AN INTERDISCIPLINARY ASSESSMENT OF TROPICAL SMALL SCALE FISHERIES USING MULTIVARIATE STATISTICS

by

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Abstract

Interdisciplinary fisheries information pertaining to sustainability were analysed with the multivariate techniques of multidimensional scaling and cluster analysis to determine how information from outside biology might help augment biological fisheries analyses or warn when more in depth biological assessments might be needed for a fishery. Tropical small-scale fisheries were used as a test model for collecting this data set as a high percentage are subject to overfishing. Defining the nature and causes of overfishing in these fisheries may help in the development of appropriate solutions to maintaining sustainability of associated fisheries, ecosystems, and communities of fishers using these resources. Measuring the sustainability of tropical small-scale fisheries was examined from the perspective of 'Malthusian overfishing', that is, overfishing due to populations increasing at a rate beyond the capacity of the resource base to supply. The mechanism of Malthusian overfishing contains three processes; increased populations, increased competition, and increased use of destructive gears. In order to identify fisheries subject to Malthusian overfishing, 54 tropical small scale fisheries were described using sustainability attributes from four fisheries disciplines; biology, economics, sociology, and technology. While information from economics seemed to be disjointed from the biological indicators of sustainability, the sociological and technological results proved complementary to those from biology. The reasons for these different congruencies are discussed. The implication of this work is that non biological information may be helpful to amplify biological warnings of overfishing as well as identify fisheries in need of greater scrutiny.

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1. Introduction

1.1. Better Ways are Needed to Assess Fisheries.

How does one assess fish population changes? This simple question is at the heart of fisheries biology. Unfortunately, the direct study of fish populations is difficult due to three aspects of their ecology and one of their economics: first, they live in an environment that is opaque to humans; second, their habitats occupy vast geographic areas; third, all fish are linked to the population fluctuations of their prey, competitors, and predators, any of which may be subject to varying degrees of competition or human exploitation; and last, a fishery's economic value is often much lower than the cost of properly understanding the population dynamics underlying a fishery. In developing nations' fisheries the combination of the factors above makes it difficult to know when exploited species are at risk and which fisheries should receive research attention.

Lack of research has all too often resulted in 'unexpected' fisheries collapses, although the frequency of such events may preclude the use of the term 'unexpected'. A widely cited paper by Garcia and Newton (1997) suggests that about two thirds of global fisheries are heavily exploited, overexploited or depleted. Indeed, a sense of negativity pervades much of the discussion in fisheries biology because it seems that too often even the best biological investigation fails to prevent, or even warn of, stock collapses (Ludwig *et al.*, 1993). In moments of black humour, fisheries scientists often describe their job as 'chronicling the decline of fish populations'. Inevitably, then, stock collapses tend to dominate the mind and thus our perception of how the world works.

That a fishery enters into a state of collapse and fails implies that such a state might have been avoided. I realise that terms such as 'sustainability' carry ideological baggage, however, I have elected to use this word in this work and shall use it in the following sense. A sustainable fishery is one that does not exhibit stock collapse, is associated with a particular group of people, gives that group a standard of living at or above the average of their society, and involves the use of gears that minimise catches of non-target species and juveniles. The word fishery can be applied to a group of people employing a particular gear, or combination of gears, to catch marine organisms for consumption and / or sale. Thus, a fishery can be as small as an individual or as big as the the total world ocean fishery. The point is that for either scale, or any in between, the sustainability of a particular fishery can be observed.

Most fisheries scientists can think of some fisheries that are sustainable in the manner defined above. For example, Pinkerton and Weinstein (1995) cite several examples of sustainability and community satisfaction in fisheries from places as far flung as North America, South America, Asia, and Oceania. Indeed, there are splendid examples of fisheries that WERE sustained for a very long time. For instance Johannes (1981) describes the traditions and methods of the fisheries of Palau, which persisted for thousands of years prior to modernisation . What distinguishes fisheries that can be sustained for a long time from those that can not? If an analysis tool were available to quickly examine a fishery and determine its status, greater efficiency may be realised in deciding which fisheries are most in need of attention from scientists and intervention by management.

The fisheries biologist has the important goal of diagnosing sustainability. What sort of questions can fisheries scientists ask? The most popular questions have been about the very things that are the most difficult and expensive to measure, i.e. estimating the number of fish in a water body. We have yet to develop any systematic way of asking the fishery and its participants themselves (i.e., the patients) "Where does it hurt?" Since fishers are directly linked to the populations of fish they exploit, the status of the former should be linked to that of the latter.

Like medical doctors biologists often rely on expensive technologies that measure directly the biological parameters of their subject, because this helps avoid the intrusion of subjectivity. Just as many hospitals are well stocked with complex and expensive machines to assess the biological status of patients, fisheries researchers in developed countries tend to use exotic equipment and complex computer models.

This study is not an attack on that technology, much of it has been put to good use. A large part of the problem of the technology approach is that it is expensive and time consuming. Fisheries biologists do not always have the luxury of money or time when called upon to comment on the sustainability of a fishery. However, fishers' communities, their economic well being, and the technology fishers use should reflect the status of the fish populations they rely on. We should therefore be able to infer much about the biological status of fish populations by examining the social and economic status of the human communities that depend upon them. To argue otherwise would preclude the significant effect of human fishers on the fish they pursue, as is suggested by those who tie fisheries productivity to environmental effects. See Beamish (1995) for a collection of works that present different aspects of climate change to explain fish population dynamics in many temperate stocks and the Thompson / Burkenroad debate on the causes of population changes in Pacific halibut (Hilborn and Walters, 1992).

Properly understanding the biological particulars of fish populations to change is always complex and, thus, often expensive and time consuming. Many countries lack the resources and time to effectively address highly technical biological phenomena such as bottom up or top down effects on their respective fisheries. What they often need is a method for deciding which fisheries are most in need of such research to maximise the utility of each dollar spent on them. Such a perspective is especially meaningful in the context of the diversity that exists in many developing world aquatic ecosystems. This diversity is often translated to the catch profile of species taken by many developing-nation fisheries. For example, the artisanal fishery on Yorke Island in the Torres Strait comprises approximately 70 species (Johannes and MacFarlane, 1991). Likewise, the small scale fishery of San Miguel Bay in the Philippines is made up of about 175 species (Silvestre *et al.*, 1994). Even fresh water fisheries in developing nations may yield impressive diversity. Turner (1995) suggests that fishers on Lake Malawi rely on more than 200 species for their catch. The cost of stock assessments for suites of species as large as these examples would likely challenge even the research capacity of fisheries science in the all of the European Union and North America. It is unrealistic, therefore, to suggest that such intensive and expensive research can or should be done in developing nations with relatively more stocks. However, this connundrum may not be as intractable as it first appears.

Another parallel with medical science suggests that it might be more useful to use an assessment tool to determine the sustainability of a fishery. Epidemiology locates patterns of diseases within communities and populations. Kark (1974) uses a triangle to show a relation between "the state of health of a community", "the biological, social, and cultural characteristics of a community" and "the environment and material resources of the community". Each vertex is a source of familiar attributes used in epidemiological studies of humans. Such a triangle should also be familiar to anyone who has participated in debates on incorporating interdisciplinarianism into fisheries science. Some great successes in epidemiology have been achieved through the association of certain diseases with certain social, economic or environmental conditions. A famous example includes John Snow's association of a cholera epidemic with a London water pump (Tufte 1983), based on mapping the locations of victims. Another example was the association of cancer with smoking by Doll and Hill in 1950 (Harper and Lambert 1994). Epidemiology allows medical researchers to examine how diseases may be treated by other means than attacking the disease *itself*.

It is by now an accepted practice in many nations, especially developed ones, to enact policies that discourage smoking due to its association with several biologic conditions such as cancer. Using the classic approach of addressing the biology alone implies establishing a causal link between smoking and cancer, then deciding how fast cancers grow in the body, and then how they might best be treated. This brute force approach needs vast sums to fuel the research of medical schools across the land to study cancer. However, think of how many fewer cancers the population of a nation might have if everyone simply stopped smoking. The comparative cost effectiveness of eliminating smoking versus spending money on finding a cure for cancer is startling. If an association such as that between a social phenomena, i.e., smoking, and a biological outcome, i.e., cancer, was mere chance then insurance companies would not pay actuaries stunningly large salaries to calculate amortisation tables for different social groups based on cigarette consumption.

If human populations can be classified into groups that are deemed to be more or less likely to be associated with medical conditions or biological phenomena based on their economic and social attributes, then why should fisheries be exempt from similar comparisons? What this implies is that just as fish are classified in cladograms of 'primitive' to 'advanced' forms, based on the analysis of several attributes and characteristics, fisheries could be classified in groups ranging from 'sustainable' to 'unsustainable', based on characteristics that adressed those in biological, economic, and sociological terms. This turns the problem of measuring population parameters on its head by examining the fisheries themselves. If we can establish patterns of sustainability between the social, economic, and biological characteristics, we may gain some insight to the biological status of any fish population by determining the right social and economic characteristics to examine in an associated fishery. Therefore, if it is true that the fishery will be as sustainable as the fish it pursues we should expect to see some parallels between human social and economic indicators and the biological indicators of a fishery's sustainability.

1.2. Malthusian Overfishing as a Test for New Assessment Techniques

Malthusian overfishing was first discussed by Pauly (1988, 1990) as an observation on the generalised effects of population growth in developing countries in which more people are forced to compete for the fisheries resources. Later the phenomena was more formally defined as being "..what happens when these new fishers [i.e., people who migrate to the coast in search of food and work] lacking the land based livelihood of 'traditional' fishers (e.g., a small plot of land or seasonal work on nearby farms or plantations), and faced with declining catches, induce wholesale resource destruction in their effort to ensure their immediate survival" (Pauly 1997). McManus *et al.* (1992) developed a case study, from the Bolinao Reef flat, which displayed hierarchical symptoms of the progression of Malthusian overfishing first described by Pauly (1988); use of illegal gear and net meshes, use of gear not sanctioned by the fishing community, use of ecologically destructive gear, and use of gear that does all of the above while being potentially very harmful to the fishers themselves, e.g., cyanide and dynamite. Malthusian overfishing, thus links social phenomena of countries with small scale fisheries to biological phenomena. Three components can be percieved from the above description which make up the mechanism of Malthusian overfishing; human population growth outstripping its resource base, new competition causing the breakdown of traditional regulations and controls, and the introduction of increasingly destructive gear types.

1.2.1. The Population Problem

Thomas Malthus was the cleric and political commentator who in his essay "An Essay on the Principle of Population" forwarded two ideas that would later be of fundamental importance to another discipline: biology. On the tendency of populations, and the resources they use, he wrote that

> Through the animal and vegetable kingdoms Nature has scattered the seeds of life abroad with the most profuse and liberal hand; but has been comparatively sparing in the room and the nourisment

necessary to rear them…. In Plants and animals the view of the subject is simple. They are all impelled by a powerful instinct to the increase of their species; and this instinct is interrupted by no reasoning or doubts about providing for their offspring. Wherever, therefore, there is liberty, the power of increase is exerted; and the superabundant effects are repressed afterwards by want of room and nourishment, which is common to plants and animals; and among animals, by their becoming the prey of each other" Malthus (1803).

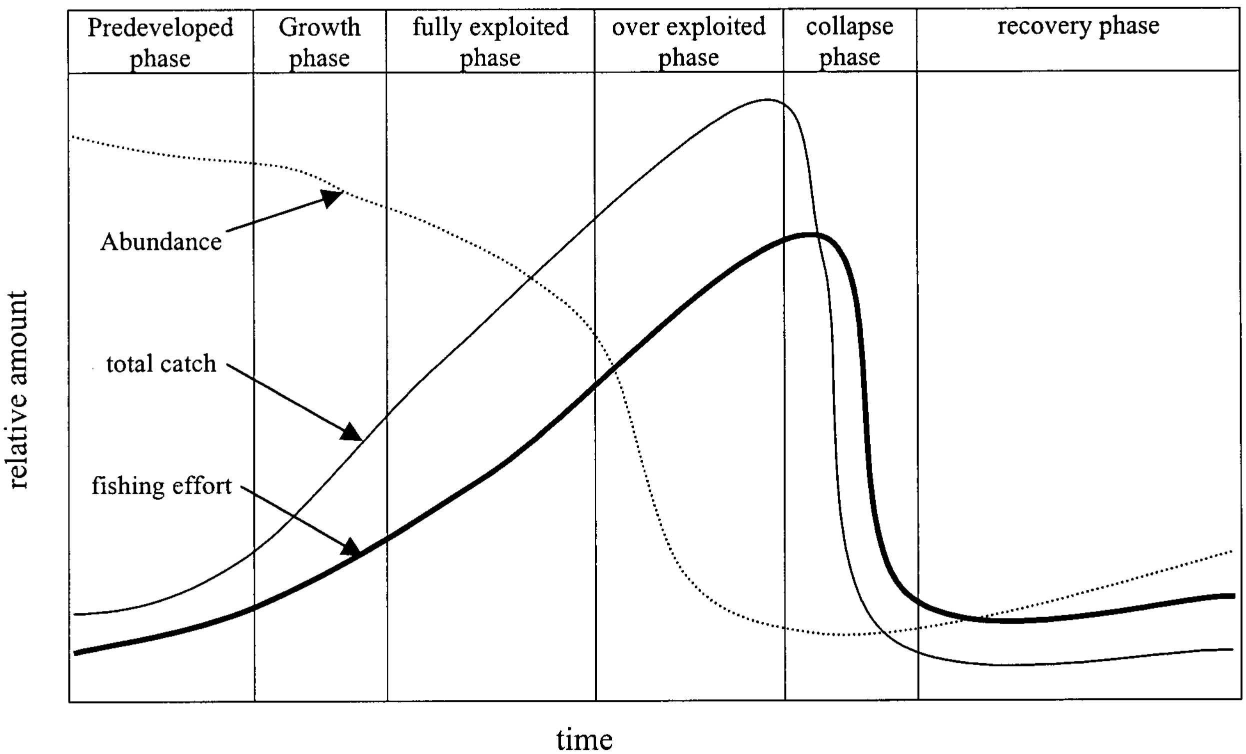

Figure 1.1: Potential trajectories of catch, effort and stock abundance over time in an uncontrolled fishery. Figure adapted from Hilborn and Walters (1992).

He noted, however, that the effects of such restrictions on human populations "…are more complicated" because of differences of custom, and technological advance between societies (Malthus 1803). He concluded that

"... population when unchecked goes on doubling itself every twenty-five years, or increases in a geometrical ratio... [but]... considering the present state of the earth, the means of subsistence, under circumstances the most favourable to human industry, could not possibly be made to increase faster than in an arithmetical ratio" (Malthus 1803).

This was the famous axiom of Malthus, that human populations will tend to outgrow the food resources needed to support them. In the case of fisheries this theory can be thought of as operating in the fashion illustrated in Fig. 1.1. Not much modification needs to be made to the dynamics behind this figure to arrive at the situation Malthus described. Fig. 1.1, as pointed out by Hilborn and Walters (1992), does not represent every uncontrolled fishery because the sequence of stock response to fishing effort will be dependent on the biology of the species caught. The important point is that the amount of fish taken by the fishery can increase only so far. In some cases fish stocks might be quite robust to high fishing mortality, e.g., highly cannibalistic species (Sparholt 1995). More likely though is the situation illustrated in Fig. 1.1, in which a new fish stock is exposed to increasing pressure. At the onset new entrants are rewarded by increasing catches and even more people will therefore decide to enter the fishery and the fishery moves to a full exploitation status. As the stock approaches its ability to match fishing rate with recruitment it enters an overexploited state. If fishing rates remain high the stock will collapse and most fishers will be forced to leave the fishery (Hilborn and Walters 1992).

The case of Malthusian overfishing, however, is even more stark in terms of the relation between fisher and stock. Whereas in many developed world fisheries there are tools available to the nation to cover the diplacement of fishers, i.e., social assistance, jobs in other economic sectors, in the developing world nations rarely have many other options for displaced workers. The proposed mechanism of Malthusian overfishing, therefore, is that fishers in developing countries will tend to stay in a fishery despite stock collapses. Indeed, the number of fishers may actually increase, despite collapse.

This process is catalysed by several phenomena. Blakie (1985) wrote about the two-way effect of a deterioration in land-based food production due to soil erosion on deteriorating social standards in developing nations. The despoilment of previously productive areas can be shown to be a direct cause of poverty and suffering and large scale displacement of people (Blaikie 1985). These individuals might turn to fishing as a means of at the very least providing their families with food and perhaps also gaining a meagre source of income. Stated more bluntly, fisheries may be an occupation of last resort (Neal 1982, cited in Pauly 1997). The fishing communities these people enter into are often governed by elaborate rules about who is allowed to fish and what sort of gear they may use. Johannes (1981) provides an excellent case study from Palau of how the erosion of traditional management techniques resulted in a decline of the fish resource. Newcomers, however, will tend to ignore such rules due to their alienation from pre-existing social mores. More important though, is the relatively high value that fish protein will have in such a situation. Since few reliable sources of income are present the apparent cost of obtaining food resources can become high enough to offset potential future economic loss. That is, it makes economic sense to deplete the resource because today's survival is more important, or valuable, than the potential economic payoffs in the distant future. Natural resources often can achieve such unlimited apparent prices in times of scarcity (Costanza *et al.* 1997). The natural rate of population growth in the community itself may exacerbate the effect of newcomers.

1.2.2. Unhealthy Competition

Another catalyst for Malthusian overfishing results from competition within the traditional small scale sector and between it and industrialised gears or foreign fleets. The fisheries of Lake Victoria provide an example of the first type of competition. The Ugandan sector has experienced increases of 3 300 in 1971 to 8 000 in 1990 of boats

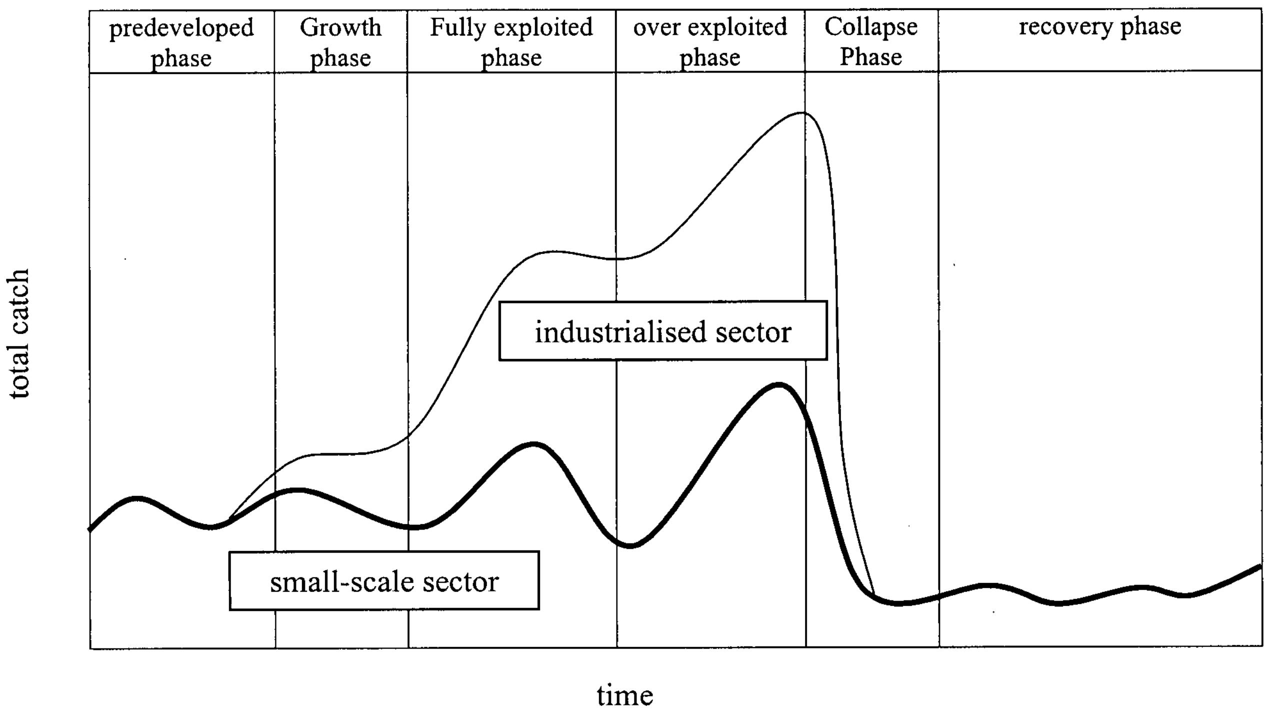

Figure 1.2: Potential trajectories of catches over time in an uncontrolled developing country fishery where a small-scale fishery becomes faced with competion from an industrialised sector. Adapted from Pauly (1997) and Hilborn and Walters (1992).

involved in the fishery (Kudhongania *et al.* 1992), the Tanzanian sector has seen significant large increases in fishers (Mwamoto and Hoza 1992), while there have been increases in landings in the Kenyan sector (Adhiambo 1991). All of these increases are focused upon the same fishing resource, the fish stocks move all over the lake. It is doubtful that fishing in Lake Victoria can continue to increase unchecked. Indeeed, an analysis of African lake fisheries indicates the limits may have already been reached in the case of Lake Victoria (Preikshot *et al.* 1998). Compounding this dire situation were the devastating effects on the Lake Victoria ecosystem of the introduction of Nile Perch, *Lates niloticus*. The introduction has succeeded so far in providing economic benefits (Reynolds *et al.* 1995), but also risks a process like that illustrated in Fig. 1.1. as the Nile Perch itself becomes subject to overexploitation.

A useful example of intersectoral competition was provided by fisheries off Indonesia. During the 1970s competition between the industrial trawler sector and small scale fishers in western Indonesia became very intense and led to overfishing. This led, in turn, to severe social unrest. The end result was a trawling ban in 1980 (Priyono and Sumiono, 1997). A second type of intersectoral competition to small scale fisheries is that from foreign fleets. In the case of Mauretania, foreign fleets have taken almost 100 % of fish catch within the exclusive economic zone (EEZ) since at least 1972 (Bonfil 1998). Mauretania, a nation suffering periodic severe droughts is presently enlarging its small scale fleet in an effort to reduce unemployment (Bonfil 1998).

Fig. 1.2 represents what can occur to a tropical developing nation's fishery when intersectoral competition is introduced. Fig. 1.2 uses the logic of Fig. 1.1 to help explain how competition in general can lead to Malthusian overfishing in particular. Note that there are at least four other concepts; growth overfishing, recruitment overfishing, ecosystem overfishing, and economic overfishing (Pauly, 1994), to explain why overfishing occurs. In the case presented in Fig. 1.2, once competition begins, the overfishing effects described by Fig. 1.1 are set in motion. Particular effects created by the competition should be noted. As the industrial sector takes more fish, the fluctuations in catch become more drastic as new fish populations are discovered and eliminated. The competition within the small scale fleet also increases as new entrants join. Often, too, more modern and less selective gear (described in the next paragraph) help push up the small scale catch despite the increased industrial take. Eventually the fishery enters the collapse phase, whereupon the industrial fleet moves to different fishing areas. If the industrial competition includes foreign fleets, these simply move on to a different area, leaving the small scale fishery with a reduced overall catch which may take a very long time to recover.

1.2.3. New Gears

The final catalyst which promotes Malthusian overfishing is change in gear used. Gears change as a result of the first two effects; population growth and competition with other sectors. New entrants to the traditional fishery will have little knowledge of, or respect for techniques, taboos, and traditions used by the fishers who had previously been sole users of the resource. This is not to argue that in all cases there must have been some small scale user group that was living in some sort of edenic balance with nature. It means something similar to that found by Johannes (1981) in Palau; a long term user group exploiting the fish resource that had many rules governing how and when to fish and who had the right to fish. A similar violation of such informal management can be seen in places like Diani-Kinondo Reef in Kenya. There village elders noted a deterioration of their fish resource concomittant with increasing pressure from outsiders and newcomers who failed to adhere to traditional rules and gear types (McClanahan *et* *al.* 1996). Here another comparison to the study of epidemiology may be drawn. As Harper and Lambert (1994) note, before the biological basis of many diseases were understood ancient civilisations nevertheless devised rules and systems which succeeded in preventing the spread of many diseases. For example, drainage systems and water closets, which appeared as early as the time of the Minoans, ca 3000 B.C., had become developed as fully integrated sewage networks available for use by whole cities by the height of Roman influence (Harper and Lambert 1994). Public sewers were a fundamental step in the prevention of disease, before people understood the mechanistic causes of disease. Misuse, abuse, or disuse of such traditional sanitation techniques would surely have lead to greater incidences of diseases in the classical world.

Many non traditional gear types tend to be highly non-selective, e.g., monofilament nets or extremely destructive, e.g., dynamite and cyanide. In San Miguel Bay, for example, the use of cyanide and dynamite is recent (Silvestre and Cinco, 1995) and coincident with declining catches over the last decade (Silvestre *et al.* 1995). The use of such gears may seem counterintuitive given the decline in catches. However, due to the overwhelming need to obtain food or money, destructive gears allow the fisher to extract the very last remnants of the fish biomass, which traditional or selective gears might miss.

1.3. Diagnosing Malthusian Overfishing

What means are there to identify Malthusian overfishing as a mechanism linking biological phenomena in fish populations with social, economic, and technological changes in communities of fishers ? Also, can the connexion between information from different disciplines be affected in a way that creates a tool like the one proposed earlier, which can quickly and easily contrast the sustainability of fisheries ? By examining both of these issues, Malthusian overfishing can be used as a test to determine the efficacy of a rapid appraisal tool to compare fishery sustainability by looking at data from different disciplines. How then, are the data to be assimilated to accomplish a rigorous interdisciplinary examination ?

Three components have already been described for the Malthusian overfishing mechanism; populations growing faster than their resource base, increasing competition, and increasing use of destructive gears. The description of changes in these components can be achieved by relating economic, sociological, and technological effects to biological effects. Each one of these disciplines contributes therefore to overfishing in a given fishery. Each discipline is thus a component of the fishery's sustainability or lack thereof. To determine the potential of the mechanism of Malthusian overfishing to act upon a fishery we could determine how sustainable, or unsustainable, it is in the sense of biological, sociological, economic, and technical attributes. For the Malthusian overfishing mechanism to be established more unsustainable, i.e., 'Malthusian', scores in sociological, economic, and technical attributes should be associated with biological unsustainability.

Such a test would explore the connexions between biology and the social sciences to test linkages that have been suggested by several authors. McGoodwin (1990) argues that fisheries must also be managed such that social considerations are maximised along with biological and economic returns. Many sociologists have further argued that biologists are given too much weight in fisheries management decisions (McCay and

Acheson 1987). Others have provided examples of fishers, scientists, and managers managing fisheries through inclusive co-management schemes that take account of information from a wide variety of sources (Pinkerton and Weinstein 1995). All of these, however, fail to show any mechanistic connection between sociological or economic benefit and biological sustainability. Unless some connection is shown between the biological sustainability of a fishery and the economic / social sustainability of the associated human community, then there can be no legitimate reason to suspect human benefits might be possible while sustaining a fishery.

If sustainability in general is to be measured we can easily devise a list of attributes for each discipline examined, i.e., biology, sociology, economics, and technology, each of which measure or score one aspect of sustainability. This would result in the creation of a table of data containing an array of fisheries as cases and an array of attributes in disciplines as variables. Visual inspection of the data thus amassed, however, would prove to be daunting. How then could it most effectively be interpreted ?

One method might be multiple correlations of the different variables. This presents a logistical problem. As Zar (1984) points out, in order to meet the assumptions of multiple correlation we must "... assume that for each X the Y values have come at random from a normal population [and that] the X values at each Y are assumed to have come at random from a normal population. Unfortunateley, collecting a large set of interdisciplinary data satisfying such a requirement would defeat the purpose of creating a quick and easy method to evaluate the information.

Multidimensional scaling (MDS) provides a way for the data to be summarised such that comparisons can be made between data sets. In simple terms, MDS can be applied "... if the elements of the data matrix indicate that strength or degree of relation between the objects or events represented by the rows and columns of the data matrix" (Young 1987). This is exactly the kind of information that could easily and cheaply be collected about fisheries anywhere in the world. By scoring attributes in an ordinal fashion of low, medium, or high MDS allows us to forgo the need to collect normally distributed data. MDS summarises information by taking a data matrix of high dimensionality and reducing it to a low dimensional spatial structure (Young 1987).

A low dimensional spatial structure can be thought of as a geographical map where the distances between points on the map are equivalent to their similarity. MDS therefore could help construct a map of which fisheries are sustainable in the context of different disciplines if we see which are closest to modelled fisheries, which are given high or low attribute scores. More significantly, it could allow the comparison of whether or not the fisheries maintained their groupings among disciplines, or the determination of which disciplines were most closely correlated in associating different fisheries.

By establishing similarities between assemblages of fisheries in MDSs generated for different disciplines, a new tool is created for the fisheries biologist and the fisheries manager. This essentially new source of evidence could allow a rapid assessment of the overall sustainability of any fishery. Such information would be especially valuable when making decisions about where to allocate scarce research funds (Pitcher *et al.* 1998a). Also, by demonstrating that interdisciplinary information might be used to support each other's assessment of the state of a fishery, evidence may be generated to reinforce preliminary biological surveys. It would be a true boon to biological research if a functional link were established between it and other disciplines, as this would help generate new hypotheses to explain biological phenomena.

1.4. Introduction to Multivariate Statistics

One of the most debated topics in fisheries science has been the application of interdisciplinary information to what has chiefly been a biological science. One objection to interdisciplinary fishery studies is the inherent difficulty of synthesising large amounts of different kinds of information from sources as diverse as the sociology, economics, and biology. Further, specialists within these disciplines often exhibit little willingness to find ways to compare and contrast their research. This antagonism has created different solitudes of fisheries research (Pitcher *et al.* 1998a), with little rigorous investigation of how they might mesh with and reinforce each other. Rigorous investigations of how different disciplines describe a fishery could be accomplished if there were a measurable interdisciplinary fishery 'quality'.

The distinction of measuring a quality or a quantity is an important one since much of the information collected by natural scientists is *quantitative*, whereas that collected by social scientists is often *qualitative*. While single points of qualitative data may be difficult to use for statistical investigation, there is no reason why statistics can not be used to compare groups of qualitative information. Groups of qualitative information can be examined statistically by compiling them into tables by discipline, and then summarising the multi-dimensional tables into low-dimension distance maps. Multivariate statistics may provide the crucial tool in unlocking the door to the world of interdisciplinary studies by providing a context within which qualitative information from diverse sources can be compared.

