Steve Donda, Mafaniso Hara, Maxon Ngochera,
Erling Berge (Eds.)

Fragmentation of Resource Management on the South East Arm of Lake Malawi

Dynamics around Fisheries

PLAAS

LIT

Table of Contents

1 Fragmentation of natural resource management on the Southeast Arm of Lake Malawi and the Conceptual Framework

Mafaniso HARA, Steve DONDA, Maxon NGOCHERA and Erling BERGE

Background

Large scale assemblages of natural resources commons still exist in most of Southern Africa. The term 'commons'[1] refers to common pool resources that are owned and drawn upon by multiple stakeholders, including, for example, water, fish, wildlife, wood and grass for grazing, and a combination of these. Many of these commons are extremely important for rural livelihoods. Given that they are not individually or privately owned, some kind of management is necessary to deal with problems of open access and concomitant issues of subtractability and excludability (Berkes 1989; Ostrom 1986; Oakerson 1986; Fortman and Bruce 1988). Problems of overharvesting and misuse of ecological systems are usually not attributable to one cause (Andries et al. 2007). Thus, policy makers should be aware of the inadequacy of panaceas attempting to prescribe simple solutions to complex social ecological systems (SESs)[2] (Ostrom 2007). Practically, neither full protection nor private property rights are feasible solutions so scientists, policy makers and stakeholders need to find and promote other approaches to common property management.

African commons management has largely been placed in the hands of the state, although increasingly participatory and cooperative management are being advocated.[3] However, because of economic pressures that are usually exacerbated by extreme poverty, biodiversity conservation efforts involving local communities have thus far not been very successful. One of the main reasons for this failure is the dominance of single-sector approaches that either ignore the economic problems or deal with them on a piecemeal basis leading to fragmentation in manage-

[1] Commons is a general term for shared resources in which each stakeholder has an equal right and interest, with the bundle of rights (Schlager and Ostrom 1992) in such property regimes allocated to the group (Hess 2002). Such rights may include access, use, management, exclusion and ownership rights of a shared resource (Schlager and Ostrom 1992).

[2] Also referred to as human-environmental systems

[3] In the last two decades, various forms and degrees of cooperation with local communities and/or traditional authority have been initiated in management decision-making.

ment of natural resources that ideally should be managed as large scale commons assemblages – the so called 'ecosystems approach'.

Fragmentation in commons management is a problem at many levels,[4] including the fragmentation of:

i) technical expertise between government management agencies, NGOs, and universities;
ii) resource management activities across different geographical scales;
iii) natural resources authorities between different agencies, and across local, national and international borders; and
iv) natural resource networks across sectors – for example, those involved in fisheries mainly know, interact and work with others in their sector, and those involved in forestry mainly know, interact and work with others in their sector etc.

Agencies responsible for management of commons are organised on the basis of sectors in a national hierarchy with little or no provision for the costs of cooperation at local, regional, national and international levels. The cross-sector networks needed for an ecosystem approach are only just beginning to emerge.

In developing countries such as most in Africa, science is a precious resource. Effective links between government, university, and NGO scientists are critical to ensure that the scientific resources available are optimised. Studies suggest that in most developing countries links between academic scientists and policy makers are docile and/or lukewarm in general (Shrum and Shenhav 1995). This is partly because many scientists from developing countries are trained abroad and are one step behind when trying to create local scientific communities that can relate to local contexts. In addition, systematic research on the use of scientific resources for natural resources in Africa is limited (Fairhead and Leach 2003).

An underlying difficulty in integrating both technical and social scientific knowledge in respect to interconnecting commons is that important processes operate at different scales and levels. Recent natural resource management literature focuses on the importance of 'cross-scale linkages' in science (Carlsson and Berkes 2005; Young 2008; Gunderson et al. 2006; Wilson et al. 2006). The key is to link the knowledge bases of institutions that are concerned with problems at different scales. When real exchange of strengths is able to take place, a condition that is often hampered by poor communication, the results can be very impressive (Wilson et al. 2006). Combining research-based scientific knowledge with local ecological knowledge (LEK) is an important but difficult challenge. LEK is critical in understanding local manifestations of complex ecosystem interactions,

[4] While fragmentation in commons management is a global problem, the existence and importance of complex African commons offers unique laboratories in which to learn how to deal with such problems. Hence the importance of the DARMA Project.

but such information is rarely found in a form that can be used directly to facilitate management. This requires a process of discussion between local people and scientists (Agrawal 1995; Wilson et al. 2006).

