Impact of Fishing on the Inshore Fishery of Lake Victoria (East Africa)

GERALD G. MARTEN

Environment and Policy Institute, East-West Center, Honolulu, Hawaii 96848, USA

MARTEN, G. G. 1979. Impact of fishing on the inshore fishery of Lake Victoria (East Africa). J. Fish. Res. Board Can. 36: 891–900.

The inshore fishery of Lake Victoria has symptoms of severe overfishing. Curvilinear multiple regression analysis was used to examine the large variation in fishing effort, gear composition, and catches around the lake and suggest fishing practices that would give highest yields. The overfishing problem is due to the kind of gear in use and not to excessive fishing per se. Heavy fishing is often associated with the use of small mesh gillnets and seines to catch small fish such as *Haplochromis*, a practice that does not seem to justify the damage done to catches of the larger species by the same gear. The best strategy for maximizing the total tonnage yield is to fish optimally for the herbivorous genus *Tilapia*. This means using only the larger gillnets appropriate for *Tilapia*, as well as hooks, both at a very high fishing effort. The hooks capture large predators such as *Bagrus*, *Clarias*, and *Protopterus*, an abundant resource in themselves, and simultaneously appear to increase *Tilapia* yields indirectly by reducing losses of *Tilapia* to predators.

Key words: Lake Victoria, ecosystem, succession, multispecies fishery, multigear fishery, fish yield, Africa, lake, lungfish, Tilapia, Haplochromis, catfish

MARTEN, G. G. 1979. Impact of fishing on the inshore fishery of Lake Victoria (East Africa). J. Fish. Res. Board Can. 36: 891–900.

La pêcherie côtière du lac Victoria présente des symptômes de sérieuse surexploitation. L'auteur utilise une régression multiple curviligne pour étudier la grande variation de l'effort de pêche, de la composition des engins de pêche et des prises autour du lac, et il suggère des stratégies de pêche susceptibles de donner les plus hauts rendements. Ce n'est pas la pêche excessive per se mais plutôt le genre d'engins de pêche qui est responsable du problème de la surexploitation. Une pêche intensive est souvent associée à l'emploi de filets maillants et de sennes à petites mailles pour capturer des petits poissons tels que *Haplochromis*, pratique qui ne semble pas justifier le dommage causé par ce même engin aux prises des grandes espèces. La meilleure stratégie visant à un rendement maximal en poids est de pratiquer une pêche optimale du genre herbivore *Tilapia*. Pour celà on utilisera seulement des filets maillants à grandes mailles appropriés à la capture des *Tilapia* ainsi que des hameçons, l'un et l'autre engin étant utilisés à un niveau d'effort élevé. Les hameçons capturent des grands prédateurs tels que *Bagrus*, *Clarias* et *Protopterus*, ressources en elles-mêmes abondantes, et semblent en même temps augmenter les rendements de *Tilapia* indirectement en réduisant les pertes de *Tilapia* par prédation.

Received November 1, 1977
Accepted March 8, 1979

Reçu le 1 novembre 1977
Accepté le 8 mars 1979

LAKE Victoria supports a canoe fishery that yields 110 000 t/yr, a significant source of protein for East Africa. Like many inland fisheries in Africa, Lake Victoria has experienced some alarming changes in recent years. *Tilapia esculenta*, previously the fish of greatest commercial importance, has virtually disappeared from much of the lake. Numerous other fish have declined drastically during the past decade, particularly those such as *Barbus*, *Labeo*, *Alestes*, and *Mormyrus* that migrate into streams to spawn (Fig. 1 shows the trophic relationships of the major commercial genera in Lake Victoria).

Fryer and Iles (1972) and Beadle (1974) have reviewed the history of the fishery until the mid-1960s, and Kudhongonia and Cordone (1974), Marten (1975a), Wanjala and Marten (1975), Scully (1976), and Marten et al. (1979) have described trends in catches since then. In the decades preceding the 1950s, the fishery was based primarily on two herbivores, the native *Tilapia* species, fished with gillnets of 13 cm stretch length. Since the early 1950s, however, the trend has been a continuing one of smaller mesh sizes as fish numbers and fish sizes have declined under increasingly heavy fishing pressure.

In the early 1960s, gillnets down to 9 cm came into common use for *Tilapia*, and since the late 1960s 3.8–4.6-cm gillnets have been used to harvest smaller fish such as *Haplochromis* and *Synodontis* which previously had been largely unexploited (Scully 1975). The beach seine, which captures *Haplochromis* and large numbers of spawning and juvenile *Tilapia*, has been spreading around the lake during the past decade, and the mosquito seine (1.3-cm mesh), which captures

Printed in Canada (J5029)
Imprimé au Canada (J5029)

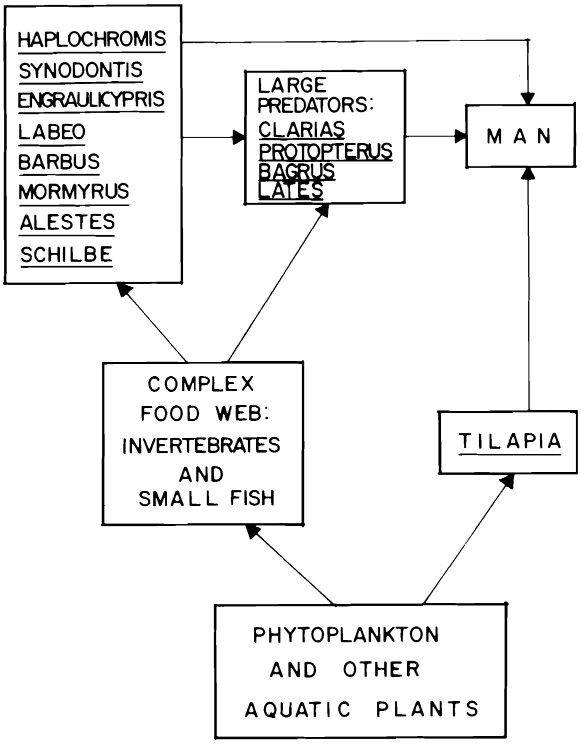

FIG. 1. Food web for the commercial genera of fish in Lake Victoria. The diagram is oversimplified for *Haplochromis*, a few of which are herbivorous.

Engraulicypris and even juvenile *Haplochromis*, has recently become popular in the more heavily fished parts of the lake.

Fishing regulations on Lake Victoria changed considerably when the three countries bordering the lake achieved political independence in 1961–63. Whereas nets below 13-cm mesh size were prohibited throughout the lake before then, no restrictions on fishing gear have been in effect in Tanzania and Uganda since then. Kenya has banned gillnets in the 6.4–9.5-cm range to protect exhausted *Labeo* stocks, and seines are prohibited in Kenya during *Tilapia's* peak spawning season. Such regulations are unpopular among fishermen because they restrict the individual fisherman's catch under circumstances where it is often difficult to get a satisfactory catch even without restriction. The fisheries manager needs to know whether such regulations have sufficient positive effect on the fishery to justify the trouble of enforcement.

Evaluation of regulations is a difficult problem due to the complex multiple-species, multiple-gear character of the Lake Victoria fishery. It is possible, however, to exploit the spatial variation in this complexity around the lake's 1300-km shoreline in order to infer the impact different fishing practices have on yields. Fishing intensities in different parts of the lake range from two to 20 canoes per kilometre of shoreline. The proportions of different kinds of fishing gear also vary considerably from one part of the lake to another in accord with local tastes for fish and fishing techniques. Therefore, as I noted earlier (Marten 1979a), "Since environmental conditions and the array of species present are similar throughout the inshore area of Lake Victoria, the conspicuous variation in abundance and composition of fish catch from one place to another can be attributed largely to variation in the quantity and quality of fishing effort. The result is a series of "experiments" which display the effects of man-induced differences in fish populations upon the yield of the fishery. The independence of each locality is reinforced by the fact that inshore fish typically travel only a few miles in their lifetime (Rinne 1975)."

