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Standardization of Scientific Freshwater Fish Sampling Methods

Exemplified by an application for the North-Eastern Himalayan Region of India








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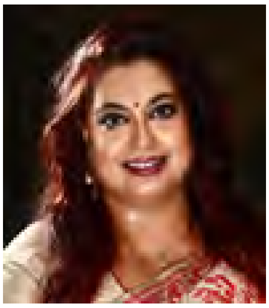
Standardization of Scientific Freshwater Fish Sampling Methods

Exemplified by an application for the North-Eastern Himalayan Region of India

Foreword from the Director, Zoological Survey of India



It gives me immense pleasure to present this pioneering document, **"Standardization of Scientific Freshwater Fish Sampling Methods,"** as a crucial step toward enhancing our understanding and conservation of India's aquatic biodiversity. This publication exemplifies our commitment to advancing scientific methodologies and fostering sustainable management practices in one of the most biodiverse regions of the world—the Northeastern Himalayan aquatic ecosystems.

India is endowed with a remarkable diversity of freshwater habitats and an extraordinary array of ichthyofauna, many of which are endemic and face growing threats from habitat degradation, pollution, and climate change. The standardized methods outlined in this manual serve as a significant contribution to scientific research, offering a unified approach to sampling freshwater fish across diverse habitats. Such standardization not only ensures the collection of high-quality, comparable data but also strengthens the foundation for informed conservation planning and policy formulation.

The methodologies presented in this document are grounded in extensive fieldwork and are adaptable to the unique challenges of the Indian subcontinent. The focus on diverse gear types, habitat-specific protocols, and innovative techniques like eDNA sampling reflects the evolving nature of ecological research. These methods, when employed systematically, can provide insights into species distribution, abundance, and habitat preferences, enabling the identification of critical areas for conservation intervention.

This manual is not merely a technical guide; it is a tool for capacity building among researchers, academicians, and field practitioners. By promoting best practices, it encourages the scientific community to adopt a more rigorous and standardized approach, ensuring that the data generated is robust and reliable. Such an approach is indispensable in addressing the multifaceted challenges posed by biodiversity loss and in meeting global commitments to conserve freshwater ecosystems.

I extend my heartfelt gratitude to the authors, collaborators, and partners, including GIZ, for their invaluable contributions to this endeavour. Their dedication and expertise have been instrumental in bringing this manual to fruition. I am confident that this publication will become a cornerstone reference for freshwater fish research and will inspire future initiatives in aquatic biodiversity conservation.

As the Director of the Zoological Survey of India, I take great pride in supporting this landmark achievement and encourage its widespread dissemination and application. Together, let us strive toward a future where the richness of India's freshwater ecosystems continues to thrive for generations to come.

Dr Dhriti Banerjee
Director

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1 INTENTION OF THIS DOCUMENT

This document aims to support the planning, implementation, and documentation of future scientific field surveys in aquatic ecology, fish biology, and fisheries science in India. It includes a typology of Indian water bodies and suggestions for a type-specific and result-oriented selection of fishing methods. The suggestions intend to standardise future research with the aim of uniform method selection, comparable execution in the field, similar data collection and recording. This standardisation potentially improves the comparability of fish data - both for analysis of time series within and for comparison between water bodies. Overall, the sustainable usability of the data hopefully is improved. The present document focuses on practical issues and targets people who plan or conduct scientific investigations.

In this report you will find:

- Parameters used for classification of water bodies and a typology for Indian rivers and lakes.
- A comprehensive description of fishing methods with suggestions for their standardisation in scientific fish sampling and concrete comments on their relevance in India.
- Suggestions for type-specific fishing methods with proposals for Indian water body types.
- Recommendations for the collection of data: sampling site, habitat conditions, sampling procedure and fishing results, including proposals for field protocols for fish sampling in India.
- Basic suggestions for data storage.

You will not find detailed literature reviews with the scientific standard of a peer-reviewed paper in this document, references are made to selected summarizing papers or reviews. The report does not include guidance on scientific analysis of the fish data obtained, e.g. how to describe, analyse or compare species inventory, species number, diversity, evenness, composition, population trend, or vulnerability.

The authors intend to provide a hands-on guidance to support future scientific field investigations of freshwater fish in India. We hope it might be of general use for scientists and other persons conducting field trips, teachers, trainers and students of fish biology or fishery science.

2 ADVANTAGES OF STANDARDIZATION

At first glance, fishing methods seem to be of a manageable number, unchanged since centuries, and more or less globally distributed. Set nets, hooks and lines, push nets, pull nets, cast nets or lift nets can be found all over the world. They are primarily used to catch fish for nutrition, but methods for scientific investigations are similar. With respect to scientific questions, all these gears provide positive evidence of fish species and sizes caught at the sampling site. They may also enable the investigator to provide categorical estimates of abundance in comparisons to former catches with the same method or based on expert judgement. A potential result of using these methods without further specification could be: "With the cast nets, we caught 10 individuals of a certain catfish species. They had lengths between 50 and 60 cm and the species apparently is abundant in the area." Such positive evidence is valuable for species inventories of sites, distribution areas of species, or biodiversity estimates.

However, all fishing methods are biased. They provide information on gear-specific species with gear-specific sizes in gear-specific habitats that have been caught during a specific sampling time. Within a gear type, small deviations of the specifications can have significant influences on the catch. Among others, mesh or hook sizes, baiting, daytime, duration of exposure and location vitally influence fishing results. Therefore, differences between sites (status) or within time (trends), quantitative measures of abundance or reliable information on species' compositions can only be obtained, if the specifications of gear are kept comparable, i.e. if the fishing method and its application are standardized. As this is not a new insight, fishing methods might have long been standardized within federal countries, states, institutions, universities or working groups. However, scientific standard methods for freshwater fishing on a national or international level tend to be the exception rather than the rule. To the best knowledge of the authors, it has been after the new millennium that such standards became published (Bonar et al. 2009b; EN 14757 2005; EN 14962 2006).

India is one of the biodiversity hot spots of the world, it has a uniquely diverse fish fauna with records of 1027 freshwater fish species (Gopi et al. 2017). The fish fauna is of extraordinal conservational interest, many species are rare, endemic, highly specialized, or endangered. Indian scientists are aware of this unique situation and there are comprehensive overviews of species inventories, richness, distribution areas, or number or percentages of endangered species (Allen et al. 2010; Chandra et al. 2018; Lakra et al. 2010a; Molur et al. 2011). However, there is no national Indian guidance for the scientific sampling of fishes, i.e. no national standard of fishing methods and sampling strategy. As mentioned above, a standardized fishing procedure extends the potential data analyses far beyond the species level. Additional possibilities are:

- Species inventories can be related to gear and effort and are thus made comparable.
- The population sizes of species can be parametrized by the 'catch per unit of effort' in appropriate gear, and reliable quantitative estimates of abundance become possible.
- If standardized, several methods allow analyses of size distributions which can be used to characterize fish populations and to trace changes.
- This allows for comparisons of status: inventory, composition, abundance and sizes of fish at different localities.

- Furthermore, trends can be identified based on standardized catch. Temporal changes of the above-mentioned fish community traits are of special relevance to investigate climate change, which is the most challenging threat to biodiversity.

Summarized, standardization is the process of making fish data comparable. The authors feel that standardized fishing on a national Indian level could help improving the quality of future fish sampling campaigns and of the data obtained by them, as well as increase the possibilities of future data analyses. The additional effort by a standardization should be low compared to the additional possibilities. A standardization is of special relevance for India. The country is inhabited by an exceptionally high number of fish species and therefore has a special responsibility for the current biodiversity and its heritage to future generations - not only for India itself but worldwide.

Further reading: Standards for fishing methodology (Bonar et al. 2009a; EN 14962 2006), information about fish biodiversity in India (Arunkumar et al. 2018; Gopi et al. 2017; Lakra et al. 2010b; Pathak et al. 2014; Sarkar et al. 2013; Sarkar et al. 2012).

3 Typology for Water Bodies

3.1 Introduction

Classification and categorization are ubiquitous aspects of biology and ecology. For biological investigations of fresh waters, water bodies are classified on the basis of abiotic and/or biotic conditions which define a potential range of habitats, species and community compositions. Embedded in the framework of a typology, analyses of catches can refer to the ranges expected within types. A typology can help comparing communities of different origins, e.g. in identifying the type-dependent differences and the influences of anthropogenic stressors. A typology of water bodies is essential for the standardization of methods. Coming back to fish, standardization is the basis for selecting appropriate fishing methods and for defining the specific effort required to get a reliable picture of the fish community.

The basic classification of freshwaters is the division into rivers and lakes. These two essential water body types can be further subdivided based on abiotic criteria, biotic criteria, or on a combination of them. Below, potential criteria for differentiating river types (see 3.2) and lake types (3.3) are listed. The lists have been reduced to the most significant criteria and may be biased towards European classifications.

Please note: Fish-orientated typologies of water bodies are often named after the dominant fish species or fish family, even if they are based on environmental descriptors - e. g. the salmonid river region describes the upper stretches with clear, well oxygenated water and coarse substrate. This might be confusing, because there are also typologies primarily based on fish communities. Prominent example is the transition of species dominance in lakes along a salmonid → percid → centrarchid/cyprinid dominance in dependence on trophic and structural changes (Persson et al. 1991; Ryder 1981). Such fish-based typologies are avoided for the methodology presented here, because they are based on the fishing results themselves, therefore they are of limited use to plan fishing campaigns or evaluate fishing results. Furthermore, they are probably much less transferable to Indian conditions then typologies based on non-organismic criteria. Therefore, only environmental characteristics are presented as classification criteria in the following two chapters. Measuring the relevant characteristics required to classify lakes and rivers needs to be part of the fishing campaign. Several abiotic and biotic parameters are part of the field protocols added at the end of this document.

Further reading: The European Natura 2000 Directive (92/43/EEC 1992) and the Water Framework Directive (2000/60/EC 2000) provide criteria for typologies, they are supported by reports for their implementation (CIS 2003a; Poikane 2009). Technical reports provide detailed overviews of all national typologies used in Europe for rivers (Jepsen et al. 2007), lakes (Gassner et al. 2014; Olin et al. 2014; Ritterbusch et al. 2017) or the definition of modified/anthropogenic water bodies (CIS 2003b). Jupke et al. (2023) provide additional overviews of typologies for rivers and Lyche Solheim et al. (2019) for lakes. Bonar et al. (2009b) provide a functional typology for standardization of fishing methods.

3.2 General criteria for the classification of rivers

Rivers are stretches of running waters. The watercourse usually increases in size from a trickle at the source to a potentially extended delta in the estuary. Alongside, most other river characteristics change with the distance from the source. Potential criteria for classification of rivers are:

- Abiotic criteria
  - Biogeographic classification, e.g. ecoregion, region or river catchment
  - Altitude above sea level (concrete range a.s.l., or lowland / mid / highland)
  - Geology (siliceous, calcareous, organic/humic)
  - Origin (natural creeks, rivers or streams vs. anthropogenic channels or ditches)
  - River continuity
  - Current velocity
  - Size (width)
  - Depth
  - Substrate (mud, sand, gravel, stones, rocks)
  - Structural diversity (variation of depth, width, or substrate, side-arms, floodplains)
  - Temperature (mean or maximum)
  - Oxygen
  - Transparency
  - Salinity
  - Alkalinity
- Biotic criteria
  - Organic material
  - Aquatic flora - submersed or emerging vegetation, littoral reeds
  - Aquatic fauna, benthic invertebrates, food organisms for fish
- Combinations
  - Fish regions are a combination of river size and structural diversity, current velocity, substrate, temperature and characteristic fish species (e.g. salmonid region)
  - Natural habitat types: a combination of ecoregion, climatic subdivision, vegetation types and presence of certain plant species of conservational value (used in the European Fauna-Flora-Habitat-Directive)

3.3 General criteria for the classification of lakes

Lakes are standing waters. Their sizes range from a few hectares to tens of thousands of square kilometres, their depths can reach hundreds of meters. Potential criteria for classification of lakes are:

- Abiotic criteria
    - Biogeographic classification, e.g. ecoregion, region or river catchment
    - Altitude above sea level (concrete range a.s.l, or lowland / mid / highland)
    - Geology (siliceous, calcareous, organic/humic)
    - Origin (natural lakes vs. anthropogenic ponds or reservoirs)
    - Connected or isolated
    - Size (surface area)
    - Depth (mean or maximum)
    - Substrate (mud, sand, gravel, stones)
    - Structural diversity (variation of depth, shoreline, or substrate)
    - Thermal conditions
        - mean or maximum temperature
        - stratification
    - Oxygen: mean concentration, depth-dependent depletion (anoxic hypolimnion)
    - Transparency
    - Nutrients
    - Salinity
    - Alkalinity
- Biotic criteria
    - Aquatic flora - phytoplankton
    - Aquatic flora - submersed or emerging vegetation, littoral reeds
    - Aquatic fauna, e.g. zooplankton, benthic invertebrates, food organisms for fish
- Combinations
    - The trophic level: is not defined consistently, but usually includes combinations of nutrient concentrations of Nitrogen and Phosphorous (abiotic) with descriptors of phytoplankton abundance, i. e. Chlorophyll a and Secchi-Depth (biotic)
    - Clear water lakes and turbid water lakes is a typology based on differences of nutrient concentrations and phytoplankton vs. macrophyte abundance
    - Natural habitat types are a combination of ecoregion, climatic subdivision, vegetation types and presence of certain plant species of conservational value (used in the European Fauna-Flora-Habitat-Directive)
    - Fishery lake types are based on the commercial fish yield of relevant species or combinations of species under the given circumstances (lake area, depth, trophic characteristics)

3.4 Typology of water bodies of North-Eastern Region of India

The diverse aquatic ecosystems in the North-Eastern region of India offer a unique opportunity for typological classification, encompassing high-altitude lakes, lowland floodplain wetlands, rivers, streams, and human-made water bodies (Choudhury et al. 2022). The classification of these water bodies is often performed using geomorphological parameters, such as size, shape, altitude, and hydrological connectivity (Balian et al. 2008). In the case of rivers and streams, parameters like current speed, depth, substrate, and slope are also used (Bonar et al. 2009b). The typology recognizes the significant influence of major river basins like Brahmaputra in shaping these aquatic ecosystems (Borah et al. 2022). These classifications aid in comparative analysis, conservation planning, and scientific study of these unique ecosystems. While the existing European and the North-Eastern Indian typologies share the primary bases for categorization - such as ecoregion/major river basin, altitude, size, depth, and human influence - the unique characteristics and variability of North-Eastern India's aquatic environments call for a more tailored approach.

Ecoregion/Major River Basin: For North-Eastern India, this would entail specific divisions by major river basins, such as Brahmaputra, Barak, Chindwin and Kaladan river basins.

Altitude: The North-Eastern India's unique altitudinal range spans the floodplains of the Brahmaputra to the montane ecosystem of the Eastern Himalayas. This creates a range of habitats for a diverse array of fish species.

Size: The North-Eastern Indian classification could introduce more categories, considering the variety of water bodies, including marshes, ponds, streams, rivers, and large lakes.

Depth: The North-Eastern India, being tectonically active, has many deep-water bodies in the form of high-altitude lakes and deep river channels.

Human-impacted Water Bodies: Water bodies made by humans or significantly modified by human activities, like ponds and reservoirs or ditches and channels are considered separate types. However, the specific manifestations of anthropogenic modifications might differ.

Current speed, slope, substrate, temperature: North-Eastern India's tropical monsoon climate and significant rainfall lead to varying current speeds and river temperatures. Moreover, the varied topography plays a critical role in differentiating the ecosystems. "Cool" waters generally refer to those with temperatures that are moderate and suitable for temperate aquatic species. "Cold" waters, on the other hand, refer to temperatures that are typically less than 12 °C which are suitable for cold water fish species such as trout.

Based on the above criteria's the aquatic ecosystems of the North-Eastern region of India can be classified as shown on the next page.

Table 1: Water body types in the North-Eastern Region of India.

All water body types below must first be categorized by the major river basin they lie within. For the North Eastern Region of India, these are Brahmaputra, Barak, Chindwin and Kaladan.	
Type Nr.	**Type Name**
1	**Natural Running Waters**
1.1	Rivers
1.1.1	Lowland Warm River
1.1.2	Mid-Altitude Cool River
1.1.3	High-Altitude Cold River
1.2	Streams
1.2.1	Lowland Warm Stream
1.2.2	Mid-Altitude Cool Stream
1.2.3	High-Altitude Cold Mountain Torrential Stream
2	**Natural Lakes**
2.1	Lowland Warm Lake
2.1.1	Polymictic Lowland Lakes
2.1.2	Stratified Lowland Lakes
2.2	Mid-Altitude Cool Lake
2.2.1	Polymictic Mid-Altitude Cool Lake
2.2.2	Stratified Mid-Altitude Cool Lake
2.3	High-Altitude Stratified Cold Lake
3	**Human-Impacted Running Waters**
3.1	Channels
3.1.1	Lowland Warm Channel
3.1.2	Mid-Altitude Cool Channel
3.1.3	High-Altitude Cold Channel
3.2	Ditches
3.2.1	Lowland Warm Ditch
3.2.2	Mid-Altitude Cool Ditch
4	**Human-Impacted Standing Waters**
4.1	Reservoirs
4.1.1	Lowland Warm Reservoir
4.1.2	Mid-Altitude Cool Reservoir
4.1.3	High-Altitude Cold Reservoir
4.2	Ponds
4.2.1	Lowland Warm Pond
4.2.2	Mid-Altitude Cool Pond
4.2.3	High-Altitude Cold pond

4 METHODOLOGY WITH GENERAL SUGGESTIONS FOR STANDARDIZATION

4.1 Introduction and overview

Table 2 shows an overview of gears and methods used in freshwater commercial fishing and scientific fish sampling. The upper part of the table follows the ISSCFG classification (CWP 2016; FAO 2021, 2023), the middle part is classified by the authors. We describe these fishing methods in the following chapters 4.2-4.17. The lower part of Table 2 names three special methods or groups of methods that are not exactly fishing gears, but used for specific kinds of fish investigations. We describe them shortly in chapter 8, but detailed descriptions or suggestions for standardization are beyond the possibilities of this document.

Several methods cannot be found in the subsequent text (Table 3). We avoid methods currently not applied in freshwaters for neither fisheries nor scientific fish sampling and which lack the potential to be used in future. Harpoons, spears and clamps are locally used under certain circumstances, but their application is limited and rarely contributes to scientific investigations. We do not describe highly destructive methods like poisons, toxicants or explosives which severely harm the fish community, the environment and which are potentially hazardous to human health. These methods are illegal throughout the country. However, they are still used to kill and gather fish in India (Gurumayum et al. 2009; Prasad et al. 2013; Sankararaman 2019; Verma 2015; Verma et al. 2022), most authors characterize them as common to very common and hazardous to biodiversity. There are a few examples of scientific sampling with poisons (e. g. rotenone), but we see no need for a standardization for India. We do not mention gear for molluscs or crustaceans or gear exclusively applied in marine environments.

Gear names and descriptions follow the 'International Standard Statistical Classification of Fishing Gear ISSCFG, 2016' (CWP 2016; FAO 2004) and are taken from FAO and EC websites (EC 2023; FAO 2023), where applicable. These sources focus on commercial fishery and were supplemented with modifications needed for classification of scientific gear. The structure of the general description is similar for each method:

- Short description of gear type according to EC (2023); FAO (2023)
- Description of method
- Suitability for water bodies / habitats
- Selectivity
- Pros / Cons
- Summary
- Possibilities for standardization
- Further reading

Before starting with the descriptions of methods, the authors want to take the precaution of mentioning that fishing is an exhausting and dangerous job. The conductors of scientific fishing surveys are exposed to bad weather, dangerous and instable environments, turbulent waters with high currents, and to potentially harmful plants and animals. **The following method descriptions don't provide safety instructions**. However, we want to very shortly mention essential recommendations for all members of fishing field teams everywhere and at any time: avoid working alone, tell your colleagues when and where you are, have a mobile phone with you to call or be called, carry a GPS device for orientation, and have a training in first aid (Bonar et al. 2009b).

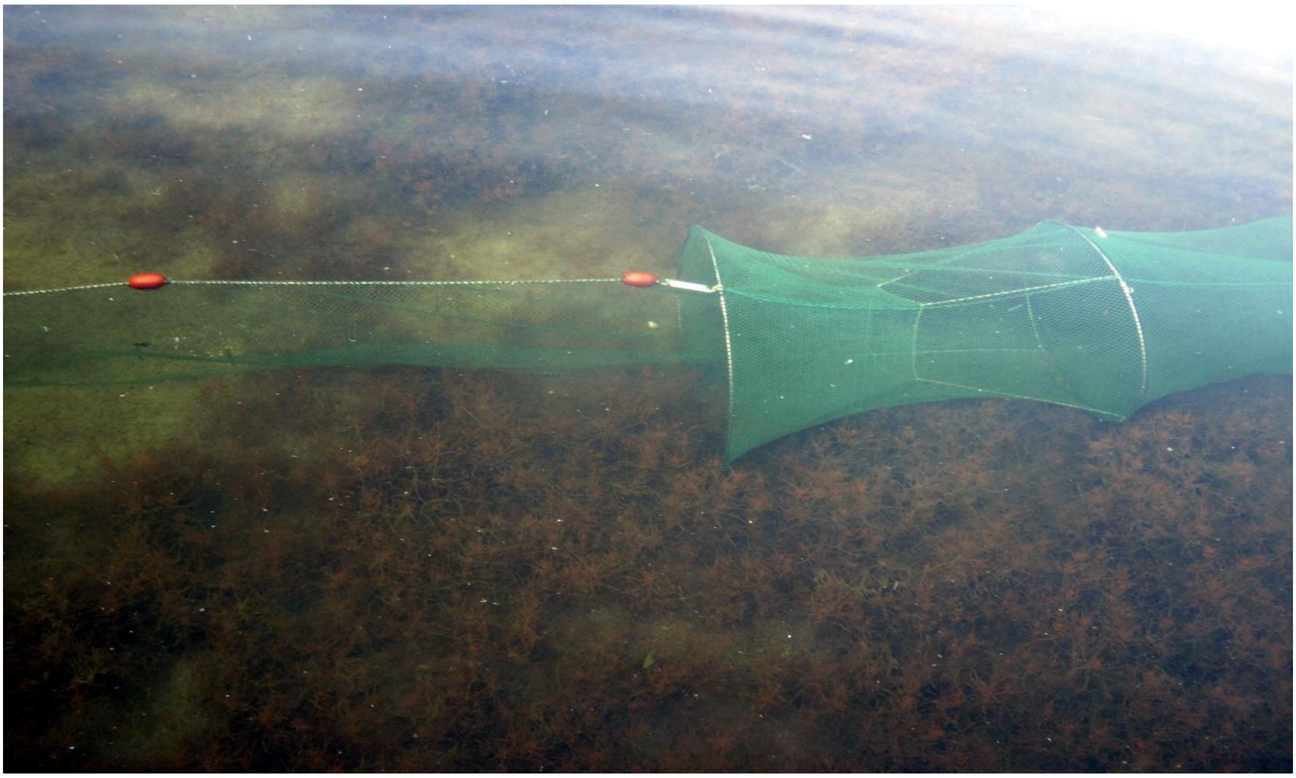
Further reading: Comprehensive overviews of fishing methods, their classification, technology and fields of application are provided by Bonar et al. (2009b), EN 14962 (2006), FAO (2021), FAO (2023), Nédélec (1996) and Zale et al. (2012). Boopendranath (2012) provides "Basic Principles of Fishing Gear Design and Classification" with some specific examples of corresponding net types in India (although the special reference to India in this chapter is subordinate). More specific references will be given in the corresponding chapters. As there is a huge amount of literature describing traditional fishing methods in India, we focus on sources referring to North Eastern India.

Table 2: Fishing gear used in India for freshwater fishing or scientific freshwater fish sampling, including gear that might potentially be used in future. Water bodies include natural and artificial types for rivers (types 1 and 3 in Table 2) and lakes (types 2 and 4).

Gear group	Gear type	Water Body	Comment
Gillnets / entangling nets	Set nets	All	Versatile and used in a variety of aquatic environments.
	Trammel nets	All	Useful for catching a variety of species in freshwater systems.
	Drift nets	Rivers	Effective in river systems where fish may move with the current.
Encircling nets	Encircling gill nets	Lakes	Can be used in enclosed freshwater systems like lakes and pond.
Seine nets	Boat seine	Lakes	Suitable for larger bodies of freshwater like lakes or reservoirs.
Trawls	Trawl nets	Lakes	Effective in open water bodies, e. g. larger lakes and reservoirs.
	Draught nets	All	Used in a variety of aquatic environments.
Fish traps	Pots	Lakes	Used in standing water bodies, like ponds and lakes.
	Fyke nets	All	Suitable for trapping fish in lakes, rivers and streams.
	Stationary pound nets	Lakes	Applicable in larger water bodies, such as lakes and reservoirs.
Falling gear	Cast nets	All	Useful for catching fish near the surface in various environments.
Lifting gear	Lift nets	All	Can be used in both running and standing freshwater bodies.
Hook and line	Hook and line	All	Versatile and effective in almost all types of aquatic environments.
Electrofishing	-	All	Often used for scientific surveys in various freshwater habitats.
Hand operated gear	Scoop nets	All	Effective for sampling fish in shallow waters and during field research.
Non-invasive methods	Visual detection, diving	All	Suitable for clear-water bodies for species identification and count.
Local knowledge/data	Interviews / surveys / Fishery statistics	All	Useful for gathering historical and local knowledge about fish, applicable everywhere where fishing occurs.
Special method	Hydroacoustics	Lakes	Used for estimating fish distribution and/or biomass in larger lakes.
	eDNA	All	Revolutionary technique for detecting species presence and abundance.
	Marking and tagging	All	Methods for studying fish migration and population dynamics.

