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GOOD PRACTICES GUIDELINES FOR DATA COLLECTION SYSTEMS TO SUPPORT SUSTAINABLE INLAND AND RECREATIONAL FISHERIES IN THE WESTERN BALKANS REGION

Cover photograph: Fly fishing in Lim River, Plav Montenegro. © Ivan Randjelovic

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GOOD PRACTICES GUIDELINES FOR DATA COLLECTION SYSTEMS TO SUPPORT SUSTAINABLE INLAND AND RECREATIONAL FISHERIES IN THE WESTERN BALKANS REGION

by

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Preparation of this document

FAO Members in the Western Balkan region (WBR) expressed concerns to FAO about the lack of the proper tools for data collection, measurement and management of their inland fisheries. As a response to address those concerns, the FAO Technical Cooperation Programme project (TCP/RER/3706) on "Improved data collection for sustainable management of inland fishery resources in the Western Balkans" was initiated by the FAO Regional Office for Europe and Central Asia (REU). As part of the project, current data collection practices in three countries of the WBR were assessed, namely: Albania, Montenegro and North Macedonia. Country profiles and strengths, weaknesses, opportunities and threats (SWOT) analyses were prepared with stakeholders which highlighted the existing challenges and some of the common issues with the currently available data and information. The country case studies were authored by National Consultants Arian Palluqi (Albania), Danilo Mrdak (Montenegro) and Zoran Spirkovski (North Macedonia) under supervision of Victoria Chomo, project Lead Technical Officer and Eva Kovaks, FAO fisheries consultant who carried out field missions in the three countries. In addition, the Natural Resources Institute Finland (LUKE) produced FAO Fisheries and Aquaculture Technical Paper No 649, "Data Collection Systems and Methodologies for the Inland Fisheries of Europe", 2020. Its findings revealed that current methods of data collection for inland fisheries of West and Northern Europe are highly variable across countries. Although catch statistics are mandatory for most commercial fisheries, recreational fisheries continue to be underreported. Given the overall decline in European inland capture fisheries and the increased economic importance of recreational fishing to the socio-economics of riparian communities, there was a recognized need to provide guidance on data collection methodology to support the sustainable management of inland fishery resources, specifically for better data coverage of the recreational fishery activities throughout Europe. As part of TCP/RER/3706, good practices were compiled into guidelines by T.A.M. Visser, FAO consultant on Fisheries Catch Assessment, Chiang Mai, Thailand; John Valbo Jorgensen, Fishery Resources Officer, Marine and Inland Fisheries Branch, FAO Rome; and Victoria Chomo, Senior Fisheries Officer and Secretary of the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC), FAO. Technical review of the guidelines was kindly provided by European inland fisheries experts: Teppo Vehanen, Chair of EIFAAC Technical and Scientific Committee (Finland), Marina Piria (Croatia), Martin Cech (Czechia), Christian Skov (Denmark) and Fiona Kelly (Ireland). The authors thank the reviewers for their excellent contributions to the guidelines.

Abstract

These guidelines illustrate recommendations for good practices on data collection in Eastern European inland fisheries, and in particular the Western Balkan region, based on the methodologies and approaches used in countries throughout Europe and from FAO experience of inland fisheries in other regions . They provide guidance on the options available to inland fishery managers based on particular circumstances i.e. commercial fishing or recreational use, and they are especially relevant for assisting the economies-in-transition in Europe, Caucasus and Central Asia. These guidelines are not an overarching work on inland fisheries management, nor do they provide advice on the environmental aspects or competing uses of inland water bodies. They focus on issues of data collection to support fishery managers whether they be government agencies, fishers or angler associations co-responsible for the management of inland resources in European rivers and lakes.

Contents

Abbreviations and acronyms

ASFIS	aquatic sciences and fisheries information system
CBD	Convention of Biological Diversity
CCRF	Code of Conduct for Responsible Fisheries
CDS	catch documentation scheme
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on Migratory Species
COFI	FAO Committee on Fisheries
CPUE	catch per unit of effort
CSO	Central Statistics Office
CWP	coordinating working party
DIME	development impact evaluation
DoF	Department of Fisheries
EAFm	ecosystem approach to fisheries management
EC	European Commission
EIFAAC	European Inland Fisheries and Aquaculture Advisory Commission (since 2010)
EIFAC	European Inland Fisheries Advisory Commission (now EIFAAC)
ELEFAN	electronic length frequency analysis
ERA	ecological risk assessments
ERAEF	ecological risk assessment for the effects of fishing
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FISAT	FAO ICLARM stock assessment tools
FISMIS	fisheries information system and management information system
FMO	Fisheries Management Organization
FMU	fishery management unit
GDP	gross domestic product
GPG	good practices guideline
GSI	gonadosomatic index
ICLARM	International Center for Living Aquatic Resources Management (now WorldFish)
ISSCAAP	international standard statistical classification of aquatic animals and plants
IT	information technology
IUCN	International Union for the Conservation of Nature
IUU	illegal, unreported and unregulated fishing
LEK	local ecological knowledge
LSMS	living standards measurements study
LUKE	Natural Resource Institute Finland
MARD	Ministry of Agriculture and Rural Development
NGO	non-governmental organization
OAA	other aquatic animals
PAP	pre-analysis plan
PC	personal computer
PDF	portable document format
QA/QC	quality assurance and quality control
QAP	quality assurance plan
REU	FAO Regional Office for Europe and Central Asia
RFB	regional fishery body
SDG	Sustainable Development Goal
SEI	Shannon Evenness Index
SFC	sport fishing club
SWOT	strengths weaknesses opportunities and threats
UN	United Nations
VGSSF	Voluntary Guidelines for Small-Scale Fisheries

1. Introduction

The many rivers and lakes of Europe harbour significant aquatic biodiversity and provide valuable ecosystem services to society, including food provision, transportation, delivering fresh water to people, industry and farms, removal of waste, recreation, tourism and hydropower. Some of these uses have had detrimental and sometimes irreversible impacts on inland ecosystems and associated aquatic resources. In European countries, the role of inland fisheries has increasingly provided recreational services, biodiversity conservation, and eco-tourism. Recreational fisheries in this study are defined as all fishing activities conducted for the sole purpose of sport or leisure activity, whether released or consumed at home, and not for commercial fishing purposes. Recreational fishing is becoming more common in many areas of the world and, where it develops, tends to supplant commercial food fisheries and replace revenue from declining commercial inland fisheries. In other regions, recreational fisheries may contribute more directly to food supply as in many cases they are of a subsistence or artisanal nature (Aps *et al.*, 2004).

Information on recreational and artisanal inland fisheries is scarce. This is both because of the perception that there is no need for management as these fisheries are often considered to have a low impact on fish stocks[1] or limited contribution to local economies, and because of a lack standardised data collection methods for inland fisheries compared to commercial fisheries. Countries implement a wide variety of data collection methods and intensity, because they manage inland fisheries individually without common guidelines. Failing to account for recreational fisheries in stock assessments can reduce the chance of fishing sustainably, but routine collection of data on recreational fisheries is challenging. In particular, to account for the small-scale and part-time nature of recreational fishing, surveys are expensive to conduct (Vølstad *et al.*, 2006) and involve complex methods that may not overcome significant bias (Hartill and Edwards, 2015), which all limit the precision and extent of data that can realistically be collected.

Since the industrial revolution and the modernization of the agricultural sector began in Europe, priority has been given to economic growth with limited consideration of environmentally sustainable development. Smaller sectors such as inland fisheries, which have since Neolithic times, contributed to the food security of European populations, have received little or no attention and therefore have not benefited from the higher requirements for ecosystem integrity and limited ecosystem impact that marine fisheries faced, especially over the last 20 years. This has resulted in decisions regarding water shed management, such as hydroelectric dams, dredging, and irrigation, that gave least priority to inland fisheries. In Central and Eastern Europe and the Western Balkans region in particular, fishing makes a small but essential contribution to household protein, however this home consumption is not accurately accounted for in national statistics and thus the sector is undervalued.

In order to ensure sustainable management of fisheries and achieve national or sub-national social and economic objectives, enough information about the fisheries must be generated through data gathering, analysis and research. Only when there is sufficient knowledge will it be possible to formulate useful policies for the entire fisheries sector and manage particular fisheries in a sustainable way.

[1] Based on low daily allowable catch, absence of incentives from fish trade and prevalence of catch and release fisheries.

In a review of data collection methods currently implemented for the inland fisheries of Europe (Vehanen *et al.*, 2020), it was found that most data collection focuses on salmonid species, whereas other fish species are far less covered. However, where data from other fish species are collected, the methods employed include postal or telephone recall surveys using a random subset of citizens of the country e.g. in Norway, Finland and Sweden. Moreover, whereas commercial fisheries are widely monitored, recreational fisheries often were not routinely monitored in European countries, except for mandatory reporting of catch data on salmonids (and sometimes eel) such as in Albania, Belgium, Denmark, Iceland, and Portugal. More detailed surveys were used to assist national surveys or were used independently in specific sites of importance using various methods, like postal surveys targeted to fishing license holders, online reporting of catches, or catch reports and logbooks. Many European countries provided fishing license buyers with catch return forms or logbooks to be filled in during fishing occasions and/or returned at the end of the fishing season. Meanwhile voluntary self-reporting, including citizen science, is limited, but is practised in Bulgaria, Denmark and France. Commercial inland fisheries are very limited in most European countries. In countries where commercial fishing is important, in most cases the fishers were registered and obliged to report their catches. The reliability of self-reporting of commercial catches is questionable and there is a current trend towards web-based online reporting of inland fisheries data, which some countries like Croatia, Czechia, France, and others have already implemented.

However, the main take away from the review (Vehanen *et al.*, 2020) is that reporting for recreational, but also for commercial fisheries, is at best sporadic and there seems to be a significant uncertainty on the level of exploitation of inland fisheries. In addition, there are large differences in legal requirements between countries and the state of available statistics, even at basic levels e.g. the total number of recreational fishers.

The absence of proper data collection systems for inland fishers and anglers means that it is not possible to place social and economic value on the sector to guide policymakers; and the real value of inland fisheries in terms of their contribution to livelihoods, recreation and food security is still not well measured in Europe. For this reason, policymakers remain hesitant to give the importance to this sector that it rightly deserves when making decisions that affect fishery habitats (EIFAC, 2008a). When allocating freshwater resources among competing uses, the lack of reliable data and thus the undervaluation of inland fisheries, results in policy decisions which historically have favoured the construction of dams for hydroelectric generation, dredging for sand production or transport, and flood control measures to protect cities. Many of these factors have contributed to habitat fragmentation through loss of lateral and longitudinal connectivity of rivers and streams essential for sustaining viable fish populations. In addition, freshwater supplies to cities or agriculture producers can have severe consequences on reproduction of river and lake species at critical periods in their life cycles.

A significant complication for the management of many river and lake basins in Europe is that fish stocks are shared by several countries. Sustainable management requires agreement among countries on the management objectives and measures, as well as the collection methodology to ensure compatibility and the regular sharing of data. This particular concern over fisheries management in shared water bodies was expressed by several governments in the Western Balkans region.

Fishery policies and management plans need to address the fishery sector as a contributor to the economy at local, national and regional level, and as a critical component of the overall ecosystem. Data collection should cover all aspects of a fishery i.e. the resource, the fishers, traders, industry and consumers. However, when compared to marine fisheries and

aquaculture statistics, inland fisheries statistics are typically less complete and accurate due to the greater complexity of inland fisheries and the problems with obtaining the necessary data from them. In addition, governments are usually more motivated to monitor marine fisheries and aquaculture due to the prospects of tax income and foreign revenue generation in the former two sectors (Coates, 2002). This is a vicious circle as the undervaluation of inland fisheries due to a lack of accurate statistics, especially recreational fishing which adds significantly to the economies of Europe, contributes to the underappreciation of these resources in policy decisions related to freshwater resources.

Thus, there is a clear need for accurate statistics and viable data collection methodologies for inland fisheries managers that will serve two-fold benefits: ensuring sustainable management of fishery resources and a fair valuation of aquatic species when making broader decisions on watershed use and freshwater resource management.

A number of key documents that cover aspects of the importance of data collection for fisheries in general and inland fisheries in particular are:

FAO Code of Conduct for Responsible Fisheries
The purpose of 1995 FAO Code of Conduct is to set international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity. A ground-breaking, unique and voluntary instrument, the 1995 FAO Code of Conduct is probably the most cited, high-profile and widely diffused global fisheries instrument in the world after the 1982 UN Convention.

Related to data collection it states that countries should ensure that timely, complete and reliable statistics on catch and fishing effort are collected and maintained in accordance with applicable international standards and practices and in sufficient detail to allow sound statistical analysis. Such data should be updated regularly and verified through an appropriate system. States should compile and disseminate such data in a manner consistent with any applicable confidentiality requirements (CCRF, Article 7.4, paragraph 7.4.4, FAO, Rome, 1995).

A key principle included in the FAO Code of Conduct is the **precautionary approach**:

> "*States and subregional and regional fisheries management organizations should apply a precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment, taking account of the best scientific evidence available. The absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or depended species and non-target species and their environment*". Code of Conduct for Responsible Fisheries (CCRF, Article 6, paragraph 6.5, FAO, Rome, 1995).

The precautionary approach aims at reducing the probability of occurrence of bad events within acceptable limits and is used when the level of uncertainty and the potential costs are significant, when full reversibility may not be ensured (but AT LEAST partial reversibility is highly likely). It requires, *inter alia*, the maintenance of a flexible, resilient fishery system (including the fish stock, the associated species, the fleet and the management agency regulating it). It addresses meso-issues which are central to the management of the fishery system such as resources sustainability and recruitment overfishing, protection of non-target and endangered species, environmental management of aquaculture, development of new fisheries and maintenance of ecosystem productivity (FAO Fisheries and Aquaculture Department, http://www.fao.org/3/W1238E03.htm).

EIFAC Code of Practice for Recreational Fisheries
The European Inland Fisheries Advisory Commission (EIFAC) Code of Practice (CoP) for Recreational Fisheries is intended to complement and extend the FAO CCRF and is framed specifically towards recreational fishery practices and issues. It serves as the core document that describes the minimum standards of environmentally-friendly, ethically-appropriate and – depending on local situations – socially-acceptable recreational fishing and its management. Recreational fishing constitutes the dominant or sole use of many freshwater stocks in the EIFAC region. Its importance is also increasing in economies in transition of that region. (EIFAC, 2008b).

FAO Technical Guidelines for Responsible Fisheries. No. 13, Recreational Fisheries
These technical guidelines are focused on recreational fisheries and describe strategies to promote environmentally sustainable and socially responsible management of such fisheries. To this end, the document details policy, management and behavioural recommendations for sustainable recreational fisheries that are an increasingly important component of global fisheries. Specifically, the guidelines translate the relevant provisions of the FAO Code of Conduct for Responsible Fisheries into specific advice for recreational fisheries. The concept of aquatic stewardship is introduced as an overarching ethical framework needed to achieve ecologically sustainable recreational fisheries on a global scale. Within this normative mindset, the adaptive management philosophy based on quantifiable and transparent objectives, continuous learning and feedback loops is proposed along with the acknowledgement of principles such as the ecosystem approach and the precautionary approach. Detailed sections on policy and institutional frameworks (tailored towards policymakers), recreational fisheries management actions and strategies (tailored towards fisheries managers), recreational fisheries practices (tailored towards individual recreational fishers) and recreational fisheries research (tailored to researchers and managers) provide tangible advice for responsible recreational fisheries (FAO, 2012).

The Voluntary Guidelines for Securing Sustainable Small-scale Fisheries (VGSSF)
Most of the world's inland fisheries, particularly in Europe, are small-scale. The FAO Voluntary Guidelines for Securing Sustainable Small-scale Fisheries in the Context of Food Security and Poverty Eradication (VGSSF) (FAO, 2015) provides valuable guidance on supporting small-scale fisheries. The VGSSF support equitable distribution of the benefits yielded from responsible management of fisheries and ecosystems, rewarding small-scale fishers and fish workers, both men and women. This includes adoption of legislation that supports habitat restoration, fish passes and other mitigation measures where European rivers or streams have already been fragmented by past policies, which did not consider inland fisheries. Their leverage in future policymaking depends on how well fishery managers can capture data on the contribution of this underreported sector to the socio-economics of the nation.

The guidelines *inter alia* emphasise that "States should establish systems of collecting fisheries data, including bioecological, social, cultural and economic data relevant for decision-making on sustainable management of small-scale fisheries with a view to ensuring sustainability of ecosystems, including fish stocks, in a transparent manner."

