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# Pollution Special Study (PSS)

## *Studies in Tanzanian Waters*

by
F. Chale

2000

**Pollution Control and Other Measures to Protect Biodiversity in Lake Tanganyika (RAF/92/G32)**
**Lutte contre la pollution et autres mesures visant à protéger la biodiversité du Lac Tanganyika (RAF/92/G32)**

| | |
|---|---|
| Le Projet sur la diversité biologique du lac Tanganyika a été formulé pour aider les quatre Etats riverains (Burundi, Congo, Tanzanie et Zambie) à élaborer un système efficace et durable pour gérer et conserver la diversité biologique du lac Tanganyika dans un avenir prévisible. Il est financé par le GEF (Fonds pour l'environnement mondial) par le biais du Programme des Nations Unies pour le développement . | The Lake Tanganyika Biodiversity Project has been formulated to help the four riparian states (Burundi, Congo, Tanzania and Zambia) produce an effective and sustainable system for managing and conserving the biodiversity of Lake Tanganyika into the foreseeable future. It is funded by the Global Environmental Facility through the United Nations Development Programme. |

**Burundi: Institut National pour Environnement et Conservation de la Nature**
**D R Congo: Ministrie Environnement et Conservation de la Nature**
**Tanzania: Vice President's Office, Division of Environment**
**Zambia: Environmental Council of Zambia**

Enquiries about this publication, or requests for copies should be addressed to:

Project Field Co-ordinator
Lake Tanganyika Biodiversity Project
PO Box 5956
Dar es Salaam, Tanzania

UK Co-ordinator,
Lake Tanganyika Biodiversity Project
Natural Resources Institute
Central Avenue, Chatham, Kent, ME4 4TB, UK

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## 1. Introduction

Lake Tanganyika is about 650km long, with a width varying between 50 and 80km. It is the second deepest lake in the world (Coulter & Spigel, 1991) and has a large volume of water. Owing to its large size and volume, one would not expect its water quality to be affected by human activities. The pelagic zone of the lake is considered to be oligotrophic with high water transparency and low phosphorus levels (Coulter, 1963; Hecky *et al.*, 1991; Edmond *et al.*, 1993). Hecky and Kling (1981) showed that phytoplankton biomass expressed as chlorophyll *a* was usually low (mean 0.5 µg/l) for the central portion (off Kigoma) of the lake. High concentrations of chlorophyll (mean 1.2µg/l) were obtained during October – November and this was attributed to *Anabaena* blooms (Hecky & Kling, op.cit.; Hecky, 1991; Hecky & Fee, 1981).

With increasing pace of agricultural activities in the catchment, the tendency to cultivate on steep slopes bordering the lake shore and the inflowing rivers, the use of fertilisers and pesticides, all these can contribute to the deterioration of the lake's water quality.

Towns are also located along the lake shore. Bujumbura which is the capital city of Burundi, with a population of more than 300,000 people is situated on the northern side of the lake and Kigoma on the eastern side of the lake is an important port in Tanzania. The town has an estimated population of about 90,000. Important towns on the lake shore in the Democratic Republic of Congo include Kalemie and Uvira, and Mpulungu is an important harbour in Zambia. The towns and villages depend on the lake as a source of domestic water supplies and waste disposal, fishing and bathing. Bujumbura bay, for example, has been reported to be polluted because of both industrial and domestic effluents (Caljon, 1992). High levels of plant nutrients (phosphorus and nitrogen) and chlorophyll *a* have been observed. Baker (1992) has reported the potential of oil pollution in Lake Tanganyika as a result of accidental spillages and oil exploration.

## 2. Fertiliser and Pesticide usage in Kigoma and Rukwa Regions

Fertiliser run off from agricultural activities in the catchment into the lake could lead to the eutrophication of the lake. This could cause reduction in phytoplankton species diversity, with subsequent dominance of a few species whose populations would increase. Some pesticides, such as DDT, are not easily biodegradable, and could be bioaccumulated by the biota. These could then be biomagnified through the food chain.

The studies have found out that fertiliser and pesticide applications in the two administrative regions are rather low. For Kigoma region, the annual average amount of fertilisers used between 1995/96 and 1997/98 growing seasons was 2,236 metric tonnes, with mean quantities of chemicals (pesticides and herbicides) being 28 metric tonnes and 6,000 litres per year. Rukwa Region used an annual average of 4,963 tonnes of fertilisers between 1991/92 and 1996/97 growing seasons and 5.4 tonnes and 3,161 litres of other chemicals annually, during the same period (Table 1).

