Ingondola, Tshinganda, Lumbungo, Mbungo, Tshikanda, Dibonga ya Kajama, Lwasa AN; Sibutu UZ
Leptoglanis	rotundiceps	
L.	dorae	
Clarias	dumerilii	
C.	gariepinus	Mburi AN, Mandev, Maramba, Mukonzwe, Mubondo LK, LZ, MZ, US; Ndombi UZ; Shamwe Chilu LS
C.	ngamensis	Mburi AN; Ndombi UZ
C.	stappersii	Tshiwende, Iwende, Kambangaji, Tumbangaji, Tshota mualwa, Lundembe AN; Ndombi UZ
C.	theodorae	Tshota mualwa, Iota mualwa, Kambangaji, Musonji, Tshimbua AN; Minga UZ
Clariallabes	platyprosopos	
Heterobranchus	longifilis	Lenda, Tshota mualwa AN; Vundu LK, MZ; Njume LZ
Chiloglanis	fasciatus	
Synodontis	leopardinus	Songonge UZ
S.	macrostoma	
S.	macrostigma	Tshingele AN; Singonge UZ
S.	nigromaculatus	Tshingondola, Tshingele AN; Cingwele UZ
S.	thamalakanensis	
S.	vanderwaali	
S.	woosnami	Tshingele AN; Songonge UZ
Schilbe	intermedius	Zeza, Kanzema AN; Mvenga LS; Lubangu UZ

Table 12. (cont.)

Aplocheilichthys	hutereaui	Kakenga matako AN
A.	johnstoni	Kakenga matako, Mukitshi, Munyanya ou Namuquidji AN; Pipinka LK
A.	katangae	Kakenga matako ou Kanga AN
Hemichromis	elongatus	Lutundwa, Tundwa, Thundwa, Tshikele, Ikele, Mbungo, Kanzema, Tunzema, Lwasa, Tsha wamba, Sese AN; Linwalala, Liulungu UZ
Oreochromis	andersonii	Njinji UZ
O.	macrochir	Khundu, Mahumbwe, Tshimbua, Keji AN; Mu UZ
Pharyngochromis	acuticeps	Tshinganga, Tshilamba AN; Imbalata LK
Pseudocrenilabrus	philander	Tshakala, Matshakala, Tshikele, Mbowo, Thundwa, Tsha wamba, Lwasa AN; Hangalole LK
Serranochromis	altus	
S.	angusticeps	Tshimbua, Khele AN; Mushuna, Lisamba UZ
S.	carlottae	Likumbwa LK, UZ
S.	codringtonii	Seao LK, UZ
S.	giardi	Sieo LK; Seao UZ
S.	greenwoodi	
S.	longimanus	
S.	macrocephalus	Tshimbua, Khele AN; Mulumbo LK, UZ
S.	robustus jallae	Tshikele, Ikele AN; Nembwe LK, UZ
S.	thumbergi	Mununga UZ
Tilapia	rendalli	Tshikele, Ikele, Khundu, Kapa, Tshimbua AN; Mbanje LK, MZ, LZ, US; Mudile LK, Mbungu LS; Mbufu UZ
T.	ruweti	Liumbwe, Mbowo, Tukeya, Kakeya AN
T.	sparrmanii	Mgwaya LK, MZ; Situ, Situhu UZ
Ctenopoma	ctenotis	
C.	multispinis	Mbundu UZ
Aethiomastacembelus	frenatus	Mutomi UZ
A.	vanderwaali	

Table 13. Traditional and contemporary gears used in the Kavango and Caprivi Provinces (from van der Waal 1991).

Fish funnel (shikuku, chikuku, sikuku)
Funnel shaped structure made of grass stems and palm leaves used by women and children in backbays and shallow, weedy areas. Used singly, or in groups with people churning the water and trampling the vegetation, herding the fish into the funnels. Selective for small fish.

Fish corral trap (sintunga)
Rectangular shaped mat-like structures constructed from woody stems and sedges. These are used as traps (sometimes baited), driven into the substrate in a kidney shape, leaving a small gap for fish to enter. These were most commonly used in backwater areas during flood stage. Selective for small fish.

Fish fence (masasa) with valved traps (muduwa) and corrals (erera)
Fences constructed of reeds, sedges and palm leaves and staked across bays or channels. Selective for large fish.

Scoop basket (tambi)
Oval shaped baskets constructed from reeds and sedges and pulled through aquatic vegetation. Most effective in shallow areas after floods recede. Selective for small fish.

Push basket (sididi, makundo)
Conically shaped basket constructed of woody stems and weeds, with a hole on the side to retrieve fish. Used in shallow pools by plunging over swimming fish. Selective for small fish.

Fish bow and arrow (ngumba)
Constructed of sturdy wood and stems, with sharp steel shanks woven to the end. Used by men stalking large fish along shoreline or in dugout canoe (mokoro).

Set fish hook (egondo)
Large hook baited with fish or mussel and tethered to a short line attached to dried reed bundles. Selective for large fish.

Fish spear (muho)
Thin wooden pole fitted with an iron shaft with barbs along the edges. Used by men to collect large fish in shallow areas.

Hook and line (erowo)
Hooks are tied to nylon line and fastened to reed poles. Selective for all size fishes.

Table 13. (cont.)

Gill nets
Modern gill nets (homemade or stolen) stretched across backwaters and side channels. Selective for all size fishes.

Seine nets
Modern nets, sometimes fashioned with mosquito netting, and pulled through bays and side channels.

Wire mesh fykes
Homemade valved traps, used mostly in the western area of the Kavango Province.

Table 14. Length frequency data for Barbus poechii collected from the Kavango River, Namibia, 1992 (N=916).

Total Length (mm)	Feb	May	Jun	Sep	Nov	Total
20	5	4				9
25	16	5				21
30	35	2		1		38
35	30	1	1			32
40	13	6	2			21
45	6	16	4	1	1	28
50	7	24	4	4		39
55	21	24	21	7	5	78
60	16	24	38	7	4	89
65	4	28	47	7	6	92
70	3	21	38	15	29	106
75		8	47	9	78	142
80	1	9	10	9	82	111
85	1	1	7	7	43	59
90	1	1	1	1	14	18
95	1		1	3	10	15
100			1	1	5	7
105				3	4	7
110			1	1	2	4
Sum	160	174	223	76	283	916

Table 15. Length frequency data for *Pseudocrenilabrus philander* collected from the Kavango River, Namibia, 1992 (N=1973).

Total Length (mm)	Feb	May	Jun	Sep	Nov	Total
10					1	1
15	5				1	6
20	37	41	5	3	18	104
25	42	118	34	13	28	235
30	90	100	58	23	21	292
35	86	144	54	33	14	331
40	54	110	40	39	18	261
45	49	111	49	58	21	288
50	27	76	34	39	23	199
55	7	51	15	51	19	143
60	3	25	8	11	11	58
65		14	6	8	5	33
70		7	1	9	2	19
75		1				1
80				1		1
85		1				1
Sum	400	799	304	288	182	1973

Table 16. Estimated growth parameters (K) for four cichlid species from southern Africa.

SPECIES	K range	Reference
Oreochromis andersonii	.174	Duerre (1969)
	.221 - .455	Dudley (1974)
Oreochromis macrochir	.312	Duerre (1969)
	.450 - .480	Dudley (1974)
	.374	Balon and Coche (1974)
Oreochromis mossambicus	.196 - .684	Hecht (1980)
	.240 - .358	Bruton and Allanson (1974)
Tilapia rendalli	.128 - .745	Duerre (1969)
	.456 - .467	Dudley (1974)
	.138	Balon and Coche (1974)

Table 17. Length frequency data for Schilbe intermedius collected from the Kavango River, Namibia, 1992 (N=289). BVZ = van Zyl et al. data collected in June, 1992.

Fk Length (cm)	Feb	May	Jun	Sep	Nov	Total	BVZ
3	1					1	
4	2					2	
5	1	1				2	
6	1	9	6	2	6	24	7
7	2	7	33	8	13	63	25
8	4	22	32	7	38	103	35
9	1	21	12	1	8	43	7
10		17	3		2	22	17
11		9	7			16	29
12		3	4			7	114
13		1	1			2	115
14		1				1	45
15		1				1	41
16						0	35
17		1				1	56
18		1				1	60
19							53
20							78
21							31
22							16
23							13
24							9
25							3
26							2
27							1
28							1
Sum	12	94	98	18	67	289	793

Table 18. Length frequency data for *Tilapia rendalli* collected from the Kavango River, Namibia, 1992 (N=1462). BVZ = van Zyl et al. data collected in June, 1992.

Total Length (cm)	Feb	May	Jun	Sep	Nov	Total	BVZ
2	110	8			68	186	
3	252	72	17	1	213	555	1
4	159	100	23	9	57	348	18
5	60	48	19	6	7	140	53
6	21	37	14	7	7	86	76
7	11	16	20	9	5	61	46
8	7	1	17	7	6	38	26
9	1	2	9	5	8	25	18
10			4	1	7	12	6
11	1		4		3	8	
12	1				2	3	
13							
14							
15							
16							
17							1
Sum	623	284	127	45	383	1462	245

Table 19. Length frequency data for *Tilapia sparrmanii* collected from the Kavango River, 1992 (N=1269). BVZ = van Zyl et al. data collected in June of 1992.

Total Length (cm)	Feb	May	Jun	Sep	Nov	Total	BVZ
2	19	8			6	33	1
3	48	61	33	5	3	150	6
4	34	133	85	25		277	29
5	14	167	97	62	16	356	41
6	4	122	69	62	36	293	21
7	5	26	27	41	5	104	20
8	3	7	4	17	8	39	106
9		1		4	6	11	90
10				2	4	6	45
11							21
12							8
13							3
14							1
15							
16							2
17							1
Sum	127	525	315	218	84	1269	395

Table 20. Gross energy (MJ/kg), percent crude protein (%) and percent ether extract of soluble fats (%) of select fish species, by family, from the Kavango River, March 1993.

SPECIES	NUMBER	TOTAL LENGTH (mm)	GE (MJ/kg)	CP (%)	EE (%)
Mormyridae					
Marcusenius macrolepidotus	1	11	19.76	55	2.4
Characidae					
Alestes lateralis	1	8.2	17.23	-	12.6
Hydrocynus vittatus	2	17.4-23.7	20.47	74	14.3
Cyprinidae					
Barbus paludinosus	2	6.1-6.4	18.17	-	-
B. poechii	4	3.3-5.7	16.95	-	-
B. unitaeniatus	3	5.9-6.2	16.56	-	9.1
Schilbeidae					
Schilbe intermedius	1	16	18.58	-	-
Cichlidae					
Oreochromis andersonii	5	7.9-10.6	17.04	71	3.0
O. macrochir	2	7.5-9.7	17.86	52	10.8
Pseudocrenilabrus philander	5	5.1-6.5	15.54	-	3.9
Serranochromis codringtonii	4	10.5-12.6	18.77	62	10.3
S. macrocephalus	5	7.6-10.0	16.67	57	7.6
S. robustus	6	7.5-12.6	16.99	76	3.8
Tilapia rendalli	5	5.7-8.5	16.19	66	6.4
T. sparrmanii	4	6.0-7.8	16.5	69	2.3

Table 21. List of stations collected for fishes in the Eastern Caprivi Province, 1992.

Station No.	Location Description
1.	Kwando River, back channel in Sewanee Nature Reserve; 17° 43′ 25" S x 23° 22′ 26" E
2.	Kwando River, backwater at Buffalo Lodge Nature Conservation office, Sewanee Nat. Reserve; 17° 47′ 26" S x 23° 20′ 38" E
3.	Kwando River, hippo pool adjacent to Lianshulu Tourist Camp road: 18° 07′ 19" S x 23° 22′ 53" E
4.	Linyanti River, isolated buffalo pools in Nzabara Channel in Mamili National Park; 18° 12′ 14" S x 22° 13′ 25" E
5.	Linyanti River, Shibumu Pool of Sishika Channel in Mamili National Park; 18° 23′ 17" S x 23° 36′ 15" E
6.	Linyanti River, Sishika Channel crossing near Shibumu Pool in Mamili National Park; 18° 23′ 07" S x 23° 36′ 44" E
7.	Linyanti River, Chorombe Channel in Mamili National Park; 18° 20′ 52" S x 23° 37′ 08" E
8.	Linyanti River, Sishika Channel in Mamili National Park; 18° 23′ 58" S x 23° 37′ 15" E
9.	Unnamed channel of the Linyanti River system, adjacent to the Mamili National Park; 18° 24′ 00" S x 23° 37′ 16" E
10.	Linyanti River, Lina La Mukawa Channel in Mamili National Park; 18° 25′ 14" S x 23° 37′ 40" E
11.	Unnamed channel of the Linyanti River system, at ford just south of Sangwali mission; 18° 17′ 05" S x 23° 38′ 17" E
12.	Unnamed channel of the Linyanti River system, northeast of Mamili National Park; 18° 21′ 59" S x 23° 39′ 15" E
13.	Linyanti River, lagoon at Mparamure camp in Mamili National Park; 18° 23′ 44" S x 23° 45′ 32" E
14.	Zambezi River rapids, at Katima; 17° 28′ 31" S x 24° 14′ 53" E
15.	Zambezi River, at Katima; 17° 29′ 44" S x 24° 19′ 30" E
16.	Zambezi River, at Katima;17° 28′ 53" S x 24° 21′ 59" E

Table 22. Numbers of specimens of each species collected by station from the Eastern Caprivi Province, 1992.

SPECIES	Station Number									
	1	2	3	4	5	6	7	8	9	10
Hippopotomyrus ansorgii										
Marcusenius macrolepidotus									1	
Petrocephalus catostoma								1		1
Pollimyrus castelnaui						74	1	13	2	66
Brycinus lateralis		19		1						3
Hydrocynus vittatus		2								
Micralestes acutidens	1									
Rhabdalestes maunensis				65				16		
Hepsetus odoe	1						1			
Hemigrammocharax machadoi	1			3		2				
Hemigrammocharax multifasciatus						6		12		2
Barbus afrovernayi	2			5				1		
Barbus annectens	3		27	6		2	0	8		
Barbus barnardi	7			270			2			
Barbus bifrenatus	9	6		6			3			
Barbus codringtonii										
Barbus eutaenia										
Barbus fasciolatus	4					6		6		10
Barbus haasianus				35		2	24			
Barbus marequensis										
Barbus multilineatus	1			4		53	3		3	6
Barbus paludinosus				41			320			
Barbus poechii	2	3					1			
Barbus radiatus	5								1	1
Barbus thamalakanensis	23							1		
Barbus unitaeniatus		1								
Coptostomabarbus wittei							69			
Labeo cylindricus										
Opsaridium zambezense										
Amphilius uranoscopus										
Leptoglanis dorae								2		
Parauchenoglanis ngamensis								1		
Clariallabes platyprosopos										
Clarias gariepinus										
Clarias ngamensis	2	1								
Clarias theodorae	1									7
Chiloglanis fasciatus										
Synodontis sp.								1		
Schilbe intermedius						1				1
Aplocheilichthys butereaui	2		1	23	3	7	41	1	9	2
Aplocheilichthys johnstoni	11		16	135	1	19	42	23	27	11
Aplocheilichthys katangae	1				1	35		11	9	22
Hemichromis elongatus	1									
Oreochromis andersonii							8		4	
Oreochromis macrochir										
Pharyngochromis acuticeps	24	46	10	38		2			8	
Pseudocrenilabrus philander	37	3	40	44	8	43	27	31	5	50
Serranochromis angusticeps	1			2						1
Serranochromis carlottae										
Serranochromis codringtonii	2			2						
Serranochromis macrocephalus	3			1				4	1	2
Serranochromis robustus jallae	1			1				1	11	
Tilapia rendalli		1	1	2					4	
Tilapia ruweti			1	1			1			
Tilapia sparrmanii	8	4	2	27	2	11	11	5	9	10
Ctenopoma ctenotis	1		1			7				9
Ctenopoma multispinis							4			
Aethiomastacembelus frenatus						1				1
Aethiomastacembelus vanderwaali										
Number of Species	26	10	9	21	5	16	17	18	14	18
Number of Specimens	154	86	99	712	15	271	566	138	94	205

Table 22. (cont.)

SPECIES	11	12	13	14	15	16
Hippopotomyrus ansorgii				6		
Marcusenius macrolepidotus						
Petrocephalus catostoma				6		14
Pollimyrus castelnaui					4	33
Brycinus lateralis						
Hydrocynus vittatus						
Micralestes acutidens				56		
Rhabdalestes maunensis						
Hepsetus odoe						
Hemigrammocharax machadoi						
Hemigrammocharax multifasciatus					2	23
Barbus afrovernayi						
Barbus annectens		1				
Barbus barnardi						
Barbus bifrenatus						
Barbus codringtonii				3		
Barbus eutaenia						16
Barbus fasciolatus						15
Barbus haasianus						
Barbus marequensis				3		
Barbus multilineatus		1				
Barbus paludinosus		3				
Barbus poechii		2				47
Barbus radiatus						
Barbus thamalakanensis						
Barbus unitaeniatus				3		
Coptostomabarbus wittei						
Labeo cylindricus				80		4
Opsaridium zambezense				13		2
Amphilius uranoscopus				2		
Leptoglanis dorae				1	1	
Parauchenoglanis ngamensis				10		
Clariallabes platyprosopos				11		
Clarias gariepinus		7				
Clarias ngamensis		9	1			
Clarias theodorae					1	
Chiloglanis fasciatus				12		
Synodontis sp.				75	5	55
Schilbe intermedius						72
Aplocheilichthys hutereaui	7					
Aplocheilichthys johnstoni	16	1				3
Aplocheilichthys katangae	4					
Hemichromis elongatus				1	16	4
Oreochromis andersonii	2	13				
Oreochromis macrochir					4	
Pharyngochromis acuticeps				167	5	8
Pseudocrenilabrus philander	3	5		2	31	27
Serranochromis angusticeps					5	1
Serranochromis carlottae						1
Serranochromis codringtonii					10	
Serranochromis macrocephalus						19
Serranochromis robustus jallae				1		
Tilapia rendalli	1	5		13	6	
Tilapia ruweti	2					
Tilapia sparrmanii		12		47	10	4
Ctenopoma ctenotis			5			
Ctenopoma multispinis		6				
Aethiomastacembelus frenatus						
Aethiomastacembelus vanderwaali				88		
Number of Species	7	12	2	21	13	18
Number of Specimens	35	65	6	600	100	348

Table 23. List of species reported from the Zambezi River by van der Waal & Skelton (1984), but not from the Kwando/Linyanti River.

SPECIES
Hippopotamyrus ansorgii
H. discorhynchus
Nannocharax macropterus
Barbus codringtonii
B. eutaenia
B. puellus
B. tangandensis
Labeo cylindricus
Leptoglanis rotundiceps
Clariallabes platyprosopos
Amphilius uranoscopus
Nothobranchius sp.
Aethiomastacembelus vanderwaali

Table 24. Copy of van Zyl's (1992) questionnaire for the Kavango Province concerning fish utilization and desire for fish farming.

	YES N	YES %	NO N	NO %
1. DO YOU EAT FISH	3208	99,20	26	0,80
2. DO YOU BUY FISH	3005	92,92	229	7,08

	N	%
3. WHERE DO YOU BUY FISH		
CAFE	858	26,45
SHOP	898	27,70
FISHERMEN	2907	89,60
4. WHAT FORM		
TINNED	927	28,65
FRESH	2933	90,74
FROZEN	717	22.16
DRIED	580	17,94
COOKED	931	28,80
5. HOW OFTEN DO YOU BUY FISH		
SELDOM	342	10,59
REGULARLY	251	7,75
OFTEN	2641	81,66
6. HOW MUCH MONEY DO YOU SPEND BUYING FISH		(RAND/MONTH)
0 - 50	1275	39,42
50 - 100	1245	38,49
100 - 150	453	14,01
150 - 200	86	2,67
200 - 250	114	3,54
250 - 300	60	1,86

	YES N	YES %	NO N	NO %
7. ARE THERE ENOUGH FISH IN THE RIVER TO EAT -	3073	95,02	161	4,98
8. ARE THERE ENOUGH FISH AVAILABLE TO BUY	1166	36,05	2068	63,95
9. IF FISH IS AVAILABLE WOULD YOU BUY SOME	3234	100,00	0	0,0

10. WHAT KIND OF FISH WOULD YOU PREFER TO BUY	N	%
Tilapia sp.	1163	35,96
ANY KIND	864	26,72
H. vittatus	722	22,32
P. catostoma	303	9,36
Clarias sp.	66	2,04
P. castelnaui	36	1,10
H. odoë	28	0,86
Barbus sp.	22	0,68
MARINE FISH	18	0,56
S. intermedius	12	0,38

	YES N	YES %	NO N	NO %
11. ARE YOU FAMILIAR - FISH FARMING	120	3,70	3114	96,30
12. ARE YOU INTERESTED- FISHFARMING	3189	98,61	44	1,37

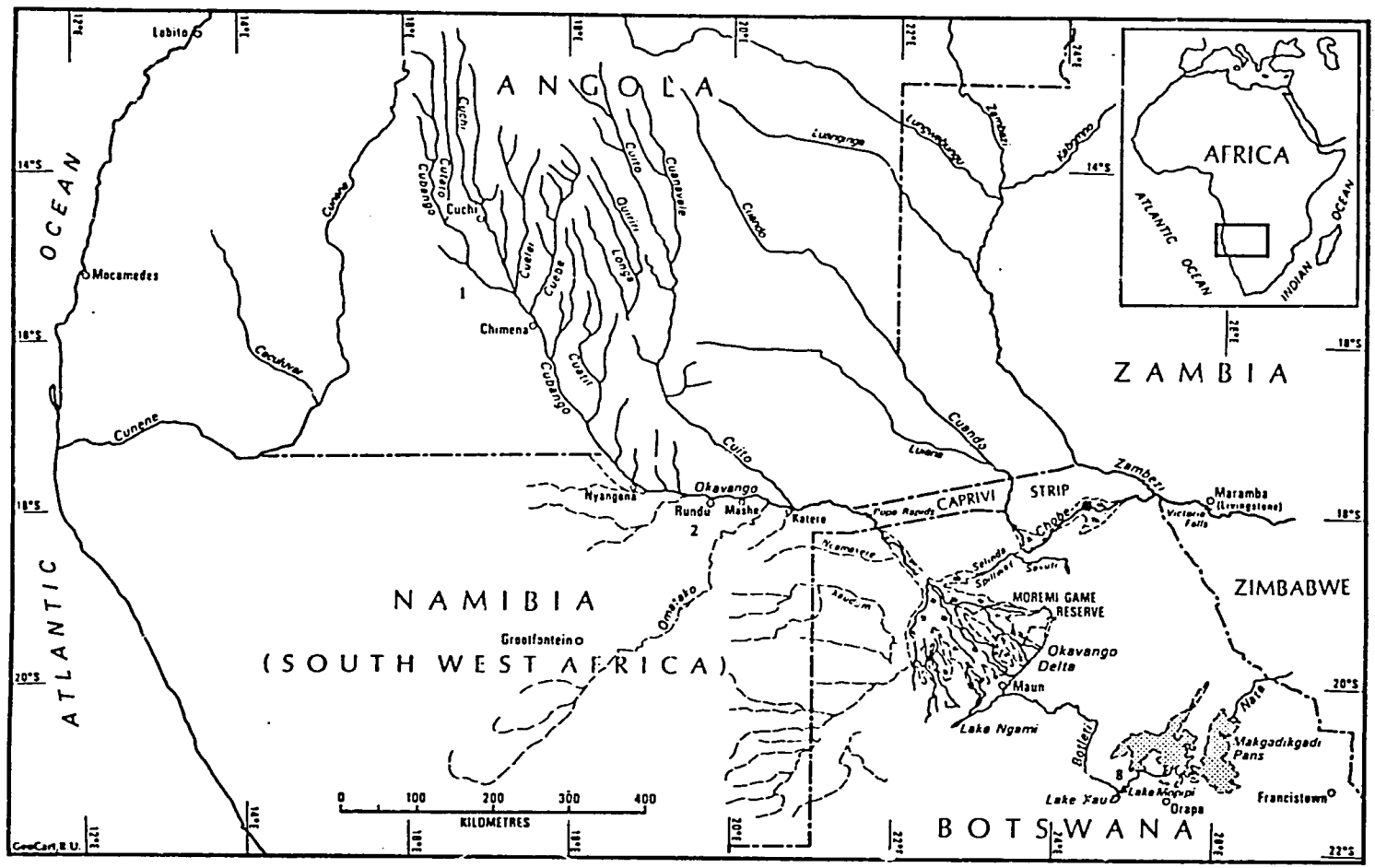

Figure 1. Drainage map of the Kavango River basin (from Skelton et al. 1985).

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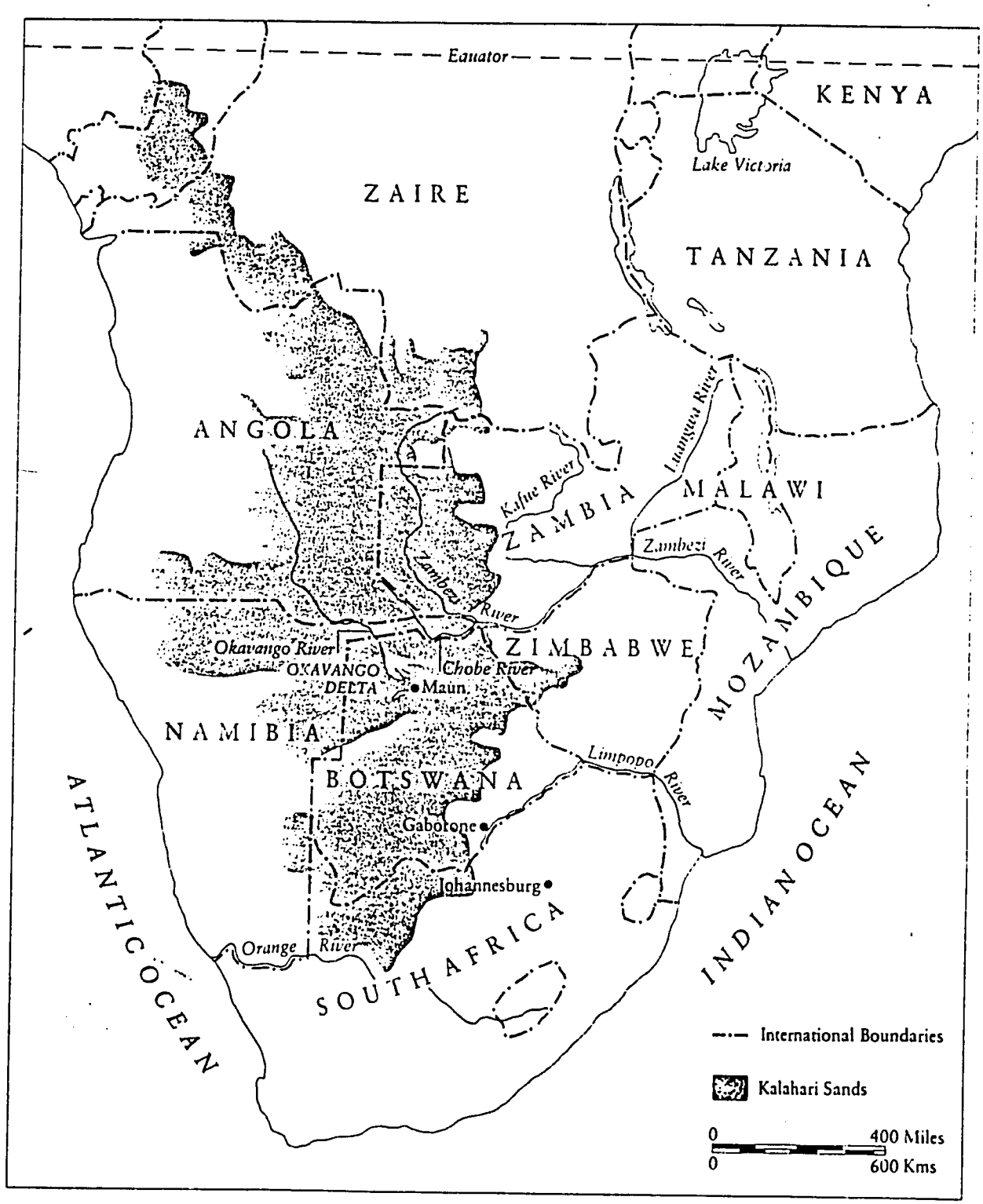

Figure 2. The Kalahari Desert biome in southern Africa (from Ross 1987).

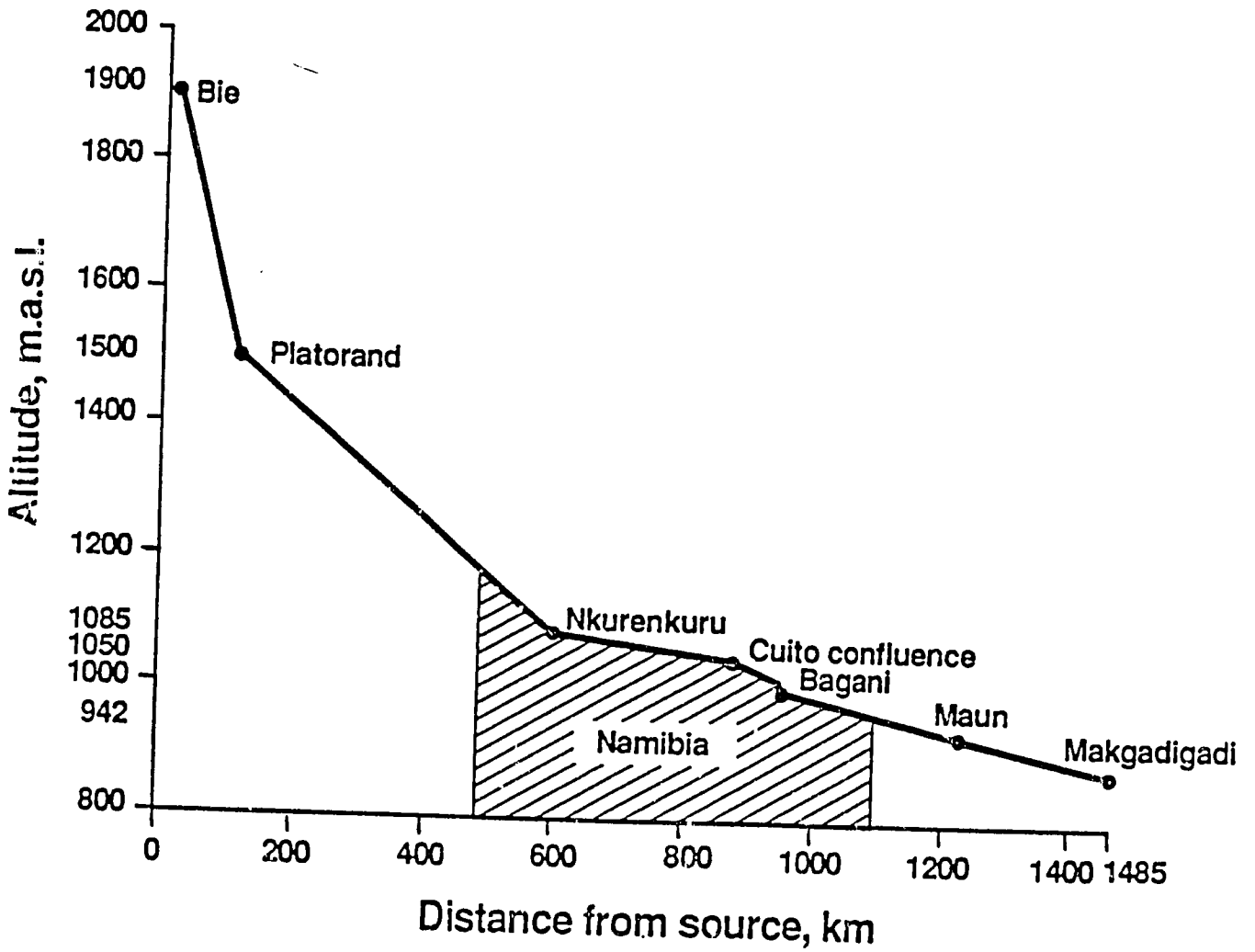

Figure 3. Longitudinal gradient profile of the Kavango River basin (from Sandlund & Tvedten 1992).