1.1. SCOPE OF THE GUIDELINES

Although these guidelines were written specifically in response to requests by countries in the Western Balkans region, they have a wider application. In particular for economies-in-transition and land-locked countries in Central and Eastern Europe, the Baltic States, the Caucasus and Central Asia, where fishers and anglers are more familiar with freshwater fish as food than in Western and Southern European countries. Many of the challenges for

implementing data collection systems, especially for the highly variable and small-scale recreational fisheries, are similar and the proposed approaches are expected to be applicable elsewhere as they follow general principles.

The scope of these guidelines is to describe commonly used data collection practices in developed countries of Europe that are relevant for management of inland fisheries, highlighting the pros and cons of each, and which can be adapted to the circumstances in the Western Balkans, Central and Eastern Europe, the Caucasus and Central Asia. National policymakers and fishery managers can review these options and choose the methods of data collection that fit their particular circumstances with the aim of improving accuracy, timeliness and reliability of data on inland fisheries in support of sustainable management. Case studies from three countries in the Western Balkans – Albania, Montenegro and North Macedonia – provide subregional examples of current practices in transition economies. With very limited commercial inland fisheries and well-established approaches for collection and validation for these fisheries, the main emphasis for these guidelines is for recreational fisheries, as they are currently under-represented, or not covered at all, presenting the largest challenge for inclusion into routine data collection.

Data collection should cover all aspects of a fishery, from exploitation of the natural resources for human well-being, to the consumers, industry and trade (de Graaf *et al.* 2015). The current guidelines only intend to cover part of these data requirements, with fishery managers as the main target audience, focusing on their need for fisheries and/or environmental data to plan for and to evaluate management interventions. More specifically, recreational and sport fisheries have grown in economic importance and may currently be the main driver in European inland fisheries and a major income source for former small-scale fishers and their communities. In this regard, sport fishers and angler associations often have significant leverage with decision-makers and may be able to influence resource decisions and investments into management and habitat restoration (Bate, 2003 and Arlinghaus *et al.*, 2019). Providing them with tools to collect more meaningful data and information will help them assess developments and evaluate management interventions, including the emergence of citizen science (Vehanen *et al.*, 2020; Blossom, 2012 and Fulton *et al.*, 2019). The European Union (EU) actively promotes the use of citizen science, and also provides tools and training resources.

These good practices guidelines can be used for self-assessment of data systems by European governments and relevant stakeholders such as fisher or angler associations, especially for the land-locked countries and economies-in-transition in Eastern and Central Europe, Western Balkans region, the Caucasus, and Central Asia. They also constitute a valuable training tool for future FAO workshops on data collection systems for management of inland fishery resources in other regions facing similar situations of data-poor occupational (commercial) and recreational inland fisheries.

1.2. THE SITUATION OF INLAND FISHERIES DATA COLLECTION IN THE WESTERN BALKANS REGION

Three countries were commissioned to investigate the current status of inland fisheries and data collection in the subregion of the Western Balkans. Although some data was available for parts of the inland fisheries, this follows the same pattern as in many other countries with limited coverage and uncertain accuracy of the available data and information. For the purpose of these guidelines, the main point of interest is the situation of the data collection systems that are currently implemented, how to identify weaknesses in the system, and the planned changes that are cost-effective while meeting the needs of fisheries managers and policymakers. Three case study examples of current situations regarding data collection for inland fisheries in the Western Balkans region are given below:

Country case study A – Currently no data collection is active (last available report on inland fisheries is for 2012), but mandatory catch reporting using online reporting is included in a 2018 fisheries law for both commercial and recreational fisheries. Data that need to be submitted: Name of fisher, date of catch, fish species, weight of the fish and location. Local authorities, through fish guards from Sport Fishing Clubs (SFC), are responsible for enforcing regulations and management, as well as fishery inspectors from the Ministry of Agriculture and Rural Development. The national statistics authority is responsible for publishing national statistics, based on reports from the Directorate of Fisheries within the Ministry of Agriculture and Rural Development.

Country case study B – Fisheries inspectors are tasked with collecting fisheries data (currently 16 for inland water bodies). This is based on reports from (Fishery Management Organizations that provide quarterly data about catch and price by species, total catch, number of fishers, and the number, length, mesh size of fishing gears and number of hooks used by the fishers. This data is in some places based on (simplified) logbooks, but how this information is collected from fishers when not using logbooks is unclear, with the data sent to central government by fishery inspectors. There are slightly different responsibilities for different types of water bodies (natural/artificial lakes, coastal lagoons and irrigation reservoirs), with no mention of river fisheries (which may be missing from the available **data).**

Country case study C – Commercial fisheries are required to report on catches (weight only), but fish catch data are mixed with farmed fish by the national statistics authority, which gives a misleading picture of the fish production from natural waters. Recreational fisheries are not covered by any monitoring scheme. Their contribution is "estimated" based on the number of (daily) licenses and the maximum allowable catch for each license.

The situation in the Western Balkans region is therefore complicated, with different levels of requirements and regulations in place. Western Balkan countries face special circumstances compared to Northern, Western and Southern European countries as economies-in-transition. They are now in the process of revitalizing their inland fisheries and freshwater aquaculture sectors for domestic food security. However, data collection, monitoring and analysis are key components of management that will need to be addressed in a systematic way. As many of these countries share rivers and lakes, coordinated and standardized methods of data collection and sharing of data are key elements in the management of shared stocks of commercial or recreational value.

2. Assessing fisheries data collection system needs

The main purpose of fisheries information in practical terms, according to van Zwieten (2002) is to:

1. Describe the state of fisheries production (to inform planning), including showing the importance of different sub-sectors for the overall economy, assess food security and livelihoods (fish is regarded as a commodity with a certain value);
2. Provide inputs for fisheries management (fish as renewable natural resource);[2] and
3. For conservation (biodiversity) purposes (where fish act as indicators for the wider ecosystem health).

The level of detail that is required in the above list, increases from top to bottom, and this affects the way a statistical system needs to be organized to provide the required information.

In addition, there may be international obligations for exchange of specific data e.g. trade in endangered species (CITES) or on fish stocks shared between multiple countries in rivers, lakes or other shared aquatic resources. European requirements for mandatory monitoring,[3] almost exclusively focus on recreational catches of certain marine fish species. As some of these species (i.e. brown trout, eel and Atlantic salmon) are diadromous, they are therefore relevant for inland fisheries reporting as part of their life cycle depends on access to freshwater habitats in Europe. In addition, the EU has specific requirements for monitoring and reporting of eel catches.[4]

Data requirements for any data collection system need to be based on a thorough assessment of both the intended purpose of the data collection and which data and information need to be collected. In most countries, the data needs – and in many cases the preferred methodology – has already been decided at a central level; and in some cases included in revised fisheries laws and government decrees. Even if the general requirements are known, the general approach for review and evaluation of the data collection system, as outlined in Figure 1, is still worth considering as it can be implemented at both national and local level by government authorities and those responsible or involved in fishery management at local level e.g. angler associations. Especially for local management, the participatory co-management approach is highly valuable, both as a planning instrument and to engage with all relevant stakeholders for data collection and management interventions.

2.1. PREPARATIONS FOR PLANNING AND CONSULTATIONS

2.1.1. Legislative framework

Fisheries regulations provide the basis for data collection by stipulating requirements for fishing licenses e.g. mandatory reporting of catches by licensed fishers, but they also often define general management interventions and responsibilities. This, however, works both

[2] As mentioned earlier in the introduction, only when there is sufficient knowledge will it be possible to formulate useful policies for the whole fisheries sector and manage particular fisheries.

[3] The EU data collection framework (DCF), regulation 2017/1004 of 17 May 2017 covers establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy.

[4] EC Regulation 1100/2007 (the Eel Regulation) imposes an obligation to prepare and implement eel management plans (EMPs) including best available estimates of the proportion of the silver eel biomass that escapes to the sea to spawn and other indicators (fishing effort and estimates of fishing mortality and mortality factors outside the fishery.

ways as perceived data requirements and relevant management approaches should be reflected in the fisheries law and subsequent ministerial decrees. Therefore, the preferred management approach should inform the fisheries law, providing support for how management and data collection need to be implemented. Participatory consultations may lead to revisions or additional decrees to clarify the legal framework to facilitate data collection and management as the situation evolves, as this is not a static process.

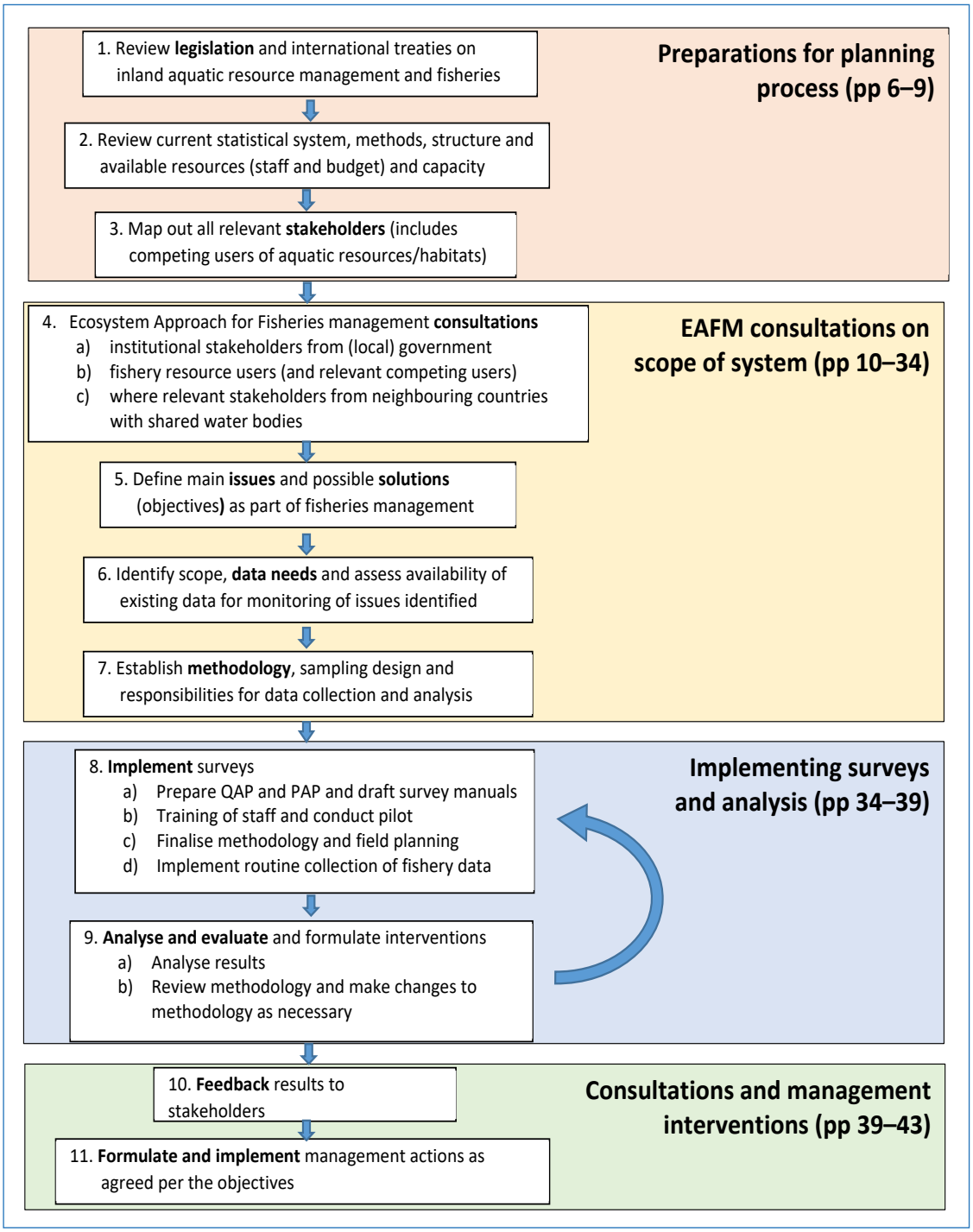


Figure 1. Generalized steps for sustainable management of inland fisheries through evaluation of the data collection system.[5]

[5] Implementing/choosing the right data collection methodology is an adaptive process, but so is decision-making and implementation of management actions, using EAFm as illustrated in Box 1 on p 12.

Data collection should take account of any monitoring and reporting obligations under international law or resulting from international or regional management and development agreements to which the country is party, or ratifications of conventions, codes of conduct or voluntary instruments concerning the status of the fisheries and the aquatic environment upon which the fisheries depend. Both the national and international legal framework will provide requirements for which data needs to be collected. This mainly pertains to shared stocks of migratory species (in aquatic habitats shared between nations), endangered species, mainly diadromous species like eels and sturgeon, and collecting environmental parameters (water quality data), as well as quantity and species of fingerlings released from hatcheries for restocking purposes.

Assessing international obligations and the implications for national (fisheries) data collection requirements, is the role of the national government not local management bodies. The practical implications of international obligations[6] for data collection (and responsibilities) need to be disseminated to local management bodies and local governments that are involved in management and data collection. Similarly, in the case where aquatic resources are shared between countries, it is necessary to be aware of management plans and measures each country has in place. Methodologies and data exchange protocols can then be discussed, while shared data collection and establishment of a common database can be considered to optimise planning and implementation of management interventions.

2.1.2. Review existing data collection system

When considering designing a new statistical system, or redesigning an existing system, some information on the existing statistical system is required to allow proper evaluation.

Collect information on objectives, data needs, methods used and information produced for the existing statistical system

All countries already have a statistical system in place i.e. a number of statistical organizations and units that jointly collect, process and disseminate official statistics on behalf of national government (OECD, 2002). It is essential to understand how the current system works, how and by whom the data is collected, at what level it is collated and reported, the linkages with licensing and responsibilities of landowners, fisher organizations and managers. The assessment should focus on what works and what does not, the weaknesses and opportunities offered by the specifics of the data collection system and linkages with how the fishery is organized and managed in terms of licensing and responsibilities by local government, owners and managers. An improved fishery statistical system will need to be built with the existing staff and expertise, therefore the existing structure, resources and capacity of staff should be known and evaluated. This needs to be done on a regular basis.

Collect information on who is involved in policy and planning in relation to fisheries

It is necessary to be aware of the targets for the information produced by the fishery statistical system. This will influence what type of information is required, what should be collected and how it should be collated. This will not be limited to the fisheries department, but will involve watershed managers, agriculture, forestry, environment and other departments that may have conflicting policies that impact fisheries (resources and habitats), and therefore should be aware of the status of the fisheries in order to make balanced decisions on the sector. Policy and planning are seldom directly influenced by the state of the fisheries, unless it is a policy of the department of fisheries. However, fishery statistics are used to assess the impacts of policies by other departments, as a measure for changes in the fishery situation.

[6] Amongst others: Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Ramsar Convention on Wetlands, Convention on Biological Diversity (CBD) including the Aichi targets, the Sustainable Development Goals (SDG), EU Framework Directive, and Convention on Migratory Species (CMS).

Formulate the objectives of the fishery statistical system

It is necessary to clearly specify what the fisheries statistics will be used for, or more to the point, the main purpose for collecting fishery statistics. Although in most countries this is to inform policy and guide planning for fisheries management, maximize employment, increase economic output, ensure food security, or human well-being, it is also to assess the effectiveness of management interventions. Additional objectives may relate to specific biodiversity goals or detailed information on the status of fisheries resources for specific aquatic habitats, at lower administrative levels. This not only affects what needs to be collected, but also the required detail e.g. whether only an overall national level catch estimate is needed or more granular information on the distribution and abundance of a particular species. Collecting data is expensive, so if there is no good reason to collect certain data, then it is best not to.

2.1.3. Stakeholder analysis

In order to draft a comprehensive fisheries management plan and identify all data and information that is needed to formulate and evaluate implementation of management interventions, it is important to include all relevant stakeholders that need to be involved in the ecosystem approach to fisheries management (EAFm) process. Stakeholders broadly include both aquatic resource users (fishers, farmers, loggers, miners, etc.), as well as institutional stakeholders representing the various sectors involved in aquatic resource policy and planning (fisheries, agriculture, forestry, environment, industry and other relevant departments). This can be prepared at national level, but when separate types of fisheries exist with different requirements for management – fisheries in lakes/reservoirs are distinct from those in rivers – local resource users and institutional stakeholders need to be identified and involved separately, before bringing results and findings up to national level for discussion and integration.

Stakeholders should include both targets for the information produced by the fishery statistical system and sectors that affect fisheries resources and habitats, and therefore should be aware of the status of the fisheries in order to make balanced decisions on the policy, planning and management. Inclusion of a wide range of stakeholders is essential for establishing what data needs to be collected, how the information produced is shared and packaged and to decide on responsibilities of various stakeholders, especially in a co-management system.