The ecosystem approach is based on a growing appreciation of the interrelatedness of both the ecological and economic dynamics in management of natural resources. New cross-disciplinary scientific networks are needed that can identify specific areas of sectoral interconnection, articulate and implement the research needed, and translate the results into advice for policy makers. The Southeast Arm of Lake Malawi case study is one of seven under the Defragmenting Resource Management in Southern Africa (DARMA) project which seeks to build networks and research frameworks that can integrate resource management.

The specific objective of DARMA is to increase national capacity in the five African partner countries for the integrated management of commons while the overall broader objective is to enhance biodiversity of exploited commons while alleviating poverty at the same time. The main strategy for achieving these objectives is the development and expansion of scientific networks and integrated knowledge bases that can combine different relevant natural and social science disciplines in a way that will be of practical use for both biodiversity conservation and sustainable development.

Integral to achieving these broad objectives is conflict resolution since ecological degradation leads to competition for the remaining resources. Therefore, effective, integrated commons management could address three related sets of problems simultaneously: a) limiting access to resources to prevent overexploitation; b) economic development that relieves poverty while respecting limited access, and c) managing the conflicts that arise when access to resources is limited. All three of these problems require knowledge. Setting limits requires the work of natural scientists while poverty alleviation and the effective implementation of management require the work of social scientists, and managing conflicts requires involving stakeholders who know the locally appropriate solutions. It is important therefore that experts from different disciplines and sectors work together to achieve these common goals.

Conceptual framework

Complex social ecological systems such as the Southeast Arm are partially decomposable in their structure (Allen and Hoekstra 1992; Ahl and Allen 1996; Koestler 1973; Wilson 2002); the elements at each lower level are sub-divisions of the elements at the level above (just as multi-celled organisms are composed of organs, organs of tissues, tissues of cells). Three aspects of decomposability are

important for understanding complex SESs better and crafting ways to improve their performance, namely:

i) **Conceptual partitioning of variables into classes and sub-classes:** These variables need to be understood to build coherent and cumulative scientific understanding (Fig. 1).

ii) **Existence of relatively separable independent subsystems, but whose many functions affect each other's performance:** Parallel functionality and adaptability is essential for enabling long-term solutions to complex SESs. Policies on one part of the system are likely to affect other parts of the system and, in a worst case scenario, a change in one variable could result in drastic changes to the whole system and may even lead to collapse of the resource complex as a whole.

iii) **Complex systems are greater than the sum of their parts:** Thus combining one set of variables (A, B, C) could lead to a system with properties that will be different if a different set of variables was combined (A, D, E).

The Southeast Arm of Lake Malawi studies made use of the multi-tier framework for analysing SESs adapted from Poteete et al. (2010). Figure 1.1 represents a very simple general framework of the highest-tier variables that were analysed when examining the Southeast Arm SES.

