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EFFICIENCY, RISK AND REGULATION COMPLIANCE: APPLICATIONS TO LAKE VICTORIA FISHERIES IN TANZANIA

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To Abou, Rajab and Asmina.

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Abstract

This thesis deals with artisanal fishers in Lake Victoria fisheries. The thesis consists of an introductory chapter and three self-contained papers, which make up the rest of the thesis chapters. The first paper relates to the measurement of efficiency and skipper skill among the artisanal fishers in Lake Victoria, the other two papers related to the measurement of fishers' behavioural motivation.

Paper 1: Lake Victoria fisheries are important to Tanzanian food security, employment and foreign exchange, but experience declining performance largely due to overfishing and overcapacity. This paper studies technical efficiency and skipper skill using Tanzanian fishery data for the two major species Nile perch and Dagaa. The relative level of efficiency is high in both fisheries and several observable variables linked to skipper skill significantly explain the efficiency level.

Paper 2: Using an experimental approach we investigate the risk preferences of artisanal fishers in Tanzania waters of Lake Victoria. The experiment concerns pairwise comparisons of hypothetical fishing trips that vary in expected mean and spread of the net revenue. The results show that about 34% of the fishers can be considered as risk neutral, 32% as risk averse, and 34% as risk seekers. Econometric analysis indicates that the likelihood of belonging to the risk seeking group increases if motorboats are used, if fishing is the main source of household income, and if the fisher is targeting Nile perch. Asset ownership and perhaps socio-economic variables influence risk preferences

Paper 3: This paper analyzes the causes for regulatory compliance using traditional deterrence variables and potential moral and social variables. We use self-reported data from Tanzanian artisanal fishers in Lake Victoria. The results indicate that fishers adjust their violation rates with respect to changes in probability of detection and punishment but also react to legitimacy and social variables. A small group of persistent violators react neither to normative aspects nor to traditional deterrence variables, but systematically violate the regulation and use bribes to avoid punishment.

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Key words: Incentives, Lake Victoria, remuneration, skipper skill, stochastic frontier, technical efficiency, Risk aversion, artisanal fishers, Tanzania, Nile perch, Dagaa, compliance, legitimacy, normative, deterrence.

Preface

I would like to express my gratitude to numerous individuals and institutions that have helped me in the course of writing this thesis. My first inspiration into the field of environmental economics and in particular fisheries economics came from Dr Jessica Anderson, who was coordinating the SIDA/SARECs Regional Marine Economics project of which I was a beneficiary during my Masters in Economics at the University of Dar-Es Salaam. For this I would like to say *Akhsante Sana* Jessica.

I joined the PhD programme in 1999, thanks to Dr Amon Mbelle and Dr Magnus Ngoile who wrote excellent letters of recommendation that helped me make my way to Gothenburg University. Since then I have been receiving continuous support and encouragement from Professor Thomas Sterner, Dr Gunnar Köhlin and other staff members of the unit. Not only were my colleagues and I introduced to the field of resource and environmental economics, Thomas Sterner went further and organized other social activities such as parties, skiing, and most recently, beach volleyball, which was co-organized with students from the Physical Resources Department.

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Chamwigu, have always supported my family and me. *Kwa wote tunasema Akhsante Sana.*

In the course of writing this thesis, I lost a very important person whose love of education, bestowed upon his children, resulted in my reaching this level. My father, Abubakari Mtiro, passed away when I was in the middle of my journey. May Almighty God place his soul in peace. I would like to thank my mother, brothers, sisters, in-laws and other members of my extended family for their love, encouragement and prayers that sustained me in my work. Last but not least, I would like to express my heartfelt thanks and love to my lover, my best friend and wife, Hadija, for her great patience, love and support. She played the dual role of father and mother to our two lovely children, Rajab and Asmina, who were born while I was still on the journey. I will be forever grateful for this. This thesis, therefore, belongs to her as much as it belongs to me. As for Abou, Rajab and Asmina, I can only hope that one day they will understand why their dad was always coming home very late at night.

Finally, I cannot forget to express my gratitude to the people and institutions that made this study possible. First and foremost, I want to thank my employer, the National Environment Management Council (NEMC), for granting me the leave that facilitated this study. I wish to thank SIDA for funding the programme and Gunnar Köhlin, Thomas Sterner and Elizabeth Földi for overseeing the smooth running of it.

As every other achievement in my life, I owe this to the Almighty God without whom this work would never have been realized. Despite all the help I have received through the years, any mistakes or errors that remain in this work are entirely mine.

Gothenburg, May 2005.

Razack B Lokina

Introduction

This thesis looks at the problems pertaining to artisanal fisheries in developing countries where management is mainly based on traditional command and control regulation. The focus is on Lake Victoria fisheries which are broadly managed as an open access resource. In open access we expect overcapitalization, a low level of biomass, and dissipation of the resource rent leading to low profitability of the participating fishers. In particular, the resource and ecosystems utilized by the artisanal fishers are increasingly over-exploited and degraded from destructive fishing practices, pollution and excessive effort (Squires et al., 2003). The fishing capacity of artisanal fisheries is often far in excess of that required to take the maximum sustainable yield, and even further in excess of that required for economic efficiency (Squires et al., 2003). With open access and overcapitalization problems, it is of interest to assess the relative performance of fishing vessels and to explore the reasons for differences if such exist, thereby providing important information to the fishery managers aimed at capacity reduction of the fishing vessels. When landing sites for artisanal fisheries are scattered, fishery managers cannot completely control fishers (Sterner, 2003), which suggests that the outcome of any regulation will be determined by the fishers' reaction to the regulation. Lack of knowledge of these reactions or ignoring them will lead to unexpected and unsatisfactory outcomes.

Entry into Lake Victoria fishery is open to anyone with enough capital and the necessary skills; there is no catch limit, thus, participating fishers can catch as much as they can, given the stock level and their vessel's capacity. Fishing requires an annual license fee of Tanzania Shillings (Tshs) 25,000, or about USD 20[1], which approximately equals the gross revenue of two days of fishing and cannot be seen as a limited access policy. The open access nature of the fishery as predicted by Gordon (1954), will lead to an effort increase up to a level where effort is earning its opportunity cost. In a situation with high unemployment and landless people, the opportunity cost of labor is close to zero, indicating high effort levels and low biomass. The equilibrium effort is reached at the level where total revenue equals total cost and the resource rent is dissipated (Clark 1990). A related prediction of the Gordon theory is

[1] USD 1≈ Tshs 1,137, January 2005.

that the fishers who remain in an open access fishery tend to have the fewest number of alternative employment opportunities available, i.e., the lowest opportunity cost. Open access to valuable fishery has been claimed to result in overfishing and subsequently to poverty among the fishermen. In particular, Gordon (1954) asserted that fishermen typically earn less than most others, even those in much less hazardous occupations or in occupations requiring less skill.

The Lake Victoria fisheries are artisanal and employ rudimentary technology. Fishers use open wood vessels, which sometimes have outboard motors, but most commonly are operated by sails or paddles. The total crew ranges from two to six persons. Owners of the boats are commonly involved in beach activities, e.g., selling the catch, and in some cases are onboard their vessels as ordinary crewmembers. There are four major types of fishing units on the Lake: Nile perch/Tilapia gill nets, longlines, Dagaa nets and beach seines. Nile perch are fished with gillnets and secondarily with multi-hook longlines. Gillnet fishers constitute the largest group of fishers in the Lake Victoria fisheries. Nets are placed in the late afternoon and retrieved in the morning. Because of the concern of theft, fishers often stay out with the net, sleeping in their boats. When targeting Nile perch, the preferred bait is Dagaa, Haplochromines or other small fish. Longlines are able to catch the Nile perch that are too large to be caught by gillnets. Dagaa is fished on moonless nights using pressure lamps to attract the fish, which limits fishing to 15 days a month. Dagaa is usually caught with gillnets, but illegal short purse seines and mosquito nets are also used. The increased use of beach seines has had damaging effects on eggs and fry, especially, and on breeding and nursery grounds, as well. Tilapias are caught with hooks and lines and in most cases, small-mesh gill nets.

During the pre-colonial era, i.e., until the late 1800s, the traditional Lake Victoria fishery was exploited by simple fishing gear such as basket traps, hooks, and seine nets of papyrus, each of which exerted little fishing effort. The resource users and the resource base started to crumble during the colonial period, 1900-1962, largely because of the considerable expansion of fishing effort. The demand for fish from Lake Victoria was stimulated by the development of urban centers along the lakeshore and the arrival of the railway at the Nyanza Gulf in 1908 (Graham, 1929). Fishing was further intensified by the introduction of flax gill nets in 1905, and later by the introduction of non-selective beach seines in the early 1920s (Kudhongania and Chitamwebwa, 1995). The introduction of more efficient fishing technologies such as gillnets and beach seine, together with population growth exerted further pressure on the Lakes' fisheries and led to falling catch per unit effort (CPUE). To replenish the declining stocks, Nile perch and Tilapia were introduced in Lake Victoria in the 1950s and early 1960s (Welcomme, 1967). These new species had minor impacts on the fisheries at first, but in the late 1970s, landings started to increase and the high price of Nile perch reinforced investments and technological development. The economic improvement, thanks to these new species, came at the expense of diminishing biodiversity. Numbers of species dropped from more than 300 to fewer than 200 (Kudhongania and Chitamwebwa, 1995): Today there are, in principle, three commercial species; Nile perch, Dagaa, and Tilapia, accounting for 60%, 20% and 10% of total landings, respectively. Nile perch fishery led to processing and export industries in Kenya and Uganda during the 1980s, and in Tanzania in the early 1990s (Reynolds et al., 1992).

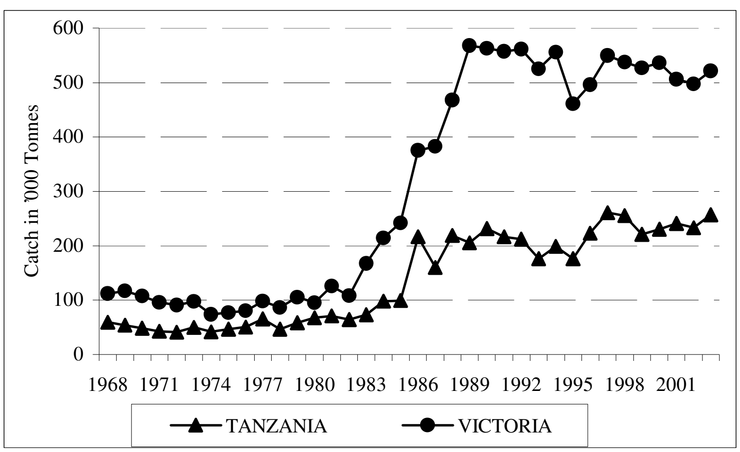

Figure 1: Catch trend for Tanzania and Lake Victoria 1968-2003
Data source: Kateregga (2005); Tanzania Fisheries Reports various issues

Figure 1 shows the trend of catch over the period 1968 to 2003. A persistent increase in catches was recorded from the 1980s to the 1990s, which can be explained by the Nile perch explosion. The catch reached a maximum of 570,000 tonnes before starting to fluctuate during the 1990s until 2002 where the catch averaged about 500,000 tonnes per year. Similarly, the number of fishing crafts increased in the late 1980s from 10,000 to about 60,000 by 2003. Figure 2 shows the annual landings per boat, a decline from 35 tonnes per boat and year in 1988 to less than 10 tonnes per year in 2002. In a study of 1,078 of the Lake's fishers, 87% claimed that catches had decreased and 74% felt that the average size of fish landed had declined. According to the fishers this is due to non-compliance of fishing regulations, excessive fishing effort and pollution, or the presence of the water hyacinth (SEDAWOG, 2000; Kateregga 2005).

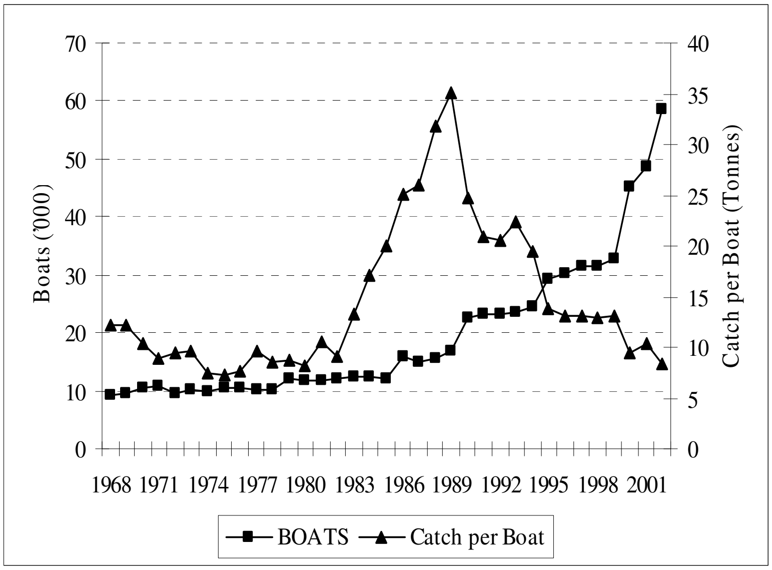

Figure 2: Trend in Boats and Catch per Boat in Lake Victoria (1968-2002)
Data source: Kateregga, (2005); LVFO, (2004);
Catch per Boat measure: Authors' computation.

The most common type of fishing gear used in Lake Victoria is the gillnet. Regulations for Lake Victoria require a minimum mesh size of 5 inches for Nile perch and Tilapia, and 10 mm for Dagaa. Previously, mesh sizes larger than the minimum were frequently used, but today most fishers use the minimum size, which means that the average size of Nile perch was reduced from 70 kg in 1981 to 7 kg in 1996. Reports show that catch per net declined by almost 60% in the Tanzanian section of the Lake (Mkumbo, 2003). Fishers respond to the decline in catch with new techniques such as multiple mounting of nets vertically to cover the whole water column (Mkumbo, 2003; own field observation). Such mounted nets can also be tied onto motorboats and towed slowly over large distances. Earlier, fish smaller than 2 kg were not accepted by the processing factories, while today immature fish smaller than 1 kg are routinely accepted (Abila and Jansen, 1997; Wilson and Medard 1999). A recent frame survey indicates that regulations are frequently violated; the most common infringements being too-small mesh size and use of beach seines (LVFO, 2004). Corruption among officials is another problem; there are reports of officials being actively involved in beach seining (Wilson and Medard, 1999; Ikiara 1999). Pitcher and Brundy (1995) found the Nile perch stock to be severely depleted and warned of a collapse if efforts continued to grow. The current stock, however, is believed to have remained within the range of previous estimates (Mkumbo, 2003). Still, the size composition, with lack of large specimens and dominance of small individuals indicates that overfishing results from two suboptimals - excessive effort and noneumetric mesh size (Clark, 1990). Lake-wide surveys rank Dagaa second in abundance (Tumwebeza et al., 2002; Getabu et al., 2002), though signs of a fall in catch per boat were also recorded (Othina and Tweddle, 1999; Nsinda, 1999). Dagaa is facing pressure from both human fishing and the predation from Nile perch (Brown et al., forthcoming). The human pressure on Dagaa, however, is mitigated by a higher production turnover due to high fecundity, high growth rate and high natural mortality (Wanink, 1991). The signs of recovery of Haplochromines (Witte et al., 1995; Mkumbo et al., 2002) and the relative abundance of the fresh water shrimp (*Cardina niloticus*) (Budeba & Cowx, 2000), indicate that some pressure on Dagaa as the only available prey to the Nile perch is mitigated.

Lake Victoria fisheries, as noted above, are largely open access. A first step towards sustainability would be coordination between the three countries involved. A second would be to address the property rights problem, which implies either some form of co-management structure or the development of a quota system (Eggert, 2001). However, as fisheries today are very far from any quota system, a pragmatic approach could be a limited access system, which in fact limits access (Christy, 1999). A co-management approach requires more serious involvement of fishers and development of the recently introduced beach management units. Today there is diminished access for small-scale fishers due to investments in outboard motors and fishing equipment. Marginal fishers turn to species other than Nile perch or choose to become crewmembers for successful fishers who often are financed or hired by the fish processing factories. Others become involved in illegal beach seining at night or in exploiting Nile perch by long lines. Wilson and Medard (1999) note that harvesting capacity for the Tanzanian Lake fisheries is now in the hands of a smaller number of fishers with less diverse gear and techniques. Our own survey indicates that approximately 66% of the sampled boats are operated by hired skippers and crewmembers, while 16% are owner-operated.

Technical efficiency and skipper skill effects in artisanal Lake Victoria fisheries

The first paper examines Lake Victoria artisanal fisheries empirically. The evidence that catch per boat is declining in Lake Victoria fisheries suggests that capacity reduction in Lake Victoria could be an important objective of the fishery managers in the region. The success of such a policy, however, depends both on the variation and the level of efficiency within the fishing fleets. If vessels with significantly lower than average efficiency levels are decommissioned, the actual reduction in fishing capacity will be less than expected. Further, if the remaining vessels are not operating at an efficient level after a decommissioning program, future improvement in efficiency may even further offset the effects of the decommissioning program. Moreover, fishing capacity can increase by changes in regulated or unregulated inputs, of which some are hard to observe and control, such as skipper skill. Skipper skill comprises a vital share of the inputs used for catching fish and therefore should be taken into consideration by fishery managers who aim to limit capacity. In general, skipper skill is an unobservable input in the production process, implying that empirical studies have to search for proxy variables such as education and fishing experience. Indicators reflecting motivation or good management have been proposed in the literature, but empirical applications are few. The objective of this paper is to analyze the relative level of efficiency and to explore potential proxies for skipper skill. We define skipper skill as technical efficiency and assess it through simultaneous estimation of a stochastic production frontier function and inefficiency function. The results suggest that the Tanzanian artisanal fishers of Lake Victoria are relatively technically efficient and that skipper skill can be significantly approximated by various variables. The potential for increasing efficiency exists if simultaneously measures are taken to check the excessive effort, overcapitalization and open access problems.