Stakeholder analysis is an iterative process, especially for resource users. Initial consultations on issues and conflicts often lead to identification of additional stakeholders. There is no single best method of stakeholder analysis, however for some examples in the context of natural resources management, see Kennon *et al.* (2009) and Mease *et al.* (2018). In most cases it is straightforward to list the main stakeholders using common sense. It is important to pay extra attention to silent voices, depending on the setting and cultural sensitivities; these can include women, youth, minorities (including immigrants) and the rural poor. During meetings, these groups need to be encouraged to speak up, and if necessary, engaged in separate group meetings. In addition, the group dynamics are important, where it is necessary to closely observe not just what is being said, but who is speaking and how this relates to their social status or position (both formal and informal). Stakeholder analysis is as much a social network analysis[7] (for examples see Nguyen *et al.* (2016) and Hukkinen, (2012)), and is closely related to the next step of the process: formulation of a management plan to assess data needs. For more information please refer to the EAFm toolkit (see next

[7] The process of investigating social structures through use of graphical representation of networks, to characterize networked structures in terms of individual actors, people, or things within the network and the relationships or interactions that connect them.

section), Scialabba (1998) and FAO (2009; http://www.fao.org/fishery/eaf-net/eaftool/eaf_tool_16)) which includes relevant guidance on stakeholder analysis for fisheries and natural resources management in general.

2.2. ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT

Whereas national and international requirements are mostly to fulfil data commitments for policy and planning, at local level, the main objective for data collection is to support formulating management interventions and evaluate their impact on agreed targets, this applies to both fishery and environmental management. Over the last couple of decades, and in particular since the adoption of the EU Water Framework Directive,[8] much more attention is given to improving environmental status of surface water bodies, and there is increasing recognition of the economic benefits involved with healthy aquatic environments. This is reflected in a move towards more holistic management principles with the EAFm, which combines classical fisheries management approaches with adaptive co-management to provide a larger sense of ownership of the data collection and management interventions by affected communities or stakeholders. EAFm leads to both better collaboration in data collection and higher levels of compliance with the management interventions, as resource users have been actively involved in the formulation of both the data collection methodologies and the management interventions.

Before deciding on data collection methodologies, the data and information requirements need to be established. The most practical approach for assessing data needs and implementing a robust data collection system comes from the EAFm approach (see Box 1).

The EAFm involves a training or workshop setting, where stakeholders (both institutional and resource users) are asked to develop a draft fisheries management plan, while considering all aspects that affect the fishery. The approach can be done at both national and local level and is both an introduction and a practical implementation of the principles of co-management. The steps as per Figure 1 are:
Step 1: Define and establish the scope of the Fishery Management Unit (FMU), whether at national or local level – identifying the fishery characteristics, its area and its stakeholders;
Step 2: Identifying and prioritizing the issues in the fishery (risk assessment),[9] and setting goals for the fishery;
Step 3: Develop EAFm plan including indicators of achievement and benchmarks (performance measures) for selected management interventions to meet the objectives for the fisheries under consideration;
Step 4: Implementing the EAFm plan including data collection for the fisheries and area under consideration; and
Step 5: Monitoring, assessment and review leading to participatory process to adjust the EAFm.

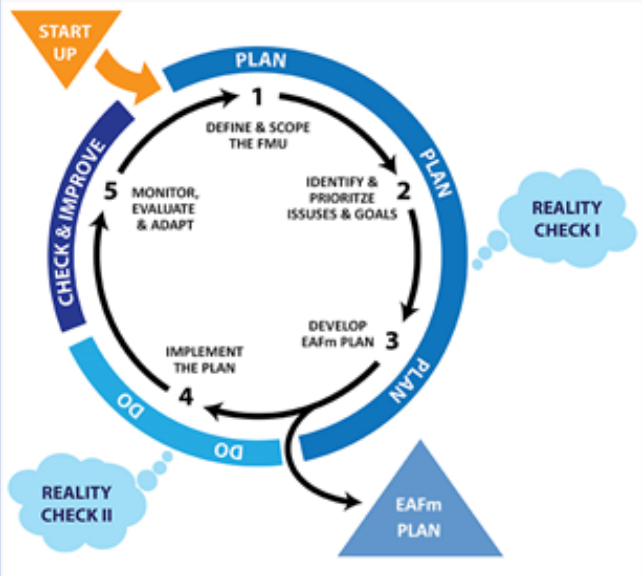
The main overlap between using EAF to develop a fisheries management plan and assess the scope and requirements for a fisheries data collection system lie in step 3. Data collection is an integral part of the EAFm process. In order to assess the effectiveness of management interventions, data needs to be collected that indicate the status of and change in the fisheries, as well as on implementation of the agreed management interventions (e.g. progress with establishing protected areas, effectiveness of patrols and compliance with

[8] https://ec.europa.eu/environment/water/water-framework/index_en.html
[9] Ecological Risk Assessments (ERA) are performed to evaluate the likelihood of adverse ecological effects occurring as a result of exposure to physical or chemical stressors. These stressors are defined as any biological, physical, or chemical factor that causes adverse responses in the environment, this is an integral part of the EAFm process. An expansion is the Ecological Risk Assessment for the Effects of Fishing (ERAEF) to identify which species, habitats and (fish) communities are at risk from the effects of fishing (Hobday *et al.*, 2011).

BOX 1
Ecosystem approach for inland fisheries

EAF is a way of managing fisheries and aquaculture that balances the different objectives of society (e.g. ecological and economic objectives) by applying an integrated approach across geographical areas that reflect natural ecosystems (Staples and Funge-Smith 2009). The term "ecosystem" includes the fishery system as an integrated social-ecological system in which humans and their activities are integral parts. There is therefore no mismatch between addressing human and ecological well-being or between conservation of biodiversity, ecosystem structure and functioning, and that of fisheries management dealing with the provision of food, income and livelihoods for humans.

It is a fundamental principle of EAFm that all relevant stakeholders are involved in the development of management objectives and plans. In many cases, objectives from different stakeholders will conflict and it will be necessary to strike a balance between these multiple objectives and identify trade-offs. The insecurity involved with adopting a management plan is dealt with through another principle, which is that management should be adaptive and therefore permit changes to the management plan as experience accumulates or new information becomes available.[1] The advantage is that management may be implemented even in a situation where almost no data on the fisheries is available, by for example, using local knowledge as the starting point when developing the management plan.



Steps for developing, implementing and monitoring a management plan using EAFm

[1] The participatory processes to adjust management plan lies at the core of the EAFm and is discussed in in detail in the ecosystem approach to fisheries management training course (FAO, 2019a through 2019d)

agreed management interventions). The current guidelines are not about the EAFm process *per se*, just about how it can facilitate identifying data needs to be covered by the data collection system. It is likely that at local level EAFm can be implemented to develop management plans that are in many cases mandatory for allowing angler associations and fisher groups to manage aquatic resources. However, the current guidelines are focused specifically on developing data collection systems, not to explain how to develop fisheries co-management plans. FAO has recently prepared a number of documents for guiding implementation of EAFm for inland fisheries (FAO, 2019a through FAO, 2019d). As part of the development of a fisheries management plan based on EAF principles, data requirements for key indicators are clarified.

The EAFm process is recommended to identify the objectives of the data collection system, the indicators to be collected and assessment of the preferred methodology for collecting the data.

2.2.1. Objectives of the data collection system

After the main fishery issues are identified and prioritized i.e. through stakeholder consultations and SWOT (strengths, weaknesses, opportunities and threats) analyses, solutions are identified and agreed upon that will form the main objectives for the data collection system. Objectives must be clearly defined (and be measurable) in line with the main legal requirements as well as fishery-related issues to be managed e.g. reducing effort, maintaining biodiversity, sustainable exploitation and institutional needs in terms of policy and planning. The main practical concern is what information is needed to support monitoring of the effectiveness of agreed management interventions and at what level of detail. This will often inform the appropriate methods and level of spatial and temporal coverage needed. In addition, the type and frequency of data collection depends on the use of the resulting information e.g. if the data is needed for sectoral planning purposes, estimates and indicators can be presented at national level for the current year. While for fisheries management or to monitor the state of the environment, monthly estimates may be preferred for either administrative units (provinces) or for individual basins, rivers, lakes and reservoirs. This is an integral part of a multi-step process to develop a management plan based on EAF. This generally starts with local level consultations with resource users and institutional stakeholders to identify the main issues that affect the fishery and possible management interventions that can be considered.

2.2.2. Data requirements

Data requirements, specifically the level of detail or spatial resolution of the available data vary depending on the management, and to a certain extent, the importance of the fishery. Data is required to assess the scale of the fisheries (total catch/value) and the severity of any threats to sustainable exploitation of fishery resources. This can cover indicators both within the fishery e.g. fishing effort, and outside the fishery e.g. ecosystem health expressed as proportion of alien/invasive species or biodiversity indicators. However, some basic requirements can be established without any knowledge of the fishery under consideration.

It is useful to distinguish between conjunctural or cyclical data that is collected in catch assessment surveys for variables that can change on a regular basis (catch, licenses, effort, fuel/gear, prices) and structural data collected for variables that do not significantly change over a year e.g. number and location of protected areas, fishing grounds, landing sites and management units (angler associations), lease/management fees (Gee *et al.*, 2017). While structural data can be obtained annually, conjunctural data needs to be collected at regular intervals to ensure the data collected is reliable. Further, there is a less clear distinction between routine collection of catch and effort vs more in-depth collection of scientific data for stock assessment e.g. length-weight relationship (Froese, 2006) or gonadosomatic index (GSI), biodiversity, socio-economy and environmental data related to ecosystem health.[10] These scientific data are often collected using similar methods to routine catch assessment, ranging from self-reporting by fishers to direct measurement by highly trained researchers.

Fishery statistics are used to monitor the status and trends of the fishery for the purpose of management and decision-making. Therefore, the variables that are collected should be used as indicators for changes in the fisheries or support calculation of composite indicators, like catch per unit of effort (CPUE) that do so. In addition, for fishery statistics to be useful it is often necessary to have time-series data available over a long period that are comparable and compatible; they should be collected in a consistent way, using the same methods and approaches.

[10] This mainly relates to assessing and maintaining natural flow patterns in rivers (minimum flow and timing of changes in flow), connectivity (migratory fish), levels of invasive (exotic) species and water quality standards.

Table 1. Types of data that can be collected from the various data sources (FAO, 1999)

	Sources					
Main Data Types	**Harvest**	**Post harvest[1]**	**Market (incl. bartering retail)[2]**	**Consumers**	**Government agencies & institutions**	**Support Industry**
Catch	●	●	○			
Effort	●				+	+
Vessel / gear data	●				●	+
Operations data	●					
Compliance data	●	○	+		●	○
Biological data	●	●	●		●	
Environmental data	○				●	
Stocking (by location/ species)					●	
Market data	○	●	●	○	○	+
Costs and earnings data	●	●	○	+	+	+
Trade data		+	+		●	
Fisher/angler data[3]	●	●			○	
Household data	○		○	●	●	+
Institutions data	●	●	●		●	

● major source ○ secondary source or important validation source + possible source or secondary validation source

[1] Post-harvest here refers mainly to fish processing and handling, which may involve others besides fishers.

[2] It is acknowledged that recreational fisheries is not allowed to be done for commercial purposes, but this table covers all inland fisheries.

[3] Includes data on age distribution, socio-economic background of fishers/anglers and quality of life (satisfaction).

Data collection, where data are collated from a wide variety of sources, is preferable over depending on a single methodology to collect most required data. An assessment of what is already collected and available is the first step in understanding any statistical system and allows to make use of all available information. Concordance of data from local surveys with national statistics may be difficult and needs to be considered when deciding on the methodology.

There is not just one method that can be used to collect a certain variable, neither is there only one source of information. Data should be collected from several sources, using different methods, both for crosschecking and for catch monitoring. Besides catch and effort surveys, this includes the use of:

- Registers as a source of information on recreational and commercial fishers;
- Research surveys for pilot areas or specific fisheries to get an idea for the fisheries yield and associated effort. With some additional data, this can be used to estimate total catch; and
- Other approaches to be considered focus on estimates of total fish catch, involvement and auxiliary information to gauge the status of the fishery. This can be done through socio-economic, consumption or fish trade surveys.

In the following sections, an overview is provided of some of the main data types that can be considered for data collection, with an emphasis on data requirements for policy and planning, fisheries management and for environmental monitoring (including biodiversity). The tables presented, include generic names for government agencies as sources of information, the names of actual sources (ministries, departments, research institutes, etc.) that are responsible

for the various sectors and are sources of data and information for specific indicators, vary between countries. Identification of the actual sources of information in a country is part of the preparatory phase, assessing available information on the fishery.

2.2.2.1. Stock assessment

The current guidelines do not cover stock assessment. However, it is important to at least cover the basic parameters and requirements for stock assessment. Catch assessment data can provide important inputs for stock assessment analysis. Many detailed texts are available on this subject such as Hoggarth *et al.* (2006) and Sparre and Venema (1998). Unfortunately, these mainly deal with 'classical' stock assessment, which is focused on marine fisheries. The collection of data sufficient for biological assessment is difficult for small-scale fisheries, and it is recognised that assessment and management approaches need to be fundamentally different to those of large-scale commercial fisheries (Andrew *et al.*, 2007). An overview of suitable approaches can be found in Lorenzen *et al.* (2016) and Haddon (2011). It is recommended that simple indicators are selected e.g. time-series of catches, effort and CPUE, as well as catch length composition. This would provide outputs to assess trends in catch, effort and abundance and potential for overfishing or changes in spawning and recruitment. Length frequency data is important for stock assessment. In particular, it is used to see what size and age classes are present in the catches. Some further developments in the use of data limited fish stock assessments are discussed by Hommik *et al.* (2020)

2.2.2.2. Policy and planning

The data requirements for policy and planning are briefly listed in Table 2. The indicators included can be obtained from structural data and socio-economic data available from license registers or can be obtained based on catch and effort data. Most of the indicators are related to the contribution of recreational inland fisheries to food security and the overall economy, and this largely is based on auxiliary surveys e.g. consumption surveys or socio-economic assessments. Estimating the contribution of inland (recreational) fishery to GDP mainly makes use of national-level data and is normally done by central level fishery departments to argue for higher budget allocation or to emphasise the need for better policies or legal frameworks to address increasing importance of the sector compared to other sectors.[11]

It is important to acquire information on socio-economic aspects of inland fisheries (e.g. expenditure at local and national level), number of license holders (income from licenses), tourism income and employment (Arlinghaus *et al.*, 2019). This covers direct employment and in support industries e.g. fish culture for stocking, tackle stores, guides, camping sites, car and boat rental etc., and contribution by related economic activities. In addition, the contribution to quality of life and general well-being of anglers, by participating in recreational fishery, needs to be considered (fishing for relaxation or as part of nature tours). Consequently, collecting data on fishing trip satisfaction is an important aspect for managing recreational fisheries.

Imputed value as a proxy indicator is somewhat problematic, because most catch is consumed by households or gifted to neighbours, friends and relatives, while catch and release fisheries (sports fisheries) poses its own set of issues to assign a value to catch that is not retained. For many countries, catch that is not retained is not recorded e.g. Croatia and France. Instead of focusing on the value, catches should be separated between weight retained and released, with the economic value taking into account the income from license fees and the management cost, especially for stock enhanced fisheries.

[11] This is particularly relevant for recreational fisheries, which should liaise with the tourism industry.

Table 2. Data for policy support and development

Type of information	Indicators	Source
Contribution to food and nutrition	Fish consumption, specifically *per capita* fish consumption	Consumption surveys
Contribution to the economy	Direct and indirect income from fishing (e.g. licenses), including imputed value of the yield	Household socio-economic surveys (e.g. LSMS), studies
Contribution to the economy	Number of recreational fishers including day, week or monthly permits	Dept. of Fisheries (DoF), Ministry of Tourism
Employment and poverty alleviation	Employees by primary, secondary and tertiary sectors and by category e.g. full-time, part-time, and occasional	Employment census
Quality of life	Satisfaction with fishing experience	Surveys by angler associations
Annual yield	Catch data	DoF: Fishery monitoring (surveys)

2.2.2.3. Data needs for fisheries management

The EAFm process identifies the data needs for fisheries management, and as a minimum it is necessary to collect **catch by species** (or species groups) in weight and the **fishing effort**. Combining catch and effort, allows for calculation of catch rates: CPUE, which is a useful indicator for the state of the fisheries, and when expressed for individual species, important to identify changes in the catchability and therefore assess sustainability considerations. Although some countries only target recording of fish catches that are removed from the system, it is important to distinguish between the fate of the fish i.e. whether it is harvested or released. Capture and release fishing do not completely avoid fish mortality, survival rates depend on the species, fishing method, temperature (air and water) and handling of the fish. See for example the section on fish welfare in relation to capture, retention, kill and catch-and-release in FAO (2012).