The multivariate branch of statistics has been extant for some time but the advent of user friendly multivariate statistics programmes and powerful, fast personal computers has increased their potential use. The potential of multivariate techniques to be used in interdisciplinary fisheries assessment is the central goal of this project. Multivariate statistics appeared at the beginning of the 20th century, as an aspect of work done by psychologists working with data from the first IQ tests (Gould, 1996). There now exists several different several different techniques within the field of multivariate statistics. The specific techniques used to examine the tropical artisanal fisheries of this study were multidimensional scaling (MDS) and cluster analysis (CA). Multiple regressions were also used to help interpret the MDS results as will be explained.

1.5. Multivariate Techniques: Origins and Use

The first technique of multivariate analysis was factor analysis, developed by the English psychologist Charles Spearman (Gould, 1996). Factor analysis was created for the study and analysis of IQ tests. By using factor analysis it was possible to reduce the information from tests which scored different aspects of intelligence such as reading, arithmetic, spatial perception, and language use to a single score. This score, termed 'Spearman's G' for 'general intelligence' was a vector drawn from the multidimensional space created by all the test scores for each individual (Gould, 1996). Multivariate statistics serve the researcher by calculating a small number of 'derived variables' from a larger set of variables (Cooper and Weekes, 1983). In MDS cases are compared by their similarities, rather than an absolute standard, as with techniques such as factor analysis. MDS was first proposed as a method of calculating distances between cases by Torgerson (1952, cited in Young 1987). Torgerson recognised that other multidimensional scaling techniques relied upon some existing knowledge of the dimensions being measured, i.e., a way of judging their absolute measurements. He reasoned that in many situations, however the absolute measures of dimensions may be difficult or impossible to obtain. Further, determining the number of dimensions to include in any analysis may also be difficult to determine. He therefore suggested the method of MDS since "... it does not require judgements along a different dimension, but utilises, instead, judgements of similarity between the stimuli" (Torgerson 1952, cited in Young 1987). Shepard (1962) and Kruskal (1964) were responsible for developing MDS into a method for general use in psychology (Clarke and Warwick 1997).

Once popularised as a method for non-metric scaling, MDS was used in a variety of disciplines outside of psychology. For example, political scientists have used it to compare political leanings of individual senators in the US by their voting histories. A distance map thus derived created groupings along two axes: Liberal / Conservative and Democrat / Republican (Young 1987). MDS has only recently been applied to biological instances due especially to work in England by Field, Clarke and Warwick in the past twenty years (Field *et al.* 1982; Clarke and Warwick 1997).

2. Methods

2.1. Multivariate Statistics Used in the Analysis

2.1.1. Multidimensional Scaling

The reduction of multi dimensional data is accomplished by the use of matrix algebra. This is necessary because data sets with more than three dimensions can not be represented graphically. Because we can not picture vectors in several dimensions, reducing the data to two or three dimensions makes it suitable for graphing or mapping.

The matrix algebra used in multivariate statistics is well established and therefore not discussed in detail here. The reader is directed towards Cooper and Weekes (1983), Manly (1986), Cliff (1987), and Tabachnick and Fidell (1996) which provide detailed discussions about the theory and structure of the data matrix, as well as the theory and derivation of the correlation and distance matrix. It is from these matrices that the two dimensional distance maps of MDS and CA are produced. The distance matrix can be thought of as an extension of the Pythagorean Theorem into multi dimensional space. Just as the distance between two points on a two dimensional plane can be described as the square root of the sum of their squared distances to the right angled vertex they would form in a right angled triangle, the squared distance 'd_{rs}^2' between two points, r and s, in a j dimensional matrix is:

$d_{rs}^2 = \Sigma(x_{rj} - x_{sj})^2$ (Cooper and Weekes 1983)

When these multiple dimensions are reduced to a two dimensional map that can be represented on paper, there will be some information lost. For a more detailed discussion of theory, uses, and limitations of MDS the reader is referred to Torgerson (1952), Cooper and Weekes (1983), Young (1987), Clark and Warwick (1994), Stalans (1995), and Statsoft (1995b).

The data is reduced in such a way that the largest possible total variance in the data is explained by the distances on the first MDS dimension. Similarly, the second dimension explains the largest amount of remaining variance not explained by the first dimension. If there is enough remaining variance, a three dimensional output may be appropriate. Determining whether a one, two or three dimensional MDS is appropriate is accomplished with a scree test, see Fig. 2.1. A

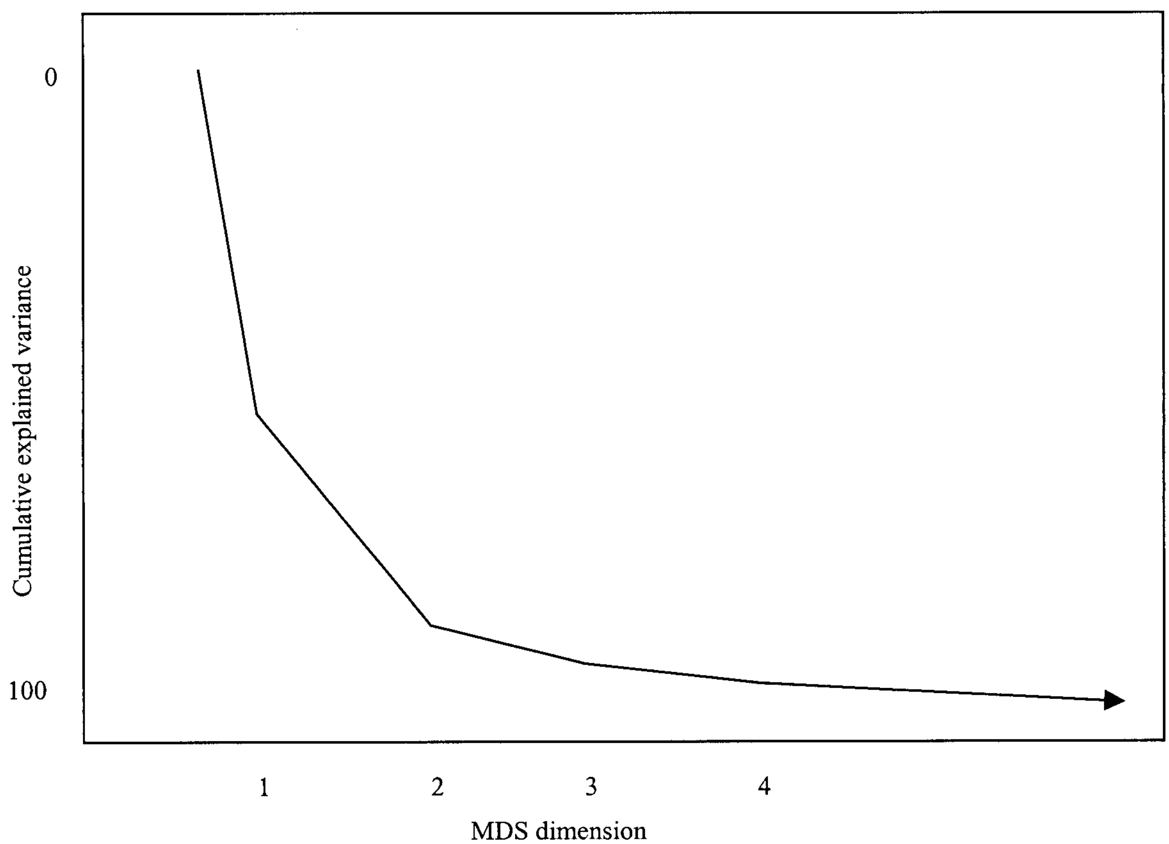

Figure 2.1: A scree test suggesting that the additional variation explained by dimensions 3 and 4 can be ignored.

scree test shows whether the addition of a new dimension adds significantly to the total possible explainable variation. The test derives its name from the geologic term for the place on a hill where falling rocks collect because of the slope break. The slope break in Fig. 2.1 suggests that the third dimension does not add significantly to the total explained variation and may therefore be ignored (StatSoft 1995b).

MDS was first devised to be used as a tool for investigating psychological phenomena, and many of its applications have been non-biological (see e.g., Clarke and Warwick 1994). The method is a useful technique for interdisciplinary analyses as it does not require the raw data to be normally distributed. As mentioned earlier much of the social science studies on fisheries tend to be qualitative. Nevertheless, social science studies can be converted readily into ordinal or ratio scores which can then, via MDS, be compared to biological data recorded on ordinal, ratio, or discrete scales. (Cooper and Weekes, 1983).

Because the technique of MDS is not contingent on normal data, it can be used to compare data sets of very different types of information, as it does not determine absolute difference between cases. MDS recognises the essential arbitrariness of variables, and it can be thought of as helping determine the relative similarity between the cases being compared (Clarke and Warwick 1997). This means that unlike factor analysis and principle components analysis, MDS distance maps may be scaled, located, rotated, or inverted to best suit presentation (Clarke and Warwick 1997). The MDS ordinations here were rotated to follow the convention that sustainable fisheries were in the upper left hand of the graph and unsustainable ones were in the opposite corner.

The distance maps of the fisheries analysed here are valuable in their own right, for they help relate the fisheries to one and another, that is, 'where' things are. However, we are left with the question: how best to interpret this derived information, that is, 'why' things are. There are two obvious visual qualities possessed by these ordinations, which may help in the interpretation of their derived information. The first is that the ordinations are two dimensional and, as such, these dimensions must have some kind of meaning, as they are derived from weighted attribute scores. If we can extract the meaning of the dimensions from this weighting then we can ascertain some general qualitative character for each axis, depending on the attributes that were most important to their creation. Second, the fisheries appear to the eye to come in groups, or clusters, which are often part of some continuum, or to contain their own internal structure. By defining where these clusters are, we can make inferences about groups of fisheries in the ordination, rather than discuss each one individually, then infer how they behave in groups.

Defining the meaning of the axes is relatively straightforward. Different methods exist to describe how each attribute affects the axes, see e.g., Pitcher (1999). Defining what an MDS axis means is important, because the definition allows the investigator to determine at least two, depending on the dimensionality of the ordinations, qualitative aspects of the fisheries being investigated. The simplest way to define the axes is to correlate the attributes used in the analysis with them (Stalans 1995). Each attribute will either be negatively or positively correlated with each axis to a lesser or greater extent. By determining which of the attributes are most important to each axis we can determine their meanings. This, in turn, allows one to make qualitative inferences about what different areas of the ordination mean (Stalans 1995). To identify real from spurious groups in the distance map, however, a different approach is required, as described in the following section.

2.1.2. Cluster Analysis

The technique of Cluster Analysis has a well established literature and those interested in the derivation and theory of the algorithms commonly used by Cluster Analysis programs are directed towards Everitt (1974), Cooper and Weekes (1983), Alt (1990), Clarke and Warwick

(1994), and Statsoft (1995a). Cluster analysis uses mathematical rules to answer the unmathematical question about what a group is. As seen in Fig. 2.2, many different data dispersion patterns are possible in a distance map. Different clustering algorithms are available to optimise group identification under such differing conditions (Everitt 1974, Clarke and Warwick 1994).

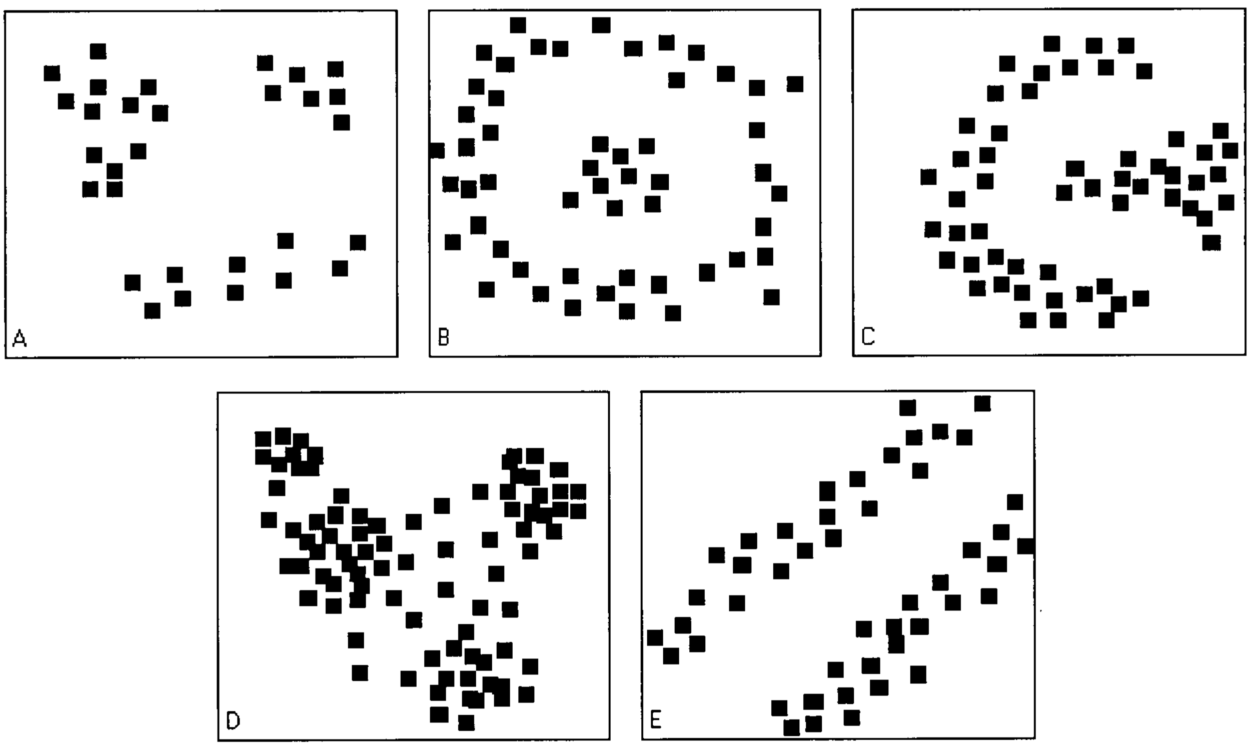

Figure. 2.2: Sample clusters that may be found in two dimensional spaces.

Cluster analysis allows the identification of groups through the use of mathematical algorithms, rather than by simply using intuition to identify groups by eye. Because groups in cluster analysis are nested within each other, some rule must be used to define useful groups that represent the largest possible amount of total variation in the data set. Similarl to the MDS analysis, a type of scree test was used to determine at what point defining the data set with extra groups was no longer helpful in explaining the total apparent variation. The scree test used here was termed an amalgamation schedule (StatSoft 1995a) and was interpretted in the same fashion as the scree tests for MDS to to determine a useful number of groups.

Table 2.1: Attributes and scale upon which they were scored in the study.

		ECOLOGIC	
1	catch/fisher	Tonnes	tonnes / person / year
2	fishery exploitation status	2, 1, 0	FAO scale; low, full, over
3	trophic level	Number	average trophic level of species in catch
4	migratory range	0, 1, 2	1, 2-3, >3 jurisdictions encountered during migration
5	catch < maturity	2, 1, 0	none, some, lots caught before maturity
6	discarded bycatch	2, 1, 0	low 0-10%, med 10-40%, hi >40% of target catch
7	species caught	0, 1, 2	low 1-10, med 10-100, hi >100 species
		ECONOMIC	
1	Price	US$/tonne	US$/tonne of landed product for analysis time
2	fisheries in GNP	0, 1, 2	importance of fisheries sector in country; low, med, high
3	GNP/person	US$/capita	in country of fishery
4	other income	0, 1, 2	mainly casual, part time, full time fishers
5	earnings by fishers	0, 1, 2	below, same, above national average for workers
6	Market	2, 1, 0	principally local, national, international
7	kin participation	0, 1	do kin sell family catch and/or process fish: no or yes
		SOCIOLOGICAL	
1	socialisation of fishing	0, 1, 2	do fishers fish as individuals, families, or community groups
2	fishing comm'y growth	2, 1, 0	over past 10 years: <10%, 10%-20%, >20%
3	education level	0, 1, 2	below, same, above population average
4	conflict status	2, 1, 0	level of conflict with other sectors; low, med., high
5	information sharing	0, 1, 2	none, some, lots
6	fisher influence	0, 1, 2	fisher influence on actual fishery regulations; low, med., high
7	fishing income	0, 1, 2	fishing income % of total income; <50%, 50-80%, >80%
		TECHNOLOGICAL	
1	trip length	Days	average days at sea per fishing trip
2	landing sites	2, 1, 0	dispersed, some centralisation, heavily centralised
3	Processing	0, 1, 2	none, some, lots gutting etc. before sale
4	use of ice	0, 1, 2	none, some, lots
5	Gear	0, 1	passive = 1, active = 0
6	selective gear	0, 1, 2	device(s) in gear to increase selectivity; few, some, lots

2.1.3. Comparisons Among MDS Distance Maps

The results from the four MDS analyses were compared to see how interfishery distances as well as fishery groupings varied between disciplines. In order to include the effect of how a fishery was grouped with its geometric position on the MDS ordination, a weighted scoring system was devised. Within each disciplinary MDS a group distance score was generated by multiplying its distance from the modelled 'good' fishery in that ordination by a group score in which **A** = 1, **B** = 2, **C** = 3, **D** = 4. In this way the effect of position was imposed on the simple scalar distance measure. Thus, within each discipline, these wieghted scores helped distinguish intermediary, i.e., group **B** and **C**, fisheries from each other. Each fishery was thus given four weighted distance scores, one for each discipline. The four disciplinary weighted distance scores for each fishery were then compared using simple linear correlation (Zar 1984).

2.2. Gathering Attribute Data

Because MDS allows the proximal comparison of cases in a study, the choice of attributes for comparison is limited only by data availability. In this study the purpose was to create an assessment tool that could be used to distinguish sustainable versus non sustainable fisheries, i.e., fisheries in a state of Malthusian overfishing versus those which had been robust to declining over the long term, in tropical developing countries. Therefore, the first consideration in selecting attributes is that each provides a distinct and discrete measurement of one aspect of fisheries sustainability. The attributes to be scored were thus chosen to capture as much independent and, therefore, uncorrelated information as possible within each subject grouping. To meet these requirements, yet still be collectable, the criteria for the selection of attributes used included; reducing autocorrelation, reducing difficulty of collecting the information, reducing

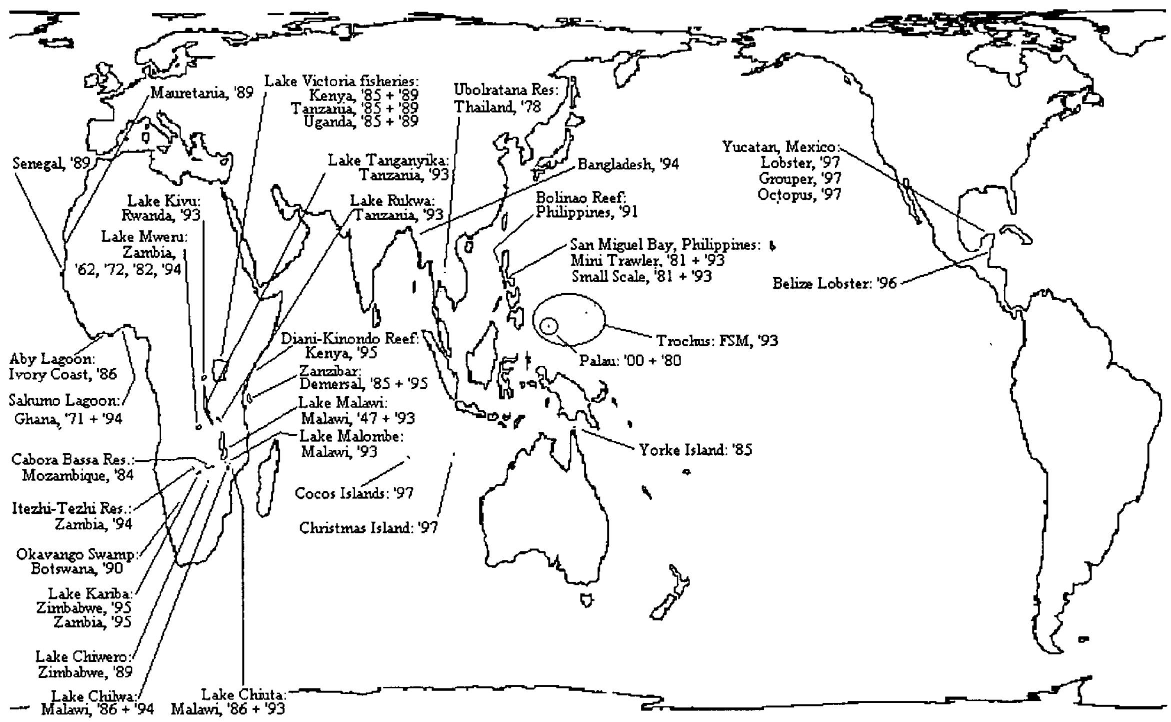

Figure 2.3: Locations and dates of fisheries analysed in this paper. A Peter's projection is used to enhance the relative area of the tropical belt.

ambiguity in selected attributes, and reducing the use of attributes that could not be used in time series comparisons (Pitcher *et al.* 1998a). For MDS, and multivariate analysis in general, most sources agree with Cooper and Weekes (1983) that there be at least three times as many cases as variables. This study placed attributes into four categories: biology, sociology, economics, and technology, see Table 2.1 for a list of attributes and scales upon which they were scored. Biological attributes addressed descriptors of the organisms being harvested and their ecosystem. Economic attributes measured both macro and microeconomic aspects of the fishers, their communities, and their countries. Sociological attributes investigated the manner in which people, families, and communities interacted in the prosecution of a fishery. Technological attributes accounted for gears used to pursue, capture, process, and distribute harvested aquatic organisms. This attribute set was derived in conjunction with Pitcher *et al.* (1998a), and deemed rigorous in the breadth of information it would represent for any small scale tropical fishery.

Table 2.2: Fisheries, their date of study, and their codes used in this paper.

Australia, Christmas Island, 1997	xmas97	Palau, 1980	pal80
Australia, Cocos Island, 1997	cocos97	Palau, pre 20th century, 1800	palpre00
Australia, Yorke Island 1985	yorke85	Philippines, Bolinao reef, 1991	bol91
Belize, coastal, 1996	bel96	Philippines, S. Miguel B. mini trawl, 1981	sbm81
Bangladesh, hilsa, 1990	bang90	Philippines, S. Miguel B. mini trawl, 1993	sbm93
Botswana, Okavango swamp, 1990	okng90	Philippines, S. Miguel B. sm scale, 1981	sbss81
Côte d'Ivoire, Aby Lagoon, 1986	aby86	Philippines, S. Miguel B. sm scale, 1993	sbss93
Fed. States of Micronesia, Trochus, 1993	fsm93	Rwanda, Lake Kivu, 1993	kivu93
Ghana, Sakumo Lagoon, 1971	sak71	Senegal, coastal, 1989	sen89
Ghana, Sakumo Lagoon, 1994	sak94	Tanzania, Lake Rukwa, 1993	ruk93
Kenya, Diani-Kinondo reef, 1995	diki95	Tanzania, Lake Tanganyika, 1993	tantz93
Kenya, Lake Victoria Nile perch, 1985	vkenp85	Tanzania, Lake Victoria Nile perch, 1985	vtanp85
Kenya, Lake Victoria Nile perch, 1989	vkenp89	Tanzania, Lake Victoria Nile perch, 1989	vtanp89
Malawi, Lake Chilwa, 1986	chil86	Tanzania, Zanzibar demersal 1985	zdem85
Malawi, Lake Chilwa, 1994	chil94	Tanzania, Zanzibar demersal 1995	zdem95
Malawi, Lake Chiuta, 1986	chiu86	Thailand, Ubolratana reservoir, 1978	ubol78
Malawi, Lake Chiuta, 1993	chiu93	Uganda, Lake Victoria Nile perch, 1985	vugnp85
Malawi, Lake Malawi, 1947	malw47	Uganda, Lake Victoria Nile perch, 1989	vugnp89
Malawi, Lake Malawi, 1993	malw93	Zambia, Itezhi-tezhi, 1994	itte94
Malawi, Lake Malombe, 1993	malb93	Zambia, Lake Kariba, 1995	krzam95
Mauretania, coastal, 1989	maur89	Zambia, Lake Mweru, 1962	muzm62
Mexico, Yucatan Peninsula grouper 1997	gpry97	Zambia, Lake Mweru, 1972	muzm72
Mexico, Yucatan Peninsula lobster 1997	loby97	Zambia, Lake Mweru, 1982	muzm82
Mexico, Yucatan Peninsula octopus 1997	octy97	Zambia, Lake Mweru, 1994a	mzml94
Modelled 'bad' fishery	bad	Zambia, Lake Mweru, 1994b	mzmh94
Modelled 'good' fishery	good	Zimbabwe, Lake Chiwero, 1989	chiw89
Mozambique, Cabora Bassa Res., 1984	cabo84	Zimbabwe, Lake Kariba, 1995	krzim95

2.3. Fisheries Studied

Because it was impossible to conduct field studies of all the fisheries examined in this study, fisheries were analysed using data extracted from published literature. In some cases, 'grey' literature was obtained from researchers and organisations familiar with the fisheries being analysed. In other cases, personal communications were used when a scientist with a high degree of familiarity with a fishery was willing to contribute his or her knowledge of the proper attribute scores. Since almost all of the attributes were scored on clearly-defined ordinal scales, the quality of data collected by any one of these methods should be similar. The data should thus have both accuracy and precision so the results can be be replicated by independent researchers.

All of the fisheries analysed will be briefly described, and accompanied by a complete list of the references used to score attributes, see Table 2.2 for a list of the fisheries and Fig. 2.3 for a map of their locations. In order to provide a basis for comparison, two modelled fisheries, one sustainable or 'good' the other unsustainable or 'bad', were included and are also described below. The actual attribute scores for all of the fisheries can be found in appendix 1.

2.3.1. Lake Victoria Fisheries

Three nations surround Lake Victoria; Uganda, Kenya, and Tanzania. All three countries have developed large fisheries on the lake. The combined fish harvest was stable at about 100 000 t per year from at least 1968 to 1980, but rapidly increased throughout the 1980s to more than 500 000 t per year (Reynolds *et al.* 1995). Almost all of the increase can be explained by increasing harvests of Nile perch. Indeed, this species, which started as a very minor constituent of the Lake Victoria fishery, came to occupy more than 60% of the harvest by the end of the 1980s (Reynolds *et al.* 1995). The Ugandan sector itself experienced a ten-fold increase in catches, to about 119 000 t per year in 1990, although a UN-sponsored conference on the Ugandan fishery noted that gears used to achieve these gains we extremely destructive to breeding grounds of many species and also took large numbers of unspawned fish (Ssentongo and Orach-Meza 1992). The fishery of Kenya experienced more modest gains, from about 25 000 to 100 000 t per year, but concerns over fishing gears being used were similar to those for Uganda (Ssentongo and Dampha 1991). Tanzania has the largest geographic share of the lake and its share of the catch is also the largest, although absolute growth has not been as rapid as the other two nations. Concerns in the Tanzanian sector, while including the effects of destructive gear, also are directed towards changes in the fishers themselves, since small scale fishers can not compete with industrialised gear (Ssentongo 1992). Data were collected from these fisheries for two representative years; 1985 and 1989 from Reynolds and Gréboval (1988), Reynolds *et al.* (1995), Ssentongo (1992), (Ssentongo and Dampha 1991), and (Ssentongo and Orach-Meza 1992).

2.3.2. Other African Lake Fisheries

Two familiar lakes of the African Rift Valley are Lake Tanganyika and Lake Malawi sharing the physical characteristics of being both long and deep. On the Tanzanian portion of Lake Tanganyika, shared with Burundi, Zambia, and the Democratic republic of the Congo, there are competing small-scale and commercial fisheries. The small-scale fisheries differ depending on the region of the lake. In the southern portion catches are dominated by the sardine-like species *Limnothrissa miodon* and *Stolothrissa tanganicae* (Pearce 1995), whereas in the northern part small-scale pelagic fleets target *L. miodon* and *S. tanganicae* and some larger *Lates* spp. (Petit and Kiyuku 1995). Both regions, however, have experienced increasing effort in the 1980s and 1990s. In the north there has been an increase in the number of catamarans, combined with mechanisation. Such expansion of catching power has resulted in outcompeting the associated commercial sector (Petit and Kiyuku 1995) in Lake Tanganyika. In the south, beach seines replaced traditional scoop nets and are estimated to have possibly trebled fishing effort. The small scale sector's share of overall catch, however, has declined over the last thirty years (Pearce 1995). Total catch for the Tanzanian portion of Lake Tanganyika is over 70 000 t per year (Anon. 1989a). Another Tanzanian rift lake was examined, Lake Rukwa. It is relatively small, but shares many gear and species characteristics with the Tanzanian sector of Lake Tanganyika (Nsiku, E., Fisheries Centre, University of British Columbia, 2204 Main Mall, Vancouver, BC, pers. comm.). Total catch of lake Rukwa is approximately 6 000 t per year (Anon. 1989a).

Lake Malawi is famous for its great variety of species and this may be one reason for the relative abundance of data available on it. Indeed, thorough investigations on the fisheries of the lake were conducted as early as 1945 (Lowe, 1952). Seventy-five % of the small scale catch (there was already competition from a commercial sector) in the late 1940s was *Tilapia* spp., caught mostly in seines and traps (Lowe, 1952). Different types of ecologically destructive fishing methods were already noticed at this early time by Lowe, e.g., "the destruction of young in the mouths of brooding female Tilapia", decreases in mean length of target species, and huge increases in effort with no corresponding increases in catch. In recent years the proportion of *Oreochromis* spp. in small scale catches has been reduced considerably, now only contributing about 20 % of all landings, whereas *Haplochomis* spp. now make up about 60 % of total landings by tonnage (FAO 1993a). It is believed that in the 18 years from 1973 to 1991, seining in the Upper Shire River, through which Lake Malawi drains into Lake Malombe, reduced stocks of migrating *Oreochromis* spp (FAO 1993a). Lowe (1952) observed that there were not many restrictions on fishing, the only noteable rule being that in river fisheries trap fences could only cover 95 % of the width of the river. In such conditions of relatively unrestricted harvesting, the decline of *Oreochromis* spp. should not be surprising.

