MultiTip: Insights and Policy Implications
Pre-Workshop Summary
November, 2022

Over the past three and a half years, MultiTip's team of researchers from Universities of Heidelberg and Kassel and our partners from the Lake Victoria (LV) region have been working together to deliver an in-depth understanding of this complex socio-ecological system and provide recommendations on its governance. In the pre-workshop summary, we provide a snapshot of the studies that will be presented during the November MultiTip workshop - *MultiTip: Insights and Policy Implications*. These studies use novel methodology and deliver valuable insights on fisheries management.

The MultiTip research that will be presented at the workshop can be categorized into three topics. First, we use mathematical modeling to understand the resource system and its interactions between the fishing industry and governance. Second, we study stakeholders' perceptions and behavior. This is done by eliciting and analyzing stakeholders' perceptions on the links between them and the ecosystem. We also examine fishers' risk-taking behavior in combination with luck, social information and cooperation and analyze the behavioral mechanisms that drive demand for governance via local institutions. Third, we assess the impact of a novel policy for incentivising gear compliance among fishers.

For detailed information on these topics or more information on MultiTip, please visit our website: www.eco.uni-heidelberg.de/multitip

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Understanding the Resource System

The Effect of Size Selectivity on Equilibrium Yield in The Nile Perch Fishery

Size structure of the fish stock plays a significant role in the sustainability of a fishery because fish age and size are tightly coupled and fish only start reproducing when they reach a certain minimum size. Fisheries need to optimize the trade-off between higher yield extraction and maintaining the stock reproductive capacity by allowing juveniles to reach the reproductive state. At LV, a slot size regulation of 50 to 85 cm was introduced to protect immature fish, harvest mature individuals and simultaneously protect larger females which have high egg-laying capabilities.

We created a size structure model of the Nile perch fishery where the rates of fish growth and natural mortality are derived from biological scaling laws. In a first step, the model was validated against empirical data, in a second step the model was simulated under modified fishing intensity and thirdly, the effect of four fleet selectivity scenarios on the equilibrium yield was analyzed. Using the empirical fleet selectivity from Gomez, Kammerer, and Mrosso (2022), we find that the simulations of the size structure are similar to the empirical size distribution from the bottom-trawl and the catch assessment survey. The size distribution of the hydroacoustic survey, however, differs from the bottom-trawl survey and the simulation.

We also estimate Maximum Sustainable Yield (MSY) and find that, under the current fleet selectivity, the empirical annual yield is close to the MSY (Table 1). Correspondingly, the empirical peak fishing mortality rate is only 2.0% above the rate that leads to the maximum sustainable yield.

scenario	Y_{Femp} (kt)	SSB_{Femp} (kt)	F_{msy} (1/yr)	Y_{msy} (kt)
open	207.5936	537.2761	1.015230	207.7713
> 50cm	244.302	701.5037	1.371135	250.0450
< 85cm	149.5158	919.8501	1.576678	158.7763
$50 - 85$cm	168.3612	1201.056	2.432108	205.6201

Table 1: Yield and spawning stock biomass (SSB) at the empirical peak fishing mortality Femp=1.035993/yr, and best fishing mortality FMSY and maximum sustainable yield YMSY for the four scenarios.

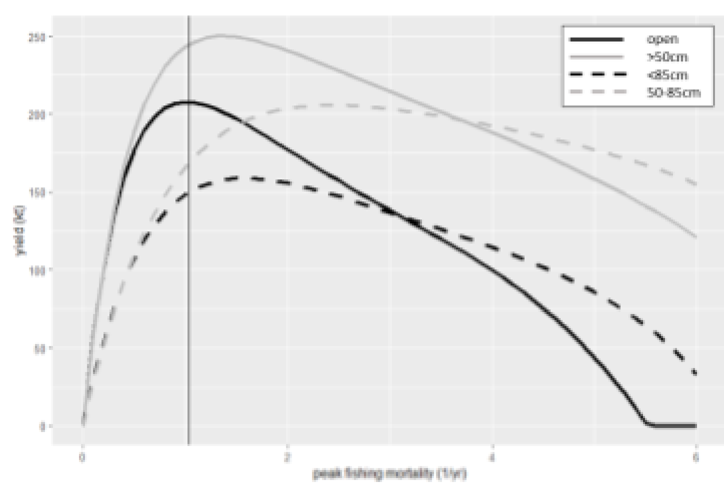

Figure 1: Yield dependent on fishing mortality for the four fleet selectivity scenarios. The black vertical line is the empirical fishing mortality.