There are many other indicators that can be considered, but this depends on the national and local requirements, as identified during the EAFm or similar planning processes. The general types of data that can be considered are:

- **Status of resource (fish stocks)** which can be obtained by analysing total catch by fishery, catch by species, fishing effort and daily catch by fisher (CPUE). Specifically, for stock assessment purposes length weight measurements, age structure and gear-based CPUE for selected species can be added mainly through limited scope catch assessment research surveys;
- **Structural information** mainly for fishing units i.e. number of fishers/licenses and, where applicable, vessel and gear numbers (for commercial fisheries). This acts as proxy indicator for effort and provides input for extrapolations for sample-based estimates for catch and effort;
- **Management interventions** includes the number and type of local management arrangements by fishing organizations and management units, including description of the regulations;
- **Compliance** by reports on infractions and fines (as measure for compliance with existing laws) e.g. the number of fishers caught without licenses or fishing within protected areas or outside the fishing season; and
- **Measure of effectiveness** of current management implementation e.g. increased compliance (or reduced violations/arrests) or sustained or increasing catches or CPUE, for indicator species (depending on targets for management interventions).

Table 3. Data for fisheries management

Type of information	Indicators	Source
Fishing pressure	Number of licensed fishers, number of fishing vessels, number and type of fishing gears, number of members of angling associations	DoF: Frame survey based on registries and surveys (including national census information)
Fishing pressure	Distribution of fishing effort in time and space	DoF: Interviews with fishers, logbooks
Status of the resource	Catch volume per species	DoF: Fishery monitoring (sample surveys and logbooks)
Status of the resource	Recreational catches, including catch and release	DoF, angling associations: Self-reporting, mailing surveys, online surveys
Status of the resource	CPUE	DoF: Fishery monitoring
Status of the resource	Catch composition (species, sizes)	DoF, research institutes: Fishery monitoring, local ecological knowledge (LEK)
Social and human dimension benefits [1]	Satisfaction (psychological benefits), contribution to health (physiological benefits), socio-cultural elements and contribution to sustainable exploitation	DoF: Fishery monitoring, research institutes, angler associations
Management measures	Permitted fishing periods, fishing gears and methods, fishing quotas,	DoF
Enforcement	Number of fishing inspectors	DoF
Compliance with law	Number of infractions	DoF
Fisheries governance	Number of management plans	DoF, NGOs
Fisheries co-management	Number of co-managed fisheries	DoF, NGOs
EAFm implementation	Number of EAFm management plans	DoF, NGOs
EAFm implementation	Number of intersectoral meetings	DoF
Level of organization	Number of fisher associations	DoF, CSOs
Level of organization	Number of organized fishers	DoF, NGOs, CSOs
Economic efficiency	Return on investments	Angler / fisher associations
Stocking	Number of stocked fingerlings by species and size	DoF, angler associations
Stocking	Number of fish stocked directly in a catchable size – put and take fishery[2]	DoF, angler associations
Biological data	Max size, size at first maturity, sex ratios, GSI, parasites/disease, length-weight relationship, growth, condition factor	Research institutes

[1] Since this aspect may not be immediately apparent, reference is made to Parkkila *et al.* (2010).
[2] For example, in Czechia or in Slovakia many fish species are stocked directly in a catchable size – put and take fishery (predominantly common carp and rainbow trout, but also e.g. brook trout, Wels catfish, Northern pike etc.).

2.2.2.4. Environmental data needs

Environmental data will typically be relevant for more than just the agency collecting the data, which is normally under the Ministry of Environment. In many countries, government agencies are not aware of which information other agencies possess and formal structures permitting exchange of information may not be in place. It is important to undertake a data inventory across ministries and establish procedures for data sharing to avoid duplicating work.

Environmental data and conservation, should focus on collecting data on:

- Water quality and ecosystem health (including flow rates in regulated rivers); and
- Biodiversity, specifically the status and trends for endangered species.[12]

Some of the indicators mentioned below are discussed in more detail in Section 2.5 on biodiversity and ecosystem health.

[12] For the Western Balkans region, the IUCN Red List has a total of 24 freshwater fish species listed as threatened (ranging from vulnerable to critically endangered), with 6 endangered and 4 critically endangered.

Table 4. Data for ecosystem monitoring

Type of information	Indicators	Source
Environmental status	Environmental flows	Ministry of Environment, Ministry of Energy
Environmental status	Pollution	Ministry of Environment
Healthy aquatic habitats (including international agreements e.g. CBD, CITES, EMS, Aichi etc.	Biodiversity (including non-commercial species), presence of indicator and flagship species	Species inventories, academia, local knowledge
Healthy aquatic habitats	Presence of exotic species	Ministry of Environment, research institutes: local knowledge, species inventories
Habitat fragmentation	Number of dams and weirs	Ministry of Environment, Ministry of Energy, Ministry of Agriculture
Habitat availability	Area of surface waters	Ministry of Environment, google maps
Habitat rehabilitation	Number of obstructions to fish passage equipped with fish passes, area of floodplains and wetlands reflooded	Ministry of Environment
Performance of habitat rehabilitation and fish passes	Presence of migratory fish species	Number of migratory fish passing through fish ladders or passes

2.2.2.5. Classifications

Routine collection of data needs to cover species, gear types and possibly fishing locations. These need to be classified clearly to ensure that data is collected consistently.

FAO has worked on standardization of classifications through the Coordinating Working Party on Fishery Statistics (CWP).[13] The CWP considers fisheries from a global or a regional perspective requiring national fisheries statistical programmes to be coherent and consistent, and demands a common set of regional or interregional statistical standards, which apply internationally-recognized definitions, classifications and codes. The CWP Handbook of Fisheries Statistics Standards was created to serve as the basis for this integration.

Since in most countries only specific gears or gear combinations are allowed in inland recreational fisheries, standardising gear names is expected to be straightforward. Somewhat more problematic is linking common names with scientific species names and associated international coding systems. This is well developed for endangered species, but possibly less so for other target species. Species coverage differs between countries, from reporting on all species caught to limited species lists. It makes sense to include all species, or at least add an additional 'other species' category, for cases where the identity of the species is unclear. It is necessary to prepare species lists and field fish identification sheets (species identification guide) to be able to describe species diversity correctly. This also can serve to be used as an identification guide and training material for fisheries officers, and as the basis for the various databases and data entry lists. For shared stocks between neighbouring countries, it is necessary to harmonise the coding systems, so data can be exchanged without issues.

As part of the Aquatic Sciences and Fisheries Information System (ASFIS) reference series, FAO established the "ASFIS list of species for fishery statistical purposes" in 2000. An updated version of the ASFIS list is released each year around March-April, after the annual closure of the FAO capture and aquaculture production databases.

The latest version of the list is downloadable from the ASFIS List web page,[14] which also provides information on the descriptors (ISSCAAP code, taxonomic code, 3-alpha code, scientific name, FAO English common name) (FAO, 2004b). It is essential that local language fish field guides are prepared both for training and use in the field to support biodiversity

[13] See: http://www.fao.org/cwp-on-fishery-statistics/en/
[14] http://www.fao.org/fishery/collection/asfis/en

assessments, but also to support development of web platforms and apps that include species identification guides to improve accuracy in species reporting and incentivize using the app to keep a personal log of all catches.

2.3. METHODS AND APPROACHES

There are two sources of information on fisheries: fisheries-dependent such as logbooks, fisheries surveys and fisheries-independent such as socio-economic studies, scientific assessments like experimental fishing, acoustic surveys i.e. not relying on fishers or the fisheries to provide data. Fishery-independent methods in inland fisheries were reviewed by Lorenzen *et al.* (2016), while data-poor assessment methods common in marine fisheries relying on fishery-dependent data (e.g. on size structure) to assess fisheries reference points has considerable potential for further use (Fitzgerald *et al.*, 2018).

In this section, we only cover fishery-dependent methods, as these are suitable to be implemented by local authorities, managers, recreational and commercial fishing associations. Research is the responsibility of national government. Current data collection practices in Europe are mostly linked with license requirements, and are either at national level, limited to specific water bodies or basins or, in some cases, specifically target salmonids. An overview of the main methods implemented can be found in a recent EIFAAC review (Vehanen *et al.*, 2020).

2.3.1. Local ecological knowledge

The more comprehensive data and information needed for the EAFm, as compared to more traditional fish centred management, may appear a daunting task, particularly for inland fisheries that notoriously are data-poor. However, it is important to understand that while information needs are much broader for EAFm and analysis may require new skills and multidisciplinary approaches, this does not necessarily call for new cost-intensive surveys. EAFm requires that the elements in the ecosystem and the linkages between them are identified. Management can focus on governing processes using adaptive management principles and simple indicators without necessarily requiring high levels of precision or large databases.

The focus is on simple indicators, which need to:

- Reflect the actual condition of the fishery (either for monitoring, but preferably also predictive);
- Rely on low-cost observations;
- Are accepted and can be applied by (fisher/institutional) stakeholders and the general public; and
- Conform to the pressure-state-response framework, as shown in Figure 2.

An example of a simple indicator is the percentage of sexually mature fish in the catch, with the target being 100 percent i.e. no juveniles are targeted or caught by the fishery. The approach would be using a ruler to assess the minimum length when fish become sexually mature, making it very easy to use in the field (Froese and Binohlan, 2000). Other approaches that are used are based on participatory mapping (e.g. Burdon *et al.*, 2019; Corbett, 2009), which allow identification of spawning locations and nursery areas and timing of fish migrations, for example in support for developing consensus on protected areas.

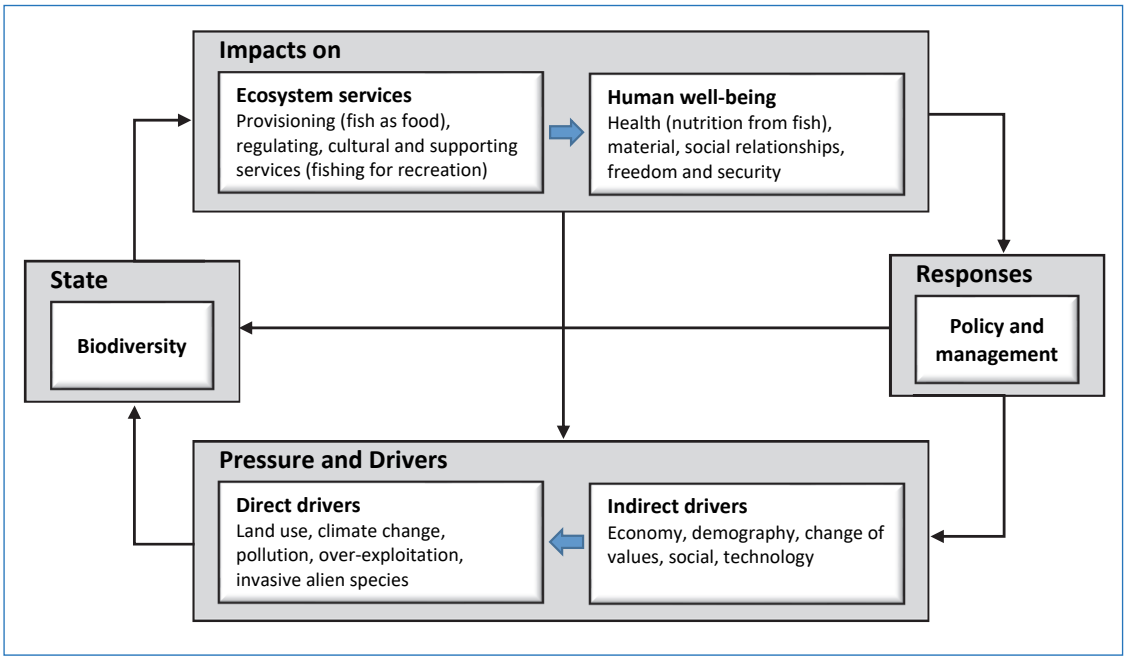


Figure 2. Relationships between inland fisheries, ecosystems and human well-being (Santos-Martín *et al.*, 2013).

It is important to realize that scientists (who traditionally provide evidence-based information) do not have a knowledge monopoly, and lack of formal "scientific knowledge" does not necessarily imply that knowledge of the fishery does not exist. Fishers have a wealth of knowledge and experience that is extremely valuable for the management of fisheries and there is ample scope to involve stakeholders directly in data collection (Silvano and Valbo-Jorgensen, 2008; Arlinghaus *et al.*, 2002). By carefully selecting indicators for inland fisheries performance, fishers and anglers can monitor the indicators themselves, and the cost-effectiveness of data collection can be markedly improved. Although it can be argued that the goal of the fisher is maximizing the livelihood or recreational benefits for oneself and one's family in the short to medium term, while the goal of the fisheries manager is to maximize the benefits for the society in the long term, there is a considerable overlap in the type of knowledge that is relevant for the fisher/angler and the fisheries manager (Thornton and Maciejewski-Scheer, 2012). There is no reason why fisheries management decisions should ignore the knowledge possessed by the fishers especially in situations where no scientific information is available. Fishers and scientists generate knowledge in different ways and it comes in different formats i.e. scientific knowledge is the result of systematic sampling over short periods at certain intervals, while fishers develop their knowledge through less systematic, frequent, long-term observations. The two knowledge systems are thus to a large extent complementary (Anbleyth-Evans and Shaw, 2019).

Involving resource users, recreational and commercial fishers, is not only a cost-effective way to collect data, it also allows them to become more aware of the state of the resources, the need for management, and take part in decision-making based on own needs and concerns. Stakeholders have a strong incentive to become involved and with proper facilitation, local stakeholders may participate in both the design, collection and analysis of data or alternatively would like to do their own analysis (Halls *et al.*, 2005).

2.3.2. Sampling vs census

There are two ways of collecting statistics:

- Census, a complete enumeration or count of all elements in a population; and
- Sampling, selecting only a few measurements and using these to estimate the average and subsequently the total.

The classical census approach, where a government department collects data from registries or through mobilising field teams, is generally only appropriate for counting populations or other fixed amounts (fishers, vessels, landing sites, markets), that do not change rapidly. Census approaches in fisheries often relate to frame surveys, to count the number of vessels or gears, which can be used to design sample surveys and to allow raising the estimates from sample surveys to overall totals at provincial or national levels. For most parameters that are of interest to fishery management, it is normally not possible to collect them cost-effectively (nor reliably) by using a census approach of field enumerators. Instead of relying on a survey team for data collection, the burden for reporting and recording catch and effort data is shifted to the resource users, anglers and fishers as a requirement to obtain a license. For most countries, this is the most efficient method for sustainable data collection. Self-reporting using logbooks, especially electronic logbooks or phone apps or dedicated web-sites, can make census approaches feasible for reporting of catch and effort in real time. However, app-based logbooks are still in their infancy and more evaluations are needed to confirm if the method is accurate (Jiorle *et al.*, 2016; Hartill and Thompson, 2016).

The alternative to a census is to count and measure only a subset of fishers and fishing days and use the average catch and effort from these to estimate the total. This is called sampling, and compared to classical census approaches using field enumerators, it is cheaper and easier to implement, with some caveats. Designing sample surveys for complex fisheries is difficult. Recreational fisheries are especially difficult to cover, due to their small-scale, part-time operations spread out over a large range of different aquatic habitats using a wide variety of gears. Recreational fishing is also highly seasonal, with often a high degree of specialization in gears used or species targeted. Sampling often focuses on registered licensed individuals, which may omit day or week license holders (as well as any foreign fishers, tourists). Only a few European countries (Croatia and Czechia) include catches by foreign tourists. Hence, it is important to include all individuals in the sample frame, possibly by using an existing sample frame developed for socio-economic surveys by the national statistics office and assess the importance of foreign tourists. Then, ensure that these are separately monitored if warranted by the level of their fishing activities, and economic contribution to local communities.

Sample surveys, whether on-site or off-site, are therefore best implemented for a limited scope (e.g. for monitoring the status of endangered species, biodiversity assessments, socio-economic surveys and environmental monitoring). However, some countries like Sweden, use a sampling survey, utilising questionnaires to collect fishery data for recreational fisheries. In view of the inherent issues associated with relying on mandatory reporting of catch and effort (see section on bias), another important application of sample surveys is for validation of self-reporting census approaches. The main principles for designing sample surveys, sample size and stratification are explained in later sections.

