Supporting information for MSC's evidence requirements: technical considerations for evaluating at-sea observer and electronic monitoring programmes

A report produced for the MSC

October 2023

How to refence this report: Pierre, J.P., Andrews, J.W. and Blyth-Skyrme, R. 2023. Supporting information for MSC's evidence requirements: technical considerations for evaluating at-sea observer and electronic monitoring programmes. Published by the Marine Stewardship Council [www.msc.org], 84 pages.

Supporting information for MSC's evidence requirements: technical considerations for evaluating at-sea observer and electronic monitoring programmes

Final report: 20 October 2023

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Glossary

AIS	Automatic Identification System
ALC	Automatic Location Communicator
CAB	Conformity Assessment Body
CAMLR Convention	Convention on the Conservation of Antarctic Marine Living Resources
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CAMP	Coordinated Aquatic Monitoring Program
CCMs	Western and Central Pacific Fisheries Commission Members, Cooperating Non-Members, and participating Territories
CITES	Convention on International Trade in Endangered Species
CMM	Conservation and Management Measure
CMS	Conservation of Migratory Species of Wild Animals
COI	Conflict of interest
CPUE	Catch per unit effort
CV	Coefficient of variation
GSGSSI	Government of South Georgia and the South Sandwich Islands
IATTC	International Commission for the Conservation of Atlantic Tunas
IOTC	Indian Ocean Tuna Commission
EM	Electronic monitoring
ERF	Evidence Requirements Framework
ETP	Endangered, Threatened and Protected species
FFA	Pacific Islands Forum Fisheries Agency
FNA	Fins naturally attached (as relevant to sharks)
FO	Fisheries observer (e.g. working onboard vessels at sea)
GSGSSI	Government of South Georgia and the South Sandwich Islands
MSC	Marine Stewardship Council
NRW	Natural Resources Wales
PIRFO	Pacific Islands Regional Fisheries Observer
RSME	Relative root mean square error
RR	Risk ratio
SISO	(CCAMLR) Scheme of International Scientific Observation

TAC	Total Allowable Catch
VME	Vulnerable Marine Ecosystem
VMP	Vessel Monitoring Plan
VMS	Vessel Monitoring System
WCPFC	Western and Central Pacific Fisheries Commission

Executive summary

The Marine Stewardship Council (MSC) sets a third-party global standard for sustainable fishing. In October 2022, version 3.0 of the MSC Fisheries Standard was published. This included the first version of the MSC Fisheries Standard Toolbox. The Evidence Requirements Framework (ERF) is one component of the Toolbox, and guides assessors on the evaluation of how fishery information is collected, reported, handled and analysed. The ERF is designed to apply across fishery information systems, recognising that there are many different approaches that can be effective in delivering the information required to support sustainable fisheries management. Three core concepts established in statistical theory are central to the ERF: accuracy, trueness and precision.

This report provides supporting information for ERF users, focusing on fishery monitoring and especially two methods of independent observation: human fisheries observers and electronic monitoring. Building on the information included in the Toolbox, the report steps through ERF requirements that can be met by different monitoring methods, development of monitoring programmes, auditing considerations for assessors, and approaches to transition monitoring programmes to meet ERF requirements.

The monitoring capabilities of fisheries observers and electronic monitoring overlap significantly. With their own characteristic advantages and disadvantages, both methods can be used to record information describing fishing location, effort, gear characteristics, catch composition, catch handling and compliance with management requirements. The systems and processes that support both types of independent observation also have commonalities. For example, to be most effective both methods require defined data collection protocols that address clear monitoring objectives, appropriate amounts of representative monitoring coverage, and effective information management and programme management. Data collected by both methods also requires appropriate analyses for best use.

Auditing considerations for fishery assessors are set out as lists of questions to build an understanding of the information systems and processes supporting fisheries under assessment. Strengths and potential weaknesses of these systems should become apparent to assessors through an enquiry process.

For fisheries wishing to enter certification under version 3.0 of the MSC Fisheries Standard, the report sets out a transition process to structure the development of monitoring systems to meet fishery data needs. Examples of monitoring challenges are provided, with suggestions on how these can be addressed through independent observation and other complementary methods.

Case studies of MSC-certified fisheries show how assessors can approach evaluating fisheries against the ERF requirements. Case studies include smaller to larger scale fisheries, using a range of gear types in different regions, with a range of information systems in place. All fisheries considered in case studies have some monitoring in place, and suggestions to augment that are set out where ERF scores can be increased.

The ERF embeds key concepts from information theory in a practical fisheries context, to improve the consistency and comparability of fishery assessments against the MSC Standard. Bridging theory and practice requires pragmatism and an agile approach. For some fisheries, implementing monitoring with independent observation at the level required by the ERF will be a continuation or expansion of business-as-usual. For others, novel solutions may be needed. For all, fishery management is expected to be better supported by robust, high-quality information.

Contents

1. Introduction

1.1 The Marine Stewardship Council Fisheries Standard

The Marine Stewardship Council (MSC) sets a globally applicable third-party standard for sustainable fishing. The first version of MSC Principles and Criteria for Sustainable Fishing was published in 2002. Since then, requirements that candidate fisheries must meet to be certified as sustainable by MSC have been reviewed and revised several times[74]. In October 2022, the MSC published version 3.0 of the MSC Fisheries Standard (the Standard). This included the first version of the MSC Fisheries Standard Toolbox, in which various tools are set out for use by fishery assessors, to evaluate whether fisheries meet the requirements of the Standard. The Evidence Requirements Framework (ERF) is one component of the Toolbox, and the focus of this report[73].

The ERF guides assessors on the evaluation of fisheries information systems: how information relevant to the fishery is collected, reported, handled and analysed. The ERF is designed to apply across fishery information systems, recognizing that there are many possible system elements and configurations that can deliver the information required to support sustainable fisheries management. The ERF is built around three core concepts established in statistical theory: accuracy, trueness and precision[73].

Fisheries monitoring has always been considered in assessments of fisheries against the requirements of the MSC standard. Building on that, the ERF sets out a structured approach for assessors to use as part of version 3.0 of the Standard, to evaluate the information that monitoring provides about a fishery. The ERF is explicit about the need for independent verification[a] and independent observation[b] of fishery catches.

1.2 Purpose and structure of this report

This report provides supporting information to Conformity Assessment Bodies (CABs), their assessors, fishery clients and other stakeholders on how to evaluate fishery monitoring methods in the context of the ERF. The report focuses on two fishery monitoring methods that can meet the ERF requirements for independent observation: fishery observer programmes and electronic monitoring. It builds on the information included in the Toolbox, setting out:

- The requirements of the ERF that can be met by different monitoring methods
- How these methods, with a focus on human fishery observers and electronic monitoring (EM), can provide the information required by the ERF
- Auditing considerations for assessors evaluating fishery observer and EM programmes, in the context of the ERF
- Real-world examples of how bias may arise in fishery information, and possible solutions to address that; and,
- Case studies demonstrating the application of the ERF, changes to information systems that are needed to meet its requirements, and focusing on independent observation.

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[a] To be interpreted as "verification of the trueness of catch data on an ongoing basis by a competent third party using an appropriate methodology" (GB1.3.2 (Tool B in MSC 2022))

[b] To be interpreted as "an objective method of observing catches and other direct effects, on an ongoing basis, that is expected to produce information with a high degree of trueness" (GB1.2.3 (Tool B in MSC 2022))

The report is accompanied by checklists capturing key points on the use of fishery observer and EM to meet the ERF's requirements for independent observation. Checklists provide quick reference guides for:

- assessors implementing the ERF
- fishery clients, seeking to understand what information they need to support an assessment and how this could be effectively acquired
- non-client stakeholders who may wish to contribute information to an assessment process, to understand how that will be considered in the context of the ERF, and,
- Fishery Improvement Project practitioners preparing fishery clients for MSC assessments.

2. Independent verification methods

The scope of the ERF encompasses information supporting catch estimation (including all direct fishery impacts on ETP[c]), implementation of a fins naturally attached (FNA) or non-retention policy, evaluation of habitat impacts (including compliance with management measures for more sensitive habitats), and a broader assessment of compliance[73]. All information sources may be affected by systematic and random error. Table B1 in the ERF sets out the PIs for which assessors must explicitly consider these through evaluating trueness (TG guideposts) and precision (PG guideposts). For PIs requiring the evaluation of precision, independent verification of catches (ERF B1.3.2[73]) and/or independent observation of catches (ERF B1.3.3[73]) are necessary.

An overview of monitoring methods that can enable independent verification is presented below, followed by a more detailed examination of human observers and electronic monitoring, as monitoring methods comprising independent observation. Capabilities, advantages and disadvantages are considered for all methods.

2.1 Vessel position monitoring

Vessel Monitoring Systems (VMS) and Automatic Identification Systems (AIS) are the predominant methods in current large-scale use for vessel position monitoring. In addition, other GPS-based methods are in use among smaller-scale fisheries.

2.1.1 Vessel Monitoring Systems

2.1.1.1 The method

Since the 1990s, VMS has been fundamental for monitoring fishing vessel locations in near real time, using an onboard Automatic Location Communicator (ALC) and GPS[34]. The VMS unit is located onboard the vessel and via satellite, transmits point-in-time information to one or more designated receivers at regular pre-set intervals (e.g. a government fisheries monitoring agency, or a nominated third party). The receiver(s) will typically also be able to obtain position information from the unit on demand, known as polling[19]. VMS is generally focused on the transmission of vessel identity, position, date/time, speed and heading information, but as a system of communication, can also be used to transmit other information[57].

2.1.1.2 Performance standards

Minimum performance standards for VMS usually cover position accuracy, velocity, operational reliability, incorruptibility, capability to transmit adequate information, frequency of position reporting, polling and format requirements[19]. VMS use is often supported by mandatory approval processes (e.g. as conducted by the Forum Fisheries Agency (FFA)[52], the VMS service

[c] ERF GB 1.2.2, Guidance to Table B3

provider to the Western and Central Pacific Fisheries Commission (WCPFC)). Units can be switched off onboard and this situation is routinely addressed in regulatory requirements (e.g. notification of the management agency, manual recording and call-in of vessel position at specific intervals[19,111]). VMS is not tamperproof, though tampering is not straightforward[58]. Error in VMS information could result from VMS equipment failures (e.g. in extreme weather) or operators powering down the system when fishing in prohibited areas. Evaluating systems in place to address outages of VMS would therefore be relevant to the ERF.

2.1.1.3 Usage

Appropriateness for different use cases varies with the frequency of VMS transmissions, and alternative arrangements in place for when systems are not functioning as required. For example, if the average duration of a trawl is 6 hours, and the VMS unit transmits a location every 7 hours, entire trawl events will occur without a fishing location being transmitted. In this case, VMS would not be effective for monitoring fishing locations and detecting fishing in closed areas.

When VMS is used consistently through fishing trips at a transmission frequency that is appropriate to the fishing method and monitoring objective (e.g. habitat impacts, incursion into closed areas), and with effective review procedures in place, it is a robust monitoring and verification method.

Key considerations for assessors: Vessel Monitoring Systems

- How does the frequency of location transmission align with the fishing method (e.g. the duration of a fishing event)?
  - What are the consequences of transmission interval for verifying fishing effort, occurrence of fishing activities in closed areas, habitat impacts of fishing gear, etc.? For example, are there multiple locations transmitted within each set?
- What systems and requirements are in place for when VMS units cease functioning (e.g. manual reporting)?
- Is VMS transmission is sustained throughout fishing trips?
- If there are transmissions missing during fishing trips:
  - What is the duration of any such dark periods?
  - Are there opportunities for fishing activities during those periods (e.g. entering, fishing, and exiting closed areas)?
  - Were required actions implemented to address signal failure?
- How do management agencies and other recipients review and use VMS information?
  - Is a sample of locations reviewed or are all locations reviewed?
  - Is geofencing is in place?
  - Do (and how do) analysts interpolate any missing locations?

2.1.3 Automatic Identification Systems

2.1.3.1 The method

Vessel position monitoring can also be undertaken using AIS. AIS was initially developed in the 1990s as an anti-collision system[61] and its use for monitoring fishing vessel locations and movements emerged more recently[77]. AIS is based on the autonomous transmission of radio signals from vessels, which are picked up by ground-based stations (T-AIS) or satellites (S-AIS). AIS broadcasts vessel identity, location, course and speed information. Transmission frequencies are variable, e.g. from seconds to minutes apart. AIS signals are public, unlike VMS which is a closed system transmitting to designated receivers only[82].

2.1.3.2 Performance standards

Because AIS was not designed to monitor fishing vessel movements, performance standards for that specific purpose have not been defined. The International Maritime Organisation sets requirements for AIS carriage and use[54]. Some national fisheries management agencies also set out geospatial position reporting requirements for fishing vessels, using outcome standards that can be met by AIS (e.g. in New Zealand[33]).

AIS signals may be interrupted due to extreme weather or poor satellite coverage, and transponders can be switched off. Vessels going dark by switching off AIS may be using this to mask illegal activity[65]. However, vessel captains may also legitimately decide to go dark for safety reasons, e.g., where piracy occurs[113]. However they occur, data gaps introduce bias and error into datasets[94].

2.1.3.3 Usage

The value of AIS compared to VMS for vessel monitoring is increased by the more frequent transmission of vessel locations by AIS than is generally the case for VMS (i.e. more data points are available, enabling finer scale analysis of vessel locations and activities). Overall, AIS is less robust than VMS as a definitive source of location information. When used together however, VMS and finer-scale AIS data provide accurate and comprehensive information on fishing vessel locations and enable strong inferences on vessel activities to be made[65].

As a globally significant user of AIS information, Global Fishing Watch provides a summary of some of the data processing and interpretation issues encountered using AIS datasets[49].

Key considerations for assessors: Automated Identification Systems

- How does the frequency of location transmission align with the fishing method (e.g. the duration of a fishing event)?
- Is AIS specifically intended to collect information to monitor fishing operations, or is use for that purpose is opportunistic? Are there minimum standards in place for either usage?
- Are there requirements in place for continuous transmission, or are vessels permitted to 'go dark' ceasing transmitting for periods?
- Are there standards, systems and processes in place to address cessation of AIS operation (e.g. due to equipment malfunction)?
- How is AIS information used by management agencies (if part of the management framework) or other users?

2.1.3 Other GPS-based location monitoring systems

VMS and AIS were designed for use by industrial scale vessels, and location monitoring in small-scale fisheries can involve a range of other GPS-based tools. To date, these have included handheld GPS devices, smartphone apps and hand-held tablets, with different software often developed for use in a specific fishery. The information provided by such systems varies, while the same information accuracy considerations apply as for the more established monitoring methods, such as reliability, tamper resistance, security, level of automation, potential for bias resulting from error in data outputs (e.g. due to incomplete recording), etc.[35,82]

2.2 Dockside monitoring (including landing accounting and port sampling)

2.2.1 Monitoring retained catch

Dockside monitoring can be an effective method for monitoring retained catch. Dockside monitors undertake a range of monitoring functions in fisheries around the world, including:[10,115]

- documenting species composition of landed catch
- verifying landed catch against logbook records (also known as catch reconciliation, or catch or landing accounting)
- measuring/verifying lengths and/or weight of catch items
- collecting biological samples, e.g. tissue samples, otoliths.

Dockside monitoring can be undertaken on a census (100% of landings monitored) or sample (less than 100% monitored) basis[10]. For census approaches, a key consideration is the feasibility of landing catch such that it isn't subject to monitoring, e.g. in another port, when monitors are not working, or by not completing a 'hail in' whereby the intent to return to port carrying catch subject to monitoring is used to coordinate monitors to attend landings. For sample-based approaches to dockside monitoring, the representativeness of sampling and opportunities for bias to be introduced must be considered (e.g. are catches from more distant fishing grounds landed at night or in certain ports, are weighed/measured fish selected randomly from the catch, are there seasonal differences in ports used)[10,115]. For both census and sampling approaches, assessors need to consider whether the required coverage is being achieved effectively in practice (both the amount of coverage, and distribution of it in space, time and among the fleet).

2.2.2 Monitoring shark non-retention or fins naturally attached policies

If dockside monitoring is used to monitor shark FNA or non-retention policies or finning prohibitions[46], it must be complemented by other monitoring methods such as vessel inspections in port, to ensure shark fins have not been retained onboard vessels for separate unloading (e.g. at an unmonitored port or after the dockside monitor departs).

Dockside monitoring will clearly not be effective in monitoring discards or ETP captures[106], unless it is mandatory to return these catch components to port and this requirement is monitored on vessels and enforced. In such cases, the marginal benefit of dockside monitoring may be low in any case and focused on limited monitoring objectives (e.g. met using tissue sampling or measuring length of catch).

Key considerations for assessors: Dockside monitoring

- What are the objectives of dockside monitoring?
- Can the programme design effectively support the monitoring objectives?
- How is the comprehensiveness (if a census approach) or the representativeness (if a sampling approach) of monitoring delivered by the programme design?
- What are the opportunities for the evasion of monitoring?
- Are any compliance monitoring activities in place to detect evasion?
- Who are the monitors? Are they independent from the UoA, and if not, what mitigation measures are in place to ensure data integrity?

2.3 At-sea/on-water inspections

At-sea (or on-water, for freshwater fisheries) inspections are generally limited in coverage and the information collected provides a snapshot of a subset of fishing activities. Nonetheless, boardings from patrol vessels are a long-standing component of MCS systems[34] and can provide another source of evidence for assessors to consider when applying the ERF.

Noting the above constraints, boardings comprise an opportunity to verify catch reports and the presence of required ETP bycatch reduction equipment onboard vessels[91]. Shark finning may also be detected by at-sea inspections[81].

Key considerations for assessors: At-sea inspections

- What is the nature and extent of at-sea inspections (how many, when, where, by whom, for what purpose)?
- What information collection systems are used during inspections (e.g. vessel inspection protocols, systematised recording of information, method(s) for capturing/recording opportunistic observations)?
- Are there any limitations or constraints in place that may introduce bias (e.g. health and safety requirements that prevent inspectors accessing certain areas on a vessel)?

2.4 Reference fleets

Directed fishing operations that mimic commercial fishing can produce information contributing to independent verification (noting the independence of the reference vessel operations must be considered carefully). The intent is that the reference fleet is representative of commercial fishing activities, and therefore the fishing fleet overall[66,85]. For example, if reference fleet activities are representative, significant deviations between the reference fleets' catch composition and that of other vessels may indicate inaccurate reporting or non-compliance, e.g. with discarding regulations[25].

The Norwegian Reference Fleets provide one example, comprising two groups of fishing vessels, one operating in the high seas and one in coastal fisheries. These vessels conduct routine fishing operations that produce data on fishing effort, catch composition, catch species lengths, otolith and scale samples for aging, discarding, and ETP interactions. Every four years, a public tender opens for new vessels to join the fleet[51].

When reference fleet participation is voluntary, bias may be introduced as willingness to volunteer is likely to be linked to the conduct of compliant fishing practices and attitudes towards fishery management measures in place.

Key considerations for assessors: Reference fleets

- How are reference fleet participants selected?
  - Is there potential for bias to result from the selection method?
- How representative is the reference fleet of the UoA (e.g. similar vessels, processing practices, fishing effort, fishing season and location)?
- Is the reference fleet independent from the UoA?
  - If not, how is this lack of independence managed?

2.5 Fishery observers and electronic monitoring

Fishery observers and EM are effective methods of both independent verification, and independent observation. Regardless of which the programme is intended to provide, programme design considerations and requirements will be similar. These are considered in detail in section 4.

