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Fisheries research towards resource management on Lake Tanganyika

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Abstract

Lake Tanganyika hosts one of the largest inland fisheries in Africa and is a significant source of food and livelihood to millions dwelling inside and outside of its basin. The lake and its environs support a wide array of subsistence and commercial activity as well as a remarkable assemblage of tropical flora and fauna, including highly diverse populations of endemic fish. This paper describes efforts undertaken through the FAO/FINNIDA Lake Tanganyika Research Project (LTR) to investigate the lake's production and potential and to advise on modalities for the optimal management of its resources, in order to serve present and future human welfare and conservation needs. Specifically, the paper essays to: (a) provide background on the scope and content of LTR Project work; (b) situate project research and methodologies in terms of contemporary developments in fisheries management theory and application; (c) identify and characterise, with reference to research outcomes generated through the project's Scientific Sampling Programme, socio-economic investigations and legal-institutional studies, major development and management challenges that confront fisheries resource users, administrators, planners, and policy makers; and finally, (d) consider various policy options appropriate to conditions of ecosystem uncertainty, plural stakeholder interests and complex interactions between fishing and non-fishing sectors of the wider economy. It is argued that the Lake Tanganyika situation defies diagnosis and prescription according to conventional 'stock assessment driven' management thinking. The lake instead presents a compelling case for the application of multi-disciplinary management approaches, involving strong levels of community participation.

Introduction

Lake Tanganyika represents a vital resource base for the populations of its four littoral countries – Burundi, Democratic Republic of Congo (DRC, former Zaire), Tanzania, and Zambia – and of the East-Central Africa region generally. The lake provides income, food, drinking water, and a transportation corridor for an estimated 10 million inhabitants of its catchment area. Many more millions of people residing within the wider trading orbit of the Tanganyika basin benefit from its resources as consumers of fishery products (Hanek, 1994; Hanek & Craig, 1996; Quan, 1996).

The conservation and scenic values of the lake and its littoral zone are also quite outstanding (Beadle, 1981; Coulter, 1991; Quan, 1996). Like the other great African lakes of Victoria and Malawi, it features extremely high rates of endemism amongst the population of aquatic invertebrates and for both cichlid and non-cichlid fishes. (Indeed, the lake is famous in the ornamental fish trade as a source of prized aquarium stock.) Moreover, Tanganyika's deep and near pristine waters and dramatic setting offer great potential for the development of 'eco-tourism.' The lake is cradled between high eastern and western escarpments of the Great Rift Valley and features extensive stretches of unspoilt beaches and rocky promontories, numerous bays, estuaries and inshore islands. Bordering areas of wetland, forest and savannah, contain a remarkable assemblage of tropical flora, terrestrial fauna and bird-

life. Tourist amenities including lodges, beach resorts, sport fishing and gameviewing services, already exist at various places around the north-eastern, eastern and south-western shoreline and more are gradually being developed. Several of these facilities trade on the attractions of game parks and reserves adjacent to the lake, such as the Rusizi delta in Burundi, Nsumbu National Park in Zambia and Mahale and Gombe National Parks in Tanzania.

Second only to Lake Victoria as the largest inland fishery on the continent (FAO, 1995a), Tanganyika's role as food provider for East-Central Africa has become all the more critical for the general region in recent decades owing to steadily increasing human populations and the disruption of crop and livestock production brought on by chronic civil turmoil and episodes of severe drought. In consequence, growing concern is expressed about the environmental status, endangered biodiversity, and possible over-fishing of this unique lake. Efforts to investigate its biological production and fishery potential are thus of considerable regional and international importance. The Lake Tanganyika Research Project (GCP/RAF/271/FIN, hereafter LTR), operating since 1992 and executed by the Food and Agriculture Organization (FAO) of the United Nations, has been a major channel for such efforts. From 1995 another major undertaking, the Lake Tanganyika Biodiversity Project (LTBP), has complemented LTR's fisheries-related investigations. Established with funding provided through the UNDP/Global Environmental Facility (GEF), LTBP's remit is to address wider, basin-scale management problems of pollution control, conservation, and the maintenance of biodiversity (LTBP, 1998).

In this article, we first provide some background on the LTR Project and the historical development and present circumstances of Lake Tanganyika fisheries. Project research and methodological orientations are next situated with reference to contemporary reappraisals of fisheries management theory and praxis. Observations collected through LTR and previous scientific studies are then used to construct an inventory of development and management challenges that the lake now poses for fisheries resource users, administrators, planners and policy makers. Research outcomes and management implications are considered according to multiple dimensions of sustainability, anthropological as well as biological in nature (Charles, 1994), and to principles laid out in the FAO *Code of Conduct for Responsible Fisheries* or CCRF (FAO, 1995b). Finally, discussion turns to the resolution of policy issues in the face of problems inherent to conditions of lacustrine ecosystem uncertainties, plural stakeholder interests and the interactions between fishing and other sectors of the wider economy. It is argued that the Lake Tanganyika situation defies diagnosis and prescription according to conventional 'stock assessment driven' management thinking (see Mahon, 1997). The fishery system of the lake instead presents a compelling case for the application of multidisciplinary management approaches involving strong levels of community participation.

Lake Tanganyika Research Project

Recognition of the need to bolster regional integration of fisheries management efforts on the lake led to the tabling of a draft project document at the First Session of the Committee for Inland Fisheries of Africa (CIFA), Sub-Committee for Lake Tanganyika, convened in 1978. This initiative was followed up through a series of draft revisions and eventually resulted in the establishment, under FAO execution and with funding mainly from Finland, of the LTR Project (FAO, 1992). The project became fully operational in 1992, with the aims of assessing the size and structure of the lake's fishery resources, determining the state of their exploitation and devising modalities for their optimal management to serve present and future human welfare and biological conservation needs. Extensive analysis of the lake's trophic structure and fishery (see Sarvala et al., 1999, this issue), complemented with socio-economic investigations (Reynolds & Hanek, 1997; Reynolds, 1999) and legal-institutional studies (Cacaud, 1996, 1999; Maembe, 1996), has provided a comprehensive set of reference points for developing a regional, lake-wide approach to fisheries management (for further reviews of scientific work and project structure, also see Lindqvist & Mikkola, 1989; Hanek et al., 1996).

The project design calls for all aspects of the research programme to be conducted in full collaboration with the national fisheries authorities and institutes of the respective lacustrine states and to this end strong training and other institution-building components are incorporated. Headquarters were established at the beginning of the project on the compound of the Département des Eaux, Pêches et Pisciculture in Bujumbura (Burundi) and the national research institutes at Uvira (DRC), Kigoma (Tanzania) and Mpulungu (Zambia) have from the outset provided fa-

cilities and counterpart staff for the operation of LTR sub-stations around the lake.

Core research related to hydrodynamics, limnology, fish and zooplankton biology, remote sensing, fish genetics and fisheries statistics was organised under the Scientific Sampling Programme (SSP), which started in July 1993 (immediately upon completion of the project's preparatory phase). The project's research vessel, *Tanganyika Explorer*, was used extensively as a platform for the conduct of complementary hydroacoustic studies (to develop biomass estimates) and sampling surveys related to various other SSP components.

During 1997, with most of the hydrobiological and fisheries research activities initiated over the first five years of the project either complete or nearing completion, the LTR team embarked on a programme of socio-economic investigations that involved a lakewide survey of landing sites, fishers and trader/processors. Particular efforts were made to collect information on fishery problems and prospects from the viewpoint of local stakeholders (Reynolds & Paffen, 1997).

Table 1. Number of fishing units by type on Lake Tanganyika in 1995 (Paffen et al., 1997)

landing sites	786
active fishermen	44 957
vessels total	19 356
vessels operational	18 243
- fishing vessels	13 192
- lamp carriers/ helpers	2 256
- transport boats	532
- motorised vessels	1264
- fishing lamps	20 379
traditional gear	
-lines	20 744
- gill nets	6300
- lusenga (scoop nets)	316
- traps	13
artisanal gear	
- liftnets	2976
- beach seine (day)	1143
- kapenta beach seine (night)	154
- apollo liftnets	128
- chiromila seines	16
industrial gear	
- purse seiner units total	52
- purse seiner units operational	28
- Zambia	16
- Congo	6
- Tanzania	4
- Burundi	2

The Fisheries and Fisherfolk of Lake Tanganyika

Harvest sector

Distribution of catch and effort

According to the aerial frame survey and parallel ground surveys in 1992 (Coenen, 1995) and 1995 (Paffen et al., 1997) conducted under LTR auspices, Lake Tanganyika presently hosts 44 960 active fishers, 18 240 operational fishing craft and 786 landing sites (Table 1). Present-day fishing operations primarily exploit six endemic species. These include the two schooling clupeid 'sardines' (known variously as 'ndagala' (Burundi and DRC), 'dagaa' (Tanzania), or 'kapenta' (Zambia) along different sections of shoreline), *Limnothrissa miodon* and *Stolothrissa tanganicae*, together with four major predators, all centropomids of the genus *Lates – viz.*: *L. stappersii*, *L. angustifrons*, *L. mariae* and *L. microlepis*. Of the *Lates* species, the latter three are incidental to the catch: the lake's commercial fishery is essentially based on the two clupeids (ca. 65% by weight) and *L. stappersii* (ca. 30% by weight). Annual harvest levels in recent years have been estimated to vary in the range of 165 000–200 000 tonnes – volumes that translate into annual earnings on the order of tens of millions of US dollars. The harvest is shared between the littoral states roughly in the order, if not exact proportion, of each state's share of the total lake area. Thus fishers in the DRC (45% of lake area) land about 50% of the annual pelagic catch, whilst those in Tanzania (41% of lake area) land about 31%, in Burundi (8% of lake area) about 21%, and in Zambia (6% of lake area) about 7%.