2.3.3. Comparison of commonly implemented methodologies

The most relevant methodologies for routine data collection and validation in recreational fisheries are census[15] or sample approaches. Logbooks (either paper-based or electronic recording) can be implemented both as a census or sample survey, while direct measurement (landing survey) and recall surveys (both interviews-based and as questionnaire) are generally implemented as sample surveys.[16]

An overview of common data types and various available data collection methodologies are presented in Table 5, based on the overview included in guidelines for the routine collection of capture fishery data (FAO, 1999). Not all data categories included are relevant for recreational fisheries (but they do apply to commercial fisheries), especially the section on post-harvest, although some trade and bartering likely exists in European inland fisheries, for example in touristic areas where locally caught fish are often served in restaurants. A general approach that has had some success in Europe is the implementation of citizen science (see Box 2, on page 23). For an example of how citizen science compares with traditional scientific data, refer to Silvano and Valbo-Jorgensen (2008).

Table 5. Types of data that can be collected by the various data collection methods (FAO, 1999)

	Data categories	Observation or direct measurement	Register	Questionnaire	Interviews		Reporting (Logbooks)	
					Open ended	*Structured*	*Harvest*	*Post-harvest*
Complete enumeration	Catch			●			●	+
	Effort			●			●	
	Vessels-gears		●	●		●	●	
	Operations	●		●			●	
	Compliance	●	●				●	
	Biology						○	+
	Environment						○	
	Markets			○				+
	Fishers/anglers[1]		●				○	
	Households							
	Institutions			○				
Sampling	Catch	●		●	○	●	+	+
	Effort	●		●	○	●	+	
	Vessels/gears	●		●	○	●	+	
	Operations	●		●	●	●	+	
	Compliance	●					+	
	Biology	●					+	○
	Environment	●					+	
	Trade							
	Fishers/anglers			●	●	●	+	○
	Households			●	●	●		
	Institutions			●	●	●		+

● Major source ○ Secondary source or important validation source + Possible source or secondary validation source

[1] As mentioned previously, this is data on fishers and anglers, including data on age distribution, socio-economic background of fishers/anglers and quality of life (satisfaction).

[15] Many countries depend on reporting of all fishing activities and catches as part of the requirements when obtaining a fishing license, even if in practice this is not a census (Vehanen et al., 2020).

[16] Population census also employs a recall methodology, but this is very labour-intensive and costly and therefore not recommended, unless fisheries questions can be inserted into a large scale socio-economic or agriculture survey/census.

BOX 2

Citizen science

Citizen science is scientific research conducted, in whole or in part, by amateur (or non-professional) scientists. Involving citizen scientists in research has become increasingly popular in natural resource management and allows for an increased research effort at low cost, distribution of scientific information to relevant audiences, and meaningful public engagement (EIFAAC, project on citizen science, 2020). This is not to be confused with LEK, which is more focused on obtaining information from fishers using participatory techniques as opposed to involving them as collaborators contributing to routine data collection.

Citizen science has many benefits to both the general public and the organizations involved in fisheries management. These include raising awareness on the state of fish populations, gathering required information to help manage fish stocks and assess the quality of inland water bodies. It can be used to encourage collaboration between agencies and invested stakeholders such as anglers, commercial fishers and general water users such as kayakers, divers, etc. The type of data being collected already under citizen science includes water quality, marine debris, invasive species and biodiversity. Fishery scientists cannot monitor every stretch of river, every lake and transitional water in their jurisdiction, but by using citizen scientists, they can get baseline data recorded for a greater number of sites. It also allows a better coverage in both space and time using knowledge accumulated over a given period and can provide historical information. Combining fishery scientists' data with citizen science data will enable extrapolation from data-rich areas to data-poor areas.

A major component in the collaborative reciprocal relationship between scientists and volunteers who report data is building trust that the data is not misused and ensuring that it is properly anonymized before publishing. Especially in Europe, data collection should adhere to the rules developed under the General Data Protection Regulation (GDPR), a regulation on data protection and privacy in the European Union and the European Economic Area.* Besides general apathy towards collaboration, a major concern is privacy, especially on detailed catch location data. This can be addressed by implementing privacy settings, where anglers control what data can be seen publicly or by trusted friends, while still ensuring access by scientists to relevant data.

In 2016, a citizen science approach was introduced for catch data collection as well as CPUE data from anglers in Denmark (Gundelund *et al*., 2020). Anglers can report their fishing trips with information about fishing location, hours fished, target fish species as well as information about catches i.e. species, length, weight, fate (released or retained), gear used as well as other information.

The digital platform (www.fangstjournalen.dtu.dk) is available for PCs and smartphones, with the latter also available in German and English, enabling international fishing tourists to report. Motivating anglers to contribute is important and several incentives are considered e.g. it is possible to explore catch statistics for different fishing locations, compare own fisheries statistics with that of other anglers, keep catches private or open for public access and providing various opportunities to brag about catches, and share information and images from the platform via Facebook or Twitter. It is also possible to enter a monthly prize draw, and finally, to get site-specific information about fishery regulations. Summary statistics for specific fishing waters are shared with the platform users, and examples of preliminary statistics calculated across fishing waters, is regularly published on a dedicated Facebook page. The main purpose of the Facebook page is to further motivate anglers to use the platform by showing how standardized angling data can inform about trends in catch rates and size structure of various fish species. By June 2019, around 10 000 users had signed up to the platform.

*https://gdpr.eu/

Other sources of general information on relevant survey methodologies for recreational fisheries can be found in Vehanen *et al.* (2020) and Jones and Pollock (2012).

2.3.3.1. Registers

Registers and licenses are particularly valuable for census approaches, but are limited to variables that change slowly, such as numbers of fishing vessels and licenses. Many registers only concentrate on commercial fisheries; however, registries are widely used for licenses and permits and are generally used to select participants for questionnaires or online or telephone recall surveys e.g. in Denmark and Ireland. They are often used to obtain frame data on the number of vessels, fishers and anglers. The amount of error can be estimated by taking a small random sample of the units in the register and compare the information in the register with the real-world situation. Registers often provide the lists for designing sample surveys i.e. they are used as the basis for random selection of fishers, anglers or households based on registrations linked to licenses and permits, for assessing catch, effort and other fishery related information, using sample surveys.

Table 6. Main advantages and shortcomings of registers for frame data (Tessier *et al.*, 2016, Visser *et al.*, 2016 and Vehanen *et al.*, 2020).

Advantages	Shortcomings
Can be used to monitor number of fishers / anglers accessing the resource	Keeping registers up-to-date and clean requires considerable staff resources and effort
Provides record of legally registered gear and gear permits	Registers tend to lag behind issuing of licenses and permits and therefore are unreliable
Maintenance can be paid from license fees as management cost	Does not cover data on illegal recreational and commercial fishers or those that do not need a license (including omission of tourists or short-term license holders (daily-weekly licenses))
Provides legal authority to prosecute violators	

2.3.3.2. Logbooks

Catch logbooks allow anglers/fishers to enter their catch and effort records, either as catch return forms or as logbooks to be returned at the end of the fishing season. They are widely implemented in both commercial marine fisheries and in inland fisheries in Europe and are the main data collection methodology used, mostly as mandatory requirements for fishing licenses and permits. Logbooks are used at national level and/or for specific water bodies and fishing grounds of interest. Although almost all European countries use logbooks to monitor commercial fisheries, several countries e.g. Denmark, France, Bulgaria and the Netherlands, also use them for recreational fisheries, although follow-up and collection of these mandatory logbooks is variable. For example, in Bulgaria submitting catch logbooks is not compulsory, while in France the emphasis is on salmonids, while for other species of angling interest (mainly pike, sander, brown trout), anglers' catch reports are only monitored in a few cases (some lakes, some river sections) and often for limited time.

The advantage of using logbooks is that it requires less investment in human and financial resources by the responsible authorities. The disadvantage is lack of collaboration by the informer, and potentially deliberate distortion of data (Halls *et al.* 2005). Non-pecuniary incentives such as renewal of licenses can encourage cooperation and is preferred to monetary incentives unless these are given to co-management associations to facilitate monitoring and reporting.

Paper-based logbooks are gradually being replaced by website and/or apps for data recording e.g. in Croatia and France, but also in many other countries. Collaboration with stakeholders may be improved by guaranteeing their confidentiality as part of the agreement for data submission and in line with European data privacy regulations, as mentioned earlier, and statistical outputs of surveys should not contain information related to individual fishers or companies (FAO, 1999). Where stakeholders submit their own data, it is important that

the data gathering and submission procedures do not overwhelm them in terms of required time, cost or capacity. It is also important that the reporter understands the benefits of accurate data reporting in terms of improved fishery resources. The main advantages and shortcomings are included in Table 7.

Table 7. Main advantages and shortcomings of logbooks for catch and effort (Tessier *et al.,* 2016, Visser *et al.,* 2016 and Vehanen *et al.,* 2020).

Advantages	Shortcomings
Daily records possible (census)	Scope for under- and non-reporting and various sources of reporting bias e.g. no weighing, based on memory, only include sales records at landing site, leaving out consumption and discards/bycatch
Low cost data collection method for mandatory logbooks, suited for electronic logbooks	Intensive and sustained follow-up necessary to highlight importance of full reporting
Can be verified through sample-based validation surveys or spot checks	Complex and relatively costly to implement validation surveys
Renewal of license can be linked to submission of logbooks	Inconsistent quality of reported data e.g. issues with taxonomic accuracy[1]
Depending on method, more accurate than recall surveys, allows for detailed data on catch, effort, species and disposal (including length frequency)	Time consuming for recreational and commercial fishers, affecting data coverage and drop-outs
Great for use in co-management together with other participatory data collection methods (e.g. LEK)	
Entries can be clarified by follow up interviews	

[1] When using online reporting, this can somewhat be mitigated by allowing anglers to upload photos.

2.3.3.3. Direct measurement [17]

Direct measurement refers to surveys where field teams weigh and measure the catch by recreational and commercial fishers. This is mainly implemented when detailed and accurate data is required such as for stock assessment purposes or for scientific assessments of environmental parameters and biodiversity. It is generally implemented by highly trained field staff, supervised by scientists and/or managers, although angler participation (self-reporting) can be considered under specific circumstances (see Box 2 on citizen science).

Table 8. Main advantages and shortcomings of direct measurement surveys for catch and effort (Tessier *et al.,* 2016, Visser *et al.,* 2016 and Vehanen *et al.,* 2020)

Advantages	Shortcomings
Provides a good picture of available phase of the population if fishing effort is significant and known	Restrictive spatial coverage (landing sites or other locations with competitions), depends on up-to-date frame survey for total catch estimation (boat/gear)
Recreational fishery has few discards, most fish caught are brought ashore and released at the end of the day	Data not reliable if the fishery is unregulated, or if the data is recorded in the absence of enumerator/administrator
Data collected is considered reliable if the fishery is regulated or if the form is completed in the presence of an enumerator	Data only for target fish species of specific recreational of sports fishery
Appropriate method for estimating fish catches and effort	Biases possible depending on fishing gear used e.g. fishing involving attraction device
Participation of fishers/anglers possible	Selectivity of several fishing gear unknown
Possible to preserve specimens	Expensive in time and manpower, especially for establishing frame survey

Due to the high cost, this type of survey is carried out at less frequent intervals, and at easily accessible sites. Thus, it is not an option for difficult terrain or remote locations or for data that needs to be collected with higher frequency such as monthly reporting. Direct

[17] This is a sub-class of on-site surveys, other data collection methods, e.g. recall survey may be conducted on-site as well as off-site

measurement is not widely implemented, but a good example are the efforts in Sweden, particularly for Lake Oulujärvi (Vehanen *et al.*, 2020).[18]

2.3.3.4. Recall surveys

Recall surveys use interviews (or questionnaires) to collect data after the fishing activity. Interviews are well suited for sample surveys, while questionnaires are more suited to census approaches. Both are important survey instruments, and are widely implemented for population census, socio-economic surveys and food consumption studies. Recall surveys have been implemented for catch monitoring, although this is relatively staff-intensive for sufficient detailed coverage (Visser *et al.*, 2016, Cottet and Visser, 2017). Recall surveys cover any methodology that depends on memory for providing data, and includes phone interviews, online or postal questionnaires and field visits to locations where anglers are found to be fishing or at their homes.

Information in interviews is obtained through inquiry and recorded by enumerators. Structured interviews are performed by using survey forms, whereas open interviews use notes taken while talking with respondents. The notes are subsequently structured (interpreted) for further analysis. Open-ended interviews, which need to be interpreted and analysed even during the interview, have to be carried out by well-trained observers and/or enumerators (FAO, 1999). Open-ended interviews are often for explorative qualitative information, while structured interviews resemble questionnaires with a fixed set of questions often focusing on quantitative data. Interviews are more expensive than questionnaires however in order to reduce costs, interviews can be conducted by telephone (FAO, 1999).

When data from other fish species besides salmonids were collected nationally, the methods used included postal or telephone recall surveys using a sample of citizens of the country. In Denmark, as part of the EU data collection framework, biannual recall surveys are conducted twice a year. Although the survey focuses on marine catches, respondents are also asked about temporal patterns (quarterly) of harvest of eel and brown/sea trout in freshwater. The survey is web-based, where potential participants are recruited via mail (Vehanen *et al.*, 2020).

Table 9. Main advantages and shortcomings of interview-based surveys (Tessier *et al.*, 2016, Visser *et al.*, 2016 and Vehanen *et al.*, 2020).

Advantages	Shortcomings
More detailed information can be requested than in logbooks	Relies on memory, which negatively affects accuracy for all parameters if the recall period is longer than a week
Allows for more complex questions to be asked compared to questionnaires and logbook and is more flexible	Requires highly skilled field staff to get best results
Survey can monitor long periods	Effort often only expressed as fishing day
High reliability for species occurrence, fishing location and general effort (duration)	Susceptible to sampling bias as wealth status affects gear use and fishing frequency or dependence
If based on trade information accurate (weight and value)	Less reliable for catch amounts and effort data, than logbooks
Provides immediate feedback, to ask for clarifications or rephrase questions	Precision for catches can vary by gear and species
Burden on respondents is less than for logbooks and questionnaires	Several sources of bias, such as digit preference, telescoping, non-response bias, and rule-based estimation

Questionnaires are survey forms filled out by respondents without assistance from an enumerator. They can be used where census type coverage is required. However, in most cases they are implemented as sample surveys. Some countries such as Finland, Germany, the

[18] Although not that common in Europe, on-site surveys to collect data on catch rates and sometimes effort are very often used in surveys of recreational fisheries e.g. in US and Australia (pers. comm. C. Skov)

Netherlands and Sweden conduct national-level sample surveys using questionnaires, which are sent out once or multiple times a year. Other countries use them for specific purposes or species e.g. for salmonid catches in Scotland. Questionnaires are either handed out or sent by mail with prepaid addressed envelopes. More recently online questionnaires have been used in some fisheries.

Because there is no pressure or support from an enumerator, the best guarantee for a high return rate is to keep the questionnaire short and simple. Questionnaires should only ask for information that is readily available, or in a format that conforms with existing records. Asking for data that needs to be calculated from existing data, and that requires manipulations and regrouping of categories will reduce the response rate and the reliability of the information obtained. As for logbooks, it is desirable to reduce the amount of work for the respondent to the absolute minimum so questions with tick boxes, and a limited scope of the questionnaire will help both to focus the respondents and tempt them to complete the questionnaire. The writing should be reduced to the absolute minimum, perhaps only asking for numerals, this will also facilitate data processing. In addition, the questions should be easy to understand; complex issues can be addressed in questionnaires but are best handled by spreading them out over a larger number of more simple questions. The advantages and shortcomings are very similar as those listed for interview-based surveys and some further points are included in Table 10.

Table 10. Main advantages and shortcomings of questionnaires (Tessier *et al.,* 2016, Visser *et al.,* 2016 and Vehanen *et al.,* 2020).

Advantages	Shortcomings
Low-cost data collection, compared to interviews	Complex (and potentially expensive) to implement)
Allows for more detailed information to be requested than logbooks	Time consuming for fisher/angler to fill out
Highly suitable for online implementation	No guarantee for data accuracy
Great for one-off or annual data collection	Requires follow-up interviews for more detailed data and clarifications
	Voluntary, with variable return rate
	Location-specific catch data not available for national-level surveys, needs targeted local surveys

Answers obtained by both interviews and questionnaires are based on the opinion of the respondent and can be hard to validate; data on variables such as catch or effort are potentially subject to large errors, due to poor estimates or intentional errors of sensitive information (FAO, 1999). Most, if not all, data collection methods depend on memory, and recall surveys in particular have several sources of bias, such as digit preference, telescoping, non-response bias, and rule-based estimation (Pollock *et al.*, 1994). Digit preference has respondents rounding to 0 or 5, telescoping means that catches outside of the survey period are included, non-response bias is the finding that fishers who do not want to participate tend to fish and catch less, the results thereby tend to overestimate actual catch and effort. Rule-based estimation is when a respondent only remembers the average catch and applies a multiplication to estimate the catches.