Table 3: Fishing gear not mentioned or only shortly explained in the following chapters. Reasons are: a) gear is not used in freshwater fishing or scientific freshwater fish sampling in India, b) it has negligible potential for future application in scientific fish sampling, c) it might be applied in freshwater fisheries, but the gear is illegal, highly and non-selectively damaging the environment or considered unethical.

Gear group	Gear type	Comment
Encircling nets	Purse seine	Used in coastal or marine environments, short description added in chapter 4.5 (encircling gillnets).
Seine nets	Beach seine	Used in coastal or marine environments, short description added in chapter 4.6 (boat seines).
Dredges	-	Cages towed by boats above the bottom to catch molluscs or crustaceans, marine and in many cases destructive. Not described.
Fish traps	Aerial traps	Used in India, but local, special application and highly individual gear, see Pravin et al. (2011a). Not described in the following chapters.
Hooks and Line	Snagging	The external piercing of fish with unbaited hooks is damaging and has no potential for fish sampling. Shortly mentioned in chapter 4.13.
Hand operated	"piercing gear"	Harpoons, spears, or clamps are only used in specific conditions, such as ice fishing or for certain species. Not described.
Destructive	Explosives	Highly destructive, unspecific and illegal method. Not described.
	Poisoning	Highly destructive, unspecific and illegal method. Not described. There are some degradable and less destructive natural poisons applied locally, but we have no comprehensive access to this traditional, indigenous knowledge.



4.2 Set gillnets

Short description of gear type according to EC (2023); FAO (2023): A set gillnet consists of a single netting fixed to the bottom, or at a certain distance above it, by means of anchors or weights (Figure 1).

Description of method: Nets are involved in many of the fishing methods described in the present chapter 4. A very common variety of net application are set nets, where panels of nets are vertically distributed within the water body. The nets are fixed at a specific location with anchors and held open with a weighted bottom leadline and an upper floatline with higher buoyancy. In commercial fisheries, the nets can also be mounted on stakes, but this variant is not considered relevant for scientific investigations. Fish swim into the nets and entangle behind the gills. After a certain amount of time, the nets are hauled and the catch is processed. Set gillnets are globally applied and very common. For scientific fish sampling in freshwaters, nets are usually manufactured out of clear, monofilament nylon. Set gillnets are also referred to as anchored or stationary nets.

Suitability for water bodies / habitats: The operation of set sets is limited to standing waters or very slow flowing regions in rivers (e.g. backwaters, oxbow lakes). The nets can be set on the bottom to catch benthic fish. They can also be placed in defined depths of the open water column using buoys and lines with adjusted lengths to catch pelagic fish (Figure 1). They cover a range of habitats but are of limited use in very shallow waters (below net height). Benthic nets will be less effective if set in dense vegetation and are prone to loss or destruction if the bottom is covered by dead trees or bushes.

Selectivity: Set nets are highly selective. Being a passive method, they select towards fish that are actively moving during the period of setting. Hidden, inactive or territorial species are underrepresented, e.g. ambush predators hidden in littoral plants will rarely be caught. Set nets are size-selective - the mesh sizes determine the potential range of fish sizes caught. Multi-mesh nets counteract the size selectivity to some degree. Set nets also select towards fish with a 'typical' body shape while high backed, flat bodied, round, slender or snake-shaped fish are underrepresented. Fish species with a hard skin, spiny or branched protrusions are more effectively caught in comparison to those with smooth, mucous skin. A further aspect of species-specific catchability is the "caution" of the fish; which is a combination of swimming speed, sensory organs, sensitivity and maneuverability of the species. Examples for underrepresented species are eel, carp and catfish. Selectivity is a disadvantage for several subjects of investigation, e.g. for scientific investigations of species inventory or composition. On the other hand, selectivity can be a great advantage of set nets if specific species or sizes are targeted, e.g. by commercial fishermen. It is possible to have a high chance of catching desired species in desired size ranges by choosing appropriate mesh sizes and setting locations.

Pros: Set gillnets are cheap, comparably easy to use and can be left unattended for the duration of exposure. They can cover a wide range of habitats in lentic water bodies and catch a wide spectrum of species and specimen sizes. **Cons:** Set nets are installed for a certain duration and can be lost, stolen or vandalized meanwhile. They cannot be applied in very shallow water or near submerged obstacles. Set nets are selectively catching active species of a certain size spectrum. Set gillnets are highly lethal or at least heavily damaging. Lost nets keep catching fish and other organisms.

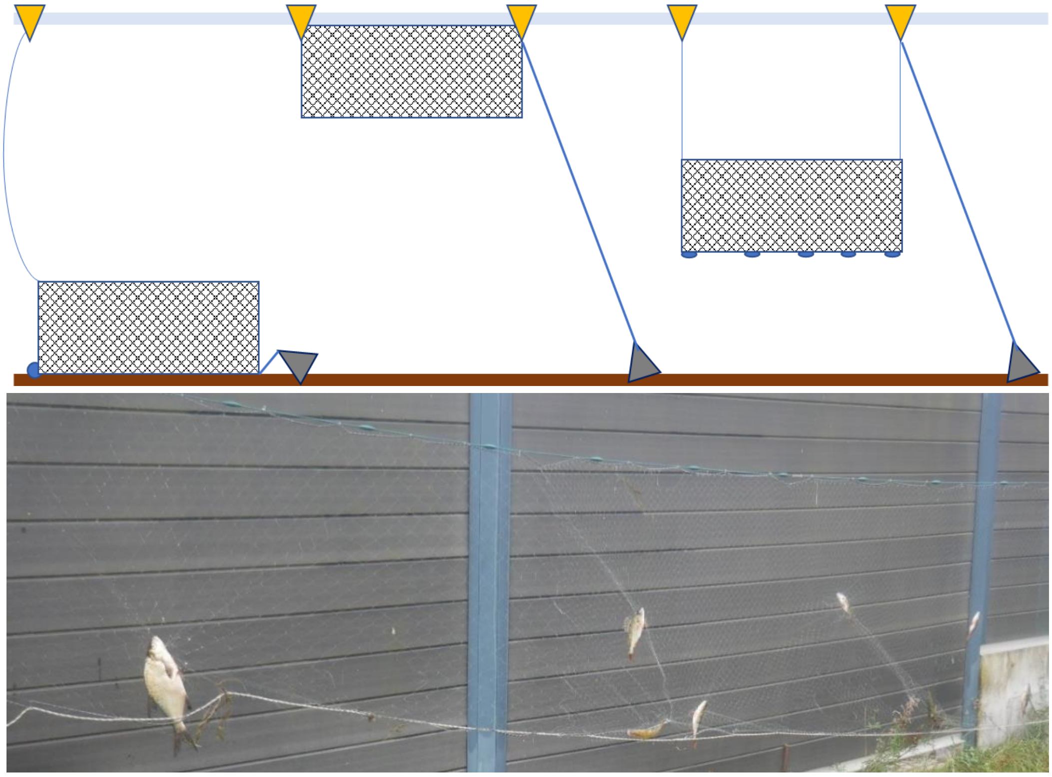


Figure 1: Above: Benthic set nets are sinking and lay on the bottom (left). Swimming pelagic nets have a floatline with high buoyancy (middle). Sinking pelagic nets are balanced in such a way that they descend slowly. They are suspended from buoys, and the setting depth can be adjusted by the length of the ropes (right). All nets require prominent buoys for retrieval and anchors to prevent drifting. Below: The varying mesh sizes of multi-mesh nets allow for the detection of different species and sizes. Sketch D. Ritterbusch, Photo F. Pfaff.

Aspects of method description and standardization: For documentation, gear description should provide net lengths, net heights and mesh sizes. For multimesh-nets the number of different mesh sizes (panels), panel lengths and heights need to be included. The sampling procedure is specified by the horizontal distribution of the nets (e.g. along depth strata) and by the vertical distribution: random vs. even, habitat-specific, east-west, inflow-outflow. Concrete information should be given for season or date of the sampling, months or water temperature can be used as additional criteria. Time and duration of the setting of the nets should be described: daytime, dawn, night or dusk with the total number of hours in water.
A standardization of fishing with set gillnets includes the fishing effort (number of nets set), which should depend on area and depth of the water body. It also includes guidance on the vertical and horizontal distribution of the nets. For more details, net material as well as lengths, weight or buoyancy of lead and floating lines can be specified.

Summary: Set nets are a simple and cheap fishing method and probably the most common gear used for fishing and for scientific fish sampling. They cover a wide range of habitats, fish species, and specimen sizes. Set gillnets are a very common method in Indian freshwater fisheries and also very common in scientific fish sampling worldwide. They provide data on species inventory, composition and abundance. The main disadvantages are selectivity and lethality. Multi-mesh gillnets are used to counteract the selectivity of single mesh sizes.

Further reading: Pravin et al. (2011b; 2009) provide comprehensive descriptions of gill net types used in Assam. Further descriptions of gillnets used in Indian freshwater are: Chakravartty et al. (2013), Das et al. (2015), Devi et al. (2013), and Gurumayum et al. (2009). There are descriptions of standardized methods for sampling fish with multimesh-gillnets in Europe (EN 14757 2005, 2015) and in the US (Bonar et al. 2009b).

4.3 Set trammel nets

Short description of gear type according to EC (2023); FAO (2023): A bottom-set net made with three walls of netting, the two outer walls being of a larger mesh size than the loosely hung inner netting panel. The fish get entangled in the inner small meshed wall after passing through the outer wall (Figure 2).

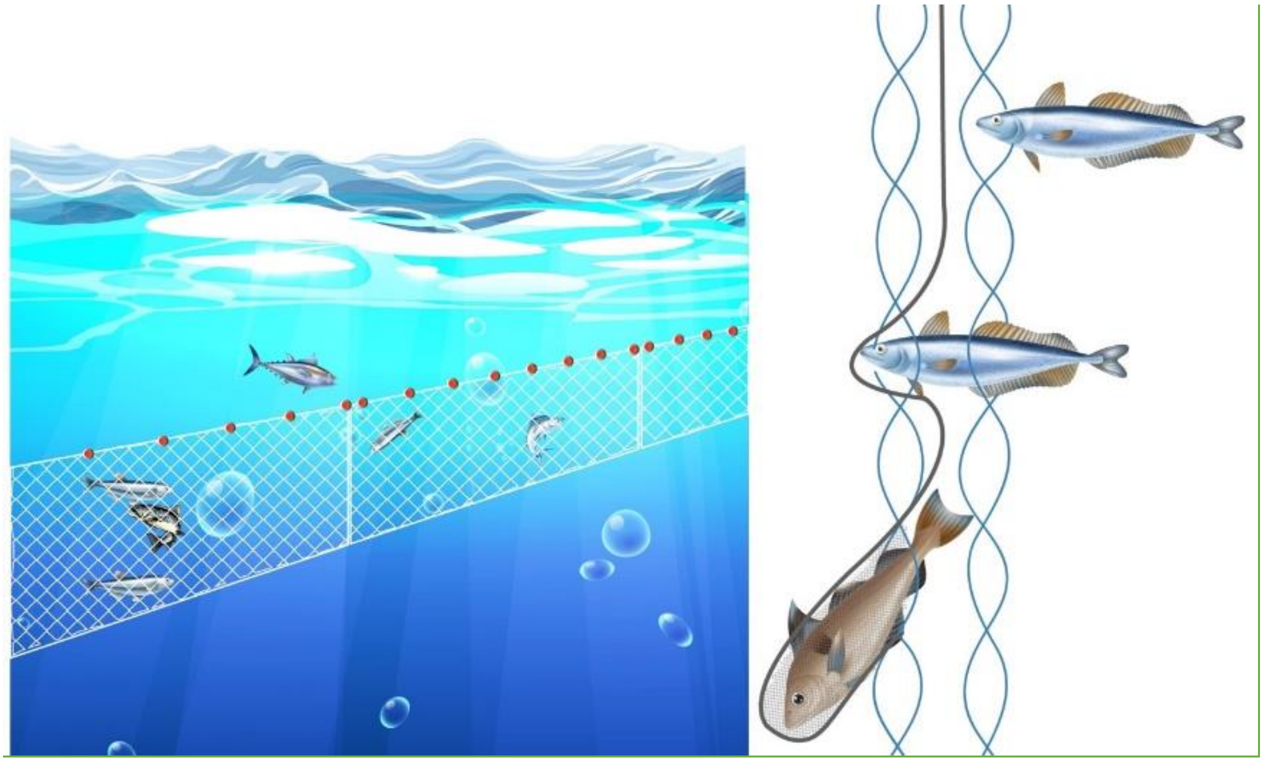


Figure 2: A trammel net catches the fishes in poaches of small meshed nets along a or between a big meshed net. Figure FAO (2021), adapted.

Description of method: Trammel nets are a common and widespread method of fishing. They are mainly used in marine environments, mostly in smaller scaled coastal fisheries. They predominantly target species with special body shapes or without gills, i.e. benthic fish or benthic and pelagic crustaceans or cephalopods. For fish, they are less injuring/lethal then gillnets in general and less selective then single mesh gillnets. Trammel nets are used in freshwater fisheries, but they have a much lower significance then gillnets. A potential application is the catch of littoral species by setting the nets in front of reeds and then flushing the inhabiting fish out into the nets. Potential reasons for their absence in freshwaters are: a lack of target species with special morphology (fish) or without gills (non-fish), the need to flush the fish to swim into the wall of small meshes and time and patience needed for clearing the entangled fish. To the knowledge of the authors, set trammel nets are not used for scientific fish sampling, probably because of their selectivity (there are no multimesh trammel nets).

Trammel nets are similar to gillnets in terms of operation. See previous chapter 4.2 for information about suitability for water bodies/habitats, selectivity, pros/cons and aspects of standardization.

Aspects of method description and standardization: Set trammel nets is a rare method in Indian freshwater fisheries. A precise description of the method includes gear (e.g. mesh size(s), net lengths, net height), selection of habitats (net depths), specifications of date and time and a measure of fishing effort (depth- or habitat-dependent number of nets). Details about the gear operation would describe how the nets are set. It is possible to standardize scientific freshwater fish sampling with trammel nets, but the authors are not aware of literature sources.

Summary: Set trammel nets are a simple and cheap fishing method and common in marine fisheries. If used for catching fish, they have many disadvantages in relation to gillnets. They are not regularly used in scientific freshwater fishing. Because of lower mortality in relation to gillnets, trammel nets have a potential for size- and species-specific fishing of living individuals in littoral zones.

Further reading: Pravin et al. (2011b; 2009) provide comprehensive descriptions of net types used in Assam. Trammel nets are mentioned as present in the region but no information about their importance is given, implicating that its much lower than gillnets. We found no description of an application of set trammel nets in scientific freshwater fish sampling (but a drifting variant is used in the US - see next chapter 4.3).

4.4 Drift nets

Short description of gear type according to EC (2023); FAO (2023): A net kept on the surface, or at a certain distance below it, by numerous floats. It drifts freely with the current, sometimes separately or, more often, attached to a boat (Figure 3).

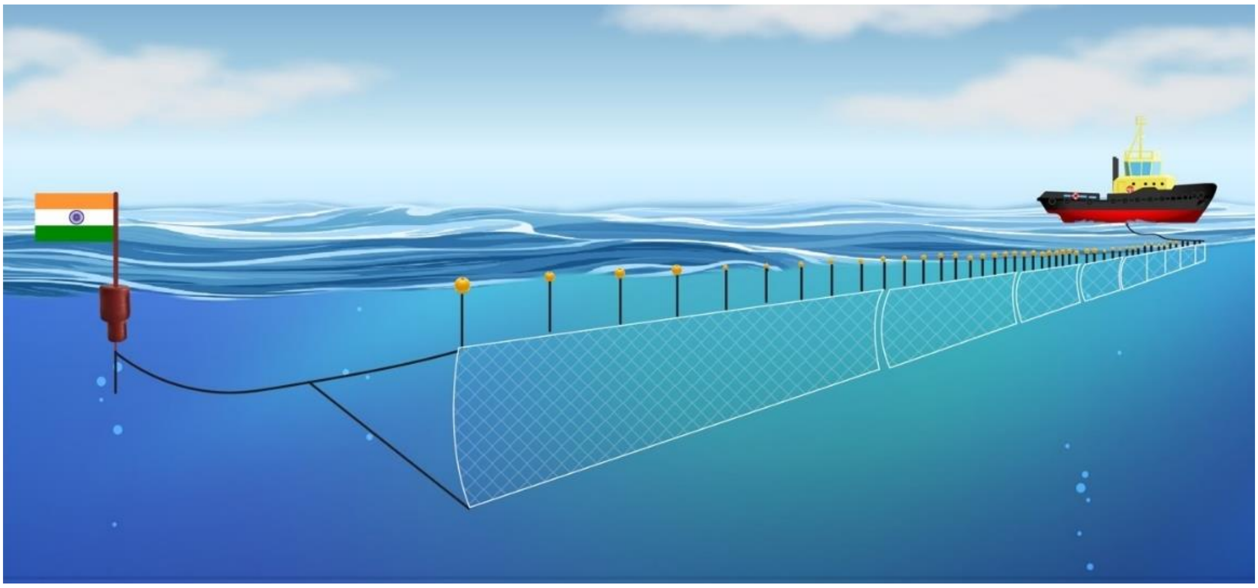


Figure 3: A drift net floats with the current. Figure FAO (2021), adapted.

Description of method: In freshwaters, drifting nets are used to catch fish in large rivers and channels (drifted by currents) or in lakes (drifted by wind). Drift-netting with single mesh gillnets is a common fishing method in India. The nets are usually drifting at the water surface, but benthic drift nets are also used. Mesh sizes are adapted to the targeted fish species. For scientific fish sampling, drifting trammel nets are used to cover a comparably wide range of fish sizes.

Suitability for water bodies / habitats: Drift nets can be used to sample stretches of bigger running waters. The nets can cover nearshore habitats, e.g. inside and outside bends or groyne fields but might also be drifting midstream. The current in the sample area has to be fast enough for drifting, but slow enough for manoeuvrability of boat and net. The river bed in the area of application must be free of bigger obstacles, submerged trees or rough boulders, otherwise the net might get snagged.

Selectivity: Drifting nets are size-selective with the selectivity being dependent on the mesh sizes. It can be assumed that spiny fish with protrusions, slow fish and those with lower flight distances might be caught more effectively. Drifting trammel nets for scientific investigations seem to have a low catch efficiency and many of these investigations focus on sturgeons.

Pros: Drift nets provide the possibility to quantitatively sample riverine fish species at habitats outside the close nearshore areas. They can provide information about species and individuals that are not represented in the catches with littoral electrofishing (e.g. pelagic species, bigger individuals, non-littoral stages). **Cons**: Fishing with drift nets in freshwaters is technically demanding and dangerous. The need for precise steering in high currents, the possibility that other boats might cross the way of the net, the dangers of snagging nets or sudden sideway turns of the boat and the huge powers of currents are challenging, especially if nocturnal fishing is chosen. Drift net fishing should only be carried out by experienced persons.

Aspects of method description and standardization: Drift nets, predominantly drifting gillnets, are a common method in Indian freshwater fisheries. A precise description of the method includes gear (e.g. mesh size(s), net lengths, net height), selection of habitats, specifications of date and time and a measure of fishing effort (shore length, area covered). Details about the gear operation would describe how the net is set. It would be possible to standardize scientific freshwater fish sampling with drift nets, but the authors are not aware of literature sources.

Summary: Drift nets can be used for quantitative scientific investigations of riverine habitats, that cannot be sampled otherwise. Drift netting with single mesh size nets is a common fishing method. Scientific fish sampling can be done with drifting trammel nets, but a standard procedure does not exist.

Further reading: Pravin et al. (2011b; 2009), Chakravartty et al. (2013), Das et al. (2015) describe drift nets used in North Eastern India. Bonar et al. (2009b) provide a detailed description of scientific drift net fishing with trammel nets, including gear specifications, tips and trick for operation and general considerations.
Please note that we refer to drifting nets - the term 'drift nets' is also used for stationary nets that catch drifting organisms in running waters, e.g. fish eggs or larvae and benthic invertebrates.

4.5 Encircling gillnets

Short description of encircling gillnets according to EC (2023); FAO (2023): A long vertical gillnet set in a circle, generally used in shallow water. After the fish have been encircled by the net, noise or other means are used to force them to gill or entangle themselves in the netting surrounding them.

Figure 4: An encircling gillnet is set around the fish which are then scared to rush into the meshes. Figure FAO (2021), adapted.

Description of method: Encircling gillnets are comparably large and set by boat. The boat drives in a circle to enclose an area, where fish aggregations have been noticed or are suspected. If the net-circle is closed, fish are scared with noises to make them flee into the nets and mesh themselves up. Scaring the fish into the net and closing the net might also be done simultaneously.

Suitability for water bodies / habitats: To be effective, the float line should swim on the surface while the lead line lies on the bottom. Therefore, encircling nets are useful for more shallow regions, but concrete depth of application depends on net height.

Selectivity: Like all gillnets, encircling variants are selective with respect to fish size, body shape and roughness of skin. In deeper waters, pelagic to superficial fish might be caught more effectively with this method because benthic fish are more difficult to flush and might hide in structures instead of swimming into the net. If the fishermen encircle specific fish aggregations noticed beforehand, the catch is highly selective with narrowed ranges of sizes and species.

Pros / Cons: Encircling nets provide the possibility to sample fish at habitats close to the shore of lakes and slow running rivers. It is possible to completely cover bays or bends with a haul. They can provide information on bigger individuals or sizes not caught with electrofishing. On the other hand, encircling nets are highly selective depending on the mesh size chosen. Thus, seining would be an alternative method to get more representative information on the fish community, which should be envisaged for most scientific investigations.

Aspects of method description and standardization: Encircling nets are a regular method in Indian freshwater fisheries. A precise description of the method includes gear (e.g. mesh size(s), net lengths, net height), selection of habitats, specifications of date and time and a measure of fishing effort (area covered). Details about the gear operation would describe how the net is set and how the fish are flushed. It would be possible to standardize scientific freshwater fish sampling with seines, but the authors are not aware of case examples or literature sources.

Summary: Encircling nets are used for fishing in comparably shallow areas. They are used for fishing in freshwater, but neither widely distributed nor frequently used. They are used to catch Snakeheads (*Channa* spp.), Perches (*Badis* spp.) or Carps (*Pethia* spp.) and mainly operated as described above, but sometimes similar to seines Pravin et al. (2009). Carps and perches are also collected using this method.
Scientific fish sampling with encircling nets could be executed using standardized procedures. ZSI used this technique in a survey in the Chandubi lake d obtained catches of *Parambasis ranga*, *Parambasis lala* and *Pethia conchonius*. However, we are not aware of regular scientific investigations with this method in India or elsewhere. Encircling nets are size selective and seining is an alternative method to get more representative information on the fish community, which is envisaged for most scientific investigations.

Further reading: Pravin et al. (2009), (Chakravartty et al. 2013), (Devi et al. 2013) describe the use of encircling nets in inland fisheries in North Eastern India.

A **purse seine** is a special encircling net characterized by the purse line at the bottom. Purse seines are not applied in Indian freshwater fisheries and therefore only shortly mentioned. The fish are encircled with the net and the purse line is closed to retain the fish. Purse seines can be very large and are operated by one or two boats (EC 2023; FAO 2023). In marine environments, purse seines are usually used for catching shoaling pelagic fish and are applied both for commercial and scientific purposes. In freshwaters, small purse seines could potentially be used for sampling pelagic waters of large and deep lakes, but the authors are not aware of any scientific application of this method.