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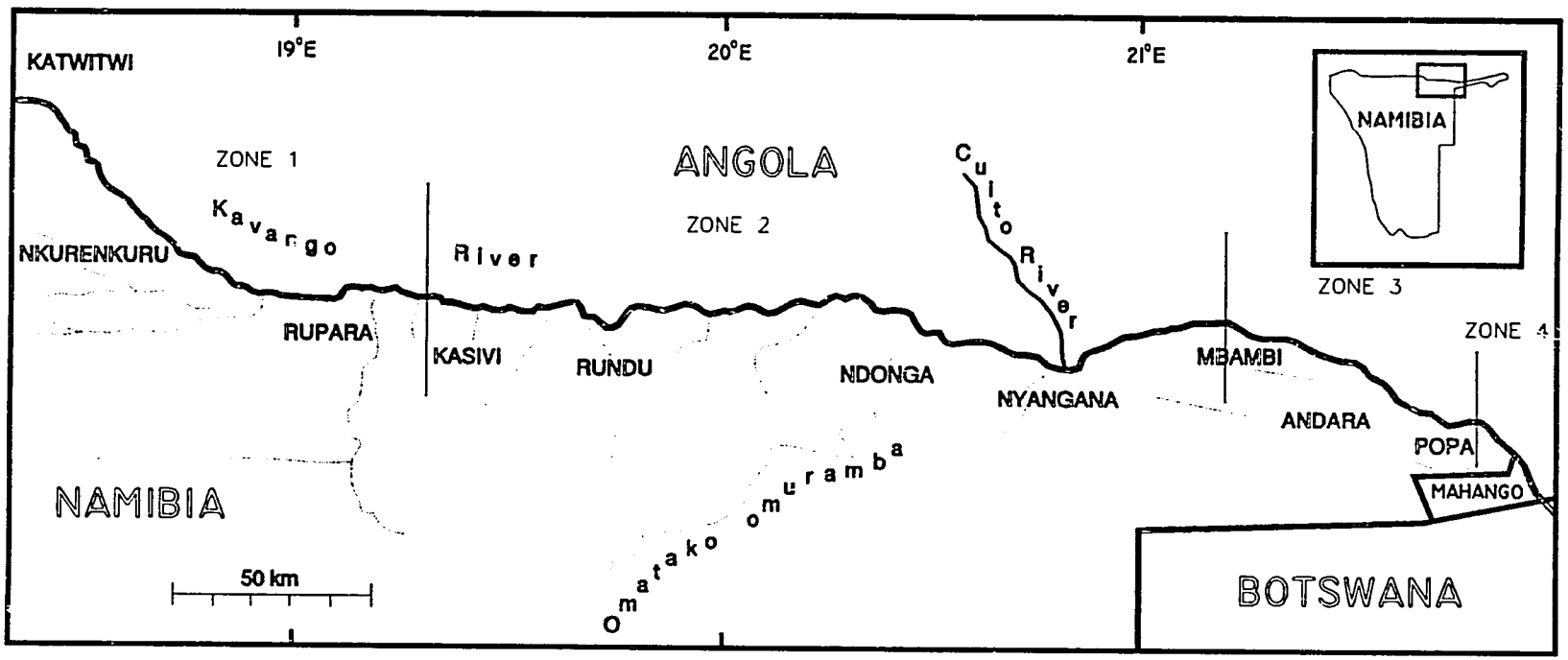


Figure 4. The Kavango River area of study, with zonal divisions.

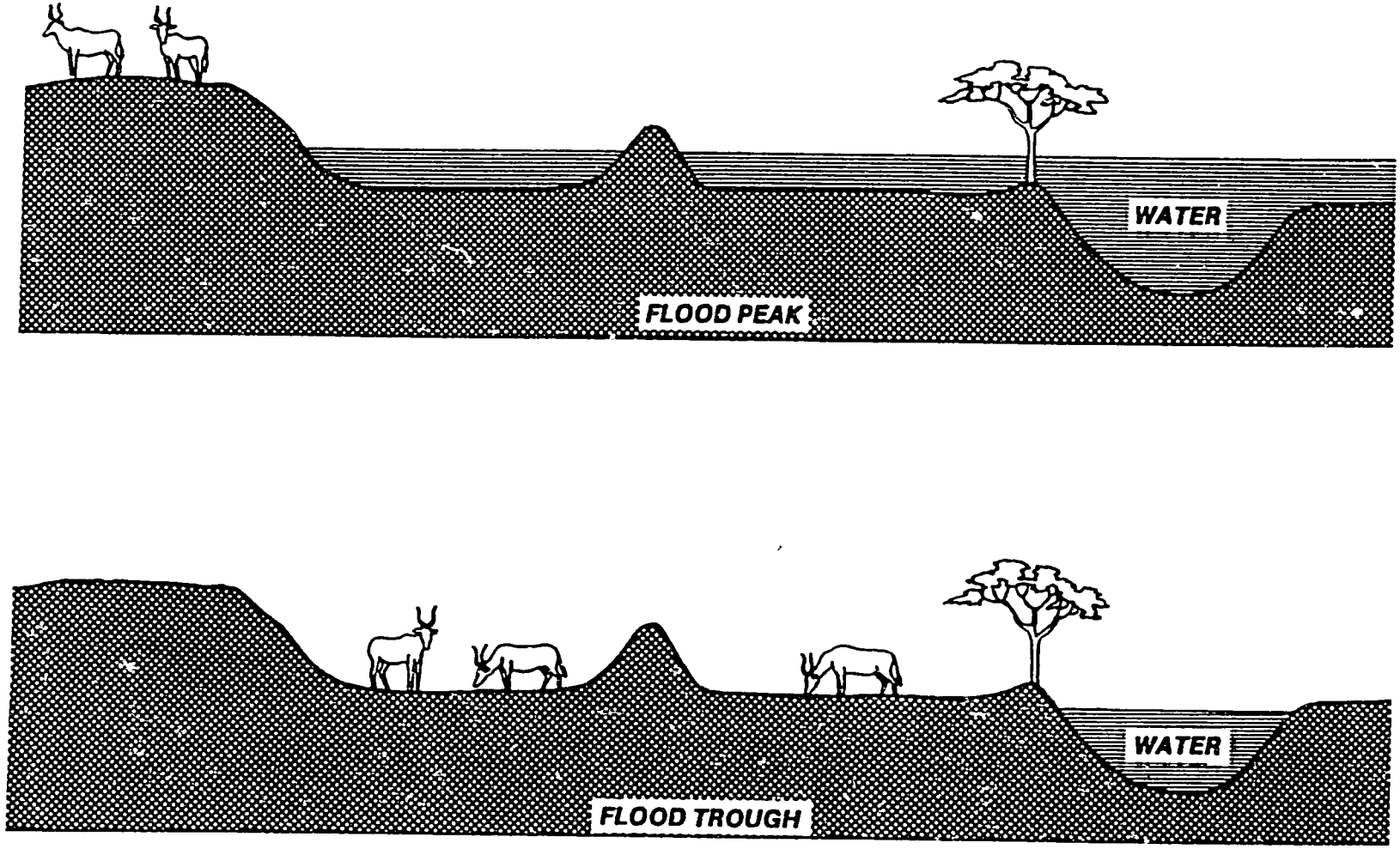


Figure 5. Schematic diagram of floodplain river (from Forrester et al. 1988).

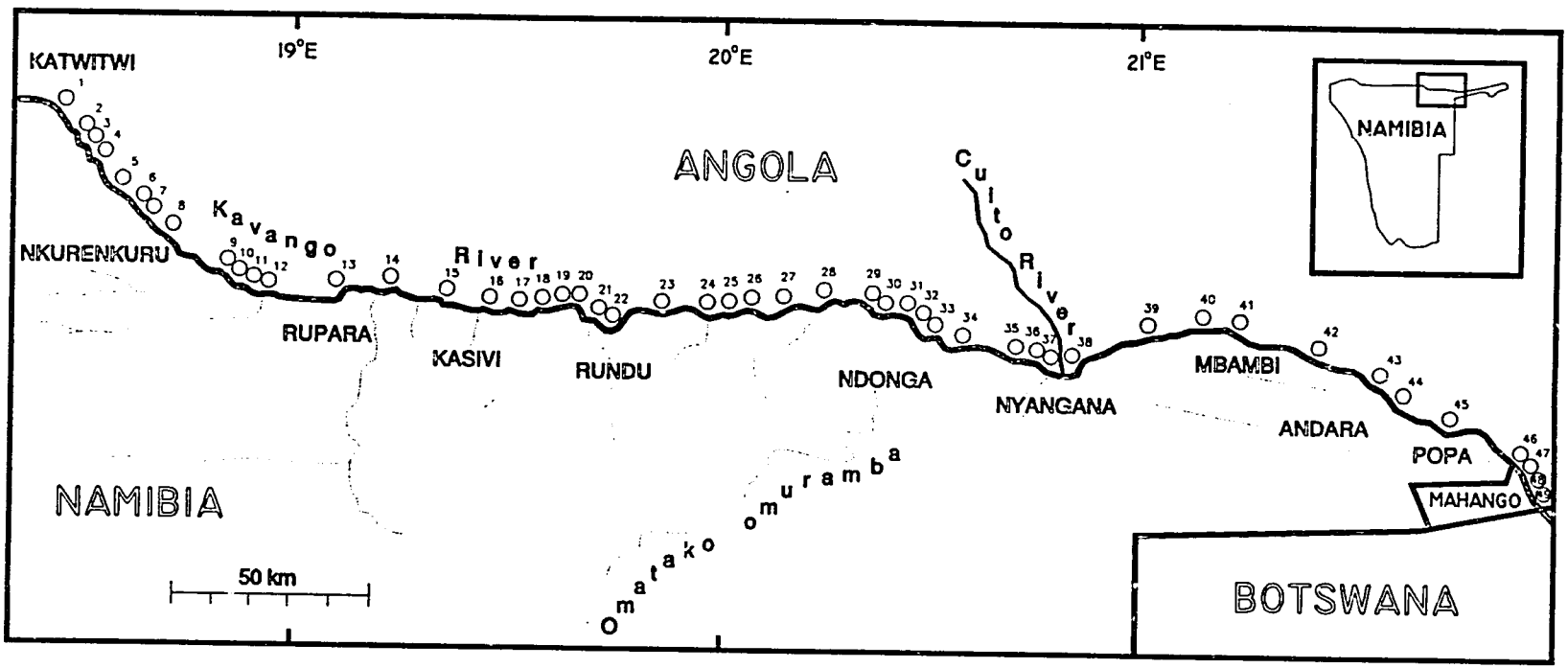


Figure 6. Map depicting distribution of sampling locations in the Kavango River, 1992.

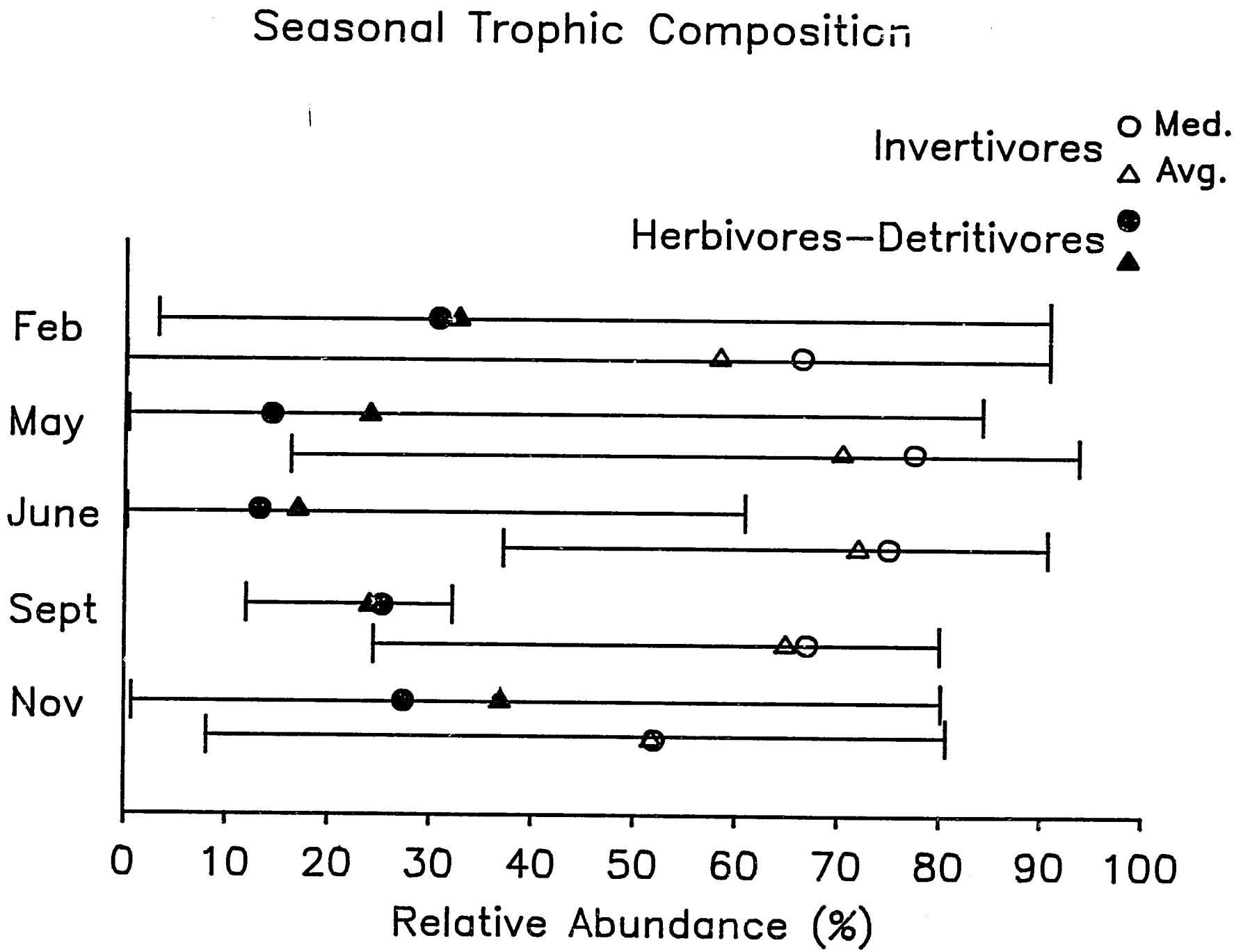


Figure 7. Seasonal trophic composition in relative abundance for principal invertivore and herbivore-detritivore feeding groups.

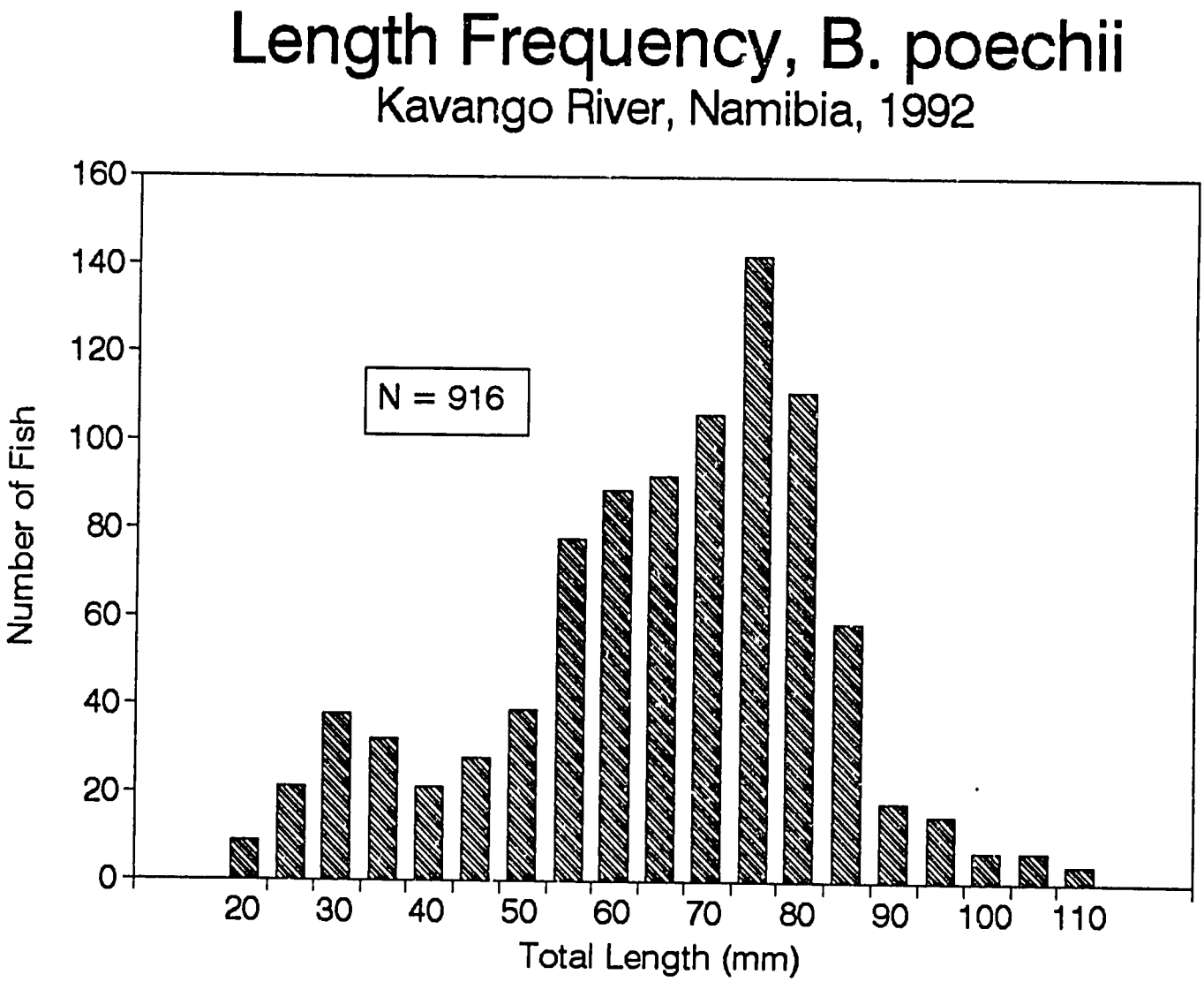


Figure 8. Length frequency plot for Barbus poechii.

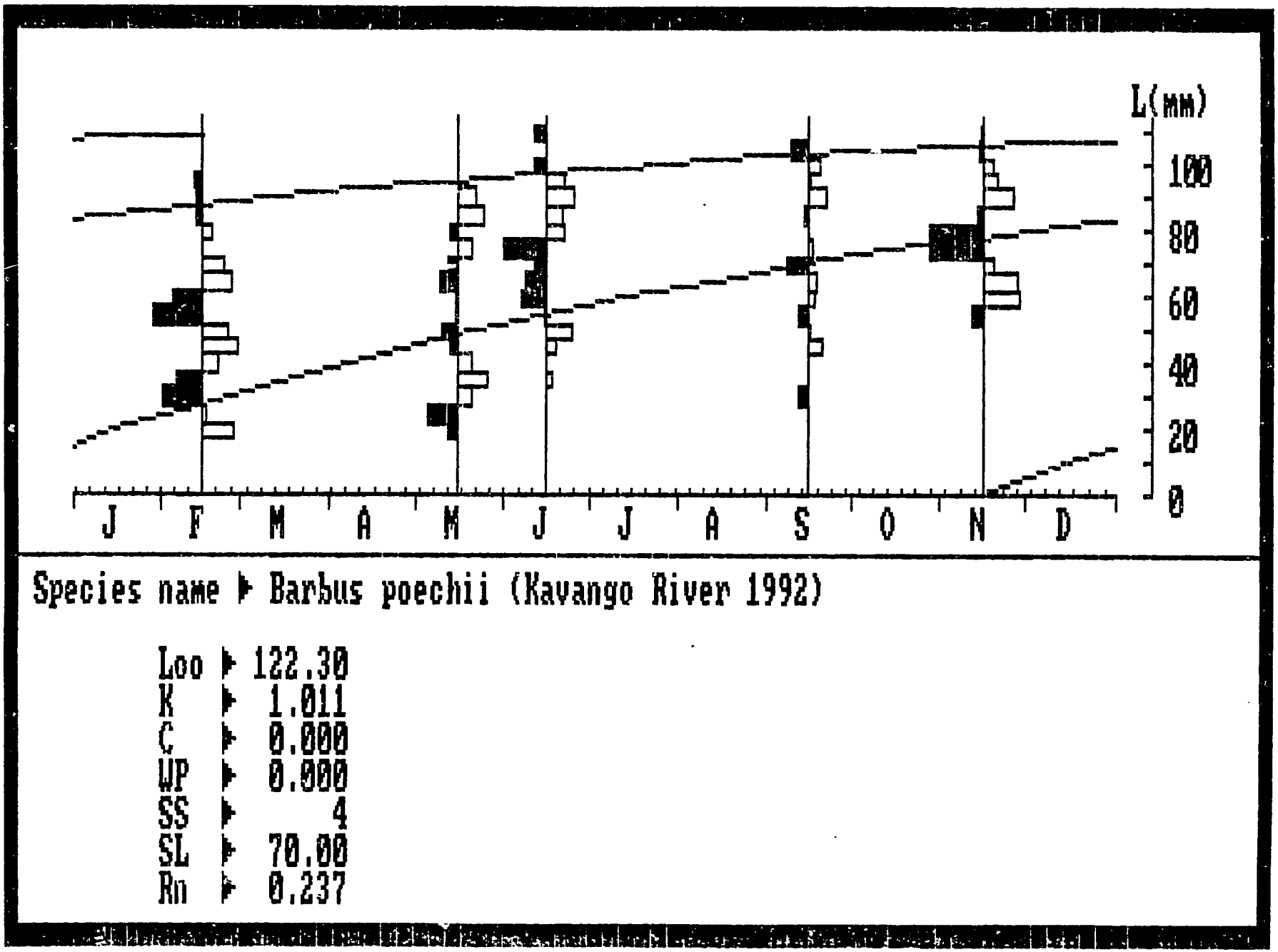


Figure 9. Re-structured length distribution for Barbus poechii.

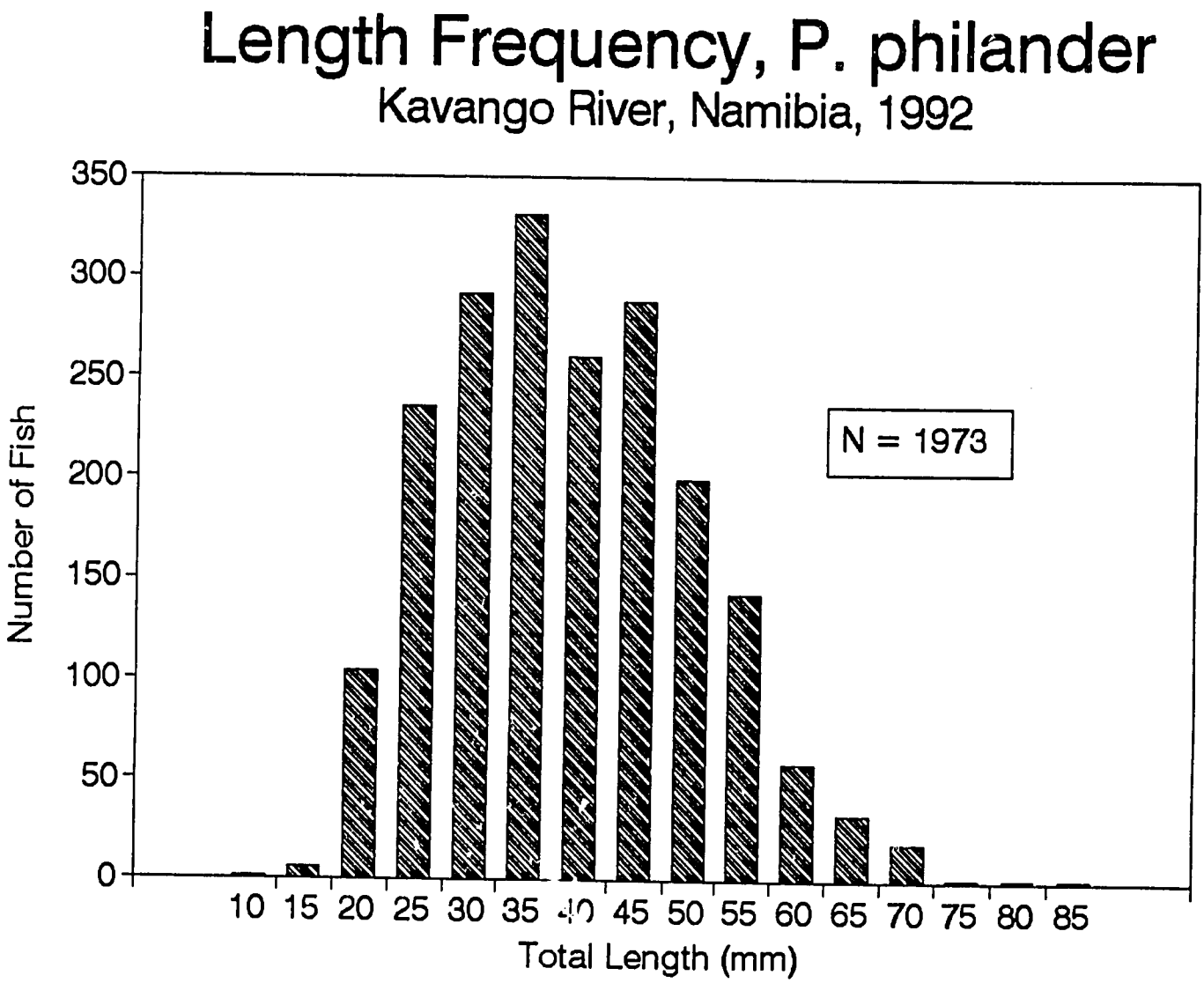
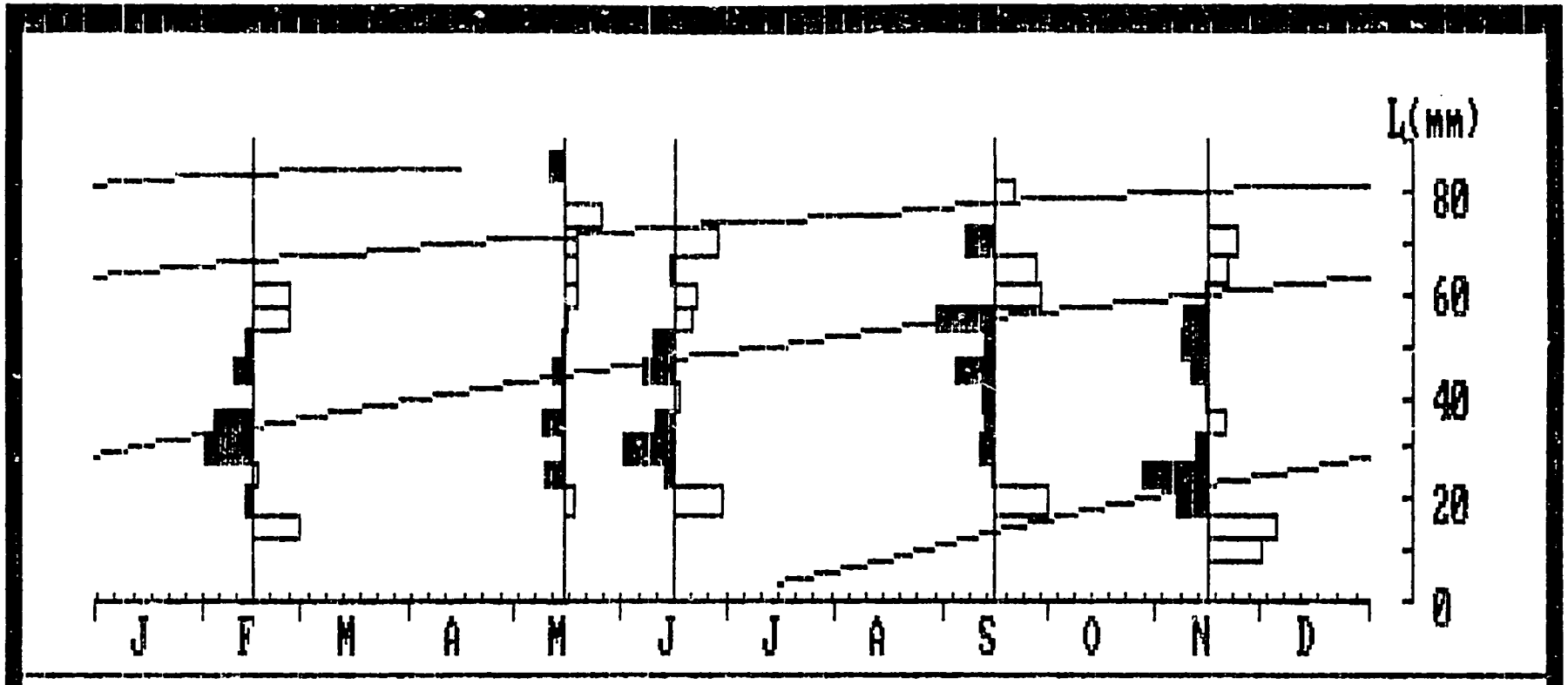


Figure 10. Length frequency plot for Pseudocrenilabrus philander.



Species name ▶ Pseudocrenilabrus philander (Kavango River, 1992)

Loo ▶	101.80
K ▶	0.640
C ▶	0.000
WP ▶	0.000
SS ▶	5
SL ▶	22.50
Rn ▶	0.351

Figure 11. Re-structured length distribution for Pseudocrenilabrus philander.

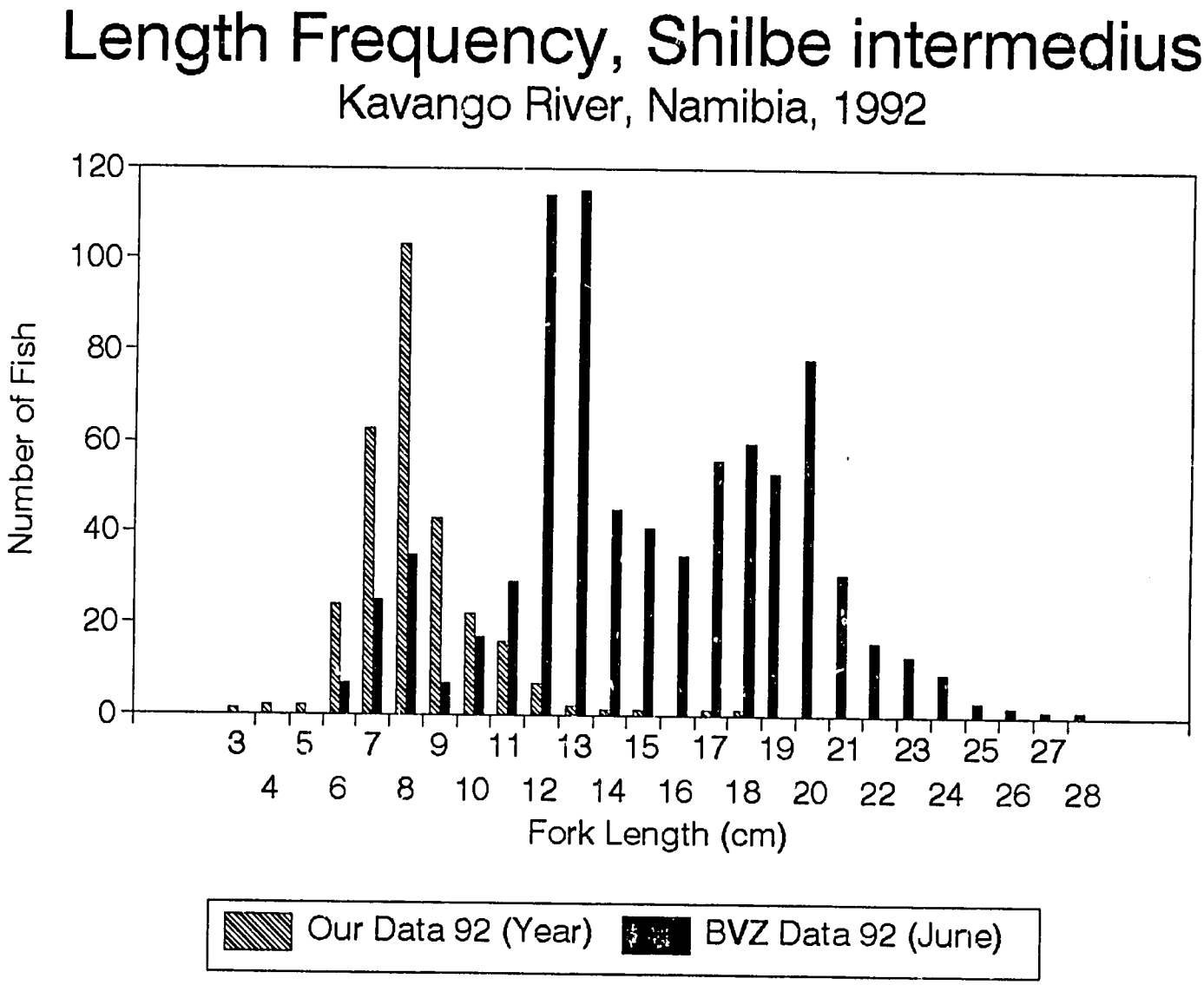


Figure 12. Length frequency plot for Schilbe intermedius.