Considering EM as a verification tool, data collected from reviewing a sample of EM imagery are compared to logbook reports allowing the deviations between the two datasets to be identified[26,59]. If fisher-reported data meet pre-defined accuracy thresholds in this audit process[103], logbook data are accepted as the source of fishery data at the fleet scale, and additional verification is not required. EM data are not scaled up, and logbook reporting becomes the fleet-level record[26].

Ideally, samples used for audit are selected using a random or stratified random approach. Where differences between EM and logbook datasets are significant at audit, further investigation is required. This could involve additional EM review and evaluation of logbook data to identify issues for improvement. Verification is required on an ongoing basis to ensure the quality of logbook data is understood over time, and to enable issues affecting data quality to be addressed promptly[26]. Where logbook data are of low quality across a fleet, the audit approach will not work well[18] and low conformity with acceptance thresholds are expected.

2.5.1 The observer effect

Where an audit model is in place, potential for the observer effect requires careful consideration. 'Observer effects' occur when fishers change their behaviour because an observer is present, to create a falsely positive impression of their fishing operation and/or fishery. For example, gear configuration, target species, fishing area or location, trip duration, catch handling practices, compliance and reporting may all be changed. Observer effects result in monitoring data that is biased and unlikely to be representative of the vessel or fleet[72].

When data reported by fishery observers is used for audit, depending on the relationship between observers and those they observe (usually vessel captains and crew), the respective catch reports may not be independent. Further, the presence of monitoring onboard vessels, and therefore the potential for detection of non-compliant reporting, can spur improvements in the accuracy of logbook reports[32,59,108].

Key considerations for assessors: Verification by fishery observers and electronic monitoring

- Is documentation in place for observer and EM information collection (covered in detail in section 4)?
- Are audit systems and processes documented in defined protocols?
- How is the audited sample selected?
- Is the audited sample representative of the UoA?
- What are the scope and process of the audit?
- What acceptance thresholds are in place and how they were chosen?
- What are the next steps when acceptance thresholds are not met?
- What is the potential for observer effects in the information available for audit?
- Is the audit provider independent from the UoA?
    - If not, are measures in place to manage and mitigate a lack of independence?

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3. Independent observation by at-sea human observers and electronic monitoring

3.1 Fishery observers and electronic monitoring

Human observers have been a mainstay of fisheries monitoring since the 1970s[51], recording their observations of fishing operations to support the activities of management agencies onshore[34,63]. Fishery observers are able to collect data across all aspects of fishery operations, including characterising landed and discarded catch, gear deployed, ETP interactions, biological sampling, compliance and conformance with mandatory and voluntary management measures, and broader interactions between fishing operations and the environment such as gear loss and pollution events[10,63,88,96].

EM using on-vessel cameras has been in development since the 1990s. EM systems include cameras that record imagery of fishing operations, GPS positioning, a control unit that monitors the operation of the system and records data, and satellite reporting of system status. EM systems often also incorporate gear sensors. These are triggered by gear movement, indicating the start and duration of fishing activity. Trials of EM have been conducted in more than 100 fisheries to date, and the monitoring method has been operationalised in some[26,87,109]. The monitoring capabilities of EM are broad, and EM can meet many of the same fishery monitoring objectives as human observers (Table 1)[31,39,75,112].

3.1.1 Independent observation and the ERF

Human fishery observers and electronic monitoring are considered methods of independent observation for the purposes of the ERF. In this section, we consider whether these monitoring methods can provide the data required by the ERF, and key considerations for assessors in the evaluation and use of this information.

Note: The terms "electronic monitoring" and "remote electronic monitoring" have been variously applied to electronic fisheries monitoring methods. For the ERF and in this report, EM is monitoring conducted using imagery and associated information that is collected by cameras and other electronic devices installed on fishing vessels. The imagery recorded is central to EM.

3.2 Data recorded

3.2.1 Fishing location

Fishing locations are generally recorded by observers at the start of a set. The definition of start location varies with fishing method, but very broadly, it can be described as when the first unit of fishing effort or gear is deployed (e.g. release of the skiff in a purse seine operation, when the first longline buoy is thrown into the water). Location at the end of the set is also commonly recorded, defined for fishery observers as when the last piece of gear (which may be specifically identified for a fishing method, or generic) enters the water[44,110].

EM systems record location continuously at pre-set intervals (e.g. one minute). Position coordinates are displayed on-screen with imagery as well as recorded in a file. Fishing location information, such as set and haul positions, are readily available from imagery and associated information (e.g. sensor data). Furthermore, for methods covering horizontal ground, detailed location information is recorded on gear path, e.g. trawl tow path. Analogous to VMS, position information can be transmitted as required.

Sensors enable determination of a precise start time and location for fishing activity (e.g. when the longline drum turns to start releasing the line at setting), noting that this would be different from common definitions used by observers. Therefore, the requirement for comparability would need to be considered in the EM programme design and data definition stages. Start and end times and locations as defined as for fishery observers could be obtained at review.

3.2.2 Fishing effort

Effort metrics are critical for catch monitoring, enabling catch rates to be determined and catch estimates to be calculated. Observers record a range of effort metrics as appropriate to gear type, e.g., hooks (per set), tows, dive duration, net metres, etc. The efficacy of EM for monitoring fishing effort has been demonstrated for longline, purse seine, trawl, gillnet and pot/trap methods[26,87,109]. For purse seine fishing, effort characteristics include searching and setting time and whether sets are made on fish schools associated with floating objects, or unassociated schools. Both fishery observers and EM can provide such information[76,98].

3.2.3 Gear characteristics

Gear characteristics that are particularly relevant to catch composition and estimation vary by fishing method. Both fishery observers and EM have broad capabilities for recording a range of gear specifications, though some fine-scale gear characteristics may be difficult to record using EM. For example, both fishery observers and EM are capable of recording the numbers of longline hooks and floats. However, hook type and size are readily discernible by observers but not considered feasible on a per-set basis for EM currently[31,112].

Gear components normally considered in association with bycatch reduction are also relevant to catch composition, such as the likelihood of unobserved mortalities of ETP, and compliance with management requirements (e.g. use of tori lines[26]). Bycatch mitigation devices are readily detectable by both fishery observers and EM, e.g. branchline weights and tori lines for reducing seabird catch, pingers deployed on gillnets to reduce cetacean impacts, and exclusion devices in nets for turtles and marine mammals[3,32,86]. Operational practices to reduce ETP bycatch can also be visible with EM and recorded by fishery observers, such as backdowns to release cetaceans from purse seine sets[95]. Length or distance specifications such as tori line length are not currently feasible to measure from EM imagery, without a secondary reference point in place[36]. Fishery observers present on vessels would be able to measure these if required.

3.2.4 Catch composition

Human observers and EM can both be used to quantify catch, when supported by appropriate data collection systems and processes[87,97,98, 109]. Fishery observers and EM must be able to view all catch, or a representative sample of the catch, to collect accurate information on catch composition. The approach required to effectively document catch will vary among gear types and between vessels with different configurations. Capturing catch information is straightforward for both fishery observers and EM when catch items come aboard serially (e.g. piece by piece on a longline) or in small clusters (e.g. in a gillnet). By contrast, accurate determination of catch composition is more difficult when catch is landed on deck or into storage holds in bulk (e.g. purse seine and trawl methods).

There are numerous studies that compare catch composition quantified by observers and EM, inferring 'accuracy' of either or both methods. Generally the results of such studies are comparable, and differences can be attributed to individuals, camera views, or other factors which can be addressed to improve data quality[15,42]. This highlights that fishery observers and EM provide a different version of the truth, neither of which may be accurate.

3.2.4.1 Observing landed and discarded catch

Observers have the ability to choose a catch sampling station best suited to each vessel they are deployed on, in accordance with their sampling tasks and approach (e.g. sample- or census-based catch quantification). For EM, any necessary catch management processes to support sampling must be identified and implemented in advance. In fisheries using all gear types, catch handling protocols can facilitate EM-based catch enumeration and identification, and assessments of size and life status. For bulk fishing gears, catch handling protocols are essential to support quantitative EM-based data capture from larger catches[64].

Discarded catch items may be landed on deck or released into the water without being brought aboard. For catch brought onboard, identification and enumeration are readily possible using both fishery observers and EM. When catch items are removed from gear, released in the water or drop from gear before being brought aboard, EM-supported enumeration is achievable with appropriate camera placement. Similarly, fishery observers would need to be in position at the right time to observe and document these events. For both observers and EM, identification may not be possible to the same level of granularity as when catch items are brought aboard in such cases. Identification to family or genus level, rather than species, may be required. Assessing life status and size is also less achievable using EM when catch items are not brought aboard vessels[39], and the same constraints apply to fishery observers.

While accurate information on catch composition is important, survival prognoses for some taxa may be improved by releasing animals from gear while in the water[56]. Therefore, in-water release is preferable to increasing fishery impacts by landing such species on deck (e.g. ETP sharks, rays[47,54,56]). Alternative methods may then be required to understand fishery impacts and likely catch composition[37].

3.2.4.2 Observing ETP 'catch'

Noting that the ERF interprets 'catch' of ETP as encompassing all direct effects of the UoA, interactions that happen outside the typical monitoring phases of gear setting, hauling, and processing also require consideration. The ERF provides the example of seabird mortalities resulting from collisions with fishing vessels (GB1.2.2). Detection of these events by fishery observers has been largely opportunistic to date, and vessel collisions (also known as deck strikes) are considered to be under-reported[24,45]. EM has not yet been trialled for monitoring collisions with vessels. By contrast, both fishery observers and EM have been used to characterize seabird strikes on trawl warp cables[1,86]. With current approaches, EM is not considered effective for monitoring warp interactions[86], though recent developments in machine learning may improve this (A. Angel, pers. comm.).

3.2.4.3 Unobserved mortality

Unobserved mortality is difficult to quantify using both fishery observers and EM. Predictors of unobserved mortality provide one approach, e.g. survivorship probabilities based on condition at release. However, there is significant uncertainty inherent in these predictions[56]. Using precautionary data definitions for interactions that may result in mortality provides another approach. (Also see section 4.8 on estimating cryptic mortality).

3.2.5 Catch handling

Catch handling practices can be monitored by both fishery observers and EM. EM provides the potential for more comprehensive monitoring (e.g. monitoring entire hauls, cameras in multiple locations onboard vessels recording simultaneously). Feedback from fishery observers and information collected at EM review can be used to improve handling practices for catch released alive, e.g. through training and developing guidance materials[26].

Observers and EM may detect shark finning, depending on when and where on the vessel it occurs. To evaluate the trueness of observer observations that shark finning is not occurring onboard a vessel, assessors must understand observer monitoring of places and times that finning may occur, and the likelihood of detection by observers and/or cameras at such times, e.g., to establish whether finning may occur when fishery observers are working elsewhere on the vessel or off duty. Unlike observers, EM can provide uninterrupted monitoring of multiple locations when and where finning may occur, e.g., through entire longline hauls[37].

Table 1. Overview of the feasibility of collecting fishery information using human fishery observers (FO) and electronic monitoring (EM), when appropriate data collection protocols are in place. Monitoring capability is indicated by (✓), with (*) shown for limited or opportunistic capability. $^{+}$Discarded catch characteristics are more difficult to assess in the water compared to on the vessel, for both FO and EM. FAD=Fish Aggregating Devices, used in purse seine fisheries.

	Catch and discard information						**Gear and operational information**				
Method	**Catch species / stock**	**Landed catch size**	**Discarded catch species / stock^{+}**	**Discarded catch size^{+}**	**Discarded catch life status^{+}**	**Shark finning**	**Hooks set, hauled**	**Floats**	**Set / haul time / location**	**FAD use, type**	**Gear abandoned / discarded**
FO	✓	✓	*	*	*	✓	✓	✓	✓	✓	*
EM	✓	✓	*	*	*	✓	✓	✓	✓	✓	*
	Bycatch mitigation usage information										**General**
Method	**Tori lines**	**Line weights**	**Hook-shielding devices**	**Dyed bait**	**Bird curtain**		**Fish waste discharge**	**Wire traces**	**Dehooker / linecutter use**	**Bycatch / unwanted catch handling**	**Marine pollution**
FO	✓	✓	✓	✓	✓		✓	✓	✓	✓	*
EM	✓	✓	✓	✓	✓		✓	✓	✓	✓	*

3.3 Adoption of management regulations

The objectives for observer monitoring and EM often include collecting information that allows detection of non-compliance and non-conformance with mandatory and voluntary management measures (noting that enforcement is typically not an observer role) [34,87]. The efficacy of each monitoring method will vary with the specifics of management regulations, and the extent to which monitoring protocols are designed or able to collect relevant data. For fishery observers and EM analysts, training in relation to management requirements will improve their ability to appropriately identify and describe non-compliance.

A significant advantage of EM in the detection of non-compliance and non-conformance is that incidents can be viewed multiple times by approved parties. By contrast, observer accounts can be contested and difficult to verify. Furthermore, EM is not subject to the occupational health and safety issues associated with observing and reporting non-compliance on some vessels[37].

4. Monitoring programmes that deliver independent observation

The ERF requires assessors to take a systematic view of fisheries information. In this section, we consider the different components of monitoring programmes that deliver independent observation, and the systems underpinning those programmes. We cover:

- Design of programmes for independent observation
- Independence and conflicts of interest
- Monitoring objectives
- Coverage requirements
- Programme documentation
- Information collection systems and processes
- Information management; and,
- Catch estimation methods.

For each topic above, we include key considerations for assessors evaluating programmes for independent observation.

4.1 Programme design

4.1.1 Programme structure

Fishery monitoring programmes must be run by someone. Programme governance creates the framework to support a successful programme. For example, the governance structure identifies who is accountable and responsible for decision-making, where responsibility for different parts of the programme lies, the feedback loops in place between different points of responsibility, and an escalation pathway for when issues arise. In any programme, it is essential that programme participants understand their roles so they can perform them well.

There are many different ways to structure programmes for independent observation. Very generally, a monitoring programme will have the components shown in Figure 1. These components need not all be separate, though roles and responsibilities within the programme must be clear and understood by affected parties. Programme review provides a defined opportunity to ensure objectives are still being met, and to consider whether any changes would be beneficial in improving the programme. Any and all components may be subject to review, and formal and/or informal reviews may be effective. Documentation from reviews, e.g. covering process, findings and consequent recommendations and/or actions, provides assessors with evidence that review has occurred.

4.1.2 Programme participants

In addition to the fishery client, stakeholders in monitoring programmes may include fishery and wildlife managers, fishery and conservation scientists, compliance and enforcement personnel, monitoring service providers, data managers, non-governmental organisations representing industry and environmental interests, and supply chain participants such as seafood buyers. In addition, vessel owners, operators, captains and crew are critical participants and stakeholders in any monitoring programme. Lack of buy-in from these industry participants can have significant implications for data quality. The reason for any lack of buy-in may also have relevance to data accuracy considerations (e.g. completeness, if fishers intervene in data collection to reduce the detection of some catch events[90]).

Key considerations for assessors: Programme design

- Is there an organigram available that sets out the structure of the programme?
- Are the roles of those involved in the monitoring programme well defined and clearly documented?
- Is the governance structure defined and documented, including decision-making and feedback loops?
- Is there acceptance among stakeholders that roles are appropriate for the programme, and being performed well?
- Do stakeholders consider that the governance and management of the programme are effective?
- Can stakeholders have the level of interaction with the programme that they desire (e.g. contributing to setting objectives, receiving reports of outputs)?
- Do stakeholders consider that the level of programme transparency is appropriate?
- Is a legal framework in place for the programme? What does this cover?
- If a legal framework is not in place, are there any consequential programme issues (e.g. with vessel participation)?
- If there is no legal framework supporting the programme, what is in place to ensure voluntary conformance with monitoring requirements?
- Do stakeholders in the programme consider that the regulated or voluntary implementation framework is effective?
- Is there industry buy-in? If not, what problems could that cause with respect to information accuracy?
- Is there evidence of programme review? Have the findings been actioned?

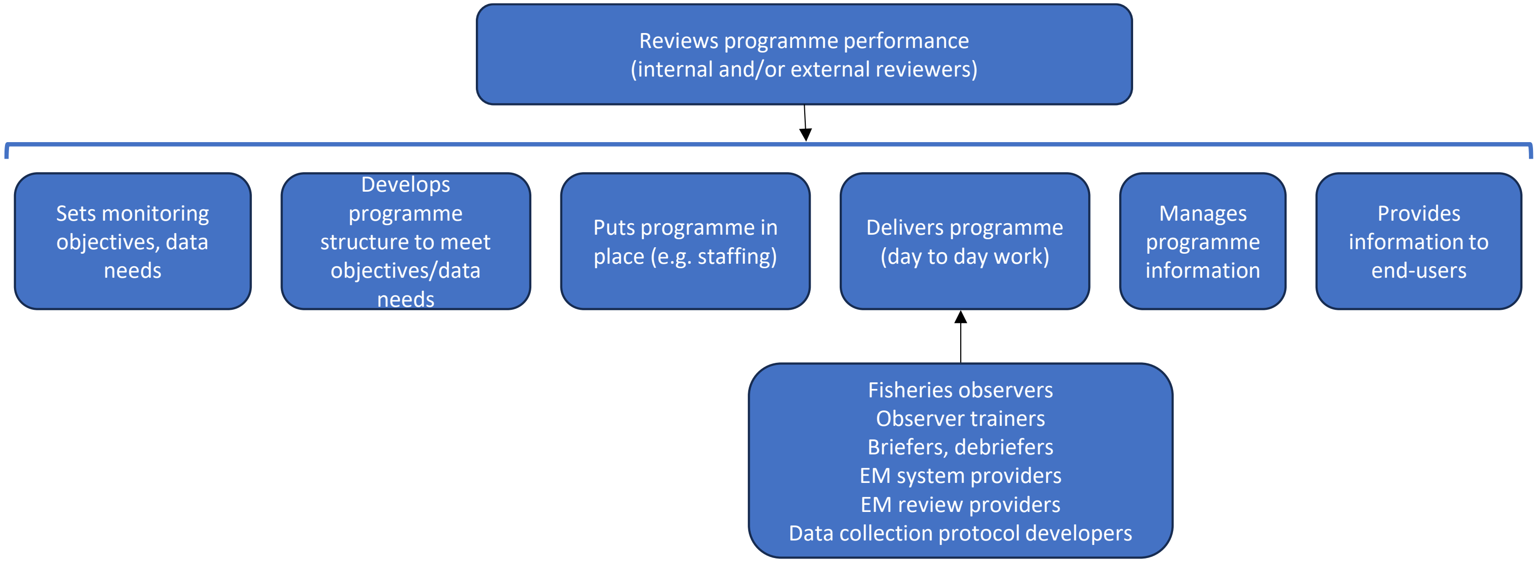

Figure 1. Generalised key roles in a monitoring programme providing independent observation.

4.2 Independence and conflict of interest

The ERF requires assessors to consider objectivity as part of evaluating the trueness of information. This involves consideration of the independence of information from the assessed fishery, and the likelihood that conflicts of interest (COI) could affect information. There is potential for COIs to manifest in any component of a monitoring programme providing independent observation. However, the most direct effects of COI would be at the data collection phase. Social and economic incentives could create COIs, such as personal and/or business relationships between those conducting independent observation, and the UoA.

4.2.1 Mitigating conflicts of interest

COIs can be mitigated and managed in many ways. The need for mitigation and most appropriate methods will vary between fisheries. Mitigation methods such as the following are all readily verifiable by assessors:

- Deploying fishery observers of a different nationality to the vessel flag state (e.g. in tuna fisheries operating in the Western and Central Pacific Ocean high seas[46]).