## 3. Water sampling in Kigoma Bay

Routine sampling was carried out in Kigoma bay to try to determine if the bay's water quality had any effect on aquatic biodiversity.

(i). Shipping and Harbour Oil Spills

Kigoma port handles goods destined for Burundi and the eastern part of the Democratic Republic of Congo. Mixed dry cargo and oil products pass through the harbour. Table 2 shows the number of ship rotations and the amount of oil products exported. Shipping activities by the Tanzania Railways Corporation (Marine Services) have so far shown to cause insignificant or no pollution to the bay.

Used oils from the Corporation's ships are collected and sent to TRC headquarters in Dar es Salaam for disposal. Waste water from the passenger ships, MV Liemba and MV Mwongozo toilets is discharged off shore as the ships ply the lake. Similarly, at the TRC oil terminal at Kibirizi no oil slicks have been observed. However, at the harbour there are anchored a number of ships from DRC. Some of these contaminate the harbour through leakage of oil.

(ii). Power generation

For a long time, it has been observed that waste oil from the Tanzania Electricity Supply Company (TANESCO) Ltd; has been flowing into the bay. The oil finds its way into the lake through both underground seepage (through out the year) and above ground run off during the rainy season. There is a substantial accumulation of oil in the sediments (about 0.30%) and an absence of molluscs.

## 4. Eutrophication of Kigoma Bay

### 4.1 Introduction

Kigoma Bay (*Figure* 1) is about 4km long and 3km wide, surrounded by Kigoma town which has an estimated population of about ninety thousand. The bay is shallow with a maximum depth of less than 25m and is the source of the town's domestic water supply. The town does not have a waster water treatment facility. Many households have built toilets with pipes leading to the Rubengera Storm Water drain. The Rubengera drain, hence acts as a conveyor of domestic effluents which enter the bay. The bay also receives effluents from the Kigoma Prison and Police quarters.

### 4.2 Materials and Methods

Five sampling stations were established in the bay (Figure 1). TK1 (Off oil terminal), TK3 (Docks), TK4 (Kibirizi), TW (Town Water intake) and TT (Off TAFIRI). An off shore station (TK2), which was about 4km from Nondwa Point, acted as a control

station. Initially samples were collected four times per month in the bay. Sampling frequency was later reduced to twice a month. At the offshore station sampling was carried out once a month. The studies were carried out between March, 1998 and June, 1999.

**Figure 1. Kigoma bay and offshore Station showing sampling locations**

(TK1 = off oil terminal; TK3 = Docks; TK4= Kibirizi; TW= Water Intake; TT= Off TAFIRI; TK2= Off shore)

Integrated water samples were collected to depths of 10 m using a 2.5 cm internal diameter flexible plastic pipe weighted at the bottom. After lowering the pipe to the desired depth, the upper open end was stopped with a rubber bung and the pipe hauled using a 2mm diameter nylon string. The samples were then transferred to plastic buckets which had previously been rinsed with aliquots of the collected water. Two litres and one litre capacity plastic bottles were then filled with the samples, stoppered tightly and immediately stored under ice. The two litre samples were later used in chlorophyll *a* determinations, while the one litre samples were used for nutrient analyses. Sample pH and temperature were determined in the field on aliquots of the collected water immediately after collection using a model HI 9023 microcomputer pH meter, while conductivity values were obtained with a model HI 8033 Portable Multi Range Conductivity/ TDS meter manufactured by Hanna Instruments, Italy. The conductivity values were then expressed at 25º C. The pH meter was always standardised using pH 4.01 and pH 7.01 buffers.

Transparency was obtained with a 20 cm diameter secchi disc. Samples for dissolved oxygen determinations were collected at the surface and at 10 m depths using a 2 litre capacity Van Dorn water sampler. The samples were then immediately fixed in the field by addition of 2 ml manganous sulphate and 2 ml of alkali-iodide solutions, for later dissolved oxygen determinations using the modified Winkler Method (APHA, 1981). In the laboratory, 50 ml aliquots of the acidified solution were titrated against 0.025N Sodium thiosulphate solution using starch as indicator.

In the laboratory, 500 ml sub samples from the one litre bottles were filtered through pre-washed 0.45µm Whatman GF/C filters for soluble reactive nutrient determinations. In most cases, the filtered samples were analysed on the day of sample collection. When it was not possible to carry out the analyses on the day of sampling, the samples were ice frozen and analysed the following day. The unfiltered portions of the samples were used for total phosphorus determinations.

