A Review of Impact Assessments for Deep-Sea Fisheries on the High Seas

Against the FAO Deep-Sea Fisheries Guidelines

DOSI DEEP-OCEAN STEWARDSHIP INITIATIVE

Fisheries Working Group Report

July 2022

Image credit from top:
Marine E-tech, JC125
Malcolm Clark, NIWA, NZ

DOSI DEEP-OCEAN STEWARDSHIP INITIATIVE · SYNCHRONICITY EARTH · ARCADIA A CHARITABLE FUND OF LISBET RAUSING & PETER BALDWIN

Summary

The intensity of deep-sea fisheries on the high seas and the impacts on the marine environment call for effective measures to ensure that fishing does not compromise the commitments established for protecting biodiversity in the deep ocean by the United Nations. In order to prevent significant adverse impacts (SAIs) on vulnerable marine ecosystems (VMEs), high seas fishing nations agreed to stop fishing activities where VMEs are known or likely to occur unless the fishing can be managed to prevent SAIs on VMEs. To determine whether fishing activities can be conducted in a sustainable manner that prevents impacts on VMEs, States agreed on criteria for conducting impact assessments (IAs) for deep-sea fisheries through a set of Guidelines negotiated under the auspices of the United Nations Food and Agriculture Organisation (FAO Guidelines). The FAO Guidelines were adopted in 2009 (FAO 2009) and later that year the UN General Assembly (UNGA) expressly committed States to ensuring that bottom fishing is prohibited unless prior impact assessments consistent with the FAO Guidelines have been carried out. Despite progress made by States and Regional Fisheries Management Organisations and Agreements (RFMO/As) to conduct IAs, there remain significant gaps in the implementation of the IAs following the FAO criteria and commitments in the UNGA resolutions.

This report describes the results of a review of a selection of IAs for deep-sea fishing on the high seas conducted by members of the Fisheries Working Group of the Deep-Ocean Stewardship Initiative (DOSI), consisting of a multidisciplinary group of deep-sea ecology, fisheries and policy experts. The nine selected IAs have either been submitted by States to RFMO/As, have been conducted by the RFMO/A itself, or represent an independent evaluation prepared by a fishing nation. The overall goal of the review was to evaluate the content and consistency of the selected IAs against the science-based criteria established in the FAO Guidelines in light of the UNGA resolutions committing States to conduct the assessments consistent with the Guidelines.

The specific objectives of this study were to:

1) Review the IAs for deep-sea fisheries on the high seas and compare their contents to the IA criteria in the FAO Guidelines.
2) Through this review, identify any major issues with the current IAs and, where necessary, suggest ways to improve the effectiveness of future IAs in order to comply fully with the UNGA resolutions on deep-sea fishing.

The results of this review demonstrate that the IAs vary considerably in quality and detail, with little consistency in format and methodological approaches. Data availability, especially with regards to the spatial distribution of VMEs and their composite species, is the key factor impeding comprehensive impact assessments. The resulting shortcomings across all reviewed IAs are the inadequate presentation of sources of data and the unexplained rationale underpinning the assessments of the impacts of fishing.

Other key weaknesses in the reviewed IAs include:

- Consideration of impacts on many of the species associated with VMEs and on other ecosystem components apart from VMEs is missing in most IAs, with pelagic organisms largely left unaddressed.
- Assessment of uncertainties is mostly inadequate, and most IAs did not consider the implications of the data gaps or other sources of uncertainty for the final assessment and management decisions.
- Risk Assessments (RA) are missing in many documents, and if included, the focus of the RA is only on VMEs.

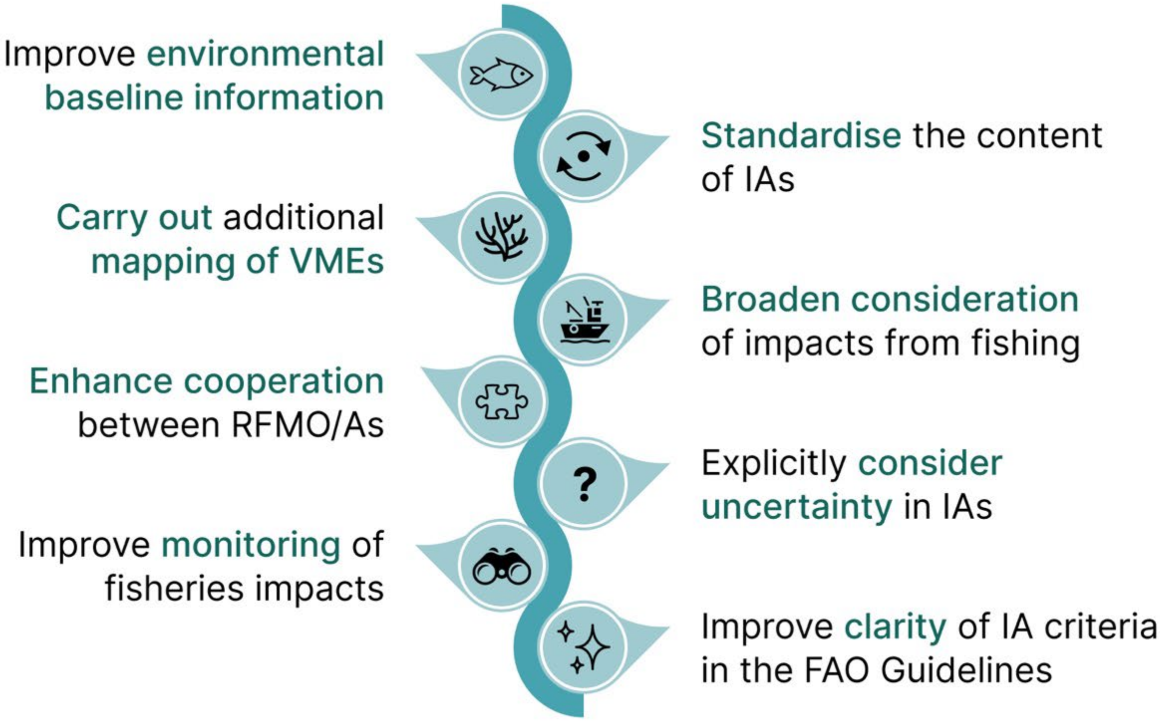
This analysis concludes that the reviewed IAs are not able to robustly demonstrate that deep-sea fishing activities on the high seas can be managed to prevent significant adverse impacts on vulnerable marine ecosystems and that fishing is conducted in a sustainable manner. For the majority of the criteria in paragraph 47 of the FAO Guidelines, the information required to effectively assess the impact of fishing is either completely lacking or inadequately addressed. Even the most comprehensive assessments are not fully compliant with the FAO Guidelines and, by extension, the UNGA resolutions.

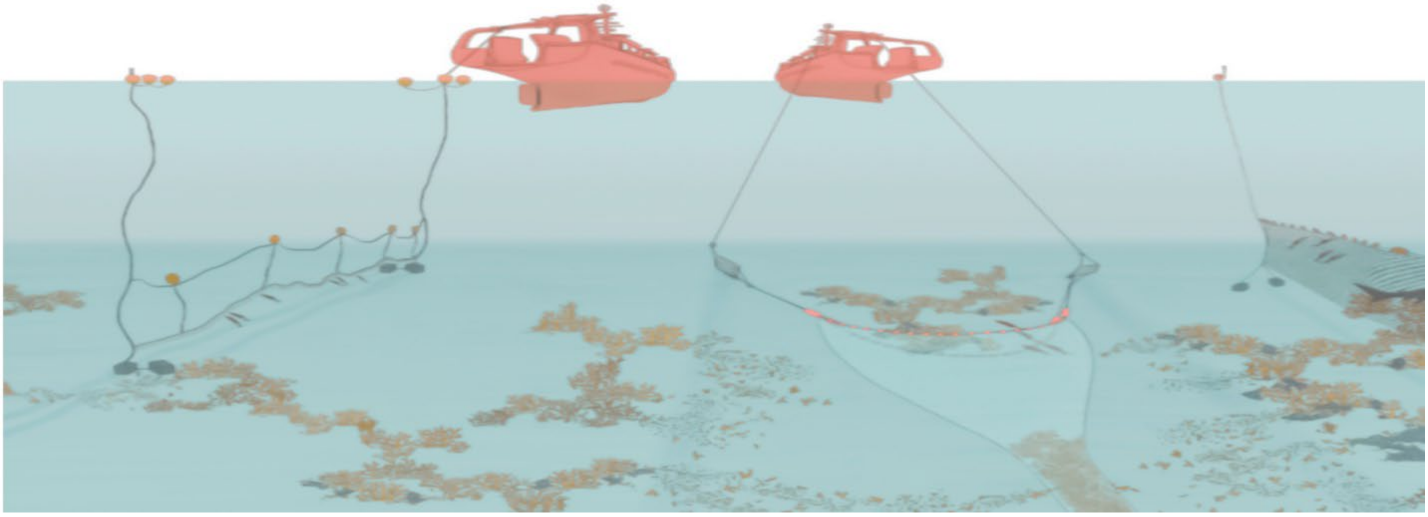
While there are severe data gaps and other deficiencies in the IAs, there are many simple ways the IAs could be improved by clarifying data sources, making data available to support claims about impacts, explaining why data are not shown, and detailing the methods used to conduct the IA. In addition to these simple improvements, the major issues discussed above could potentially be addressed by making the IA criteria more prescriptive about the information required.

Recommendations:

- Improve environmental baseline data, particularly related VMEs and fisheries through mapping areas where VMEs are known or likely to occur, application of habitat suitability and species distribution modelling, and obtaining improved information on species associated with VMEs and non-VME species likely to be impacted by deep-sea bottom fisheries;
- Standardise the content of the IAs so as to be able to compare the IAs and better assess their consistency with the FAO Guidelines;
- Assess the risk to VMEs and low-productivity fishery resources arising from fisheries in the context of cumulative impacts such as climate change and other human activities, and consider the potential for recovery;
- Improve monitoring of fisheries impacts on bycatch species and non-target fish species
- Enhance coordination and co-operation between RFMO/As and IA authors to manage historical cumulative impacts of different countries' fisheries;
- Improve consideration of uncertainties in the IAs by developing objective approaches to quantify the confidence in assessments (including data layers used in the analyses);
- Provide clearer rationale for the efficacy of mitigation and management measures to prevent SAIs on VMEs and ensure long-term conservation and sustainable utilisation of low-productivity fishery resources;
- Improve the clarity of the criteria for IAs in the FAO Guidelines where warranted and develop more detailed recommendations on their operation to assist States and RFMOs in better implementation.