Lake Kivu straddles the border of the Democratic Republic of the Congo (DRC) and Rwanda. It is also distinguished by a relative paucity of fish species, there being only 16, one of which is the introduced *L. miodon* (de Iongh *et al.* 1995). Although introduced in the late 1950s no small-scale *L. miodon* fishery took root until the late 1970s. By the late 1980s there were almost 100 boats engaged in the fishery, employing about 800 fishers catching nearly 400 t. per year (de Iongh *et al.* 1995). It is not known to what extent the civil war from 1990 to 1993 and the genocide of 1994 changed the characteristics of the fishery, although it can be assumed the changes were substantial. Since there was great displacement of people it seems likely that the fishery may have been abandoned allowing fish populations to grow. Given the relative stability in Rwanda since 1995 it would be interesting to see if the same fishers returned, or if there are lots of newcomers.

Outside of the Rift Valley lakes tend to be shallower and much more variable in their size due to large seasonal variation in precipitation. The ecosystem where Lake Ngami meets the Okavango delta / swamp exemplifies the effects of seasonality. 'Lake' Ngami can dry up after repeated drought years and the Okavango swamp may become a lake in years of abundant water. Further, when fisheries collapsed elsewhere in Botswana, due to a drought in the late 1980s, those of the Okavango persisted (Mmopelwa and Nengu 1988, Anon. 1989a). The patterns of fishing around these water bodies are consequently ephemeral and variable. Because fishing is a way to supplement diet and income, there are many fishers taking a few fish. Catches for 1990 were about 1900 t. per year (FAO 1993b). Most of the fisheries in the Okavango / Ngami system focus on the Okavango swamp (Anon 1989a). The large number of water diversion projects under consideration for agriculture in this arid region may threaten the future of its fisheries.

The Lake Mweru / Luapula River complex contains an ecosystem similar to that of the Okavango / Ngami. Lake Mweru, shared between Zambia and the DRC, can significantly expand or contract its surface area depending on interannual moisture regimes. Due to difficulties of finding reliable data from the DRC, only the Zambian sector of the lake was analysed. *Tilapia* spp. are the most valuable component of the small scale fishery, another important component is 'chisense' or river sardine (*Mesobola brevianalis*) (Anon 1989). The chisense component of the fishery is caught by lift nets and exported to the DRC, competing with an idustrial fishery in the DRC. Zambia contends that the DRC's industrial boats often encroach on Zambian waters (Anon 1989). Total fish production of Lake Mweru was on a downward trend in the 1980s, peaking at 12 700 t. per year in 1982 and decreasing to 8 500 t. per year in 1986 (Chibwe *et al.* 1988). As in several other fisheries, more than one data point existed as time series data were available for the years 1962, 1972, 1982, and 1994, thanks to the assistance of Paul van Zwieten (van Zwieten, P.A.M., Van A Tot Z, Pomona 208, 6708 Ch Wageningen, Netherlands, pers. comm.). With the help of Edward Nsiku (Fisheries Centre, University of British Columbia, 2204 Main Mall, Vancouver, BC, V7R-2L7, pers. comm.), a second source was available to describe the Lake Mweru fishery in 1994

In order to provide water for agriculture, industry, and people, many African countries with seasonal dry spells have had dams constructed. Lake Itezhi-tezhi lies entirely within Zambia and was created by damming the Kafue River in 1977 (Cowx and Kapasa 1995). There was a significant change in fish species composition after impoundment, the system and catch becoming dominated by cichlids by the early 1990s. After impressive catches soon after impoundment, 900 t. in 1980, overfishing by an influx of new entrants and drawdowns of lake water for irrigation caused a crash to the present level of about 100 t. per year (Cowx and Kapasa 1995).

Among the most renown reservoirs in the world is Lake Kariba, situated between Zambia (north shore) and Zimbabwe (south shore). This artificial lake was created in the early 1960s and has seen major species changes in its short history, from the riverine *Labeo* spp. (a carp-like group), *Distichodus* spp. (characins), Mormyrids (elephant fish), and Clarias (catfish) to lacustrine cichlids (Karenge and Kolding 1995). Although the introduction of *L. miodon* has resulted in a thriving commercial open water fishery targetting that species, the small scale inshore fisheries of both Zambia and Zimbabwe are the focus of this discussion. In the Zambian small-scale fishery, the largest gear component is monofilament nets, which are set from canoes to catch tigerfish, 23 % of catch, and tilapia, 22 % of catch, and an assortment of others, including the brown squeaker, elephant fish, and catfish (Hachongela *et al.* 1995). On the Zimbabwean side of the lake, bream, tigerfish, and catfish dominate the small scale catch, contributing 41%, 23%, and 15%, respectively, to total landings. Gill nets and seine nets take most of the catch on the Zimbabwean portion, although there also are a limited number of hook and line subsistence fishers as well. The total annual harvest for the inshore fishery on both sides of the lake is about 1 000 to 2 000 t per year (Hachongela *et al.* 1995 and Sanyanga and Mangoro 1989). Catch levels are believed to be influenced by drawdown on the dam so in arid years fish production can suffer. As might be expected this effect is heightened on the inshore species, because their habitat for feeding, hiding, and nesting is decreased when drawdown occurs (Karenge and Kolding 1995). Another lake within Zimbabwe is the small, 6 000 Ha, lake Chiwero, formerly known as McIlwaine, (Anon. 1999a). An inshore fishery on the lake uses seines and gill nets deployed from canoes (Sanyanga and Mangoro 1989). The fishery is considerably smaller than that of Lake Kariba, but it targets much the same species with similar gear.

The Cabora Bassa reservoir in Mozambique was relatively underexploited at the time analysed (Nsiku, E. Fisheries Centre, University of British Columbia, 2204 Main Mall, Vancouver, BC, pers. comm.). Most of the Mozambiquan fishing effort is dedicated to marine waters, although the lake represent a potential take of at least 10 000 t per year (Anon. 1989a).

Fisheries represent an extremely important sector of the Mozambique economy. At least 100 000 people were employed in fisheries, which accounted for 7% of national earnings (Anon. 1989a)

Lakes Malombe, Chilwa, and Chiuta all lie entirely within Malawi. Although much separates their ecosystems and their fisheries, they are similar in that Malawi is a land-locked nation that relies quite heavily on its fisheries. Turner (1995) states that fish supplies as much as 70% of the protein intake of Malawians. Also, fisheries in Malawi account for some 4% of gross domestic product and provide employment for 20 000 small-scale fishers, 1 000 commercial fishers, and as many as 200 000 shore workers in fishery-related jobs such as fish trading, boat-building, and net-making (Anon. 1989a).

Lake Malombe is relatively shallow, the maximum depth is only 17 m. It is polymictic and thus has excellent nutrient cycling. The productive zone of the lake extends to the bottom and runoff also contributes significantly to overall production (FAO 1993a). Fisheries of Lake Malombe focus on *Oreochromis* spp., and the two main gear types are seine nets and gill nets. The beach seine nets can run up to 1 000 m in length, although the majority are about 100 m long. Gill nets deployed from planked boats are typically between 100 and 200 m long. They usually are operated in a fashion similar to a purse seine, except that the foot of the net is weighted to the bottom before the top of the net is closed like a bag (FAO 1993a).

Lake Chilwa, like several others in Africa, can increase or decrease in size dramatically depending on moisture regimes. This dramatically influences productivity. The maximum depth of the lake reaches only 2.5 m, although the mean depth can vary from almost nothing to 2 m. Landings vary from as little as 100 t per year in a drought to almost 10 000 t per year when water is abundant (Pitcher and Hart 1995).

Although a small portion of Lake Chiuta is within Mozambique, most of it lies within Malawi. The lake is quite shallow, much of its area being covered with emergent vegetation (Donda 1997). Four species dominate the small scale catch: Makumba (*Oreochromis shiranus*), Chilunguni (*Tilapia rendalli*), Matemba (*Burbus paludinosus*), and Mlamba (*Clarias gariepinus*). In the recent past the number of fishers has actually decreased, mostly as a result of changing gear types. Traditional gears such as gill nets require lots of helpers and have increasingly been been replaced by traps that can be operated by one person. In the time during which this change occurred, 1990-1996, average catches have risen, suggesting increased catching power (Donda 1997).

2.3.3. Indo-Pacific Reef Fisheries

Turning to Indo-Pacific reef ecosystems, one encounters diverse fisheries, in terms of species targetted and methods. All these reef fisheries are dependent on coral for the base of the ecosystem's trophic and physical structure. This association generates fisheries that target a variety of species year round. The trochus (*Trochus niloticus*), or top shell, fishery of the Federated States of Micronesia (FSM), however, is highly specialised and targets one high value species for only a short time every year. Trochus is a reef dwelling gastropod that has been introduced throughout the South Pacific. Its shell provides mother of pearl, which is exported in raw form to Japan, Taiwan, and South Korea for manufacturing into buttons and for inlay work. In the FSM trochus occurs naturally in Yap, but has been introduced to the states of Pohnpei, Kosrae, and Chuuk (Clarke and Ianelli 1995). There are some differences in harvesting rules and regulations among the four states but in general the season lasts one to two weeks, during which the trochus are taken by hand, scuba gear being forbidden. The harvest varies but averaged just over 100 t per year during the 1980s. Not much of the meat is ever used (Clarke and Ianelli 1995).

Most Indo Pacific reef fisheries are like that of Palau, an island within the FSM that has a long history of fishing. Information about the fishery both as it existed prior to the twentieth century and today is included in this study. The fishers on the island traditionally followed strict rules and regulations about who could harvest aquatic organisms and when the different species were allowed to be taken, and with what gear. These regulations applied to the dozens of fish species islanders harvested (Johannes 1981). Consequently, the selectivity of the gear used in the 1800s was quite high. In the Palau fishery today, however, gill nets and seines are more common and traditional regulations are mostly ignored. These changes have been accompanied by increasing catches of undersized fish and declining standards of living for fishers relative to the community at large (Johannes 1981).

Yorke Island is a small (less than 10 km long) coral reef in the Australian jurisdiction of the Torres Strait that supports a seasonally varying population of about 160 persons. Most of these people rely on a mixture of government support and fishing. Most fishing is devoted to gathering food for the family but depending on market conditions and species availability, such high value species as trochus (*Trochus niloticus*), Spanish mackerel (*Scomberomorus commerson*), green turtles (*Chelonia midas*), and lobster (*Panulirus ornatus*) may also be sold, if possible. These species make up about 80% of all landings, although as much as 75 different species are taken (Poiner and Harris 1991). Most fish are taken by trolling, while lobster are obtained by diving. Turtles are simply chased by boats and then manhandled until they can be wrestled onto the craft. There is a general perception among islanders that local fishing resources have been degraded by commercial prawn operations in the Torres Strait (Poiner and Harris 1991).

The Christmas and Cocos islands are two territories of Australia located in the Indian Ocean, southwest of Indonesia, halfway between Australia and Sri Lanka. The population of Christmas Island was largely dependent on a now defunct phosphate mine; now tourism is being developed as an economic engine for the island. Cocos Island is also small but largely dependent on agriculture and cash transfers from Australia, although tourism is being developed there as well (Central Intelligence Agency 1995). Both islands have ready access to the sea and islanders take a large quantity of fish for personal use (approximately 200 kg per person per year) or for sale to tourists (Alder, J. School of Natural Sciences, Edith Cowan University, 100 Joondalup Drive. Joondalup, WA, 6020, pers. comm.)

The Diani-Kinondo coral reefs of Kenya differ from coral reef fisheries discussed thus far in that there is a continental hinterland to the reef system. This has resulted in greater pressure on the reef ecosystem since there has been more opportunity for immigration from surrounding areas creating more fishers and hence more fishing effort. This immigration has also brought with it agricultural development and increased tourism, both of which have adversely affected the reef system (McClanahan *et al.* 1996). The fishery used to employ traditional gear such as hook and line, traps, and large-mesh gill nets, but fishers have increasingly turned to smaller meshes, beach seines, and spear guns, which have greatly increased effective fishing effort. While many of the new gear types are shunned by the elders of the people traditionally living in the community, the newcomers and younger people tend to ignore the traditional regulations and gears (meant to preserve stocks). In the current fishery the fishers catch about 4 to 6 kilos of fish per day per person, depending on gear used. Spear guns are especially popular, because they involve the smallest expenditure of time to obtain fish (McClanahan *et al.* 1996).

The Bolinao reef flat in the Philippines (which provided the background for Pauly's initial definition of Malthusian overfishing (Pauly 1988)) is an excellent example of the tremendous diversity of products some reef fisheries can have. For example, some 286 species have been observed in the Bolinao fish markets (McManus *et al.* 1992). Fisheries provide almost one third of direct employment in the Bolinao area, about 18 000 jobs, but fishers earn less than the national average income. Low relative income, along with rapid population growth, has resulted in the increasing use of such destructive fishing methods as dynamite and cyanide in addition to more traditional methods such as hook and line, gill nets, fish corrals, and fish traps. Total catch averages about 500 t per year, but there has been a marked decline in the number of large, less than 30 cm long, fish found in fishers' catches (McManus *et al.* 1992).

Fisheries are of vital importance to Zanzibar, a cluster of islands of Tanzania off the East coast of Africa. More than 20 000 people are directly employed in fishing and another 6 000 in related industries (Jiddawi and Muhando 1995). Small-scale fisheries are the vast majority of the 7 000 to 20 000 t per year annual harvest, and there are suggestions that this resource has progressed rapidly from a state of full exploitation in the mid 1980s to overexploitation today (Jiddawi and Muhando 1995). Gear such as gillnets, handlines, traps, seines, cast nets, and sharknets are deployed from such traditional craft as dugouts, outriggers, and dhows (Lyiko and Pandu 1988). The catch is made up of fish from many taxonomic groups including; flat fishes (Pleuronectiformes), thread fin breams (Nemipteridae), African catfishes (*Clarias* spp.), silver bellies (Leiognathidae), goatfishes (Mullidae), rock cod (Sebastidae), and sharks and rays (Elasmobranchii) (Lyiko and Pandu 1988).

2.3.4. Other fisheries

San Miguel Bay in the Philippines has a well documented fishery thanks to the effort of researchers from both the Philippine government and the International Centre for Living Aquatic Resources Management (ICLARM). The studies conducted by the two groups provided data for analysis of two different small-scale fisheries in the area over the period from the early 1980s to the early 1990s. The two major small scale sectors are small trawlers, that target shrimps and another 'grouped' sector employing hook and line, lift nets, gill nets, corrals, and push nets, which take no less than 175 different species of fishes and invertebrates (Padilla *et al.* 1995, Silvestre *et al.* 1995). There are 74 fishing villages on the bay, home to about 4 800 full time fishers. Interviews with fishers, in the early 1990s, reveal that most of them thought that their catches had been declining in the past few years (Sunderlin 1995). The small-scale trawlers, locally called 'mini' and 'baby' trawlers, take 6 000 t of shrimp per year, while the 'grouped' small-scale sector takes 11 000 t per year. There total catch has declined over the last twenty years, although this is not manifested in the small-scale fleets since most of the reduction in catch has been by the commercial industrial shrimp fleet (Silvestre *et al.* 1995).

The coastal waters of Western Africa are famous for their high fish production due the high primary productivity created by upwelling from Ekman transport on the equatorward Canary current. Mauretania and Senegal have both benefited from harvesting fish in these waters, although the benefit for Senegal has been much greater. Both countries have had to manage the combined harvest of foreign distant water fleets and a domestic small-scale fleet. In the case of Senegal, fish exports have become a means of raising foreign capital, now about 25% of export revenue, after the collapse of prices for traditional exports like phosphate and peanuts in the 1980s (Goffinet 1992). Small-scale fisheries have a long tradition in Senegal and they make up most of the total annual catch in Senegalese territorial waters, about 350 000 t per year. Most of the small scale fleet is motorised and uses purse seines, longlines, and fishtraps to catch such species as sardines (*Sardina pilchardus* and *Sardinella aurita*), horse mackerels (*Trachurus trachurus* and *T. trecae*), and redfish (Sparidae) (Bonfil 1998).

Mauetania does not have either as many people as Senegal, nor an history of small-scale fisheries. As in Senegal, Mauretanian fisheries have become a way to attract foreign revenue, but a large proportion of this revenue is from joint ventures with the distant water fleets of other countries. Almost all of the small-scale fleet has been motorised. Of the more than twenty species caught, the most important are octopus (*Octopus vulgaris*), squid (*Loligo* spp.), redfishes (Sparidae), and horse mackerels (*Trachurus trachurus* and *T. trecae*) (Maus 1997). Although Mauretanian fisheries now average about 85 000 t per year, a level maintained since the mid 1980s, this represents only 3.5% of the total catch in its exclusive economic zone (EEZ), the rest taken by foreign distant water fleets. This is in marked contrast to the case of Senegal, in which foreign distant water fleets only take about 4.4% of the catch within the country's EEZ (Bonfil 1998).

The Aby lagoon system is located in the east of Côte-d'Ivoire near the border with Ghana. In the early 1990s there were at least 65 villages surrounding the lagoon complex, providing many landing areas.These villages were home to 3600 fishers and about 2100 people in fish processing and marketing. The total annual catch was about 6600 t per year (Charles-Dominique 1994). The vast majority of gear used consisted of beach seines and purse seines, various types of gill nets, longlines, traps, and crab pots. Bonga (*Ethmalosa fimbriata*), about half of the total catch, is taken by seines and gillnets. Catfish (*Chrysichthys walkeri*, *C. auratus*, and *C. filamentosus*), about 20% of the total catch, are caught with seines, longlines, and traps. Three species of cichlid (*Tilapia guineensis*, *Tylochromis jentinki*, and *Sarotherodon melanotheron*) make up another 20% of the catch and are harvested with gill nets, seines, and traps. Crustaceans (*Callinectes latimanus* and *Panaeus duorarum*) are caught opportunistically and represent only about 5% of the catch (Kponhassia and Konan 1997).

Belize, a small nation in Central America differs from its neighbours in that it is relatively underpopulated and has a coastal fishery that has not yet experienced any sort of catastrophic collapse. The small scale fishery is highly regulated and fishers profit from catching such high value species as spiny lobster (Gillett, V. UBC Fisheries Centre, 2204 Main Mall, Vancouver, BC, V7R 2L7, pers. comm.).

Three fisheries from the Yucatan peninsula, Mexico, were examined here; gouper, octopus, and lobster. Although fisheries are not important to the Mexican economy in general (CIA 1995) the economic performance of some of them in particular is nevertheless quite impressive. Lobster, for example commands a wholesale price as high as $US 35 per kg, while the wholesale price of octopus can be as high as $US 4 per kg (Anon. 1999). The value of grouper is similar to that of octopus. This price difference is largely driven by the market destination of the three species, but represents the chance for revenue generation that is unheard of in many other small-scale tropical fisheries. Whereas grouper and octopus are consumed locally, or within Mexico, lobster is mostly exported (Salas, S. UBC Fisheries Centre, 2204 Main Mall, Vancouver, BC, V7R 2L7, pers. comm.). The ecological impact of the lobster fishery is small as they are taken by traps, and the catch is small, each fisher taking only a couple of hundred kilograms per year. Grouper and octopus are more heavily exploited and the fishers take a considerably larger harvest of both at about one tonne per year (Salas, S. UBC Fisheries Centre, 2204 Main Mall, Vancouver, BC, V7R 2L7, pers. comm.).

The Sakumo Lagoon of Ghana has been well studied over the last 25 years and provided fisheries from the early 1970s and early 1990s for investigation. Manuscripts for three papers were provided by researchers in Ghana (Koranteng *et al.* 1997a, Koranteng *et al.* 1997b, and Entsua-Mensah *et al.* 1997.) who provided most of the information used here in addition to Pauly (1975). Gears used in the early 1990s fishery include seines, cast nets, gill nets, traps, and hook and line (Koranteng *et al.* 1997a), whereas in the early 1970s only cast nets, seine nets, and gill nets were recorded (Pauly 1975). Over this time span total fishing effort has increased considerably, with the new gears taking a greater diversity of species. The principle species caught in the lagoon (*Serotherodon melanotheron*) has exhibited a decrease in average lengths from 80-90 mm standard length to 70-74 mm standard length (Koranteng *et al.* 1997a), suggesting growth overfishing may have occurred over the last 20 years. Total catch in the lagoon has nevertheless doubled over this period to about 120 t per year (Koranteng *et al.* 1997b).

Ubolratana Reservoir, located in Thailand, was completed in 1965. It has a maximum surface area of 410 km^2, although this can decrease considerably during dry periods. Average depth is approximately 16 m (Bhukaswan 1985). Fishing in the reservoir began as soon as the locals discovered the newly available resource and the number of fishers grew from 268 in 1966 to 5628 in 1978. Cyprinids made up the majority of the catch, which is largely taken in gill nets (Bhukaswan 1985).

The floodplains of Bangladesh are an important source of cheap protein, in the form of fish, for local people. The same plains that produce periodic and cataclysmic floods also sustain a very productive aquatic ecosystem. A variety of small-scale gears such as push nets, lift nets, small trawls, and traps are used to capture a wide variety of fresh and salt water species (Alam *et al.* 1997). Fishers typically operate in family groups of males, although some women do participate in the processing and maketting of fish (Ahmed, M. 1997). Most fishers are part timers using the fish to supplement income and nutrition (Ahmed, N. 1997).

The final cases included in this analysis are the so-called ‘good’ and ‘bad’ fisheries. These fisheries were included as a qualitative anchor for the analysis by providing a known reference point for defining sustainable versus non-sustainable regions of the MDS ordination. Because the MDS ordinations are based on attributes measuring fisheries sustainability and the derived axes of the ordinations measure general sustainability, having ‘good’ and ‘bad’ fishery provided two end points for a continuum upon which the real fisheries were dispersed. The ‘good’ and ‘bad’ fishery were created in a fashion similar to that suggested by Pitcher and Preikshot (2000). For each attribute the highest, i.e., most sustainable, score found for all fisheries in the analysis was the attribute score for the ‘good’ fishery. Conversely, the ‘bad’ fishery was created by giving it all the lowest, i.e., least sustainable, scores for each attribute from the fisheries analysed. Thus, in the MDS ordinations the ‘good’ and ‘bad’ represent idealised high and low sustainability fisheries. In terms of the mechanism proposed to explain this unsustainability for tropical small scale fisheries, Malthusian overfishing, the ‘bad’ fishery can be thought of as one that exhibits all the characteristics possible which are diagnostic of Malthusian overfishing. Though unrealistic, these fisheries serve as reference points which, in addition to MDS ordination, definition of axes, and cluster analysis help provide a baseline upon which the fisheries in the analysis were related.

3. Results

3.1. Biological Analysis

For a complete accounting of the ordination scores generated by subjecting the biological attributes to MDS refer to appendix 2. Before ordinating these scores on a distance map they were further subjected to cluster analysis, see Fig. 3.1. The hierarchical clustering algorithm that was used was the complete linkage rule. This was deemed appropriate because the data appeared in 'clumps' of relative high density (Alt 1990, Statsoft 1995a), similar to Fig. 2.2 A and D. This cluster analysis technique nests groups within each other, thus a scree test was used to define a useful number of groups for further analysis, see Fig. 3.2.

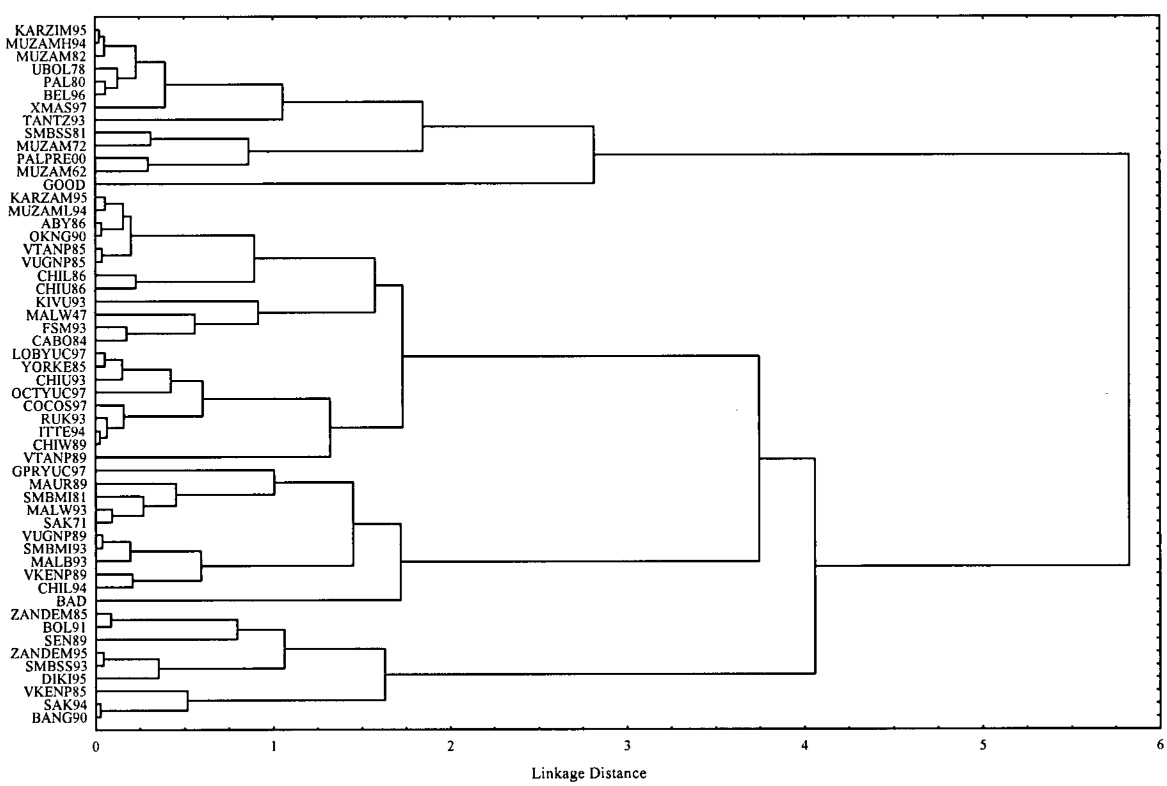

Figure 3.1. Hierarchical cluster analysis of biological MDS.

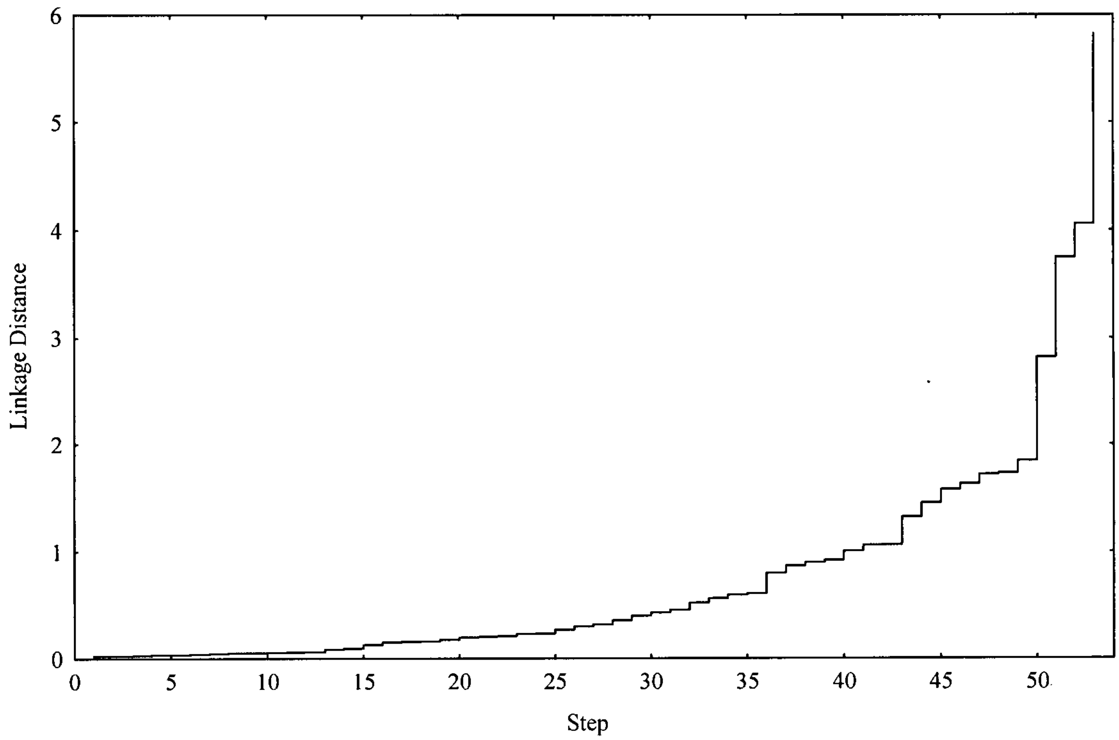

Figure 3.2. Scree diagram of group amalgamation schedule from cluster analysis of biological MDS co-ordinates indicating that more than four groups yields progressively smaller information about the total variation.

The distance map produced for the biological attributes can be seen in Fig. 3.3. The figure combines information from the MDS analysis (the scores plotted on the first two MDS axes), the cluster analysis (how the fisheries are grouped), and the correlation analysis (defining axes and thus sustainable and non-sustainable regions of the chart).

Fig. 3.3. shows that the 'good' and 'bad' fisheries are positioned at the extreme upper left and extreme lower right, respectively. This was true of all subsequent MDS ordinations. A two-dimensional representation was acceptable because the improvement of Young's S-stress by the addition of a third dimension would have only explained 0.2% more of the total variance with respect to the original distance matrix. The third dimension was not deemed necessary, because the S-stress improvement was less than 1% of the second dimension's S-stress value.

