RESILIENT RIVERS: COUNTING FISH FROM FORESTS

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Recognising that forests and freshwater ecosystems are inextricably linked within watersheds, the Fisheries and Aquaculture and Forestry Divisions of the Food and Agriculture Organization of the United Nations (FAO) are jointly implementing a series of activities under the umbrella "Resilient Rivers: Counting Fish from Forests". Under this initiative, innovative technologies including satellite imagery, drone footage and e-Learning, and also more traditional approaches such as stakeholder surveys and water temperature loggers are used to gather information and build capacity for integrated forest and fisheries management across watersheds.

The Fisheries and Aquaculture and Forestry Divisions at FAO are joining forces to implement a series of activities focused on forest, freshwater and inland fisheries linkages

Freshwater and other inland water ecosystems, i.e. flowing and standing waterbodies away from the sea, offer provisioning, regulatory, and supporting services such as energy, food, fibres, nutrition, flood control, and nutrient cycling that underpin the livelihoods of riparian communities, as well as non-material benefits or cultural services.

Among all ecosystem types, inland waters are the most valuable, delivering significantly higher benefits per unit area than terrestrial ecosystems (Coates, in press[1]). Globally, more than 11 million tonnes of aquatic animals are extracted from inland water ecosystems every year, corresponding to the animal protein requirements of approximately 158 million people (McIntyre et al. 2016[2]).

For many of the world's poorest populations, inland fisheries are crucial for food security, nutrition, and livelihoods, and they have the potential to make a significant contribution to achieving sustainable development. However, despite their importance, inland fisheries are often overlooked in international frameworks such as the Sustainable Development Goals, where inland systems are embedded as one of many foci in Target 15.1 "ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and dryland" for SGD 15 (Life on Land); but are absent from all indicators in SDG 14 (Life Below Water), which are limited to marine fisheries (Lynch et al. 2020[3]). One reason for this lack of visibility is the absence of data that permit quantifying the contributions of inland fisheries at sufficient scale which is a consequence of them being spread over vast remote areas, often with poorly developed infrastructure, and involving small-scale, part-time and highly seasonal activities.

Productivity and production cycles within inland water ecosystems and terrestrial ecosystems are dynamically intertwined. Forests and freshwater ecosystems, for example, are inextricably linked within watersheds, with many inland fish species relying on habitats that are maintained and supported by forests. Forests provide bank and hillslope stabilisation, support resilient food webs, foster healthy soil development, regulate temperature, offer shade and shelter, promote nutrient recycling and input organic matter including fruits, seed and invertebrates that serve as food for fish and other organisms. Changes in land use have the potential to

[1] *Coates, D. in press. Ecosystem restoration and inland food fisheries in developing countries – opportunities for the United Nations Decade on Ecosystem Restoration (2021–2030). FAO Fisheries and Aquaculture Circular No. 1231. Rome, FAO.*

[2] *McIntyre, P.B., Liermann, C.A.R. and Revenga, C. 2016. Linking freshwater fishery management to global food security and biodiversity conservation. Proceedings of the National Academy of Sciences of the United States of America 113(45) 12880-12885. https://doi.org/10.1073/pnas.152154011*

[3] *Lynch, A.J., Elliott, V., Phang, S.C., Claussen, J.E., Harrison, I., Murchie, K.J., Steel, E.A. and Stokes, G.L. 2020. Inland fish and fisheries integral to achieving the Sustainable Development Goals. Nature Sustainability 4: 1-9.*

shift landscape productivity but are likely to have immediate consequences for the functioning of aquatic ecosystems. Fish as highly mobile organisms also support forests; some species transport nutrients by migrating thousands of kilometres from the sea or downstream reaches to nutrient-poor river sections far upstream and headwaters (Helfield & Neiman 2006); other species may transfer energy and nutrients between the river mainstream and floodplains (Winemiller & Jepsen 1998[4]). In addition, fruit and seed eating fishes serve as dispersing agents within river networks thus promoting plant diversity and forest restoration (Gottsberger 1978[5]; Horn et al. 2011[6]).

Freshwater is a precious resource and there is strong competition among sectors to meet societal needs. The consequence for inland water ecosystems is often devastating. The current rate of inland water habitat loss is three times higher than that of forest loss, and the population decline of species in inland waters continues to be much higher than in either terrestrial or marine ecosystems with direct implications for the services they provide, including fisheries. Agriculture is the largest user of water globally, and the dominant driver of land-use change affecting inland water catchments, as well as a major source of water pollution[7]. While agriculture supports economic development and has a fundamental role in reducing hunger and poverty, it consistently under-recognises or neglects sectors that rely primarily on ecosystem services for their livelihoods, such as inland fisheries (Lynch et al. 2019[8]).