Improving impact assessments for deep-sea fisheries on the high seas





Prepared by DOSI Fisheries Working Group Members:

Laura Kaikkonen, University of Helsinki, Finland (lead author and coordinator)
Lissette Victorero, Norwegian Institute for Water Research, Norway (DOSI Fisheries WG co-lead)
Matthew Gianni, iAtlantic Project; Deep Sea Conservation Coalition, Netherlands (DOSI Fisheries WG co-lead), Netherlands
Teresa Amaro, Centre for Environmental and Marine Studies (CESAM), University of Aveiro, Portugal
Sofia Graça Aranha, CCMAR, University of Algarve, Portugal
Peter J. Auster, Mystic Aquarium and University of Connecticut, USA
David M. Bailey, School of Biodiversity, One Health and Veterinary Medicine, University of Glasgow, UK
James Bell, Centre for Environment, Fisheries, and Aquaculture Science, UK
Angelika Brandt, Senckenberg Research Institute and Natural History Museum & Goethe University, Germany
Jeff Drazen, University of Hawaii, USA
Malcolm R. Clark, National Institute of Water & Atmospheric Research, New Zealand
Cherisse Du Preez, Deep-Sea Ecology Program, Fisheries and Oceans Canada, Canada
Elegbede, Isa Olalekan, Brandenburg University of Technology, Germany, Lagos State University, Nigeria, IUCN CEESP-TGER, Switzerland
Elva Escobar-Briones, Universidad Nacional Autónoma de México, Instituto de Ciencias del Mar y Limnología, Mexico
Eva Giacomello, Institute of Marine Sciences - Okeanos, University of the Azores, Portugal
Kerry L. Howell, School of Biological and Marine Sciences, University of Plymouth, UK
Andrew F. Johnson, MarFishEco Fisheries consultants Ltd, Edinburgh | MarineSPACE group, The Lyell Centre, Heriot-Watt University, UK
Lisa Levin, Center for Marine Biodiversity and Conservation and Integrative Oceanography Division, University of California San Diego, USA
Lucien Maloueki, Institut National de Recherches en Sciences Exacte et Naturelles, Congo Brazzaville
Rosanna J. Milligan, Guy Harvey Oceanographic Center, Nova Southeastern University, USA
Tina N. Molodtsova, Shirshov Institute of Oceanology RAS, Russia
Stephen Oduware, Health of Mother Earth Foundation (HOMEF) and FishNet Alliance, Nigeria
Tabitha R R Pearman, South Atlantic Environmental Research Institute, Falkland Islands
Christopher K. Pham, Institute of Marine Sciences - Okeanos, University of the Azores, Portugal
Sofia P. Ramalho, Centre for Environmental and Marine Studies (CESAM), University of Aveiro, Portugal
Ashley A. Rowden, National Institute of Water & Atmospheric Research, New Zealand
Tracey T. Sutton, Guy Harvey Oceanographic Center, Nova Southeastern University, USA
Michelle Taylor, University of Essex, UK
Les Watling, University of Hawaii at Manoa, USA
Patience Whitten, Blue Growth Law and Governance Initiative, Environmental Law Institute, USA

Abbreviations and acronyms

CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
DOSI	Deep Ocean Stewardship Initiative
DSF	Deep-sea fisheries
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organisation of the United Nations
FAO guidelines	FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (2009)
HSM	Habitat suitability model
IA	Impact assessment
NAFO	Northwest Atlantic Fisheries Organisation
NPFC	North Pacific Fisheries Commission
RA	Risk assessment
RFMO/A	Regional Fisheries Management Organisation Or Arrangement
SAI	Significant adverse impact
SDM	Species distribution model
SEAFO	South East Atlantic Fisheries Organisation
SIOFA	Southern Indian Ocean Fisheries Agreement
UNGA	United Nations General Assembly
VME	Vulnerable marine ecosystem

1) Introduction

Concerns over the environmental impacts of deep-sea fisheries on the high seas prompted the United Nations General Assembly (UNGA) to adopt a series of resolutions to address the impacts of deep-sea fisheries. The UNGA resolution 61/105 (paragraphs 80–91) adopted in 2006 committed States fishing on the high seas to apply the precautionary approach and ecosystem approach through conducting impact assessments (IAs) to determine whether bottom fisheries would put potential vulnerable marine ecosystems at risk. Based on the outcome of the IAs, States further committed to prohibit a bottom fishery if it was not possible to demonstrate that the fishery can be managed so as to *"prevent significant adverse impacts on vulnerable marine ecosystems"*.

In the second half of 2022, the UNGA will review the implementation of the previous UNGA resolutions on bottom fisheries, including the conduct and efficacy of IAs following criteria established in paragraph 47 in the International Guidelines for the Management of Deep-sea Fisheries in the High Seas (the FAO Guidelines) (FAO, 2009).

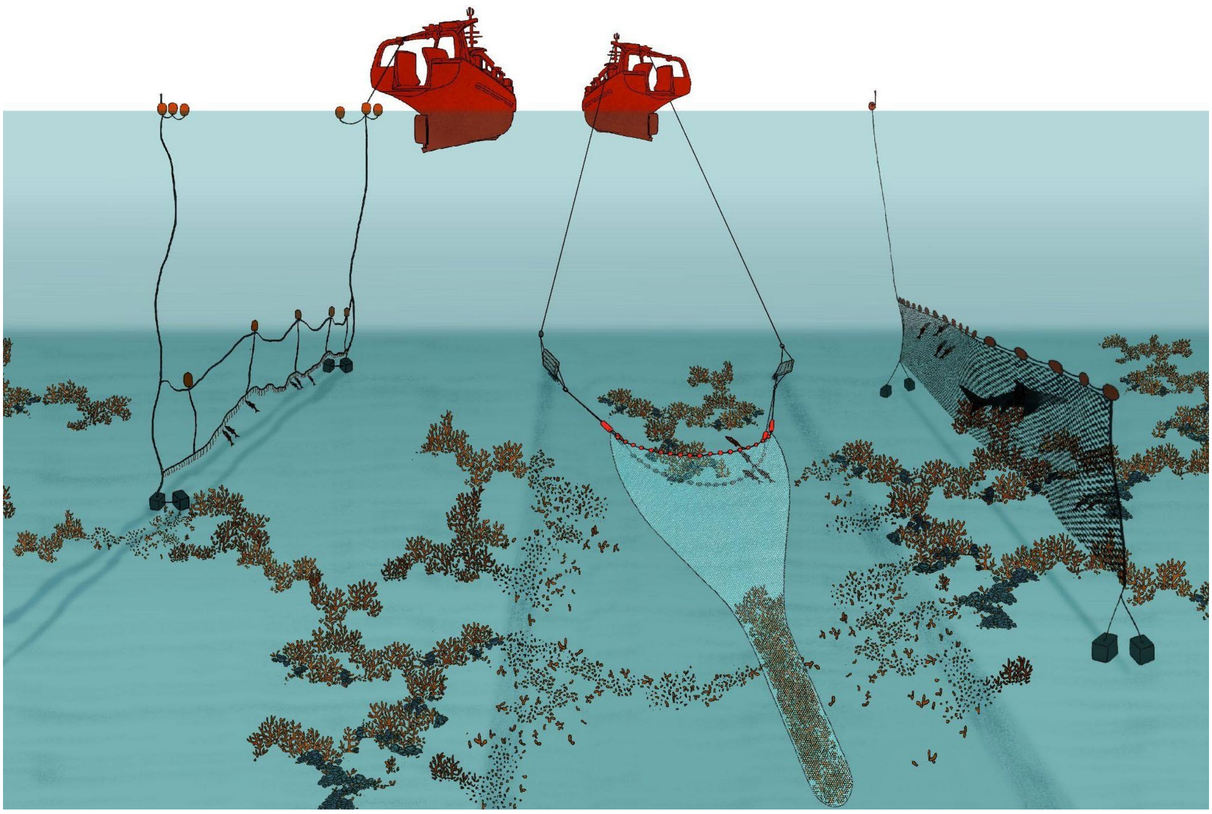
This document describes the outcomes of a review of the IAs for deep-sea fishing on the high seas conducted by members of the Deep-Ocean Stewardship Initiative's (DOSI) Fisheries Working Group. This group consists of deep-sea ecology, fisheries and policy experts and seeks to integrate science, technology, policy, law and economics to advise on ecosystem-based management and strategies to maintain the integrity of deep-ocean ecosystems. The goal of the review is to evaluate the content and consistency of the selected IAs against the science-based criteria established in the FAO Guidelines and the UNGA resolution commitments. Based on the review, this report discusses the reporting standards to elevate the quality of IAs and provides recommendations on how to improve their effectiveness.

1.1 Deep-sea fisheries and their impacts

Deep-sea fishing has occurred on an industrial scale since the 1950s. The footprint of deep-sea fishing extends across all ocean basins within the jurisdictional waters of nations that have had deep-sea fishing capacity and on the 'high seas' (areas beyond/outside of national jurisdiction). Industrial deep-sea fishing is conducted by gillnets, longlines, and trawling (pelagic and bottom), with bottom trawling being the most extensive fishing technique. Trawling is particularly prominent in deep-sea habitats such as the continental slope, ridges, banks, canyon margins, and seamounts (including knolls and hills).