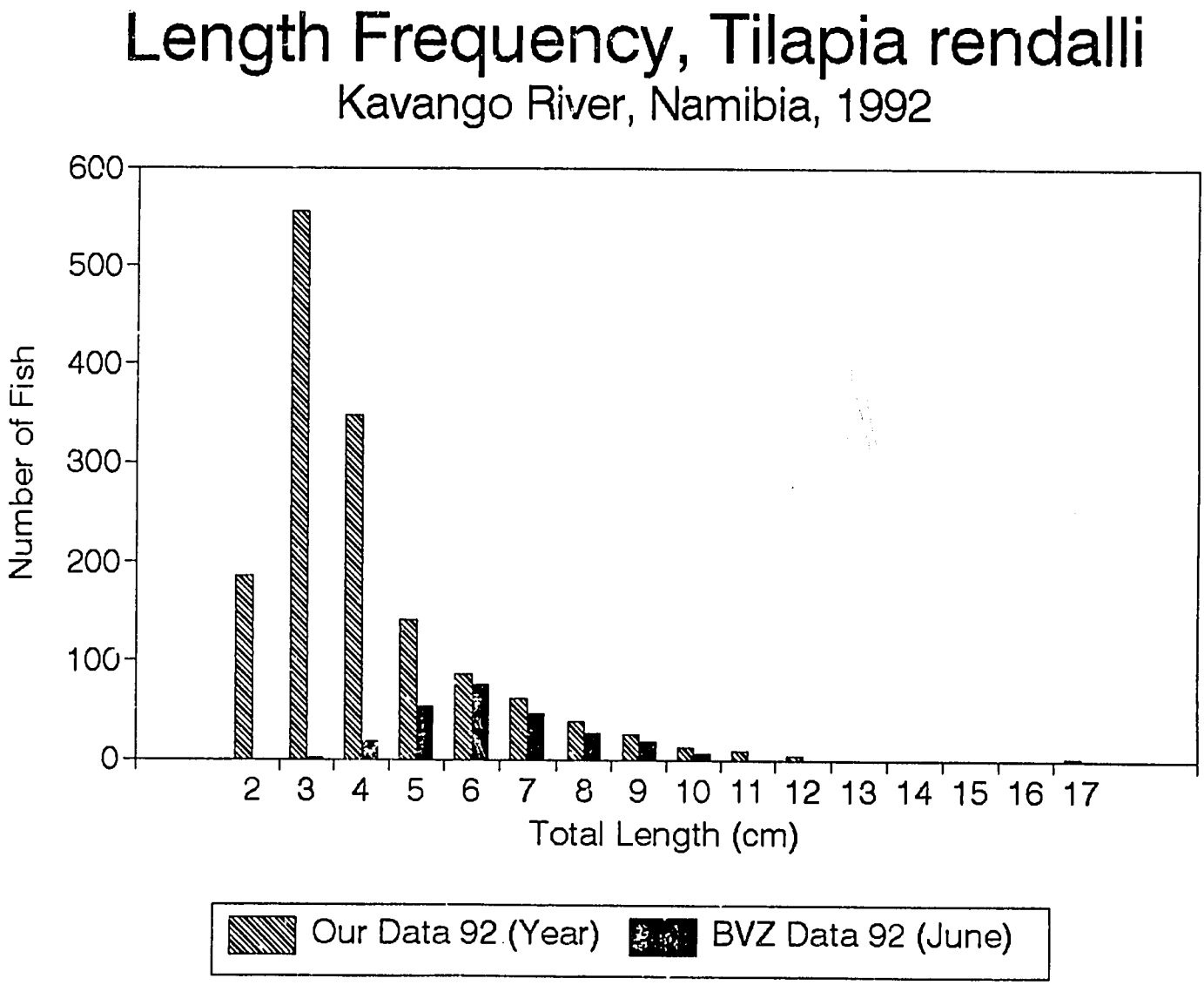


Figure 13. Length frequency plot for Tilapia rendalli.

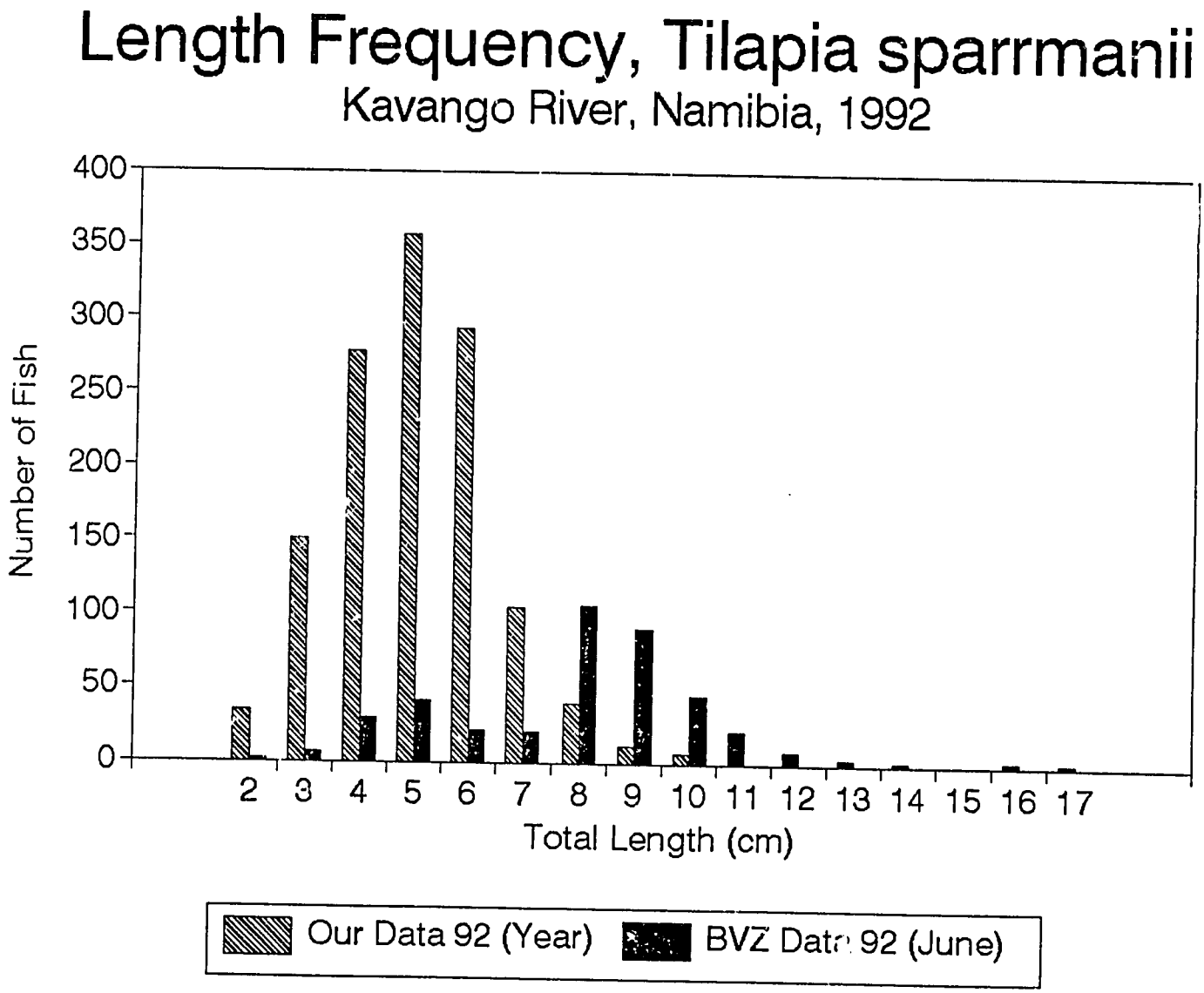


Figure 14. Length frequency plot for Tilapia sparrmanii.

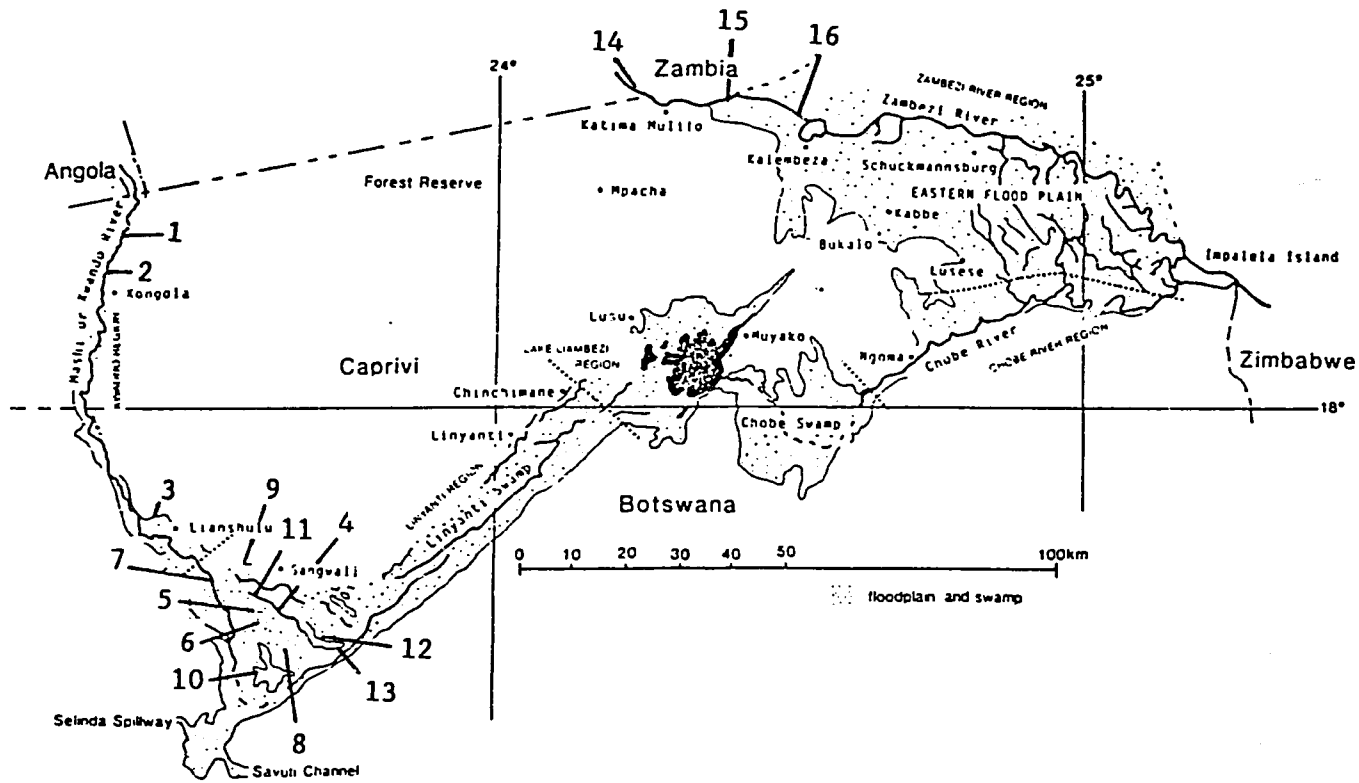


Figure 15. Map of Eastern Caprivi Province depicting approximate sampling localities (from van der Waal 1989).

Appendix A. List of scientific and common names of the fishes of the Kavango and Caprivi Provinces (synthesized from a number of references),

FAMILY	GENUS	SPECIES	COMMON NAME
Mormyridae			
	Hippopotamyrus	ansorgii	slender stonebasher
	H.	discorhynchus	Zambezi parrotfish
	Marcusenius	macrolepidotus	bulldog
	Mormyrus	lacerda	western bottlenose
	Petrocephalus	catostoma	churchill
	Pollimyrus	castelnaui	dwarf stonebasher
Characidae			
	Brycinus	lateralis	striped robber
	Hydrocynus	vittatus	tigerfish
	Micralestes	acutidens	silver robber
	Rhabdalestes	maunensis	Okavango robber
Hepsetidae			
	Hepsetus	odoe	Kafue pike
Distichodontidae			
	Hemigrammocharax	machadoi	dwarf citharine
	H.	multifasciatus	multibar citharine
	Nannocharax	macropterus	broadbarred citharine
Cyprinidae			
	Barbus	afrovernayi	spottail barb
	B.	annectens	broadstripe barb
	B.	barnardi	blackback barb
	B.	barotseensis	Barotse barb
	B.	bifrenatus	hyphen barb
	B.	codringtonii	Upper Zambezi yellowfish
	B.	eutaenia	orangefin barb
	B.	fasciolatus	red barb
	B.	haasianus	sicklefin barb
	B.	lineomaculatus	linespotted barb
	B.	marequensis	largescale yellowfish
	B.	multilineatus	copperstripe barb
	B.	paludinosus	straightfin barb
	B.	poechii	dashtail barb
	B.	radiatus	Beira barb
	B.	tangandensis	redspot barb
	B.	thamalakanensis	Thamalakane barb
	B.	unitaeniatus	longbeard barb
	Coptostomabarbus	wittei	upjaw barb
	Labeo	cylindricus	redeye labeo
	L.	lunatus	Upper Zambezi labeo
	Mesobola	brevianalis	river sardine
	Opsaridium	zambezense	barred minnow

Appendix A. (cont.)

Amphiliidae		
Amphilius	uranoscopus	stargazer mountain catfish
Bagridae		
Auchenoglanis	ngamensis	Zambezi grunter
Leptoglanis	rotundiceps	spotted sand catlet
L.	dorae	Chobe sand catlet
Clariidae		
Clarias	dumerilii	Okavango catfish
C.	gariepinus	sharptooth catfish
C.	ngamensis	blunttooth catfish
C.	stappersii	blotched catfish
C.	theodorae	snake catfish
Clariallabes	platyprosopos	broadhead catfish
Mochokidae		
Chiloglanis	fasciatus	rock catlet
Synodontis	leopardinus	leopard squeaker
S.	macrostigma	largespot squeaker
S.	macrostoma	
S.	nigromaculatus	spotted squeaker
S.	thamalakanensis	
S.	vanderwaali	
S.	woosnami	Upper Zambezi squeaker
Schilbeidae		
Schilbe	intermedius	silver catfish
Cyprinidontidae		
Aplocheilichthys	hutereaui	meshscaled topminnow
A.	johnstonii	Johnston's topminnow
A.	katangae	striped topminnow
Cichlidae		
Hemichromis	elongatus	barred jewelfish
Oreochromis	andersonii	three spot tilapia
O.	macrochir	greenhead tilapia
Pharyngochromis	darlingi	Zambezi happy
Pseudocrenilabrus	philander	southern mouthbrooder
Serranochromis		
Sargochromis	carlottae	rainbow happy
S.	codringtonii	green happy
S.	giardi	pink happy
S.	greenwoodi	Greenwood's happy
Serranochromis		
Serranochromis	altus	
S.	angusticeps	thinface largemouth
S.	macrocephalus	purpleface largemouth
S.	robustus jallae	nembwe
S.	thumbergi	brownspot largemouth

Appendix A. (cont.)

Tilapia	*rendalli*	northern redbreast tilapia
T.	*ruweti*	Okavango tilapia
T.	*sparrmanii*	banded tilapia
Anabantidae		
Ctenopoma	*intermedium*	blackspot climbing perch
C.	*multispinis*	manyspined climbing perch
Mastacembelidae		
Aethiomastacembelus	*frenatus*	shorttail spiny eel
A.	*vanderwaali*	ocellated spiny eel

Appendix B. List of gear used and numbers of fishes collected per site in the Kavango River, 1992.

SPECIES	1	2	3	4	5	6	7	8	9	10
Hippopotomyrus ansorgii	2		4			4				
Hippopotomyrus discorhynchus		2					1			
Marcusenius macrolepidotus	1						1		1	
Mormyrus lacerda				2						
Petrocephalus catostoma		2	3	2		1	3			
Pollimyrus castelnaui	10		1		1	1	15		1	
Bryconaos lateralis	2	1					6	5	1	1
Hydrocynus vittatus					(A)1	1		(O)4		
Micralestes acutidens	26	122	15	5	1	1	8	26	2	
Rhabdalestes maunensis							1			
Hepsetus odoe								(O)3		
Hemigrammocharax machadoi										
Hemigrammocharax multifasciatus					1					
Nannocharax macropterus										
Barbus afrovernayi							3			
Barbus annectens										
Barbus barnardi		1								1
Barbus barotseensis										
Barbus bifrenatus				1	11	9			106	11
Barbus eutaenia	2	6	1	5			2			
Barbus fasciolatus		2								
Barbus haasianus										
Barbus lineomaculatus	1									
Barbus multilineatus										
Barbus paludinosus										
Barbus poechii	2	1		10	5		11		8	
Barbus radiatus		1					5			
Barbus thamalakanensis		2			7				6	
Barbus unitaeniatus										
Coptostomabarbus wittei										
Labeo cylindricus	4		12	13		11	4			
Labeo lunatus						2		(O)1		
Opsaridium zambezense		37			7	3	3	42		2
Amphilius uranoscopus			1							
Leptoglanis dorae										2
Leptoglanis rotundiceps										
Paranchenoglanis zygameiensis										
Clarias gariepinus									1	
Clarias ngamensis	1						1			
Clarias theodorae										1
Chiloglanis fasciatus	2		5			1	8			3
Synodontis sp.	3	8	8	1		9	3	1		
Schilbe intermedius	2			4	2	1	10		5	
Aplocheilichthys huterensis										
Aplocheilichthys johnstoni	32	6	20	16	2	19	14	10	74	9
Aplocheilichthys katangae										
Hemichromis elongatus								1		
Oreochromis andersonii		2			2	37	1	8		3
Oreochromis macrochir	1						1			
Pharyngochromis acuticeps	5	39	4	5	19	32	10	49	6	8
Pseudocrenilabrus philander	5	13		9	9	3	14	2	61	5
Serranochromis Sargo. cariottae										
Serranochromis codringtonii				1		3				
Serranochromis gardi										
Serranochromis Serrano. angusticeps						1	2			
Serranochromis macrocephalus			1	1	2	2	2		3	1
Serranochromis robustus jallae	4	4		1	1	2		2	4	
Tilapia rendalli	7	4			72	18	21	26	42	14
Tilapia rueppelli										1
Tilapia sparrmanii	2	4	1	8	1	3	1	3	4	4
Clarias gariepinus multipunctatus										
Aethiomastacembelus frenatus	2						1			
Aethiomastacembelus vanderwaali			8	2						
Number of Species	21	19	14	17	17	22	27	15	16	15
Number of Specimens	116	257	84	46	143	164	152	175	325	66
Collecting gear used	E*	S	E	R	S	E, S	E, S	S, T	R, S, T	S

Appendix B. (cont.)

SPECIES	11	12	13	14	15	16	17	18	19	20
Hippopotamyrus ansorgi										
Hippopotamyrus discorhynchus		1						2		
Marcusenius macrolepidotus		9					7	3		
Mormyrus lacerda	5									
Petrocephalus catostoma	5	14					5			
Pollimyrus castelnaui	4	12					1	11		
Brycinus lateralis		53			3					
Hydrocynus vittatus										
Micralestes acutidens	2		4		17	1		29	12	4
Rhabdalestes maunensis										
Hepsetus odoe										
Hemigrammocharax machadoi										
Hemigrammocharax multifasciatus	2	23	2				1	4	2	
Nannocharax macropterus										
Barbus afrovernayi		5								
Barbus annectens										
Barbus barnardi	3	109			2					
Barbus barotseensis										
Barbus bifrenatus	44	24			6					
Barbus eutaenia			1							
Barbus fasciolatus	3	7								
Barbus haasianus							1			
Barbus lineomaculatus		2								
Barbus multilineatus										
Barbus paludinosus	1			2	6		8			
Barbus poechii	1			11		36				
Barbus radiatus		10								
Barbus thamalakanensis	2	1					3		4	
Barbus unitaeniatus										
Coptostomabarbus wittei										
Labeo cylindricus		1			3	1				
Labeo lunatus										
Opsaridium zambezense			24		2				2	1
Amphilius uranoscopus		11								
Leptoglanis dorae	1									
Leptoglanis rotundiceps										
Parauchenoglanis ngamensis	7	1							5	
Clarias gariepinus	1		2	1		3				
Clarias ngamensis	1			4		2	4		5	
Clarias theodorae	1					3				
Chiloglanis fasciatus		5								
Synodontis sp.	13	1		2		3	1		118	
Schilbe intermedius	2	14		4				1		
Aplocheilichthys katangae										
Aplocheilichthys johnstoni	34	4	2	4	8		2	1 22	2 35	2
Aplocheilichthys katangae										
Hemichromis elongatus		2		2						
Oreochromis andersonii		1	2		1	1			23	
Oreochromis macrochir										
Pharyngochromis acuticeps	12	6	5	4	88	16	2		16	9
Pseudocrenilabrus philander	74	41	34	27	16	48	40	14	7	11
Serranochromis Serranochromis carlottae							1			
Serranochromis codringtoni							1		3	
Serranochromis giardi							1			
Serranochromis Serranochromis angusticeps		10	1							
Serranochromis macrocephalus	1	1	2		4		1		2	
Serranochromis robustus robustus	2	3		2			1		4	
Tilapia rendalli	15	31	1	67	27	19	5		31	14
Tilapia rheneri										1
Tilapia sparrmanii	23	2	18	35	7	12	112	4	28	5
Ctenopoma multispinis										
Aethomastacembelus frenatus										
Aethomastacembelus vanderwaali	1	1			1					
Number of Species	26	30	13	13	15	12	19	10	17	8
Number of Specimens	260	405	118	165	191	145	197	91	299	47
Collecting gear used	R, S	E, S	R, S	R	E, S	R, S	E	R, S	S, T	R, S

Appendix B. (cont.)

SPECIES	21	22	23	24	25	26	27	28	29	30
Hippopotomyrus nasergis										
Hippopotomyrus discorhynchus										
Marcusenius macrolepidotus							3			
Mormyrus lacerda										
Petrocephalus catostoma	10									19
Pollimyrus castelnaui	7	9					1			6
Brycinus lateralis	2		4	2						4
Hydrocynus vittatus							1			
Micralestes acutidens	4		386	6					7	
Rhabdalestes maunensis										
Hepsetus odoe										
Hemigrammocharax machadoi										4
Hemigrammocharax multifasciatus	6	1	1				2			25
Nannocharax macropterus										
Barbus afrovernayi		8	8	2						8
Barbus annectens										2
Barbus bernardi	1	2		1						8
Barbus barotseensis										10
Barbus bifrenatus			2	1						30
Barbus eutaenia						6				
Barbus fasciolatus	3									5
Barbus hasemani										
Barbus kerremansiatus										
Barbus multilineatus										
Barbus paludinosus	6	2		19					14	31
Barbus poechii	75					21	10	2		98
Barbus radiatus	2		7							241
Barbus thamalakanensis	2		51		1	1	6			15
Barbus unitaeniatus										1
Coptostomabarbus wittei										
Labeo cylindricus										
Labeo lunatus										
Opsaridium zambezense				1						
Amphilius uranoscopus										
Leptoglanis dorae										
Leptoglanis rotundiceps										
Parauchenoglanis ngamensis										
Clarias gariepinus					2	1				
Clarias ngamensis				1	1					1
Clarias theodorae										
Chiloglanis fasciatus										
Synodontis sp.	2		1				2			2
Schilbe intermedius	9	1	12							20
Aplocheilichthys katangae	2	1		6	2	3	2		33	10
Aplocheilichthys johnstoni	17	20	1	10	9	31	2	2	35	33
Aplocheilichthys katangae										
Hemichromis elongatus										
Oreochromis andersonii				77	1					
Oreochromis macrochir										
Pharyngochromis acutidens			8	1	4	2		2		1
Pseudocrenilabrus philander	24	54	61	78	11	17	9		30	31
Serranochromis Sargo. carlottae										
Serranochromis codringtoni										1
Serranochromis giardi										2
Serranochromis Serrano. angusticeps	1									5
Serranochromis macrocephalus	2		1	3			2			17
Serranochromis robustus jallae	1			1	4	3	2	2		10
Tilapia rendalli	1		12	18	54	16	2	2	24	35
Tilapia rueppelli					16					
Tilapia sparrmanii	4	45		17	5	3	9		3	93
Ctenopoma multispinis					1					
Aethiomastacembelus frenatus		1								
Aethiomastacembelus vanderwaali										
Number of Species	21	11	14	17	13	11	14	5	7	30
Number of Specimens	181	144	555	244	111	104	53	10	146	769
Collecting gear used	D, R	R	R, S	S	R, S	R	R, S	S	S	R, S

Appendix B. (cont.)

SPECIES	31	32	33	34	35	36	37	38	39	40
Hippopotamyrus ansorgi										
Hippopotamyrus discorhynchus										
Marcusenius macrolepidotus				6	1	36			1	
Mormyrus kannume										
Petrocephalus catostoma									1	
Pollimyrus castelnaui					3	2			1	
Brycinus lateralis			70	4	26	2		1	11	
Hydrocynus vittatus			25	3						
Micralestes acutidens				5		2			7	
Rhabdalestes maunensis										
Hepsetus odoe										
Hemigrammocharax machadoi					1	1			1	
Hemigrammocharax multifasciatus						3		1	69	
Nannocharax macropterus									1	
Barbus afrovernayi				1					7	
Barbus annectens										
Barbus barnardi					3					
Barbus barotseensis										2
Barbus bifurcatus					3				2	20
Barbus eutaenia						1				
Barbus fasciolatus					1				69	
Barbus hassianus										
Barbus holomelanus					25				9	
Barbus multilineatus										
Barbus pelindensis			6	3	1	6			7	14
Barbus poechii		27	106	11	5	1		4	7	18
Barbus radiatus			3						23	3
Barbus thamalakanensis	1				22				47	12
Barbus unitaeniatus		9							52	
Coptostomabarbus wittei										
Labeo cylindricus										
Labeo losetus										
Opsaridium zambezense										
Amphilius uranoscopus										
Leptoglanis dorae										
Leptoglanis rotundiceps										
Parauchenoglanis ngamensis										
Clarias gariepinus				2		1				
Clarias ngamensis			1			2				
Clarias theodorae				3		1				
Chiloglanis fasciatus										
Synodontis sp.	2		1	4					2	
Schilbe intermedius			55		7	4			1	
Aplocheilichthys katangae	1			2	1				1	
Aplocheilichthys johnstoni	27	3	4	5	57	24	1	1	4	8
Aplocheilichthys katangae										
Hemichromis elongatus										
Oreochromis andersonii			3	3			176	2		
Oreochromis macrochir				1						
Pharyngochromis acutidens	2		13	12	2			16		
Pseudocrenilabrus philander	23				71	36	29	4	27	109
Serranochromis Sargo. carlottae										
Serranochromis codrogenus				2		5				
Serranochromis giardi				1						
Serranochromis Serrano. angusticeps					4	1				
Serranochromis macrocephalus				20	5	4		3	1	
Serranochromis robustus jallae		1		1					3	
Tilapia rendalli	1	13		16	4			11	1	5
Tilapia rivulata	5									3
Tilapia sparrmanii	38			1	58	19	1		12	46
Ctenopoma multispinis										
Aethiomastacembelus frenatus										
Aethiomastacembelus vanderwaali										
Number of Species	9	5	11	21	20	19	4	9	26	11
Number of Specimens	100	53	287	106	301	151	207	43	367	260
Collecting gear used	R	R	B, S	B, S	S	E, R	R, S	S	R, S	R

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Appendix B. (cont.)

SPECIES	41	42	43	44	45	46	47	48	49	50
Hippopotamyrus ansorgi							1		1	
Hippopotamyrus discorhynchus									6	
Marcusenius macrolepidotus					2				1	4
Mormyrus lacerda			1					1		
Petrocephalus catostoma			6				4	1	5	
Pollimyrus castelnaui		1	13					4	1	7
Bryconus lateralis								2	2	
Hydrocynus vittatus		2	6							
Micralestes scudderi	1							16		
Rhabdalestes maunensis										
Hepsetus odoe										
Hemigrammocharax machadoi			8		2					
Hemigrammocharax multifasciatus			1	2				1	1	1
Nannocharax macropterus										
Barbus afrovernayi			13	2						
Barbus annectens										
Barbus barnardi										
Barbus barotseensis				3	4					1
Barbus bifrenatus			22	2	4					
Barbus eutaenia	1							2		
Barbus fasciolatus			6							
Barbus hassianus			5							
Barbus lineomaculatus										
Barbus multilineatus										
Barbus paludosus				345	4					
Barbus poechii	10	3	1	88	6	36	12	1	12	2
Barbus radiatus			2		5				1	4
Barbus thamalakanensis			1	17	9					30
Barbus unitaeniatus										
Coptostomabarbus wittei										
Labeo cylindricus							15	2	12	
Labeo losatus										
Opsaridium zambezense			1				2			
Amphilius uranoscopus										
Leptoglanis dorae									1	
Leptoglanis rotundiceps										1
Parauchenoglanis ngamensis										2
Clarias gariepinus		1								
Clarias ngamensis		1	1			1				
Clarias theodorae										5
Chiloglanis fasciatus									3	
Synodontis sp.							9	1	18	4
Schilbe intermedius			1							4
Aplocheilichthys heterevai										
Aplocheilichthys johnstoni	1	1	18		12	1		2	8	4
Aplocheilichthys katangae		1								
Hemichromis elongatus										
Oreochromis andersonii		5			1		1			
Oreochromis macrochir										
Pharyngochromis acutidens	6	8	5	47		10	4	1	1	2
Pseudocrenilabrus philander	5	2	82	89	63	14	8	14	3	63
Serranochromis Sargo. carlottae										
Serranochromis codrogiosus		2							2	
Serranochromis giardi										
Serranochromis Serrano. angusticeps									1	1
Serranochromis macrocephalus	1	12	3	2	1	2	128	1	2	1
Serranochromis robustus jallae			1	2		6	2		1	3
Tilapia rendalli	3	11	10	36	4	77	5			5
Tilapia rueppelli				9						
Tilapia sparrmanii	9	5	76	124	6	5	3			18
Oreochromis mortimeri										
Aethiomastacembelus frenatus										
Aethiomastacembelus vanderwaali			2						1	
Number of Species	9	14	24	14	14	9	13	14	21	20
Number of Specimens	37	55	285	768	123	152	194	49	83	162
Collecting gear used	R	R,S	R	R	R,S	R	E	R,S	E,S	R,T

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Appendix B. (cont.)