Soluble reactive phosphorus was determined as the orthophosphate ion using the ascorbic acid method (APHA,1981). Fifty millilitre aliqouts of filtered samples were treated with 4.0 ml combined reagent and the absorbance read at 881nm. Standards containing 0.50 µg/ml phosphorus were similarly treated with combined reagent. Nitrate- nitrogen was determined as the nitrite ion using the sulphanilamide method (Wetzel & Likens, 1991) after reducing the nitrate ion through a copper-cadmium column (Mackereth *et al*., 1989). Initial determinations of ammonia and nitrite showed the absence of the two ions, and hence they were not analysed further. Silica was determined on filtered samples using the molybdosilicate method (APHA,1981).

Total phosphorus was determined on unfiltered samples by the ascorbic acid method, after digestion with 5 ml of 5% w/v potassium persulphate solution (Wetzel and Likens, 1991). Sample digestion with a mixture of potassium persulphate and conc. sulphuric acid as described in the Standard Methods (APHA, 1981) was consistently found to give erroneous results and hence was abandoned. It may be possible that the lake's water chemistry may be the cause. The water has high magnesium (35 mg/l),

calcium (12.3 mg/l), carbonate (190 mg/l) and chloride (28.1 mg/l) contents (present study).

All the nutrient concentrations were determined using a Jenway 6300 Spectrophotometer. Initially phosphorus was determined using a 1cm cell, but the results always showed the absence of soluble reactive phosphorus in the water . The limit of detection of phosphorus with the 1cm cell was found to be 2 µg P/l. Later a 4 cm cell was used. Nitrate-nitrogen and silica were determined using a 1 cm cell.

Chlorophyll *a* determinations were carried out by extraction with 90% aqueous methanol. Two litre water samples were filtered through 0.45 µm Whatman GF/C filters. The filters were then folded and put in 50 ml capacity tubes containing 10 ml of the aqueous methanol. The tubes were then capped and wrapped in dark cloth and left overnight in a refrigerator. All nutrient level and chlorophyll *a* determinations were carried out in duplicate.

## 4.3 Results

Table 3 gives the mean annual values for the various parameter determined in Kigoma Bay and the outer station . Apart from a few parameters, such as pH, dissolved oxygen and silica, which are of about equal magnitudes in the bay and outer station, most of the values at the two locations (Kigoma Bay and outer station) are different. With the exception of TT which is located at the mouth of the bay (Figure1), the pelagic waters are about 2.23 times more transparent than the bay, and the mean annual water temperatures for the latter are 1.7 ºC warmer than the former. The high transparency in the open waters has also been reported by others (Beauchamp, 1939; Hecky & Kling, 1981; Hecky *et al.*, 1991; Hecky, 1991). The mean conductivity value in the bay (630 µS/cm) was lower than in the open waters (639 µS/cm) and this could be a result of dilution of the bay during the rainy season through run-off from the surrounding area. Both nitrogen (56 µg/l) and phosphorus (12.55 µg/l) levels were much higher in the bay than the open waters (44 µg N/l and 6.47 µg P/l). This could indicate that nutrient input into the bay from external sources was important. The high mean chlorophyll *a* value in the bay (2.37 µg/l) compared to the open water (mean 1.55 µg/l) shows high phytoplankton populations per unit volume in the bay relative to the open water.

## 4.4 Discussion

The data presented shows marked differences in the water characteristics of Kigoma Bay and the offshore waters. The high water transparency in the open waters had previously been reported by others (Coulter 1963; Hecky & Fee 1981; Hecky and Kling, 1981; Edmond *et al.*, 1991). The high transparency coupled with low phosphorus levels in the pelagic zone could indicate that the pelagic zone is oligotrophic (Beauchamp, 1939; Coulter, op. cit.; Hecky & Kling, op. cit.). During October 1998, when transparency was the lowest at the outer station (7.70m), chlorophyll *a* values were the highest obtained during the study period (4.80µg/l). The

low transparency in October had also been reported earlier (Coulter 1963; Hecky & Fee, 1981; Hecky & Kling, 1981; Hecky, 1991). The authors attributed the decline in transparency to *Anabaena* blooms which occurred during that period. In the bay where chlorophyll *a* values were usually high, secchi disc readings were low. Though no phytoplankton counts were made at the sampling locations, it may be assumed that the low transparency was also caused by high phytoplankton populations.

Nutrient concentrations in the bay were usually higher than in the open waters (Table 3). Edmond *et al.* (1993) and Hecky *et al.* (1991) had reported low phosphorus concentrations in the surface waters of the pelagic region of the lake. Phosphorus replenishment in the pelagic region was effected by water mixing and nitrogen through fixation of atmospheric nitrogen by *Anabaena* spp. (Hecky, 1991; Hecky & Kling, 1981). Nitrogen fixation by *Anabaena* spp. had also been reported for North American Great Lakes (Megard, 1972).