Deep-sea fishing has several impacts on the environment and its biota (Box 1). The most commonly described impacts include direct disturbance of the seafloor, including: scraping and ploughing of the seabed, routine removal of most of the benthic fauna from trawling on hard substrate, declines in faunal biodiversity, cover and abundance (Clark et al., 2016); loss of biogenic habitat complexity in the sediment and destruction or disruption of microhabitat provided by sessile epifaunal organisms caused by dragging trawls over infaunal communities (Gage et al., 2005); significant biogeochemical alterations, resuspension of sediments which can smother seafloor organisms, unintentional catch of benthic animals in the fishing gear (Pham et al 2014, Kaiser et al. 2019); and the disposal of bycatch and processing wastes (Clark et al. 2016), and direct pollution (discarded/lost fishing gear). Trawling also has a substantial impact on target and non-target species, including sharks, rays, and skates, undersized fishes, or species for which fishers have no quota (Bailey et al. 2009, Zeller et al., 2017). Although bottom longlining is more selective than trawling and has a reduced impact on benthic communities, it still may affect vulnerable organisms (i.e., long-lived species with very slow growth rates), causing possible shifts in community structure if not effectively managed (Pham et al., 2014).

Fisheries for species targeted by deep-sea bottom trawling are often characterised by "boom and bust" cycles (Victorero et al., 2018). For example, unmanaged and/or large volume seamount fisheries tend to last around a decade (Clark and Koslow, 2007). Recovery of the impacted seafloor communities, if possible, takes a long time, with estimates ranging from decades to centuries (Probert et al. 1997, Althaus et al., 2009, Clark et al., 2019, Baco-Taylor et al., 2019). The recovery of fish populations may also take decades and potentially centuries after all fishing has ceased, depending on their life histories (Baker et al., 2009; Simpfendorfer and Kyne, 2009). Many potentially impacted taxa are extremely long-lived; for example, bamboo corals on seamounts may reach 4000 years (Watling et al., 2011), black corals may live up to 4200 years (Roark et al., 2009), and Greenland sharks may live over 400 years (Cailliet et al., 2001, Nielsen et al., 2016).



Box 1. Overview of the evaluated deep-sea fishing methods. Bottom long-line fishing (left) may harm structure-forming organisms, such as coral and sponges when the fishing gear is retrieved from the bottom. Bottom trawling (middle) is considered to be the most damaging to benthic ecosystems as the gear is dragged across the seabed (ICES 2010; 2021). Bottom gillnet fishing (right) causes mortality of non-target species and if lowered directly onto the seafloor, may harm vulnerable marine ecosystems. Figure not to scale. Illustrated by Anni Kaikkonen.

1.2 Deep-sea fisheries management

Given the vulnerability of deep-sea ecosystems to anthropogenic disturbances, it is critical that fishing activities in these sensitive areas are carefully monitored and regulated. Deep-sea fisheries on the high seas are managed by seven Regional Fisheries Management Organisations/Agreements (RFMO/As) and one Antarctic Treaty organisation. There are large areas where bottom fishing is not regulated by an RFMO/A (Fig. 1). Most of the RFMOs with the legal competence to manage deep-sea bottom fisheries have adopted measures designed to implement the provisions of the UNGA resolutions on managing deep-sea fisheries on the high seas and key provisions of the FAO Guidelines (Gianni et al., 2016). The key provisions of the FAO Guidelines establish internationally agreed criteria for conducting IAs of deep-sea fisheries (paragraph 47, Box 2), identifying vulnerable marine ecosystems (VMEs, Box 3) (paragraph 42), and assessing for Significant Adverse Impacts (SAI, Box 4) (paragraphs 16-20) (FAO 2009). These in turn reflect general obligations under international law, for example, the obligation of States and RFMO/As to:

"*assess the impacts of fishing, other human activities and environmental factors on target stocks and species belonging to the same ecosystem or associated with or dependent upon the target stocks*" (1995 UN Fish Stocks Agreement (Article 5(d)).

The FAO Guidelines, once adopted, were endorsed by the UNGA, including in relation to conducting impact assessments. UNGA resolution 64/72 called on States and RFMO/As to:

"*conduct the [impact] assessments consistent with the [FAO] Guidelines, and to ensure that vessels do not engage in bottom fishing until such assessments have been carried out"* (Resolution 64/72, paragraph 119 (a))

and reinforced the call on flag States and RFMO/As to adopt and implement measures:

"...*consistent with the [FAO] Guidelines, and not to authorise bottom fishing activities until such measures have been adopted and implemented*" (Resolution 64/72, paragraph 120).

The UNGA resolutions further committed States to identify areas where VMEs are known or likely to occur and to close such areas to bottom fishing unless fishing in the area can be managed to prevent SAIs on VMEs. The resolutions also committed States and RFMO/As to making the IAs publicly available so as to allow other States, non-governmental organisations (NGOs), scientists, and other concerned parties to review what has been done. This is reflected in paragraph 51 of the FAO Guidelines:

"51. States, in accordance with domestic laws, and RFMO/As should make publicly available: (i) impact assessments as described in paragraph 47; (ii) existing and proposed conservation and management measures; and (iii) advice and recommendations provided by the appropriate RFMO/A scientific or technical committee, or other relevant body."

The established RFMO/As have conducted IAs based on the FAO Guidelines that were negotiated by States in 2008 at a technical consultation established by the UN FAO Committee on Fisheries. The FAO Guidelines establish internationally agreed criteria for conducting IAs of high seas bottom fisheries (paragraph 47, see Box 2). For the most part the UNGA measures have been adopted on paper, but previous assessments have indicated that the actual implementation of the resolutions and criteria varies widely across RFMO/As and States and is often unsatisfactory (e.g., Weaver et al. 2011, Rogers and Gianni 2010, Gianni et al. 2016).

Box 2. Criteria for carrying out impact assessments (IAs) outlined in paragraph 47 in the International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO 2009).

> 47. Flag States and RFMO/As should conduct assessments to establish if deep-sea fishing activities are likely to produce significant adverse impacts in a given area. Such an impact assessment should address, inter alia:
>
> i. type(s) of fishing conducted or contemplated, including vessels and gear types, fishing areas, target and potential bycatch species, fishing effort levels and duration of fishing, harvesting plan;
>
> ii. best available scientific and technical information on the current state of fishery resources and baseline information on the ecosystems, habitats and communities in the fishing area, against which future changes are to be compared;
>
> iii. identification, description and mapping of VMEs known or likely to occur in the fishing area;
>
> iv. data and methods used to identify, describe and assess the impacts of the activity, the identification of gaps in knowledge, and an evaluation of uncertainties in the information presented in the assessment;
>
> v. identification, description and evaluation of the occurrence, scale and duration of likely impacts, including cumulative impacts of activities covered by the assessment on VMEs and low-productivity fishery resources in the fishing area;
>
> vi. risk assessment of likely impacts by the fishing operations to determine which impacts are likely to be significant adverse impacts, particularly impacts on VMEs and low-productivity fishery resources; and
>
> vii. the proposed mitigation and management measures to be used to prevent significant adverse impacts on VMEs and ensure long-term conservation and sustainable utilisation of low-productivity fishery resources, and the measures to be used to monitor effects of the fishing operations.

In 2016, the UNGA reviewed the implementation of its previous resolutions on deep-sea fisheries and concluded that further effort was required by States to ensure effective implementation of the resolutions. Based on this review, UNGA resolution 71/123 was adopted, which reiterated the importance of impact assessments for high seas bottom fisheries and committed States and RFMO/As:

"to ensure that impact assessments, including for cumulative impacts of activities covered by the assessment, are conducted consistently with the [FAO] Guidelines, particularly paragraph 47 thereof, are reviewed periodically and are revised thereafter whenever a substantial change in the fishery has occurred or there is relevant new information, and that, where such impact assessments have not been undertaken, they should be carried out as a priority before authorising bottom fishing activities".

The need for a standardised IA and reporting framework for consistent reporting of the likely impacts on VMEs and other impacted biota from bottom fishing activity has been recognised and applied within some RFMO/As (SPRFMO, SPRFMO, 2019; and CCAMLR, Sharp et al., 2009). However, there is no universally accepted IA standard across RFMO/As nor in regions where no RFMO/A is in place.

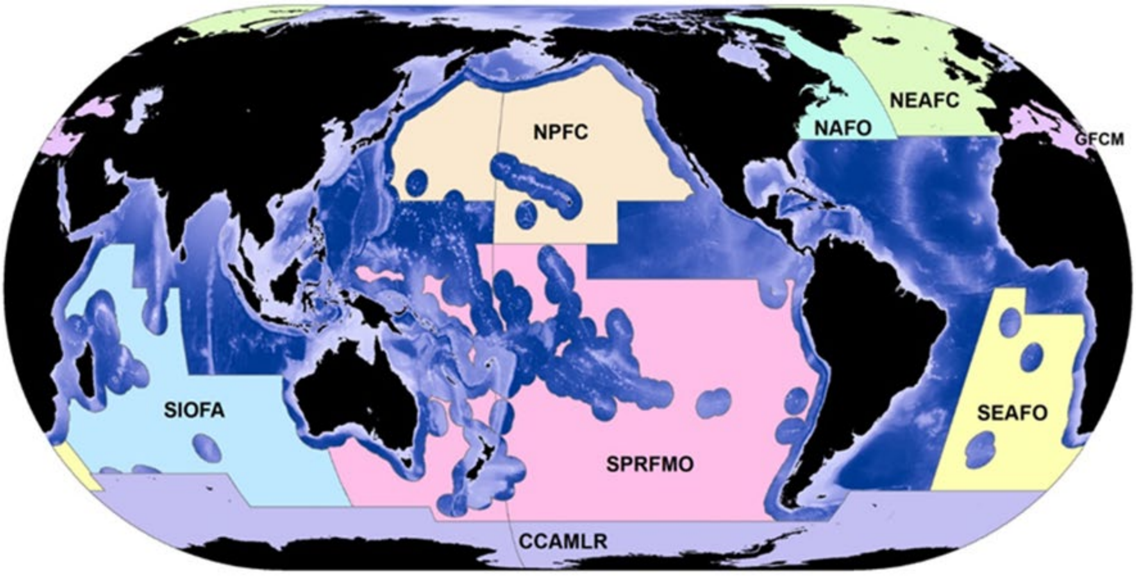


Figure 1. Map of the RFMO/As and CCAMLR regulating bottom fisheries on the high seas. From Watling et al. (2020).