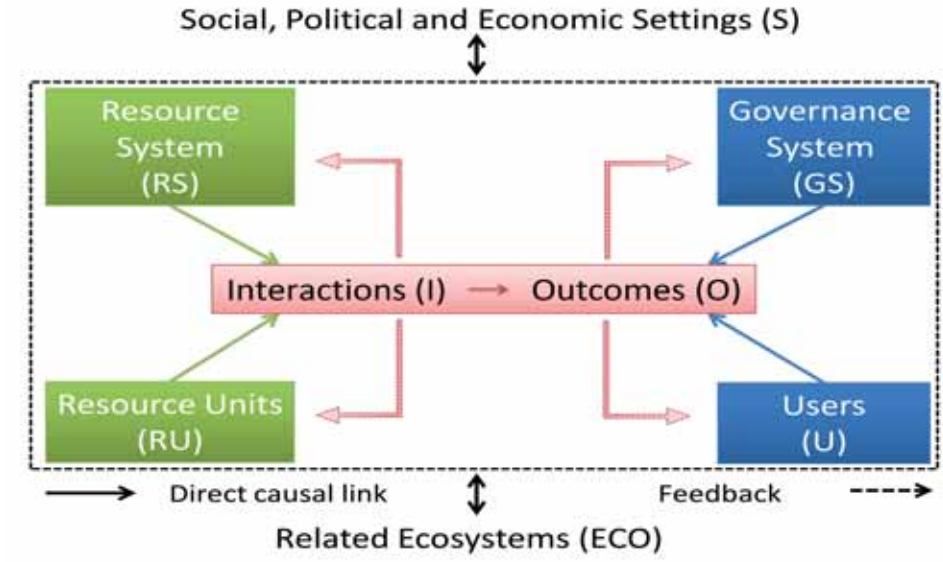

Figure 1-1: A multi-tier framework for analysing an AES. Adapted from Poteete et al. *(2010)*

This framework has four broad variables, namely:
i) Resource system
ii) Resource units
iii) Governance system
iv) Users.
The resource system comprises all the biotic and abiotic components existing within the Southeast Arm ecosystem, including both aquatic and terrestrial (within the area that forms part of the Southeast Arm catchment area) components. Resource units comprise individual species and identifiable biotic components within the ecosystem that can be harvested and need conserving. Governance system comprises both the formal and informal institutions and structures that influence or are responsible for (sustainable) management of the system. Users comprise all stakeholders with economic, social, political and cultural interests in the ecosystem and its resources.

The four variables *interact* and produce *outcomes*, with feedback loops of these interactions and outcomes. These interactions and outcomes take place (or are embedded) within (external) *related ecosystems* and *social, economic and political* settings. These external factors influence the interactions and outcomes.

Using this framework, we can analyse how attributes of (i) the resource system (e.g. fishery, lake, etc); (ii) the resource units generated by the system (e.g. fish, water); (iii) the users of the system (e.g. fishers, tourists, etc); and (iv) the governance system, jointly affect and are affected indirectly by interactions and resulting outcomes achieved at a particular time (temporal). What is key and important is the identification of the initial core conceptual variables that characterise a given SES at a particular time. Using this framework also enables us to categorise how these attributes may affect and be affected by the external factors – social, economic and political on the one hand, and ecological settings on the other.

Having identified and described the core conceptual variables, a diagnostic analysis of their interactions, which produce negative or positive and sustainable or unsustainable outcomes, can then be undertaken. The interactions and outcomes in a SES depend on the specific interactive combination of several of these variables at one or multiple tiers (Netting 1976; 1981; Low et al. 2003; Schlager 1994). The direction (e.g. whether negative or positive) and strength of impact of one variable depends on the other variables with which it interacts or combines (Poteete and Ostrom 2004a; 2004b), and the past combinations and processes within the SES in question.

Research questions

The long-term goal for the Southeast Arm is to recognise which combination of variables could lead to relatively sustainable and productive use of the Southeast Arm SES and which combination of variables could lead to collapse of the system and therefore to high social-economic cost for users. The use of the SES framework could enable development of cumulative, coherent, and empirically supported answers to the following three broad research questions related to sustainable utilisation (Ostrom 2007) of the Southeast Arm for the benefit of all stakeholders:

i) How robust is a particular configuration of users, resource system, resource units and governance system in response to external and internal disturbances?
ii) What patterns of interactions and outcomes (e.g. overuse, conflict, collapse, stability and increasing returns) are likely to result from a particular set of use patterns, ownership, rate of harvesting, technologies used, approaches to governance, and the socio-economic and political environment?
iii) What is the likelihood of endogenous development of governance arrangements, use patterns and outcomes without external material inducements or imposed rules?

Description of the study area (resources, sectors and activities)

The Southeast Arm of Lake Malawi denotes the eastern arm of the two arms at the southern end of the lake. It is located between 13° 50′ to 35° 10′ east and 13° 44′ to 14° 25′ south (Fig. 1.2). The area is about 80 km long from the northern to southern outlet into the Shire River. At the northern end it is about 30 km wide. The Southeast Arm has a total surface area of about 2,000 km^2.