The purpose of the analysis that follows is to suggest fishing practices, in terms of types and quantities of fishing gear, which can be expected to generate the greatest yields. It is purely empirical. It is a statistical way of noting which patterns of fishing lead to more successful catches in the long term and which do not. It deals with the resultant effects of each type of gear on the fishery — a consequence of biological processes such as mortality, growth, recruitment, and competition; and technical processes such as gear effectiveness and competition between different gear for the same fish — while dealing with none of these complicated actions and interactions explicitly.

Methods

The information was divided into predictor and response variables to be used for multiple curvilinear regression analyses. The response variables were fish catches per kilometre of lake shoreline (henceforth referred to as yield). The predictor variables were fishing effort per kilometre of shoreline (henceforth referred to as gear density when applied to one type of fishing gear, and fishing intensity when applied to all types of gear together). There were six predictor variables:

Small gillnets (X_{SM}) — 3.8–5.1 cm
Medium gillnets (X_M) — 6.4–9.5 cm
Large gillnets (X_L) — 10–12 cm
Extra large gillnets (X_E) — 13–20 cm
Hooks (X_H)
Seines (X_{SE}).

It was necessary to group gillnets into four size-classes to reduce the problem to manageable dimensions. The above categories were selected to conform to size groupings used for present and past regulations. The categories also correspond to functional groupings of gillnets as they occur in fishing boats. This was verified by a statistical analysis of detailed records of gear densities at 200 landings in the Tanzania 1973 Annual Canoe Survey. (The only exception was that 13-cm gillnets tended to be used with large rather than extra large gillnets.)

Details of data sources and tabulation procedures, as well as complete tables of boat densities, gear densities, and average daily catches of each kind of fish at each of 49 landings in 1972 and 1973 are given by Marten (1979b). The data were tabulated primarily from records of the Fisheries Departments of Tanzania, Kenya, and Uganda. The procedure in all cases was to estimate the average daily catch per boat and number of gear units per boat at each fish landing recorded during 1972 and 1973. It was essential to work with annual averages because of the large fluctuations that occur in fish catches in different seasons of the year (Marten 1975b). The number of boats per kilometre in the vicinity of each landing was based on a strip extending 15 km in each direction from the landing. Catch per boat and gear per boat were then multiplied by boats per km to give daily catch per km and gear density per km at each landing. *Engraulicypris*, *Alestes*, *Labeo*, *Schilbe*, *Lates*, *Barbus*, and *Mormyrus* were omitted from the analysis because they were reported as nil from most landings.

Curvilinear Regression Analysis

A separate regression equation was fitted to each of the response variables (i.e. to the yield of each kind of fish). Each equation was quadratic for all six predictor variables and forced through the origin, allowing a description of the joint effect of each type of gear on yield. The form of the equation was

$$Y = \sum_i a_i x_i + \sum_i b_i x^2_i + \sum_i \sum_j c_{ij} x_i x_j.$$

A quadratic equation for six independent variables has 27 terms. Because I felt the data did not contain sufficient information to estimate all 27 terms with precision, the regression equations were fitted in two stages. First, only linear and quadratic terms were fitted. Second, the fitting procedure was repeated, including all linear and quadratic terms but only those crossproducts involving variables whose linear terms were significantly positive. This was because only those cross products associated with positive linear terms were actually to be used in the optimization to follow.

Equations of this form have a curvature that is well suited to describe yields that increase with fishing intensity to a maximum and decrease at higher fishing intensities. They also lend themselves to both qualitive and quantitave interpretation. Qualitatively, the coefficients of linear terms in the equation indicate whether a particular type of gear makes a positive or negative contribution to yield or none at all. This is not the same as gear efficiency. A particular type of net may be very effective at capturing fish, but if it depletes fish stocks or deprives other types of gear in the fishery of the opportunity to harvest fish at the proper size, its overall contribution may be nil or negative.

When the linear term is positive, the coefficient of the square term indicates how quickly increased gear density leads to diminished returns due to reduced fish size or stock size. Yields level off or even decline as gear density passes the optimum. If the coefficient of the square term is zero, it means that yields continue to increase with increasing gear density, at least over the range of densities represented by the data.

Cross product terms indicate interaction between fishing gear. Although the nature of the interaction could be complex, an example is direct competition between different gear for the same fish. The yield when two types of competing gear are in use is less than the simple sum of the yields from each in use by itself, and this is reflected in a negative crossproduct term. Square and cross product terms are important to the optimum mix of gear because even a gear that makes a positive contribution at low densities may be excluded from the optimum if it displays diminishing returns and interacts negatively with other gear at high gear densities.

Regression equations were fitted separately to the data for 1972 and 1973 to compare the results from the two years. Although the numerical values of regression coefficients for the 2 yr were not exactly the same, they were always of the same sign and magnitude. This suggested that random errors were not generating spurious results, and regression equations were consequently fitted to the data for 1972 and 1973 combined, with statistical degrees of freedom ranging from 76 to 81. Only terms significant at the 75% level of confidence are included in the equations presented below.

Optimization

Quantitatively, quadratic equations lend themselves to calculating the optimum: the gear densities at which yield is a maximum. This is done by taking the derivatives of the regression equations with respect to each predictor variable (i.e. with respect to each type of gear), setting the derivitives to zero, and solving the resulting simultaneous linear equations. It is necessary to take precautions that the solution is at a maximum rather than a minimum (i.e. that all second derivitives are negative); and that negative values of gear densities (which are physically impossible) are not allowed to occur.

Quadratic programming such as described by Kunzi and Krell (1966) could have been used, but the following procedure was easier under the circumstances: (1) solve the equations with some of the variables removed (i.e. some gear densities forced to zero), (2) calculate the yield that follows from that solution, (3) repeat the procedure for all 63 combinations of zero and nonzero variables, and (4) select the solution resulting in the highest yield.

It is necessary to caution about extrapolation. The yield equations are valid only over the range of gear densities existing in the data. Yields cannot be calculated for gear densities greater than those in the data, nor can an optimum be located above that range. If maximum yield falls within the range of the data, it can be located with reasonable precision. However, if computations indicate a maximum above that range, it cannot be known with certainty whether yield levels off or declines at higher gear densities. It can only be said that the fishery has the capacity for greater yields from heavier fishing.

Finally, although the results are given in quantitative terms they should in the end be interpreted qualitatively. The optimum numbers in Tables 1 and 3 are not to be taken as precisely the final word for management, because those numbers are subject to numerous statistical errors. However, the regression equations should be suitable for indicating which types of gear are useful or harmful to the fishery as a whole. The optimization calculations indicate directions in which gear densities might be changed to produce better yields in the current fishery.

Results

Overview of the Fishery

In Fig. 2 the relationships between fishing gear and fish catches throughout the fishery are summarized by principle components analysis (Cooley and Lohnes 1971). Those gear that are used together are close together on the graph, and fish catches that are associated

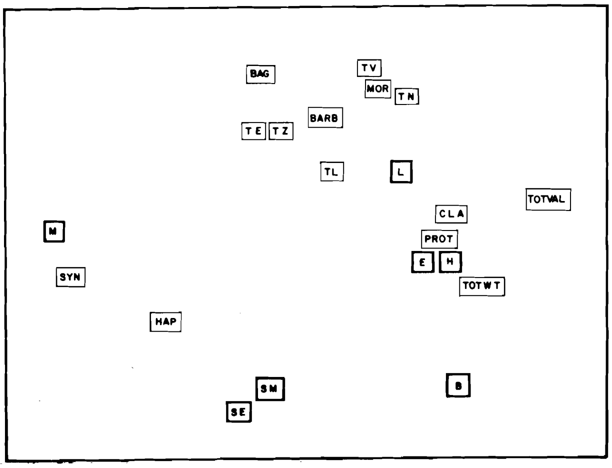

FIG. 2. Factor loadings of the first two principal components based on intercorrelations between fishing effort and fish catches at 49 fish landings on Lake Victoria during 1972–73. Densities of fishing gear are shown in thick boxes, and fish catches are shown in thin boxes. HAP = *Haplochromis*; SYN = *Synodontis*; PROT = *Protopterus*; CLA = *Clarias*; TE = *Tilapia esculenta*; TV = *T. variabilis*; TN = *T. nilotica*; TZ = *T. zillii*; TL = *T. leucosticta*; BAG = *Bagrus*; BARB = *Barbus*; MOR = *Mormyrus*; SM = 3.8–5.1-cm gillnets; M = 6.4–9.5-cm gillnets; L = 10–12-cm gillnets; E = 13–20-cm gillnets; H = hooks; SE = seines; B = boat density; TOTWT = total weight; TOTVAL = total value.

with each other and with particular gear are likewise close to each other.