The high chlorophyll *a* values in the bay may have been due to the high nutrient levels in the bay (Schindler, 1978). The bay receives some untreated domestic waste water and run-off from the surrounding area. Increases in nutrient levels and corresponding increases in algal population have also been reported for the Bay of Bujumbura in Burundi (Caljon, 1992). The bay receives untreated industrial and domestic effluents.

Silica concentrations were very high in the bay and open waters (Table 3). It can therefore be assumed that silica can not limit the productivities of the two ecosystems.
According to Wetzel's (Table 12-1) ranking of lake productivity levels, Kigoma Bay with a mean total phosphorus concentration of 12.55µg P/l is considered to be meso-eutrophic, while the open waters with a mean total phosphorus concentration of 6.46µg P/l is oligotrophic (Wetzel, 1975).

### 4.5 Conclusion

The water characteristics of Kigoma Bay are markedly different from those of the pelagic waters. The bay is becoming enriched with plant nutrients, leading to high phytoplankton biomass. Untreated domestic sewage from Kigoma town may be responsible for the high phosphorus and nitrogen concentrations in the bay. Since the bay is also the source of the town's domestic water supplies, the discharge of untreated sewage effluents into the bay may also constitute a health hazard. In order to minimise the danger of the bay becoming eutrophic, sewage effluents should not be allowed to freely drain into the bay.

## 5. Trace Metal Levels in Fish and Bivalves in Lake Tanganyika

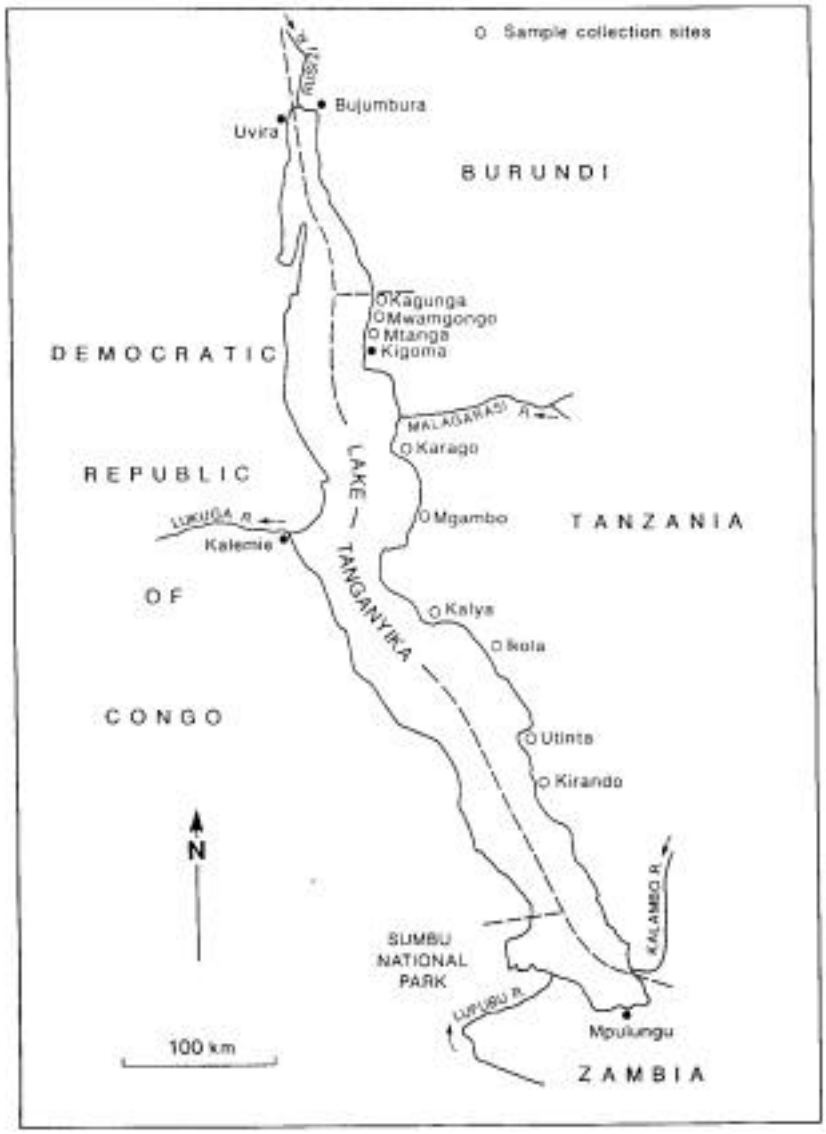
### 5.1 Introduction

Fish from Lake Tanganyika serves as the main source of animal protein for the population surrounding the lake in Burundi, Democratic Republic of Congo, Tanzania