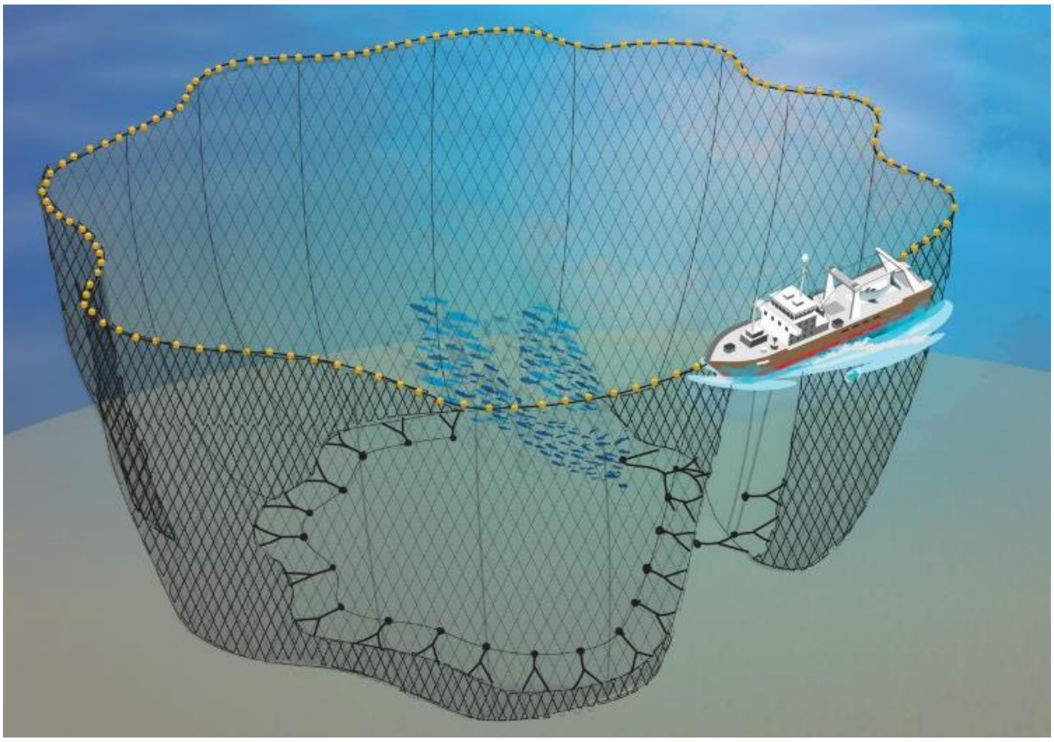


Figure 5: A purse seine. Figure FAO (2021), adapted.

4.6 Boat seines

Short description of gear type according to EC (2023); FAO (2023): Seines are long nets, with or without a bag in the center, which are set either for surrounding a certain area or a fish swarm. They are operated with two (long) ropes fixed to its ends for hauling and herding the fish. A boat seine is operated in the open water using two boats or a boat and a buoy. A beach seine is operated from the land.

Boat seines are used in Indian freshwater fisheries. Beach seines are not applied in fisheries or fish sampling and therefore only shortly explained at the end of the chapter.

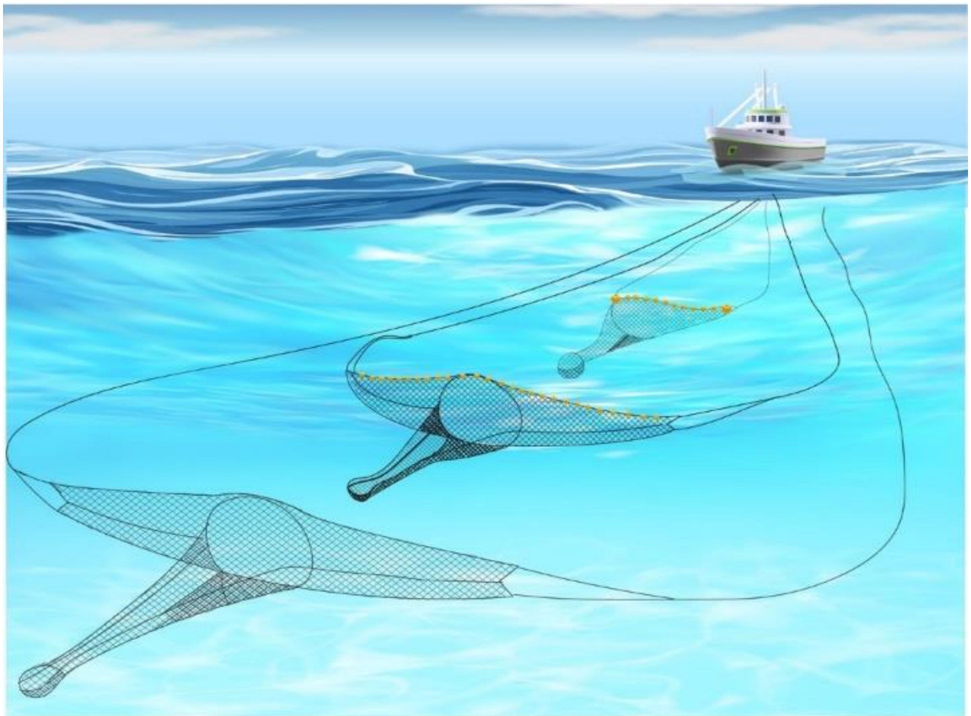


Figure 6: Boat seines close while they are towed to the boat. Figure FAO (2021), adapted.

Description of method: A boat seine consists of a central part with cod end, wings and long ropes. Central part and wings have an upper floating rope and a lower lead rope. For boat seining, one end of the net is attached to a buoy and released, either floating or fixed with an anchor. The boat then releases the net while encircling the designated area. After returning to the starting point, the net is retrieved and hauled. The ropes and the wings herd the fish into the central part of the net. The mesh size at the cod end determines the size of the fish caught.

Seines and trawls might look similar, especially if both have cod ends. However, the principle of seines is catching fish by closing the net, either in open water or by towing it to the land. Trawls, on the other hand, work by towing the open nets through the water and concentrating fish in the cod end.

Suitability for water bodies / habitats: Boat seines can be used in bigger open waters, either standing or slowly running. Seines scrape the ground and cover benthic or near-benthic habitats (depending on net height). The grounds have to be evenly shaped, free of snagging structures like rocks or trees and must not be covered by dense vegetation.

Selectivity: Fishing with seines primarily targets bottom dwelling or near-ground fish species and size classes. This functional selectivity is relative to the relation between water depth and net height. Seines are size-selective in dependence on the mesh size in the cod end or at the central part of the net - small mesh sizes catch more small fish, but bigger fish might escape because the hauling is slower.

Pros: Seines are an active fishing method and comparatively unselective with respect to fish size. They can provide a rather unbiased picture of the benthic or benthopelagic fish fauna of deeper regions of lentic waters.
Cons: Seining requires open, structure-free water bottoms. The method can damage bottom vegetation and organisms.

Aspects of method description and standardization: A precise description of the method includes gear (e.g. mesh size(s), net lengths, net height, rope lengths), selection of habitats, specifications of date and time and a measure of fishing effort (area covered by the closing net). Details about the gear operation would describe how the net is set. It would be possible to standardize scientific freshwater fish sampling with seines, but the authors are not aware of case examples or literature sources.

Summary: Boat seining applied in Indian freshwater fisheries, although rarely. It is practiced regularly in the Dheer Beel using two motor boats and nets with large mesh sizes. Different species of carps, perches and catfishes are collected with this technique.
Seines can provide comparably representative information about benthic fish communities in deeper water bodies. However, their operation is complex and time consuming and requires a boat and large water bodies with open grounds. To the knowledge of the authors, boat seines are not used for scientific freshwater fish sampling.

A **beach seine** is similar to a boat seine, but is operated from the land instead of a boat. Beach seines have cod ends in most cases, but sometimes the catching zones consists of smaller mesh sizes in the center of the net. In comparison to encircling gillnets fish are not gilled, and thus the catch is less selective and can include small individuals. Beach seines can be applied for scientic fish sampling in freshwaters (Lyons 1986; Pierce et al. 1990; Říha et al. 2008), e.g. for catching littoral species or juvenile individuals (Figure 7). They are of limited useability at vegetated shores or if submerged structures are abundant. Despite their potential to support investigation of littoral fish comunities, they are not frequently applied in fish science.

Figure 7: Scientists hauling a small beach seine designed for sampling juvenile fish. Photo J. Simon.

4.7 Trawls

Short description of gear type according to EC (2023); FAO (2023): Trawl nets are cone-shaped nets which are towed by boats on the bottom or in midwater. The horizontal opening of the gear is maintained by beams, otter boards or by the distance between two towing vessels in pair trawling. Floats and weights and/or hydrodynamic devices provide the vertical opening.
Draught nets are trawl nets (i.e. with fixed openings) that are set with boats and afterwards brought ashore with winches. Push nets are nets with fixed openings that are not towed behind, but pushed in front a boat.

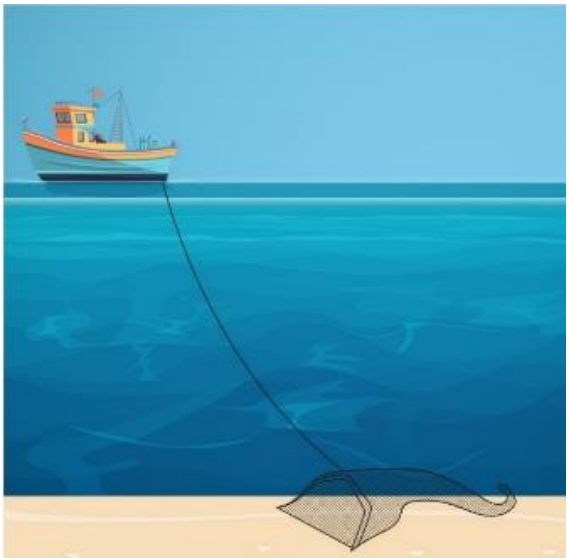


Figure 8: Scheme of bottom beam trawl. Figure FAO (2021), adapted.

Description of method: In trawling, the net is released from the boat and then towed. A variety of trawling methods exist, depending on net type, the way the net mouth is kept open horizontally (beams or otter boards) or vertically, the water depth of the net, the type of groundgear or the number of nets.

Suitability for water bodies / habitats: Trawls can be applied in lakes big enough to allow a significant travelling distance for the boat. Bottom trawling catches fish in benthic habitats, which must be free of snagging structures like rocks, trees or dense vegetation. Benthic trawling is likely to be more frequent in fisheries, while pelagic trawling is more frequent in fish sampling.

Selectivity: The configuration of the trawling gear determines the water depth of the nets and thus a functional selectivity towards bottom-dwelling or pelagic fish. The mesh size influences both minimum size of the retained fish and the towing speed of the net. Trawls with small mesh sizes catch small fish, but bigger fish might be able to escape the slowly moving net - whereas big mesh sizes catch big fish while small fish slip through the net.

Pros: Trawls is an active fishing method and comparatively unselective with respect to fish size. It can provide a rather unbiased picture of benthic, benthopelagic or pelagic fish fauna. **Cons:** Bottom trawling requires open, structure-free water bottoms. The method can heavily damage bottom vegetation and organisms. Trawling is methodologically complex and restricted to larger water bodies.

Possibilities for standardization: A precise description of the method includes gear (e.g. mesh size(s), net lengths, net height), selection of habitats (net depths), specifications of date and time and a measure of fishing effort (area covered). Details about the gear operation would describe how the nets are set. It is possible to standardize scientific freshwater fish sampling with trawls, but the authors are not aware of literature sources.

Summary: Trawling is restricted to bigger lakes. It is a complex method depending on specialised gear and boats. Trawling is a rare to absent in Indian freshwater fisheries. It is also rarely used in inland fisheries or scientific freshwater fish sampling worldwide. If applied, trawling gear is adapted to local conditions and specific scientific questions and therefore not standardized.

Further reading: General descriptions of different trawl fishing methods can be found in FAO (2021).

Trawling is a common fishing method in the coastal regions of India and used in industrial and artisanal fisheries. Its application in India has both positive and negative implications for the environment and the livelihoods of fishing communities. Large-scale industrial trawlers with powerful engines and sophisticated technology catch fish in significant quantities. This has led to concerns about overfishing. Trawling can have significant environmental consequences, such as damaging the seabed, destroying habitats, and causing bycatch of non-targeted species, including endangered marine life. This has raised concerns about the sustainability of India's marine resources. While industrial trawling has created job opportunities for many fishermen, it has also negatively impacted traditional fishing communities that rely on small-scale, artisanal fishing practices. Trawling has enabled India to meet the high demand for fish both domestically and for export. Efforts are being made to introduce more sustainable trawling practices in India.

4.8 Pots

Short description of gear type according to EC (2023); FAO (2023): Pots are cages or baskets, with dimensions ranging up to two meters, made from various materials. They might have one or more openings and are usually, but not always, set on the bottom. Pots can be baited.

Figure 9: Different pots used in artisanal fisheries in India. Photos S. Inaotombi.

Description of method: There is a huge variety of fishing pots used in India for catching fish and crustaceans. They work with the principle of tapered entrance(s), or connected tapering chambers. Fishing pots may or may not be baited. The pots can have the shapes of cylinders, boxes, or spindles and are made of all kinds of materials, but bamboo is frequently used in India. They are applied at all kinds of water bodies. Fish pots in general have to be surveyed and emptied regularly. It is not possible to provide an overview of Indian fish trap methodology here, please see last paragraph of the chapter for more literature with reference to India.

Suitability for water bodies / habitats: Fish pots are usually benthic and catch bottom dwelling fish seeking shelter or food. They can be operated in all kinds of water body types, but are mainly used in standing waters. Pots are advantageous in shallow, densely vegetated areas where other methods cannot be used.

Selectivity: Fish pots are highly selective. They catch benthic species that enter submersed structures. The size of the fishes caught is determined by the trap opening and the species composition of the catch will be influenced by potential baiting.

Pros: Pots can be used to catch fish species that might be difficult to catch with other gear, e.g. eel-like, flat-bodied, nocturnal or structure-bound species. The method is harmless to the fish and keeps them alive. Pots can be applied at habitats inaccessible with most other gear, e.g. densely vegetated wetlands or muddy shallows. **Cons:** Pots have to be controlled regularly. They are attached to a fixing point and are prone to loss, theft or vandalism. The catch is limited in number and selective in size and species.

Aspects of method description and standardization: A precise description of fish pots includes gear (e.g. length, width of pot and entrance, 'mesh' size), selection of habitats (water body type, depth, structures), specifications of date and time and a measure of fishing effort (number of pots, hours or days of exposition).

Summary: Pots are frequently used in Indian freshwater fisheries. There is a diversity of pot-types and their operation depends on fish species, environments, local traditions and maybe personal preferences. Pots have a limited potential for scientific fish sampling. Major drawbacks of the method are the need for regular controls, the small amount of fish caught and the selectivity. However, pots can provide information on certain species or habitats, and be used to catch living specimens. Pots have a restricted field of application and the authors are not aware of a proposal of a scientific routine for fish pots.

Further reading: Pravin et al. (2011a), Chakravartty et al. (2013), Das et al. (2015), Devi et al. (2013), and Gurumayum et al. (2009) provide comprehensive information on fish traps used in North Eastern India including pots, fyke nets, barriers, plunge baskets and shelter traps.

4.9 Fyke nets

Short description of gear type according to EC (2023); FAO (2023): A fyke net consists of cylindrical or cone-shaped netting bags mounted on rings or other rigid structures. It has wings or leaders which guide the fish towards the entrance of the bags. Fyke nets are fixed on the bottom by anchors, ballast or stakes. Fyke nets can be baited.

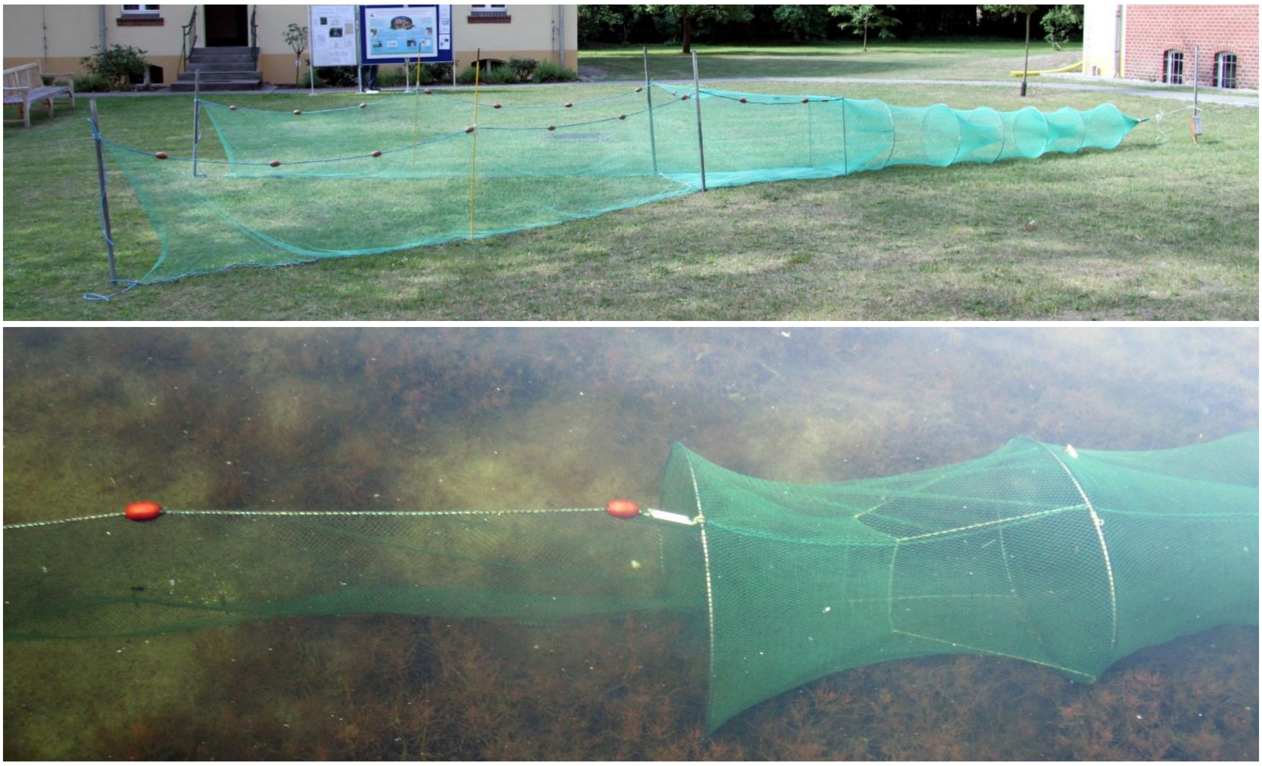


Figure 10: Above: A fyke net set up on dry land for demonstration purposes. On the left are the two wings, on the right the narrowing chambers. Below: A small fyke net with one central wing set in clear water. Photos J. Simon.

Description of method: Fyke nets are based on the principle of a tapered entrance or connected tapering chambers. Leading wings guide fish into the trap. Fyke nets differ from pots by their size and the wings. They are installed at shorelines of lakes or slowly running waters. Bigger ones are stationary. Fyke nets, like other fish traps, have to be surveyed and emptied regularly.

Suitability for water bodies / habitats: Fyke nets can be operated in the littoral areas of standing or slowly running waters. They predominantly catch benthic and littoral species, although the heights of trap and leading wings determine the range of the water column covered.

Selectivity: Fyke nets are stationary and catch fish passively. Fishes moving along the shoreline will be overrepresented in the catch. Therefore, the method is selective towards active, littoral species or life-stages. The minimum size of the fishes caught is determined by the mesh size in the final chamber of the trap. Baiting will also influence the species composition caught.

Pros: Once installed, fyke nets are comparably easy to operate and may provide fish at regular intervals. The method is comparably harmless to the fish and keeps them alive. Fyke nets catch a wide spectrum of fish species and sizes. **Cons:** Fyke nets have to be controlled regularly. They are installed at a fixed place and are prone to destruction and loss, theft or vandalism.

Aspects of method description and standardization: A precise description of fyke nets includes gear (e.g. length, width, height and mesh sizes of fyke net and wings, number of chambers), habitat (water body type, depth), specifications of date and time and a measure of fishing effort (days of exposition). It is possible to standardize fishing with fyke nets by precise recommendations for gear, habitat and effort. However, a potential standardization would only be useful for small and mobile versions and the authors are not aware of a standardized scientific routine.

Summary: Fyke nets are regularly used in Indian freshwater fisheries. There is a diversity of types and their operation depends on fish species and environments. Big fyke nets can be applied in streams, rivers or lakes (Pravin et al. 2011a), smaller variants made of bamboo (called *Phum*) are used for trapping hillstream fishes in the torrential rivers and streams of Manipur.

Fyke nets have a limited potential for scientific fish sampling. Main problems are that they are complex to install, catch low numbers of fish per time (usually) and have to be controlled regularly. Small, mobile fyke nets can be used for scientific sampling in field campaigns, e.g. if nocturnal littoral species are investigated and living individuals are needed. Stationary fyke nets are useful if a continuous (daily) control is possible, e.g. by cooperation with local partners. As an example, robust stationary fyke nets are used to control the effectivity of fish migration devices. Summarized, the application of fyke nets in scientific investigations is limited to special environments and species.

Further reading: Pravin et al. (2011a) provide a description of fyke nets used in Assam.

4.10 Pound nets (stationary, uncovered)

Short description of gear type according to EC (2023); FAO (2023): Stationary uncovered pound nets usually consist of net walls anchored or fixed on stakes, reaching from the bottom to the surface. The nets are open at the surface and include various types of fish herding and retaining devices. They are mostly divided into chambers.

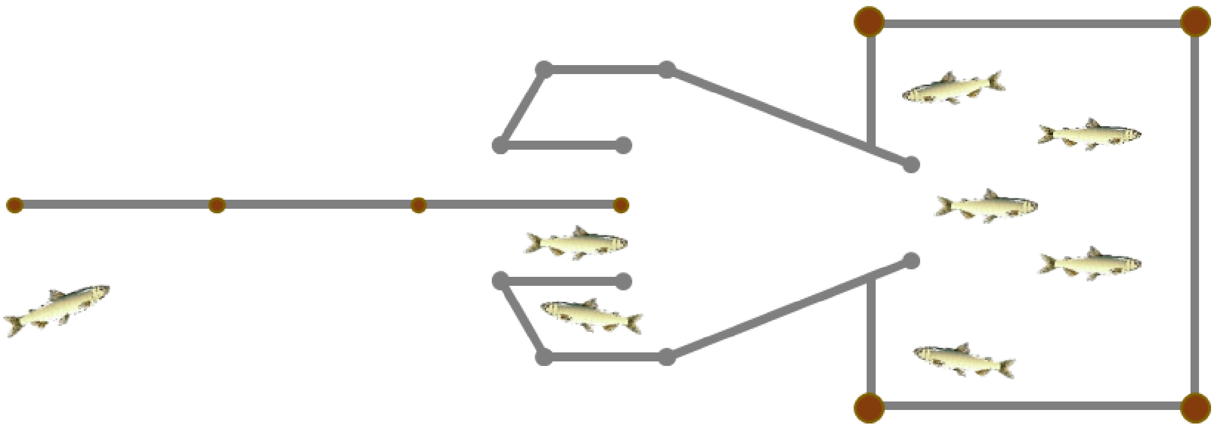


Figure 11: Above: Sketch showing the functioning of an uncovered pound net with wing, first chamber in the shape of a heart and pound (from left to right). Below: A fisher recovers fish by lifting the ground net in the pound. Sketch D. Ritterbusch; photo A. Sidow.

Description of method: Pound nets are based on the principle of a tapered entrance or connected tapering chambers and leading wings. Pound net nets differ from pots by their size and the more open construction. Usually, only the final chamber is closed at the bottom with a net to retrieve the fishes. Pound nets are permanently installed at shorelines or shallow areas of lakes or slowly running waters. Like other fish traps, they have to be controlled and emptied regularly.

Suitability for water bodies / habitats: Pound nets can be operated in the littoral areas of standing or slowly running waters. They predominantly catch littoral species, although lengths and heights of trap and leading wings might cover a wide range, both vertically and horizontally.

Selectivity: Pound nets are stationary and catch fish passively. Migrating fishes moving along the nearshore areas will be overrepresented in the catch. Therefore, the method is selective towards active, littoral species or life-stages. The minimum size of the fishes caught is determined by the mesh size in the final chamber of the trap.

Pros: The method is comparably harmless to the fish and keeps them alive. Pound nets catch a wide spectrum of fish species and sizes. **Cons:** Pound nets have to be controlled regularly and need maintenance. They are complex to install and emptying of the net is complicated and requires boats. Pound nets are permanently installed and are prone to destruction and loss, theft or vandalism.

Aspects of method description and standardization: A precise description of fyke nets includes gear (e.g. length, width, height mesh sizes, arrangement of wings and chambers, number of chambers), habitat (water body type, depth), specifications of date and time and a measure of fishing effort (days of exposition). Pound nets are adapted to local conditions and targeted fish, a standardized operation is unlikely.

Summary: The transition between pound nets and fish barriers with catching chambers is continuous. Fish barriers are used in Indian freshwater fisheries, for example between rivers and beels or to effectively barricade rivers and catch migrating fish (Pravin et al. 2011a). Pound nets have a very limited potential for scientific fish sampling because of their complex installation, control and maintenance. They could (theoretically) be useful at survey sites if continuous control is possible. However, the use of pound nets for freshwater scientific purposes is rare to absent and the authors are not aware of any proposal of a scientific routine.

4.11 Cast nets

Short description of gear type according to FAO (2023): A cast net is a cone-shaped net with weights and a drawstring which is cast by a fisher.

Figure 12: A fisher throwing a cast net in Dikhu River, Nagaland. Photo B. Shangningam.

Description of method: Cast nets are cone-shaped nets thrown into the water from shore or boats. The net lands on the water surface in circular shape and encloses fish while the outer lead line drags it under water. The net is then retrieved by a pull cord. Bags in the net or a cord arrangement which makes net-bags while pulling increase the retention rate.