- For EM programmes, providers documentation of EM analyst (and other staff's) potential COIs. Further, data itself could be audited through a second review of EM information conducted by another analyst, or an independent external party.

- The COI introduced when a UoA directly funds a monitoring service provider could be mitigated in part by payment taking place prior to data provision. Providers could also choose to undergo external audit of systems in place to manage COIs.

For small-scale fisheries based out of tight-knit local communities, a suite of COI management measures addressing social and economic COIs could be appropriate. For example, COI management measures could include that:

- families of active fishers cannot be observers
- observers cannot monitor their immediate family's fishing activity
- observers are rotated among captains and vessels (i.e. an individual fisher or vessel is not monitored by the same observer over time); and,
- external observers conduct a certain proportion of observed trips in an audit role with observers present or in a data collection role without observers present (with data compared to observer records from similar trips/vessels).

4.2.2 Verifying mitigation approaches for conflicts of interest

Assessors can seek to verify that measures mitigating conflicts of interest are in place and adhered to by reviewing available documentation, and interviewing fishery participants, monitoring service providers (including managers, observers and EM analysts, and those assigning observers/EM analysts to vessels/imagery analysis tasks), and other stakeholders.

Key considerations for assessors: Independence and conflicts of interest

- What is the relationship between those performing each programme function and the assessed fishery?
- Where could potential COI occur among those with roles in the programme (e.g. due to social connections or financial incentives)?
- How are potential COI identified or recognised, and managed?
- What provides evidence that COI management is taking place, and is effective?
- Are COI management measures documented and formalised, or less formal?
- What makes COI management measures likely to be effective, or do they require improvement?
- Are COI management measures perceived to be effective by stakeholders?
- Do stakeholders consider the information emerging from the monitoring programme to be robust to any perceived potential or actual COI?

4.3 Monitoring objectives

Fishery management goals define monitoring objectives. In turn, monitoring objectives define monitoring programmes. Clear monitoring objectives are critical for programme efficacy as these underpin virtually all programme decision-making and have a fundamental influence on the quality of the information collected. For example, monitoring objectives for programmes of independent observation determine appropriate coverage and review rates, hardware, data collection protocols, fishery catch handling protocols, training requirements for fishery observers and EM analysts, quality assurance needs, data analysis methods, staffing, stakeholder identification, etc. Typically, programmes will have more than one objective and there may be many. When multiple objectives exist, prioritisation is necessary to support robust programme design and implementation decisions, and to ensure that fishery observer workload is feasible.

Examples of monitoring objectives that fishery observer and EM programmes can support include to:

- estimate catch composition, by species, to specified levels of precision
- determine whether sustainable catch limits for one or more ETP species are being exceeded
- verify that shark finning is not occurring
- verify implementation of ETP handling and release methods to promote post-release survival
- verify that mandatory seabird bycatch reduction measures are in place
- verify that fishing effort limits are not being exceeded.

Key considerations for assessors: Monitoring objectives

- What are the monitoring objectives set for the programme?
- Is the prioritisation of monitoring objectives clear?
    - How would a lower priority level affect the accuracy of information emerging (e.g. is there less information, is it more likely to be biased, is it less representative)?
- Are monitoring objectives reviewed?
    - What is the process for this?
    - What are the inputs to the review process?
    - What happens when monitoring objectives change (e.g. updating other elements of the programme in response)?
- How do the monitoring objectives of the fishery-specific programme for independent observation align with the information needs of the ERF?

4.4 Coverage of fishing operations

The appropriate amount and allocation of coverage by independent observation will depend entirely on the monitoring objectives set. Monitoring coverage considerations can then be considered by asking three questions: where, when and how much?

4.4.1 Representativeness

The ERF identifies a requirement at PG2 for 'independent observation of catches with coverage that is representative of the UoA's fishing operations' (ERF B1.3.3[73,d]). There are many dimensions to "representative" monitoring coverage, including spatial and temporal characteristics of fisheries, and operational factors (e.g. vessel type, gear type, gear use, fishing depth, etc.). It is not practical for assessors to consider these factors individually at an analytical level for an assessment. However, at the systems level, approaches to allocating monitoring effort can readily be evaluated.

4.4.1.2 Achieving representative coverage

Some coverage of more vessels/operations will be more representative than more coverage of fewer vessels/operations. Practical considerations in achieving this include the following:

- Coverage is more likely to be representative with independent observation of an individual vessel conducted at different times of year including if it is covered in successive years. Conversely, monitoring the same vessel every year at the same time of year, and at the cost of not monitoring other vessels, reduces representativeness.

- When fishing activities occur 24 h/day, independent observation would be required during night and daytime sets. If, for example, observers do not work at night, data returned from the fishery would not be representative of its activities. If only larger vessels in a fleet have bunks for fishery observers, activities of smaller vessels must be monitored using another method, to provide a representative dataset.

- Where census approaches are not possible, monitoring some number of sets across the largest possible number of trips demonstrably increases precision of catch estimates[84]. For example, if there is monitoring capacity to cover 100 sets, recording catch data from

[d] The representativeness requirement also applies to independent verification, at PG1 (B1.3.2).

five sets conducted on each of 20 trips would be expected to produce catch estimates with better representativeness and precision than for 20 sets sampled from each of five trips. The former approach is readily possible for EM, while the logistics of fishery observer deployments are more complicated.

- Stratifying a fleet can facilitate the implementation of representative monitoring. For example, vessels that are landing catch fresh are likely to operate differently than those with freezers onboard, and vessels of a particular flag state may operate differently from vessels from another flag state even if both use the same gear type. In such cases, ensuring independent observation of catches is in place among all subgroups of vessels (the 'strata') will be facilitate achieving representative coverage.

4.4.1.3 Retrospective EM review to provide representative coverage

When fishery observers are chosen to provide independent observation, it is obvious that they cannot collect monitoring information when absent. The same applies for EM when not all vessels carry an EM system. Best practice for EM (which also minimises the observer effect) is to install and operate EM systems on all vessels, recording all fishing activity[26]. Then, the allocation of 'independent observation' which is provided by EM review is completed at review. This approach ensures that at the data capture stage, monitoring is representative of the fleet. Opportunities for representativeness are not lost if, for example, vessels deviate from anticipated fishing patterns by travelling to different fishing grounds, changing gear configuration, or other unexpected behaviours.

4.4.1.4 Using fishery data to demonstrate representativeness

Fishery clients may choose to provide empirically-based examples to inform an assessment team's consideration of representativeness (e.g. monthly fishing locations, catch composition and amount and trip duration, for observed and unobserved vessels by vessel type[93]). Alongside the system-level evaluation that assessors must undertake, such examples can provide useful indicative information on the adequacy of independent observation. However, the provision of such examples is not a required part of the assessment process.

4.4.2 Amount of independent observation

4.4.2.1 How much independent observation is needed?

The amount of independent observation required to meet fishery monitoring objectives has been investigated by practitioners using numerous methods. Over time, despite the diverse methods used to explore the question of how much is enough, estimates of required levels of independent observation are broadly convergent among published sources. These estimates therefore provide indicative levels of independent observation that can inform the design and evaluation of monitoring programmes. For example, to estimate catch of a target species caught in most sets, independent observation covering 5 – 10% of fishing effort is likely to be sufficient to provide catch estimates with moderate CVs. By contrast, independent observation of 10% of fishing effort cannot be expected to support robust catch estimates for a rarely caught species, such as a seabird or turtle (Table 2).

Estimates of the required amount of independent observation can be refined using stratification[60,87,99]. For commonly caught species, stratification enables lower levels of independent observation to be effective for meeting monitoring objectives (e.g. a species-specific catch estimate with a defined level of precision). For rarely caught species, stratification is less effective at reducing the level of independent observation required. Higher levels of independent observation are also required to estimate (with comparable levels of precision) catch of a species caught in multiples very rarely, compared to a species caught in ones or twos more often[8,30].

4.4.2.3 Understanding the actual level of independent observation in place

To understand how much fishing effort is actually monitored by independent observation, fishery assessors must consider the details of fishery observer tasking and EM review. For example, an fishery observer deployment scenario that appears to provide 20% monitoring coverage may in reality cover significantly less fishing effort (Table 3). Scaling up catch to fleet level is a common practice when independent observation covers a sample of fishing effort. Considering the actual level of coverage in place is vital for this, with scaling amplifying the effects of any systematic or random error associated with lower levels of observation achieved.

Once fishery observers disembark vessels, data collection is completed and cannot be revisited. However, review opportunities are more flexible for EM. EM imagery and associated information can be sampled and resampled after it is collected. Provided EM captures all fishing activity, the review rate and sample selection process can both be set in advance and adjusted retrospectively, in accordance with unexpected changes in fishing operations, compliance risk, resourcing, and any other relevant factors. This supports an agile and adaptive approach to adjusting the level of independent observation.

4.4.2.4 Tools for estimating coverage requirements

Two publicly available modelling tools that use fishery-specific information to investigate the level of independent observation needed to estimate fishery catches are *ObsCovgTools* (designed for fishery observer programmes[28]) and *EMoptim* (which considers EM as a standalone monitoring tool and enables stratification[87]).

Key considerations for assessors: Coverage of fishing operations

- How are coverage levels set for independent observation?
- How are fishery observers or EM review effort allocated among vessels in a fleet? What factors are considered in making allocation decisions?
- Is allocation random, or conducted using a stratified random approach?
- Are all vessels in the fleet subject to monitoring? If not, why not?
- Are all fishing periods subject to monitoring (e.g. all times of day/year/seasons)?
- Is monitoring in place throughout the fishing grounds?
- For each monitoring objective set, what is the actual level of fishing effort that is observed by fishery observers or sampled at EM review? Is this demonstrated (or likely) to be sufficient?
- How does the fishery definition of fishing effort used to allocate monitoring relate to the ERF definition of 'fishing event'[e]?
- Are there opportunities for the observer effect?
    - Are fishery observers or EM present on all vessels?
    - Are fishery observers deployed on vessels often enough for long enough that vessel operations are likely to be the same on monitored and unmonitored trips?
    - Do stakeholders perceive that there may be an observer effect? Why?
- At lower coverage levels, what are the potential sources of bias? Are these considered/evaluated/addressed in the data analysis phase?

[e] A "fishing event" is defined as "a haul, set or other unit of capture that is appropriate in the context of the UoA". (GB1.3.3.2 (MSC 2022))

- Could there be rare species in the catch?
    - Has the likely need for a higher level of independent observation to estimate catches of these species been considered?
- Have the statistical distributions of catch events been considered in the monitoring design (e.g. a single animal caught per capture event, or, multiple animals caught per event in events that occur less often but catch a similar total number of animals)?
- Can the monitoring objectives be met by the independent observation design?

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*Table 2. Indicative levels of independent observation, as a proportion of fishing effort, required to achieve specific catch monitoring objectives, as described in published studies. CV=Coefficient of Variation; RRMSE=Relative Root Mean Square Error. In almost all cases explored in Pierre et al. (2022), the level of observation required decreased when observation effort was stratified using fishery-specific information on catch distribution (see reference source). Stratification was least effective in reducing the level of observation required for very rarely caught taxa and when greater precision was required (i.e. smaller value CVs). *This fishery conducts 80 trips per year and a total of 500 gillnet sets.*

Level of observation	Monitoring objective achieved	Reference
5%	Detect the existence of bycatch in a fishery (presence/absence of any bycatch, not species-specific occurrence or bycatch rates)	37
5 – 10%	Estimate catch of species caught in 60 – 100% of sets, with a CV of 0.3	87
10%	90% of purse seine catch species poorly estimated (RRMSE>50%)	5
10 – 40%	Estimate catch of species caught in 60 – 100% of sets, with a CV of 0.1	87
20%	Species comprising 35% of the catch estimable within 10% of their actual catch level 90% of the time	8
25%	Seabird bycatch detected when occurring at rates of around 0.2 birds/1,000 longline hooks	6
10 – 50%	Estimate catch of species caught in 10 – 25% of sets, with a CV of 0.3	87
40%	95% probability of observing catch of a sea lion species that is caught on 21% of gillnet fishing trips annually*	28
50%	40% of purse seine bycatch species estimated with RRMSE<50%	5
>50%	Species comprising <0.1% of the catch estimable within 10% of true levels 90% of the time	8
70 – 95%	Estimate catch of species caught in 10 – 20% of sets, with a CV of 0.1	87
75 - ~99%	Estimate catch of species caught in 5 – 10% of sets, with a CV of 0.3	87
85 – close to 100%	Estimate catch of rare and rarely caught taxa (e.g. sea turtles, seabirds)	60
88%	95% probability of observing catch of a seabird species caught species that is caught on 4.5% of gillnet fishing trips annually*	28
90 – ~99%	Estimate catch of species caught in 1 – 5% of sets, with a CV of 0.3	87
95%	95% probability of observing catch of a whale species caught on 0.2% of gillnet fishing trips annually*	28
95 – ~99%	Estimate catch of species caught in 5 – 10% of sets, with a CV of 0.1	87
~99%	Estimate catch of species caught in 1 – 5% of sets, with a CV of 0.1	87
100%	Census of all catch items; catch estimation not required	26

Table 3. Example calculation of the level of independent observation in place when at-sea observers (FOs) are present on 20 longline vessels among a fleet of 100 vessels.

FOs deployed on 20 vessels in a 100 fleet	Level of independent observation
20 monitored vessels execute 30% of fleet effort.	FOs are present to observe, at most, catch resulting from 30% of the fleet's fishing effort.
50% of hooks are hauled while FOs are asleep.	FOs can monitor, at most, catch resulting from 15% of fleet fishing effort.
33% of hooks in each daylight haul are observed.	FOs are observing catch resulting from 5% of fleet fishing effort.

4.5 Programme documentation

Monitoring programmes that deliver independent observation are complex. Programme documentation provides critical evidence supporting the evaluation of programmes against the ERF requirements. Examples of documentation that should be in place recording system and process requirements (also called standards) for fishery observer and EM programmes are summarised Table 4.

Such documentation requires updating as monitoring programmes develop and evolve. Version control of documentation is part of best practice, enabling retrospective data interrogation (e.g. investigating how observer species identifications may have changed over time, when a particular system change may have had unintended consequences that require subsequent correction, etc.).

When programmes span different jurisdictions, overarching standards are critical to provide a common understanding of system and process requirements, and a basis for comparable information to be collected through otherwise separate programmes. As with any standards-based approach, an approval process should then be applied to ensure participating programmes meet the overarching requirements set.

For EM programmes, outcome-driven standards are recommended where appropriate, e.g. specifying what imagery must capture, rather than defining a specific number of cameras[4]. However, outcome standards must be balanced with the need for a clear programme baseline to eliminate approaches that will not meet monitoring objectives, e.g., a requirement for waterproof hardware such as IP66 or IP68, and a minimum frame rate and resolution for cameras. Standards are also required for system operations, such as function tests, response to system failure, etc. (Table 4)[7,71].

4.5.1 Example standards for programmes of independent observation

Examples of standards for larger scale fishery observer and EM programmes include those drafted and adopted by RFMOs. For example, WCPFC has adopted Regional Observer Programme standards and guidelines[49] and the status of development of minimum standards for EM systems has been benchmarked among multilateral fisheries management bodies[37]. The International Commission for the Conservation of Atlantic Tunas (ICCAT) recommended the adoption of minimum standards for purse seine vessels on which EM was voluntarily implemented in 2016 and 2017[101]. The Indian Ocean Tuna Commission (IOTC) adopted EM standards in 2023[7].

For EM programmes in particular, standards can be very detailed and technical. It is recommended that EM service providers are engaged in MSC fishery assessment processes so assessors can discuss the efficacy and potential weaknesses of the monitoring systems in place with providers directly.

Key considerations for assessors: Programme documentation

- Is it feasible that the programme monitoring objectives can be met as envisaged using fishery observers and EM, given the standards in place?
- What do monitoring service providers consider to be weaknesses of the systems in place? How could these affect emergent data quality and integrity?
- Is version control in place to create a record of changes in the monitoring systems and data collection protocols over time?
- What is the relationship between UoA participants and the fisheries observer or EM service provider?
- What methods or tools are in place to ensure the integrity and independence of the monitoring process, and the information collected (i.e. from data collection through to data being available to end-users)?
- What opportunities are there for tampering with information at any point from data collection through data storage and reporting?
- What systems are in place to provide the chain of custody for fisheries observer and EM-derived information, to ensure its integrity? Are these systems robust? What is the weakest point?
- Is there anything missing from the documentation of the independent observation programme's systems and processes that would affect the quality of information emerging from the programme?

Table 4. Examples of system and process documentation for monitoring programmes delivering independent observation. 'Forms' is used here to represent hard copy or electronic formats. (AI=Artificial Intelligence, incorporating machine learning, COI = Conflict of interest, FO=Fishery observer, EM=Electronic monitoring, QA=Quality assurance).

Scope	FO programme	EM programme
Training	FO training materials Training materials for FO briefers and debriefers Refresher training (e.g. on protocol changes)	Training process for hardware installers EM analyst training Refresher training (e.g. on installation or protocol changes)
Information collection	FO Prioritised tasks FO data collection protocols and forms Debriefer information collection protocols and forms	System specifications System operations EM hardware standards Required camera views Vessel-specific documentation of EM systems and requirements Data formats (e.g. .csv, .avi, .mp4) EM review protocols and forms Reporting and/or debriefing processes
Information transmission / retrieval	Frequency and method for record provision/collection Designated information receiver	Frequency and method for record provision/collection Security requirements for transmission Designated information receiver
Information storage and security	Secure data storage (hard copy forms, electronic devices at sea and on land) Backup systems/processes Information chain of custody	Secure storage (e.g. hard drives at sea, cloud-based onshore) Encryption of stored information EM system tamper resistance and tamper evidence (hardware and software) Backup systems/processes Chain of custody for EM imagery and associated information
Quality assurance	FO data validation/verification processes Refresher training for FOs and other programme participants (e.g. targeted to issues identified by quality assurance checks)	EM data validation and QA (e.g. double review as an audit process) Refresher training for EM analysts and hardware installers (e.g. targeted to issues identified by quality assurance checks) Acceptance thresholds for EM data extracted by AI/machine learning tools
Conflict of interest	Statement of presence/absence of potential personal and commercial COIs Process for managing COI relevant to monitoring programme	Statement of presence/absence of potential personal and commercial COIs Process for managing COI relevant to monitoring programme

4.6 Information collection

4.6.1 Seeing what matters

Fishery observers primarily monitor fishing activities visually. EM includes a strong visual component through the recording of imagery, augmented by the collection of associated information (such as from gear sensors and geolocators). Fishery observers and EM cameras must be able to see the components of fishing operations as relevant to monitoring data needs. Understanding where on the vessel activities occur, and product flows when catch comes aboard through to when it is stored, will help assessors evaluate the efficacy of independent observation protocols in place.

4.6.2 Data collection by fishery observers

To ensure data quality, it is critical that observers are well trained, briefed before deployment, and receive clear instructions on their tasking, including the priority order of their assigned tasks. Clear and detailed data collection protocols setting out what must be observed or sampled, and when and how to record the required data are also essential. In turn, any deviations from the protocols issued that observers decide to implement in practice must be recorded (with rationale and other relevant contextual information), to ensure data processors and analysts can deal with observer data appropriately. Such feedback may also contribute to protocol improvements (which should be documented with versioning in place).

Onshore validation of data collected by fishery observers should also be undertaken, with any anomalies promptly discussed with observers to increase the likelihood that context for the anomaly can be recalled. In some cases, observer information will be recorded on paper forms for entry into electronic data storage programmes. Errors may be introduced during this process, and the independence of data entry providers from the UoA requires consideration. Data validation and checking processes should be in place where manual data entry occurs.