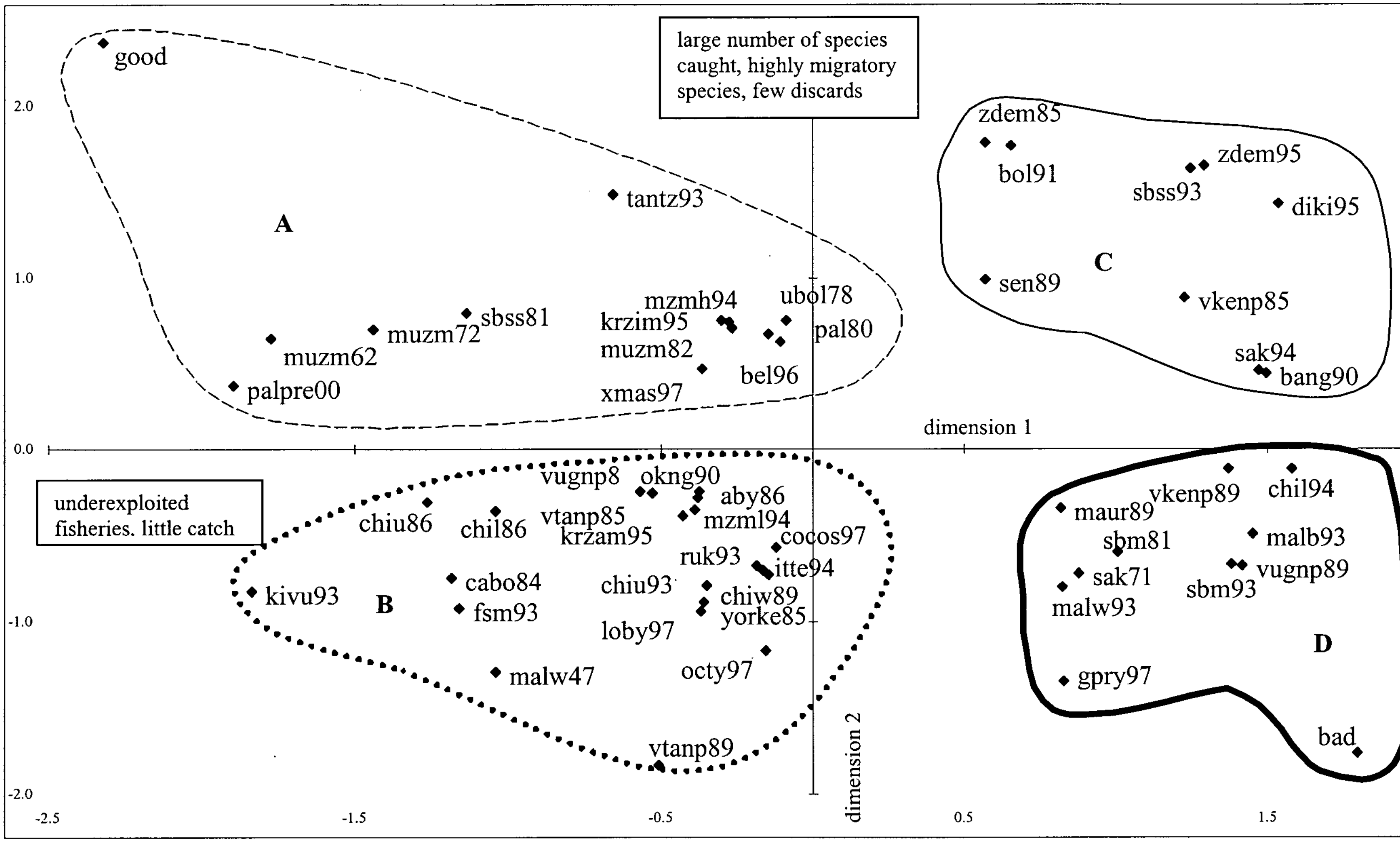

Figure 3.3. Biological MDS ordination with groupings. The fisheries in group **A** were associated with the modelled 'good' fishery. The fisheries group **D** were associated with the modelled 'bad' fishery. Group **B** was more closely associated with the 'good' group whereas group **C** was more similar to the 'bad' group. The left hand side and upper portion of the graph are labelled with the attributes characterising those areas. Therefore the fisheries in the upper left maximises them all, while fisheries in the lower right minimises them.

The goodness of fit stress for the ordination was 0.237. Clarke and Warwick (1997) say that stress values close to 0.2 are useful but that values closer to 0.3 indicate increasingly ambiguous distance maps. They point out, however, that the complementary use of cluster analysis is recommended when stress is higher than 0.1, as was done in this analysis (Clarke and Warwick 1997). The squared correlation was 0.775 indicating that almost 80% of the variance of the original biological distance matrix was explained by the 2 dimensional biological ordination seen in fig. 3.3.

For all MDS analyses the clusters were based on each fishery's score on both the x and y axes. Four groups were judged adequate in explaining most of the variation for the biological MDS, see Figs. 3.1 and 3.2. The four groups implied from this analysis are indicated on Fig. 3.3 as **A**, **B**, **C**, and **D**, with fisheries in **A** being most closely associated with the modelled good fishery and fisheries in **D** most closely associated with the modelled bad fishery. Fisheries in **B** and **C** represent weaker associations with the modelled good and bad fisheries, respectively.

In order to further help decide whether the groups generated by the cluster analysis were meaningful, a Tukey test (Zar 1984), $q_{crit} = q_{.05, 50, 4} = 3.791$, was conducted. The data analysed were the distances of fisheries on the MDS from the modelled good fishery. According to this investigation all groups were different, except for groups B and C. This implies groups B and C lie a similar distance away from the good fishery, but does not mean they are the same since the absolute distance, a scalar value, does not account for directionality. One can say, however, that there are strong distinctions between the other groups.

Table 3.1. Correlations of biological attribute scores with derived MDS axis scores. Numbers in **bold** indicate significant correlations at $p < 0.05$.

	Catch per fisher	Exploit'n status	Trophic level of catch	Migration Range	Catch before maturity	Discards	Number of species
Dim. 1	-0.11	**-0.91**	-0.22	-0.22	**-0.90**	-0.05	0.06
Dim. 2	0.10	-0.07	0.16	**0.39**	0.00	**0.58**	**0.91**

Analysis of the correlations of fisheries scores in the original attributes with scores on the two derived MDS dimensions indicated some clear associations, seen in Table 3.1. The first dimension, i.e., the x-axis, was strongly negatively correlated with exploitation status and catch before maturity. This implies that fisheries located towards the left-hand side of the MDS have underexploited ecosystems and little catch before maturity. The second dimension, i.e., the y-axis, had a weak positive correlation with migration range. Therefore, fisheries targeting long range migrators tend to be located higher on the ordination. The second dimension had strong positive correlations with amount of discards in catch and number of species caught. This means fisheries towards the top of the MDS had few discards (since the attribute scored few discards high) and targetted a variety of species. The attributes significantly correlated with the MDS axes are used to label the left hand side and upper portion of Fig. 3.3.

3.2. Economic Analysis

The linkage diagram for the economic ordination scores is shown in Fig. 3.4, the amalgamation schedule in Fig. 3.5. Fig. 3.6. shows the MDS ordination produced from the economic attributes. The two dimensional representation of Fig. 3.6 was acceptable because the addition of a third dimension increased the total explained variation less than 1% over the second dimension's S-stress value. The goodness of fit stress for the

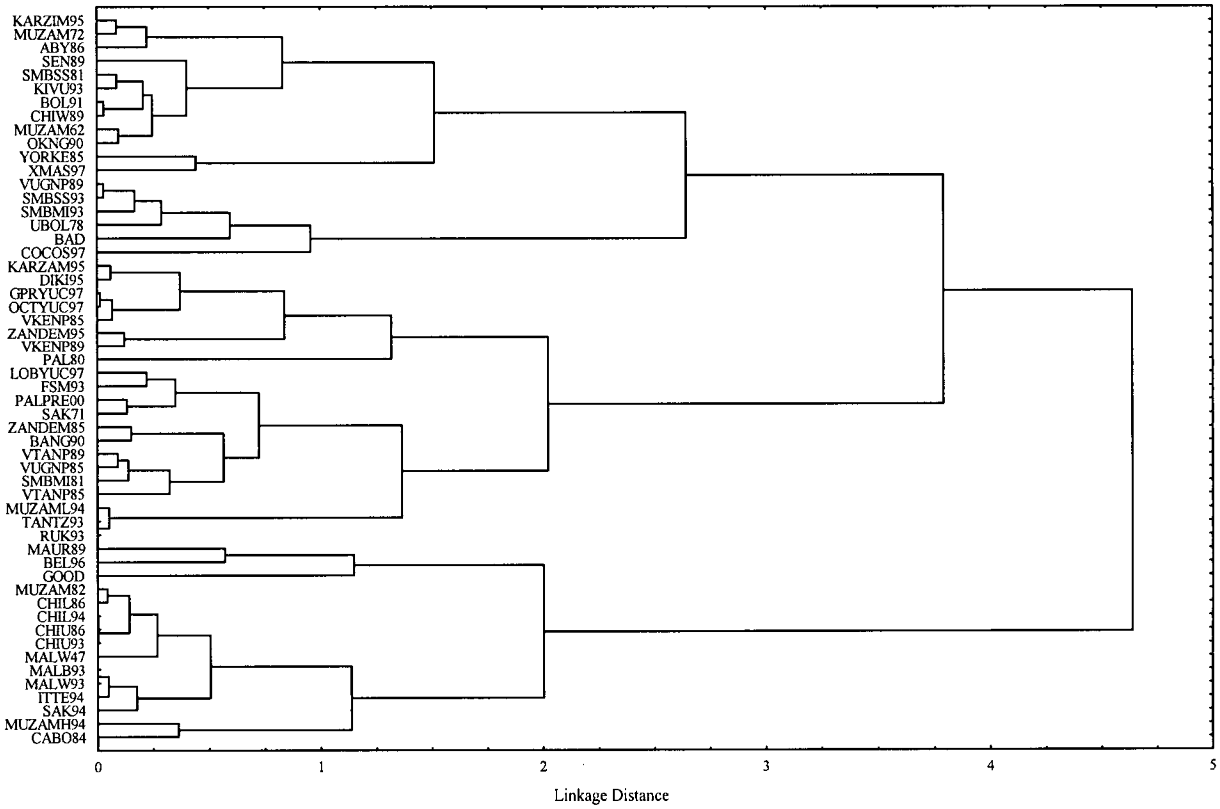

Figure 3.4. Cluster analysis of co-ordinates from economic MDS.

ordination was 0.255. The squared correlation was 0.714 indicating that over 70% of the variance of the original economic distance matrix was explained by the 2 dimensional ordination seen in fig. 3.6.

The cluster analysis of the economic MDS scores suggested that six groups best explained variation in the data, see Figs. 3.4 and 3.5. The six groups thus created were; group **A** and **a**, most closely associated with the good fishery and groups **D** and **d** most closely associated with the modelled bad fishery. Groups **B** and **C** were intermediate in being weakly associated with the good and bad fisheries respectively. Although these six groups were suggested, four were used for ease of making comparisons with the other MDS distance maps. These four were made by amalgamating the very close Groups **A** and **a** (henceforth called group **A**) and the similarly close groups **D** and **d** (henceforth

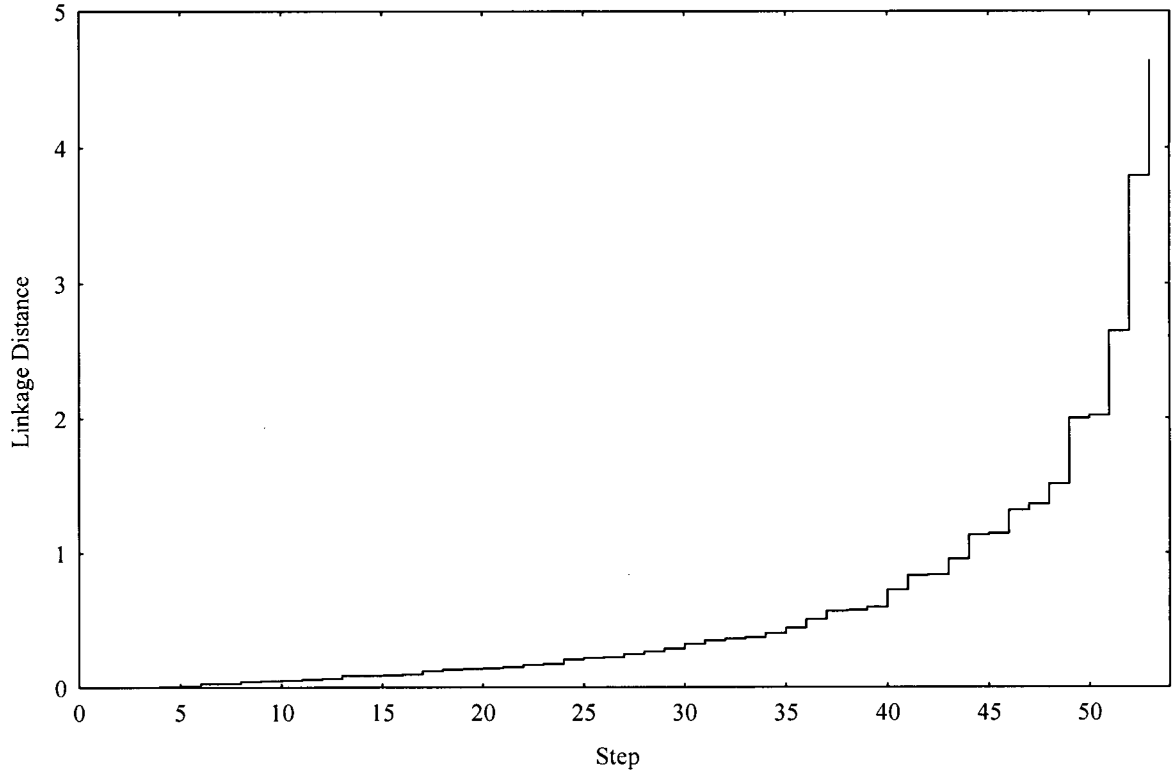

Figure 3.5. Scree diagram of group amalgamation schedule from cluster analysis of economic MDS co-ordinates

called group **D**). A Tukey test (Zar 1984), $q_{crit} = q_{.05, 50, 4} = 3.791$, was conducted on the four groups thus created. All groups were found to be different, except for groups **C** and **D**. This similarity results from the size of group **D**. As in the case of the biological MDS, however the distance measured from good has only one dimension and does not account for the very real difference that can be seen between groups **C** and **D** due to their vertical positions on the ordination.

The results of the correlation analysis of the original economic attributes to the two derived MDS axes are shown in Table 3.2. The first dimension was strongly negatively correlated with amount of kin help, implying that fisheries to the left of the of the graph had high levels of kin participation. There was a rather weak negative

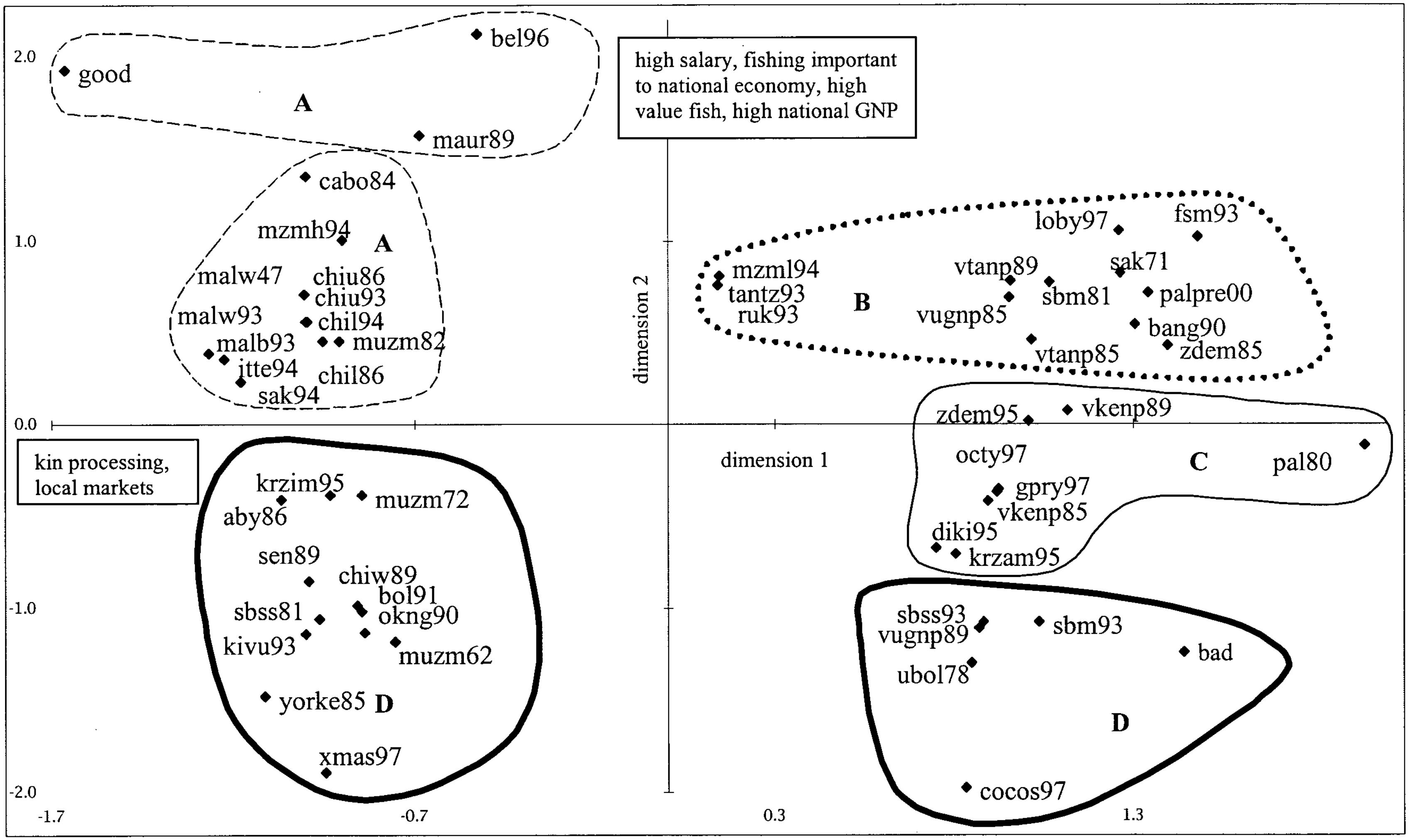

Figure 3.6. Economic MDS ordination. Group **A** was associated with the modelled 'good' fishery, group **D** with the modelled 'bad' fishery. Group **B** was more closely associated with the 'good' group whereas group **C** was more similar to the 'bad' group. The left part of the x-axis and the upper part of the y-axis are labelled with the attributes most associated with those regions, thereby characterising the fisheries analysed.

correlation with location of markets, which means that fisheries to the left tended to be oriented to local market, those to the right would sell more to national and international markets. The second dimension was strongly positively correlated with the relative income attribute meaning that fisheries in the upper parts of the MDS tended to have fishers earning relatively high salaries compared to other citizens of the same country. There was also a correlation with importance of fishing in the economy, so that fisheries nearer to the top were usually in countries where fishing made a significant contribution to the GNP. There was also a weak correlation to value of the fish caught, indicating a tendency for fisheries targetting higher value species to be nearer the top of the MDS. A very weak negative correlation existed with GNP per person, i.e., high GNP nations would tend to be lower on the graph.

Table 3.2. Correlations of economic attribute scores with derived MDS axis scores. Numbers in **bold** indicate significant correlations at $p < 0.05$.

	Price per tonne ($US)	Importance of fishing in economy	GNP per peson in country	Casual / part / full time fishing	Income relative to other jobs	Location of markets	Processing / marketting by kin
Dim. 1	-0.14	0.16	-0.13	-0.22	-0.13	**-0.33**	**-0.97**
Dim. 2	**0.37**	**0.52**	**-0.31**	0.20	**0.86**	-0.23	0.07

3.3. Sociological Analysis

The cluster analysis for the sociological MDS ordination scores is shown in Fig. 3.7, the amalgamation schedule, suggesting the appropriate number of groups to plot, is in Fig. 3.8. The two-dimensional distance map summarizing the sociologic attribute scores is seen in Fig. 3.9. A two-dimensional distance map was judged sufficient since the improvement of Young's S-stress by the addition of a third dimension would have only explained 0.3% more of the total variation, less than 1% of the second dimension's

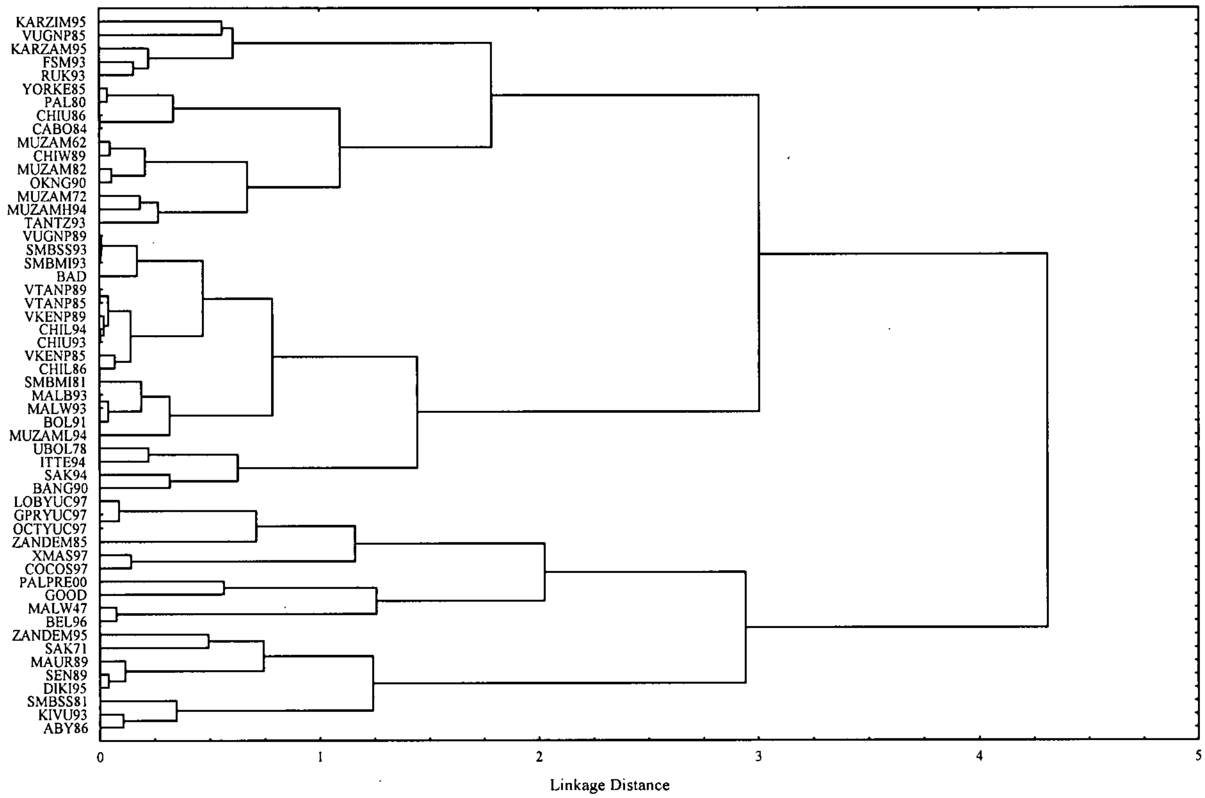

Figure 3.7. Cluster analysis of co-ordinates from sociological MDS.

S-stress value. The goodness of fitstress for the ordination was 0.237. The squared correlation was 0.794 indicating that about 80% of the variance of the originalsociologic distance matrix was explained by the 2 dimensional ordination in fig. 3.9. The cluster analysis of the sociologic MDS scores suggested that six groups were a useful way to divide up the fisheries data (refer to Figs. 3.7 and 3.8). These six groups were; **A** and **a** which were fisheries closely associated with the good fishery, **D** and **d** containing fisheries very similar to the modelled bad fishery, group **B** fisheries which were weakly associated with the modelled good fishery, and group **C** and **c** represented fisheries weakly associated with the modelled bad fishery. As in the economic MDS, although six groups were suggested, only four were used in order to facilitate comparisons with the other disciplinary MDS distance maps. These four were made by amalgamating groups **A**

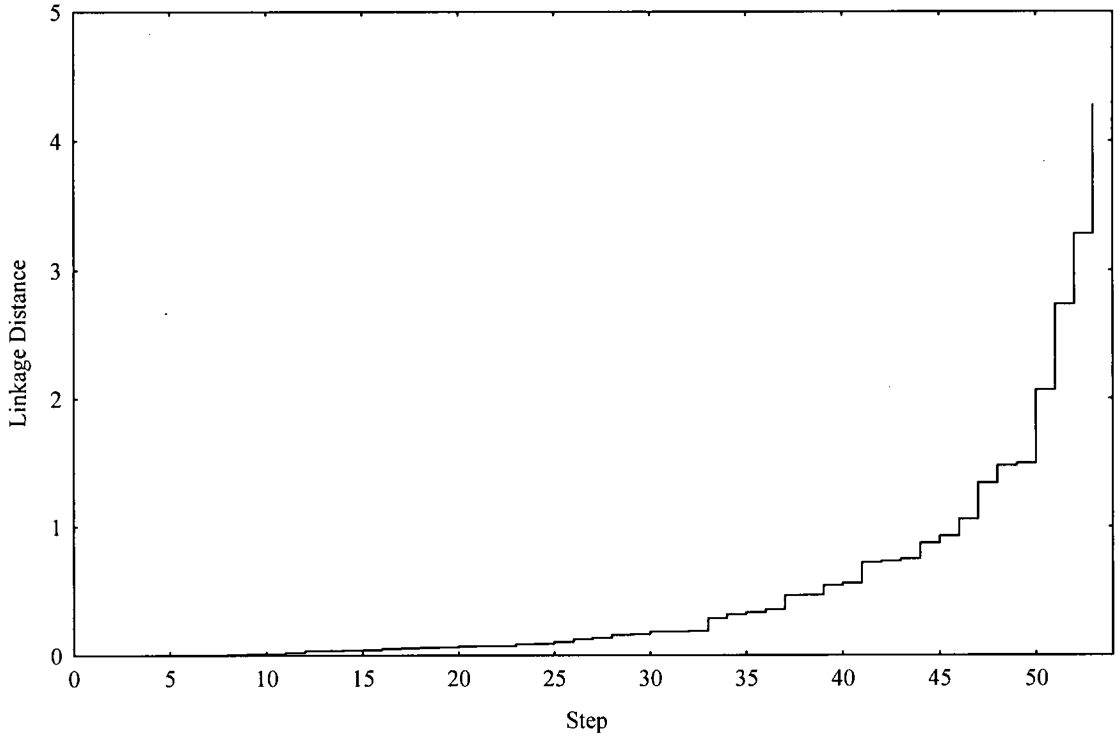

Figure 3.8. Scree diagram of group amalgamation schedule from cluster analysis of technologic MDS co-ordinates.

and **a** (henceforth called group **A**) and groups **C** and **c** (henceforth called group **C**). A Tukey test (Zar 1984), $q_{crit} = q_{.05, 50, 4} = 3.791$, showed that all groups were significantly different.

The results of the correlation analysis are shown in Table 3.3. The first dimension was negatively correlated with socialisation of fishing and fisher influence on regulations. Thus, fisheries to the left of the graph tend to have fishers who fish in community groups, rather than as individuals, and have a relatively large degree of influence on fisheries regulations. There was a negative correlation with information sharing so fisheries to the left of the MDS would tend to be characterised by information sharing between fishers. The y-axis had a very strong correlation with population growth, so that fisheries in countries with small population growth were at the top of the chart. There were also

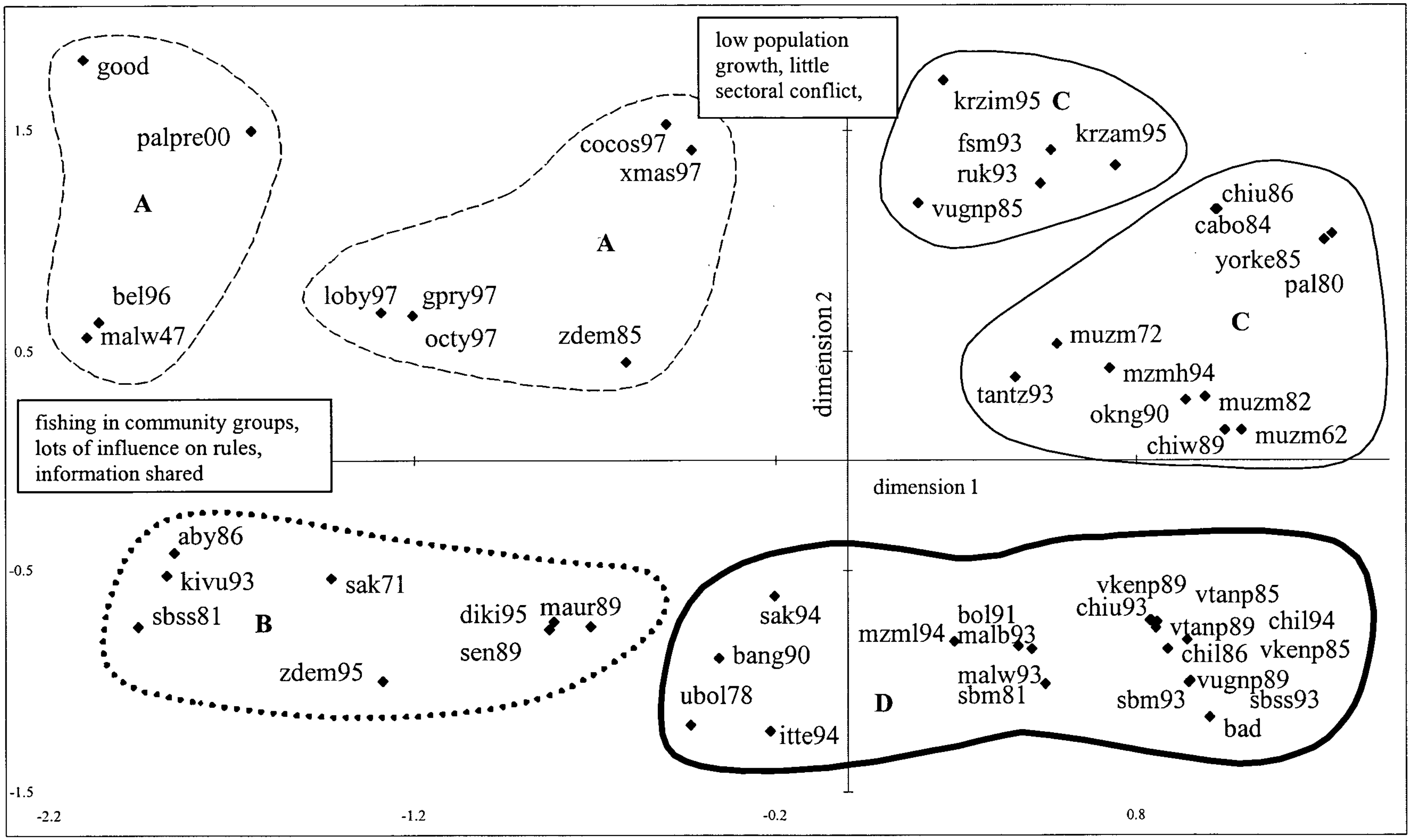

Figure 3.9. Sociological MDS ordination. Fisheries in group **A** were associated with the modelled 'good' fishery. Fisheries in group **D** were associated with the modelled 'bad' fishery. Group **B** was more closely associated with the 'good' group whereas the group **C** was more similar to the 'bad' group. Attributes associated with the upper y-axis and the left of the x-axis are listed to characterise different regions of the ordination.