Suitability for water bodies / habitats: Cast nets can be operated in all kind of water bodies, except at high currents or dense vegetation. They are used at littoral areas of standing or slowly running waters but can also be used to fish the surface areas of bigger water bodies. Cast nets primarily cover the water body very close to the surface - but benthic fish are caught in shallow waters. The efficiency of catching benthic fish depends on water depth, sinking speed of the net and flight distance of the benthic species.

Selectivity: Cast nets can be used to catch a wide range of species and specimen sizes, but the selectivity of this method is difficult to estimate. It depends on the mesh size; smaller mesh sizes reduce the minimum size of fish caught but also reduce the sinking speed, thus increasing the probability for bigger fish to escape. As mentioned, cast nets primarily catch fish at the water surface and bottom-dwelling fish will be underrepresented. Species with a high flight distance will react faster to the approach of the fisher, shape and shadow of the flying net and the noise of the impact on the water surface. There is also a selectivity by the fisher, who chooses the destination area of his cast (most likely not random).

Pros: Cast nets are small and mobile. They catch a wide spectrum of fish species and sizes. They can be used to specifically target fish aggregations or habitats of interest. Cast nets are comparably harmless to fish and keep them alive. **Cons:** Cast net operation is limited to the close distance of the fisher. Bottom-dwelling, "timid" and big fish are not caught or underrepresented.

Aspects of method description and standardization: A precise description of cast nets includes gear (e.g. mesh size, area covered on impact, bagging mechanisms), habitat (water body type, depth, structures), specifications of date and time and a measure of fishing effort (casts). Cast net fishing can be standardized based on gear an effort. However, the use of cast nest in scientific investigations of freshwater fish communities is rare to absent in international literature and the authors are not aware of a proposal of a scientific standard routine.

Summary: Cast nets are frequently applied in freshwater fisheries in India. They are used all over the country in a variety of water body types. They are widely and worldwide applied for a range of purposes in recreational (bait fish for anglers), artisanal (livelihood) and commercial (sampling ponds in aquacultures) fisheries. They have properties that make them useful for scientific fish sampling: highly mobile, definable fishing effort, possibility to sample shallow and very small water bodies, possibility to sample selected habitats or fish aggregations, active method with low selectivity against passive fish, caught fish are living.

Further reading: Chakravartty et al. (2013), Das et al. (2015), Gurumayum et al. (2009) describe cast nets used in different localities in North Eastern India. Casts nets are frequently used for scientific investigations in the region (Choudhury et al. 2018; Dey et al. 2018; Munilkumar et al. 2021; Talukdar et al. 2017).

4.12 Lift nets

Short description of gear type according to FAO (2023): Lift nets are horizontal net panels or net bags which are submerged, left for a while, and then lifted out of the water.

Figure 13: A portable shore operated lift net in Singra River, Assam. Photo B. Shangningam.

Description of method: Lift nets are combined with a rod in most cases. They can be small and lifted directly by hand, of intermediate size and lifted with a portable lever or attached to a permanent construction with levering beams. Boat operated lift nets are not used in freshwater fisheries. Fish are often attracted with baits or light.

Suitability for water bodies / habitats: Lift nets are operated from or directly at the shoreline in shallow waters. They can be applied in standing or slowly running waters.

Selectivity: Lift nets are lowered and then lifted after a certain time and possibly baiting. They catch the fish that swim into the water body above the net in the meantime. These will predominantly be smaller, pelagic individuals. It can be expected that bigger, hidden and benthic species / stages are entering the catching area later and in a smaller amount, but selectivity strongly depends on gear operation, like baiting and exposure time. No investigations about selectivity of lift nets have been available.

Pros: Lift nets can be small and very mobile. They potentially catch a wide spectrum of fish species and sizes. Lift nets can be constructed to catch very small fish and fish larvae. **Cons:** The catch is limited to fish that enter the area above the net and lowering of the net might scare fish. There are probably huge differences in catch in dependence on the individual operation.

Aspects of method description and standardization: A precise description of the lift nets includes gear (e.g. frame size, mesh sizes, lifting construction), selection of habitats (depth), specifications of date, time and lowering time and a measure of fishing effort (number of lifts). It would be possible to standardize scientific freshwater fish sampling with lift nets to a certain degree, but the authors are not aware of literature sources.

Summary: Lift nets are regularly used in Indian freshwater fisheries, especially in lakes and ponds. They are also operated in the rivers in monsoon season. In the Loktak Lake of Manipur, the fisherwomen operate the lift net on move from the edge of a boat.

Lift nets can be used for scientific fish sampling in shallow and littoral regions of many kinds of water bodies. Potential fields of application in dependence on mesh size are the investigation of small to intermediate fishes or the sampling of very small species or juvenile individuals that can be difficult or impossible to catch with other methods. Major drawbacks are the selectivity and difficulties to make fishing procedure comparable. It can be expected that lift nets contribute considerably to qualitative investigations (species or reproduction) but standardization is unlikely.

Further reading: Chakravartty et al. (2013), Das et al. (2015), Devi et al. (2013), Gurumayum et al. (2009) describe a variety of lift nets used in North Eastern India.

4.13 Hooks and lines

Short description of gear type according to FAO (2023): Hooks and lines are gear where the fish is caught by a natural or artificial bait placed on a hook fixed to the end of a line.

Description of method: There are many variations and combinations of hooks and lines:

- Handlines
- Hand-operated pole-and-lines (often with reels)
- Mechanized lines and pole-and-lines
- Longlines with a mainline and snoods with baited hooks at regular intervals (Figure 14)
- Hooks and lines can be used vertically or horizontally
- Hooks and lines can be set, drifting or trolled

Hooks and lines are used all over the world, at all water bodies and their application ranges from poles with fixed short lines and small hooks to catch small littoral fish close to the fisher up to the catch of big pelagic predators with drifting longlines of several kilometres of length. Hooks and lines are used for fishing for livelihood, recreational fishing, small scale fisheries and big scale commercial fisheries. A special, but not uncommon method of fishing with hooks and lines is snagging where unbaited hooks are vigorously jerked to pierce fish externally (outside the mouth). Snagging can cause harmful wounds and will not be considered in this chapter.

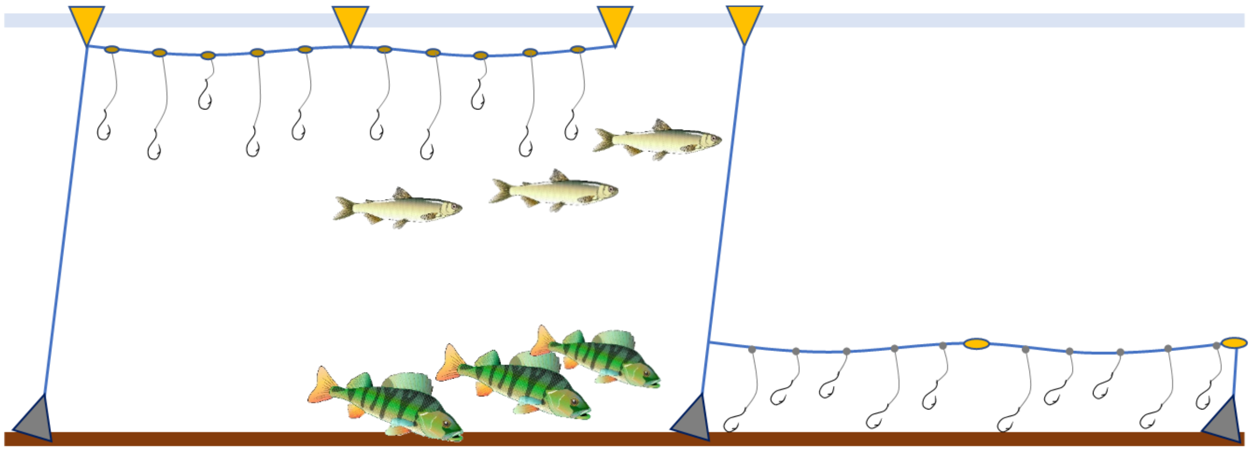


Figure 14: Scheme of longlines set at the surface (left) and at the bottom (right). Figure D. Ritterbusch.

Suitability for water bodies / habitats: Hooks and lines can be used in all kinds of habitats, but gear configuration might differ significantly; natural baits can be placed at designated habitats with floats or ground weights and a huge range of artificial baits covers all kinds of prey.

Selectivity: Fishing with hooks and lines is highly selective. The fish to be caught are dependent on hook size, bait placement, general bait category (plants, animals, artificial), bait type (e.g. invertebrates or fish) and bait size. A range of species cannot be caught by hooks and lines because of their food or feeding habits, e.g. some herbivorous, planktivorous, or filter feeding fish. Very small species or larval/juvenile stages also cannot be hooked.

Pros: Hooks and lines is a cheap, simple, mobile and very versatile gear. It can be used to specifically catch species or specimen sizes, e.g. for food or for verification of presence, that might not be caught with other gear. In most cases, fish mortality is low. **Cons:** Fishing with hooks and lines is highly selective. Besides being gear dependent, there is a strong component of "luck" determining quality and quantity of the catch. Luck means a combination of the fisher's knowledge of the environment, fish preferences and fish behaviour, his experience at the locality and his ability to adapt the gear to the given conditions, to choose baits and to present them in a tempting way.

Aspects of method description and standardization: A precise description of sampling with hooks and lines includes gear (hook size and type, number of hooks and distance between them, type of line, presentation), habitats (type, depth, distance from shore), bait, date and time and fishing effort (duration, total number of hooks for longlines). It is possible to standardize fish sampling with hooks and lines, but the method is rarely applied scientific investigations of freshwater environments.

Summary: Hooks and lines have a restricted potential for scientific fish sampling. Major advantage is the versatility and the possibility to catch species or specimen sizes difficult to catch with other methods. Drawbacks are the small area covered by the method, the low number of fishes caught per time, the difficult standardization and the impact of unmeasurable "luck" (see above). Catches with hooks and lines can be considered relevant for investigations of species inventories and have a certain potential for proving the presence or even for quantification of big predators. However, a regular implementation in scientific fish sampling and a standardization is unlikely.

Further reading: There are many literature sources about fishing with hooks and lines for commercial or recreational purposes, and also about scientific stock investigation using longlines in marine environments. Fishing with hooks and lines is very common in Indian freshwater fisheries. It contributes to self-supply with food, small scale commercial fishing, and recreational fishing. Please find below some selected sources with information about:

- hooks and lines used for self-supply or small-scale fisheries in Indian freshwaters (Devi et al. 2013) (Gurumayum et al. 2009)
- hooks and lines used for recreational fisheries in Indian freshwaters: Gupta et al. (2015a; 2015b; 2016; 2014; Gurumayum et al. 2009)
- hooks and lines used for scientific fish sampling in freshwaters (Arterburn et al. 2002; Diana et al. 2006; Hetrick et al. 2006; Kubečka et al. 2022; Kuriyama et al. 2019; Watson et al. 2023). Hooks and lines are predominantly used to catch larger predators like catfish. The method can be standardized and used for abundance estimates of target species, however, it is more of a niche technique in freshwater fish sampling.

4.14 Electrofishing

Short description of gear type according to FAO (2023): For fishing with electricity, an electrical field is generated in the water which narcotizes fish. The fish are then caught with a scoop net. Electrofishing is advantageous in shallow waters with obstacles and underwater vegetation.

Figure 15: Fishing with electricity from a boat in the shallow littoral of a lake. The left person steers the boat with a sculling oar, the right person fishes with the anode. Photo J. Simon.

Description of method: Electrofishing uses electricity to create an electric field in the water. The field is established between a positive, catching anode (often a metal ring with a scoop net) and a negative cathode. Fishes within the field have an uncontrollable reaction of the nervous system - they swim towards the anode where they are stunned. The immobilized fish are then scooped by the electrofisher or an accompanying catcher.

Electrofishing can be done by wading or boating. For wading, portable battery-powered backpack devices are used, or sometimes small generators on floats. If done by boating, bigger generators can be used to produce more and longer lasting electrical output. A variety of anodes exists for electrofishing by boat; the above-mentioned single metal hand scoop, one or several radial anodes fixed at the boat, or arrays of anode stripes in front or at the side of the boat.

The concrete implementations of electrofishing depend on the goals of the investigations: habitat-specific fishing can provide information about presence and abundance of specialized fish species while representative fishing of shoreline stretches provides information about community abundance and composition.

Electrofishing is a very common method for scientific fish sampling worldwide. The method can be comparably gentle with over 95 % survival of individuals caught (Janáč et al. 2011; Pottier et al. 2020; Teulier et al. 2018). Catching success and fish mortality are inversely related and influenced by the settings of voltage, the operation mode (direct current, pulsed direct current or alternating current), environmental parameters like salinity or temperature and fish species.

Suitability for water bodies / habitats: Electrofishing is effective in shallow waters with maximum water depths of 1-2 m. The limiting factors are wading depth, radius of the electric field, and the visibility of narcotized fish. The method can be applied in habitat conditions difficult to sample with other active methods: in dense aquatic vegetation, at boundaries of reeds, within fallen trees, shrubs, roots or branches, or between large stones. Electrofishing is predestined for shallow littoral areas. It is possible to sample the upper layers of open waters in big rivers or amidst lakes, but this is ineffective in most cases (very shallow big lakes or rivers might be exceptions). Standing or slowly running waters are easier to sample, torrential streams can be electrofished but require experience (e.g. scooping downstream the anode).

Selectivity: A wide range of species and size classes can be sampled with electrofishing. The method is selective for the species inhabiting shallow waters and structured habitats. Electrofishing is also size-selective. It is an effective and sometimes the only method to catch small, littoral and hidden species or the littoral juvenile stages of otherwise benthic or pelagic species. On the other hand, big individuals, good swimmers with high flight distances, and well camouflaged species are underrepresented in the catches.

Pros: Electrofishing can be comparably harmless to fish and environment and has the potential to catch a wide range of species and sizes. The method provides information about aspects that are difficult to estimate with other gear: fish community in structured habitats, shallow water species or juvenile stages. The active operation warrants a constant eye on the gear and the possibility to react to environmental conditions. **Cons:** Electrofishing is limited to shallow littoral areas and the upmost water body near the surface. It has a reduced efficiency at low salinities and low water visibility. If not operated adequately and carefully, it can be lethal for fish and dangerous for fishers. A specific training and protective clothing should be mandatory. If electrofishing is legally forbidden, scientific fish sampling might require special permits, and thus organisational effort.

Aspects of method description and standardization: A precise description of sampling with electrofishing includes gear (e.g. manufacturer, settings, operation mode), selection of habitats (vegetation, substrate), specifications of date and time and a measure of fishing effort. The fishing effort is essential for standardization. Various measures are applied: the time spent fishing, the length of the sampled stretch or the number of dips (a dip is one plunge of the anode). The time spent for fishing is the least useful. Length is often used as a measure for effort for representative fishing of shoreline stretches with the aim to get an overview of the fish community composition. Dips are used to apply the so-called point-abundance estimation, i.e. the abundance of fish within the radius of the electric field. Dips are an advantageous unit for habitat-specific fishing or estimates of densities. Both stretch length and dips can be converted to area based on the field radius - however, comparability between the units is limited because stretch length does not exclude the stretches between the dips.

Summary: Electrofishing has a high potential for scientific sampling. The method is useful in streams and rivers where other gears are not possible to operate. It provides the overall species composition in torrential streams and is effective in collection of hillstream fishes. Different fishing strategies can be pursued and standardization should be done accordingly. The results are applicable both for qualitative inventories and quantitative population estimates. Main advantage is the methods potential to efficiently sample fish habitats and species unavailable to other gear. Main drawback is the need for special training to ensure an application which is gentle to the fish and safe for the fishers.
Electrofishing is illegal in India with the threat of severe punishments. Despite this fact, it is not uncommon and carried out with different gear from self-made electro shockers with car batteries to the use of overhead electric lines. Illegal fishers thus expose themselves to considerable danger and death (Balachandran et al. 2013). The extent of illegal electrofishing and its damage to fish populations, other organisms and environments are not documented (Sankararaman 2019). Information based on illegal fishing practices cannot contribute to scientific sampling, as fishers won't distribute their knowledge.

Further reading: Gurumayum et al. (2009), (Rahman 2020) mention the application of electrofishing in local fisheries North Eastern India. Electrofishing is also used for scientific investigations in the region (Choudhury et al. 2018; Dey et al. 2018; Munilkumar et al. 2021; Talukdar et al. 2017) and elsewhere in India. With respect to standardization of quantitative sampling, detailed descriptions of electrofishing gear and operation are provided by Reynolds et al. (2012), and Bonar et al. (2009b) describe varieties of electrofishing standards in different water body types.

4.15 Scoopnets (syn. dip nets)

Short description of gear type according to FAO (2023): Scoop nets are small hand operated devices formed like bagnets and used to scoop fish out of the water.

Figure 16: Scoopnetting for scientific sampling at Doloni Beel in Assam (left) and Chakpi River in Manipur (right). Photos B. Shangningam.

Description of method: Scoopnets are made of a frame holding a net bag. Scoopnets are widely distributed but construction and handling differ substantially depending on local habits, fields of application and target species. Scoopnets can used as scoops, pushed forward as pushnets or backwards as manual "dredges". The latter two types of scoopnets have reinforced frames.
Scoopnets are actively operated by hand. They are in most cases operated in wadeable waters and therein limited to depths, where the nets can be moved fast enough to catch fish. Scoopnets can also be used from boats. Scoopnets are mainly used in small scale fishery. The final catching process of electrofishing and of hook and line is often done with scoopnets, but the present chapter focuses on an operation independent on additional gear.

Suitability for water bodies / habitats: Scoopnets have advantages in shallow, wadeable, and structured environments. Examples are densely vegetated shallows, marginal reeds, roots of floating plants, rocky bottoms or woody banks. Their application is limited by water depth, currents, size of the scoopnet frame and meshsize of the bag. Scoopnets might become ineffective if structures leave only narrow gaps that cannot be fished.

Selectivity: Scoop nets catch species or sizes of fish with comparably low flight distances, i.e. slow ones or those hiding in structures. They can be applied in littoral and shallow benthic habitats and are useful to catch small, hidden, structure bound, specialized or unobtrusive fishes - characteristics which are typical for rare, protected, or endemic species. With a high suitability for small littoral fish, scoopnets may be used to catch juveniles or even larvae.

Pros: Scoopnets are small, portable and cheap. They are actively used in special habitats, where sampling with other gear might be difficult or even impossible - thus enabling researchers to sample habitats often used by target species of nature conservation. Scoopnets can be used to catch small and very small individuals. Fish caught by scoopnets are alive and can immediately undergo further treatment (measuring) or be released.
Cons: Scoopnets can only be operated in shallow waters and sampling can be time-consuming and physically demanding. The catch is highly selective for species and sizes.

Aspects of method description and standardization: A description of scoopnets includes form, size and material of frame and handle as well as material, size and mesh size of the net bag. The description of the concrete operating in field shall specify date and time and include a habitat characterisation (water depth, vegetation, bottom structure). Catches should be analysed separately for different habitats (to derive species requirements). The effort of scoopnetting can be described using the number of individual scoops and the number of working hours spent for scoopnetting (number of persons and total time). A standardization of scoopnet-fishing requires a specification of the gear and the effort recommended per habitat. Because of the active manual operation, it can be assumed that the personal effect of the fisher on the fishing success is high. The individual know-how of promising habitats, the capacity to approach fish without chasing them away and strength, speed and agility in scoopnet handling will have major, but unmeasurable influences.
Scoopnets are widely distributed, target specialized species and can catch fish alive. There is literature describing scoopnets. However, the authors are not aware of a description of a standardized scoopnet fishing procedure, even otherwise comprehensive compendia of fishery and fish sampling techniques provide no information.

Summary: Fish caught with scoopnets are alive and in good condition, the method is very important for the catch of ornamental fish, which is economically important in many regions of India. Scoopnets can be used in shallow, structured habitats to catch specialized fish species. Therefore, it has a high potential for scientific fish sampling. However, scoopnets are highly selective and the focus of the method lies in proving presence of rare, specialized or endangered species, i.e. in assessing species' inventories. A standardized application for investigations of abundance and community composition still has to be developed, a suggestion is provided in chapter 5.4.2.

Further reading: Fishing with scoopnets is a frequent method in Indian freshwater fisheries. Scoopnets can be handcrafted, are cheap, easy to operate and target small fish which are preferred for human consumption in India. They are used all over the country and in shallow habitats of a variety of freshwater bodies.
Chakravartty et al. (2013), Das et al. (2015), (Devi et al. 2013), Gurumayum et al. (2009) describe scoopnets used in North Eastern India. As mentioned, we did not find recommendations for a standardized application of scoopnets in scientific fish sampling.

4.16 Observations, visual detections

Description of method: This chapter describes the investigation of fish by directly observing them in their natural environment. Under certain circumstances, it is possible to determine species, counting individuals and sometimes even estimate their lengths. Thurow et al. (2012) classify observations into three categories: surface (land-based, aerial, boat-based), underwater by divers (snorkel, scuba) and remote methods (cameras with or without remotely operated vehicles). At smaller rivers or shallow lakes with clear water, fish **observations** from outside the water can be possible and reliable. Experienced specialists might be able to identify several species by just walking along the shore and observing the fish. In narrow rivers, counting of individuals per stretch length is also possible. Fish observations are probably the easiest, cheapest and fastest way for mapping distribution areas and for quantitative monitoring of certain fish species (Tiberti et al. 2022). In rivers and streams with limited currents, in bigger water bodies or at greater depths, **snorkelling or scuba diving** can provide information about species and abundance. **Cameras** can be stationary, they are often installed at sites with high fish densities or baited. Moving underwater cameras can be operated by divers or mounted on remotely operated vehicles. Visual observations are especially promising at aggregations, for example spawning fish at shallow shores or migrating fish stopped by barriers.

In some cases, it is possible to indirectly identify the presence of fish species with structures that are unequivocally associated with them, examples are specific caves, spawning holes, or remains left by predators.

Pros: Visual detections are non-destructive and harmless to the observed fish. They provide additional information about habitats and observers could extract detailed habitat mapping and species-specific preferences of micro-habitats. Visual detections from the shore need no special equipment except polarized sunglasses. **Cons:** Visual detections by diving and the operation of remote vehicles require special training and equipment. Documentation of findings can be problematic without highly specialized camera equipment.

Selectivity: Fish observations are highly selective and restricted to clear waters, specific habitats, and a limited number of species. Identification of species is difficult for small fish, similar species (e.g. mid-sized, semi-round and silver), or good swimmers with high flight distances. Cryptic and nocturnal species will not be observed. The probability of observation can depend on age/size of the individuals, e.g. big individuals might be observed at spawning sites during spawning time but remain undetected throughout the rest of the year because of high flight distances.

Aspects of method description and standardization: Visual fish censuses and surveys can be standardized by defining strip width, depth, swimming speed, and time of assessment. A standardized abundance can refer to the number of individuals observed per investigated stretch length.

Summary: Fish community investigation by visual detections is not a common method for freshwaters, but several applications have been made. Despite the bias of the visual methods, they show comparable or even superior results to invasive fishing gears (which are also biased, but differently). Visual detections are limited to clear waters. An implementation of a sophisticated fish observation methodology including standardized censuses with divers or remotely operated vehicles is rather unsuited for sampling conditions in Indian freshwaters. Most water bodies are turbid and fish communities are often composed by a high number of small species, which cannot be identified by observing them in the water.

Further reading: Scientific investigations by visual methods are abundant in marine environments, especially at reefs. For freshwaters, Thurow et al. (2012) provide an excellent compilation of techniques for fish observations. Examples for scientific visual investigations of freshwater fish and comparisons with other methods are Hankin et al. (1988), Holubová et al. (2019), Jordan et al. (2008), Macnaughton et al. (2015), Mayo et al. (2006), and Turner et al. (1985). No explicit application of visual techniques in scientific fish investigations in Indian freshwaters was found, but visual detection surely is a major source of local knowledge (see next chapter).

4.17 Using local knowledge: Interviews, creel surveys, fishery statistics

Description of method: The gathering of scientific data by tapping local knowledge is not a fishing method, but nonetheless an effective way to gain information about water bodies, species inventories, compositions and abundances. A lot of information obtainable by local knowledge cannot be obtained otherwise. We use the term 'local knowledge' to summarize all kind of helpful information that can be gained by asking people that have experience with the water body of interest and the fishes within. Sources of information can be fishers residing there, other locals but also game anglers who came as tourists. Local knowledge includes traditional, artisanal or tribal sources, but also those based on modern fishing gear.
The type of information that can be gathered with local knowledge is highly diverse and depends mainly on the locals themselves: their profession and interests, their attitude towards nature and fish, and their willingness to share their knowledge. Some examples of local knowledge valuable for scientific investigations may be:

- the environment
    - long-term and/or large-scale: land use in the region, climate,
    - shorter scale: weather
    - the catchment: dams, upstream water abstraction, dry-outs
- the water bodies
    - long term changes: physico-chemical water traits (e.g. transparency), algal blooms, shoreline and aquatic vegetation, in- or decreases of predator abundance
    - short term, possibly catastrophic events: floods, discharge of nutrients or pollutants, destructive fishing events
    - anthropogenic stressors: rural run-offs, local abstractions, discharges, use intensity, shoreline degradation, fishery methods and intensity
- the fish community
    - species inventories
    - species composition
    - appearance/loss of fish species, both native or alien
    - die-offs
    - semi-quantitative information (e.g. a species stock increased)
    - information about size and reproduction (big individuals caught, observations of juveniles)

Suitability: Local knowledge can support the investigations of all water bodies within the reach and interest of local residents.

