AN ABSTRACT OF THE THESIS OF

BENNY WANJALA for the degree of MASTER OF SCIENCE

in FISHERIES presented on February 9, 1978

Title: THE ASSOCIATION AND DISTRIBUTION OF FISH SPECIES IN NYANZA GULF, LAKE VICTORIA, EAST AFRICA, 1975.

Abstract approved: Redacted for Privacy

James D. Hall

A trawling survey was conducted on Nyanza Gulf, Lake Victoria, East Africa during March-December 1975 to investigate association and distribution of the major fish species and to provide information for management of the fishery. A total of 139 sites was sampled and all fishes caught were counted, measured, and weighed. At each site, depth, bottom type (substratum), offshore distance, season, and time of day were recorded.

Species association and patterns of occurrence were investigated by the Bray-Curtis clustering strategy and interrelationships between species and environmental data were analyzed by canonical correlation. Patterns of the trawl data suggested that fish species responded to variation in physical features of the Gulf and time of sampling. These environmental factors showed significant associations with species breeding and feeding habits. Depth seemed to be the most important factor in species distribution and had a positive correlation with substrate coarseness.

Although the Gulf could be divided into three geographical areas (Uyoma-Naya, Homa, and Winam) according to physical features, statistical analyses showed two rather distinct patterns of ichthyomass; one at Uyoma-Naya dominated by *Tilapia nilotica*, *Tilapia variabilis*, *Lates albertianus*, and *Clarias mossambicus*; and the other at Homa-Winam dominated by *Haplochromis* spp., *Bagrus docmac*, *Protopterus aethiopicus* and *Clarias mossambicus*.

As little is known about species life histories, management strategies may be based upon ichthyomass patterns instead. On the Gulf, there is too much fishing effort to make it practical to sample the entire catch for purposes of assessing the effect of different gears and regulations on the fishery. However, if sufficiently small exploratory 'fishery windows' are established in each of the major localized ichthyomass areas, management policies could be developed experimentally without destroying the assemblages. A tentative exploratory management program is suggested based on the identified ichthyomass patterns, and both direct and indirect management strategies are proposed.

The Association and Distribution of Fish Species in Nyanza Gulf, Lake Victoria, East Africa, 1975

by

Benny Wanjala

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1978

APPROVED:

Redacted for Privacy

Associate Professor of Fisheries
in charge of major

Redacted for Privacy

Head of Department of Fisheries & Wildlife

Redacted for Privacy

Dean of Graduate School

Date thesis is presented FEBRUARY 9, 1978

Typed by THE COPY SHOP for BENNY WANJALA

ACKNOWLEDGEMENTS

I am deeply indebted to the East African Freshwater Fisheries Research Organization (EAFFRO) who financed, provided equipment and personnel for the study; and Dr. O. O. Okorie who supervised the project. My course of study in the United States was supported by the Agency for International Development through the National Oceanic and Atmospheric Administration. Mr. Frederick J. Laney of that organization was particularly helpful.

I gratefully acknowledge the guidance and patience of my major professor, Dr. J. D. Hall who encouraged and arranged facilities for data analysis, and helped in criticizing the manuscript. My thanks are also due to Dr. A. Tyler for his counsel and suggestions throughout the course of data analysis. Their comments and criticisms were helpful in re-writing and interpreting the final results.

I am very grateful to Ms. D. Worden and Mr. B. Kirkham who assisted in programming and executing some computer programs. Their efforts saved many hours of work.

My special thanks are due to Mr. Mike Murphy who spent many hours with me discussing the project. Many of the ideas presented in this thesis were developed in discussions with Mike, Drs. D. McIntire and M. Richardson, Mr. K. Howe, EAFFRO staff of 1975, and several colleagues at Oregon State University.

Acknowledgements are also due to my parents, Ndugu Esinasi and Yona Nambago; and my roommate, Citoyen M. Tshibuabua for their understanding, material and moral support during the course of thesis writing.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF ILLUSTRATIONS

THE ASSOCIATION AND DISTRIBUTION OF FISH SPECIES IN NYANZA GULF, LAKE VICTORIA, EAST AFRICA, 1975

INTRODUCTION

Lake Victoria, like the other ancient lakes of East Africa (Malawi and Tanganyika), is inhabited by about 200 endemic fishes whose abundance and distribution have affected the importance of the fishery and economy of fishermen. Although the lake developed as a series of lakes during the Miocene era, the present lake developed during mid-Pleistocene era when the tremendous tectonic movements that formed the great East African Rift Valley system uplifted the eastern and western scarps and ponded the westward flowing rivers (Figure 1); Pritchard 1962; Kendall 1969; Fryer and Iles 1972). Therefore, the endemic fish fauna largely represents the various levels of success attained in adapting to the lacustrine environment (Brooks 1950; Greenwood 1951; Whitehead 1962).

In addition to the endemic species, *Tilapia nilotica*, *Tilapia zillii*, *Tilapia leucosticta*, *Tilapia melanopleura*, and *Lates albertianus* were introduced into the lake from 1951 to 1962 to augment the fishery (Fryer 1959; Welcomme 1964, 1966, 1967). *T. nilotica* and *L. albertianus* have since become important in the fishery. All of the endemic species subjected to fishing, except the large piscivores have declined. Apart from the basic biology of the ichthyofauna, very little is known about the distribution, abundance, and

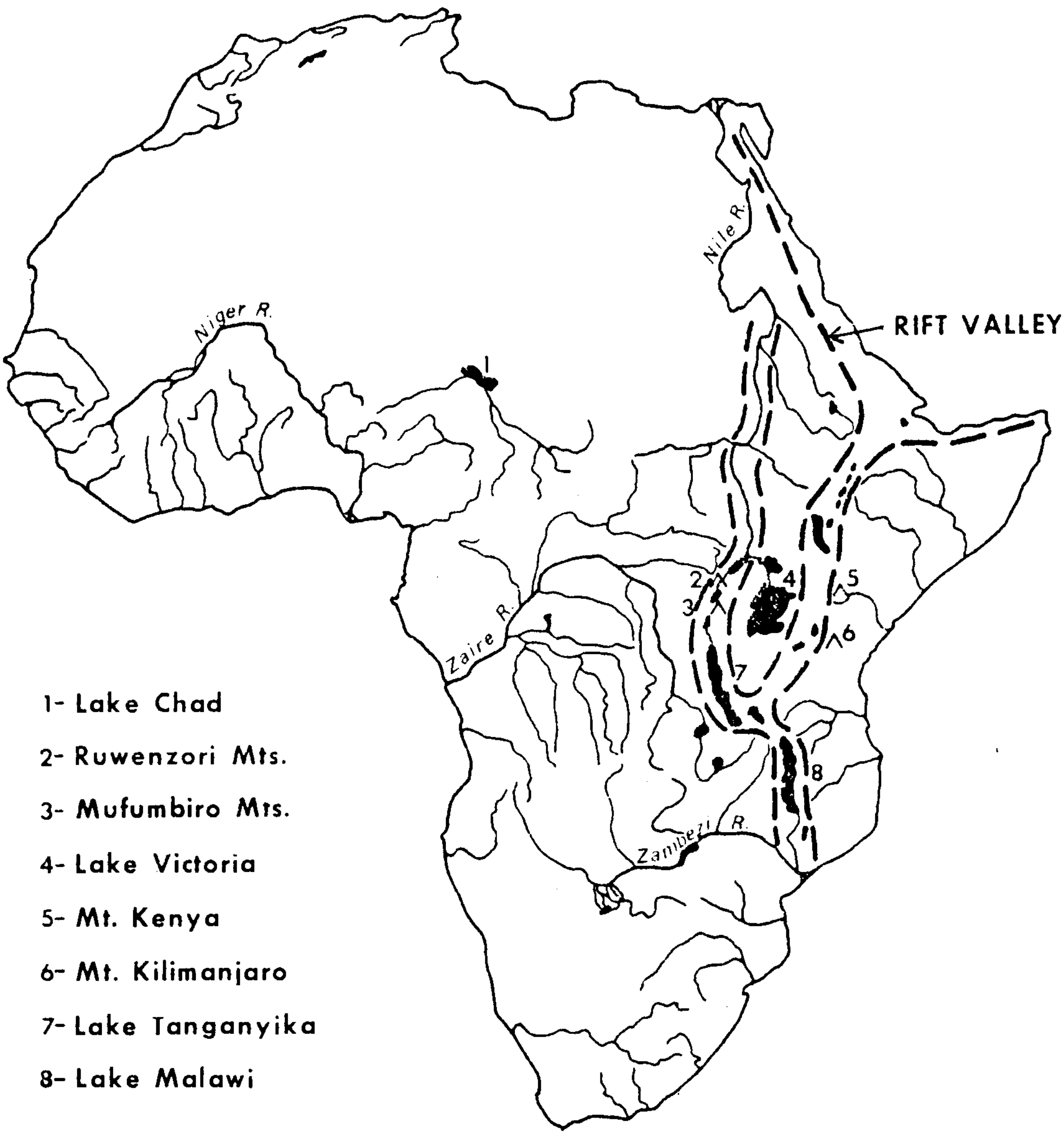

Figure 1. Drainage systems in Africa during mid-Pleistocene.

associations of the fishes inhabitating the lake (EAFFRO 1967).

Inasmuch as the fishery has undergone changes in recent years, the need for ecological information has become acute. Therefore, in 1969-1971 and 1975, sampling programs were undertaken in the Nyanza Gulf by the East African Freshwater Fisheries Research Organization (EAFFRO) to obtain information for management of the fishery.

This study presents an analysis of the data collected during the 1975 trawling program and reports on the distribution, abundance, and habitat associations of the major fish species in Nyanza Gulf, Lake Victoria.

Past and Present of the Nyanza Gulf fishery

The Nyanza Gulf fishery, established in 1905, has changed considerably during recent years. *Tilapia esculenta*, previously the fish of greatest commercial importance, has declined since 1960, when it accounted for about 92 percent of the total yield, to only 3 percent during 1973 (Garrod 1960, 1961; Wanjala and Marten 1974). During the past decade, most endemic species, particularly the adfluvial ones (*Alestes baremose*, *Barbus altianalis*, *Labeo victorianus*, *Mormyrus kannume*, and *Schilbe mystus* have declined drastically (Cadwalladr 1965). While yields of most endemic target species have declined, those of Haplochromis spp., Bargrus docmac, Clarias mossambicus, and Protopterus aethiopicus have either remained the same or increased slightly (Marten 1975). Of the introduced species (Tilapia nilotica, T. leucosticta, T. melanopleura T. zillii, and Lates albertianus), T. nilotica and L. albertianus accounted for 2.2 and 1.3 percent respectively of the total yield from the Gulf during 1975, but the other introduced species were not yet established in commercial quantities.

During the period 1905-1973, fishing effort increased tremendously. The Gulf was fished by 150 licensed canoes with 5-inch mesh gill nets in 1918; 331 canoes in 1954; 2,853 canoes and 157 seines in 1966; and 2,000 canoes and 532 seines in 1973. The number of gill nets per canoe increased from 10 to about 100 during the same period (Graham 1929; Garrod 1957, 1960; Marten 1975). During the past fifteen years, gill net mesh size decreased to 1½ and 1 $\frac{7}{8}$ inches, and in 1951, beach and 'mosquito' seines were introduced to exploit Synodontis, Haplochromis, and Engraulicypris.

From the onset of organized commercial fishing, the fishery was based on T. esculenta and T. variabilis but the decreasing quantities of these species with time have forced fishermen to turn to the other species originally regarded as 'trash'. The fishery on the Gulf is an active means of livelihood and basis of commerce and trade for hundreds of thousands of people in Nyanza Province (Ominde 1971).