and Zambia. In Tanzania, for example, the clupeids (*Limnothrissa miodon* and *Stolothrissa tanganicae*), popularly known as "dagaa" are sold through out the country. Trace metals can be accumulated by fish both through the food chain and water (Hodson, 1988; Sindayigaya *et al.*, 1994). Metals can also bind to particulate matter in the water column and settle to the lake bottoms (Kidd *et al.*, 1998). Very few studies have been reported on the accumulation of trace metals in fish of Lake Tanganyika (Benemariya *et al.*, 1991; Sindayigaya *et al.*, 1994).

In this report are presented results of a sampling survey on trace metal concentrations in fish and the bivalve (*Mutela spekei*) in Rukwa and Kigoma Regions in Tanzania. The survey was carried out in November, 1998 at Kirando, Utinta and Ikola in Rukwa and Kalya, Mgambo, Karago, Mtanga, Mwamgongo and Kagunga in Kigoma Region (Figure 2).

**Figure 2. Sampling locations for Trace metals**



## 5.2 Materials and Methods

Fish samples were collected using a beach seine and monofilament gill nets of graded mesh sizes. In addition to the experimental gear, some fish were bought from fishermen. Bivalves were collected by a diver. The species collected included: *Lates mariae, L. stappersi, Limnothrissa miodon, Stolothrissa tanganicae, Chrysicthys sp., Raiamass moorii, Oreochromis sp., Alestes macropthalmus* and the bivalves *Mutela spekei*.

For the fish, at each location the samples were divided into the various species and random sub samples taken from each species. Standard lengths were then taken for the sub samples. Except for the clupeids and characinids (*Alestes macropthalmus*.) where whole fish were used, for the other fin fishes a small piece of flesh was cut from each sample above the lateral line forwards of the dorsal fin. For each species a composite sample of the cut flesh removed from the opened shells and composited. In the field the samples were sun dried and later oven dried at 105 ºC to constant weights in the laboratory. After cooling the samples were milled to pass a 1 mm mesh laboratory sieve.

The powdered samples were analysed for trace metals at the Eastern and Southern African Mineral Centre in Dar es Salaam. The trace metals analysed included: copper, iron, manganese, zinc, lead and cadmium. At the ESAMC the samples were again oven dried to constant weights at 105 C, cooled and then dissolved in conc. Nitric acid. The trace metals were then determined using an atomic absorption spectrophotometer.

## 5.3 Results and Discussions

Table 4 shows the mean trace metal concentrations in the various species obtained in Lake Tanganyika. Apart from *Alestes macropthalmus.* Which contained relatively high levels of copper, the other species has low amounts of copper in their bodies. The mean copper values for *L. miodon* and *S. tanganicae* are within the ranges reported by Benemariya *et al*. (1991) and Sindayigaya *et al*. (1994). The bivalves had very high levels of iron and manganese. Bivalves are not consumed in Tanzania and as such are of no economic importance in the country. The clupeids' iron and zinc concentrations are higher than for the other fin fishes. Similar observations had been reported in Burundi (Benemariya *et al*., op. cit.; Sindayigaya *et al*., op. cit.). These species only muscle tissues were analysed. The clupeids are eaten whole. The centrapomidae species (*L. mariae* and *L. stappersi*) had nearly equal levels of iron, zinc, lead and cadmium in their muscles. L. mariae had about double the amount of manganese than *L. stappersi*. Table 5 shows the trace metal levels reported by Benemariya *et al.* (1991) and Sindayigaya *et al.* (1994)

*Lates mariae* from Ikola had the highest copper content followed by those from Mwamgongo (Table 6). *L. mariae* from Utinta had the lowest levels, close to that reported for Burundi waters (Benemariya *et al.*, 1991). Low values of iron were obtained at Kirando, Utinta, Ikola, Mwamgongo and Kagunga for *L. mariae*. The zinc

levels obtained for *L. mariae* were within the ranges reported by Benemariya *et al*. (1991). High lead values (11.1µg/g) were found at Ikola, followed by Mgambo (7.5µg/g) and Utinta (6.5µg/g)

The levels of copper in the muscle of *L. stappersi* at Utinta were about equal to those reported in Burundi (Benemariya *et al*.,1991; Sindayigaya *et al*., 1994). Highest levels were found at Mtanga, Mwamgongo and Kagunga (Table 6). Similarly, for iron and zinc, the levels were of about the same as those in Burundi (Benemariya *et al*,, op. cit.; Sindayigaya *et al.*, op.cit.). Manganese levels were much lower while lead levels were higher than those reported by Sindayigaya and others for the species.