Selectivity: Local knowledge is highly selective and much more accurate for noteworthy species; i.e. edible or tasty fishes, species with special body shapes, flashy colours or big sizes and those well known by traditional or religious reasons.

Pros: Local knowledge can support sampling at nearly all water bodies. In many cases, not only the current situation is depicted, but comparisons to former conditions can be made. Local knowledge is useful, effective and inexpensive and some kind of informal interview with local fishers or a common look at their catches should be included in every sampling campaign, if possible. **Cons**: Despite the many possibilities offered by local knowledge, there are many limitations. Hereafter, we focus on limitations concerning the fish community, but those relating to environment and water body are comparable. The quality of information depends on the observer, i.e. his skills in determining fish species, the general knowledge of ecology, his presence at the water and his personal motivation to make observations and draw conclusions. Reliable local knowledge about the fish community will in most cases be restricted to presence or rareness of selected species and maybe an impression, if these species' population increased or decreased.

Aspects of method description and standardization: Local knowledge about fishes is based on observations and catches with local fishing gear. There are countless different local fishing methods in India. Drift nets and set nets are used to catch bigger fish and frequently applied in bigger waters like lakes or lower stretches of rivers. Lift nets, fish traps and scoop nets are used to catch small fishes and represent the common gear in smaller rivers, at shallow inundation areas, or in the beels. Their local application depends on region, water body type and targeted fish species. The gear is manufactured with a wide range of materials, from traditional bamboo scoops to modern monofilament nylon nets.
If compiling local knowledge, the investigator should make efforts to precisely describe the fishing methods (details are provided in the previous chapters). However, a standardization of gear and effort is almost never possible. While gear information might be obtainable, effort data are very unreliable - few fishers will prepare precise statistics of effort and catch without further need. In some cases, it might be possible for scientific institutions to cooperate with local fishers by contracting them to provide their statistics including effort (e.g. number of nets or pots set, daily catch). This kind of cooperation offers an opportunity to obtain long-term information.
Fish market surveys are a good possibility to obtain additional information about the local fish species inventory. Huge numbers of fish and different species might be present at fish markets; but the offer is skewed towards good selling fish for livelihood. Fishmongers frequently can provide additional information about the origin of their goods.
Surveys of anglers are also local knowledge. There are some complex approaches using standardized questionnaires, creel surveys or web-based applications. These methods are not relevant for scientific investigations in India, because fishing for recreational purposes has only local importance.
The analysis of local knowledge is exposed to a degree of uncertainty. The investigating person will have to evaluate the individual reliability and species-specific expertise of their local partners.

Summary: Local knowledge can provide positive evidence of the presence of well-known species that can unambiguously be identified. Sometimes semi-quantitative information or population trends will be available. Local knowledge is less suitable for species with similar appearance, for inedible fish or fish not caught for livelihood by other reasons, rare or hidden species, and species treated as functional groups (e.g. loaches, minnows, catfishes). Local knowledge can add valuable information to scientific surveys but is insufficient to gain comprehensive information about the fish community, especially about rare, endangered or confoundable species.

Further reading: Local knowledge is a widely used source of information in Indian scientific literature about fish and fishing gears (Bene et al. 2009; Chakravartty et al. 2013; Das et al. 2015; Devi et al. 2013; Dubey et al. 2023; Gupta et al. 2015c; Gurumayum et al. 2009; Inaotombi 2019; Inaotombi et al. 2016; Inaotombi et al. 2019; Kalita et al. 2010; Mandal et al. 2015; Mohite et al. 2017; Parida et al. 2013; Prasad et al. 2013; Pravin et al. 2011a; Pravin et al. 2011b; Pravin et al. 2009; Puri, R. 2023, Raju et al. 2016; Sandhya et al. 2020; Syed et al. 2016; Verma 2015; Verma et al. 2022). The authors use a range of methods to gather local or traditional knowledge: from personal observations to conversation, structured questionnaires and interviews.

5 Developing a standard procedure for scientific fish sampling - exemplified for North-Eastern India

5.1 Introduction

Descriptions of fishing standards for scientific purposes exist to some extent. Bonar et al. (2009b) provide a comprehensive guide to fish sampling methods and standardization in North American freshwaters and conclude that gill nets, electrofishing and fyke nets are the best methods. For Europe, EN 14962 (2006) in combination with EN 14011 (2003) for electrofishing and EN 14757 (2015) for multimesh-gillnetting represent a comprehensive standardization. Large scale standardizations of fish sampling methods are possible, making fishing results comparable on bigger geographical ranges and time scales (e.g. Emmrich et al. 2012; Mehner et al. 2021; Ritterbusch et al. 2022; Trochine et al. 2018).

However, it is futile to simply convey these standards to most other regions of the world, where different water bodies, different fish communities and different possibilities to access sampling sites prevail. Multimesh gillnets cannot be set in densely vegetated water bodies and might not be appropriate for fish communities with predominantly small specimens. Electrofishing gear needs special training and safety measures, and maintenance cannot be guaranteed during long-lasting fishing campaigns in remote areas without access to technical infrastructure. Not to speak of the fact that aims and objectives of scientific investigations can differ significantly from the above-mentioned examples.

The following chapter shows the fishing methodology of the Zoological Survey of India applied in surveys in North Eastern India. It includes already applied methods and standards as well as descriptions of standards planned for the future. The aim of the chapter is not only to a provide a description of a concrete standard but to show how the theoretical suggestions for standardization given in the previous chapters can be practically implemented.

5.2 Step 1: Defining the objectives

For a scientific fish sampling event, the demands on fishing gear, effort and documentation strongly depend on the objectives of the investigation. Data obtained with scientific fish sampling might be divided into four categories.

Species inventories are lists of species occurring at a certain place based on comprehensive knowledge of their presences. Species inventories are valuable tools for conservational issues, e.g. red lists or protected areas. Geographical distribution maps can be created which provide information about habitat requirements of species. Inventories are also used for ecological indication. Surveys aiming at compiling inventories have frequently discovered new species.
For surveys, a variety of sampling gear fishing for different species and sizes in different habitats will provide highest numbers of species - especially if a huge fishing effort is applied. For the proof of presence of specific species adjusted gear with particular gear modification (e.g. mesh size) and application in suitable habitats need to be chosen. The main challenge for compiling species inventories is the estimation of the probability of species' absences. Even if targeted with high effort, the absence of a species is never determined with certainty, but only made likely.
Species inventories require a basic standardization. Generally, the guideline "the more the better" is applicable, but this recommendation has limited practical value. Therefore, standardization is implemented by defining minimum requirements: description of gear that has to be applied at least, definition of sampled habitats, and specification of minimum effort per habitat and gear.

Species compositions are relative descriptions of fish communities based on species' percentages of number or weight. They are a valuable tool for ecological indication, e.g. to evaluate local conditions or impacts of pressures. Besides the local status, species compositions can also be analysed with respect to differences between sites or temporal changes. All fishing methods are selectively applied in specific habitats and catch fish within a gear specific size range (as shown in chapter 4). Species compositions are therefore always related to the deployed gear and the sampling routine. Consequently, obtaining reliable data about species composition needs a high level of standardization. The gear, gear specifications, number of gears used, fished habitats and fishing effort have to be specified in detail.

Species abundances are absolute values for abundance of species described by standardized catches of number or weight. Measuring the abundance of species is useful for analysing ecological indication, status of populations, differences between sites and temporal developments. Additionally, abundance data are needed for evaluating fish stocks of species without relating to other species: It is a difference if a population is evaluated as vanishing because of a decreasing abundance or because of increasing abundance of other species (composition). Abundance data are essential in most fish and fishery models based on stock abundance, population structure and fishery yield. These models are used for estimating perspectives and management plans.

Similar to composition data, abundance data are always related to the deployed gear and the sampling routine. Species abundance does usually not represent the true abundance (number or weight) of species or all the fish in a water body but standardized catches are used as proxies. Exceptions are drainable ponds or very small and easily accessible water bodies.
Obtaining reliable data about species composition needs a high level of standardization. The gear, gear specifications, number of gears used, fished habitats and fishing effort have to be specified in detail - fishing effort is particularly important.

Size data represent the sizes of fish at a site: minimum length and size distribution. A huge number of small individuals of a species indicates reproduction, and size data can be used to analyse population structure and growth. Size data can be useful for ecological indication, proof of the presence of spawning habitats, evaluation of recruitment or size-specific mortality, and estimation of growth conditions.
Size data are dependent on gear and gear operation, especially on the gear specifications that determine the size of the catch (e.g. mesh size).
The required level of standardization for size data collection depends on the scientific aims: proof of juveniles or reproduction might be obtained with targeted and non-standardized gear selection and operation. The evaluation of a population structure, however, requires a high level of standardization, and the gear has to cover a reasonable range of size classes of the targeted species.

Several other aspects play a major role in the decision-making process for standardization besides the data categories needed for future analyses.

Perspective and repeatability: Before implementing a standard, it has to be decided if the objective of the fish sampling is a singular event targeting specific conditions at a specific site at a specific moment. Investigations might be narrowed down, clearly defined and unlikely to be repeated. In this case, an appropriate fishing method or combination of methods has to be chosen, but no standardization is needed. A standardization has to find a compromise between a customized methodology for specific objectives, fish communities and water bodies and a generalized methodology for wide application and comparability. If investigations are to be repeated and the results compared, a standardization is necessary. This applies to repeated sampling of a site to investigate temporal changes and to the comparison of sampling results at different sites. In-site standardization comprises standardization of the gear and its application. It makes sure, that the same gear is always operated in the same way. Between-site standardization provides guideline for fish sampling within comparable water bodies (see Chapter 3 for water body types). The gear must be usable in any water body of the corresponding type, a comparable operation must be possible, and it should be suitable for all type-specific fish communities.

Practical implementation: Several non-scientific aspects are decisive in the possibilities to develop and implement a standardized fishing procedure. The gear and its operation must be:

- affordable concerning acquisition, maintenance and wear costs,
- mobile and technically sustainable within the conditions of remote field trips,
- manageable within the limits of manpower, time and physical performance of the sampling teams,
- manageable within a reasonable degree of training and specialization of the personnel,
- safe.

Regardless of the investigation's objectives, results are rarely meant to stand alone; rather, scientists aim to find correlations between fish traits and environmental parameters, structural conditions, habitat types, or anthropogenic stressors. Therefore, defining standards for specific scientific objectives requires not only the standardization of fishing methods but also a consistent set of **environmental descriptors** that are measured, recorded, and analyzed with equal diligence. A set of potential descriptors is proposed in the field protocols in chapter 6, including climate, weather, morphometry, hydrology, and the physical and chemical characteristics of sampled water bodies, stretches, or sites.

The Zoological Survey of India (ZSI) was established on 1916 to promote survey, exploration and research to advance knowledge of the exceptionally rich biodiversity in India. Scientists in ZSI are engaged in exploring, naming, describing, classifying and documenting animals from all over the country. The current primary objectives of ZSI are identification and monitoring of species, analysis of biodiversity, conservation, sustainable use of biodiverse resources and environmental impact assessment. Thus, species inventories are a major focus of fish ecology and fish sampling.

The following standard description for fish sampling in North Eastern India aims to improve current methods and increase their future comparability. Changing fishing methods would not have been appropriate; the methodology is adopted to the prevailing conditions of field trips, water bodies, and fish communities, and a significant change of methods would have made future data incomparable with the existing ones. As recommendable for sampling species inventories of fishes, scientists at ZSI use a wide range of methods: cast nets, scoop nets, gill nets and local knowledge like interviews or fish market surveys. ZSI regularly contacts local fisherman and uses all information available based on fish catches with local or traditional gear.

In India limited scientific information exists on the freshwater fishing villages, crafts, and gears, which could be valuable for designing effective sampling plans. Fishing practices not only vary across different regions but also change seasonally within the same area. In northeast India, local fishermen have adapted various methods to harvest fish. For instance, in lakes and reservoirs, boats equipped with gill or seine nets are often used for regular fishing. Fish specimens are collected from these catches using multiple techniques throughout the year, including nets, traps, hooks, hand-picking, and purchasing from fishermen or fish markets. Although some traditional fishing communities use plant poisons for community fishing, harmful practices such as dynamiting and electrofishing are sometimes employed in remote areas but are actively discouraged by local authorities due to their environmental impact. The ecological damage caused by destructive fishing methods is becoming more recognized, leading to greater awareness and advocacy for sustainable practices.

For any fish collection effort, the primary goal should always be to ensure comprehensive sampling across all habitats within the aquatic system. It is important to assume that fish are present in all areas—whether on different bottoms, depths, or along varying environmental features—unless proven otherwise. Effective fish collectors strive to gather specimens from diverse habitats, such as riffles, pools, ponds, weed beds, riverbanks, shoals, and deep waters, employing suitable techniques and gear tailored to each specific environment. Local fishermen possess valuable knowledge about fishing techniques and gear, making collaboration with them essential for the success of fish collection efforts. Their insights, especially regarding non-commercial species, can be critical for scientific studies.

Although fishing can be conducted at any time, in regions with intense summer heat, such as Assam, collections are typically made in the early morning or evening further night fishing using short seines is also practiced. Unconventional habitats, including caves, wells, and swamps, may harbor unique species; for example, blind loaches and mahseer have been found in the caves of Meghalaya. Depending on the environment, available resources, and the skills of the collector, a representative fish collection can be assembled using techniques such as hand-catching. Scoop nets are effective for bottom-dwelling fish and those living in aquatic vegetation, while cast nets are predominantly used in slow-flowing, shallow streams to catch surface and shallow-water species. In deeper areas, dragnets are deployed where the distance between banks is not extensive. Reservoirs and other deep-water bodies often utilize gill nets along the shore, set at various depths (floating, bottom-set, and column-set), while longlines with hooks are used for species like eels, minnows and carps. Bamboo baskets are particularly useful for catching true loaches fish like cobitids and nemacheilids in sandy habitats, and long seines are effective for mid-water species. Anglers use rods and tackle to catch game fish such as mahseers and trout.

In hill streams, fish collectors sometimes construct temporary bunds by damming the river and diverting the stream, allowing the riverbed to dry. This exposes species like loaches, sisorids, and torrent minnows, which can then be hand-picked from beneath rocks and boulders. Unfortunately, traditional fishing practices often overlook smaller fish species, such as *Balitora*, *Erethistes*, *Pseudolaguvia*, *Akysis*, *Glyptothorax*, *Parambasis*, and *Psilorhynchus*. However, modern conservation efforts emphasize upon the sustainable fishing techniques and the protection of all species, including smaller and less commercially valuable fish, to preserve biodiversity and the overall health of aquatic ecosystems. To avoid indiscriminate fishing, ichthyologists often collaborate with experienced local fishermen to ensure a more selective and sustainable approach to fish collection.

We decided to implement standards for these well-established methods, and hence, we provide gear specifications to assure the application of identical gear in future. We also provide operational guidelines to ensure consistency in the application of fishing gear. Additionally, we enhance the level of detail for estimating effort by specifying units, methods of quantification, and clear requirements for data logging. Our aim is to maintain the compilation of species inventories but to open up future possibilities for the evaluation of species composition and, to some extent, for species abundance and size analyses. The standardization should increase the opportunities for comparisons between fishing sites and for analysing time series.

5.3 Step 2: Type-specific methodology

As a main step of a standardization, we specify the recommendations for gear application in the relevant water body types. Table 4 provides an overview, details about the gear can be found in the next section 5.4.

The gear type selection aims to cover a wide range of habitats, species, and specimen sizes. It is comparable with former investigations and provides a basis for future comparability. We are aware that the method combination needs to be improved in providing data for certain habitats and fish: deeper benthic habitats in lakes, pelagic habitats in lakes and deeper mid-stream riverine habitats are not represented well; big fish are likely to be underrepresented. However, the combination of gear promises a good overview of species inventories, an approach to composition and a perspective for investigations of abundance of selected species. It provides a good proof of small fish, i.e. the analyses of reproduction, but analyses of population structure analyses may be possible for small species only.

Table 4: Fishing gear for standardized fish sampling in water body types of North-Eastern India.

Nr.	Type Name	Cast nets	Scoop nets	Gill nets	Lift nets	Locals
1.1.1	Lowland River	*			*	*
1.1.2	Mid-Altitude River	*	*			*
1.1.3	High-Altitude River		*			*
1.2.1	Lowland Stream	*		*[1]		*
1.2.2	Mid-Altitude Stream	*	*			*
1.2.3	High-Alt. Stream		*			*
2.1.1	Lowland Poly Lake	*	*	*	*	*
2.1.2	Lowland Strat Lake	*		*	*	*
2.2.1	Mid-Alt. Poly Lake	*	*	*		*
2.2.1	Mid-Alt. Strat Lake	*		*		*
2.3	High-Alt. Poly Lake	*	*	*		*
	High-Alt. Strat Lake	*		*		*
3.1.1	Lowland Channel	*				*
3.1.2	Mid-Alt. Channel	*				*
3.1.3	High-Alt. Channel	*	*			*
3.2.1	Lowland Ditch					*
3.2.2	Mid-Alt. Ditch		*			*
4.1.1	Lowland Reservoir	*		*		*
4.1.2	Mid-Alt. Reservoir	*		*		*
4.1.3	High-Alt. Reservoir	*		*		*
4.2.1	Lowland Pond	*	*		*	*
4.2.2	Mid-Alt. Pond	*	*			*
4.2.3	High-Alt. Pond	*	*			*

1: only in backwaters

5.4 Step 3: Defining a standardized methodology

5.4.1 … for cast nets

Gear specification: The cast nets used by ZSI in North Eastern India are described in Table 5.

Table 5: Specifications of cast nets used by ZSI for fish sampling in North Eastern India

Abbr.	Specifications	value
CastN01	Application	streams
	Diameter	2000 mm
	Area covered	3 m²
	Mesh size / material	white nylon, 8 mm
	weight	2000 g
	Max casting distance	5 m
CastN02	Application	rivers
	Diameter	3000 mm
	Area covered	7 m²
	Mesh size / material	White nylon, 14 mm
	weight	3500 g
	Max casting distance	6m
CastN03	Application	Lakes (from boat)
	Diameter	5000 mm
	Area covered	20 m²
	Mesh size / material	white nylon, 24 mm
	weight	8000 g
	Max casting distance	10m
CastN04	Application	ponds
	Diameter	3000 mm
	Area covered	7 m²
	Mesh size / material	White nylon, 32 mm
	weight per diameter	3000 g
	Max casting distance	2

Sampling routine (operation, habitats, water body types): Cast nets are thrown from the shore or in nearshore water within wadeable depths (Figure 17). The caster approaches the target area slowly, evenly and avoiding fast movements. The casting distance is limited. Therefore, water depth in the sampled area usually is between 0.5 and 2.0 m in streams and rivers. The effectivity of cast nets decreases in deeper waters because the time from surface to ground contact increases, i.e. the time needed to enclose the fish. Cast nets are applied at nearly all water bodies, but not at higher currents. The net types applied at each water body type are shown in Table 6. During a sampling event, all distinguishable habitats should be sampled with cast nets (different currents, ground substrates, vegetation types). The targeted sampling area shall not be too vegetated and the ground must be clear from obstacles like roots or big stones. Entering the habitat description in the field protocols is essential to allow future analysis of composition and abundance parameters in comparable habitats.

Because both gears sample similar habitats, cast nets and scoop nets shall be applied at separate stretches of river or lake shores.

Specification of effort: Effort is measured as number of casts and standardized catches can be given as number/weight per cast. In combination with the gear specification, effort can be transferred to sampled area, with standardized effort given as number/weight per m^2 of net area. This might be relevant for comparing catches of cast nets with similar mesh sizes but different areas.

The catch data should ideally be analysed and transferred to the protocols for each cast separately. If this is not possible, catch data obtained by similar casts with the same type of cast net at the same habitat can be combined.

Figure 17: Fish sampling with a cast net in Doloni Beel in Assam. Photo B. Shangningam.

Table 6: Standardized effort for fish sampling with cast nets in water body types of North-Eastern India.

Nr.	Type Name	Cast net type	Minimum effort per net type
1.1	Rivers	CastN01, 02	20 casts, 1 cast per 10/20 m river stretch
1.2	Streams	CastN01	20 casts, 1 cast per 20 m stretch, both shores
2.1	Lowland Warm Lake	CastN02, 03	25 casts per 100 ha of lake area
2.2	Mid-Alt. Cool Lake		30 casts per 100 ha to ensure coverage of habitat complexity in mid-altitude lakes.
2.3	High-Alt. Cold Lake		35 casts per 100 ha to ensure adequate sampling across the typically deeper and colder zones.
3.1	Channels		20 casts, 1 cast per 20 m river stretch
3.2	Ditches		No casts
4.1	Reservoirs	CastNO2, 04	25 casts per 100 ha of reservoir area
4.2	Ponds	CastNO4	50 casts per 100 ha of pond area

Species: Cast nets catch small to intermediate species in littoral or shallow benthic regions up to depths of 2 m in the streams and rivers. Examples of genera/species caught with cast nets are: *Schistura, Devario*, *Danio*, *Barilius, Mastacembelus, Garra, Pethia, Glyptothorax, Puntius*, and *Cyprinus* as examples for common fish with high importance for ecologic functionality or people's livelihood, and *Neolisochilus*, and *Tor* for rare or endangered genera/species of high conservational value.

5.4.2 … for scoop nets

Gear specification: The scoop nets used by ZSI in North Eastern India are described in Table 7.

Table 7: Specifications of scoop nets used by ZSI for fish sampling in North Eastern India

Abbr.	Specifications	value
Scoop01	Application	streams
	Frame material-shape	Wood - Trapezium
	Frame length	100 cm
	Frame perimeter	300 cm
	Opening surface area	2.6 m^2
	Handle length	20 cm
	Bag length	80 cm
	Mesh size / material	White nylon, 1.5 mm
Scoop02	Application	rivers
	Frame material-shape	Bamboo - rectangular
	Frame length	150 cm
	Frame perimeter	700 cm
	Opening surface area	2.1 m^2
	Handle length	150 cm on both side
	Bag length	150 cm
	Mesh size / material	Nylon, 0.6 mm
Scoop03	Application	lakes
	Frame material-shape	Bamboo - Triangle
	Frame length	180 cm
	Frame perimeter	400 cm
	Opening surface area	1.61 m^2
	Handle length	30 cm, sometimes no handle
	Bag length	180 cm
	Mesh size / material	blue nylon, 0.3 mm

Sampling routine (operation, habitats, water body types): Scoop nets are used in the operator's immediate vicinity (Figure 18). The scooper approaches the target area slowly, evenly and avoiding fast movements. The water must be wadable and depth in the sampled area usually is between 0.2 and 1.2 m. Scoop nets are applied in littoral habitats of many water bodies. The target areas should be structured - scooping becomes ineffective in open habitats above smooth substrates, especially if the water is clear. During a sampling event at a site, all distinguishable habitats should be sampled with scoop nets (different currents, ground substrates, vegetation types). The scoop net types applied at each water body type are shown in Table 8. Cast nets and scoop nets shall be applied at separate stretches of river or lake shores.

Table 8: Standardized effort for fish sampling with scoop nets in water body types of North-Eastern India

Nr.	Type Name	Scoop net type	Minimum effort per net type
1.1	Rivers	Scoop01, 02	40 scoops, 1 scoop per 2/5 m river stretch, both sides
1.2	Streams	Scoop01, 02	40 scoops, 1 cast per 2/5 m stretch, both shores
2.1	Lowland Warm Lake	Scoop003	60 scoops per 100 ha of lake area, because of variability in depth and vegetation
2.2	Mid-Alt. Cool Lake	Scoop003	70 scoops per 100 ha, as cooler lakes may have more diverse or less accessible microhabitats
2.3	High-Alt. Cold Lake	Scoop003	80 scoops per 100 ha to account for the difficulty in accessing fish in high-altitude lakes
3.1	Channels	Scoop01, 02	40 scoops, 1 scoop per 2/5 m river stretch
3.2	Ditches	Scoop01, 02	30 scoops, 1 scoop per2/5 m river stretch
4.1	Reservoirs	Scoop01, 02	70 scoops per 100 ha of lake area, reservoirs are large and can have varied depth profiles, high effort to cover different zones
4.2	Ponds	Scoop01, 02	60 scoops per 100 ha of pond area, ponds are smaller, but vegetation or shallow areas require effort for accurate sampling

Specification of effort: Effort is measured as number of scoops and standardized catches can be given as number/weight per scoop. The opening area and an estimated mean scooping length allow an estimation of the sampled water volume. Therefore, standardized can also be given as number/weight per m³ of scooped volume. This might be relevant for comparing catches of scoop nets with similar mesh sizes but different opening areas.
Entering the habitat description in the field protocols is essential for future analyses of composition and abundance parameters in comparable habitats. The catch data should ideally be analysed and transferred to the protocols for each scoop separately. If this is not possible or inconvenient, scoops at the same habitat are counted and combined catches might be analysed.
As mentioned in the methodology section, there is no information about standardization of scoop net fishing. The present chapter is meant as a proposal. ZSI will test the recommendations in practice and compare standardized catches. The results should reveal, if the number of scoops was chosen appropriately and how strong the influence of the scooper's skills and experience on the catches are.