SPECIES	51	52	53	54	55	56	57	58	59	60
Hippopotamyrus ansorgi										
Hippopotamyrus discorhynchus										
Marcusenius macrolepidotus		1		1						
Mormyrus lacerda					4					
Petrocephalus catostoma										
Pollimyrus castelnaui										
Brycinus lateralis				2						
Hydrocynus vittatus						1				
Micralestes acutidens		1								
Rhabdalestes maunensis										
Hepsetus odoe								1		
Hemigrammocharax machadoi										
Hemigrammocharax multifasciatus					3		2			
Nannocharax macropterus										
Barbus afrovernayi					1					
Barbus annectens								1		
Barbus barnardi				2	1					
Barbus barotseensis					2			15		
Barbus bifrenatus					2			7		
Barbus eutaenia			1	2	6			8		
Barbus fasciolatus										
Barbus kerstenii										
Barbus lineomaculatus										
Barbus multilineatus										
Barbus paludosus	79				1					
Barbus poechii		7		22	17		2	8		
Barbus radiatus				9	42		4			
Barbus thamalakanensis			1		67		1	13		
Barbus unitaeniatus							1	3		
Coptostomabarbus wittei										
Labeo cylindricus					18			3		
Labeo lunatus										
Opsaridium zambezense										
Amphilius uranoscopus										
Leptoglanis dorae										
Leptoglanis rotundiceps										
Paranchenoglanis zgambensis										
Clarias gariepinus	6	1						3		
Clarias ngamensis			2		4		2	1		
Clarias theodorae										
Chiloglanis fasciatus										
Synodontis sp.				1	3		5		4	2
Schilbe intermedius				3	8					
Aplocheilichthys katangae										
Aplocheilichthys johnstoni		1			4			22		
Aplocheilichthys katangae							1	1		
Hemichromis elongatus										
Oreochromis andersonii		2		2		9	1	5		16
Oreochromis macrochir										
Pharyngochromis acutidens		58		3	39		27	31		7
Pseudocrenilabrus philander		11	3	10	54		141	168		4
Serranochromis Sargo. carlottae										
Serranochromis codrongtonii				11						
Serranochromis gardi										
Serranochromis Serrano. angusticeps					2					
Serranochromis macrocephalus		1		1	7		8			1
Serranochromis robustus jallae		1			24	2	9	6		1
Tilapia rendalli		25		7	231		15	100		42
Tilapia rweti							15	70		3
Tilapia sparrmanii		2		16	21		92	44		3
Ctenopoma multispinis			1					1		
Aethiomastacembelus frenatus										
Aethiomastacembelus vanderwaali										
Number of Species	2	12	5	15	23	3	16	21	1	9
Number of Specimens	85	111	8	92	561	12	346	511	4	79
Collecting gear used	R	S	E	S	R	S	R.S	R	O	S

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Appendix B. (cont.)

SPECIES	61	62	63	64	65	66	67	68	69	70
Hippopotamyrus ansorgi										
Hippopotamyrus discorhynchus		4	1		8					
Marcusenius macrolepidotus		1			2				2	
Mormyrus longa			1			1		1		
Petrocephalus catostoma			1		1	2		30	12	
Pollimyrus castelnaui			1		3	1				1
Hyphanus latenis	1	1								2
Hydrocynus vittatus	(A)8	(A)23		5			4			1
Micralestes acutidens	13	118				37	2	1		39
Rhabdalestes maunensis		1								
Hepsetus odoe		1				3				
Hemigrammocharax machadoi						3				
Hemigrammocharax multifasciatus			1			32			9	
Nannocharax macropterus										
Barbus afrovernayi			3							
Barbus annectens										1
Barbus barnardi										
Barbus barotseensis										
Barbus bifrenatus			3		1			1	17	1
Barbus eutaenia	11				1	1		6		1
Barbus fasciolatus									1	
Barbus hassianus										
Barbus kneomaculatus		2				2			10	
Barbus multilineatus			1							
Barbus paludinosus			1							
Barbus poechii	1	1	1			3		26	2	5
Barbus radiatus		72	1			10		1	1	
Barbus thamalakanensis			5		4	7			53	
Barbus unitaeniatus	2	11								
Coptostomabarbus wittei										
Labeo cylindricus	3				6			51		3
Labeo lunatus								1		
Opsaridium zambezense	23						86	4	11	48
Amphilius uranoscopus										
Leptoglanis dorae										
Leptoglanis rotundiceps										
Parauchenoglanis ngamensis								1		
Clarias gariepinus		1								
Clarias ngamensis										
Clarias theodorae										
Chiloglanis fasciatus										
Synodontis sp.	1	6	2		41	8		7	1	1
Schilbe intermedius		22				34		5	8	1
Aplocheilichthys katangae	1	1	10			2				
Aplocheilichthys johnstoni	4	85	15	6	1	29	1	1	4	
Aplocheilichthys katangae		6	1							
Hemichromis elongatus							3	1		2
Oreochromis andersonii	7	8	1	2			3		1	17
Oreochromis macrochir										
Pharyngochromis acutidens	19	12		4	1	1	4	3		13
Pseudocrenilabrus philander	6	21	66	6	7	2	3	2	19	4
Serranochromis Sargo. carlottae										
Serranochromis codringtoni										
Serranochromis giardi										
Serranochromis Serrano. angusticeps										
Serranochromis macrocephalus				1	1					
Serranochromis robustus pilae	1	7	5	1	9	3	1	2	2	2
Tilapia rendalli	42	79	6	173	3	1	18	8	5	24
Tilapia rueppelli	6	215	20	2	1	3				
Tilapia sparrmanii	15	43	25	6	29	3	1	1	6	6
Ctenopoma multispinis		17					4			
Aethiomastacembelus frenatus										
Aethiomastacembelus vanderwaali										
Number of Species	18	25	22	10	17	22	12	20	18	19
Number of Specimens	156	735	171	206	119	188	130	153	164	172
Collecting gear used	T	S,T	R,S	S	E,S	R,S	S	R	R,S	S

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Appendix B. (cont.)

SPECIES	71	72	73	74	75	76	77	78	79	80
Hippopotamyrus sauvagei				2	2	3				
Hippopotamyrus discorhynchus				2						
Marcusenius macrolepidotus				3		5		2		
Mormyrus lacerda	2									
Petrocephalus catostoma	27	1	2	32	12	8		1		
Pollimyrus castelnaui			1	4	4	2		x		
Brycinus lateralis				1	1			1	4	
Hydrocynus vittatus										8
Micralestes acutidens				3	7	4				
Rhabdalestes maunensis									7	
Hepsetus odoe										
Hemigrammocharax machadoi								6		
Hemigrammocharax multifasciatus			2					5		
Nannocharax macropterus										
Barbus afrovernayi							2	14		
Barbus annectens										
Barbus barnardi									1	
Barbus barotseensis										
Barbus bifrenatus			8	8	2	2		1	2	
Barbus eutaenia		2	1	75	35	82				
Barbus fasciolatus					2			19	6	
Barbus hassianus									18	
Barbus lineomaculatus										
Barbus multilineatus							2	9		
Barbus paludinosus			1				2			
Barbus poechii			8	9	124	29		1	1	
Barbus radiatus			6					7		
Barbus thamalakanensis			9	1	1	2		8	1	
Barbus unitaeniatus										
Coptostomabarbus wittei								1		
Labeo cylindricus	15	10		23	38	46				
Labeo lunatus										
Opsaridium zambezense		22		2	3	2				
Amphilius uranoscopus				1	2	1				
Leptoglanis dorae										
Leptoglanis rotundiceps										
Parauchenoglanis ngamensis	1			2						
Clarias gariepinus				1						
Clarias ngamensis					1					
Clarias theodorae			2	1	2			1		
Chiloglanis fasciatus		1			1	1				
Synodontis sp.	2	1		2	6			3		
Schilbe intermedius	39	1		12	6	2		1		
Aplocheilichthys katangae							2	13		
Aplocheilichthys johnstoni		3	1	3	3	2		76	5	
Aplocheilichthys katangae								17		
Hemichromis elongatus	7	3	2							
Oreochromis andersonii									6	1
Oreochromis macrochir									3	
Pharyngochromis acutidens	16	3	1	6	7	11			1	
Pseudocrenilabrus philander	1	5	36	5	4	7	2	10		
Serranochromis Sargo. carlottae										
Serranochromis codrinatoni										
Serranochromis giardi										
Serranochromis Serrano. angusticeps										
Serranochromis macrocephalus	1								1	
Serranochromis robustus jallae	4				1			1	1	
Tilapia rendalli	1	7	6	1	1			(A)1	12	
Tilapia rueppelli										
Tilapia sparrmanii	1	2	1				2	8		
Oreochromis multicolor								11		
Aethomastacembelus frenatus	1									
Aethomastacembelus vanderwaalsi					1					
Number of Species	14	13	16	23	24	17	6	25	15	2
Number of Specimens	118	61	87	199	266	211	12	224	69	9
Collecting gear used	R	E, S	R, S	E*, T	E, R, T	E	D	E*, R	C	A, G

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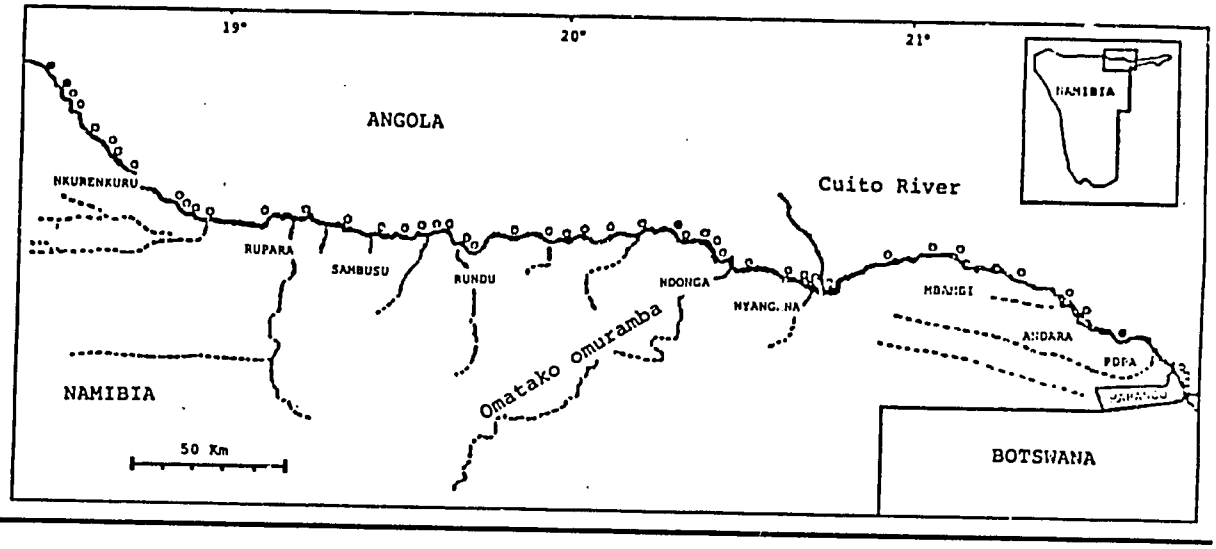
Appendix B. (cont.) Key to collecting gears used.

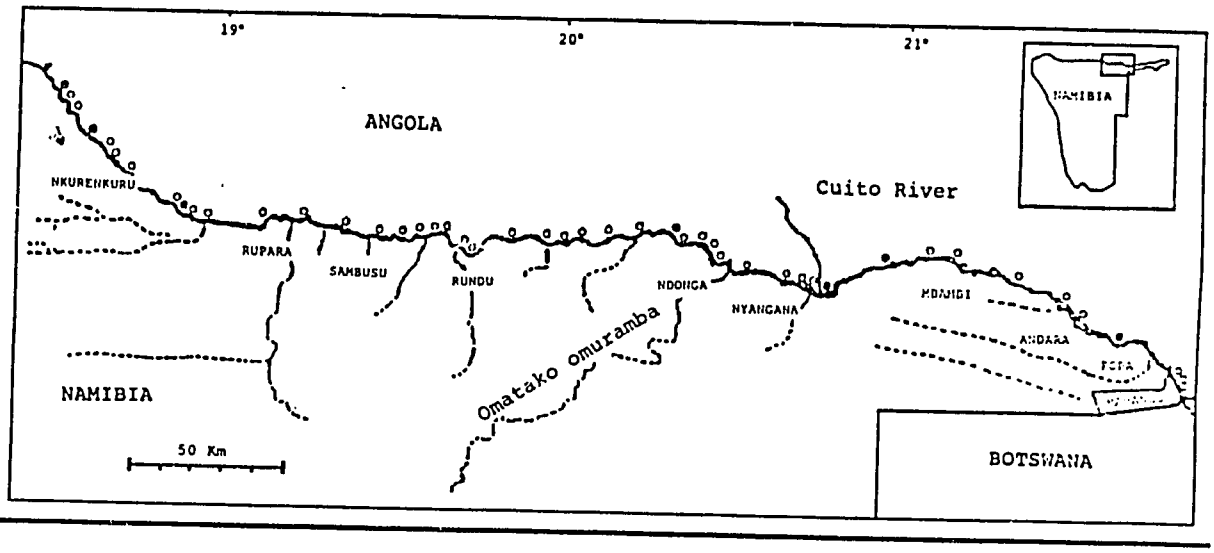
A - angling with rod and reel
B - bag seine
C - beach seine
D - dip nets
E - backpack electroshocker (Smith-Root model)
E*- backpack electroshocker (Dekka model)
G - gill nets
R - rotenone
S - 3 x 1.5 m seine
T - fish traps

Appendix C. An atlas of distributional maps for each fish species collected from the Kavango River, 1992.

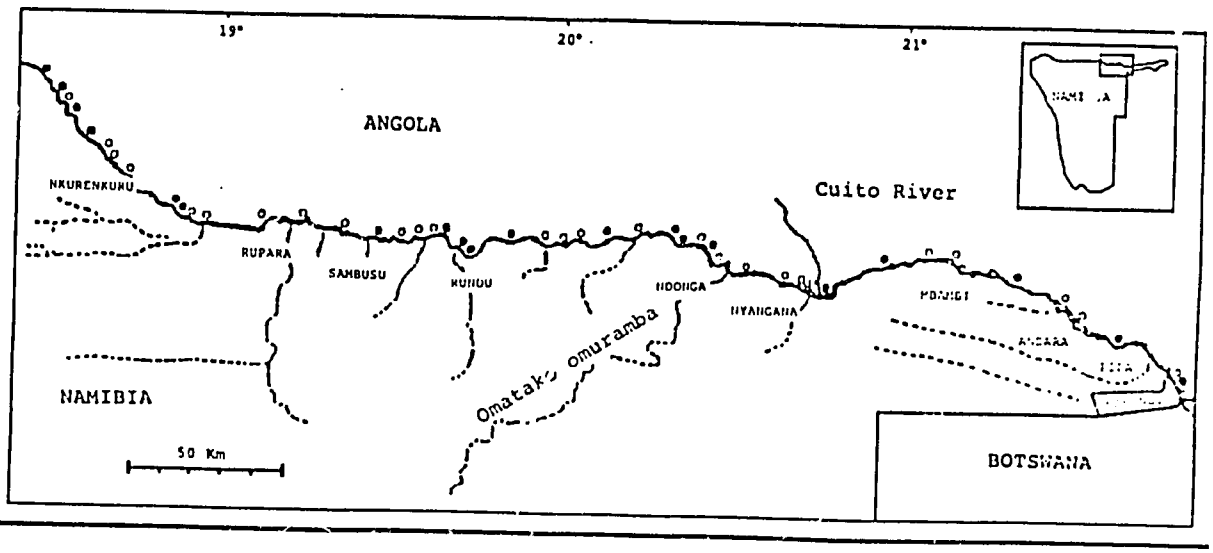
Hippopotomyrus ansorgii



Hippopotomyrus discorhynchus

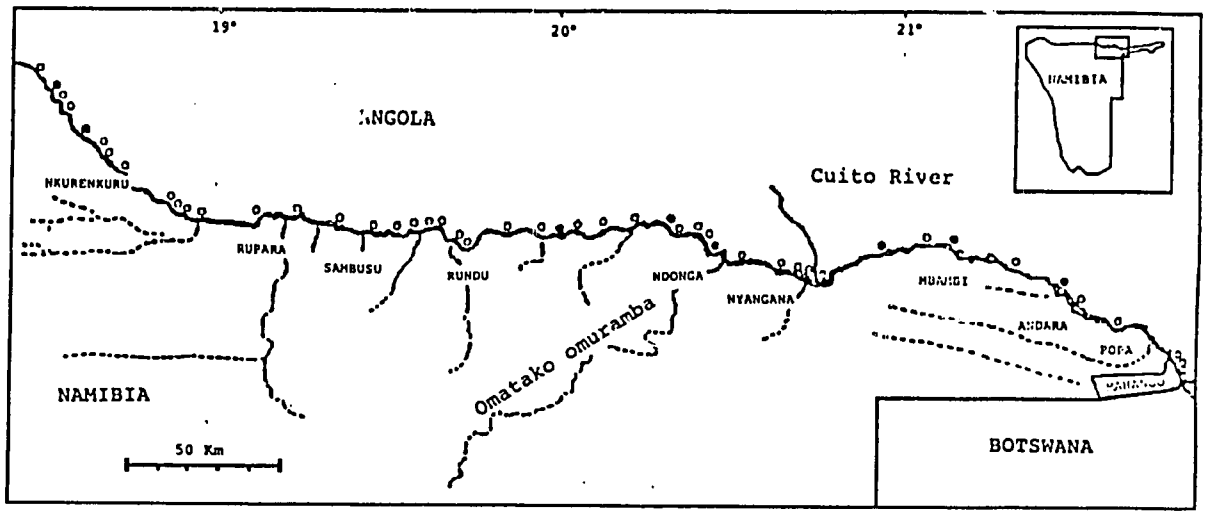


Marcusenius macrolepidotus

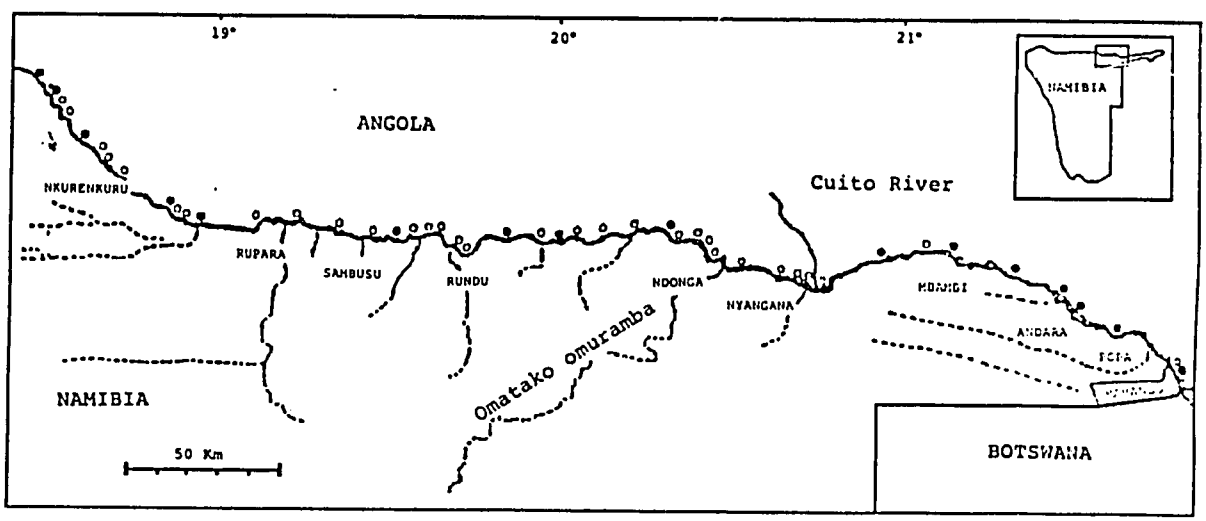


Appendix C. (cont.)

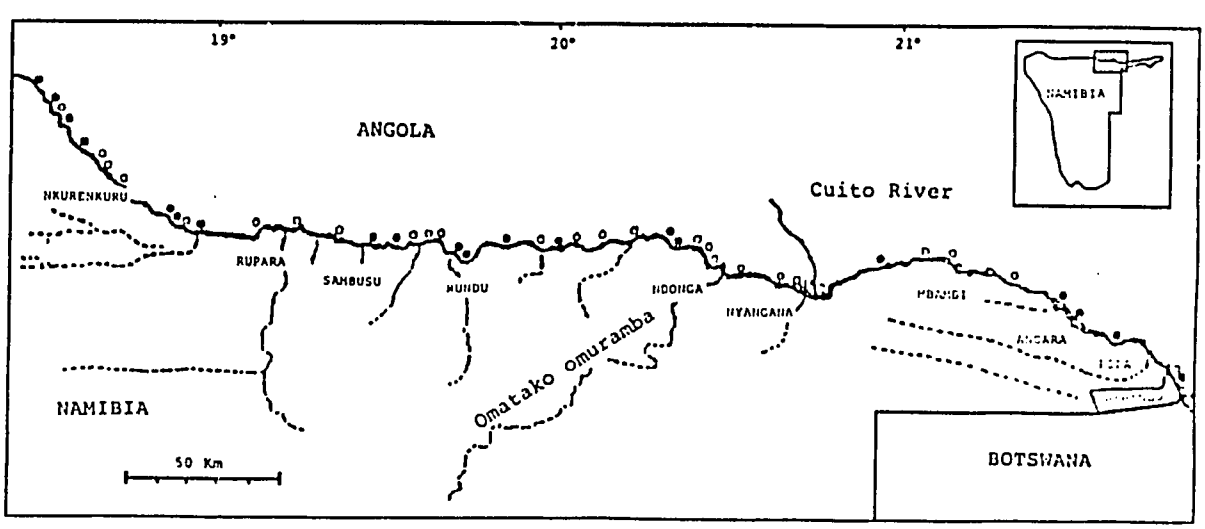
Mormyrus lacerda



Petrocephalus catostoma

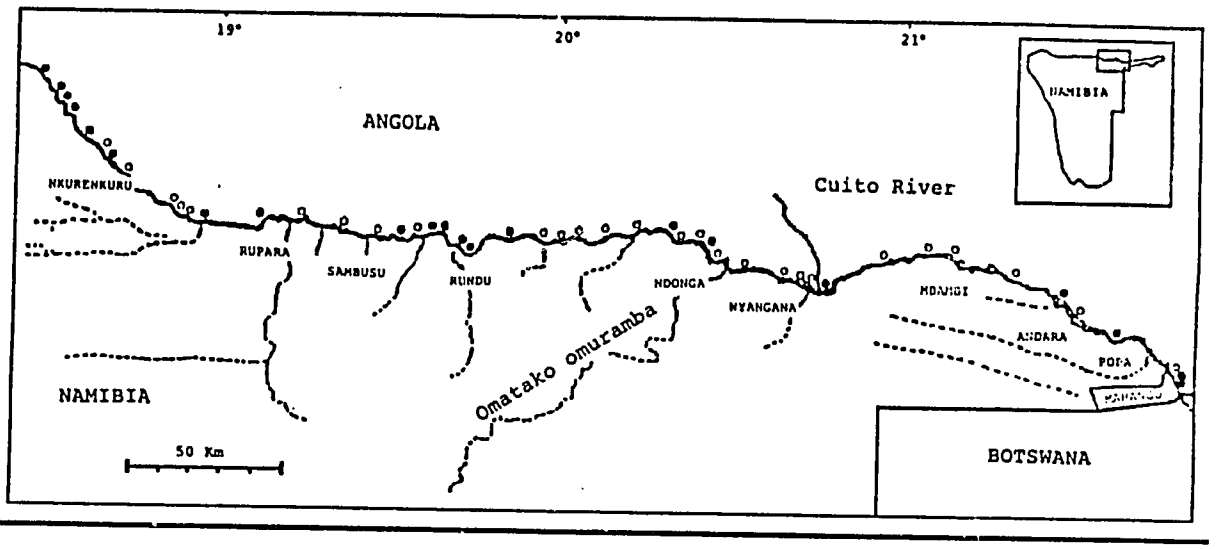


Pollimyrus castelnaui

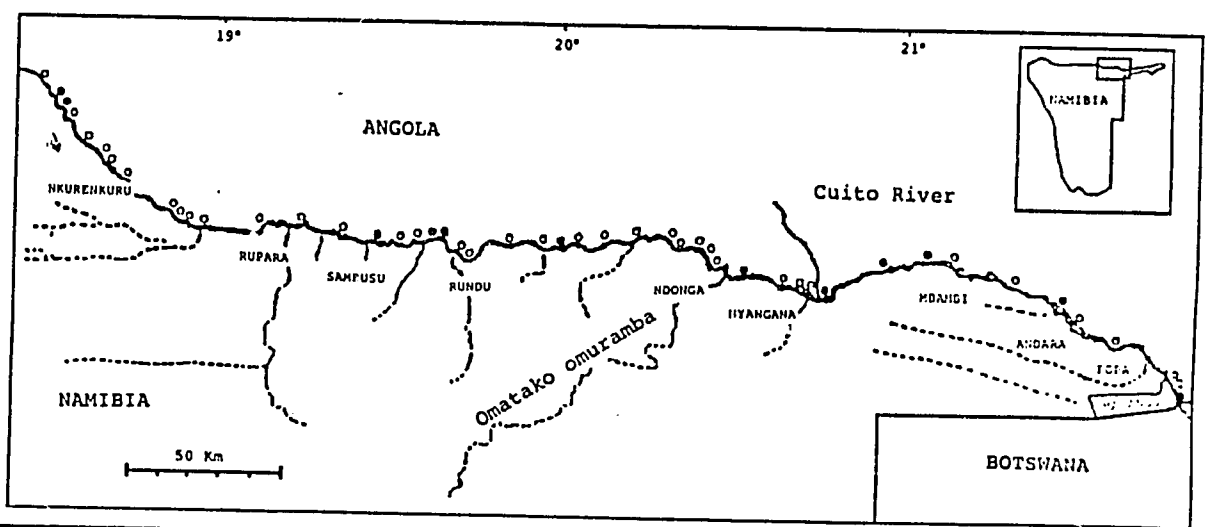


Appendix C. (cont.)

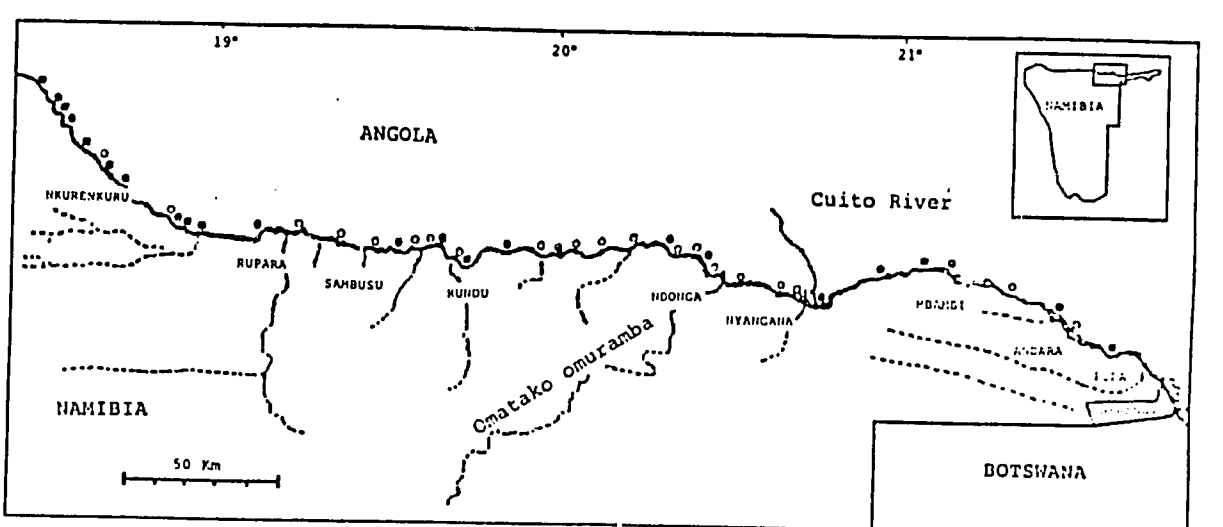
Brycinus lateralis



Hydrocynus vittatus

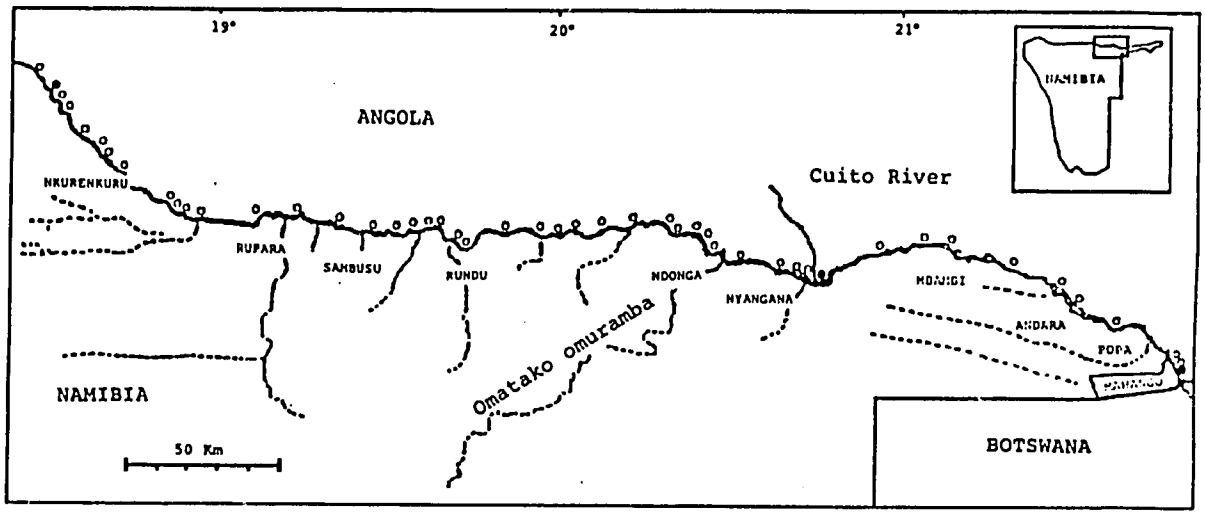


Micralestes acutidens

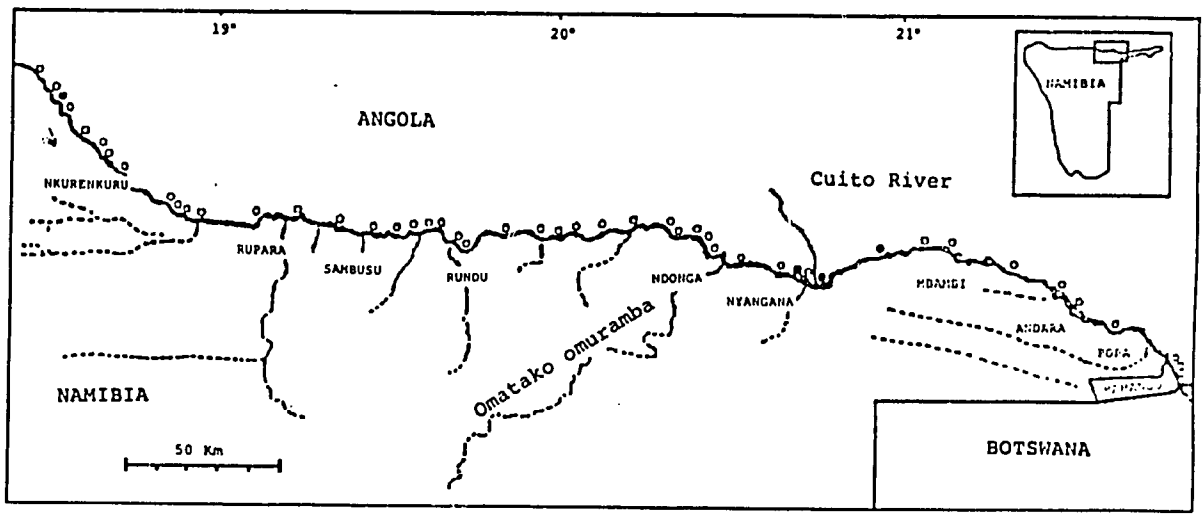


Appendix C. (cont.)