To predict the effect of the selectivity on the fish stock and the equilibrium yield, we simulated three hypothetical fleet selectivity shapes: fishing only >50 cm, fishing only <85 cm and strict adherence to the slot size 50-85 cm (Figure 1). Our results show that sparing all fish below 50 cm, while keeping the fishing mortality above 50 cm the same, increases the annual yield by 17.7%. Catching no fish above 85 cm, decreases yield by 28.0%. The maximum sustainable yield is highest in the scenario where fishing is only above 50cm, and lowest in the scenario where fishing takes place only below 85cm.

Researchers: Prof. Timo Goeschl, Ph.D., Prof. Dr. Anna Marciniak-Czochra, Dr. Santiago Gomez-Cardona, Johannes Kammerer (Ph.D. Candidate).

Partner: Dr. Chrisphine Nyamweya (KMFRI)

An Agent-Based Model of the Nile Perch Fishery

We developed an agent-based model that incorporates the size structure of the fish stock with fisher's responses to catch profitability. This allows for modeling fishing with open entry and active decisions on choosing gear with different selectivity profiles. In the model, each agent corresponds to an individual boat that has to make a decision whether to fish and which gear to use. They update the decision as their fishing outcomes change and they observe the outcomes of other agents. Individual variation in profits comes from the natural variability of catch. The model is calibrated using real data on the biological stock parameters, gear selectivity and the outcomes and costs of fishing activities. The model facilitates incorporating policies that change agents' decisions, e.g. the consequences of price subsidies and enforcement can be analyzed.

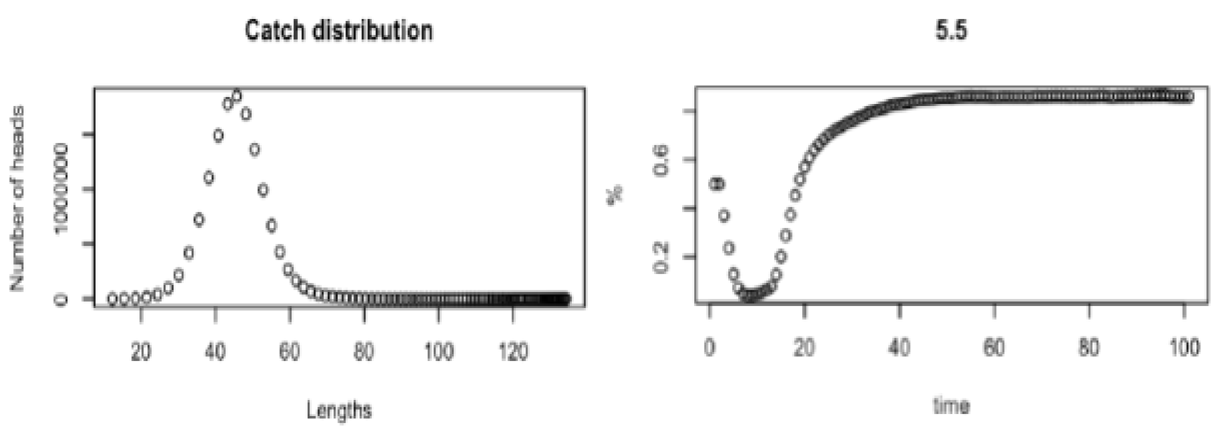

Figure 2: Left: final catch distribution variation along the size length dimension of captured fish (y-axis: heads number, x-axis: size length class); Right: Evolution of fishers (%) using gillnets in time. In the model 40K agents (roughly the real size Nile Perch fleet) make decisions on fishing and choosing between using gillnets or longlines. Time is measured in tenths of a year (10 = 1 year) (y-axis: % of fishers using gillnets, x-axis: time evolution).