Species: Scoop nets catch small species in littoral or shallow benthic regions up to depths of 1.2 m. Examples of genera/species caught with scoop nets are the hillstream fishes, *Glyptothorax, Schistura, Lepidocephalichthys, Garra, Balitora, Pangio, Pseudecheneis, Pseudolaguvia, Amblypharhyngodon, Psilorhynchus, Cabdio, Pethia, Parambasis, Devario, Channa* for common species with high importance for ecologic functionality or people's livelihood, and *Erethistes*, *Schizothorax*, *Badis* for rare or endangered genera/species of high conservational value.

Figure 18: Sampling shallow waters with scoop nets at Chakpi River in Manipur (left) and Kakoijana stream in Assam (right). Photos B. Shangningam.

5.4.3 ... for gillnets in general

Gear specification: The gillnets used by ZSI in North Eastern India are described in Table 9.

Table 9: Specifications of gill nets used by ZSI for fish sampling in North Eastern India

Abbr.	Specifications	value
GillN01	Application	Lakes, reservoirs, rivers, ponds
	Net length	25 m
	Net height	1 m
	Material, mesh size	Blue nylon, multimesh
	Topline length/boyancy	0.25 m / corkline
	Leadline length/weight	0.05 m / 3 kg/100m
	Number /length of panels	multimesh with 5 panels / 5 m each
	Mesh sizes of panels	05 / 10 / 15 / 25 mm
GillN02	Application	Lakes, reservoirs, rivers, ponds
	Net length	6 m
	Net height	0.6 m
	Material, mesh size	White nylon, 17 mm single mesh
	Topline length/boyancy	0.2 m
	Leadline length/weight	0.04 m
GillN03	Application	Lakes, reservoirs,
	Net length	15 m
	Net height	2.5 m
	Material, mesh size	Blue nylon, 30 mm single mesh
	Topline length/boyancy	0.5 m
	Leadline length/weight	0.4 m
GillN04	Application	Lakes, rivers
	Net length	12 m
	Net height	2 m
	Material, mesh size	Blue nylon, 35 mm single mesh
	Topline length/boyancy	0.5 m
	Leadline length/weight	0.03 m

Sampling routine (operation, habitats, water body types): Gillnets are operated as benthic set nets and applied in standing and running waters, i.e. rivers, lakes, reservoirs and ponds. Gillnets are operated in the rivers throughout the year except in the monsoon season. The sampling team tries to cover a variety of depth zones using boat and echosounder to identify target areas. The nets should be distributed evenly among the lake or randomly at the shores. Areas with dense vegetation or branched obstacles should be avoided. In rivers, the gillnets are exposed before dusk and lifted after dawn. Occasionally, the gillnets are set in the day for a period of 4-5 hours at the shores of the rivers or reservoirs.

The numbers of gillnets of each type applied at different water body types are shown in Table 10. In few cases, gillnets are applied in the lentic backwaters of streams, but no standard is proposed for this.

Figure 19: Above: Pelagic gillnet set in Doloni Beel in Assam. Below: Short gillnets used in lentic stretches of Khudengrim River of Meghalaya. Photos B. Shangningam.

Specification of effort: Effort is initially measured as number of nets set for one night each (gillnet-night). For catches with the same gillnet type, standardized catches can be given as number/weight per gillnet-night. For comparison of catches with those of other gillnets, standardized catches are calculated as number/weight per 100 m² of net area and gillnet-night.

Habitat descriptions cannot be provided for benthic nets but setting depth shall be recorded. This allows the analyses of depth-dependent standardized catches or compositions. The catch should be analysed and protocolled for each net separately.

Species: Gillnets catch intermediate to big individuals in benthic regions. Examples of genera caught with gillnets are: *Barilius, Garra* for common species with high importance for ecologic functionality or people's livelihood, and *Raiamas, Botia, Tor* for rare or endangered species of high conservational value.

Table 10: Number of nets set in different depths for standardized sampling with gillnets in standing waters of North-Eastern India. Effort is given as gillnet-nights and depends on area (tables from above to below) and depth (rows) of the water body

Area < 50 ha	00-05 m	05-10 m	10-20 m	20-50 m	> 50 m
GillN01	4	4	3	2	-
GillN02	4	4	3	2	-
GillN03	4	4	3	2	-
GillN04	4	4	3	2	-

Area 50-100 ha	00-05 m	05-10 m	10-20 m	20-50 m	> 50 m
GillN01	6	6	5	3	2
GillN02	6	6	5	3	2
GillN03	6	6	5	3	2
GillN04	6	6	5	3	2

Area 100-200 ha	00-05 m	05-10 m	10-20 m	20-50 m	> 50 m
GillN01	8	8	7	4	3
GillN02	8	8	7	4	3
GillN03	8	8	7	4	3
GillN04	8	8	7	4	3

Area 200-500 ha	00-05 m	05-10 m	10-20 m	20-50 m	> 50 m
GillN01	10	10	8	5	4
GillN02	10	10	8	5	4
GillN03	10	10	8	5	4
GillN04	10	10	8	5	4

Area 500-1000 ha	00-05 m	05-10 m	10-20 m	20-50 m	> 50 m
GillN01	12	12	10	6	5
GillN02	12	12	10	6	5
GillN03	12	12	10	6	5
GillN04	12	12	10	6	5

5.4.4 … for pelagic gillnets

Gear specification: The pelagic nets used by ZSI in North Eastern India are described in Table 11.

Table 11: Specifications of pelagic nets used for fish sampling in North Eastern India

Abbreviation	Specifications	Value
PelN01	Net length	50 m
	Net height	4 m
	Material, mesh size	Clear nylon, multimesh
	Topline length/buoyancy	0.4 m / buoyed corkline
	Leadline length/weight	0.05 m / 2 kg/100 m
	Number/length of panels	5 panels / 10 m each
	Mesh sizes of panels	10 / 15 / 20 / 30 / 40 mm
PelN02	Net length	25 m
	Net height	3 m
	Material, mesh size	Clear nylon, 15 mm single mesh
	Topline length/buoyancy	0.3 m / buoyed corkline
	Leadline length/weight	0.04 m / 1.5 kg/100 m

The **sampling routines** for pelagic nets are provided in Table 12.

Table 12: Sampling routines for pelagic nets applied by ZSI

Water Body Type	Pelagic Net Type, minimum effort, sampling routine
Lowland Warm Lakes	PelN01, PelN02
	15 nets per 100 ha of lake area
	nets set at varying depths (0-4 m for PelN01, 0-3 m for PelN02)
Mid-Alt. Cool Lakes	PelN01
	20 nets per 100 ha of lake area
	nets set at varying depths to target fish in different zones
High-Alt. Cold Lakes	PelN02
	25 nets per 100 ha
	nets set at varying depths to cover surface and mid-water species
Reservoirs	PelN01
	15 nets per 100 ha
	Placed along depth profiles from surface to deeper waters (0-4 m)
Rivers, Channels	PelN02
	10 nets per 100 m stretch of river
	placed in areas with visible pelagic fish movement

Speficiations of efforts: Pelagic nets are essential tools for sampling mid-water and surface-dwelling fish species in the lakes, reservoirs, and rivers of Northeast India. These nets are deployed at various depths to capture a range of pelagic species, with efforts tailored to the size and type of water body. For example, in larger lakes and reservoirs, 15 to 25 nets per 100 hectares are typically set at depths ranging from 0 to 4 meters, ensuring comprehensive coverage of the pelagic zone. Overnight setting of the nets, from dusk to dawn, maximizes the catch of species that are more active during the night. This method provides valuable data on fish diversity and abundance in the region's unique aquatic ecosystems.

Species: Pelagic nets are designed to capture fish that live in the open water, away from the shore and the bottom. These nets are typically set at various depths in the water column, targeting fish species that swim in mid-water or near the surface rather than along the bottom.

5.4.5 … for benthic gillnets

Gear specification: The benthic nets used by ZSI in North Eastern India are described in Table 13.

Table 13: Specifications of benthic nets used for fish sampling in North Eastern India

Abbreviation	Specifications	Value
BentN01	Net length	20 m
	Net height	1 m
	Material, mesh size	Blue nylon, 25 mm single mesh
	Topline length/buoyancy	0.3 m / buoyed corkline
	Leadline length/weight	0.05 m / 2 kg/100 m
BentN02	Net length	50 m
	Net height	1.5 m
	Material, mesh size	Clear nylon, 30 mm single mesh
	Topline length/buoyancy	0.4 m / buoyed corkline
	Leadline length/weight	0.06 m / 3 kg/100 m
	Number /length of panels	5 panels / 10 m each
	Mesh sizes of panels	10 / 15 / 20 / 30 / 40 mm

The **sampling routines** for benthic nets are provided in Table 14.

Specifications of efforts: Benthic nets are used for sampling fish species that live near or on the bottom of shallow water bodies, such as lakes, reservoirs, and rivers in the littoral zones (0–10 meters depth). These nets are typically set in areas with submerged vegetation, rocks, or soft substrates, where benthic species are most active. Designed for flexibility in shallow environments, benthic nets vary in size and mesh configurations, allowing researchers to capture a wide range of species. They are generally deployed overnight, from dusk to dawn, to maximize efficiency and capture nocturnally active fish. Shorter daytime sets can be used in rivers because the nets cannot be left unattended overnight. Benthic nets provide valuable data on fish communities in habitats that are often overlooked by other net types.

Species: Benthic nets in Northeast India are effective for capturing various bottom-dwelling fish species that inhabit the region's lakes, rivers, and streams. Some of the key species of Northeast India include *Glyptothorax spp.* (Torrent Catfish), *Neolissochilus hexagonolepis* (Copper Mahseer), *Schizothorax spp.* (Snow Trout), *Botia dario* (Bengal Loach), and *Channa stewartii* (Stewart's Snakehead), which are commonly found in rocky or sandy substrates of rivers and streams. Other species like *Pangio pangia* (Barred Loach) and *Garra spp.* (Stone Suckers) are also frequently caught in these nets due to their preference for shallow, fast-flowing waters and bottom habitats. These nets provide valuable insights into the diversity of fish species that inhabit the benthic zones.

Table 14: Sampling routines for benthic nets applied by ZSI

Water Body Type	Pelagic Net Type, minimum effort, sampling routine
Lowland Warm Lakes	BentN01
	20 nets per 100 ha
	Set in shallow areas near shoreline (0-10 m depth)
	Overnight (dusk to dawn)
Mid-Alt. Cool Lakes	BentN01
	25 nets per 100 ha
	Set near shore with submerged vegetation or rocky areas
	Overnight (dusk to dawn)
High-Alt. Cold Lakes	BentN01
	30 nets per 100 ha
	Set in shallow areas near boulders or logs
	Overnight (dusk to dawn)
Reservoirs	BentN02
	20 nets per 100 ha
	Set along edges of reservoirs in shallow zones
	Overnight (dusk to dawn)
Rivers, Channels	BentN02
	10 nets per 100 m river stretch
	Set along riverbanks or slow-moving sections
	Daytime (4–6 hours)

5.4.6 … for local knowledge

The gathering of local knowledge by ZSI is not standardized. However, we stress the importance of personal interactions with locals and invest significant effort into this essential source of information. Local knowledge is a vital source of information and data. Fishermen, local communities, and indigenous people often possess a wealth of information about the aquatic ecosystems in their region. Local individuals have a deep understanding of the fish species present in a particular water body. Resident fishermen are familiar with specific fishing techniques that are effective in capturing fish species under the given conditions. They use traditional fishing gear and equipment well-suited for capturing specific types of fish. Local techniques involve traditional practices that have been passed down through generations. Furthermore, fishermen often have detailed knowledge about the preferred habitats of different fish species. Thus, they offer insights into the seasonal behaviours of fish, such as spawning periods, migration patterns, and changes in feeding habits. Locals contribute to understanding the impact of environmental changes on fish populations and guide researchers in selecting relevant study sites.

Local knowledge is especially helpful for fish inventories. ZSI applies a wide range of methods to tap into local knowledge:

- Interviews
- Creel surveys
- Fish market surveys
- Questionnaires
- Oral Interaction

ZSI tries to get an impression about overall species abundance and stock development asking for categorical estimations (absent/rare/steady/common/abundant). Blending local knowledge with scientific data enhances the overall quality and comprehensiveness of fish species inventories. With respect to fish data quality, local knowledge might be prone to represent individual impressions. It is of minor use for analyses of composition and abundance. Gear specifications, sampling routines, and efforts applied by the local fishermen are often not identifiable, let alone can they be standardized.

Besides information on fish, ZSI also gains expertise of fishery intensity at the sampling site and gathers information about local fisheries management regulations (e.g., size limits, gear restrictions). Interviews are very helpful in estimating the local pressure intensity and identifying catastrophic events in the recent past. In northeast India, fish hold cultural significance in many communities. Local knowledge can shed light on the importance of certain fish species for food, rituals, or traditions.

Ultimately, involving local communities in fish collection activities fosters collaboration, builds trust, and promotes a sense of shared responsibility for the conservation of aquatic resources. This engagement can lead to more sustainable and community-supported research initiatives.

5.5 Perspective

The Zoological Survey of India (ZSI), being the leading organization of the Government of India, remains committed to its main aim of evaluating and maintaining comprehensive inventories of India's biodiversity including the freshwater fish biodiversity. One of the primary aims of ZSI is to ensure that these inventories are based on rigorous and standardized data collection methods, which are critical for long-term conservation and management efforts.

In the previous chapters of the manual, we proposed standardization protocols for fish sampling techniques. Unlike other published approaches, this proposal does not describe an established standard but rather introduces a new framework specifically for the Eastern region that is subject to future evaluation. This flexibility allows us to refine and improve the methods based on real-world sampling data and analyses, ensuring that the standards are robust and applicable across various regions of India.

Our proposed standardization focuses on a selection of the most commonly used fishing methods in India. By creating consistent protocols for these methods, we aim to improve the comparability and reliability of data across different studies and regions. These methods have been selected based on their frequent application in Indian freshwater systems and their effectiveness in capturing diverse fish species.

Further, if more data is collected using these standardized methods, future analyses will allow us to assess the feasibility and accuracy of analyzing fish composition, abundance, and community structure through this approach. The success of these methods will ultimately depend on their ability to provide reliable data for monitoring and conserving the fish biodiversity of the region. Therefore, the iterative process of evaluation and refinement will ensure that the proposed standards evolve to meet the needs of ongoing scientific research and conservation efforts.

6 Field Protocols

6.1 Introduction

On the following pages, we provide templates for protocols for fishing sites, gear and fish catch. The proposal of templates for protocols aims at two aspects: provide an overview of relevant information that needs to be recorded and ease the establishment of standardized field protocols in future planning of field trips. The protocols are suggestions of the authors based on their experiences, with support from Chandra et al. (2018). The protocols can, of course, be adapted to upcoming needs or special research questions. Examples are the replacement of latitude and longitude by waypoint IDs or the addition of haul date, if not all nets are hauled the next day. We provide the following templates:

- Base data: include site descriptions with general and more or less invariable information about the water body. Examples are type, name and geographical position. The site description is usually not done in the field but during planning of the fishing campaign. For standing waters, the whole water body is described in most cases. For running waters, the site description might be separated into a base description of the whole river and an additional description of the investigated river section.
- Campaign: includes information about the specific date and time of sampling and the conditions during the sampling event. The environmental information recorded here is potentially variable (although it might be constant for years).
- Gear protocol: The gear protocol is used for recording date, time, location and microhabitat conditions for the application of an individual gear. It also includes information about effort, which is essential for standardization.
- Catch protocol: includes the basic fish traits measured in the field: number, length and weight. Lab protocols might differ, e.g. include sex, age, or other measures of interest.

The protocols include selected environmental descriptors, e.g. for the morphology of sampled waters, habitat types, or anthropogenic stressors. The selection consists of common measurements, but focuses on the needs of the current investigations of ZSI.

6.2 Lakes - field protocols

Lakes - Base Data

Site			
Lake **name**		Lake type	
State		National Code/ID	
Main catchment			
Longitude		Inflows	
Latitude		Outflows	
Altitude			

Size			
Area		Max. depth	
Shoreline length			
Max. length			
Max. width			

Region			
Forest type		Average temperature	
Terrain type		Average precipitation	
Soil type			

Lakes - Campaign

Campaign			
Date Start		Institution	
Date End		Team	
		Project	
Aim		Methods	
Weather		Temperature at campaign	
		Precipitation at campaign	
		Water level at campaign	
Comments			

Structure Substrate		**Structure Shoreline**	
Gravel		Reeds	
Cobbles		Submerged plants	
Boulders		Forest edges	
Bedrocks		Sandy beaches	
Fine sand		Stony shores	
Slit		Steep banks	
Clay		Settlements	

Human Impacts on lake		… in surroundings	
Shoreline modification		Natural	
Water withdrawal		Settlements	
Nutrient pollution		Agriculture	
Other pollution		Nutrient pollution	
Use (bathing, boating)		Pesticides	
		Mining	

Fishing	
Fishing intensity	
Bycatch	
Discards	

Potential categories for grey fields:
- absent, low, medium, high, very high
- absent, rare, common, frequent, dominant
- percentages: e.g. 0, 5, 10, 25, 50, 75, 100 %

Lakes - Gear

Lake	
Date	
Gear Type	

Separate page for each gear type

Gear ID / Code	Date	Time	Longitude	Latitude	Effort (number)	Water depth	Habitat

habitats: open water / reeds / macrophytes / forest edges / beaches / stony shores / steep bank / settlement

Modifications: the gear protocol shall be modified according to the gear. The **specification of the effort is essential** for the calculation of abundances and must be done according to the gear. Examples are a) number for nets, hauls, throws or dips, b) stretch length for electrofishing, c) number of casts/lifts for cast nets/lift nets, or d) hours of exposure for set nets or traps. For nets and traps, the addition of haul date and haul time is recommended, and the depth of setting is important for pelagic nets. For fishing gear referring to shoreline stretches (e.g. electrofishing), the values of Long/Lat for the end of the stretch might be added.

6.3 Rivers - field protocols

Rivers - Base Data

Site			
River Name		State	
Main Catchment		National Code/ID	
River Type			
Total length		Total Catchment Area	
Source		**Mouth**	
Longitude		Longitude	
Latitude		Latitude	
Altitude		Altitude	
		Flowing into	

Rivers - Campaign

Campaign			
Date Start		Institution	
Date End		Team	
		Project	
Aim		Methods	
Depth at campaign		Weather	
Width at campaign		Temperature at campaign	
Velocity a. c.		Precipitation at campaign	
		Water level at campaign	
Comments			

Structure Substrate		**Structure Shoreline**	
Gravel		Reeds	
Cobbles		Submerged plants	
Boulders		Forest edges	
Bedrocks		Sandy beaches	
Fine sand		Stony shores	
Slit		Settlements	
Clay			

Human impacts on river stretch		**… in surroundings**	
Barriers (dams, weirs)		Natural	
Shoreline modification		Settlements	
Sedimentation		Agriculture	
Nutrient pollution		Nutrient pollution	

Other pollution		Pesticides	
Bottom (dredging)		Mining	
Water withdrawal			
Use (bathing, boating)			

Fishing	
Fishing intensity	
Bycatch	
Discards	

Potential categories of grey fields:
- absent, low, medium, high, very high
- absent, rare, common, frequent, dominant
- percentages: e.g. 0, 5, 10, 25, 50, 75, 100 %

Rivers - Stretch data

River stretch and river size at stretch			
River Name		Next Settlement	
Stretch Name		National Code/ID	
River Stretch Type		Longitude	
Distance from source		Latitude	
Distance f. confluence		Altitude	
Mean width		Mean slope of stretch	
Mean depth			

Region			
Forest type		Average Temperature	
Terrain Type		Average Precipitation	
Soil type			

Rivers - Gear protocol (refers to concrete sampling site and microhabitats)

River	**Stretch**
Date	
Gear Type	Separate page for each gear type

Gear ID / Code	Date	Time	Longitude	Latitude	Effort (number)	depth	shore	Habitat

Shore: left / right / total
River habitats: fall (fast) / riffle (fast, shallow, over boulders) / run (smooth unbroken, connects riffle with pool) / pool (slow, deep) / settlement
Stream habitats: open water / reeds / macrophytes / forest edges / beaches / stony / steep bank / settlement

Modifications: the gear protocol shall be modified according to the gear. The **specification of the effort is essential** for the calculation of abundances and must be done according to the gear. Examples are a) number for nets, hauls, throws or dips, b) stretch length for electrofishing, c) number of casts/lifts for cast nets/lift nets, or d) hours of exposure for set nets or traps. For nets and traps, the addition of haul date and haul time is recommended, and the depth of setting is important for pelagic nets. For fishing gear referring to shoreline stretches (e.g. electrofishing), the values of Long/Lat for the end of the stretch might be added.

6.4 Catch protocol (lakes and rivers)

Lake	
Date	
Gear Type	
Gear ID/ Code	

Separate page for each gear used

Species	Length	Weight	Length max	Number	Sex	Ind ID

It is important to complete one catch protocol for each gear application (GearID). This is needed to track if no fish was caught (use "no catch" in this case) or if the protocol it was forgotten or lost. Species shall be documented with photos, if possible showing taxonomically relevant body structures.

Length max and number are added for group measurements. This might become necessary if shoals of juvenile fish are caught. If multiple fish are entered in one line, Length represents the minimum individual length in the group, Length max the maximum length, and weight the total weight of the group. Sex data (female/male) is optional and depends on the detectability of sexual dimorphisms. Sex can be evident in various ways, including size, coloration, and reproductive structures. This is often observed in hillstream fishes. During breeding season, males may develop brighter and more vibrant colours or structures for transferring sperm. Females may have structures associated with egg-laying. Sex might be undistinguishable for many species in the field or outside the spawning season (unless the body cavity is opened). IndID is added to link individual fish to their photos or to samples taken for lab analyses (scales, tissue, whole specimen).

6.5 Hydrochemical parameters (lakes and rivers)

Environmental traits provide information for fish habitat characterisation. Hydromorphological traits of the water bodies were mentioned in the protocols before. For hydrochemical traits, we will limit ourselves on general recommendations without concrete protocols. Reason is that data acquisition depends on the corresponding research questions and on the technology available in field and/or in the lab. Hydrochemical traits might be added to the corresponding field protocols. If separate protocols for hydrochemical sampling are created, they need to include name of the water body, longitude, latitude, date, time of the day, weather, sampling team, and some kind of sample ID.

Environmental traits shall be analysed as per standard protocols, details cannot be provided here. The measurement of traits needs to be adapted to the water body: one sampling point might be sufficient for river description at a sampling site, multiple points might be useful in streams (bottom, midstream, surface) and depth profiles might be needed in lakes (e.g. for temperature or oxygen).

1) A set of relevant and easy-to-measure environmental traits is
   a) water temperature
   b) transparency
   c) water colour
   d) water odour
2) Common environmental traits measured with electronic devices in the field are
   a) pH
   b) dissolved oxygen
   c) electrical conductivity
3) Some environmental traits require taking water samples which are then analysed in labs. These analyses often include descriptors of the trophic situation and other parameters relevant for fish health and distribution
   a) Chlorophyll a
   b) Phosphate
   c) Nitrate
   d) Ammonia
   e) alkalinity
   f) hardness
   g) chloride
   h) free CO2
   i) Silicate

The pollution with noxious substances usually requires the analyses in specialised laboratories with adequate equipment. Examples are heavy metals (cadmium, lead, mercury), pesticides (DDT), and polyaromatic hydrocarbons.

6.6 Additional information (lakes and rivers)

The present document aims at a hands-on guide to fishing methods, their standardization and the documentation of fishing results. However, scientific investigations of fish are often carried out in complex frameworks exceeding the fish themselves and their exploitation by fishery. Other backgrounds might be: animal protection or conservation, landscape conservation, social investigations, economic values, implementation of legal provisions, risk assessment and action planning. This very general list makes clear, that no standardized protocol can handle all potential aspects of fish investigations. However, we recommend to generally support future analyses of fish data with informal reminders on certain topics during every field campaign:

- Stakeholder engagement and participation
- Ecosystem services provided by the aquatic ecosystem
- Threats
    - Human (other than those in protocols)
    - Non-fish invasive species (e.g. competition, predation, disease)
- Measures
    - Habitat restoration and management (e.g. dam removal, stream restoration)
    - Climate adaptation measures (managed retreat, habitat restoration)
    - Conservation plans and actions if any
- Research needs

Many of this information can be obtained by using local knowledge.