There are four constellations: (1) large gillnets — *Tilapia*, *Barbus*, *Bagrus*, *Mormyrus*; (2) hooks and extra large gillnets — *Protopterus* and *Clarius*; (3) seines and small gillnets — *Haplochromis*; (4) medium gillnets — *Synodontis*.

Judging from the positions of boat density, total weight (summed over all species), and total value in Fig. 2, regions of higher boat densities tend to emphasize either seines and small gillnets or hooks and extra large gillnets. Landings that emphasize hooks and extra large gillnets have the highest yields in total weight and value. Regions of low boat densities tend to emphasize large gillnets or, at some landings, medium gillnets.

Figure 3 indicates that total weight yield (summed over all species) increases to a maximum as boat densities increase. Once the maximum is reached, yield stays about the same even at higher densities. Many of the landings in Fig. 3 fall short of the total weight yield realized by other landings at the same boat density, possibly because of differences in the kinds of fishing gear in use. Regression equations that extract the separate effects of each type of gear, as well as particular gear combinations, can indicate how much of the variation of the points in Fig. 3 is in fact due to gear composition.

TOTAL WEIGHT AND VALUES OF THE FISHERY

The total weight yield of the fishery (summed over all species) is the best indicator of its production of human food. There is no single optimal management strategy for a multiple-species fishery like Lake Victoria; the mix of gear which is optimal for one species is less than optimal for others. Optimizing total weight yield therefore involves a mix of gear that is not necessarily best for any species in particular, but exploits as much as possible of the productive potential of all of them together.

The regression equation for total weight yield per kilometre is

$$Y = 48X_{SM} - 1.8X^2_{SM} + 50X_L - 1.1X^2_L + 10X_E - 0.2X^2_E + 110X_H - 6.4X^2_H - 23X_{SM}X_L - 2.2X_LX_H - 4X_{SM}X_{SE} - 8X_HX_{SE} - 1.0X_LX_E - 1.6X_{SM}X_E.$$

To facilitate comparison of the impacts of different kinds of fishing gear, the coefficients of all equations have been adjusted so that X_{SM}, X_M, X_L, X_E, X_H, and X_{SE} each refer to one "boatload" of the respective type of gear. This is based on average levels of use of 40 gillnets per boat, 800 hooks per boat, and one seine per boat.

There are no linear terms for X_M and X_{SE} in the above equation because their coefficients are not significantly different from zero. That is, medium gillnets and seines make no contribution to the overall tonnage yield of the fishery. However much medium gillnets and seines are catching themselves, they are depriving the rest of the fishery of an equal amount. Considering the linear terms for the other types of fishing gear, extra large gillnets make a positive contribution but are not nearly as effective as small gillnets, large gillnets, and hooks.

Turning to cross product terms, the enormous negative interaction between small and large gillnets suggests that both cannot coexist at the optimum, and in fact the optimum (Table 1) includes only large gillnets and hooks. Small gillnets lose out to large gillnets because of the stronger diminishing returns of small gillnets at high levels of use (i.e. small gillnets have a larger negative square term).

Optimal fishing (Table 1) consists of a mix of large gillnets and hooks at the highest levels now in use and no use at all of other types of gear. The resulting yield would be $460\,kg \cdot km^{-1} \cdot d^{-1}$, 70% above the present average. (The reader is reminded that because of the limited precision inherent in the method, these figures and all those that follow are not to be taken literally; they should be regarded as qualitative indicators. The results must also be qualified by the fact that no single equation can provide a precise description for all of Lake Victoria. Because ecological conditions are not absolutely uniform around the lake (Wanjala 1978), the precise responses of fish stocks to fishing, and the optimum that follows, can be expected to vary accordingly.)

TABLE 1. Optimal mixes of fishing gear for total weight ($kg \cdot km^{-1} \cdot d^{-1}$) or total value (US $\$ \cdot km^{-1} \cdot d^{-1}$) summed over all kinds of fish.

	Optimum gear densities (per km)								
	3.8–5.1-cm Gillnets	6.4–9.5-cm Gillnets	10–12-cm Gillnets	13–20-cm Gillnets	Hooks	Seines	Current average yield	Optimum yield	Multiple correlation[a]
Total weight	0	0	410	0	2850	0	270	460	0.94
Total value	190	0	170	170	4300	0	66	150	0.95

[a]This pertains to the regression equation used for optimization.

Table 2 shows that optimal fishing for total weight yield from the entire fishery involves a drastic change in catch composition compared with the present. All catches of *Haplochromis* and *Synodontis* are sacrificed to attain even greater increases in the catches of *Tilapia*, *Bagrus*, and *Protopterus*.

The total gross value of the fish catch (summed over all species) is an appropriate measure of earnings to the fishing industry. The optimum for total value (Table 1) is different from that for total weight because total value depends not only on the quantity of fish but also on the species composition of the catches and the prices of different kinds of fish.

The regression equation for total value (in U.S. $\$ \cdot km^{-1} \cdot d^{-1}$) is

$$Y = .14\,[20X_{SM} + 3X^2_{SM} + 51X_L + 18X_E + 6.4X^2_E + 88X_H - 7.0X^2_H - 32X_{SE} - 6X_{SM}X_L - 6X_{SM}X_E + 3X_{SM}X_H - 5X_LX_E + 3X_LX_H].$$

The contribution of medium gillnets to total value is nil, and seines make a negative contribution. Large gillnets and hooks make the greatest contributions to total value, but the contributions of small and extra large gillnets are significant enough to justify their inclusion in the optimum (Table 1). Diminishing returns do not set in nearly so rapidly for total value as they do for total weight. It appears that higher fish prices, which accompany diminished catches due to supply and demand, hold up total value under heavy fishing conditions even when total weight yield has declined. As a consequence, the optimal densities of nets and hooks for total value are higher than for total weight, giving a potential optimal average value yield double the present one (Table 1).

TABLE 2. Percentage yields to be expected from each kind of fish under optimum fishing for total weight yield (i.e. 410 large gillnets and 2850 hooks/km) compared with percentages in the current (1972–73) fishery. The sum of percentages is <100 because of minor species which are not included in the table.

	Current	Optimum
Tilapia	15%	41%
Bagrus	12%	16%
Clarias	15%	10%
Protopterus	26%	32%
Haplochromis	22%	0%
Synodontis	2%	0%

INDIVIDUAL GENERA

The optimal quantities of gear and their corresponding yields, as calculated from the regression equation of each commercially important fish genus, are presented in Table 3 and discussed along with the equations below. The different kinds of fish are given individual treatment not because the fishery should be managed for any one particular species but rather to indicate the effects of different gear on that kind of fish, as well as the potential yield of that fish compared with its present yield.