Table 3.3. Correlations of sociological attribute scores with derived MDS axis scores. Numbers in **bold** indicate significant correlations at $p < 0.05$.

	Socialisation of fishing	Population growth	Relative education	Sectoral conflict	Information sharing	Influence on regulations	Fishing as % of income
Dim. 1	**-0.95**	0.04	-0.12	-0.12	**-0.27**	**-0.71**	0.05
Dim. 2	0.15	**0.97**	0.19	**0.29**	0.25	**0.31**	0.01

positive correlations such that fisheries with little inter-sectoral conflict and large fisher influence on regulations tended to be at the top of the graph.

3.4. Technological Analysis

The cluster analysis linkage tree and group amalgamation schedule for the technological MDS scores are shown in Figs. 3.10 and 3.11 respectively. The two-dimensional distance map shown for the technologic attributes is seen in Fig. 3.12. A

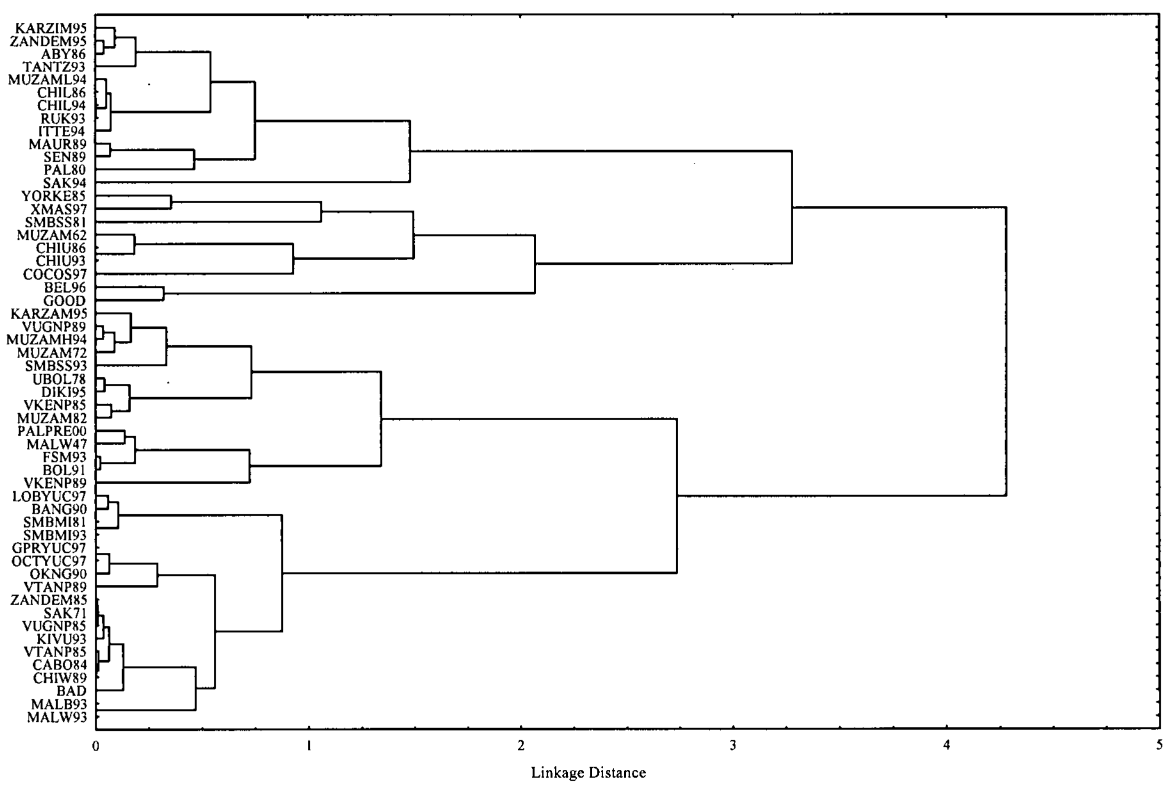

Figure 3.10. Cluster analysis of co-ordinates from technogical MDS.

two- dimensional MDS was adequate since another dimension would have only yielded an increase in explained variance less than 2% more than the second dimension. The

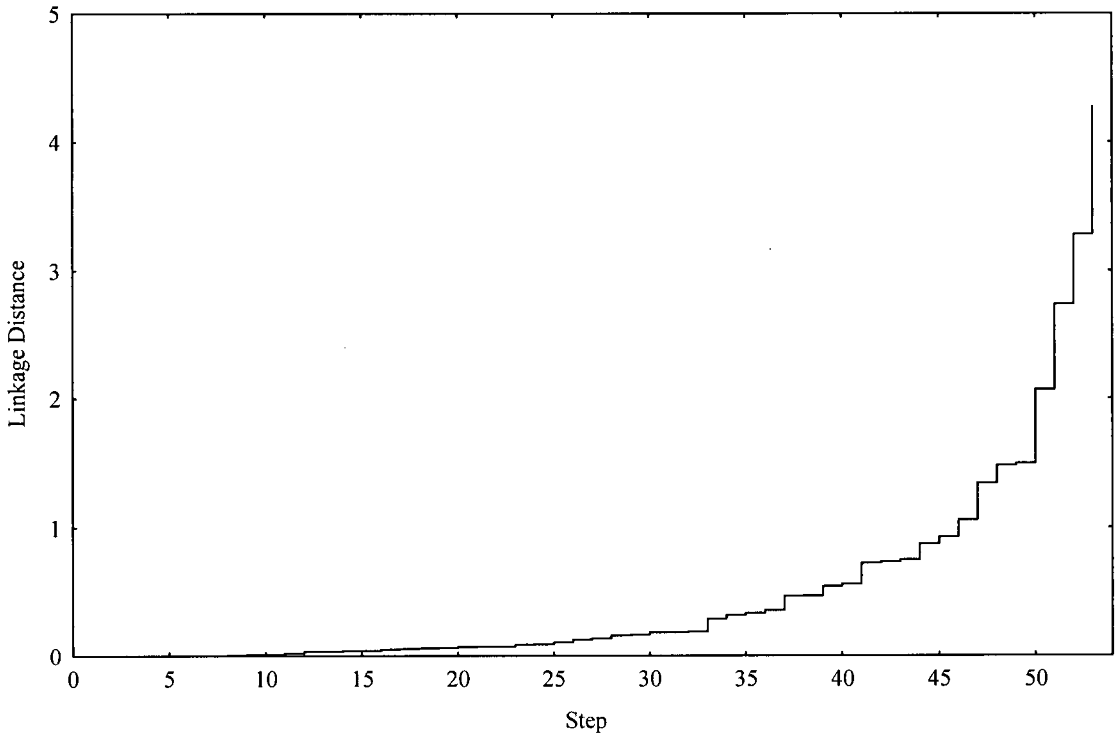

Figure 3.11. Scree diagram of group amalgamation schedule from cluster analysis of technological MDS co-ordinates.

goodness of fit stress for the ordination was 0.247. The squared correlation was 0.773.

The cluster analysis of the technological MDS scores suggested that four groups were a useful way to divide up the fisheries, see Figs. 3.10 and 3.11. The groups so generated **A**, **B**, **C**, and **D** represent decreasing similarity to the modelled good fishery. A Tukey test (Zar 1984), $q_{crit} = q_{.05,\,50,\,4} = 3.791$, found all groups to be significantly different, except for groups **B** and **C**.

The results of the correlation analysis of the original technologic attributes to the two derived MDS axes are shown in Table 3.4. The first dimension, was strongly

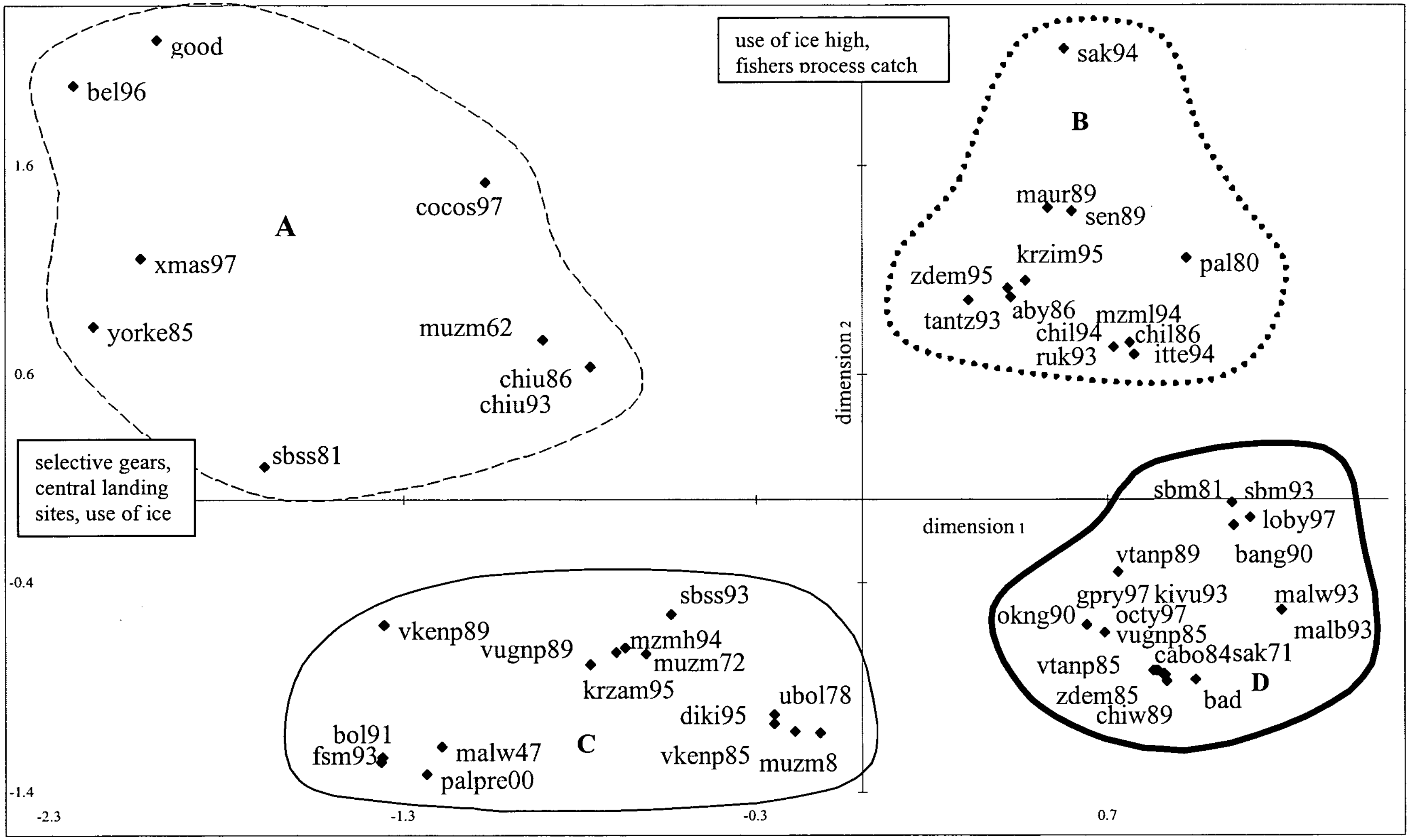

Figure 3.12. Technological MDS ordination. Group **A** fisheries were associated with the modelled 'good' fishery, those in group **D** were associated with the modelled 'bad' fishery. The group **B** fisheries were more closely associated with the 'good' group whereas those of group **C** were similar to the 'bad' group. The upper y-axis and the left side of the x-axis are labelled with the attributes associated with those regions of the ordination.

Table 3.4. Correlations of technologicic attribute scores with derived MDS axis scores. Numbers in **bold** indicate significant correlations at $p < 0.05$.

	Trip length	Landing site dispersal	Processing by fishers	Use of ice	Passive or active gear	Selectivity of gear
Dim. 1	-0.15	**0.27**	**-0.29**	**-0.48**	0.07	**-0.95**
Dim. 2	-0.26	-0.24	**0.94**	**0.48**	0.24	-0.05

negatively correlated with gear selectivity, so fisheries deploying selective gear types would be found on the left hand side of the graph. The left hand side of the MDS was also correlated with centralised landing sites. There were further correlations with processing by fishers and use of ice. The second dimension showed correlations with processing and the use of ice.

3.5. Comparisons Among MDS Distance Maps

This analysis showed no correlation between the weighted economic results and any of the other attribute sets. However, there were significant correlations between the weighted scores from the biological, sociological, and technological data, see Table 3.5. An interesting correlation was shown to exist between the weighted biological scores and a score which combined the sociological and technological scores, i.e., a 'combined' social/technology distance weighted score, see Fig. 3.5. The comparison of weighted

Table 3.5. Correlations of fishery MDS scores between disciplines.

	biology	economics	technology	sociology	Comb. T+S
Biology	1	0.090	0.43	0.40	0.47
Economcs		1	0.051	0.038	0.052
Technology			1	0.18	0.67
Sociology				1	0.78
Comb. T+S					1

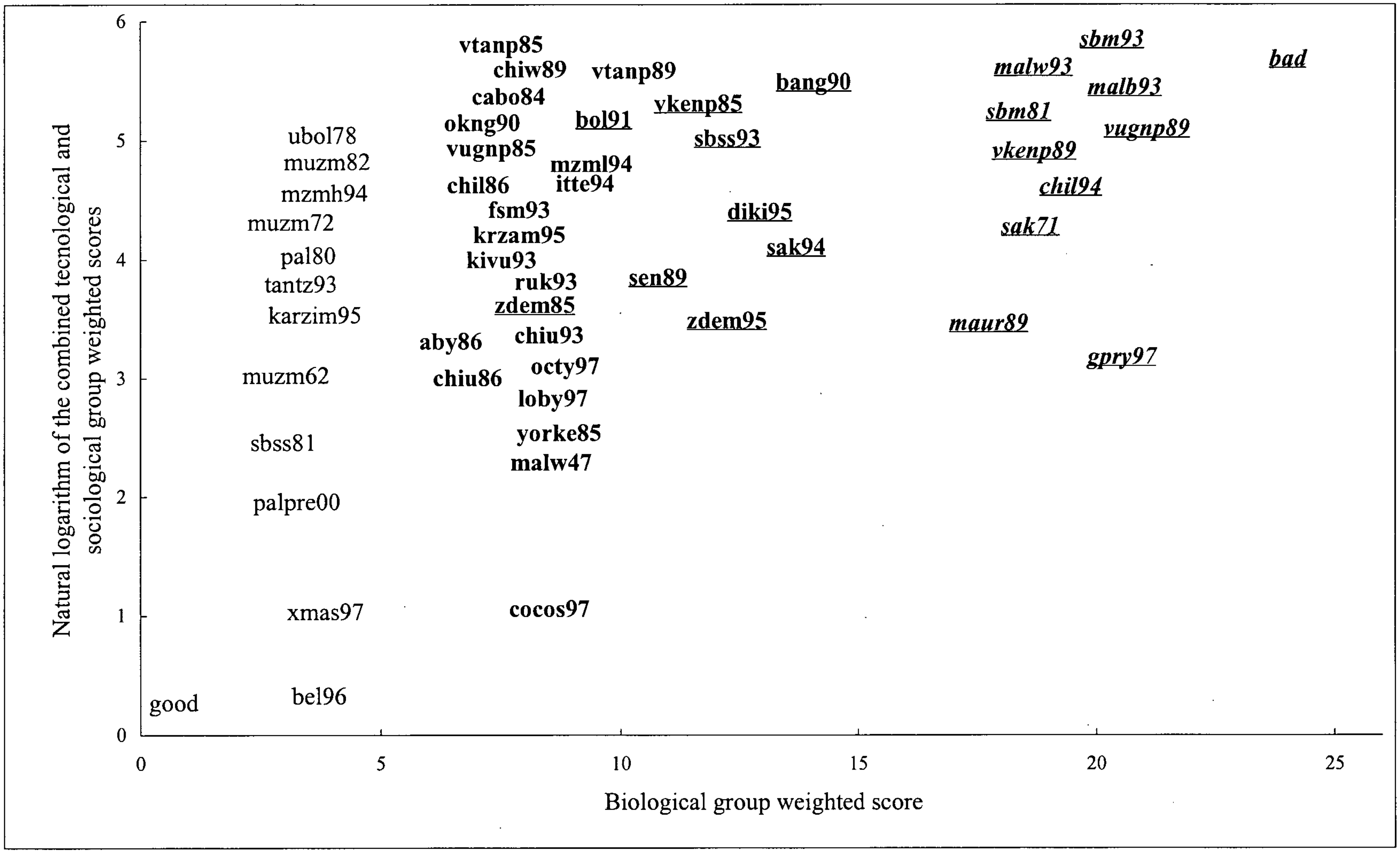

Figure 3.13. Comparison of group weighted biological scores with the combined weighted sociological and technological scores. The four fonts on the graph indicate groupings from the biological MDS. Fisheries in the normal font belonged to group **A**, those in **bold** group **B**, those in **<u>bold and underlined</u>** group **C**, and those in ***<u>bold underlined italics</u>*** group **D**.

biological scores against the combined sociological / technological showed that a fishery's weighted score in the sociological and technological analyses had an increasing tendancy to be identified with group **D** as the weighted biological score changed from group **A** to group **D**. This observation about weighted scores was supported by an examination of the correlation between the unweighted MDS axis coordinates from fisheries in the four disciplinary MDS analyses. The fisheries' coordinates on the x and y axes from the biological, sociological, and technological ordinations showed high correlations, whereas the two economic axes were not significantly correlated with any of the others.

4. Discussion

4.1. General Issues

What can the four MDS distance maps created here tell us about the 54 fisheries under analysis ? If there was consistent information being extracted from each of the four disciplinary attribute sets there should be similar taxonomies describing whether fisheries are sustainable, unsustainable or between the two extremes. Each MDS has a different basis for the two axes they possess. In a general sense each axis measures an aspect of sustainability. It must be kept in mind that even a slightly different data set will provide completely different weightings on the MDS axes derived. For example, in this analysis the biological MDS x-axis was most strongly influenced by exploitation level of the fishery and the level of catch before maturity. However, in Preikshot *et al.* (1998) a group of African lakes analysed with the same attributes list produced a biological MDS in which the x-axis was most strongly influenced by catch per fisher, trophic level, and migratory range. The purely African lake analysis did not differ from this one in that Nile perch fisheries of Lake Victoria and recent fisheries in Lake Malawi and Malombe were most strongly identified with unsustainability in the biological MDS. Thus, while the interpretation of the axes is important to understanding why certain fisheries cluster where they do, the clusters themselves seem to have more scientific precision and therefore robustness. Thus, a caution against reification, because there do not appear to be set definitions for each axis when different data sets are subjected to MDS.

4.2. Biology

In the biological MDS there are two well-defined 'poles' between sustainability and nonsustainability. One aspect of MDS discussed earlier is that the different regions of the graph can be 'interpreted' because they are generated by, in this case, different attribute weightings

(Stalans 1995). The first dimension of the MDS was heavily correlated with exploitation level and amount of catch before maturity, while the second was strongly correlated to number of species caught. The second dimension also had weak correlations with discard level and migratory range of target species, see Table 3.1. Thus, the x-axis is more easily identifiable as a direct guage of sustainability, while the y-axis is related to attributes which indirectly affect sustainability. The worth of the qualitative ranking suggested by a fishery's position on the x-axis is borne out by a wealth of fisheries science literature warning of the ill effects of catch before maturity as a cause of overfishing, see e.g., Ricker (1954), Beverton and Holt (1957), for some of the first explorations of these phenomena and Hilborn and Walters (1992) and Pauly (1994a) for more recent commentaries. Beverton and Holt (1957) were also the first to point out that fisheries could actually push a stock to extinction. With respect to overexploitation, the global crisis of fisheries and the universally high incidence of this phenomenon was discussed effectively by Garcia and Newton (1997), who also warned that global overcapacity and persistent industrialisation of fisheries in developing nations is a direct threat to their sustainability. An example of one of the processes that fosters this overcapacity is the transfer of old fishing vessels from developed countries. When such vessels go to tropical developing countries they are often added to the pre-existing capacity, which puts more pressure on the resource, and thus forces increased effort and use of destructive gear. Such a process would add to the internally generated causes of Malthusian overfishing.

The second dimension appears to engender qualities that indirectly indicate fisheries sustainability. Of all the attributes that had significant correlations to the y-axis, number of species caught, migratory range, and discard level were known to directly influence sustainability, although this was difficult to assess directly. For instance, discards represent globally about 27 million t per year, about 30% of total ocean capture fisheries (Alverson *et al.*

1994). The higher the level of discarding in a fishery, the more unlikely it is to be sustainable. However, in the early stages of such a fishery it might be difficult to detect ill effects on the environment from discarding, because classic stock assessment procedures have focused on the single species being targetted. Thus, single species stock assessment might ignore ecosystem impacts. This failure of single species modelling to protect species subject to bycatch and discards has been critiqued by Walters *et al.* (1997) and Walters *et al.* (in press), in which dynamic and spatial mass balance ecosystem models are proposed as a potential method of coping with such management. The MDS assessment discussed here might allow the identification of fisheries systems most in need of such analysis.

The effect of migratory range was thought to be rather straightforward; a species with a large migratory range would have a *de facto* refuge against pressure from local fisheries whenever it moved. As Hilborn and Walters (1992) point out for non-migratory or 'sedentary' stocks the population dynamics will be more dependent on past fisheries practices. Stocks which move around more will have abundances at any one location, or for any localised fishery, dependent on their abundance elsewhere. This distance effect can either be through maintaining some kind of proportional relationship to other areas' populations or by the stock adjusting its overall range so that local concentrations are constant (Hilborn and Walters 1992). Both processes would help increase a local stock's robustness to exploitation.

What this suggests is that the first dimension is more directly identifiable with overall sustainability, whereas the second dimension delimits qualitative factors that can influence whether that sustainability is more robust or more transient. Under such a scheme the fisheries can be classified as follows;

Group A: Sustainable and robust,

Group B: Sustainable but non-robust,

Group C: Non-sustainable but robust,

Group D: Non-sustainable and non-robust.

In metaphoric terms, think of the MDS as measuring the tendency of a fishery to become Malthusian. If the tendency is like a sled on an icy slope, the first dimension measures how steep the slope is and the second dimension measures the slickness of that slope. Given this perspective it is clear why fisheries in group B with time series often appear in their later incarnations as Malthusian, e.g., Lake Victoria, Lake Chilwa, and Lake Malawi and fisheries in Group A tend to stay there, e.g., Lake Mweru and Palau. The San Miguel Bay small scale fishery does move from Group A to Group C, but it is tied to the overall ecosystem effect of its sister fishery (the San Miguel Bay mini trawlers), which was classified in the Malthusian group. Fisheries in Group C are therefore Malthusian in many characteristics, but likely would have to be hard pressed, indeed, to become completely unsustainable.

The Lake Victoria Nile Perch cases present good examples of apparently 'sustainable' fisheries that were weakened by having characteristics of non-robustness. The high trophic level Nile Perch was introduced to Lake Victoria along with other tilapiine species, such as the herbivore *Oreochromis niloticus*, beginning in the 1950s (Kudhongania 1990 Balirwa 1990). The pre-introduction ecosystem had about 350 species of fish, approximately 300 of which were haplochromine cichlids (Kudhongania 1990), compared to 200 today (Bwathondi 1992). The original fish species were usually at the top of short food webs feeding as detritivores or herbivores. The introduced species eventually either outcompeted their confamilial competitors, as *O. niloticus* did with the native *Tilapia esaculenta*, or simply ate them, as the Nile Perch did many of the fish species. By the early 1980s there was widescale species depletion in the lake (Balirwa 1990). It has been suggested that the cannibalistic behaviour of Nile Perch might act as a break on its population growth (Kudhongania 1990), but as Hilborn and Walters (1994) point out, cannibalistic species are often subject to overcompensatory density dependent mechanisms. Under such a process as the spawning stock increases survival of young may decrease due to cannibalism. Therefore, a fishery on the adults may actually favour survival during earlier life history stages. Such a model would explain the observed decline of Nile Perch prey species in the face of record harvests in Lake Victoria, which now consist almost entirely of introduced species, especially Nile Perch. This also explains why the trophic level attribute was not significantly correlated with either axis of sustainability as might be suggested by the mechanism of fishing down food webs as described in Pauly *et al.* (1998). Fishing down food webs suggests that overexploitation of a fishery can lead to the 'mining out' of high trophic level species. Thus, one signature of overfishing for fisheries with time series should be lower trophic level target species as time goes on, or at least declining catches. Note that the failure of catch per fisher to correlate significantly with either of the biological MDS dimensions could be explained by the 'negative trophic signature' of Nile Perch. There were, however, indications by the early 90s that overfishing was beginning to affect the average size of Nile Perch caught in the Kenyan sector of the lake (Ssentongo 1991).

The characterisation of fisheries within Groups **C** and **D** as Malthusian is validated by scrutiny of previous assessments. Indeed, the Bolinao fishery, in Group **C**, was used as a prototype case to demonstrate Malthusian overfishing (Pauly *et al.* 1989, Pauly 1994b). The two fisheries of San Miguel Bay that were included in this analysis provide a cautionary example of how sectors can influence each other. In the cases from the early 1980s an assessment of trawl fisheries by Vakily (1982) noted that large and medium trawlers (not included in this analysis) were having the effect of removing most of the large fish from the bay. The mini trawlers (which were included in this analysis) were, although selective, experiencing explosive growth in their numbers (Tulay and Smith 1982 and Vakily 1982). Total catch from the bay was estimated to be about 15 000 t per year, evenly divided between all trawl fisheries and the small scale sector (Pauly 1982). Catches soon peaked at about 19 000 t per year, and by the time of the assessment for the early 1990s had declined to 17 000 t per year, despite sharply increased effort and the almost total elimination of large and medium trawlers from the bay (Silvestre *et al.* 1994). This led to the conclusion that "Indication [*sic.*] of biological overfishing in the bay are quite evident" (Silvestre *et al.* 1994). Thus the positive characteristics of the small-scale sector in the early 1980s were being influenced by internal growth and competition from the trawlers such that inherent unsustainability was manifested. In terms of the metaphor used earlier, the fishery has been placed upon a very steep slope that it has begun to slide down despite some favourable characteristics.

The case of Lake Malawi illustrates the second mechanism, suggested above, of slipping into Malthusian overfishing: being on a shallow, but slippery, slope. Assessments of the fishery in the late 1940s described the Tilapia fishery as being close to maximum sustainable yield and perhaps even in a state of overfishing, especially in the south-east arm of the lake (Lowe 1952), although some controlled expansion in other areas and for other species was feasible. Unfortunately the increase in fishing pressure was such that by the assessments of the early 1990s, the FAO warned that for the Lake Malawi area, i.e., including the connected Shire River and Lake Malombe, the continued open access to new users and increasing use of non selective gears had led to all stocks being either fully or overexploited leading to some stock collapses (FAO 1993). Since the stocks are restricted to a relatively small area, all of the Lake Malawi and Lake Malombe system is within easy reach of fishers, they are never in any effective refugia. The continued use of non selective gears over the whole time period along with a high degree of catch before maturity (Lowe 1952 and FAO 1993) throughout the whole period made it easy for the originally sustainable fishery to slip into a Malthusian state.

4.3. Economics, Sociology, and Technology

4.3.1 The Island of Economics

The potential value of an interdisciplinary assessment tool, such as that explored here depends on whether or not the results of the biological analysis are related to the results of the other disciplinary examinations. In this case, economics, sociology, and technology were chosen as categories of analysis. The most surprising result must surely be the lack of correlation between the information contained in the economic MDS and that of the biological MDS. Indeed, the economic analysis provided results that were seemingly unrelated to any of the other three data sets. This is despite the fact that the study of economic aspects of fisheries have become an increasingly important tool of fisheries management. Indeed, authors such as Hannesson (1998) even claim that "The reasons for the [global] fishery crisis are economic and organisational. Fishing … is an activity people engage in to make a living. They do so to the extent they see their interests being better served by fishing than by doing something else. Clearly, if there is too much fishing going on, people do not face appropriate incentives, they are encouraged to engage in fishing on a greater scale than is appropriate."

