Fish Sanctuaries as means for Stock Protection and Enhancement

Manual on Practical Measures and Evaluation of Effects

Ministry of Environment, Forest and Climate Change

Potsdam Institute of Inland Fisheries

Department of Fisheries
GOVERNMENT OF MEGHALAYA

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GOVERNMENT OF MEGHALAYA
DIRECTORATE OF FISHERIES :: SHILLONG

Preface : Fish Stocking Manual

The establishment of fish sanctuaries in Meghalaya has become popular in the recent past since Meghalaya is blessed with a very rich and diverse Inland aquatic ecosystem having a wide variety of aquatic resources such as Rivers, Streams, lakes, bheels etc. The Department has taken the initiative by incorporating Mini Mission III: "Establishing sanctuaries for conserving indigenous and endemic species" under the Meghalaya State Aquaculture Mission. Till now, about 81 numbers of fish sanctuaries have been established. With the establishment of these fish sanctuaries, fish stock has been protected and population enhanced.

I am delighted to learn that GIZ in collaboration with the Department of Fisheries, Government of Meghalaya developed the "Fish Stocking Manual" as part of the NERAQ-project initiative. On behalf of the Department of Fisheries, Government of Meghalaya, I take this opportunity to express my thanks and gratitude to the publication of this manual which will serve as a comprehensive guide for those involved in fish stocking, from fisheries managers to conservationists, and even recreational anglers.

This manual is designed to offer clear, research-backed methods, best practices, and essential considerations for successful stocking programs. Emphasizing the importance of selecting appropriate species, maintaining genetic diversity, and monitoring ecological impacts, this manual will equip readers with the tools to carry out stocking initiatives that are both environmentally responsible and scientifically sound.

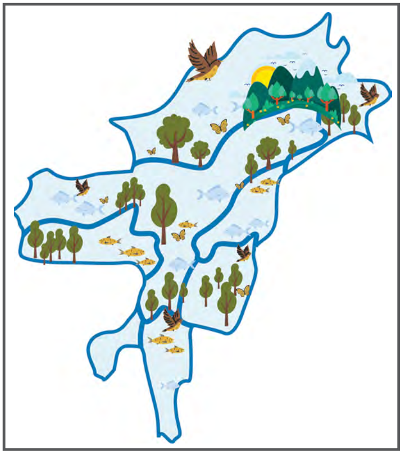
Our mission is to put our hands together in the restoration and management of fish populations while minimizing any potential negative impacts on the environment.

I wish use of the manual a success and will be used widely.

Director of Fisheries
Meghalaya, Shillong

01

INTRODUCTION



Northeast India is characterised by an exceptionally high level of aquatic biodiversity. This includes more than 550 freshwater fish species described, a considerable proportion of which are endemic, and additionally several species are described for the first time every year. Due to their high functional diversity and specialisation these species play a variety of roles in aquatic communities.

At the same time, freshwater fish are utilised by the local population as a very important component in their diet. This resource, however, is endangered by numerous environmental stressors including climatic changes and increasing utilisation pressures. In the terrestrial sector it is a long-established and optimised method of local and regional species and resource management to create areas of special conservation and protection status together with measures to regulate utilisation. In freshwater ecosystems the impact of this approach is less well understood, partly due to a number of challenges in measuring and assessing effects. In northeast India use and restrictions to protect water bodies and fish are anchored in the traditional knowledge and practices of local communities. However, there is a lack of systematic data-based assessment of measures applied in sanctuaries and their effects and outcomes.

Against this background, a workshop to **"Understand and develop methodology for assessing the development of stocks in community fish sanctuaries"** was initiated by the NERAQ-project, implemented by GIZ and conducted in Tura, West Garo Hills, State of Meghalaya, in March 2024. This short manual is summarising main topics elaborated in this context.