The following equations describe weight yields of the *Tilapia* species:

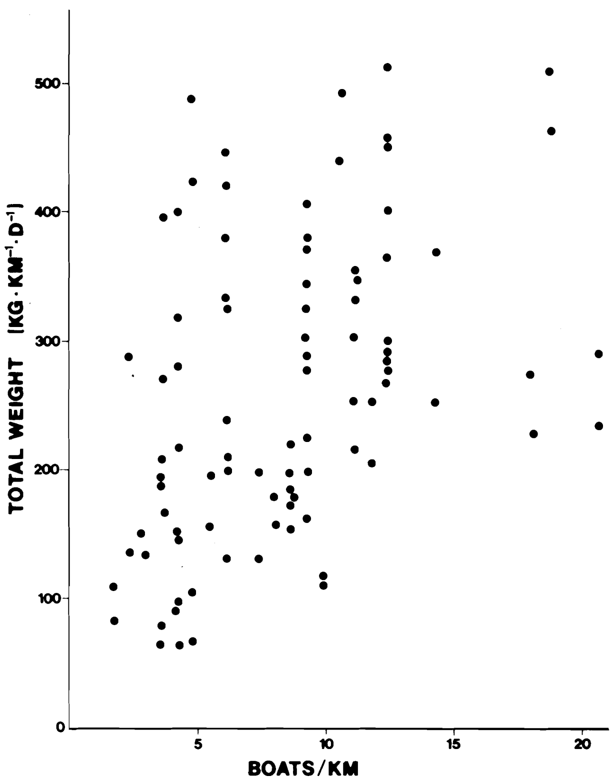

FIG. 3. Daily total weight yield (summed over all species in the fishery) per kilometre of shoreline vs. boat density per kilometre of shoreline.

TABLE 3. Optimum mixes of fishing gear (if each type of fish were managed to maximize production of it alone) and the yields to be expected under optimum harvesting compared with current yields.

	Optimum gear densities (per km)						Yields ($kg \cdot km^{-1} \cdot d^{-1}$)		
	3.8–5.1-cm Gillnets	6.4–9.5-cm Gillnets	10–12-cm Gillnets	13–20-cm Gillnets	Hooks	Seines	Optimum	Current average	Multiple correlation[a]
Current average	90	12	100	68	1240	0.65			
Maximum occurring	383	120	400	240	2420	7.72			
Optimum for each kind of fish									
Tilapia	0	0	450	0	2300	0	240	40	0.85
Bagrus	0	0	400	0	0	0	96	33	0.74
Clarias	0	0	0	150	3700	0	150	40	0.89
Protopterus	0	0	0	0	6800	0	390	70	0.87
Haplochromis	0	0	0	0	8100	4.2	300	58	0.88
Synodontis	400	120	0	0	0	0	81	5.8	0.83

[a]This pertains to the regression equation used for optimization.

T. esculenta (native)

$$Y = -2.2X_{SM} + 2.4X_L + 2.5X_E - 0.56X^2_E + 9.6X_H + 1.3X^2_H + 7.1X_{SE} - 0.7X^2_{SE} - 1.0X_LX_E$$

T. variabilis (native)

$$Y = -6.4X_{SM} + 14X_M + - 3.5X^2_M + 1.84X_L + 6.2X_H - 0.6X^2_H + 3.1X_{SE} - 0.7X^2_{SE} - 0.5X_{SM}X_L - 0.8X_{SM}X_{SE}$$

T. nilotica (introduced)

$$Y = -2.5_{SM} + 4.0X_L + 3.2X_E + 6.7X_H - 6.4X^2_H - 8.3X_{SE}$$

T. zillii (introduced)

$$Y = -0.56X_{SM} + 1.3X_M - 0.3X^2_M + 4.5X_H -0.5X^2_H - .06X^2_{SE}.$$

The equations for *T. nilotica* and *T. zillii* must be interpreted with caution because both species are still spreading around the lake. *Tilapia esculenta* also demands caution because it is in the process of disappearing from the lake.

Nonetheless, the major features of the equations deserve consideration. Small gillnets make a negative contribution in all cases. Medium gillnets are significant for *T. variabilis* and *T. zillii* but give a diminished return above 50 nets/km. Large gillnets are significant for *T. esculenta*, *T. variabilis*, and *T. nilotica* and interestingly show no indication of saturation (i.e. no negative quadratic term) over the range of net densities occurring in Lake Victoria. Seines have a negative effect on *T. nilotica* and *T. zillii*. Although seines have a positive effect for *T. esculenta* and *T. variabilis*, the contribution declines above 3 seines/km in the case of *T. esculenta* and 1 seine/km in the case of *T. variabilis*. The most surprising result is the positive contribution of hooks in all cases, particularly since hooks seldom catch *Tilapia*.

The equation for all *Tilapia* grouped together is

$$Y = -4.8X_{SM} + 6.2X_L + 0.8X^2_L + 8.8X_E + 0.4X^2_E + 29X_H - 3.2X^2H - 0.7X^2_{SE} - 2X_EX_L - 0.2X_{SM}X_L - 0.4X_{SM}X_{SE} - 0.4X_EX_{SE}.$$

The equation indicates that small gillnets and seines are depressing *Tilapia* yields. Consulting Table 3, *Tilapia* yields could be 6 times the present average if they were fished intensely by only large gillnets at slightly greater than the maximum density of gillnets now occurring in Lake Victoria, supplemented by hooks near their present maximum density. This gear mix is quite similar to that for optimum total weight yield in Table 1.

The regression equation for weight yield of *Haplochromis* is

$$Y = 21X_{SM} - 1.0X^2_{SM} - 9.6X_M + 9.6X^2_M - 20X_E + 8.8X_H - .26X^2_H + 124X_{SE} - 9.0X^2_{SE} - 5.6X_{SM}X_{SE}.$$

Small gillnets and seines make the largest contribution to *Haplochromis* catches, with a strong negative interaction between the two. Medium gillnets do not make nearly so large a contribution, but the positive sign for the square term indicates continually increasing returns over the range of medium gillnets now in use. Hooks, which do not themselves catch many *Haplochromis*, have a positive effect. From Table 3, the optimum would have seines at about half the maximum level now in use, supported by the heavy use of hooks. The maximum yield of $300\ kg \cdot km^{-1} \cdot d^{-1}$ for *Haplochromis* is 5 times the current average on Lake Victoria and corresponds to the highest *Haplochromis* yields now being obtained.

The regression equation for weight yield of *Bagrus* is

$$Y = 6.4X_{SM} - 0.2X^2_{SM} + 20X_L - 0.6X^2_L - 9.0X_{SE} - 0.8X_{SM}X_L.$$

Small and large gillnets contribute significantly to *Bagrus* catches. Seines, which are known to catch large numbers of juveniles, have a negative effect. From Table 3, the overall *Bagrus* yield could be more or less tripled if small gillnets and seines were not in use and large gillnets were used at the maximum density now occurring in Lake Victoria.

The regression equation for weight yield of *Clarias* is

$$Y = 8.4X_{SM} - 0.7X^2_{SM} - 6.0X_L + 19X_E - 2.2X^2_E + 9.6X_H - 1X_{SM}X_E + 1X_{SM}X_H + 3X_EX_H - 2X_{SM}X_{SE}.$$

Small gillnets make a contribution but quickly reach diminishing returns. Hooks harvest *Clarias* without diminishing returns over the full range of hooks now in use. The optimum is a mix of hooks and extra large gillnets, but it cannot be calculated because it lies above the range of the data. Setting hooks and extra large gillnets at the present maximum, the optimum (Table 3) would yield at least 4 times the present average catch of *Clarias.*

The regression equation for weight yield of *Synodontis* is

$$Y = 3.2X_{SM} - 0.1X^2_{SM} + 5.2X_M + 3.4X^2_M - 2X_E - 3X_H + 0.3X^2_H + 2.8X_{SE} - 0.1X^2_{SE} - 0.2X_{SM}X_{SE}.$$

Beach seines and small and medium gillnets contribute positively to *Synodontis* yield. Medium gillnets make the largest contribution and show no sign of diminishing returns. The exact coefficients must be taken with caution because there are not many data on medium gillnets, and the coefficients for medium gillnets have large errors. The optimum for *Synodontis* would include small and medium gillnets, but it cannot be calculated because it lies above the limits of the data. The value entered for the optimum in Table 3 is at the maximum numbers of small and medium gillnets now used in Lake Victoria, more than 10 times the present yield.

The regression equation for weight yield of *Protopterus* is

$$Y = -9.6X_{SM} - 28X_M + 1.8X^2_E + 66X_H - 2.6X^2_H - 55X_{SE}.$$

Seines and small and medium gillnets make a negative contribution. The optimum number of hooks is greater than the maximum now in use. It is not possible to calculate the optimum number of extra large gillnets because it lies above the range of the data. Setting extra large gillnets at the maximum now in use, the maximum possible yield for *Protopterus* (Table 3) is at least 5 times the present average yield.