For the clupeids, *L. miodon* from Kalya had the highest copper concentrations, while for *S. tanganicae* high levels were found in the fish from Mgambo and Mwamgongo (Table 6). The copper levels for *L. miodon* were nearly as those previously reported in Burundi (Benemariya *et al*., 1991). Apart from iron levels at Mgambo which were 171µg/g, *S. tanganyikae* had higher levels of the element at all the sampling locations than *L. miodon*. Similarly, for manganese and zinc, the levels obtained for *L. miodon* were lower than for *S. tanganicae.* Lead concentrations in *S. tanganicae* were much higher than reported in the northern part of the lake in Burundi (Sindayigaya *et al*., 1994).

The cat fish (*Chrysicthys spp*.) had high levels of copper at Mgambo and Mtanga, while low iron levels were found at Kirando and Kalya (Table 6).

The bivalve (*Mutela spekei*) from Kirando had very high concentrations of both iron and manganese. Also, all the other trace elements, except zinc, were much higher at Kirando than at Utinta. Unfortunately, owing to the prevalence of crocodiles at the sampling locations, no diving was undertaken beyond Utinta.

Lates species and the clupeids are of great economic importance in the countries surrounding the lake and high trace metal levels in these fishes would pose health hazards to the consumers. Apart from the high iron and manganese levels found in the bivalves, the levels for all the elements in the other species are below those recommended for human consumption (Benemariya *et al*., 1991). *Mutela spekei* is not eaten in Tanzania, hence the high trace metal body burden is of no concern to human health. The trace metal concentrations are likely to be a result of natural background levels rather than pollution (Sindayigaya *et al.*, 1994)

## 5.4 Conclusion

The levels of trace elements in the clupeids were generally higher than for the Lates species. The clupeids were milled whole, while muscle tissues were used in the case of the other fin fish species. The values obtained are within those reported by others (Benemariya *et al.*, 1991; Sindayigaya *et al*., 1994). The bivalves had very high levels of iron and manganese in their bodies. The bivalves are of no economic value in Tanzania. Apart from the bivalves, the trace element levels obtained are below those

recommended for human consumption. Natural levels of the various trace elements in the water and sediments could be the main source of the trace metals in the fish and bivalves rather than pollution from the catchment and the towns situated along the lake shore.

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**Tables**

Table 1. Agricultural Inputs consumed in Kigoma and Rukwa Regions

Kigoma Region

| | | 1995/96 | 1996/97 | 1997/98 |
|---|---|---|---|---|
| Fertilisers | tonnes | 2251 | 1647 | 2810 |
| Chemicals | tonnes | 24 | 32 | 0 |
| Chemicals | litres | 11496 | 500 | 0 |
| | | | | |

Source: RALDO Office- Kigoma

b) Rukwa Region

| | | 1991/92 | 1992/93 | 1993/94 | 1994/95 | 1995/96 | 1996/7 |
|---|---|---|---|---|---|---|---|
| Fertilisers | t | 6200 | 7470 | 5330 | 2630 | 2900 | 5250 |
| Chemicals | t | 4.2 | 1.2 | 5.0 | 4.7 | 1.9 | 15.4 |
| Chemicals | Lt | 1810 | 1300 | 2500 | 3370 | 1080 | 8905 |

Source: Regional Agricultural Profile (1997) – Rukwa Region

Table 2. Number of crafts operating in Kigoma Harbour and volume of oil exported (1992- 1997)

| Year | Ship Rotations | Volume of oil ($m^3$) |
|---|---|---|
| 1992 | 307 | - |
| 1993 | 336 | - |
| 1994 | 405 | - |
| 1995 | 453 | 25,524 |
| 1996 | 327 | 18,576 |
| 1997 | 244 | 11,453 |