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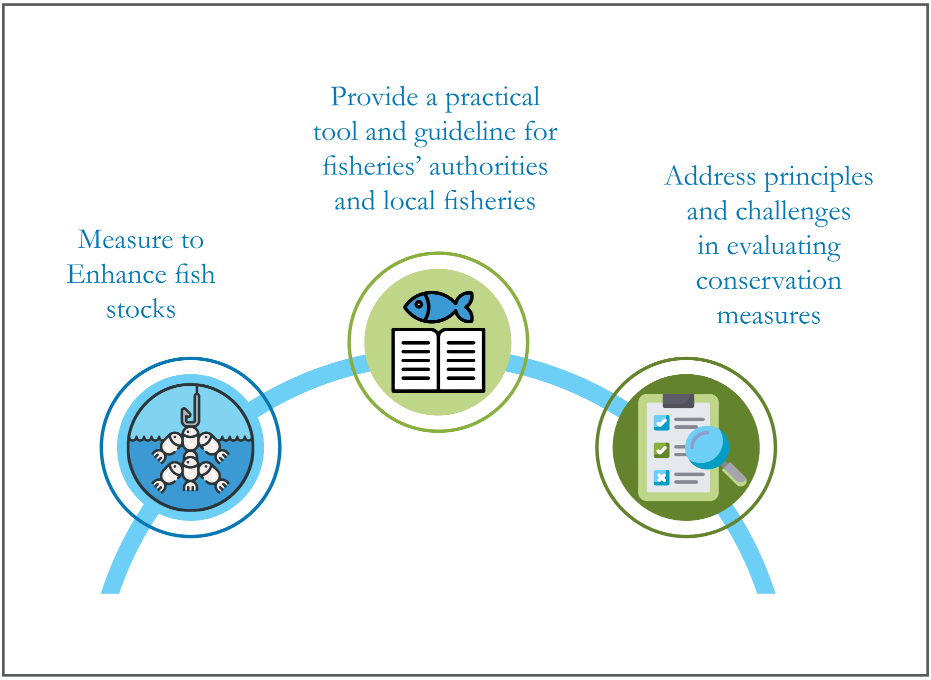
OBJECTIVES OF THIS DOCUMENT

This manual is aimed to provide a practical tool and guideline for fisheries' authorities and local fisheries' managers in the development of fish sanctuaries. Specifically, measures to enhance fish stocks as well as basic principles and challenges in evaluation of the effects of such measures are addressed.



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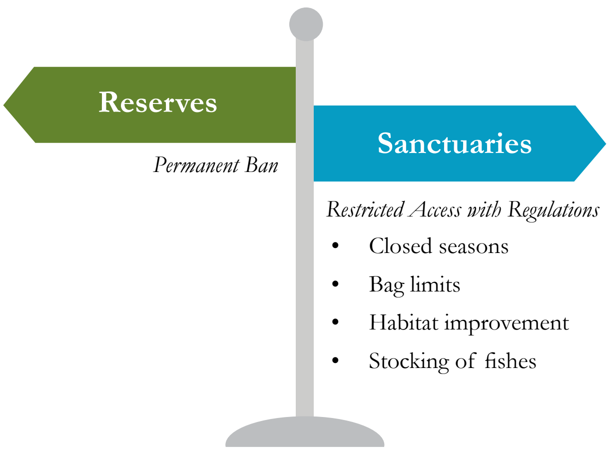
FISH SANCTUARIES IN FISHERY MANAGEMENT

The delineation of areas with specific rules and regulations to protect species and their habitats is a traditional and widespread concept in conservation policy. With respect to fishery the level of regulation spans from reserves with a permanent fishing ban to sanctuaries, where access is restricted and additional specific input and output regulations as well as management measures apply, such as closed seasons, bag limits, habitat improvement measures, stocking of fishes, etc. Such regulations and measures are typically fixed in regional fishery laws, ordinances, and other types of regulations and are obligatory to fishermen and managers in general. In sanctuaries, regulations and/or measures are extended beyond the obligatory level in the region.