Debriefing is another key component of fishery observer programmes, which contributes to data quality, quality assurance, early identification of issues (e.g. problems with data collection protocols, refresher training needs), and presents observers with a structured mechanism for providing feedback.

4.6.3 Data collection using EM

4.6.3.1 Capturing information

For EM, data collection is a two-step process. EM system hardware and software are installed on vessels to capture imagery and associated information. Subsequently, data are extracted from information recorded at sea by onshore review. Vessel Monitoring Plans (VMPs) are a common form of vessel-specific documentation of EM systems and requirements. For example, VMPs may list the components of the EM system installed on the vessel, required views, camera placement, and supporting tasks for crew such as catch handling requirements and daily lens cleaning[78]. By reviewing these documents, assessors can explore whether the cameras will be effective in capturing the information they are meant to (e.g. catch composition, tori line deployment, ETP handling and release, etc.). Providing prompt feedback to vessel operators, captains and crew on any issues relevant to EM performance (enabling those to be addressed), as well as what is working well on the vessel, helps improve the quality of data collected[26,87].

4.6.3.2 Review of EM imagery and associated information

EM review processes also require documented protocols, setting out how imagery will be selected for review, data that must be recorded, and how they must be recorded. It is important to ensure data definitions used by analysts are appropriate for EM. If these are directly transferred from fishery observer to EM programmes, data collection or quality may be compromised if data definitions are not suitable for use with EM, for example, methods used by fishery observers to assess injury status as a proxy for post-capture mortality[87]. Analogous to observer programmes, EM programmes should also include data validation processes, and a mechanism for analysts to provide feedback on issues and improvements.

4.6.4 Errors in programmes of independent observation

A critical difference between independent observation conducted by fishery observers and EM is that observer data can never be verified completely, while EM imagery and associated information can be reviewed repeatedly, in whole or in part, an infinite number of times (until it is deleted). This provides unprecedented flexibility, including for data verification and quality assurance. For example, tasking two analysts with the same EM review segment and comparing findings provides insight into analyst accuracy and efficiency[86,101].

EM also enables targeted auditing, such as checking analyst accuracy in assessing catch species identified. Auditability can be facilitated by codifying identification methods, e.g. requiring analysts to record two characteristics used to identify a catch item. Where catch items are difficult to identify, imagery (as video or stills) can be shared with species experts[26,79,86].

An example of the extent of errors made by fishery observers is provided where observer identifications of seabirds are checked against expert identifications in New Zealand. In that case, 75% of seabirds bycaught in recent years were correctly identified to species level[12,13]. In a second example, around 80% of carcharhinid sharks were identified correctly by observers in northern Australia[107]. By contrast, lower observer error rates were reported from the North Pacific for target commercial fish species[104].

In most fishery observer programmes, there is little ability to determine that observers have correctly recorded what they saw (e.g. identification of discarded catch items, or non-compliant behaviours). This constrains the ability to understand bias that may affect information trueness. It also limits the ability to focus training or other corrective actions where needed to improve observer and fishery performance.

4.6.5 Use of Artificial Intelligence (AI) in EM analysis

EM increasingly provides the opportunity for automated review using AI. As one area of AI, machine learning (ML) is based on algorithms that train computer-based models to conduct EM review tasks that would otherwise have been undertaken by a human EM analyst. Standards for review conducted by AI are yet to be established or adopted on any scale, or by a multilateral fisheries management body.

4.6.5.1 Trueness in automated EM review

For EM, high trueness rates can already be achieved for some automated tasks. For example, detecting humans interacting with gear or present on deck has been investigated by EM provider Saltwater Inc. as a machine learning tool for directing EM analysts to the occurrence of events of interest. This has been achieved with 95% accuracy, dramatically decreasing the amount of human analysts' time consumed by scanning uninformative video[87].

Another computer vision tool developed by Saltwater Inc. achieves close to 100% accuracy when automatically detecting and event-marking fishing gear. The tool finds and pre-identifies pots for sampling in a fishery where gear deployment can involve more than 1,000 pots per trip. Pot sampling rates can be customised, so the tool selects and flags the number of pots required to meet monitoring objectives. Other machine learning applications that increase the efficiency of EM review include discard compliance monitoring, species identification, and low-level analysis of EM system performance[22]. Experimental work for seabird identification has also shown high accuracy rates for some species[62].

4.6.5.2 Acceptance thresholds

Just as fishery observers and EM analysts make mistakes, data emerging from ML-supported review may not be 100% correct. For EM analysts and ML, error rates are auditable and can be reduced with additional training. For observers, that is often not the case (as described above). Analogous acceptance thresholds could be applied to EM review facilitated by ML as are accepted from human EM analysts and fishery observers, ideally alongside an objective of improving data quality with corrective actions as appropriate to the monitoring or analysis method (e.g. training fishery observers and EM analysts, or algorithms).

4.6.6 Independent observation of compliance

When fishery observers and EM are used for compliance monitoring, the differences in how information is collected come to the fore. Observers are mobile on vessels, but can only be in one place at once. EM cameras are fixed, but can be installed to view any part of the vessel (and fishing operation) and operate simultaneously. The efficacy of each monitoring tool in detecting non-compliance varies with the type of non-compliance that may be occurring. Fishery observers can record their observations at sea and potentially document them with photos/video including for evidential purposes. EM analysts can also be tasked with documenting untoward behaviours observed during imagery review, with replay possible and the use of EM imagery as evidence for law enforcement (noting evidential chain of custody requirements that apply)[26].

Key considerations for assessors: Information collection

Data collection

- Do fishery observers or EM cameras have the fields of view needed to effectively collect the required information?
- Are fishery observer and EM data collection protocols and forms available for assessors?
- Can monitoring objectives be met by the observer data collection and/or EM review protocols?
- Do data definitions provide a precautionary basis for assessing impacts, that could include unobserved mortality?
- Have EM data fields been defined specifically for that method of independent observation (or their suitability for EM reviewed, if data definitions are taken from fishery observer programmes)?
- Are vessel-specific requirements for EM performance documented, e.g. EM system components and where on the vessel they are installed, camera views, designated catch sorting areas, catch handling protocols, lens cleaning requirements?
    - Are these documents reviewed to ensure the requirements continue to be effective?
    - What is the process for ensuring these documents remain up to date when changes occur?
- Is there a systematised approach (e.g. reporting protocol, and escalation pathway) for fisheries observers to report alleged non-compliance, and for EM analysts to identify potential non-compliance and untoward behaviours that may indicate non-compliance?

Data quality and integrity

- What quality assurance processes are in place for observer and EM programmes?
- What are the validation and verification processes used for data collected by fishery observers and EM analysts?
- Is information available on the error rates of fishery observers and EM analysts (e.g. for species identification)? What are impacts of errors on information accuracy? Can errors be linked to a type (or source) of bias?
- If AI is used for EM review, what are the associated quality control processes relevant to the emergent data (e.g. is a proportion also manually audited)?
- If AI is used for EM review, are acceptance thresholds defined and implemented? What procedures are in place if these are breached?
- Are there training, briefing and debriefing processes in place for fishery observers and EM analysts?
    - Are these programme elements documented?
- Where are the key uncertainties and data gaps in the data used for generating catch estimates (i.e. sources of mortality resulting from direct fishery impacts that are not effectively quantified by the monitoring protocols)?
    - What level of impact could these uncertainties/gaps have on the accuracy of catch estimates?
    - Are any measures in place to mitigate these, during data collection or at the analysis stage?
- Are feedback mechanisms in place to provide fishing vessel owners/operators, captains and crew information on how the efficacy of EM can be improved (e.g. if VMP requirements for catch handling and lens cleaning are not being carried out as needed), what is working well on their vessels, and other findings from EM review?
- Are there evidential chain of custody requirements for information collected, for this to be used in enforcement proceedings? Is there evidence that these are being adhered to?
- Are fishery observer reports provided to fishing vessel operators, captains and crew for their information, after observer deployments end?

4.7 Managing monitoring information

Information collected by fishery observers and EM requires secure management at sea and onshore. There are many approaches to ensuring information security, with different data formats (e.g. electronic or paper) and operating environments (e.g. large or small vessels) requiring different approaches.

EM systems typically encrypt information for storage, and encryption remains in place when data are transmitted. Tamper resistance and tamper evidence is incorporated into off-the-shelf EM systems. EM systems may transmit some or all information over the internet, and/or information may be held on hard drives that are retrieved in port or mailed for review.

Backup processes should be in place to prevent monitoring data loss. Assessors should evaluate the extent and reported causes of losses of monitoring data, to assess whether this could be systematic (e.g. could cameras be turned off when ETP bycatch events occur?)[90].

Understanding the movement of monitoring information from the vessel to shore, to its final storage destination will aid assessor identification of potential weaknesses that could affect the independence of the information from the UoA, and opportunities for the loss of information or introduction of errors.

Key considerations for assessors: Managing monitoring information

- How is information collected through independent observation transmitted or retrieved from vessels and who is responsible for this?
- How is the integrity of fishery observer and EM information protected?
    - How do observers store their records when on vessels?
    - How do observers provide their records to the shore-based programme team?
    - Is EM imagery and associated information stored and transmitted in an encrypted form?
- Are EM hardware and software tamper-evident and tamper-resistant?
- Is stored monitoring information backed up?
- How much monitoring information has been lost, e.g. missing observer paperwork, EM system downtime or file corruption? Can losses be accounted for?
- Who holds information collected through independent observation and what is their relationship to the UoA?
- How is access to information managed, and by whom (and what is their relationship to the UoA)?
- Are information management systems and processes documented, and documentation kept up to date?
- When errors are found in stored information, is there a documented process for correcting those? Is there version control in place that maintains data traceability?
- Are chain of custody requirements in place and documented for information collected through independent observation?

4.8 Catch estimation using fishery observer and EM-derived data

There is an extensive literature on the analysis of fisheries catch data to generate species-specific total catch estimates. The structure of monitoring programmes requires consideration when estimation methods are selected (e.g. representativeness of data collection and proportion of fishing effort from which catch information is recorded, see section 4.4). When census approaches are not used for monitoring, estimation methods are needed to scale up the catch to the level of effort the fishery deploys. The statistical characteristics of capture events are a critical determinant of the appropriate analytical method for this. In turn, the assumptions of an analytical method determine its suitability for calculating estimates from a catch dataset[21,66,105]. Different estimation approaches are likely to be appropriate for commonly caught and rarely caught species. Biased catch estimates and incorrect conclusions regarding catch patterns (and consequent risks to species caught) can result from using inappropriate analytical methods[23,68].

Quantitative catch estimation is a highly technical field. Seeking expert advice is recommended for fishery clients developing catch estimates for their fishery, and stakeholders wishing to understand the strengths and limitations of different estimation methods.

4.8.1 Ratio estimators

Ratio estimators have been widely used for estimating species catch from fisheries observer data, scaling catch from the monitored proportion of effort to the fleet level. This method is sample (not model) based, assuming the ratio of bycatch to fishing effort is the same for the observed and unobserved parts of the fishery. The ratio derived from the observed effort is therefore multiplied by the effort in the unobserved activity, and the two estimates are added to generate total estimated catch of a species. The assumption that the ratio is the same in both components of the fleet may not be supported by reality, particularly when monitoring coverage is low. Spatial considerations are not explicit and implicitly, ratio estimators assume a linear relationship between catch of target and non-target species, which may not be appropriate.

4.8.2 Model-based estimation

Model-based estimators offer solutions to such issues, again, with the appropriateness of the methods determined by the statistical characteristics of the dataset. For example, ETP catch is typically characterised by zero-inflated distributions and overdispersion (i.e. there are many more units of fishing effort without ETP catch events than with ETP catch events). Negative binomial or Poisson distributions have been appropriate for model-based estimation of catches of these species, while other methods will produce less accurate estimates[1,79,84]. Methods that may be used to generate catch estimates include generalised additive models, generalised linear mixed models, random forests, and regression trees[20,27,105,113]. In recent years, the use of Bayesian methods has become prevalent for estimating catches[43,67,83]. Comparative studies in which more than one estimation method is used are valuable for highlighting strengths and weaknesses of the various estimation methods available[9,16,72].

4.8.3 Estimating unobserved and unobservable mortality

Incorporating unobserved and unobservable mortalities (also known as cryptic mortality) provides another challenge for accurate catch estimation. In some cases, fishery-specific information may be available describing unobserved mortality[17,54,68]. For example, multipliers for cryptic mortalities of seabirds in trawl and longline fisheries have been developed in the southern hemisphere[88]. Multipliers based on the best available information provide a pragmatic approach to estimating unobserved mortality[79]. As described for the information collection stage (see section 4.6), using precautionary data definitions when impact is quantified provides another approach to incorporating unobserved mortalities in catch estimates.

Key considerations for assessors: Catch estimation

- Does the catch estimation method include spatial and/or temporal components?
    - If not, is there a justification for that?
- Are catch events largely individual, or are they characterised by multiple captures (clusters)?
    - How/does the analysis consider this?
- Are the assumptions made for the analysis appropriate for the characteristics of the dataset (e.g. the statistical distribution used to describe catch events)?
- How do catch estimation methods consider unobserved (cryptic) mortalities?
- Are mortality estimates precautionary?
- What are the key uncertainties underlying the estimation of catches, both at the data collection stage and at the analysis stage?
- Are there confidence intervals associated with catch estimates available?
- Do stakeholders have confidence that the catch estimation methods are robust?

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5. Troubleshooting and transition

Throughout this report, we have highlighted how the different components of the design and implementation of programmes of independent observation can affect the trueness and precision of fishery information collected. Understanding the potential for bias inherent in the monitoring approach chosen is essential to enable that bias to be managed, and to ensure a monitoring programme meets ERF requirements.

Below in Table 5, we set out real-world examples from fishery monitoring programmes showing how bias can arise among monitoring approaches focussing on independent observation. The likely effects and significance of this are also discussed, and examples of possible solutions/mitigations are provided. This is not an exhaustive list of monitoring issues or solutions, and it is intended to illustrate that a breadth of diverse approaches could be applied[38].

For most fisheries entering the MSC programme, some level of monitoring will already be in place. Such existing monitoring programmes may require adapting and augmenting to provide information that meets the requirements of the ERF. For fishery clients and others developing monitoring programmes to meet ERF requirements, potential weaknesses in existing programmes could be identified through a gap analysis process, starting with identifying information already collected and that newly required, and culminating in the consideration of sources of bias and their management (Figure 2). At each step of this process, content from other sections of this report can support the evaluation required (e.g., data collection capabilities of different methods of independent verification and observation, documentation of monitoring programmes, extent and allocation of independent observation likely to be required, etc.).

There are many resources available on the design and implementation of fishery monitoring programmes for independent observation, including published reports and web-based information[29,35,65,71]. The ERF provides a new framework for participants in MSC fishery programmes to apply and work within. However, the concepts on which the ERF is based have been central to robust fishery data collection, including monitoring design and implementation, for many years. For all fisheries, higher quality information enables better fishery management, understanding of sustainability risks and increased confidence in management outcomes.

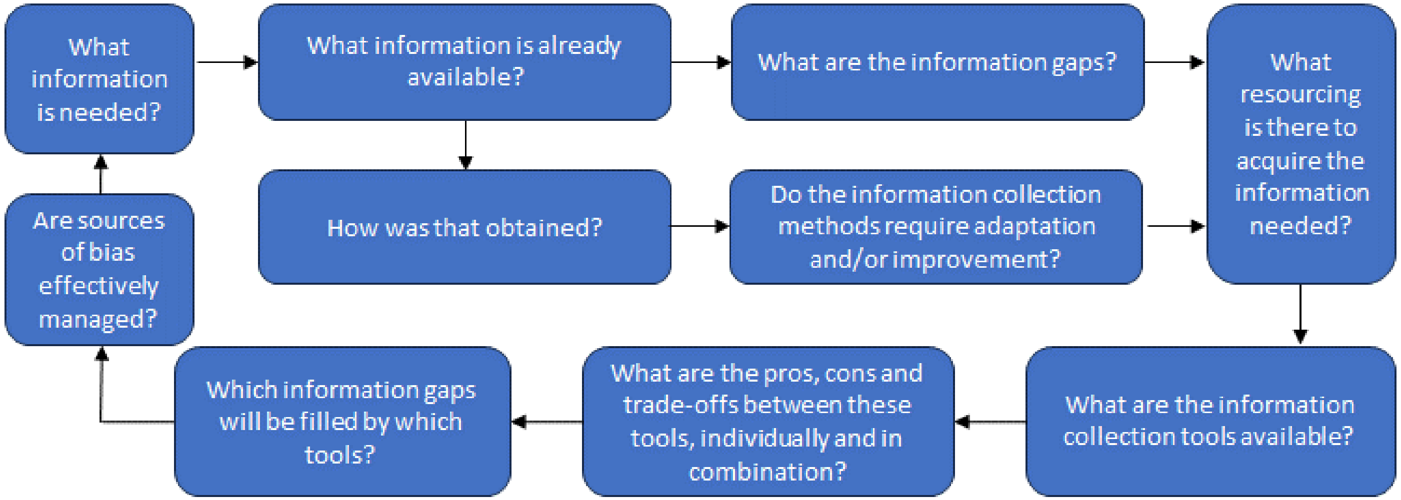

Figure 2. Schematic of a stepwise approach to evaluating information collection needs and tools to meet the requirements of the ERF.

Table 5. Examples of sources of potential biases affecting the accuracy of fishery monitoring information, their effects, and possible solutions. In all cases, bias introduced to fishery information could be consequential if unaddressed. FO=Human fishery observers; EM=Electronic monitoring.

Source of bias	Effects	Significance	Possible solutions
Implementing representative monitoring			
Dockside monitoring to verify catch is conducted in one of five ports used by a fleet.	Dockside monitoring is unlikely to provide representative verification of the fleet's operations.	Landed catch composition information may overestimate some catch components, while underestimating others.	Explore whether landings at the monitored port could be representative of the fishery (e.g. vessels landing there, temporal and spatial fishing effort that is reflected in landings). Expand monitoring programme to include other ports. Reallocate monitoring effort to cover catches at sea on a representative sample of vessels.
FOs do not work at night for health and safety reasons.	Information obtained by independent observation is not representative of the fishing operation.	Any fishing practices occurring at night will be underestimated in observer data.	Conduct a focused study to explore differences between night and day operations, to identify potential biases and consequences, and consider how these could be mitigated. Implement EM to provide independent observation of night-time fishing operations.
In a mixed-size fleet, FOs are not deployed on small vessels because bunks are not available or vessels cannot carry additional people onboard.	Information obtained by independent observation is not representative of the fishing operation.	The fishery as a whole cannot be understood (e.g. catch composition, compliance).	Explore differences between the activities of small vessels and others in the fleet, to understand potential impacts on representativeness (e.g. fishing locations, seasons, effort used, depths fished). Implement EM to provide independent observation of small vessels.
EM imagery includes corrupted segments during which catch cannot be documented and compliance cannot be monitored.	Catch composition and operational information that is available may be inaccurate.	Understanding of fishery impacts and compliance may be compromised.	Establish whether losses appear systematic or random (e.g. mostly on one vessel, mostly in an area of high bycatch risk, mostly when one skipper is aboard, etc.). Consider the information relevant to failures that is available from the EM system, e.g. whether tamper evidence indicates deliberate interference, whether lost segments result from equipment failure such as a faulty sensor. Consider the breadth of fishing activity that occurred while the EM system was not operating, and the potential for untoward activities to occur within that timeframe (e.g. discarding a bycaught ETP species, finning of sharks). Determine whether EM analysts observed untoward behaviours prior to the unavailable segments (e.g. unusual crew movements on deck, or unusual gear movements detected by sensors). Investigate any systems or processes in place at the programme level to investigate and rectify such issues.
Accurate catch quantification (observable mortalities)			
EM is used to audit fisher logbook information on ETP species. Identification of some	Catch composition information is likely to include inaccuracies.	Catch estimates are expected to be imprecise; there is a commensurate lack of clarity	Introduce handling protocols to provide clear camera views of seabirds caught (e.g. fishers holding birds up to cameras, with key identifying areas such as head and feet displayed). If practicable and non-injurious to crew and seabirds, take close-up photos of birds prior to release and provide these to experts onshore.