Although changes in the fishery have been attributed primarily to fishing or introductions of species, changes in the environment may also affect populations of fish in the Gulf depending on the ecological attributes (habitat requirements and diet) of particular species (Table 1). Drastic seasonal changes in rivers have frequently interrupted breeding of adfluvial species (Van Someren 1961). A rise in water level, which began with the floods of 1961 and reached a peak of 1.4m above average in 1964, drowned the sandy habitat of *T. esculenta* and other shallow water brooding species, but favored *P. aethiopicus*, *C. mossambicus*, *L. albertianus*, *T. nilotica*, *T. zillii* and *Haplochromis* spp. (Temple 1966).

Numerically, cichlids (*Haplochromis* spp. in particular) are the most successful fishes in the Gulf. Their abundance may be attributed to their fast turnover, versatile feeding habits, and adaptation to the lacustrine environment. Future of the fishery on Nyanza Gulf will depend largely on fishing activities, ecology of the target and associated species, and magnitude of environmental changes.

Table 1. Biological data of the principal fish species in Nyanza Gulf, Lake Victoria, East Africa, 1975 (data from various sources: Lowe-McConnel 1959; Greenwood 1966; Fryer and Iles 1972).

Species	Family	Longevity (years)	Breeding Habitat	Main diet	Notes
Protopterus aethiopicus	Lepidosirenidae	16	Papyrus swamps	Molluscs and fish	Large size
Mormyrus kannume	Mormyridae	4-8	stream or exposed rocky shores	Insect larvae	
Labeo victorianus	Cyprinidae	4-8	Streams or rivers	Detritus and awfuchs	adfluvial
Barbus altianalis	"	4-8	Streams or rivers	Insect larvae, small fishes and molluscs.	"
Alestes baremose	"	3	Streams, rivers or swamps	Insect larvae	"
Engraulicypris argenteus	"	3	"	"	"
Synodontis victoriae	Mochokidae	3	Rocky areas	Insect larvae and molluscs	
S. afrofischeri	"	3	"	"	
Schilbe mystus	Schilbeidae	3	Rivers and exposed shores	Haplochromis and insect larvae	
Clarias mossambicus	Claridae	up to 10	Plant debris, swamps, rivers and rocky areas	Omnivorous (insect, molluscs and plants)	Large size
Bagrus docmac	Bagridae	up to 16	Exposed rocky shore	Haplochromis juvenile fishes and crustacea	Large size
*Lates albertianus	Centropomidae	up to 10	shallow, calm bays	Fish	Large size
*Tilapia zillii	Cichlidae	4-8	Substratum-brooder	Macrophytes	
*T. leucosticta	"	4-8	mouth-brooder	Detritus and Phytoplanktons	
T. esculenta	"	4-8	mouth-brooder	Phytoplanktons	
T. variabilis	"	4-8	mouth-brooder	Phytoplanktons, algae and detritus	
*T. nilotica	"	4-8	mouth-brooder	Omnivorous	
Haplochromis spp.	"	3	mouth-brooder	Various	

*Introduced

Description of the Study Area

The Nyanza Gulf (lat. 0°04'S to 0°32'S; long. 34°13'E to 34°52'E) is a bay on the eastern side of Lake Victoria at an altitude of 1,134 m above sea level. It extends 60 km into the Nyanza Province of Kenya (Figure 2). The Gulf covers an area of approximately 1,920 km^2, with a mean depth of 6 m and an average secchi disc reading of 1.0-1.5 m. Although at its widest the Gulf reaches 30 km, it is joined to the lake by a strait only 6 km across. The bottom consists of mud, sand, gravel, or rock. The northern shore is generally rocky and precipitous, but the southern shore is flat and swampy. The Nyando and Sondu rivers draining the western slopes of the Mau range provide the major water inputs besides direct rainfall, but subsidiary inflows also come from the lesser rivers flowing from the Nandi and Kissi Highlands.

The Gulf developed on a mid-Pleistocene lacustrine bed and was possibly detached from Lake Victoria, in which case it later joined the lake through vulcanism, faulting, and tilting (Saggerson 1952; Cooke 1958; Temple 1966).

The equatorial location provides the Gulf with a relatively constant climate. Day length is constant at 12 hours and mean annual air temperature is about 22-24°C. The Gulf may show a pronounced thermocline in the morning, but it breaks down in the early afternoon (Melack 1975).

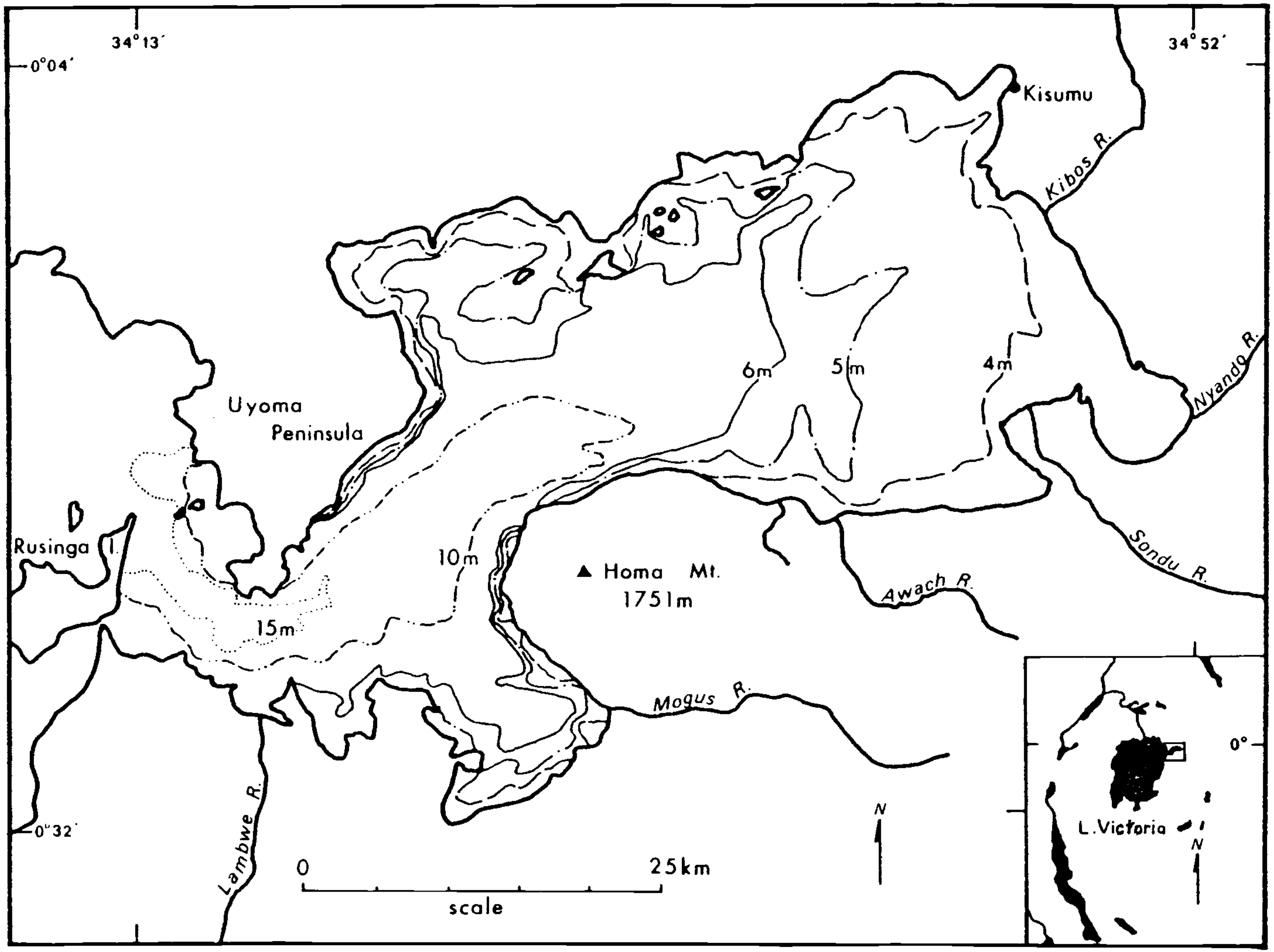

Figure 2. Physical features of the Nyanza Gulf, Lake Victoria, East Africa.

The heat budget is about 9,000 cals/cm^2 daily and the annual evaporation is about 200-220 cm (Ominde 1971). Rainfall shows two peaks soon after the equinoxes, and pronounced dry seasons occur during January-February and June-August.

MATERIALS AND METHODS

Sampling Procedures

Extensive trawling was conducted on a monthly basis during the period March-December 1975 with a 180-hp boat, the 'Ibis', and covered 139 sites (Figure 3). The vessel is 17.2 m long, has a 4.9 m beam, a 2.4 m draft, and displaces about 75 metric tons of water. The otter trawl used was 24 m long, 2.3 m deep, and 9.0 m wide at the mouth. It was set and retrieved by a 2-ton capacity hydraulic winch operated at the stern. The cod-end mesh used was 19 mm, but occasionally a second net with a 10-mm mesh liner was alternately fished with the other net to check for the amount of smaller species and juveniles escaping (Ellis 1963). Each tow was a 5.6-km, one hour bottom haul made at a speed of 3 knots in areas deeper than 4 m. All species were assumed equally liable to capture by trawling at that speed and about 75 percent of the fishes encountered were retained (Capt. Mukasa, personal communication 1975).

Three different areas were recognized during the survey (Figure 3): 1) Uyoma-Naya, a transition zone between the Gulf and the Lake, experienced strong alternate tidal currents from both water bodies and had rocky outcrops in the predominantly gravelly bottom; 2) Homa

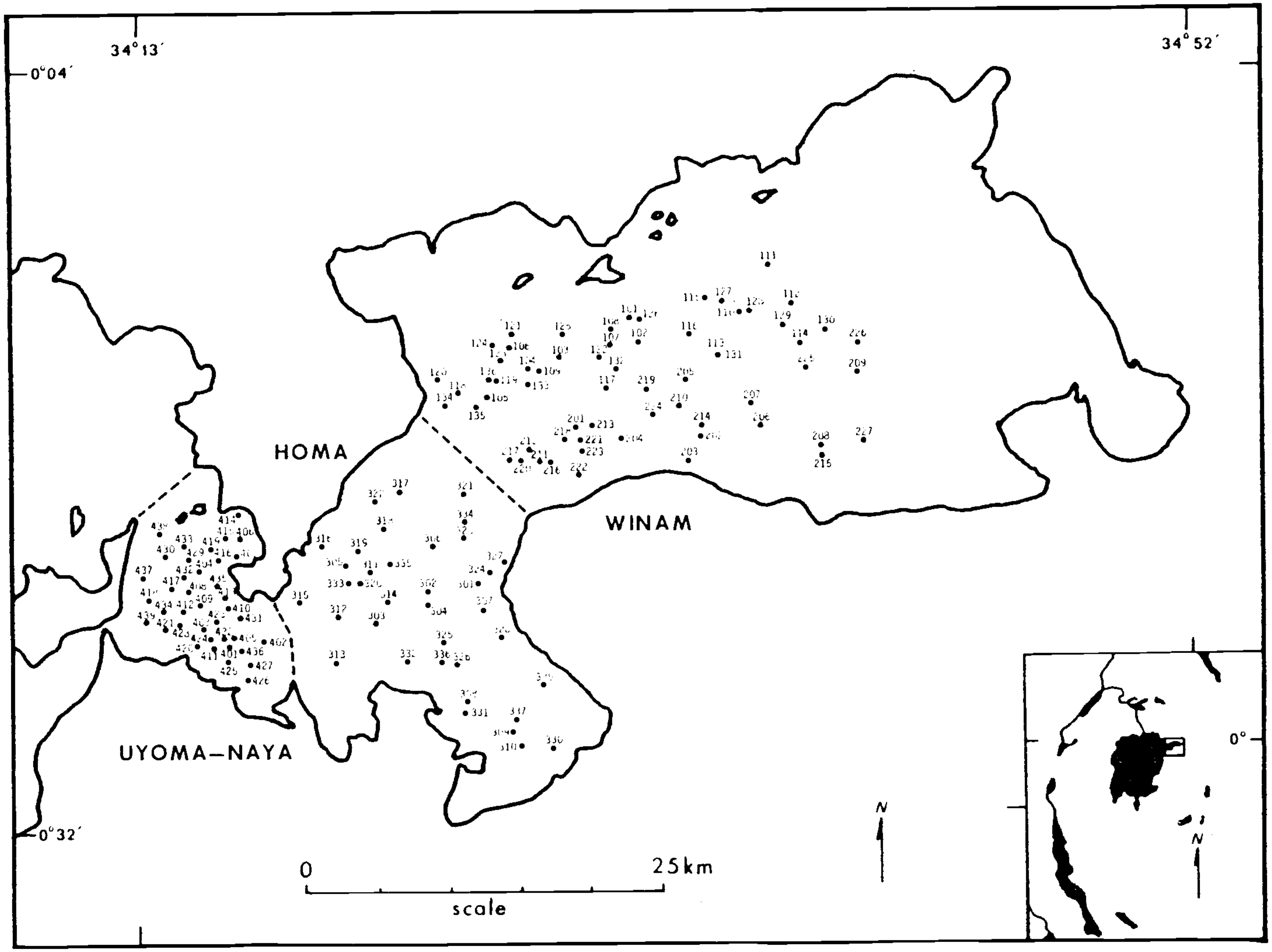

Figure 3. Location of exploratory trawling sites in Nyanza Gulf during 1975.