Despite suggestions of the strong connexion between biological and economic phenomena in fisheries, no discernible relationship was suggested in this analysis. Rather than refuting the overall relation between biology and economics in fisheries, however, this lack of connectivity between the two attribute groups may be a result of the very nature of tropical small-scale fisheries that puts them at risk of becoming Malthusian. For example one of the key components of Hannesson's (1998) diagnosis of economics as the chief reason for the global

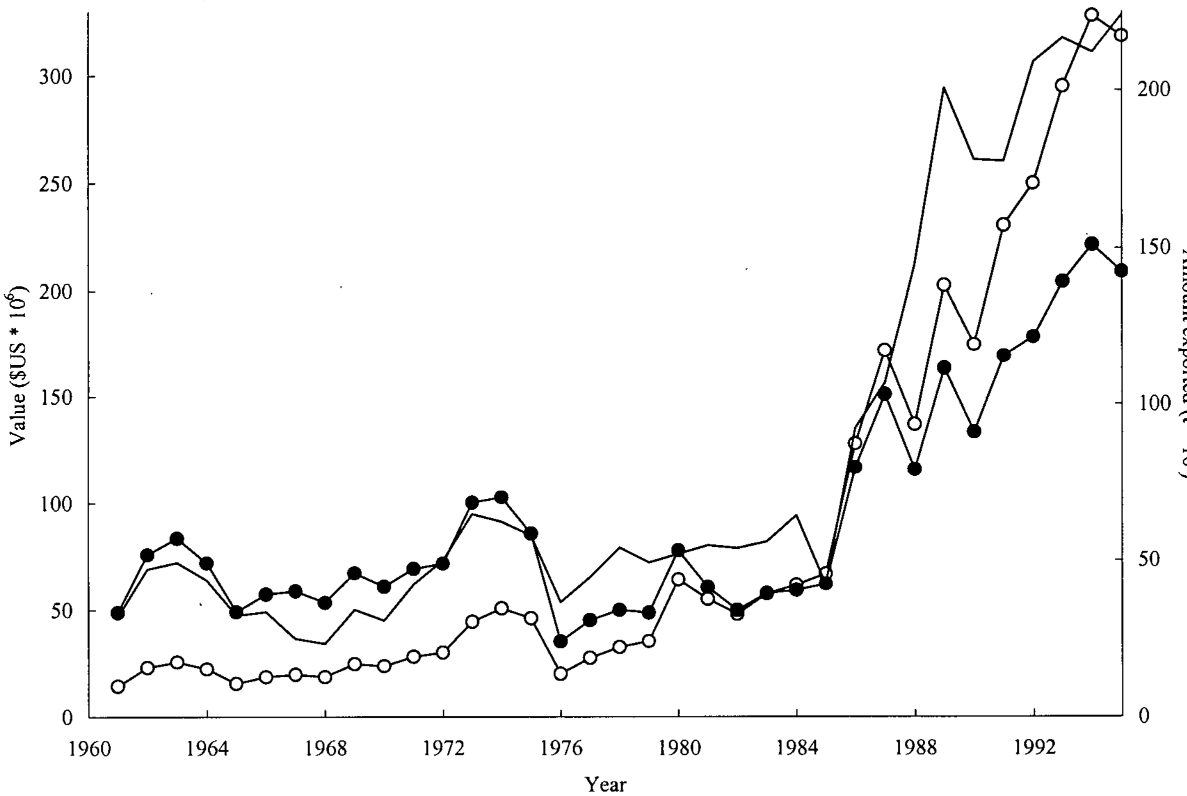

Figure 4.1. The right hand axis measures total fish exported by a representative group of 20 developing tropical nations, shown as the unmarked line. The left hand axis measures total value for fish exported in non deflated value (open circles) and deflated value (solid circles). These data were derived from the FAOSTAT fisheries online database (FAO 1998) and the US consumer price index (Anon. 1998).

fisheries crisis was that fishers fish so as long as there is no incentive to do something more profitable. As discussed earlier, however, the contrary observation is a characteristic major cause of Malthusian overfishing in the first place: there simply is nothing else *at all* for the fishers to do, i.e., fishing is an employment of last resort (McManus 1996). In fact, Hannesson (1998) goes on to admit that with respect to economic tools to deal with overfishing they "... would appear to be most difficult [to use] in small-scale fisheries where the catches are landed without any elaborate equipment and used for human consumption in local communities."

However, even beyond the local community, there is much evidence to refute the logical relationship of direct economic interest to the fishers in a tropical small scale setting. For

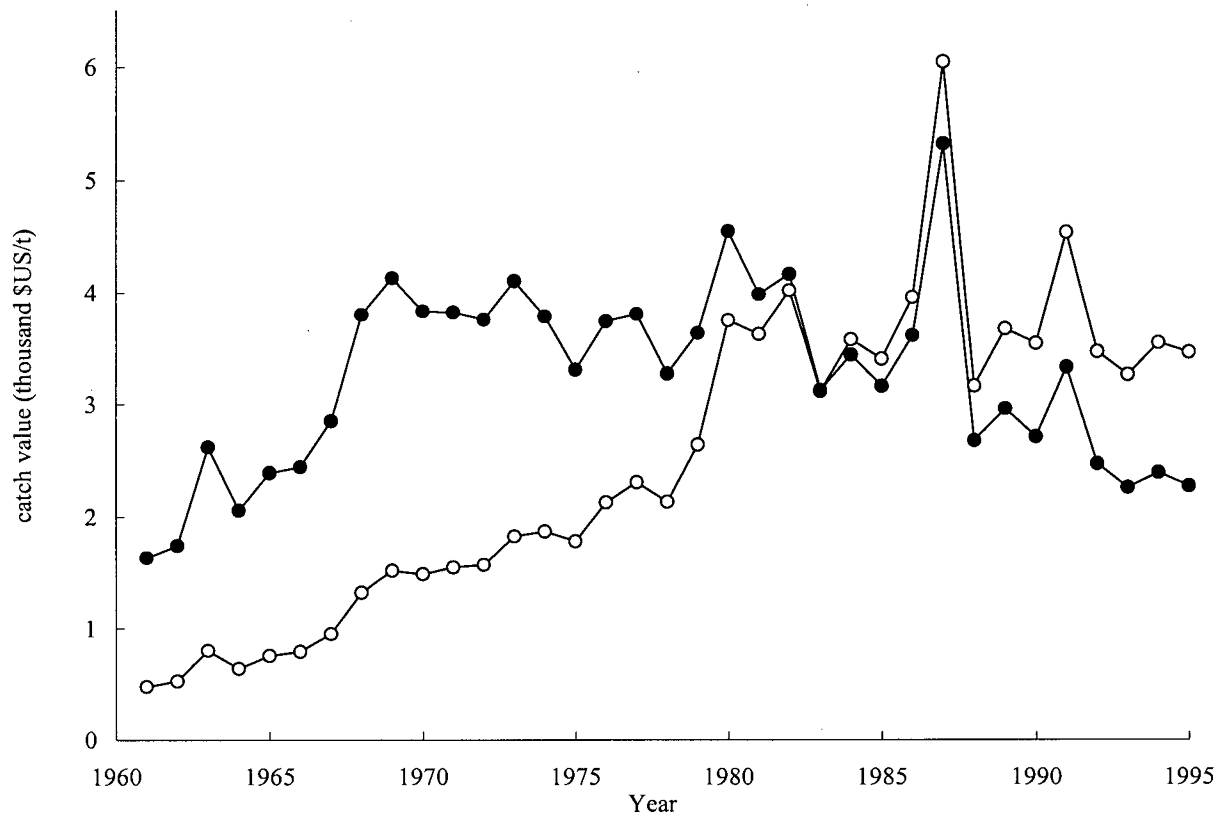

Figure 4.2. Value ($US per tonne) of fish exported from 20 selected developing nations in non-deflated (open circles) and deflated terms (closed circles). These series were derived from the FAOSTAT fisheries online database (FAO 1998) and the US consumer price index (Anon. 1998).

example, Fig. 4.1. shows that over the last 40 years although exports for fisheries have been rising, the actual value for those exports has not kept pace. This decreasing real value is especially pronounced after the late 1980s. The stagnation, or loss, of value means that the money fishers get for their catch is actually smaller per unit than what they received in the past. Given that none of the fisheries in this study showed decreasing numbers of participants, the implication is that, in real terms, fishers get less money now than 40 years ago! Such suspicions are strengthed by conclusions drawn from examination of Fig. 4.2. The graph was constructed from the same FAO database as the previous figure. Although prices for fish originating in developing countries appears to have risen over the last 40 years (closed circles) the buying power of the money derived from these fish has been relatively stable (open circles). In fact, since 1970 it appears that except for a spike in valuation during the late 80s, the unit value of the catch has declined. More troubling is that it has become necessary to split these earnings between an increasingly large number of participants in almost all developing world fisheries.

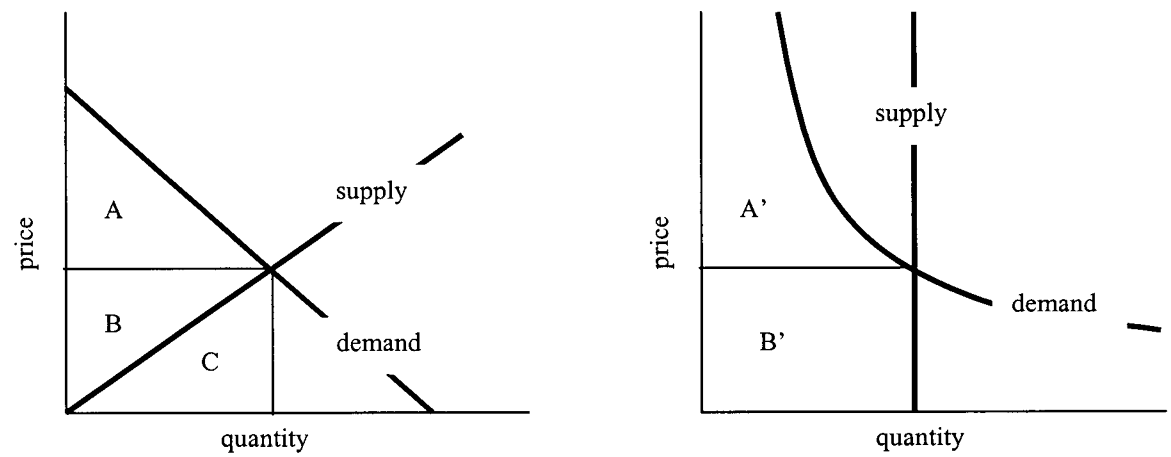

Figure 4.3. Comparison of classic economic description of supply and demand (left hand graph) with a description based upon supply and demand from ecological sources (right hand graph). Figure adapted from (Costanza *et al.* 1997). Area C represents the cost of producing a good, effectively nothing for natural resources, hence there is no cost in the right hand graph. Areas B and B' represent rents from the products. Areas A and A' represent the benefit to the consumer above the price paid.

Lastly, the economic attributes chosen for this analysis may not be the best to measure sustainability. As Costanza *et al.* (1997) point out, many ecosystem goods are not substitutable, i.e., there is a fixed amount / renewal rate, and therefore their supply curves look like the right hand graph of Fig. 4.3. Further, since goods like fish as food (or air!) can command infinitely high prices, as they disappear, their demand curve is also quite different from that predicted by classic economics. If this is the case, measuring the economic performance of a fishery within a larger economy may for many indicators be valid only within a narrow range from a starting equilibrium. A further complication arises from the fact that oceanic ecosystems provide services other than food production. These include waste water treatment, gas regulation, nutrient cycling, recreation, and biological control. The disturbance of aquatic ecosystems by unsustainable harvesting practices will change the direct human economic welfare from them, yet there is no generally agreed upon method for measuring the value of these services. Costanza *et al.* (1997) estimate that the effect of ecosystem disturbance has likely been a levelling of economic performance since the 1970s, not the growth suggested simply by measuring world gross national product.

4.3.2. Sociology and Technology

As was the case in the biological analysis, the MDS graphs for the sociological and technological attributes show the modelled good and bad fisheries at extremes and all the others occupying a place on the spectrum between. In the sociological MDS, the two attributes that correlated most with the x-axis were socialisation of fishing and influence on regulations, with information sharing being weakly correlated. These attributes all measure the cohesiveness of a community and get at the heart of one of the central phenomena of Malthusian overfishing; the degree of disturbance that has occurred within the community due to immigration of new fishers from surrounding areas (Pauly 1997). Fishers within an established community that has been engaged in fishing for a long time are more likely to fish in groups, share their information, and have an essentially self regulating system, i.e., high influence of rules. As outsiders enter, or competition for resources leads to the use of non sanctioned or destructive gears, the likelihood of any of the above three conditions continuing must diminish. The y-axis is almost entirely a measure of one attribute: population growth. The lower a fishery is on the second dimension the higher the population growth in the country as a whole, thus increasing the potential of migrants towards fishing areas.

It should not be surprising that given the attribute structure of the sociological MDS, two of the most sustainable fisheries are from before the 1950s; Lake Malawi in 1947 and pre 20th century Palau. The MDS suggests that the relative degree to which the fishing community has disintegrated in Palau is troubling, given that it has become closely identified with sociologically unsustainable fisheries. Other cases fitting the constraints of sociological sustainability are the the Cocos Islands and Christmas Island, two communities where the population is essentially all maritime and no immigration from outlying communities is possible (due to their isolation in the Indian Ocean). This condition mirrors biological buffers which tend to mitigate overfishing in insular tropical reef areas. These areas are hard to fish industrially, because of topographically rich habitat, which also encourages the use of selective gears (Ruddle 1996). Use of selective gears will be discussed in greater detail in the technological attributes section.

The Nile perch fisheries of Lake Victoria were strongly associated with unsustainable sociological characteristics, as in the biological MDS. This is hardly surprising as Tanzania, Uganda, and Kenya all exhibit high population growth, extreme poverty, and a large degree of internal tensions (Central Intelligence Agency 1995). For instance, the Tanzanian portion of Lake Victoria experienced an increase from 20 587 fishers and 3 997 boats to 29 000 fishers with 7 757 boats during the 1980s (Mwamoto 1992). This represents both an increased number of fishers and a higher degree of mechanisation. A similar history unfolded in the Kenyan sector of the lake. During the 1980s numbers of fishers increased from 18 000 to 30 000 with numbers of dependents increasing from 120 000 to 210 000 (Ogari 1991). Given the context of the changing structure of the ecosystem and new fishers engaged in the pursuit of the relatively high value Nile Perch, communities must be under great stress, indeed. This situation would be most worrying in the case of Kenya, which occupies only 6% of Lake Victoria (Arunga 1991), yet depended on the lake for 90% of its fish harvest at the time of analysis (Adhiambo 1991).

The technological MDS was also complementary to the biological MDS. The x-axis was highly correlated with gear selectivity and weakly associated with amount of processing by fishers, landing site dispersal, and use of ice. Fisheries associated with sustainability on the x-axis would thereore tend to use selective gears, process much of the catch themselves, use large amounts of ice for for transport and marketting, and land catches at centralised places. The y-axis was correlated with processing and use of ice. Therefore fisheries associated with sustainability on the second dimension were characterised by a high degree of processing by fishers and frequent use of ice. Since the processing attribute had a higher correlation to the second dimension than the first, it would be more appropriate to associate it with the y-axis than the x-axis in defining them. The 'use of ice' attribute correlated equally well with both dimensions, and therefore may have acted as a source of autocorrelation. Since gear selectivity is the most correlated attribute with the x-axis the axis would appear to measure the ecological impact of gears used. The y-axis, which is most associated with processing seems to be a measure of the value added to the catch because of gear used.

As occurred in the biological and sociological MDSs coral reef islands like Christmas Island, the Cocos Islands, pre 20th century Palau, and Yorke Island were associated with the modelled sustainable fishery. Because the coral reef environment is so varied, islanders often have to devise dozens of ingenious devices, traps, lures, and methodologies to capture different aquatic organisms. See, for example, Johannes (1981) for an excellent discussion of how the people of Palau established a rich tradition of seafaring and fishing, that endowed them with a tremendous store of knowledge as to the biology of the surrounding marine ecosystem. Also similar to the biological and social MDSs, early fisheries, like that of pre-20th century Palau and Lake Malawi in 1947, scored favourably.

Fisheries that were associated with Malthusian characteristics are typified by those of Lake Malawi, Lake Malombe, and San Miguel Bay. The Lake Malawi / Lake Malombe system was mentioned before as being characterised by much overfishing. This state of affairs in the two Malawiian lakes has been exacerbated by the uninterupted entry of new participants and the increasing use of fine meshed seine nets (FAO 1993). Although local fisheries authorities have recommended that such gear be banned they remained in use at the time of sampling. In San Miguel Bay one of the largest areas of gear expansion has been gillnets. Although they can be quite selective, there are many different sizes targetting all the different sized organisms. Further, devices are used to scare fish and drive them into the gill nets. By the beginning of the 1990s the number of nets had almost doubled. This was accompanied by an increase in effort per net (Silvestre *et al.* 1994). A final example of a Malthusian type fishery was shown by the Tanzanian Nile Perch fishery on Lake Victoria. Beach seines had become an increasingly popular method of harvesting fish but one authority pointed out that mesh sizes were unacceptably small and that the seines themselves destroyed habitat for spawning and juveniles (Ssentongo 1992).

As a final comment on the Nile perch fishery, Fig. 4.4. shows trends in harvests of Nile perch in Lake Victoria over the last years for which data was available. What is surprising is the display of all of the symptoms of a fishery headed for trouble; exponentially increasing catches (Reynolds and Gréboval 1988), large scale perturbation of the surrounding ecosystem, uncontrolled entry of new participants (Reynolds *et al.* 1995), and the increasing use of destructive gears (Ssentongo 1992, Ssentongo and Dampha 1991, and Ssentongo and Orach-Meza 1992). Most observers point to the increasing economic benefits arising from the catch of this high value fish, which was being exported to Europe by the late 1980s, bringing in amounts of cash never before earned by local fishers (Reynolds and Gréboval 1989). Government agencies predicted increases in catch well into the 1990s and they allowed the catch to grow. It seems doubtful that such expansion could be continued given the similarity of the catch history of Nile perch to other boom and bust fisheries modelled in Fig. 1.1. Another argument against the likelihood of sustained high catches of Nile perch is the ecological instability of Lake

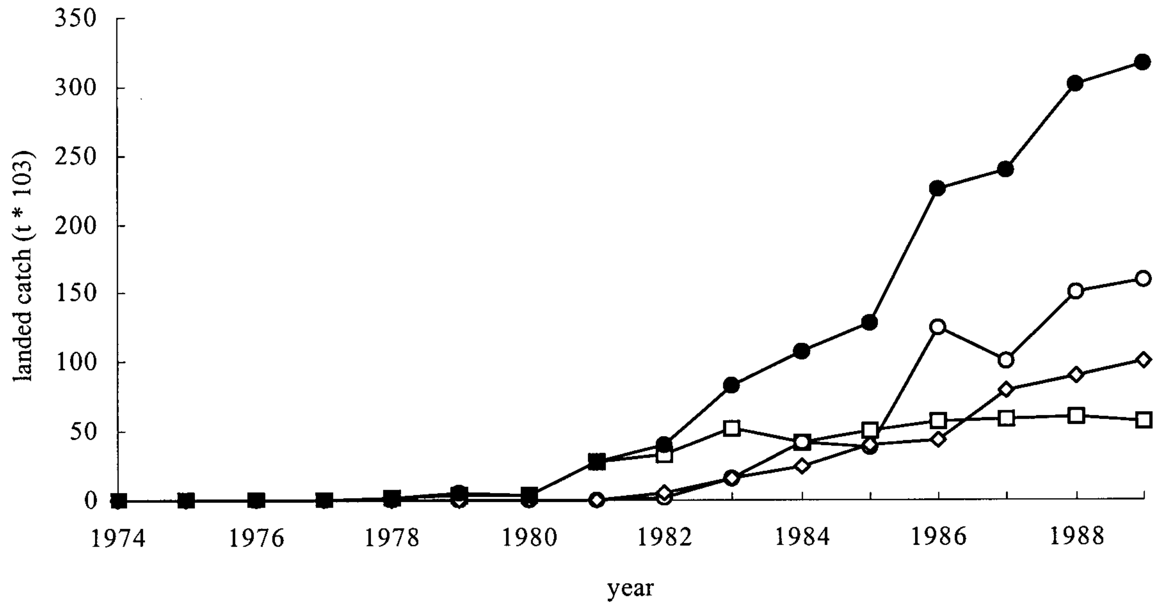

Figure 4.4. Catches of Nile perch in Lake Victoria by country. The line with open circles is Tanzania, that with open diamonds is Uganda, and the line with open squares is Kenya. Total catch for all countries is shown by the line with solid circles. Data based on Pitcher and Hart (1995) and Reynolds and Gréboval (1989).

Victoria over the last three decades. Since Nile perch was introduced species fluctuations have occurred across clades and species groups (Reynolds *et al.* 1995), there is no compelling argument to suggest that Nile perch is somehow immune from such population shifts in the future.

4.4. Potential Problems of Multivariate Analysis

When analysing multivariate outputs, such as an MDS distance map, it is easy to fall into the trap Stephen J. Gould (1996) calls "the error of reification". Gould's discussion of early IQ testing and the debate over "general" intelligence in *The Mismeasure of Man* is illustrative of this problem. Two of the pioneers of multivariate statistics, Cyril Burt and Charles Spearman, used factor analysis to examine the results of several aptitude tests for a variety of subjects. They called the first principal component derived from this analysis "G", for general intelligence (Gould, 1996). The problem of this view, however, was that there was no biological or psychological proof of a portion of the human brain housing "general intelligence". Rather, Spearman and Burt had a preconceived notion that there were differences in the general intelligence of ethnic groups and social classes (with rich, white, Northern European males assumed to be the peak of this elitist hierarchy) and used their tests to illustrate this to be so (Gould, 1996). Instead of questioning whether poor people and non-whites tended to test poorly overall due to economic and social marginalisation, the two scientists used a derived factor to represent what they wanted to believe: that there was a general intelligence that linearly ranked different groups (Gould, 1996). Multivariate techniques provide us with useful tools to *interpret* data, but caution must be used when they are employed to *define* results. The former is more of a dynamic process, whereas the latter is a static end point. This truth is attested to by the thousands of children who, after being subjected to IQ tests, were either promoted or held back in school and later occupations on the determination of their "aptitude" by a statistic.

Another problem for this analysis arises from the potential of spatial autocorrelation within the data set. This problem was discussed by Hinch *et al.* (1994) and Nash *et al.* (1999). Hinch *et al.* (1994) point out that geographically near sampling sites in lakes are likely to have similar abiotic factors affecting parameters such as species abundances. In the case of the data collected here, such autocorrelation must be borne in mind when examining how the geographic groupings, e.g., African Lakes and Indo Pacific Reefs, affect the way a fishery was grouped when scored for sustainability in any of the four MDS maps. Even more important may be the very obvious serial autocorrelation implied by the time series data. A related problem was illustrated by Nash *et al.* (1999), who tested the conclusion of Randall *et al.* (1995) that rivers were significantly more productive than lakes on a general global scale. Nash *et al.* (1999) point out that the lakes were from geographically similar areas, as were the streams. After correcting for spatial autocorrelation Nash *et al.* (1999) found lake and stream production differences to be more trivial than originally suggested by Randall *et al.* (1995). The groupings of fisheries within the MDs distance maps suggests that many of the attributes measured do not autocorrelate spatially. This may be especially true of the non biological attribute sets, which capture variables that were specifically chosen such that they would alow for comparison through time. Observation of changes in biological sustainability displayed as much variation as any of the other attribute sets. For example, the fisheries of lake Malawi, San Miguel Bay, Lake Victoria, and Sakumo lagoon all changed sustainability groupings depending on the date of the fishery, see Fig. 3.3. Concerns arising from arguments in Nash *et al.* (1999) are also addressed by the results since the appearance of a fishery in a sustainability grouping is unrelated to geographic qualities. For example, the sustainable fisheries in Fig. 3.3. include pre-20th century Palau, Lake Mweru in 1962, Christmas Island in 1997, Belize in 1996, and Ubolratana Reservoir in 1978, a diverse group in terms of geographic qualities.

4.5. Synthesis

This study has tried to establish a link between biological fisheries sustainability and fisheries sustainability as measured through other disciplines like economics and sociology. In the introduction it was emphasised that for such social science concerns to be relevant to biologists, some mechanistic connection between the different disciplines had to be established. The fisheries examined here helped test the Malthusian overfishing mechanism and its three components; human populations growing faster than their resource base, increasing competition, and the increasing use of destructive gear types. The four attribute sets in this analysis were all designed to capture such Malthusian characteristics. Based on the relation between sustainability groupings in the biological, social, and technological data sets significant support is provided to the Malthusian overfishing mechanism.

The Malthusian overfishing mechanism was illustrated in two major ways. The most important way was provided by directly examining the distance maps and the sustainability groupings suggested by cluster analysis, as in sections 3.1., 3.2., 3.3., 3.4., and 4.2. Defining what attributes were most important to describing sustainability further helped in the direct interpretation of each MDS distance maps. For example, in Figs. 3.3., 3.6., 3.9., and 3.12. the axes have real meanings that describe more subtle qualitative aspects of changes in sustainability. Thus, if a fishery changes its sustainability in any MDS we can see what aspect of that sustainability changed. The other illustration of the Malthusian mechanism was the interdisciplinary examination, which linked the results of the different MDS analyses, seen in sections 3.5., 4.3., and 4.4.

How do the groups suggested by cluster analysis of the four MDS maps compare between the four analyses? All four MDS distance maps produced easily identified clusters. For each MDS at least one cluster was closely identified with sustainability and one with unsustainability, i.e., Malthusian overfishing. In Fig. 3.5 there a strong link suggested between the biological MDS and those for the sociological and technological analyses. As fisheries become more Malthusian in their biological ranking, they are more likely to have a poor score in either, or both, the social or technological MDS. Indeed, for the fisheries that scored lowest in the combined social and technical scoring there was no chance at all of having being associated with a high score in the biological MDS. Bear in mind, however, the converse case, that of fisheries which scored high in the biological MDS: there was no clear association with sustainability or lack thereof in the social or technological MDS. In simple terms this suggests that if a fishery displays characteristics of biological unsustainability, it is highly likely to have Malthusian characteristics in other disciplines as well.

Many other researchers studying tropical fisheries have commented on the links between such social, biological, and gear-associated phenomena. Writing about tropical estuarine fisheries have established similar links between ecological, sociological, and technological phenomena. Blaber (1997) suggested that widespread overexploitation was due to increased numbers of fishers, more efficient gear, mechanisation, lack of accurate data, loss of nursery habitat, and industrial pollution. Harris (1998) said that the ecosystem collapse in Lake Victoria after the introduction of Nile perch was aided by the increased catching power of a growing industrial fishery, agricultural eutrophication, changing land use around the lake, and the breakdown of the traditional fish trading system. With respect to coastal fisheries in Asia, Silvestre and Pauly (1997) argue that excessive fishing effort, inappropriate exploitation patterns, post harvest loss, intersectoral conflict, and habitat degradation all require increased management attention.

The potential value of coherent taxonomies for small scale fisheries in particular was stressed by Christy *et al.* (1991), who in a report to the World Bank recommended the "development of 'rapid fishery assessment' methodologies similar to 'rapid rural assessment' methodologies". The assessment technique examined here provides such taxonomies and provides an interdisciplinary forum that shows a link between the fishing community and the aquatic resources upon which it depends. McManus (1996) argues that fisheries management be approached with a consideration of the social sciences:

> Since fisheries management involves the regulation of human activities, it should properly be considered a social science. Unfortunately, social aspects of management have been largely neglected compared to natural science investigations of the population biology of harvested organisms... Fisheries management is the act of influencing human activities so as to enhance some characteristics

of a harvestable resource, such as production, economic yield, equitable success or sustainability. Thus it is primarily an applied social science, which operates with respect to predictions and recommendations stemming from natural science investigations.

The use of MDS to compare information from different disciplines shows that in many ways the conclusions can be cross validating. Determining which fisheries are most in jeopardy can go a long way in helping decide how to allocate scarce research resources to truly troubled fisheries,

This study has used the concept of Malthusian overfishing as the standard by which to classify fisheries in a way that links biological phenomena to social, economic, and technical aspects of associated fisheries. This is not, however, the limit of this technique. For instance, Pitcher (1999) has used attributes based upon ethics and adherence to the United Nations code of conduct for responsible fisheries (FAO 1995) to generate other MDS analyses. The value of this methodology is the rapidity with which a researcher can compare a fishery anywhere in the world to other fisheries that have been analysed with this method. This methodology has been applied to many different fisheries in many different ecosystems beyond those explored here, for instance, ocean fisheries off Argentina, New Zealand, Scotland, Canada (Pitcher *et al.* 1998a), Alaska, the North Sea, Peru, and the Adriatic (Pitcher *et al.* 1998b).

Successful refinement of this method will involve the following steps;

i: deciding which disciplinary data sets to use,

ii: defining attributes for all disciplinary data sets,

iii: refining measures used to score attributes to,

iv: assessing more fisheries using this technique,

v: including more time series data for fisheries analysed,

vi: comparing scores from different experts for the same fisheries,

vii: including scores from 'non-experts' for comparison.

To aquire a greater degree of precision when carrying out different analyses, it will be particularly important that steps iii, iv, and v be implemented. With respect to refining attributes it would be useful if they were defined more in terms of temporal change. That is, more of the attributes should be questions addressing how change has been manifested over some period of time. This would provide a good complement to recommendations iv and v, providing more of a change in time perspective from which the classification of fisheries can be conducted. If these modifications were successfully implemented fisheries managers would then have a truly rapid, powerful, and visually compelling way to compare the fishery they study to others around the world, using disciplinary perspectives that reinforce each other. Implementation of recommendations vi and vii would be beneficial in broadening the sources of information of this technique and in helping to make the assessment process more transparent to user groups. The last benefit would be the most valuable of all because if biologists can not communicate with the people affected by our recommendations, then we will not be able to effectively serve them by providing useful advice on the fish populations upon which their communities depend.

References

Adhiambo, W.J.O. 1991. Some socio-economic aspects of Lake Victoria artisanal fisheries resources (Kenya). *In* G.W. Ssentongo and N.J. Dampha (eds.), Report of a national seminar on the development and management of the Kenyan fisheries of Lake Victoria; Kisimu Kenya 22-24 July 1991. UNDP/FAO regional Project for Inland Fisheries Planning, RAF/87/099/TD/27/91 (En): pp. 74-92.

Ahmed, M. 1997. Ch. 6: Socioeconomic and policy issues in the floodplain fisheries of Bangladesh. *In* C. Tsai and M. Youssouf Ali (eds.). Openwater fisheries of Bangladesh. The University Press Ltd., Dhaka: pp. 89-98.

Ahmed, N. 1997. Ch. 8: Marketing of fish from selected floodplains in Bangladesh. In. C. Tsai and M. Youssouf Ali (eds.). Openwater fisheries of Bangladesh. The University Press Ltd., Dhaka: pp. 115-125.

Alam, S. S., M. Y. Ali, and C. Tsai. 1997. Ch. 10: Fishing gears of floodplain fisheries of Bangladesh. In. C. Tsai and M. Youssouf Ali (eds.). Openwater fisheries of Bangladesh. The University Press Ltd., Dhaka: pp. 137-152.

Alt, M. 1990. Exploring hyperspace. McGraw-Hill Book Co. Ltd., London: 139 p.

Alverson, D.L., M.H. Freeberg, S.A. Murawski, J.G. Pope. 1994. A global assessment of fisheries bycatch and discards. FAO Fish. Tech. Pap., 339: 233 pp.

Anon. 1989a. SADCC/EEC regional fisheries survey: country situation reports. Gopa Consultants, Bad Homburg: 184 p.