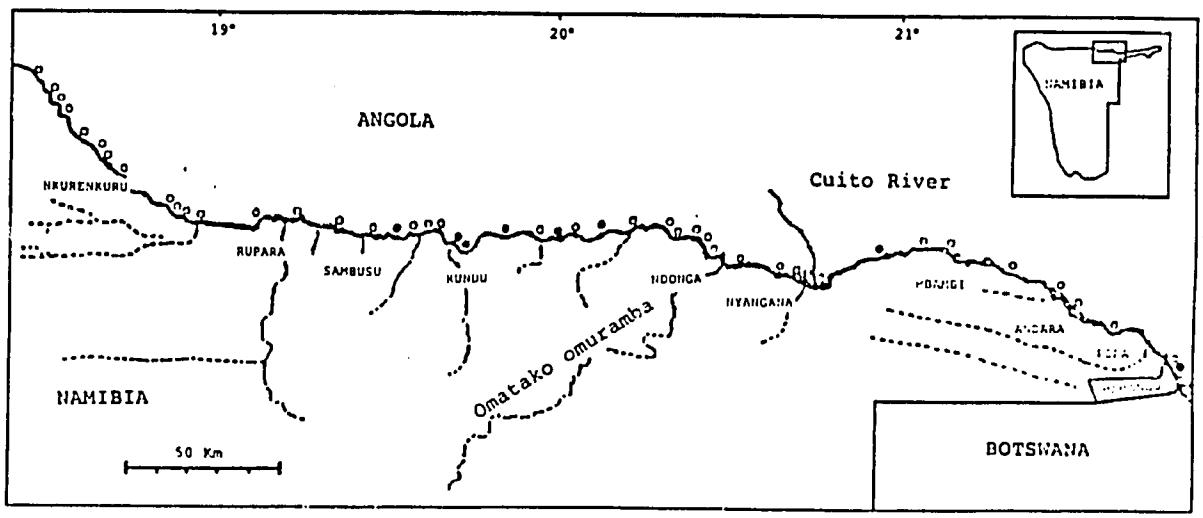
Rhabdalestes maunensis



Hepsetus odoe

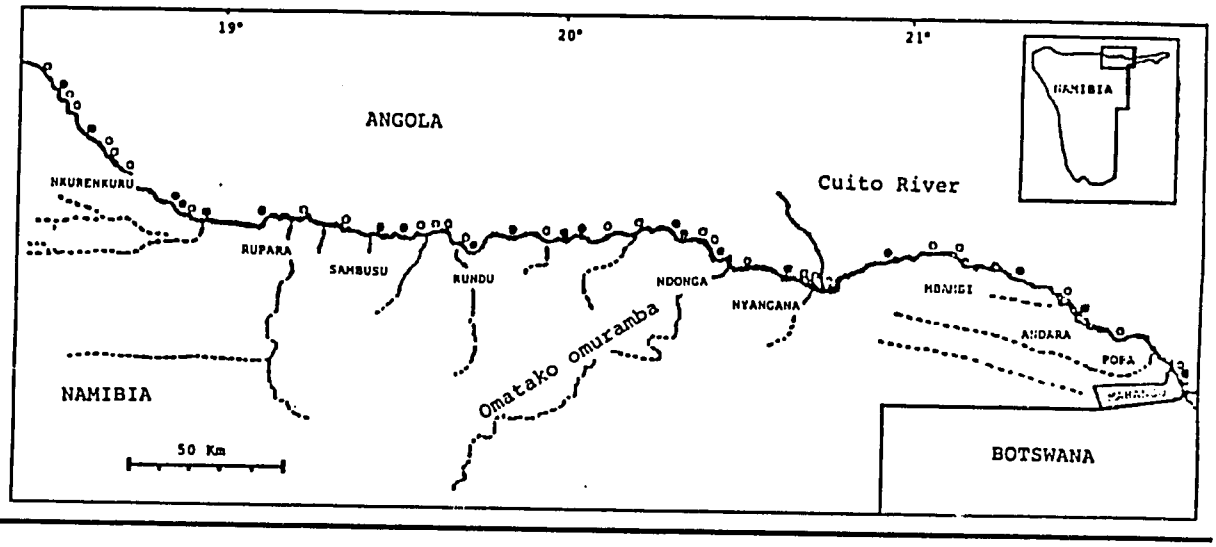


Hemigrammocharax machadoi

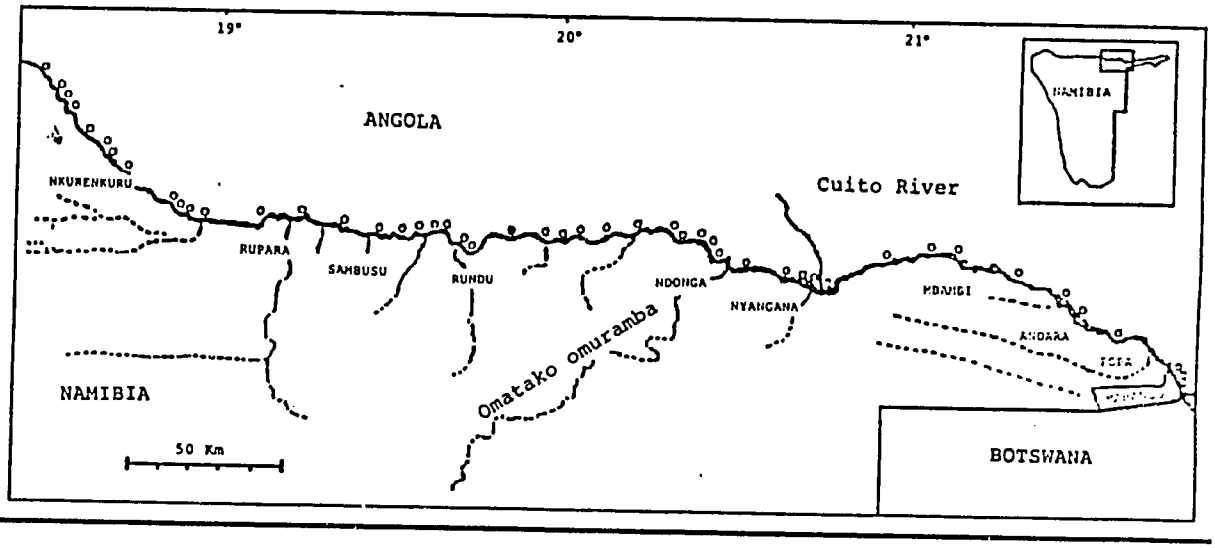


Appendix C. (cont.)

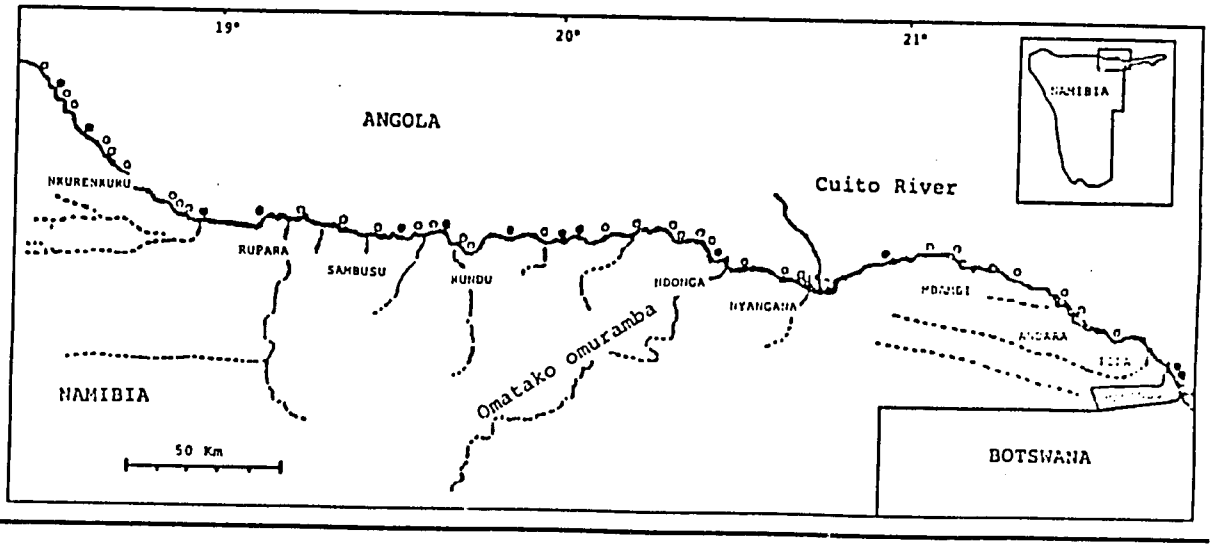
Hemigrammocharax multifasciatus



Nanocharax macropterus

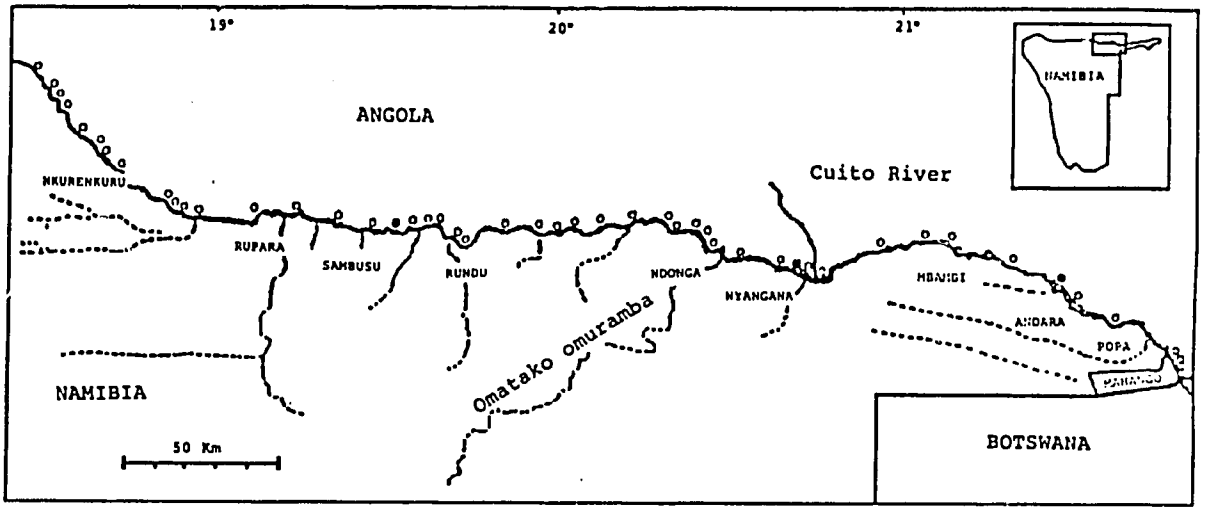


Barbus afrovernayi

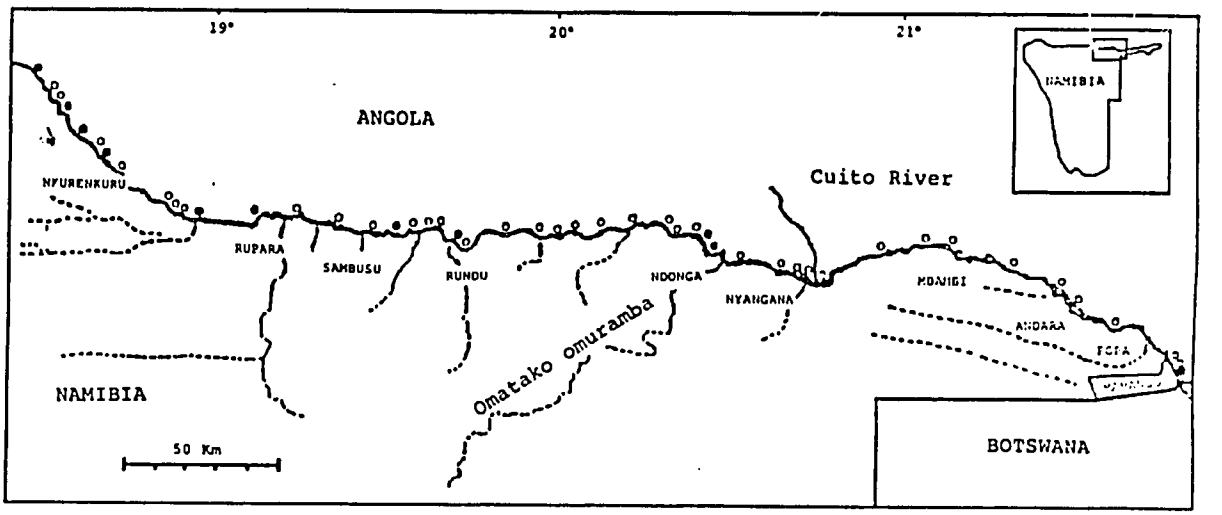


Appendix C. (cont.)

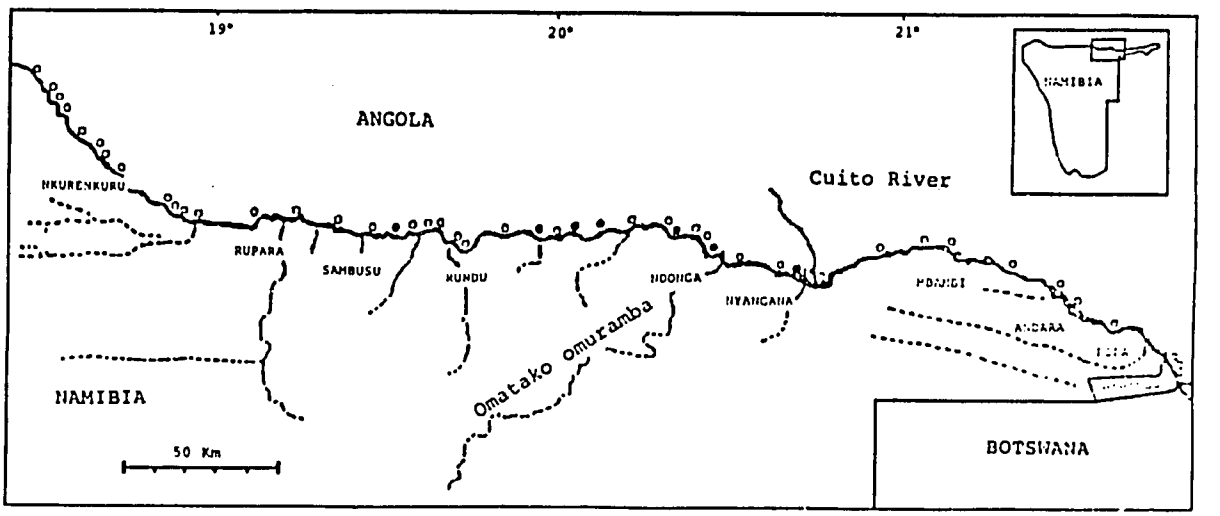
Barbus annectens



Barbus barnardi

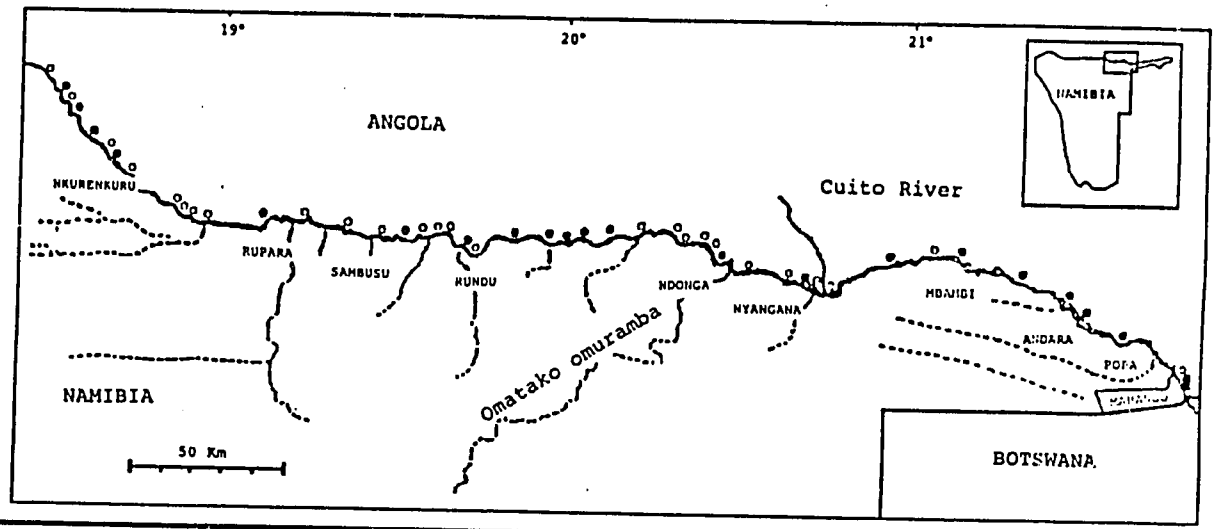


Barbus barotseensis

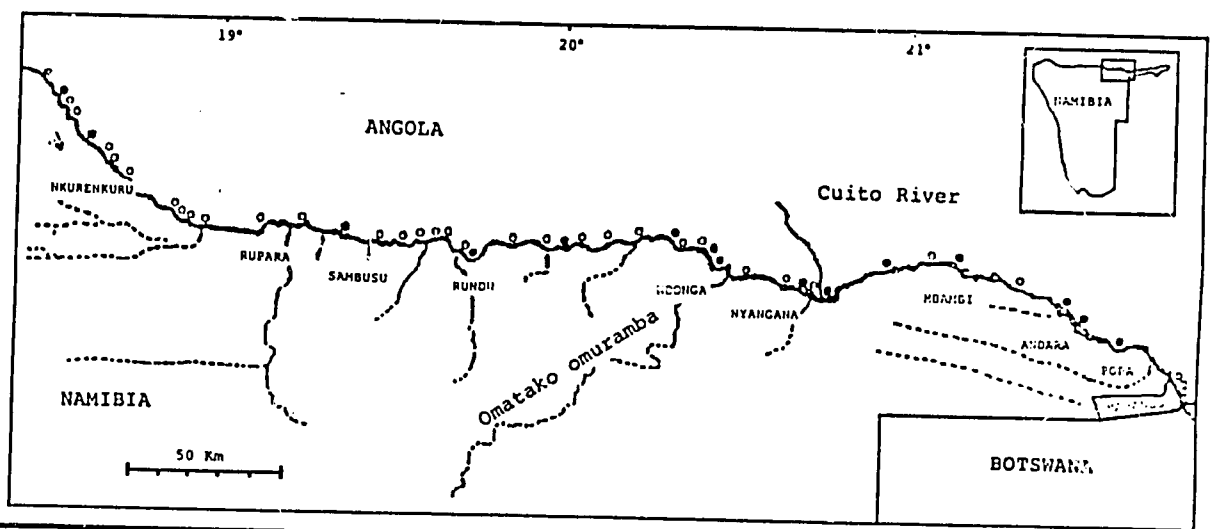


Appendix C. (cont.)

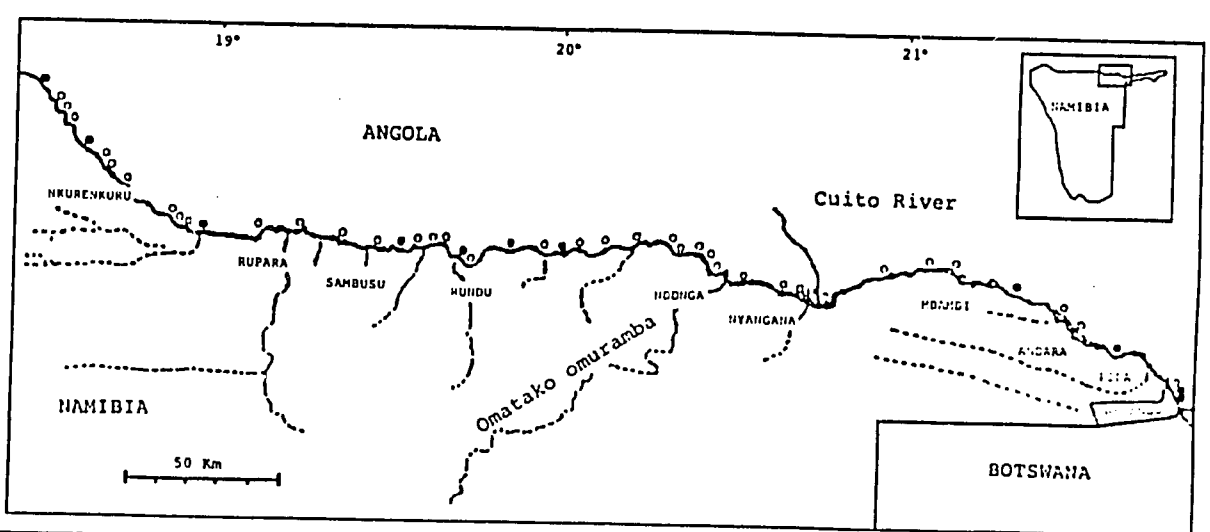
Barbus bifrenatus



Barbus eutaenia

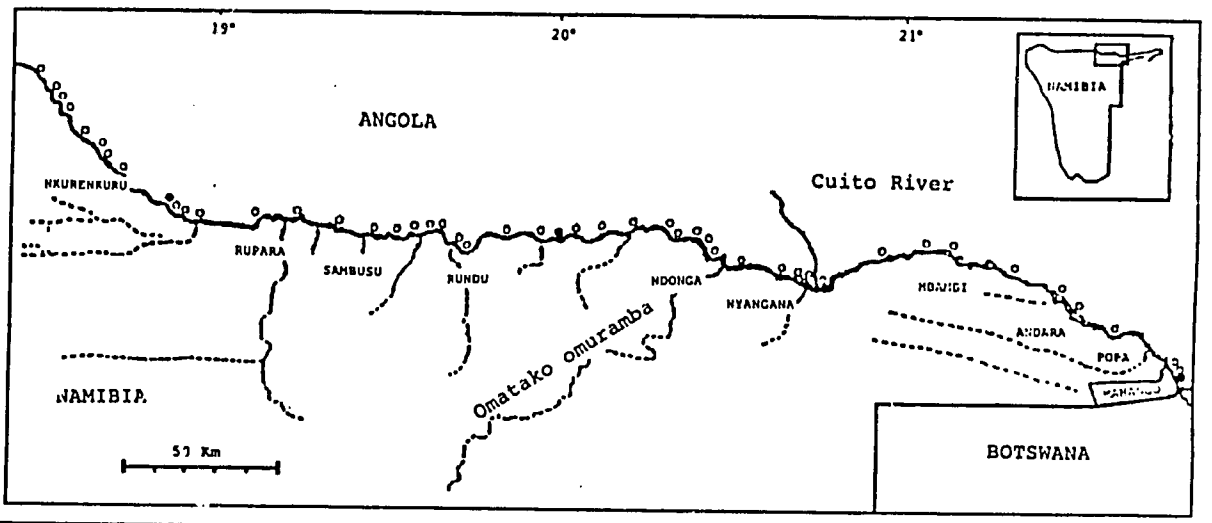


Barbus fasciolatus

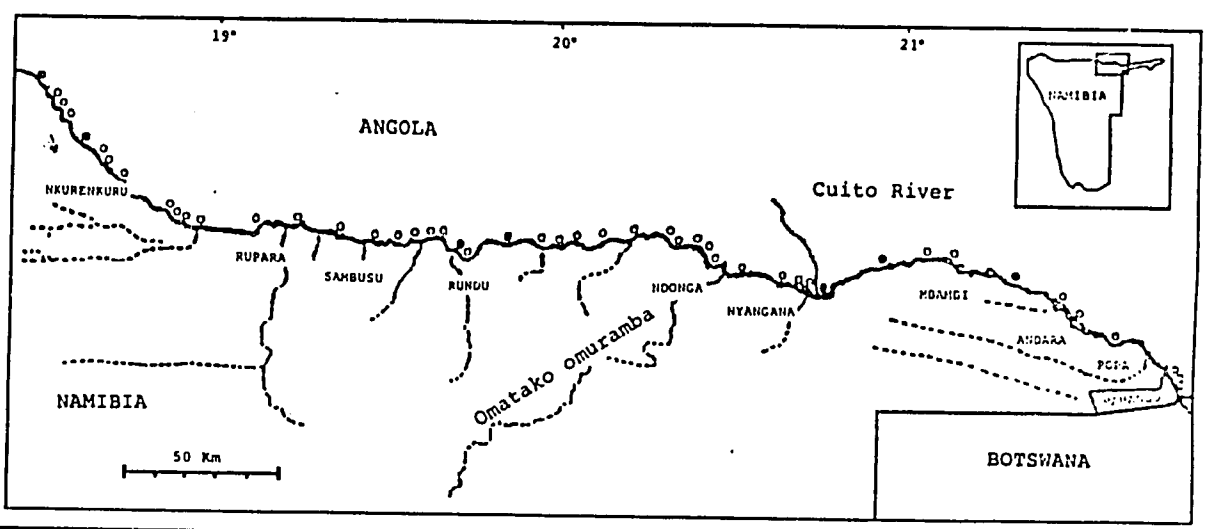


Appendix C. (cont.)

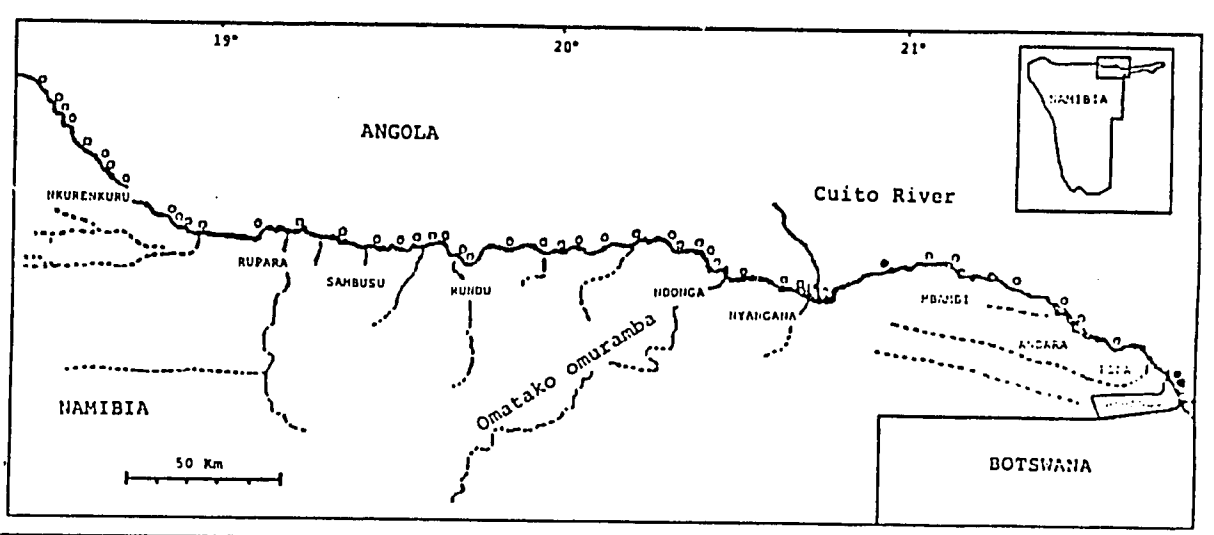
Barbus haasianus



Barbus lineomaculatus

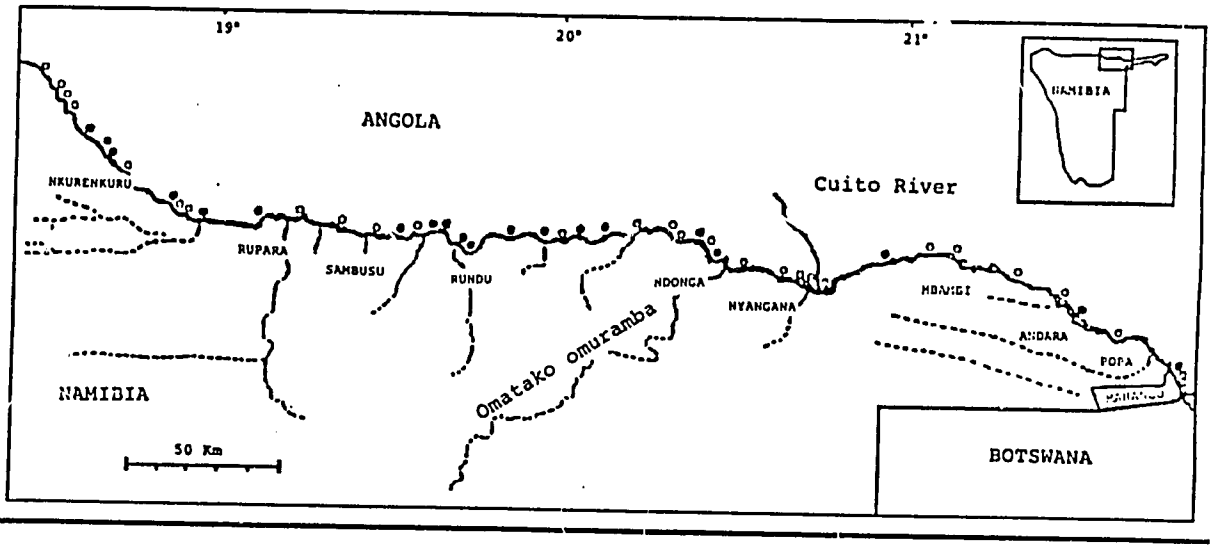


Barbus multilineatus

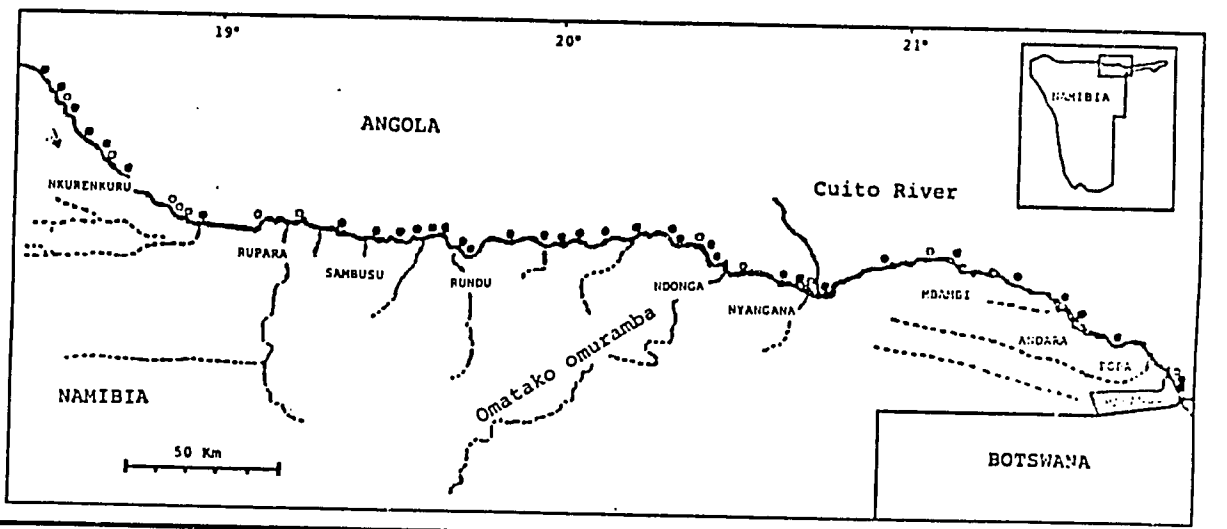


Appendix C. (cont.)