Basin had relatively calm water coves, swampy shores to the south, rocky outcrops at the northern fringes, and mostly muddy bottom; and 3) Winam, a relatively shallow section ($\leq$ 8 m), had several extensive bays, large rivers, numerous sandy beaches, and muddy or sandy bottom.

Hauls were randomly taken in each area and courses were located by grid coordinates at the end of each tow. We made single representative tows for each course because, repeated tows along the same transect at a particular time over a period of 24 and 48 hours did not give significant differences in catches (Cordone and Kudhongonia 1972). Trawling depth was controlled by varying the lengths of the towing warps as different depths were encountered. Depth of the course was recorded as the average for the whole course from the traces of an echo-sounder. Bottom type (substratum) was recorded as flocculent mud, firm mud, sand, gravel, or rock as found on the cod-end and otter boards. Offshore distance was estimated as the average distance from both ends and middle of the course to the nearest shoreline. Tows were made during the heavy rains (March-May), dry season (July-August), transition from dry to wet (September), and light rains (November-December) to include variability caused by seasons (rainfall). Also, tows were scheduled at different times of the day (24 hours) to include variability due to different light intensities.

From each haul, fishes caught were identified, counted, weighed and their stomach contents examined. A total of 41.5 metric tons of fish was caught during the 9-month study period.

Data Analysis

Data consisted of numbers and biomass of all fish species caught, measurements of depth in meters, offshore distance in kilometers, bottom types (substratum) coded 1-5 (i.e., (1) flocculent mud, (2) firm mud, (3) sand, (4) gravel, and (5) rock); season coded 1-4 (i.e. (1) dry, (2) transition period, (3) light rain, and (4) heavy rain); and time of day coded 1-5 to correspond with general light intensity from darkest to brightest (i.e., (1) 2400-0500 hours, (2) 1900-2400 hours, (3) 1600-1900 hours, (4) 0500-0900 hours, and (5) 0900-1600 hours).

Species associations and patterns of occurrence were analyzed by the Bray-Curtis clustering strategy (Richardson 1976) and interrelationships between species and environmental data were analyzed by canonical correlation (Cooley and Lohnes 1971). To identify possible associations among species, I transformed standardized species data according to $y=\log_{10}(x+1)$, as catch per haul exhibited a skewed distribution (see Table 2), where x is the biomass of individuals of a particular taxon in a sample. Without standardization, the Bray-Curtis strategy would group species together based on overall abundance which provides little ecological information. The method assumes normal distrubution; log transformation appreciably improved symmetry of the distributions (Table 2). I then used a computer program MCRLIB (Richardson 1976) for further analysis. Bray-Curtis dissimilarity coefficients between all possible pairs of the 15 fish species were given by

$$S_{1,2} = \frac{\sum_{1}^{n} \left| x_{1j} - x_{2j} \right|}{\sum_{1}^{n} (x_{1j} + x_{2j})}$$

where $S_{1,2}$ represents a dissimilarity measure between species 1 and 2; x_{1j} and x_{2j} are the respective biomass of species 1 and 2 at site j; and n is the total number of sites (139). A trellis-table of Bray-Curtis dissimilarity coefficients between all possible species pairs was constructed. Values are constrained between 0 and 1 where 0 represents perfect similarity and 1 complete dissimilarity.

To identify possible associations among sites and examine species data for patterns of occurrence, I used species log transformed data and Program MCRLIB (Richardson 1976). Data were not standardized in this case, because the absolute abundance of each species was an important criterion for cluster formation. Bray-Curtis dissimilarity coefficients between all possible pairs of the 139 sites were given by

$$B_{1,2} = \frac{\sum_{1}^{n} \left| x_{1j} - x_{2j} \right|}{\sum_{1}^{n} (x_{1j} + x_{2j})}$$

where $B_{1,2}$ represents a dissimilarity measure between site 1 and 2; x_{1j} and x_{2j} are the respective biomass of individuals of the j^{th} species at site 1 and 2; and n is the total number of species caught at the two sites (15). With the calculated Bray-Curtis dissimilarity coefficients, I grouped sites in a hierarchical order (dendrogram) by the group average fusion strategy (Sokal and Sneath 1963; Clifford and Stephenson 1975) to show the closeness or distinctness of their ichthyomass patterns. Sites with mutually lowest dissimilarity coefficients or conversely highest similarity coefficients) were selected to form the initial pairs (clusters), which were dispersed according to the dissimilarity between them. For the second and subsequent clustering cycles, new members were added to the established clusters if their inclusion did not produce an average correlation between the new member(s) and the established cluster lower than the previous level of junction by more than the established criterion (0.03) (Sokal and Michener 1958). I used a Bray-Curtis dissimilarity value of 0.4 as break point for clusters on the produced site dendrogram. After examining all the clusters included within the level, I decided to confine discussion of results to those clusters containing at least four sites.

To determine the major species constituting each cluster, I compared the species means in each cluster with the overall mean for the Gulf. As most species were encountered in almost all the clusters, it was necessary to identify the clusters or groups of clusters to which the principal species best belong. Also, as it was necessary to identify patterns in cluster variation based on the configuration of their species composition, I subjected the 6 major clusters to stepwise discriminant analysis (Program BMDØ7M). The method is explained in Sampson (1972) and Dixon and Jennrich (1973).

To determine the relationship between species and environmental data, I used canonical correlation analysis, computer program CANON (Cooley and Lohness 1971). Species biomass and environmental data measured concurrently at all 139 sites were standardized ($\bar{x} = 0$, $s = 1$) and axes representing standardized variables were centered so that they all passed through a common origin. The two sets of data were then compared to show the extent to which sites occupied the same relative positions in the two coordinate spaces.

A derivation of the canonical correlation analysis may be found in Anderson (1958, Chapter 12); and Cooley and Lohnes (1971, Chapter 6).

Since two of the environmental measures (substrate and time) were measured on an ordinal rather than equal interval scale, one assumption of parametric correlation analysis was not met. However, use of the canonical correlation analysis was felt justified in this exploratory study. A comparison was made with the sample correlation analysis (see Table 12) by computing the non-parametric rank correlation coefficients (Spearman r_s). In all cases, the non-parametric measure was very similar to the parametric r.

RESULTS AND INTERPRETATION

Occurrence of the major fish species

The relative composition of trawl catches (Table 2) was generally similar to the composition of commercial catches (Table 3). The species that were abundant in trawl samples were also abundant in commercial catches and those that were scarce in samples were also scarce in commercial catches.

The distribution of species in the Uyoma-Naya, Homa, and Winam areas of the Gulf showed significant contrast (Figure 4). Haplochromis was the most abundant taxon, accounting for 43.5, 60.8, and 55.8 percent of the ichthyomass in samples from Uyoma-Naya, Homa, and Winam respectively. Haplochromis spp. also contributed about 50 percent of the total recorded yield in 1975 (Table 3). The second most abundant species in the trawl catch was B. docmac, but it was fourth in rank of commercial importance after Haplochromis spp., P. aethiopicus and C. mossambicus. Its abundance showed a pattern similar to that of Haplochromis spp. Catches of C. mossambicus and L. albertianus were greatest at Uyoma-Naya but low in both Homa and Winam areas; P. aethiopicus showed the opposite trend. Catches of T. nilotica, T. variabilis, and S. victoriae were also greatest at Uyoma-Naya, but scarce

Table 2. Acronyms, frequency of occurrence, mean weight and biomass per haul, and skewness of biomass distribution over sites of fish species caught during exploratory trawling in Nyanza Gulf, 1975.

Species Name	Acronym	Frequency of occurrence	Mean weight (g)	Mean biomass per haul (kg)	Species skewness per haul before transformation	After trans-formation
Haplochromis spp.	HAPL	ubiquitious	11.7	164.75	3.2	0.7
T. nilotica	NILO	Common	671.9	17.78	1.8	1.0
L. albertianus	LATE	Common	5,631.7	16.48	2.8	0.8
C. mossambicus	CLAR	Common	1,780.5	16.19	2.6	-0.1
B. docmac	BAGR	ubiquitious	904.6	52.15	1.0	0
P. aethiopicus	PROT	Common	4,784.0	27.24	2.3	0
T. variabilis	VARI	Common	187.2	2.19	3.2	1.9
S. victoriae	SYNO	Common	40.6	.69	4.6	2.3
B. altianalis	BARB	Rare	65.1	.04	7.2	6.0
S. mystus	SCHL	Scarce	45.5	.30	3.3	2.6
M. kannume	MORM	Rare	121.3	.08	5.5	4.8
T. esculenta	ESCU	Rare	117.5	.03	6.0	5.1
T. zillii	ZILL	Rare	103.2	.02	7.0	6.9
T. leucosticta	LEUC	Rare	110.1	.01	11.7	11.6
L. victorianus	LABE	Rare	45.8	.01	5.9	5.7

Table 3. Commercial catches (Kilograms) of fish species in Nyanza Gulf, 1969-1975 (minor amounts of very small species not included)

	1969	1970	1971	1972	1973	1974	1975
Haplochromis spp.	297,026	204,266	190,105	287,885	327,218	473,362	476,412
T. nilotica	4,439	10,357	10,591	14,655	19,705	20,855	20,713
L. albertianus	707	1,945	4,819	3,444	7,920	10,258	12,442
C. mossambicus	65,986	78,073	81,732	98,622	138,621	106,310	113,227
B. docmac	48,220	51,708	57,111	51,919	56,226	53,288	62,135
P. aethiopicus	81,018	126,197	115,237	110,530	106,780	105,249	175,383
T. variabilis	17,756	41,428	21,182	29,310	41,844	26,194	14,620
S. victoriae	13,621	18,182	19,403	20,510	16,172	18,048	24,649
B. altianalis	8,101	7,211	15,501	14,237	10,361	18,462	18,081
S. mystus	5,040	7,121	9,942	8,906	9,176	15,349	15,026
M. kannume	8,040	7.152	7,574	10,051	8,474	14,117	12,601
T. esculenta	210,994	320,962	197,604	122,560	26,564	4,260	769
T. zillii	-	-	-	-	-	-	-
T. leucosticta	-	-	-	-	-	-	-
L. victorianus	8,139	7,863	9,174	8,698	5,701	3,813	1,763
Total weight	769,087	882,465	739,975	781,327	774,762	869,565	947,821