1.3 Aims of the review

The intensity of fishing on the high seas, and the potential impacts on VMEs, require effective measures to ensure that the fishing permitted does not compromise the targets set for protecting biodiversity in the deep ocean established by the UNGA resolutions. In order to effectively implement the UNGA resolutions, the IAs must comprehensively evaluate the impacts fishing activities are having or are likely to have on the environment. The aim of this study was to review a set of selected IAs and to compare their contents against the criteria in the FAO Guidelines. Through this review, a further aim was to identify any major issues with the current IAs and, where necessary, suggest ways to improve the effectiveness of future IAs in order to comply fully with the UNGA resolutions on deep-sea fishing on the high seas.

Box 3. Vulnerable Marine Ecosystems

Vulnerable marine ecosystems (VMEs) are defined by the FAO Guidelines as groups of species, communities or habitats that are easily damaged and slow to recover from impacts of short-term or chronic disturbance, in this context bottom-contact fishing activities.

Criteria for identifying VMEs include:

- Uniqueness or rarity
- Functional significance of the habitat
- Fragility
- Life-history traits of component species that make recovery difficult, e.g., slow growth rates associated with longevity, and episodic recruitment.
- Structural complexity

Image courtesy of Marine E-Tech, JC125.

To facilitate identification of VMEs, the FAO Guidelines provide examples of species groups, communities, habitats, and features that could support VMEs (paragraph 42 and Annex 1 of the FAO Guidelines). In addition to these examples, RFMO/As have identified VME indicator taxa present in their jurisdictions that when present in bycatch signifies the possible occurrence of VMEs. In areas where VMEs have been identified and fishing activities are assessed to cause, or likely cause, SAIs, the FAO Guidelines recommend a range of conservation and management measures to prevent SAI on VMEs (e.g., paragraph 70–71).

Box 4. Significant Adverse Impacts

The FAO Guidelines define Significant Adverse Impacts (SAIs) as those that compromise ecosystem integrity by altering ecosystem structure or function in a permanent or long-lasting manner. The FAO Guidelines established six factors that should be considered when determining the scale and significance of an impact:

1. intensity or severity of the impact at the specific site being affected;

2. spatial extent of the impact relative to the availability of the habitat type affected;

3. sensitivity/vulnerability of the ecosystem to the impact;

4. ability of an ecosystem to recover from harm, and the rate of such recovery;

5. the extent to which ecosystem functions may be altered by the impact;

6. timing and duration of the impacts relative to the period in which a species needs the habitat during one or more of its life-history stages. The Guidelines define temporary impacts as those that are limited in duration and allow the ecosystem to recover over an acceptable period of time (set to 5–20 years). See paragraphs 17–20 of the FAO Guidelines.

2) Methodology

The IAs included in the review were selected from the IAs produced by RFMO/As or individual States to represent major fisheries occurring on the high seas across different ocean basins. As there is no shared repository for all IAs prepared by individual States or submitted to RFMO/As, this review only includes documents which were publicly available online or could be accessed through the RFMO/A's online documents libraries (IAs submitted to CCAMLR, for instance, could not be accessed). To gain an overview of the approaches taken in conducting IAs by the different RFMO/As and States fishing in different regions, nine IAs were selected for the review (Table 1). Whenever possible, the most recent version of the IA and any known updates to the IA were considered in the review. The basis of selection reflects geographical variability (i.e., IAs prepared by different States and RFMO/As), fishing conducted by different gears, and the availability of documents. Most of the assessments addressed fisheries already operating or were conducted for past fishing activities, with the exception of Japan's IA for an exploratory fishery in the SEAFO convention area. In the case of the Southwest Atlantic where no RMFO/A has been established, an IA conducted by the Spanish Institute of Oceanography undertaken for the bottom trawl fishery by the Spanish fleet operating on the high seas in the SW Atlantic was selected. While it is acknowledged that the nine IAs do not fully portray all existing approaches taken by RFMO/As and States or cover all high seas regions where bottom fishing occurs, they have been selected for the review to provide a representative sample of different methodological approaches to assess impacts of fishing as required by the UNGA resolutions.

Table 1. **Overview of the reviewed impact assessment documents.** Full details of the documents and web links to access them are contained in Annex 1.

Document title	Submitted / prepared by	RFMO/A	Area	Year	Abbreviation used in this report
Cook Islands SIOFA Bottom Fishery Impact Assessment	Cook Islands	SIOFA	Southern Indian Ocean	2018	Cook Islands SIOFA
Australian report for the Southern Indian Ocean	Australia	SIOFA	Southern Indian Ocean	2011 (and update from2020)	Australia SIOFA
Provisional Bottom Fishing Impact Assessment for Japanese bottom trawl fisheries in SIOFA convention area	Japan	SIOFA	Southern Indian Ocean	2017	Japan SIOFA
Cumulative Bottom Fishery Impact Assessment for Australian and New Zealand bottom fisheries in the SPRFMO Convention Area, 2020	Australia and New Zealand	SPRFMO	South Pacific	2020	Australia-NZ SPRFMO
An assessment of the potential impacts of Japanese bottom fisheries on vulnerable marine ecosystems (VMEs) within fished seamounts of the Emperor Seamounts region	Japan	NPFC	North Pacific	2018	Japan NPFC
Study of Vulnerable Marine Ecosystems in international waters of the Southwest Atlantic	Spain	No RFMO	Southwest Atlantic	2012	Spain SW Atlantic
Report of the NAFO Scientific Council Meeting 27 May -11 June 2021	NAFO Working Group on Ecosystem Science and Assessment (WG-ESA)	NAFO	Northwest Atlantic	2021	NAFO
Notice of Intent and preliminary impact assessment for the 2019 exploratory fishing by Japan	Japan	SEAFO	Southeast Atlantic	2019	Japan SEAFO
Spanish IA for its proposed deepwater bottom gillnet fisheries in the South Pacific	Spain	SPRFMO	South Pacific	2009	Spain Gillnet SPRFMO

To evaluate how well the studied impact assessments addressed the IA criteria of the FAO Guidelines (see Box 2), a questionnaire (Table 2) was developed to aid in the assessment of whether the IAs provide sufficient information to evaluate the impacts of fishing activities on VMEs. The aim of the questionnaire was to enable standard evaluation of contents of the IAs, particularly where the FAO's IA criteria give little or partial operational guidance on the topics the IAs should address. The questionnaire included both multiple choice and open-ended questions based on the IA criteria in the FAO Guidelines (2009) (Table 2).

Table 2. Questionnaire used to evaluate the impact assessments based on the impact assessment criteria in the FAO Guidelines (2009).

Criterion number and topic under paragraph 47 of the FAO Guidelines	Question
i. Description of the fishing activity	Does the document describe the vessels and gear types used?
	Does the document include a harvesting plan?
	Are fishing grounds described in the document (location and spatial extent)?
	Does the document describe target species (including a list of species, their ecology, and population status)?
	Does the document describe potential bycatch species (including a list of species, their ecology and population status)?
ii. Baseline information	Does the document contain information on the topographical, environmental, and other features of the area relevant to assessing the ecological vulnerability* of the area?
	Does the document describe abiotic hydrographic properties of the area (e.g., T, S, O2, pH) likely to change over time and affect habitat suitability for target species?
	Are the biological components of the ecosystem, and information on their life history characteristics, connectivity, source and sink populations and other relevant information described in the document?
	Does the document estimate/refer to the carrying capacity of the environment (e.g., approximated with estimates of surface primary production and seafloor carbon or nitrogen flux)
	Are variations in species composition, community structure by depth, latitude etc (e.g., 'biomes') specified, including both 'VME indicator' and other species belonging to the VME ecosystem?

iii. Identification of VMEs	What definition and criteria of VMEs is/are used (e.g., are existing definitions from literature cited, list of taxa/topographical features or other areas e.g., where “rare” species are known or likely to occur?)
	What methods are used to identify potential VMEs?
	If modelling studies or acoustic mapping is used, have the findings been validated?
iv. Description of used data and methods	What kind of data/information is used to assess impacts (e.g., empirical data, literature, modelling, expert assessment, fishery logs, traditional or local knowledge, not specified)
	Does the impact assessment document describe (or present) the data used in the assessment?
	Does the impact assessment document describe the methods used in the assessment?
	Are the limitations and uncertainties of the assessment (e.g., gaps in data) acknowledged and how are they addressed?
v. Assessment of potential impacts	Does the document describe the spatial extent of direct impacts on the seafloor communities and bottom water characteristics?
	Does the document describe or discuss the spatial extent of indirect impacts to nearby areas and depth zones?
	Does the document identify impacts on pelagic organisms (including the larval life stages of many species living in the benthos? (bycatch species; low productivity ‘fishery resources’, rare species (cross reference paragraph 42), other species potentially impacted by the fishing)
	Does the document define what is considered significant adverse impacts (SAI, reference paragraphs 17–20 in FAO Guidelines)?
	Does the document describe the temporal extent of the impacts?
	Are cumulative impacts evaluated (i.e., is historical fishing impacts accounted for? Are interactions between different pressures evaluated e.g., climate-related impacts)?
	Is climate vulnerability included in the VME assessment? (e.g., discussion of warming, deoxygenation, acidification impacts).
	Is the scale on which impacts are evaluated (e.g., low/high impact) explained? Does the impact assessment demonstrate the basis on which conclusions of the severity of the impacts are drawn?

vi. Risk assessment	Are the potential risks identified?
	What is the focus of the risk assessment (e.g., fisheries/VMEs)?
	What type of a risk assessment is applied?
	Is the risk assessment methodology (adequately) described?
vii. Mitigation measures and monitoring	Are possible mitigation measures described?
	Does the document identify how to monitor implementation of these measures?
	If so, has the monitoring demonstrated that the mitigation measures are having the intended effect?
	Are alternative fishing scenarios identified (including displacement of activity, change of gear types, restricting fishing effort and its spatial footprint, and no fishing)?
	Does the document compare impacts of these alternatives to the proposed implementation plan?