Small-scale Fishers and Risk Preferences

Paper two is empirical and studies how fishers make fishing trip decisions. As long as total effort cannot be completely controlled, a more thorough understanding of fishers' supply responses to decisions will be beneficial for fishery managers. The framework is that the daily trip decision is carried out under uncertainty, which makes the structure of fishers' risk preferences important. In general, fishers have to make several choice decisions on a day-to-day basis. These choices may include selecting target species, gear type, and location. The beliefs of profitability of different locations and the decision of how long to fish particular locations are likely to affect the variability of fishers' incomes. Thus, fishers targeting the same species may have different net returns depending on location choice. The fishers' problem therefore is to select the location that will yield the highest expected utility. Choosing a fishing location obviously involves financial risk. Hence, the decision of where to go on a particular fishing trip can depend on fishers' risk preferences and is likely to have implications for fishers', within regulations such as closed area or seasonal. For example, if a closed area is characterized by low variation in net revenue, a risk averse fisher will likely be hurt more than a risk neutral or a risk seeking fisher. Given this tendency, we subject the fisher in the sample to a hypothetical fishing trip and a hypothetical pay-off. The fishers' choices in this case are used to infer fishers' risk preferences. We use a relative risk premium to characterize the fisher as risk averse, risk neutral or risk seeking. Results show that a relatively small group of fishers are found to be risk averse, which is in direct contrast to the findings regarding poor farmers in developing countries. Econometric analysis shows that risk seeking fishers use motorboats, fish long hours, and that fishing is the main economic activity.

Compliance in Lake Victoria Fisheries

The third paper concerns compliance with the mesh size regulation. Poor people are frequently compelled to exploit their surroundings for short-term survival, and are regularly the one who are most exposed to natural resource degradation which in most cases are open access. The outcome is often a situation with seriously depleted fish stocks and a substantial level of overcapacity both in terms of vessels and in number of fishers. To comply or not comply with the inadequate existing regulation is therefore often a question of making ends meet. Risk of detection encourages a backdoor of corruption and bribery. Several regulation measures are in use in Lake Victoria including licensing, closed areas/seasons, bans on the use of poison and other destructive gear, e.g., beach seine and mosquito nets. This paper analyzes the causes of regulatory compliance. In addition to traditional deterrence variables such as risk of detection and expected gains from violation, we explore potential reasons for adherence to regulations such as being moral and doing the right thing, obeying the rules due to peer pressure, and perceiving the regulation as legitimate. We use self-reported data from Tanzanian artisanal fishers in Lake Victoria and focus our analysis on the mesh size regulation. We choose to study mesh size compliance because it is the most widely enforced regulation and the most well-known among the fishers. In addition, given the current trend in fish stock, mesh size becomes one of the most violated regulations. The results indicate that fishers adjust their violation rate with respect to changes in deterrence variables such as probability of detection and punishment. We find that legitimacy and social values are important in increasing compliance, as is fisher involvement in design and implementation of the regulations.

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Technical Efficiency and Skipper Skill in Artisanal Lake Victoria Fisheries

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Abstract

Lake Victoria fisheries are important to Tanzanian food security, employment and foreign exchange, but experience declining performance largely due to overfishing and overcapacity. This paper studies technical efficiency and skipper skill using Tanzanian fishery data for the two major species Nile perch and Dagaa. The relative level of efficiency is high in both fisheries and several observable variables linked to skipper skill significantly explain the efficiency level.

Keywords: incentives, Lake Victoria, remuneration, skipper skill, stochastic frontier, and technical efficiency

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1.0. **Introduction**

Lake Victoria is the world's second largest and Africa's largest fresh water body. The Lake has faced major problems in the late 20th century manifested in loss of fish species and decline in catch per unit effort. The open access nature of the Lake fisheries combined with rapid population growth, lack of employment opportunities and the lucrative nature of fishing connected to the Nile perch boom have led to an increasing number of fishers and depletion of fish stocks (Ikiara, 1999). This decline concerns one-third of the population (or about 30 million people) supported by the Lake basin in Kenya, Tanzania and Uganda (LVFO, 1999). The Lake fisheries contribute significantly to the Tanzanian economy in terms of food supply, foreign exchange and employment opportunities. The contribution to GDP has grown from 0.4% in 1993 to 1.8% in 1998 and the Nile perch export value share of total export values has risen from 1.4% to 12.7% during the same period (Kulindwa, 2001). To secure the livelihoods of the people and to render possible a sustainable management of the Lake fisheries, the pressing issues of open access and overcapacity need to be rigorously addressed.

Limiting the number of boats can cap fishing capacity, but capacity will most likely be expanded by other means and will continue to place pressure on fish stocks and dissipate rents. Fishing capacity can increase by expansion in unregulated inputs (Wilen 1979; Dupont, 1990), via productivity growth (Squires, 1992), or by changes in inputs that are hard to observe and control, such as fishing skill (Hilborn and Ledbetter 1985; Kuperan et al, 2001). Skipper skill basically comprises all knowledge that influences the productivity of a fishing vessel; skipper skill has been highlighted in a number of recent studies (Kirkley et al 1998; Kirkley and Squires, 1999; Eggert, 2001; Pascoe and Coglan, 2002 and Squires et al 2003). In general skipper skill is an unobservable "input" in the production process, which means that empirical studies have to search for proxy variables such as education and fishing experience. Technical efficiency studies in developing countries are scarce and there are mixed results concerning the usefulness of these particular proxy variables in explaining the role of skipper skills. Kuperan *et al* (2001) and Squires *et al* (2003) found the variables to be insignificant and signalled a need for other indicators that can proxy skipper skill and be managed and regulated. Other indicators reflecting motivation or good management of the skipper have been proposed in the literature (see Mundlak 1961, Kuperan *et al* 2001, Squires *et al* 2003), but empirical applications are still lacking.

This paper studies technical efficiency and skipper skill using Tanzanian fishery data for the two artisanal fisheries targeting either Nile perch or Dagaa in Lake Victoria. The objective is to analyze the relative level of efficiency and to explore potential proxies for skipper skill. The effects of skipper skill are included in technical inefficiency and assess it through simultaneous estimation of a stochastic production frontier function and an inefficiency function. The results suggest that the Tanzanian artisanal fishers of Lake Victoria are relatively technically efficient and that skipper skill does play a role in the efficiency of the boat. For the Nile perch fishery, efficiency increases with the skippers' experience and education. The two factors of skippers owning their vessels and revenues being shared after cost deduction imply increased efficiency. For Dagaa fishery, efficiency increases with skipper experience while efficiency decreases with average gill net age. In both fisheries efficiency increases if the owner shares 50-50 with the crew and if the skipper enjoys an extra bonus. A particularly interesting finding for both fisheries is that the local management (Beach Management Units or BMUs) leads to improved efficiency. Development of the BMUs can potentially contribute to necessary limitations of capacity, which would render possible sustainable efficiency improvements for the Tanzanian fishers of Lake Victoria.

2.0 Lake Victoria Fisheries

Lake Victoria is a shared resource of three East African countries: Kenya, Uganda and Tanzania. The Tanzanian section is the largest of the three, encompassing 49% of the Lake's surface; Uganda has 45% and Kenya 6%. To enhance the fisheries of Lake Victoria, an exotic species, Nile perch (*Lates niloticus*), was introduced to Lake Victoria in the 1950s and experienced an explosive growth in population in the late 1970s (Brundy and Pitcher, 1995). During the 1980s the Nile perch provided a new source of inexpensive protein for people around the Tanzanian shoreline. Tanzanian fishers christened the Nile perch the "saviour" (Reynolds and Gréboval 1988). Though understandable to view the

Nile perch this way, the species has also led to the destruction of the Lake's ecosystem and thus the disappearance of the native biodiversity. The biological diversity of the Lake has declined from an estimated 350-400 species of fish in the earlier years of the 20th century, to less than 200 at present (Brundy and Pitcher, 1995). Today there are only three commercially important species; Nile perch (*late niloticus*), the sardine-like Dagaa (*Rastrineobola argentea*) and the Nile tilapia (*Oreochromis niloticus*), which is also a non-native species. Recent estimates show that Nile perch, Dagaa and Nile tilapia constitute 60%, 20%, and 10% respectively of Tanzania's total Lake Victoria landings (Ssentongo and Jlhuliya 2000).

The Nile perch is a large, white meaty fish that is exported to Europe, Asia and North America. Processing and export industries were established in Kenya and Uganda during the 1980s and in Tanzania in the early 1990s (Reynolds et al 1992). The fish is exported as frozen fillets from processing plants that have been built onshore. The export demand has driven up the price of Nile perch and has led to an increase in capital investments in fish harvesting equipment. The degree to which this demand is felt varies at different parts of the Lake, but there is swift expansion in capacity for collecting fish by boat rather than truck, which ensures penetration to beaches in even the more remote areas. Dagaa on the other hand is a sardine-like species, which to a large extent is processed domestically for household consumption and animal feed (fishmeals). In addition to local consumption, there is substantial long-distance trade in Dagaa. It is shipped to major Tanzanian cities, including Dar-es Salaam, and to neighboring countries such as Burundi, Rwanda, Zambia and the Democratic Republic of Congo.

Small-scale fishing units generate almost all of the fishing effort on the Lake. These fishers use boats or canoes that are fitted with motor or a sail/paddle and take a total crew of two to six people including the captain. There are generally four major types of fishing units on the Lake Nile perch and tilapia gill nets, long lines, hook and lines, and Dagaa nets. Nile perch is fished with gill nets and also with multi-hook long lines. The focus of this study is on gill net fishers, who tend to move further offshore and reduce mesh sizes in order to maintain their catches. Nets are placed in the late afternoon and retrieved in the morning. Because of concerns with theft, fishers often stay out with the net, sleeping in their boats.

Dagaa is fished at moonless night using pressure lamps to attract the fish. Several types of gear are used; short purse seine and mosquito nets is the most common. In many of the areas surveyed, wind and weather are the main constraints on the Dagaa fishers because lamps are easily lost in rough conditions. Hence the fishers are more dependent on particularly sheltered environments and are thus more limited in the number of fishing areas they can reach from a particular beach. The Dagaa fishers' choices of where to fish are therefore limited to beaches fairly close to one another.

Crewmembers are generally younger than owners or renters. The average age is 32 with a maximum age of 82. Owners of the boats are sometimes involved in the actual fishing either as skippers or as ordinary crewmembers of their own boats. The crew, including the skipper, usually is paid based on a share of the catch. There are various kinds of remuneration systems used in the Lake Victoria fisheries and we divide them into two major categories. The first category is when the share is allotted *before* daily operating costs of the boat are deducted (of which fuel is a large component). This share can be 70:30 or 80:20 for owner and crew respectively. The second category is when the crew gets its share *after* operating costs are deducted. This is generally 60:40 or 50:50 for owner and crew (including the skipper) respectively. The share arrangements above provide different incentives to the skippers and are therefore expected to influence the productivity of the skipper. The most striking difference between the two systems is that skippers who receive their share of revenues after running costs are deducted face the risk of no income at all. In addition to the variation in sharing mechanisms some skippers receive an extra bonus, which is unknown in size; to capture its potential effect we use a dummy variable.

3.0 Stochastic Production Frontier

Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977) simultaneously introduced the stochastic production frontier models. The advantage of the stochastic production frontier is that the impact of weather and luck can at least in principle be separated from the contribution of variation in technical efficiency. A frontier model with output-oriented technical inefficiency[2] is specified as follows:

$$Y_{it} = X'_{it}\,\beta + (\,\varepsilon_{it} = V_{it} - U_{it}) \qquad (1)$$

Where Y_{it} the output in kg of firm i (i=1, 2,…, N) at season t (t=1,2,3); X_{it} is the corresponding matrix of K inputs and β is a Kx1 vector of unknown parameter to be estimated. The disturbance term consists of two independent components, $\varepsilon_{it} = V_{it} - U_{it}$ where $V_{it} \sim N(0,\ \sigma_v^2)$, and U_i is a one-sided error term. The noise component V_{it} is assumed to be i.i.d and symmetrically distributed independent of U_{it}. The term V_{it} allows random variation of the production function across firms and captures the effects of statistical noise, measurement error and exogenous shocks beyond the control of the firm. The U_{it} are non-negative random variables associated with technical inefficiency in production, which are assumed to arise from a normal distribution with mean μ, and variance σ_u^2 which is truncated at zero (i.e. $U_{it} \sim (\mu,\ \sigma_u^2)$. The one-sided, non-negative random variable, U_{it}, representing output-oriented technical inefficiency, must be non-negative so that no firm can perform better than the best-practice frontier. The independent distribution of V_{it} and U_{it} is what allows the separation of noise and technical inefficiency. If U_{it} =0, then $\varepsilon_{it} = V_{it}$ suggesting that production lies on the frontier and production is said to be technically efficient. If $U_{it} > 0$, production lies below the frontier and thus there is evidence of inefficiency.

As shown in Jondrow *et al* (1982) ε_{it} contains information about U and makes it possible to estimate mean technical efficiency over all observations. It is also shown that firm-specific technical efficiency can be inferred from asymmetry in the residuals around a fitted production and its calculation rests on the higher moments of these residuals. Following Jondrow *et al*. (1982) we find the expected value of U_{it} conditional on the value of ε_{it}, i.e. $E(U_{it}|\varepsilon_{it})$. The maximum likelihood estimation of equation (1) provides the

[2] An input-conserving approach (Kumbhakar and Lovell, 2000) is also possible, but given the lack of any constraint on catch or effort, efficiency improvement is likely to imply output expansion.

estimators for βs and variance parameters $\sigma^2 = \sigma^2_v + \sigma^2_u$ and $\gamma = \sigma^2_u / \sigma^2$. Technical efficiency (TE) for each firm is obtained as $TE_i = Y / f(x;\beta) * \exp(v)$,

where $Y = f(x;\beta)*exp(v)*exp(-u)$, hence we can define $TE_i = exp(-u)$; *exp* is the exponential operator (Battese and Coelli 1988). The range of technical efficiency for vessel i, in season t, (TE_{it}) is in the range of 0-1, where TE_{it} =1 represents the achievement of maximum output (adjusted for random fluctuations) for the given input.

3.1 Specification of the Stochastic Frontier

The paper employs the approach by Battese and Coelli (1995) to analyse the relationship between technical efficiency and input variables such as crew size, net length, and hours fished. The estimated frontier is stochastic since fishing is sensitive to random factors such as weather, resource availability and environmental influences (Kirkley et al., 1995). The translog flexible functional form is relatively easy to estimate, permits a limited determination of the underlying technology, and easily accommodates the inclusion of a one-sided error term to allow estimation of technical efficiency (TE) for each observation. The two main commercially important species are fished using different techniques and we estimate separate models for Nile perch and Dagaa.

$$LnY_{it}=\beta_0+\beta_1 lnL_{it}+\beta_2 lnN_{it}+\beta_3 lnH_{it}+\beta_{11}(lnL_{it})^2+\beta_{22}(lnN)^2{}_{it}+\beta_{33}(lnH)^2+\beta_{12}lnL_{it}lnN_{it}$$
$$+\beta_{13}nL_{it}lnH_{it}+\beta_{23}lnN_{it}lnH_{it}+\beta_5 lnDS+\beta_6 Motor+\beta_7 Mwanza+\beta_8 Mara+\beta_9 Peak$$
$$+\beta_{10}Normal+\varepsilon_{it} \qquad (2)$$

When $\beta_{ij} = 0$ *for all* $i \le j=1,2,3$, this would imply a Cobb- Douglas production function. Symmetry has also been imposed by $\beta_{ij} = \beta_{ji}$ and inputs are *L, N,* and *H*. Total output (catch) in kg is denoted by *Y* which is the catch representing two species, Nile perch and Dagaa, that currently dominate the Lake Victoria fisheries' daily landings. Crew size (*L*) is the number of crewmembers employed per vessel per trip including the captain, and the gill net capital stock (*N*) is measured by its length in meters multiplied by the number of hauls of the gill nets per day. Hours fished (*H*), measures the length of time gillnets were left active in the water. Distance from the shore to the fishing ground is proxied by hours travelled (*DS*) and in this case is considered an environmental variable beyond the control of the fishers. It provides for differences in resource conditions that vary by distance from shore and by water depth. Because distance from the fishing grounds represents an environmental parameter, it is specified as a single-order term in the stochastic frontier. We also have a motorboat dummy, (*Motor=1/0*), to capture the effects of boats with and without outboard motors in the productivity. The region dummy captures the variation in stock abundance, where *Mwanza* and *Mara* are dummies for the Mwanza and Mara regions respectively. To avoid a dummy variable trap, Kagera is the reference region. The seasonal dummies, where *Peak* is the peak season and *Normal* is the normal season, capture seasonal variation. Off-season is the reference category.

Stock abundance is expected to be a major determinant of harvest across the different sections of the Lake. However, for a short panel study like this, it is not possible to have the stock abundance be variable at each point. Stock abundance can vary consistently across fishing grounds and over seasons (or different time periods). We thus use the variable distance from shore to fishing ground (*DS*), regional and seasonal dummies to capture the spatial difference in stock abundance. Table 1 provides the description of the variables used in the analysis.