7 DATA HANDLING AND DATABASES

Fish sampling in the field is complex, time consuming and expensive in terms of manpower and gear. The fishing teams disappear into the wilds for up to several months and come back with preserved specimens and a lot of data. Data are the main result of the field trips and therefore a valuable treasure that needs to be handled with care: once a protocol is completed in the field, it should never be taken back to the water. Data should be appreciated in the office or institute, too. They need to be transferred to electronical form, to save them and to make them analysable. If possible, this should be done as soon as access to the IT infrastructure is granted because valuable details might be forgotten quickly.

Data management systems differ - similar to the choice of gear they depend on objectives and perspectives of the investigation (see chapter 5.2). The basic requirement is the transfer of protocol information into a spreadsheet that can be analysed electronically: filtered, summarized, extracted, and calculated. Spreadsheets are adequate for data of narrowed down, clearly defined sampling events that are unlikely to be repeated. Databases, as an alternative, ease the avoidance of redundancy and inconsistency, allow the analysis of changing (increasing) data and improve the number of processable datasets.

There are plenty of programs for creation of databases, both commercial and open source. Relational databases for fish sampling data consist of connected tables with the aim of having every information stored just once. The most frequent relationship between the tables is one-to-many (1:N); with one dataset in a table linked to multiple datasets in a subordinate table. We cannot offer a comprehensive introduction into databases. However, we experience that the structure of fish databases is similar in most institutions and we feel that a short introduction might be helpful for those searching for a good possibility to improve the saving and processing of their fish sampling data.

The structure of a fish sampling database, i.e. content and arrangement of the tables, corresponds to content and hierarchy of the field protocols. Figure 20 shows the structure for two databases - one for standing and one for running waters. It represents the basic requirements for storing field data in database. Further information might be added for specific analyses. We recommend to add and link a table with information about species, e.g. conservation status, functional traits, or ecological preferences.

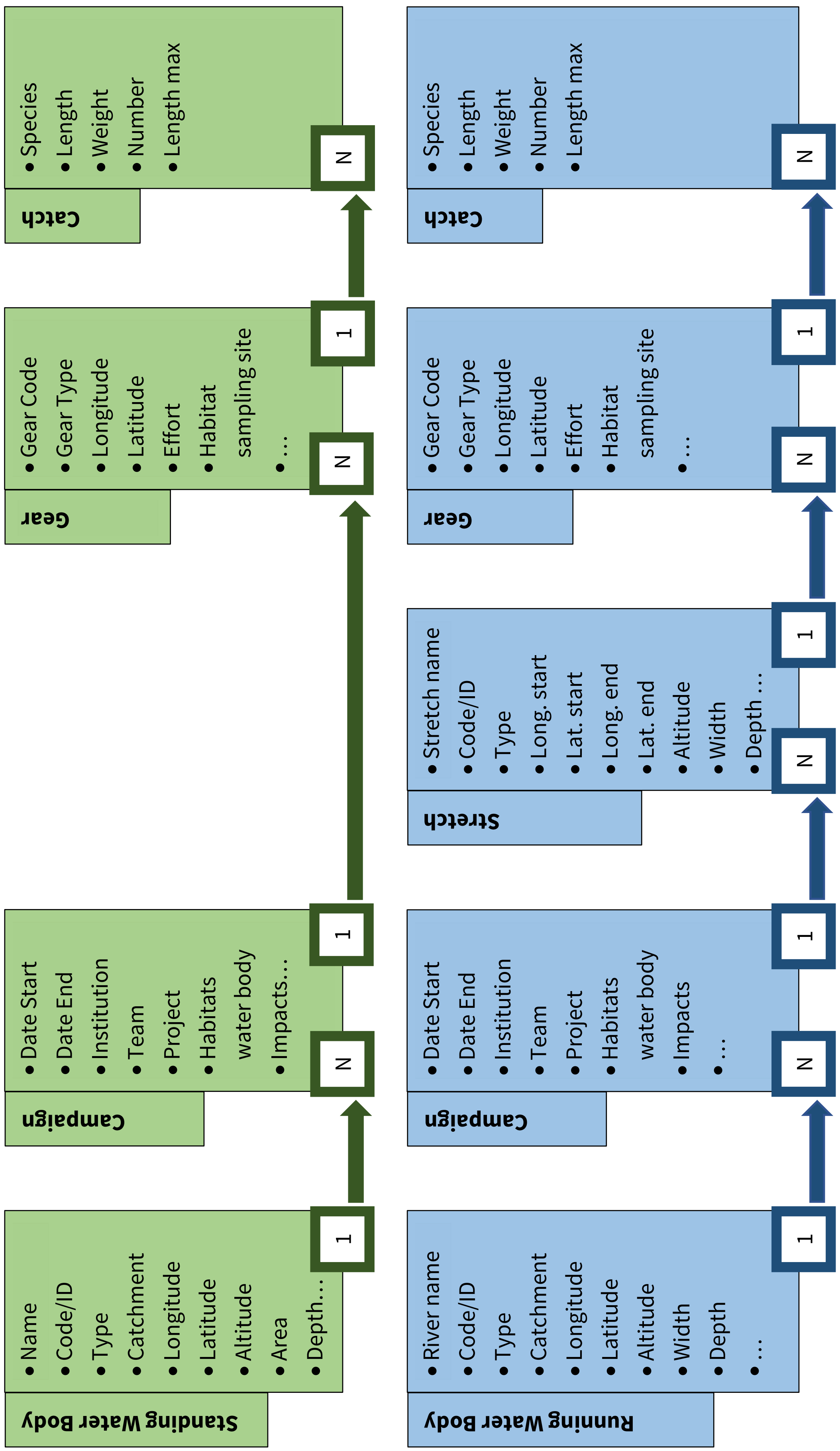


Figure 20: Generalized structure of 1:N relations of relational databases for fish sampling data in lakes (green, above) and rivers (blue, below).

8 SPECIAL SCIENTIFIC METHODS

The following methods are used for investigations of fish or fish communities. They are not exactly methods of catching fish and are associated with a high level of technical equipment, specialised training and personnel effort. Their detailed description or even standardization would exceed the aim of the present document. We shortly describe these methods but do not propose standard procedures for future investigations in India.

8.1 Hydroacoustics

Hydroacoustics (syn. sonar, echosounding) describe a range of methods providing information about underwater obstacles by means of sending sound waves and analysing their echoes. Hydroacoustic devices are nearly ubiquitous in cargo shipping and fishing vessels. They are used to determine water depth, to find shallows, or to find underwater structures. They can also be used to locate large individual fish or schools of fish and thus support boat fisheries from big marine commercial fishing vessels to individual recreational anglers. Small, mobile echosounder are also recommendable for scientific fishing with boats. They can provide valuable measurements of environmental parameters (depth and macrophyte cover) and are important for safety reasons (shallows).

Special echosounders are available for scientific purposes. These high-priced devices can precisely count numbers and measure the lengths of small objects in the water column, down to 2 - 3 cm. Mobile hydroacoustics with a vertical sound beam is the most common way of scientific application. This method is used to determine pelagic fish abundance, length frequency distributions and calculate biomasses, which are important data for fish ecology and fishery science, e.g. the modelling of sustainable yields. Horizontal hydroacoustics can be used in shallow waters or for investigation of upper water layers, but length measurements vary in dependence on the actual orientation of the fish. Mobile and stationary hydroacoustic devices are also used as imaging sonars, an alternative to optical cameras in turbid waters, e.g. for surveys at fish passages.

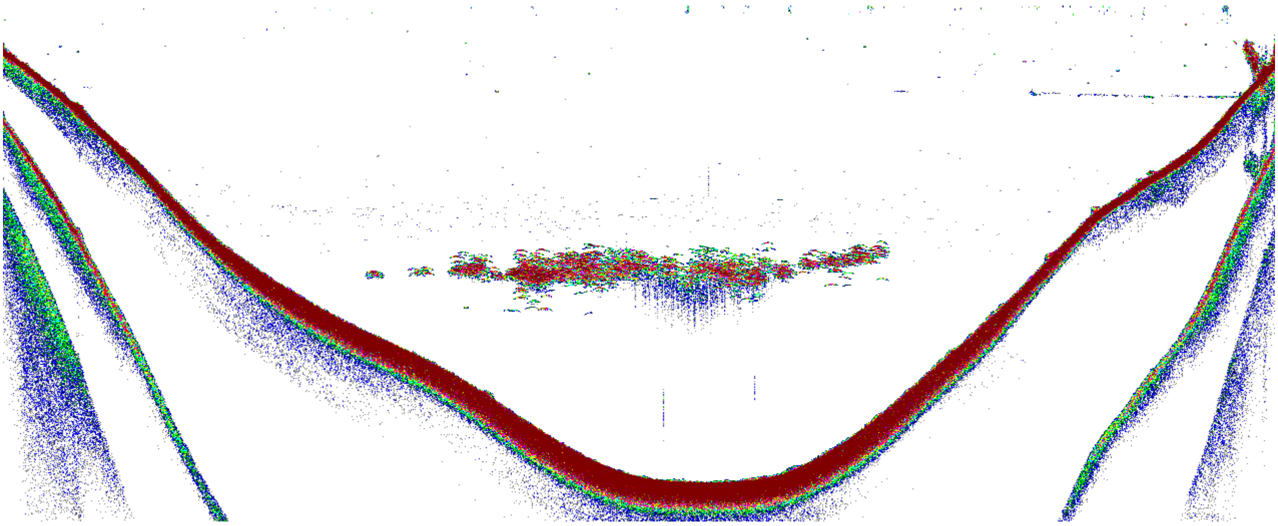


Figure 21: An echogram showing a dense aggregation of pelagic fish in a limited depth layer. Figure D. Ritterbusch, IfB.

In comparison to other methods of fish or fish stock surveys, hydroacoustics have the decisive advantage of not having an influence on the fish. The data describes living fish behaving in their natural habitat without any influence of their examination. The fish detections and length measurements are absolutely non-selective. Moreover, large areas of water bodies can be investigated with relatively little effort (once a routine is established). On the other hand, scientific hydroacoustics has important disadvantages. A main problem is that the species of the detected fish cannot be identified. The equipment is costly and needs operators and analysts with special training for gear and software. For vertical hydroacoustics, there are blind zones at the surface (2 - 5 m) and at the bottom (< 1m) due to impact of the boat on fish and physical limitations of the sound processing. Fish hidden in benthic structures or vegetation cannot be detected. Thus, major parts of freshwater fish communities remain unconsidered, i.e. littoral, benthic and upper pelagic individuals. Scientific vertical hydroacoustic investigations in freshwaters are restricted to the mid-pelagic water body of deeper lakes. Horizontal use and imaging variants are rather specialized areas of application.

Further reading: Parker-Stetter et al. (2009), Simmonds et al. (2005), Rudstam et al. (2012)

8.2 eDNA

Environmental DNA (eDNA) has become a valuable tool for monitoring and studying freshwater fish and its ecosystem. By analysing genetic material obtained from water samples, one can gain insights into presence, distribution, and abundance of various freshwater fish species. Through eDNA analysis, one can acquire comprehensive data on the distribution, diversity, and conservation status of freshwater fish populations, contributing to the sustainable management and protection of freshwater ecosystems.

In this method, water samples are collected from freshwater bodies such as rivers, lakes, ponds, and streams to capture the genetic material shed by fish through mucus, scales, excretions, and bodily fluids. These samples are filtered to extract the eDNA, which is then subjected to molecular analysis. eDNA studies enable the detection and monitoring of a wide range of freshwater fish species, including both common and rare or elusive species within a given habitat. The technique facilitates the assessment of freshwater fish biodiversity and allows researchers to study the diversity and composition of fish communities, track changes in species composition over time, and assess the impact of environmental factors on fish populations. The studies on eDNA can help in the early detection of invasive fish species in freshwater ecosystems and prevent the spread, thereby preserving the native fish communities and maintaining the ecological balance of the freshwater habitats. The eDNA contributes to the conservation and management of threatened freshwater fish species. It aids in the identification of endangered or threatened species, facilitates the assessment of population dynamics, and informs conservation strategies aimed at preserving and restoring freshwater fish habitats.

When considering the application of eDNA analysis specifically for freshwater fishes, there are certain disadvantages and limitations. Environmental factors such as water temperature, pH levels, and the presence of organic matter can influence the stability and detectability of eDNA in freshwater habitats. Freshwater ecosystems can exhibit complex spatial structures, including various habitats such as rivers, streams, lakes, and wetlands. Assessing the distribution and abundance of freshwater fish species using eDNA may be challenging due to the heterogeneous nature of these habitats.

Understanding these limitations is crucial for the appropriate design and implementation of eDNA studies focusing on freshwater fishes. Addressing these disadvantages requires the development of standardized sampling protocols, the use of appropriate controls for minimizing contamination, and the integration of complementary monitoring techniques to ensure the robustness and accuracy of eDNA-based assessments in freshwater ecosystems.

Further reading: (selected articles from after 2020): Bernos et al. (2023), Goutte et al. (2020), Piggott et al. (2021), Rojahn et al. (2021), Schenekar (2023), Spear et al. (2021), Thomson-Laing et al. (2022), Wang et al. (2021).

8.3 Marking and tagging

Marking and tagging are techniques to make individual fish or groups of fish distinguishable from others of the same species. Marking describes modifications of the fish themselves while tagging is the attachment of a foreign object. Marks or tags can be internal or external. They always impair the target fish to a certain amount and expose them to catch, handling and physical intervention. The degree of impairment and the durability of marks/tags differ significantly between techniques. The most natural method of marking is the identification of unique body marks, e.g. colour patterns, morphometric traits or natural scars. Computer based methods have led to reliable application of this approach, especially for colouring (Cisar et al. 2021; Stien et al. 2017), but it is restricted to species with clear and distinctive patterns. Marking and tagging are elaborate methods and require special knowledge and equipment as well as experience to reduce injury of the investigated fish. **Marks** often are yes/no identifiers or have a limited number of combinations:

- Fin clips (cuts, punches or notches) are modifications of the fins and the most basic method. Fish with fin clips can be identified externally. Realization and position of fin clips make it possible to distinguish a (low) number of individuals or groups. Fins recover in most cases and the duration of this marking is limited.
- Epidermal colour injections are external markings with durable colours. Position and colour can code the marks but the number of codes is limited and coding is elaborate. Therefore, colour codes are used for group marking in most cases. Colour injections can be realized with needles or with pressure injections.
- Chemical or freeze brandings are external marks and similar to colour codes in their properties.
- Otoliths can be marked by bathing fish in fluorescent chemicals, eg Alicarin, Calcein, Oxytetracyclin (Figure 22), or by inducing thermal or chemical shocks. Otolith marking is possible for huge batches of small fish, but the marking is internal and the analysis requires the lethal retrieval of the otoliths.

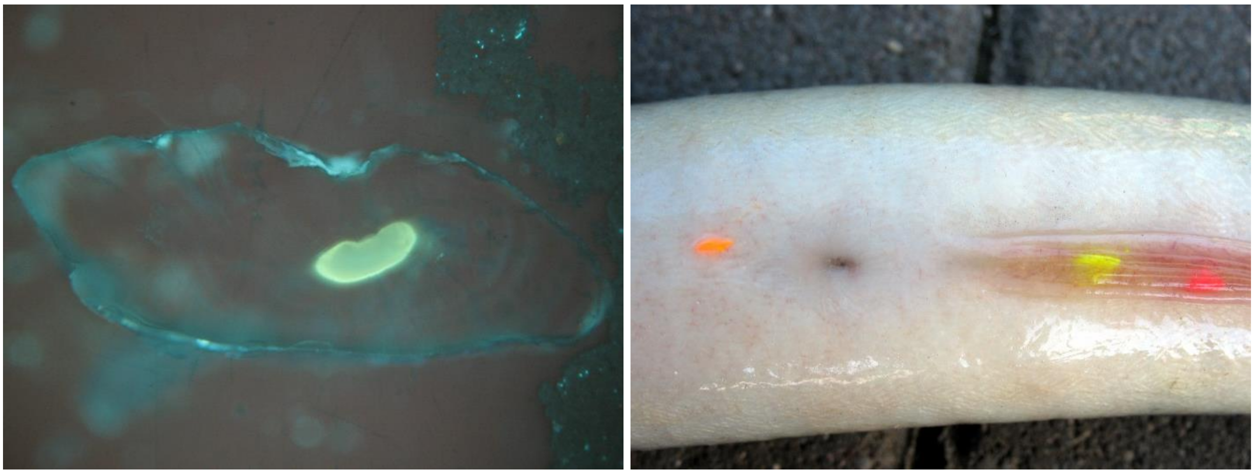


Figure 22: Left: Otolith with internal mark of Oxytetracyclin at the center. Right: External tag made with visible implant elastomers. Photos J. Simon.

Some **tags** can have a huge number of potential codes and are used for individual identification:

- Visible implant elastomer tags are coloured liquids that are injected in the hypodermis and harden afterwards (Figure 22). They are placed at translucent body parts like fin bases or near the eyes to remain visible. With limited possibilities for coding, this technique is used for group marking.
- It is also possible to implant numbered elastomer tags that remain externally visible. This technique allows individual coding.

- Wire Tags and Coded Wire Tags are very small pieces of wire, which can have codes written on them. They are injected into the fish body, often in dorsal muscles or in the nostrum. The presence of a tag can be detected at the living animal (external), but the retrieval of the internal tag for microscopical decoding of the individual number is lethal.
- External streamers, flags or tubes with codes (e.g. consecutive numbers) are attached to the fish by t-shaped anchors or barbed darts. These tags are often attached below the dorsal fin between the pterygiophore bones (Figure 23).
- Passive integrated transponder tags are implanted into the body cavity or into muscles and submit their identification code if activated by an external energy source in the tag reader. The tag reader must be in close range of less than 1 m even for the biggest passive transponder tags.

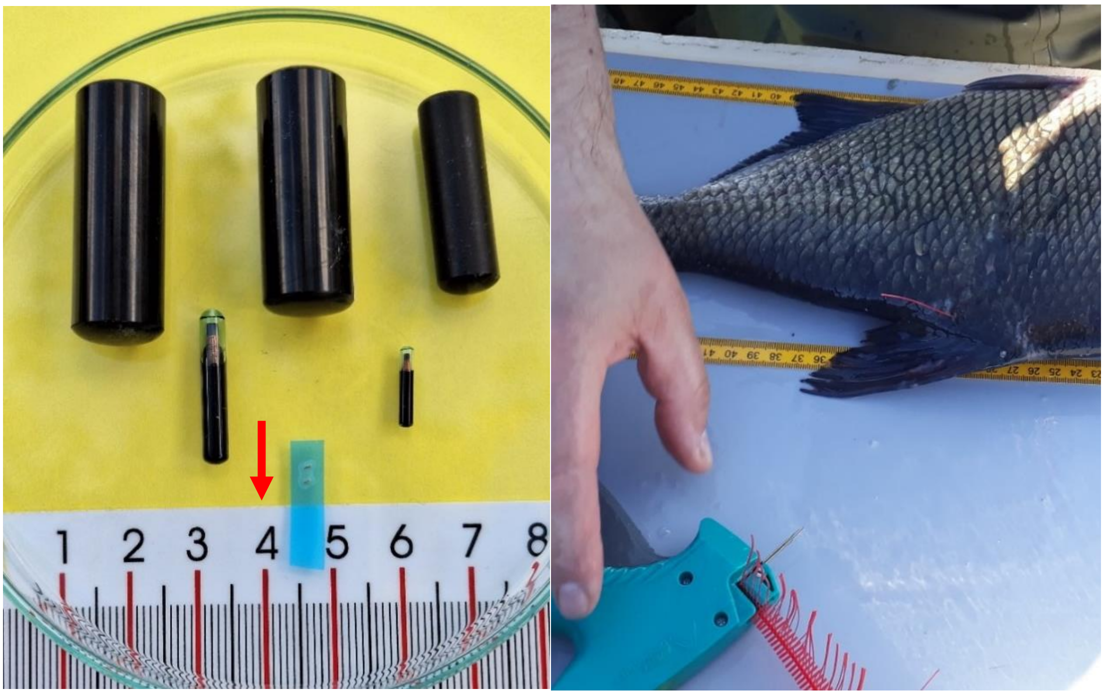


Figure 23: Left: Active acoustic transmitters (upper row), passive integrated transponders (middle row) and 1 mm wire tags without code (on blue strip). Right: A fish tagged with a t-shaped anchor tag at the dorsalis. Photos D. Ritterbusch (left) and T. Pagel (right).

Our examples focus on modern, less invasive methods that are suitable for freshwater fish and we avoided naming brands. Marking and tagging require elaborate techniques, but there are no alternatives to address various scientific investigations. Examples are estimations of population densities by mark-recapture methods, assessment of the contribution of stocking to the population by marking stocked fish, estimations of mortality, estimations of specific predation rates by counting of tags retrieved at feeding places of predators or the survey of precise individual growth rates.

A special case is telemetry, where active transmitters are implanted into or connected to the fish and continuously transmit radio or acoustic signals. The fish does not need to be caught but can be detected with a receiver from a boat or the shore. This enables the scientist to study migrations, movements, or habitat choices of fish in their natural environment, e.g. diurnal or seasonal behaviour. Transmitters are comparably big, they require a battery and their size increases with required distance and duration of transmission.

For further information on methods and analyses, we refer to (Lucas et al. 2000), McKenzie et al. (2012), Parker et al. (1990) and Pine et al. (2012), and for telemetry to Cooke et al. (2013); Cooke et al. (2012).

9 Literature

92/43/Eec (1992): Council directive on the conservation of natural habitats and of wild fauna and flora as of 21.05.1992. Abl. L 206 p. 7, last change 20.12.2006.

2000/60/Ec (2000): Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000 establishing a framework for Community action in the field of water policy as of 22.12.2000. Official Journal of the European Communities L327/1.

Allen, D. J., S. Molur & B. A. Daniel - editors (2010): The Status and Distribution of Freshwater Biodiversity in the Eastern Himalaya, India. IUCN, Cambridge, Gland, Coimbatore.

Arterburn, J. E. & C. R. Berry Jr (2002): Effect of Hook Style, Bait Type, and River Location on Trotline Catches of Flathead and Channel Catfish. North American Journal of Fisheries Management 22: 573-578.

Arunkumar, A. A. & A. Manimekalan (2018): Freshwater fish fauna of rivers of the southern Western Ghats, India. Earth System Science Data 10: 1735-1752.

Balachandran, A., B. Krishnan & L. John (2013): Accidental deaths due to electrocution during amateur electro-fishing. Journal of Evolution of Medical and Dental Sciences 2.

Balian, E. V., H. Segers, C. Lévèque & K. Martens (2008): The Freshwater Animal Diversity Assessment: an overview of the results. Hydrobiologia 595: 627-637.

Bene, C., E. K. Abban, P. V. Zwieten, H. R. Dankwa, R. Brummett, J. K. Ofori, N. Obirih-Opareh & J. Kolding (2009): Engaging Local Communities in Aquatic Resources Research and Activities: A Technical Manual. Technical Manual 1951, T. W. Center, Penang (Malaysia).

Bernos, T. A., M. C. Yates, M. F. Docker, A. Fitzgerald, R. Hanner, D. Heath, A. Imrit, J. Livernois, E. Myler, K. Patel, S. Sharma, R. Young & N. E. Mandrak (2023): Environmental DNA (eDNA) applications in freshwater fisheries management and conservation in Canada: overview of current challenges and opportunities. Canadian Journal of Fisheries and Aquatic Sciences 80: 1170-1186.

Bonar, S. A., S. Contreras-Balderas & A. C. Iles (2009a): An Introduction to Standardized Sampling. In: S. A. Bonar, W. A. Hubert & D. W. Willis (Eds.), Standard Methods for Sampling North American Freshwater Fishes, pp. 1-12. American Fisheries Society, Bethesda, Maryland.

Bonar, S. A., W. A. Hubert & D. W. Willis - editors (2009b): Standard Methods for Sampling North American Freshwater Fishes. American Fisheries Society, Bethesda, Maryland.

Boopendranath, R. (2012): Basic Principles of Fishing Gear Design and Classification. In: S. N. Thomas, L. Edwin, P. Pravin, M. P. Remesan, P. M. Ashraf, M. Baiju & V. R. Madhu (Eds.), Fish Harvesting Systems for Resource Conservation, pp. 71-83. Central Institute of Fisheries Technology, Cochin (India).

Borah, L., B. Kalita, P. Boro, A. S. Kulnu & N. Hazarika (2022): Climate change impacts on socio-hydrological spaces of the Brahmaputra floodplain in Assam, Northeast India: A review. Frontiers in Water 4.

Chakravartty, P. & S. Sharma (2013): Different Types of Fishing Gears Used by the Fishermen in Nalbari District of Assam. International Journal Of Social Sciences & Interdisciplinary Research 2: 177-190.

Chandra, K., B. Tripathy, L. K. Sharma, K. Mondal, H. Kumar, J. Saini, S. Sajan, P. Chatterjee, A. Payra, D. Ghosh, D. Ck & S. Sen (2018): Toolkit for Long-term Monitoring of the Faunal Resources in the Indian Himalaya. Zoological Survey of India Kolkata: 84.

Choudhury, B. U., G. Nengzouzam, M. A. Ansari & A. Islam. (2022): Causes and consequences of soil erosion in northeastern Himalaya, India. Current Science 122: 772-789.