Source of bias	Effects	Significance	Possible solutions
petrel species is difficult especially when birds are wet and incomplete. Fishers may record inaccurate identifications.		about fishery impacts on seabird species.	For seabirds landed dead by the fishing operation, return carcasses to shore for expert confirmation of identification.
Single FOs on a vessel cannot observe any discarding that may occur when catch comes aboard on deck, while processing is also occurring in the factory.	Catch discarded by crew before it reaches the factory will not be captured in the dataset.	Independent observation may not be monitoring or documenting total catch.	Conduct a targeted study to document the nature and extent of catch discards from the deck from a representative group of vessels, e.g. for one year. Determine the extent of bias resulting from a lack of deck observations, and consequences of this. Amend monitoring arrangements to capture discarding from the deck if this is significant (e.g. adjusting FO tasks so the deck and factory are monitored on alternate hauls, deploying two FOs to vessels for concurrent monitoring of two locations aboard, introducing EM where FOs are not present). If the targeted study finds discarding from deck is not significant, audit this on an ongoing basis to ensure practices have not changed.
EM is used to monitor discarding in a bulk fishery. The volume of catch makes quantification by species difficult.	Catch composition information may be inaccurate.	Independent observation of catch may not be effective.	Work with crew to introduce catch handling practices that support effective catch quantification. For example, it may be feasible to route discards overboard via a conveyor that passes under a camera, or catch may be sorted into species-specific bins where bin volumes are known to represent approximate weight.
EM is used to provide independent observation of a pot fishery. Strings of pots are set, and sometimes a new pot is emptied into the catch sorting bin before the previous pot's contents are cleared.	Catch cannot be effectively quantified for each pot, and therefore an individual pot is not a useful effort metric.	Catch estimates will be biased when pot contents overlap.	If there is room on the vessel, introduce another sorting bin such that the contents of sequentially hauled pots can be separated for EM review. Redefine the effort metric as a pot string, with catch composition defined per string.
The accuracy of skate and ray identifications conducted by FOs is unknown and similar-looking species are caught in the fishery.	Catch composition information may be inaccurate.	Fishery impacts are not understood.	Task observers with taking photos of any skates and rays brought aboard the vessel. Consider retaining dead animals. For retained dead specimens and/or photos, confirm identifications with onshore experts to ascertain FO accuracy rates. Conduct training to improve observer identification skills and provide effective resources to support better identification at sea. Monitor any improvements in FO identifications using photos taken by observers. If improvements have occurred, continue verifying identifications (e.g. through occasional audits) to ensure ongoing accuracy. If improvements have not occurred, consider the

Source of bias	Effects	Significance	Possible solutions
			reason for this and whether photos should become the primary source of identifications of difficult species. Consider requiring FOs to identify skates and rays to genus level and estimate species composition using alternate methods, such as a risk assessment approach using fishery independent and fishery dependent information describing correctly identified species captures and occurrences (e.g. capture location, depth, temperature, eDNA).
Fishing gear goes not effectively retain sensitive habitat-forming benthic organisms.	Fishery-dependent information is likely to misrepresent habitat impacts.	Fishery impacts are not understood.	Implement independent observation with dedicated data collection protocols to collect fishery-specific information. Undertake predictive modelling using available information with the goal of better understanding of where sensitive habitats could occur, i.e. where fisheries are more likely to interact with them Conduct underwater camera surveys to identify sensitive areas (*de novo* or to validate and potentially refine modelling predictions)
Quantification/estimation of unobservable mortalities			
Seabird mortalities can occur in trawl fisheries due to warp cable strikes. Quantifying warp strikes and assessing the fate of birds struck are both difficult.	Most warp-related mortalities will be unobserved and unquantified.	Direct effects of the UoA are not understood; seabird 'catches' are underestimated.	Considering implementing dedicated FO monitoring of warp strikes, using established precautionary protocols To address the unobservable fate of birds that experience cable strikes, use a precautionary definition of this interaction (e.g. all strikes are considered to result in mortality). Include multipliers based on the best available information to represent unobserved mortalities in seabird catch estimates.
Cetaceans may drop out of gillnets during hauling, before they are detected as captures.	Drop-out mortalities will be unobservable and not quantified.	Direct effects of the UoA are not understood; cetacean catches are underestimated.	Ensure protocols for independent observation are maximally effective for detecting drop-outs, e.g. observers on-deck during hauling, and EM camera views covering the net being hauled to an appropriate distance. Consider reported drop-out rates in other fisheries, and whether a multiplier is appropriate at the fleet level to reflect this type of unobserved mortality.
Post-capture survival of sharks released from fishing gear is poorly understood and generally unobservable.	Post-release mortalities are unknown.	Direct effects of the UoA are not understood and impacts may be underestimated.	Assume all releases are mortalities unless evidenced otherwise. Implement (and monitor) handling measures correlated with increased survival rates.
Post-capture survival of turtles released from fishing gear is poorly understood and generally unobservable.	Post-release mortalities are unknown.	Direct effects of the UoA are not understood and impacts may be underestimated.	Consider implementing data collection to assess proxies for post-release mortality, using expert-developed criteria based on animal condition at release.

Source of bias	Effects	Significance	Possible solutions
Depredation of animals caught in fishing gear is often unobservable.	If no traces remain, mortalities are unobserved and unquantified. Where remnants are in place, species may not be identifiable.	Fishing-related mortality may be underestimated.	If fishery-specific information is not available, applying multipliers based on best available information may be a pragmatic option.
Cetacean mortalities can result from vessel strikes, with the fate of the animal unknown.	Mortalities are likely to be unobserved and unquantified.	Direct effects of the UoA are not understood and impacts may be underestimated.	Consider risk factors affecting the fate of the struck animal, such as vessel speed and species.
Compliance/conformance information gaps			
FOs monitor implementation of a fishing company's policy prohibiting retention and finning of sharks. Due to limits on FO hours of work, hauls are only partially observed.	Conformance with the policy requirements cannot be assessed comprehensively.	Confidence to conclude shark finning is not occurring is limited and unmonitored haul practices must be considered.	Ascertain residual risk due to gaps in FO observations. Conduct catch inspections onboard vessels, where shark parts may be stored if retained. Implement monitoring onshore which includes vessel and catch inspections, to enable detection of any shark parts retained. Complement FO deployment with EM coverage to augment monitoring in place onboard vessels.
EM is used to monitor implementation of a fishing company's policy prohibiting retention and finning of sharks. Crew sometimes handle sharks out of camera view.	Conformance with the policy requirements cannot be assessed comprehensively.	Confidence to conclude shark finning is not occurring is undermined.	Working with crew, develop catch handling protocols for sharks such that releases occur in view of cameras. Update camera configurations to ensure all shark release points onboard vessels are monitored. Taking a precautionary approach, any shark that is taken outside camera view would be assumed to be retained or finned in the first instance. Implement monitoring onshore which includes vessel and catch inspections, to enable detection of any shark parts retained.
Independence from the UoA			
FOs living working in a small community are socially connected to the fishers they are monitoring.	There is potential for social conflicts of interest, especially if the community does not support fishery monitoring.	Observers may feel pressure to report favourably on fishers they have connections with.	Rotate FOs among vessels to avoid prolonged deployments on any one vessel. Implement a policy setting out the closeness of personal connections that an FO can and can't monitor. Ensure an external party provides remuneration for FOs (e.g. the management agency). Ensure briefings and debriefings are conducted by an external party, and these explore potential for any impacts of social context during a deployment. Consider complementing FO-collected data with EM-derived information, with a comparison of differences conducted.

Source of bias	Effects	Significance	Possible solutions
UoAs directly fund observer and EM programmes, and there is no programme administered by the management agency.	There is potential for conflict of interest when UoAs pay providers directly.	FO and EM data may be seen as not independent from the UoA.	Use a recognised third-party provider of monitoring services. Document how independence is managed and maintained in a policy document that is publicly available, and formalise that as a part of the monitoring contract. Supplier provides data to UoAs after payment for services has been received.
Fishery monitoring data is stored at an industry-funded facility.	There is potential for conflict of interest if data is accessible to those with direct or indirect UoA interests.	Monitoring data may be seen as not independent from the UoA.	Ensure data access is closely managed, with unique logins and permissions based on administrator need. Ensure appropriate management of extracted information including chain-of-custody procedures. Conduct regular independent audits of the security of the system.

6. Checklists

The following checklists are designed to provide a quick reference guide on what to consider when evaluating the accuracy of fishery information, as required by the ERF. Key considerations for assessors that are identified for independent verification (section 2) and independent observation (sections 3, 4) are checked against relevant trueness and precision considerations that underpin the criteria used in the ERF to structure the evaluation of trueness (ERF Table B4) and precision (ERF Table B6).

Detailed descriptions and explanations of the checklist items are provided in the report.

Checklist 1: Independent verification methods

	Trueness criteria				Precision criteria		
Method	**Objectivity**	**Relevance**	**Completeness**	**Consistency**	**Fishing operations**	**Ecological characteristics**	**Monitoring design**
Vessel monitoring systems (VMS)	Who receives, analyses and stores information? Extent of manual reporting if transmission fails?	Transmission interval appropriate to the fishing method? Reporting back-up for non-transmitting periods?	Operational on all vessels? Are there non-transmitting periods? Sample or census review? Interpolations when locations are missing?	Information from VMS accords with other sources (e.g. AIS, on-water inspections)? Detection of tampering?	Operational on all vessels? Transmitting at an interval appropriate to the fishing method and effort?	Operational on all vessels?	Operational on all vessels? Sample or census review? Interpolation methods when locations are missing?
Automatic Identification Systems (AIS)	Who analyses and stores information? Extent of manual reporting if transmission fails?	Transmission interval appropriate to the fishing method? Standards for AIS use/performance in place?	Operational on all vessels? Are there non-transmitting periods? Sample or census review? Interpolations when locations are missing?	Information from AIS accords with other sources (e.g. VMS, on-water inspections)? Detection of tampering?	Operational on all vessels? Transmitting at an interval appropriate to the fishing method and effort?	Operational on all vessels?	Operational on all vessels? Sample or census review? Interpolation methods when locations are missing?
Dockside monitoring	Who are the monitors, and who pays them? Who stores the information collected? Is COI mitigation needed, and in place?	Can the programme design support the monitoring objectives? Are protocols documented and available?	What are the opportunities for evasion of monitoring? Is evasion monitored? What is the target coverage of landings? Is information collection systematised?	Consistency of monitoring findings with any other verification of landed catch?	Is a sample or census or landed catch monitored? If a sample: • how are monitored sites/vessels/operations chosen? • how do these represent the UoA activities as a whole?		
At-sea/on-water inspections	Who is conducting the inspections? Who stores the information collected? Is COI mitigation needed, and in place?	Can the programme design support the monitoring objectives? Are protocols documented and available?	Is information collection systematised? How does coverage reflect UoA activities? Are there restrictions (e.g. due to health and safety) that limit information collection?	Consistency of inspection findings with other verification methods?	How are sites/vessels chosen for monitoring? To what extent can the monitoring be considered to represent the UoA activities as a whole?		

Method	Trueness criteria: Objectivity	Relevance	Completeness	Consistency	Precision criteria: Fishing operations	Ecological characteristics	Monitoring design
Reference fleets	How are participants selected? What is the relationship of fleet participants with the UoA? How is reference fleet information collected, handled and stored? Is COI mitigation needed, and is this in place?	Can the fleet programme design support the monitoring objectives? Are protocols documented and available?	Is information collection systematised? To what extent do vessels/operations chosen reflect activities of others in the UoA?	Consistency of findings with other methods that contribute to verification?	Is the diversity of vessels in the reference fleet representative of those in the UoA (e.g. vessel size, gear use)?	Is the diversity of vessel operations in the reference fleet representative of those in the UoA (e.g. spatial and temporal operational characteristics)?	Are reference fleet participants operating independently or together? Can the reference fleet effectively represent UoA activities?
Fishery observers and electronic monitoring (see detailed checklist for Independent Observation)	Who provides the monitoring and verification services? How are the service providers paid? Is the information secured as it is collected? Who receives and stores the information? Is COI mitigation needed, and is this in place?	What is the scope and process for verification? Are protocols documented and available?	Is information collection systematised? How is the audit sample selected? Is the audited sample representative of the UoA?	Is information consistent with other verification methods (e.g. dockside monitoring), and information sources (e.g. logbook data)? Are any acceptance thresholds in place, between audit information and other datasets?	Are vessels carrying observers and electronic monitoring systems representative of those in the UoA (e.g. vessel size, gear use)?	Are vessels carrying observers and electronic monitoring systems representative of UoA fishing operations (e.g. area, season)?	Could there be an observer effect occurring? How is electronic monitoring review structured? How do observers deploy data collection effort while onboard?

Checklist 2: Independent observation by fishery observers and electronic monitoring (EM)

Programme component / attribute	Summary of key considerations for each component/attribute	Relevance to criteria for evaluating:						
		Trueness			Precision			
		Objectivity	Relevance	Completeness	Consistency	Fishing operations	Ecological characteristic	Monitoring design
Programme design	Are the programme structure and governance defined? Are roles defined, including as these align with decision-making responsibilities? Is the level of transparency appropriate for the programme, and considered as such by stakeholders? Is there an effective legal framework in place to support the programme? Is there is not an effective legal framework in place, is there a voluntary one? Is the programme reviewed, and findings actioned, to maintain and improve performance?	✓	✓	✓				
Independence and conflicts of interest	What are the social and commercial relationships of the programme staff and the UoA? How are potential conflicts of interest identified and managed? Do stakeholders perceive that the programme maintains independence, and the emergent information is robust to conflicts of interest?	✓						
Monitoring objectives	Have clear monitoring objectives been identified and prioritised for the programme? Are monitoring objectives reviewed, and how is that done? What is the extent of alignment of monitoring objectives with information needs of the ERF?		✓	✓	✓	✓	✓	✓
Coverage	How are coverage levels set for independent observation? What factors are considered in making monitoring allocation decisions among fishing operations (e.g. allocating observers to vessels in a fleet, or selecting EM imagery for review)? For each monitoring objective, what proportion of fishing effort is actually covered by independent observation? Could the 'observer effect' be occurring? Have catch patterns been considered in designing and allocating monitoring coverage? Can the coverage planned and achieved be reasonably expected to meet the monitoring objectives?		✓	✓		✓	✓	✓
Programme documentation	Are standards and specifications documented, as relevant to the observer or EM programme? Can monitoring objectives be met, given the standards and specifications in place for the programme? Is documentation updated as changes are made through time? Is there anything missing from programme documentation, that could affect the quality of information collected by observers or EM? Are there specific requirements documented for the use of information collected by observers and EM in evidential proceedings?	✓	✓	✓	✓	✓	✓	✓
Data collection	Are the data collection protocols used by observers, and for EM review, documented and available for assessor review?		✓	✓	✓	✓	✓	✓

Programme component / attribute	Summary of key considerations for each component/attribute	Relevance to criteria for evaluating: Trueness				Precision		
		Objectivity	Relevance	Completeness	Consistency	Fishing operations	Ecological characteristic	Monitoring design
	Are data collection protocols expected to be effective? Are data fields defined for the method of independent observation, or if not, are data definitions feasibly comparable between observer data collection and EM review feasible? Do these protocols support precautionary catch estimation, e.g. for ETP/OOS species? Do fields of view enable effective information collection? Are vessel-specific requirements for EM performance documented? Is there a systematised approach to identifying and reporting potential non-compliance?							
Data quality and integrity	What quality assurance processes are in place for the programme of independent observation? Where might error occur in data used for generating catch estimates? Is information available on error rates of observers and EM analysts? When errors are detected in data collected by observers and EM analysts, have the sources of error been investigated, and are they linked to any identifiable bias? If EM review is automated, how is accuracy reviewed and assured? Are observers and EM analysts trained, briefed and debriefed? Are fishers provided with reports on the findings of independent observation of their fishing operation, after deployments or when review is completed?	✓	✓	✓	✓	✓	✓	✓
Managing monitoring information	How is information collected through independent observation transmitted or retrieved from fishing operations (e.g. vessels), and stored? Who is responsible for information collection, storage, back-ups, and access? How is the integrity of fishery observer and EM information protected (e.g. storage, encryption, tamper evidence and resistance)? How are lost data accounted for (e.g. missing datasets, corrupted EM imagery)? Are data management systems up to date and documented? When errors are found in stored data, is there a version-controlled process for their correction? Is the maintenance of an evidential chain-of-custody established in the programme?	✓		✓	✓			
Catch estimation	Does the catch estimation method include spatial and temporal components? Are the assumptions made by the analytical methods appropriate for the data characteristics? How is unobserved mortality considered in catch estimation? Are mortality estimates precautionary? Who conducts the analysis and what is their relationship to the UoA?	✓	✓	✓	✓			✓

7. Case studies

Fisheries currently in the MSC programme were evaluated using the ERF requirements, based on information in assessment reports, published literature, assessor knowledge, and fishery client input. For each fishery, strengths and weaknesses in relation to the ERF are identified, and proposed solutions to improve fishery information are suggested. Solutions are not exhaustive, and those proposed are preliminary.

7.1 Cedar Lake walleye (*Sander vitreus*) and northern pike (*Esox lucius*) fishery

Information sources:

K. Casper, I. Kitch, G. Klein, D. Kroeker, C. Phillips; see section 10.1

7.1.1 Fishery description

The fishery operates in northern Manitoba, Canada. As well as the assessed commercial fishery, subsistence indigenous and recreational fishing occurs in the lake. The commercial fishery is estimated to account for 80 – 82% of the annual fishing mortality of walleye and pike. Commercial landings of walleye in Cedar Lake ranged from 162 – 254 tonnes in the 10-year period 2009 – 2019. For pike, landings ranged from 98 tonnes to 254 tonnes in the same period. There are 40 licensed commercial fishers.

The fishery comprises two distinct seasonal components. Summer fishing occurs in open water 1 June – 31 October. Bottom set gill nets 80 - 100 m long are set in strings, with an anchor at each end of the string. Nets are generally lifted on a daily basis. The net is brought up over the bow or amidships to remove catch, remaining attached to the anchor throughout the operation. Winter fishing occurs using nets set under the lake ice, and left in place for 3-7 nights. In winter, catch is removed after nets are disconnected from anchors and brought to above the ice through auger-drilled holes. Nets are then reset below the ice. There are seasonal differences in the location of fishing on the lake.

Regulations applying to the Cedar Lake fishery include quota species and total quota limits, designated seasons, a minimum gillnet mesh size and maximum net length. In addition, seasonal closures are in place to protect spawning fish. A permanent closure to commercial fishing is in place in Cross Bay, for other users. The maximum total length of net that can be fished by a licence holder is 1,400 m.