Traditional units (gillnets, longlines and scoop nets) are the dominant fishing type, followed by liftnets and beach seines. Together these fishing types account for more than 90% of annual fish yield. The densest fishing effort per km of shoreline is found around Uvira (north-west coast, DRC), due to high

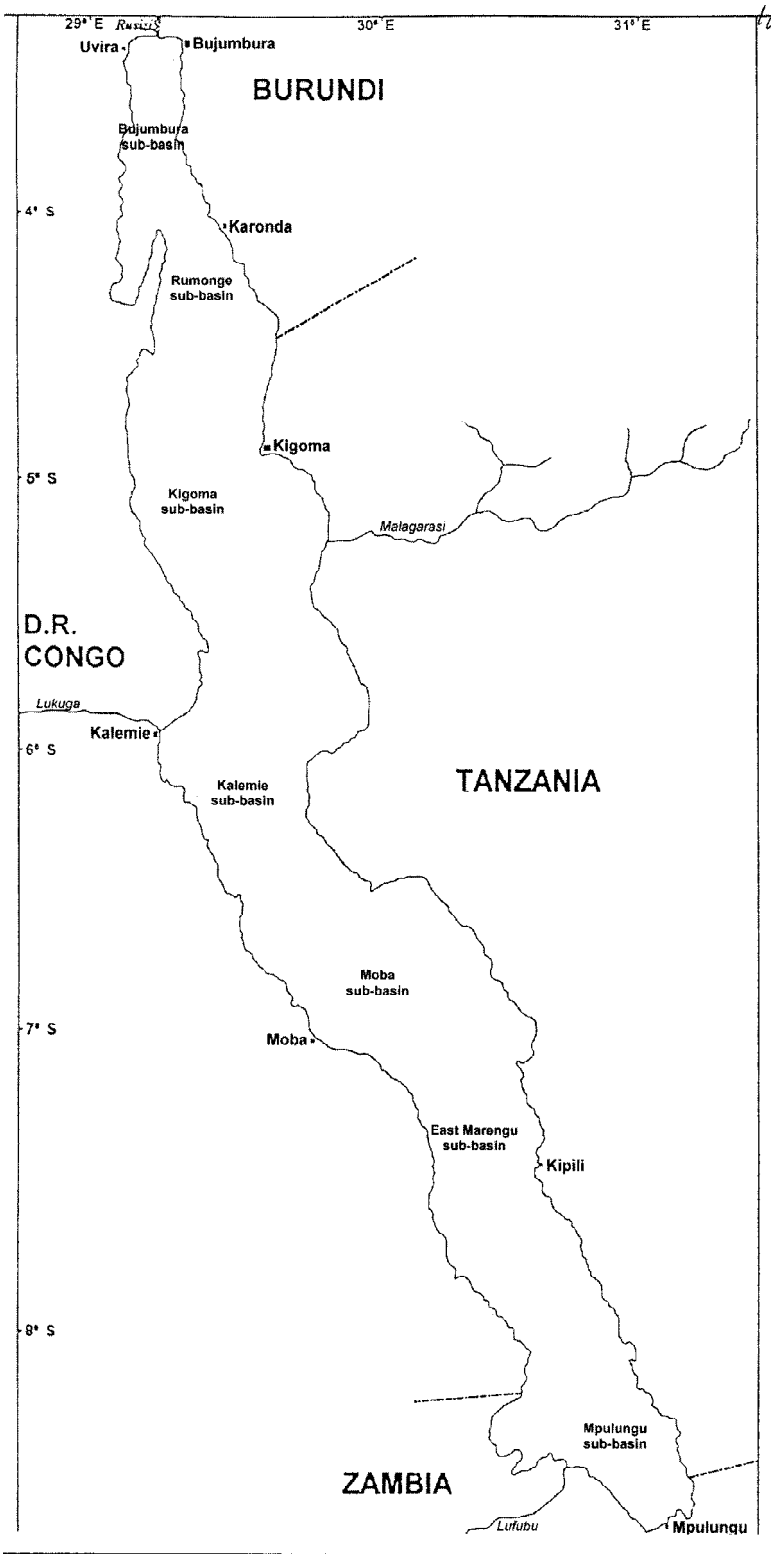

Figure 1. Map of Lake Tanganyika.

concentrations of liftnets and traditional units. Next densest distribution of effort is found around Moba (south-west coast, DRC), the East Coast and Mpulungu areas (Zambia). Least dense effort areas cover Bururi and Makamba (Burundi), Rukwa (Tanzania) and Nsumbu (south-west coast, Zambia). When effort of all units is standardised in terms of the dominant gear kit, i.e. scaled as 'traditional effort units,' in order to derive a longitudinal north-south profile for the lake (Figure 1), it becomes clear that the northern and southern extremities are subject to the greatest fishing pressure per unit of fishing area. In the case of the far north end, this outcome can be attributed to the high concentration of lift net units; for the far south, it results from the combined effects of industrial purse seine and traditional unit operations. As for the greater expanse of the lake that lies in between, a decreasing effort gradient running from north to south is apparent.

Annual recorded catches on Lake Tanganyika have shown an upward trend since the 1970s and today stand at 196 570 tonnes, as estimated via catch-per-unit-effort (CPUE) calculations based on an average of 250 fishing days per annum (Coenen et al., 1998). Recent estimates per country indicate a yield of about 21 000 tonnes for Burundi in 1995, just before a period of civil unrest and security restrictions resulted in a drastic reduction in fishing activity. Production for Tanzania is estimated at around 55 000 tonnes during 1994–95, as compared to figures of 72 000 and 80 500 tonnes in 1992 and 1993, respectively. The 1992 total annual yield estimate for Zambia is 12 700 tonnes, comprised of 9100 tonnes from traditional/ artisanal units and 3600 tonnes from industrial purse seiners. In Congo, the estimated annual fish yield for 1995 is about 90 000 tonnes, based on extrapolated fishing effort counts (Coenen et al., 1998).

These estimates translate into an average catch range of 54–66 kg ha^{-1} for the whole lake. The kg ha^{-1} figures are much higher in Burundi and Zambia – 95 and 69 kg ha^{-1}, respectively – than elsewhere. In the Tanzanian and DRC waters, which in combination amount to 86% of the total lake area, catch figures register at 60 and 34 kg ha^{-1}, respectively. Such differences may reflect greater fishing intensity rather than actual lake productivity, however (Coenen, 1995). Sarvala et al. (1999) claimed the observed yields in Bujumbura to be closest to the potential yield of 100 kg ha^{-1} yr^{-1} estimated by Coulter (1977).

Recent developments in artisanal and industrial fishing

During the 1950s there was a clear lakewide shift from traditional subsistence fishing units towards catamaran lift-net and industrial units. The average efficiency of a single unit has increased remarkably from 3 ton yr^{-1} in the early years up to an overall average of 14 ton in the 1990s, with annual peak averages in Burundi an Zambia ranging as high as 30 ton yr^{-1} (Coenen, 1995). In recent years, artisanal units (mostly liftnets and beach seines) are contributing an increasingly proportion of total production at the expense of industrial purse seine units. The maximum yields within the artisanal sector in Burundi are 106 ton yr^{-1} for apollo ('super' liftnet) units, and 41 ton yr^{-1} for regular liftnet units. In Zambia they are 62–68 ton yr^{-1} for kapenta (beach) seine or chiromila (boat) seine, but only 10 ton yr^{-1} for liftnet units.

Declining CPUE coupled with the adoption of powerful 'apollo' type liftnet units in the artisanal fishery and disincentives generated by Government tax and licensing requirements has led to a drastic decline of industrial fishing in Burundi waters. Of the 13 industrial units active in 1992, only two were enumerated as active in the 1995 Frame Survey. The remainder have either been decommissioned or have been shifted to Zambia in the south of the lake. The DRC has witnessed a similar decline in purse seining operations based in Kalemie and Moba, though this probably owes more to political instability than to adverse fishing conditions. In Tanzania the industrial fishery never developed to the same extent as elsewhere, though here too purse seining has fallen off in recent years. Of the 4 operational units enumerated in 1995, only one remains active at the present time.

Over the last 15 years or so, there has been a sevenfold growth in purse seining effort in Zambian waters (from 3 to 23 active units since 1983), almost exclusively harvesting *Lates stappersii*, which now comprise 95% of the industrial catch. As Coulter (1970, 1991) has pointed out, development of the purse seine fishery from the 1950s soon resulted in a substantial reduction in the harvest of other *Lates* species, i.e. *L. mariae*, *L. microlepis* and *L. angustifrons*, all of which seem to be particularly vulnerable to localised over-fishing. Today's simple composition of the pelagic stocks, with two clupeids and *L. stappersii*, is one very striking outcome of the selective pressures imposed by the mechanised large-scale fishery.

It is notable that *S. tanganicae* was the dominant target species of the purse seine fishery in the Zam-

bian waters of the lake during the 1980s. Although the *S. tanganicae* decline coincides with the expansion of purse seining in Zambia, the stock in northern waters, at least until recently, seems to have withstood decades of high fishing pressure in fairly confined areas. This strongly suggests that environmental factors have played a role in hastening the southern stock's decline. A succession of poor recruitment periods brought on by environmental perturbations can rapidly reduce the size of short-lived clupeid stocks (Mannini, 1998).

LTR survey results confirm a more uniform lakewide distribution of the *L. miodon* stock in comparison with that observed for *S. tanganicae*. Catch composition observations indicate that *L. miodon* contribute less to the lift net and purse seine harvests than do *S. tanganicae* and *L. stappersii*. At the same time, the species dominates catches in the highly unselective beach seine (= kapenta seine) fishery that operates close inshore over shallow, sandy bottoms, particularly along the southernmost coastlines. Since juvenile *L. miodon* tend to be concentrated within the inshore areas beach seine hauls are mostly comprised of immature fish. The widespread use of very fine mesh covers on the seines further intensifies pressure on the immature stock (Mannini, 1998).