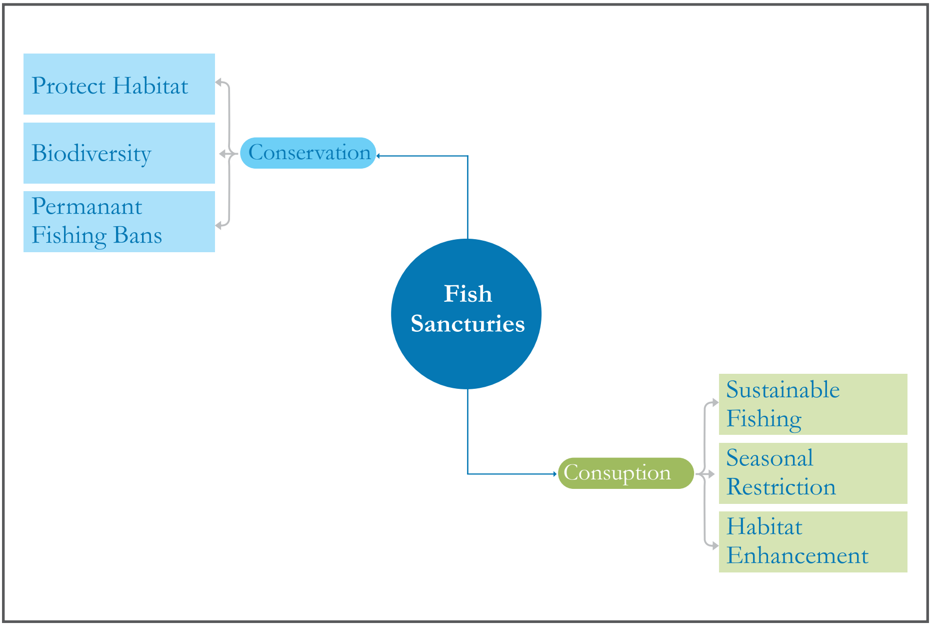
When the establishment of sanctuaries with specific regulations and measures is considered in fishery management, the following issues are important:

1. Definition of purpose/objective
2. Delineation of sites and habitats, scaling
3. Selection of appropriate management measures



3.1 Purpose & Objective

Sanctuaries may be established for a variety of purposes and objectives. This spans from pure conservation of habitats and protected vulnerable species or species biodiversity (conservation oriented) to the securing of fishery resources and sustainable fish yield (consumption oriented). In the first case a management concept restricting anthropogenic impacts on the waterbody up to a permanent fishing ban, as in a fish reserve, might be considered appropriate. If the prime objective is sustainable fisheries, though, management measures will be directed towards securing maximum sustainable productivity of fished stocks. This may include at least temporal and spatial fishery restrictions as well, e.g. extended no-fishing seasons or habitats, and might be combined with measures to enhance stocks as additive stocking, for example, or habitat modification.



3.2 Sites and Habitats

Dynamics and productivity of fish stocks are driven by various factors (see next section). In order to sustain high stock productivity and resilience against impacts recruitment and growth are key. Therefore, stock specific spawning and nursery grounds as well as feeding habitats are of prime importance in site selection for sanctuaries.

Scale: Fishes are mobile organisms that migrate between habitats for different reasons. Some movements follow seasonal patterns, e.g. between feeding and spawning grounds. Others follow diurnal patterns or are related to ontogenetic development stages. Dispersal or compensation are additional triggers for migration. Consequently, dynamics of fish stocks are driven by factors impacting various habitats on a larger spatial scale. Management requires to account for this by considering larger parts of catchments including side waters and flood plains when developing concepts and selecting measures and when evaluating effects. There are hardly any general figures for a minimum area for fish sanctuaries, but there is likely to be a positive correlation between the size of a sanctuary, respectively its percentage share of a stock`s home range, and its effect. A patchwork-design consisting of separate and rather small sized sanctuaries covering specific habitats can also provide a reasonable approach. In this case, a comprehensive concept covering the home range of target stocks in conjunction with co-ordinated management of all single sanctuaries is advisable.