Researchers: Dr. Santiago Gomez-Cardona, Johannes Kammerer (Ph.D. Candidate), Hamsa Zazai (Master Student in Economics), Grigori Schapoval (Bachelor Student in Computer Science)

The Surprising Spatiality of the LV Resource System

Our spatial model shows that LV's large area and shape can create de-facto protected fish habitats where low or no fishing effort takes place (white patches in Figure 3). These habitats are distant from the nearest shore, some up to 70 km away. In these areas, artisanal fishing is economically unprofitable given fishing technology, fuel cost and fish prices. This also explains why most of the fleet fish close to the shore despite localized competition for fish. These low-fishing-effort areas can act as potential reserves, increasing the resilience of the resource system to continued harvesting pressure and external shocks. Nevertheless, technological changes and increases in prices can affect the system's stability and resilience.

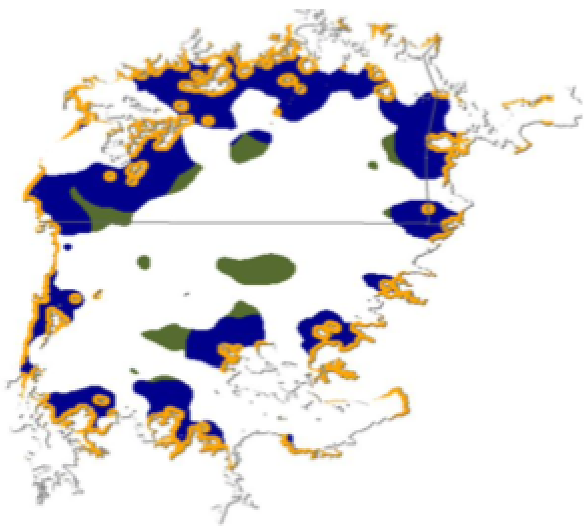

Figure 3: Map of fishing areas from the spatial model. Map shows the existence of different fishing methods/technologies. In yellow: paddle propelled boats. In blue: motorized boat with one day trips. In green: motorized boats, able to stay several days in the lake (using ice to preserve fish). The underlying distribution of fish stock in the water correspond to yearly averages drawn from the Lake Victoria's Acoustic Survey (2010-2019).

Researcher: Dr. Santiago Gomez-Cardona

Understanding Stakeholders Perceptions and Behaviour

Understanding Stakeholders Mental Models

Mental models consist of causal beliefs on how a system functions and can provide insights on perceptions and behavior. We created an innovative universal tool for mental model elicitation called the Mental Model Mapping Tool or M-Tool. Compared to existing software it has two main advantages. First, It allows participants to create mental models with minimal literacy and numeracy requirements via video instructions, pictograms and audio descriptions. Second, researchers can provide participants with a set of system variables to construct their mental models which enables mental model comparability. Once the researcher has created the variables, they can share the study with participants via a link on the web-based app or set it up on a tablet via the application.

The M-Tool software can be downloaded for free in the App store and Google Play Store and a web-based application can be found on www.m-tool.org. It has already been downloaded over 1000 times.

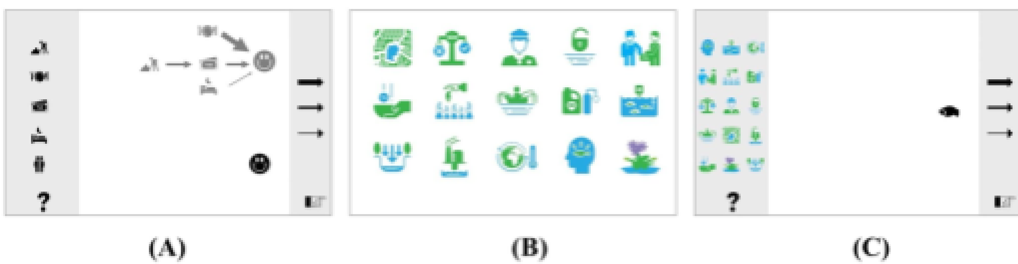

Figure 4: Screenshots of M-Tool: (A) practice session on how to create a mental model (B) presentation of the pictograms and (C) the mental model mapping screen.

