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## **ECOSYSTEM APPROACH TO INLAND FISHERIES: RESEARCH AND IMPLEMENTATION STRATEGIES**

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Isni Nurruhwati and Achmad Rizal  
Faculty of fisheries and Marine Science, Universitas Padjadjaran

Email correspondence: [isni@unpad.ac.id](mailto:isni@unpad.ac.id)

### **Abstract**

Inland fisheries are a vital component in the livelihoods and food security of people throughout the world, as well as contributing huge recreational and economic benefits. These valuable assets are jeopardized by lack of research-based understanding of the impacts of fisheries on inland ecosystems, and similarly the impact of human activities associated with inland waters on fisheries and aquatic biodiversity. To explore this topic, an international research was organized in order to examine strategies to incorporate fisheries into ecosystem approaches for management of inland waters. To achieve this goal, a new research agenda is needed that focuses on: quantifying the ecosystem services provided by fresh waters; quantifying the economic, social and nutritional benefits of inland fisheries; improving assessments designed to evaluate fisheries exploitation potential; and examining feedbacks between fisheries, ecosystem productivity and aquatic biodiversity. Accomplishing these objectives will require merging natural and social science approaches to address coupled social–ecological system dynamics.

**Keywords:** *inland fisheries; ecosystem approach; research agenda.*

### **1. Introduction**

Ecosystem changes from altered flows can have multiple impacts on fish, including changes to physical habitat, habitat access, food supplies, behaviour, community composition, energy expenditure, and population dynamics. There is growing evidence of the potential negative consequences of altered flow regimes on fluvial ecosystems and the fisheries they support. As such, the scientific and policy communities have acknowledged the need for maintaining or restoring natural flow variability in order to sustain ecological health of fluvial ecosystems. However, for resource managers, making decisions on the potential effects of flow alterations on fish productivity has been problematic because there are still uncertainties regarding flow-fish productivity relationships. Therefore, to ensure the maintenance of healthy and productive aquatic ecosystems and the sustainability of riverine fisheries, a better understanding of the impacts of flow alteration on fish productivity is needed. Due to the wide scope of this review, and the diversity of fish productivity outcomes used to evaluate flow alteration impacts, the set of studies will be quite heterogeneous. Therefore,

prior to undertaking a comprehensive and quantitative synthesis, we propose to begin with a systematic map to provide an overview of the available evidence on the impacts of flow regime changes on fish productivity. We will also use this systematic map to identify subtopics that are sufficiently covered by existing studies to allow full systematic reviewing.

Inland fisheries provide a vital source of commerce, employment, nutrition and recreation for people throughout the world [1,2]. This is particularly so in subsistence and artisanal inland fisheries, where fisheries constitute a 'safety net' for millions of rural poor people by providing an essential source of food and supplemental income. In industrialized nations, and increasingly in developing nations, the importance of inland fisheries shift towards recreation, but still constitutes a major economic activity facing numerous management challenges [3]. As a result of the spatial dispersion of catches over thousands of lakes and rivers, along with the perception of low per-fishery economic value, inland waters are usually neglected in discussions of global fisheries. Inland fisheries also operate in many hotspots of aquatic biodiversity, creating a source of concern from a conservation perspective [4,5], although the impact of fishing is sometimes small relative to other threats [6].

Fisheries are one of many ecosystem services provided by inland aquatic ecosystems to society. In both the developed and developing world, inland waters suffer from multiple competing demands for water (e.g. hydropower, withdrawal for agriculture, industrial processes or transportation), resulting in management trade-offs between freshwater fisheries and other uses [2]. The complexity and uncertainty inherent in decisions about managing water resources requires an ecosystem approach that involves stakeholders from all sectors. Inland fisheries are often given low priority relative to other uses of water [2]. This arises, in part, from poorly constrained estimates of the status and trends in catches, as well as difficulties in estimating their total production, economic and societal value [1].