3.3 Management Measures

A fishery can be viewed as a socio-ecological system comprised of three key components, namely the aquatic environment, fish stocks, and the people who fish. When it comes to management in practice, measures can be assigned according to these 3 components. With regard to the environment examples for such measures are: the development and restoration of key fish habitats, the improvement of lateral and longitudinal connectivity, the management of flow regimes particularly in modified waters (e.g. reservoirs, waterways), and the control of water pollution and increased nutrient loads. Most common measures directly affecting the fish stocks are stocking operations. But also fishing regulations, such as minimum size limits, bag limits, closed seasons and no-fishing areas do affect the stock directly. Their effectiveness depends on people and their compliance to regulations. In the context of community-managed sanctuaries, education and purposeful regulation are essential for acceptance, engagement and implementation of management measures. Awareness and outreach programmes are key to this end.

As variable factors drive the dynamics, not only in target stocks but the aquatic ecosystem in general, rigid concepts have a high probability of not achieving goals in the long run and undermining stakeholder`s acceptance and compliance. Instead, a decision-making framework that includes stakeholders, considers trade-offs, and adjusts after an evaluation of effects of past decisions is essential (Figure 1). A Co-management approach integrating stakeholders in this process, including decision making and monitoring, have proven successful in developing, implementing and adjusting well-tailored sets of management measures. They have been found to strengthen acceptance and compliance to regulations and restrictions. Delegating management and its adaptation to stakeholders is a promising concept for sanctuaries when it comes along with capacity building and spatial coordination in the catchment.

Figure 1: Concept of adaptation in fishery management. Integral to it are both a decision component and an opportunity to learn. Structured decision-making (green circles) is an organized and transparent approach to the decision process for identifying and evaluating alternatives and justifying complex decisions. White circles symbolize a process of iteration and consequential higher-order learning. Source: FAO, 2012, adapted

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PRINCIPLE MEANS TO ENHANCE FISH STOCKS

Key determinants in exploited fish stock dynamics are recruitment, growth, natural mortality, and fishery mortality. They are driven by natural and anthropogenic conditions and impacts, whereby the latter may be internal or external to fishing (Figure 2). Fishery management concepts in open waters like rivers, wetlands or lakes are tailored to address these determinants in such a way that fish biomass production of target stocks is optimised. To select and combine effective measures, information on morphometric, hydrologic, physico-chemical and limnological characteristics of the waterbody, life-history traits of target species and stocks, respectively, as well as stock status is required (Table 1).