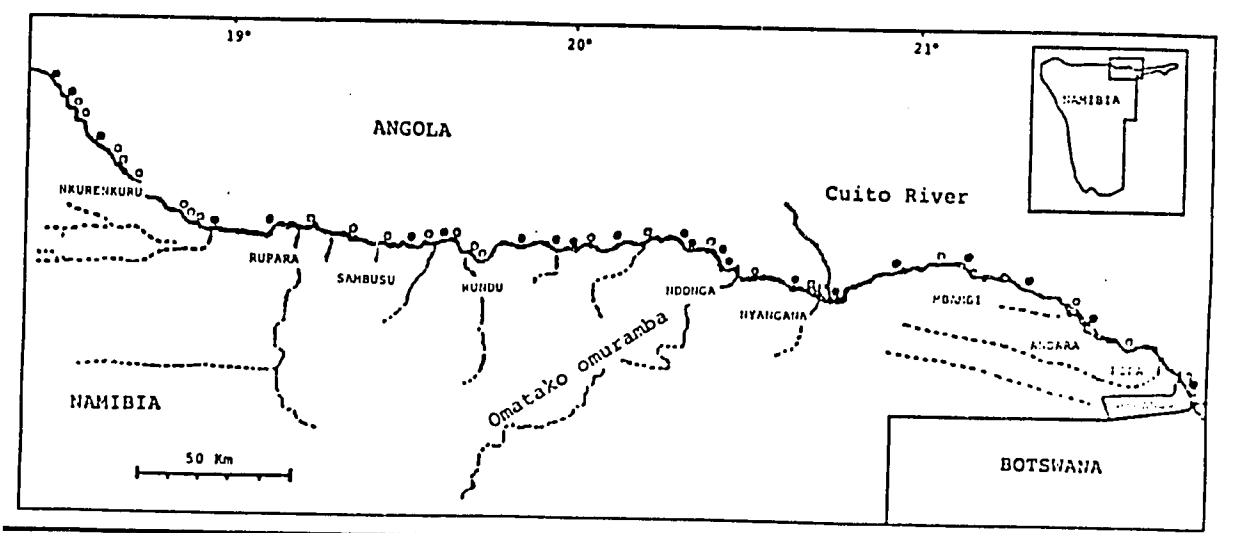
Barbus paludinosus



Barbus poechii

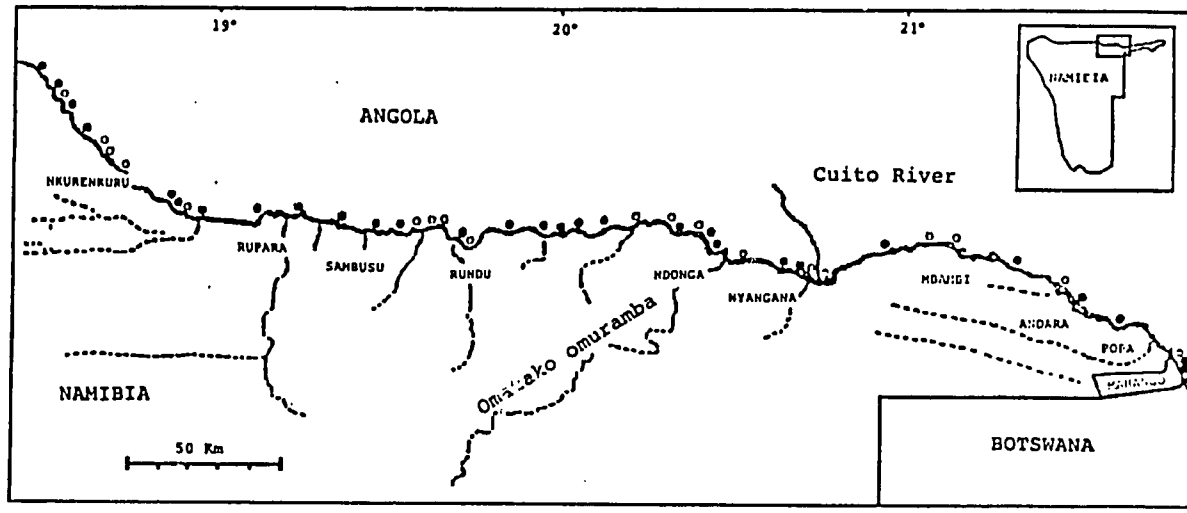


Barbus radiatus

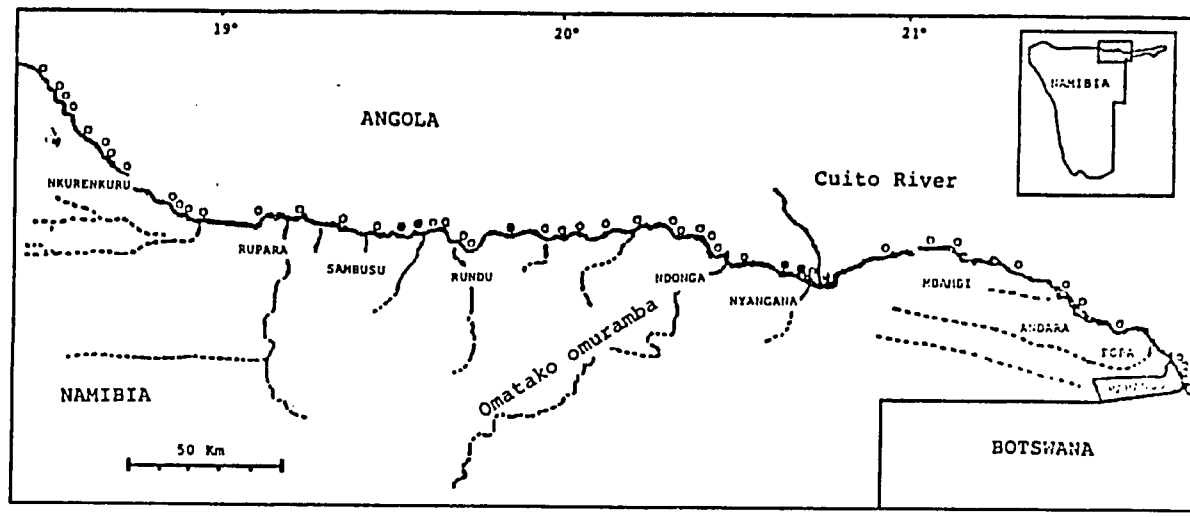


Appendix C. (cont.)

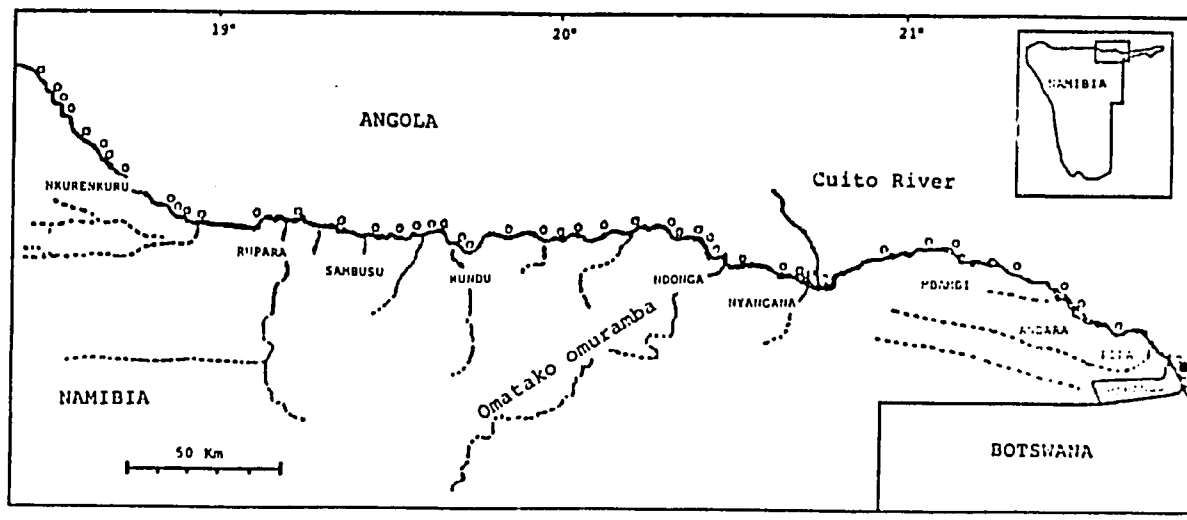
Barbus thamalakanensis



Barbus unitaeniatus

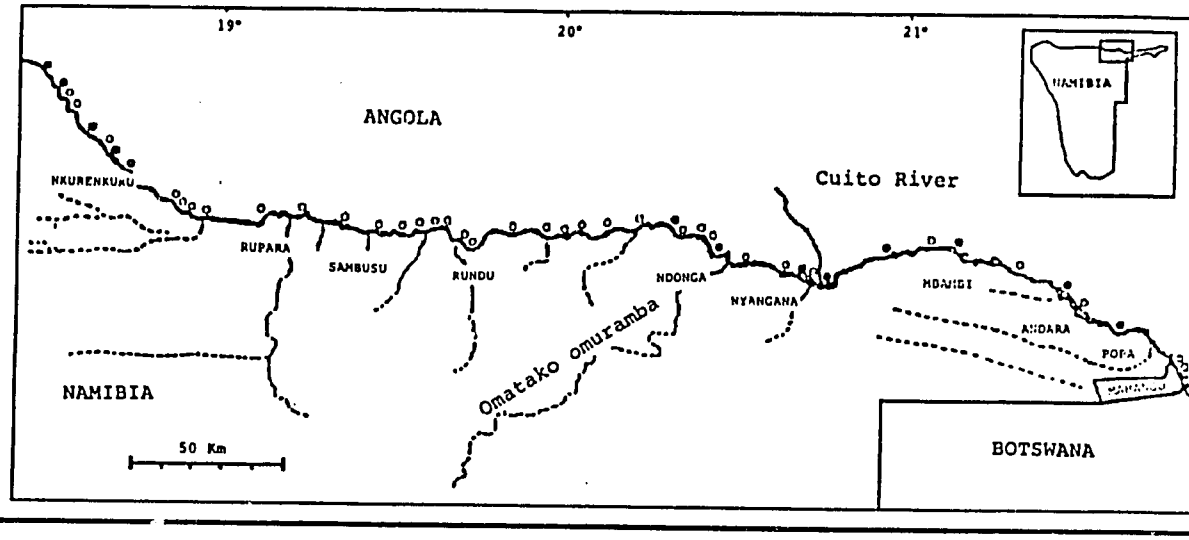


Coptostomabarbus wittei

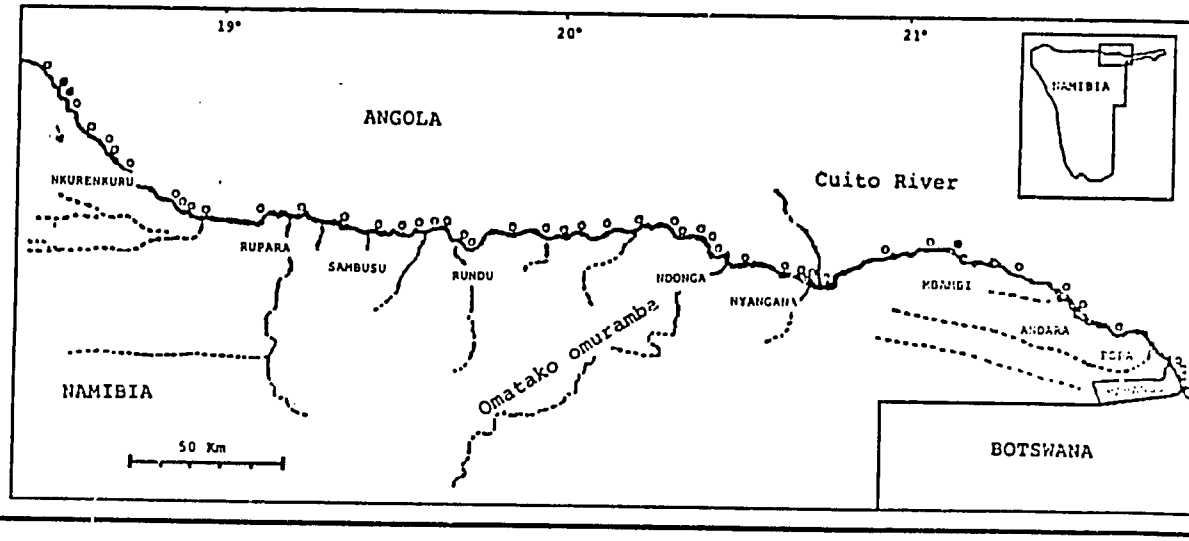


Appendix C. (cont.)

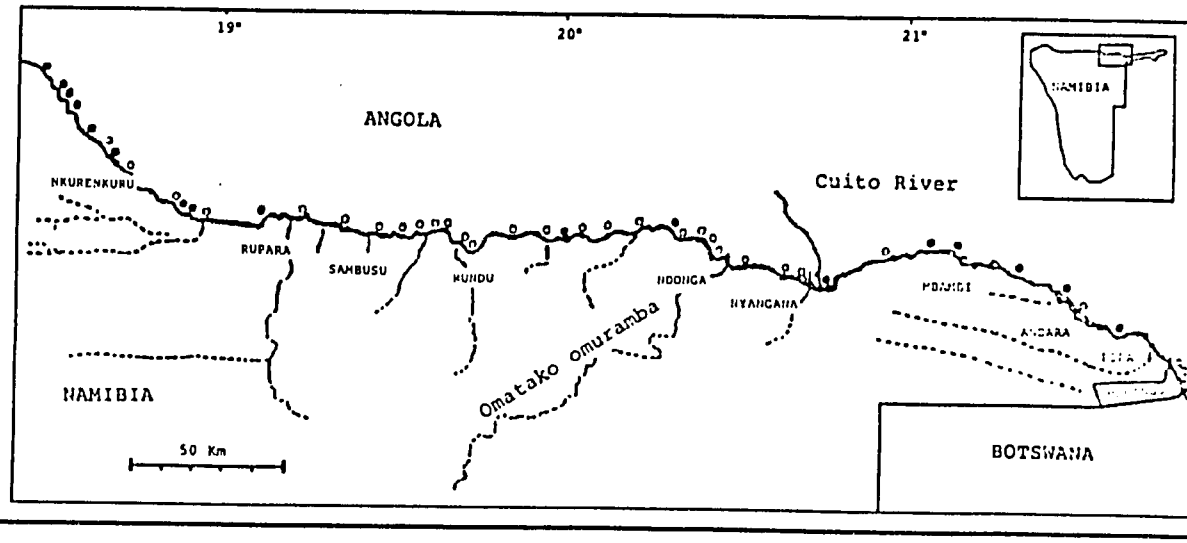
Labeo cylindricus



Labeo lunatus

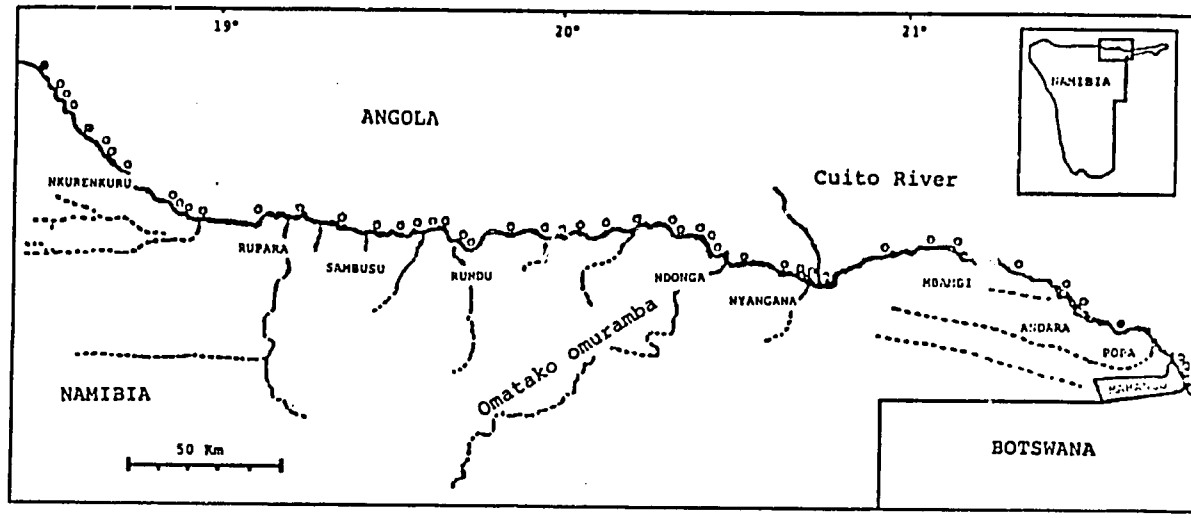


Opsaridium zambezense

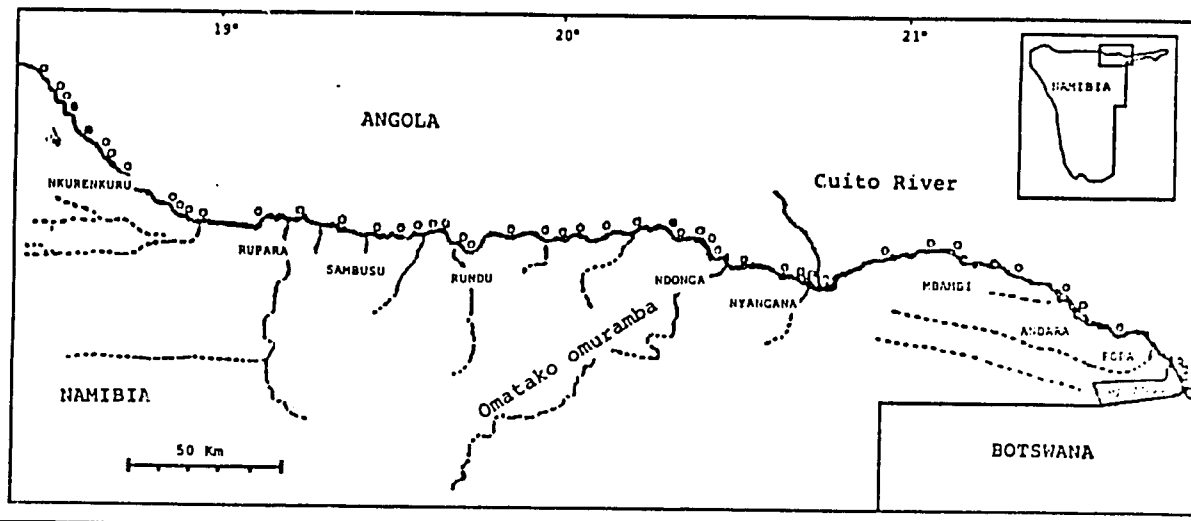


Appendix C. (cont.)

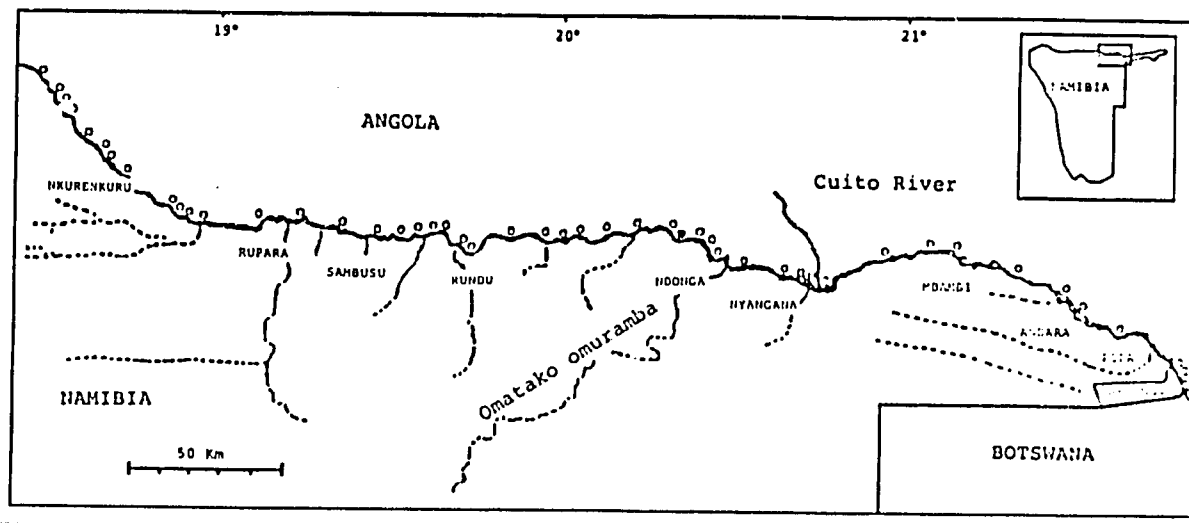
Amphilius uranoscopus



Leptoglanis dorae

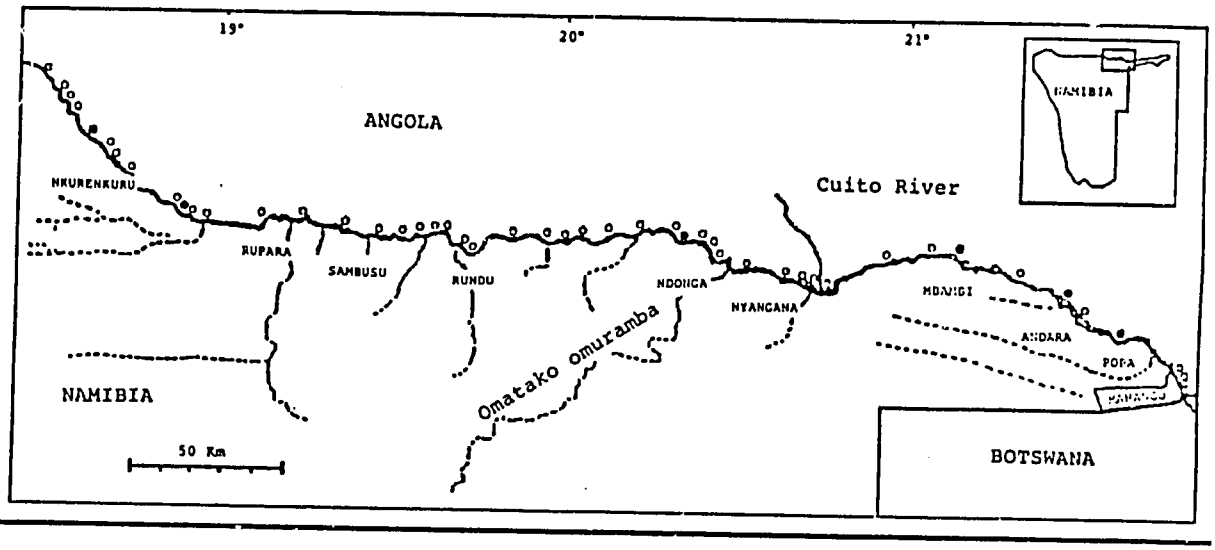


Leptoglanis rotundiceps

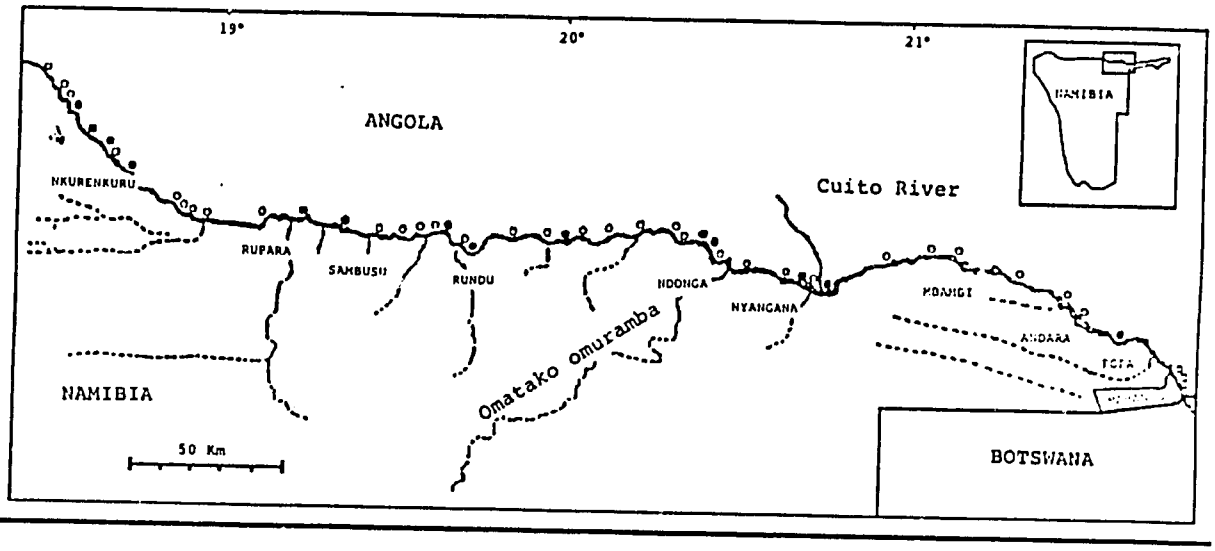


Appendix C. (cont.)

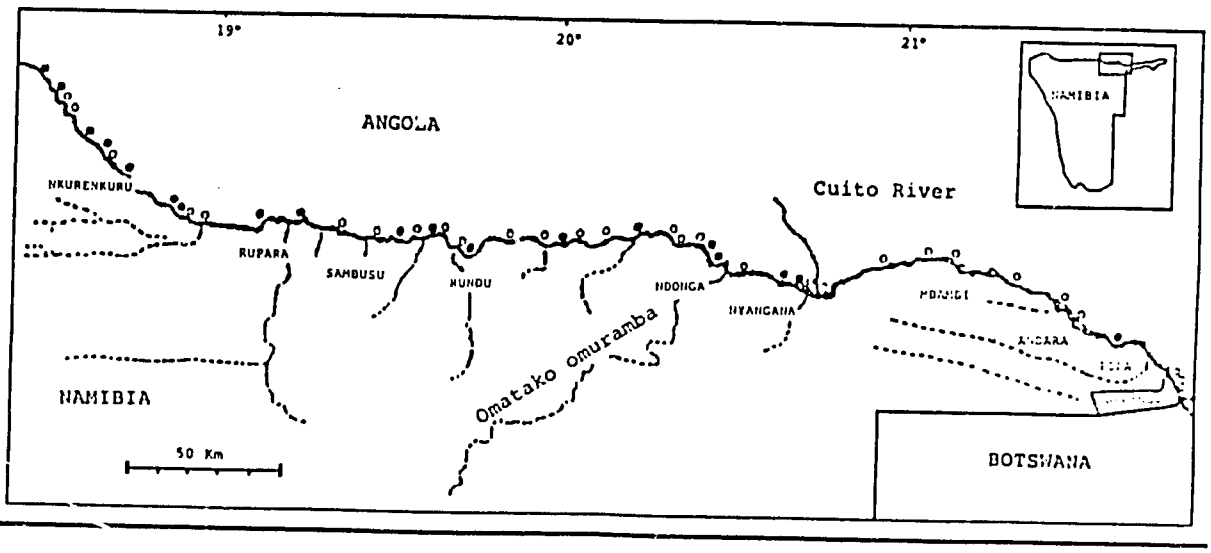
Parauchenoglanis ngamensis



Clarias gariepinus

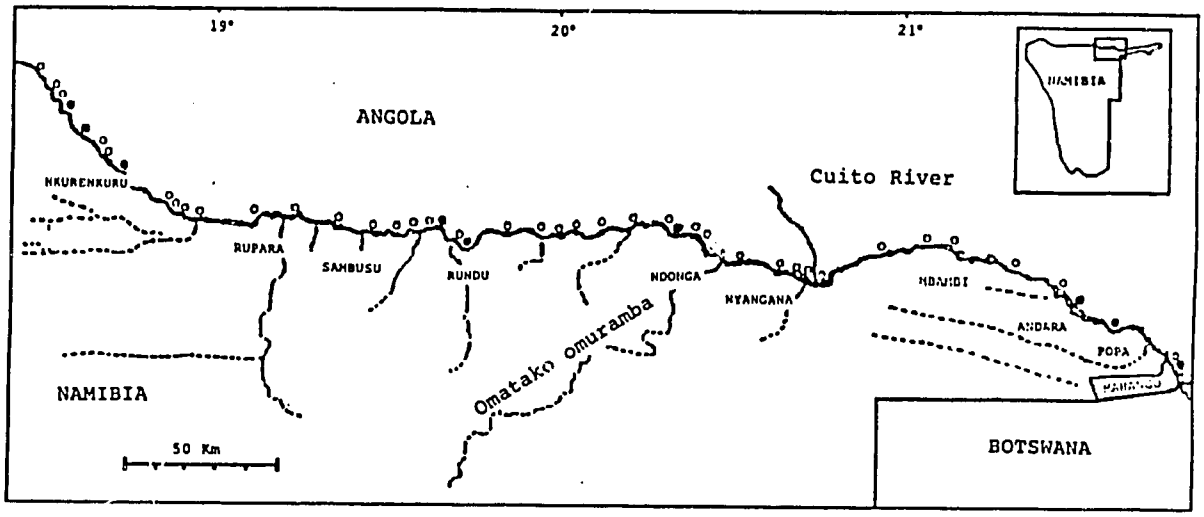


Clarias ngamensis

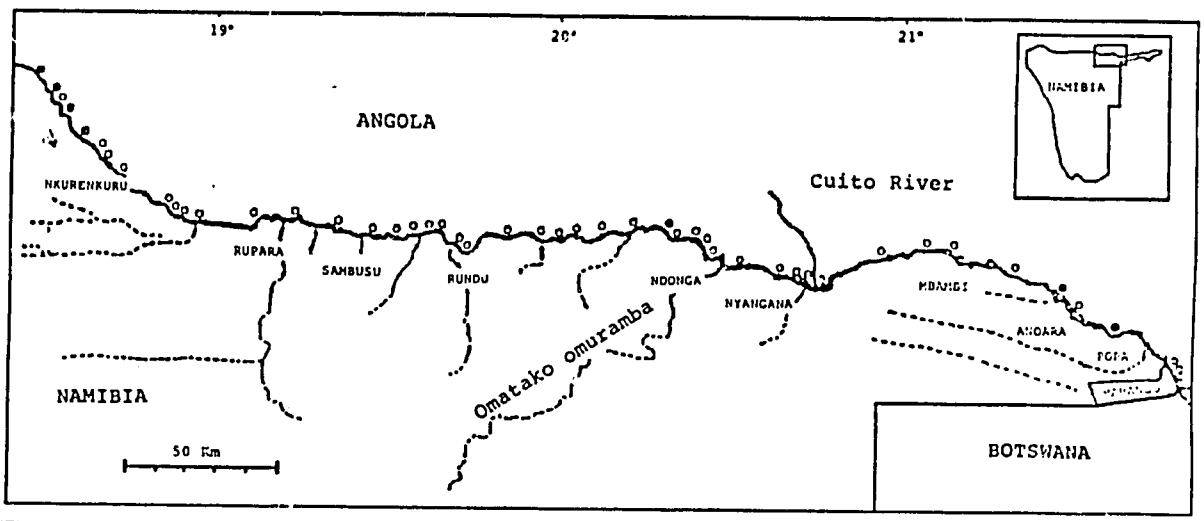


Appendix C. (cont.)

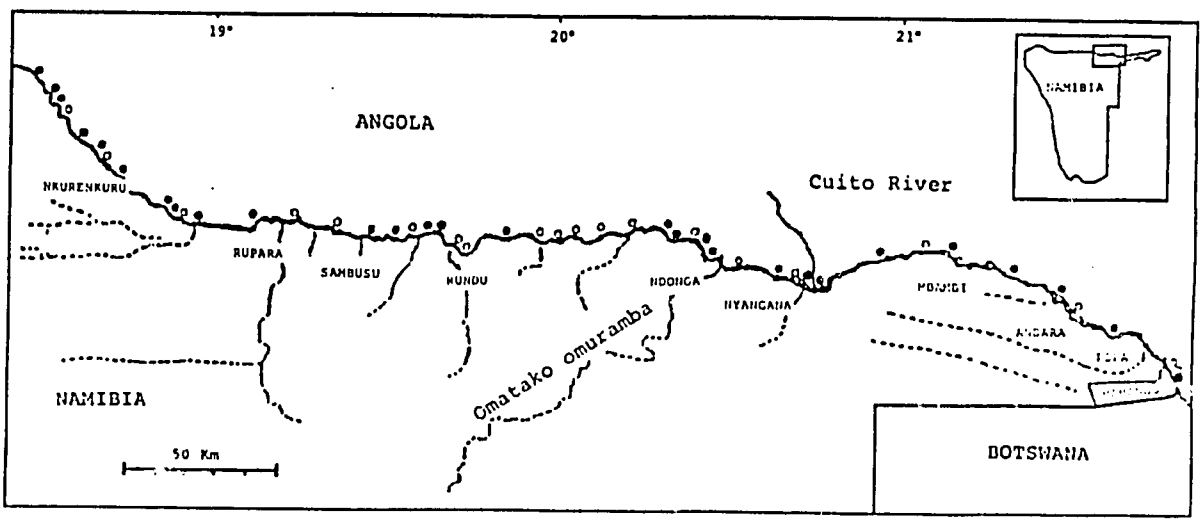
Clarias theodorae



Chiloglanis fasciatus

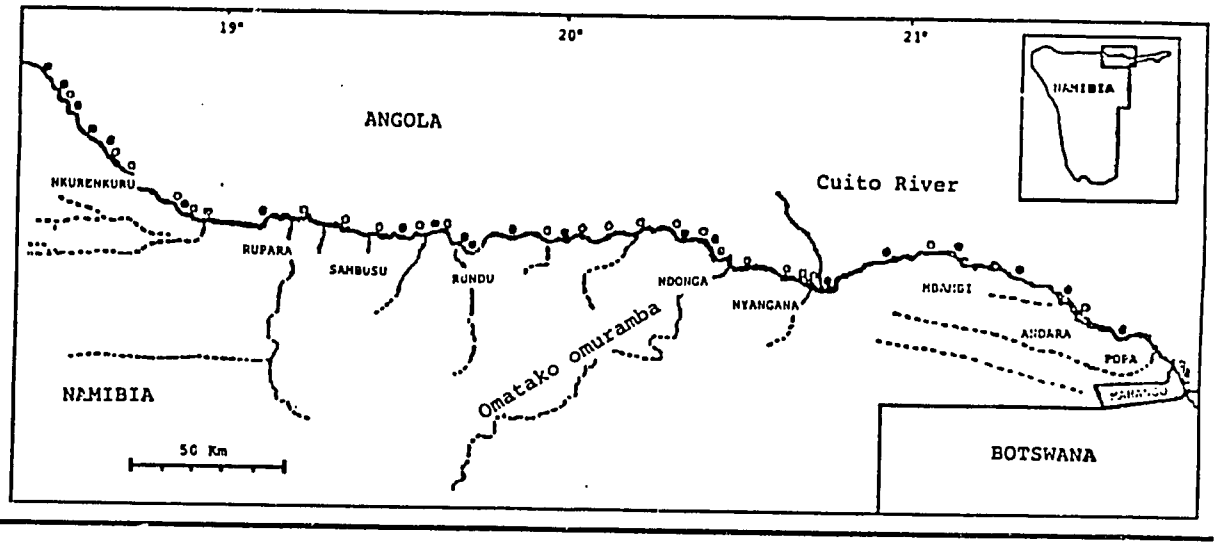


Synodontis spp.