Furthermore, inland fisheries are jeopardized by lack of research-based understanding of how other human activities affect the production potential of rivers and lakes [3]. Owing to incomplete understanding of how inland waters function, policy makers and managers often fail to intervene when fisheries are in decline, until the ecosystem has virtually collapsed [7]. There is a pressing need for a comprehensive, scientific basis for decision-making about management of inland aquatic ecosystems for multiple types of services, including how inland fisheries may contribute to poverty generation, loss of inland aquatic biodiversity and loss of important freshwater ecosystem services. To explore these issues and identify key research needs for inland fisheries, an international research was held in Vientiane, Lao PDR from 7 to 10 December 2010 under the auspices of the United Nations Food and Agricultural Organization (ID-FAO), United States Geological Survey and the Network of Aquaculture Centres in Asia-Pacific. Twenty five researchers with worldwide experience in inland fisheries participated in the research. We used the Ecosystem Approach to Fisheries (EAF) as outlined by Garcia et al. [8] to frame the discussion. Implementation of the EAF in managing inland fisheries relies on a better understanding of the dynamics and magnitude of catches, the trade-offs underlying management decisions, and the market and non-market values of fisheries. Given the interest in EAF as a management strategy, the specific goals of the research were to: — identify solutions to shortcomings in catch monitoring and reporting; — quantify societal benefits of inland fisheries as an ecosystem service;

## 2 Methods

This systematic map will compile evidence on the impacts of flow regime changes on fish productivity. All studies that evaluate the effects of flow regime change on direct outcomes of fish productivity, will be included in the review. We will use a broad definition of fish productivity to include any measurement related to: biomass, abundance, density, yield, diversity, growth, survival, individual performance, migration, reproduction, recruitment, or surrogate thereof. Relevant causes of a change in/modification to flow regime can include: (1) anthropogenic causes: dams, reservoirs (impoundments), hydroelectric facilities, locks,

levees, water withdrawal (abstraction), water diversion, land-use changes, and road culverts; or (2) natural causes: climate change (possible indirect anthropogenic cause as well), floods, droughts, seasonal changes. Any freshwater or estuarine fish species or species groups in temperate regions will be considered. The review will include a wide range of sources including primary and grey literature and use public databases, search engines and specialist websites. A searchable database containing extracted meta-data from relevant included studies will be developed and provided as a supplementary file to the map report. The final narrative will describe the quantity and key characteristics of the available evidence, identify knowledge gaps for future research and identify subtopics that are sufficiently covered by existing studies to allow full systematic reviewing — identify and examine trade-offs in management of freshwater ecosystem services; and — determine strategies for applying an ecosystem approach to a multitude of inland water types.

### **3. Research Approach**

At the Research, we used a combination of case studies from experts and facilitated discussion in order to draw out the key research and management issues necessary for implementing ecosystem approaches to inland fisheries. Case studies focused on barriers to EAF as well as success stories. We then organized a series of papers and discussion sections aimed at identifying research priorities to support more informed decision-making about inland fisheries. Sessions focused on issues, such as overcoming data limitations, benefits and problems associated with stock-enhancement of inland waters using native and exotic species, regulatory problems in management of inland fisheries, exploitation trends in inland fisheries, competing demands for inland water resources, and the role of biodiversity conservation in managing inland fisheries.

### **4. Data And Research Needs For Inland Fisheries**

The ID-FAO is responsible for collation of national data on inland fisheries production, and this voluntary system is known to yield widespread under-reporting. The research identified numerous barriers to improved reporting, including the complexity of stock composition, variety of fishing methods, diverse demographics of fishers, diffuse spatial patterns of catches, low economic value of individual fisheries and lack of information on subsistence fishing. Overcoming these problems is an immense challenge. National authorities are unlikely to invest the required resources in data collection when the magnitude of their inland fisheries is unclear, yet such investments are required to quantify the cultural and economic value of these fisheries and to improve their management. Additional challenges arise from the view that inland fisheries are an old-fashioned activity whose replacement by industrial and agricultural activities will boost national production outputs and contribute to economy and social well-being.

This attitude, coupled with a lack of appreciation for the risks of overexploitation, leads to minimal investment in research and assessment. Development of research using a landscape approach that estimates production using characteristics of water bodies would be an important first step towards a broad indication of potential catches from each region. A second approach identified by the research for estimating fisheries production indirectly is through household surveys of fish consumption. Such an approach would address the problem that a significant proportion of inland fish consumed in the developing world does not go through traditional landings and markets, but instead are consumed by the fisher's family or bartered locally. Similarly, recreational fishers do not sell their catch and often release fish alive. In the case of recreation, longitudinal, panel research may provide an improvement over expensive creel surveys in order to monitor catches, effort and harvest. Achieving a science-based management regime for inland fisheries requires understanding

the full range of ecosystem services from rivers and lakes, and how services are related to fisheries.