Sources: AMI Branch office – Kigoma; Customs Dept.- Kigoma

Table 3. Mean Parameter Levels at Sampling Stations

| Parameter | Station TK1 | Station TK3 | Station TK4 | Station TW | Station TT | Station TK2 |
|---|---|---|---|---|---|---|
| Transparency (m) | 6.06 | 4.05 | 5.33 | - | 9.48 | 11.42 |
| Temperature (ºC) | 27.7 | 28.4 | 28.2 | 27.9 | 28.4 | 26.4 |
| pH | 9.07 | 9.07 | 9.07 | 9.08 | 9.07 | 9.05 |
| Conductivity (25 ºC) µS/cm | 628 | 629 | 623 | 637 | 635 | 639 |
| Dissolved Oxygen (mg/l) | 7.50 | 7.20 | 7.60 | 7.3 | 7.3 | 7.3 |
| $NO_3$-N (µg/l) | 56 | 61 | 60 | 52 | 52 | 44 |
| $PO_4$-P (µg/l) | 4.42 | 4.34 | 3.96 | 3.50 | 2.99 | 2.23 |
| Tot. P ($\mu g1^{-1}$) | 12.61 | 14.7 | 10.60 | 12.73 | 12.11 | 6.46 |
| Silica (mg/l) | 1.56 | 1.56 | 1.52 | 1.46 | 1.48 | 1.56 |
| Chlorophyll *a* ($\mu g1^{-1}$) | 2.44 | 2.46 | 2.26 | 2.44 | 2,27 | 1.55 |

Table 4: Mean levels of trace metals (+/SD) in fish species (µg/g d.wt)

| Taxon | Cu | Fe | Mn | Zn | Pb | Cd |
|---|---|---|---|---|---|---|
| *Lates mariae* | 4.04 (3.1) | 34 (9.9) | 1.15 (0.82) | 16 (4.1) | 4.96 (3.1) | 0.25 (0.06) |
| *Lates stappersi* | 3.40 (1.4) | 33 (6.1) | 0.59 (0.17) | 18 (2.5) | 5.03 (4.6) | 0.28 (0.70) |
| *Limnothrissa miodon* | 3.60 (1.2) | 125 (25) | 7.81 (1.8) | 101 (15) | 4.64 (1.8) | 0.38 (0.08) |
| *Stolothrissa tanganicae* | 5.90 (2.3) | 169 (26) | 11.74 (1.49) | 133 (25) | 4.96 (1.68) | 0.39 (0.13) |
| *Chrystysts sp.* | 5.90 (3.4) | 42 (14.1) | 2.18 (0.98) | 23 (8.0) | 5.3 (2.35) | 0.28 (0.15) |
| *Mutela spekei* | 3.30 | 11075 | 6544 | 74 | 6.6 | 0.43 |
| *Raiamas moorei* | 3.50 | 47 | 1.60 | 58 | 6.1 | 0.20 |
| *Oreochromis sp.* | 5.0 | 21 | 0.90 | 28 | 2.7 | 0.20 |
| *Alestes macropthalmus* | 14.0 | 63 | 6.9 | 59 | 5.3 | 0.20 |

Table 5: Mean levels of trace metals (+/-SD) in fish species (µg/g dry weight) from Burundi (Benemariya *et al.,* 1991)

| Species | Zn | Cu | Se |
|---|---|---|---|
| *Boulengerochromis microlepis* | 24.9 (0.1) | 1.3 (0.2) | 1.5 (0.2) |
| *Oreochromis niloticus* | 21.8 (0.04) | 0.9 (0.2) | 1.7 (0.2) |
| *Lates mariae* | 17.3 (1.8) | 0.9 (0.3) | 1.3 (0.2) |
| *Lates stappersi* | 15.5 (3.3) | 1.7 (0.3) | 1.7 (0.1) |
| *Limnothrissa miodon* | 76.4 (1.9) | 3.5 (0.1) | 1.5 (0.1) |
| *Stolothrissa tanganicae* | 147 (21.3) | 5.5 (1.2) | 2.1 (0.1) |

and Sindayigaya *et al*., 1994)

| Element | *Stolothrissa tanganicae* | | *Lates stappersi* | |
|---|---|---|---|---|
| Cu | 3.2 | (0.4) | 1.7 | (0.2) |
| Zn | 134 | (18) | 21 | (5) |
| Mn | 17 | (12) | 5 | (2) |
| Fe | 200 | (52) | 35 | (2) |
| Pb | 0.04 | (0.02) | 0.01 | |
| Cd | 0.27 | (0.11) | 0.30 | (0.01) |