While the northern part of Lake Malawi is generally deep, even close to the shore, the southern half is shallower and more gently shelving. The South East Arm is the shallowest part of the lake in which winter mixing caused by seasonal South East winds (locally called *Mwera*)[5] and upwelling drives the thermocline to the bottom, causing the entire water column to mix and bring the nutrient-rich bottom water up to the euphotic zone. The existence of internal waves also helps with mixing of the water, as nutrients sedimented at the bottom are returned directly to the water column and help in maintaining the fertility of the area (Eccles 1962). This occurs in the entire Southeast Arm area, resulting in very high phytoplankton production in the area. As a result, the Southeast Arm supports a much richer fishery and has the highest production per unit area of the entire lake.

[5] Winds of speeds up to 40 km hr^{-1} generating waves of about 2 m high are common during winter.

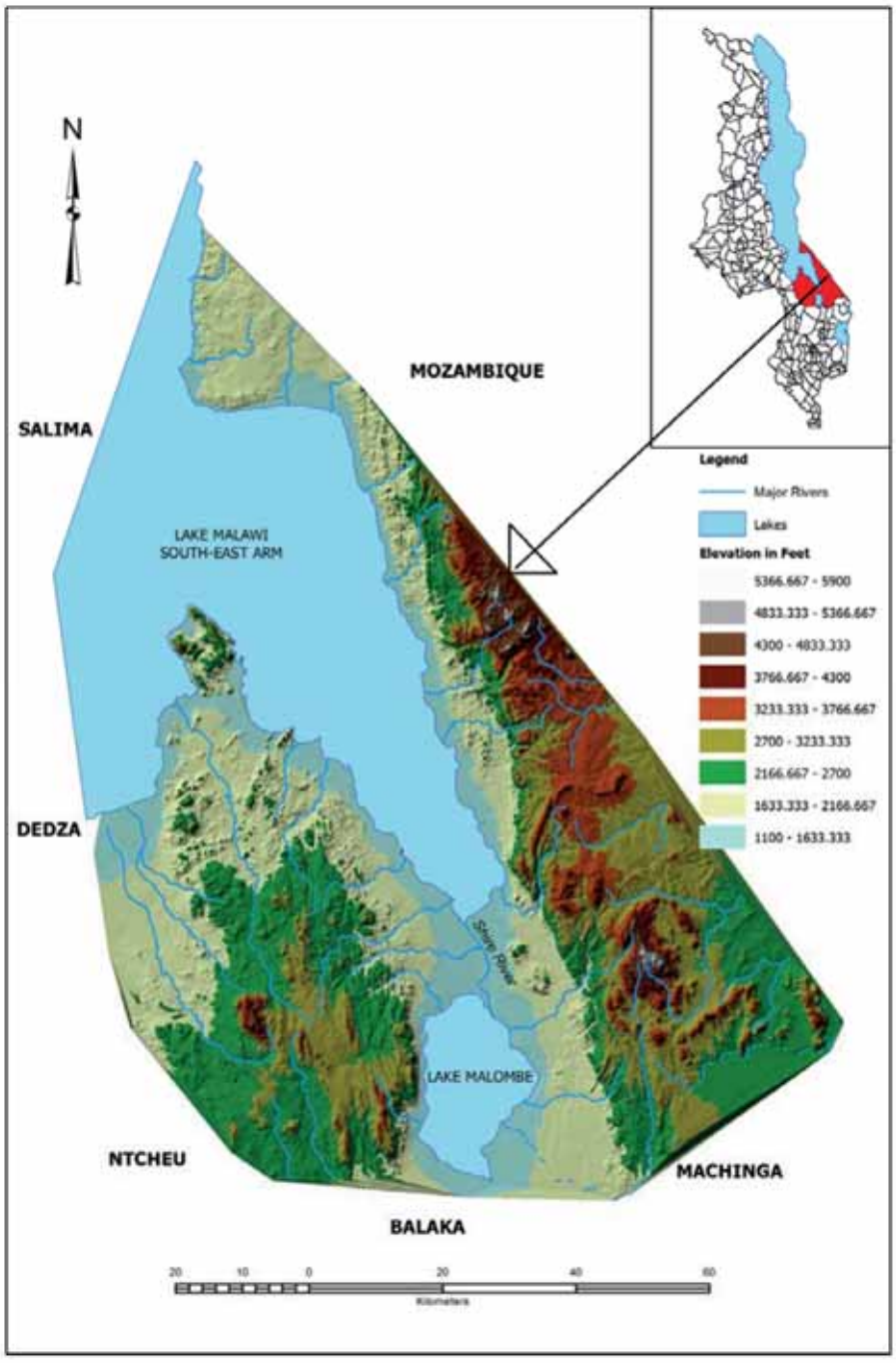

Figure 1-2: Map of Mangochi District showing the Southeast Arm relative to the topography and drainage pattern (source: Department of Surveys, GoM, 2013)

The Southeast Arm supports an artisanal fishing sector that lands on average 19,000 mt of fish per annum, which translates to about 27 % of the total fish production in Malawi (see Chapter 5). The area also supports cage culture activities by MALDECO fishing company. In addition to MALDECO's plans to expand their existing production from cage culture, other private investors are also showing interest in this practice. This could increase the area for cage culture on the Southeast Arm.

The sandy beaches of the Southeast Arm mean that the area is also the most popular part of the lake for tourism. As a result, there are many hotels and guest houses in the area, in addition to the mushrooming of privately owned and corporate (belonging to companies) cottages and holiday homes over the last two decades. These homes, also commonly termed tourist accommodation units, are usually built on customary land obtained from local chiefs. In 2011 there were over 40 tourist accommodation units on the beaches on the Southeast Arm.

The north-western part of the Southeast Arm around the Nkhuzi Bay area forms part of the Lake Malawi National Park. Snorkeling for colorful and attractive rock dwelling ornamental cichlid fish (*mbuna)* is a popular tourist attraction in the Lake Malawi National Park. The Southeast Arm is part of the African Rift Valley. The Namwera and Namizimu hills on the eastern shores and the Phirilongwe hills on the western shores form the physical boundaries of the catchment area for the Southeast Arm (Fig. 1.2). Within this catchment area, there are high levels of agricultural activity and population densities, and thus a shortage of agricultural land. Deforestation is a common problem.