Table 1. Description of input and skipper-specific variables

Variables	*Description*
Input **(X-variables)**	
Crew Size (*L*)	Total number of crewmembers in the boat, including the skipper
Net length (*N*)	Net length (in meters) multiplied by the number of gill nets hauled per trip
Hours fished (*H*)	Total number of hours spent fishing each trip
Distance travelled (*Distance*)	Distance travelled from the shore to the fishing ground measured in hours
Motor	Value1 if the boat is fitted with outboard-motor, 0 otherwise
Mwanza	Value 1 for Mwanza region, 0, otherwise
Mara	Value 1 for Mara region, 0, otherwise
Peak	Value 1 for peak season, 0, otherwise
Normal	Value 1 for normal season, 0, otherwise
Boat, gear and skipper-specific **(Z-variables)**	
Skipper experience (*Skip-exp*)	Number of years the skipper has worked as a skipper
Years of schooling (*Educ*)	Number of years skipper spent in school
Age of net (*Netage*)	The average age of gillnets in years
Crew share (CrewS)	Value 1 if the unit gets a share equal to the owners'; 0 if the owner gets more than half.
Owner on board (*Ownerpcr*)	Value 1 if owner is part of crew but not a skipper, 0 otherwise
Owner-operated (*Ownerop*)	Value 1 if boat is operated by the owner; 0 otherwise
Remuneration method (*Remun*)	Value1 if the sharing of the proceeds is after cost deduction; 0 if gross revenues are shared
Extra bonus (*ExB*)	Value 1 if the skipper is getting extra payment for his role; 0 otherwise
Local management (*BMU*)	Value 1 if the beach has active beach management unit; 0 otherwise

3.2 The Technical Inefficiency Model

Using the Battese and Coelli (1995) inefficiency effect model, the one-sided error term is specified as:

$$U_{it} = \delta_0 + \sum_{j=1}^{11} \delta_j Z_{ji} + \omega \tag{3}$$

where Zs are various operator and vessel-specific variables used to explain efficiency differentials among fishers, δ's are unknown parameters to be estimated and ω_i is an iid random variable with zero mean and variance defined by the truncation of the normal distribution. Using our specific *Z*-variables the above model can be specified as follows:

$$U_{it}=\delta_0+\delta_1 lnSkipExp_{ji}+\delta_2 lnCrewS_{ji}+\delta_3 lnNetage_{ji}+\delta_4 Educ_{ji}+\delta_5 Ownerpcr_{ji}+\delta_6 Ownerop_{ji} + \delta_7 Remun_{ji} + \delta_8 ExB_{ji} + \delta_9 BMU + \omega, \tag{4}$$

where U_{it} is the boat technical inefficiency measure and *SkipExp* is the number of years as crew leader. We also include the share taken by crew including the skipper (*CrewS*), age of the gillnet in years (*Netage*), education of the skipper in years (*Educ*) and a number of dummy variables to capture some immeasurable skipper and gear attributes. These include dummy variables for the ownership of the boats (*Ownerprc=1*/0); owner being the skipper (*Ownerop*=1/0); remuneration system used in the unit (*Remun=1/0*); and extra bonus (*ExB=1/0*). We also have a dummy variable that captures the effect of local management measures on the efficiency of the vessel (i.e. Beach management units, *BMU*s=1/0)

The technical inefficiency equation (4) can only be estimated if the technical inefficiency effects, *U*i, are stochastic and have particular distributional properties (Coelli and Battese, 1996). Therefore the following null hypotheses are of interest to test; no technical inefficiency, $\gamma = \delta_0 = \delta_1 = \ldots = \delta_n = 0$. Under $\gamma = 0$, the stochastic frontier model reduces to a traditional average response function, thus no technical inefficiency effect.[3] These null hypotheses can be tested using the Likelihood Ratio test, given by:

$$\lambda = -2[ln\{L(H_0)\} - ln\{L(H_1)\}] \quad (5)$$

Where $L(H_0)$ and $L(H_1)$ represent the values of likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. Technical inefficiency for each firm, *i* in season *t*, is defined as the ratio of actual output to the potential frontier output.

3.3 Data

Data were collected between November 2002 and October 2003, from 22 randomly selected fish-landing sites (referred to as beaches throughout the rest of the paper), on the Tanzania waters of Lake Victoria. We gathered the data by administering questionnaires.

[3] A value of γ zero indicates that the deviation from the frontier is due entirely to noise, while a value of one would indicate that all deviations are due to technical inefficiency. Hence $0 < \gamma < 1$ indicates that the deviation from the frontier is both due to data noise and technical inefficiency.

The face-to-face interviews were conducted in collaboration with the staff of the Tanzania Fisheries Research Institute (TAFIRI) in Mwanza which has long working experience in the field and has regular contact with fishers around the Lake. The survey was carried out in three regions bordering the Lake; Mwanza, Mara, and Kagera.

The data was collected by randomly sampling the beaches and the fishermen. The sampling of beaches was done with the help of district fishery officers. Summary statistics of the data are given in Table 2. The average skipper has a primary education of 6-7 years in school and also has relatively few years of experience as a skipper; 4 years in Nile perch and 5 years in Dagaa fishery. On average, Nile perch boats carry 3 crewmembers including the skipper, while Dagaa boats tend to carry a larger crew per trip; the average crew number is 4. Both fisheries have indicated nearly identical fishing hours.

Table 2. Summary Statistics of the Variables

Variable Name	Units	Nile Perch fishery		Dagaa Fishery	
		Mean	Std. Dev.	Mean	Std. Dev.
Average catch/day trip	Kg	70.07	61.05	48.95	37.87
No. of crew in boat/day trip	No.	3.09	0.80	3.79	0.66
Net length/day trip	Meters	3767	2329.5	1495	1636
Hours fished/day trip	Hours	5.96	3.27	5.37	3.48
Education of the skipper	Years	6.46	2.25	6.60	2.25
Number of years as a kipper	Years	4.43	4.29	5.20	5.77
Motorboat (1 or 0)		0.44	0.50	0.28	0.39
CrewS (1 or 0)		0.23	0.42	0.37	0.49
Owner part of crew (1 or 0)		0.24	0.34	0.31	0.40
Owner the skipper (1 or 0)		0.31	0.39	0.57	0.37
Remuneration system (1/0)		0.38	0.49	0.60	0.40
Extra bonus to skipper (1/0)		0.43	0.50	0.40	0.49

Table 3 presents the correlation coefficients of variables used in both the frontier and inefficiency models. The results show that the correlation coefficient is relatively low for all the inputs; around 0.1 or below. As expected, fishing experience of the skipper is highly correlated with number of years working as a skipper (skipper experience); the correlation coefficient is .78 (See Table 3). Similarly, number of years as a skipper and fishing experience are fairly correlated with the age of the skipper; the correlation coefficient is

0.44 and 0.35 respectively. Based on this we dropped fishing experience and age of the skipper in the analysis.

Table 3. Correlation matrixes of variables used in the estimation

Variables	Crew size	Net length	Hours	Education	Age	Experience	SkipExp
Crew size	1.00						
Net length	0.10	1.00					
Hours	0.09	0.05	1.00				
Education	0.08	-0.01	-0.01	1.00			
Age	-0.05	-0.01	0.04	0.03	1.00		
Experience	0.01	0.01	0.06	-0.02	0.44	1.00	
SkipExp.	0.00	-0.01	0.03	-0.02	0.35	0.78	1.00

4.0 Empirical results:

The parameters of the stochastic production frontier model, equation (2), and those for the technical inefficiency model, equation (4), are estimated simultaneously using the maximum-likelihood estimation (MLE) program, FRONTIER 4.1 (Coelli, 1996). To confirm the choice of the functional form of the stochastic frontier, we need to test the adequacy of Cobb-Douglas relative to the less restrictive Translog form. Several hypotheses concerning model specifications are presented in Table 4.

Table 4: Hypothesis Tests

Null hypothesis	*Log-likelihood*	χ^2 *statistics*	*Critical* $\chi^2_{v,\,0.95}$	*Decision*
1. H_0: $\beta_{ij} = 0$ *for all* $i \leq j=1,2,3$ (Cobb-Douglas Frontier)				
Nile perch fishery	-1940.73	812.22	$\chi^2_{6\,0.95}$ =12.59	*Reject* H_0
Dagaa fishery	-204.55	21.63	$\chi^2_{6\,0.95}$ =12.59	*Reject* H_0
2. H_0: $\gamma=\delta_1=\ldots=\delta_9=0$ (No tech. Inefficient fn)				
Nile perch fishery	-1942.29	815.35	Mixed $\chi^2_{10,\,0.95} = 7.67$	*Reject* H_0
Dagaa fishery	-209.90	32.34	Mixed $\chi^2_{9,\,0.95} = 16.27$	*Reject Ho*

Note: Mixed $\chi^2_{v,\,0.95}$ values are taken from (Kodde and Palm, 1986, Table 1, p 1246)

The first null hypothesis that the Cobb-Douglas production function is an adequate representation for the Lake Victoria fisheries data (H_0: $\beta_{ij} = 0$ for all $i \leq j=1,2,3$) is strongly rejected, suggesting that the translog production function is the preferred model specification. The hypothesis that the parameters of the inefficiency effects are absent (i.e. H_0: $\gamma = \delta_1 = \ldots \delta_9 = 0$) is also rejected by the data. This indicates that the majority of skippers in the sample operate below the output-oriented technical inefficiency frontier. This also suggests that the traditional average production function does not adequately represent the production structure of the fishers in the sample.

Figures 1 and 2 show the distribution of efficiency scores for Nile perch and Dagaa fisheries respectively. Our results indicate that over 87% of the fishers in the sample have efficiency scores of over 70% for Nile perch fishery, while for Dagaa fisheries about 67% of the samples have efficiency scores over 70%. Similarly only 2.3% of the fishers are operating below 50% of the efficiency level in Nile perch fishery, while about 11% of the Dagaa fishers are operating below the 50% efficiency level. Furthermore only 0.38% are operating at 90% or more efficiency in Nile perch fishery, whereas in Dagaa fishery about 0.58% are operating at 90% or more efficiency.

A limited number of boats display substantially lower levels of technical efficiency in both fisheries. The arithmetic means of the individual efficiency scores are 0.78 for Nile perch and 0.71 for Dagaa fishery. These results compare well with Squires et al (2003) for the Malaysian gill net fleets of artisan fishers, but are comparatively higher than those found in Kuperan et al (2001) in Malaysian Trawl fishery. This comparatively high efficiency score is consistent with Schultz's (1964) thesis of "poor and efficient" smallholders and peasant farmers in developing country agriculture.

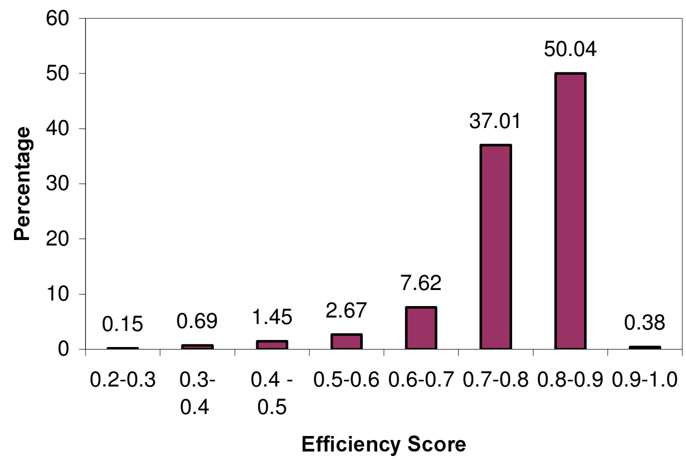

Figure 1: Technical Efficiency Scores for Nile Perch Fishery

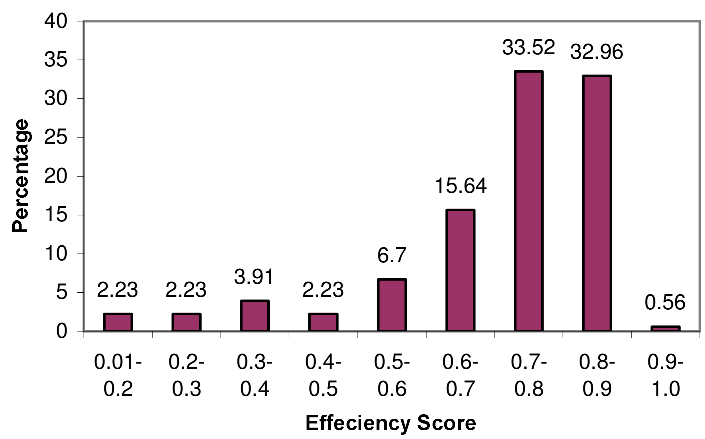

Figure 2: Technical Efficiency Scores for Dagaa Fishery

The results suggest that the variance of the one-sided component is 0.831 and 0.767 for Nile perch and Dagaa fisheries respectively, indicating that output-oriented technical inefficiency is important in explaining the total variability of the fish harvest. The remaining portion is due to factors beyond the control of the skipper (weather, luck, illness, etc). These results imply that the relative contribution of the inefficiency effect to the total variance term was estimated[4] to be 0.639 and 0.545 (i.e. 64% & 55%) for Nile perch and Dagaa fisheries respectively. This suggests that more than half of the variation in catch not accounted for by physical factors was attributed to the differences in technical efficiency rather than "luck" in Nile perch and Dagaa fisheries.

"Season" is considered to be an important variable in explaining variation in stock abundance over time. The seasonal variable was included in the frontier model to capture these variations in stock abundance. The variables were found to be positive and highly significant in Dagaa fishery but insignificant in Nile perch fishery. Analyzing the efficiency score over season we found that the mean efficiency was distributed as follows; 0.79, 0.78, 0.77 for peak, normal and off-seasons respectively for Nile perch fishery. This implies that most vessels targeting Nile perch in the sample are technically efficient at around 0.77 in all seasons (Figure 3). This shows that there might not be any significant variation in Nile perch availability at different times of the year contrary to what fishers claim. This lack of significant variation could also be explained by the stock being so overfished that there is no longer any clear variation in catch over season. The result is also consistent with the insignificance of seasonal dummy variables in the frontier model. Generally in Nile perch fishery, high efficiency scores dominate for all seasons. These results contrast with those found in Kuperan et al (2001) for Malaysian Trawl fishery where the lower efficiency scores dominated the high scores in normal and off-season.

[4] The estimate of γ provided by in the MLE results is only an approximation of the contribution of inefficiency to total variance as the true variance of μ is proportional but not exactly equal to σ_s^2. The corrected relative contribution of inefficiency is given by $\gamma^* = \gamma/[\gamma + (1-\gamma)\,\pi/(\pi - 2)]$ (Coelli 1995)

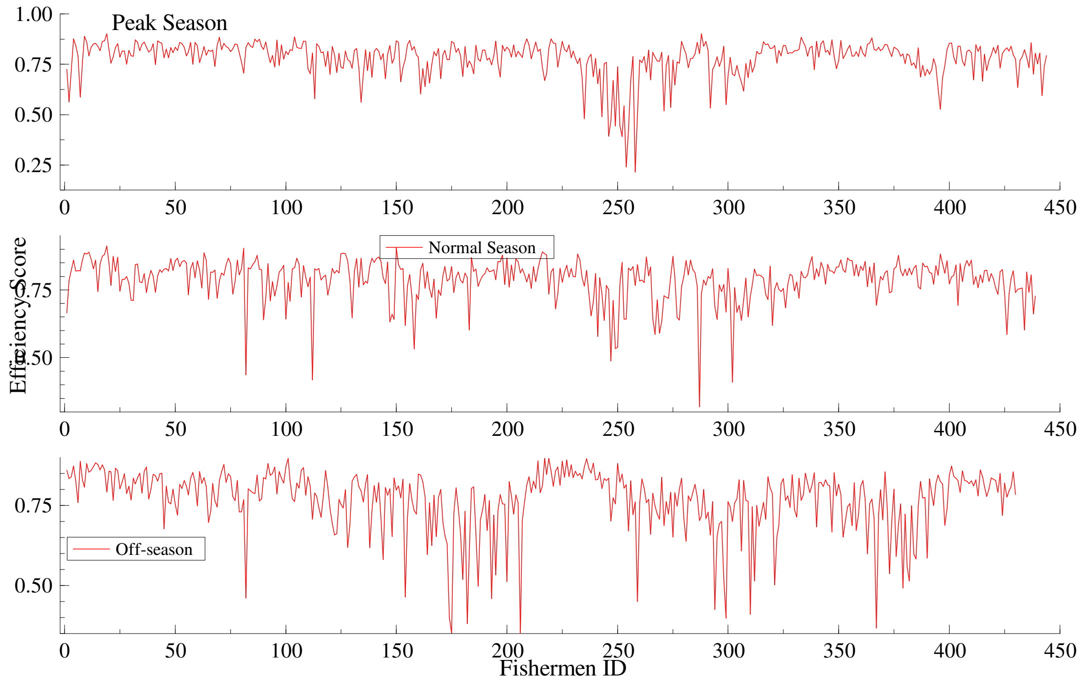

Figure 3. Technical Efficiency over Season for Nile Perch fishery

Seasonal effects seem to exist in Dagaa fishery, (Figure 4). The normal and off-season efficiency scores are relatively comparable; however a comparison with the peak season figure indicates that vessels are more efficient in peak seasons than in the normal and off-seasons. In this fishery, the peak season is dominated by high efficiency values while the normal and off-seasons are dominated by relatively low efficiency values, which is consistent with the previous study by Kuperan et al (2001).