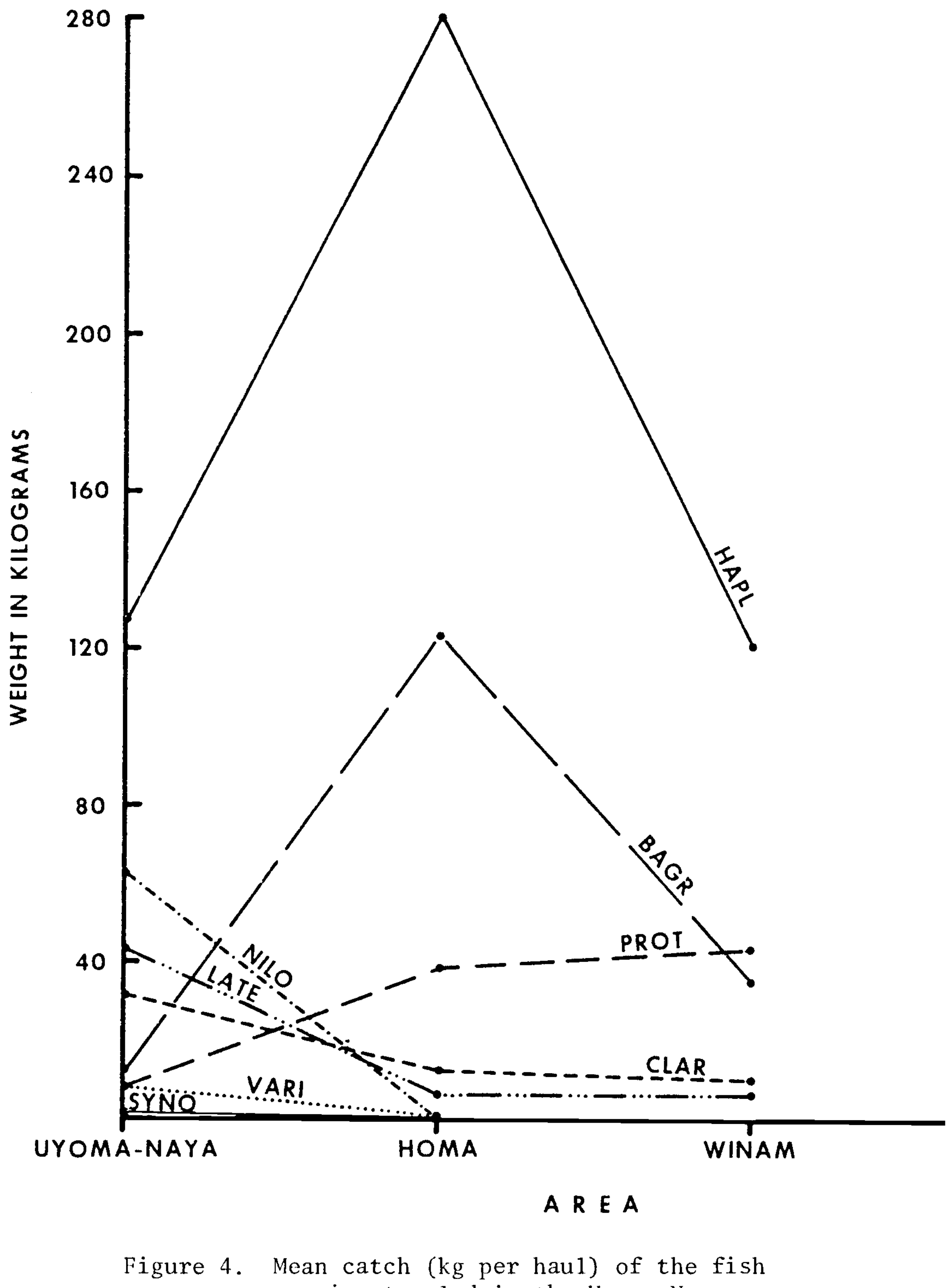

Figure 4. Mean catch (kg per haul) of the fish species trawled in the Uyoma-Naya, Homa and Winam areas of Nyanza Gulf, 1975.

elsewhere. Catches of *B. altinalis*, *S. mystus*, *M. kannume*, *T. esculenta*, *T. zillii*, *T. leucosticta*, and *L. victorianus* were generally small in the trawl samples partly because the species were scarce and tended to concentrate in shallower waters ($\leq$ 4 m) or snaggy areas that were not trawled.

Differences in species composition among the three areas may be due to many factors including depth, substrate type, or amounts of inflow from rivers and streams.

Species Associations

Species associations were inferred from Bray-Curtis dissimilarity coefficients (Table 4). Two patterns of association were apparent. *T. nilotica*, *T. variabilis* and *L. albertianus* formed one association and *Haplochromis* spp., *B. docmac*, *C. mossambicus*, and *P. aethiopicus* formed the other.

Associations among species may be due to several causes among which are mutual habitat selection and distribution of predators and prey. The associations of *T. nilotica* and *T. variabilis* may be due to mutual habitat selection, but their association with *L. albertianus* indicated prey-predator relationship as observed in stomach contents of some adult *L. albertianus*. Also, stomach contents of *B. docmac*, *C. mossambicus*, and *P. aethiopicus*

Table 4. Trellis-table of Bray Curtis dissimilarity coefficients between all possible pairs of fish species (1.0 indicates complete dissimilarity and 0.0 indicates perfect similarity). Significant associations are underlined (< 0.500).

	NILO	ZILL	LEUC	VARI	ESCU	HAPL	SYNO	LABE	MORM	BARB	BAGR	SCHL	CLAR	PROT
ZILL	.961													
LEUC	.996	1.000												
VARI	.367	.943	.955											
ESCU	.885	1.000	1.000	.932										
HALP	.667	.984	.982	.644	.931									
SYNO	.677	.995	1.000	.751	.892	.579								
LABE	.970	1.000	1.000	.967	1.000	.945	.971							
MORM	.971	1.000	1.000	.971	1.000	.903	.891	.921						
BARB	.883	.845	1.000	.877	1.000	.958	.940	1.000	1.000					
BAGR	.763	.988	.984	.722	.949	.185	.618	.934	.867	.966				
SCHL	.836	1.000	1.000	.891	.965	.686	.707	.933	.892	.980	.663			
CLAR	.559	.989	.991	.650	.894	.257	.567	.933	.905	.960	.325	.721		
PROT	.779	.990	.982	.696	.930	.351	.703	.919	.932	.972	.389	.811	.457	
LATE	.491	.948	.992	.549	.916	.613	.653	.981	.957	.936	.667	.773	.623	.730

contained some remains of *Haplochromis* spp. (Chilvers and Gee 1974). Co-occurrence of these piscivores may be due to the distribution of their lush food. Species showing strong dissimilirity were usually rare and occurred erratically in the samples.

Species Biomass Patterns

The group average fusion strategy showed 11 clusters (A-K) from 125 sites, each with at least four sites at .40 Bray-Curtis dissimilarity value (Figure 5). These clusters exhibited two apparent geographical locations; clusters A-D and H-K comprised mostly sites in Homa and Winam areas, and clusters E, F and G comprised exclusively sites in Uyoma-Naya area (Figure 6). A comparison of the species cluster mean with the overall mean for the Gulf also showed distinct differences between and within the two cluster assemblages (Table 5). Clusters A-D and H-K had a mean biomass of *Haplochromis* similar to that for the whole Gulf, but clusters E, F and G had less. Also, clusters A-D and H-K had a higher mean biomass of *B. docmac* than E-G. However, clusters A-D had a lower mean biomass of *P. aethiopicus*, *C. mossambicus*, *T. nilotica*, *T. variabilis*, and *S. victoriae* than clusters H-K in the same geographical location. Clusters E, F and G had the greatest mean biomass of *C. mossambicus*, *L. albertianus*,

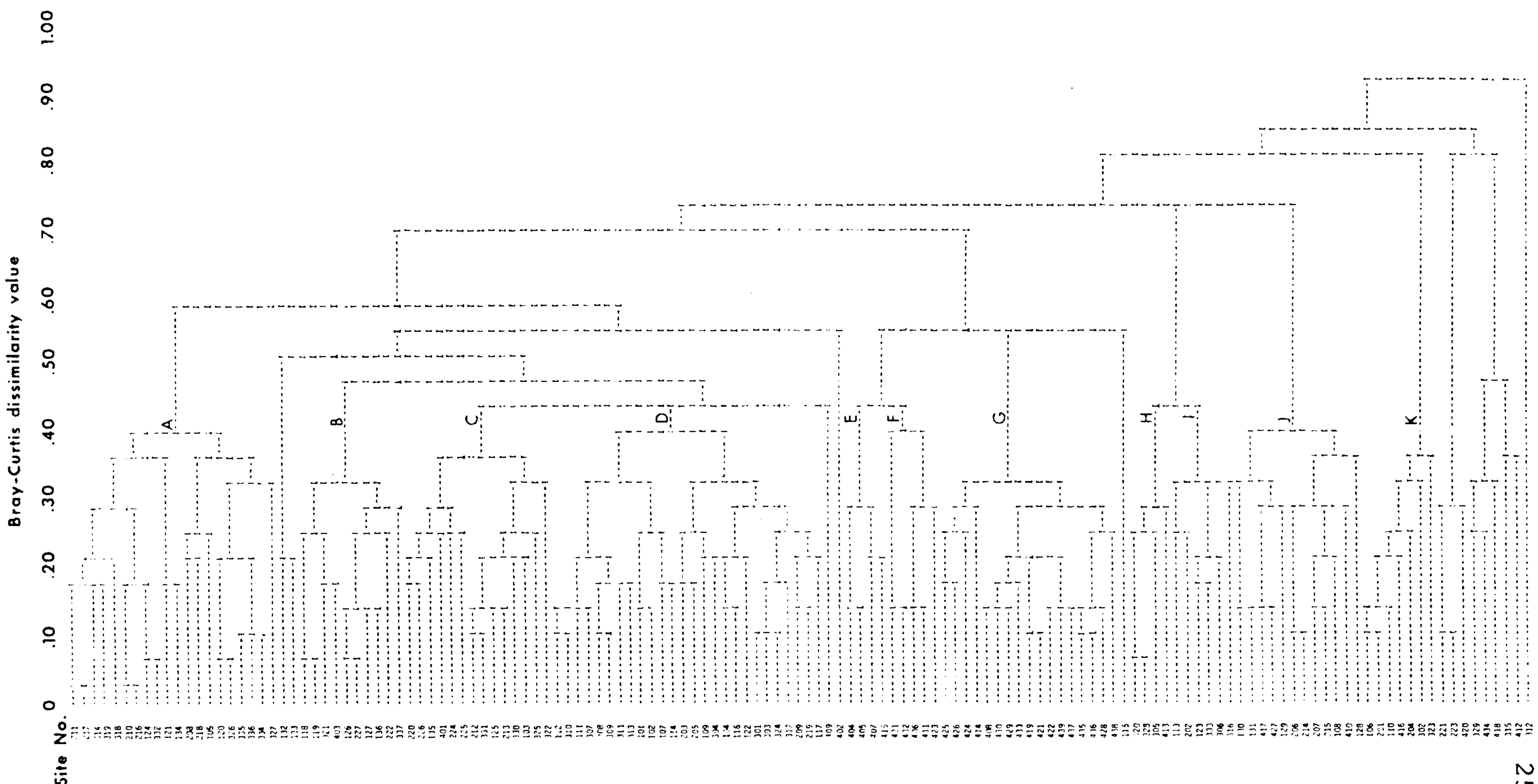

Figure 5. Dendrogram of site groups indicating fish biomass patterns of Nyanza Gulf, 1975 derived from trawl data by the group-average sorting of Bray-Curtis coefficients between all possible pairs.