Improving the accuracy of recall surveys can be done by reducing the recall period to a duration where respondents can be expected to remember details for each fishing trip accurately. This can be based on observed activity patterns, but a typical recall period for recreational fisheries is one to two months. The alternative is to acknowledge that the accuracy of this methodology is limited and only use it to identify overall year-on-year trends.

2.3.3.5. Electronic data recording

There is no methodological difference between paper-based approaches or electronic data reporting. The benefits of electronic logbooks include reducing illegible entries, reducing data entry errors, quickly verifying authorised data entries, timely submission of catch and other information in relation to management requirements (including lower occurrence of recall-related errors), increased efficiency, reduction of costs of data entry, timely verification from other data sources (FAO, 2004a). To be effective, electronic logbooks should facilitate fishers to enter catch data in a simplified format. The most effective means of minimizing errors of data entry is to use symbols and pictures. Reducing the amount of typing is a critical requirement, especially for data entry on small mobile phone screens.

The use of technology in monitoring fisheries, especially in small-scale fisheries, is in its infancy. There is an opportunity to socialize and mainstream the use of participatory, human-centred design processes in European inland fisheries. This is crucial to the creation of successful monitoring programmes that rely on fishery adoption, because the diversity of technologies and systems available to fisheries means that there are many ways in which fishing communities can choose to engage with them, and many ways in which technologies can fail to be adopted or produce useful data (Fujita *et al.*, 2018). For example, some electronic logbook apps are highly structured, with specific tabs and inputs, while others allow fishers to enter logbook data in a more flexible way. Choosing an app design that allows flexible input where self-reporting is unreliable and where there are many ways to make input errors may result in unreliable data. Recreational fisheries are perhaps the least monitored fisheries in the world, therefore there is great potential to improve monitoring and this is where electronic logbooks can provide a useful opportunity (Fujita *et al.*, 2018).

Self-reporting programmes for recreational fish have been widely studied. The general consensus is that they often suffer from biases concerning variation in willingness of recreational and commercial fishers to provide catch data, drop-outs, and lack of representativeness (i.e. the data does not represent the entire fishery). But these systems have the ability to provide data where traditional methods cannot. The proliferation of angler apps as a new source of fisheries-dependent data is both an opportunity and a challenge. However, app data are only useful if they are abundant and relevant, of reasonable quality, and can be integrated into existing research and management frameworks (Venturelli *et al.*, 2016). If data reporting methods to correct such biases are developed, programmes like iAngler have the potential to provide valuable catch rate data to fisheries managers (Jiorle *et al.*, 2016). Despite the many advantages of electronic data recording (both using field enumerators and relying on self-reporting), there are a few drawbacks that are discussed below, with some possible solutions:

1. **Recruitment and retention of participants** in self-reporting apps is challenging, but are more likely when participants perceive an advantage, participation is simple and compatible with the participant's existing habits, and there are opportunities for trial participation or to observe others participating (Rogers, 1995). This means simple interface, ease of use, digital catch log, optional social sharing, licence renewal, transparency on data use and easy access to a range of relevant information (Venturelli *et al.*, 2016).
2. **Data quality and bias** need to be considered, for instance, app data are likely to suffer from avidity bias (Jiorle, 2015), as well as omission of non-catch effort, and mis-identification of species. In addition, fishers and anglers without smart phones, Internet access or familiarity with digital tools are left behind, leading to potential bias; less interaction with participants, makes follow up with validation surveys even more critical (Venturelli *et al.*, 2016).
3. **Complexity** – required IT systems are more complex to setup and maintain than conventional surveys.

BOX 3
FAO SmartForms[1]

In support of data collection programmes, FAO has developed SmartForms, a mobile multilingual application to collect and review 'lightweight' fishery data. The platform combines a builder to design forms according to survey need, a mobile App (Android only) loaded with the designed forms and a web hub for data review, analyses and authorized exchanges with any third-party database system. The platform is built on a participatory approach to allow stakeholders to share the same application and collect data under international standards with linkages to national and regional standards.

SmartForms can be customised to cover a wide variety of data collection methods. It is already set up to catch photos and videos for each observation. The App is designed to customize the form according to the needs of the users, so it can be designed to record traditional logbook type information, as well as other data/survey types.

[1] For an overview see: http://www.fao.org/fi/static-media/MeetingDocuments/cwp/ReferenceHarmonization/2018/S3_3.pdf

2.3.4. Improving current license-linked census approaches

Many currently planned or implemented data collection systems are linked to licenses and mandatory reporting of all fishing activities, using monthly logbooks or electronic reporting. Relying on a census approach can result in under-reporting or non-reporting and issues more often associated with recall surveys such digit preference, telescoping, non-response bias, and rule-based estimation.[19] These issues are often ignored by taking the reported data at face value, which at best[20] may suggest trends, but cannot be relied on for more robust estimates of catch and effort. A better, but more complex approach, is to assess the bias and accuracy by implementing independent sample-based validation surveys (or statistical manipulations to uncover bias using resampling techniques).[21] Several European countries (Croatia, North Macedonia, Serbia) indicate that their self-reporting systems are unreliable, but there is little information on the level of error and bias. Most surveys that rely on mandatory or voluntary reporting suffer from intentional deception, recall bias, prestige bias or lack of knowledge e.g. species misidentification (Jones and Pollock, 2013). Whereas national sampling surveys, like the one used in Finland, introduce issues related to insufficient coverage of individual water bodies or rare species when extrapolating to the national level (Vehanen *et al.*, 2020). Validation surveys to establish the level of errors and bias are therefore important but can be expensive. Another approach successfully implemented in the Netherlands (Van der Hammen *et al.*, 2016), is using a rotating panel of randomly selected participants to keep a catch logbook or diary for a period of 12 months, with intensive follow-up by the survey team to participating anglers. Although this leads to greater accuracy in the resulting catch estimates, it is relatively costly.

In population census terms, validation surveys are called accuracy and coverage evaluations. These evaluate the results of a census by implementing a sample survey for a sub-sample of the target population. This is normally done using a recall survey (interviews) for key data

[19] See for a brief explanation of these issues, Section 2.3.3.4

[20] Implementation of panel analysis (using a fixed sample with the same fishers/anglers) can often correctly identify trends, even within the limitations of using a biased data set.

[21] Resampling techniques assign measures of accuracy (bias, variance, confidence intervals, prediction error, etc.) to sample estimates. This technique allows estimation of the sampling distribution of almost any statistic using random sampling methods.

items like total daily catch and active fishing days, or by implementing direct measurement (landing site) surveys. Validation surveys should be done regularly, every 3–5 years, to provide an assessment of the available data. Implementing a validation survey and statistical manipulations using re-sampling techniques are not the responsibility of local managers, but instead should be done by national authorities (scientists). These can serve as an evaluation of the available data to develop approaches to either correct the data obtained or formulate ways to improve reporting and the accuracy of mandatory logbook reporting.

Small-scale quality control can be implemented by local managers, by regularly interviewing fishers as they are encountered during patrols to get an independent estimate for effort, fishing days and (species) catch. By formalising this, randomly selecting anglers as they leave with their catch, the reported data can simply be validated. In addition, the knowledge that 'inspections' are implemented, will influence the accuracy of the reported data, even by those not selected for an interview. The random inspections should reflect the nature of the fishery i.e. whether the fishing activity occurs during seasonal periods or during different times of the day and night.

The root cause for observed issues of non-reporting or inaccurate reporting lies with the nature of the fisheries. Whereas a subset of recreational fishers that engage in competitions or are focused on advertising their achievements will often already weigh, measure and record their catches, many recreational fishers fish for relaxation or subsistence and therefore do not keep their own records. This means they depend on memory to estimate weights and numbers, which introduces a level of inaccuracy into the data. Since there are limited or no consequences for non-reporting or under-reporting, there is also little incentive for submitting accurate logbooks. In this regard, it is important for fishers / anglers to have incentives to report accurately, either as co-managers of the resource or through incentive programmes, such as offering discounts on license fees or access to data summaries.

Although having an idea about the bias and accuracy of reported catches is obviously important, it makes more sense to improve the available data by providing incentives for submitting timely logbooks while also considering penalties for non-reporting. A strict system implemented in Czechia is considered to work well (Vehanen *et al.*, 2020), where data are collected using mandatory logbooks by managers of officially established fishing grounds that are under a ten-year management contract. Compliance of highly localized fishing regulations are enforced by angler guards. The system features a general (national) fishing license and fishing ground-specific permits. The Czech example may not be appropriate for implementation elsewhere, but some elements may be relevant for other countries. For data collection, systems that seem to work well are online reporting – which reduces the delay between fishing and reporting – and providing map-based data summaries on what fishers have caught, when and where. Electronic reporting is already implemented or planned in several European countries. An excellent example is from Denmark, which operates a voluntary citizen science approach (see Section 2.3.3). Besides the above-mentioned incentives, other options that can be considered are adding fish identification tools, interactive maps, links to weather services, emergency support, and data summaries with accessible analytical tools.

The recommended approach is to use self-reporting of catch and effort as a census linked to licensing requirements (and if possible, location-specific fishing permits), while also implementing sampling surveys for validation (assessing bias and accuracy) and for limited scope surveys. Given the proximity and local knowledge of communities and angler associations for their respective river or lake fishery, engaging these groups in co-management can improve reporting frequency and data quality.

2.3.5. Bias

There are two types of bias to consider, one is related to selection of anglers/fishers through sampling and the other is related to reporting and recall. Bias can be introduced as a consequence of:

1. How fisher/angler lists are compiled or sampled, or how certain groups may be left out because of their status (immigrants, minorities or foreign tourists), access to smart phone (or Internet) or language capabilities[22]
   a. selection bias when some individuals are more likely to be selected for a survey than others; and conversely
   b. exclusion bias, due to the systematic exclusion of certain individuals from a survey.
2. How data is reported, or rather which catches are not or are under-reported:
   a. reporting bias involves a skew in the availability of data, such that observations of a certain kind are more likely to be reported (large fish are reported, small fish are not, or some species are reported e.g. trout while others are not); and
   b. recall bias arises due to differences in the accuracy or completeness of participant recollections of past events, as already covered in the previous Section 2.3.4 on census approaches.

It is important to be aware of the effect of bias on the estimated values e.g. by means of statistical analysis and comparing self-reported data with data on the same fishery from direct measurement by field staff.

One of the main objectives of sound survey and sampling design is to reduce sample bias in estimates. The main method to minimize selection/exclusion bias is to use random sampling. The selection of target fish species, recreational and commercial fishers, households or boats should be done randomly, without a systematic aim or purpose. This means not selecting or rejecting any element of a population because it looks typical or atypical, nor favouring or ignoring any part of a population because of its accessibility or lack of it.

In practical terms, when choosing towns/districts/provinces, households, individuals or other collections to be sampled/interviewed, households or individual fishers that are not available or are not willing to co-operate needs to be replaced. Certain households may refuse to be involved and certain individuals may be unwilling to provide answers. A list of sampling units needs to be made that can be used to select each unit to be sampled. This can be a community household list, members of an angler association or anglers with a current fishing license, ordered by a randomly-generated list, or a random sequence to select targets for a sample survey. If the fishery is small enough, it may be feasible to sample 100 percent of the target group, although this is unlikely and random surveys will be more cost-effective even in small fisheries and will put less time burden on the fishers.

Random numbers to sample units from a list can be obtained from tables, from random number generators in statistical software or spreadsheets (Excel) or from an Internet-based source (e.g. www.random.org is an excellent free source for generating random sequences).

Since selecting a true random sample can be very time consuming, it is best that some sort of pre-selection or master sample is applied. This can be based on a simple random selection from lists of members of angler associations or from localized angler licenses/registrations by province/district or simply from any existing master sample used for the national socio-economic and

[22] Other sources of bias can be introduced via the sampling frame, as certain groups of recreational fishers fall outside the sampling frame i.e. landowners and certain anglers (often licenses are age based) who can fish legally without annual license, those that choose to not get a license (thus fishing illegally),as well as foreigners and holders of daily or weekly licenses.

agriculture surveys that may identify recreational and commercial fishers. Within each unit, sub-samples can be taken from pre-selected groups e.g. 10–20 randomly selected anglers are sampled for a number of randomly selected angler associations. Pre-selecting groups that will be sampled greatly simplifies fisher/angler selection and is the default approach used in all large-scale survey efforts. It is necessary to seek the advice of a statistician for developing the sampling strategy (stratification and sample size). The sample size should take into account non-responsive recreational and commercial fishers.

Reporting or recall bias can only be assessed and mitigated by adjusting the methodology for collecting the data e.g. reducing the recall period for validation surveys to less than a week and optimising the questions and data to what can feasibly be collected. Even with simple concepts of catch and effort, survey form and questionnaire design is critical for obtaining accurate data. Much has been written on writing good survey questions (e.g. see Fowler, 1995; Converse and Presser, 1986; White *et al.*, 2005), but the basics are included in Section 2.4.

2.3.6. Sample size

It is not always necessary to take many samples to be able to make a reliable estimate of a true value. The number of samples to be taken before a reliable estimate can be made, mainly depends on the variation in the daily catches i.e. the difference between the catches by different fishers, the level of error that is still acceptable and the confidence we want to have that our estimate is close to the actual average (Stamatopoulos, 2002). There are numerous approaches for stratification and deciding on the sample size. It is by far the most important consideration for managers, as sample size and stratification decide the cost of a survey in terms of staff and budget. The current guidelines include a few recommendations on sample size and stratification, but it is best to involve a statistician in the planning for new surveys, or re-design of old surveys. In practical terms, there are two ways to establish the sample size, and it depends if there is existing data or not.

Existing catch data available

The sample size depends on the acceptable margin of error, the certainty that the resulting estimate falls in the margin of error specified (accuracy) and the variation in the parameter to be estimated (de Graaf *et al.*, 2015):

$n = [[t_{n-1} * s]/(\varepsilon * x)]^2$

n	number of samples
t_{n-1}	student-t value for n-1
s	standard deviation of sample
ε	maximum relative error
x	mean of the sample

This is just an example of a formula that can be used. There are many different variations, but all follow the same principle. The main disadvantage of this formula is that it is necessary to have a reasonable idea of the variation in the catch data. In cases where no reliable estimate can be made, it should be either over estimated, or the sample size is determined while collecting the data by monitoring the estimate for the sample standard deviation. It is also necessary to have an idea of the mean of the population while the population should be equally distributed around the indicator that needs to be estimated e.g. the average daily catch (this is referred to as normally distributed). In addition, as n (the number of samples) and tn-1 are related, n cannot be calculated, but has to be estimated by calculating the relative error for a range of sample sizes and selecting the sample size where the relative error approaches the selected value of ε.[23]

[23] For example, this can be done in Excel using the TINV function.

BOX 4
Example of calculation

To estimate the number of monthly samples in a reel and rod fishery, we need to know the number of rods used, combined with the proportion that is active each day, to get the total number of monthly fishing days (to allow to look-up the student-t value) and the average catch per fishing day.

When we allow for a ten percent margin of error (ε) for a set of values that have a mean of 12.25 kg per 'trip' with a variation (s) of 5.6, then we would select a value for t of 1.6 (90 percent reliability) to get:

$n = [[1.6*5.6]/(0.1*12.25)]^2 = 53$

In this case we would need to sample 53 daily catches reel and rod anglers catches each month for this stratum to be able to estimate the average value within a 90 percent reliability rate. If the reliability were to be 95 percent, the number of samples should be 81.

Note the difference in the number of samples in this example between 90 percent and 95 percent accuracy. Also note that according to the formula used, **the sample size is not related to the total number of anglers fishing**. The total number of fishers in each stratum has limited influence on the number of samples needed. It is not a fixed percentage of the total fleet or total number of fishers that needs to be sampled. Generally, there is no large difference in the number of samples needed between a group of 500 or 5 000 recreational or commercial fishers. The sample size is mainly determined by the variance in the samples and the required accuracy (the student-t value) of the estimate. Therefore, reducing the variation for each group sampled, by selecting appropriate strata, is very important, as this reduces the sampling required.

No existing catch data available

In many situations, the values for the average catch and standard deviation (s) is not known. Therefore, we can either replace it with a large, but plausible, guess just to be on the safe side, or start with a small sample and let the observed value for the standard deviation (s) determine whether more data are required. This allows the above mentioned formula to be used while collecting data, in order to adjust the sample size during the survey.