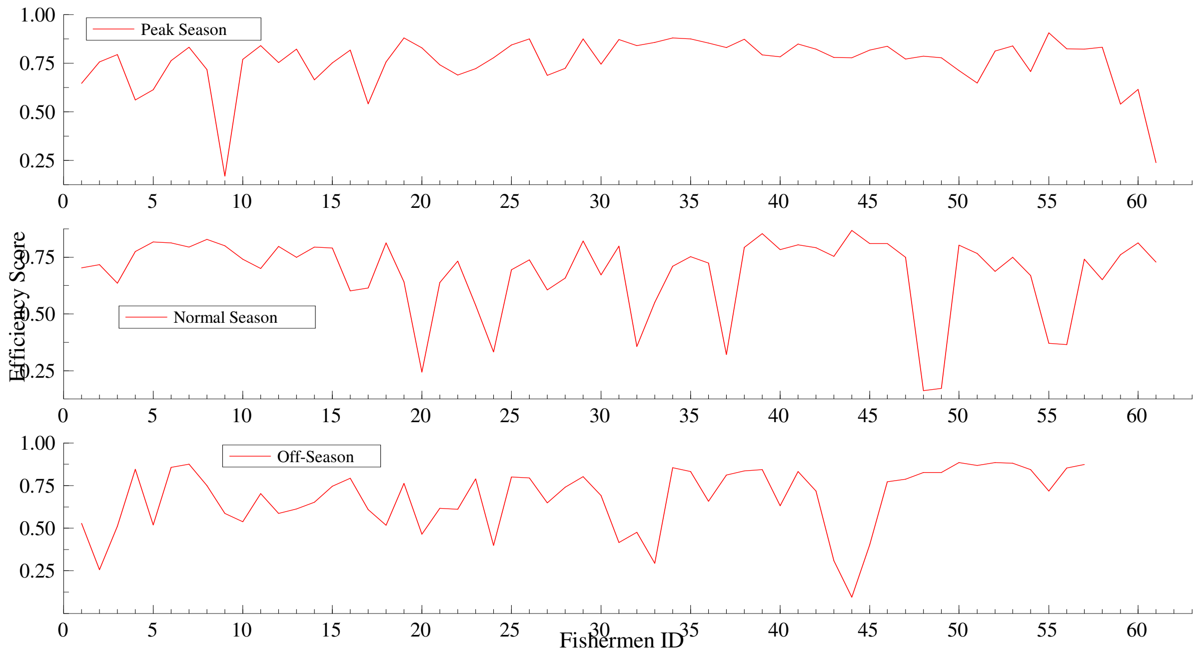

Figure 4: Technical Efficiency over season for Dagaa Fishery

Table 5 reports the results of the frontier model (top panel) and the inefficiency model (bottom panel). Most variables in the frontier model are significantly different from zero, however interpretation of the individual parameters of a translog may not be particularly meaningful. We therefore focus on the inefficiency model. The technical inefficiency function has the technical inefficiency dependent variable so that a negative sign will indicate an increase in technical efficiency or a decrease in technical inefficiency. A majority of the variables in the technical inefficiency function are significant, especially in Nile perch fishery. The captains' fishing skill is often considered to be an important determinant of a boats' catch and efficiency. Among the captains' attributes, we expect fishing experience to imply better knowledge of fish location, weather patterns, currents and tides, bottom conditions and how to best catch the fish. However, we find that it is the experience as a captain that matters, while previous experience, as a regular crewmember is insignificant.[5] The result indicates that efficiency increases with skipper experience. In

[5] The variable experience was included in the model in the initial analysis, but was found to be insignificant; because of its high correlation coefficient with the number of years as a skipper it was removed in the model.

addition to fishing experience, long experience as a skipper generally implies experience from working with different crews and thereby better skills in finding the best crew for the boat.

To capture the efficiency effects of incentives given to the skipper we include dummy variables for extra bonus given to the skipper; a dummy variable indicating whether owner takes equal share with the crew and mode of remunerations system, i.e., whether the share was calculated after or before deducting the daily running cost. The results indicate that extra bonus to the skipper leads to increased efficiency in both fisheries. And also efficiency increases if owner share 50-50 with the crew. We also find that sharing after deducting operating costs leads to increased efficiency in the Nile perch fishery. A potential explanation is that the risk of receiving zero payment forces the crew to work harder, which is reflected as increased efficiency.

Ownership patterns and particularly owner participation in actual fishing can affect efficiency and incentives. The variable (*ownerop*) is significant, which indicates that captains owning their vessels are more efficient than hired captains. An interesting result is that boat owners without skipper skills are better off hiring a captain and staying ashore. The presence of an owner on board reduces efficiency; one reason for this is that the boat owner might interfere with the skills of the skipper.

Table 5 Parameter Estimates of the Stochastic Production Frontier and Inefficiency Models

	Nile Perch		Dagaa	
	Coeff.	t-ratio	Coeff.	t-ratio
Stochastic Production Frontier				
Constant	2.335***	4.395	4.331**	2.214
Ln(Crew size)	0.185**	2.215	-2.970	-1.405
Ln(Net length)	1.049***	8.735	0.145*	1.850
Ln(Hours)	0.636**	2.247	1.297*	1.665
Ln(crew size X ln(crew size)	-0.022***	-5.852	-0.199	-0.229
Ln(Net length X ln(Net length)	-0.049***	-7.365	-0.014	-0.493
Ln(Hours) X ln(Hours)	-0.124**	-2.064	-0.126	-0.715
Ln(Crew size) X ln(Net length)	-0.036***	-3.584	0.418**	2.425
Ln(Crew size) X ln(Hours)	0.018	1.395	0.737	1.353
Ln(Net length) X ln(Hours)	-0.007	-1.016	-0.263***	-3.062
Ln(Distance in Hours)	0.009	0.303	-0.003	-0.033
Motorboat dummy	0.116***	2.535	0.122	1.004
Mwanza region	0.123***	2.572		
Mara Region	-0.041	-0.846		
Peak season	0.004	0.035	0.689***	3.324
Normal Season	-0.125	-1.024	0.651***	3.274
Variance parameter				
σ^2	2.258***	3.347	1.553***	4.232
γ	0.831***	8.383	0.767***	9.708
Technical inefficiency Model				
Constant	-2.555	-0.501	-9.136*	-1.722
Ln(Skip-exp)	-0.059**	-2.735	-1.381**	-1.996
Ln(Netage)	0.206	1.274	2.543*	1.851
Ln(education)	-0.413*	-1.702		
Dummy Variables				
Crew share (*CrewS*)	-0.958*	-1.665	-3.905*	-1.645
Owner part of crews (*Ownerpcr*)	1.823*	1.753	-0.469	-0.654
Owner operated (*Ownerop*)	-3.410**	-2.039	-1.270	-1.135
Remuneration (*Remun*)	-1.545**	-2.843	-0.164	-0.314
Extra bonu (*ExB*)	-0.449**	-2.365	-2.688*	-1.793
BMU	-0.773**	-2.757	-3.369*	-1.678
Log likelihood		1535.610		193.730
Mean efficiency.		0.778		0.705
No. Of observations		1313.000		179.000

Notes: t-statistics in brackets

*** Significant at 1% level; ** Significant at 5% level; * significant at 10% level

Additional schooling can improve literacy and cognitive skills, which may be important in increasing efficiency by increasing the ability of skippers to adopt technical innovations. The number of years the skipper spent in school was found to be statistically significant, suggesting that addition years of schooling or training could be important in increasing efficiency among the inefficient skippers in Nile perch fishery.

In 1998, the Tanzanian Government through the Lake Victoria Environmental Management project (LVEMP) introduced local management units commonly known as Beach Management Units (BMUs). These units were established to enhance community participation in the surveillance and management of the Lake resources. Though the BMU leaders do not have legal power to arrest anyone, they can point out culprits to the enforcement officials. Their most important task, however, is to help prevent the use of destructive gear. The existence of BMUs has led to increased efficiency in both fisheries, which is possibly explained by fishermen exchanging information and learning from each other at the regular BMU meetings.

5.0 Discussion and conclusion:

Lake Victoria fisheries can be regarded as open access with no restrictions on entry or total catch neither regionally, nor nationally. There are no limits on effort and the only measure for preventing stock depletion is a minimum mesh size regulation, which is widely violated by the fishers (Lokina, 2004). The lack of alternative employment opportunities coupled with the open access nature of the fisheries have led to a substantial level of overcapacity both in terms of vessels and in numbers of fishers. This study focuses on the Tanzanian section of Lake Victoria, but the results should also apply to the Kenyan and Ugandan sections where fishers employ comparable technology and harvesting practices and operate under similar management. There is a great need for the three governments sharing the Lake to direct their policies towards resource conservation and support for sustainable livelihoods including incentives for fishers to diversify into other professions.

The results indicate variation in efficiency, but that boats on average have a relatively high level of efficiency with the majority above 77% or more in Nile perch fishery and 71% in Dagaa fishery. The inefficiency models indicate possibilities for improving performance in both fisheries. For Nile perch fishery, efficiency increases by years of skipper experience and by years of education of the skipper. A number of significant dummy variables indicate increased efficiency when the skipper owns the vessel, if the crew is paid the same share as the owner and if the revenues are shared after cost deduction. An extra bonus to the skipper increases efficiency, while owners (non-skippers) joining the crew reduces efficiency. For Dagaa fishery efficiency increases with skipper experience, while efficiency decreases with average gill net age. Efficiency also increases if the crew receives an equal share and if the skipper enjoys an extra bonus. A common feature for both fisheries is that the existence of local management over fish resources, commonly known as Beach Management Units (BMUs), leads to improved efficiency. These BMUs have elimination of destructive gear practices as their prime objective, but the repeated meetings with fishers may for instance imply information sharing accompanied by learning effects.

From the perspectives of equity and of distribution, improved efficiency is desirable; the results above provide some suggestions for policy. One such idea is if the hired skippers in Nile perch fishery could buy their vessels, they would likely increase the rate of return. This suggests that improved credit facilities would improve efficiency in Lake Victoria fisheries. Probably it was for these reasons that the government quite recently removed all the import duties and value added tax (VAT) on fishing gear and motors as a move to enable more fishers to own their vessels (URT, 2004). This government move can be seen as an attempt to subsidize the fishing sector to maintain employment and make fishers technologically competitive in the face of declining stocks. But improving efficiency when neither effort nor catch is limited could lead to further depletion of stocks. Conclusions about efficiency are subject to biological limits. Given the stock conditions, it is not possible to increase the long-run catch by increasing fishing effort since the practice would lead to depletion. Increased efficiency at the aggregate level is thus only possible if fishing effort is limited. One potential option would be the retirement of a number of boats, preferably those least efficient. Improved efficiency would then lead to similar catch levels with a smaller number of boats and fishermen.

However, such a prescription is problematic for two reasons. Firstly, it presupposes control at the aggregate level, which is currently not available. Secondly, it requires the decommissioning of a number of boats and the unemployment of a number of fishermen. Theory states that in the long run, improved stocks and increased profits for the remaining fishermen should in principle be sufficient to compensate those who are forced out of the industry, but there remain serious issues of distribution, enforcement and monitoring.

In the absence of aggregate control of effort and the exit of less efficient fishermen, we have a different situation. The existing variation in efficiency can be a problematic rather than constructive element. Potentially it contributes to hiding the problem of over-fishing; unsuccessful fishermen will compare themselves to successful fishermen and may see a difference of skill rather than stock decline. The results show that some of the variation in efficiency is due to differences in equipment, skill or organizational variables such as the structure of incentives and the relationship between the owner and the skipper. These tangible differences can be remedied but the competition for increased efficiency may reinforce overcapacity. One example is that some boats use extremely long, fine-meshed nets and "stack" these nets on top of each other. If such a practice spreads throughout all of Lake Victoria, the stocks will be further depleted, while improved landing will only be a temporary phenomenon. In this respect overcapitalisation is also an extra financial burden for poor fishermen.

Given the current situation in Lake Victoria fisheries there is a need for curbing overcapacity. From a theoretical perspective a Warming landing tax is attractive (Warming, 1911; Weitzman, 2002); it would reduce the attraction of the fisheries to new entrants and limit the incentive schemes, which according to our results influence efficiency and potentially restore rents in the long run. However, for a fishery without landing records and total allowable catches, such reform would face tremendous problems. Our results correspond to Squires et al (2003); that development aid should focus on human and social capital rather than on vessel and gear upgrade. Pomeroy (1994) and Squires et al (2003) hold that strategies for cooperative and community management can help to control fishing activity and promote sustainable fishing practices, while Christy (1999) suggests that limited entry could be beneficial for developing fisheries. Almost half of the studied artisan fishing communities in Lake Victoria have BMUs. The current structure of these management units is quite disorganized, as evidenced by a lack of resources and lack of power to enforce the law. Though these BMUs were found to have a negative effect on mesh size compliance (Lokina, 2004) but positive effect with regards to efficiency. It is believed therefore that an overall restructuring would be beneficial for the BMUs to be able to play an effective role in fishery resource management. With such reform the BMUs could potentially carry out a limited entry policy, which would render possible efficiency improvements and sustainable fisheries on Lake Victoria.

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Small-scale Fishers and Risk Preferences

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Abstract

Using an experimental approach we investigate the risk preferences of artisanal fishers in Tanzania waters of Lake Victoria. The experiment concerns pair wise comparisons of hypothetical fishing trips that vary in expected mean and spread of the net revenue. The results show that about 34% of the fishers can be considered as risk neutral, 32% as risk averse, and 34% as risk seekers. Econometric analysis indicates that the likelihood of belonging to the risk seeking group increases if motorboats are used, if fishing is the main source of household income, and if the fisher is targeting Nile perch. Asset ownership and perhaps socio-economic variables influence risk preferences.

Key words: Risk aversion, artisanal fishers, Tanzania, Lake Victoria, Nile perch, Dagaa

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1. Introduction.

Fishing location decisions, be it in commercial or artisanal fisheries, are inherently overshadowed by a multitude of risks including yield and price risks. The uncertainties of product prices, imperfect information about resource abundance and location, and vagaries of the weather all complicate fishers' location decisions, thus making fishing a risky profession. Beliefs about profitability of different locations and the decision of how long to fish in a particular location are likely to affect the variability of fishers' incomes. Thus, fishers targeting the same species may have dramatically different net returns depending on their location choice (Mistiaen and Strand, 2000; Smith, 2000). The fishers' problem is to select the location that will yield the highest expected utility. For the fishers, the choice depends on their risk preferences, the distribution of the catch and the costs associated with each fishing location. A key aspect of modeling and analyzing fishers' behavioral motivations is therefore to understand their risk preferences. Each time the skipper puts out to sea, a choice of fishing ground is made and the choice may convey information about the skippers'/owners' risk preferences. Sandmo (1971) showed that a risk averse firm facing output risk would produce less than a risk neutral firm. Following Sutinen (1979), it has almost been taken for granted that fishers are risk averse. The scant empirical evidence on fishers' risk preferences tends to confirm the hypothesis of Sutinen that fishers are risk averse (e.g. Bockstael and Opaluch, 1983; Dupont 1993; Mistiaen and Strand 2000).

The work of Bockstael and Opaluch (1983) on fisheries' supply response was the first to incorporate uncertainty and risk preferences into the behavioral motivation of the fishers. Examining the role of expected utility maximization in a random utility model of fishing location choice with substantial income level at stake, Bockstael and Opaluch (1983) found that fishers tend to respond to economic incentives and confirmed the hypothesis that fishers are homogenous in risk preferences with a constant relative risk aversion equal to one. Hence, fishers respond to locations with a higher expected average gain, but would sacrifice some of the expected mean in order to lower the variability of gain. Applying the same framework as Bockstael and Opaluch and adding price uncertainty into the model, Dupont (1993) could confirm the restrictive assumption of homogenously risk averse fishers in three of the four vessel types. Mistiaen and Strand (2000) studied fishers' location choice at the trip level, where a majority of the fishers were using fishing grounds that were easily accessed. Despite allowing for heterogeneity, Mistiaen and Strand (2000) found that at least 95% of the trips could be characterized as risk averse. Studying commercial fishers' behavior when facing both financial and physical risks, Smith and Wilen (forthcoming) confirmed risk averse behavior among sea urchin fishers when making a daily decision trip.

Recent research, however, casts doubt on risk aversion in small stake experiments, i.e., when the difference in income among alternatives in the experiment is relatively small. Rabin (2000) has shown that the implication of risk aversion for small differences in income will imply quite extreme risk aversion for large changes in income. Similarly, Eggert and Martinsson (2004) have survey evidence that risk aversion is not an important influence for choice among locations. Fishers often make decisions on a more short-term basis like target species, gear choice and location. These are recurrent decisions made on a per trip basis, indicating a time span of 1 to 30 days, in which we find the stake involved in each trip to be relatively small. Repeated risk aversion behavior for modest stakes will lead to substantial income reduction in the long run, i.e., the more risk averse the fisher is, the lower the aggregate income he will earn. Holland and Sutinen (2000) found risk-loving behavior, but held that fishers in their sample tried to reduce risk in ways that were not captured by their model. Some recent empirical studies indicate that a substantial share of fishers are risk neutral. Strand (2004) used a random utility model and confirmed risk averse behavior, but finds that fishers' risk preferences vary spatially. In his sample, fishers from New York tend to have the greatest relative risk aversion, while fishers from the Florida Keys exhibit behavior more consistent with risk neutral preferences. Eggert and Tveterås (2004) find that 30% of the trips in a sample of Swedish trawlers reflect behavior consistent with risk neutral preferences. Similarly, using a choice experiment, Eggert and Martinsson (2004) find that about half of a sample of Swedish commercial fishers responds in a manner inconsistent with risk aversion. The empirical evidence of risk neutral fishers is also supported by McConnell and Price (2004), who argue that risk neutrality is common in fisheries and that the lay system is not based on pure risk sharing, assuming that both parties are risk averse, but used as a device to handle moral hazard in teams.