**Ecological vulnerability refers to potential of an ecosystem to modulate its response to the fishing impacts across spatiotemporal scales - therefore accesses the inability of an ecosystem to tolerate the impacts of fishing*
**Cumulative impacts in this context are considered to encompass the different pressures arising from fishing, accumulated effects of past fishing, as well as cross-sectoral impacts and environmental changes*

The documents were evaluated based on the following grading guidance:

No - *No mention of the topic in the impact assessment OR relevant terms appear in general preambles or as passing mentions in various parts of the document but not in the overall aims or specific objectives of the impact assessments, suggesting that the criteria were not the focus of the evaluation.*

Partial inclusion - *Key terms appear in the document, but no detail is presented in subsequent sections that focus on the specific criteria or only part of the topics included in the sections are covered.*

Yes - *Key terms of the criteria appear in clearly stated sections and are discussed in the impact assessment. There was clear discussion in the document of how the criteria in question was analysed.*

The selected IA documents were reviewed by members of the Fisheries Working Group of the Deep-Ocean Stewardship Initiative (DOSI), consisting of a multidisciplinary group of deep-sea ecology, fisheries, and policy experts (see names of co-authors of this report). Each IA document was evaluated by 2–3 reviewers, with the lead author having read all of the assessed documents to ensure consistency in the review approach. The results were discussed inter-sessionally among the reviewers to reach an agreement on the assessment results. In cases where there was discrepancy between the reviewer assessment, preference was given the middle option 'partially addressed', with additional comments included in the final assessment to clarify which parts of the criteria had been addressed (Annex 1). Based on the review results and the grade for each subsection of the IA criteria (Table 2), each IA has been attributed an overall grade. The overall grade has been attributed based on the assessment result on the majority of the subsections of the criteria (i.e., certain subsections may have received a different assessment than the average grade).

3) Results

This section presents the results of the review with respect to the IA criteria in the FAO Guidelines. Full assessment results with detailed responses to the questions regarding the implementation of the criteria are presented in Annex 1 of this report.

The reviewed IAs were conducted between years 2009–2021. The documents varied in detail, extent, and quality, with the shortest being only 14 pages (Japan for SIOFA and SEAFO) and the most comprehensive one being over 200 pages long (Australia-NZ for SPRFMO and Spain for SW Atlantic). There is little consistency in format and the methodological approaches across RFMO/As.

The reviewed IAs included both those focusing on the fishing activity and estimating the intensity of fishing in specific areas, and those prioritising assessment of VMEs to estimate impacts of fishing. Most reviewed IAs were carried out for past or ongoing fishing activities, with two of the reviewed documents addressing newly proposed fishing (Japan's IA for SEAFO and EU/Spain's IA for the proposed bottom gillnet fishery in the SPRFMO area). Overall, the main shortcoming of the IAs was considered to be the inadequate transparency regarding sources of data and the rationale underpinning the assessments of the impacts of fishing. The results comparing the IA criteria against the FAO Guidelines are summarised in Table 3.

Table 3. **Simplified overview results of the RFMO/A IA review with respect to the impact assessment criteria in the FAO Guidelines.** The responses in the cells indicate whether the IA addresses the IA criterion in paragraph 47 of the FAO Guidelines. The overall response is based on the assessment results for the majority of the subsections of the criterion (i.e., certain subsections may have received a different assessment than the overall response shown in the cell). The note 'N/A' refers to the criterion being completely omitted from the IA. Colours in the table correspond to the evaluation grades.

Impact assessment	Description of fishing activity	Baseline information	Identification of VMEs	Description of used data and methods	Assessment of potential impacts	Risk assessment	Mitigation measures and monitoring
Cook Islands SIOFA	Partially	No	Acoustic mapping = No	Partially	No	No	Partially
Australia SIOFA	Partially	No	Bathymetry, trawl catches = Partially	Partially	Partially	Partially	Partially
Japan SIOFA	Partially	No	Trawl catches = Partially	Partially	No	No	No
Australia-NZ SPRFMO 2020	Partially	Partially	SDMs, trawl catches = Partially	Yes	Partially	Yes	Partially
Japan NPFC	Partially	Partially	Visual surveys = Partially, small spatial coverage	Yes	Partially	No	Partially
Spain SW Atlantic (no RFMO)	Partially	Yes	Visual surveys, trawl catches, topographical features = Yes	Yes	No	No (N/A)	Partially

NAFO 2021	Yes	Yes	Trawl catches, SDMs = Partially	Yes	Partially	Yes	Partially
Japan SEAFO	Partially	No	Longline catches = No	No	No	No (N/A)	Partially
Spain Gillnet SPRFMO	Partially	No	Bycatch from gillnets = No	No	No	No (N/A)	Partially

Criterion i. Type(s) of fishing conducted or contemplated, including vessels and gear types, fishing areas, target and potential bycatch species, fishing effort levels and duration of fishing, harvesting plan

Description of the fishing gear and vessels was the criterion that was the best covered across the reviewed IA documents, as all IAs contained some information about the fishing activity (Table 3). Most IAs included diagrams and specifications of each vessel and gear type in detail, with the exception of Spain's IA for SPRFMO where diagrams were illegible due to poor image quality, and Japan's IA for NPFC which only mentioned the used gears.

The fishing grounds were described broadly. All reviewed IAs contained some information on the fishing grounds, but most described the area using low-resolution maps within the RFMO/A's convention area. Exceptions were Australia's IA in the SIOFA area and the Spanish study of VMEs and fishing impacts in the SW Atlantic, which contained detailed information on the area where fishing is taking place, including depth zones. While the NAFO IA also described the spatial extent of the fishing areas for each demersal fishery, only the areas where bottom trawling takes place were described in the IA document.

Target species were included by providing a list of species that the fishery is targeting. Information on the fishery was often very brief, with one IA not containing any information on the target species (Japan's IA for bottom fishing in the NPFC area) and two out of nine IAs only including a list of targeted species with no further information (the Spanish IA for gillnet fishing in the SPRFMO area, and the Provisional Bottom Fishing IA for Japanese bottom trawl fisheries in SIOFA convention area).

Fishing effort levels were documented from fishery logbooks or Vessel Monitoring System (VMS) data. However, several of the IAs were missing units for the fishing effort or did not provide information on how the footprint or fishing intensity were calculated. For instance, in the Cook Islands' IA for bottom fishing in the SIOFA region, fishing footprint was calculated from recorded trawl lengths and logged fishing hours. The results of the calculations are not shown and it is unclear how the spatial data of fishing intensity was used in the assessment. Similarly, in the Australian IA for the SIOFA region, while the IA gives estimates of the fishing footprint with respect to ecologically relevant bathomes, the footprint unit is unclear regarding the temporal aspects. Generally, the footprint of bottom fisheries and fishing effort [estimated from fishing logbook or VMS data] were indicated in the IAs, however, the intensity and specific area covered were not given. Two out of the nine documents contained no information on the intensity of the fishing operations (the Spanish IA for gillnet fishing in the SPRFMO area and the Provisional Bottom Fishing IA for Japanese bottom trawl fisheries in SIOFA convention area).

Bycatch information was given at a coarse taxonomic level, and mostly concerned bycatch of VME indicator taxa. In certain IAs, chondrichthyans and seabirds were listed as potential bycatch species (Cook Islands' IA for SIOFA, Australia-NZ IA for SPRFMO and the NAFO IA). Even in the IAs where some fish species were listed as bycatch, the information is given as the average percentage of the total catch, not providing information on their ecology or stock status (e.g., Australia's and Japan's IA for SIOFA). While some IAs mentioned high (up to 100%) observer coverage on the fishing vessels, no further bycatch data were given in the IAs despite suggesting an observer is present at all times.

Most IAs did not include a harvesting plan, nor any information about how many future operations are planned, or where. The exception was the Japanese IA for the SEAFO area, which briefly described the harvesting plan for the exploratory fishing, including proposed dates for the fishing activities. In general, information on past activity, depths and number of fishing operations per year are well covered.

Criterion ii. Best available scientific and technical information on the current state of fishery resources and baseline information on the ecosystems, habitats and communities in the fishing area, against which future changes are to be compared

The description of the baseline information on the environment was limited in the reviewed IAs (Fig. 2). Four out of the nine IAs did not contain any information on the environmental conditions in the areas targeted for fishing (Spain gillnet for SPRFMO, Japan SEAFO, Japan SIOFA and Cook Islands IA for SIOFA). In all of these IAs, such information is suggested to be available, but is not contained or adequately referenced in the documents. For instance, the Japanese IA for SEAFO references baseline information on ecosystems, habitats and communities collected by 2012-2016 exploratory fishing, but these data are not shown or detailed. Similarly, the Cook Islands IA notes that a full habitat mapping exercise has been carried out but "These results are commercially sensitive and confidential to the work of the Scientific Committee". In the absence of such information on the data used for each IA, the "best available" criterion could not be addressed in this review.

Oceanographical conditions, such as spatio-temporal variation in temperature and salinity, were considered in two IAs (Spanish IA for SW Atlantic and the NAFO IA). Information on the geomorphology of the fished area, including seafloor characteristics, topographical features (such as seamounts) was provided in two documents (Spanish IA for SW Atlantic and Japan's IA for NPFC). In the NAFO IA, information on bathymetry is shown in maps of estimates of the level of impacts on VMEs and bathymetry is noted to be used in habitat modelling and the design of current closed area network, but bathymetric data are not contained in the document. In the Australian-NZ IA for SPRFMO, information on the topographical features is used in the assessment for identifying areas with potential VMEs and spatial prioritisation, yet, the data were not presented in the document.

Only half of the analysed IAs contained any information on the state of the fishery resource (target species) (Australia's IA for SIOFA, Australia-NZ IA for SPRFMO, NAFO and Cook Island's IA for SIOFA). This omission stems from a lack of scientific information on stock structure, size frequencies, life history, recruitment, depletion status, range or distribution of the stocks of deep-sea species. Most IAs do not describe the stock status of the target species in detail, with the exception of the Australia-NZ IA for SPRFMO. However, it is acknowledged that in most RFMOs stock assessments for target species are conducted by separate working groups or processes outside of the scope of the IA. Nevertheless, references to the documents where stock assessment information can be found were not included in the IAs.