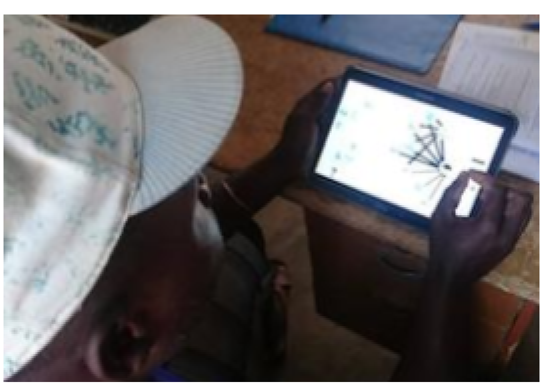

Image 1: A participant using the M-tool app.

We tested the M-tool's application in two field studies with fishers in Tanzania. We compared the M-tool to an alternative technique that is used to elicit mental models among participants with low literacy: semi-structure, face-to-face interviews. Despite similar model composition, we found that M-tool mental models were significantly more complex in the total number of drivers that participants used. We also related the M-tool models to participant's education level and confirmed that, similar to other studies, the higher the level of education, the more complex the participants mental model. Thus, the

M-tool is validated in this context and can successfully capture mental models among diverse individuals.

Researchers: Dr. Karlijn van den Broek, Dr. Sina Klein, Dr. Helen Fisher, Dr. Jan van den Broek

Partners: Joseph Luomba (TAFIRI), Lambdaforge

Differences in Mental Models Between Stakeholders

Diverse mental models may be associated with different behavior or policy preferences and this can affect collaborative conservation efforts. During the preparatory phase of MultiTip, we explored the mental models of 76 stakeholder participants from 33 different institutions (including government organizations, NGO's, business organizations, research institutions and community groups) in Uganda, Kenya and Tanzania. This analysis revealed large differences in the perceptions among stakeholders about the state of the Nile perch stocks and drivers of changes to the stock. These differences are important as they may hinder management. In our following studies, we looked at what may influence these differences.

First, we looked at how perceptions structurally differ when the participant received knowledge of the system formally versus informally. We conducted a survey on 225 participants across Tanzania, Uganda and Kenya and found that most participants agreed that the stock has declined. However, participants with informally acquired knowledge focused on examples of fewer drivers related to tangible human activities (e.g., use of illegal fishing gear), whilst participants with formally acquired knowledge used more abstract and a larger variety of drivers related to the presence of humans (e.g., overpopulation).

Next, we explored mental models for content and complexity differences across experience levels, migration status, and regions. We mapped the mental model of drivers of the Nile perch fish stock fluctuation for 185 Tanzanian fishers. The findings show that (1) fisher's mental models were complex and diverse, (2) mental models focused on the causal influence of destructive fishing activities, (3) mental model complexity, but not content, varied across regions, and (4) fishing experience and migration status were not consistently related to complexity or content. We also find that fishers converge in their perception that fisher's activities, in particular

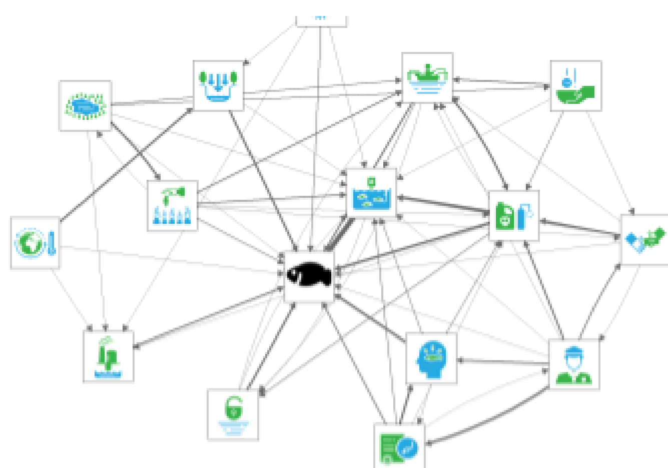

Figure 5: Aggregate mental model of Tanzanian fishers of the drivers of the Nile perch stock. Figure shows how fisher's' mental models focus on fishing in breeding grounds, the use of destructive gear and overfishing.

non-compliance with regulations, contributes to stock decline.