Summarizing the regression equations for individual genera, seines have emerged as particularly destructive to the yields of the larger genera of fish, making a negative contribution in nearly all cases. Medium gillnets make a nil or negative contribution to the catches of the larger genera. Although small gillnets have a negative effect on *Tilapia* and *Protopterus* yields, they are positive for the large catfish *Bagrus* and *Clarias* (but with quickly diminishing returns).

For nearly every genus there is one type of gear that makes a large positive contribution and shows little diminishing returns over the range of use now existing in the fishery. In other words, most kinds of fish have some kind of gear for which they can sustain increasing yields under increasing fishing effort over the range now existing in the fishery.

Discussion

Points of Caution

The regression approach used here has some risks that deserve mention. First of all, the results can be biased by unknown factors that are correlated with the measured variables. For example, variations in biological productivity in different regions of Lake Victoria could lead to variations in yields. This could lead to more favorable regression coefficients for those types of gear that predominate in areas of high yields due to high biological productivity. A similar bias could arise from the fact that the data come from four different recording systems in four regions of Lake Victoria. If the reporting from one of the recording systems is too high, it could favorably bias the coefficients for the gear predominating in that area.

Perhaps the most serious limitation of the analysis is that it supposes fish catches in the vicinity of each landing to be the consequence of long-term effects of the densities of various fishing gear in use in the area. In other words, fish catches are assumed to be in approximate equilibrium, despite any changes in gear that may have taken place during recent years. A decline in *T. esculenta* catches from 1972 to 1973 indicates this is not the case for this species at many landings. Catches of the other kinds of fish are reassuringly similar for both years, although it is known that in recent years in Kenya and some parts of Tanzania there has been a consistent decline in *Tilapia* and a slow but equally consistent increase in large predator catches (Kudhongania and Cordone 1974; Marten 1975a).

Total Fishing Effort

Because human population growth will most likely lead to increasing fishing pressure throughout Lake Victoria in the future, the question of overfishing is an important one. Referring to Fig. 3, where on the average the highest yields occur at the highest fishing intensities, there is not a problem of overfishing in the sense of too many fishermen. In fact, the density of fishermen on Lake Victoria is not high compared with many other African lakes (Henderson and Welcomme 1974).

The flat peak at high fishing intensities in Fig. 3 might well be expected. Experience with other fisheries indicates a typical consequence of heavy fishing is a succession of species, some dropping out as fishing increases while others take their place in the ecological vacuum. Yields remain high as long as fishermen adapt their techniques to the changing species composition of the fishery (Henderson and Welcomme 1974).

There is evidence of this tendency in the Lake Victoria fishery. Each species shows a peak yield at some intermediate boat density, but the peaks of the different species occur at different boat densities. For example, *T. esculenta* and *T. variabilis* peak at about 7 boats/km of shoreline (Fig. 4a), whereas *Clarias* and *Protopterus* peak at 12 boats/km (Fig. 4b). When the curves of

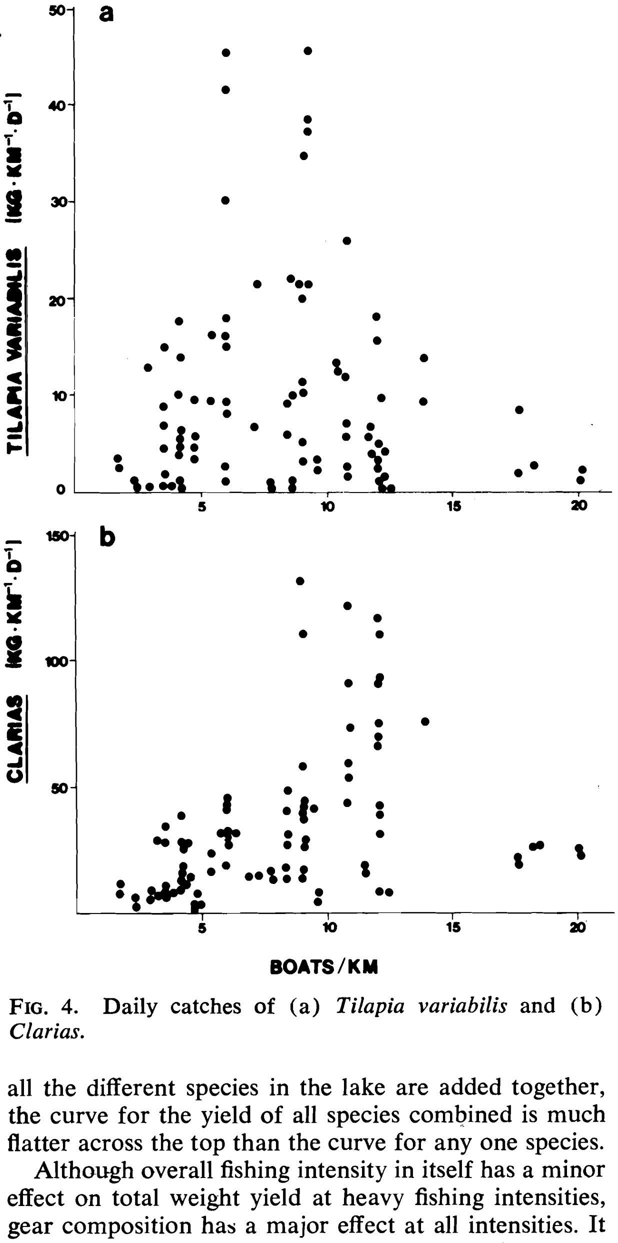

FIG. 4. Daily catches of (a) *Tilapia variabilis* and (b) *Clarias*.

all the different species in the lake are added together, the curve for the yield of all species combined is much flatter across the top than the curve for any one species.

Although overall fishing intensity in itself has a minor effect on total weight yield at heavy fishing intensities, gear composition has a major effect at all intensities. It appears that gear composition is in fact a major source of the variation of points for total yield vs. boat density in Fig. 3. This is strongly suggested by the regression equation for total weight yield, whose optimum (Table 1) is equivalent to 14 boats/km at present rates of gear usage, well above the present average density of 9 boats/km on Lake Victoria. Landings now below 14 boats/km can expect to increase their total weight yield as boat densities increase, provided they use appropriate gear. Although we do not have much information concerning fishing intensities above 14 boats/km, the available data suggest (through the regression equation for total weight yield) that yields could be sustained close to the optimum level, even at fishing intensities as high as 25 boats/km, conditional upon the proper mix of gear (hooks and large gillnets).

ROLE OF DIFFERENT FISHING GEAR

Small gillnets can make a significant contribution at low fishing intensities because they take advantage of the extensive *Haplochromis* and *Synodontis* stocks. Furthermore, considering the high predation experienced by juveniles of the larger fish species (Marten et al. 1979), small gillnets are probably an effective way to crop even the larger species under light fishing conditions where the survival of an adequate spawning stock is not a problem. Cropping the larger species as young as possible brings a larger share of fish to the fishermen rather than to fish-eating predators.

The maximum potential harvest with small gillnets appears to be limited, however. Despite the numerous species and general abundance of *Haplochromis*, inshore *Haplochromis* in the heavier fished areas of Lake Victoria already seem to be cropped at the limits of their potential. This is suggested by the observation that *Haplochromis* lengths have been declining rapidly in heavily fished areas in and around the Kavirondo Gulf during the past decade, with the result that average lengths in heavily fished areas are less than half those in lightly fished areas (Wanjala and Marten 1975; Marten et al. 1979). This implies the virtual disappearance of the larger *Haplochromis* species from the heavily fished areas. *Haplochromis* may have a lower potential yield than larger predators, because the large predators do not themselves experience much natural predation while they are at fishable sizes. The great quantity of natural predation experienced by *Haplochromis* due to the large predators (Chilvers and Gee 1974) means a relatively small share of *Haplochromis* is available to fishermen, such that stocks cannot sustain the double burden of heavy fishing and natural predation.