7.1.2 Scoring elements

In-scope species

Catch composition includes four main in-scope fish species and eight in-scope minor species. (Main species include the two target species in alternate UoAs). Main species are:

- Walleye *Sander vitreus*
- Northern pike *Esox lucius*
- Lake whitefish *Coregonus clupeaformis*
- White sucker *Catostomus commersoni*

Stock assessments are conducted for Cedar Lake populations of northern pike and walleye. Stock assessments are not available for lake whitefish or minor species, though some biological and life history information is available including from work conducted at Cedar Lake.

ETP/OOS species

Three out of scope species that may be caught in the fishing gear are double-crested cormorant (*Nannopterum auritus*), lesser scaup (*Aythya affinis*) and common loon (*Gavia immer*). The assessment team identified two additional bird species that could interact with the fishery given their distribution and diving habits – horned grebe (*Podiceps auritus*) and western grebe (*Aechmophorus occidentalis*). These species are both protected in Canada under the Migratory Birds Convention Act 1994 (and the Migratory Bird Treaty Act 1918 in the USA).

These aquatic bird species are all distributed far beyond Cedar Lake; none have restricted distributions. Any interactions with aquatic birds could only occur during summer fishing, because the lake freezes over in winter and aquatic birds migrate from the region.

Status information available on the five species of aquatic birds includes:

- Double-crested cormorant: IUCN Least Concern, increasing population; population is estimated to have increased 120% per decade from the late 1960s to 2007.
- Common loon: IUCN Least Concern, stable population estimated at more than 600,000 individuals, the substantive majority of which occur in North America.
- Lesser scaup: IUCN Least Concern, stable population estimated at 3.7 million adults, all in the Americas.
- Western grebe: IUCN Least Concern, stable population; population estimate of 80,000-90,000 adults, occurring mostly in Canada and the USA.
- Horned grebe: IUCN Vulnerable, decreasing population; 30% per annum decline reported in North America from the late 1960s through to 2007.

An anecdotal estimate of one loon captured per fisher per year was reported by the assessment team.

Lake sturgeon (*Acipenser fulvescens*) is designated as an ETP species under v3.0 of the MSC Standard, as it is listed on both CMS Appendix II and CITES Appendix II. The species was also classified as Endangered by the IUCN in 2022. Commercial and recreational harvest of lake sturgeon is not permitted and release is mandatory. Holders of indigenous harvest rights may take this species. The extent of overall catch is estimated as 'a few hundred per year'. Around 80 are estimated to be retained. Mark-recapture work conducted two-yearly provides some information to estimate abundance.

Habitats

Benthic habitats comprise boulder, cobble and clay and silt loams. Habitats are sampled on an ongoing basis through a dedicated programme. Fishing gear is set on soft substrates, and anchors are expected to cause only shallow disturbance to benthic habitats. Open water gillnets are rigged with anchors of 25 - 40 lb. These are left in place on the substrate while the nets are hauled. In the absence of wave action, winter nets use anchors weighing 1 – 5 lb. Nets are reported to be set away from the nearshore area in summer (on clay and/or silty loam substrates), and along the shoreline near Easterville in the winter.

Natural habitat disturbances include ice and wave action, and are expected to be more significant than any disturbance from the fishery. Ice results in gravel, cobbles, and boulders up to a metre in diameter being lifted several metres off the lake bottom by shifting ice. Wave action resuspends finer materials distributing them to deeper areas of the lake. Resuspended sediments are estimated to be accumulating below the deposition boundary depth at a rate of 1-2 cm per decade. With such natural disturbances ongoing, all habitats that the assessed fishery interacts with are considered 'less sensitive'[6], for assessment under v3.0 of the Standard.

Gear must be marked and cannot be left in place when not actively being fished. There is no information on lost gear; this is not reported.

7.1.3 Monitoring arrangements

Fish catch is recorded from commercial landings and an index netting programme. Composition of catch landed differs significantly between index nets and commercial gillnets.

Commercial fishers' landed catch that is sold through a fish dealer must be reported on a Fish Purchase Form (FPR) and its predecessor (the Daily Catch Record). Catch weights by species are recorded at the packing shed. The licence holder name, fisher number and fisher signature must be included on the FPR. Copies of FPR are distributed to the fisher, the buyer, the agent (who uses the form as a shipping invoice), and the Government. The packing shed staffer who weighs the catch is a member of the local community. They are trained by Presteve Foods Ltd, the owner of the packing station, but employed by the Cedar Lake Fisheries Association. (Fishers pay a fee to the Association to support its activities). From the packing shed, the landed catch is transported out-of-province to Presteve's packing station in Ontario. Deliveries of fish are checked on arrival at the packing station. In the past, any misalignment of fish delivered with delivery records was charged back to

[6]MSC Standard v3.0 SA3.11.3(a): The team shall define a less sensitive habitat as a habitat that would be able to recover to at least 80% of its unimpacted structure and function within 20 years if fishing were to cease entirely.

fishers, and the government notified. It is uncertain if this continues. This two-step arrangement provides some verification of the quantities of landed catch taken, though not independent from the UoA. The Cedar Lake Fisheries Association and Presteve are distinct entities. Presteve pays the fishers for their catch.

Fishers are provided a weekly printout of the catch delivered to the packing shed. Fish dealers provide weekly electronic reports to Manitoba Natural Resources and Northern Development (Fish and Wildlife).

There is also the legal ability for fishers to make direct catch sales. Catch sold directly must be reported on a Trade Record by the fisher. (Private sales are minimal to non-existent for the Cedar Lake fishery).

Quantitative information is not collected from the commercial fishery on discarded catch, which would not be landed for sale. Similarly, any fish deemed non-saleable at the packing shed would not be recorded. (Index netting information could be used to make inferences about potential discards from the commercial fishery).

Index nets are set at 12 sites in the southeast basin of the lake annually. The nets are set by a commercial fisher with one or two technicians, and the catch is processed jointly with Manitoba Natural Resources and Northern Development (Fish and Wildlife) staff. Index netting in the Southeast Basin is conducted annually because this basin receives the greatest commercial fishing effort. Every 3 years, 12 similarly selected stations are fished in the shallower Northwest Basin to better understand the entire Cedar Lake fish community and populations. Index netting is conducted in late August and early September over approximately 5 to 7 days.

The index net sampling protocol is well documented. The protocol includes coarse and fine-mesh nets, with a range of mesh sizes designed to catch large and small-bodied fish. Catch information recorded includes catch weight, numbers, and percentages by species. Some biological sampling also occurs. The power of the index netting programme to detect changes in walleye abundance (as the target species) has been estimated. The level of index net effort is around 50% of the effort needed, on average, to detect a 20% decrease in the number of walleye caught in meshes $\geq$76 mm. To achieve 70% and 80% power, 37 and 50 sets would be required, respectively.

No quantitative catch records of ETP/OOS species are available from the commercial fishery. Index netting provides some information (zero bird catch 2008-2022, for a known quantity of netting effort), noting that gear specifications differ from commercial fishing gear.

Habitat information documenting the lake's physical, chemical, and biological conditions has been collected since 2009 through the Coordinated Aquatic Monitoring Program (CAMP). This programme is operated by the Government of Manitoba and Manitoba Hydro. The location of habitat and ecosystem-focused CAMP sampling are coincident with the location of fishing activities in the lake. The Southeast Basin is sampled annually, while the West Basin is sampled every three years. Benthic macroinvertebrates have been sampled in both nearshore and offshore areas and characterised in terms of species abundances, species richness, and species diversity. Ecological status of habitats is characterised based on total number of invertebrates, EPT:C ratio (combined abundances of Ephemeroptera [mayflies], Plecoptera [stoneflies], Trichoptera [caddisflies] relative to the abundance of Chironomidae [non-biting midges]), total taxonomic richness (family level), and EPT richness.

A District Monitoring Control and Surveillance Operational Plan is drafted annually, which provides the basis of MCS work and deployment of resources within the region. Compliance monitoring is undertaken by three Conservation Officers, through patrols conducted during the year. Shore-based inspections and a patrol boat are used in summer. Skidoos are used in winter. Officers increase their presence on the lake if notified of potentially non-compliant activity. Patrol logs were introduced in 2021/22, and record the number of fishers and nets checked, the number of compliant and non-compliant incidents, the compliance issue identified and the location. In that year, five fishers and 11 nets were checked. One net was found to be non-compliant, and charges were laid re improper marking of gillnets. Also in 2021/22, two warnings were issued relating to permit conditions. Officers also review commercial fish production records to determine potential issues/violations with respect to quotas.

7.1.4 Meeting the ERF requirements

Strengths and weaknesses in relation to the ERF are summarised in Table 6 and Table 7.

Table 6. Key strengths identified in the Cedar Lake fishery, in relation to the Evidence Requirements Framework.

Strengths
Some key components of a catch monitoring system are in place.
The index netting programme and CAMP provide independent information on various components of the lake ecosystem, including fish communities and habitats.
Stock assessments are available for two main in-scope species.
Time series data to support ETP bird population trend assessments is available from external programmes.
There is a compliance programme in place, which recently initiated the collection of structured patrol log information.
There is a strong relationship between the fishery client and government fishery managers, and the fishery is relatively small, involving 40 licensees. These characteristics support agility in management and operations.

Table 7. Key weaknesses and possible solutions identified in the Cedar Lake fishery, in relation to the Evidence Requirements Framework. Solutions in italics contribute to meeting TG1 or PG1 requirements only and cannot meet higher guideposts. Other solutions shown contribute to meeting TG2 or PG2 requirements (and higher guideposts).

Weaknesses	Possible solutions
Independent verification of catch requires strengthening.	• *Index netting conducted to mimic the commercial fishery, setting commercial gear (analogous to the 'reference fleet' approach).* • *Verification of landed catch by a third-party at the packing shed, at a level that is representative of the UoA (noting that this will not address discards or ETP/OOS catch).*
A programme of independent observation is not in place.	• Introduce a programme of independent observation appropriate to the remote location, tight-knit local community, and small vessels in operation. • COI is possible for observers recruited from the community. This could be mitigated by recruiting observers as socially distant as possible from fishers, introducing policies for observers to not monitor their immediate families, and training and payment of observers by the Government management agency. (The strong sustainability culture among the UoA should contribute to community members being effective as observers). • Observers could be assigned to fishing operations daily. Rotating observers among fishers improves representativeness and reduces impacts on fishers.
Lack of quantitative information on discarded catch	• Establish a programme of independent observation that includes recording discarded catch (catch monitoring on vessels in summer and at ice fishing locations in winter).
Lack of information on unobserved mortalities	• Consider the level of unobserved mortality in the fishery, and/or infer from index netting and/or other comparable fisheries.
Lack of stock status information for lake whitefish, lake sturgeon	• Compile existing information and collect new information as appropriate to understand the status of these stocks.
Quantitative data on ETP/OOS captures is not available from the commercial fishery.	• *Consider the extent to which independent verification is in place through the index netting programme.* • Establish a programme of independent observation.
Available information on population status of two ETP birds is dated.	• Update status and trend information using information that appears to be available.
There is general, not detailed, information on fishing locations (limiting the potential for assessment of habitat impacts).	• Require fishers to report fishing locations, e.g. using GPS, landmarks, grid maps. • Verify a proportion of reported locations, to ascertain the accuracy of reporting (e.g. by Conservation Officers conducting spot checks and/or transects in fished areas). • Establish a programme of independent observation (catch monitoring on vessels in summer and at ice fishing locations in winter).
The trueness of compliance information cannot be evaluated effectively, with respect to relevance and completeness.	• Continue the use of patrol logs to build an evidence base enabling the evaluation of compliance effort relative to the scale of the fishery. • Record any additional or opportunistic compliance monitoring that occurs. • Enhance and/or redirect compliance effort if not representative of the UoA.

7.2 Western and Central Pacific Ocean tuna longline fishery

Information sources:

See section 10.2.

7.2.1 Fishery description

Across all tuna target species and gear types, almost 100 tuna fisheries are currently certified or in assessment in the Pacific Ocean. Twenty-two of these are longline fisheries. These fisheries are diverse, occurring within national jurisdictions and on the High Seas, encompassing smaller and larger vessels, and including distant water operations. In the Western and Central Pacific Ocean (WCPO), fishery management is underpinned by the WCPFC Convention. Almost 2,000 longline vessels were active in the WCPFC Statistical Area in 2021, and the total catch of the key tuna species reported in 2021 was 194,800 t (including albacore, bigeye, yellowfin and skipjack). This case study is provided as an example WCPO longline fishery. Identifying details of the fishery have been anonymised at the request of the fishery client. Many of the issues and possible solutions identified are expected to be relevant to other WCPO longline fisheries.

A detailed regulatory framework overarches longline fishing operations in the WCPFC Convention Area. This includes reporting and monitoring, control and surveillance requirements, various catch and capacity limits, and prohibitions on retention of certain species. WCPFC has also adopted best practice handling guidelines to promote the survival of ETP caught in longline operations, e.g. seabirds, turtles, mobulid rays. Management frameworks of other regional bodies and individual nations (applicable to EEZ-based fishing activities) may include additional regulatory measures (e.g. reporting requirements, spatial closures, national ETP designations).

The case study is focused on a fishery operating in the EEZ of a Pacific Island coastal state. There are three flag states and more than 50 vessels in the UoC. Flag states include Pacific Island and distant water fishing nations. Longlines are up to 50km in length, with around 1 km of mainline between floats and 25 hooks per basket. Branchlines around 20 m long and circle hooks are used. There are larger (>35 m) and smaller (<35 m) vessels operating in the fishery, and these types of vessels conduct longer (~80 day) and shorter (~50 day) trips respectively. Hook depth during fishing ranges from around 50 – 300 m.

7.2.2 Scoring elements

In-scope species

In-scope main species include the target tuna species in alternate UoAs (South Pacific albacore *Thunnus alalunga*, WCPO bigeye *Thunnus obesus*, WCPO yellowfin *Thunnus albacares*), and Pacific blue marlin (*Makaira nigricans*). Two bait species are also main (Indian oil sardine (Oman) *Sardinella longiceps*, Japanese pilchard (Pacific) *Sardinops sagax*).

A range of minor species are caught, largely from unmanaged stocks. One minor species is used as bait (Pacific saury *Cololabis saira*).

Stock status has been rigorously assessed for the main WCPO tuna species, including as described in the assessment report.

As assessment of stock status of Indian oil sardine is not available. However, on average, the UoAs used 906 t/year as bait, across the three years of available data (2016-2018). Average landings 2012-2020 were 161,395 t/year. Bait use in 2018 was 340 t, and 2019 reported landings from the stock in Oman were 416,096 t). Therefore, bait used by the UoAs comprises an extremely small proportion of reported landings.

Stock status of the Pacific stock of Japanese sardine was estimated as above MSY in 2019, with fishing mortality around FMSY in 2019 and predicted to remain so for 2020.

Stock status of most minor species has not been assessed. Exceptions are southwest Pacific striped marlin, swordfish and WCPO skipjack, for which stock assessments have been accepted by WCPFC. Pacific saury stock status has also been assessed, and this assessment accepted by the North Pacific Fisheries Commission.

ETP/OOS species

Out-of-scope species caught by tuna longline fisheries in the WCPO include seabirds, turtles, cetaceans, and pinnipeds. Many of these species are also ETP, e.g. due to protection designated in national jurisdictions, listing on CITES and CMS appendices, and inclusion in Annex 1 of the Agreement on the Conservation of Albatrosses and Petrels.

Various chondrichthyan species are also ETP in WCPO longline fisheries. These species may be protected at the RFMO level, within national jurisdictions or designated ETP by MSC requirements (e.g. as a result of listings on CMS and CITES Appendices and not meeting the requirements of modification criteria specified under SA3.1.4 of the Standard).

At the EEZ level, all sharks, rays and chimaeras are legally protected. Retention of these species and their parts is prohibited. Non-retention takes precedence over any fins naturally attached (FNA) policy.

Examples of ETP/OOS caught in the focal fishery are listed in Table 8, with summary stock/population status information.

Table 8. Summary of stock status of example ETP/OOS scoring elements caught in the focal fishery. WCPO=Western Central Pacific Ocean; RMU=Regional Management Units.

Scoring element	Summary of information used to understand status
Blue shark (Southwest Pacific) *Prionace glauca*	Stock status was assessed in 2021. 90% of model runs showed $F_{2020} < F_{MSY}$. 96% of model runs showed the biomass to be above SB_{MSY}. Minimum estimated SB of 0:3S_{B0}. There in uncertainty in the model, but on average, the stock does not appear to be overfished and overfishing is not occurring.
Shortfin mako shark (South Pacific) *Isurus oxyrinchus*	The assessment models had high levels of uncertainty and sensitivity, and very few models provided outcomes considered plausible. However, the authors concluded that relatively consistent estimates of fishing mortality and related reference points suggest recent catch declines may have reduced fishing mortality below critical levels.
Bigeye thresher shark (South Pacific) *Alopias superciliosus*	The stock status is unknown. A risk assessment conducted in 2017 found that post-capture survival rate scenarios of 30-70%, in most years there is a >50% probability that fishing mortality is greater than a derived sustainability threshold based on 0.5r, and a >20% probability in most years based on 0.75r (where r is maximum intrinsic population growth rate).
Silky shark (WCPO) *Carcharhinus falciformis*	SB_{2016}/SB_0 is estimated at 47%. Biomass is estimated as above MSY while there is considerable uncertainty around this (SB_{2016}/SB_{MSY} = 1.178; 95% CI: 0.590-1.770). Fishing mortality is estimated to be above FMSY (F_{2016}/F_{MSY} = 1.607, Pr($F_{2016} > F_{MSY}$) = 84%). Overfishing is occurring, while the stock is not yet overfished. The stock was predicted to decline to a level below SB_{MSY} within around 5 years if the catch continued at "current" levels.
Giant manta (WCPO) *Manta birostris*	Taxonomic resolution of mobulid rays in WCPO observer data was low until the mid-2000s. The average capture rate for manta and devil rays combined was 4.2 individuals per million observed hooks (for the years 2016-2018). Given data and reporting limitations, a spatial risk assessment was considered the most appropriate method for an assessment of the species in the short term. Life history information is scarce.
Olive ridley turtle (Western Pacific RMU) *Lepidochelys olivacea*	IUCN Red List: Vulnerable with decreasing population size; last assessed in 2008. Considered to be subject to high bycatch impact, high threat, and low risk.
Loggerhead turtle (South Pacific RMU) *Caretta caretta*	IUCN Red List: Vulnerable with decreasing population size; last assessed in 2015. Considered high risk, high threat, high bycatch impact.
False killer whale *Pseudorca crassidens*	IUCN Red List: Not Threatened, unknown population trend

Habitats

Pelagic longline gear has transient impacts on the water column and would only interact with other habitats when gear is lost. Hooks would degrade over time, such that buoys, longline, and branchlines would be the residual elements of potentially lost gear. Hooks lost could be inferred based on the available information (hooks onboard at the start and end of the trip). There is no information on other gear lost.

In the EEZ the fishery operates in, some spatial closures to fishing have been implemented to protect reef habitats. VMS data were considered by the assessment team to provide evidence that the closures are well respected.

7.2.3 Monitoring arrangements

WCPFC requirements for longline fisheries include a 5% minimum level of observer coverage (WCPFC CMM 2018-05). Coverage may be considered as number of hooks, days fished, number of trips, and days at sea. This requirement has been in place since 2012. The number of hooks most accurately reflects the level of fishing effort monitored by observers deployed in a fishery. The case study fishery's Public Certification Report sets out estimates of coverage based on the proportion of landed albacore catch observed, in the absence of information supporting other metrics. Observer monitoring in the UoAs covered an average of 3.5% of albacore catch, ranging from 1.4 – 5.2% in the years considered (2015 – 2018). The assessment team noted that this method was suboptimal for determining catch composition at anything beyond order of magnitude indications, but was necessary due to the limitations of the available information. National prioritization of observer placements on domestically-flagged vessels fishing in the EEZ within which the certified fishery operates to reach a coverage level of 20% may have resulted in reduced coverage of foreign-flagged vessels such as in the UoA.