If we move the perspective to poor artisanal fishers, even less is known regarding their risk preferences, although there is rich literature in agricultural economics on farmers' risk preferences in low-income environments. A majority of these works have found that most subsistence farmers in developing countries exhibit risk aversion, which increases as payoffs are increased (Dillon and Scandizzo, 1978; Rosenzweig and Binswanger, 1993; Binswanger and Sillers, 1983). Using an experimental approach, Binswanger (1980) found that among farmers in rural India, more than 50% could be characterized as risk averse and only 15% as risk neutral.[2] Artisanal fishers are poor and often tend to use less sophisticated fishing technology. Many began fishing in accordance with the dictates of family tradition, and therefore fishing may be considered a way of life. Hence fishers may be reluctant to relocate despite the worsened conditions for the particular fishery. Fishers in Lake Victoria typically carry out daylong trips, therefore making repeated short-run decisions. The gamble connected to each trip for these fisheries is therefore relatively small; according to economic theory, a rational agent would choose a risk neutral strategy, which in the long run would maximize the profit. Despite the inherent riskness of their chosen profession, it is important to know if fishers try to reduce risk by choosing alternative locations with less variability in revenue. This is especially important to the artisanal fisheries where fishers do not have the electronic fish-finding gear common to commercial fisheries that can help find an aggregation of fish en route. Artisanal fisheries are also characterized by substantial price uncertainty that involves timing a boat's return to port to sell the harvest and prevent deterioration of the fish, due to the lack of preservation facilities onboard. Thus the decisions of where to fish and how long to fish are intricately related and lead to variation in exposure to financial risk.

The objective of the experiment is to measure risk preferences of individual fishers. In particular, we measure risk preferences of artisanal fishers by means of two alternative fishing trips, which only differ in terms of expected mean and variation of net revenues. Thus, fishers' risk preferences are appraised via their choices between hypothetical fishing trips involving risky alternatives. We are also interested in identifying factors that possibly determine the degree of absolute risk aversion in Lake Victoria fisheries. Our results could also be of importance to examine whether risk preferences in artisanal fisheries in Lake Victoria can be in line with the general findings of farmers' risk preferences in low-income environments. A better

[2] Risk preferences of the remaining farmers are unclear.

understanding of fishers' risk preferences is important in understanding the welfare consequences of regulatory policies such as closed areas or seasons and other biological modifications. If, for example, a particular target species yields high expected profits with high variability, the welfare consequences from a temporary closed season of this fishery will vary depending on whether fishers are risk averse, risk neutral or risk seeking.

2. Description of the Lake Victoria Fishery

Small-scale fishing units generate almost all of the fishing effort in Lake Victoria. These fishers use open, wooden-hulled vessels with a total crew of from 2-6 persons. About 50% of the vessels in the sample are fitted with outboard motors, while the others use sails and/or paddles. Fishers have a limited range of options with respect to the target species and basically concentrate on two major species - either Nile perch or Dagaa. A few fishers alternate between the two major targets species, while some of the Nile perch fishers also catch a third species, Tilapia, but this is of minor economic importance. Thus the fishery to enter is already known in prior, the daily decision is mostly concerned with the choice of fishing ground. Nile perch and Tilapia fishing is generally done with gillnets, while sometimes long lines or hooks are used. Dagaa is mainly caught with Dagaa nets, but some fishers use even smaller mesh sizes, so-called mosquito nets. The fishing frequency for Nile perch and Tilapia is usually 5-6 days a week throughout the month and is on a daily basis due to lack of preservation facilities; fishers leave in the afternoon and come back for landing in the morning. Dagaa is fished at moonless night (which limits the number of fishing days to about 15 a month) using pressure lamps to attract the fish. Dagaa fishers also dry catches on land, which requires work onshore.

Fishing in Lake Victoria is carried out both inshore and offshore. A majority of sail/paddle fishers fish inshore, while those equipped with motors can move around the fishing grounds with relative ease and exploit both inshore and offshore fishing grounds. Most of the fishers go repeatedly to the same fishing ground and about 65% report that they usually fish the same ground up to seven days in a row.

3. Methodology.

The seminal work by Arrow (1965; 1971) and Pratt (1964) established that under the expected-utility hypothesis, one-to-one relationships exist between preferences over random income or wealth and the measures of risk aversion. Since then, the various measures of risk aversion have played a central role in determining comparative static results of behavior under uncertainty. It is common in applied welfare economics to assume a special class of utility functions characterized by constant relative risk aversion (CRRA), as proposed by Atkinson (1970).[3] The assumption of constant relative risk aversion also implies decreasing absolute risk aversion, i.e., the higher the level of initial wealth an individual has, the higher the level of risk he or she is willing to accept. The function is modeled under the assumption of concavity of utility function over wealth, suggesting that the expected utility maximizer would always want to take a sufficiently small stake in any positive expected value bet (Arrow, 1971). This means that expected utility maximizers are (almost everywhere) arbitrarily close to risk neutral when stakes are small. Rabin (2000) showed that risk aversion, even to quite sizeable stakes, implies a “huge risk aversion” to a large stake. Hence, if subjects in experimental studies are found to be risk averse for small stakes, they are not expected to be utility-maximizers (Rabin, 2000). The CRRA specification states that individuals’ risk preferences depend on initial wealth. However a reasonable proxy for initial wealth is typically difficult to obtain, hence, specifications which are wealth independent are used in the literature (see e.g., Ali, 1977; Eales and Wilen 1986; Golec and Tamarkin, 1998; Mistiaen and Strand 2000; Eggert and Martinsson, 2004). Prospect theory (Kahneman and Tversky, 1979) is a critique of expected utility theory as a descriptive model of decision making under risk, and claims that risk preferences are independent of initial wealth. According to prospect theory, subjects are found to be risk averse in choices involving sure gains and risk seeking in choices involving sure losses.

In the experiment, the subjects were presented with pairwise choices of hypothetical payoffs. The subjects are skippers, of whom about 30% own their vessels.

[3] Atkinson’s utility function; $U(x) = \left(x^{1-r}\right) / (1-r)$, where r is the constant relative risk aversion (CRRA) coefficient, r = 0 denotes risk neutral, r < 0 and r >0 implies risk aversion and risk seeking, respectively. When r = 1, U(x) = ln(x).

They are offered choices with an expected mean corresponding to the average individual net revenues from five days of fishing trips. The alternative choices presented to the subjects follow the approach used by Eggert and Martinsson (2004). The experiment requires individuals to choose among alternatives in which an increase in expected returns can be purchased only by increasing risk or the dispersion of outcomes. Because we lack good measures of wealth data, we do not use the CRRA specification, but rather the relative risk premium (RRP), which is a utility-free approach (Dillon and Scandizzo, 1978), to predict whether the subject is risk averse, risk neutral or risk seeking. Thus, our model is not based on a particular utility function and can be viewed as an approximation to mean-standard deviation representation within the expected utility theory suggested by Meyer (1987). An individual who is risk averse towards financial risk, *ceteris paribus*, will prefer higher expected revenue, and lower variance of revenue. The RRP in this case can be seen as the amount of money in terms of a reduced expected mean that the respondent is willing to trade off for a reduced risk. If the RRP is positive, the individual is risk averse, while a negative RRP implies that the individual is risk seeking. Consider a choice between the following two hypothetical fishing alternatives, where the probabilities for expected outcomes follow a uniform distribution that cannot be influenced by the fisher.[4] The first alternative has an expected outcome in the range of Tanzanian Shillings (Tshs) 500-9,500, i.e., the expected mean is Tshs 5,000. The second alternative has an expected outcome in the range of Tshs 650-5,850, i.e., the expected mean is Tshs 3,250. A fisher who prefers the first alternative has a positive RRP larger than Tshs 1,750, which means that he is willing to accept such a reduction in expected mean in order to receive the given reduction in variation of outcome; such a fisher is labeled risk averse. Those fishers who prefer the second alternative have a RRP smaller than Tshs 1,750 and are either risk averse, risk neutral or risk seeking. By letting respondents carry out several pair-wise choices, where the mean and the spread is gradually changed for the second alternative while the first alternative is kept constant, we obtain an upper and a lower bound of the RRP for each individual, which enable us to classify each respondent's risk preferences.

[4] The assumption of uniform distribution might be a problem to some, especially if they deem themselves more skilled than others and that their high skill can enable them to influence the variance of the outcome.

4. Description of the Experiment.

The choice experiment concerns risk preferences of Tanzanian artisanal fishers in Lake Victoria. Data was collected in a field survey conducted during August-October 2003 in three regions bordering the Lake. A total of 499 fishers were interviewed face-to-face (approximately 160 fishers from each region), in collaboration with the staff of the Tanzania Fisheries Research Institute (TAFIRI) in Mwanza.[5] After explaining the experiment, the respondents were given time to read the details of the experiment and ask questions. At the end of the experiment the respondents were asked if they wished to change any of their choices, and were allowed to do so. Results from the pre-test of the experiment indicated that almost all subjects had a basic education level and could read and write. Thus, during the interview the subjects were given a copy of instructions of the experiment and the payoff table of the alternatives as presented in Appendix B. Respondents were also asked a few follow-up questions on their stated choices and about their socio-economic conditions, including age, education level, income, assets, ownership status of the vessel, etc. The length of the interview was approximately 45-60 minutes. Pre-testing of the experiment on three beaches in the Mwanza region led us to the choice of the mean income and the five-days of fishing trip values given in the experiment. We also use production data collected from the same respondents on this and two other occasions for another study (Lokina, 2004).

In the introduction of the experiment the respondents were asked to imagine that they were actually faced with the choice between two fishing alternatives, described as Alternative A and Alternative B. The responses were anonymous and the instructions specified that there was no 'correct' answer to the problem; the aim of the study was to find out how fishers choose between risky alternatives. The respondents were informed that the described alternatives could differ from their actual experience, but that they should base their judgments on the alternatives as presented in the experiment. It was stressed that despite their great skills as fishers they could not influence the probability of the outcome.

[5] The staff at TAFIRI in Mwanza have a long working experience in the field and have regular contact with fishers around the Lake; most if not all fishers are aware that they are not enforcement officials.

The respondents were given five pairwise choices as presented in Appendix B. Each pair was to be evaluated independently and the respondent could go back and change a previous choice. Alternative A_i, had the same mean and spread over the five choices, while alternative B_i started with a significantly lower mean and spread, then gradually increased over the five choices both in terms of mean and spread. For fishing Alternative A, weekly revenue income always varied uniformly between Tshs 500 and Tshs 9,500, hence, the average income was Tshs 5,000. The net revenue varied less for fishing Alternative B**,** while the expected mean increased from Tshs 3,500 to Tshs 5,850. In order to reduce the cognitive burden of handling potential negative outcomes, all alternatives entailed a positive outcome. The assumption of positive outcomes has some empirical support as a total of 1,554 trip observations for these fishers led to positive net revenues in 95% of them. From economic theory we expect respondents to be risk neutral. Given the modest stake, it is rational to prefer A_1 and A_2 to B_1 and B_2. B_3 yields equal expected mean with less variance and, hence, should be preferred to A_3. The mean and interval levels used are given in Table 1, which is also the order in which the alternatives were presented in the experiment.[6]

Table 1: Fishing Alternatives in the Absolute Risk Aversion Experiment

Alternatives A and B	*Min. Income*	*Mean Income*	*Max. Income*	*Std Dev (Spread)*	*Relative risk Premium if indifferent between A and B*
Trip $A_{1\text{-}5}$	500	5000	9500	4500	
Trip B_1	650	3250	5850	2600	1750
Trip B_2	1600	4400	7200	2800	600
Trip B_3	2000	5000	8000	3000	0
Trip B_4	2300	5500	8700	3200	-500
Trip B_5	2600	5850	9100	3250	-850

All values are in Tanzanian shilling (Tshs). (USD 1 ≈ Tshs 1,137, January 2005)

[6] There is a potential ordering effect here, i.e., the answers may depend on the order in which the choices are made. Johansson-Stenman et al (2002) explicitly tested for ordering effects in a similar experiment, but did not find evidence of the problem. This strengthens our belief that the ordering effect is not a serious problem in our study.

5. Results

The final analysis consisted of 473 respondents.[7] Table 2 presents the summary statistics of the variables used in the analysis. The variable asset was constructed by accounting for all assets owned by the skipper as mentioned in the survey, which include livestock, bicycles, fishing boats, etc. We valued livestock at the prevailing market price, while other assets were valued by asking the fisher to state the maximum price he was willing to pay if he was offered to buy it.

Table 2: Descriptive Statistics for Responding Skipper

Variable	Description	Mean	Std. dev.
Age	Age in years of the skipper	31.4	8.71
Education	Number of years the skipper spent in school	6.58	2.28
Household	Total household size	6.3	3.8
Fishing	A dummy variable =1 if fishing is the main economic activity of the Household; 0, Otherwise.	0.61	0.48
Asset owned	A dummy variable =1 if skipper owns assets worth at least Tshs 250,000; 0,otherwise	0.57	0.50
Dagaa specie	Dagaa is target specie (binary)	0.20	0.39
Mwanza	Fisher from Mwanza region (binary)	0.35	0.48
Mara	A dummy variable = 1 for Mara region; 0, otherwise	0.34	0.47
OwnerSkipper	A dummy variable =1 if owner is the skipper of the boat; 0, otherwise	0.26	0.37
OwnerCrew	A dummy variable =1 if owner is part of the crew; 0, otherwise	0.31	0.41
Motor	Boat fitted with outboard motor, A dummy variable = 1; 0, otherwise	0.54	0.50
Crew size	The size of crew on board	3.13	0.73
Net quantity	The number of gillnets onboard on a day trip (meters)	34.67	23.67
Netlength	Net length (in meters) multiplied by the number of gill nets hauled	3,686	2,022
Hours fished	Total active net hours spent fishing per trip	8.72	3.13
Skill	Self-rated fishing skill (1=better or better than average; 0, otherwise	0.75	0.43
Habit	A dummy variable = 1 if he has being fishing in the same ground for more than 7 days; 0, otherwise	0.35	0.48

The results of the risk experiment are presented in Table 3. Of the 473 respondents, 22% consistently prefer Alternative B to Alternative A, which indicates a RRP larger than Tshs 1,750. We group these with the next group of respondents who have a RRP in the range of Tshs 600-1,750 and label them risk averse. Respondents belonging to this group constitute 32% of the sample and are willing to accept a reduction in expected mean by more than Tshs 600 to achieve a reduction in the spread. About 32% of the

[7] Initially 499 respondents made up the sample, but during the experiment, 26 respondents (about 5%) made at least one inconsistent choice, i.e., they violated the transitivity assumption. We thus omitted them from the final analysis.

respondents always prefer Alternative A to Alternative B, indicating a RRP less than Tshs -800. For further analysis we grouped those with the next group of respondents preferring a lower mean and a higher variation, i.e., those who preferred trips A_{1}-$_{4}$ to B_{1}-$_{4}$ but chose trip B_5 instead of trip A_5. These respondents constitute 34% of the responding fishers in our sample and are classified as risk seekers. Those who preferred alternative A at least until trip A_3 and then switched to alternative B, that is having a RRP bounded between 600 and –500, are classified as risk neutral and comprise 34% of the fishers.

The use of hypothetical questions raises the issue of whether the respondent actually reveals his true preferences. We found that about 55% of the respondents consequently chose either Alternative A or Alternative B, while 45% preferred the riskier trip A_1 to B_1 but switched to trip B as the mean of B approaches the mean of Alternative A. A potential problem is that some of the respondents may have chosen the extreme alternatives as a means of reducing the cognitive burden in answering the questions, which implies an under representation of risk neutrals in this study. Some of the respondents may have spent most effort on the first pair-wise choice and then repeatedly marked the same type of alternative. This potential problem of a majority of the respondents choosing one of the two extreme alternatives was also experienced in Eggert and Martinsson (2004). Camerer and Hogarth (1999) review a number of experimental papers and hold that hypothetical experiments may induce a majority of respondents to prefer the extreme alternatives. It may be that the survey design leads to overestimates of the two categories risk averse and risk seeking, while the number of risk neutrals is underestimated.

Table 3: Results of the Absolute Risk Aversion Experiment

Relative risk premium (Tshs)	*Frequency*	*Percentage*	*Category*
1750 < RRP	103	22.49	Risk averse
600 < RRP ≤ 1750	44	9.61	
0 < RRP ≤ 600	67	14.63	Risk neutral
-500 < RRP ≤ 0	88	19.21	
-800 < RRP ≤-500	9	1.97	Risk seeking
RRP ≤-800	147	32.10	

The low figure of only 32% risk-averse skippers as indicated in Table 3 is clearly at odds with the common findings in commercial fisheries (Bockstael and Opaluch 1983; Dupont 1993; Mistiaen and Strand 2000) and for poor farmers in developing countries (Binswanger and Sillers, 1983; Rosenzweig and Binswanger, 1993). According to the results 34% of the fishers are risk-seeking. The question then arises of whether these artisanal fishers are true risk seekers or if their behavior is induced by the study design. A potential problem is the assumption of a uniform probability distribution equal to all respondents. Even though it was stressed in the experiment that fishers could not influence the outcome, self-esteem could have led to an increased number of risk seekers in the experiment. A third issue is whether the whole experiment is too hypothetical, i.e., can respondents relate to the described choices?