The harmful effects from small nets and seines have been most conspicuous and unfortunate under the heaviest fishing conditions. The spiral of smaller nets, smaller fish, and smaller fish stocks that has often accompanied heavy fishing appears also to generate a species succession from *Tilapia* to large predator "trash" fish. This may be a consequence of the fact that local tribal tastes generally consider at least one of the large predator species unfit for human consumption. Unpalatable large predators, which are particularly lightly fished when large gillnets pass out of use with the decline in *Tilapia*, are allowed to increase in abundance and probably accelerate the decline of *Tilapia* on which they feed.

I would hypothesize that the succession from *Tilapia* to large predators is accompanied by a fundamental "switch" in the ecological pathways between photosynthesis and human consumption (Fig. 1), which further accelerates the succession and diminishes the potential yield of the fishery. Initially, with light fishing, the fishery exploits *Tilapia*, which feed on phytoplankton and provide a direct link between photosynthesis and human consumption. However, when small mesh nets come into use and *Tilapia* numbers are reduced, phytoplankton not consumed by *Tilapia* are consumed by zooplankton or drop to the lake bottom. Biological production is channeled through complicated food chains involving invertebrates, small fish, and finally predatory fish (e.g. *Haplochromis*, *Protopterus*, *Bagrus*, and *Clarias*) large enough to be cropped by fishermen. Because the biological production passes through long food chains with considerable metabolic losses along the way, less of the original primary production is available for human consumption than if it had passed directly from phytoplankton to *Tilapia* to man.

The large negative interaction between small and large gillnets in the equation for total weight yield indicates there is not a place for both small and large gillnets under heavy fishing conditions. If both are in heavy use, insufficient adults of the larger species survive to spawn, and stock numbers decline. It seems that the potential yields of the small species which are cropped most effectively by seines and small gillnets are not great enough to compensate for the damage these nets do to the catches of the larger fish. (It could be worthwhile going after smaller fish such as *Haplochromis* and *Synodontis* if fishing techniques were developed that would not simultaneously interfere with the stocks of larger species.)

Medium gillnets do not appear to make any overall contribution to the fishery and should generally be discouraged. Extra large gillnets appear incapable of making as great a contribution to the fishery as large gillnets because the extra large gillnets are too large to crop most species intensively. The colonial policy of only allowing gillnets 13 cm or larger appears not only unnecessary but also unduly restrictive.

According to the equation for total weight yield, large gillnets in combination with hooks should lead to the highest yields under heavy fishing conditions (Table 1). As was noted in Fig. 2, this combination, which is also optimal for *Tilapia*, is in fact not common under heavy fishing conditions. The combination of large gillnets and hooks seems to be an effective strategy for intense fishing, however, because it can be used in large quantities before diminishing returns set in. This is probably because large gillnets can intensively crop the large species of fish such as *Tilapia* and *Bagrus* without taking an excessive number of juveniles.

Hooks seem to be effective for several reasons. First, they exploit the significant productivity of *Clarias* and *Protopterus*. The potential yields of *Protopterus* appear particularly high, perhaps because cropping *Protopterus* is an effective way to exploit the high biological productivity of the extensive marshy margins of Lake Victoria. *Protopterus* may have such a high potential because, feeding upon detritus, snails, and other detrital animals, it is at the end of relatively short food chains.

Second, the regression equations produced the surprising observation that hooks stimulate the catches of species that are not themselves caught by hooks. We can speculate that this is because hooks reduce predator populations, thereby decreasing losses of fish to predators and correspondingly increasing the portion going to fishermen. *Tilapia* catches, for example, are particularly restricted where predators are abundant (Marten 1979). Prey fish like *Tilapia* can be expected to tolerate a heavier cropping load from fishermen if they are not simultaneously bearing a heavy burden due to natural predators. Regardless of the explanation, the indirect effect of hooks seems to be as important as the catches of hooks themselves.

Although there may not be a local incentive to harvest large predator trash fish, every unpalatable predator species is considered a delicacy by at least one tribe. It should, therefore, be possible to encourage the fishing of large predators that have reached nuisance proportions by developing markets to areas where they are worth many times what they are locally.

Reviewing the overall picture for Lake Victoria's inshore fishery, it appears that some landings already realize approximately the highest total weight yields possible, but most landings could increase their yields by heavier fishing and/or changes in gear composition. Optimal gear densities could lead to overall yields on the order of 70% above the present average (Table 1), and 70% of a large fishery like Lake Victoria is an immense quantity, well worth pursuing. Nonetheless, as optimal management cannot be expected to even double the yield of the inshore fishery, it cannot be expected in the long term to improve per capita fish yields for the exponentially growing human population in the area.

Acknowledgments

I thank the staff of the East African Freshwater Fisheries Research Organization for their encouragement and support. In particular, S. Sowobi, J. Olonge, I. Otieno, and G. Isyagi should be mentioned for the assistance they provided in data tabulation. L. Guluka and B. Wanjala collaborated during numerous stages of the research. I am grateful to the Fisheries Departments of Kenya, Uganda, and Tanzania for making available their records of Lake Victoria fish landings, and I am particularly indebted to the Regional Fisheries Officers in Kisumu, Entebbe, Masaka, Bukoba, Mwanza, and Musoma for their generous cooperation.

BEADLE, L. C. 1974. The inland waters of tropical Africa. Longman, New York.

CHILVERS, R. M., AND J. M. GEE. 1974. The food of *Bagrus docmac* and its relationship with *Haplochromis* in Lake Victoria, East Africa. J. Fish Biol. 6: 483–505.

COOLEY, W. W., AND R. P. LOHNES. 1971. Multivariate data analysis. John Wiley and Sons, Inc., New York, N.Y.

FRYER, G., AND T. D. ILES. 1972. The cichlid fishes of the great lakes of Africa. TFH Publications, Neptune City, N.J.

HENDERSON, F., AND R. L. WELCOMME. 1974. The relationship of yield to morpho-edaphic index and numbers of fishermen in African inland fisheries. FAO Committee for Inland Fisheries of Africa Occasional paper No. 1, FAO, Rome.

KUDHONGONIA, A. W., AND A. J. CORDONE. 1974. Past trends, present stocks and possible future state of the fisheries of the Tanzania part of Lake Victoria. Afr. J. Trop. Hydrobiol. Fish. 3: 167–182.

KUNZI, H. P., AND W. KRELLE. 1966. Nonlinear programming. Blearsdell, Waltham, Mass.

MARTEN, G. G. 1975a. Trends in the Kenya fishery of Lake Victoria (1968–1973). East African Freshwater Fisheries Research Organization 1973–1974 Annual Report: 20–22.

1975b. Fluctuations in fish catches and prices and their correlations with climatic factors. East African Freshwater Fisheries Research Organization 1973–1974 Annual Report: 69–75.

1979a. Predator removal: effect on fisheries yields in Lake Victoria (East Africa). Science 203: 646–648.

1979b. Implications of 1972–1973 fisheries records on Lake Victoria for improving fisheries practices. Afr. J. Trop. Hydrobiol. Fish. (In press)

MARTEN, G. G., B. WANJALA, AND L. GULUKA. 1979. Exploratory trawling of the Lake Victoria fishery in Kenya during 1975. Afr. J. Trop. Hydrobiol. Fish. (In press)

RINNE, J. N. 1975. Age, growth, tagging of *Tilapia* and reproductive biology of siluroid catfishes in Lake Victoria. East African Freshwater Fisheries Research Organization Report: 60 p.

SCULLY, R. J. 1975. The importance of furu (the *Haplochromis* species flock) in Lake Victoria's gillnet fisheries. East African Freshwater Fisheries Research Organization Report: 25 p.

1976. Species composition estimates of commercial and experimental gillnet catches from the Tanzania waters of Lake Victoria (October 1973–January 1975). East African Freshwater Fisheries Research Organization Report: 60 p.

WANJALA, B. 1978. The association and distribution of fish species in Nyanza Gulf, Lake Victoria, East Africa, 1975. M. Sc. thesis, Oregon State University, Corvallis, Oreg.