In the EEZ where the UoA operates, the coastal state's national observer programme's observer capacity is supported by WCPFC/FFA-trained observers available on-call from other Pacific Islands' national observer programmes. FFA member-nations' observers are trained by the Secretariat of the Pacific Community (SPC) and FFA under the Pacific Islands Regional Fisheries Observer (PIRFO) framework and standards. Competency standards are established for observers, and debriefers. Standards are periodically reviewed and updated. Observer and debriefer manuals and forms, and videos from observer training sessions are available online. The PFIRO programme is recognized as meeting the requirements of the WCPFC Regional Observer Programme (ROP).

The WCPFC ROP is a well-established component of the WCPFC management framework, established in 2007 and effective since 2008 (WCPFC CMM 2007-01). The scope of the ROP is set out in WCPFC CMM 2018-05, and it is supported by a suite of documented systems, protocols and processes. Programme documentation is detailed and publicly available.

Other elements of the catch monitoring system include VMS (required by WCPFC and monitored in real time by government officials in the coastal state as well as FFA, and with published standards, specifications and procedures), port inspections and at-sea boardings (scale and scope unknown in relation to the UoAs). The majority of the UoA catch was reported to be landed in a Pacific port outside the EEZ and coastal state where fishing takes place. In that port, systematic inspections by that government's fisheries officers occur. Usually one of two agents from the coastal state in which the UoA operates, who are based in the landing port, will also conduct offloading inspections and collect the trip completion and offloading hardcopy forms.

Fishers maintain logbooks on retained catch. E-reporting of catch, bycatch and protected species interactions was reported to be in place except on some vessels operated by one flag state in the UoAs; this was a work in progress when the assessment took place. E-reports and scans or copies of any physical logsheets are submitted to the government management agency regularly – reports are described as submitted daily, weekly or after the completion of a trip.

WCPFC CCMs are required to complete annual country reports, and the Commission produces an annual Compliance Monitoring Report.

7.2.4 Meeting the ERF requirements

Strengths and weaknesses in relation to the ERF are summarised in Table 9 and Table 10.

Table 9. Key strengths identified in the WCPO longline fishery in relation to the Evidence Requirements Framework.

Strengths
The observer programme is established and well-documented.
Stock/population status is known for most main UoA-impacted stocks.
VMS provides robust information on compliance with spatial closures to protect coastal reef habitats.
A legislated non-retention policy is in place for sharks.
Comparisons have been done by WCPFC CCMs of the efficacy of observers and EM for collecting catch and operational information in WCPO longline fisheries.

Table 10. Key weaknesses and possible solutions identified in the WCPO longline fishery in relation to the Evidence Requirements Framework.

Weaknesses	Possible solutions
Independent observation does not meet ERF requirements.	• Expand current observer programme and/or introduce electronic monitoring to provide the level of independent observation required.
It is unclear whether observers are collecting information on all direct impacts of the UoA on ETP/OOS species, including vessel interactions.	• WCPFC ROP observer protocols exist to record interactions with vessels, as one example of interactions that do not result from longline hooks directly. If already implemented, information from these protocols should be made available. This area of observation could be expanded as part of increasing the level of independent observation overall.
Unobserved mortality is not currently considered for ETP/OOS.	• This can be considered using published literature.
UoA impacts on ETP/OOS stocks and populations are poorly understood.	• Compile information available including improved information on UoA impacts collected from higher levels of independent observation. Consider UoA impacts on ETP/OOS stocks using the body of information available.
Documentation of monitoring, control and surveillance activities relevant to the UoA is unavailable.	• Useful information would cover interruptions in VMS functionality, number of vessel inspections completed, landings monitored, at-sea boardings undertaken, and penalties applicable in the case of non-compliance. Protocols for information capture should also be documented. • Protocols for handling and storing monitoring, control and surveillance information should also be documented (if not already).
EM reporting requirements have not yet been set by WCPFC, but standards are in development.	• The efficacy of EM in WCPO longline fisheries is well researched, and this is a viable method of independent observation for WCPO longline fisheries. WCPFC adoption of EM standards would support EM implementation.

7.3 New Zealand hoki (*Macruronus novaezelandiae*) trawl fishery

Information sources:

See section 10.3.

7.3.1 Fishery description

The New Zealand hoki trawl fishery comprises two UoAs within a trawl fishery that also catches two other species (hake *Merluccius australis*, ling *Genypterus blacodes*) through targeted fishing or as bycatch from hoki-directed effort. Hake and ling UoAs are not considered in this case study. All in-scope fishing occurs within the New Zealand EEZ.

Hoki are widely distributed through New Zealand waters. Adults tend to occupy deeper waters while juveniles prefer shallower depths. Distribution varies seasonally. The main spawning aggregations occur in Cook Strait and off the west coast of the South Island, and these become a focus for fishing activity in winter. Smaller aggregations can also occur. Outside the spawning season, fish disperse and fishing activity is concentrated on the Chatham Rise and Campbell Plateau.

Most fishing occurs between depths of 300 – 700 m, using demersal or midwater trawl gear. Spawning aggregations are mostly fished midwater (e.g. 81% of tows were midwater, 2020/21) while trawling outside the spawn is predominantly demersal (e.g. 99% of trawl tows were demersal, 2020/21).

Various voluntary and regulated spatial and temporal management measures have been implemented in the fishery over time, designed to meet management objectives for the target species. Legislated Benthic Protection Areas are in place in the New Zealand EEZ, as part of the management regime for benthic habitats. These areas are closed to demersal trawling and dredging. Regulations are in place specifying seabird bycatch reduction measures that must be in place during trawl tows, to reduce the risk of seabird strikes on trawl warp cables. (Such strikes can be injurious and fatal).

7.3.2 Scoring elements

In-scope species

Catch composition recorded by government fishery observers comprises around 80% target species, and more than 40 other species. Excluding hoki, only six species comprise >1% of the catch and none comprise 5% or more. Catch composition was broadly stable 2013/14 – 2017/18, the most recent year for which this information is available. Discarded catch of the hoki fishery and others it is assessed alongside (see above) comprised 6% of the total catch, in 2016/17.

There are no main species. Stock status information (such as stock assessments) is available for some, but not most, minor in-scope species.

ETP/OOS species

OOS caught in the hoki fishery include seabirds, pinnipeds and cetaceans. These taxa are all designated ETP in New Zealand. Two chondrichthyan species were also designated ETP. The basking shark (*Cetorhinus maximus*) is a legally protected species in New Zealand. The leafscale gulper shark (*Centrophorus squamosus*) was designated ETP using MSC criteria (Table 11).

The quality and quantity of information on population status of ETP species varies considerably (Table 11).

Table 11. ETP/OOS taxa reported caught in the New Zealand hoki fishery 2015-2020, and summary information on population status. The risk ratio (RR) is an estimate of annual hoki fishery related deaths (excluding vessel interactions) as a proportion of the Population Sustainability Threshold (PST). PopI: Proportion of carrying capacity K after long-term constant exploitation rate (See references for information sources).

Scoring element	Summary of information used to understand status
Basking shark *Cetorhinus maximus*	IUCN Red List classification of Endangered with a decreasing population. Observed capture rate 0.01/100 tows, 2015-2020. Conservation status is Vulnerable in New Zealand waters, with aggregations not detected since the 1990s. Qualitative risk assessment score of 13.5/25 points.
Leafscale gulper shark *Centrophorus squamosus*	IUCN Red List classification of Endangered, with a decreasing population. Species comprised ≤0.1% of the annual observed hoki fishery catch, 2013/14 – 2017/18. Conservation status is Not Threatened in New Zealand. Qualitative risk assessment score of 18/25 points.
New Zealand fur seal *Arctocephalus forsteri*	IUCN Red List classification of Least Concern with an increasing population. Estimated average annual catch 210 animals, 2013/14 – 2017/18. Estimated population size of 200,000. Population impact by NZ fisheries (PopI): 0.749–0.937 (90% credible interval).
Common dolphin *Delphinus delphis*	IUCN Red List classification of Least Concern; unknown population trend. Insufficient data to quantitatively assess fishery risk.
Salvin's albatross *Thalassarche salvini*	IUCN Red List classification of Vulnerable. Population size estimated at ~80,000 adults; unknown trend. Assessed risk of the hoki fishery to the population; RR = 0.120.
Campbell albatross *Thalassarche impavida*	IUCN Red List classification of Vulnerable. Population size estimated at ~43,000 adults; increasing trend. Assessed risk of the hoki fishery to the population; RR = 0.010.
White-capped albatross *Thalassarche steadi*	IUCN Red List classification of Near Threatened. Population size estimated at ~203,600 adults; decreasing trend. Assessed risk of the hoki fishery to the population; RR = 0.042.
Westland petrel *Procellaria westlandica*	IUCN Red List classification of Endangered. Population size estimated at 8,000-14,000 adults; unknown trend. Assessed risk of the hoki fishery to the population; RR = 0.068.
Black petrel *Procellaria parkinsoni*	IUCN Red List classification of Vulnerable. Population size estimated at 5,500 adults; stable trend. Assessed risk of the hoki fishery to the population; RR = 0.009.
Flesh-footed shearwater *Ardenna carneipes*	IUCN Red List classification of Near Threatened. New Zealand population size estimated at 10,000-15,000 breeding pairs. Decreasing trend. Assessed risk of the hoki fishery to the population; RR = 0.008.
+ 2 additional marine mammal taxa and ~40 additional seabird taxa	

Habitats

Reporting fishing locations is required, via fishers' catch and effort reports, which transitioned from hard copy to electronic reports from 2017. Electronic reports provide more granular information than was available previously. In addition, regulated automated geospatial position reporting is in place, through devices meeting government-set specifications (including VMS, AIS).

The trawl footprint has been analysed from multiple perspectives, including depth zones, fishery impact timeframes, target fisheries, surficial sediments and environment types identified by the bespoke 'benthic-optimised marine environment classification'. Overall, the deepwater trawl footprint (which includes the hoki fishery) covers 25% of the seabed at trawlable depths (i.e. <1,600 m), for the years 1989/90-2018/19. Sediment types affected by deepwater trawl fishing include carbonate, gravel, mud and sand.

Biogenic habitats including VME-indicator taxa occur within the trawl footprint. Three orders and one family of habitat-forming corals are legally protected taxa in New Zealand waters. These species have been the focus of particular research and monitoring efforts in the last decade, e.g. on fishery impacts, predictive distribution modelling, and genetic connectivity.

Research undertaken in New Zealand waters on benthic habitats (including corals and other biogenic habitat-forming organisms) has included investigations of the impacts of trawling. For example, research has explored effects of trawling including physical disturbance, destruction of organisms, effects of sediment resuspension, post-fishing mortality, long-term changes to benthic assemblages including coral abundance, and timeframes for recovery.

As at 2021, 19.6% of the New Zealand Territorial Sea and 30.2% of the EEZ were closed to demersal fishing including trawling, through a range of spatial control measures.

7.3.3 Monitoring arrangements

Government fishery observers have been deployed in the hoki fishery for decades. In the 10 years 2010-2020 (the most recent year for which information was available), observers were present onboard vessels to monitor 19 – 40% of tows annually. Overall, 37% tows were observed on average, 2015-2020. Observer monitoring rates broadly track fishing effort, with both occurring throughout the year and peaking June – August. Observer duties cover catch sampling, including catch of target, non-target and ETP species. They also report on implementation of voluntary and mandatory measures intended to reduce fishery impacts on protected species (e.g. seabird bycatch mitigation measures).

Observers take photographs of ETP species caught in the fishery using documented protocols. They also retain selected dead seabird specimens onboard, for expert necropsy onshore. Similarly, observers photograph corals landed in trawls, and collect voucher specimens which are provided to experts onshore who confirm identifications. Marine mammals are photographed for confirmation of identifications onshore, and genetic samples are taken from dead animals before their bodies are returned to the sea.

Compliance monitoring is a key component of fishery management. Risk profiling is conducted on an ongoing basis. Compliance personnel monitor fishery catch reporting and geospatial position reporting, including compliance with area closures. Observer information also contributes to compliance activities, including risk profiling, investigations and prosecutions.

The observer programme and compliance monitoring (as well as some fisheries research) are funded through a legislated cost recovery programme. Thus, these activities are paid for by industry levies in whole or in part, while they are operated by the government.

7.3.4 Meeting the ERF requirements

Strengths and weaknesses in relation to the ERF are summarised in Table 12 and Table 13.

Table 12. Key strengths identified in the New Zealand hoki fishery, in relation to the Evidence Requirements Framework.

Strengths
Independent observation by human observers is in place on around 37% of tows, and is conducted in accordance with documented protocols. The observer programme includes observer training, briefing and debriefing processes.
Observers record fishery catch composition, including non-target and ETP species, as well as information on fishing operations that can be used for compliance monitoring, and to understand fishery impacts (e.g. deployment of seabird bycatch mitigation measures).
Identifications of ETP caught during observer deployments are generally confirmed by experts.
Analytical methods used for estimating ETP catch are robust, published and subject to review.
There is some information available on the unobserved mortality of seabirds in the fishery.
There are risk assessments available that explore fishery impacts on most ETP species.
Fishery and environmental risk factors contributing to captures of some ETP taxa have been explored.
Population research programmes are undertaken for some ETP species interacting with the fishery, contributing to an understanding of status and fishery impacts.
Fisher reporting of fishing locations is required, in electronic form and near real-time. Regulatory requirements for automated geospatial position reporting are also in place. Therefore, high quality information is available on the distribution of fishing effort relative to habitats, and also for monitoring compliance with habitat protection areas closed to fishing.
Habitat classifications and predictive modelling continue to develop, providing good information with which to evaluate fishery impacts on habitats, including sensitive habitats.
Fishery research outputs produced from government-funded work are generally published online, and therefore there is a substantial body of knowledge relevant to the fishery that is available to MSC assessors and stakeholders.

Table 13. Key weaknesses and possible solutions identified in the New Zealand hoki fishery, in relation to the Evidence Requirements Framework.

Weaknesses	Possible solutions
Additional information is required to evaluate the representativeness of observer monitoring among the UoA fleet, including with respect to smaller vessels.	• The assessment report includes information on fleet characteristics across the three target species trawl fisheries that are assessed for MSC certification. Refining this for each assessed fishery would be informative. Presenting information on systems for observer allocation including how this considers fleet characteristics would facilitate the evaluation of representativeness.
Observed catch composition information is not available after 2017/18.	• For information to be considered up-to-date, more recent catch composition data should be compiled. (It appears such data have been collected, based on observer coverage levels reported to be in place).
Vessel interactions (seabird deck strikes) are not incorporated in mortality and risk estimates for ETP/OOS species currently.	• Update data inputs to mortality and risk estimates to include vessel interactions, to facilitate assessors' consideration of this component of the fishery's 'catch' as required by the Standard.
Legislated FNA requirements apply to some, but not all, shark species.	• The FNA policy applicable in the UoAs must cover all shark taxa or a non-retention policy must be in place for all sharks. Implementation of the policy would then be evaluated using the ERF.
Most fishery-dependent data not collected by observers (e.g. fisher-reported catch and effort) is managed by an organisation owned by the seafood industry, that is engaged by government.	• Systems and processes in place to manage the lack of independence of this data manager, and to mitigate the apparent conflict of interest, require evaluation (including documentation).

7.4 South Georgia Patagonian toothfish (*Dissostichus eleginoides*) longline fishery

Information sources:

See section 10.4.

7.4.1 Fishery description

In this fishery, demersal longlines are set at depths of 700 - 2,250 m around the island of South Georgia in the South Atlantic. The fishery is managed by the Government of South Georgia and the South Sandwich Islands (GSGSSI) within the South Georgia EEZ and takes place within the area covered by the Convention on the Conservation of Antarctic Marine Living Resources.

The fishery has limited entry and is subject to a TAC for Patagonian toothfish as the target species, spatial and temporal controls to protect ETP species and benthic habitats, and limits on catch composition designed to prevent any non-target species forming more than 5% of the catch. The fishery is only allowed to operate during the austral winter (May-Sept) and vessels can only fish at night, as part of a comprehensive strategy to mitigate impacts on seabirds.

7.4.2 Scoring elements

In-scope species

The only main in-scope species in the fishery is Humboldt squid (*Dosidicus gigas*), which is sourced from outside the UoA (Peru) and used as bait.

As a species complex, Macrouridae (4 species) make up 5% of the catch. However, it is likely that no individual species comprises more than 2% of the catch. Blue antimora (*Antimora rostrata*) is the only other in-scope species for which catch is not negligible but still minor, at 2.2%. Two species of skates are also minor catch elements. A skate tagging programme has been in place since 2006. Tagging information has been used to assess skate biomass and fishery impacts.

Five other bait species sourced from outside the UoA have also been used in minor quantities. Of these, two are used on an ongoing basis: Argentine shortfin squid (*Ilex argentinus*) sourced from the Atlantic/Falkland Islands and northeast Atlantic mackerel (*Scomber scombrus*) from Norway.

ETP/OOS species

All seabird and marine mammal species in the UoA are protected.

A low number of seabird mortalities have been reported by observers. Since 2016, 77 seabirds have been reported from the fishery as killed or with injuries likely to substantially reduce long-term survival. 94% of these birds were white-chinned petrels (*Procellaria aequinoctialis*). Other taxa included black-browed albatross (*Thalassarche melanophris*) and southern giant petrel (*Macronectes giganteus*). In 2019 the start date of the fishing season was pushed back by 2 weeks to avoid overlap with the tail end of the seabird fledging and there have only been 2 incidental mortalities since then.

Vessel strikes accounted for 27 recorded mortalities in 2020. One vessel reported 16 bird mortalities arising from collisions with the vessel: ten unidentified petrels and shearwaters, three South Georgia diving petrels (*Pelecanoides georgicus*), one white-chinned petrel, one diving petrel (*Pelecanoides urinatrix*) and one giant petrel (*Macronectes* spp.). The UoA is presently carrying out research into the impact of vessel strikes on seabirds.

No marine mammal mortalities have been recorded in the fishery since 2014.

There is one catch record of the porbeagle shark (*Lamna nasus*). This species is evaluated as ETP based on MSC requirements relating to its listing on Appendix 2 of both the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and Convention on International Trade in Endangered Species (CITES).

Habitats

The less sensitive habitats encountered are fine, flat muddy and sandy habitats with small erect fauna and burrowing infauna. There are very limited interactions with some sensitive habitats with larger and more fragile erect faunal species.

The GSGSSI has recognised that whilst the fishing gear is not effective at retaining benthic invertebrates and VME indicator species. To address this, observers have attached small underwater cameras to longlines deployed in parts of the UoA to gather data from the seabed about the extent and nature of these interactions.

The use of EM to monitor interactions with benthos has also been investigated. Predictive habitat modelling has been undertaken. Initially cameras were deployed opportunistically, whenever possible, on a high proportion of longlines, however data collection has now been refined with the development a GSGSSI "camera protocol" for making ongoing observations of UoC interactions with seabed habitats. This protocol is due to be implemented in 2023 and requires the mandatory deployment of cameras on longlines set within four VME buffer zones in addition to within designated Benthic Closed Areas. It also identifies seven further priority areas for camera deployments in areas where data is currently sparse.