Methodological approach

Diagnosing the problems and potentialities involved in exploitation of SESs requires methods and approaches that acknowledge that these systems are complex, multi-variable, nonlinear, cross-scale and constantly changing (Holling et al. 1998). It is key to recognise that many variables affect patterns of interactions and outcomes. In order to analyse the Southeast Arm as a SES, it was necessary to establish cross-disciplinary scientific networks and establish the research framework.

The first activity was the identification of subject matter specialists to establish a core network team of scientists from various research disciplines who were familiar with and working on the Southeast Arm complex with the aim of pooling critical common resources expertise. The following seven key specialists were identified: three from the University of Malawi – specialising in ecology, forestry and socio economics; three from the Department of Fisheries – one fisheries economist, one fisheries biologist and one limnologist; and an agriculturist

from the Department of Land Resources, the Ministry of Agriculture and Food Security. These scientists held a series of scientific meetings.

Literature reviews based on current scientific literature were undertaken to inform cross-sectoral interactions by the scientists comprising the core group of the network. Critical areas for review were identified and the following review papers were commissioned:

- Historical settlement patterns and conflicts in the Southeast Arm
- The ecology of the Southeast Arm
- Southeast Arm of Lake Malawi: limnology, pollution, siltation and habitat change
- Fishing, management and conflicts in the Southeast Arm
- Forestry management in the Southeast Arm catchment area
- The economy of and livelihoods in the Southeast Arm
- Institutional structures and governance in the Southeast Arm.

The reviews were presented to a meeting of the whole network of scientists and resource users in the area to provide an opportunity for people involved in fishing and managing the commons to respond to the review findings, and launched the process of identifying the key conflicts requiring mitigation strategies. Feedback from these meetings informed development of an inter-disciplinary research framework for action research in the Southeast Arm.