Some of these issues were dealt with in the follow-up questions. About 66% of the respondents thought that the hypothetical Alternatives A and B corresponded to real fishing grounds in Lake Victoria where A, with higher mean and spread, resembled areas offshore while B could be seen as inshore fishing grounds. Fishers were asked to state the reason for their selections made concerning the first and the fifth pair-wise choices. The 71% who preferred B_1 to A_1 said that they were guided by the minimum revenue in the alternatives. This could be caused by the fishers following a maximin strategy (Mas-Colell et al., 1995), i.e., they maximize the minimum gain. In our study this corresponds to constantly preferring B trips to A trips; B-alternatives always result in the highest revenue for bad luck at all levels, which is consistent with risk averse behavior. For those who preferred trip A_5 to B_5, 85% said that maximum revenue was the main force behind the choice. The choice of trip A_5 is a typical risk seeking strategy, i.e., the fisher is willing to sacrifice almost a 20% reduction in a weeks' income for the small chance of achieving the slightly larger maximum income in trip A_5 compared to trip B_5. Respondents were asked to rate their own fishing skills in comparison to their fellow fishers at their common landing beach; 75% rated themselves as good. From a strict profit-maximizing perspective, risk neutral fishers are more skilled than the other two groups, as they earn more in the long run. As a test of the implications of the findings in the stated preference survey, the risk preference variables were included in a production function using production data from the fishers. Table 4 presents the results from a Cobb-Douglas specification for the 473 respondents. All the parameters are significant at the 5% or less level of significance and the traditional inputs have the expected signs. Having a motor leads to substantially higher landing values, while the opposite applies for those targeting Dagaa species. Given the log-log specification, we immediately see that risk averse fishers in fact earn 23% less than risk seeking, while risk neutral fishers earn 15% less than risk seeking. Hence, risk seekers seem to be the best fishers when we adjust for the inputs in this simple specification.[8]

Table 4: Cobb-Douglas Production Function of Landing Values

Variable	Coefficient.	P-Value
LogCrew size	0.261	0.024
LogNetlength	0.148	0.000
LogHours	0.291	0.000
Motor	0.796	0.000
Risk Averse	-0.228	0.004
Risk Neutral	-0.152	0.032
Dagaa	-0.356	0.000
Constant	8.231	0.000
Adj. R-squared	0.330	
Number of Observations	473	

Of additional interest is to identify factors that possibly determine risk preferences. Using the three risk categories as dependent variables, we analyze them with a multinomial logit (MNL) model (Greene, 2000). Because the direction of change in an explanatory variable is not clear from the sign of associated coefficient (Long, 1997), the maximum likelihood estimates of the MNL model are reported in Appendix A. Table 5 reports the changes in probability evaluated at the mean of the variable. Regarding estimation, estimates of one risk category must be normalized to zero to estimate probabilities. The coefficients of the other risk categories are interpreted with reference to the normalized category, in our case. The risk seeking behavior is the omitted category. The sign of a coefficient shows how the ratio of probability of a fisher in a particular category changes relative to the risk seeking category when a covariate changes. Because the changes depend on values of all explanatory variables, the partial change effect and the associated coefficient can have different signs. Furthermore, the

[8] The difference between risk averse and risk neutral fishers is not statistically significant at the 10% significance level.

MNL puts restrictions on agents' choices, i.e., the independence of irrelevant alternatives (IIA), assumption. The Hausman specification test for the IIA assumption is implemented and the results suggest that the null hypothesis of independent risk alternatives cannot be rejected (see Table 2 in Appendix A).

Table 5 shows that the probability of belonging to the risk averse category declines with household size, while household size increases the probability of belonging to the risk neutral group. For example, an increase in household size reduces the probability of belonging to the group of risk averse fishers by 0.12 units, while it increases the probability of being risk neutral by 0.9 units.

Table 5: Multinomial Logit Estimates, Changes in Predicted Probabilities.

	Risk Averse		Risk Neutral		Risk Seeking	
Explanatory Variable	Coefficient	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Age	0.0001	0.003	0.001	0.003	-0.001	0.00
Education	0.013	0.012	-0.007	0.011	-0.006	0.01
Household size	-0.119***	0.035	0.089**	0.032	0.030	0.03
Dagaa specie[A]	0.155**	0.059	-0.076	0.072	-0.080	0.07
Mwanza region	-0.036	0.066	-0.094	0.060	0.130*	0.07
Mara region	-0.039	0.067	-0.090	0.063	0.129*	0.07
Owner, the skipper	0.028	0.071	0.073	0.071	-0.101	0.07
Owner, part of crew	0.032	0.063	-0.083	0.061	0.051	0.07
Motorboat	-0.441***	0.042	0. 110**	0.047	0.331***	0.04
Crew size onboard	0.012	0.035	0.069**	0.034	-0.081**	0.04
Number of nets onboard	0.001	0.001	0.000	0.001	0.000	0.00
Self-rated skills	-0.247***	0.052	0.030	0.050	0.217***	0.05
Hours spent fishing	-0.012	0.009	-0.018**	0.009	0.029***	0.01
Fishing habits	0.086	0.065	-0.014	0.066	-0.072	0.07
Fishing the main income	-0.228***	0.053	0.279***	0.046	-0.052	0.05
Asset owned	-0.169*	0.104	-0.005	0.098	0.174**	0.08

***, **, * Indicate significance levels at 1%, 5% and 10% levels respectively.
[A] Discrete change for dummy variable is from 0 to 1.

The effect of boat size on risk preference is captured by a motor dummy variable and a crew size variable. The results show that skippers operating a motorboat are more likely to be risk seekers. The likelihood of fishers belonging to the risk seeking category increase by 0.33 units if motorboats are used, while the probability of being risk averse is reduced by 0.44 units. This may reflect the fact that motorboats in Lake Victoria fisheries in general imply more expensive gear, as the majority of fishers with outboard motors have direct or indirect connections with the processing factories which provide them with credits for buying fishing crafts and gear.[9] This result can be compared with the results in Eggert and Martinsson (2004) where trawl fishers were found to be less risk averse compared with others. This finding is also comparable to results in Binswanger (1980), where mechanized farmers in low-income environments tended to be less risk averse than less-mechanized farmers.

The results also show that larger crew size increases the probability of being risk neutral and decreases the probability of being risk seeking. Similarly, we find that the longer the hours the fisher spends fishing, the more likely that he belongs to the risk seeking category and the less likely that he is risk neutral. A fisher with high self-esteem is more likely to belong to the risk seeking category, as well. According to Table 4, risk seeking fishers are more skilled than others, which also is how they perceive themselves, according to Table 5. These fishers believe that, thanks to their skills, they can influence the uniform probability distribution in the experiment and land the maximum figure. From the analysis of the observation of revenue and without accounting for input use, we find that while a risk averse fisher earns an average of Tshs 3,500 (4,100) in a five-day trip, a risk neutral fisher receives an average net revenue of Tshs 6,100 (6,000) and risk seekers earn an average of Tshs 6,300(7,900) with the standard deviation in parentheses over the same period. This indicates that risk seeking fishers earn almost the same amount as risk neutral, but with relatively more variation in their income than risk neutral fishers. We find a highly significant relationship between asset ownership and the degree of risk aversion, indicating that more wealthy fishers are less likely to be risk averse. The result is consistent with the view that risk aversion is a decreasing function of wealth.

The results further show that regional dummies have a significant influence on fishers' risk preferences; fishers operating from the Mwanza and Mara regions are found to have a higher likelihood of being risk seekers compared to those in the Kagera region. The market potential in Mwanza may explain this phenomenon. Of the 13 fish-processing factories in the Tanzanian region, 11 are located in Mwanza, 2 are in Mara, while none are in Kagera. Also the market in Mwanza is more easily accessible for fishers from Mara than from Kagera.

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[9] The general attitude of a majority of fishers in Lake Victoria is that the fisher operating a motorboat is considered well-established and more commercially oriented

6. Discussions and conclusion.

A key aspect when modeling and analyzing fishers' behavioral motivation is that of risk preferences. Although there is growing interest in fishers' risk preferences, most if not all studies focus on commercial fisheries in developed countries. To our knowledge, this is the first study dealing with fishers' risk preferences in a developing country and artisanal fishery context. The study measures risk preferences of artisanal fishers in Tanzania waters of Lake Victoria fisheries from a sample of 473 fishers. Our results suggest that artisanal fishers are risk averse to a lesser extent than what is indicated from evidence of risk aversion in low-income environments in the agricultural economics literature (e.g. Dillon and Scandizzo, 1978; Rosenzweig and Binswanger, 1993). In our sample, 32% can be characterized as risk averse, which also challenges earlier findings in commercial fisheries using revealed preference data, where a vast majority was found to be risk averse. The results, however, are consistent with recent findings in Eggert and Tveterås (2004) and Eggert and Martinsson (2004) for Swedish commercial fishers[10].

Stemming from this analysis we find that risk averse fishers have small households, use boats without motors, target Dagaa, have low self-esteem regarding their skills, earn only part of their income from fishing, and possess limited assets. Risk neutral fishers have large households, use motorboats, have large crews, fish shorter hours and earn their main income from fishing. Risk seeking fishers are not from the Kagera province, use motorboats, have small crews, have high self-esteem regarding their skills, fish long hours, and possess substantial assets. From a profit-maximizing perspective, we would expect risk neutral fishers to earn more compared to the other two groups in the long run. This study finds that risk averse fishers have a substantially lower average income, while this does not apply to the risk seeking group. The risk seeking fishers have an average income comparable with the risk neutral, though with higher variance.

Either risk seekers are true gamblers that sacrifice the expected mean because they enjoy variation in daily income and the potential chance of striking 'gold', or they are in

[10] While Eggert and Martinsson, (2004) had one alternative reflecting true risk seeking behavior, in our case we designed the experiment to have two alternatives reflecting true risk seeking behavior and two alternatives reflecting risk averse, with a middle alternative reflecting true risk neutrality.

fact more skilled than others; their skill leads to high average income despite the fact that they take ‘too’ high risks with regard to maximizing income. A second element supporting their risk seeking behavior is that they enjoy the positional welfare that comes from being “top scorers” among their colleagues at the landing beach.[11] Our result of less than a third being risk averse is not supportive of previous assumptions of both owners and crew being risk-averse, therefore preferring revenue-share contracts (Sutinen 1979; Plourde and Smith, 1989). The finding that a substantial share of fishers are risk neutral is more in line with the argument by McConnell and Price (2004), that fishers are risk neutral and that the sharing system is used to control the problems of moral hazard and team agency.

The production relations that prevail in Lake Victoria fisheries could possibly explain the fact that risk averse fishers are the minority group in our sample, especially since our results contradict the main findings in low-income environments. Many of the fishers, especially the Nile perch fishers, have direct or indirect links to the fish-processing factory, which quite often extends credit for buying crafts and gear in return for the fishers supplying the catch to the factory daily. This arrangement can be seen as a risk sharing deal from the factories; it enables fishers to invest in outboard motors for facilitating moving around the fishing grounds in search of the most productive ground, hence, taking chances becomes part of the daily routine. These fishers might be enjoying relative wealth compared to poor farmers; hence they are consistent with traditional neoclassical risk taking with increasing wealth.

We found from our results that risk preferences are related to a set of important structural variables that characterize the fishers in the sample, e.g., target species, vessel type, skills or regional dummies. Though risk aversion can be positive as far as resource conservation is concerned, it can lead to significant distortions from risk-neutral levels of input use (Hardaker, 2000). Risk aversion may lead fishers to use resources less intensively than would be the case if they were indifferent to risk. The implication of this on the fishers’ welfare very much depends on the extent to which the individual fisher manages to diversify his source of income. A poor fisher who depends largely on

[11] It is well established that both absolute and relative income matters to individuals, e.g., Johansson-Stenman et al., (2002). If the relative standings are asymmetric, i.e., landing the highest catch one day and the lowest the next yields higher welfare than two average catches, the risk seekers are better off when the relative income effect is taken into account.

fishing for his daily household needs may be trapped in the risk averse strategy for daily survival, despite knowing that a more risk neutral strategy would be beneficial. The group of risk averse fishers in our sample earns significantly lower income than the others. While it may be a legitimate role of public policy to consider reduction in the cost of risk aversion for farmers in developing countries in order to reduce the social welfare loss from farm-level risk aversion (Rosenzweig and Binswanger, 1993; Hardaker, 2000), this arrangement may be weakly justified for fisheries. For instance, improving credit facilities for poor fishers could enable them to invest in motors and gear which would increase their choice set of fishing grounds and target species and potentially increase their earnings. However, increased landings, *ceteris paribus,* would reinforce the trend of declining fish stocks in Lake Victoria and lead to overall reductions of landings over time. It may be the case that in order to improve the situation in the long run, some individuals will have to be worse off in the short run, i.e., motorboats for all fishers is a desirable prospect only if the number of vessels and fishers decrease over time. The signs of over-fishing in Lake Victoria are likely to generate traditional measures for improving stocks, which often include closing fishing grounds. If the chosen grounds are those with low mean and low variance in yield, which according to the fishers in this study correspond to inshore grounds that also are easy to monitor and enforce, the risk averse fishers will be worse off. The fact that they fish without motors also implies a limitation of accessible substitutes, further intensifying their poverty problem.

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Appendix: A

Table 1: Parameter Estimate of Multinomial Logit Model of Fishers' Risk Preferences

Explanatory Variable	Coeff.	Std. Err.	P-value	Coeff.	Std. Err.	P-value
	Risk averse			Risk neutral		
Age of the skipper in years	0.003	0.015	0.840	0.004	0.017	0.797
Education of skipper in years	0.051	0.061	0.405	-0.009	0.064	0.888
Household size	-0.419**	0.175	0.017	0.226	0.177	0.200
Dagaa specie	0.720**	0.350	0.040	-0.037	0.365	0.919
Mwanza region	-0.452	0.336	0.180	-0.693*	0.365	0.057
Mara region	-0.454	0.342	0.184	-0.676*	0.378	0.073
Owner, the skipper	0.379	0.357	0.288	0.542	0.385	0.160
Owner, as part of crew	-0.051	0.313	0.871	-0.436	0.348	0.210
Motorboat	-0.652**	0.265	0.014	-2.634***	0.304	0.000
Crew size onboard	0.259	0.176	0.141	0.465**	0.191	0.015
Number of nets onboard	0.002	0.005	0.674	-0.001	0.005	0.898
Self-rated skill of the skipper	-1.321***	0.267	0.000	-0.540*	0.296	0.068
Hours spent fishing	-0.114***	0.044	0.010	-0.143***	0.048	0.003
Habit of fishing in the same ground	0.454	0.353	0.198	0.143	0.359	0.691
Fishing is the main income	-0.471*	0.264	0.074	1.261***	0.317	0.000
Asset owned by the skipper	-1.031**	0.536	0.054	-0.648	0.612	0.290
Constant	1.429	1.106	0.196	1.275	1.204	0.290
Sample size	=	473.000				
Pseudo R2	=	0.204				
Log-Likelihood		-393.553				

***, **, * Indicate significance levels at 1%, 5% and 10% levels respectively.

Table 2: Hausman Test Statistics of IIA Assumption for Multinomial Logit model.

Omitted	*Ch-sq.*	*Df.*	*p-value*	*Decision*
Risk Averse	-1.130	17	1	Accept Ho
Risk neutral	-2.698	17	1	Accept Ho

Risk seeking is the reference category

Appendix B:

Experiment Design in Risk Preferences.

The National Environment Management Council (NEMC) in collaboration with the Tanzania Fisheries Research Institute (TAFIRI) is undertaking a study on how fishers respond to variation in catch and revenue in different time periods. The study is being conducted in Mwanza, Mara and Kagera regions. You have been randomly chosen as one of the respondents for this study. We believe that your experience in fishing will greatly help us learn more. We would like you to participate in this study by answering the following questions. Your response will be used for research purposes only. Your individual responses will not be revealed in any way. Only average or aggregated responses will be reported. The responses will be anonymous.

Consider the following scenario

As a fisher, you face potentially large numbers of choices in different circumstances. However in this scenario, we require you to assume that you can make the choice of fishing in one location for each trip before switching to another location. Assume that you have two fishing alternatives from which you can choose and that you are going for the next days' fishing trip. The two Alternatives are characterized by high and low variation in net revenue. For the first Alternative, net revenue will vary a lot, while not so much for the other. Assume that catch net revenue is guaranteed between the given intervals (i.e., the stated highest and lowest net revenue). The chance is equal for all outcomes (uniform distribution). Variation in net revenue can be due to the choice of the fishing location. It is possible that the described alternatives can differ from what you use to get from your daily trip, but we still want you to judge the alternative Alternatives as presented.

The two fishing Alternatives are named A and **B.** They vary in spread and average; you are not sure about the distribution of the stock in the two Alternatives but we can assume that you can choose between two fishing alternatives with different catch profiles. For fishing Alternative **A**, the net revenue will always vary from Tshs 500 to Tshs 9,500 with an expected mean of Tshs 5,000 per five days of fishing trips. For fishing Alternative B**,** the net revenue does not vary as much and the expected mean increases from as low as Tshs 3,500 to as high as Tshs 5,800. This variation in net revenue is outside your control and even if you are a skilled fisher you cannot influence the decision outcome.

We ask you to make your choice between the two different Alternatives. There is no correct answer; thus you can go back and change them. We are only interested in your choices. We acknowledge that these choices are not perfectly equal to real-life fishery choices, but we are very interested in your judgment. We assume that you are a skilled fisher, but you cannot influence the probability outcome. The net revenue from the Alternative is somewhere in the stated interval and each interval has equal probability of occurring.

In this scenario we ask you to make five pairwise comparisons. Each comparison is independent of the previous. In this example, the distribution of revenue from the two fishing grounds is given in the table you have. How would you choose?