Addressing the bottlenecks preventing inland fisheries from prospering and achieving their full potential requires coordinated landscape-level management across sectors. Inland fisheries are most often poorly positioned to influence decision-making in basin development and water use. A more inclusive framework that promotes ecosystem approaches and integrated management across watersheds is necessary to rebalance social, economic, and ecological outcomes. Sustainable inland fisheries will require that the needs of freshwater systems are accommodated within decision-making processes that govern other sectors. This requires clear articulation of the needs of inland fisheries for water, particular habitats and broader ecosystem health as well as recognition of the economic, environmental, and ecological justification for sustainable inland fisheries.

A watershed-based approach recognises[9] that rivers and terrestrial ecosystems are interconnected, and that effective fisheries management requires holistic planning that considers processes operating from the headwaters to the outflow. Such an approach demands the coordination of stakeholders, including government agencies, fishing communities, and conservation organisations, to develop and implement management plans that balance economic development and environmental conservation. The watershed approach further emphasises the need for adaptive management, where monitoring and evaluation of management interventions are conducted regularly to improve the effectiveness of management strategies.

Project: "Counting Fish from Forests for Food Security"

In 2020, the Director-General of FAO called for the submission of interdisciplinary project proposals, prompting the FAO Fisheries and Aquaculture, and Forestry Divisions to join forces and develop a project titled "Resilient River Basins – Counting Fish from Forests for Food Security." With the UN Decade on Ecosystem Restoration as an overall framework, the project aimed at identifying multidisciplinary and innovative low-cost solutions to gather data and information to inform management at a watershed scale, empower stakeholders, create awareness, and foster collaboration between the two sectors.

After being selected for funding, a pilot project was designed for the upper Kafue River in Zambia, a sub-basin of the Zambezi River watershed. This project was designed to address issues related to the sustainable use of ecosystem resources, build awareness of upstream and downstream connections, promote the importance of freshwater ecosystems for food security, and encourage recognition of the importance of watershed location for fisheries and riparian forest management.

[4] Winemiller, K.O. and Jepsen, D. B. 1998. Effects of seasonality and fish movement on tropical river
food webs. Journal of Fish Biology 53 (Sup. A), 267–296.

[5] Gottsberger, G. 1978. Seed Dispersal by Fish in the Inundated Regions of Humaita, Amazonia.
Biotropica 10 (3). 170-183. https://doi.org/10.2307/2387903

[6] Horn, M.H., Correa, S.B., Parolin, P., Pollux, B.J.A., Anderson, J.T., Lucas, C., Widmann, P., Tjiu, A., Galetti, M. and Goulding, M. 2011. Seed dispersal by fishes in tropical and temperate fresh waters: The growing evidence. Acta Oecologica 37(6): 561-577. https://doi.org/10.1016/j.actao.2011.06.004.

[7] Coates, D. in press. Ecosystem restoration and inland food fisheries in developing countries – opportunities for the United Nations Decade on Ecosystem Restoration (2021–2030). FAO Fisheries and Aquaculture Circular No. 1231. Rome, FAO.

[8] Lynch, A.J., Baumgartner, L.J., Boys, C.A., Conallin, J., Cowx, I.G., Finlayson, C.M., Franklin, P.A., Hogan, Z., Koehn, J.D., McCartney, M.P., O'Brien, G., Phouthavong, K., Silva, L.G.M., Tob, C.A., Valbo-Jørgensen, J., Vu, A.V., Whiting, L., Wibowo, A. and Duncan, P. 2019. Speaking the same language: can the sustainable development goals translate the needs of inland fisheries into irrigation decisions? Marine and Freshwater Research 70: 1221-1228. https://doi.org/10.1071/MF19176

[9] Coates, D. in press. Ecosystem restoration and inland food fisheries in developing countries – opportunities for the United Nations Decade on Ecosystem Restoration (2021–2030). FAO Fisheries and Aquaculture Circular No. 1231. Rome, FAO.

To synergise multidisciplinary approaches surrounding the forestry and fisheries nexus, the project was divided into four simultaneous components: (i) information collection in the target watershed; (ii) development of an e-Learning module; (iii) capacity building and stakeholder workshops; and (iv) scaling-up an integrated adaptive ecosystem management for forestry and fisheries.

(i) ***Information collection and coordination*** acted as a foundational step to generate local information about the linkages between forests and fish in the target watershed, which could be integrated into the other components. One of the goals was to demonstrate the wide variety and types of information that can be collected and synthesised at relatively low cost, even in what might be perceived as data-poor situations.