WANJALA, B., AND G. G. MARTEN. 1975. Survey of the Lake Victoria fishery in Kenya. East African Freshwater Fisheries Research Organization 1973–1974 Annual Report: 81–85.

LAKE VICTORIA FISHING GEAR AND CATCH DATA (1972-1973)

Gerald G. Marten
East West Center, Honolulu, Hawaii
Email: marteng@eastwestcenter.org

The tables on the following pages were compiled by visiting the fisheries department headquarters for Kenya (Kisumu), Uganda (Entebbe), and Tanzania (Mwanza) in 1975. The following were tabulated for each fish landing from the original data sheets that the headquarters had received from regional offices:

- average quantity of each category of fishing gear per boat;
- average daily catch (in kilograms per boat) for each category of fish;
- average daily value of the catch (in shillings per boat) for each category of fish.

For each fish landing, the above data were multiplied by the number of boats per mile of shoreline in the vicinity of that landing, to convert them to:

- gear density per mile of shoreline;
- catch in kilos per mile of shoreline;
- catch in shillings per mile of shoreline.

The number of boats per mile of shoreline in the vicinity of each landing was estimated from the number of boats within 9 miles each side of that landing.

The data were than used to generate multi-dimensional "Schaefer curves" by conducting a series of quadratic multiple regression analyses with:

- the catch or value of each category of fish (as well as total catch and total value, summed over all categories of fish) as dependent variables;
- the six categories of fishing gear as independent variables.

The data and results from the quadratic multiple regression analyses were used for two publications on the Lake Victoria fisheries:

- Gerald G. Marten. 1979. **The impact of fishing on the inshore fishery of Lake Victoria**. *Journal of the Fisheries Research Board of Canada* 36:891-900. (www.gerrymarten.com/publicatons/pdfs/GM_Fishery-of-Lake-Victoria.pdf)
- Gerald G. Marten. 1979. **Predator removal: its impact on fish yields in Lake Victoria (East Africa)**. *Science* 203:646-647. (www.gerrymarten.com/publicatons/pdfs/GM_Predator-Removal.pdf)

APPENDIX 1

DENSITIES OF BOATS AND DIFFERENT TYPES OF FISHING GEAR PER MILE OF SHORELINE ON LAKE VICTORIA DURING 1972 AND 1973

	Gill Nets						
	1"-2"	2 1/2"-3 3/4"	4"-4 1/2"	5"-8"	HOOKS	SEINES	BOATS
1972-1973							
PORT VICTORIA	371	5	51	191	1645	.48	15
USENGE	157	5	168	152	5545	1.48	17
WICHLUM	200	5	178	151	2326	.71	14
KALOKA	370	5	88	276	1861	3.66	20
DUNGA	429	5	299	369	2726	8.08	33
KUSA	289	5	309	74	1724	12.45	30
KENDU	391	5	121	200	1333	4.92	19
HOMA BAY	617	5	191	300	1208	4.32	20
WANYAMA	180	22	202	75	2065	2.50	15
KARUNGU	331	5	123	78	1408	.81	14
MAJANJI	276	0	322	322	4700	.60	23
BUGOTO	72	72	180	180	297	.00	9
MASESE	48	120	132	120	996	.00	12
KIYINDI	0	0	170	170	820	.12	10
KATOSI	0	0	147	147	0	.00	7
KISENYI	98	0	238	140	2400	.14	14
KIGUNGU	60	0	645	390	930	.20	15
KASAKA-SENYONDO	42	0	420	100	350	.00	10
KATEBO-KAZIRU(E)	51	0	185	90	4800	.00	15
NAMIREMBE(E)-KIWAMI	126	0	108	180	2520	.15	18
LWALARO	342	0	450	162	2880	.00	18
KIWANGA	240	0	200	360	1300	.00	20
LUWUKI-NABISUKIRO-KAZIKAKE	36	1	268	156	6000	.00	20
KAMUWANGA-BULINGO	16	0	66	306	3000	.00	20

	Gill Nets						
	1"-2"	2 1/2"-3 3/4"	4"-4 1/2"	5"-8"	HOOKS	SEINES	BOATS
NAKIGGA-KATTA-MITENDO	0	0	40	20	6900	.00	20
BUKYAMBIRYA	220	0	40	0	6200	.00	20
MAKONZI-KASSA-ZZIRWE	0	0	195	15	6300	1.50	15
BUKAKATA-LAMBU	10	0	270	70	3100	.00	10
SENERO-KAZIRU(W)-MANGATTI	160	0	75	0	3600	.05	10
NAMIREMBE (W)-BAALE	260	5	150	1	3200	.12	10
DIIMU	120	0	150	28	1050	.35	7
MALEMBO	125	0	77	14	510	.15	7
SANGO	0	0	134	30	2550	.20	15
KYABASIMBA-KIBUKO-IGOMA	54	0	90	162	1620	.00	18
1972							
SOTA	57	0	181	0	106	.00	6
MUSOMA	130	37	153	15	98	.00	7
GUTA	183	101	64	13	384	.07	6
MAJITA	18	12	60	0	0	3.40	6
UKEREWE	304	151	38	5	0	1.77	8
MWANZA	92	81	50	5	380	.07	5
NYAKALIRO	31	12	22	5	360	.22	3
KALAMERA	91	101	136	3	54	.09	4
BUZILAYOMBO	3	5	89	11	1701	.00	6
NYAMIREMBE	6	1	93	24	942	.21	7
KATUNGURU	55	115	82	37	2769	.00	13
BUKOBA	132	20	64	10	597	.00	16
KABINDI	44	15	45	0	702	.52	8

	Gill Nets				HOOKS	SEINES	BOATS
	1"-2"	2 1/2"-3 3/4"	4"=4 1/2"	5"-8"			
1973							
SOTA	40	14	161	2	334	.24	6
MUSOMA	84	51	88	18	355	.39	7
GUTA	152	193	45	0	386	.09	6
MAJITA	2	1	254	0	71	1.84	6
UKEREWE	222	133	31	2	5	1.85	8
MWANZA	91	83	58	7	172	.09	5
NYAKALIRO	26	8	14	5	366	.43	3
KALAMERA	67	172	45	6	157	.49	4
BUZILAYOMBO	1	0	35	20	2775	.00	6
NYAMIREMBE	5	0	95	26	148	.21	7
KATUNGU	50	17	146	172	371	.00	13
BUKOBA	187	7	57	0	314	.18	16
KABINDI	39	34	40	0	167	1.52	8

APPENDIX 2

FISH CATCHES PER MILE OF SHORELINE ON LAKE VICTORIA DURING 1972 AND 1973

	T. esculenta	*T. variabilis*	*T. nilotica*	*T. zillii*	*T. leucosticta*	*Haplochromis*	*Bagrus*	*Clarias*	*Synodontis*	*Protopterus*	*Barbus*	*Mormyrus*	Total Weight	Total Value
LWALARO	41	17	29	0	0	24	33	181	0	223	10	3	564	479
KIWANGA	15	4	133	1	19	30	10	65	0	234	1	0	511	460
LUWUKI	24	20	43	1	3	20	73	153	0	386	2	0	731	695
KAMUWANGA	25	5	23	3	6	5	17	183	0	460	4	0	729	555
NAKIGGA	5	1	6	6	4	1	1	111	1	333	0	0	468	304
BUKYAMBIRA	0	11	1	4	40	353	2	117	0	575	0	0	1104	629
ZZIRWE	18	36	38	5	5	168	25	75	0	178	8	1	554	491
BUKAKATA	48	60	78	17	18	358	117	71	6	293	17	10	1099	955
SENERO	2	16.	19	7	3	53	16	56	1	203	9	1	384	346
NAMIREMBE WEST	4	62	39	12	9	161	129	55	2	185	11	2	675	668
DIIMU	2	25	20	12	0	160	107	22	1	86	6	2	450	431
MALEMBO	1	25	20	5	2	78	88	43	1	72	13	2	347	425
SANGO	18	9	35	7	11	3	7	49	0	99	18	0	256	308
KYABASIMBA	19	7	31	2	7	0	16	90	0	151	50	1	485	384
SOTA	0	1	0	0	0	23	58	10	2	1	2	1	101	82
MUSOMA	27	22	0	0	0	37	17	21	1	17	1	0	146	169
GUTA	11	0	0	0	0	140	17	12	79	14	1	0	335	192
MAJITA	19	14	0	2	0	475	41	58	3	9	9	8	639	225
UKEREWE	18	15	0	1	0	465	26	5	133	8	4	1	790	454
MWANZA	7	1	0	0	0	52	36	11	101	1	1	0	240	265
NYAKALIRO	25	4		1	0	38	2	15	1	23	0	0	131	122
KALAMERA	23	2	0	0	0	52	58	5	34	4	0	0	220	150