For instance, drinking water quality and maintaining biodiversity are enhanced by many of the same factors that promote healthy fisheries, while using inland waters for hydropower generation, agricultural irrigation and industrial processes is generally detrimental to fish and fisheries. Proper valuation of fisheries [9], along with all the other services provided by inland water ecosystems, will be critical for making well-informed management decisions [10]. Given that many inland fisheries have long been 'data poor', research participants concluded that it is unrealistic to assume that sufficient resources for comprehensive monitoring will become available. Instead, there is a need for generic models that can use reasonable fish production parameters from wellstudied sites to assess the implications of alternative management regimes for fisheries and other human activities. Such models must also include social and economic dimensions in order to allow the evaluation of trade-offs and facilitate the identification of win – win, win –lose and lose –lose decisions in a multi-use environment.

Development of decision-support systems that incorporate valuation in decision-making is one approach, but the notion of decision-support is a 'western' centric approach to management. Research that firmly identifies ways to incorporate traditional knowledge, especially in data-poor situations in the developing world, will be necessary to make appropriate decisions about the importance of inland fisheries. Finally, there is an urgent need for rapid appraisal methods that empower local decision-making for small-scale fisheries in the developing world [11]. Similar systems may also be applicable to many small-scale recreational fisheries in developed countries.

Finally in developing countries, the importance of small-scale inland fisheries demands more research to identify different models of governance and local co-management arrangements, especially as many of these fisheries are under threat from other activities associated with the target aquatic ecosystems. Given the large scale of recreational fisheries in the developed world and growing interest in the developing world, the research identified a number of specific research needs specific to recreational fisheries. These include monitoring participation and landings, developing landscape fisheries models that incorporating social –ecological feedbacks and angler behaviour, and evaluating the relationship between ecosystem biodiversity and the recreational fishery productivity. An improved understanding of the long-term benefits and costs of stocking compared with other management strategies is also needed.

## 5. Conclusion

The industrialized world has already experienced a shift from commercial to recreational fishing that was associated with large-scale societal shifts, and was largely independent of fisheries. Indeed, participants in the research concluded that a stereotypical sequence of events seems to occur across all aquatic ecosystems as economic development proceeds: intensification of management of fisheries, habitat change (usually environmental degradation) owing to nonfishery influences, loss of commercial fishing and replacement by recreational fishing, and ultimately increased emphasis on 'restoration' of degraded ecosystems. Given the history of freshwater fisheries in the industrialized world and their current importance in the developing world, it is essential that the research community devote greater resources and attention to inland fisheries management. The research agenda outlined above addresses a wide variety of information needs regarding both fundamental and applied issues.

The research participants agreed that the most pressing next steps include: — quantifying the full range of ecosystem services, including fisheries, provided by fresh waters; —

quantifying the economic and societal benefits that inland fisheries provide to society (Millennium Development Goals); — using rapid assessments of stocks to evaluate where fisheries are over- versus under-exploited; — determining the relationship between aquatic biodiversity and fishery productivity; and — viewing inland fisheries as closely coupled social–ecological systems with dynamics that depend upon human behaviour, societal norms and environmental quality. Many of these areas require a seamless merger of natural and social science methods to address coupled socialecological system dynamics. As such, the proposed research agenda requires state-of-the-art efforts in traditional fisheries science, ecosystem ecology, stock assessment, environmental impact assessment, environmental economics, human dimensions scenario-based global biophysical modelling and multi-criteria decision analyses. To draw attention to these research needs, the ID-FAO, during its last report on the state of global fisheries, and during the upcoming 29th Committee of Fisheries meeting in February 2011, will highlight the importance of inland fisheries to food security, social well-being and global fisheries. As such disciplinary innovations become available; they must be combined to generate a synthetic strategy for sustaining inland fisheries. This will be challenging in light of ongoing declines in research infrastructure for studying inland fisheries, but increasing appreciation for multidisciplinary research, and global attention to ecosystem services, offer reason for optimism for the future of inland fisheries.

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