Researchers: Dr. Karlijn van den Broek, Dr. Helen Fisher, Dr. Sina Klein

Partners: Dr. Jan van den Broek, Joseph Luomba (TAFIRI), Horace O. Onyango (KMFRI), Bwambale Mbiling (NaFIRRI), Joyce Akumu (NaFIRRI)

The Effect of Social Information and Luck on Risk Behaviour of Fishers

Risk is an essential component of fishers decisions, especially in a complex and potentially tipping resource system. To understand how experiencing luck and social information influence fishers' risk decisions, we conducted a lab-in-the-field experiment with Tanzanian fishers at LV. Here, fishers made a risky investment decision where their experiences of good or bad luck and information about the behavior of other fishers differed. While the experience of good or bad luck does not significantly affect decision making, we find positive feedback effects - when fishers learn that other fishers engage in risky behavior (high information), they take more risk than fishers who get no information. However, the feedback effect is asymmetric - when fishers learn that other fishers engage in low-risk behavior (low information), their risk-taking does not differ from fishers who get no information.

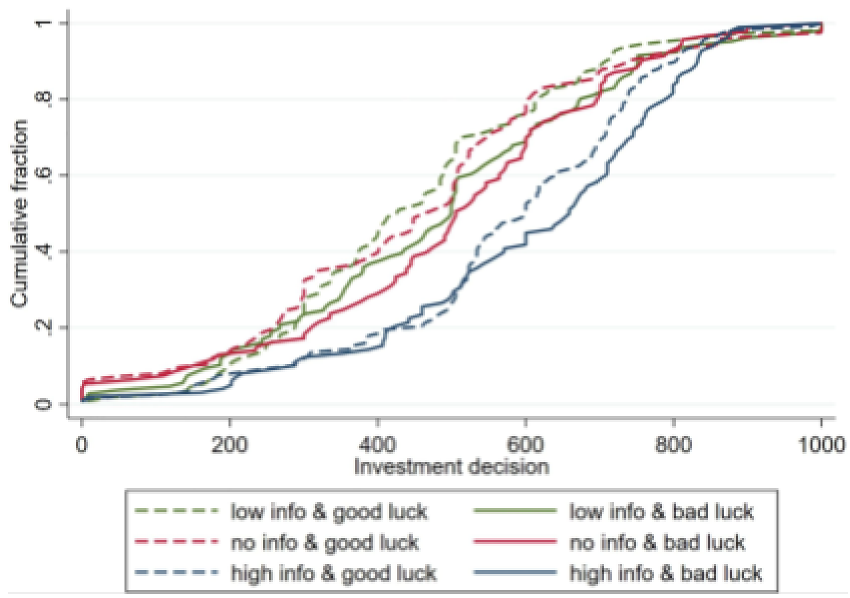

Figure 6: Cumulative distribution of fishers' investment decisions by experience of good or bad luck and social information (low information, no information or high information)

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Partner: Joseph Luomba (TAFIRI)

The Effect of Scarcity, Migration and Stochastic Externalities on Fishers' Behaviour

We conducted two lab-in-the-field experiments with Ugandan fishers at LV to examine how interactions between fishers affect risk-taking and cooperation. In our first experiment, we examine how individual risk decisions are altered due to potential effects on another individual. Through our unique design, we can show whether fishers change their decisions depending on how a risky decision affects the income of another individual. We also examine which risky decisions are sanctioned by the individuals involved. In our second experiment, fishers played a resource extraction game. Here, we examine how fish scarcity changes their willingness to engage in cooperative resource management and whether fishers behave more or less cooperatively when they know that another fisher will join them later (through migrating), making him or her dependent on their prior decisions.

With this study, we can examine how fisher's behavior is affected by the impact of one's behavior on others and changes in environmental conditions and social structures. This will lead to a better understanding of the behavior and the influence of their perception of the socio-ecological environment on that behavior. The study was conducted in August/September 2022 and data analysis is ongoing.

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Partner: Dorothy Birungi (NaFIRRI)

Demand for Incomplete Punishment Institutions to Promote Corporation

Enforcement of rules and regulations at LV has become increasingly centralized. A frequently cited reason for this is the weak enforcement of illegal fishing activities by local institutions. However, literature indicates that Fishers prefer local community enforcement to enforcement by the government.