In general, therefore, it can be said of the contemporary situation that even though the major commercial pelagic stocks are distributed throughout all sectors of Lake Tanganyika, its northern half is dominated by a clupeid-based fishery, whilst the southern areas feature a *L. stappersii*-based fishery (Mannini, 1998).

Local artisanal and traditional fishers

Results of the 1997 LTR socio-economic (SEC) sample survey of artisanal and traditional fishers (N = 923) and post-harvest operators (N = 431) at 66 landing sites around the lake are reported in a series of technical documents covering each of the four national sectors (Reynolds, 1997a,b,c,d), as well as a lakewide synthesis (Reynolds & Hanek, 1997). Survey results indicate that local fishers of all categories (artisanal or traditional, unit owner or crew member):

(a) are almost exclusively men;
(b) generally fall within an age range of 18 – 50 years;
(c) tend to have low levels of formal education (lack a primary school certificate);
(d) are often not native-born residents of their current landing site bases;
(e) generally engage in fishing as their principal job, though are commonly involved in secondary occupations in subsistence or combined food crop/cash crop farming.

Available information suggests that artisanal owners earn substantially more than their crew members. No such disparity is evident in the traditional fishery. Average earnings within the artisanal sector (no earnings data available for DRC sample populations) are estimated to run well above per capita annual income for the working age population within the respective lacustrine countries. Traditional sector earnings typically run much lower, though are still comparable to regional per capita averages – bearing in mind that the overall East-Central Africa context, as measured by standard international 'quality of life' and income indices, is one of extreme poverty and underdevelopment (World Bank, 1999).

Post-harvest sector

Processing and marketing

LTR survey observations (Reynolds & Hanek, 1997) confirm previous accounts of how poor infrastructure and natural barriers impose heavy constraints on fish processing and marketing possibilities. Steep escarpments limit overland access to much of the shoreline. Roads link the principal towns like Kigoma, Kalemie, Moba, and Mpulungu with their hinterlands, but feeder routes between towns and their outlying areas are not effectively developed. Railway lines exist only at Kigoma, in Tanzania (with service to Tabora and Dar es Salaam) and at Kalemie, in the DRC, with connections (when operable) west and eventually to the southern Shaba mining districts. Furthermore, there are few facilities for energy-intensive techniques of fish handling and processing, e.g. chilling, freezing or canning. The best equipped plants are found in Mpulungu and on a more limited basis in Kalemie.

The bulk of fish landed at most sites must, of necessity, be processed in some fashion in order to extend its shelf life for marketing purposes. Simple sundrying on the beach or ground is easily managed under local conditions, requiring little input other than labour. It is by far the most common method of processing clupeids and *L. stappersii*, which constitute the greater bulk of the lakewide catch (Reynolds & Hanek ,1997).

Although reliable statistics are lacking on the volume of product flow along the various marketing channels that reach beyond the lake basin, the major outlets for dried fish are long established and well known. In addition to the mining districts of Shaba

Province in the DRC and the Zambian Copperbelt, supplies reach the Dar es Salaam market through the railway connection from Kigoma. North of the lake, Bukavu and Goma in the DRC and towns in Rwanda and further afield have in recent years become important market destinations as well, owing in no small part to the growth of displaced populations resulting from regional civil conflicts, and the requirements of various agencies involved with emergency food assistance for refugee camps and repatriation schemes (Reynolds & Hanek, 1997; Reynolds, 1998).

Local processors and traders

Women are well represented in the fisheries post-harvest sector around the lake, and even appear to constitute a majority of the small-scale processor/trader population in Zambia and parts of the DRC. Survey data indicate that post-harvest operators:

(a) are relatively younger as a group than the fisher population;
(b) have a low overall level of education, particularly amongst women;
(c) tend to originate from places other than their current landing site bases; and
(d) are usually involved in fish processing or trading as a main occupation, though are typically engaged in secondary jobs either in some other fishing-related activity (e.g. gear owner) or in farming (Reynolds & Hanek, 1997).

Post-harvest income levels appear to be generally lower than those of the harvest sector, and especially in comparison with levels found in the artisanal fishery. Based on survey data (Reynolds & Hanek, 1997) and World Bank (1999) figures, it is estimated that average income for women in some cases runs well below national per capita averages.

Sustainability and Lake Tanganyika Fisheries Management Challenges

A great deal of commentary in recent years has focussed on the need for fundamental reappraisal of standard approaches to fisheries management and indeed a considerable literature covering various facets of the topic now exists (e.g. Larkin, 1977; Lindqvist, 1977; Ludwig et al., 1993; Myers et al., 1997; Roberts 1997; Beverton 1998; de la Mare 1998; Holt 1998; Pauly 1998; Pitcher et al. 1998). Many observers have pointed out how the normative concepts, analytical orientations and application strategies that have guided much of fisheries research, development, and administration over the modern era are seriously flawed. Such diagnoses are borne out by what has aptly been termed the 'litter of failures' (Roberts, 1997) across the fisheries of the world. This is manifested in repeated episodes of declining yields and economic return, stock collapse and, ultimately, crises of social dislocation and lost biodiversity.

A common characteristic of conventional management systems in fisheries is their 'command and control' nature, expressed as 'top-down' directed communication channelled through highly bureaucratised structures (cf. Harris, 1998). Decision-making on critical issues is seen as the preserve of state functionaries, who rely on fisheries scientists for technical advice. Minimal allowance is made for the participation of local-level resource users. Ironically, the 'objective' scientific advice that is supposed to underpin the whole process is itself open to question. Roberts (1997), for example, criticises conventional fisheries management decision-making for its over-dependence on population biology models and methods that do not take species interactions into adequate account and that allow insufficient leeway for error in circumstances that are fraught with great uncertainty.

LTR research from the very outset has been guided by recognition of the inadequacies of simple 'stock assessment driven' analyses (Lindqvist & Mikkola, 1989). Thus, none of the SSP studies – whether of pelagic trophic structure (Sarvala et al., 1999), biophysical interactions (Huttula, 1997; Plisnier, 1997; Salonen et al., 1999; Vuorinen et al., 1999; Kurki et al., 1999), or pelagic fish stock mass (Szczucka, 1998) – were performed with the intention of establishing an accurate level of Maximum Sustainable Yield (MSY) and Total Allowable Catch (TAC). Use of the MSY model was deemed totally unsuitable given the highly complex, dynamic, and unpredictable conditions obtaining in the lake. The model not only neglects the significance of life-history adaptations and inter-specific relationships in multi-species stocks, but overlooks the effects of complex patterns of adaptive behaviour within the human communities that exploit them (see Larkin, 1977; Lindqvist, 1977).

In an important contribution that reviews the evolution of management paradigms and sustainability concepts over the modern era, Charles (1994) synthesises major strands of 'new school' fisheries science thinking into a unitary framework. He argues that resource conservation is a necessary but not sufficient condition for sustainability. Because sustainable fisheries

development involves multiple objectives, various biological, socio-economic, culturo-communal and institutional dimensions must be taken into account. He goes on to propose a conceptual approach through which these different dimensions or components may be ordered, evaluated, and integrated.

Another and much more extensive and programmatic synthesis of contemporary fisheries management precept and practice, though one that touches many of the same themes, is provided in the FAO *Code of Conduct for Responsible Fisheries* (hereafter CCRF). The CCRF principles (FAO, 1995b), along with their accompanying series of *Technical Guidelines*, provided critical reference points for the LTR team as it set about the task of collating various research programme outcomes and using them to build a provisional 'Framework for Regional Fisheries Management' (Reynolds, 1998) for submission to the CIFA Sub-Committee for Lake Tanganyika.

The CCRF first verifies the pressing need for a fundamental reorientation of global fisheries priorities and then elaborates a voluntary model framework through which such reorientation can be effected. The points of responsibility it highlights include, *inter alia*:

(a) Use of whole ecosystem perspectives on problems of resource base and environmental preservation;
(b) dedication to present social welfare needs, consistent with sustainability;
(c) adoption of the 'precautionary approach' in management and conservation decision-making; and
(d) effective participation of stakeholder groups in the decision-making process, with particular attention to small-scale fisher interests.

Using the analytical approach developed by Charles (1994) in conjunction with the CCRF framework, we consider in this section the circumstances of Lake Tanganyika fisheries and their management needs in terms of four principal components of sustainability – *viz*. ecological, socio-economic, communal and institutional.

Ecological sustainability

The basic criterion for ecological sustainability in fisheries is the maintenance of the resource base (stocks and species) at viable levels – i.e., so as '. . . not to foreclose future options' (Charles, 1994:204). More generally, of course, this entails the need to secure the integrity and build the capacity of the overall ecosystem. Under CCRF guidelines, similar themes are expressed in terms of the 'precautionary approach,' which imposes broad obligations of 'prudent foresight' in the management of fisheries systems. Precautionary requirements include, for example, such interrelated measures as: the maintenance of system balance and productivity for the benefit of future generations; careful and constant restraint on harvesting and processing capacities in accordance with the dynamics of resource renewal; and giving automatic priority to conservation of productive capacity when the outcomes of development interventions are uncertain (FAO, 1996a, 1997).

Pelagic fish production

The ecological basis of pelagic fish production as investigated under the LTR Project and through earlier studies is reviewed in some detail by Sarvala et al. (1999, this volume). Salient points include the following.

Hydrophysical, limnological, food web, stock assessment, fish biology and related studies provide a basis for reassessing the pelagic trophic structure of Lake Tanganyika, which has been claimed to be unique in the proportion of fish biomass to phytoplankton biomass (Hecky, 1984). Ecological studies and catch surveys have also evaluated the vulnerability of the fish stock to increased fishing pressure and possible over-fishing.

Hydrophysical patterns, nutrient fluxes and related primary production of Lake Tanganyika are highly dynamic and affected by climatic, hydrological and internal factors (Huttula, 1997; Plisnier, 1997; Salonen et al., 1999), all of which are non-predictable and capable of dramatic fluctuation.