In most IAs, the document did not contain information on other ecosystem components than the species targeted by the fishery. If any additional information on the environment was provided, most reviewed documents focus on VME indicator taxa and/or other benthic fauna (Fig. 3). The exception to this is the Australian-NZ IA for SPRFMO, which included estimates of the distribution of seabirds that could be directly affected by the fishing activity. The IA also included estimates of percentages of rare species found in the existing and proposed spatial management areas. Information on pelagic ecosystem components, including non-target fish species, micronekton, and plankton, were missing in all documents, with the exception of certain fish species (teleosts and chondrichthyans) mentioned briefly as potential bycatch for the fishery. However, in all these cases, the documents simply listed the species or taxa that are potentially affected, but did not provide information on their ecology, distribution, biomass, or population status. The characteristics of the water column communities were not mentioned or further discussed in any of the reviewed IAs.

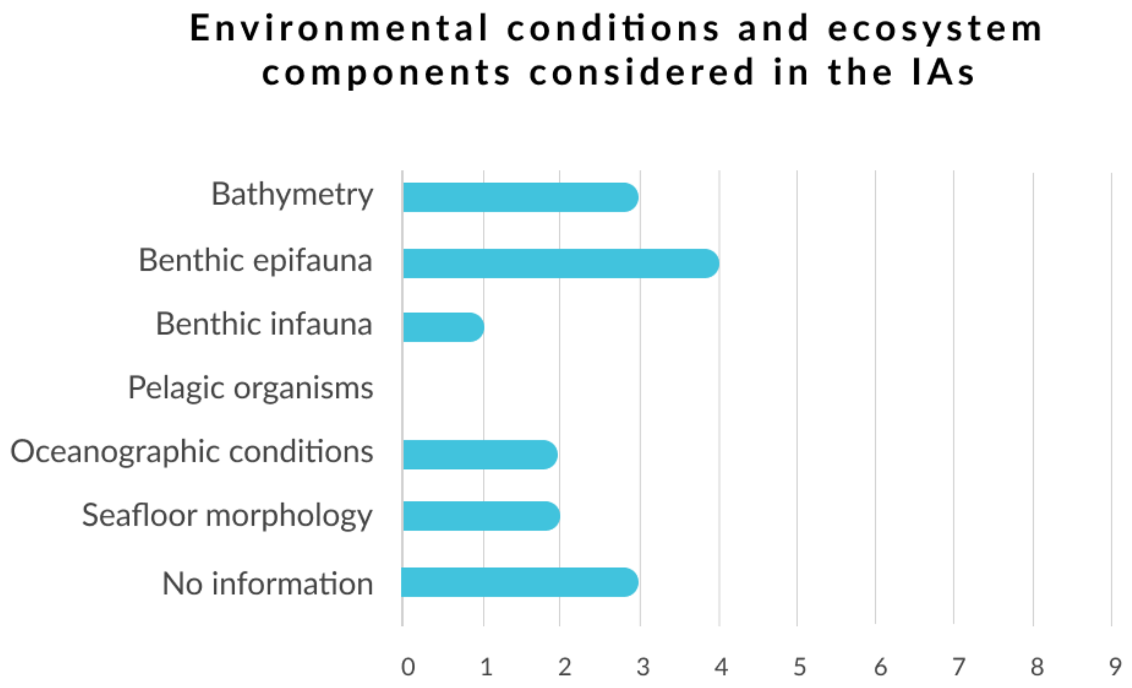


Figure 2. Number of the nine reviewed IAs including different ecosystem components in the assessment (excluding the target species for the fishery). The category 'no information' refers to the number of IAs that did not contain any information about relevant environmental conditions.

Criterion iii. Identification, description and mapping of VMEs known or likely to occur in the fishing area

Definitions of what is considered a VME varied considerably between the reviewed IAs. Some IAs specifically listed which taxa are considered as indicators for potential VME presence. For instance, the joint IA for SPRFMO prepared by Australia and New Zealand used the VME indicator taxa defined by the SPRFMO Scientific Committee to identify potential VMEs. These indicator taxa consist of 13 of the 15 VME taxa groups that were identified by the Scientific Committee as satisfying FAO Guidelines for identifying potential VMEs and that met an additional two criteria related to their suitability as VME indicator taxa (Geange et al. 2019). Similarly, the NPFC and NAFO assessments referred to taxa defined by the RFMO based on the FAO VME criteria reviewed against taxa occurring in the convention area to identify VME indicator taxa.

However, the NPFC only considers a limited number of taxonomic groups of corals as VME indicator species, which has resulted in limitations in the measures adopted to protect VMEs. In some cases, references to other parties' definitions were used. For instance, the assessment by Australia in the SIOFA area defined VME indicators based on taxa identified by CCAMLR (CCAMLR, 2009). However, while certain RFMO/As' VME indicator taxa lists are known to exist (e.g., SEAFO), they were not explicit in all reviewed IAs. In the documents where no formal definition was given, live corals and sponges were mentioned as VME indicator taxa that are considered in the bycatch monitoring.

The location of potential VMEs was most often inferred from bycatch information from observer programs and/or the fishery logbooks (e.g., in Japan's IA in the SEAFO region for longline fishing), or from trawl catches from scientific fishery surveys (e.g., in the NAFO IA) (Fig. 3). Visual seafloor surveys to identify VMEs were used in only two IAs: Spain's report on VMEs in the SW Atlantic, and to a lesser extent Japan's assessment in the NPFC area. Both of these IAs focused on the mapping of the VMEs rather than detailing the impacts of the fishing activity. Acoustic seafloor mapping was used in the IA by the Cook Islands in the SIOFA region, but no information on the validation of the mapping results was included in the document.

Habitat Suitability Models (HSMs) or Species Distribution Models (SDMs) (i.e., models that use environmental conditions to predict the occurrence of species) were used in three of the analysed IAs to identify the distribution of potential VMEs (Australian-NZ IA in the SPRFMO area, the NAFO IA, and Spanish IA in the SW Atlantic). In the NAFO and SPRFMO IAs, the VME indicator taxa data underpinning the modelling were based on scientific surveys and VME indicator taxa bycatch data. Both IAs contained detailed information on how the modelling was performed, either in the IA or the referred documents. The Australian-NZ IA for SPRFMO applied an ensemble of SDMs (random forest, maximum entropy and boosted regression tree methods) for ten taxa and the NAFO assessment presented a combination of kernel density analysis (an extrapolation technique that does not use environmental data as predictors) and random forest modelling for nine VME indicator groups. The SPRFMO IA explicitly stated that validation has been performed with an independent test dataset and included results from the validation exercise. In the NAFO assessment, the validation results were not included in the reviewed IA, but the IA references a previous submission to the NAFO Scientific Committee where the results are presented (Kenchington et al. 2019). Modelling was also used in the Spanish IA in the SW Atlantic, yet the details of the modelling are not contained in the IA and are better described in an English translation of the study (Portela et al. 2012).

Most other documents did not specify, beyond VME indicator taxa, which other natural elements ("species groups, communities, habitats and features [which] display characteristics consistent with possible VMEs"; ANNEX 1, FAO 2009) were considered when identifying potential VMEs. It was often unclear which attributes are used in the mapping of the potential VMEs in the area, but it was explicitly stated in the Cook Islands IA for SIOFA that VME features (e.g., seamounts) are not considered VMEs although they may have VMEs present. However, IAs of other RFMO/As noted that VME indicator elements, such as topographical features, are considered explicitly as potential areas for VMEs, and the Australian IA for SIOFA and the Spanish IA in the SW Atlantic used bathymetric data to identify seamounts as potential VMEs. Connectivity of areas with potential VMEs was estimated in only one of the reviewed IAs (NAFO).

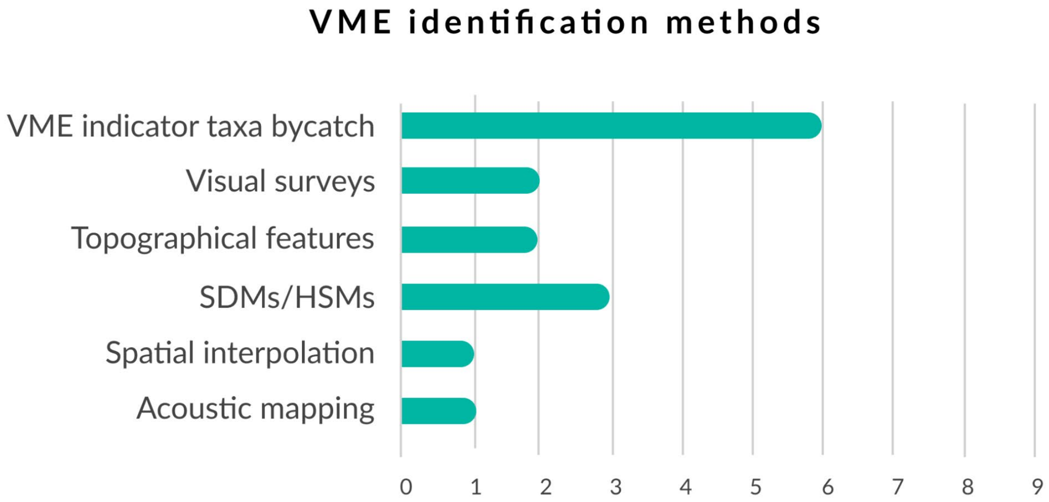


Figure 3. Methods applied in the reviewed impact assessments to identify potential VMEs. SDM stands for Species Distribution Model and HMS for Habitat Suitability Model.