1972	*T. esculenta*	*T. variabilis*	*T. nilotica*	*T. zillii*	*T. leucosticta*	*Haplochromis*	*Bagrus*	*Clarias*	*Synodontis*	*Protopterus*	*Barbus*	*Mormyrus*	Total Weight	Total Value
PORT VICTORIA	113	58	45	20	0	173	83	186	11	232	25	4	493	636
USENGE	45	21	4	8	0	134	60	378	0	25	7	2	708	758
WICHLUM	158	35	2	16	0	21	26	45	0	3	4	1	316	402
KALOKA	7	2	1	0	0	307	3	15	3	39	0	0	447	472
DUNGA	28	2	4	0	0	109	14	41	3	88	0	0	379	383
KUSA	13	4	8	1	0	136	4	24	4	104	1	1	817	651
KENDU	14	9	1	3	0	168	8	29	2	44	1	0	330	312
HOMA BAY	63	13	12	4	0	62	47	32	1	106	1	2	364	431
WANYAMA	86	72	34	10	0	87	80	67	0	3	5	1	466	401
KARUNGU	3	0	0	0	0	43	18	23	34	16	13	0	244	190
MAJANJI	3	22	44	2	5	114	40	221	1	133	17	12	633	833
BUGUTO	2	26	29	2	4	9	120	43	0	58	11	11	316	557
MASESE	2	34	125	6	39	6	17	25	0	51	4	6	319	509
KIYINDI	0	24	16	0	4	1	190	55	6	10	4	4	315	441
KATOSI	0	10	8	0	0	0	69	30	1	7	1	14	142	204
KISENYI	3	15	44	0	0	60	108	81	6	29	6	7	357	525
KIGUNGU	2	34	125	6	39	6	17	25	0	51	4	6	319	509
KASAKA	72	13	45	1	4	31	32	53	0	82	3	0	337	337
KAZIRU EAST	5	5	18	3	3	24	44	99	0	377	2	0	579	493
NAMIREMBE EAST	9	1	50	0	10	7	4	123	0	139	0	2	344	341

	T. esculenta	T. variabilis	T. nilotica	T. zillii	T. leucosticta	Haplochromis	Bagrus	Clarias	Synodontis	Protopterus	Barbus	Mormyrus	Total Weight	Total Value
BUZILAYOMBO	55	7	0	9	0	1	6	48	0	141	0	1	268	223
NYAMIREMBE	49	6	0	25	0	12	6	49	0	93	0	0	241	182
KATUNGURU	4	1	0	4		85	99	24	10	9	7	5	251	230
BUKOBA	12	5	0	1	0	86	41	16	0	6	7	3	180	190
KABINDI	13	9	0	5	0	55	23	15	1	28	2	3	170	138
1973														
PORT VICTORIA	2	61	47	20	0	69	53	121	1	53	9	12	487	564
USENGE	2	20	4	6	0	235	88	396	2	4	6	3	774	664
WICHLUM	30	16	1	4	0	26	58	55	0	2	6	3	291	302
KALOKA	3	6	2	2	0	221	7	14	0	143	0	0	449	327
DUNGA	4	3	4	0	0	149	12	40	1	90	6	0	463	513
KUSA	9	4	10	2	0	55	6	43	6	103	1	0	745	907
KENDU	16	10	1	3	0	259	6	32	7	35	1	1	404	311
HOMA BAY	20	35	32	12	0	86	45	36	1	127	2	3	439	570
WANYAMA	4	34	19	10	0	450	25	25	1	4	7	0	654	360
KARUNGU	1	1	0	0	0	79	42	31	38	12	9	0	280	252
MAJANJI	0	15	46	0	1	48	71	128	6	55	13	17	405	549
BUGOTO	0	15	27	0	1	3	126	29	0	32	6	7	248	333
MASESE	0	11	106	2	12	0	14	24	0	33	2	2	209	427
KIYINDI	0	13	23	0	2	0	119	33	6	5	2	3	211	366
KATOSI	0	9	10	0	0	0	46	19	3	9	1	4	102	177
KISENYI	0	9	19	0	0	11	106	70	4	14	5	5	290	512
KIGUNGU	71	55	54	0	1	2	279	69	4	61	6	6	609	1104

	T. esculenta	T. variabilis	T. nilotica	T. zillii	T. leucosticta.	Haplochromis	Bagrus	Clarias	Synodontis	Protopterus	Barbus	Mormyrus	Total Weight	Total Value
KASAKA	114	26	86	0	0	18	48	46	0	191	8	2	538	611
KAZIRU EAST	4	8	10	0	0	25	40	56	0	296	3	1	443	434
NAMIREMBE EAST	9	4	64	1	34	12	4	75	0	201	0	0	402	406
LWALARO	19	11	7	0	0	34	179	100	0	177	5	0	533	594
KIWANGA	5	1	49	8	9	63	12	71	0	298	1	0	481	505
LUWUKI	12	8	19	0	0	18	56	56	0	414	1	0	585	575
KAMUWANGA	26	4	28	1	4	0	9	196	0	543	13	0	824	898
NAKIGGA	0	6	5	1	2	0	4	127	0	279	0	0	426	415
BUKYAMBIRA	0	0	9	8	26	171	10	154	0	264	3	0	645	711
ZZIRWE	19	32	34	2	3	210	30	70	0	104	15	3	520	624
BUKAKATA	51	66	48	10	5	40	127	72	2	251	39	6	720	972
SENERO	2	15	9	5	1	204	25	73	0	276	3	1	614	676
NAMIREMBE WEST	8	29	12	1	0	195	124	54	0	89	8	2	523	560
DIIMU	11	28	9	2	0	156	339	49	1	43	7	1	643	842
MALEMBO	14	8	5	0	0	46	253	66	0	108	8	4	512	592
SANGO	30	17	29	13	9	1	9	65	0	165	21	1	360	303
KYABASIMBA	21	3	29	0	1	0	82	154	0	198	69	0	558	583
SOTA	1	3	0	0	0	35	60	12	3	8	2	1	126	115
MUSUMA	15	16	1	0	0	61	15	20	1	21	2	0	156	179
GUTA	10	1	0	0	0	217	16	11	85	35	1	0	436	271
MAJITA	35	24	1	0	0	158	58	20	1	11	5	2	313	167
UKEREWE	9	6	0	2	0	458	18	2	100	1	1	1	685	382
MWANZA	9	20	0	1	0	95	14	17	47	1	1	0	217	186
NYAKALIRO	17	5	0	1	0	65	4	20	0	38	0	0	173	157

	T. esculenta	*T. variabilis*	*T. nilotica*	*T. zillii*	*T. leucosticta*	*Haplochromis*	*Bagrus*	*Clarias*	*Synodontis*	*Protopterus*	*Barbus*	*Mormyrus*	Total Weight	Total Value
KALAMERA	32	0	0	0	0	144	28	11	99	12	0	0	466	271
BUZILAYOMBA	69	3	0	26	0	1	15	49	0	147	0	1	310	251
NYAMIREMBE	33	11	0	12	0	11	18	27	0	127	1	0	238	202
KATUNGURU	0	0	0	0	0	64	169	30	5	10	7	1	287	316
BUKOBA	1	4	0	0	0	100	58	10	0	3	4	0	184	260
KABINDI	18	7	0	6	0	50	7	6	2	7	3	2	109	109