If no catch data is available for the fisheries to be monitored, there are empirical tables available that allow to select a 'safe' sample size.

Table 11 is taken from Stamatopoulos (2002) and allows selection of the sample size based on the required accuracy and the target population size for landings, which is equivalent to fishing trips. Although these were initially developed for landing site surveys for catch and effort, the tables can also be used as a starting point for surveys that do not depend on fixed landing sites. They can also be applied to recreational and commercial fisheries, to provide a rough estimate of the required sampling effort.

When reading the table, keep in mind that the target population is not the number of recreational or commercial fishers in a stratum, but the total monthly fishing trips (landings). In the case of recreational fisheries that means that with an average of four fishing days for each angler/month, with a total number of 3 000 anglers in an area, there would be 12 000 monthly fishing trips. The average catch could then be estimated with 95 percent accuracy by sampling the catches for 127 fishing trips (1.1 percent) for that specific area

(fishing ground or province). If it is necessary to have independent estimates for catch and effort for a number of different fishing grounds (habitats) or by province, this would mean that each stratum would need to be sampled separately, increasing the required number of samples. The sample sizes included in the tables are for each stratum separately, and a safe starting point for new sampling surveys. After starting the sampling survey, the observed variation in the data can be used to adjust the sample size by monitoring the variation in the data collected and using the aforementioned formula to calculate the sample size.

Table 11. Safe sample sizes for 'landings' at varying accuracy levels and target population size.

Accuracy (%)	90	91	92	93	94	95	96	97	98	99
Data population size	Safe sampling sizes (landings or fishing trips)									
300	29	35	43	54	69	90	120	163	218	274
400	30	36	44	56	73	97	133	188	267	356
500	30	37	45	58	75	102	143	208	308	432
600	30	37	46	59	77	106	150	223	343	505
700	31	37	47	60	79	108	156	236	373	574
800	31	38	47	60	80	110	160	246	400	640
900	31	38	47	61	81	112	164	255	424	703
1 000	31	38	48	61	82	114	167	262	445	762
2 000	32	39	49	63	85	120	182	302	572	1 231
3 000	32	39	49	64	86	123	188	318	632	1 549
4 000	32	39	49	64	87	124	191	327	667	1 778
5 000	32	39	50	64	87	125	192	332	690	1 952
6 000	32	39	50	65	88	125	194	336	706	2 088
7 000	32	39	50	65	88	126	195	339	718	2 197
8 000	32	39	50	65	88	126	195	341	728	2 286
9 000	32	39	50	65	88	126	196	342	735	2 361
10 000	32	39	50	65	88	126	196	343	741	2 425
15 000	32	39	50	65	88	127	197	347	760	2 638
20 000	32	39	50	65	89	127	198	349	770	2 760
25 000	32	39	50	65	89	127	198	351	776	2 838
30 000	32	39	50	65	89	128	199	352	780	2 893
35 000	32	39	50	65	89	128	199	352	782	2 933
40 000	32	39	50	65	89	128	199	353	785	2 964
45 000	32	39	50	65	89	128	199	353	786	2 989
50 000	32	39	50	65	89	128	199	353	788	3 009
> 50 000	32	40	50	65	89	128	200	356	800	3 201

2.3.7. Stratification

Stratification for sampling is needed to reduce the number of samples. This applies to all sample-based methods but is especially important for surveys covering a wide range of habitats or fisheries (de Graaf *et al.*, 2015). Stratification creates sub-groups in the total population that are sampled separately. Stratification is done to reduce the sample size, reducing the variation by grouping households/anglers by socio-economic status or age group, separating fisheries by main gear, target species or habitats (lakes vs rivers) or fishing grounds by size. These sub-groups are called strata, and each stratum needs to be sampled separately.

Each stratum created should, ideally, be as different as possible. Heterogeneity among strata with homogeneity within strata is thus the primary feature that should guide the establishment of strata. It can easily be seen from this feature why urban and rural areas are often established as two of the strata for a household fishery survey. Urban and rural populations are different

from each other in many ways (type of employment, source and amount of income, average household size, access to fishing etc.) while being similar within their respective sub-groups.

It is important to not over stratify, as this will increase the cost for implementing a survey. As mentioned for the sample size, stratification should be designed with the assistance of a statistician and should be part of a detailed survey plan and field implementation approach.

2.4. PLANNING AND FIELD IMPLEMENTATION

Quality assurance and quality control (QA/QC) are essential for ensuring that any data reported and collected correctly represents the actual situation. There are different issues with different types of data collection methodologies, but this section will provide a general overview of what can be done to obtain the highest quality data. The content in this section is partially based on the World Bank guidelines for Development Impact Evaluation or DIME (https://dimewiki.worldbank.org/wiki/Main_Page), which provides tools for Living Standards Measurement Surveys (LSMS) and other household surveys, as well as authors' practical experiences related to fish consumption, catch recall and catch logbook surveys.

Collection of primary data by means of surveys, logbooks or interviews may result in low quality data because of three main reasons, all linked to human nature:

- **Respondents** in either a recall or a logbook survey have imperfect memory, may lack motivation due to a variety of reasons and/or can become tired or annoyed by repeatedly answering questions or entering information they do not care for or do not understand the reason for;
- **Enumerators** can make mistakes recording information, fill answers to unasked questions (because the answer is 'obvious') or even completely skip interviewing and fill out forms in the comfort of their office or home. Similarly, they may fix answers, because they do not trust the respondents or adjust logbook data without consulting with respondents, because they cannot be bothered to contact them (in person or by phone). Fieldwork is hard and can be stressful, so it is somewhat understandable that these issues occur. Issues can include long days, respondents who are hard to find, hand-writing that cannot be read, unclear guidelines, a lot of travel, perhaps having to deal with people that are equally frustrated by weather, traffic, family issues and more.
- **Field managers** often fail to implement quality control efforts in a timely manner, perhaps they try to avoid confrontation with enumerators who are underperforming, or they may have insufficient time or experience to deal with stressful problems.

These three main issues can be mitigated, if not completely overcome through survey design, field management, and high frequency checks. QA/QC for field surveys very much depends on the type of survey. Different issues crop up during recall survey for catch or fish consumption than for census-based logbook surveys for catch and effort for recreational fishery, but some general guidelines are provided below. Even though some of the above mentioned issues can be avoided when relying on self-reporting by anglers and fishers, especially when data is recorded using a smart phone app or website, there is a need for QA/QC to ensure the highest quality data. The overview of steps for planning and field implementation are included in Annex 4, and are especially relevant for sample-based validation surveys and other sample-based surveys for stock assessment, environmental variables and biodiversity.

Survey teams for sample surveys using field staff to collect data can be a good approach to work in teams of two enumerators. Especially in those cases where interviews are held, the interviewer can concentrate on performing the interview and keeping the discussion going while the second person can note down the information on the survey form. This will also ensure a quality check during the interview if the interviewer forgets to ask for clarification, or when the information given is insufficient.

Validation where possible, (for example for frame survey data or mandatory catch logbooks) a sample survey should be conducted to redo part of the survey to verify the results (this needs to be specified in the pre-analysis plan, see Annex 4). In case of catch monitoring (fisheries research), it may be possible to use the length/frequency data together with length/weight data to estimate the catch separately, this then may be used to verify the results of catch assessments obtained through surveys of catch and effort.

Logbooks and observers: especially for mandatory logbooks for licensed fisheries there is a large potential for intended and unintended under-reporting. This can be mitigated by field-level presence (angler association representatives, fish guards or managers) and ensuring during license application that the forms and responsibilities are clearly explained, in addition to implementing validation surveys.

2.5. BIODIVERSITY AND ECOSYSTEM HEALTH

Biodiversity is an important indicator for ecosystem health and a major factor in ecosystem resilience against disturbances, either man-made or natural. If there is a general trend in reduction of fish species diversity, this is a sign of environmental disturbance (e.g. climate change, pollution, flow alteration), while changes in abundance can also be caused by unsustainable harvest.[24] Monitoring biodiversity as an indicator of the economic health of fisheries, is essential to manage the fishery, but the effectiveness of biodiversity indicators to evaluate ecosystem health, depends on the level and type of fishery enhancements. If the fishing population at a fishing ground is mainly determined by stocking, biodiversity indicators make little sense. For further reading on the topic of biodiversity and ecosystems, reference is made to some of the EU Water Framework Directive classification tools that have been developed for European lakes and rivers, such as Kelly *et al* (2012); Olin *et al* (2013) and Argillier *et al* (2013).

Data collected from the catch assessment can support biodiversity analysis, but dedicated biodiversity assessments also need to be considered. Usually these data are collected by different ministries or government agencies (DoF, Ministry of Environment), thus data collaboration is as important as data collection. Species resolution in the data is important and ideally data need to be available by individual species for it to be useful for biodiversity assessments. However, fisheries data are often limited to species of commercial value or sport value to anglers, while new species unknown to anglers may well be misidentified, which is an issue when using data from both commercial and recreational fisheries that also tend to group species together in economic groups or use less precise common names. Although relevant data can be obtained from catch assessments, this will only describe fisheries target species and accidental bycatch for fisheries. This approach is likely to leave out numerous native and invasive species in the habitat that can only be found using scientific taxonomic surveys. However, as long as the bias in catch assessment data is acknowledged (target species for fisheries) it can still provide valuable information on the state of biodiversity within the species targeted by fisheries and can be used to compare different areas (e.g. under management or without management) or between assessments. With preliminary estimates based on fisheries data in place, this can then be compared with research data when collected in limited scope surveys using experimental fishing.

Daily/monthly household catch for native fish species

Catch is not intended as a measure of the ecological health of the river or lake environment. Catch represents a social, recreational and economic benefit extracted from the environment. However, as an ecological indicator it holds little value since variable levels of exploitation

[24] In highly managed and regulated fisheries that depend on regular restocking, these trends may be difficult to ascertain.

muddles interpretations relative to exact catch location (habitat) and ecological health. Using catch solely as an economic (livelihood) indicator is more useful, indicating the health of the fishery and its contribution to the community. This utilizes comparison of catch assessment data obtained from relevant surveys. It is suggested to only focus on the median CPUE or the efficiency of fishing operations as this combines both catches and effort and is easy to compare between different levels of exploitation and areas using monthly bar graphs.

An expansion of the above analysis using the reported species catch from catch assessment surveys could be considered, assessing the fish species complex based on specific traits[25] (Pont *et al.*, 2006, Pauly and Palomares, 2005). However, this relies on detailed and non-ambiguous information on the ecological niche for species, and this is not available for all species. Instead of using the shifts in species traits groups as a monitoring tool, it may make more sense to use available species information[26] to explain why shifts in species abundance occur, and this analysis can be included in regular reporting on the status of the fisheries. This approach can be based on available information included in FishBase and other resources.

Abundance of exotic (alien) fish species

For inland fisheries, the fraction of non-native biomass to total fish biomass is frequently regarded as an indicator of ecological impairment.[27] In natural systems, non-native species can sometimes compete with desirable native species, thereby reducing their abundance and distribution. However, many inland fisheries are based on ongoing stocking, often of non-native species; the value of using this indicator thus depends on the type of stocking that is practiced. However, in semi-natural aquatic habitats, tracking non-native fish biomass provides direct information on the prominence of non-native species and may indicate stresses on native fish assemblages. This indicator is the proportion of total fish biomass composed of several non-native species that may be present in the fisheries e.g. introduced species or escapees from aquaculture. This indicator is relatively simple and visually shows impairment or improvement in the system by presenting data in a stacked bar graph by non-native species. Stacking by species for subsequent years/period visually show shifts in dominance within the non-native species monitored. This can only be obtained from routine (daily) catch assessments by calculating the contribution to the total reported catch by introduced species. Relative importance of exotic (alien) species in the fisheries generally indicates disturbance of the available ecosystems (Arthington and Pearson (eds), 2007) with estimates available on a monthly basis.

Fish diversity index

Ecological health of any aquatic ecosystem is described in part by the diversity of fish species present. This indicator describes the diversity and structure of the fish community observed annually. Although scientific assessments are preferred, this is costly and unlikely to be sustainable.

It is recommended in terms of analysis of catch assessment data, to include species diversity index (Shannon) and species evenness or dominance (Shannon Evenness Index (SEI)). It is also informative to express diversity as the total species number (species richness) which can be easily calculated using available plug-ins for Excel, or as part of the standard reporting system. The number of species present by survey round (or over the whole year) between areas is also indicative for the relative occurrence of species.

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[25] For example: tolerance/resilience, trophic level (food), reproduction, habitat and migration

[26] Information on migration guild (or transboundary stocks for highly mobile species), local ecological status, feeding guild (including detailed info on food and feeding habits), IUCN status and other relevant information should be added to a species information base (linked to existing resources, like FishBase and the IUCN website).

[27] A related issue concerns the proportion of escaped farmed fish compared to conspecific wild fish. This is for example an issue in salmon fisheries in Norway.

Many criticisms have been made against the usefulness of diversity indices when employed separately in assessment of river systems (Metcalfe, 1989); it is preferable to use these indices together with other metrics (Li *et al.*, 2010). Multi-metric indices represent a means to integrate a set of variables or metrics, which represent various structural and functional attributes of an ecosystem (e.g. taxa richness, relative abundance, density, functional feeding groups (guilds) and life strategies (e.g. growth rate, reproduction), presence of disease in combination with fisheries and livelihood based indicators), thereby providing robust and sensitive insights into the responses of an assemblage to natural and anthropogenic stressors (Karr, 1981).

Proportion/abundance of forage fish

The abundance of forage (or prey) fish represents production at lower trophic levels, which provides food for large predatory fish that are important to the fisheries. Since this includes many fast-growing species with a short life cycle, these will respond faster to changes than slower-growing species that take longer to mature. Significant changes in forage resources indicate shifts in ecosystem health and function (Arthington and Pearson (eds), 2007). Data is unlikely to be available, as this depends heavily on dedicated surveys as neither recreational nor commercial fisheries should be targeting juvenile or smaller fish species, but this could be done using scientific studies.

In the absence of data on forage fish, the EU Marine Strategy Framework Directive (MSFD) experience (and recent work in Inland Fisheries Ireland) shows that it may be more appropriate to use length data from desirable high total length target species or those that attain large maximum body size. Not only will angler catch data be available for these species, but also show far less environmental fluctuation than forage fish, being influenced predominately by size-based fishing pressure. Loss of these species reduces predation pressure on lower total length fish, leading to trophic cascades. This can be implemented using simple empirical length-based indicators (e.g. Shephard *et al.*, 2019) or the modified length-based spawning potential ratio (Hommick *et al.*, 2020) to track trends in this component of the fish assemblage for biodiversity monitoring. These approaches also support data-limited stock assessments for important target species.

2.6. ANALYSIS, REPORTING AND FISHERIES INFORMATION SYSTEMS

To support fisheries policymaking, planning and management, the collected data must be processed to generate fisheries information.

If possible, linkages between all existing database and information systems on fish, fisheries and environmental data should be developed, with a single user-interface to create a Fisheries Information System and Management Information System (FISMIS). The main focus is to provide data summaries and access to information (reports, tables, graphs and maps) derived from each database, to ensure that all data and information is accessible. Estimates can largely be automated i.e. data summaries, tables with estimates and graphs with time-series are generated on demand depending on a selection by the user for data types, period and area. The base requirements for information to be available depends on the existing reporting requirements e.g. monthly estimates for total catch, total catch by species, average number of fishing days and average catch per fishing day (CPUE). Estimates can be made by province and at national levels, as well as by management area (individual fishing grounds, lakes and river basins). It is also important that levels of error and variation are indicated, so that the estimates to be interpreted.

Capacity building for local managers of fishing grounds and especially with fishery management organizations, including angler associations or fishing clubs where these are directly involved in data collection and fishery management, is important. In many European countries, data collection is devolved to managers (or license holders) of individual fishing grounds or by angler associations. Since it is often at these levels that management plans are developed and implemented, it is important that they have capacity to analyse and interpret

the data, to inform planning and decision-making, as well as to allow genuine discussions between government and those responsible for local fisheries through co-management arrangements with national authorities.

It is especially useful to present spatial data in graphical form as this allows presenting different types of data of relevance to fisheries at the same time such as important fishing grounds, spawning areas, protected areas, key habitats rivers, streams, floodplains, wetlands, weirs and dams etc. (FAO, 1999). See FAO (2003b) for examples of use of GIS for fishery management and planning.

The development of an information system is a specialist job and can best be done by an external company or specialized government service. It is recommended that the department responsible for fisheries develops the necessary expertise to manage and maintain information systems and databases through access to well-trained and capable IT staff. This will ensure that the system will be serviceable in the future and compatible with other government systems. Moreover, it is important to use tools that are generally understood by more than just the local programmer, as this will ensure that the system can be expanded and adapted by anyone familiar with the system and the standard development tools.