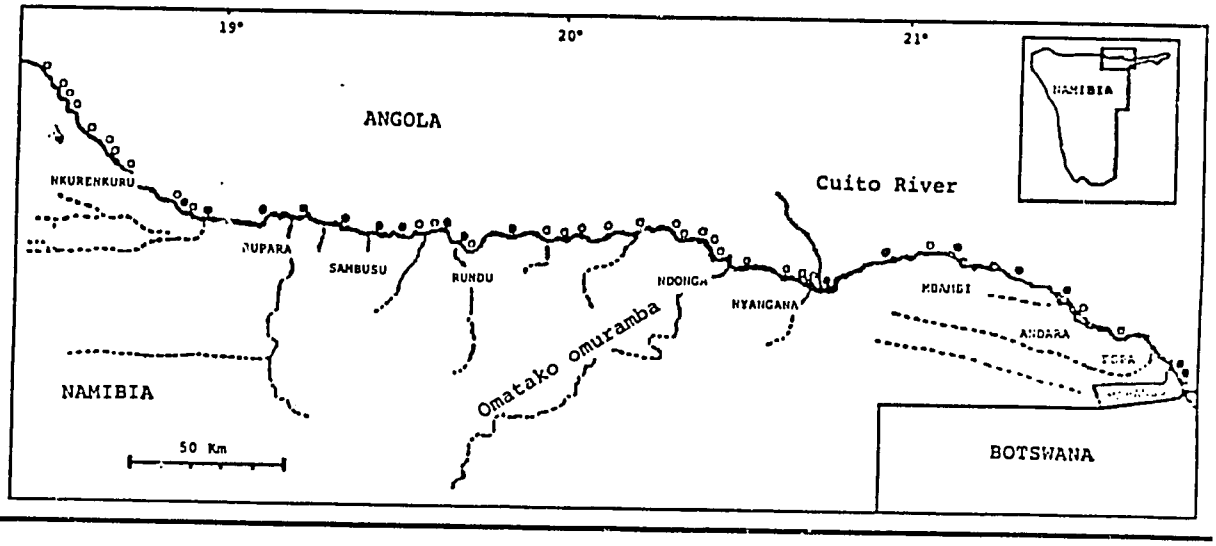


Appendix C. (cont.)

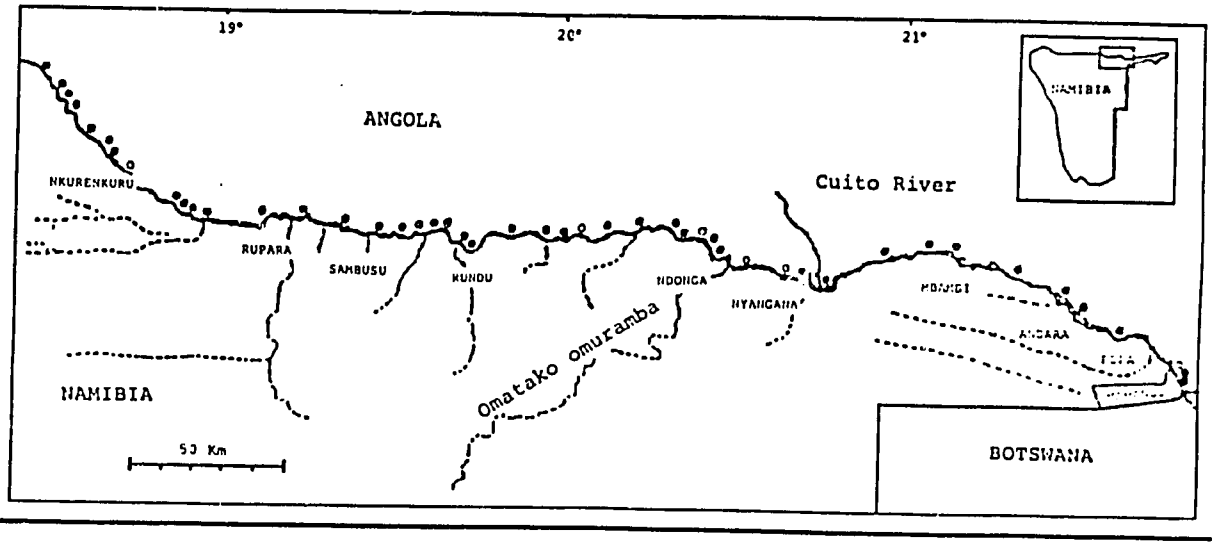
Schilbe intermedius



Aplocheilichthys hutereaui

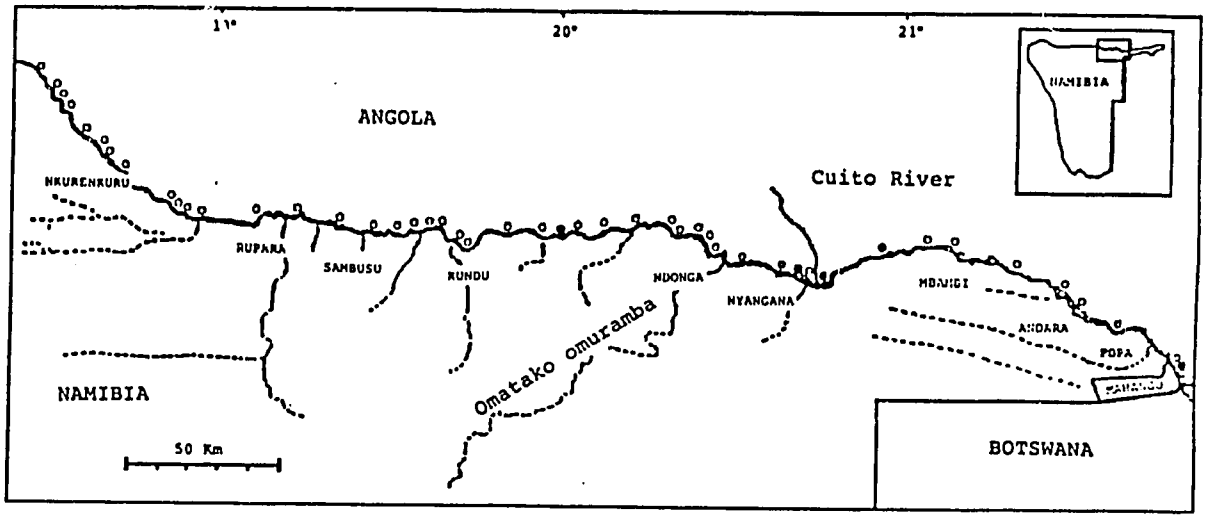


Aplocheilichthys johnstoni

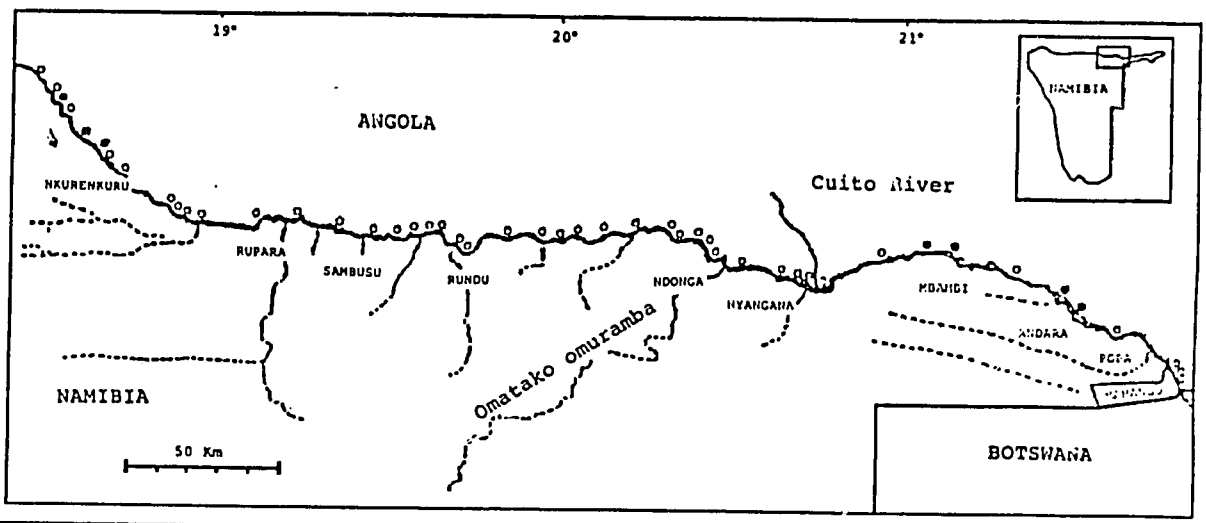


Appendix C. (cont.)

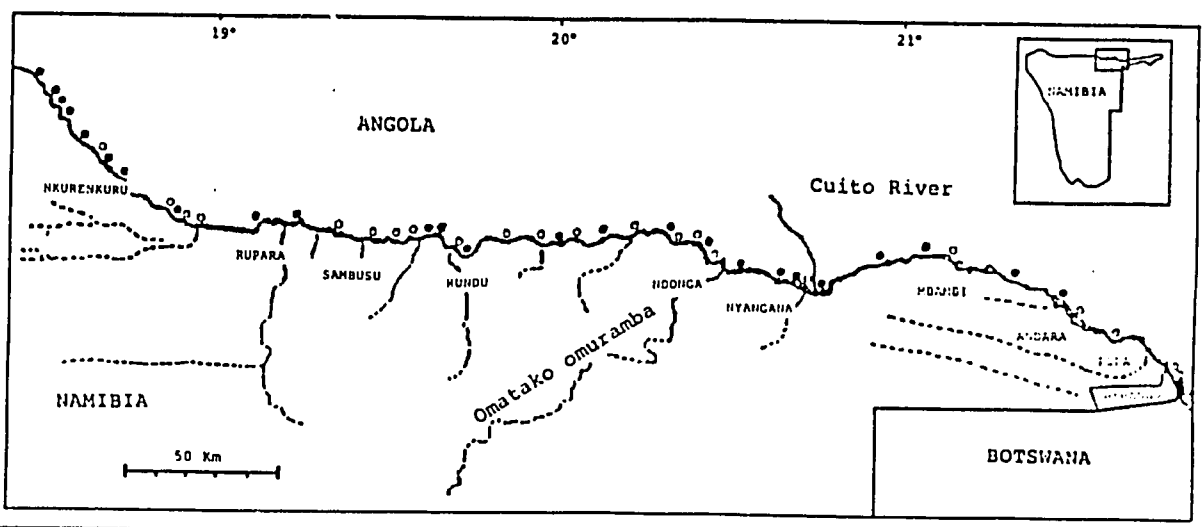
Aplocheilichthys katangae



Hemichromis elongatus

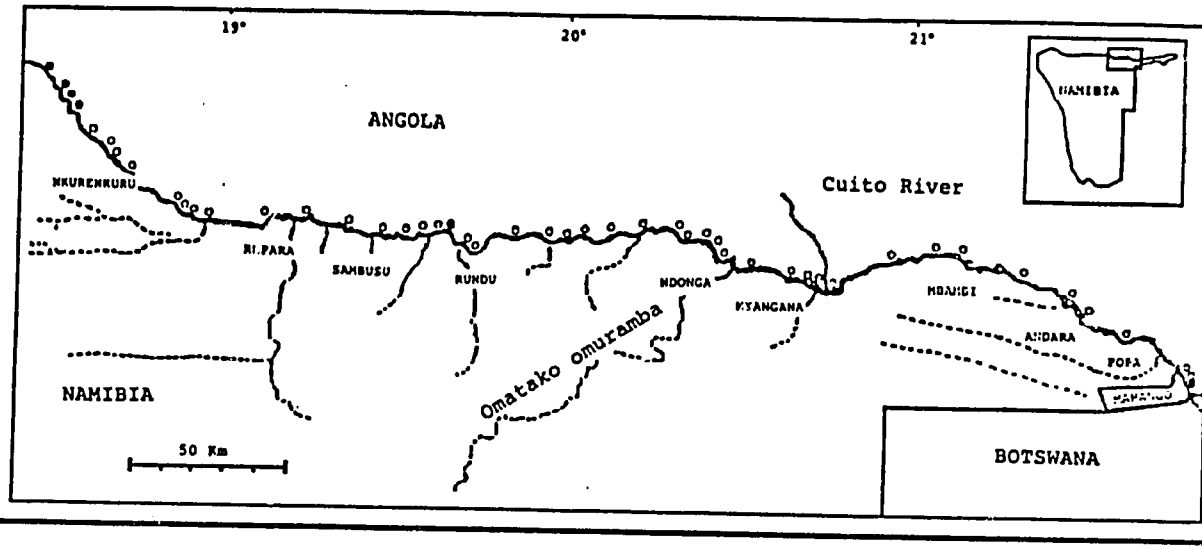


Oreochromis andersonii

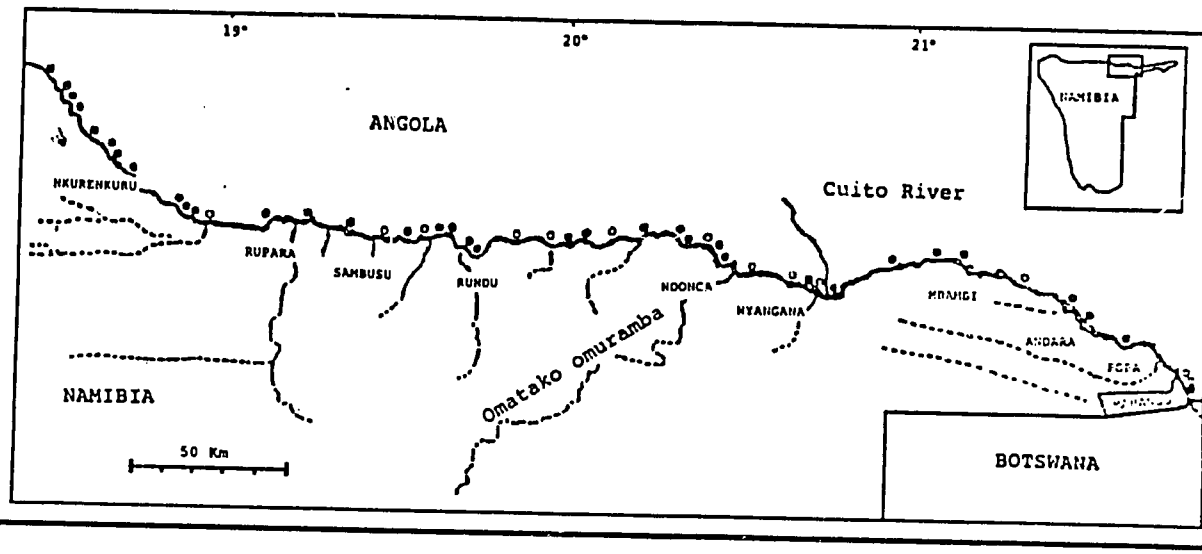


Appendix C. (cont.)

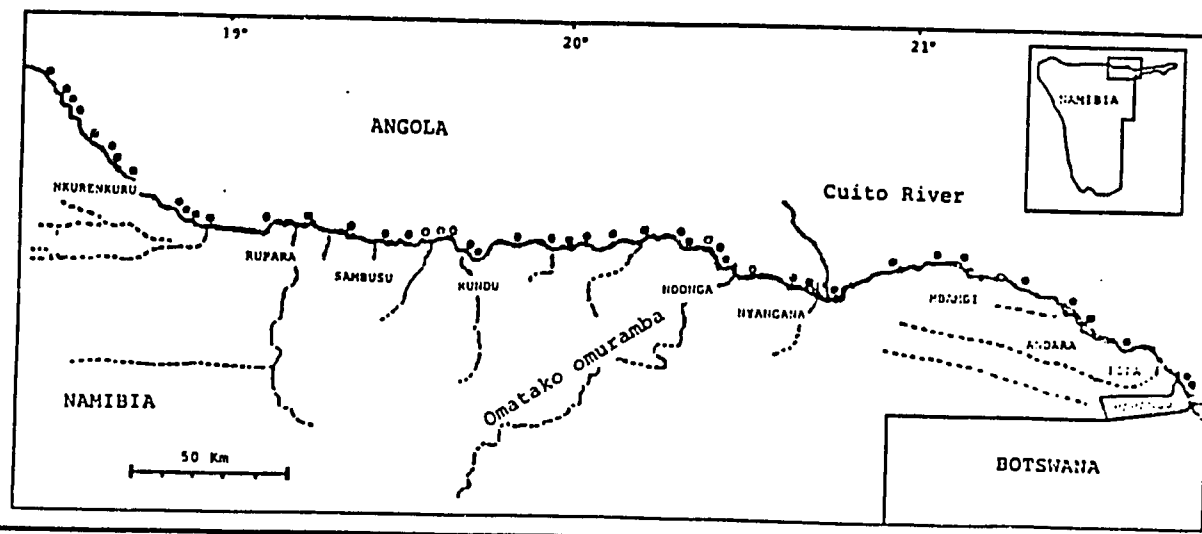
Oreochromis macrochir



Pharyngochromis acuticeps

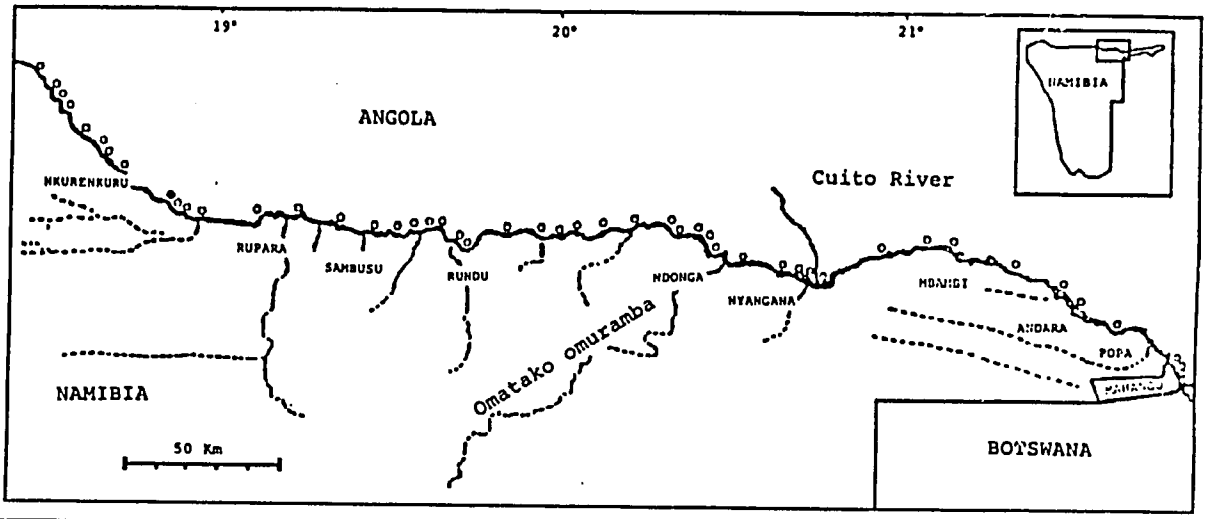


Pseudocrenilabrus philander

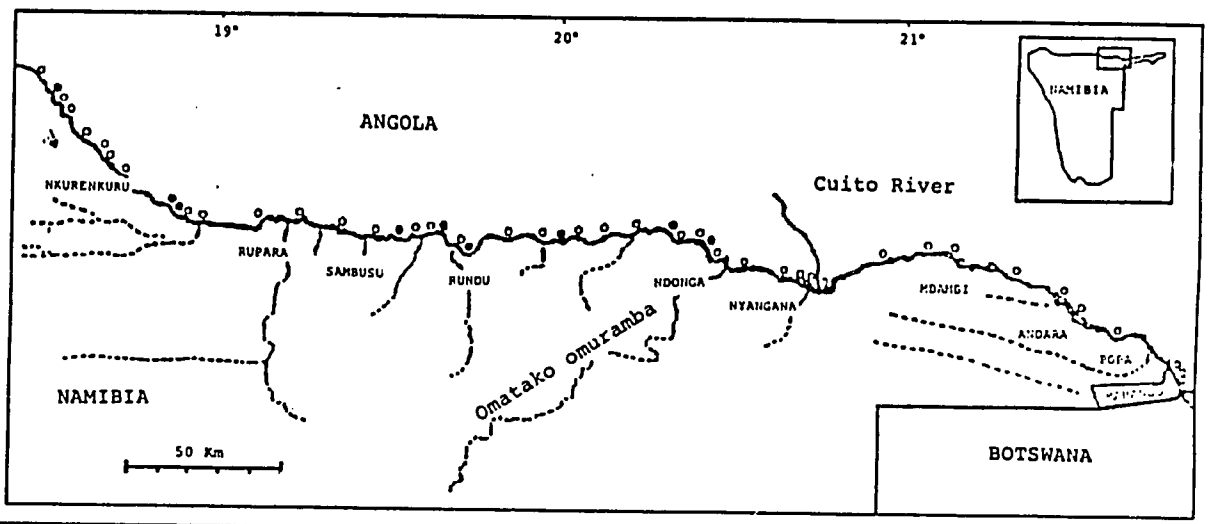


Appendix C. (cont.)

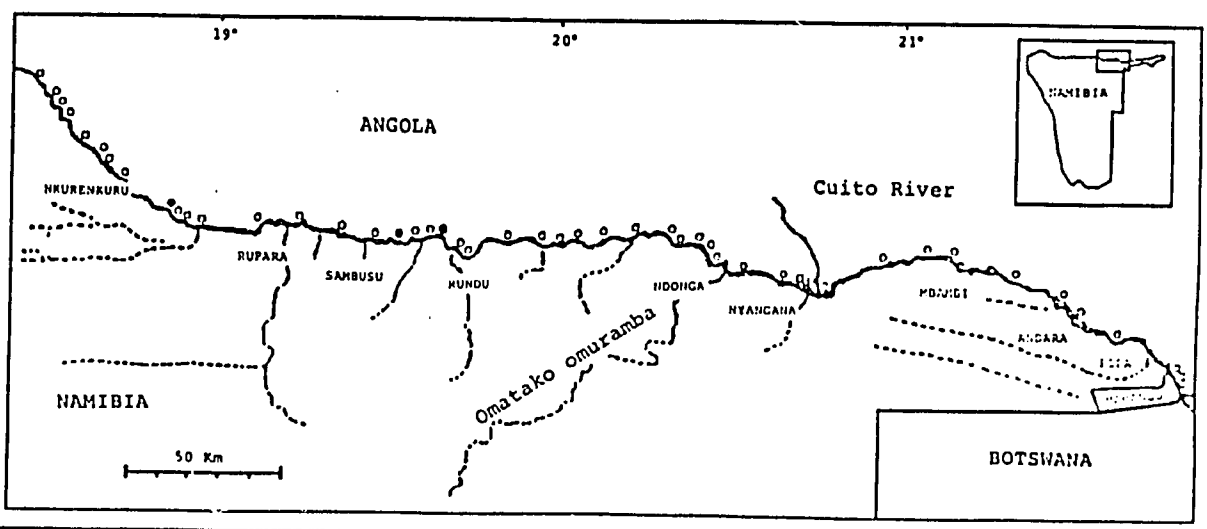
Serranochromis Sargo, carlottae



Serranochromis Sargo, codringtonii

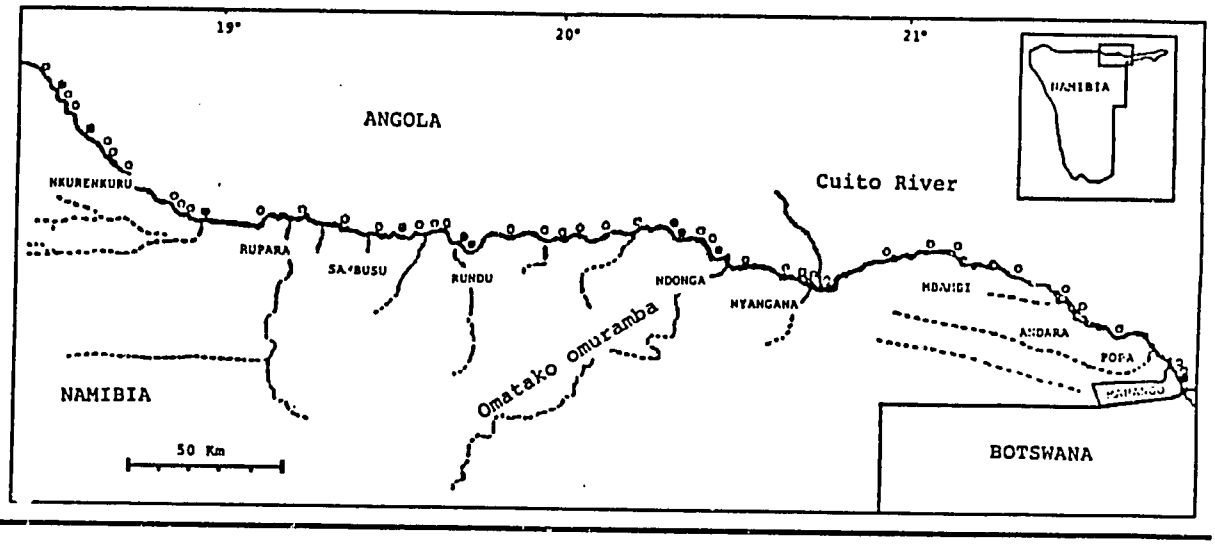


Serranochromis Sargo, giardi

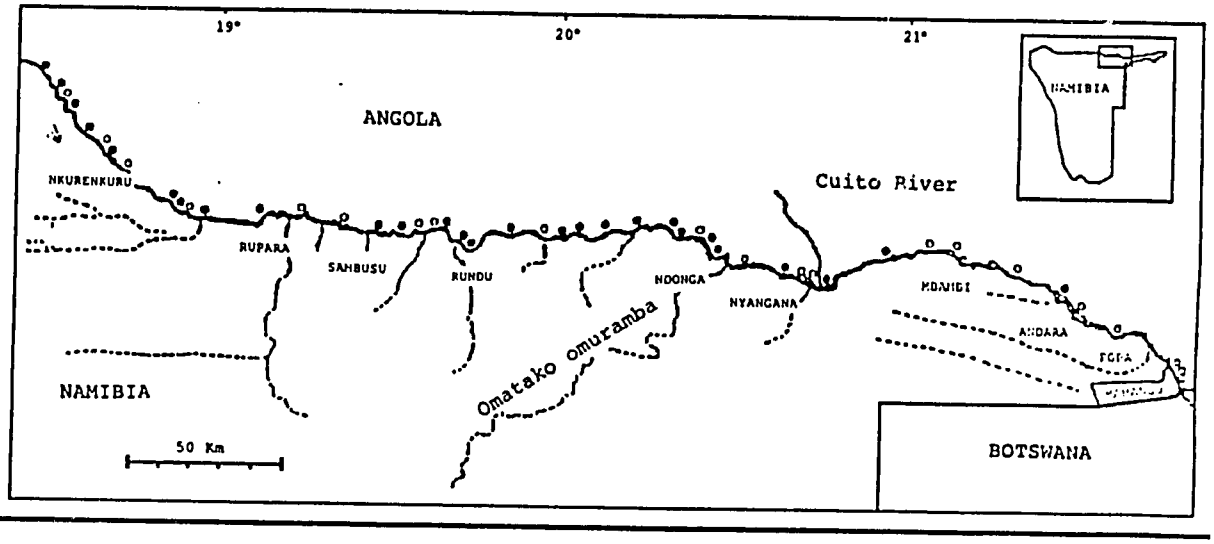


Appendix C. (cont.)

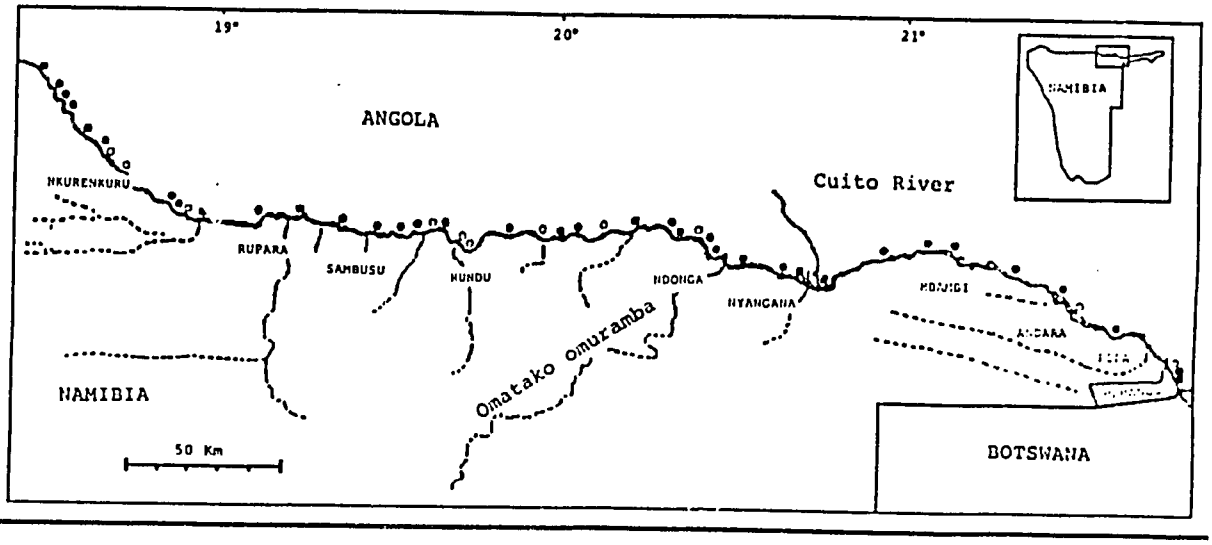
Serranochromis Serrano. angusticeps



Serranochromis Serrano. macrocephalus

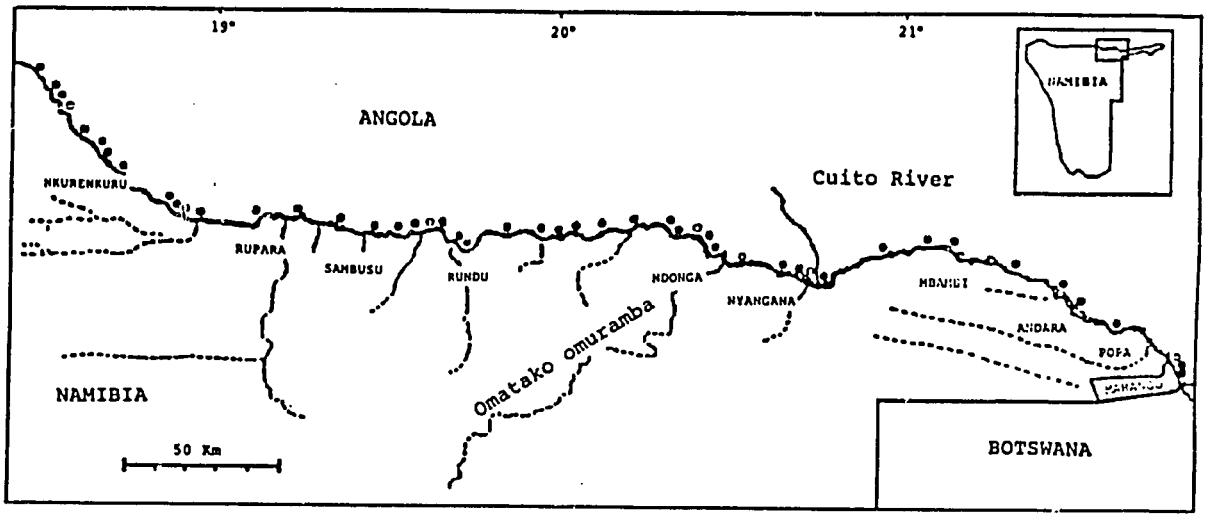


Serranochromis Serrano. robustus jallae

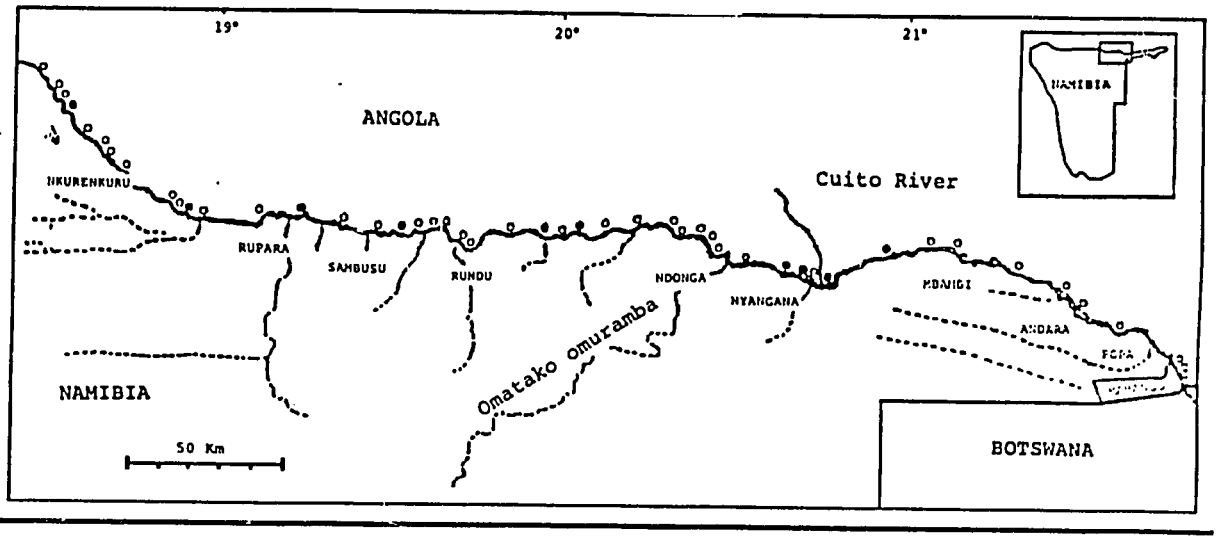


Appendix C. (cont.)