A number of No-Take Zones have been implemented within the Maritime Zone where the fishery is prohibited from operating to protect vulnerable benthic taxa and also provide a refugia for toothfish and bycatch species.

7.4.3 Monitoring arrangements

Scheme of International Scientific Observation

Observers are deployed in accordance with the requirements of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Scheme of International Scientific Observation (SISO). This Scheme was adopted in 1992, under Article XXIV of the CAMLR Convention. Since then, all fishing vessels operating in the Convention Area have been required to carry at least one scientific observer.

At the Commission level, CCAMLR agrees on the information requirements to be met by observers. These are documented in a manual for observers that is prepared by the CCAMLR Secretariat, with data collection forms and 'Cruise Report' templates also prepared to capture the required information. Observer programme materials are available online. The CCAMLR Secretariat coordinates implementation of SISO through national technical coordinators designated by Commission Members.

CCAMLR require that fishery observations encompass target species, bycatch species, interactions with ETP/OOS, and deployment of mandatory seabird bycatch mitigation devices. CCAMLR observers in this assessed fishery typically monitor 20-30% of all hooks hauled on a trip. The observer determines the sections of a haul that they will monitor at random before hauling takes place, and informs the vessel operator of their sampling plan. The logbook data can be inspected by the vessel skipper during a fishing trip, but the Cruise Report is confidential. It is submitted by the observer to CCAMLR at the end of the trip and then released to the CCAMLR Receiving Member as a record of the trip.

GSGSSI often add additional sampling and scientific requirements to the fishery observer work plan for enhanced data collection (e.g. additional seabird and marine mammal observations, collecting fishery samples for research projects, and monitoring interactions with VME taxa).

Electronic monitoring

After an initial trial starting in 2014, basic EM is now a licence requirement for all vessels in the fishery. Operators have also voluntarily installed enhanced EM across the fleet including electronic sensors fitted to equipment aboard the vessels including the baiter, hauler, hook counter, hatch doors, and haulers. EM is used to monitor all longline setting and hauling operations, e.g., to verify compliance with regulations such as the deployment of tori lines and night-setting. Infra-red cameras are used at night, capturing imagery of tori lines deployed during setting. EM imagery and associated information must be retained by the vessel for 24 months following the expiry of their fishing licence.

There is ongoing discussion at CCAMLR about the role of EM in fishery monitoring, recognising the complementarities and respective strengths of the two monitoring methods. EM could contribute to reducing observer workloads improving overall monitoring coverage, and enable automating of some compliance checking routines (e.g. enabling the linking of GPS and day length data to verify that line setting time complies with licence requirements).

Compliance monitoring

Compliance with fisheries regulations governing the timing and location of activity is also monitored. VMS equipment is used to determine fishing location (all vessels are equipped with two tamperproof VMS transponders), a dedicated Fishery Patrol Vessel (*Pharos SG*) is active in the UoA throughout the fishing season, all vessels are inspected before, during and after fishing operations, and military aircraft are used to overfly the UoA and monitor the location of fishing vessels independently. Regular satellite surveillance monitors the Maritime Zone for IUU vessels, and other compliance monitoring approaches, such as passive sonar buoys, are being trialled to monitor the extent of IUU fishing activity.

7.4.4 Meeting the ERF requirements

Strengths and weaknesses in relation to the ERF are summarised in Table 14 and Table 15.

*Table 14. Key strengths of the South Georgia Patagonian toothfish (*Dissostichus eleginoides*) longline fishery, in relation to the Evidence Requirements Framework. SISO=Scheme of International Scientific Observation, developed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). VMS=Vessel Monitoring System, AIS=Automatic Identification System.*

Strengths
All vessels are required to carry independent observers.
Observers record information such as gear configuration (including measures to reduce catch of ETP/OOS taxa), fishing operations (including catch composition), biological measurements of target and by-catch species, vessel sightings and data on indicators of vulnerable marine ecosystems.
Observer tasks, data recording and reporting requirements are set out in the CCAMLR SISO documentation, which applies to all fisheries within CCAMLR's purview and is also publicly available.
Observer cruise reports are submitted for validation by the CCAMLR Secretariat and are available on request subject to CCAMLR data sharing rules
Observers are trained to identify major catch components and interactions with ETP species.
There are procedures in place to ensure that observer reports cannot be influenced by the vessel crew, operators, or the UoA managing authority.
Vessels are required to submit catch reports to GSGSSI (daily) and CCAMLR (every 5 days). All product has to undergo catch verification on landing to confirm the accuracy of vessel reporting.
Reporting of vessel position using VMS and AIS is a statutory requirement. Therefore, high quality information is available on the distribution of fishing effort relative to habitats, and also for monitoring compliance with habitat protection areas closed to fishing.
Habitat classifications and predictive modelling provide good information with which to evaluate fishery impacts on habitats, including sensitive habitats.
Electronic monitoring equipment is installed on all UoA vessels and is used to support compliance monitoring.

*Table 15. Key weaknesses and possible solutions identified in the South Georgia Patagonian toothfish (*Dissostichus eleginoides*) longline fishery, in relation to the Evidence Requirements Framework.*

Weaknesses	Possible solutions
Observers do not routinely identify all non-target species to the species level. Macrouridae are difficult to identify to the species level.	Identify methods to improve estimation of interactions with individual Macrouridae species without increasing fishery impacts. Options could include: • Retaining dead animals for expert identification onshore, either as part of targeted research which develops tools for identifying species onboard on an ongoing basis, or, on a sample basis for ongoing verification purposes to inform catch estimation over time (e.g. updated every 5 years). • If the required resolution is present in existing data, consider whether habitat partitioning could be applied to infer/scale up catch composition information for Macrouridae taxa.
The monitoring system has not been designed to account for the variability of impacted species distributions or their productivity dynamics – it simply records interactions.	• Review the ecological characteristics of the impacted species to determine whether the spatial and temporal coverage of the monitoring programme is adequate to meet ERF requirements.
Vessel strikes are not incorporated in seabird mortality and risk estimates.	• Research is underway into the impact of vessel strikes on ETP/OOS bird species.
There is no census of impacts despite observer presence on all vessels in the fleet.	• Investigate whether 20-30% of hooks provides adequate accuracy in catch estimates. • Continue to investigate and implement complementary monitoring methods to increase the proportion of hooks covered, building on EM work already undertaken.

7.5 Intertidal cockle fishery

Information sources:

See section 10.5.

7.5.1 Fishery description

In this fishery, common cockles (*Cerastoderma edule*) are harvested from intertidal sandbanks. Harvesting is conducted at low tide using hand-rakes and sieves. The cockle beds are accessed by fishers using vessels. Identifying details of the fishery have been anonymised at the request of the fishery client.

The extent of cockle beds varies annually with variation in stock abundance. In the 2022 season, less than 1% of the total area of estuary mudflats and sandflats was accessed by the cockle fishery license holders.

The fishery management plan is reviewed annually. A TAC is in place for the cockles, and this is adjusted annually with reference to stock status. In 2021, the TAC was set at ~5,032 tonnes. A daily catch limit is also in place, and this and the TAC can be adjusted within the year in accordance with a specified process.

7.5.2 Scoring elements

In-scope species

There are no in-scope species taken in the fishery, due to the selectivity of the harvesting method. Fishers target areas where cockles are most abundant, and use rakes to dislodge cockles from the sand before sieving the catch. Small cockles, as well as any other small infaunal invertebrates, fall through the sieve straight back on to the sand. The resulting catch is made up entirely of cockles. Catches of non-target species and impacts on their stocks are considered to be "negligible".

ETP/OOS species

There are no ETP/OOS species caught in the fishery. However, indirect impacts on ETP require consideration due to habitat disturbance and food source disruption resulting from cockle harvest. Cockles are an important food source for birds inhabiting the estuary. Further, there are detrimental impacts on infauna inhabiting the sediments disturbed by the fishing process (collection, sorting).

Indirect impacts of this fishery on ETP birds are considered in the Standard at GSA 3.14.5.

Habitats

Habitats are tidal, and therefore defined by these dynamic twice-daily disturbances. Habitat elements include mudflats, sandflats, and estuary bays, and these are all considered to be less sensitive to fishery impacts. Two habitat types affected by the fishery are considered to be more sensitive: annual plants (e.g. *Salicornia* spp.) colonising mud and sand, and Atlantic salt meadows.

Habitat impacts of the fishery result from physical disturbance (trampling, raking of cockles). There is some evidence from the estuary that sand-dwelling taxa (e.g. crustaceans (*Corophium* spp.), molluscs (*Hydrobia* spp.), annelid worms (*Nephtys* spp.) disturbed by catch collection and sorting recover within one year. Historical data includes information on species present, providing some baseline against which to document changes in species representation and abundance. The available information shows little change since the 1970s.

The relative extent of habitat impacts due to vessels used to access the beds and harvesting is not considered to be significant at the scale of the managed area. The access and harvesting on the features of the Protected site is assessed annually by a Habitats Regulations Assessment (HRA) which takes account of risks of damage to sensitive habitats and sets out mitigation measures.

7.5.3 Monitoring arrangements

Stock structure and productivity of the target species is monitored twice annually used to set the initial TAC for each year.

Fishers submit landings data to the fishery management authority, through daily catch return reports. These data are used to monitor stocks, progress against TAC and review daily catch limits.

Fishers are required to place their catch in cockle bags issued by the management authority. Cockle bags are individually labelled with licence holder numbers and have accompanying documentation detailing catch date, area, landing location and catch weight, each document is triplicate with one accompanying catch, one kept by the fisher & one given to the management authority.

Bird surveys are conducted at least annually, during the overwintering period.

Regular walk-over surveys of cockle beds occur, to monitor progress of the fishery (with additional surveys if needed to respond to emerging issues e.g., die offs/disease). There are also regular (random and targeted) landings inspections. During inspections, enforcement officers sample 10% of landed bags to check weight and for undersized cockle.

The management authority hosts a 24-hr emergency hotline for reporting enforcement related issues.

7.5.4 Meeting the ERF requirements

Strengths and weaknesses in relation to the ERF are summarised in Table 16 and Table 17.

Table 16. Key strengths identified in the focal cockle fishery, in relation to the Evidence Requirements Framework.

Strengths
Landings of the target species are reported to the management authority and monitored by that authority.
Habitat characteristics are mapped in the UoA.
Habitat impacts of hand-raking have been investigated.
There are no direct effects on ETP/OOS species.
Data collection on ETP birds is ongoing (overwintering surveys).
There is some understanding of indirect effects of the UoAs on ETP bird species.

Table 17. Key weaknesses and possible solutions identified in the focal cockle fishery, in relation to the Evidence Requirements Framework. (Text in italics below is relevant to meeting PG1 requirements only).

Weaknesses	**Possible solutions**
There is no reported take of non-target species, but this appears to not be monitored.	• *Expand catch verification to provide evidence that cockles are the only catch retained in the fishery.* • Establish a programme of independent observation.
Independent observation is not in place.	• Establish a programme of independent observation to provide information on catch and other direct effects of the fishery.
Compliance monitoring is evidently in place, but systematic documentation of this would be required.	• If not already in place, document the level of compliance monitoring effort, to inform an evaluation of the adoption and enforcement of management requirements.

7.6 Germany North Sea Saithe (*Pollachius virens*) trawl fishery

Information sources:

See section 10.6.

7.6.1 Fishery description

The fishery comprises eight vessels from Germany that operate in the North Sea, fishing for saithe (*Pollachius virens*) using otter trawls. Most fishing occurs on the western side of the Norwegian Trench in Norwegian, EU and UK waters. All UoC vessels are equipped with VMS transmitters which report position every 2 hours, in accordance with a legal requirement that was established in the EU in 2002. These provide an accurate position of vessel location, speed and heading throughout the extent of the fishery at all times of year. VMS data are available (Figure 3).

During the period 2018-2021 a total of 13 observer trips were carried out aboard 4 of the 8 UoC vessels. On the basis of this information and a recent review by the International Council for the Exploration of the Sea, the level of observer coverage in this fleet is estimated to be around 0.5% (Figure 3).

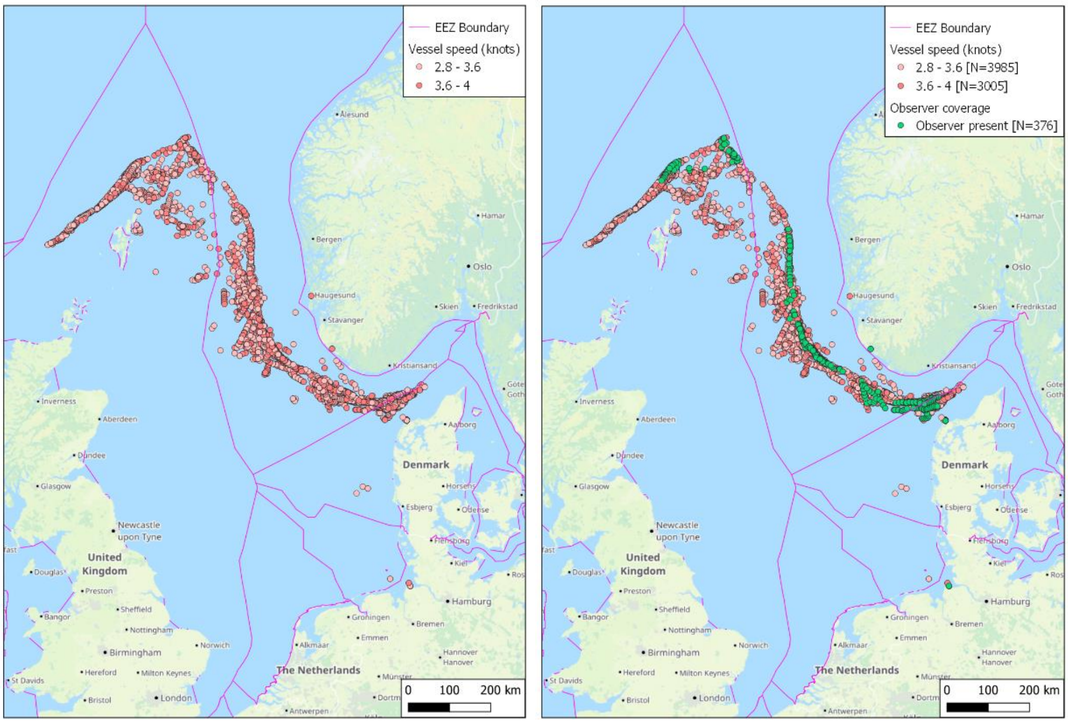

Figure 3. VMS data for the German North Sea Saithe trawl fleet in 2022 at fishing speeds (left) and showing the VMS records transmitted when observers were aboard the UoC vessels (right, green dots). (Source: ICES 2022a)

7.6.2 Scoring elements

In-scope species

Forty in-scope species have been recorded by observers. Only two of these have ever comprised more than 5% of the catch in a single year (Atlantic cod *Gadus morhua* and haddock *Melanogrammus aeglefinus*). All other species (e.g. pollack *Pollachius pollachius*) are reported caught in numbers comprising less than 2% of the catch on average. There are no records of any sharks in the catch.

ETP/OOS species

There have been no observer reports of interactions with OOS species.

There are very small and occasional catches of one ETP species, the starry ray (*Amblyraja radiata*), which is listed as a prohibited species by the EU. Observers have also recorded small catches (~6 kg per year) of unidentified rays in samples on observer trips, which could include *A. radiata*.

In the past there have been occasional catches of another ETP species, the common skate (*Dipturus batis*) but none have been reported in the move recent five year period for which data are available.

Habitats

The location of fishing activity is recorded throughout each trip, and observers record the location of sampled hauls. The observer reports provide no information about catches of marine benthos.

7.6.3 Monitoring arrangements

The EU has an overall strategy for collecting fisheries data to support scientific advice called the 'Data Collection Framework'. There is a multiannual programme for collecting data including a list of mandatory surveys and thresholds to collect data. The programme requires, *inter alia*, that data are gathered on catches of target species, ETP species and VME indicator species at levels that are adequate to meet 'end user needs' (i.e., to allow scientific advisors to derive the necessary assessments for the taxa concerned).

No thresholds are specified in terms of observer coverage, the precision of the data, or the level of precision that the data are required to attain. EU Member States are required to submit a detailed work plan to the EU setting out how they will meet these requirements.

The German work plan sets out the survey and at-sea observer activity that will be carried out by Germany as its contribution to the DCF between 2022-24. This plan includes sampling of the eight German vessels that catch saithe and other gadoids in the North Sea throughout the year, typically a total of 4-5 observer trips each of 1-2 weeks duration, with at least one in each quarter. The tasks and procedures that observers are required to follow and the equipment that they are required to use are set out by the national scientific advisor. Observers report the quantity of each species caught, retained and discarded.

The ICES WGCATCH working group found that the data gathered by specialised ETP observers indicate higher levels of ETP interactions than the data reported by scientific observers engaged in catch monitoring and biological sampling. The effect of bias in data describing interactions between EU fisheries and ETP mammal species was examined at a workshop on mortality of marine mammals due to bycatch. It was concluded that bias is likely to be considerable.

Compliance monitoring is organised separately. The Norwegian Coastguard are responsible for compliance in Norwegian waters and the European Fisheries Control Agency (EFCA) coordinates compliance monitoring in EU waters through a Joint Deployment Plan.

7.6.4 Meeting the ERF requirements

Strengths and weaknesses in relation to the ERF are summarised in Table 18 and Table 19.

Table 18. Key strengths identified in the Germany North Sea saithe fishery, in relation to the Evidence Requirements Framework.

Strengths
The observer programme has been independently defined by a national scientific institution to meet predetermined EU objectives for data collection from fisheries.
Observers are trained fishery technicians from a national scientific institution.
Observers record fishery catch composition, including non-target and ETP species caught, using a specified sampling protocol.
Most interactions are recorded to the species level of identification.
Statutory reporting of vessel position using VMS and AIS is required. Therefore, high quality information is available on the distribution of fishing effort relative to habitats, and also for monitoring compliance with habitat protection areas closed to fishing.
Habitat classifications and predictive modelling, provide good information with which to evaluate fishery impacts on habitats, including sensitive habitats.
The Coastal States bordering the UoC collaborate through the EU Data Collection Framework and through their membership of the International Council for the Exploration of the Sea to share data and to assess fishery impacts on target species, non-target fish species, ETP/OOS, marine habitats and the marine ecosystem of the North Sea.

Table 19. Key weaknesses and possible solutions identified in the in the Germany North Sea saithe fishery, in relation to the Evidence Requirements Framework.

Weaknesses	Possible solutions
Additional information is required to evaluate the representativeness of observer monitoring among the UoA fleet, particularly for irregularly caught ETP species (starry ray and common skate).	• Statistical evaluation of the time series of observer data to determine the level of coverage that would be required to meet the Trueness and Precision Guideposts of the ERF, noting that current observer coverage is estimated to around 0.5% of fishing operations.
The monitoring system has not been designed to account for the variability of impacted species distributions or their productivity dynamics – it simply records interactions.	• Review the ecological characteristics of the impacted species to determine whether the spatial and temporal coverage of the monitoring programme is adequate.
Gear interactions with benthic invertebrate species are not recorded.	• Revise observer procedures to include recording of interactions with benthic invertebrates.

8. Acknowledgements

Many people have contributed their expertise to this project. The authors particularly wish to thank:

- participants in the fisheries certification workshop held at the International Fisheries Observer and Monitoring Conference in Hobart (March 2023[92])
- contributors to the case studies presented, and,
- T. Davies and E. Quinn, of the Marine Stewardship Council.

In completing this work, the authors greatly appreciated the support of the Marine Stewardship Council's Ocean Stewardship Fund.

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