Action research was identified as the appropriate tool to assess research frameworks through local ecological knowledge and identify conflicts arising from the management and multiple use of complex commons. In addition, action research is intended to stimulate thinking and initiate development of corrective actions by the resource users, which could impact positively on sustainability and resolution of conflicts between resource users. It is in this way that the multi-disciplinary scientific network can link to both policy makers and managers that need scientic information, and the local people who depend on the common pool resources for their livelihoods. Thus action research was conducted as fieldwork and lies at the very heart of this research.

The outputs from this process were seven ecosystem-based cross-disciplinary reviews. Two experts (one independent and the other an associate partner on the project) were identified to peer-review the draft reviews and assist with synthesising issues drawn from all the papers produced. These papers and all of the above activities form the basis of this book, which is aimed at policy makers and the scientific community concerned with sustainable governance of the Southeast Arm and the user community, especially the local communities. It is hoped that the book will provide insights towards a holistic approach to the governance of the Southeast Arm as a SES, conflict mitigation strategies, incentive institutions and

regimes for integrated resource governance, along with policy lessons for managers and governors.

Introduction to the chapters

The meeting between the sectoral scientists and resource users identified the following 1st tier variables as characterising the Southeast Arm as a social ecological system: a) fish; b) water; c) forest cover; d) land; e) beach; f) birds; and g) wildlife. Fish was identified and selected as the key variable for further analysis in terms of its interactions with the other variables.

Therefore, papers were developed for review and analysis of the following issues and aspects of the Southeast Arm:

- Resource system (sector, location, system boundaries, size of resource system, productivity of system, indicators of productivity, system equilibrium properties, predictability of system dynamics, human constructed facilities, etc);
- Resource units (resource unit mobility, growth or replacement rate, interaction among resource units, economic value, size, spatial and temporal distribution, distinctive markings, etc);
- Governance system (government organisations, NGOs, network structure, property rights systems, operational rules, collective-choice-rules, constitutional rules, monitoring and sanctioning processes, etc); and
- Users (number of users, socioeconomic attributes of users, history of use, location, leadership/entrepreneurship, norms/social capital, knowledge of SES, dependence on resource, technology used).

Chapter 1: Fragmentation of natural resource management on the Southeast Arm of Lake Malawi and the conceptual framework

This introductory chapter provides the background and context to the book, the underlying conceptual framework, the research questions addressed, a summary description of the study area, the methodological approach used and an outline of the book chapters.

Chapter 2: A history of the early development of the Southeast Arm of Lake Malawi fishery and conflicts

This chapter reviews the history of development of the Southeast Arm of Lake Malawi fishery. It does this by examining the history and political organisation of the people of the area around the issues of the fishery; the early development of the fishery; how the fishery was managed in terms of regulatory controls and resolution of conflicts; issues of custodial and stewardship rights; conservation concerns of the era and how these were handled; and who the main actors were in all these issues surrounding the fishery.

Chapter 3: The ecology of the Southeast Arm of Lake Malawi
This chapter reviews the ecological research that has been conducted in the Southeast Arm of Lake Malawi, which has attracted a lot of fishing activities and has seen the establishment of cage culture. A literature review reveals that much research has been done, though fragmented and uncoordinated. The chapter concludes with proposals for future research areas so that the rich species diversity in the lake can be enhanced, including research that could help ventures into ecological aquaculture to reverse the reported high levels of eutrophication in the Southeast Arm.

Chapter 4: Southeast Arm of Lake Malawi: Limnology, pollution, siltation and habitat change
This chapter reviews the biophysical characteristics of the Southeast Arm, with emphasis on nutrient status, pollution levels, sediment loading and siltation, and habitat characteristics. From the review in this chapter, it is clear that most data available on the area is scanty and sporadic. Available data indicate that the Southeast Arm is undergoing considerable stress due to increasing human population and poverty levels, resulting in increasingly evident overexploitation of aquatic resources, especially fish. High soil erosion rates within the lake's catchment are increasing siltation of the shallow areas and covering rocks with silt. These are the habitats of most of the cichlid fishes and their food source. In addition, erosion is affecting water quality and fish breeding habitats, jeopardising the potential for fish production. The promotion of irrigation and cage culture development in the area, if not properly designed, could be a source of new nutrient loads into the Southeast Arm of Lake Malawi.