Table 6. Trace metals at sampling locations (µg/g. d.wt)

| Species | Location | N | Cu | Fe | Mn | Zn | Pb | Cd |
|---|---|---|---|---|---|---|---|---|
| *Lates mariae* | | | | | | | | |
| " | Kirando | 16 | 3.5 | 27 | 0.90 | 14 | 4.7 | 0.25 |
| " | Utinta | 10 | 1.2 | 26 | 2.2 | 13 | 6.5 | 0.30 |
| " | Ikola | 40 | 10.1 | 24 | 0.30 | 13 | 11.1 | 0.20 |
| " | Kalya | 18 | 2.0 | 42 | 0.7 | 18 | 2.8 | 0.23 |
| " | Mgambo | 8 | 2.6 | 40 | 1.6 | 16 | 7.5 | 0.37 |
| " | Karago | 13 | 2.1 | 47 | 2.7 | 15 | 4.1 | 0.30 |
| " | Mtanga | 18 | 3.9 | 46 | 0.5 | 20 | 2.2 | 0.20 |
| " | Mwamgongo | 7 | 8.6 | 28 | 0.7 | 25 | 3.0 | 0.20 |
| " | Kagunga | 8 | 2.4 | 23 | 0.8 | 13 | 2.8 | 0.20 |
| *Lates stappersi* | Kirando | 90 | 3.5 | - | 0.5 | 22 | 9.3 | 0.40 |
| " | Utinta | 55 | 1.8 | 36 | 0.7 | 17 | 4.6 | 0.30 |
| " | Ikola | 8 | 2.2 | 29 | 0.6 | 16 | 3.8 | 0.30 |
| " | Karago | 28 | 2.1 | 38 | 0.7 | 19 | 13.0 | 0.25 |
| " | Mtanga | 40 | 5.4 | 23 | 0.3 | 18 | 0.8 | 0.20 |
| " | Mwamgongo | 56 | 4.4 | 32 | 0.5 | 16 | 3.2 | 0.20 |
| " | Kagunga | 25 | 4.1 | 38 | 0.8 | - | 0.5 | 0.30 |
| *Limnothrissa miodon* | Kirando | 32 | 3.9 | 100 | 9.1 | 120 | 6.1 | 0.38 |
| " | Utinta | 45 | 2.6 | 109 | 10.3 | 116 | 6.7 | 0.47 |
| " | Ikola | 60 | 2.7 | 105 | 7.4 | 95 | 6.2 | 0.50 |
| " | Kalya | 25 | 5.7 | 127 | 7.5 | 82 | 3.5 | 0.40 |
| " | Mgambo | 20 | 3.0 | 171 | 9.2 | 92 | 2.2 | 0.3 |
| " | Karago | 30 | 3.5 | 120 | 5.9 | 102 | 2.7 | 0.31 |
| " | | | | | | | | |
| *Stolothrissa tanganicae* | Utinta | 55 | 5.3 | 143 | 9.3 | 109 | 4.8 | 0.41 |
| " | Ikola | 101 | 4.0 | 156 | 11.4 | 122 | 3.9 | 0.40 |
| " | Kalya | 36 | 5.5 | 149 | 12.7 | 117 | 7.4 | 0.20 |
| " | Mgambo | 20 | 9.1 | 139 | 10.4 | 101 | 4.1 | 0.30 |
| " | Karago | 201 | 5.2 | 177 | 13.3 | 138 | 3.0 | 0.40 |
| " | Mtanga | 91 | 3.4 | 195 | 12.7 | 175 | 3.6 | 0.40 |
| " | Mwamgongo | 56 | 9.1 | 186 | 10.8 | 139 | 5.5 | 0.39 |
| " | Kagunga | 40 | - | 206 | 13.3 | 159 | 7.4 | 0.65 |
| *Chrysicthys sp.* | Kirando | 11 | 1.9 | 22 | 1.4 | 14 | 4.5 | 0.20 |
| " | Ikola | 36 | 7.1 | 44 | 1.4 | 34 | 8.4 | 0.20 |
| " | Kalya | 44 | 3.1 | 30 | 1.4 | 17 | 5.1 | 0.20 |
| " | Mgambo | 38 | 9.4 | - | 3.8 | - | 7.0 | 0.60 |
| " | Karago | 13 | 10.0 | 58 | - | 30 | 2.2 | 0.20 |
| " | Mtanga | 15 | 5.3 | 52 | 2.7 | 17 | 2.7 | 0.30 |
| " | Mwamgongo | 40 | 2.1 | 48 | 2.4 | 23 | 7.2 | 0.25 |
| " | | | | | | | | |
| *Mutela spekei* | Kirando | 50 | 4.5 | 12981 | 7892 | 76 | 8.4 | 0.50 |
| " | Utinta | 36 | 2.1 | 9169 | 5195 | 72 | 4.8 | 0.36 |
| *Raiamas moorii* | Kirando | 21 | 3.5 | 47 | 1.6 | 58 | 6.1 | 0.20 |
| *Oreochromis sp.* | Utinta | 15 | 5.0 | 21 | 0.9 | 28 | 2.7 | 0.20 |
| *Alestes macropthalmus* | Utinta | 30 | 14.0 | 63 | 6.9 | 59 | 5.3 | 0.20 |