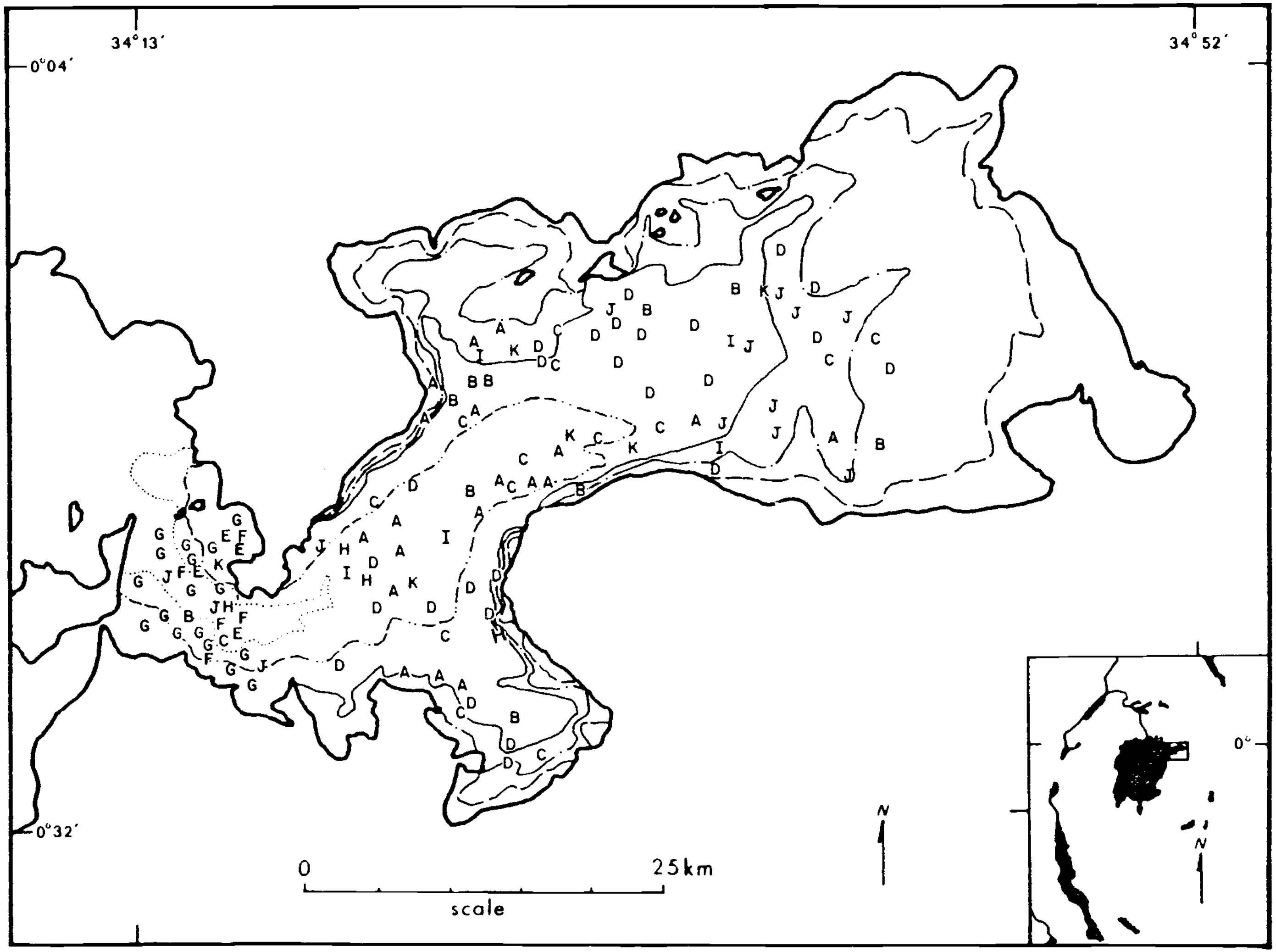

Figure 6. Distribution of fish biomass patterns in Nyanza Gulf, 1975.
Letters identify each cluster, A-K.

Table 5. Mean species biomass for site clusters derived from trawl data, Nyanza Gulf, 1975.

Particulars	Overall Mean	CLUSTERS A	B	C	D	E	F	G	H	I	J	K
Hauls	139	20	10	14	26	4	5	17	4	6	12	7
Mean catch	kg/site	kg/site	kg/site	kg/site	kg/site	kg/site	kg/site	kg/site	kg/site	kg/site	kg/site	kg/site
Haplochromis spp.	164.75	173.91	118.98	138.80	229.35	156.18	172.00	109.85	185.00	196.68	199.63	188.17
B. docmac	52.15	78.90	53.15	54.07	109.43	29.68	21.18	5.18	74.00	109.80	25.44	86.63
P. aethiopicus	27.24	9.70	3.74	13.69	18.68	5.75	4.68	7.86	10.83	34.75	21.63	49.87
C. mossambicus	16.19	7.78	6.79	13.82	10.50	56.25	26.90	14.43	29.95	16.75	26.83	29.77
L. albertianus	16.48	5.21	13.47	.40	2.75	10.21	54.03	68.29	19.13	2.80	5.18	2.60
T. nilotica	17.78	.78	.57	.60	.02	16.63	46.88	82.79	9.68	.83	29.25	10.97
T. variabilis	2.19	0	0	.36	.21	.15	3.46	12.76	0	.53	.50	.56
S. mystus	.30	1.59	0	0	0	.08	.20	.06	.60	.03	.05	.53
S. victoriae	.69	.22	.04	0	0	2.20	7.06	2.31	.48	.57	1.93	.26
M. kannume	.08	.01	0	0	.33	0	0	0	1.88	.33	0	.09
B. altianalis	.04	0	0	0	.02	.04	0	0	0	0	0	0
T. esculenta	.04	0	0	0	0	0	0	0	0	0	0	0
T. zillii	.23	0	0	0	0	0	0	0	0	0	0	0
T. leucosticta	.20	0	0	0	0	0	0	0	0	0	0	0
L. victorianus	.13	0	0	0	0	0	0	0	0	0	0	.13
Total biomass	298.49	278.10	196.74	221.74	371.17	277.17	336.39	303.53	331.55	363.07	310.04	369.45

T. nilotica, *T. variabilis*, and *S. victoriae*.

Based on similarity of ranking species biomass by geographical areas, where number 1 represents most abundant and number 15 the least (Table 6), the Gulf exhibited two rather distinct ichthyofaunal areas, Uyoma-Naya and Homa-Winam.

Table 6. Species rank dominance by geographical areas (Uyoma-Naya, Homa and Winam) Nyanza Gulf, 1975.

	Uyoma-Naya	Homa	Winam
Haplochromis spp.	1	1	1
T. nilotica	2	7	6
L. albertianus	3	5	5
C. mossambicus	4	4	4
B. docmac	5	2	2
P. aethiopicus	6	3	3
T. variabilis	7	10	7
S. victoriae	8	8	8
B. altianalis	9	11	12
S. mystus	10	6	9
M. kannume	11	9	11
T. esculenta	12	12	10
T. zillii	14	15	14
T. leucosticta	15	14	15
L. victorianus	13	13	13

Discriminant analysis of the 6 major clusters (A-d, G, and J) showed two assemblages (Figure 7.) Clusters A-D were collinear and arranged in a hierarchi-

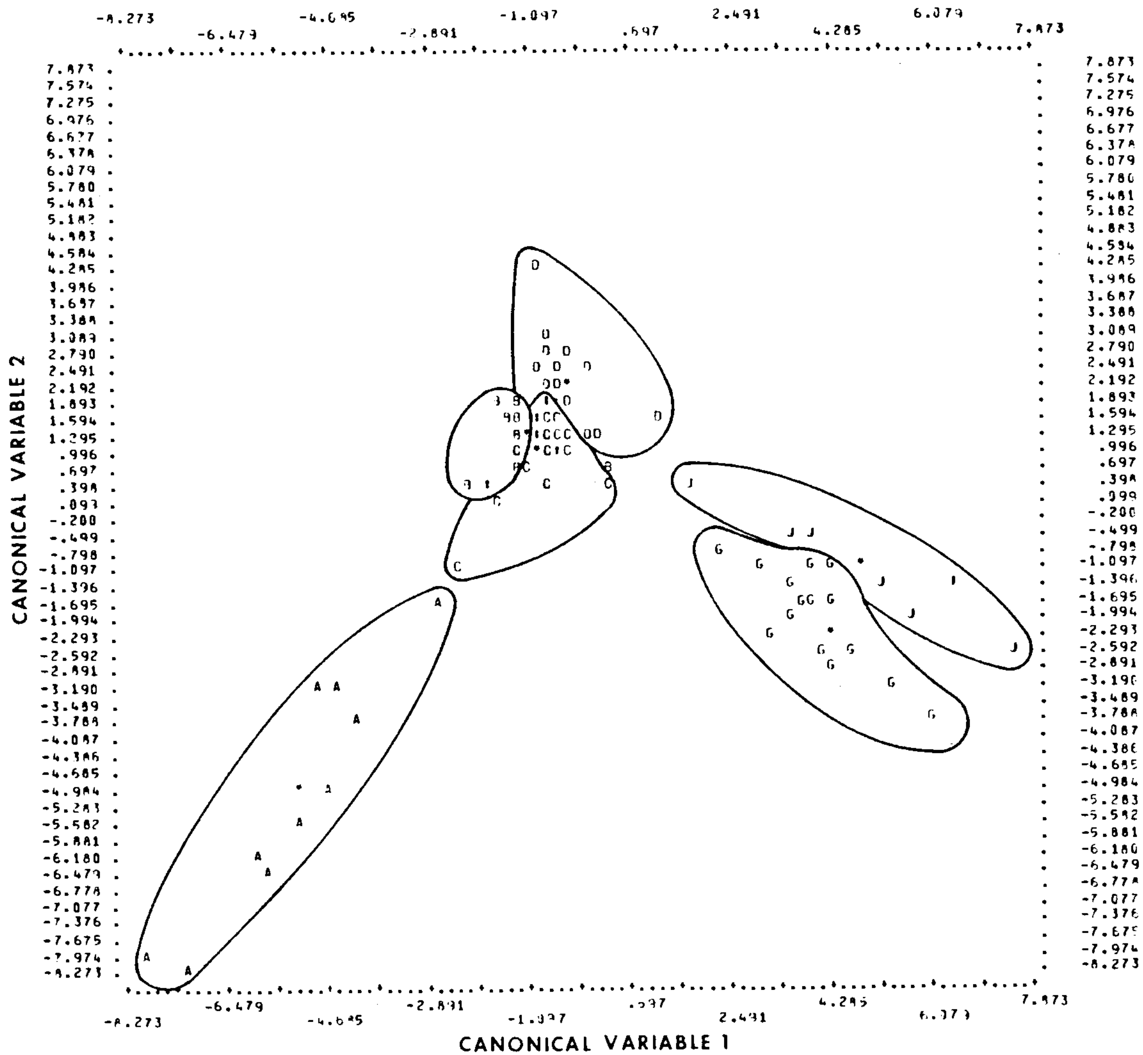

Figure 7. Dispersion of the major fish biomass patterns (A-D, G, and J) derived from trawl data, Nyanza Gulf, 1975.

cal order, but clusters G and J, parallel to each other were arranged transverse to A-D. These arrangements were due to the relative correlation of the principal species comprising each cluster with the first two canonical axes. Clusters A-D were dominated by two species, B. docmac and Haplochromis spp., while clusters G and J were dominated by five species of which three were the same. Cluster G was dominated by C. mossambicus, L. albertianus, T. nilotica, T. variabilis, and S. victoriae; and cluster J was dominated by Haplochromis spp., P. aethiopicus, C. mossambicus, T. nilotica, and S. victoriae. The ratio of the mean biomass in each cluster to the number of species present was 3.4, 4.0, 4.5, 4.6, 3.7 and 3.8 in A-D, G, and J respectively. This ratio, with a hierarchical sequence in A-D and almost the same value in G and J, corresponds with the mean ichthyomass in each cluster.

Location of clusters showed significant contrast with depth, offshore distance, substratum coarseness, and time of sampling (Table 7). Clusters A, C, E, F, G, and H had a mean depth $\geq$ 10.0 m, but clusters B, D, I, J, and K were in areas with a mean depth $\leq$ 7.4 m. Whereas clusters A-D and H-K were on the average $\geq$ 3.0 km offshore, clusters E, F, and G were only $\leq$ 1.4 km offshore. Most sites in clusters A-D and H-K were over predominantly firm mud, but most sites in cluster E and F were over predominantly gravelly substrate and G was over sandy substrate. Most sites in

Table 7. Environmental characteristics of site clusters derived from Nyanza Gulf data, 1975.