We conducted an online experiment with German students to understand the general mechanisms that drive demand for incomplete punishment institutions (local institutions) in a highly controlled setting. Participants played a public goods game (6 persons) with a punishment option. Our study examines the general willingness to vote for the severity of a punishment institution that automatically punishes non-cooperative behavior of either all or a subset of players. We compare the demand for a complete punishment institution that affects all players equally with the demand for an incomplete punishment institution that affects only a subset consisting of half of the players.

Since imposing a severe punishment makes it rational to contribute everything to the public good, standard economic theory predicts that rational participants would vote for a severe punishment institution if they benefit from the cooperation of the bound group. Otherwise, they would vote against punishment. To test this prediction for complete and incomplete punishment institutions, we varied the marginal group return (MGR) of the public good in different experimental treatments.

Our study shows that when the punishment institution is complete and all participants are bound to the same punishment institution, participants vote for severe punishment, as predicted by standard economic theory (Figure 7). However, our results also show that in the case of incomplete punishment institutions, participants choose the severity of punishment not only according to whether it is beneficial for them based on the return function, but that their decision is also influenced by other factors.

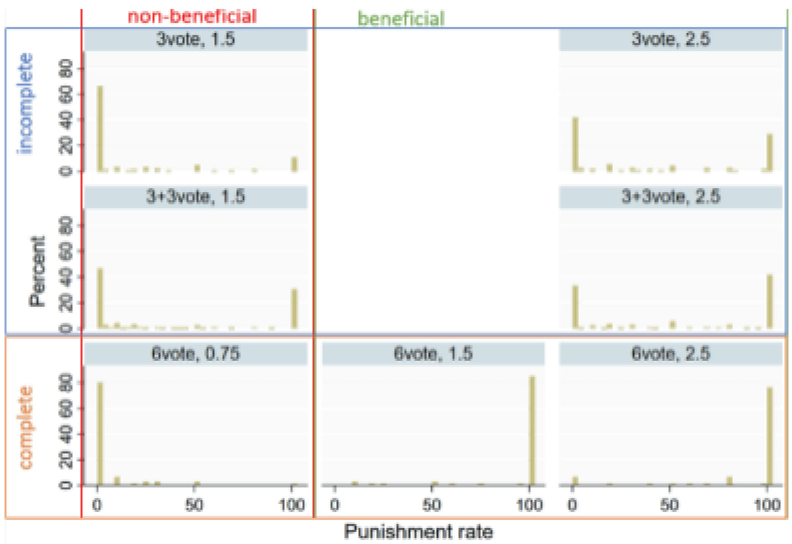

Figure 7: Histogram of frequency of chosen punishment rates (severity) in different treatments divided on whether cooperation of bound group is beneficial or not and on whether the punishment institution is complete or incomplete.
The treatments describe who is able to vote (one small group (3vote), both small groups (3+3vote) or all participants (6vote)) and the marginal group return of the public good for all 6 players (0.75, 1.5, 2.5).

Thus, the demand for incomplete punishment institutions is driven by different factors than the demand for complete punishment institutions. Drawing on behavioral economic theories, we are currently analyzing the data to better understand these other factors. This will help to better understand the general determinants of successful implementation of local (incomplete) punishment institutions as proposed by fishers.

Researchers: Prof. Dr. Astrid Dannenberg, Dr. Christoph Bühren, Phillipp Händel (Ph.D. Candidate)

Analyzing Regulatory Tools

Compliance Subsidies as Novel Regulatory Instruments

The current governance of LV's resource system relies on a coercive regime favoring direct enforcement. In theory, this is supposed to deter illegal gear use as fishers consider the probability of detection and punishment. In reality, the system leads to sporadic, but harsh enforcement that generates limited deterrence at high cost, destroys assets (boats and gear, some of it legal), and regularly leads to fatalities among both fishers and enforcers.

A field intervention has tested regulatory alternatives to the current detect-and-burn approach. For this the Dagaa fishery was chosen as it represents a simple fishery in terms of technology and fishing dynamics that facilitated reaching the intervention goals. At 20 landing sites in Tanzania, a workshop was held in which fishers had the opportunity to buy legal sized nets using an explicitly designed mechanism for the task: a Multiple Price List Mechanism. Additionally, a verbal nudge that incentivizes cooperation was also tested as a procedure to increase the effectiveness of the intervention.