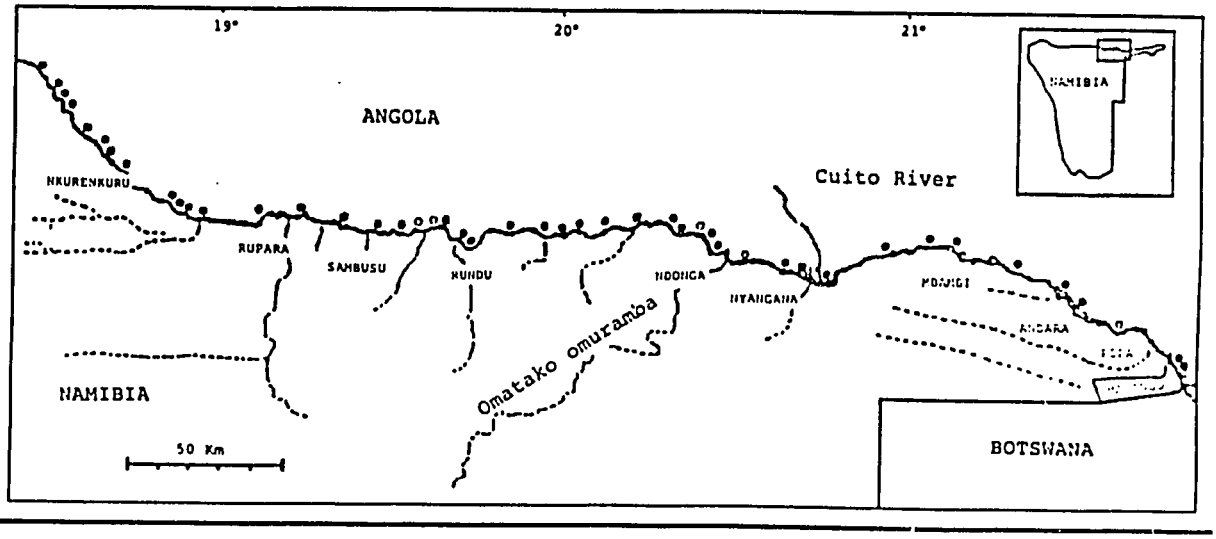
Tilapia rendalli



Tilapia ruweti

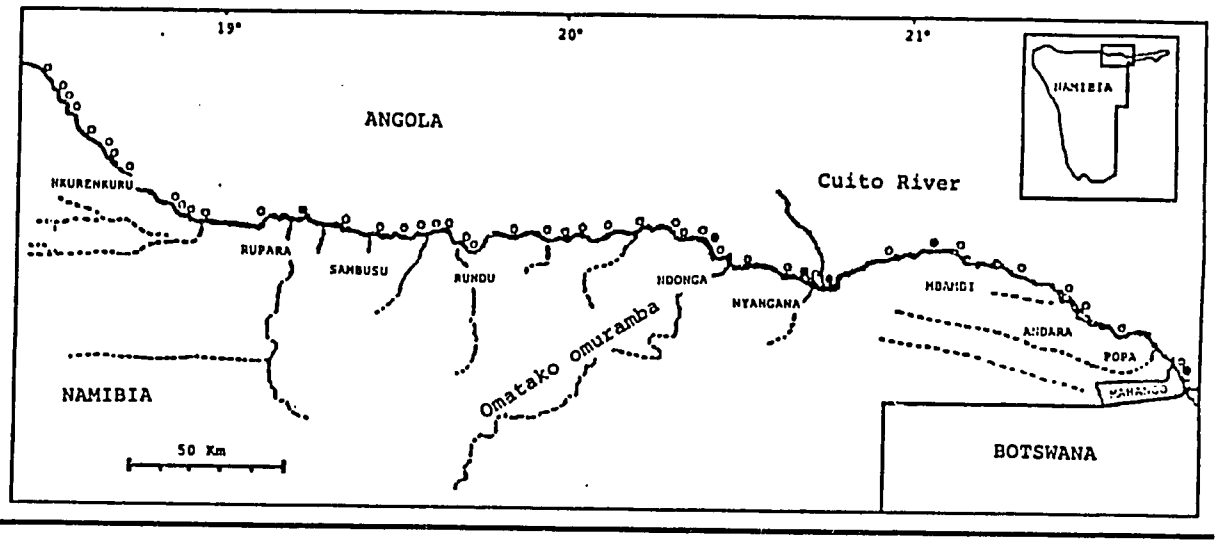


Tilapia sparrmanii

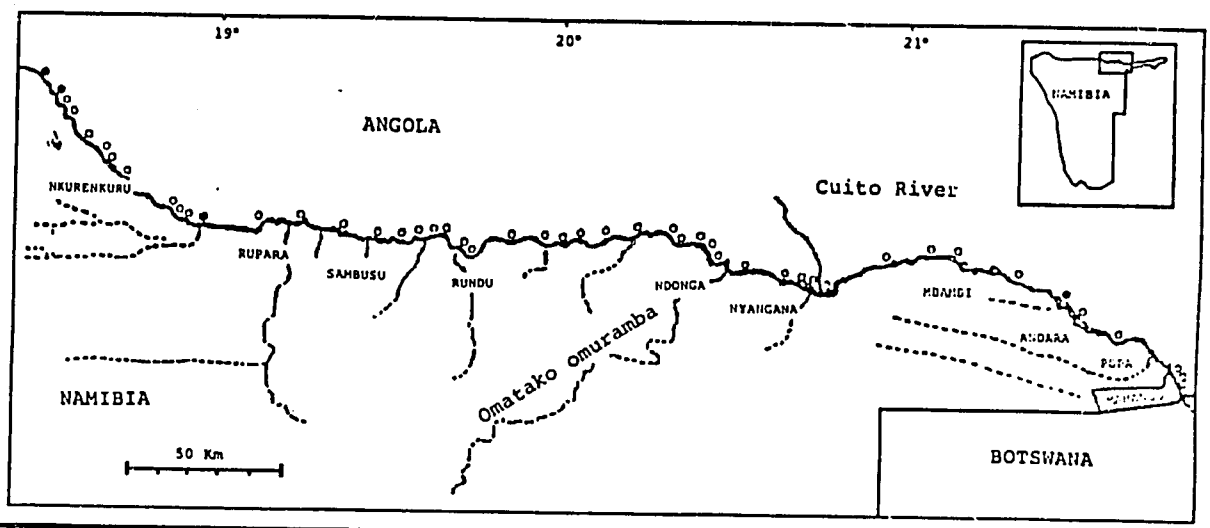


Appendix C. (cont.)

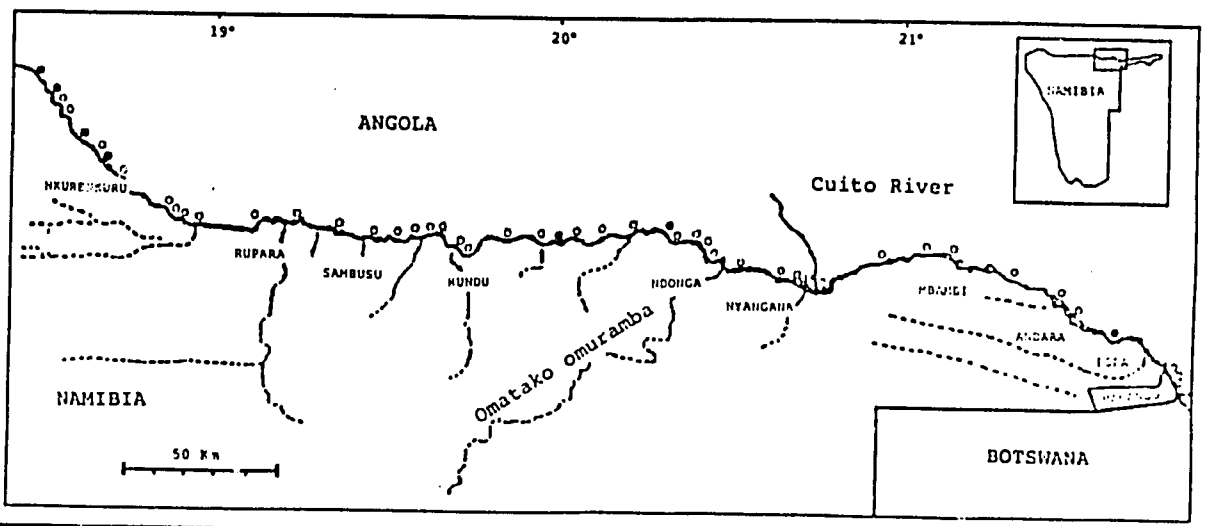
Ctenopoma multispinus



Aethiomastacembelus frenatus



Aethiomastacembelus vanderwaali



Appendix D. Preliminary key to the freshwater fishes of Namibia.

KEY TO THE FAMILIES OF FRESHWATER FISHES OF NAMIBIA

1a. Body scaleless; mouth with barbels.....2
1b. Body with scales; mouth with or without barbels.....7

2a. Dorsal fin long (≥ 1/3 of body length) and without spines .....**Clariidae**
2b. Dorsal fin much shorter than one-third of total length, with or spines.....3

3a. Anal fin base nearly one-half of total length.....**Schilbeidae**
3b. Anal fin base much less than one-half of total length.....4

4a. Dorsal, pectoral fins lacking spines.....**Amphiliidae**
4b. Dorsal and pectoral fins with spines.....5

5a. Mouth with branched barbels .....**Mochokidae** (in part)
5b. Mouth with un-branched barbels.....6

6a. Inferior sucker-like mouth.....**Mochokidae** (in part)
6b. Mouth terminal or sub-terminal, but not sucker-like....**Bagridae**

7a. Body serpentine; dorsal and anal fins continuous around tail..8
7b. Body not serpentine; dorsal and anal fins not continuous.....9

8a. Series of small isolated spines along dorsum...**Mastacemblelidae**

8b. No spines along dorsum.....**Anguillidae**

9a. Opercular bones hidden beneath skin; caudal fin scaled..... .....**Mormyridae**
9b. Opercular bones not hidden by skin; caudal fin not scaled....10

10a. Scales very small, numbering >80 in lateral series; males with haped shell-shaped disk over .....**Kneriidae**
10b. Scales larger, numbering <80 in lateral series; no shell-shaped disk over operculum in males.....11

11a. Adipose fin present (except some Distichodontidae).....12
11b. Adipose fin absent (except some Distichodontidae).....14

12a. Dorsal fin origin far posterior to pelvic fin insertion..... .....**Hepsetidae**
12b. Dorsal fin origin more or less situated over pelvic fins....13

13a. Body with 16-22 vertical stripes....**Distichodontidae** (in part)
13b. Body without several vertical stripes.....**Characidae**

14a. Pelvic fin modified into thin "whisker-like" filament, half as long as standard length, and located anterior to pectoral fin origin.....**Belontiidae**
14b. Pelvic fin normal, distinctly rayed and located posterior to pectoral fin origin.....15

15a. Dorsal fin situated far back, either over or posterior to anal fin origin.....16
15b. Dorsal fin origin distinctly anterior to anal fin origin....18

16a. Anal fin origin anterior to dorsal fin origin.....**Poeciliidae**
16b. Dorsal fin origin over anal fin origin.....17

17a. Caudal fin margin rounded..... **Aplocheilidae**
17b. Caudal fin margin forked.....**Cyprinidae** (in part: Mesobola)

18a. Dorsal fin with or without a single bony spine.....19
18b. Dorsal fin with 3 or more spines.....20

19a. With ciliated scales.....**Distichodontidae** (in part)
19b. With cycloid scales.....**Cyprinidae** (most spp.)

20a. Single lateral line.....**Centrarchidae**
20b. Two lateral lines present.....21

21a. Anal fin with 3 or 4 spines.....**Cichlidae**
21b. Anal fin with 8 or more spines.....**Anabantidae**

Preliminary Key to the Species of Freshwater Fishes of Namibia

Mormyridae

1a. Mouth superior, lower jaw protruding beyond upper jaw **Marcusenius macrolepidotus**
1b. Lower jaw not protruding beyond upper jaw.....2

2a. Dorsal fin longer than anal fin.....3
2b. Dorsal fin shorter than anal fin.....4

3a. Snout blunt, prominent chin; subterminal mouth; dorsal fin about 1 1/2 times longer than anal fin.... **H. discorhynchus**
3b. Snout long, mouth terminal; dorsal fin 4-5 times longer than anal fin..... **Mormyrus lacerda**

4a. Dark vertical band situated from dorsal fin origin to just behind anal fin origin, prominent chin present **Hippopotamyrus ansorgii**
4b. No vertical bands present.....5

5a. Mouth subterminal; nostrils closely spaced; dorsal fin margin falcate; pointed caudal fin lobes...**Petrocephalus catostoma**
5b. Mouth terminal; nostrils not in close proximity; dorsal fin margin straight to rounded; rounded lobes to caudal fin and peduncle.....**Pollimyrus castelnaui**

Kneriidae

1a. **Kneria polli**
1b. **K. maydelli**

Characidae

1a. Large exposed canine-like teeth..... **Hydrocynus vittatus**
1b. No large exposed canine-like teeth.....2

2a. Dorsal, caudal and anal fins bright red; black lateral spot posterior to opercle.....**Astyanax orthodus**

2b. Fins not bright red; no lateral spot.....3

3a. Black lateral band extending through to caudal rays **Brycinus lateralis**
3b. Black lateral band not extending to form black spot on caudal rays.....4

4a. Dorsal fin origin above pelvic fin base, dorsal fin often tipped with black and orange, no dark slash of pigment at anal fin base **Micralestes acutidens**
4b. Dorsal fin origin behind pelvic fin base, no color on dorsal fin tip, dark band of pigment along anal fin base **Rhabdalestes maunensis**

Distichodontidae

1a. Pectoral fin extending past origin of pelvic fin, absence of pigment between lateral band and dorsal origin **Nannocharax macropterus**
1b. Pectoral fin not extending past origin of pelvic fin.....2

2a. Adipose fin absent.....**Hemigrammocharax machadoi**
2b. Adipose fin present.....**H. multifasciatus**

Cyprinidae

1a. Dorsal fin base 1/3 of total length.....2
1b. Dorsal fin base less than 1/3 of total length.....3

2a. One pair, or usually no maxillary barbels; lateral line scales 26-30.....**Carassius auratus**
2b. Two pair of distinct maxillary barbels; lateral line scales 35-38 (except in nearly scaleless "mirror" or "leather" carp **Cyprinus carpio**

3a. Dorsal and Anal fin origins opposite.....**Mesobola brevianalis**
3b. Dorsal fin more or less opposite pelvic fin.....4

4a. Barbels absent.....5
4b. Barbels present (excluding **B. afrovernayi** & **B. puellus**).....6

5a. Lateral line present, paired vertical bars on body .....**Opsaridium zambezense**
5b. Lateral line absent, no bars on body..**Coptostomabarbus wittei**

6a. Mouth normally subterminal, LL scales 34-44.....**Labeo** 7
6b. Mouth normally terminal, lateral line scales 22-36..... .....**Barbus**

7a. Restricted to the Orange River drainage; a pair of well defined barbels either side of the mouth.....8
7b. Indigenous to the northern drainages; a single barbel on each side of mouth, or one obscured by folds of upper lip if 2 are present 9

8a. Scales larger with 42-50 along the lateral line, and 20-22 around the caudal peduncle.....**L. capensis**
8b. Scales smaller, with 53-68 along the lateral line, and 26-34 around the caudal peduncle.....**L. umbratus**

9a. Lateral line scales 34-37; with stepped snout..**L. cylindricus**
9b. Lateral line scales greater than 37; snout not stepped....10

10a. Dorsal fin crescent shaped and twice head length; angular pre-dorsal profile; pectoral fin with black leading edge; 37-40 lateral line scales..... **L. lunatus**
10b. Dorsal fin shorter than twice head length; cylindrical pre-dorsal profile; pectoral fin without black leading edge; lateral line scales 40-44..... **L. ruddi**

11a. Scales radiately striated; dorsal fin origin anterior, over or posterior to pelvic fin origin.....12
11b. Scales longitudinally striated; dorsal fin in advance of pelvic fin origin.....33
12a. Lateral line absent..... **B. haasianus**
12b. Lateral line complete or incomplete.....13

13a. Black caudal peduncle spot underlying 2-4 scales.....14
13b. Black caudal spot if present, is small.....19

14a. Only a single lateral spot on the caudal peduncle.....15
14b. 3 or more black spots along side of body.....17

15a. Lateral line complete, barbels present.....**B. poechii**
15b. Lateral line incomplete, barbels absent 16

16a. Dorsal fin positioned distinctly posterior to pelvic fins; dorsal fin spine serrated; mouth turned up, superior like **B. afrovernayi**
16b. Dorsal fin over to slightly posterior to pelvic fins; dorsal ray simple, and not serrated; mouth terminal **B. puellus**

17a. Dorsal fin origin over or slightly in advance of pelvic fin origin; no spot at anal fin base..... **B. trimaculatus**
17b. Dorsal fin posterior to pelvic fin origin; spot at anal fin base.....18

18a. Two pair of short barbels, with the longest (posterior) being ca. 1/2 length of eye diameter; lacking chevron marks on LL scales..... **B. barotseensis**
18b. Barbels longer, with posterior pair ca. 1.5-2x the length of eye diameter; with distinct chevron marks along LL; **B. lineomaculatus**

19a. Vertical stripes along side of body..... **B. fasciolatus**
19b. No vertical stripes along side of body.....20

20a. Dorsal fin origin anterior to pelvic fin origin.....21
20b. Dorsal fin origin over or posterior to pelvic fin origin..24

21a. Barbels greatly reduced in length, black leading edge and margin to dorsal fin.....**B. radiatus**
21b. Posterior barbel length equal to eye diameter, no black leading edge to dorsal fin.....22

22a. Lateral line scale count high (29-37), anterior barbel length about equal to eye diameter, without anal spot **B. unitaeniatus**
22b. Lateral line scale count low (25-30), anterior barbel less than eye diameter, with anal spot.....23

23a. Typically with thin black lateral band ending as a small distinctive spot on caudal peduncle; band extends forward onto snout to maxillary where color diffuses sharply; slender body; posterior barbels 1 to 1.5 eye diameter **B. thamalakanensis**

23b. Broad black lateral band extending onto snout and maxillary; posterior barbels 0.5 to 0.75 of eye diameter; thicker body **B. annectens**

24a. Dorsal fin origin far back, posterior to pelvic fin insertion.....25

24b. Dorsal fin origin above or slightly posterior to pelvic fin origin 26
(NOTE: need assistance for **B. breviceps, B. dorsolineatus**)

25a. Lateral line scales 37-39; extended dorsal fin forming 60° angle with dorsum; Orange River only.....**B. hospes**

25b. Lateral line scales 30-38; extended dorsal fin forms 90° angle with dorsum; ubiquitous distribution....**B. paludinosus**

26a. Long concave-shaped snout; serrated last simple ray of dorsal fin.....**B. mattozi**

26b. Snout not concave shaped; last simple ray of dorsal fin not serrated.....27

27a. Body with mid-lateral band 28

27b. Body without mid-lateral band ..... **B. manicensis**
(this species known from upper Zambezi, but not yet recorded in Namibia)

28a. Black lateral stripes above mid-lateral band, which carries onto caudal fin in live specimens (may be indistinct in preserved specimens)..... **B. multilineatus**

28b. No stripes above mid-lateral band.....29

29a. Barbels extremely short, with anteriors ones sometimes absent.....30

29b. Two pairs of developed barbels.....31

30a. Lateral line scales 33-37; no black pigmentation at base of anal fin; pre-dorsal fin ridge with out black "pepper" spots ..... **B. anoplus**

30b. Lateral line scales 29-33; black pigmentation at base on anal fin; pre-dorsal fin ridge often punctuated with black spots .....**B. barnardi**

31a. Deeply pigmented lateral line pores dipping below and then coming back to join mid-lateral band, giving appearance of 2 stripes.....32

31b. No appearance of 2 stripes.....33

32a. Mid-lateral stripe runs from snout, through eye to caudal peduncle..... **B. bifrenatus**

32b. Mid-lateral stripe runs from behind opercle to caudal **B. viviparus**

33a. Chubby body, sometimes lateral stripe wavy, extending from snout to caudal peduncle, 24-28 scales along lateral line.....**B. eutaenia**
33b. Deep body, black lateral stripe starts behind gill cover and ends on caudal peduncle, 22-24 scales along lateral line, red spot on opercle..**B. kerstenii = B. tangandensis?**

34a. Lateral line scales 29-32; dorsal fin origin in advance of pelvic fin origin.....**B. codringtonii**
34b. Lateral line scales 36-45; dorsal fin origin posterior to pelvic fin origin.....35

35a. Mouth small, sub-terminal; distance from the eye to the pre-opercular groove less than snout length.....**B. aeneus**
35b. Mouth large, terminal; distance from eye to pre-opercular groove equal or greater than snout length..**B. kimberleyensis**

Siluriformes

1a. Second dorsal or adipose fin nearly as long as first dorsal fin **(known from U. Zambezi??) Heterobranchus longifilis**
1b. Lacking second dorsal or adipose fin or much smaller in size than first dorsal.....2

2a. Dorsal fin long (≥ 1/3 of body length) and without spines .....**Clariidae** 6
2b. Dorsal fin short or absent, with or without spines.....3

3a. Anal fin base almost 1/2 of total length...**Shilbe intermedius**
3b. Anal fin base short.....4

4a. Dorsal, pectoral fins lacking spines....**Amphilius uranoscopus**
4b. Dorsal and pectoral fins with spines.....5

5a. Mouth with unbranched barbels 12
5b. Mouth with branched barbels.....17

6a. Broad, almost triangular-shaped head nearly as wide as it is broad.....**Clariallabes platyprosopos**
6b. Head not broad or triangular shaped.....7

7a. Skin devoid of pigment; eyes degenerate...**Clarias cavernicola**
7b. Skin not devoid of pigment; eyes not degenerate.....8

8a. Small catfish with thin, cylindrical body and extremely short head 1/5 to 1/6 of total length (TL); maxillary barbels about equal to head length.....**Clarius theodorae**
8b. Adults small or large, but with head 1/4 to 1/3 of TL....9

9a. Body distinctively blotched in colouration, with white lateral line; 4 pairs of barbels, none which exceed 2/3 of head length.....**C. stappersii**
9B. Body variable coloured, but lacking white lateral stripe; maxillary barbels exceeding head in length.....10

10a. Small catfish, maximum size about 18 cm total length, maxillary barbels reaching end of pectoral fin..... .....**C. liocephalus**

10b. Large adult catfish, maxillary barbels not reaching end of pectoral fin.....11

11a. Adipose fin present or rudimentary; two bands of maxillary teeth, with posterior band forming a half-moon ..... **C. ngamensis**
11b. Adipose fin absent; posterior band of maxillary teeth forming a "V", with apex pointed anterior.....**C. gariepinus**

12a. Inferior sucker-like mouth.....13
12b. Mouth not inferior or sucker-like.....14

13a. **Chiloglanis fasciatus**
13b. **C. neumanni**

14a. Four pairs of circum-oral barbels; restricted to the Orange River drainage in the south.....**Austroglanis sclateri**
14b. Three pairs of circum-oral barbels; restricted to the northern rivers.....15

15a. Elongated head, with eyes somewhat laterally on flattened snout; elongated nares lying side-by-side, about half-way between eyes and tip of snout; all barbels point forward.....**Parauchenoglanis ngamensis**
15b. Short head, width about equal to length, eyes located dorsally; nares pore-like, one nearly touching eye; barbels point to the side or to the rear.....16

16a. Caudal fin truncate; indistinct brown bar running through caudal fin .....**Leptoglanis dorae**
16b. Caudal fin forked; dark blotch on caudal peduncle, vertical stripe on caudal fin.....**L. rotundiceps**

17a. **Synodontis**
17b. (Skelton & White)

Poeciliidae

1a. Anal fin of males modified into a copulatory gonopodium; introduced to Namibia.....2
1b. Anal fin of males not modified into gonopodium; native...3

2a. Ventral rays of caudal fin of females much longer than other rays, giving the appearance of elongated point..... .....**Xiphophorus helleri**
2b. Ventral rays of caudal fin of female not modified into an elongated point.....**Poecilia reticulata**

3a. Dorsal fin situated far behind anal fin origin; slender body; 18-20 scales around body just anterior to ventral fins,..... .....**Aplocheilichthys johnstoni**
3b. Dorsal fin situated just posterior to anal fin origin.....4

4a. Dark lateral band present below midline of body...**A. katangae**
4b. Dark lateral band absent.....5

5a. .....**A. hutereaui**
5b. .....**A. macrurus**

Cichlidae

1a. Small species; with 2 enlarged (but **not** large) canine teeth present in upper jaw, lateral bands and vertical stripes forming distinct H markings.....**Hemichromis elongatus**
1b. Small and large species without canine teeth.....2

2a. Small species, double-knob shaped gill rakers short and stout numbering 2-10 on lower arch.....**Pharyngochromis acuticeps**
2b. Variable characters, but gill rakers not double-knob shaped.....3

3a. Small species, rounded caudal fin and small concavity on snout; 27-30 scales along lateral line, with incomplete pores..... **Pseudocrenilabrus philander**
3b. Small or large species, rounded or truncate caudal fin, no concavity on snout.....4

4a. With very small scales along sides and abdomen, numbering ????? in the lateral series; abdomen with bilateral scaleless patches; Kunene R. only.....**Orthochromis machadoi**
4b. Scales latrge on ventro-lateral aspects of body; abdomen completely scaled.....5

5a. Abrupt change in size of small abdominal scales, and larger ventro-lateral scales; greatly thickened, often lobate lips; Kunene R. only.....**Thoracochromis albolabris**
5b. Gradual change in size of smaller abdominal scales and larger ventro-lateral scales; lips normal, and never lobate.....6

4a. Gills rakers slender, numbering less than 15 on lower anterior arch; mouth small; juveniles with "tilapia" mark on soft dorsal..... **Tilapia** 5
4b. Gill rakers thick or stout (excluding **S. angusticeps**); mouth large or small.....7

5a. Rounded caudal fin, dorsum and abdomen form snout near mid-line of body, vertical bands on caudal fin.....**T..ruweti**
5b. Caudal fin not rounded.....6

6a. 5-6 vertical bands alternating thick and thin; orange anal fin, abdomen and pelvic fins without black pigment **T. rendalli**
6b. 8-8 vertical bands parallel and consistent in width; anal fin without orange color; abdomen and pelvic fin with black pigment **T. sparrmanii**

7a. 20-25 gill rakers on lower anterior arch..... **Oreochromis** 8
7b. Gill rakers fewer in number.....**Serranochromis** 10

8a. Head with steep and rounded profile; without 3 lateral spots, but with numerous black spots on dark green head; abdomen with pigmentation.....**O. macrochir**
8b. Head with straight profile; often with 3 spots on side; head not dark green, and lacks black spots; abdomen without pigmentation.....9

9a. Gill rakers 16-20 on lower portion of anterior arch..... .....**O. mossambicus**
9b. Gill rakers 20-25 on lower part of arch.....**O. andersonii**

10a. Body depth about .5 standard length; LL count 28-34.....11
10b. Body depth less than .5 of standard length; LL scale count 35-41.....13

11a. Concave snout; rounded caudal fin.....**S. carlottae**
11b. Snout not concave; caudal fin emarginate to truncate....12

12a. Snout straight with slender head profile..**S. codringtonii**
12b. Snout rounded with rounded, heavy head.....**S. giardi**

13a. Snout upturned.....14
13b. Snout not turned up 15

14a. Speckling on mouth, cheek, opercle and abdomen **S. angusticeps**
14b. Abdomen without speckling.....**S. altus**

15a. Body darkly mottled brown and white, long pectoral fin, 33-40% of standard length.....**S. longimanus**
15b. Body without mottling, pectoral fins less than 30% of standard length.....16

16a. Adults without red margin to dorsal fin; 3 to 4 rows of teeth in upper jaw; lateral line scales 38-41.**S. thumbergi**
16b. Adults with red margin to dorsal fin; 2 rows of teeth in upper jaw; lateral line scales 34-39.....17

17a. Lateral line scales 34-37; a single dark lateral band; juveniles with up to 7 vertical and mottled bands .....**S. macrocephalus**
17b. Lateral line scales 36-39; two dark lateral bands .....**S. robustus**

(NOTE: need to include **Chetia**, **Orthochromis**, **T. guinasana**, **Thoracochromis** spp.)

Anabantidae

1a. Pectoral fin rays greatly elongated into filaments longer than total body depth.....**Trichogaster trichopterus**
1b. Pectoral fins not elongated, but rounded, being shorter than body depth.....2

2a. Posterior edge of both dorsal and anal fins pointed; black spot at base of caudal fin, black lines radiating from eye.....**Ctenopoma intermedium**
2b. Posterior edge of both dorsal and anal fins rounded; no black spot at base of caudal fin; no black lines radiating from eye.....**C. multispinus**

Mastacembelidae

1a. 29-32 spines along dorsal surface, snout elongated in the form of mental appendage projecting way past lower jaw **Aethiomastacembelus frenatus**
1b. 22-27 spines along dorsal surface, snout elongated **A. vanderwaali**

Other Monotypic families in Namibia (see family key)

Anguilla bengalensis labiata
Hepsetus odoe
Austroglanis sclateri
Micropterus salmoides - introduced
Nothobranchius sp.