The various hydrophysical and biological processes regulating secondary production likewise induce fluctuations in zooplankton, medusae and shrimp abundance and distribution. These effects are seen in high seasonality, strong daily vertical migration and patchy horizontal distribution. Some degree of areal variation is also apparent (Vuorinen et al., 1999; Kurki et al., 1999).

The dominant pelagic fish species (clupeids and *L. stappersii*, as distinct from the other *Lates* spp.) display an r-selected life-history strategy typified by features of high juvenile mortality, early maturity and recruitment to fishery, relatively short life cycle, and high turn-over rate (Mannini et al. 1996). Such features are consistent with an adaptation towards non-predictable conditions (Stearns, 1976) and, as estimated by Adams (1980) for a large number of marine fish species, provide resistance to high fish-

ing pressure targeted even to young age classes. Great reproduction potential, multiple spawning and migrations lead to regular recruitment and fast recovery after exposure to over-exploitation and highest actual yield and yield/ recruitment (Adams, 1980; Armstrong & Shelton, 1990; Fogerty et al., 1991). Such recovery of stock was shown in Burundi after the fishing was temporarily closed in 1996.

Annual catch of planktivorous fish figures at about 23% of total estimated production for the whole lake, and as high as 66% in the case of Burundi waters, which are the most heavily fished. For piscivorous fish, the lakewide catch is reckoned to be some 70% of total estimated production. These figures suggest that the present fishing pressure in Lake Tanganyika is very high (Sarvala et al., 1999). Normally it is supposed that only 20–25% of fish production can be harvested (Houde & Rutherford, 1993).

Variations in stocks and yields

Tanganyika's fish stock levels and yields are characterised by substantial year-to-year, season-to-season and area-to-area fluctuations, often associated with dramatic shifts in the relative abundance of clupeids and *Lates*. Such fluctuations may be caused by variable success in fish recruitment which, in turn, is regulated in complex and non-predictable ways by physical, biological and fishing-related factors (for clupeids, see Cole & McGlade, 1998). LTR researchers have established that temporal and areal variations of commercial stocks are associated with the strength and timing of nutrient upwelling and related plankton succession in Lake Tanganyika, particularly in the south. In other words, patchy and ephemeral distribution of the target pelagic species matches the patchy and ephemeral availability of their prey – copepods for clupeids and shrimps and clupeids for *Lates* (Plisnier & Coenen, 1997; Coenen et al., 1998; Mannini, 1998).

Fluctuations in the relative abundance of pelagic species are also apparently linked to migrations between different sub-basins of the lake. Although not systematically studied by the LTR project, the likelihood of migration occurrence was demonstrated indirectly through catch studies (Coenen et al., 1998), fish biology data (Mannini, 1998), and assessments of population genetic discreteness (Kuusipalo, 1994, 1999; Hauser et al., 1998). The lack of distinct genetic population structures suggests that a significant exchange of individuals takes place between different parts of Lake Tanganyika. Mannini et al. (1996) claimed the same for fish biology data obtained from catch samples. Mannini (1998) later noted that although *L. stappersii* is capable of moving and mixing freely across all sub-basins of the lake, from a management perspective it is possible to discriminate a 'northern' and 'southern' stock on the basis of spawning and exploitation patterns. There are indications that the Kigoma sub-basin provides spawning and nursery areas for the 'northern' stock and that the Moba and East Marungu sub-basins fulfil the same roles for the 'southern' stock.

Signs of excess fishing pressure of *S. tanganicae* stocks (high juvenile content and smaller mean length in catches) exist for the northern end of the lake, on both west and east coasts north of Karonda (Burundi coastline, about 75 km from the northern tip of the lake). Furthermore, the highly unselective beach seine fishery, mostly prosecuted in Zambia, is heavily targeting juvenile *Limnothrissa miodon* in their shallow, inshore nursery grounds (Mannini, 1998). The seines are in addition inflicting untold damage on the mainly cichlid coastal fish community.

Although total catches show an increasing trend, CPUE for industrial units (purse seiners) have been declining. Nightly CPUE of industrial units in Burundi dropped from 166 kg in 1994 to 111 kg in 1996 and in Mpulungu from 877 kg in 1994 to 535 kg in 1996. The industrial nightly CPUE's in Congo have also decreased to 433 kg from the 780–950 kg of the early 1990s (Coenen et al., 1998).

Declining catchable stocks of *L. stappersii* in southern waters, especially around the vicinity of Mpulungu, are indicated by the significant decline in industrial CPUE and increased duration of fishing trips (Coenen et al., 1998; Mannini, 1998). Indications of possibly excessive exploitation pressures on *L. stappersii* have also been noted for the northern end of the lake, as a result of the effects of successive waves of heavy industrial fishing and artisanal fishing. *L. stappersii* now make up only around 20% of the commercial catch in northern waters, with juveniles accounting for most of this contribution (Mannini, 1998).

Socio-economic and community sustainability

The typology proposed by Charles (1994) treats human welfare dimensions of fishery sustainability under two separate components. An analytical distinction is made between 'socio-economic sustainability' and 'community sustainability' depending respectively on whether 'individual' or 'group' perspectives are adopted.

Socio-economic sustainability pertains to the generation, distribution and maintenance of benefits amongst individual actors or 'players' in a fishery arena. Criteria for assessing sustainability in this connection thus include, for example, the extent to which a fishery provides employment, income, and food security advantages to small-scale harvesters and traders, the extent to which different players share in these advantages, and the extent to which they will remain a viable basis of livelihood.

Community sustainability pertains to the issues of wider collective identity and welfare. It is measured with reference to such criteria as the extent to which a fishery:

(a) contributes to community stability in the long run;
(b) allows local group access to the resource base and community involvement in resource management and development decision-making; and
(c) affects the fortunes of various community subgroups such as women, youth, etc.

CCRF principles likewise recognise that socio-economic and community welfare are crucial fishery issues. Management aims for maintaining resource base viability must be pursued in the context of human requirements for '. . . food security, poverty alleviation and sustainable development' (FAO, 1995b:4). Decisions related to the regulation of fishing effort, the protection of fragile stocks and so on, are bound to carry implications for the activities and even the basic livelihood of those who participate in a fishery system as resource users. CCRF technical guidelines therefore emphasise that an understanding of socio-economic and cultural patterns and processes is an essential component of responsible fisheries management, in order '. . . to anticipate the nature and extent of these impacts and to make decisions so as to optimize them' (FAO, 1997:32–33).

LTR socio-economic and community investigations

Readings on human welfare dimensions of sustainability for Lake Tanganyika fisheries are provided by findings from two major LTR investigations – the lakewide socio-economic (SEC) survey that was conducted in 1997 (Reynolds & Hanek, 1997), and the community referenda exercise that was completed in late 1998 (Reynolds, 1999). The latter involved a series of public meetings around the lake for the exchange of information and views between local fisheries stakeholder groups and national LTR field teams. Local community residents were briefed on major outcomes of LTR hydrobiological and socio-economic studies over the previous six years and on how these have been integrated into a provisional framework for regional fisheries management. Each meeting involved free-ranging discussion of major management proposals followed by formal polling of participant opinion of their merits.

The following summary of key points is presented with the caveat that, as with any capsule depiction based on aggregated survey findings and field observations, it is only possible to provide a very broad and simplified picture of local realities.

Fisheries as livelihood

The communities bordering Lake Tanganyika clearly share in the conditions that, on the basis of various 'quality of life' indices, have ranked East-Central African countries amongst the world's most poverty-stricken and underdeveloped (World Bank, 1999). LTR Project SEC survey findings, for example, confirm a picture of weak and deteriorated physical infrastructure around the lakeshore, and of a critical scarcity in basic social services and amenities. At the same time, however, the data show that there is considerable variation of socio-economic circumstances within local and regional settings. In Kigoma Region of Tanzania, to take a case in point, it can very roughly be estimated on the basis of survey returns that fishing-derived income for most artisanal unit owners amounts to the equivalent of some US$640 per year (Reynolds, 1997b), or about twice as high as the estimated Tanzanian national working age population per capita annual income of US$290 (based on figures available in World Bank, 1999). The comparative annual income figure for most Kigoma Region artisanal unit crew members is US$340 (just over the national working age average). On the other hand, estimated earnings for traditional fishers (whether owner or crew member) are US$190 (about two-thirds the estimated national working age average). For the Kigoma Region post-harvest sector, a strong gender-related discrepancy shows up in the income figures (Reynolds 1997b). It is estimated that a majority of male processors/traders earns some US$340 per year (similar to artisanal crew earnings), whereas a majority of their female counterparts earns about US$140 per year (less than half of the estimated national working age average; estimates based on figures reported in World Bank, 1999).

In a context where the overall rural economy offers very limited opportunities for gainful employment, the attractions of fisheries work may be quite strong (cf.

Skjønsberg, 1982); there is the promise of moderate remuneration, depending on the job, and conditions of entry seem relatively easy (low initial requirements for skills, working capital, or investment in productive equipment and supplies). This observation is borne out by SEC survey findings related to respondents' future employment preferences (Reynolds & Hanek, 1997). Strong majorities across all job categories in all four countries indicated a wish to continue with their respective present lines of work.

On the other hand, local views on the state of commercial fish stocks indicate that a degree of pessimism, or at least uncertainty, exists with regard to the ability of the lake's fisheries to sustain adequate levels of livelihood security (Reynolds & Hanek, 1997). Fishers and post-harvest operators are very pessimistic in their appraisals of catch trends over recent years: majorities in all cases take the view that they have been on the decrease. Opinion as to whether future catches will be lower, higher, or the same tends to be divided or undetermined (i.e. responses of 'No opinion').

Sample respondents were also asked if they thought the lake would always provide 'enough fish for everybody.' Here too a division of opinion is apparent. DRC and Zambian fishers and post-harvest operators all take a decidedly negative view, whereas those in Tanzania are largely uncertain and those in Burundi tend towards a positive view (Reynolds & Hanek, 1997).