Fisheries data are routinely reported on a monthly and annual basis, mainly because this covers seasonal periodicity in the fisheries, but also because most national- and local-level reporting is based on a monthly cycle of data collection. For recreational fisheries, often a longer timeframe is used for reporting, as in many cases data may only be reported/collected annually (or seasonally). However, when data is reported for individual fishing trips, through apps or websites, then monthly summary reports can be generated. Annual reports can be used to summarise monthly reports and to conduct a more in-depth assessment of status and trends between years, of interest to policymakers and managers. These reports should be available through a website (as PDFs) and a dedicated fisheries app in addition to any personal data summaries made available to recreational and commercial fishers as part of the web- or app-based data reporting interface.

Feedback to resource users (and local fishery management units) is crucial and this can be combined with regular co-management meetings or any other meetings by angler associations, as an interactive exchange. Relevant stakeholders may be difficult to assemble, in which case a representative subset such as a president of a fishers or anglers association, community leaders and, where available, a panel of recreational and commercial fishers can be invited to represent the interests of all fishers. Providing feedback to fishers on changes and trends in the fishery should whenever possible be integrated with co-management meetings. This is because monitoring the effectiveness of management interventions depends both on the data itself as the acceptance of the validity of the data presented. Sharing and discussing the data provided by the recreational and commercial fishers directly with them contributes to this dynamic and informs them of the usefulness of their inputs in management of their resources. On the other hand, disregarding the importance of feedback to stakeholders would severely constrain co-operation, with informants becoming suspicious about the outcome of the analysis and the dissemination of the information (Sparre, 2000).

In general, feedback from informants and data users should always be encouraged to ensure that the information system responds to the needs of all parties, as effectively as possible (FAO, 2012). If the feedback mechanism recognizes inadequacies in the data collection system, these should be addressed immediately and monitored. Consequently, the system should always be sufficiently flexible to allow for periodic adjustments, in particular when the target fishery is dynamic and subject to change (Sparre, 2000).

3. Conclusions and recommendations

In order to manage inland fisheries, information is needed about the level of catch, exploitation (effort), and the status of both fish stocks and the aquatic environment and human dimension aspects of the fisheries, including recreational fisheries. Data needs to be collected in some form, monitored over time, and analysed. According to the European Commission's (EC) Common Fisheries Policy (Article 25(2)), the key principles of data collection are: accuracy; reliability and timeliness; avoidance of duplication through improved coordination; safe storage in database systems; improved availability of data; compliance with laws on personal data protection; and access for the EC, to check on availability and quality of data and the methodology to collect them. Although this Article does not apply to inland fisheries of EU members, nor does it apply to land-locked EU countries, the guidance is valuable and should be adopted in a wider sense to allow public access to the available data in aggregated form as part of co-management implementation by inland fisheries managers, whenever possible. This also ties in with the recommendation for self-reporting using web-based platforms and phone apps, which allows for more control by resource users, who have full access to the data provided.

Although some examples are given throughout the current guidelines, for those interested in the systems currently implemented for inland fisheries in Europe, a description of the main relevant methodologies for commercial and recreational inland fisheries as well as some general recommendations, the report on data collection systems and methodologies for the inland fisheries of Europe by LUKE (Vehanen *et al.*, 2020), Pollock *et al.*, 1994 and Jones and Pollock, 2013 are mandatory reading.

Many European countries seemingly aim for a census of fishery data through mandatory reporting, for both commercial and recreational fisheries, quite often recall-based, which is poorly adhered to by both commercial and recreational fishers as well as rights holders (associations or private owners). The poor state of available fishery data is worse for recreational compared to commercial fisheries, with few exceptions (Czechia); recreational fisheries are either poorly covered or not monitored at all. Often the main monitoring is focused on specific species or species groups, specifically salmonids (salmon, trout and char), while largely ignoring other less sought after species by recreational or commercial fishers. This does not include CITES-listed species, such as European eel, which have their own reporting requirements, in particular within the EC. However, most methods currently used suffer from poor coverage and thus unreliable estimates, either due to partial reporting of catches and effort, guess-based data or non-reporting.

Although fisheries scientists often recommend sample surveys, as they tend to be cost-effective, it is clear that in many countries cost (budget, staff resources and time) is a limiting factor in both inland fishery management and data collection. Participatory approaches that shift both authority and responsibility onto community organizations, angler associations and local management units, are widely implemented because there is not enough budget for a top-down approach. There are some creative solutions available, where sample approaches can be implemented even within a framework of mandatory reporting of all catches by recreational and commercial fishers e.g. collaboration with universities and colleges. This allow using students as affordable labour or implementing a panel survey based only on a sample of the available census-based fishery data. However, it is clear that participatory (and mandatory) data collection using logbooks, linked to obtaining fishing licenses is the main practical and cost-effective way to collect data on recreational fisheries in the Western Balkans region and elsewhere where funding for collecting fisheries statistics is low. Although this is

not an ideal, the dilemma for many countries is not the best way to collect fishery data, but rather the most appropriate approach under the existing budget, staff and time restrictions. All statistical data collection is restricted by available budget, so it would be disingenuous to propose large-scale sample-based methodologies for the Western Balkans region, despite the obvious advantages in terms of reliability and coverage. The main proposed improvements mainly relate to:

- Implement (mandatory) self-reporting through websites and phone apps, instead of cumbersome paper logbooks;
- Focus on practical basic indicators e.g. species catch, fishing effort (including gear used) and location, while recording both fish retained (harvested) and those returned;
- Incentivise fishers and anglers to share their data by providing additional services (species guides, links to social media for sharing photos, map-based overview of personal catches and full access to detailed data reports);
- Whenever possible, implementation of (simple) validation survey to estimate accuracy and bias; and
- Participatory planning for fishery management using the EAFm and co-management approaches to engage stakeholders and create better understanding for the need of accurate reporting of fishery data.

Where the responsibilities for data collection can be shared with the stakeholders, significant resource gains may be made in the long term, but it will require investment of time to generate the awareness and build the necessary capacity. The general consensus is that self-recruiting voluntary reporting of catch and effort data through websites and phone apps often suffer from bias related to variation in enthusiasm with those volunteering to provide catch data, drop-outs, and lack of representativeness i.e. the data does not represent the entire fisheries (Jiorle *et al.*, 2016 and Gundelund *et al.*, 2020). Relying on self-recruiting voluntary participation is not optimal and instead either mandatory reporting, sample-based approach (including use of panels) should be considered. Still, these voluntary self-reporting approaches have the ability to provide data where traditional methods cannot. If methods to correct such biases are used, programmes like iAngler have the potential to provide valuable catch-rate data to fishery managers (Jiorle *et al.*, 2016 and Gundelund *et al.*, 2020). However, evaluation of the quality of the data collected with this method is essential.

Every data collection system has innate biases and errors, and the implementation of limited scope validation surveys therefore needs to be considered, either at national level, or locally by management units (fishing right holders, angler associations and land owners) for individual fishing grounds, basins and other aquatic resources being exploited under their responsibility. Data is not useful if it does not reflect the real status and trends, and therefore assessments of accuracy and level of bias need to be established. This is not complicated and can be implemented locally with very limited resources.

Data needs should be driven by information requirements, which at local levels are mainly for management and enforcement (assessing compliance with management). Despite the focus on data collection methods, EAFm is crucial for sustainable exploitation of inland fisheries resources and one of the main practical objectives for a data collection system should be supporting fishery management. In data-poor fisheries, it is especially important to mobilise local knowledge about the aquatic ecosystem by identifying issues impacting inland fisheries and solutions for sustainable utilisation of the available fishery resources with the relevant stakeholders.

Since managers and management units of individual fishing grounds in many European countries (and the three Western Balkan nations included in this project) already need to develop a management plan to be eligible for obtaining concessions for managing fisheries

in individual fishing grounds, it makes sense to make the EAFm methodology mandatory in preparation of a comprehensive management plan. Community management is already widely accepted throughout the region. What is perhaps lacking is the capacity for angler associations or community groups to implement the participatory planning processes necessary to develop a comprehensive and realistic management plan and associated data collection scheme. Therefore, capacity building is essential to ensure that fishery officers representing local and national governments are capable of guiding local planning exercises. Funding for these private co-management partners is another area that must be addressed in developing a successful data collection system.

The main weaknesses reported by stakeholders during interactive workshops in the three countries in the Western Balkans region, cover:

- Technical support and capacity;
- Lack of compliance with reporting;
- Unreliable data (including lacking species detail); and
- Insufficient resources (budget and staffing).

Identifying weaknesses and issues is important, but more important is to jointly come up with possible solutions and a realistic approach to data collection to implement a management plan. Fisheries professionals are clearly aware of the in-country limitations. Despite efforts to make these guidelines as practical as possible, it is merely an introduction to the main considerations when developing a data collection system. Practical follow-up action will be required such as for the above-mentioned capacity building where it is necessary to develop in-country expertise with government facilitators, creating trainers and facilitators familiar with EAFm and co-management principles. Practical action plans need to be developed setting clear goals for improving inland fisheries management and data collection, through a series of national and local level workshops to establish a comprehensive management plan both at national level down to individual fishing grounds, with data requirements clarified, and a plan to improve both the data quality and the periodicity of data collection.

Recreational fisheries, or inland fisheries in general, are not a top priority for most countries (Arlinghaus *et al.*, 2019), due to a lack of appreciation by authorities that this sector has important impacts on human well-being, food security, rural livelihoods and aquatic ecosystems. Not only is it necessary to collect and analyse more relevant and higher quality data for policymakers, management of inland fisheries in Europe needs to shift towards targets related to the quality and variety of fishing opportunities as inland recreational fishing has largely displaced commercial fishing. Instead of focusing on typical fishery indicators and targets associated with commercial fishing, like CPUE, bio-economic and socio-economic indicators need to be considered. It is hoped that improved data and information will lead to the realization that recreational fishing generates substantial benefits both to recreational fishers, the national economy, and wider society, while fostering non-pecuniary externalities such as ecological sustainability.

It is clear that these guidelines alone will not be suffice to bring about the required changes in how data on commercial and recreational fisheries in Europe are collected. Support to fishing communities and collaboration with national counterparts is essential to facilitate and clarify the options proposed in these guidelines.

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Annex 1. Endangered species as listed by IUCN for the Western Balkans region

Scientific Name	IUCN Red list category
Acipenser naccarii	Critically Endangered
Alburnus macedonicus	Critically Endangered
Anguilla Anguilla	Critically Endangered
Valencia letourneuxi	Critically Endangered
Gobio skadarensis	Endangered
Hucho hucho	Endangered
Luciobarbus graecus	Endangered
Pelasgus prespensis	Endangered
Salmo obtusirostris	Endangered
Salmo peristericus	Endangered
Alburnus sp. nov. 'Volvi'	Near Threatened
Chondrostoma vardarense	Near Threatened
Pelasgus thesproticus	Near Threatened
Squalius sp. nov. 'Aoos'	Near Threatened
Alburnoides ohridanus	Vulnerable
Alburnoides prespensis	Vulnerable
Alburnus belvica	Vulnerable
Alosa sp. nov. 'Skadar'	Vulnerable
Chondrostoma prespense	Vulnerable
Cobitis meridionalis	Vulnerable
Gobio ohridanus	Vulnerable
Rutilus prespensis	Vulnerable
Salmo ohridanus	Vulnerable
Salmo pelagonicus	Vulnerable

Annex 2. Recommended steps in planning and field implementation

1. Prepare a Quality Assurance Plan (QAP), which considers everything in data collection that could go wrong ahead of time and makes a plan to pre-empt these issues.
2. Make a pre-analysis plan (PAP), a document that includes:
   a. Description of the sample/census approach to be used in the study (sample design).
   b. Key data sources, both for survey design (e.g. population census or vessel registry) and used for verification of comparison (e.g. results from relevant previous surveys/ research).
   c. How the data will be analysed (whenever possible tabulations, graphs and statistical methods/tests to be used as well as specific software packages or approaches to be used (e.g. FISAT, ELEFAN for length frequency analysis).
   d. Methods for estimating the main variables.
   e. A plan to deal with attrition of survey participants.
   While the main objective of a PAP is to prevent data mining and post-survey specification searching, it can also help the researcher think through survey/questionnaire design and, once the data is collected, make data analysis much quicker and easier.
3. Ensure co-operation from local government, community leaders and especially respondents/ participants:
   a. Introduce the survey team and provide contact details (phone, email, messenger apps).
   b. Clearly explain objectives and scope of the survey and what the data will be used for.
   c. Indicate who will have access to the data (if at all possible, allow respondents access to the data in some form e.g. data summaries or through online portal).
   d. Emphasise that participation is voluntary, how participants were selected and what is expected (type of information sought, methodology), include interview duration, length of period during which interviews are conducted, or logbooks that have to be submitted, expected interruption of fish landings and any compensation for lost time.
   e. Clarify how data will be anonymised or how confidentiality of the data will be secured (tax concerns are potentially big when asking for fish catches or other livelihood/ income related information).
   f. Ask for co-operation/permission, never demand it.
   g. Do not pressure anyone into agreeing to participate, give sufficient information and time for prospective participants to make a decision (and then respect that decision).
   h. If a participant agrees, get a signed agreement.

4. Establish amount of budget required.
5. Detail the sampling design, target population, sample size, acceptable error and statistical certainty, this includes how the sample will be selected e.g. by selecting angler associations from which random members will be selected for random sampling of participants.
6. Design questionnaire, survey form, logbooks carefully:
   a. Focus on the information available in the fisheries. Fewer data of good quality are preferable. For example, catches are usually dominated by five species at any location (50–80 percent of total weight), so records of their catches and weights may suffice for fisheries research or logbooks.
   b. Simple questions, which have categorical answers, are less prone to error than questions that require estimation or a narrative. In the case of assessing involvement, it is easier to assess the type of involvement than the level (in hours/days or percentage of available time).

   c. categories of species, catches, effort, gears, habitats or food sources should be standardised as far as possible.
   d. Visual aids should be used in interviews, as well when introducing (training) households to fill in logbooks. In particular, a comprehensive set of photos is needed for fish (species flipchart) and other aquatic animals, where there is confusion over terminology and definition.
   e. Optimise survey design for quality assessments. Simple checks can be used to ensure higher data quality, like recording start and finish of interviews to allow comparison of survey times between enumerators to identify discrepancies. This is especially useful when using digital survey forms where time-stamps can be collected automatically to allow analysis of interview flow. Asking the same information twice in different ways allows to check for inconsistencies in the information recorded.
7. Design pilot survey to finalise the survey form and survey protocol.
8. It is important that the experience gained during implementation of the pilot survey in step 7 is standardised and fully documented in a field implementation guide, where possible to the smallest survey detail and that any changes/updates to the approach are duly incorporated in the guidelines/manual.
9. Careful translation of survey forms, recording sheets, logbooks and survey guidelines, do not leave room for nuanced interpretations, use pilot surveys to fine-tune the logbooks and questionnaires.
10. Training of enumerators based on a clear (enumerator) manual:
    a. Overview of study objectives;
    b. All survey protocols (selection of households/landings, for interviews in home: number of retries before replacement, recording drop-outs/fishers refusing to collaborate, strategy for selecting replacements, approach for random sampling fish/landings, measurements and species identification);
    c. Roles and responsibilities of field staff, or angler association representatives;
    d. Definitions of key terms;
    e. Where appropriate, instructions for using (and troubleshooting) tablets;
    f. Questionnaire/survey conventions;
    g. Module-by-module coverage of questionnaire/logbook/recording sheet;
    h. Class room testing (mock-up survey/interviews); and
    i. Field testing and evaluation.
11. Training for fishers participating in logbook surveys is limited to practical training and intensive follow-up during the first few months of a logbook survey, with any data collected discarded until the participating households have adjusted and non-co-operative/incapable participants are replaced.
12. Strict planning of survey activities; enumerators should know where to go to when following a fixed schedule that can be checked by supervisors.
13. Observation/initial survey period(s) e.g. enumerators could initially be paired with field managers attending surveys/interviews, giving feedback after landings/interviews or interactions with logbook holders.
14. Immediate checks for data and forms/data sheets for completeness. Data should be checked in the field shortly after collecting it while there is still a chance to correct missing data or obtain clarifications from respondents/fishers.
15. Strict supervision with regular activity reports for spot-checks. Supervisors should know where different teams of enumerators are on each given day and time and should conduct some surprise visits to landing sites or villages that should be covered and check if the visits where done on the days specified.
16. Monthly activity reports should be prepared for enumerators and supervisors.

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