This intervention showed that subsidies on legal gear have the potential to drive out illegal gear at acceptable cost, but also evidence that soft measures that appeal to 'good fishing practices' are ineffective. Figure 8 presents the estimation of the costs that are needed for reaching a target proportion of fishers using legal nets. Ongoing work is using data on the selectivity of legal and illegal gear to provide an estimate of the damages that can be avoided by increasing the proportion of fishers using legal nets.

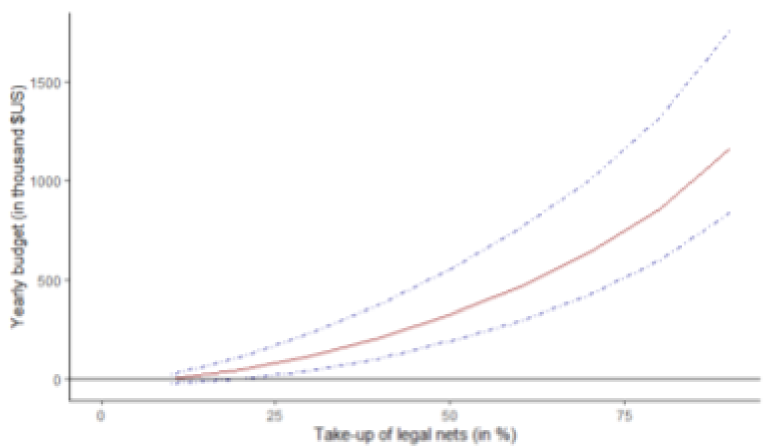

Figure 8: Annual costs for increasing the take-up of legal size nets in the Dagaa fishery, with 95% confidence interval, that is needed to reach different target levels of compliance with net sizes (x-axis: proportion of fishers using legal nets, y-axis: budget that must be allocated in on year to a subsidy program).

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Partner: Joseph Luomba (TAFIRI)

Publications

Dannenberg, A., Diekert, F. & Händel, P. (2022) The Effects of Social Information and Luck on Risk Behavior of Small-Scale Fishers at Lake Victoria, *Journal of Economic Psychology*,90,102493. https://doi.org/10.1016/j.joep.2022.102493

Diekert, F., Eymess, T., Goeschl, T., Gómez-Cardona, S. & Luomba, J. (2022) Subsidizing Compliance: A Multi-Unit Price List Mechanism for Legal Fishing Nets at Lake Victoria. *AWI Discussion Paper 0711*, Heidelberg University. http://nbn-resolving.de/urn/resolver.pl?urn=urn:nbn:de:bsz:16-heidok-313400

Gómez-Cardona, S., 2022, Spatial Structure effects on Fisheries Management for Lake Victoria's Nile Perch. *AWI Discussion Paper 713*, Heidelberg University. https://doi.org/10.11588/heidok.00031342

Kammerer, J., Gómez-Cardona, S., and Nyamweya, C. (2022). Size selective fishing: The effect of size selectivity on the equilibrium yield in the Nile perch fishery of Lake Victoria. *AWI discussion paper series*, dp720.

Klein, S. A., van den Broek, K. L., Luomba, J., Onyango, H. O., Mbilingi, B., & Akumu, J. (2021). How knowledge acquisition shapes system understanding in small-scale fisheries. *Current Research in Ecological and Social Psychology*, 2, 100018.

van den Broek, K. L. (2018). Illuminating divergence in perceptions in natural resource management: A case for the investigation of the heterogeneity in mental models. *Journal of Dynamic Decision Making*, 4, 1–5. https://doi.org/10.11588/jddm.2018.1.51316

van den Broek, K. L., Klein, S. A., Luomba, J., & Fischer, H. (2021a). Introducing M-Tool: A standardised and inclusive mental model mapping tool. *System Dynamics Review*, 37(4), 353–362. https://doi.org/10.1002/sdr.1698

van den Broek, K. L., Luomba, J., van den Broek, J., & Fischer, H. (2021b). Evaluating the Application of the Mental Model Mapping Tool (M-Tool). *Frontiers in Psychology*, 12, 761882. https://doi.org/10.3389/fpsyg.2021.761882

van den Broek, K. L., Luomba, J., van den Broek, J., & Klein, S. (Under review). Fishers' mental models reveal their perceived role in conserving fish stock and regional differences.