	Fishing trip A	**Fishing trip B**
Lowest/highest net revenue (Mean value):	Tshs 500 - 9500 (Tshs 5000)	Tshs 650 - 5850 [Tshs 3250]
Your choice:		

	Fishing trip A	**Fishing trip B**
Lowest/highest net revenue (Mean value):	Tshs 500 - 9500 (Tshs 5000)	Tshs 1600 – 7200 [Tshs 4400]
Your choice:		

	Fishing trip A	**Fishing trip B**
Lowest/highest net revenue (Mean value):	Tshs 500 - 9500 (Tshs 5000)	Tshs 2000 – 8000 [Tshs 5000]
Your choice:		

	Fishing trip A	**Fishing trip B**
Lowest/highest net revenue (Mean value):	Tshs 500 - 9500 (Tshs 5000)	Tshs 2300 - 8700 [Tshs 5500]
Your choice:		

	Fishing trip A	**Fishing trip B**
Lowest/highest net revenue (Mean value):	Tshs 500 - 9500 (Tshs 5000)	Tshs 2600 - 9100 [Tshs 5850]
Your choice:		

Compliance in Lake Victoria Fisheries

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Abstract

This paper analyzes the causes for regulatory compliance using traditional deterrence variables and potential moral and social variables. We use self-reported data from Tanzanian artisanal fishers in Lake Victoria. The results indicate that fishers adjust their violation rates with respect to changes in probability of detection and punishment but also react to legitimacy and social variables. A small group of persistent violators react neither to normative aspects nor to traditional deterrence variables, but systematically violate the regulation and use bribes to avoid punishment.

JEL classification: K42, L51, Q22

Keywords: compliance, fishery, Lake Victoria, legitimacy, normative, deterrence

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1. Introduction

Poor people are frequently compelled to exploit their surroundings for short-term survival, and make up the group most regularly exposed to natural resource degradation (World Bank, 2002). Natural resources are often of common pool resource type, which implies problems with overexploitation that sometimes are hard to manage, even in well-developed countries. Fish is a major source of protein for many poor people (UNEP, 2002) and a resource where the previous discussion applies. Almost half of the world's landings are from tropical waters (Pauly, 1996) and from countries where development is at a low or medium level. These fisheries are frequently open access with no restrictions on entry or total catch, and regularly lack even rudimentary tools for management, such as landing records. In such poor institutional settings, how individuals act and interact is of utmost importance to whether or not fish stocks can be sustained.

Predictions from the traditional economics of crime model are quite pessimistic. The seminal contribution by Becker (1968) basically outlines a choice between the legal and the illegal option. The major determinant for this choice is the expected payoff, which simply put, is a function of the risk of being punished, the expected punishment and the net profit from violating the law. On the one hand, the management implications from the deterrence model are that monitoring must increase and that penalties must be higher.[2] On the other hand, it is socially desirable that enforcement policy creates marginal deterrence,[3] which rules out the use of severe penalties for relatively mild violations such as fishing a closed area or landing fish below minimum size. Monitoring and enforcement of fisheries is costly and accounts for 25-50% of the public expenditures on fisheries (Sutinen and Kuperan, 1999), which raises doubt as to whether increased monitoring and enforcement leads to social net benefits. Recent research in the social sciences also extends the deterrence model to include normative aspects of complying with the law such as personal morality and legitimacy (Tyler, 1990).

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[2] Becker (1968) assumes that the individual wants to maximize utility and the utility function may of course include moral and social aspects. Becker refers to "his willingness to commit an illegal act", which seems to be exogenous; in general, little attention is given to this aspect in policy conclusions from the deterrence model.

[3] The term was first used by Stigler (1970) and refers to those not deterred from doing harm should have a reason to moderate the level of harm they cause, i.e., most sanctions should be less than maximal.

This paper analyzes the causes of regulatory compliance in a developing country context. In addition to traditional deterrence variables such as risk of detection and expected gains from violation, we explore potential reasons for following the rules such as being moral and doing the right thing, obeying the rules due to peer pressure from other fishers, perceiving the regulation as legitimate, and perceiving that they (the fishers) have been involved in the regulation process. We use self-reported data from Tanzanian artisanal fishers in Lake Victoria and focus our analysis on the minimum mesh-size regulation. The results indicate, as expected, that fishers adjust their violation rate with respect to changes in deterrence variables such as probability of detection and punishment. Fishers also react to legitimacy and social variables, which inter alia means complying more when they perceive the regulation to be legitimate as well as when they are influenced by peer groups. We also find a small group of persistent violators who appear to react neither to normative aspects nor to traditional deterrence variables. These fishers systematically violate the mesh-size regulation and when arrested, bribe their way out of punishment.

2. Lake Victoria Fisheries

Lake Victoria is the worlds' second largest and Africa's largest fresh water body. Kenya, Uganda and Tanzania share Lake Victoria; the Tanzanian section encompasses 49% of the lakes' surface, while the Ugandan and Kenyan sections encompass 45% and 6%, respectively. The Nile perch was introduced to Lake Victoria in the 1950s and experienced explosive population growth in the 1970s. Its introduction led to increasing landings and a new source of cheap protein, while severely reducing biological diversity; the original 350-400 species of fish in the early 1900s is now fewer than 200 (Brundy and Pitcher 1995; Kudhongania and Chitamwebwa 1995). Today there are three commercially important species: Nile perch, Dagaa and the Tilapia, which constitute 60%, 20%, and 10%, respectively, of Tanzania's total Lake Victoria landings (Ssentongo and Jlhuliya 2000). The open access nature of the lake fisheries combined with rapid population growth, lack of employment opportunities and the increasing Nile perch market, have led to an increasing number of fishers and depletion of fish stocks (Ikiara, 1999). This decline concerns one-third of the population or about

30 million people supported by the lake basin in Kenya, Tanzania and Uganda (LVFO, 1999).

The Nile perch is exported to Europe, Asia and North America. Processing and export industries were established in Kenya and Uganda during the 1980s and in Tanzania in the early 1990s. Dagaa is to a large extent processed domestically for household consumption and animal feed (fishmeal). Small-scale fishing units generate almost all of the fishing effort on the lake. These fishers use boats or canoes that are fitted with outboard motors or a sail/paddle and take a total crew of two to six people, including the skipper. Fishers place their nets in the late afternoon and retrieve them in the morning. Dagaa is fished at night when the moon is dark with pressure lamps to attract the fish. Due to the need for lamps, Dagaa fishing location choice is limited to sheltered environments and areas fishers can easily reach from their own beaches.

The current regulation requires fishers to pay an annual fee of approximately USD 20, which is equivalent to gross revenues from 1-2 days of fishing. Several minor restrictions exist, but the most important is the minimum gillnet mesh size, which is five inches (125 mm) for Nile perch and Tilapia, and 0.4 inch (10 mm) for Dagaa. There are 63 Tanzanian fisheries officers who act as both extension and enforcement officers (LVFO, 2004). The focus of this study is on gillnet fishers, who either target Nile perch and Tilapia or Dagaa. As a response to declining catch per unit of effort, fishers have increased their number of nets and the use of a mesh size smaller than that prescribed. In the short run, smaller mesh size leads to a larger catch, but the long-run implication is a smaller stock and smaller sustainable landings. Reports in Tanzanian district fisheries offices show that fishers' compliance with regulations is poor, with the most violated regulations being the use of illegal mesh size, beach seine, and fishing in closed areas (Wilson, 1995).

In 1998, the Tanzanian Government, supported by the World Bank, introduced local management units commonly known as Beach Management Units (BMUs), through the Lake Victoria Environmental Management project. The aim is to enhance community participation in surveillance and management and to put an end to detrimental fishing practices such as using poison or dynamite. The BMU leaders do not have any legal authority, but can point out culprits to the enforcement officials. The existence of BMUs has led to increased efficiency in both Nile perch and Dagaa fisheries (Lokina 2004), which is possibly explained by fishers exchanging information and learning from each other at the regular BMU meetings.

3. Survey Description and Data

The data for this study was collected using a questionnaire during April-June 2003. The questionnaire was administered in face-to-face interviews with vessel skippers with an assurance of individual anonymity and confidentiality. Consideration was taken in the design of the questionnaire to maximize the likelihood of honest responses, in particular regarding questions about the fishers' own violation behavior. The questionnaire was administered in collaboration with the staffs of the Tanzania Fisheries Research Institute (TAFIRI).[4] A pilot survey was conducted on three landing sites, i.e., beaches that were not in the sample, followed by revisions and minor changes. The respondents were asked about their own violation rate during the last twelve-month period and gave answers such as "zero", "one month", "two to three months" or "twelve months", etc. We identified three subgroups, which we label purely honest, alternating violators, and persistent violators, with zero, one to ten months, and eleven months or more of violation, respectively. Zero violation means that the respondent has not broken violations for the past twelve months; one month means that during the past twelve months he broke violations only one month, and so on. Sixty-minute interviews were carried out individually and included questions on respondents' attitudes and perceptions about legitimacy of mesh size regulation, social pressures to comply, attitudes towards violation and feelings of obligation to comply. Questions related to legitimacy concerned the perceived effectiveness and fairness of mesh size regulations, the legitimacy of management institutions, and the involvement of fishers in the management. These questions were statements for which the respondents ranked their level of agreement on a four-digit scale, where a higher score means stronger agreement. Socioeconomic characteristics of the fisher were recorded either directly, (e.g., age and experience as a skipper, household size), or where appropriate, using interval scale, e.g., household income was recorded in this way to minimize the concern

[4] The staff at TAFIRI in Mwanza has long working experience in the field and has regular contact with fishers around the Lake. Most if not all fishers are aware of the staff as not being part of the enforcement officials.

of confidentiality and accuracy. We also included questions related to subjective probability of detection, arrest and conviction. Respondents were asked to report their own compliance behavior as well as their perception of other fishers' compliance behavior at the same beach. Further, questions related to the level of fishers' involvement in policy formulation and enforcement were asked. Self-reports may imply a risk of biased data, especially as respondents were asked about their own illegal activities, but the overall impression was that the fishers were cooperative and generous with their answers, including their own violations. Nonetheless, the potential magnitude of penalties in the case of conviction seemed to be impossible for many of the fishers to assess, which led to exclusion of that question.

4. Methodology

The original deterrence model by Becker (1968) led to a large number of empirical papers testing the hypothesis (Starting with Erlich, 1973; Gaviria, 2000 is a recent extension), which by and large confirmed the theory. Whether the deterrence conclusion is confirmed has been debated, however, and one level of critique is methodological. This critique stresses that the theory is developed on the individual level, while much of the empirical work is based on some level of aggregation. If crime rate is defined as crime per capita, and probability to be arrested is measured as the ratio of arrests to crimes, we have the number of crimes in the denominator of the independent variable and in the numerator of a dependent variable, which can imply spurious correlation. Similarly, if notorious criminals are arrested and kept in custody, it implies a lower crime level, but the negative correlation between crime and arrest rates is not due to the risk of being arrested, but to the actual captivity. Finally, more crimes lead to more expenditures on law enforcement, which implies a simultaneous relationship between crime and enforcement levels. Manski (1978) suggested survey-collected individual self-reports as a means of avoiding these problems, since each individual will have a negligible impact on each of the three objections raised. Furlong (1991) applied these ideas to Canadian fishers and found the fishers to be most sensitive to changes in the likelihood of detection, while fines appeared to create the greatest deterrence among various penalties.

Social science research on why people follow the law has been dominated by the instrumental perspective, which is based on deterrence literature and reaches the same policy conclusions as the economics research following the Becker approach. However, given the weak deterrent threat facing people for minor violations, this approach cannot explain why the vast majority of people act in a way consistent with the law (Robinson and Darley, 1997). Recent contributions to legal thought, which to a large extent are revivals of older ideas, provide several suggestions. One reason for following the rules is to avoid the disapproval of your social group, another is that you see yourself as a moral being who wants to do the right thing (Robinson and Darley, 1997). A third factor is legitimacy, which means that the individual feels that the authority enforcing the law is entitled to dictate behavior. This in turn depends on whether individuals think that the law is fair and applied in a fair manner. Whether legitimacy is maintained or undermined is dependent on people's experiences with legal authorities (Tyler 1990). Some of these ideas also gain support by contributions in behavioral economics (e.g. Camerer et al, 2004). People often behave in a nicer and more cooperative way than predicted by the self-interest model and are at the same time willing to incur costs just to punish those who have deviated from some norm of fairness (Fehr and Gächter, 2000). The predicted behavior for a profit maximizing firm is partly halted by the concern of fairness (Kahneman, Knetsch, and Thaler, 1986). Further, empirical evidence support the idea that people may follow rules backed by mild sanctions because of norm-activation (Tyran and Feld, 2002).

Enforcement in fisheries has been a fairly neglected area (Sutinen and Hennessey, 1986). The early contributions are theoretical and deal with optimal stock if non-zero enforcement costs are introduced (Sutinen and Andersen, 1985; Milliman, 1986) and the choice of optimal government policy (Anderson and Lee, 1986). The first empirical study confirmed the deterrence model showing that increased risk of detection and conviction reduce the violation rate in a fishery (Sutinen and Gauvin, 1989). The simple deterrence model predicts that most fishers will violate the regulation. The risk of detection is low, fines are modest, and the profits from violation are substantial. Still, a vast majority of fishers in various fisheries seem to comply with the regulation, which contradicts the predictions based on this model (e.g. Sutinen and Kuperan, 1999; Eggert and Ellegård, 2003). Extended analysis is therefore necessary to include both the instrumental and the normative perspective. The empirical evidence from such an approach is mixed. Kuperan and Sutinen (1998) found that compliance in a Malaysian fishery depended on the tangible gains and losses, as well as the moral development, legitimacy, and behavior of others in the fishery, whereas Hatcher et al (2000) and Hatcher and Gordon (2005) found less evidence in favor of normative influence on fisher compliance, while again confirming the deterrence effect. These studies deal with trawl fisheries where the capital input is substantial, while our study is the first to analyze artisan fishers. The fishers in our sample all have low levels of capital input, i.e., they operate simple open wooden-hulled vessels; almost half of the fishers lack motors and have to use sails or paddles to propel their vessels. The theoretical model that we follow is the one which extends the neoclassical utilitarian model of individual violation behavior to include normative and social judgments (Sutinen and Kuperan, 1999; Hatcher and Gordon, 2005), of the form

$$V_i = f\,(Y_i, D_i, M_i, L_i, S_i\ X) \qquad (1)$$

Where V_i is a self-reported violation rate, Y_i is the variable related to financial incentive to violate, D_i is a vector of deterrence variables such as the probability of detection and expected fine if detected, M_i is a vector of variables measuring moral obligation to comply, L_i is a vector of variables trying to capture perceived regulatory legitimacy, S_i is a vector of social influence variables and X measure personal characteristics. The hypotheses of interest in this study therefore are:

$$\frac{\partial V_i}{\partial Y_i} > 0,\quad \frac{\partial V_i}{\partial Di} < 0,\quad \frac{\partial V_i}{\partial M_i} < 0,\quad \frac{\partial V_i}{\partial L_i} < 0,\quad \frac{\partial V_i}{\partial S_i} < 0$$

The main assumption here is that higher measurements of M_i, S_i and L_i correspond, respectively, to: stronger moral judgments against violation, perceptions of stronger social norms against violation and increasingly positive judgments concerning legitimacy of regulations and of the regulating authorities. We do not have prior predictions of the direction of X variables.

4.1 Econometric specification

The point of departure is that the dependent variable, *violation*, is a latent variable that describes the degree to which fishers are in violation of the mesh size regulation. The violation is measured in months in which the fisher violated the mesh size regulation. The values therefore range from 0 for non-violators to 12 months for persistent violators. In general we specify our model as:

$$V_i = X_i'\beta + \varepsilon \qquad (2)$$

where X is vector of observable variable possibly governing V, and ε is normally distributed with mean 0, standard deviation σ. Data on V are only observed when $V = j$ for some j in (0, 1, 2), where 0 is for non-violators, 1 is for those who violated from one to 10 months (occasional violators) and 2 is for those who have been violating from eleven months or more (persistent violators). We are interested in why fishers may choose to comply rather than violate the rules and vice versa. It is often found that for any regulation there is a small subgroup of persistent violators (Feldman, 1993), a condition which seems also to exist in fisheries (Kuperan and Sutinen, 1998). Further, those who always obey (violate) the rules may on some occasions be attracted to deviate from their normal behavior, but lack the possibility to do so. A simple reason could be that they do not possess the illegal (legal) gear, which implies that the model will fit those who actually alternate between legal and illegal acts. Excluding the others would be a waste of information and lead to biased estimates, as there is self-selected participation. In this study we use the generalized Heckman procedure (Heckman 1979). In the first step, the probability that a given individual fisher will violate the mesh size regulation is determined from an ordered probit model using all available observations in the three categories. In the second step, the inverse Mills ratio term[5] is used as an instrument variable in the regression on the sub-sample of occasional violators to correct for bias. The advantage of using least square method is that it allows us to

[5] $\lambda(x) = \phi(X)/[1-\Phi(X)]$, Where X is a vector of regressors related to the violation decision, Φ is the cumulative normal distribution and ϕ is the density normal distribution.

directly interpret the parameter in the selection model as conditional marginal effect. The ordered probit model is:

$$V^* = x_i'\beta + u \qquad (2)$$

$$V = \begin{pmatrix} 0 \text{ if } v^* \le \mu_1 \\ 1 \text{ if } \mu_1 < v^* < \mu_2 \\ 2 \text{ if } v^* \ge \mu_2 \end{pmatrix}$$

where *V** is not observed and *V* is its observed counterpart, x_i is a vector of explanatory variables, μ_1 and μ_2 are threshold parameters to be estimated with the βs', the subscript *i* index of the individual and the error term *u* is distributed as standard normal (Greene, 2000).