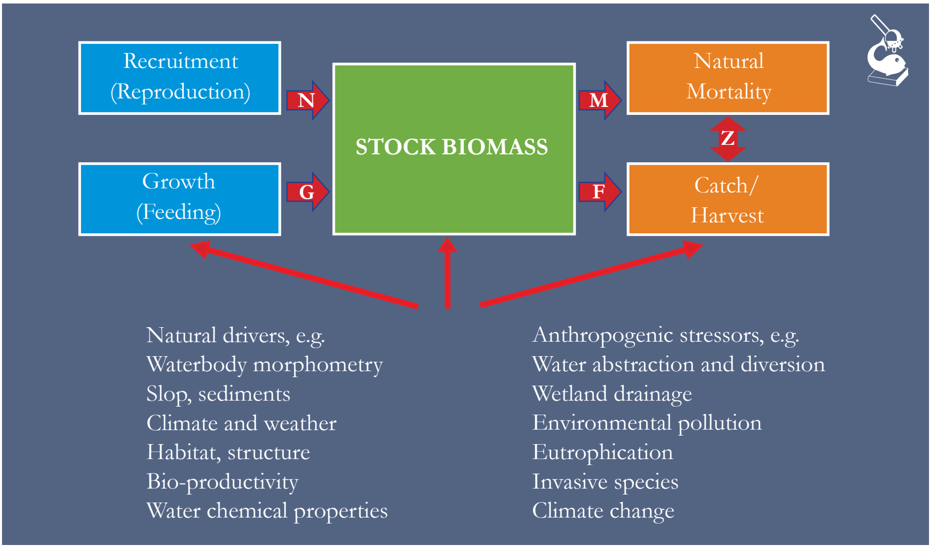

Figure 2: Key determinants in fish stock dynamics: Traits leading to biomass increase are highlighted light blue, traits reducing biomass are highlighted orange. Some natural and anthropogenic factors impacting stocks are listed below the boxes.

Some principle approaches to stock enhancements are listed below.

Table 1: Basic parameters to support effective management concepts

Area	Characteristics	Parameter (examples)
Waterbody	Morphometry, hydrology, physico- chemical and biological attributes	• area, depth structure, sediment, discharge, obstacles • seasonal patterns in temperature, pH, salinity, nutrients, turbidity • biological productivity
Fish species	Life history traits	• typical size at age • age at first maturity • fertility per kg female • natural mortality • optimum and critical temperature range
	Autecology	• oxygen requirement • current preference • spawning type • migration and ontogenetic habitat shift • nutrition
Stock status	Stock parameter	• stock size (individuals) per cohort • spawner biomass and sex ratio • growth • survivorship
Fishery	Fishing operation	• fishery stakeholder, fishing types and gear • fishing effort and seasonality • catch

4.1 Recruitment Enhancement

Habitat management and stocking are two major approaches to strengthen reproduction of stocks and the recruitment of individuals into the spawning stock in addition to maintaining a healthy spawning stock size. In terms of features like cost-benefit ratio, economy, risks and success on the long run, habitat management is of principle advantage in comparison to the stocking of translocated individuals for replacement of missing recruits.

4.1.1 Habitat protection and development

This is a measure targeting the aquatic environment, and aimed at reduction of anthropogenic modification and disturbance as well as restoration of a natural-like status. If this is not possible, measures for rehabilitation and enhancement of habitats and to mitigate disturbance might be called for (Box 1).

Box 1

Targets of habitat management

Protection:
Avoiding habitat change altogether

Restoration:
Attempting to reach historical state (often an illusion)

Rehabilitation:
Attempting to achieve some element of a past state (e.g., meandering river)

Enhancement:
Improvement over existing conditions (e.g., in-stream structure placement)

Mitigation:
Minimizing negative impacts (e.g., fish passage facilities)

Options in physical habitat management, which have proven successful, include:

- Enlarge substrate structures, e.g. add woods to littoral areas,

- Protect or support development of pool and riffle stretches in rivers, e.g. by installation of structures in monotonous sections,

- Create shallow shoreline bays, structured shoreline development,

- Improve longitudinal connectivity by fish passes and lateral connectivity by water level management and connect river bed and floodplain.

Some issues to be considered in habitat management measures include the functioning of structures improved or added, minimum scale to reach effects and costs as well as legal aspects incurred in modification of habitats in nature.

Figure 2: Examples for habitat development: mitigation of fish migration barriers by construction of a technical fish pass, creation of shallow bays in a gravel pit lake, structure enrichment and current diversion by installation of tree trunks and branches (clockwise from upper left; photo credits: S. Zahn, IfB (1) and F. Möllers, Anglerverband Niedersachsen (2-4))

4.1.2 Stocking of fishes to increase stock size

Translocating fish to a waterbody or part of it is a widespread management approach. Objectives for stocking operations span from species conservation via impact compensation to fishery enhancement-oriented motives. In all cases, the actual size of the recipient stock is believed to be smaller than under reference conditions and the carrying capacity of the waterbody, respectively. At first, these assumptions need to be challenged by stock size monitoring and ground truthing of expectations before any stocking exercise (Box 2). As a basic rule, carrying capacity of a water body sets the upper limit for stock biomass, stocking beyond this threshold will have no additive effects.