Chapter 5: Fishing, management and conflicts in the Southeast Arm
This chapter evaluates the importance of fisheries activities in the study area and Mangochi District as a whole. It then looks specifically at the challenges of fisheries management in the Southeast Arm of Lake Malawi in view of competing uses of the catchment area and how these affect the fishery of the area. The chapter outlines how other terrestrial activities end up affecting productivity of the fishery, and how the fragmented resource management approach in the area contributes to the problems of fisheries management.

Chapter 6: Forest management in Mangochi District, with emphasis on the Southeast Arm of Lake Malawi catchment
This chapter focuses on how forest resources in the catchment area of the Southeast Arm of Lake Malawi are managed and identifies the challenges facing sustainable management of forest resources in the area. The forest reserves are increasingly encroached upon by human settlements as population grows and demand for cultivation land increases. There is also pressure on forests as wood

is required for numerous purposes: curing tobacco on the estates in the district, especially the Namwera area; fish processing; boat and canoe construction; and firewood for sale and domestic use. All of these activies result in deforestation and forest degradation. The chapter argues that the problem does not lie with the forestry sector alone; the fisheries, wildlife, tourism, environment and agriculture sectors (including local government) have their own policies and regulations that are not particularly aligned or complementary to forest policy and regulations. It concludes that forest resources need to be managed in an intersectoral and interdisplinary manner by all the sectors and authorities involved if sustainable utilisation is to be achieved.

Chapter 7: Economy of and livelihoods on the Southeast Arm of Lake Malawi
This chapter looks at the formal economy of the area and livelihood profiles of the communities in the Southeast Arm area. It considers how an inter-sectoral approach to economic development and holistic governance of natural resources that provide for the livelihoods profiles of the communities are important for sustainable livelihoods and the economic development of the people of Mangochi. Special emphasis is given to the fisheries resources and their contribution to the economy and livelihoods in the area and the district as a whole.

Chapter 8: Institutions and organisations for governance of fisheries resources in the Southeast Arm of Lake Malawi
This chapter considers and evaluates current and proposed institutional and organisational arrangements for governance in the area and Mangochi District and how these influence resource management. The chapter looks at issues of power, formal administrative structures, devolution of responsibility and authority, decentralisation, distribution of power/power relations and transparency and accountability. These issues are discussed in relation to development approaches and governance of fisheries.

Chapter 9: Discussion and recommendations for defragmentation of resource management in the Southeast Arm of Lake Malawi
The final chapter provides the overall analysis and concludes with suggestions and recommendations to defragment natural resource management on the Southeast Arm of Lake Malawi. Using fisheries as a case study, the negative interactions arising from fragmentation of policy, legislation and institutions are demonstrated, based on the findings of action research. The negative impact of these factors is evaluated and discussed.

References

Agrawal, A. 1995. Dismantling the divide between indigenous and western knowledge. *Development and Change* 26 (3): 413 - 439.

Ahl, V, and T.F.H Allen. 1996. Hierarchy Theory. In *Toward a Unified Ecology* edited by T. F. H. Allen and T. W. Hoekstra. New York: Columbia Univ Press.

Allen, T.F.H., and T.W. Hoekstra. 1992. *Toward a unified ecology*. New York: Columbia University Press.

Andries, J.M., A.A. Rodriguez, M.A. Janssen, and O. Cifdaloz. 2007. Panaceas, uncertainty, and the robust control framework in sustainability science. Proceedings of the National Academy of Sciences. 104 (39): 15194 - 15199.

Berkes, F. 1989. Common Property Resources. In *Ecology and Community-Based Sustainable Development*, edited by F. Berkes. London: Belhaven Press.

Carlsson, L., and F. Berkes. 2005. Co-management: concepts and methodological implications. *Journal of Environmental Management* 75: 65 - 76.

Eccles, D.H. 1962. An internal wave in Lake Nyasa and its probable significance to the nutrient cycle. *Nature* 194: 832 - 833.