Choudhury, H., S. Thaosen, A. Dey, S. Basumatary & D. Sarma (2018): Length-weight relationships of three fish species from the Jatinga River (Barak drainage) in Assam, India. Journal of Applied Ichthyology 34: 1089-1090.

Cis (2003a): River and lakes - Typology, reference conditions and classification systems. Common Implementation Strategy for the Water Framework Directive (2000/60/EC) - Guidance Document, 10, REFCOND, European Commission, Luxembourg.

Cis (2003b): Identification and designation of heavily modified and artificial water bodies. 4, Common Implementation Strategy for the Water Framework Directive (2000/60/EC) - Guidance Document, European Commission,, Luxembourg.

Cisar, P., D. Bekkozhayeva, O. Movchan, M. Saberioon & R. Schraml (2021): Computer vision based individual fish identification using skin dot pattern. Scientific Reports 11: 16904.

Cooke, S., J. Midwood, J. Thiem, P. Klimley, M. Lucas, E. Thorstad, J. Eiler, C. Holbrook & B. Ebner (2013): Tracking animals in freshwater with electronic tags: past, present and future. Animal Biotelemetry 1: 5.

Cooke, S. J., S. G. Hinch, M. C. Lucas & M. Lutcavage (2012): Biotelemetry and Biologging. In: A. V. Zale, D. L. Parrish & T. M. Sutton (Eds.), Fisheries Techniques, pp. American Fisheries Society, Bethesda, Maryland.

Cwp (2016): Handbook of Fishery Statistical Standards - International Standard Statistical Classification of Fishing Gear (ISSCFG, 2016). https://www.fao.org/cwp-on-fishery-statistics/handbook/introduction/en/, latest access 30.06.23.

Das, B. K., N. R. Singh, P. Boruah & D. Kar (2015): Fishing devices of the river Siang in Arunachal Pradesh, India. Journal of Fisheries.

Devi, B. N., S. K. Mishra, L. Das, N. Pawar & T. I. Chanu (2013): Traditional fishing methods in Central valley region of Manipur, India.

Dey, A., H. Choudhury, S. Basumatary, R. C. Bharali & D. Sarma (2018): Length–weight relationships of three freshwater fish species from the Kameng River (Brahmaputra basin) in Arunachal Pradesh, northeast India. Journal of Applied Ichthyology 34: 1002-1003.

Diana, C. M., J. L. Jonas, R. M. Claramunt, J. D. Fitzsimons & J. E. Marsden (2006): A Comparison of Methods for Sampling round Goby in Rocky Littoral Areas. North American Journal of Fisheries Management 26: 514-522.

Dubey, S. K., K. Gogoi, B. Belton, A. Padiyar, S. Rajendran & F. Rajts (2023): Preserving cultural heritage: Community fishing among the Rabha community in Assam. . WorldFish, Penang (Malaysia).

Ec (2023): European Commission - Oceans and fisheries - Sustainable fisheries - Markets and trade - Seafood markets - Commercial designations - Fishing gears. https://fish-commercial-names.ec.europa.eu/fish-names/fishing-gears_en, latest access 30.06.23.

Emmrich, M., S. Brucet, I. J. Winfield, E. Jeppesen, T. Lauridsen, P. Volta, C. Argillier, S. Pedron, K. Holmgren, T. Hesthagen, D. Ritterbusch & T. Mehner (2012): Changes in size structure of fish assemblages in European lakes along eutrophication and hydromorphological pressure gradients. WISER deliverable 3.4-2.

En 14011 (2003): European Standard: Water quality - Sampling of fish with electricity ICS 13.060.70; 65.150.

En 14757 (2005): European Standard: Water quality - Sampling of fish with multi-mesh gillnets ICS 13.060.70; 65.150.

En 14757 (2015): European Standard: Water quality - Sampling of fish with multi-mesh gillnets as of 27.06.05. ICS 13.060.70; 65.150, last change 01.08.2015.

En 14962 (2006): European Standard: Water quality - Guidance on the scope and selection of fish sampling methods as of 04/2006. ICS 13.060.70; 65.150 p. 25.

Fao (2004): CWP Handbook of Fishery Statistical Standards. Food and Agricultural Organization of the United Nations (FAO), Rome.

Fao (2021): Classification and illustrated definition of fishing gears. FAO Fisheries and Aquaculture Technical Paper 672.

Fao (2023): Fisheries and Aquaculture - Search technology factsheets - Fishing gear type. https://www.fao.org/fishery/en/geartype/search, latest access 30.06.23.

Gassner, H., D. Achleitner, M. Luger, D. Ritterbusch, M. Schubert & P. Volta (2014): Water Framework Directive Intercalibration Technical Report - Alpine Lake Fish fauna ecological assessment methods. JRC Technical Reports: 73.

Gopi, K. C., S. S. Mishra & L. Kosygin (2017): Pisces. In: Zoological Survey of India (Ed.) Current status of freshwater faunal diversity in India, pp. 527-570.

Goutte, A., N. Molbert, S. Guérin, R. Richoux & V. Rocher (2020): Monitoring freshwater fish communities in large rivers using environmental DNA metabarcoding and a long-term electrofishing survey. Journal of Fish Biology 97: 444-452.

Gupta, N., R. Raghavan, K. Sivakumar, V. Mathur & A. C. Pinder (2015a): Assessing recreational fisheries in an emerging economy: Knowledge, perceptions and attitudes of catch-and-release anglers in India. Fisheries Research 165: 79-84.

Gupta, N., S. D. Bower, R. Raghavan, A. J. Danylchuk & S. J. Cooke (2015b): Status of Recreational Fisheries in India: Development, Issues, and Opportunities. Reviews in Fisheries Science & Aquaculture 23: 291-301.

Gupta, N., S. D. Bower, S. J. Cooke, A. J. Danylchuk & R. Raghavan (2016): Practices and attitudes of Indian catch-and-release anglers: identifying opportunities for advancing the management of recreational fisheries Journal of Threatened Taxa 8: 8659-8665.

Gupta, N., P. Nautiyal, A. Borgohain, K. Sivakumar, V. B. Mathur & M. A. Chadwick (2014): Catch-and-release angling as a management tool for freshwater fish conservation in India. Oryx 50: 250-256.

Gupta, N., A. Kanagavel, P. Dandekar, N. Dahanukar, K. Sivakumar, V. B. Mathur & R. Raghavan (2015c): God's fishes: religion, culture and freshwater fish conservation in India. Oryx 50: 244-249.

Gurumayum, S. & M. D. a. M. Choudhury (2009): Fishing methods in the rivers of Northeast India. Indian Journal of Traditional Knowledge 8: 237-241.

Hankin, D. G. & G. H. Reeves (1988): Estimating Total Fish Abundance and Total Habitat Area in Small Streams Based on Visual Estimation Methods. Canadian Journal of Fisheries and Aquatic Sciences 45: 834-844.

Hetrick, N. J. & J. F. Bromaghin (2006): Sampling Bias of Hook-and-Line Gear Used to Capture Rainbow Trout in Gertrude Creek, Alaska. North American Journal of Fisheries Management 26: 13-23.

Holubová, M., M. Čech, M. Vašek & J. Peterka (2019): On the use of a visual census in surveying fish communities in lentic water bodies. Ecological Indicators 105: 1-5.

Inaotombi, S. (2019): Building socio-ecological resilience to climate change for fisheries through local skill and indigenous knowledge. Proceedings of FishAdapt: the Global Conference on Climate Change Adaptation for fisheries and Aquaculture 61, Bangkok: 125-134.

Inaotombi, S. & C. Mahanta (2016): Fisheries Related Traditional Knowledge of Meitei Community of Manipur, India. Asian Fisheries Science 29S: 181-191.

Inaotombi, S. & P. C. Mahanta (2019): Pathways of socio-ecological resilience to climate change for fisheries through indigenous knowledge. Human and Ecological Risk Assessment: An International Journal 25: 2032-2044.

Janáč, M. & P. Jurajda (2011): Mortality induced by electrofishing and handling in five young-of-the-year cyprinids: effect of the fish size, species and anode size. Journal of Applied Ichthyology 27: 990-994.

Jepsen, N. & D. Pont (2007): Intercalibration of Fish-based Methods to evaluate River Ecological Quality. JRC Scientific and Technical Reports: 193.

Jordan, F., H. L. Jelks, S. A. Bortone & R. M. Dorazio (2008): Comparison of visual survey and seining methods for estimating abundance of an endangered, benthic stream fish. Environmental Biology of Fishes 81: 313-319.

Jupke, J. F., S. Birk, A. Apostolou, J. Aroviita, A. Baattrup-Pedersen, P. Baláži, L. Barešová, S. Blanco, M. Borrego, H. Van Dam, E. Dimitriou, C. K. Feld, M. T. Ferreira, G. Gecheva, J. Gomà, N. Hanžek, I. M. Haslev, T. Isheva, A. Jamoneau, J. Jyrkänkallio-Mikkola, M. Kahlert, I. Karaouzas, S. M. Karjalainen, A. Olenici, P. Panek, P. Paril, E. T. H. M. Peeters, M. Polášek, D. Pont, A. Pumputyte, L. Sandin, L. Sochuliaková, J. Soininen, I. Stanković, M. Straka, M. Šušnjara, T. Sutela, J. Tison-Rosebery, M. G. Udovič, M. Verhofstad, P. Žutinić & R. B. Schäfer (2023): European river typologies fail to capture diatom, fish, and macrophyte community composition. Science of The Total Environment: 165081.

Kalita, B., A. Dutta, S. K. Bhagabati & A. Sharma (2010): Indigenous technical knowledge for fish harvesting in Karbi-Anglong district of Assam. Indian Journal of Traditional Knowledge 9: 252-255.

Kubečka, J., H. Balk, P. Blabolil, J. Frouzová, T. Kolařík, M. Kratochvíl, M. Muška, M. Prchalová, M. Říha, Z. Sajdlová, K. Soukalová, A. Souza, M. Tušer, L. Vejřík & V. I. (2022): Methodology of monitoring fish communities in reservoirs and lakes. B. C. CAS, České Budějovice.

Kuriyama, P. T., T. A. Branch, A. C. Hicks, J. H. Harms & O. S. Hamel (2019): Investigating three sources of bias in hook-and-line surveys: survey design, gear saturation, and multispecies interactions. Canadian Journal of Fisheries and Aquatic Sciences 76: 192-207.

Lakra, W. S., U. K. Sarkar, A. Gopalakrishnan & S. A. Kathirvelpandian (2010a): Threatened Freshwater Fishes of India. National Bureau of Fish Genetic Resources, Lucknow.

Lakra, W. S., U. K. Sarkar, R. S. Kumar, A. Pandey, V. K. Dubey & O. P. Gusain (2010b): Fish diversity, habitat ecology and their conservation and management issues of a tropical River in Ganga basin, India. The Environmentalist 30: 306-319.

Lucas, M. C. & E. Baras (2000): Methods for studying spatial behaviour of freshwater fishes in the natural environment. Fish and Fisheries 1: 283-316.

Lyche Solheim, A., L. Globevnik, K. Austnes, P. Kristensen, S. J. Moe, J. Persson, G. Phillips, S. Poikane, W. Van De Bund & S. Birk (2019): A new broad typology for rivers and lakes in Europe: Development and application for large-scale environmental assessments. Science of The Total Environment 697: 134043.

Lyons, J. (1986): Capture Efficiency of a Beach Seine for Seven Freshwater Fishes in a North-Temperate Lake. North American Journal of Fisheries Management 6: 288-289.

Macnaughton, C. J., S. Harvey-Lavoie, C. Senay, G. Lanthier, G. Bourque, P. Legendre & D. Boisclair (2015): A Comparison of Electrofishing and Visual Surveying Methods for Estimating Fish Community Structure in Temperate Rivers. River Research and Applications 31: 1040-1051.

Mandal, F. B. & N. C. Nandi (2015): Loss of small indigenous fish species in India: a case of concern. Journal of Environment and Sociobiology 12: 35-45.

Mayo, J. S. & D. A. Jackson (2006): Quantifying Littoral Vertical Habitat Structure and Fish Community Associations using Underwater Visual Census. Environmental Biology of Fishes 75: 395-407.

Mckenzie, J. R., B. Parsons, A. C. Seitz, R. K. Kopf, M. G. Mesa & Q. Phelps - editors (2012): Advances in Fish Tagging and Marking Technology. American Fisheries Society Symposium.

Mehner, T. & S. Brucet (2021): Structure of Fish Communities in Lakes and Its Abiotic and Biotic Determinants. In: Reference Module in Earth Systems and Environmental Sciences, pp. Elsevier.

Mohite, A., T. Kazi, R. Jadhav & S. Kamble (2017): Comparative analysis of encircling gill nets with special reference to Ratnagiri, Maharashtra, India. Journal of Experimental Zoology India 20: 1175-1177.

Molur, S., K. G. Smith, B. A. Daniel & W. R. T. Darwall - editors (2011): The Status and Distribution of Freshwater Biodiversity in the Western Ghats, India. IUCN, Cambridge, Gland, Coimbatore.

Munilkumar, S., Y. Rameshori, W. R. Mangang, M. Kamei, Y. Chinglemba, A. Pavan-Kumar, B. K. Mahapatra, A. Das, M. A. Hanif & M. a. B. Siddik (2021): Length-weight relationships of six Nemacheilid fish species (Teleostei: Cypriniformes) from different rivers of Manipur, India. Journal of Applied Ichthyology 37: 356-358.

Nédélec, C. (1996): Fishing Gear in the European Community E. Commission, Office for the official publications of the European Commission, Luxembourg.

Olin, M., K. Holmgren, M. Rask, M. Allen, L. Connor, A. Duguid, W. Duncan, A. Harrison, T. Hesthagen, F. Kelly, A. Kinnerbäck, R. Rosell & R. Saksgård (2014): Water Framework Directive Intercalibration Technical Report - Northern Lake Fish fauna ecological assessment methods. JRC Technical Reports: 73.

Parida, S., S. K. Karna, K. S. Bhatta & B. C. Guru (2013): Distribution of Fishing Gears in India's Largest Brackish Water Lagoon, India. Bulletin of Environment, Pharmacology and Life Sciences 2: 62-67.

Parker-Stetter, S., L. Rudstam, P. J. Sullivan & D. M. Warner (2009): Standard operating procedures for fisheries acoustic surveys in the Great Lakes - Prepared for the Study Group on Fisheries Acoustics in the Great Lakes. Great Lakes Fishery Commission.

Parker, N. C., A. E. Giorgi, R. C. Heidinger, D. B. Jester & G. A. Winans - editors (1990): Fish marking techniques. American Fisheries Society Symposium.

Pathak, A. K., U. K. Sarka & S. P. Singh (2014): Spatial gradients in freshwater fish diversity, abundance and current pattern in the Himalayan region of Upper Ganges Basin, India. Biodiversitas 15: 186-194.

Persson, L., S. Diehl, L. Johansson, G. Andersson & S. F. Hamrin (1991): Shifts in fish communities along the productivity gradient of temperate lakes - patterns and the importance of size-structured interactions. Journal of Fish Biology 38: 281-293.

Pierce, C. L., J. B. Rasmussen & W. C. Leggett (1990): Sampling Littoral Fish with a Seine: Corrections for Variable Capture Efficiency. Canadian Journal of Fisheries and Aquatic Sciences 47: 1004-1010.

Piggott, M. P., S. C. Banks, B. T. Broadhurst, C. J. Fulton & M. Lintermans (2021): Comparison of traditional and environmental DNA survey methods for detecting rare and abundant freshwater fish. Aquatic Conservation: Marine and Freshwater Ecosystems 31: 173-184.

Pine, W. E., J. E. Hightower, L. C. Coggins, M. V. Lauretta & K. H. Pollock (2012): Design and Analysis of Tagging Studies. In: A. V. Zale, D. L. Parrish & T. M. Sutton (Eds.), Fisheries Techniques, pp. American Fisheries Society, Bethesda, Maryland.

Poikane, S. (2009): Water Framework Directive intercalibration technical report - Part 2: Lakes. Joint Research Center.

Pottier, G., W. R. Beaumont, F. Marchand, P.-Y. Le Bail, D. Azam, J. Rives, R. Vigouroux & J.-M. Roussel (2020): Electrofishing in streams of low water conductivity but high biodiversity value: Challenges, limits and perspectives. Fisheries Management and Ecology 27: 52-63.

Prasad, L. R. V., R. Jalaj, S. K. Pandey & A. Kumar (2013): Few indigenous traditional fishing method of Faizabad district of eastern Uttar Pradesh, India.

Pravin, P., B. Meenakumari, M. Baiju, J. Barman, D. Baruah & B. Kakati (2011a): Fish trapping devices and methods in Assam - A review. Indian Journal of Fisheries 58: 127-135.

Pravin, P., S. N. Thomas, B. Meenakumari, M. Baiju, D. Baruah, J. Barman & B. Kakati (2011b): Gill Nets of Assam. Fishing Chimes 31: 68-71.

Pravin, P., S. N. Thomas, B. Meenakumari, M. V. Baiju, D. Baruah, J. Barman, B. Kakati, P. Daimari & V. R. Mumthaz (2009): Design and General Characteristics of Gill Nets of Assam. Fishery Technology 46: 107-122.

Puri, R. (2023): Methods Manual: Documenting Traditional Knowledge of Aquatic Resources in North East-India. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Assam.

Rahman, M. (2020): Fisheries potentialities of Krishnai River, Assam, India. International Journal of Innovative Science, Engineering & Technology 7: 312-317.

Raju, C. S., J. C. S. Rao, K. G. Rao & G. Simhachalam (2016): Fishing methods, use of indigenous knowledge and traditional practices in fisheries management of Lake Kolleru. Journal of entomology and zoology studies 4: 37-44.

Reynolds, J. B. & A. L. Kolz (2012): Electrofishing. In: A. V. Zale, D. L. Parrish & T. M. Sutton (Eds.), Fisheries Techniques, pp. American Fisheries Society, Bethesda, Maryland.

Říha, M., J. Kubečka, T. Mrkvička, M. Prchalová, M. Čech, V. Draštík, J. Frouzová, M. Hladík, E. Hohausová, O. Jarolím, T. Juza, M. Kratochvíll, J. Peterka, M. Tušer & M. Vašek (2008): Dependence of beach seine net efficiency on net length and diel period. Aquatic Living Resources 21: 411-418.

Ritterbusch, D., P. Blabolil, J. Breine, T. Erős, T. Mehner, M. Olin, G. Peirson, P. Volta & S. Poikane (2022): European fish-based assessment reveals high diversity of systems for determining ecological status of lakes. Science of The Total Environment 802: 149620.

Ritterbusch, D., C. Argillier, J. Arle, W. Białokoz, J. Birzaks, P. Blabolil, J. Breine, H. Draszkiewicz-Mioduszewska, N. Jaarsma, I. Karottki, T. Krause, J. Kubečka, T. Lauridsen, M. Logez, A. Maire, A. Palm, G. Peirson, M. Říha, J. Szlakowski, T. Virbickas & S. Poikane (2017): Water Framework Directive Intercalibration: Central-Baltic Lake Fish fauna ecological assessment methods; Part A: Descriptions of fish-based lake assessment methods. JRC Technical Reports: 101.

Rojahn, J., L. Pearce, D. M. Gleeson, R. P. Duncan, D. M. Gilligan & J. Bylemans (2021): The value of quantitative environmental DNA analyses for the management of invasive and endangered native fish. Freshwater Biology 66: 1619-1629.

Rudstam, L. G., J. M. Jech, S. L. Parker-Stetter, J. K. Horne, P. J. Sullivan & D. M. Mason (2012): Fisheries Acoustics. In: A. V. Zale, D. L. Parrish & T. M. Sutton (Eds.), Fisheries Techniques, pp. American Fisheries Society, Bethesda, Maryland.

Ryder, R. A. (1981): Eutrophication effects on fisheries - the horns of a dilemma. Water Quality Bullettin 6: 84-91.

Sandhya, K. M. & S. N. Thomas (2020): Recent Developments in Gillnet Fishing. Recent advances in harvest and post-harvest technologies in fisheries, Cochin: 157-163.

Sankararaman, V. (2019): Electro-fishing, Loktak Lake, Manipur. https://www.conservationindia.org/gallery/electro-fishing-loktak-lake-manipur, latest access 07.09.23.

Sarkar, U. K., A. K. Pathak, L. K. Tyagi, S. M. Srivastava, S. P. Singh & V. K. Dubey (2013): Biodiversity of freshwater fish of a protected river in India: comparison with unprotected habitat. Revista de Biología Tropical 61: 161–172.

Sarkar, U. K., A. K. Pathak, R. K. Sinha, K. Sivakumar, A. K. Pandian, A. Pandey, V. K. Dubey & W. S. Lakra (2012): Freshwater fish biodiversity in the River Ganga (India): changing pattern, threats and conservation perspectives. Reviews in Fish Biology and Fisheries 22: 251-272.

Schenekar, T. (2023): The current state of eDNA research in freshwater ecosystems: are we shifting from the developmental phase to standard application in biomonitoring? Hydrobiologia 850: 1263-1282.

Simmonds, J. & D. Maclennan (2005): Fisheries Acoustics: Theory and Practice. Blackwell Publishing Ltd.

Spear, M. J., H. S. Embke, P. J. Krysan & M. J. Vander Zanden (2021): Application of eDNA as a tool for assessing fish population abundance. Environmental DNA 3: 83-91.

Stien, L. H., J. Nilsson, S. Bui, J. E. Fosseidengen, T. S. Kristiansen, Ø. Øverli & O. Folkedal (2017): Consistent melanophore spot patterns allow long-term individual recognition of Atlantic salmon Salmo salar. Journal of Fish Biology 91: 1699-1712.
Syed, N. & A. S. Mohite (2016): Operational and design aspects of spears and scoop net used in Wular and Dal Lake of Kashmir, India. International Journal of Agricultural Engineering 9: 140-144.
Talukdar, B., F. Jabeen, H. K. Kalita, S. Basumatary, H. Choudhury & D. Sarma (2017): Length–weight relationships of two Nemacheilid fish species [Schistura fasciata Lokeshwor and Vishwanath, 2011 and Schistura reticulofasciata (Singh and Bănărescu, 1982)] from Simsang River, Meghalaya, India. Journal of Applied Ichthyology 33: 1036-1037.
Teulier, L., L. Guillard, C. Leon, C. Romestaing & Y. Voituron (2018): Consequences of electroshock‐induced narcosis in fish muscle: from mitochondria to swim performance. Journal of Fish Biology 92: 1805-1818.
Thomson-Laing, G., J. D. Howarth, M. J. Vandergoes & S. A. Wood (2022): Optimised protocol for the extraction of fish DNA from freshwater sediments. Freshwater Biology 67: 1584-1603.
Thurow, R. F., C. A. Dolloff & J. E. Marsden (2012): Visual observation of fishes and aquatic habitat. In: A. V. Zale, D. L. Parrish & T. M. Sutton (Eds.), Fisheries Techniques, pp. American Fisheries Society, Bethesda, Maryland.
Tiberti, R., T. Buchaca, E. Cruset, L. Iacobelli, M. Maini, V. Osorio, M. Puig, Q. Pou-Rovira, I. Sabás & M. Ventura (2022): Evaluation of visual encounter surveys as a method for the rapid assessment of fish presence and relative density in high mountain lakes. Aquatic Conservation: Marine and Freshwater Ecosystems 32: 1520-1528.
Trochine, C., S. Brucet, C. Argillier, I. Arranz, M. Beklioglu, L. Benejam, T. Ferreira, T. Hesthagen, K. Holmgren, E. Jeppesen, F. Kelly, T. Krause, M. Rask, P. Volta, I. J. Winfield & T. Mehner (2018): Non-native Fish Occurrence and Biomass in 1943 Western Palearctic Lakes and Reservoirs and their Abiotic and Biotic Correlates. Ecosystems 21: 395-409.
Turner, L. J. & W. C. Mackay (1985): Use of Visual Census for Estimating Population Size in Northern Pike (Esox lucius). Canadian Journal of Fisheries and Aquatic Sciences 42: 1835-1840.
Verma, R. C. (2015): Use of diverse fishing techniques in mid-Himalayan landscape of Central Himalaya, Uttarakhand. International Journal of Science, Technology & Management 4: 89-96.
Verma, R. S., P. Sharma & L. S. B. Upadhyay (2022): A survey on the traditional and indigenous fishing methods in the Kali River, Uttarakhand, India. FLORA AND FAUNA.
Wang, S., Z. Yan, B. Hänfling, X. Zheng, P. Wang, J. Fan & J. Li (2021): Methodology of fish eDNA and its applications in ecology and environment. Science of The Total Environment 755: 142622.
Watson, J., A. M. Edwards & M. Auger-Méthé (2023): A statistical censoring approach accounts for hook competition in abundance indices from longline surveys. Canadian Journal of Fisheries and Aquatic Sciences 80: 468-486.
Zakęś, Z., M. Rożyński, E. Ziomek & K. Demska-Zakęś (2017): Tagging juvenile European perch (L.) with passive integrated transponders (PIT) – impact on growth, condition, and physiological indexes. Fisheries & Aquatic Life 25: 201-207.
Zale, A. V., D. L. Parrish & T. M. Sutton - editors (2012): Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

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