In a first step, available fisheries data was synthesised and it was found that the information was patchy in terms of both space and time. There were few years of data for most species, and the data records came mostly from areas with established inland fisheries such as reservoirs rather than for dispersed fishing occurring throughout the watershed. Where data was available, it indicated that the length of fish captured decreased over time, suggesting a need to further investigate the call for fisheries regulations and potential links with environmental conditions.

Forest conditions were assessed using remotely-sensed data that are freely available and forest cover change across sub-watersheds was estimated. As expected, protected areas showed relatively little forest cover loss while the areas with the most rapidly increasing human populations showed high rates of forest cover loss. Despite regulations aiming at limiting or preventing riparian forest harvest, forest loss in riparian areas was apparent.

River flow data over time was also synthesised where it was available, and a network of water temperature monitors was installed. Though there was little overlap in historical forest, flow and fisheries data, the possibility to create effective and inexpensive monitoring programmes was evident.

A survey of riparian households demonstrated that, at the local level, awareness of the interdependence between forestry and fisheries and the need for better monitoring and management to detect and correct recent declines was high.

Finally, climate forecasts were created for both precipitation and air temperature by month from freely available information. The information collected was synthesised in a large map poster (FAO et al. 2023[10]), which was provided to communities and managers and can be used in coordination with the eLearning component.

(ii) ***e-Learning*** aimed at enhancing the capacity of stakeholders to understand the linkages between forestry and fisheries and integrate this knowledge into management practices. The course covered watershed function, the role of forests in watersheds, key elements of freshwater habitat assessment, fisheries assessment options in a watershed context, and monitoring indicators.

The e-Learning builds on data and examples from the upper Kafue River in Zambia, the Atrato and Magdalena Rivers in Colombia and other river systems studied by experts around the world. The first section focuses on watersheds as the fundamental organisational unit of natural systems. It includes topics such as the nested nature of watersheds and stream order. The next three units teach learners about particular elements of a watershed: forests, freshwater, and fish. In each unit, there is an emphasis on seasonal cycles, global diversity, ecological function, and values to humans. Each unit ends with a suite of relatively simple ideas for monitoring indicators. The final unit integrates information across all the earlier units to provide guidance on developing multi-sectoral watershed governance. The voices of managers and stakeholders from the upper Kafue River are embedded as a case study. Climate forecasts are introduced; opportunities for watershed councils are described; and selection of the best suite of monitoring indicators for a particular situation are considered.

(iii) ***Capacity building and stakeholder workshops*** brought together a range of stakeholders from the target basin, including government representatives and experts in forestry and fisheries, with whom the e-Learning, data and information and lessons learned from the target watershed were shared. The workshops also provided opportunities for representatives from the forestry and fisheries sectors to discuss how the information can be used to integrate forest and fisheries management at watershed scale to ensure sustainable resource use and conservation, including regulatory data collection

[10] *FAO, CIFOR, and Worldfish 2023. Upper Kafue River watershed. Forests, freshwater, and fisheries providing food security and sustainable livelihoods. Poster CC4795EN. FAO. https://www.fao.org/3/cc4795en/cc4795en.pdf*

and monitoring, possibilities for remote-sensing, opportunities to integrate multidisciplinary principles in education programmes; and development of management plans with stakeholder participation.

Two final workshops were held in Lusaka, Zambia, for combined groups of forestry and fisheries professionals. In the first workshop, the e-Learning was piloted. Experts observed the lessons on watersheds and provided group feedback. Multidisciplinary teams were then created to review each of the topical units: forests, freshwater and fish. Their responses to questions about how to best synthesise information and initiate a monitoring and management plan were then incorporated into the final unit of the e-Learning on watershed-based management.

The second workshop focused on identifying obstacles to, and opportunities for, watershed-based management. Local speakers from Zambia shared successes and frustrations across similar sectors, and our partner project in Colombia shared their experiences and opinions about watershed-based management. Three key ideas from this workshop were that (i) watershed-based management was difficult because freshwater systems generally seemed to fall outside the mandate of forestry or fisheries; (ii) enforcement of existing regulations is needed; and (iii) the first small steps will inevitably include partnerships across individuals and it is therefore important that people reach out to one another across sectors and from local communities to government ministries to initiate collaborative discussions and develop a multi-sectoral, multi-stakeholder vision for moving forward.

(iv) Finally, in ***scaling up of integrated adaptive ecosystem management for forestry and fisheries,*** new partnerships with international partners were created and lessons learned from the project were synthesised and shared. The aim of this component was to ensure that the knowledge gained from the project was not only applied in the target watershed but disseminated more widely to other regions and countries facing similar challenges.