Increasing demand for fish

The above survey findings on Tanganyika fisherfolk views of past trends and future prospects need to be appreciated in an overall regional context where demand for fish is constantly on the increase. Fish accounts for some 25%–40% of total animal protein supply for the populations of the four Lake Tanganyika states (Gréboval et al., 1994), so its significance for nutritional welfare is obviously considerable. At the same time, rapid population growth within the Tanganyika basin and across East-Central Africa as a whole (World Bank, 1999) fuels an ever-increasing demand for fish products, so that over the last several decades per caput supply has barely kept pace with overall fish production, despite increases in the latter (Gréboval et al., 1994).

In a region already subject to severe episodes of drought, prolonged political unrest has compounded the effects of population growth in ratcheting up demand for Lake Tanganyika fishery products. Crop and livestock production capabilities, marketing infrastructure and the general state of food security have all been severely disrupted in Burundi, eastern DRC, and Rwanda due to hostilities, attendant population displacements and breakdown of public services.

Resource access issues

Tanganyika fisheries basically operate under an open access regime. Under the broad conditions associated with national territorial partitions, everyone is free to fish. This situation is clearly untenable. Open access classically leads '. . . to overexploited resources and declining returns for all participants' because it is '. . . characterized by a race to fish in which all participants strive to catch as much of the resource. . . as they can, before their competitors do' (FAO 1997:52). Rising population pressures inside and outside the lake basin are bound to exacerbate matters.

At the same time, opinion seems to vary amongst local fisherfolk populations about what sorts of access rights, if any, ought to be maintained. A survey proposition suggesting that 'everyone should be allowed to fish anywhere they want in the lake,' for instance, drew mixed responses both within and across national boundaries (Reynolds & Hanek, 1997). Consensus on the issue is clearly lacking, yet some form of limited access will have to be established if the fisheries are to be sustained – i.e. if the classic sequence of 'free-for-all' exploitation – race to fish – resource overexploitation is to be avoided (FAO, 1997).

Local participation in management decision-making

Management approaches within the four national sectors of Lake Tanganyika were established in the classic 'top-down' model, featuring a high degree of state control over all aspects of fisheries affairs from policy definition to regulation enforcement. Although existing legislation in some cases provides for consultation between administrators and local representatives of fisher interests (Cacaud, 1999), and although fisher committees are reported to exist at various landing sites (Reynolds & Hanek, 1997), *de facto* local community participation in resource management decision-making and follow-up has been very minimal. It is nevertheless clear that at least in some localities fisherfolk would be eager to embrace management responsibilities more directly. SEC survey findings show, for example, that majorities in all respondent categories in Zambia and of both artisanal and traditional fisher groups in Tanzania, reject the proposition that 'fishing rules should only be decided by Government.' Further evidence of a willingness

to engage in management deliberation and consultation activities with fisheries officials was encountered during the community referenda exercise of late 1998 (Reynolds, 1999). Referenda meetings often proved to be quite lively and loquacious affairs and participants repeatedly observed that they appreciated the opportunity to meet directly with senior fishery officials and to air their views. It was also evident, interestingly enough, that a number of these same officials found the meetings to be quite 'eye-opening' experiences.

Adverse impacts

Prospects for human welfare sustainability in Tanganyika's fisheries are subject to potentially serious hindrances arising from pervasive inequalities in wealth and control of the means of production. One dimension of such socio-economic differentiation is seen in the sometimes fraught relations between fishing unit owners and fishworkers, particularly in the artisanal sector. The existence of broad patterns of differentiation between owners and crew members along various measures of personal circumstances and income potential (Reynolds & Hanek, 1997) has already been alluded to. Observations in the course of the 1998 community referenda exercise show further dimensions of inequality (Reynolds, 1999). Many fishworkers related accounts of poor working conditions, or manipulative and arbitrary behaviour on the part of some employers. Still others expressed a sense of powerlessness and of feeling isolated from the deliberations of local beach committees and 'rich owners.' It is obvious that serious underlying tensions exist.

The gender dimension of socio-economic inequality in local communities is expressed in terms of educational attainment and estimated income measures (Reynolds & Hanek, 1997). It is apparent in other ways as well, as noted during the 1998 Community Referenda exercise (Reynolds, 1999). Considering their actual level of participation in Tanganyika fisheries as workers, processors, traders and even occasionally as boat and gear owners, women had little voice in the general assembly or plenary sessions with which proceedings began at each venue. In their exclusion from full public participation in local decision-making processes, women as a class share something of the same disadvantages as their fishworker counterparts in the harvest sector – namely, subordinate social status and poor pay.

Another dimension of socio-economic inequality can be recognised in the relations between artisanal and traditional fishers on the one hand and the industrial purse seine fishery on the other. Small-scale fisher antipathy towards purse seining is fairly general around the lake, but is particularly strong in the southern end, where virtually all of the industrial fleet is now based (Reynolds & Hanek, 1997; Reynolds, 1999). Purse seiners are widely blamed for declining catches in the Zambian sector, and overwhelming support exists for imposing restrictions on their operation. It can of course also be argued, as company owners and officials have been known to do (Reynolds, pers. obsv.), that the industrial fishery provides benefits in terms of employment for local people as purse seine unit crew and processing factory workers and in terms of the scale and efficiency of its fish protein production to meet national needs. What is obvious in any event is that the combined pressure of industrial and small-scale fishing operations is unsustainable in the long run and will, if allowed to go unchecked, result in severely adverse effects on fish stocks and hence on human welfare.

Institutional sustainability

Charles (1994) describes institutional sustainability as playing a kind of intermediary role vis-à-vis the other three sustainability components of his typology: 'A prerequisite for . . . [ecological, socio-economic, and community sustainability] is the maintenance of suitable financial, administrative and organizational capability in the long-term' (*ibid*: 205). Institutional sustainability in a fisheries context, thus, turns on the ability of a state- or industry-supported research establishment effectively to monitor catch and effort trends, for example, or of a regulatory agency effectively to fashion management measures and ensure their enforcement.

The CCRF and its *Technical Guidelines* highlight the importance of both formal and informal institutional structures for the fisheries management process. In some contexts informal institutions may fulfil crucial management functions, as for instance where customary arrangements govern conditions of resource access or regulate fishing effort. Whether formal or informal, effective management planning requires a close understanding of existing institutional structures in terms of their composition and function, the fisheries interests they serve and the manner in which decisions are made and implemented. With regard to formally constituted management authorities at regional, state, or local levels, CCRF provisions lay

particular emphasis on the crucial task of fisheries monitoring, control, and surveillance, or MCS. Thus,

> "... the widespread failure of fisheries management on a global scale has, in large part, been a result of the inability of ... authorities to enforce successfully or otherwise ensure compliance with their management regulations and to monitor accurately the behaviour and performance of the fishers. Responsible fishing requires effective ... [MCS], which is dependent on the collection, collation and analysis of accurate and relevant data and information [FAO 1997:39]".

Institutional sustainability and Lake Tanganyika fisheries

An appreciation of the problems and prospects related to institutional sustainability for Tanganyika fisheries can be gained from LTR studies of relevant organisational and legal structures within the four lacustrine states (Hanek, 1994; Maembe, 1996; Cacaud, 1996, 1999), monitoring and statistical data collection work carried out in collaboration with national research institutes and fisheries department offices around the lakeshore (Coenen, 1994, 1995; Paffen et al., 1997; Coenen et al., 1998; Mannini, 1999), and findings of the 1997 lakewide SEC survey (Reynolds & Hanek, 1997) and 1998 community referenda exercises (Reynolds, 1999).

Institutional capabilities and legislative frameworks

All four lacustrine states are nominally committed to fisheries policies that emphasize socio-economic welfare objectives, consistent with the need to use resources in a sustainable, conservation-wise manner. Yet the institutional means provided for realising these objectives are woefully inadequate. In his recent detailed appraisal of regional institutional capabilities, Cacaud (1999) identifies budgetary problems as the main underlying cause of organisational dysfunction within the fisheries sector. National fisheries departments and research agencies are chronically underfunded and in some cases disastrously so. As a consequence, research agencies are unable to maintain creditable scientific monitoring programmes in order to fulfil their role as technical advisors on sound management and conservation practices, except through dependence on outside sources of funding (cf. Coenen et al., 1998; Mannini, 1999). Furthermore, fisheries departments are simply unable to marshal, in either qualitative or quantitative ways, adequate human and material resources for effecting their basic mission tasks of MCS and provision of extension services. Operational paralysis and lack of motivation amongst field personnel are rife.

Cacaud (1999) also carries out an inventory of major fisheries legal framework deficiencies within the four lacustrine states. To begin with, existing legislation, in some cases dating back to the colonial era, is in many respects outmoded or obsolete. Comprehensive overhaul is needed in order to relate it both to current realities of territorial and administrative organisation, and contemporary management imperatives. Also, umbrella-type legislation that establishes broad regulatory powers for state authorities to exercise on a national basis needs to be augmented with specific regulations to fit the particular circumstances of Lake Tanganyika.

A second major area of legal deficiency concerns enforcement. Fisheries regulations in all four lake states are widely ignored in practice, either because they are insufficiently enforced or because they are simply not enforced at all. The problem relates back to the huge financial constraints under which regional fisheries authorities must labour: it is impossible to support adequate numbers of enforcement agents in the field. As Cacaud (1999) notes, this situation is unlikely to improve in any dramatic way. New and viable enforcement solutions are obviously called for, and will require the full participation of local stakeholders in management decision-making and in follow-up actions to ensure regulatory compliance.

Monitoring needs

At the beginning of the LTR project it was apparent that fisheries monitoring and information processing capabilities at some of the lakeshore stations were extremely weak. Extensive collaborative work with national administrators and researchers was conducted in order to strengthen these capabilities and to assemble the sort of information base that is a first requirement of fisheries planning and management. It is obvious that planning and management efforts will be impossible to pursue in future unless a regular lakewide monitoring programme is kept in place. Although monitoring activities of the same scope and intensity as achieved under LTR would clearly be impractical, any future programme would need to provide some degree of coverage over the same basic set of parameters – physical, biological, statistical, and socio-economic – as those investigated under the project (Coenen et al., 1998; Mannini, 1999).