Fairhead, J., and M. Leach. 2003. *Science, society and power: Environmental knowledge and policy in West Africa and the Caribbean*. Cambridge: Cambridge University Press.

Fortman, L., and J.W. Bruce. 1988. *Whose trees? Property Dimensions of Forestry*. Westview, Boulder.

GoM 2013, Department of Surveys, Lilongwe, Malawi.

Gunderson, L.H., S.R. Carpenter, C. Folke, P. Olsson, and G. Peterson. 2006. Water RATs (resilience, adaptability, and transformability) in lake and wetland social-ecological systems. *Ecology and Society* 11(1): 16.

Hess, C. 2002. The Digital Library of the Commons. In *Proceedings of the Indiana University Forum on Digital Libraries*, edited by G. Bernbom. Office of the Vice President for Information Technology, Indiana University: Indiana University.

Holling, C.S., F. Berkes, and C. Folke. 1998. Science, Sustainability, and Resource Management. In *Linking Social and Ecological Systems*, edited by F. Berkes and C. Folke. Cambridge, UK: Cambridge Univ Press.

Koestler, A. 1973. "The Tree and the Candle" In *Unity Through Diversity*, edited by Gray. W and N. D. Rizzo. New York: Gordon and Breach.

Low, B., E. Ostrom, C. Simon, and J. Wilson. 2003. Redundancy and diversity: do they influence optimal management? In *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*, edited by F. Berkes, Colding. J and C. Folke. New York: Cambridge University Press.

Netting, R., McC,. 1981. Balancing on an Alp. Cambridge, UK: Cambridge Univ Press.

Netting, R., McC. 1976. What Alpine Peasants Have in Common: Observations on Communal Tenure in a Swiss village. *Hum Ecol* 4: 135 - 146.

Oakerson, R.J. 1986. A Model for the Analysis of Common Property Problems. Paper read at Proceedings of the Conference on Common Property Resource Management, Washington D.C.

Ostrom, E. 1986. Issues of definition and theory: Some conclusions and hypotheses. Pa-

per read at National Research Council. Proceedings of the Conference on Common Property Resources Management, Washington D.C.

Ostrom, E. 2007. A diagnostic approach for going beyond panaceas. Proceedings of the National Academy of Sciences 104 (39): 15181 - 15187.

Poteete, A, and E. Ostrom. 2004a. Heterogeneity, Group Size and Collective Action: The Role of Institutions in Forest Management. *Development and Change* 35 (3): 435 - 461.

Poteete, A., and E. Ostrom. 2004b. In Pursuit of Comparable Concepts and Data about Collective Action. *Agricultural Systems* 82(3): 215 - 232.

Poteete, A.R, M.A. Janssen, and E. Ostrom. 2010. *Working together: Collective action, the Commons, and multiple methods in practice*: Princeton University Press.

Schlager, E. 1994. Fishers' Institutional Responses to Common-Pool Resource Dilemmas. In *Rules, Games, and Common-Pool Resources*, edited by E. Ostrom, R. Gardner and J. Walker. Ann Arbor: University of Michigan Press.

Schlager, E., and E. Ostrom. 1992. Property-Rights Regimes and Natural Resources: A Conceptual Analysis. *Land Economics* 68(3): 249 - 262.

Shrum, W., and V. Shenhav. 1995. Science and technology in less developed countries. In *Handbook of Science and Technology Studies*, edited by S. Jasanoff, et al. London: Sage.

Wilson, D.C., R. Raakjaer, and P. Degnbol. 2006. Local ecological knowledge and practical fisheries management in the tropics: a policy brief. *Marine Policy* 30: 794 - 801.

Wilson, J.A. 2002. Scientific uncertainty, complex systems, and the design of common-pool institutions. In *The Drama of the Commons* edited by E. Ostrom, T. Dietz, N. Dolsak, P. Stern, S. Stonich and E. Weber. Washington, DC: Natl Acad Press.

Young, O. 2008. Institutions and environmental change. The Scientific Legacy of a Decade of IDGEC Research. In *Institutions and Environmental Change: Principal Findings, Applications, and Future Directions*, edited by O.R. Young, L.A. King and H. Schroeder. Cambridge, MA: MIT Press.