In principle, different life-stages of fishes are suitable for stocking, e.g fertilized eggs, yolk-sac fry, fingerlings, immature fish, spawner. Before selecting the life stage in a stocking operation, a thorough understanding of the bottleneck in recruitment is essential. If, for instance , natural mortality of 1-summer old fish is high due to a lack in age-specific habitats, stocking of eggs and fry would not mitigate the shortage.

With regards to the origin of stocking material, fishes from the same catchment and comparable characteristics of donor waters expose the lowest risks in terms of unsuccessful acclimatisation, genetic divergence, and parasite transmission.

An evaluation of effects as compared to the targets is of utmost importance in any stocking program. Some basic recommendations in evaluation procedures are given in the next chapter. When fishes are stocked into a naturally recruiting stock, marking of released fish is beneficial in evaluating whether stocking has added to recruitment. Additionally, standardised samplings before and after stocking as well as in non-stocked control areas are key (see BACI-design) to a successful program.

4.2 Measures to Support Somatic Growth

Box 2

Steps when planning fish stocking operation

1. Clarify the motivation and define specific targets.
2. Determine the gap between current stock size and species-specific carrying capacity of recipient water body and calculate the maximum stocking amount.
3. Analyse the age/stage of a potential recruitment bottleneck and select a suitable age/size of fishes for stocking.
4. Identify a suitable origin of fish for stocking (e.g. availability, genetic background, adaptation potential, disease and parasite transmission risk).
5. Detail a plan for timing, transport, handling and release of fish.
6. Evaluate the stocking effects against the set targets.
7. Adjust the stocking program.

Growth rate and maximum individual fish size are species-specific. It depends on actual density in relation to carrying capacity as to what extend this potential gets realised in a given stock. From this perspective, a sustainable fishery can promote somatic growth and survivorship by enlarging the window gap between current biomass and the limit set by the specific carrying capacity. Vice-versa, elevation of carrying capacity has the potential to support somatic growth of individuals. As the carrying capacity is driven by food resources and their accessibility to individuals of a target stock, measures like opening access for fish to rich feeding grounds (e.g. floodplains, oxbow-lakes) may contribute to better growth. In the same sense, flood-pulses are known to boost production of invertebrates and zooplankton, both of which are important food resources for fish. Supplementing fish feed from external origin into open waters may contribute to fish growth as well, and has been practiced in some sanctuaries in North-East India, especially when managing sanctuaries to attract angling tourism. Feeding of fish implies adding nutrients to an open system and, thereby, contributes to eutrophication and a cascade of ecosystem stressors and changes, which also impact fish habitats and living conditions. Consequently, the feeding of fishes in open waters is problematic and should always be combined with environmental impact assessments.

4.3 Harvest Control to Regulate Fishery Induced Mortality

In general, harvest control aims to regulate the quantity and composition of fish taken by the fishery in a way that fished stocks maintain their biological productivity and are capable of sustainably delivering good yields. This can be reached by controlling fishery input, e.g. regulating access to a fishery, fishing gear, and fishing effort applied, or controlling fishery output by regulating allowable quality and quantity of catches. Depending on the current stock status and regional specific legal provisions, both input and output control measures can be selected and applied concurrently. Examples for input controls are: conversion of open access fisheries into a licensing system with a restricted number of licences issued, restriction in type and number of gear allowed, introduction of closed areas and seasons, or setting time slots for fishing. All of these are aimed at directly reducing the intensity and pressure of a fishery on the stock. Established and widespread output control measures are, for example, limitations of individual harvest size and numbers of fishes that can be harvested per trip, week, or season.

05

EVALUATION OF EFFECTS AND MANAGEMENT SUCCESS

Evaluation of effects of management measures is key to improve and advance concepts, including success or failure of sanctuaries and their management in comparison to the objectives pursued. The metric or parameter to be monitored and assessed depends on the type of measures applied and the expected effects. Some examples are listed in Table 2.