Table 2a. Tanganyika sample fisher group majority views on fishing restrictions and enforcement/compliance measures (Reynolds & Hanek, 1997)*

	Burundi		DRC		Tz/Kigoma		Tz/Rukwa		Zambia	
PROPOSITION	A/Fish	T/Fish	A/Fish	T/Fish	A/Fish	T/Fish	A/Fish	T/Fish	A/Fish	T/Fish
A. RESTRICTIONS	−2	−2	−3	−3	−2	−2	−1	−1	−1	−1
1) Seasonal closures										
2) Area closures	−2	−2	−3	−2	0	0	0	0	+3	+2
3) Fisher quotas	−3	−3	−3	−3	−3	−3	−3	−3	−2	−2
4) General min. mesh sizes	+1	0	−3	−3	+2	+3	+3	+3	+3	+3
5) Controls on industrial gear	+2	+2	−1	−1	−1	−1	+1	+1	+3	+3
6) Ban on industrial gear	0	0	−1	−2	−2	−1	−1	+1	−2	−2
7) Controls on beach seining	−1	−2	−3	−3	−2	−2	−3	−2	+3	+3
8) Ban on beach seining	−3	−3	−3	−3	−3	−3	−3	−3	−3	−3
9) Controls on lift nets	−2	−3	−3	−3	−3	−3	−3	−2	+3	+3
10) Ban on lift nets	−3	−3	−3	−2	−3	−3	−3	−3	−3	−3
B. ENFORCEMENT	+1	+1	+1	+1	+3	+3	+2	+2	+3	+3
1) 'More patrol boats'										
2) 'More fisheries scouts'	+3	+3	+1	+1	+2	+1	+2	+2	+3	+3
3) 'More police involvement'	−1	0	−2	−2	+1	+2	+2	−1	−1	−1
4) 'Punish offending fishers'	+2	+3	+2	+2	+3	+3	+3	+3	+3	+3
5) 'Punish offending traders/ consumers'	+3	+3	+2	+3	+3	+3	+3	+3	+3	+3

*A/Fish = Artisanal fisher respondents; 'T/Fish' = Traditional fisher respondents. Scores: +/−1 = Majority for/opposed (> 50%); +/−2 = Strong majority for/opposed (65%); +/−3 = Very strong majority for/opposed (80%); 0 = Divided opinion, no absolute majority.

Local views on possible options to regulate fishing

Local fisherfolk views on existing or possible measures for the regulation of fishing activity on Lake Tanganyika and for encouraging compliance with them, provide further indications of challenges that will need to be overcome in building towards institutional sustainability.

During the 1997 lakewide SEC survey, members of both fisher and post-harvest sample groups were asked if they 'Agreed,' 'Disagreed,' or held 'No opinion' on measures that might involve:

1. Seasonal closures;
2. Closure of certain areas or reserves;
3. Quotas on fisher numbers;
4. General mesh size restrictions (type of net not specified);
5. Some form of restriction on industrial operations;
6. Outright prohibition of industrial operations;
7. Some form of restriction on beach seining;
8. Outright prohibition of beach seining;
9. Some form of restriction on lift net operations; and
10. Outright prohibition of lift netting.

Respondents were also asked to give their reactions to a further set of five propositions relating to regulation enforcement and compliance. These included:

1. Use of patrol boats;
2. Posting of more fisheries scouts;
3. Greater police involvement as enforcement agents;
4. Punishment of fishers who violate regulations (e.g. catching undersized fish); and
5. Punishment of fish traders or buyers (including consumers) who violate regulations (e.g. sale/purchase of undersized fish).

Findings (Table 2) indicate a broad acceptance in principle amongst local stakeholders that some sort of formal regulation is needed for the fisheries. This can be read from the high approval ratings on propositions to enhance official enforcement capabilities and to apply sanctions against regulation violators. (It is also suggested by the widespread concern, noted earlier, expressed by Tanganyika fisherfolk over the state of commercial stocks.) Such acceptance, presumably, would not be forthcoming if it were widely perceived that current resource exploitation patterns were without problems.

At the same time, however, there is rather weak agreement lakewide vis-à-vis many of the particulars that management arrangements could entail. Where consensus is found, it tends to be of a negative sort. Moderate to heavy majorities across all the national sample groups surveyed reject the idea of imposing a prohibition on beach seining or on lift net fishing; they also reject the suggestion that an overall limit be placed on the number of fishers allowed to operate on the lake.

These attitudinal findings suggest that the task of fashioning a regulatory framework for fisheries around the lakeshore will be a complicated one. Significant divergence of fisher and post-harvest operator opinion over management measures occurs not only between the four national sectors, but within them as well.

A similar pattern was witnessed to some extent during the 1998 community referenda exercise (Reynolds, 1999), when polling was conducted on core proposals set out in the LTR draft framework for regional fisheries management. Community groups were asked about their reactions, 'in principle,' to the following possible management actions:

1. Limitations on fishing in one form or another;
2. Local community participation in fisheries management;
3. The formation of management advisory groups running from local to regional level;
4. Licensing to control the number of fishers and boats allowed to operate within given areas;
5. Prohibition of industrial fishing in certain parts of the lake; and
6. Prohibition of beach seine fishing along certain areas of shoreline.

Whilst these basic management propositions largely meet with local approval and, thus, may continue to be regarded as valid and legitimate reference points for elaborating management strategy and tactics on a lakewide basis, there is by no means a universal consensus on any of them. Local stakeholder opinion appears to be especially divided on the issue of operator and craft licensing as a means to control entry to the fishery. Of the above six propositions presented to participants in the community referenda meetings, this proved to be the one case that yielded an indeterminate outcome.

Table 2b. Tanganyika sample post-harvest group majority views on fishing restrictions and enforcement/compliance measures (Reynolds &Hanek, 1997)*

PROPOSITION	Burundi P/Hvst	DRC P/Hvst	Tz/Kigoma P/Hvst	Tz/Rukwa P/Hvst	Zambia P/Hvst
A. RESTRICTIONS	−2	−3	0	+1	+2
1) Seasonal closures					
2) Area closures	−2	−2	0	+1	0
3) Fisher quotas	−3	−3	−1	−1	−1
4) General min. mesh sizes	+1	0	+2	+2	+3
5) Controls on industrial gear	−1	−3	0	−1	−1
6) Ban on industrial gear	−1	0	−2	0	−1
7) Controls on beach seining	−2	−3	0	0	−3
8) Ban on beach seining	−3	−3	−2	−2	−3
9) Controls on lift nets	−2	−3	−1	0	−1
10) Ban on lift nets	−3	−3	−1	−1	−2
B. ENFORCEMENT	+1	+1	+2	+2	+2
1) 'More patrol boats'					
2) 'More fisheries scouts'	+3	0	+1	+2	+3
3) 'More police involvement'	+1	0	+1	+1	−1
4) 'Punish offending fishers'	+3	+3	+3	+3	+3
5) 'Punish offending traders/ consumers'	+3	+3	+2	+2	+3

*Scores: +/−1 = Majority for/opposed (> 50%); +/−2 = Strong majority for/opposed (65%); +/−3 = Very strong majority for/opposed (80%). 0 = Divided opinion, no absolute majority.

Sustainability and policy: towards resource management on Lake Tanganyika

Policy considerations

For Lake Tanganyika, as for other fisheries, management challenges not only must be met across the multiple dimensions or components of sustainability discussed above, but also met simultaneously, in an integrated fashion. A number of policy considerations have thus, to be taken into account. As Charles (1994)

observes, "If each of the [sustainability] components is viewed as crucial to overall sustainability, it follows that 'sustainable development' policy must serve to maintain reasonable levels of each" (*ibid*:205). Policy orientation for the fisheries sector, he goes on to suggest, must therefore be such as to accommodate:

(a) Conditions of uncertainty and complexity;
(b) Improved local participation in management decision-making and implementation;
(c) Clearer specification of resource property rights; and
(d) Actions directed internally to ensure a balanced use of resources and externally to encourage the development of non-fishing employment alternatives within the larger economic system.

Such themes also resonate throughout the CCRF guidelines for development of responsible fishery policy and legal and institutional frameworks (FAO, 1995b, 1997). They are captured in what might be called 'five principal Ps' of responsible fishing – namely:

1. Precaution (conservative, least risk exploitation and development strategies in the face of system uncertainty);
2. Partnership (reliance on co-management approaches involving shared management responsibilities between state fisheries authorities and local stakeholders);
3. Proprietorship (recognition of limitations on rights of resource access and use);
4. Policing (monitoring, control, and surveillance and enforcement activities to secure the regulation of fishing mortality); and
5. Process (understanding management as dynamic and adaptive rather than static and fixed).

Policy options that would help foster responsible fisheries management on Lake Tanganyika – that would, in other words, be appropriate to the effective 'pursuit of sustainability' (Charles, 1994) across its several dimensions, are reviewed in the following paragraphs.

Adaptive management

The characteristics of Tanganyika's fish stock dynamics and distribution and the composition of its fisheries across different national and gear type divides, require that sustainable management policy be framed to accommodate approaches that, in a seemingly contradictory way, are both holistic and particularistic in scope. Thus, the random distribution of pelagic stocks throughout the lake, straddling national boundaries, calls for management responses calibrated at the scale of the entire lacustrine ecosystem. On the other hand, management approaches must also be capable of adjustment to meet particular episodes of stock fluctuation and attendant changes in fishery circumstances (cf. Hilborn & Sibert, 1988).