Clusters	A	B	C	D	E	F	G	H	I	J	K
Number of hauls	(20)	(10)	(14)	(26)	(4)	(5)	(17)	(4)	(6)	(12)	(7)
Mean depth (m)	10.0	6.5	10.0	7.4	10.1	15.4	15.0	13.8	6.2	6.4	6.0
Depth range (m)	5.0-13.4	4.2-15.0	4.5-15.1	4.6-14.1	4.6-15.2	4.5-15.4	4.6-24.1	6.5-14.4	5.2-14.5	5.5-15.7	5.8-12.8
Mean offshore distance (km)	3.4	3.2	3.9	3.9	1.4	1.4	1.4	3.0	4.0	4.4	4.3
Offshore distance range (km)	.9-5.8	.8-5.6	1.4-10.3	.8-7.4	.7-1.8	.9-2.4	.6-2.1	.14-3.7	1.2-6.1	1.1-6.9	.7-4.6
Predominant substrate type	firm mud				gravel		sand		firm mud		
Percentage of sites with predominant substrate type	45	50	43	46	75	80	59	50	83	67	43
Predominant season	dry		trans		heavy rain				trans		heavy rain
Percentage of sites in predominant season	45	50	64	71	80	60	71	75	67	58	86
Predominant times of trawling	day			night			dusk	day			dusk
Percentage of tows during predominant time	75	70	71	65	75	60	74	50	50	58	57

clusters A and B were sampled during the dry season while those in C and J were sampled during the transition period, and D-I and K were sampled during the heavy rain season. Also, most sites in clusters A-C and G-J were sampled during day, but those in clusters F and K were sampled during dusk; and those in D-F at night.

As the patterns in trawl data suggested that fish species were responding to variation in physical features of the Gulf and time of sampling, I examined the species data in relation to physical characteristics and time of sampling to identify physical or temporal factors that might influence fish distribution within the Gulf.

Species abundance by physical features and time of sampling

Species abundance in relation to depth showed three patterns (Table 8): B. docmac, P. aethiopicus, and S. mystus were most abundant in shallow waters ($\leq$ 8.3 m); Haplochromis spp. were most abundant at intermediate depths (8.4-12.5 m); and C. mossambicus, L. albertianus, S. victoriae, T. nilotica, and T. variabilis were most abundant in deep waters ($\geq$ 12.6 m).

Species catch in relation to substrate type indicated that several species were closely associated to substrate coarseness (Table 9): Haplochromis spp., B. docmac and P.

Table 8. Mean fish biomass (kg. per haul) by selected depth intervals in Nyanza Gulf, 1975.

Depth intervals (m).	4.2-6.2	6.3-8.3	8.4-10.4	10.5-12.5	12.6-14.6	14.7-18.8	18.9-24.1
No. of hauls	(61)	(16)	(18)	(19)	(13)	(8)	(4)
Shallow water group:							
B. docmac	47.60	86.28	64.03	57.97	54.06	9.47	8.45
P. aethiopicus	46.53	46.67	33.23	21.70	17.11	13.70	10.43
S. mystus	1.49	1.08	.53	1.24	.94	.10	.15
Intermediate water group :							
Haplochromis spp.	144.81	186.01	195.21	206.94	143.58	114.63	104.90
Deep water group:							
C. mossambicus	14.71	10.58	21.11	16.28	23.92	28.90	45.85
L. albertianus	20.16	23.27	28.25	45.43	70.62	97.10	77.50
S. victoriae	1.07	.51	1.03	2.74	3.96	2.83	1.35
T. nilotica	17.24	18.50	25.85	55.62	56.37	74.97	77.43
T. variabilis	1.77	1.37	2.05	6.01	12.47	12.36	14.15
Miscellaneous group:							
B. altianalis	1.55	0	0	0	.35	1.60	.55
L. victorianus	.10	.13	.10	.30	0	0	0
M. kannume	.45	.83	0	.96	0	.60	0
T. esculenta	.41	0	0	0	0	0	.22
T. leucosticta	0	0	.20	0	0	0	0
T. zillii	.20	0	.25	0	0	0	0

Table 9. Mean fish biomass (kg. per haul) by bottom (substrate) type, Nyanza Gulf, 1975.

Substrate type	Flocculent Mud	Firm Mud	Sandy	Gravelly	Rocky
No. of hauls	24	59	20	21	15
Flocculent mud group:					
Haplochromis spp.	245.89	149.00	152.80	153.21	168.29
B. docmac	98.20	43.76	45.10	33.17	51.45
P. aethiopicus	52.63	22.66	31.80	19.98	8.75
Sand-gravel group:					
L. albertianus	10.83	9.41	31.26	36.64	5.41
T. nilotica	6.51	15.07	32.89	23.38	19.88
T. variabilis	.45	1.96	5.16	2.57	1.38
Cosmopolitan group:					
C. mossambicus	8.63	14.34	19.07	16.41	26.36
Rock group:					
S. mystus	.19	.19	.16	.35	.57
S. victoriae	.22	.41	.37	1.34	2.03
Miscellaneous group:					
M. kannume	.04	.07	.12	.08	.09
B. altianalis	0	.02	.22	0	.05
T. esculenta	0	.07	0	0	.01
T. zillii	0	.20	.15	0	0
T. leucosticta	.20	0	0	0	0
L. victorianus	.10	.09	.14	0	0

aethiopicus tended to be most abundant on flocculent mud; L. albertianus, T. nilotica, and T. variabilis were most abundant on sandy and gravelly substrate; C. mossambicus was cosmopolitan; and S. mystus, and S. victoriae were most abundant on rocky substrate. Other species were too rare to indicate significant associations with substrate. Distribution of species in relation to substrate type indicates many factors including feeding or breeding habits of the species. Haplochromis spp. mostly feed over muddy substrate and B. docmac feeds almost exclusively on Haplochromis spp. (Chilvers and Gee 1974). However, both these species use rocky substrate for breeding and rearing (Corbet 1961; Fryer and Iles 1972). P. aethiopicus feeds and breeds in muddy and swampy areas (Greenwood 1958). L. albertianus, T. nilotica and T. variabilis feed over all substrate but prefer sandy and gravelly areas for breeding (Lowe-McConnell 1956, 1959; Hamblyn 1965). C. mossambicus, S. mystus and S. victoriae feed and breed mainly in rocky and wave swept areas of the Gulf (Greenwood 1955).

Species catches by time of day showed that abundance of some species was associated with light intensity (Table 10). Catches of Haplochromis spp., B. docmac, P. aethiopicus, and C. mossambicus were greater at night than during day, while catches of L. albertianus, T. nilotica, and T. variabilis were greater during day than at night. S. victoriae, S. mystus and M. kannume were caught mostly at dusk.

Table 10. Mean fish biomass (kg. per haul) by time of day (light intensity), Nyanza Gulf, 1975.

Time of day	(darkest) 2400-0500 hrs	1900-2400 hrs	(dusk) 1600-1900 hrs	(dawn) 0500-0900 hrs	(brightest) 0900-1600 hrs
No. of hauls	31	27	20	23	38
Night group:					
Haplochromis spp.	226.96	196.31	183.77	132.13	147.38
B. docmac	61.31	59.39	67.66	35.15	48.87
P. aethiopicus	90.18	37.43	32.33	19.14	14.64
C. mossambicus	20.43	20.95	15.42	11.16	15.61
Day group:					
L. albertianus	2.00	3.03	16.25	22.72	22.40
T. nilotica	8.89	6.82	11.64	29.56	21.58
T. variabilis	.14	.24	.64	5.16	2.76
Dusk group:					
S. victoriae	.03	.69	1.78	.36	.54
S. mystus	0	.05	.53	.24	.40
M. kannume	.11	.08	.12	.01	.08
Miscellaneous group:					
B. altianalis	0	.02	.01	.19	.02
T. esculenta	.04	0	.12	.03	.01
T. zillii	0	0	0	0	.24
T. leucosticta	0	0	0	0	.02
L. victorianus	0	0	.01	.03	.01

These distributions seem to represent circadian, vertical movements or response to changing visibility of gear. *Haplochromis* spp., *B. docmac*, *P. aethiopicus*, and *C. mossambicus* were generally more difficult to catch at slow trawling speeds. Thus, the relatively small catches of these fish during day may indicate several factors including their greater success in avoiding the trawl in daylight. *T. nilotica* and *T. variabilis* feed mainly near the surface at night and congregate in sheltered areas or on the bottom during the day (Fish 1955; Levring and Fish 1956). Also, the presence of *T. nilotica*, *T. variabilis*, and *L. albertianus* near the water surface at night was associated with the depletion of oxygen at the bottom at night (Newell 1957). The relatively high occurrence of *S. victoriae*, *S. mystus* and *M. kannume* in the trawl at dusk was associated with the emergence from mud of *Chironomus brevipera*, *Povilla adusta*, and other insect larvae composing their staple diet (Corbet 1958, 1961).

Catch during different seasons indicated two rather weak groupings (Table 11). Largest catches of *Haplochromis* spp., *P. aethiopicus*, *L. albertianus*, *C. mossambicus*, and *S.* victoriae were obtained during heavy rains; while largest catches of *B. docmac*, *T. nilotica*, *T. variabilis* and *S. mystus* were obtained during the dry season. These species showing seasonal variation in catch may migrate seasonally to shallow or very rocky areas that were not trawled.

Table 11. Mean fish biomass (kg. per haul) by season, Nyanza Gulf, 1975.

Season	Dry	Transition	Light Rain	Heavy Rain
No. of hauls	35	33	34	37
Heavy rain group:				
Haplochromis spp.	137.49	141.00	103.81	160.94
P. aethiopicus	24.42	22.32	10.28	52.88
L. albertianus	26.89	8.90	25.81	54.36
C. mossambicus	13.88	8.62	6.88	25.13
S. victoriae	.45	1.98	.26	2.21
Dry season group:				
B. docmac	63.24	57.47	31.84	56.16
T. nilotica	58.09	44.96	25.91	44.65
T. variabilis	8.21	4.25	7.23	3.67
S. mystus	1.78	1.35	1.55	.60
Miscellaneous group:				
M. kannume	0	.80	0	.88
B. altianalis	0	2.65	0	.70
T. esculenta	.23	.25	1.1	.28
T. zillii	0	0	0	.20
T. leucosticta	0	0	0	.20
L. victorianus	.30	0	0	.12

Beuchamp (1958) and Corbet (1961) showed that *B. docmac*, *S. victoriae*, *S. mystus*, and *Haplochromis* spp. spawn in rocky areas, while Lowe-McConnell (1956), Greenwood (1958), and Hamblyn (1965) showed that *P. aethiopicus*, *L. albertianus*, *T. nilotica*, and *T. variabilis* spawn in shallow and/or swampy areas. Spawning migrations within the Gulf, therefore, may have affected the abundance of these species during parts of the year.

Because all of these environmental variables act simultaneously on the fish species, it is necessary to examine associations between these variables.

Correlations among environmental variables

Correlations among the five environmental variables showed a positive association between substrate type and water depth, but negative correlations between substrate type and offshore distance, depth and offshore distance, and time of day and season (Table 12). The correlations indicated that substrate coarseness varied directly with depth, but both depth and substrate coarseness showed negative correlations with off-shore distance mainly because of the morphology of the Gulf and location of sample sites (Figure 2). In the shallow Winam area, we generally trawled further offshore than in Uyoma-Naya and Homa areas (Table 7). The negative correlation between time of day and season indicates that sampling was done closer to midday during the dry season than during the rainy season.

Table 12. Correlation matrix of the five environmental variables associated with the 139 hauls. Non-parametric Spearman rank correlation coefficients (r_s) shown in parentheses.