Anon. 1989b. 1989. Fisheries and aquaculture research capabilities and needs in Africa: studies of Kenya, Malawi, Mozambique, Mauritania, Morocco, and Senegal. World Bank Technical Paper number 149: 73 p.

Anon. 1998. Consumer price index: all urban consumers – (CPI – U) US city average. US Dept. of Labour, Bureau of Labour Statistics, http://stats.bls.gov/cpihome.htm

Anon. 1999a. Lake Chivero recreational park, http://mediazw.com/natparks/rp_chiv.htm.

Anon. 1999b. Market barometer. INFOFISH International. No. 3, May / June 1999: pp. 41-44.

Arunga, J. 1991. An overview of Lake Victoria fisheries – Kenyan sector. *In* G.W. Ssentongo and N.J. Dampha (eds.), Report of a national seminar on the development and management of the Kenyan fisheries of Lake Victoria; Kisimu Kenya 22-24 July 1991. UNDP/FAO regional Project for Inland Fisheries Planning, RAF/87/099/TD/27/91 (En): pp. 18-20.

Ataur Rahman, A. K. 1997. Ch. 7: Fish marketing in Bangladesh: status and issues. *In* C. Tsai and M. Youssouf Ali (eds.). Openwater fisheries of Bangladesh. The University Press Ltd., Dhaka: pp. 99-114.

Balirwa, J.S. 1990. The effects of ecological changes in Lake Victoria on the present trophic characteristics of *Oreochromis niloticus* in relation to the species' role as a stabilizing factor of biomanipuloation. In *Anon.* (ed)., Fisheries of the African Great Lakes. International Agricultural Centre, Fisheries and Aquaculture Unit Occasional Paper 3: pp. 58-66.

Beamish, R.J. (Ed.) 1995. Climate change and northern fish populations. Can. Spec. Publ. Fish. Aquat. Sci. 121: 739 p.

Beverton, R.J.H. and S.J. Holt. 1957. On the dynamics of exploited fish populations. 1993 Facsimile reprint, Chapman and Hall, London: 533 pp.

Blaber, S.J.M. 1997. Chapter 8: estuarine fisheries. *In* S.J.M. Blaber, Fish and fisheries of tropical estuaries. Chapman and Hall, London: pp. 233-264.

Blaikie, P., 1985. The political economy of soil erosion. Longman Scientific and Technical, London: 188 p.

Bonfil, R. 1998. Case study: distant water fleets off Mauritania and Senegal. *In* R. Bonfil, G. Munro, U.R. Sumaila, H. Valtysson, M. Wright, T. Pitcher, D. Preikshot, N. Haggan, and D. Pauly (eds.), The footprint of distant water fleets on world fisheries. Endangered Seas Campaign, WWF International, Godalming, UK: pp. 20-38.

Bhukaswan, T. 1985. The Nam Pong basin (Thailand). *In* Petr, T. (ed.), Inland fisheries in multi-purpose river basin planning and development in tropical Asian countries: three case studies. FAO Fish. Tech. Pap.: pp. 55-90.

Bundy, A. 1997. Assessment and Management of multispecies, multigear fisheries: a case study from San Miguel Bay, the Philippines. Ph.D. thesis, Resource Management and Environmental Studies, University of British Columbia: 395 p.

Bwathondi, P.O.J. 1992. The fishery resource base for the Tanzania sector of Lake Victoria. *In* G.W. Ssentongo (ed.), Report of a national seminar on the development and management of Tanzanian fisheries of Lake Victoria. UNDP/FAO Regional Project for Inland Fisheries Planning, RAF/87/099/TD/35/92 (En): pp. 21-29

Central Intelligence Agency. 1995. The World Factbook: 1995-1996. Brassey's, Washington: 512p.

Charles-Dominique, E. 1994. L'exploitation de la lagune Aby (Côte-d'Ivoire) par la pêche artisanale. Dynamique des ressources, de l'exploitation et des pêcheries. ORSTROM Travaux et Documents Microédités. ORSTROM, Paris: 407 p.

Chibwe, L.C., M.C. Simusonkwe, A.C. Phiri, and D.S. Muwowo. 1988. Zambia's presentation to the SADCC statistics workshop. *In* SADCC, Workshop on fisheries statistics in the SADCC region, Lusaka, Zambia, 25-29 April, 1988. Malawi Government Report of SADCC, Lilongwe: pp. 176-198.

Christy, F.T., Jr., C. Bailey, A. Hanson, S. Jentoft, J. Kurien, C. Nauen, J.-P. Platteau, J. Thompson, and R. Willmann. 1991. Small scale fisheries: research needs. World Bank Tech. Pap. (Fisheries Series) 152: 35 p.

Clarke, K.R. and R.M. Warwick. 1994. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth Marine Laboratory, Plymouth: 144 p.

Clarke, R.P. and J.N. Ianelli. 1995. Current paradigms in trochus management and opportunities to broaden perspectives. *In* P. Dalzell and T.J.H. Adams (eds.), South Pacific Commission and Forum Fisheries Agency workshop on the management of south Pacific inshore fisheries: Vol. 1. South Pacific Commission, Noumea: pp. 371-414.

Cliff, N. 1987. Analyzing multivariate data. Harcourt, Brace, Jovanovich, Inc., Orlando FL: 494 p.

Cooper, R.A. and A.J. Weekes. 1983. Section 10: multivariate analysis. *In* R.A. Cooper and A.J. Weekes (eds.), Data, models and statistical analysis. Philip Allan Pubs. Inc., Deddington, Oxford: pp. 240-259.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature, 387: pp. 253-260.

Cowx, I.G. and C.K. Kapasa. 1995. Species changes in reservoir fisheries following impoundment: the case of Lake Itezhi-tezhi, Zambia. *In* T.J. Pitcher and P.J.B. Hart (eds.), The impact of species changes in African lakes. Chapman and Hall, London: pp. 321-332.

de Iongh, H.H., P.C. Spliethoff, & F. Roest, 1995. The impact of an introduction of sardine into Lake Kivu. *In* T.J. Pitcher & P.J.B. Hart (eds.), The impact of species changes in African lakes. Chapman & Hall, London: pp. 277-297.

Donda, S.J. 1997. Fisheries co-management in Malawi: case study of Lake Chiuta fisheries. *In* A.K. Normann, J.R. Nielson, and S. Sverdrup-Jensen (eds.), Fisheries co-management in Africa. Institute for Fisheries Management and Coastal Community Development, Hirtshals, DK: pp. 21-40.

Entsua-Mensah, M., K.A. Koranteng, and P.K. Ofori-Danson. 1997. Governance of the fisheries resources of three West African coastal lagoons (manuscript). Principle author: Institute of Aquatic Biology (CSIR), P.O. Box 38, Achimota, Ghana.

Everitt, B. 1974. Cluster analysis. Heinemann Educational Books Ltd., London: 122 p.

FAO. 1993a. Fisheries management in the south east arm of Lake Malawi, the Upper Shire River and Lake Malombe, with particular reference to the fisheries on chambo (*Oreochromis* spp.). CIFA Technical Paper. No. 21. Rome, FAO: 113p.

FAO. 1993b. World fishery production 1950-1993: Supplement to the FAO yearbook of fisheries statistics 1993, vol. 76, catches and landings. FAO, Rome, on 2 floppy discs.

FAO. 1995. Code of conduct for responsible fisheries. Fao, Rome: http://www.fao.org/fi/agreem/codecond/codecon.asp.

FAO. 1998. http://apps.fao.org/cgi-bin/nph-db.pl?subset=fisheries

Garcia, S. and C. Newton. 1997. Current situation, trends and prospects in world capture fisheries. *In* E. Pikitich, D.D. Huppert and M. Sissenwine (eds.), Global trends: fisheries management. American Fisheries Society, Bathesda: pp. 3-27.

Goffinet, T. 1992. Development and fisheries management: the case of northwest Africa. Ocean and Coastal Management, 17: 105-136.

Gould, S.J. 1996. The real error of Cyril Burt: factor analysis and the reification of intelligence. *In* S.J. Gould, The mismeasure of man. W.W. Norton and Co., Inc., New York: pp. 264-350.

Hachongela, P., J. Jackson, I. Malasha, W. Muriritirwa, K. Nyikahadzoi, and S. Sen. 1996. An analysis of emerging co-management arrangements in the Zambian and Zimbabwean inshore fisheries of Lake Kariba. Working Paper #10 IFM, Hirtshals, Denmark: 47 p.

Hannesson, R. 1998. The role of economic tools in redefining fisheries management. *In* T. Pitcher, P.J.B. Hart, and D. Pauly (eds.), Reinventing fisheries management. Kluwer Academic Publishers, London: pp. 251-260.

Harper, A.C. and L.J. Lambert. 1994. The health of populations: and introduction (2nd ed.). Springer Publishing Co. Inc., New York: 273 p.

Hilborn, R. and C.J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York: 570 p.

Hinch, S.G., K.M. Somers, and N.C. Collins. 1994. Spatial autocorrelation and assessment of habitata-abundance relationships in littoral zone fish. Can. J. Fish. Aquat. Sci. 51: 701-712.

Jiddawi, N.S. and C.A. Muhando. 1995. Review on selected marine living resources of Zanzibar: status and issues for conservation. *In* Anon. (ed.) Coastal systems and sustainable development in Africa. UNESCO Reports in Marine Science 66: pp. 65-77.

Johannes, R.E. 1981. Words of the lagoon: fishing and marine lore in the Palau district of Micronesia. Univ. of California Press, Berkely: 245 p.

Johannes, R.E. and J.W. MacFarlane. 1991. Traditional fishing in the Torres Strait islands. CSIRO Division of Fisheries, Hobart: 268 p.

Karenge, L. and J. Kolding. 1995. Inshore fish population and species changes in Lake Kariba, Zimbabwe. *In* T.J. Pitcher and P.J.B. Hart (eds.), The impact of species changes in African lakes. Chapman and Hall, London: pp. 245-275.

Kark, S.L. 1974. Epidemiology and community medicine. Appleton-Century-Crofts, New York: 470 p.

Koranteng, K.A., M. Entsua-Mensah, and P.K. Orfori-Danson. 1997a. A 20 year change in the fish and fisheries of a small West African lagoon (manuscript). Principle author: Fisheries Department, Marine Fisheries Research Division, P.O. Box B-62, Tema, Ghana.

Koranteng, K.A., P.K. Orfori-Danson, and M. Entsua-Mensah. 1997. Comparative study of the fish and fisheries of three coastal lagoons in West Africa (manuscript). Principle author: Fisheries Department, Marine Fisheries Research Division, P.O. Box B-62, Tema, Ghana.

Kponhassia, G. and A. Konan. 1998. The traditional management of artisanal fisheries in Côte d'Ivoire: the case of Aby Lagoon. *In* A.K. Normann, J.R. Nielson, and S.

Sverdrup-Jensen (eds.), Fisheries co-management in Africa. Institute for Fisheries Management and Coastal Community Development, Hirtshals, DK: pp. 273-290.

Kudhongania, A.W. 1990. The future prospects for the Lake Victoria fishery. *In* Anon. (ed)., Fisheries of the African Great Lakes. International Agricultural Centre, Fisheries and Aquaculture Unit Occasional Paper 3: pp. 75-82.

Kudhongania, A.W., U. Jinja, and E.J. Cohen. 1992. Trends in fisheries development, prospects and limitations for Lake Victoria (Uganda sector). *In* G.W. Ssentongo and F.L. Orach-Meza (eds.), Report of a national seminar on the development and management of Ugandan fisheries of Lake Victoria; Kisimu Kenya 22-24 July 1991. UNDP/FAO regional Project for Inland Fisheries Planning (IFIP) RAF/87/099/TD/31/ 92 (En): pp. 59-76.

Lowe, R. H. 1952. Report on the tilapia and other fish and fisheries of Lake Nyasa 1945-47. Colonial Office, Fishery Publications: Vol. 1, No. 2. London: Her Majesty's Stationery Office: 126 p.

Ludwig, D., R. Hilborn and C. Walters. 1993. Uncertainty, resource explitation, and conservation: lessons from history. Science 260: 17, 36.

Lyiko, E. and V.M. Pandu. 1988. Tanzania fisheries data collection and processing system. *In* Anon. (ed.), SADDC Fisheries statistics workshop, Lusaka, Zambia. Malawi Government Report of SADDC, Lilongwe: pp. 143-175.

Malthus, T.R. 1803. An essay on the principle of population. Reprinted 1992, Cambridge University Press, Cambridge: 392 p.

Manly, B.F.J. 1986. Multivariate statistical methods: a primer. Chapman and Hall, New York: 159 p.

Maus, J. 1997. Sustainable fisheries information management in Mauretania: implications of institutiona linkages and the use of remote sensing for improving the quality and interpretation of fisheries and biophysical data. PhD thesis. University of Warwick, Coventry: 269 p.

McCay, B.J. and J.M. Acheson. 1987. The question of the commons: the culture and ecology of communal resources. Univ. of Arizona Press, Tuscon: 439 p.

McClanahan, T.R., J. Rubens, H. Glaesel, & R. Kiambo, 1996, The Diani-Kinondo coral reefs, fisheries, and traditional management. Coral Reef Conservation Project, New York: 28p.

McGoodwin, J.R. 1990. Crisis in the world's fisheries: people, problems and policies. Stanford Univ. Press, Stanford: 235 p.

McManus, J.W. 1996. Social and economic aspects of reef fisheries and their management. *In* N.V.C. Polunin and C.M. Roberts (eds.), Reef fisheries. Chapman and Hall, London: pp. 249-282.

McManus, J.W., C.L. Nañola, R.B. Reyes, Jr., and K.N. Kesner. 1992. Resource ecology of the Bolinao Coral Reef system. ICLARM Stud. Rev. 22: 117 p.

Mmopelwa, T.G. and S.M. Nengu. 1988. Problems associated with the introduction of a statistical recording system in Botswana. *In* SADCC, Workshop on fisheries statistics in the SADCC region, Lusaka, Zambia, 25-29 April, 1988. Malawi Government Report of SADCC, Lilongwe: pp. 52-54.

Mwamoto, B.A.S. and R.B. Hoza. 1992. Trends in fisheries development, prospects and limitations for Lake Victoria. *In* G.W. Ssentongo (ed.), Report of a national seminar on the development and management of the Tanzanian fisheries of Lake Victoria;

Kisimu Kenya 22-24 July 1991. UNDP/FAO regional Project for Inland Fisheries Planning (IFIP) RAF/87/099/TD/35/92(En): pp. 30-51.

Nash, C.H., J.S. Richardson, and S.G. Hinch. 1999. Spatial autocorrelation and fish production in freshwaters: a comment on Randall *et al.* (1995). Can. J. Fish. Aquat. Sci. 56: 1696-1699.

Neal, R.A. 1982. Dilemna of the small-scale fisherman. ICLARM Newsletter 5(3): 7-9.

Ogari, J. 1991. Trends in fisheries development, prospects and limitations. *In* G.W. Ssentongo and N. J. Dampha (eds.). 1991. Report of a national seminar on the development and management of the Kenyan fisheries of Lake Victoria, Kisimu, Kenya, 22-24 July 1991. Food and Agriculture Organization of the UNDP/FAO Regional Project for Inland Fisheries Planning, RAF/87/099/TD/27/91 (En): pp. 59-73.

Padilla, J.E., M.L. Dalusung, and G.B. Calica. 1995. Economics of capture fisheries in San Miguel Bay, Philippines. *In* G. Silvestre, C. Luna and J. Padilla (eds.), Multidisciplinary assessment of the Fisheries in San Miguel Bay, Philippines (1992-1993). ICLARM Tech. Rep. 47, CD-ROM. ICLARM, Manila.

Paul, S. K. and M. A. Mazid. 1997. Ch. 9: Limnology of some floodplains of Bangladesh. *In* C. Tsai and M. Youssouf Ali (eds.). Openwater fisheries of Bangladesh. The University Press Ltd., Dhaka: pp. 125-136.

Pauly, D. 1975. On the ecology of a small West African lagoon. Meerforschung / Rep. Mar. Res. 24: 46-62.

Pauly, D. 1982. History and status of the San Miguel Bay fisheries. *In* I.R. Smith and A.N. Mines (eds.), Small scale fisheries of San Miguel Bay, Philippines: economics of production and marketing. ICLARM Tech. Rep. 8: pp. 95-124.

Pauly, D. 1988. Some definitions of overfishing relevant to coastal zone management in Southeast Asia. Trop. Coastal Area Manage. 3(1): pp. 14-15.

Pauly, D. 1990. On Malthusian overfishing. Naga, the ICLARM Quarterly 13(1): 3-4.

Pauly, D. 1994a. Theory and practice of overfishing. *In* D. Pauly (ed.), On the sex of fish and the gender of scientists: a collection of essays in fisheries science. Chapman and Hall, London: pp. 89-103.

Pauly, D. 1994b. On Malthusian overfishing. *In* D. Pauly (ed.), On the sex of fish and the gender of scientists: a collection of essays in fisheries science. Chapman and Hall, London: pp. 112-117.

Pauly, D. 1997. Small-scale fisheries in the tropics: marginality, marginalization, and some implications for fisheries management. *In* E. Pikitich, D.D. Huppert and M. Sissenwine (eds.), Global trends: fisheries management. American Fisheries Society, Bathesda: pp. 40-49.

Pauly, D., G. Silvestre, and I.R. Smith. 1989. On development, fisheries and dynamite: a brief review of tropical fisheries management. Nat. Res. Modeling 3 (3): 307-329.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres, Jr. 1998. Fishing down marine food webs. Science 279: pp. 860-863.

Pearce, M. 1995. Effects of exploitation on the pelagic fish community in the south of Lake Tanganyika. *In* T.J. Pitcher and P.J.B. Hart (eds.), The impact of species changes in African lakes. Chapman and Hall, London: pp. 425-441.

Pinkerton, E. and M. Weinstein. 1995. Fisheries that work: sustainability through community-based management. The David Suzuki Foundation, Vancouver: 199 p.

Petit, P. and A. Kiyuku. 1995. Changes in the pelagic fisheries of northern Lake Tanganyika during the 1980's. *In* T.J. Pitcher and P.J.B. Hart (eds.), The impact of species changes in African lakes. Chapman and Hall, London: pp. 443-453.

Pitcher, T. 1998. A cover story: fisheries may drive stocks to extinction. Rev. fish. Biol. Fisheries. 8 (3): pp. 367-370.

Pitcher, T. and P.J.B. Hart (Eds.). 1995. The impact of species changes in African lakes. Chapman and Hall, London: 601 p.

Pitcher, T., A. Bundy, D. Preikshot, T. Hutton, and D. Pauly. 1998a. Measuring the unmeasurable: a multivariate and interdisciplinary method for rapid appraisal of the health of fisheries. *In* T. Pitcher, P.J.B. Hart, and D. Pauly (eds.), Reinventing fisheries management. Kluwer Academic Publishers, London: pp. 31-54.

Pitcher, T., S. Mackinson, M. Vasconcellos, L. Nøttestad, and D. Preikshot. 1998b. Rapid appraisal of the status of fisheries for small pelagics using multivariate, multidisciplinary ordination. *In* F. Funk, T.J. Quinn II, J. Heifetz, J.N. Ianelli, J.E. Powers, J.F. Schweigert, P.J. Sullivan, and C.-I. Zhang (eds.) Fishery stock assessment models. Alaska Sea Grant College Program Report No. AK-SG-98-01. University of Alaska, Fairbanks: pp. 759-782.

Pitcher, T. and D. Preikshot. 2000. Rapfish: a rapid appraisal technique to evaluate the sustainability status of fisheries. Fish. Res. In Press.

Pitcher, T. 1999. Rapfish, a rapid appraisal technique for fisheries, and its application to the code of conduct for responsible fisheries. FAO Fisheries Circular 947: 47 p.

Poiner, I.R. and A.N. Harris. 1991. Fisheries of Yorke Island. In R.E. Johannes and J.W. MacFarlane (eds.), Traditional fishing in the Torres Strait Islands. CSIRO, Hobart: pp. 115-143.

Pomeroy, R.S. and M.D. Pido. 1995. Initiatives towards fisheries co-management in the Philippines. Mar. Pol. 19(3): 213-226.

Preikshot, D. and D. Pauly. 1998. Multivariate interdisciplinary assessment of small-scale tropical fisheries. *In* F. Funk, T.J. Quinn II, J. Heifetz, J.N. Ianelli, J.E. Powers, J.F. Schweigert, P.J. Sullivan, and C.-I. Zhang (eds.) Fishery stock assessment models. Alaska Sea Grant College Program Report No. AK-SG-98-01. University of Alaska, Fairbanks: pp. 803-814.

Preikshot, D., E. Nsiku, T. Pitcher, and D. Pauly. 1998. An Interdisciplinary evaluation of the status and health of African lake fisheries using a rapid appraisal technique. J. Fish. Biol. 53(A): 381-393.

Priyono, B.E. and B. Sumiono. 1997. The marine fisheries of Indonesia, with emphasis on the coastal demersal stocks of the Sunda Shelf. *In* G. Silvestre and D. Pauly (eds.), Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53: pp. 38-46.

Pryor, F.L. 1988. Income distribution and economic development in Malawi: some historical statistics. World Bank Discussion Papers: 36. 83 p.

Randall, R.G., J.R.M. Kelso, and C.K. Minns. 1995. Fish production in freshwaters: are rivers more productive than lakes ? Can. J. Fish. Aquat. Sci. 52: 631-643.

Reynolds, J.E. and D.F. Gréboval. 1988. Socio-economic effects of the evolution of Nile Perch fisheries in Lake Victoria: a review. CIFA Tech. Pap., 17: 148 p.

Reynolds, J.E., D.F. Gréboval and P. Mannini. 1995. Thirty years on: the development of the Nile perch fishery in Lake Victoria. *In* T.J. Pitcher and P.J.B. Hart (eds.), The impact of species changes in African lakes. Chapman and Hall, London: pp. 181-214.

Ricker, W.E. 1954. Stock and recruitment. J. Fish. Res. Bd. Can. 11: pp. 559-623.

Ruddle, , K.R. 1996. The Geography and human ecology of reef fisheries. *In* N.V.C. Polunin and C.M. Roberts (eds.), Reef fisheries. Chapman and Hall, London: pp. 137-160.

Samonte, G.P.B. and R.S. Pomeroy. 1995. Fish marketing and distribution in the coastal municipalities adjoining San Miguel Bay, Philippines. *In* G. Silvestre, C. Luna, and J. Padilla (eds.). Multidisciplinary assessment of the fisheries in San Miguel Bay, Philippines (1992-1993). ICLARM Tech. Rep. 47, CD-ROM. ICLARM, Manila.

Sanyanga, R.A. and V. Mangoro. 1989. Organisation of fish catch data in Zimbabwe. *In* SADCC, Workshop on fisheries statistics in the SADCC region, Lusaka, Zambia, 25-29 April, 1988. Malawi Government Report of SADCC, Lilongwe: pp. 199-233.

Silvestre, G. E. Cinco, R. Gatchalian and J. Diaz. 1994. Catch and effort in the fisheries of San Miguel Bay, Philippines. *In* G. Silvestre, C. Luna, and J. Padilla (eds.). Multidisciplinary assessment of the fisheries in San Miguel Bay, Philippines (1992-1993). ICLARM Tech. Rep. 47, CD-ROM. ICLARM, Manila.

Silvestre, G., and E. Cinco. 1995. Capture fisheries and coastal resources management issues. San Miguel Bay capture fisheries – an overview. *In* ICLARM, The San Miguel Bay Story. CD-ROM, Manila, Bureau of Fisheries and Aquatic and Fisheries Sector Program.

Silvestre, G., E. Cinco, R. Gatchalian, and J. Diaz. 1995. Catch and effort in the San Miguel Bay fisheries. *In* G. Silvestre, C. Luna and J. Padilla (eds.), Multidisciplinary assessment of the Fisheries in San Miguel Bay, Philippines (1992-1993). ICLARM Tech. Rep. 47, CD-ROM. ICLARM, Manila.

Silvestre, G. and D. Pauly. 1997. Management of tropical coastal fisheries in Asia. an overview of key challenges and opportunities. *In* G. Silvestre and D. Pauly (eds.), Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 58: pp. 8-27.

Smith, I.R., A.N. Mines, and G. Banacia. 1982. The research site, data collection and methods of analysis. *In* I.R. Smith and A.N. Mines (eds.) Small-scale fisheries of San Miguel Bay, Philippines: economics of production and marketing. ICLARM Tech. Rep. 8: p. 1-26.

Smith, I.R., D. Pauly, and A.N. Mines. 1983. Small scale fisheries of San Miguel Bay, Philippines: options for management and research. ICLARM Tech. Rep. 11: 80 p.

Sparholt, H. 1995. Using the MSVPA/MSFOR model to estimate the right-hand side of the Ricker curve for Baltic cod. ICES J. Mar. Sci. 52: 819-826.

Ssentono, G.W. 1991. An overview on fisheries development and management issues for the Kenyan sector of Lake Victoria. *In* G.W. Ssentongo and N. J. Dampha (eds.), Report of a national seminar on the development and management of the Kenyan fisheries of Lake Victoria, Kisimu, Kenya, 22-24 July 1991. Food and Agriculture Organization of the UNDP/FAO Regional Project for Inland Fisheries Planning, RAF/87/099/TD/27/91 (En): pp. 21-28.

Ssentongo, G.W. (Ed.). 1992. Report of a national seminar on the development and management of Tanzanian fisheries of Lake Victoria. UNDP/FAO Regional Project for Inland Fisheries Planning, RAF/87/099/TD/35/92 (En): 86 p.

Ssentongo, G.W. and N. J. Dampha (Eds.). 1991. Report of a national seminar on the development and management of the Kenyan fisheries of Lake Victoria, Kisimu, Kenya, 22-24 July 1991. Food and Agriculture Organization of the UNDP/FAO Regional Project for Inland Fisheries Planning, RAF/87/099/TD/27/91 (En): 124 p.

Ssentongo, G.W. and F. L. Orach-Mesa (Eds.). 1992. Report of a national seminar on the development and management of Ugandan fisheries of Lake Victoria. UNDP/FAO Regional Project for Inland Fisheries Planning, RAF/87/099/TD/31/92 (En): 137 p.

Stalans, L.J. 1995. Multidimensional scaling. Pp. 137-168, in L.G. Grimm and P.R. Yarnold (eds.), Reading and understanding multivariate statistics. American Psychological Association, Washington: 373 p.

StatSoft. 1995a. Cluster analysis. In Anon. (ed.) Statistica for windows: vol 3. StatSoft Inc., Tulsa, OK: pp. 3135-3164.

Statsoft. 1995b. Multidimensional scaling. In Anon. (ed.) Statistica for windows: vol 3. StatSoft Inc., Tulsa, OK: pp. 3165-3196.

Stoneman, C. and L. Cliffe. 1989. Zimbabwe: politics, economics and society London: Printer Publishers Ltd: 210p.

Sunderlin, W.D. 1995. Livlihood options for fishing families in San Miguel Bay, Philippines. *In* G. Silvestre, C. Luna and J. Padilla (eds.), Multidisciplinary assessment of the Fisheries in San Miguel Bay, Philippines (1992-1993). ICLARM Tech. Rep. 47, CD-ROM. ICLARM, Manila.

Tabachnick, B.G. and L.S. Fidell. 1996. Using multivariate statistics 3rd ed. Harper Collins Pubs. Inc.: 880 p.

Torgerson, W.S. 1952. Multidimensional scaling I: theory and method. Psychometrica 17: 401-419.

Tufte, E.R. 1997. Visual explanations: images and quantities, evidence and narrative. Graphics Press, Cheshire, CT: 157 p.

Tulay, E. and I.R. Smith. 1982. Costs and earnings of mini trawlers. *In* I.R. Smith and A.N. Mines (eds.), Small-scale fisheries of San Miguel Bay, Philippines: economics of production and marketing. ICLARM Tech. Rep. 8: pp. 64-77.

Turner, G.F. 1995. Management, conservation and species changes of exploited fish stocks in Lake Mala i. *In* T.J. Pitcher and P.J.B. Hart (eds.), The impact of species changes in African lakes. Chapman and Hall, London: pp. 365-395.

Vakily, J.M. 1982. Catch and effort in the trawl fishery. *In* D. Pauly and A.N. Mines (eds.), Small-scale fisheries of San Miguel Bay, Philippines: biology and stock assessment. ICLARM Tech. Rep. 7: pp. 65-94.

Walters, C., V. Christensen, and D. Pauly. 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. Rev. Fish. Biol. Fisheries 7 (2): 139-172.

Walters, C., D. Pauly, and V. Christensen. In press. Ecospace: prediction of mesoscale spatial patterns in trophic relationships of exploited ecosystems, with emphasis on the impacts of marine protected areas. Ecosystems.

Yater, F., A.E. Esporlas, and I.R. Smith. 1982. Economic aspects of processing and marketing, p. 104-130. In: I.R. Smith and A.N. Mines (eds.) Small scale fisheries of

San Miguel Bay, Philippines: economics of production and marketing. ICLARM Tech. Rep. 8.

Young, F.W. 1987. Chapter 1: History. *In* F.W. Young and R.M. Hamer (eds.) Multidimensional scaling: history, theory, and applications. Lawrence Erlbaum Associates, Hillsdale, NJ: 317 p.

Young, R. 1988. Zambia: adjusting to poverty. Ottawa, the North-South Institute. 52p.

Zar, J.H. 1984. Biostatistical analysis (2nd ed.). Prentice-Hall, New Jersey: 718 p.