Criterion iv. Data and methods used to identify, describe and assess the impacts of the activity, the identification of gaps in knowledge, and an evaluation of uncertainties in the information presented in the assessment

The majority of the data presented in the IAs originated from fishery logs or other data sources related to fishing activities, including bycatch data, VMS data, and observer data (Fig. 4). While some data sources were named in the majority of documents (with the exception of the Spanish IA for gillnet fishing in the SPRFMO area), nearly all reviewed documents had ambiguity as to the data that were used in their impact assessment (i.e., some data sources were better described than others). The data and units used were often not well specified in the documents. Either no data were shown (e.g., Spain gillnet IA for SPRFMO and Cook Islands IA for SIOFA), only part of the data were described (e.g., expert assessment is not described in the Australian-NZ IA for SPRFMO), or the units were not specified (e.g., units of "fishing footprint" are not given in the Australian IA for SIOFA).

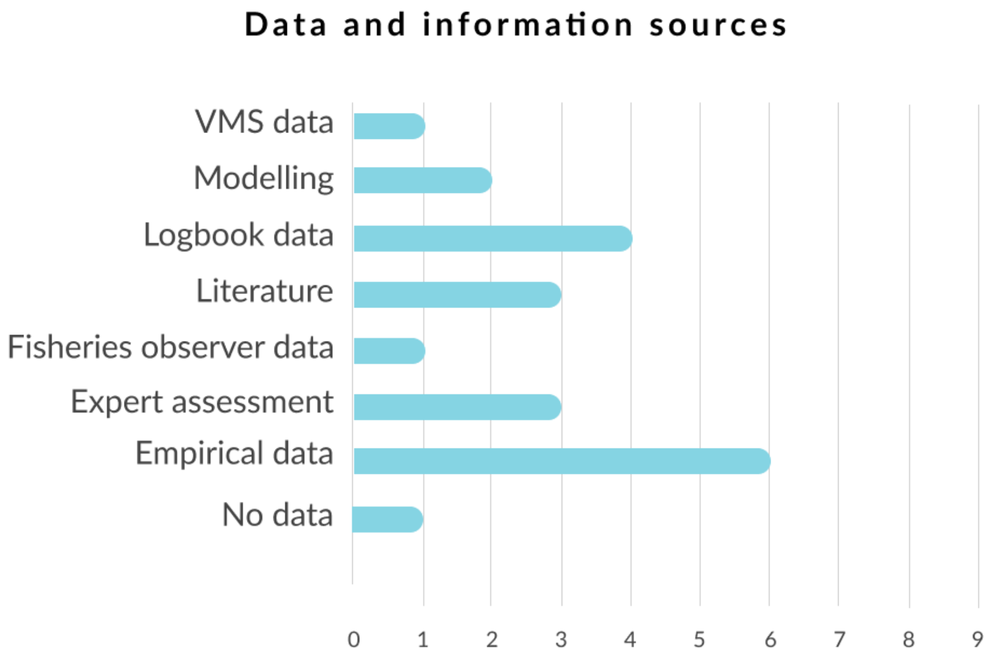


Figure 4. Sources of data and information used in the reviewed IAs to assess the impacts of fishing. VMS stands for Vessel Monitoring System.

Four out of nine IAs did not specify what kind of methods had been used in preparing the assessment. Several IAs present evidence and different types of data (with some information on e.g., how the fishing footprint was calculated), but it is unclear how the impacts of fishing on VMEs or other ecosystem components were defined. Contrarily, those IAs that described the methods used (NAFO IA, Australian-NZ IA for SPRFMO, and Japan for NPFC) did so in detail. Modelling was used in two IAs and the modelling methodology was generally well described.

Similarly, the best described source of uncertainty in the reviewed IAs was regarding the outputs of SDMs or HSMs that were used for estimating potential VME occurrence in two of the IAs (NAFO IA and Australian-NZ IA for SPRFMO). These IAs recorded model uncertainty and other related sources of uncertainty (e.g., environmental data coverage). Beyond describing the model uncertainties, uncertainty in the assessment of fisheries impacts was narrowly addressed in all of the IAs. In several IAs the paucity of data was acknowledged and highlighted. However, while the different data gaps are mentioned, few of the analysed IAs considered the implications of how these data gaps relate to the overall assessment of the impacts. They further did not give confidence ratings to the final impacts assessment or the data sources that were used. The IAs also raised other sources of uncertainty related to the cumulative impacts (e.g., climate change, other human impacts, including other types of fisheries), but did not address them directly.

Criterion v. Identification, description and evaluation of the occurrence, scale and duration of likely impacts, including cumulative impacts of activities covered by the assessment on VMEs and low-productivity fishery resources in the fishing area

This criterion of the FAO Guidelines for IAs calls for identification, description, and evaluation of the occurrence, scale and duration of likely impacts, including cumulative impacts of activities covered by the assessment on VMEs and low-productivity fishery resources in the fishing area. This criterion implies the consideration of multiple impacts from fishing, including the direct impacts from the fishing gear on seafloor ecosystems, indirect impacts to adjacent areas, as well as impacts on the water column and demersal species and past impacts from historical bottom fishing. However, most reviewed documents focused only on the direct impacts of fishing gear on benthic communities, with little evaluation of how other ecosystem components will be affected. The exception to this was the Australian-NZ IA for SPRFMO, which considered potential impacts on teleosts, sharks, rays, and seabirds.

The only IA that explicitly discussed the definition of SAI with respect to the assessed fishing activities was the IA prepared by NAFO. This IA based the SAI definition on the spatial coverage of a habitat or community being impacted. Other IAs considered SAI more generally, either in practical terms as any bottom-contact fishing activity and status of VME taxa (Australian-NZ IA for SPRFMO and Japan for NPFC) or referred to formal definitions of SAI (Australia IA for SIOFA). Five out of nine IAs did not define SAI in the IA. Several assessments (e.g., Japan's IA in the SEAFO area) stated that there will be reduced and little risk of SAI, due to the fishing gears used (in this case, longlining). However, clear reference to evidence of lesser bottom impact of the different gear types was missing. Overall, justifications for the final impact statements were not described in detail in the reviewed IAs.

The fishing footprint in the IAs was calculated for the assessed fisheries for the analysed years. Most of the analysed IAs did not explicitly refer to impacts on the seafloor or bottom-water masses, but simply calculated the fishing effort and overlapped this with VME indicator taxa distribution. The exception to this was the Australian-NZ IA for SPRFMO, which applied a metric for "naturalness" of the seafloor communities to include an assessment of the impact that this fishing has already presumably had on the VME indicator taxa, based on information on past fishing activity, in addition to the impacts from currently ongoing fishing.

While some IAs briefly mentioned potential impacts on bycatch species (such as chondrichthyans), none of the reviewed IAs considered impacts to other pelagic organisms, such as fishes, crustaceans, cephalopods, and gelatinous zooplankton that inhabit the benthic boundary layer (and in some cases are known to aggregate within this layer). Even in the case of IAs that provide a list of which groups are potential bycatch, they do not further discuss how they are affected by fishing (level of risk, number of organisms affected etc). The IAs also did not define what "low-productivity fishery resources" (e.g., non-target fish species, shellfish, cephalopods) are present, or how they would be impacted.

In seven out of the nine reviewed IAs, cumulative impacts were not included in the assessment. If cumulative impacts were addressed, they referred only to direct impacts from past fishing activities, and not to any other pressures. Most IAs, however, focused only on the fishing activity which was being assessed, and did not evaluate if other industries and fisheries operated in the area (with the exception of Australian-NZ IA for SPRFMO and NAFO). While the cumulative impacts from other sectors on the environment were mentioned in several documents, they were not further considered in the assessment and the subsequent management guidance. Climate-change related impacts, for example changes induced by warming, acidification or deoxygenation, were not considered in any of the IA documents.

Criterion vi. Risk assessment of likely impacts by the fishing operations to determine which impacts are likely to be significant adverse impacts, particularly impacts on VMEs and low-productivity fishery resources

In most IAs, risk assessments (RAs) were either missing (four of nine; Fig. 5) or the methods were inadequately described. In the IAs where a RA was included, only three were quantitative or semi-quantitative with a brief description of the methodology applied and the sources of information used in the RA (Australian-NZ IA for SPRFMO, NAFO IA, and Australian IA for SIOFA). Three out of nine RAs were qualitative, with the RA section consisting of only a statement of the level of risk without further analysis.

The focus of the RA in those IAs that did contain one was the risk of SAI on VMEs. The exception among the reviewed documents was the Australian-NZ IA for SPRFMO, which contained several RAs separately for different taxa, including: qualitative assessments for seabirds, marine mammals and reptiles; semi-quantitative or fully quantitative assessments for a range of fish stocks and other species of concern (including deep-water chondrichthyans); and a quantitative assessment for VMEs. None of the RAs considered impacts on low-productivity fishery resources.

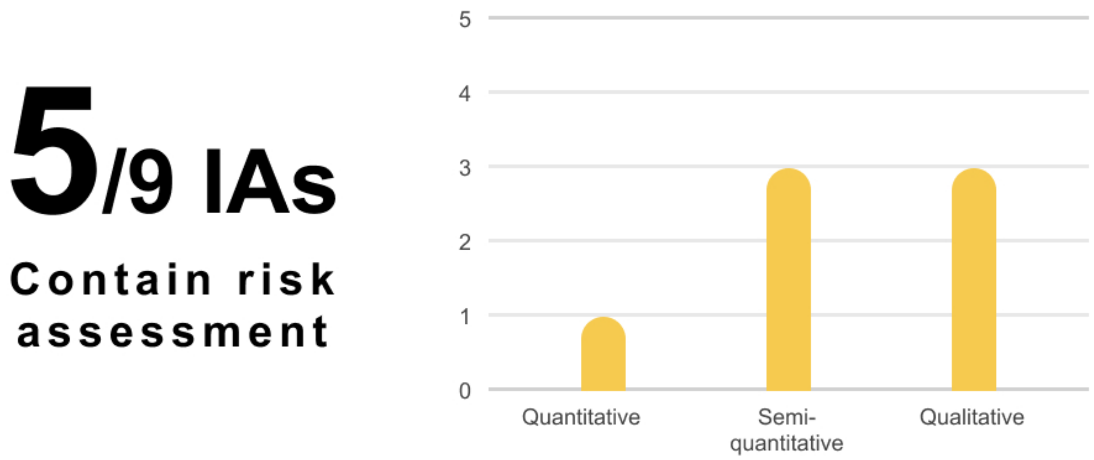


Figure 5. Type of risk assessments used in the IAs. Note that certain IAs contained several different types of RAs while some contained none.