Table 2: Selection of management measures, their target effect and examples of metrics and parameters to be monitored in evaluation efforts

Measure	Sphere[1]	Effect aimed at	Metric or parameter to be monitored
Stocking	Resource	More recruits, increased abundance ("post" recruits can also be stocked)	Stock abundance, year class strength, proportion of stocked individuals in population
Connectivity improvement	Environ-ment	Improved recruitment, growth, survivorship; higher species diversity, more functional groups	Young of the year abundance, year class strength and mortality, growth, species richness, diversity indices
Spawning habitat restoration	Environ-ment	More recruits	Spawning aggregation and activity on habitat, young of the year abundance, year class strength
Minimum size limit	Resource, People	Increased spawning stock biomass, increased proportion of fish that spawn, reduced selection pressure	Stock length frequency, young of the year abundance Fishing yield per unit of effort, compliance with regulation
Fishing ban	Resource, People	No (additional) fishing mortality, which results inlarger spawning stock	Stock abundance, year class strength and mortality, diversity, Fishing yield per unit of effort, Compliance with regulation

[1] *See chapter 3.3 on management measures*

5.1 Design of Evaluation Study

Evaluation procedures in fishery management are aimed to assess the effects of interventions applied. Because in fish sanctuaries typically a set of management interventions on the environment, the stock and the fishing activities are applied concurrently, responses in fish stocks are generally not just the result of a single measure but of their interaction. In addition, sanctuaries typically are spanning areas with different habitats and are open systems connected to riparian areas. Changes in stocks inhabiting a sanctuary may therefore be attributed to developments outside the sanctuary and driven by factors external to fishery management approaches and measures. Consequently, a pure documentation of fish stock changes over time within a sanctuary area after implementing management measures fails to dis-entangle the changes caused by natural and external drivers from the effects caused by the applied management measures. The same is true for a pure comparison over space, such as documenting and comparing parameters between a managed sanctuary and a control site with no or different management measures. From this, it is advisable to include both time and space by documenting and comparing changes in control (no management) as well as in treated/managed sites before and after the start of management applications. In practice, a group of control sites and a group of sanctuaries with similar characteristics are sampled multiple times before and after application of management measures in the sanctuaries. Such a Before-After Control-Impact (BACI) design (Figure 4) has proven advantageous in dis-entangling natural variability and other anthropogenic impacts from responses in a system caused by management regimes or measures.