During the UN 2023 Water Conference (https://sdgs.un.org/conferences/water2023), a side event was held to launch the final version of the e-Learning which is now accessible for free on FAO's Online Academy. An innovative Sepal Resilient Rivers and Basins application was also introduced, which provides users with easy access to data and graphical analysis describing forest cover change over time across sub-watersheds. This watershed-based information on forest cover change is critical to develop effective management strategies that promote sustainable use of natural resources. The side event featured international experts from around the world who highlighted the importance of forestry-fisheries collaboration in integrated watershed monitoring and management. It was emphasised that rivers and their associated ecosystems are crucial for achieving the Sustainable Development Goals, particularly in terms of water security, food security, nutrition, livelihoods, and life on land. To achieve sustainable management of these resources, it is essential to work across sectors and disciplines to ensure equitable distribution of benefits.

Effective policies and management solutions require an understanding of forest, freshwater, and inland fisheries linkages

Outcomes of the project

Maintaining inland water ecosystems and the services they provide including inland fisheries is dependent on the management of land and water use; and to achieve sustainable management, collaboration is necessary across all sectors using or having an impact on aquatic ecosystems. FAO's strategic framework "Better Production", "Better Nutrition", "Better Life" and "Better Environment" is well suited to address the challenges involved with multidisciplinary management of watersheds and to ensure their continued delivery of services.

Data to guide management can be obtained from datasets that are available on the internet free of charge, and at the local level from riparian communities that frequently possess a high degree of knowledge and awareness of both aquatic and terrestrial biodiversity, and in particular their interdependencies. Communities living in close proximity to

the river system are often highly motivated to sustain the fish, the forests, and their linkages essential for their livelihoods. In fact, communities living across the watershed and sometimes far from the main river all benefit from coordinated, multi-sector watershed-based monitoring and management.

It is thus not only necessary to think across disciplines and come up with innovative solutions. It is equally important to ensure broad participation of stakeholders that can make the true value of ecosystem services visible, better inform management on trade-offs, and help sustain ecosystem services to benefit human society. Broad participation of stakeholders can help ensure not only balanced and sustainable development, but also an equitable distribution of the benefits. Many of the most successful strategies prioritise co-management with local communities using their extensive local knowledge of ecosystem functions, biodiversity and priorities for effective management.

One way of achieving broad participation of stakeholders and communities is by establishing cross-sectoral watershed councils. Such councils can facilitate cooperation and collaboration among different stakeholders, helping to ensure that diverse perspectives are taken into account in decision-making. Additionally, multi-disciplinary watershed-based management requires identifying key institutions that drive change and can define clear organisational roles and responsibilities. There are for instance successful examples such as water boards in The Netherlands, watershed councils in the Pacific Northwest USA, and *consejos de cuenca* in Colombia that can serve as models which can be adapted to the local context.

Conclusions and next steps

The relationship between land use and fisheries is stronger than what the traditional paradigm indicates. Forests, for example, have positive effects on fish habitats, and forest growth reduces water and sediment runoff. Policies that consider the linkages between forests, inland water ecosystems, and fisheries must be strengthened where they already exist and developed in new areas, and the interdependence between these resources must be considered in all management and conservation efforts. In areas where there is construction of additional infrastructure, stakeholder involvement in decision-making in the context of watershed-based management is particularly important.

Bringing together scientific and local knowledge and empowering local authorities and community members, can create opportunities to work towards more sustainable and resilient river basins for future generations. Sharing e-Learning and innovative tools like the Sepal Resilient Rivers and Basins application can help promote sustainable management practices, providing a basis for project development, monitoring plans, development of watershed councils, creation of integrated university courses, and more. By taking these steps, it is possible to promote sustainable management of forests and inland fisheries, while also ensuring food security and protecting aquatic ecosystems.

The UN Decade on Ecosystem Restoration provides a particular opportunity to make the goods and services provided by freshwater ecosystems more visible in policy arenas. The value of these services are often not fully recognised and, therefore, may be given low priority in basin development strategies. These ecosystems will therefore benefit from the increased awareness that can be generated during the decade of the far-reaching impacts of land and water-use across watersheds and of the need for an integrated approach to management.

Further, all parts of a watershed are interconnected and the activities taking place in a terrestrial area in one part of a watershed can have a significant impact on river networks, and associated lakes, reservoirs, and wetlands far away. Thus, for forests and inland fisheries to be managed sustainably a systematic and watershed or basin approach is essential making the catchment the basic unit of management.

It is crucial to continue the dialogue surrounding the interactions and consequences of forest-freshwater-fisheries linkages, advocating for a better understanding of these relationships. The momentum for collaboration across watersheds is growing globally, and we must harness this momentum to create a sustainable future, including resilient rivers, biodiversity, food security, and opportunities for all. Collaboration and integration of scientific and local knowledge are essential to manage these resources sustainably and equitably.

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