Appendix 1

Table A1. Attribute scores for the 54 fisheries analysed in the biological attribute set

Fishery	Catch / fisher	Exploitation status	Trophic level	Migratory Range	Catch before Maturity	Discards	# Spp
aby86	2.90	1.00	2.80	1.00	1.00	2.00	0.00
bad	0.01	0.00	1.00	0.00	0.00	0.00	0.00
bang90	0.04	0.00	2.50	0.00	0.00	2.00	1.00
bel96	0.32	1.00	2.50	0.00	1.00	2.00	1.00
bol91	0.30	0.00	2.00	1.00	1.00	2.00	2.00
cabo84	4.20	2.00	2.90	0.00	1.00	2.00	0.00
chil86	11.89	1.00	2.90	1.00	1.00	2.00	0.00
chil94	9.84	0.00	2.90	1.00	0.00	2.00	0.00
chiu86	3.44	2.00	2.90	1.00	1.00	2.00	0.00
chiu93	4.79	1.00	2.90	1.00	1.00	1.00	0.00
chiw89	1.50	1.00	2.50	0.00	1.00	2.00	0.00
cocos97	0.20	1.00	2.70	0.00	1.00	1.00	1.00
diki95	1.50	0.00	2.50	0.00	0.00	2.00	2.00
fsm93	0.05	1.00	2.00	0.00	2.00	2.00	0.00
good	14.00	2.00	5.00	2.00	2.00	2.00	2.00
gpry97	0.60	0.00	4.50	0.00	1.00	1.00	0.00
itte94	1.37	1.00	2.80	0.00	1.00	2.00	0.00
kivu93	0.46	2.00	2.50	1.00	2.00	1.00	0.00
krzam95	1.27	1.00	2.50	1.00	1.00	2.00	0.00
krzim95	3.20	1.00	2.70	1.00	1.00	2.00	1.00
loby97	0.02	1.00	3.20	1.00	1.00	1.00	0.00
malb93	2.00	0.00	2.50	0.00	0.00	2.00	0.00
malw47	3.92	2.00	2.20	0.00	1.00	1.00	0.00
malw93	1.44	1.00	2.50	0.00	0.00	2.00	0.00
maur89	1.24	0.00	2.50	1.00	1.00	2.00	0.00
muzm62	3.50	2.00	3.30	1.00	2.00	2.00	1.00
muzm72	1.30	1.50	3.40	1.00	2.00	2.00	1.00
muzm82	1.80	1.00	2.90	1.00	1.00	2.00	1.00
mzmh94	4.50	1.00	2.30	1.00	1.00	2.00	1.00
mzml94	1.04	1.00	2.50	1.00	1.00	2.00	0.00
octy97	1.10	1.00	3.20	0.00	1.00	1.00	0.00
okng90	2.50	1.00	3.00	1.00	1.00	2.00	0.00
pal80	0.31	1.00	3.00	0.00	1.00	2.00	1.00
palpre00	0.37	2.00	3.00	0.00	2.00	2.00	1.00
ruk93	3.58	1.00	2.70	0.00	1.00	2.00	0.00
sak71	1.00	0.00	2.40	0.00	1.00	2.00	0.00
sak94	2.19	0.00	2.20	0.00	0.00	2.00	1.00
sbss81	1.80	1.00	3.19	1.00	2.00	2.00	1.00
sbss93	2.50	0.00	3.05	1.00	0.00	2.00	2.00
sen89	6.26	0.00	2.60	1.00	1.00	2.00	1.00
smbm81	10.00	1.00	3.19	1.00	0.00	2.00	0.00
smbm93	3.62	0.00	3.05	1.00	0.00	1.00	0.00
tantz93	7.80	1.00	3.80	2.00	1.00	2.00	1.00
ubol78	0.33	1.00	2.00	0.00	1.00	2.00	1.00
vkenp85	6.00	0.00	3.50	1.00	0.00	2.00	1.00
vkenp89	4.50	0.00	3.60	1.00	0.00	2.00	0.00
vtanp85	5.63	1.00	3.50	1.00	1.00	2.00	0.00
vtanp89	6.83	1.00	3.60	1.00	0.00	0.00	0.00
vugnp85	4.69	1.00	3.50	1.00	1.00	2.00	0.00
vugnp89	4.41	0.00	3.60	1.00	0.00	1.00	0.00
xmas97	0.20	1.00	2.70	1.00	1.00	1.00	1.00

Table A1. Continued

Fishery	Catch / fisher	Exploitation status	Trophic level	Migratory Range	Catch before Maturity	Discards	# Spp
yorke85	1.25	1.00	3.00	1.00	1.00	1.00	0.00
zdem85	0.83	1.00	3.00	1.00	0.00	2.00	2.00
zdem95	0.45	0.00	3.00	1.00	0.00	2.00	2.00

Table A2. Attribute scores for the 54 fisheries analysed in the economic attribute set

Fishery	Price	Fishing in GNP	GNP / Pers.	Other $	Fisher vs ave. income	Kin help	Location of markets
aby86	373.18	0.00	947.79	2.00	1.00	1.00	2.00
bad	0.00	0.00	0.00	0.00	0.00	0.00	0.00
bang90	1701.54	2.00	765.11	1.00	1.00	0.00	1.00
bel96	8005.10	2.00	1720.84	1.00	2.00	1.00	0.00
bol91	702.55	1.00	1236.89	1.00	0.00	1.00	2.00
cabo84	649.66	2.00	124.16	2.00	2.00	1.00	2.00
chil86	162.41	0.00	231.93	1.00	2.00	1.00	1.00
chil94	265.86	0.00	404.86	2.00	2.00	1.00	1.00
chiu86	32.85	0.00	231.93	2.00	2.00	1.00	1.00
chiu93	101.73	0.00	415.22	2.00	2.00	1.00	1.00
chiw89	256.45	1.00	520.97	1.00	0.00	1.00	2.00
cocos97	0.00	0.00	11900.31	0.00	0.00	0.00	2.00
diki95	656.17	0.00	787.40	2.00	1.00	0.00	2.00
fsm93	761.25	1.00	1038.06	0.00	2.00	0.00	0.00
good	9000.00	2.00	1300.00	2.00	2.00	1.00	2.00
gpry97	1489.10	0.00	2498.27	2.00	1.00	0.00	1.00
itte94	2.11	0.00	283.40	2.00	2.00	1.00	2.00
kivu93	467.13	0.00	553.63	2.00	0.00	1.00	2.00
krzam95	530.84	0.00	74.80	1.00	1.00	0.00	2.00
krzim95	530.84	0.00	380.58	1.00	1.00	1.00	1.00
loby97	5040.50	0.00	2498.27	1.50	2.00	0.00	0.00
malb93	337.99	0.00	415.22	2.00	2.00	1.00	2.00
malw47	134.53	1.00	254.30	1.00	2.00	1.00	2.00
malw93	337.99	0.00	415.22	2.00	2.00	1.00	2.00
maur89	403.23	2.00	411.29	2.00	1.00	1.00	0.00
muzm62	1655.63	0.00	5794.70	1.00	0.00	1.00	1.00
muzm72	2392.34	0.00	3110.05	1.00	1.00	1.00	1.00
muzm82	725.39	0.00	1398.96	1.00	2.00	1.00	1.00
mzmh94	168.35	0.00	759.11	1.00	2.00	1.00	0.00
mzml94	2.11	1.00	262.98	1.00	2.00	0.50	1.00
octy97	1090.34	0.00	2498.27	2.00	1.00	0.00	1.00
okng90	1182.10	0.00	803.37	1.00	0.00	1.00	2.00
pal80	303.40	2.00	2742.72	2.00	0.00	0.00	0.00
palpre00	0.00	2.00	0.00	2.00	1.00	0.00	2.00
ruk93	65.45	1.00	175.09	1.00	2.00	0.50	1.00
sak71	617.28	1.00	987.65	0.00	2.00	0.00	2.00
sak94	236.17	0.00	1012.15	1.00	2.00	1.00	2.00
sbss81	399.75	0.00	825.08	2.00	0.00	1.00	1.50
sbss93	523.00	0.00	588.24	2.00	0.00	0.00	1.00
sen89	403.23	1.00	580.65	2.00	0.00	1.00	1.00

Table A2. Continued

Fishery	Price	Fishing in GNP	GNP / Pers.	Other $	Fisher vs ave. income	Kin help	Location of markets
smbm81	210.40	0.00	825.08	2.00	2.00	0.00	0.50
smbm93	460.21	0.00	588.24	2.00	0.00	0.00	0.50
tantz93	65.45	1.00	175.09	1.00	2.00	0.50	1.00
ubol78	306.75	0.00	7668.71	1.00	0.00	0.00	1.00
vkenp85	195.85	0.00	1115.24	1.00	1.00	0.00	1.00
vkenp89	186.61	1.00	967.74	1.00	1.00	0.00	0.50
vtanp85	250.16	0.00	557.62	1.00	2.00	0.00	1.00
vtanp89	177.42	1.00	483.87	1.00	2.00	0.00	2.00
vugnp85	339.69	0.00	1115.24	2.00	2.00	0.00	2.00
vugnp89	483.87	0.00	967.74	1.00	0.00	0.00	1.00
xmas97	0.00	0.00	11900.31	0.00	0.00	1.00	2.00
yorke85	1933.09	0.00	10566.91	1.00	0.00	1.00	2.00
zdem85	557.62	2.00	557.62	1.00	1.00	0.00	2.00
zdem95	577.43	1.00	393.70	1.00	1.00	0.00	1.00

Table A3. Attribute scores for the 54 fisheries analysed in the sociological attribute set

Fishery	Socialisation	Community growth	Education level	Conflict	Info. sharing	Influence on regs	Fishing income
aby86	2.00	0.00	1.00	2.00	1.00	1.00	2.00
bad	0.00	0.00	0.00	0.00	0.00	0.00	0.00
bang90	1.00	0.00	1.00	1.00	1.00	0.00	1.00
bel96	2.00	1.00	1.00	1.00	2.00	2.00	1.00
bol91	0.00	0.00	0.00	1.00	1.00	1.00	1.00
cabo84	0.00	2.00	1.00	2.00	1.00	0.00	2.00
chil86	0.00	0.00	0.00	2.00	1.00	0.00	2.00
chil94	0.00	0.00	1.00	2.00	1.00	0.00	2.00
chiu86	0.00	2.00	1.00	2.00	1.00	0.00	2.00
chiu93	0.00	0.00	1.00	2.00	1.00	0.00	2.00
chiw89	0.00	1.00	1.00	0.00	1.00	0.00	1.00
cocos97	1.00	2.00	0.00	2.00	2.00	1.00	0.00
diki95	1.00	0.00	0.50	0.00	2.00	1.00	2.00
fsm93	0.00	2.00	1.00	2.00	2.00	1.00	1.00
good	2.00	2.00	2.00	2.00	2.00	2.00	2.00
gpry97	1.00	1.00	0.00	2.00	1.00	2.00	2.00
itte94	0.00	0.00	1.00	1.00	0.00	2.00	1.00
kivu93	2.00	0.00	0.50	2.00	1.00	1.00	0.00
krzam95	0.00	2.00	1.00	0.00	1.00	1.00	1.00
krzim95	0.00	2.00	1.00	1.00	1.00	2.00	1.00
loby97	1.00	1.00	0.00	2.00	0.00	2.00	2.00
malb93	0.00	0.00	0.00	1.00	1.00	1.00	2.00
malw47	2.00	1.00	1.00	1.00	0.00	2.00	2.00
malw93	0.00	0.00	0.00	1.00	1.00	1.00	2.00
maur89	1.00	0.00	0.00	1.00	1.00	1.00	2.00
muzm62	0.00	1.00	0.00	2.00	1.00	0.00	1.00
muzm72	0.00	1.00	1.00	2.00	1.00	1.00	2.00
muzm82	0.00	1.00	1.00	2.00	1.00	0.00	2.00
mzmh94	0.00	1.00	0.00	2.00	1.00	1.00	2.00
mzml94	0.50	0.00	1.00	2.00	1.00	0.00	2.00

Table A3. Continued

Fishery	Socialisation	Community growth	Education level	Conflict	Info. sharing	Influence on regs	Fishing income
octy97	1.00	1.00	0.00	2.00	1.00	2.00	2.00
okng90	0.00	1.00	1.00	2.00	1.00	0.00	1.00
pal80	0.00	2.00	0.00	0.00	1.00	0.00	1.00
palpre00	2.00	2.00	1.00	2.00	2.00	1.00	1.00
ruk93	0.50	2.00	1.00	2.00	1.00	0.00	2.00
sak71	1.00	0.00	0.00	2.00	2.00	2.00	1.00
sak94	0.50	0.00	1.00	1.00	1.00	1.00	1.00
sbss81	2.00	0.00	0.00	0.00	2.00	1.00	1.00
sbss93	0.00	0.00	0.00	0.00	1.00	0.00	2.00
sen89	1.00	0.00	0.00	1.00	2.00	1.00	2.00
smbm81	0.00	0.00	0.00	0.00	1.00	1.00	2.00
smbm93	0.00	0.00	0.00	0.00	1.00	0.00	2.00
tantz93	0.50	1.00	1.00	2.00	1.00	0.00	2.00
ubol78	1.00	0.00	1.00	2.00	0.00	0.00	0.00
vkenp85	0.00	0.00	1.00	2.00	1.00	0.00	0.00
vkenp89	0.00	0.00	1.00	2.00	1.00	0.00	2.00
vtanp85	0.00	0.00	1.00	1.00	1.00	0.00	1.00
vtanp89	0.00	0.00	1.00	1.00	1.00	0.00	1.00
vugnp85	0.00	1.00	1.00	2.00	1.00	2.00	2.00
vugnp89	0.00	0.00	0.00	0.00	1.00	0.00	1.00
xmas97	1.00	2.00	0.00	1.00	1.00	1.00	0.00
yorke85	0.00	2.00	0.00	0.00	1.00	0.00	2.00
zdem85	1.00	1.00	1.00	1.00	1.00	1.00	1.00
zdem95	1.00	0.00	2.00	0.00	1.00	1.00	2.00

Table A4. Attribute scores for the 54 fisheries analysed in the technological attribute set. Note that for trip length a corrected trip length score was actually used for the MDS analysis in keeping with the scoring philosophy of high scores being more favourable than bad ones. The correction was achieved by taking the original trip length score and subtracting it from the highest trip length score.

Fishery	Trip length	Corrected trip lenght.	Landing sites	Processing	Ice	Passive or active gear	Selectivity of gear
aby86	0.25	4.75	2.00	1.00	1.00	0.00	0.00
bad	5.00	0.00	0.00	0.00	0.00	0.00	0.00
bang90	0.50	4.50	2.00	0.00	1.00	1.00	0.00
bel96	3.50	1.50	0.00	2.00	2.00	0.00	2.00
bol91	0.50	4.50	2.00	0.00	0.00	1.00	2.00
cabo84	1.00	4.00	2.00	0.00	0.00	0.00	0.00
chil86	1.00	4.00	1.00	1.00	0.00	0.50	0.00
chil94	1.00	4.00	1.00	1.00	0.00	0.50	0.00
chiu86	1.00	4.00	2.00	1.00	1.00	0.00	1.00
chiu93	1.00	4.00	2.00	1.00	1.00	0.00	1.00
chiw89	1.00	4.00	2.00	0.00	0.00	0.00	0.00
cocos97	0.50	4.50	0.00	1.00	2.00	1.00	1.00
diki95	0.50	4.50	1.00	0.00	0.00	0.00	1.00
fsm93	0.50	4.50	0.00	0.00	0.00	0.00	2.00
good	0.25	4.75	2.00	2.00	2.00	1.00	2.00
gpry97	1.00	4.00	2.00	0.00	1.00	0.00	0.00

Table A4. Continued

Fishery	Trip length	Corrected trip lenght.	Landing sites	Processing	Ice	Passive or active gear	Selectivity of gear
itte94	1.00	4.00	2.00	1.00	0.00	0.50	0.00
kivu93	0.50	4.50	0.00	0.00	0.00	0.00	0.00
krzam95	0.50	4.50	0.00	0.00	1.00	0.00	1.00
krzim95	0.50	4.50	2.00	1.00	1.00	0.00	0.00
loby97	1.00	4.00	2.00	0.00	1.00	1.00	0.00
malb93	1.00	4.00	2.00	0.00	0.00	1.00	0.00
malw47	0.50	4.50	2.00	0.00	0.00	0.50	2.00
malw93	1.00	4.00	2.00	0.00	0.00	1.00	0.00
maur89	5.00	0.00	1.00	1.00	1.00	1.00	0.00
muzm62	0.40	4.60	0.00	1.00	1.00	0.00	1.00
muzm72	0.50	4.50	1.00	0.00	1.00	0.00	1.00
muzm82	0.50	4.50	2.00	0.00	0.00	1.00	1.00
mzmh94	0.60	4.40	2.00	0.00	1.00	1.00	1.00
mzml94	1.00	4.00	1.00	1.00	0.00	0.50	0.00
octy97	1.00	4.00	2.00	0.00	1.00	0.00	0.00
okng90	1.00	4.00	2.00	0.00	1.00	0.00	0.00
pal80	0.50	4.50	0.00	1.00	0.00	1.00	0.00
palpre00	0.50	4.50	2.00	0.00	0.00	0.00	2.00
ruk93	1.00	4.00	1.00	1.00	0.00	0.50	0.00
sak71	0.20	4.80	2.00	0.00	0.00	0.00	0.00
sak94	0.50	4.50	1.00	2.00	0.00	0.00	0.00
sbss81	0.10	4.90	2.00	1.00	0.00	0.50	2.00
sbss93	0.10	4.90	1.00	0.00	1.00	0.50	1.00
sen89	5.00	0.00	2.00	1.00	1.00	1.00	0.00
smbm81	0.50	4.50	1.00	0.00	1.00	1.00	0.00
smbm93	0.50	4.50	1.00	0.00	1.00	1.00	0.00
tantz93	1.00	4.00	1.00	1.00	1.00	0.50	0.00
ubol78	0.50	4.50	1.00	0.00	0.00	0.00	1.00
vkenp85	0.50	4.50	2.00	0.00	0.00	0.00	1.00
vkenp89	0.50	4.50	1.00	0.00	2.00	0.00	1.00
vtanp85	0.50	4.50	1.00	0.00	0.00	0.00	0.00
vtanp89	0.50	4.50	2.00	0.00	1.00	0.50	0.00
vugnp85	0.50	4.50	2.00	0.00	0.00	0.00	0.00
vugnp89	0.50	4.50	2.00	0.00	1.00	1.00	1.00
xmas97	0.50	4.50	0.00	1.00	2.00	1.00	2.00
yorke85	0.75	4.25	0.00	1.00	2.00	0.00	2.00
zdem85	1.00	4.00	2.00	0.00	0.00	0.00	0.00
zdem95	1.00	4.00	2.00	1.00	1.00	0.50	0.00

Appendix 2

Table A5. Sources of information by fishery:

aby86 Central Intelligence Agency 1995, Charles-Dominique 1993.
bad
bang90 Ahmed, M. 1997, Ahmed, N. 1997, Alam *et al.* 1997, Ataur Rahman 1997, Paul and Mazid 1997,
bel96 Central Intelligence Agency 1995, Gillett pers. comm.
bol91 Central Intelligence Agency 1995, McManus, *et al.* 1992.
cabo84 Central Intelligence Agency 1995, Anon 1989a, Nsiku pers. comm., Pitcher and Hart 1995.
chil86 Central Intelligence Agency 1995, Nsiku pers. comm., Pitcher and Hart 1995, Turner 1995.
chil94 Central Intelligence Agency 1995, Nsiku pers. comm., Pitcher and Hart 1995, Turner 1995.
chiu86 Central Intelligence Agency 1995, Donda 1997, Nsiku pers. comm., Pitcher and Hart 1995.
chiu93 Central Intelligence Agency 1995, Donda 1997, Nsiku pers. comm., Pitcher and Hart 1995.
chiw89 Anon. 1999a, Central Intelligence Agency 1995, Nsiku pers. comm., Sanyanga and Mangoro 1989.
cocos97 Alder pers. comm., Central Intelligence Agency 1995.
diki95 Central Intelligence Agency 1995, Mc Clanahan, *et al.* 1996
fsm93 Central Intelligence Agency 1995, Clarke, R.P. and J.N. Ianelli. 1995.
good
gpry97 Central Intelligence Agency 1995, Salas, S. pers. comm.
itte94 Central Intelligence Agency 1995, Cowx and Kapasa 1995, Nsiku pers. comm.
kivu93 Central Intelligence Agency 1995, de Iongh, *et al.* 1995.
krzam95 Central Intelligence Agency 1995, Hachongela *et al.* 1996, Pitcher and Hart 1995, Young 1988.
krzim95 Anon. 1989b, Central Intelligence Agency 1995, Hachongela *et al.* 1996, Pitcher and Hart 1995, Stoneman and Cliffe 1989.
loby97 Central Intelligence Agency 1995, Salas, S. pers. comm.
malb93 Central Intelligence Agency 1995, FAO 1993a.
malw47 Lowe 1952, Pitcher and Hart 1995, Pryor 1988.
malw93 Central Intelligence Agency 1995, FAO 1993a.
maur89 Bonfil 1998, Central Intelligence Agency 1995.
muzm62 Central Intelligence Agency 1995, Chibwe *et al.* 1988, van Zwieten pers. comm
muzm72 Central Intelligence Agency 1995, Chibwe *et al.* 1988, van Zwieten pers. comm
muzm82 Central Intelligence Agency 1995, Chibwe *et al.* 1988, van Zwieten pers. comm
mzmh94 Central Intelligence Agency 1995, Nsiku pers. comm.
mzml94 Central Intelligence Agency 1995, Chibwe *et al.* 1988, van Zwieten pers. comm
octy97 Central Intelligence Agency 1995, Salas pers. comm.
okng90 Anon. 1989a, Central Intelligence Agency 1995, FAO 1993b, Mmopelwa and Nengu 1988.
pal80 Central Intelligence Agency 1995, Johannes, R. E. 1981.
palpre00 Johannes, R. E. 1981.
ruk93 Anon. 1989a, Central Intelligence Agency 1995, Nsiku pers. comm., Pitcher and Hart 1995.
sak71 Central Intelligence Agency 1995, Entsua-Mensah *et al.* 1997, Koranteng *et al.* 1997a, Koranteng *et al.* 1997b, Pauly 1975
sak94 Entsua-Mensah *et al.* 1997, Koranteng *et al.* 1997a, Koranteng *et al.* 1997b, Pauly 1975
sbss81 Bundy 1997, Central Intelligence Agency 1995, Padilla *et al.* 1995, Pauly 1982, Pomeroy and Pido. 1995, Samonte and Pomeroy. 1995, Silvestre *et al.* 1994, Smith *et al.* 1982, Smith *et al.* 1983, Tulay and Smith 1982, Yater *et al.* 1982.
sbss93 Bundy 1997, Central Intelligence Agency 1995, Padilla *et al.* 1995, Pauly 1982, Pomeroy and Pido. 1995, Samonte and Pomeroy. 1995, Silvestre *et al.* 1994, Smith *et al.* 1982, Smith *et al.* 1983, Tulay and Smith 1982, Yater *et al.* 1982.
sen89 Bonfil, R. 1998, Central Intelligence Agency 1995.
smbm81 Bundy 1997, Central Intelligence Agency 1995, Padilla *et al.* 1995, Pauly 1982, Pomeroy and Pido. 1995, Samonte and Pomeroy. 1995, Silvestre *et al.* 1994, Smith *et al.* 1982, Smith *et al.* 1983, Tulay and Smith 1982, Yater *et al.* 1982.
smbm93 Bundy 1997, Central Intelligence Agency 1995, Padilla *et al.* 1995, Pauly 1982, Pomeroy and Pido. 1995, Samonte and Pomeroy. 1995, Silvestre *et al.* 1994, Smith *et al.* 1982, Smith *et al.* 1983, Tulay and Smith 1982, Yater *et al.* 1982.
tantz93 Anon. 1989a, Central Intelligence Agency 1995, Nsiku pers. comm., Pearce 1995, Petit and Kiyuku 1995,

Table A5. Continued

ubol78	Central Intelligence Agency 1995, Bhukaswan 1985.
vkenp85	Central Intelligence Agency 1995, Pitcher and Hart 1995, Reynolds and Gréboval 1988, Reynolds *et al.* 1995.
vkenp89	Central Intelligence Agency 1995, Pitcher and Hart 1995, Reynolds and Gréboval 1988, Ssentongo and Dampha 1991, Reynolds *et al.* 1995.
vtanp85	Central Intelligence Agency 1995, Pitcher and Hart 1995, Reynolds and Gréboval 1988, Reynolds *et al.* 1995.
vtanp89	Central Intelligence Agency 1995, Pitcher and Hart 1995, Reynolds and Gréboval 1988, Ssentongo 1992, Reynolds *et al.* 1995.
vugnp85	Central Intelligence Agency 1995, Pitcher and Hart 1995, Reynolds and Gréboval 1988, Reynolds *et al.* 1995.
vugnp89	Central Intelligence Agency 1995, Pitcher and Hart 1995, Reynolds and Gréboval 1988, Ssentongo and Orach-Mesa 1992, Reynolds *et al.* 1995.
xmas97	Alder pers. comm., Central Intelligence Agency 1995.
yorke85	Central Intelligence Agency 1995, Poiner and Harris 1991.
zdem85	Central Intelligence Agency 1995, Jiddawi pers. comm., Jiddawi and Muhando 1995.
zdem95	Central Intelligence Agency 1995, Jiddawi pers. comm., Jiddawi and Muhando 1995.

Appendix 3

Table A6. MDS scores for the four attribute sets.

	Biol. x-axis	Biol. y-axis	Econ. x-axis	Econ. y-axis	Sociol. x-axis	Sociol. y-axis	Tech. x-axis	Tech. y-axis
Aby86	-0.38	-0.28	-1.07	-0.41	-1.86	-0.42	0.42	0.97
bad	1.79	-1.76	1.44	-1.24	1.01	-1.16	0.96	-0.86
Bang90	1.50	0.44	1.30	0.55	-0.36	-0.89	1.06	-0.12
bel96	-0.11	0.63	-0.53	2.12	-2.06	0.63	-2.23	1.99
Bol91	0.65	1.76	-0.84	-1.02	0.47	-0.84	-1.36	-1.24
Cabo84	-1.19	-0.75	-1.00	1.35	1.02	1.14	0.85	-0.82
Chil86	-1.05	-0.36	-0.91	0.46	0.89	-0.85	0.72	0.73
Chil94	1.58	-0.11	-1.00	0.56	0.84	-0.73	0.72	0.73
Chiu86	-1.27	-0.31	-1.00	0.56	1.02	1.14	-0.77	0.64
Chiu93	-0.35	-0.79	-1.00	0.56	0.84	-0.72	-0.77	0.64
Chiw89	-0.15	-0.73	-0.86	-0.99	1.05	0.14	0.84	-0.82
Cocos97	-0.13	-0.57	0.83	-1.98	-0.51	1.53	-1.07	1.52
Diki95	1.53	1.43	0.75	-0.68	-0.82	-0.73	-0.25	-1.03
Fsm93	-1.17	-0.93	1.48	1.02	0.57	1.41	-1.37	-1.26
good	-2.32	2.36	-1.66	1.93	-2.10	1.82	-2.00	2.21
Gpryuc97	0.83	-1.35	0.93	-0.36	-1.20	0.66	0.69	-0.64
Itte94	-0.17	-0.71	-1.23	0.35	-0.22	-1.23	0.78	0.69
Karzam95	-0.43	-0.39	0.80	-0.71	0.74	1.34	-0.77	-0.79
Karzim95	-0.30	0.75	-0.93	-0.38	0.27	1.72	0.47	1.06
Kivu93	-1.84	-0.83	-1.00	-1.14	-1.88	-0.52	0.87	-0.87
Lobyuc97	-0.37	-0.94	1.26	1.06	-1.29	0.68	1.11	-0.08
Malb93	1.45	-0.49	-1.27	0.38	0.51	-0.85	1.20	-0.53
Malw47	-1.05	-1.29	-1.00	0.71	-2.10	0.57	-1.19	-1.18
Malw93	0.82	-0.80	-1.27	0.38	0.51	-0.85	1.20	-0.53
Maur89	0.82	-0.35	-0.69	1.57	-0.72	-0.75	0.53	1.40
Muzam62	-1.77	0.65	-0.75	-1.18	1.09	0.14	-0.91	0.77
Muzam72	-1.44	0.70	-0.84	-0.39	0.58	0.53	-0.62	-0.74
Muzam82	-0.27	0.71	-0.95	0.46	0.99	0.29	-0.12	-1.12
Muzamh94	-0.28	0.75	-0.90	1.01	0.73	0.42	-0.68	-0.71
Muzaml94	-0.39	-0.35	0.14	0.81	0.30	-0.82	0.77	0.75
Octyuc97	-0.16	-1.17	0.92	-0.37	-1.20	0.66	0.69	-0.64
Okng90	-0.38	-0.24	-0.84	-1.13	0.94	0.28	0.64	-0.60
pal80	-0.15	0.67	1.94	-0.11	1.32	1.01	0.93	1.16
Palpre00	-1.90	0.37	1.34	0.71	-1.64	1.50	-1.24	-1.32
Ruk93	-0.19	-0.68	0.14	0.76	0.53	1.26	0.72	0.73
sak71	0.88	-0.72	1.26	0.82	-1.42	-0.53	0.86	-0.83
sak94	1.47	0.46	-1.18	0.23	-0.20	-0.62	0.58	2.16
sen89	0.57	0.99	-0.99	-0.86	-0.83	-0.77	0.60	1.38
smbmi81	1.00	-0.60	1.07	0.77	0.55	-1.01	1.05	-0.01
smbmi93	1.38	-0.66	1.04	-1.08	0.95	-1.00	1.05	-0.01
smbss81	-1.14	0.79	-0.96	-1.06	-1.96	-0.75	-1.69	0.16
smbss93	1.25	1.64	0.87	-1.11	0.95	-1.01	-0.54	-0.55

Table A6. Continued.

tantz93	-0.66	1.48	0.14	0.76	0.47	0.38	0.30	0.96
ubol78	-0.09	0.75	0.85	-1.30	-0.44	-1.20	-0.25	-1.07
vkenp85	1.23	0.88	0.89	-0.42	0.94	-0.81	-0.19	-1.11
vkenp89	1.37	-0.12	1.11	0.07	0.86	-0.73	-1.36	-0.60
vtanp85	-0.57	-0.25	1.02	0.47	0.85	-0.76	0.83	-0.82
vtanp89	-0.51	-1.83	0.96	0.78	0.86	-0.76	0.73	-0.35
vugnp85	-0.53	-0.25	0.95	0.69	0.19	1.17	0.86	-0.84
vugnp89	1.41	-0.68	0.88	-1.08	0.95	-1.00	-0.70	-0.73
xmas97	-0.36	0.47	-0.95	-1.89	-0.43	1.41	-2.05	1.16
yorke85	-0.36	-0.89	-1.11	-1.48	1.34	1.04	-2.18	0.83
zandem85	0.57	1.79	1.39	0.43	-0.62	0.45	0.87	-0.84
zandem95	1.29	1.65	1.01	0.01	-1.28	-1.00	0.41	1.01