5. Results

The descriptive statistics are reported in Table 1. The sample consists of 459 fishers of whom 45% are non-violators, 47% are occasional violators and 8% persistent violators. The overall violation rate is 29%, which is substantially higher than the rate reported in previous studies (see Sutinen and Kuperan, 1999), and the persistent violators are responsible for 30% of the violations.[6] The deterrence variables include aspects such as the expected gain per unit effort from violating, how often officials have been seen, a dummy for previous arrest, and the respondent's subjective judgment of probability of detection, of arrest, of being taken to court, and of being found guilty. The probabilities are increasing, which is intuitive; those who are more likely to be convicted will more likely be brought through the legal procedures. The probability of being taken to court is an exception and this probability is lower than of being arrested. This is the stage where bribes are most likely to occur and our interpretation is that the respondents have adjusted for the use of bribes. If we disregard the effects of bribes, the average perceived overall probability of being detected and punished is 7%, which is substantially larger

[6] We assume that the number of trips per month and year are equally distributed among the three groups.

than the "below 1 percent, and often at or near zero" found in previous studies (Sutinen and Kuperan, 1999). The social and legitimacy variables were all measured by a four-digit scale. However, in the final analysis these answers were recoded as dummy variables with levels three and four being one and levels one and two being zero, where one indicates that the fisher agrees with the statement. The correlation between all of the used variables was estimated, but did not exceed 0.55.[7]

Table 1: Descriptive Statistics of variables included in the estimations

Name	*Variable description*	*Mean*	*Std dev.*
Socio-economic variables			
AGE	Age of the skipper	33.36	9.43
EDUCATION	Number of years in school	6.45	2.24
SKIP_EXP	Years of fishing experience as a skipper	4.81	4.25
SOURCE	If fishing is the main source of income (1/0)	0.86	0.35
OWNERPC	The owner is onboard either as crew or as skipper (1/0)	0.38	0.49
MOTOR	Dummy for boat outboard motor	0.54	0.50
NILE PERCH	Dummy for targeting Nile perch	0.80	0.37
MWANZA	Dummy for Mwanza region	0.39	0.49
MARA	Dummy for Mara region	0.31	0.46
Deterrence variables			
SEEN	Number of times the unit has seen the officials when landing	0.70	0.46
DCPUM	Expected difference in value (Tshs '000) of catch per crewmember between illegal and legal.	30.21	36.8
ARRERATE	The ratio of arrested or not (1/0) to violation months	0.34	0.50
PROBD	Subjective probability of being detected	0.37	0.30
PROBDA	Subjective probability of being arrested given detection	0.58	0.32
PROBDAC	Subjective probability of being taken to court given arrest	0.50	0.35
PROBDACG	Subjective probability of being found guilty given court	0.65	0.32
Social variables			
BMU	The existence of active beach management unit (1/0)	0.47	0.50
PERCOMP	Percentage of fishers perceived to be violating the regulation	0.41	0.35
ATTIT	The attitude of peers to violation (1=wrong; 0=not wrong)	0.36	0.19
Legitimacy variables			
FVIEW	Fishers' views are considered in regulation design (1/0)	0.69	0.46
RIGHT	The government is doing the right thing by imposing the regulation (1/0)	0.60	0.65
NOCONSIST	Regulation is not enforced consistently (1/0)	0.84	0.36
JUST	The mesh size regulation is a fair regulation (1/0)	0.74	0.44
EVERYONE	The mesh size regulation improves the well-being of all (1/0)	0.54	0.47
WELLEST	The mesh size regulation improves the well-being of few (1/0)	0.37	0.42
NOTEFF	The mesh size regulation is not an effective measure (1/0)	0.41	0.49
PENALFIT	The penalty given to violators 'fits' the offence (1/0)	0.56	0.49
ADEQUATE	The enforcement in your fishing area is adequate (1/0)	0.48	0.50
NODETECT	Many of the violators are not detected (1/0)	0.56	0.50

[7] The one exception was for the variables *RIGHT* and *ARREST*, which had a negative correlation of -0.67 and led to the exclusion of the *RIGHT* variable in the second stage OLS-regression reported in Table 4

Table 2: Estimated Ordered Probit Model

Variable	Coefficient	P-Value
Constant	-1.119**	0.023
Socio-economic variables		
EDUCATION	0.049**	0.071
SKIP_EXP	0.003	0.846
SOURCE	0.018	0.919
OWNERPC	-0.435***	0.001
MOTOR	0.595***	0.000
NILE PERCH	-0.030	0.859
MWANZA	0.540***	0.001
MARA	0.048	0.770
Deterrence variables		
SEEN	0.027	0.553
DCPUE	0.008***	0.000
PROBD	0.164	0.427
PROBDA	-0.085	0.661
PROBDAC	-0.188	0.262
PROBDACG	-0.055	0.775
Social variables		
BMU	0.146	0.242
ARRERATE	2.163***	0.000
PERCOMP	0.379**	0.027
ATTIT	-0.511*	0.088
Legitimacy variables		
FVIEW	-0.194	0.143
RIGHT	-0.153*	0.102
NONCONSIST	-0.070	0.665
JUST	-0.225*	0.101
EVERYONE	-0.280**	0.057
WELLEST	0.510***	0.001
NOTEFF	-0.112	0.368
ADEQUATE	-0.290**	0.020
NODETECT	0.180	0.133
PENALFIT	0.247**	0.046
μ	1.969***	0.000
Log likelihood Function		-341.755
Prob [ChiSqd]>value		0.000

Dependent variable, the violation category

***, **, * Indicate significant at 1%, 5% and 10% levels, respectively

The results of the first stage ordered probit model are presented in Table 2. A highly significant estimate of μ indicates that the three categories in the response are indeed ordered, (Liao, 1994). In the model, the dependent variable is an ordered rank of violation frequency where non-violation has rank zero, one to ten months of violation has rank one, and eleven months or more during the last twelve months receives rank two[8]. Many of the variables are statistically significant and significant variables can be found in all of the four variable subgroups, i.e., *socioeconomic*, *deterrence*, *social* and *legitimacy* variables.

In Table 3 we present the marginal effects for the statistically significant variables which measure the increased (decreased) probability that the fisher would have been in the violation category, given one more unit of the explanatory variable with the other variables held at their mean. For the binary variables, the interpretation is the increase (decrease) in probability if the binary variable is equal to one. For example, the marginal value for non-violation for education is -0.019, which indicates that the probability for a fisher being a non-violator will decrease by almost 2% for every extra year of schooling he gets. The probability of being in the group of persistent violators is higher if the fisher possesses a motor, is from the region Mwanza, believes that regulation benefits a few well-established fishers, or if the fisher has weaker social norms against violation. Otherwise, explanatory variables are not significant for this group. Whether a fisher always obeys the regulations or not is significantly indicated by a number of variables. Longer education, possession of an outboard motor, and fishing as the major source of income all imply reduced probability of always obeying the law, while having the owner onboard a vessel supports honesty.

The deterrence variable ARRERATE indicates the counter-intuitive result that the more fishers are arrested, the more likely that they violate.[9] All the *social* and *legitimacy* variables are significant indicating that these variables have an impact on the decision of being purely honest or considering breaking the rules. They all have the expected sign except for two variables; the negative *BMU* variable indicates that if the fishers are part of a beach management unit, they are less likely to be purely honest, and if they think that applied penalties fit the offense, they tend to violate according to the negative *PENALFIT* variable. While BMUs are considered successful in stopping the use of poison and dynamite (per. Comm. Fisheries officers), they seem to reduce the numbers of purely honest fishers when it comes to mesh size compliance.

[8] Several cut-off points were tested without any major difference in the parameter estimates or the level of significance.

[9] In order to reduce the problem of correlation between being arrested and violation frequency, the 0/1 value indicating having been arrested or not was divided by number of violating months.

Table 3 Marginal Effects of Significant variables.

	Non-Violators		Occasion violators		Persistent violators	
Variables	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
SOCIO-ECONOMIC VARIABLES						
EDUCATION	-0.019	0.071	0.015	0.072	0.004	0.399
OWNERPC	0.168	0.000	-0.129	0.000	-0.039	0.527
MOTOR	-0.231	0.000	0.183	0.000	0.048	0.025
MWANZA	-0.206	0.000	0.156	0.000	0.050	0.053
Deterrence variables						
ARRERATE	-0.847	0.000	0.669	0.000	0.178	0.259
DCPUM	-0.003	0.000	0.002	0.000	0.001	0.275
Social variables						
BMU	-0.057	0.033	0.045	0.047	0.012	0.734
PERCOMP	-0.148	0.027	0.117	0.028	0.031	0.339
ATTIT	0.121	0.000	-0.184	0.000	0.063	0.104
Legitimacy variables						
FVIEW	0.075	0.001	-0.058	0.000	-0.017	0.736
RIGHT	0.047	0.103	-0.060	0.102	0.013	0.370
JUST	0.089	0.000	-0.072	0.000	-0.017	0.706
EVERYONE	0.108	0.000	-0.082	0.000	-0.026	0.647
WELLEST	-0.201	0.000	0.167	0.000	0.034	0.072
NOTEFF	0.044	0.078	-0.035	0.060	-0.009	0.836
ADEQUAT	0.113	0.000	-0.090	0.000	-0.024	0.641
NODETEC	-0.071	0.009	0.056	0.016	0.015	0.664
PENALFIT	-0.097	0.000	0.077	0.002	0.020	0.524

In Table 4 we report the results of the corrected least square estimation of the violation rate. There is evidence that participation is positively selected, since the lambda (λ) is positive and statistically significant, which is now being adjusted for. From the socio-economic variables we see that older skippers tend to violate less, while fishers from the Mara region or with longer skipper experience tend to violate more. Those who target Nile perch violate to a lesser extent, which is expected, since Nile perch fishers supply the fish processing factories and these factories request a fish size corresponding to the legal mesh-size of 5 inches or more. Thus, if a fisher targets Nile perch, the market requirements reduce the probability of this fisher violating the regulation by 0.51 units compared to the others.

Table 4: Least Squares Estimates of Violation Frequency.

Variable	Coefficient	P-Value
Constant	1.103***	0.000
Socio-economic varaibles		
AGE	-0.005	0.180
SKIP_EXP	0.012***	0.017
NILE PERCH	-0.513***	0.000
MWANZA	-0.067	0.319
MARA	0.128*	0.062
Deterrence variables		
SEEN	-0.165***	0.006
DCPUM	0.002**	0.034
ARRERATE	-0.246***	0.011
PROBD	-0.148*	0.074
PROBDA	-0.155**	0.048
PROBDAC	-0.066	0.342
PROBDACG	-0.131*	0.097
Social variables		
BMU	-0.054	0.286
PERCOMP	0.215***	0.003
ATTIT	-0.108	0.384
Legitimacy variables		
FVIEW	-0.087*	0.104
NONCONSIST	0.056	0.393
JUST	-0.009	0.875
EVERYONE	-0.121**	0.042
NOTEFF	0.042	0.388
λ (Selectivity correction)	0.105***	0.007
D-W Statistic		1.659
No. of Observations		216
Adjusted R-squared		0.356

***, **, * Indicate significant at 1%, 5% and 10% levels, respectively

For the *Deterrence* variables, it is notable that all four subjective probabilities have the expected negative sign.[10] They are also statistically significant, except for the probability of being taken to court after being arrested (*PROBDAC*). The insignificance of the *PROBDAC* variable most likely reflects that it is easy to avoid punishment by offering bribes, which is what the fishers stated in the interviews. All of the 459 fishers in the sample had experience of being arrested and 40% of them had used bribes to avoid being taken to court. In fact, 23% of those who had not violated the regulation during the last twelve months had used bribes when being arrested to avoid the

[10] These probability variables are rarely estimated, and the previous attempts we know (Furlong, 1991 and Kuperan and Sutinen, 1998), both face problems with lack of significance and reverse signs.

problems of being taken to court, even though they were innocent. In the group of persistent violators, 93% avoided being taken to court when arrested by using of bribes. The difference between illegal and legal mesh size values of catch per crewmember (*DCPUM*) is significant in explaining the violation decision. The more often fishers have seen officials, the less likely they are to violate; the same applies for being fined. While in the first stage with the full sample, the variable *ARRERATE* was positive and significant; in the case of only the sub-sample of occasional violators, the variable turns out to have the expected sign, which indicates that the more they are arrested the less they violate. When it comes to *social* and *legitimacy* variables, their influence on the violation rate seems reduced compared to their importance for the decision of whether a fisher would be purely honest or violate the regulation. Those who do, in fact, violate are still influenced by the perceived compliance rate among their colleagues, by whether fishers' views are considered in the regulation design, and by whether they believe that the regulation benefits all fishers.

A fundamental question to address is whether the deterrence or the social and legitimacy variables can be excluded. If we look at the adjusted R^2 excluding social, deterrence, and legitimacy, or all three groups of variables, the full model is reduced from 0.36 to 0.34, 0.28, and 0.23, respectively. We further explore this issue using the F-statistics for various regressions. The null hypothesis that all social and legitimacy variables are zero can be rejected at the 5 percent level of significance (2.229, critical level 1.88), while zero deterrence variables can be rejected at the 1 percent level (5.223, 2.51). Hence, we conclude that deterrence and social and legitimacy variables are vital in explaining the behavior of the alternating violators.

6. Policy Implications and Conclusions

This analysis of Tanzanian Lake Victoria fishers' compliance gives support to the traditional economics of crime model. One especially striking finding is that the subjective probabilities stated by the artisan fishers significantly work as a determinant for the middle group of alternating violators. The results also show that the extension of the basic deterrence model, which includes moral development, legitimacy, and considerations regarding the behavior of others in the fishery, leads to a richer model with substantially higher explanatory power for the decision between being purely honest or maybe a violator. For those who sometimes violate, the moral and legitimacy variables have less impact, i.e., once you break the rules, such factors are less important in mitigating the violation rate, but the social and legitimacy variables significantly explain the behavior of this group, too. A potential problem in a study like this is that of self-serving bias when measuring attitudes and opinions, by asking individuals and having them provide answers to motivate their actual behavior. The fishers in this study were generous with their answers, even the answers concerning their own violation rates. For the fishers concerned with their reputations or self-images, reducing the stated violation rate instead of trying to find arguments for violation in the legitimacy and moral variables, seems more plausible. For those who are purely honest, the incentive, for instance, to state that fishers' views are taken into account to defend that they are obeying the rules seems even weaker; in the case of strategic answers we would rather expect to find insignificant variables. Unfortunately, we could not find any data from the authorities on violation rates to cross-validate the reported violation rates, which could have been an indicator of misrepresentation in the data.

In the Lake Victoria fishery, as indicated by previous studies on fishery compliance, there is a small group of persistent violators. These fishers seem to have found that constant violation is the most beneficial strategy irrespective of deterrence variables or legitimacy and social variables. Whether the fishers have undertaken any particular evasion investments are unknown, but in principal they always use the illegal mesh size and use bribes to reduce or escape from penalties. The fishery management penalty for such behavior is temporary withdrawal of the fishing license for detected violations and even incarceration if the violations are repeated. However, this is more easily said than done. According to Transparency International (TI), the TI Corruption Perceptions Index 2004 (TI, 2004) finds that 60 countries score less than 3 out of 10, indicating rampant corruption. One such country is Tanzania, with an estimated value of 2.8 and a confidence range of 2.4-3.2 securing place 90 of 146. The frequent use of bribes is also confirmed by our study; all of the respondents had experienced arrest and 40% had used bribes to avoid being taken to court. In fact, in the group of purely honest fishers, 23% used bribes to avoid the bother of court proceedings and the risk of being convicted despite being innocent. Given the fact that all fishers had experienced arrest, the high perceived overall probability of being punished (7%), and the existing corruption indicate that inspection officers' personal gain from bribes may reinforce arresting frequency. How to handle corruption is beyond the scope of this study, but increased wages for the enforcement officers could be expected to reduce the incentive for accepting bribes. One critique of the deterrence model is that fishers comply with the regulation to a larger extent than predicted by the model. Such a critique does not apply to this fishery, where the overall violation rate of 29% is substantially higher than the rate previously found in developed and newly industrialized countries. There are two potential explanations as we see it. First, Tanzanian fishers are poorer than previously studied colleagues and cannot afford moral and legitimacy concerns to the same extent. Second, the ubiquitous level of corruption most likely has a negative impact on compliance. When even those who obey the rules are arrested and must use bribes to avoid being taken to court, we expect the "distaste of crime" to be low.

Compliance with the minimum mesh size does not solve the overcapitalization problem that follows from the open access regime, but given that the minimum is large enough, female fish will be able to reproduce at least once and the overfishing will not lead to complete stock depletion (Townsend, 1986). If all fishers start to use the small mesh size, there is an increasing risk that female fish will be caught even before reaching sexual maturity, leading to a complete stock collapse (Clark, 1990). The local Beach Management Units, which have been initiated to enhance community participation in surveillance and management, seem to have been successful in putting an end to the use of poison or dynamite, but not in achieving minimum mesh size compliance. According to our results, the BMUs even reduce the chance of fishers being purely honest. Given that fishers consider violating, the information exchange within a BMU may lead to the risk of being detected and of the social obligation to comply being reduced. While fishers agree that poison or dynamite can easily harm yourself or those close to you, their perception of the stock deterioration mechanism may be more vague. Such misperceptions of bioeconomics were found in an experiment with people from the fisheries sector in Norway (Moxnes, 1998). Development of the BMUs and the understanding of the importance of conserving the juvenile fish seem to be low-cost management options. Combined with increased deterrence activity, they may even ensure sustainable fishing in Lake Victoria.

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