	Substratum	Depth	Offshore distance	Time of day (light intensity)
Season	-.01 (0.00)	.05 (.11)	.02 (-.03)	-.30 (-.29**)
Substratum (bottom type)		.44 (.44**)	-.31 (-.29**)	-.02 (-.10)
Depth			-.42 (-.39**)	.15 (.18)
Offshore distance				-.14 (-.10)

**p < .01

Because of the significant correlations among the environmental variables, it was necessary to analyze all variables simultaneously in relation to the species data with canonical correlation.

Canonical correlations of fish species and environmental variables

Canonical correlation analysis identified five factors that accounted for 40 percent of the original variance in the species data, with a total of redundancy of the species data given the environmental data of 12 percent (Table 13). Although these associations were not particularly high, the habitat data used were actually indirect measures of many factors (i.e., temperature, oxygen, inflow, and organic nutrients). Had these been measured directly, the relationship might have been better. Also, the shallowness of the Gulf ($\bar{x}$ = 6 m) may not result in strong physico-chemical gradients.

Only the first three canonical factors were examined in detail because these had relatively high canonical correlation coefficients compared to the last two factors. Interpretation of the factors was based on the factor structure, consisting of back-correlations of the factors with the original variables (Table 14).

The first factor, with a high positive correlation with depth and a negative correlation with off-shore distance, seems to express a relationship between community

Table 13. Variance extracted from community data, canonical correlation coefficient (R_{ci}), and redundancy of community data given the environmental data for five canonical factors of biomass (kg) of 15 fish species in 139 hauls, Nyanza Gulf.

Factor	R_{ci}	Variance extracted	Redundancy
1	.762	.110	.064
2	.556	.070	.022
3	.518	.095	.026
4	.340	.056	.006
5	.266	.068	.005
Total		.399	.122

Table 14. Correlations of species and environmental variables with the first three canonical factors. Significant values underlined (≥ .500)

Fish Species:	CV1	CV2	CV3
T. nilotica	.858	.009	.153
T. zillii	.053	-.027	.101
T. leucosticta	.061	-.125	-.048
T. variabilis	.622	-.200	.267
T. esculenta	-.251	-.124	-.003
Haplochromis spp.	.139	.229	-.501
S. victoriae	.119	.549	.378
L. victorianus	-.014	-.034	-.065
M. kannume	.033	.085	.076
B. altinalis	.273	-.107	-.094
B. docmac	.002	-.251	-.500
S. mystus	.005	-.383	.005
C. mossambicus	.318	.557	-.046
P. aethiopicus	-.235	.257	-.804
L. albertianus	.441	.139	.175
Environment:			
Season (rainfall)	.076	.680	-.370
Substratum (bottom type)	.194	.622	.678
Depth	.836	.062	.331
Off-shore Distance	-.781	-.203	.061
Time of Day	.208	-.460	.587

structure and water depth. Species which had high positive correlation with this factor (*T. nilotica* and *T. variabilis*) tended to be concentrated in deep waters.

The second factor, with high positive correlations with season and substrate type, identified a seasonal pattern in community structure associated with sediment coarseness. During the rainy season, coarse materials are added to the Gulf through rivers and run off. Species which had high positive correlations with this factor (*C. mossambicus* and *S. victoriae*) tended to be most abundant in rocky areas and near river mouths during the rainy season.

The third factor, with positive correlations with substrate coarseness and time of day, identified a daily pattern in species distribution in relation to substrate coarseness and light intensity. Species which had high negative correlations with this factor (*Haplochromis* spp., *B. docmac*, and *P. aethiopicus*) were reduced in trawl catches over rocky substrate during the day. This pattern suggests that these species were responding to various diurnal factors in rocky habitats. This response could include net avoidance.

DISCUSSION

The survey was conducted by trawling because the method was the most feasible in representing standing stocks and had been used earlier for similar studies in the area during 1969-71. Besides, as trawling is an active methodology, catches are influenced largely by the efficiency of the gear rather than behavior of fish. However, because trawl catches were towed over a distance of 5.6 km each time, data represent catches for a transect rather than a station. In future, it would be beneficial to make shorter tows, such as 1 km long, or to sample with a purse seine. As random sampling did not evenly cover all the trawlable area and may have influenced some clusters, uniform sampling based on a grid pattern is recommended. I would also recommend sampling with a mid-water and bottom-water trawl to differentiate demersel and pelagic species.

Fish stocks in Nyanza Gulf can be divided into three groups according to their state of exploitation and possibilities of expanding catches: underexploited, lightly exploited, and fully or overexploited. Each group presents rather different management problems.

For the underexploited stocks (Haplochromis spp.) the resource must be identified and a measure of its magnitude assessed to indicate potential yield, best fishing grounds, best seasons, and optimal gear.

For fisheries on lightly exploited stocks (*B. docmac*, *E. argenteus*, *C. mossambicus*, and *P. aethiopicus*) there is a need to increase fishing effort by either using improved gear or new techniques.

For fisheries on heavily exploited stocks (*T. esculenta*, *S. victoriae*, *M. kannume*, *L. victorianus*, *S. mystus*, *T. nilotica*, and *T. variabilis*) there is a need to control the amount of fishing, mesh size, or size of fish landed to enable increment in the production from the stocks.

Effective management would offer opportunities for increasing production, since if the excessive fishing effort on one stock can be diverted to other less heavily exploited stocks there may be increased catches from both stocks. Thus, management should not be concerned merely with maximizing physical yield from an individual stock, but in making the best use of the total resources available (Gulland 1968).

Effective management requires good scientific assessment of the state of the stocks, of the likely results of possible regulatory measures, and adequate legislative and administrative machinery for the introduction and enforcement of any appropriate measures.

The study showed that the fishery consists of many interacting species and localized ichthyomass patterns within systems that are changing due to natural and cultural factors. Therefore, abundance and yield in toto or by taxa may be influenced by changes in these factors. The decline in the abundance and yield of adfluvial species (A. baremose, B. altianalis, L. victorianus, and S. afrofischeri) is attributed to the fluctuating conditions in rivers and streams, and improper fishing methods (Garrod 1960; Corbet 1961; Van Someren 1961). The decline of T. esculenta prior to 1960 was probably caused by overfishing (Copley 1953; Garrod 1960; Welcomme 1966), but it cannot be resolved whether or not its decline since 1961 is a result of over-fishing, competition with the introduced Tilapia, drastic rise in water level that started in 1961, or any combination thereof.

Most adverse natural factors, such as those that limit early survival of species, are probably beyond control. However, adverse cultural factors such as improper fishing methods may be minimized by controlling and directing the fishing effort to achieve the economic and social objective, in the area. As there is unlimited entry (i.e., everyone has access to the resource), there is a need to allocate the resource between competing and conflicting uses to ensure safe and profitable yields from the stocks. Proper management would help to improve stock size, quantity, growth, population strengths, and maintain variety.

Whereas fishery management procedures elsewhere are generally based on the life history of the target species, this may not be possible at present on Nyanza Gulf because little is known about most species life histories. Instead, ichthyomass patterns (clusters) such as those identified in this study may be utilized as basis for formulating management policies.

If ichthyomass patterns are treated as model assemblages within the fishery, application of comprehensive exploratory management strategies to each group could facilitate development of a useful management program for the whole fishery. On the Gulf, there is too much fishing effort (Wanjala and Marten 1974) to make it practical to sample the entire catch for purposes of assessing the effect of different gears and regulations on the fishery. However, if sufficiently small exploratory 'fishery windows' are established in each statistical area (Figure 8), management policies could be developed experimentally without destroying the assemblages (Dr. A. V. Tyler, Oregon State University, personal communication). The number, size and arrangement of fishery windows would be determined, by the size of statistical area and duration of sampling.

As a tentative exploratory management program, the seven statistical areas identified from ichthyomass patterns in the Gulf could each be divided into eight equal sub-areas (fishery windows), and a pair of similar sub-areas would be explored quarterly to assess the effect of a particular

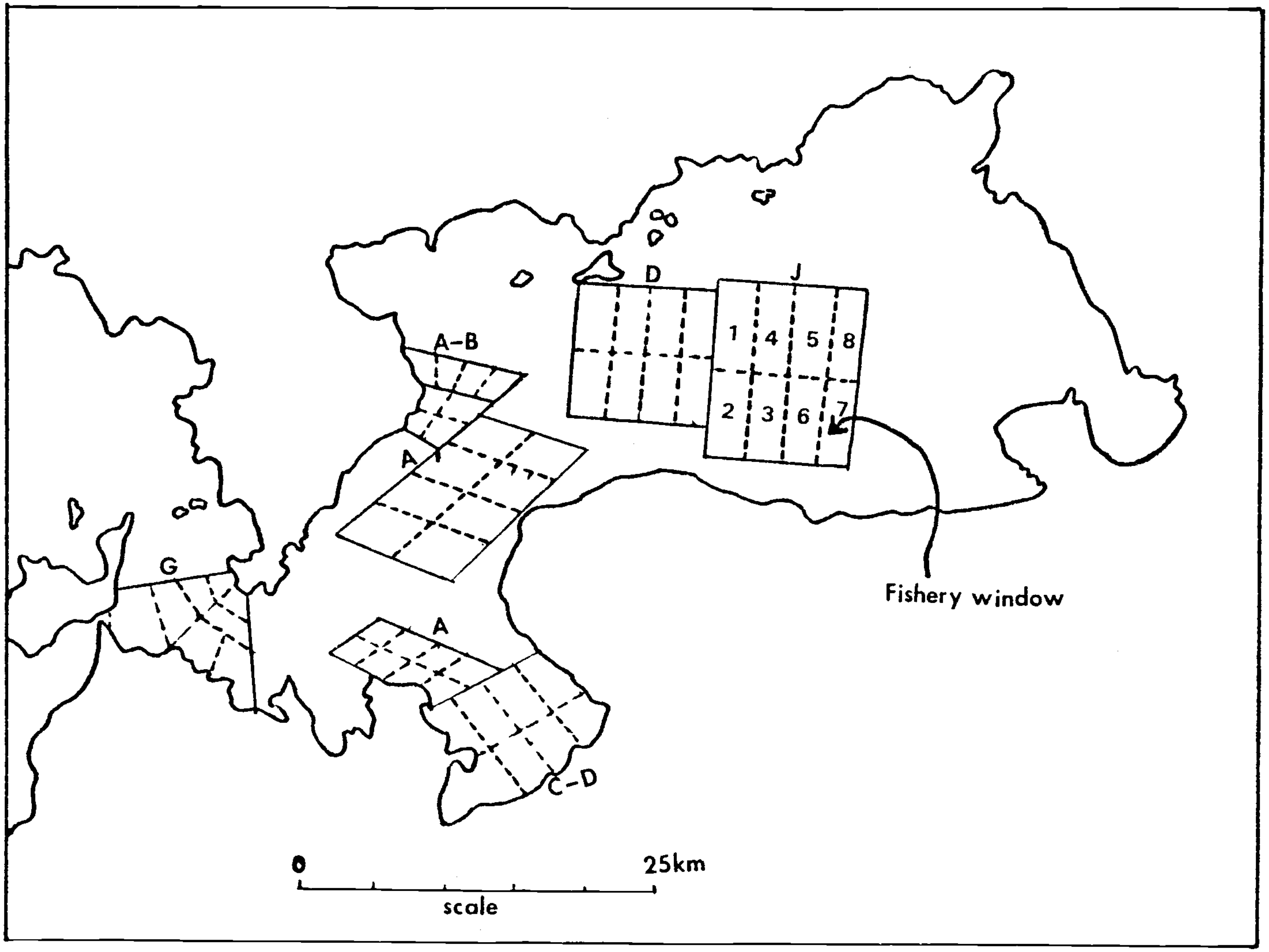

Figure 8. Statistical areas for a tentative exploratory management program, Nyanza Gulf. Letters identify each statistical area, A-B, C-D, D, G and J.

management policy or gears of interest. In each pair, the exploratory management project would only be applied to one sub-area and the other sub-area would constitute a control experiment for the investigation underway.