Inter-annual, seasonal and areal variation in stock levels and yields within Lake Tanganyika, often substantial, unexpected and marked by inverse proportions of clupeids and *Lates*, generate considerable problems for local fisherfolk and industrial operators alike, since fishing and marketing activities become difficult to plan. As earlier remarked, LTR researchers have shed some light on the mechanics of such 'process uncertainty' (cf. Caddy & Mahon, 1995), by demonstrating relationships between fish stock fluctuations, migrations and the incidence of nutrient upwelling and related plankton succession. Yet such knowledge, even when coupled with findings from the wider set of hydrophysical, limnological and related studies that have been conducted through LTR and other scientific investigations, only provides a partial understanding of pelagic fish production and distribution dynamics. It by no means allows for close 'when, where, and how much' predictions of ecosystem fluctuation. In the face of multilevel uncertainties (Francis & Shotton, 1997), a good deal of flexibility will be required to accommodate sometimes rapidly changing circumstances. Static MSY modelling and lake-wide TAC assessment are completely unequal to such a task, which is why no attempt was made to incorporate them into LTR investigations as practical management tools (Lindqvist & Mikkola, 1989). Larkin (1996) has also pointed out how trophic ecosystem models such as ECOPATH II (Christensen & Pauly, 1993), though potential predictors of gross impacts of large-scale exploitation, are of limited utility for practical depictions of temporal and spatial dynamics. 'Adaptive' or 'interactive' management practices that allow for adjustments in fishing pressure in the short-term will also allow for fishery system sustainability in the long-term.

A policy of adaptive management is appropriate to Lake Tanganyika circumstances in other ways as well. Even though pelagic stocks seem to be distributed randomly throughout the lake, with no apparent sub-populations, the difference in target species concentration between the clupeid-based fishery of the northern areas and the *L. stappersii*-based fishery to the south might require management treatments that are somewhat distinct and separate. The same holds

true with respect to the composition of national fleets and fishing units. The fisheries of the DRC and Tanzania, which respectively account for the greatest and second greatest annual take of pelagic species from the lake, are comprised mostly of traditional and artisanal units operating from landing sites distributed along vast stretches of coastline. The fisheries of Burundi and Zambia, in contrast, are limited to much more confined areas. They also feature fairly high concentrations of relatively more efficient artisanal gear – liftnet and apollo units in the case of Burundi and kapenta seines in the case of Zambia. A very high density of industrial units further distinguishes the Zambian sector.

Multi-disciplinary perspectives

Recognition of the inherent limitations of population biology models and methods for the task of comprehending the "... highly complex bio-socio-economic system" (Charles 1994:207) that a fishery represents leads also to the recognition that, from a sustainability point of view, the effectiveness of management decision-making directly depends on the use of multi-disciplinary approaches. This is particularly true in the case of the Tanganyika pelagic fishery. It is a fishery of complicated and interacting 'multiples': multiple species, subject to multiple fluctuations of abundance, are harvested and utilised by multiple interest groups deploying multiple varieties of gear and technology. Accordingly, in its bid to chart out some of the key patterns, processes, and inter-linkages of this complex system, LTR made use of a mix of observational and analytical tools from both the natural and social sciences. Plans for the immediate future call for the continuation of the regional monitoring activities started under the project's Scientific Sampling Programme, on a much reduced revised scale, under the responsibility of national teams working in tandem (Mannini, 1999).

In keeping with sustainable management needs, the extended monitoring programme will have to be capable of generating information on complex fisheries interactions involving both natural and human agencies. The design of the programme has thus made provision for collection and collation of basic data in five key indicator areas. These include:

1. 'Early alarms' signalled by changes in hydrodynamic patterns;
2. Density and distribution patterns in the meso- and macro-zooplankton communities that provide prey for planktivorous fish;
3. CPUE and fish biology data for main target species;
4. Continuities and changes in fishing communities (size, composition and infrastructure) and the socio-economic circumstances of local harvest and post-harvest operators; and
5. Continuities and changes in local views on trends in, problems with, and regulation of the fishery sector.

Of over-riding concern for future monitoring activities on Lake Tanganyika is their practicality, given current conditions of budget, staff and equipment limitations (Mannini, 1999). The extended programme has accordingly been designed to meet requirements of:

(a) feasibility (procedures commensurate with available resources);
(b) simplicity (use of uncomplicated equipment with minimum maintenance needs); and
(c) sustainability (high likelihood for regular data collection over the long run).

A useful reference for multi-disciplinary monitoring activity on Lake Tanganyika is found in the work of Preikshot et al. (1998), who use rapid appraisal techniques and multivariate statistical analysis to trace ecological and socio-economic decline in the fisheries of 32 African lakes through time. Apart from focusing on relevant parameters, monitoring activities in support of adaptive management strategy and decision-making for Tanganyika fisheries should be equipped to cope with observational and data modelling uncertainties (cf. Caddy & Mahon, 1995; Hilborn, 1997). An accepted method of dealing with uncertainty is to consider probabilities (McAllister et al., 1994), rather than just considering single answers from deterministic projections (Cochrane et al., 1998). What is basically required is that monitoring be sufficiently robust to allow for the achievement of management aims in the face of statistical uncertainty and incomplete knowledge (cf. Charles, 1985; FAO, 1996a).

Robustness may be enhanced by combining information from 'non-scientific' knowledge systems into the store of multi-disciplinary data that is generated through conventional 'scientific' approaches. Working along these lines, Mackinson & Nøttestad (1998) have elaborated an 'expert system' that helps to build mutual respect and co-operation between resource users, scientists and managers. In a similar

vein, de la Mare (1998) develops his idea for tidying up fisheries management with a new 'MOP' (Management Oriented Paradigm) using a whole system approach that requires collaboration between all concerned parties. O'Boyle (1993) likewise has noted the importance of interactions between managerial bodies, economists and end-users to improve and promote more responsible management.

Management in partnership

Variously formulated as 'management in partnership,' 'co-management,' 'participatory management,' or 'community-based management,' policies to increase local involvement in resource use decision-making and regulation are based on recognition of the inherent weaknesses of 'top-down' or 'command and control' management regimes. The latter, in addition to undervaluing the potential contributions of local knowledge systems and actors to the management process just noted above, often feature a heavy measure of state intervention. This may often result in an 'us versus them' response of disassociation amongst local fisherfolk, expressed in widespread indifference and even the deliberate violation of official regulations. In CCRF language, "... the efficiency and implementability of...management measures are often highly dependent on the support gained from the interested parties" (FAO, 1997:55). Such support is most likely to exist where resource users can identify with specific measures because they have they have helped to craft them. As Charles (1994) comments,

> "... in general the achievement of long-term sustainability requires fishers to 'buy into' management. This seems most likely if top-down regulations are replaced by decentralized arrangements that give fishers, their organizations and their communities a clear stake in managing local resources, a degree of decision-making power and the responsibility (with government) to ensure the fishery's sustainability [*ibid*: 207]."

A further consideration that lends weight to the case for co-management in fisheries concerns cost-reduction and efficiency gains that might be realised. Fisheries administrations across much of the developing world currently labour under severe financial and operational constraints (FAO, 1997) and as shown by LTR institutional studies (Maembe, 1996; Cacaud, 1996, 1999), the Tanganyika situation is no exception. As there is little likelihood that the budgetary and staffing position of local fisheries departments and research institutes will undergo any dramatic improvement in the near-term, innovative solutions are called for (Cacaud, 1999). If local stakeholders could be encouraged to assume a greater share of responsibility, it is conceivable that local fisheries authorities could accomplish MCS and enforcement purposes on a 'more-for-less' basis.

Because it offers such obvious long-term advantages, management partnership warrants strong emphasis in regional policy for Tanganyika fisheries. At the same time, the scope and pace with which partnership arrangements are implemented will depend on specific circumstances. Views on co-management appear to vary to some extent between countries and localities, and there are clear differences in fisheries and environmental circumstances, as well as attitudes towards specific regulatory measures (e.g. licensing, gear and space-time restrictions, etc.), that will have to be accommodated. Community outreach activities obviously must figure strongly as part of management partnership strategy, in order to build levels of environmental consciousness and receptivity to measures for the regulation of resource access and exploitation.

Resource access and use rights

Local control of fisheries resources is also mediated through the allocation of property rights. As noted earlier, open access regimes or regimes that, as in the case of the Tanganyika fisheries, essentially function in an open access mode under broad conditions of state resource ownership and regulation, virtually guarantee a situation of resource overexploitation. Fish harvesters, even where limited by quota and/or effort restrictions, will each race to garner as much of the resource as they can, with the ultimate result of declining returns for all. CCRF guidelines offer the reminder that the present critical status of fisheries world-wide, marked by '... a high proportion of over-exploited stocks and a general low (and often negative) profitability' (FAO, 1997:52), is in large part due to the incessant playing out of this pattern across myriad local and regional contexts. It also explains why, these days, 'Limited access is widely considered to be essential for efficient and responsible fisheries' (*ibid*). As Charles has observed, limited access arrangements in small-scale artisanal fisheries may be particularly effective when constituted as fishing rights allocated at the group or community level. There is '... an incentive for the community collectively to

(a) Ensure that the resource is managed wisely,

(b) Efficiently manage allocation of catches and fishery access (also helping to prevent the 'rush to fish'. . .), and
(c) Develop local enforcement tools' (Charles, 1994: 208).

The future sustainability of Tanganyika fisheries requires a transformation of the present rather loose 'open-access-within-national-jurisdictions' regime into one that allocates fishing rights to local communities and their respective territories. But here again a gradual policy move is indicated. Attitudes and circumstances that bear on access issues vary at both district or country levels and need to be addressed on a zone-by-zone basis through careful consultation and negotiation with local stakeholder groups. Also, in the case of the southern waters particularly, the process of fishing rights reallocation will need to accommodate the interests of industrial fishing firms, possibly as stewards of special 'offshore commercial use territories' or directly as component parts of local community zones.