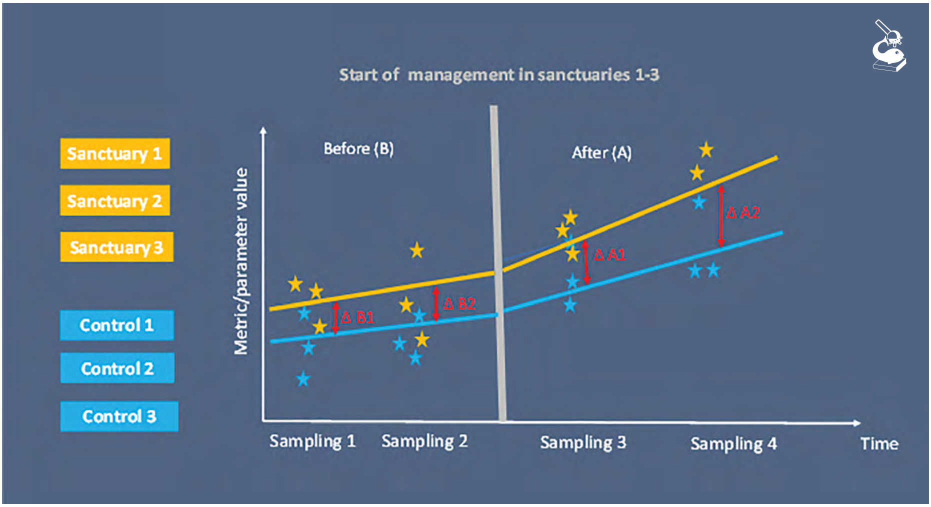

Figure 4: Principle design in Before-After Control-Impact study. An effect of treatment (here: implementing specific management in 3 sanctuaries) would be likely only, if differences between control sites and sanctuaries in sampling 4 (⊿ A2) are higher as compared to sampling 3 (⊿ A1) while accounting for differences between sites emerged from sampling 1 to 2 (⊿ B1 – ⊿ B2). The number of samplings before and after impact required for a valid comparison can be minimized by increasing the number of sites (space for time).

5.2 Sampling Strategies and Standardisation

The basis for any assessment of management effects is a thorough selection of indicative metrics and parameters that can be sampled in a representative and replicable way. Choosing metrics and parameters suitable to indicate effects on stock size, composition or recruitment success, for example, require knowledge of fish ecology and expertise in life-history traits. Some indicative parameters to evaluate the effects of specific management measures are listed in Table 2.

After selection of indicative parameters, a strategy for their sampling has to be worked out. Various aspects need to be taken into account, such as characteristics of the water body or sampling habitats (size/area, morphometry, current, sediments), sampling rationale and level (inventory of species diversity, species stock assessment), and suitable gear and methodologies (active or passive gear types, single or multiple gear sampling, number of sampling events). As an example, when a sampling gets designed to measure the effect of stocking fry on the recruitment of a target species in a river stretch, traps designed to catch juveniles could be placed in species-specific habitats before and after stocking, both in stocked and unstocked stretches. In contrast, a sampling strategy to measure the effect of single species stocking on species biodiversity with respect to competition and replacement needs to consider more habitats and gear types to document response, not only in the stocked species but on the community level.

Some basic rules listed in Box 3 help to enhance sampling strategies in terms of representativeness and comparability.

Box 3

Advice on good sampling

- Cover different habitats (e.g. littoral/shoreline and pelagic/open water).
- Define season.
- Avoid sampling during aggregation periods like spawning and seasonal migration as much as possible. If this is the only period where a species inhabits the sanctuary/sampling site, do not compare to sampling results of that species in other periods.
- Use activity peaks at dusk, dawn and night.
- Avoid saturation of equipment (traps, gillnets) as this changes the catchability.
- Correct catches for size and species selectivity.
- Keep sampling error constant.
- Consider limitations of passive gear and use active gear whenever possible.

In order to detect and evaluate responses in fish communities to management measures control for variation in sampling methodology and data analysis is essential. Because fish populations can take years to respond to management actions, standardized time series data can be used to assess their success or failure. Standardized sampling of various sites can provide sufficient sample sizes to test the effects of regulations, habitat improvements, stocking operations and other management actions. Further, it can be useful for measuring large-scale effects of climate change or anthropogenic impacts on the environment and fish stocks. Standardization can encourage and facilitate data sharing and improve communications among fisheries authorities, managers and fishermen. Additionally, standardization can promote cooperation among fisheries and biodiversity management and protection.

Elements to be considered in standardization of sampling operations include: Survey safety, sampling sites and habitats, gear and their specifics (e.g. mesh size in traps or gill nets, length and height of nets) and positioning, sampling effort (number of sampling gear set, number of campaigns), sampling season and daytime, effort, frequency, principles in measurement of catches, data correction, storage, analyses, etc.. It is recommended to consult international standards for the sampling of fish when developing sampling programs. For a compilation of scientific freshwater fish sampling methods typically applied in the North-Eastern Regions of India and means for standardization we refer to a handbook developed under the NERAQ-project [2].

[2] *Shangningam, B; Sharma, L.K. & Ritterbusch, D. (2024): Standardization of scientific freshwater fish sampling methods exemplified by an application in North-Eastern Regions of India. Zoological Survey of India, Kolkatta*

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