Using statistical area J as an example, I would apply a particular management policy, or fish with effort and gear comparable to that presently being used by fishermen in sub-area 1, but apply none of these in sub-area 2. After the quarter, say January-March, I would sample both sub-areas with a trawl or purse seine. A comparison of the data from the experimental and control areas would show the effect of the particular management policy or gear tested. During the second and subsequent quarters, one of the sub-areas in each pair would constitute an experimental site while the other would serve as control.

Although all the species form schools, there is a tendency for enormous congregations during breeding seasons (Corbet 1961), and if experimenting or sampling with a particular gear in a particular statistical area or sub-area is likely to interfere with the spawning behavior or habitats of species, the area may be closed at that time. To establish which section(s) of the statistical areas should be omitted during a particular quarter to preserve normal spawning behavior and recruitment, a pilot survey would be conducted all over the Gulf to establish how the various sections of the proposed study areas are used by various species during parts of the year. Synthesis of the results from all the statistical areas would help in the formulation of management policies for the whole fishery.

The two distinct incthyomass areas, Uyoma-Naya, and Homa-Winam may require separate management policies because of their markedly different dominant species. Uyoma-Naya, with large quantities of *T. nilotica*, *T. variabilis*, *L. albertianus*, and *C. mossambicus*, would be profitably harvested by 5-inch-mesh gill nets, but Homa and Winam areas with large quantities of *Haplochromis* spp; *B. docmac* and *P. aethiopicus* would be profitably harvested by a mix of small and large-mesh gill nets ($1\frac{1}{2}$-3 and 5+ inches).

As species abundance generally varied with depth, substrate, and time of sampling, management of the resource should be developed taking into account habitat and temporal variations. Also, as knowledge about the fishery is still limited and results are not without errors, management policies should be developed as a series of experiments and the results monitored quarterly and annually to promote better understanding of the resource and its exploitation.

In the Nyanza Gulf fishery, as in most East African fisheries, legislation alone is an ineffective management tool because most fishermen do not understand the need for control, and means of enforcing regulations are inadequate. In such fisheries, management may also require less direct means of control. This could be achieved by influencing the social and economic systems through education and encouragement of some fishermen to adopt alternative occupations such as fish farming, processing and selling, making of fishing gear and crafts, or adoption of any other occupation unrelated to fishing.

These alternative occupations may not only help to streamline fishing but also improve the economic and social status of the people in the area. Consequently, an economic motive would be attached to the fishery instead of fishing just as a tradition.

As the success of a management program does not only depend on what is suitable biologically but also on what is suitable socially, consideration of the attitude of fishermen toward the fishery and management policies is vital. Fishermen should believe that regulations are necessary to produce better catches in the future, and that other fishermen will obey them. The necessity for regulations could be demonstrated by results from the exploratory management project. To reduce suspicion among fishermen, enforcement must not only be effective but also must be seen to be effective.

Although most of the management policies on Nyanza Gulf, as with most East African Fisheries, owe their origin to political response to pressures brought to bear by commercial fishermen and local communities, priorities should include what is best ecologically and what is best for the people.

LITERATURE CITED

Anderson, T. W. 1958. An introduction to multivariate statistical analysis. John Wiley, New York. 374 pp.

Beauchamp, R. S. A. 1958. The commercial value of studies of fish behavior with particular reference to Lake Victoria. Proc. 8th Indo-Pacific. Fish Coun. III, Pg. 97-99.

Brooks, J. L. 1950. Speciation in ancient lakes. Quart. Rev. Biol. 25:131-176.

Cadwalladr, D. A. 1965. The decline in the *Labeo victorianus* Blgr. (Pisces Cyprinidae) fishery of Lake Victoria and an associated deterioration in some indigenous fishing methods in the Nzoia River, Kenya. E. Afr. Agric. For. J. 30(3):249-256.

Chilvers, R. M., and J. M. Gee. 1974. The food of *Bagrus docmac* (Forsk) and its relationship with *Haplochromis* Hilgendorf (Pisces: Cichlidae) in Lake Victoria, East Africa. J. Fish. Biol. 5:483-505.

Clifford, H. T., and W. Stephenson. 1975. An Introduction to Numerical Classification. Academic Press, New York, 229 pp.

Cooke, H. B. S. 1958. Observations relating to Quartenary environments in East and Southern Africa. Geol. Soc. S. Africa. Bull. 60:1-73.

Cooley, W. W., and P. R. Lohnes. 1971. Multivariate data analysis. John Wiley, New York, 364 pp.

Copley, H. 1953. The *Tilapia* fishery of the Kavirondo Gulf. J. E. Afr. Nat. Hist. Soc. 94:1-5.

Corbet, P. S. 1958. Lunar periodicity of aquatic insects in Lake Victoria. Nature 182:330-1.

Corbet, P. S. 1961. The food of non-cichlid fishes in the Lake Victoria Basin, with remarks on their evolution and adaptations to lacustrine conditions. Proc. Zool. Soc. Lond. 136(1):1-101.

Cordone, A. J. and A. Kudhongania. 1972. Observations on the influences of codend mesh size on bottom trawl catches in Lake Victoria, with emphasis on the *Haplochromis* population. Afr. J. Trop. Hydrobiol. Fish. 2(1):1-19.

Dixon, W. J. and R. I. Jennrich. 1973. Computer graphical analysis and discrimination *in* T. Cacoullos (ed.). Discriminant Analysis and Applications. Academic Press, New York, 434 pp.

EAFFRO. 1969. The history and research results of the EAFFRO during 1946-1966. EAFFRO Occasional Paper 2. 11 pp.

Ellis, R. W. 1963. Experiments to investigate the escape of fish through the meshes of different parts of the trawl. ICNAF Spec. Publ. No. 5:97-101.

Fish, G. R. 1955. The food of *Tilapia* in East Africa. Uganda J., 19:(1):85-89.

Fryer, G. 1959. Concerning the proposed introduction of Nile perch into Lake Victoria. E. Afr. Agric. J. 25(4):267-270.

Fryer, G., and T. D. Iles. 1972. The Cichlid Fishes of the Great Lakes of Africa, their biology and evolution. TFH Publications, Neptune City, New Jersey, 641 pp.

Garrod, D. J. 1957. A review of Lake Victoria Fishery Service records, 1951-1956. EAFFRO Pamphlet 1. 10 pp.

____________________. 1960a. Some effects of changes in mesh legislation upon the fishing industry of Lake Victoria. 3rd Symposium of hydrobiology and inland fisheries. Problems of major lakes, Lusaka 1960. Commission for Technical Cooperation in Africa/Conseil Scientifique pour l'Afrique au Sud de Sahara (CCTA/CSA) No. 63, p. 126-130.

____________________. 1960b. The fisheries of Lake Victoria, 1954-1959. E. Afric. Agric. For. J. 26(1):42-48.

____________________. 1961. The need for research on the population dynamics of tropical species with special reference to "Ningu," *Labeo victorianus* from Lake Victoria. CCTA/CSA Hydrobiology and inland fisheries 4th Symposium, May 1961. (6 pp typescript EAFFRO, Jinja, Uganda).

Graham, M. 1929. The Victoria Nyanza and its fisheries: A report on the fishing survey of Lake Victoria, 1927-28. Crown Agents, London.

Greenwood, P. H. 1951a. Fish remains from Miocene deposits of Rusinga and Nyanza Province, Kenya. Ann. Mag. Nat. Hist. 12(4):1192-1201.

__________________. 1951b. Evolution of the African cichlid fishes: the *Haplochromis* species flock in Lake Victoria. Nature 167:19-23.

__________________. 1955. Reproduction in the cat-fish *Clarias mossambicus* (Peters). Nature 176:516-519.

__________________. 1958. Reproduction in the East African lungfish *Protopterus aethiopicus* (Heckel) Proc. Zool. Soc. 130(4):547-567.

__________________. 1966. The Fishes of Uganda. Uganda Society, Kampala. 131 pp.

Gulland, J. A. 1968. The concept of the maximum sustainable yield and fishery management. FAO Fish. Tech. Pap. 70. 13 pp.

Hamblyn, E. L. 1965. The food and feeding habits of Nile perch: *Lates niloticus* (Linne) (Pisces: Centropomidae). Afr. J. Bot. Zool. 24(1-2):1-28.

Kendall, R. L. 1969. An ecological history of the Lake Victoria Basin. Ecol. Monog. 39:121-178.

Levring, T., and G. R. Fish. 1956. The penetration of light in some East African waters. Oikos 7(1): 98-109.

Lowe-McConnell, R. H. 1956. Observations on the biology of *Tilapia* (Pisces: Cichlidae) in Lake Victoria, East Africa, EAFFRO Suppl. Pub. 1. 72 pp.

__________________. 1959: Breeding behavior patterns and ecological differences between *Tilapia* species and their significance for evolution within the genus *Tilapia* (Pisces: Cichlidae). Proc. Zool. Soc. Lond. 132:1-30.

Marten, G. G. 1975. The impact of fishing on the Lake Victoria fishery. Unpublished Mimeo. EAFFRO, Kisumu, Kenya. 32 pp.

Melack, J. M. 1975. Photosynthetic productivity in Lakes Victoria and Tanganyika and its application to fisheries assessment in African lakes. Unpublished Mimeo. EAFFRO, Kisumu. 21 pp.

Newell, B. S. 1957. The nocturnal reduction of dissolved oxygen in some East African lakes. E. Afr. Agric. J. 23(2):127-129.

Ominde, S. H. 1971. Rural economy in West Kenya. pp. 207-229 in S. H. Ominde (ed.) Studies in East African Geography and Development. University of Cal. Press, Berkeley.

Pritchard, R. 1962. Evolution of the East African Drainage Systems. Columbia University Press, 351 pp.

Richardson, M. D. 1976. The classification and structure of marine macrobenthic assemblages at Arthur Harbor, Anvers Island, Antarctica. Ph.D. Thesis, Oregon State University. 142 pp.

Saggerson, E. P. 1952. Geology of the Kisumu District. Geol. Survey of Kenya Rep. No. 21. 86 pp.

Sampson, P. 1972. BMDØ7M. Stepwise discriminant analysis. UCLA Health Science Computing Facility. 20 pp.

Sokal, R. R., and C. D. Michener. 1958. A statistical method for evaluating systematic relationships. Univ. Kansas Sci. Bull. 38:1409-38.

Sokal, R. R., and P. H. Sneath. 1963. Principles of Numerical Taxonomy. W. H. Freeman, San Francisco and London. 283 pp.

Temple, P. H. 1966. Evidence of changes in the level of Lake Victoria and their significance. Ph. D. Thesis University of London.

____________________. 1966b. Lake Victoria levels. Proc. E. African Acad. 2:50-58.

Van Someren, V. D. 1961. Seasonal flood fisheries in Kenya colony. Commission for Technical Cooperation in Africa/Conseil Scientifique pour l'Afrique au Sud de Sahara (CCTA/CSA) Hydrobiology and inland fisheries 4th Symposium, May 1961.

Wanjala, B., and G. G. Marten. 1974. Survey of the Lake Victoria fishery in Kenya, 1973-74. EAFFRO Annual Rep. 1974: 81-85.

Welcomme, R. L. 1964. Notes on the present distribution and habits of the non-endemic species of Tilapia introduced into Lake Victoria. EAFFRO Annual Rep. 1962/63:10-25.

__________________. 1966. Recent changes in the Tilapia stocks of Lake Victoria. Nature 212:52-54.

__________________. 1967. Observations on the biology of introduced species of Tilapia in Lake Victoria. Rev. Zool. Bot. Afr., 76:251-279.

Whitehead, P. H. 1962. The relationship between Tilapia nigra (Gunther) and T. mossambica (Peters) in the eastern rivers of Kenya. Proc. Zool. Soc. London, 138:605-637.