The situation with regard to industrial interests must also be considered in terms of developments within the artisanal sector. A gradual pattern seems to be emerging in which artisanal units, operating with improved technology especially in the form of the powerful 'Apollo' liftnet configuration, are taking over the role of industrial purse seiners (Roest, 1992; Coenen et al., 1998). This may well be a positive development. As Hilborn et al. (1995) have argued, the consolidation of small-scale community or private ownership of productive equipment, coupled with local control of resource base access and active involvement in the management thereof, are crucial ingredients for achieving true success – i.e. long term sustainability – in the exploitation of fishery resources.

Fisheries, externalities and economic diversification

The 'pursuit of sustainability' as a basic policy objective cannot ignore the larger socio-economic environment within which local fisheries must be prosecuted, managed, and developed. From an 'inside-out' perspective, the weak performance of a poorly managed fishery will have ramifications far beyond the sector, affecting a range of local, national, or even regional welfare interests. Conversely, if there is strong internal coherence in terms of 'responsible fishing' (FAO, 1995b) or 'intelligent fishing' (Charles 1994) practices, then optimal benefits are generated not only for sector user groups but also for the larger society of which they form a part. From an 'outside-in' perspective, the play of various factors and externalities in other, non-fishing sectors, whether at the immediate local scale or across broader national, regional, and even international arenas may exert far-reaching influence on the fisheries. At local 'micro-levels' these typically include impacts arising directly from competing demands for use of the aquatic resource base (e.g. fishing versus wildlife conservation/tourism use), or indirectly from externalities generated by non-fishing activities (e.g. fishing versus sewage disposal). At national and regional 'macro-levels,' impacts might arise, for instance, from declines in agricultural production, industrial stagnation, altered terms of international trade, widespread unemployment, or shifting consumer preferences.

The Tanganyika situation involves a complex of fishing and non-fishing sector interactions, at both micro- and macro- levels of socio-economic integration, that is at once intriguing and worrisome. To begin with, a variety of conflicts, existing and nascent, can be documented between fishing and other user interests around the lakeshore (LTBP, 1998). Pollution impacts from waste discharge exist around urban areas like Bujumbura and Kigoma, and Mpulungu, for example. Other conflicts arise in connection with the wildlife conservation areas and development of tourism in the cases of Nsumbu National Park in Zambia, and Mahale National Park and Gombe Stream Reserve in Tanzania. On a wider and, at present, far more serious scale is the environmental degradation and associated threats to biodiversity within the aquatic resource base linked with the activities of a rapidly expanding population of smallholder farmers. The situation is particularly acute where population density is high, as is the case in much of Burundi. Shortage of farm land for family food production leads people to cultivate on steep hillsides, leading in turn to progressive deforestation, soil erosion, and siltation of nearshore waters (Coulter & Mubamba, 1993; Cohen et al., 1993)

Resolution or mediation of conflicts arising from multiple use demands and the interaction of sectoral externalities clearly will not be possible if regional fisheries management policy remains fixed in what might be called an 'introspective' mode. Fisheries sustainability, in other words, needs to be pursued with due recognition of the reality of fishing and non-fishing sector interactions. This once again highlights the importance of multi-disciplinary approaches for the discovery and understanding of pattern and process

in fisheries systems, except that here concern extends to relations between components of the fisheries and those of adjacent sectors (cf. Charles, 1994; FAO, 1995b). What is also indicated is the importance of policy support for 'integrated development strategies' that, '. . . deal with the full complexity of the fishery system *and* associated activities outside the fishery' (Charles, 1994:207). In fisheries such strategies are often associated with the 'Coastal Area Management' model (FAO, 1995b, 1996b) that calls for, *inter alia*:

(a) establishment of conflict resolution mechanisms to settle differences arising between fisheries resources users and other users of a coastal area;
(b) promotion of public awareness of coastal resource conservation and management needs and of public participation by affected parties in the management process;
(c) assessment of the economic, social, and cultural values that attach to different coastal resources; and
(d) use of multi-disciplinary approaches to monitor the coastal environment (*ibid*: 26–27).

With regard to Tanganyika fisheries, the development of coastal area management approaches in the immediate future might best be pursued in conjunction with the work of the GEF Biodiversity Project (LTBP, 1998).

Fishing and non-fishing sector interactions at the macro-level as they pertain to the Lake Tanganyika situation have already been characterised to a large extent in earlier discussion. Of particular note is the role of the lake as a major supplier of fish protein in a regional context marked by widespread civil turmoil, population displacements, episodes of drought and crippled or degraded capacity in other food producing sectors. These larger events, compounded by the crescive load of human inhabitants within the lake basin and across East-Central Africa generally, have not only contributed to conditions of food insecurity and placed increasing pressure on the lake's fisheries resources; they have also helped to create conditions of employment insecurity. Considering the attitudinal and income data collected during LTR's 1997 SEC survey, it may well be the case that the Tanganyika fisheries are being viewed and used by basin residents as a significant source of employment as well as food. In the face of limited alternative gainful employment opportunities, and with what seem to be relatively reasonable earnings at stake, the fisheries over the past several years may well have been serving as a labour magnet for many rural dwellers. Taken in conjunction with LTR evidence pointing to the development of over-fishing on certain stocks in certain localities in Lake Tanganyika, the effect of such a development would only be to worsen sustainability prospects for the fisheries in the short-term. Therefore, and in accordance with the strategy of integrated development advocated above, a strong dose of economic diversification would appear highly advisable as a policy prescription for Tanganyika fisheries. As Charles has noted,

> "With respect to external action, . . . diversification and the provision of employment alternatives are crucial in relieving pressure on the fishery resource as the primary source of livelihood. . . .From an economic viewpoint, diversification increases the opportunity costs of fishing, making that activity *relatively* more expensive and less desirable (compared to other options), so less effort finds its way into the fishery" [1994: 209].

The worrisome flip side of this, i.e. *failure* to promote diversification at the macro-level, is of course what ensues when prolonged conditions of easy entry into the fishery sector finally result in full-blown 'Malthusian over-fishing' (see Pauly, 1994, 1997). In this scenario, the 'expensiveness' of fishing comes to be measured in terms of the wider social costs of massive economic marginality, and possible widespread movements of displaced people in search of rare or non-existent alternative sources of livelihood (cf. Lindqvist & Mölsä, 1982).

Concluding remarks

In this contribution we have endeavoured to:

(a) Provide some background on the scope and content of LTR Project work;
(b) Situate project research and methodologies in terms of contemporary developments in fisheries management theory and application;
(c) Identify and characterise, with reference to research outcomes generated through the projects Scientific Sampling Programme, socio-economic investigations and legal-institutional studies, major development and management challenges that confront fisheries resource users, administrators, planners, and policy makers; and finally,
(d) Consider various policy options appropriate to conditions of ecosystem uncertainty, plural stakeholder interests, and complex interactions between

fishing and non-fishing sectors of the wider economy.

LTR research is very much associated with recent trends in management thinking in its explicit rejection of 'stock assessment driven' approaches to fisheries resource exploitation and conservation. Such conventional approaches are simply inadequate for comprehending the complex dynamics of Tanganyika's pelagic trophic structure and the multiple uncertainties of its fisheries. Nor are they adequate as aids to understanding the complex patterns of adaptive behaviour that are played out within local fisherfolk society.

Recognising that the Tanganyika fisheries must be treated as a complex biological and anthropological reality, the LTR research programme has made use of a combination observational and analytical tools from both the natural and social sciences. We have reviewed the outcomes of this multi-disciplinary study effort in terms of the ecological, socio-economic, communal and institutional patterns and processes that the fisheries actually entail. In building towards a fisheries management framework for Tanganyika we have made particular use of the 'components of sustainability' typology proposed by Charles (1994), and have also drawn on themes laid out in the FAO *Code of Conduct for Responsible Fisheries* or CCRF (FAO, 1995b).

What such a framework needs to aim for is the 'pursuit of sustainability' (Charles 1994) across its multiple bio-socio-economic and institutional dimensions. In CCRF terms, it needs to aim for 'responsible fisheries compliance' through simultaneous attention to what we call the 'five Ps' – *viz*:

1. Precaution (in the face of system uncertainty);
2. Partnership (to achieve consensus amongst resource users and other interested parties);
3. Proprietorship (avoidance of 'free for all' competition);
4. Policing (monitoring, control and surveillance and enforcement activities); and
5. Process (flexible accommodation to circumstance and change, and the need periodically to review and renew management approaches).

Policy initiatives for Tanganyika are called for in five broad areas, as follows.

Adaptive management: use of interactive management practices that allow for adjustments in fishing pressure and also allow for flexible application of management treatments appropriate to different circumstances encountered around the lakeshore.

Multi-disciplinary perspectives: maintenance of monitoring capability to measure across a range of bio-physical and socio-economic parameters, as appropriate to the complexities of ecosystem – human system interactions; also, cultivation and maintenance of 'non-scientific' and 'scientific' knowledge coalitions.

Management in partnership: promotion of local stakeholder group involvement in management decision-making and in fashioning modalities of enforcement and compliance.

Resource access and use rights: moves to constitute control of access and fishing rights at local community levels.

Fisheries and economic diversification: adoption of integrated development strategies and coastal area management models at the local level, to accommodate complex interactions and possible conflicts between fishing and non-fishing activities and, at national and regional 'macro-levels,' moves to foster economic diversification to reduce pressure on the fishery resource base.

In order to achieve responsibly managed fisheries, the four lacustrine states must continue to act in close collaboration with one another. After the LTR Project more permanent and formal arrangements will be required. Provision needs to be made in national plans and legislation for participation in regional efforts to guide resource use and conservation on an internationally shared basis (Cacaud, 1999). This process could be facilitated, as recommended in LTR's provisional framework plan (Reynolds, 1998), by the formation of a Lake Tanganyika Regional Fisheries Management Working Group as a successor body to the existing CIFA Sub-committee for Lake Tanganyika. A system of upward and downward linkages, involving both consultation and sharing of personnel, would tie the regional group in with co-management groups constituted at district and local community levels, and thus provide for the integration of fishery stakeholder participation across the whole Tanganyika basin.

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