Criterion vii. The proposed mitigation and management measures to be used to prevent significant adverse impacts on VMEs and ensure long-term conservation and sustainable utilisation of low-productivity fishery resources, and the measures to be used to monitor effects of the fishing operations

VME encounter protocols (or move-on rules**) and observer systems on vessels for bycatch monitoring were indicated as the main mitigation measures to prevent SAI on VMEs in five IAs (Australia for SIOFA, Japan NPFC, NAFO, Spain in SW Atlantic, Australia-NZ for SPRFMO). In addition, spatial conservation measures (fisheries closures) were another common measure to prevent SAI on VMEs described in the documents (e.g., NAFO, SPRFMO and NPFC). The effectiveness of the mitigation measures or how their implementation is monitored was explicitly discussed in only one of the analysed IAs (Australian-NZ IA for SPRFMO).

In several IAs, mitigation measures are considered unnecessary due to the IA concluding that the risk of SAI on VMEs is low, although in most cases these claims were not well justified in the assessment. For instance, in the Spanish IA for gillnet fishing in the South Pacific, mitigation measures were not deemed necessary as no VMEs have been identified in the area and the impact of the fishing activities is considered low in the assessment. Similarly, Japan's IA for long-line fishing in the SEAFO area, indicated that the use of long-line fishing is a less destructive fishing method and is a mitigation measure to avoid impacts on VMEs. While the documents contained some references to previous studies on the impacts of different types of fishing gear on VMEs, the IAs did not provide robust description of the environment where the fishing is proposed to take place nor evaluation of the impacts of the used fishing methods to support these conclusions.

In addition, the reviewed IAs did not consider the cumulative impact of a series of small encounters in their assessments. Monitoring measures to monitor the effects of fishing were briefly mentioned in most of the reviewed IAs, and were missing completely in only two IAs (Spain gillnet IA for SPRFMO and Japan's IA for NPFC, which focused on VME mapping). In addition, Japan's bottom fishing IA for SIOFA noted only VMS monitoring, which can be deemed a limited monitoring measure for fisheries impacts. In the NAFO IA, monitoring measures for the implementation of the proposed spatial fisheries closures were not mentioned in the document. Monitoring compliance is done via VMS records, but not explicitly recognised in this report (would be a matter for the compliance committee). Measures used to monitor the effects of fishing operations were limited to observer programmes to monitor bycatch from fishing operations (Cook Islands IA for SIOFA, Japan's IA for SEAFO and Australian-NZ IA for SPRFMO). The most comprehensive description of the monitoring measures was given in Australia's IA for SIOFA. In this IA, the original document listed possible monitoring measures but does not provide information on the implementation of these measures. The 2020 update gives additional information on the monitoring requirements, as well as VME encounter monitoring. Although most of the reviewed IAs focused on ongoing or past fishing operations, monitoring the effects of fishing on VMEs or other ecosystem components was not described in any detail in the documents.

***"A move-on rule is based on the premise that a fishing vessel will move a minimum distance from a location where species indicating the presence of a VME are captured by the gear." (Auster et al. 2011).*

4) Major issues with the impact assessments

The results of this review on a selected set of IAs by RFMO/As show that none of the IAs fully comply with the FAO Guidelines when measured against the criteria for IAs in paragraph 47 (FAO 2009). As a result, these IAs do not potentially provide adequate evidence that the fisheries described are sustainable and/or prevent significant adverse impacts.

While some of the reviewed IAs contain sufficient information on certain aspects of the impacts of fishing on potential VMEs on the high seas, the specific sections and information required by FAO Guidelines are either completely lacking or are partially covered in the IAs. This result of the review means the IAs are unlikely to comply with UNGA Resolutions 61/105, 64/72 and subsequent resolutions (e.g. 71/123) as there is no adequate assessment of potential impacts on VMEs from deep-sea fishing. The following section elaborates these shortcomings and their impact on the management of deep-sea fisheries.

Inconsistent content, use of terminology, and availability of documents

The IAs reviewed vary considerably in their approach with little consistency across the RFMO/As in data collection and quality, details of the analytical approaches, and presentation of findings. As a result, it is challenging to assess the contents of the IAs against the FAO Guidelines in order to evaluate the implementation of both the IA criteria and the subsequent management actions required by the UNGA resolutions. While some of the IA criteria in paragraph 47 of the FAO Guidelines offer little operational guidance, many IAs completely lack even the clearly defined elements, such as identification of potential bycatch species, identification, description and mapping of VMEs known or likely to occur in the fishing area, a harvesting plan and/or a risk assessment, which should be included. The lack of a standardised template for IAs also results in inconsistent terminology and reporting the results of the IA such as units used to assess the spatio-temporal impacts of fisheries, which is likely to compromise the ecological robustness of the IAs.

The review across the IAs further showed that references to additional sources of information that may be relevant for complying with the FAO Guidelines were not always adequately included in the documents. In addition, accessing all the existing IAs for deep-sea fishing on the high seas proved to be challenging, as many IAs can only be accessed through the RFMO/As restricted documents libraries or via direct requests to their Contracting Parties. This general lack of transparency with respect to data underpinning the assessment and the availability of documents conflicts with the UNGA resolutions to make the IAs publicly available (para. 51 in the FAO guidelines).

Absence of fisheries plan and inadequate description of the fishing activity

The limited description of the fishing activity in several IAs is a major issue in the reviewed IAs. Most IAs are for past or already ongoing fishing, which makes it surprising that there are such gaps in the description of the fishing activity, including the lack of harvesting plans for all but one IA, and limited identification of the spatial extent of fishing and the area in which a vessel/State intends to fish. The information gaps in present fisheries remain despite the requirement to submit a fisheries/harvesting plan as a part of the IAs [as per criteria i in the guidelines]. This omission partly stems from an interpretation by several RFMO/As to only conduct IAs for fishing activities occurring outside the established historical fishing grounds ("fishing footprint"). However, the UNGA resolutions make it clear that establishing a fishing footprint and exempting that area from conducting an IA is not sufficient, and IAs should be conducted for all deep-sea fishing on the high seas.

Lack of baseline information of the ecosystem and deficient VME identification

Data availability, especially with regards to VMEs, is the key factor impeding comprehensive IAs. The paucity of baseline information on the ecosystem in most of the analysed IAs stems from the fact that in many areas no scientific studies have been conducted, particularly in the southern hemisphere (Menegotto and Rangel 2018). This review of the nine selected IAs suggests that in many RFMO/As more information on the environment would be available than what was included or directly referenced in the IAs. Similarly, several IAs did not include information on the stock status of the target fishery. Here it is to be noted that certain RFMOs like NAFO, have separate, dedicated working groups for assessment of VMEs and target species and so, the absence of this information from work focussed upon SAIs, is not necessarily a shortcoming of the work of that organisation. However, adequate references to this supporting information are in this case warranted.

Most IAs address the identification of potential VMEs through the use of VME indicator taxa, with no consideration of how well these indicators reflect the distribution of the actual VMEs. As such, the IAs cannot provide adequate data on the variations in composition and structure of VMEs. It is important to recognise that taxonomic groups typically consist of a wide diversity of species. These species differ in their life history characteristics and their distribution can vary considerably within a single taxonomic group. Thus, the missing element in most IAs is the linkage between VME indicator taxa and the "species groups, communities and habitats" (Annex 1, FAO 2009) they indicate are present and potentially impacted by fishing operations.

In all IAs, the paucity of data on actual VMEs (e.g., on associated species, community composition, connectivity), as opposed to VME indicator taxa, was evident. The FAO Guidelines state clearly that the role of the Guidelines is to provide tools for *"the prevention of significant adverse impacts on deep-sea VMEs and the protection of marine biodiversity that these ecosystems contain"* (FAO Guidelines, para 6), reflecting similar language in UNGA resolution 61/105 (UNGA 61/105, para 80). In most areas reviewed here, no mapping has been carried out to identify VME locations or to characterise the oceanographic conditions or other ecosystem components that may be affected by the fishing activities. This lack of data has major implications on the future management of fishing operations, as it is unlikely that effective RAs of SAIs can be done if baseline information on the affected ecosystems are missing. If VME indicator taxa are used narrowly to infer potential VMEs by e.g., modelling the distribution of just one or two species, the uncertainties arising from such generalisations should be reflected in the final assessment.

Furthermore, there is inadequate consideration of all VME elements in the IAs, i.e., species groups, communities, habitats and features such as submerged edges and slopes, seamounts, canyons, and trenches, as well as hydrothermal vents and cold seeps as potential areas for VMEs. Only two of the reviewed IAs used topographical features in VME identification (Australia for SIOFA and Spain in the SW Atlantic), with certain IAs explicitly stating that topographical features are not considered as proxies for VMEs or considered in their identification. In addition, is worth noting that the first two of the criteria for identifying VMEs under paragraph 42 of the FAO Guidelines refer to areas, ecosystems, or habitats that contain rare, threatened, endangered or endemic species, yet it appears that none of the IAs have explicitly identified such areas or habitats as VMEs.

Several issues have been identified with scientific trawl surveys and encounter protocols, which were the most used method for identifying the location of potential VMEs. A major challenge with the use of bycaught organisms for identifying potential VMEs and mapping is that these practices allow for the damage to occur, which will gradually degrade ecosystems over time (ICES WGDEC 2010). These reactionary management strategies are not only of limited benefit to prevent SAIs, but also they are not designed to be used as a VME identification method. Trawl-catches significantly underestimate the biomass and community composition of the seafloor communities, making them an ineffective method to identify and map VMEs (Auster et al. 2011) (Fig. 7).

Furthermore, for example in the NAFO context, the scientific surveys are designed to survey a broad area, thus potentially impacting VMEs beyond areas where commercial fishing is taking place. Despite bycatch data being the only source of information that several of the IAs note as a basis of their assessment, little information is given of what organisms are at risk based on the bycatch data, even at a broad taxonomic scale.

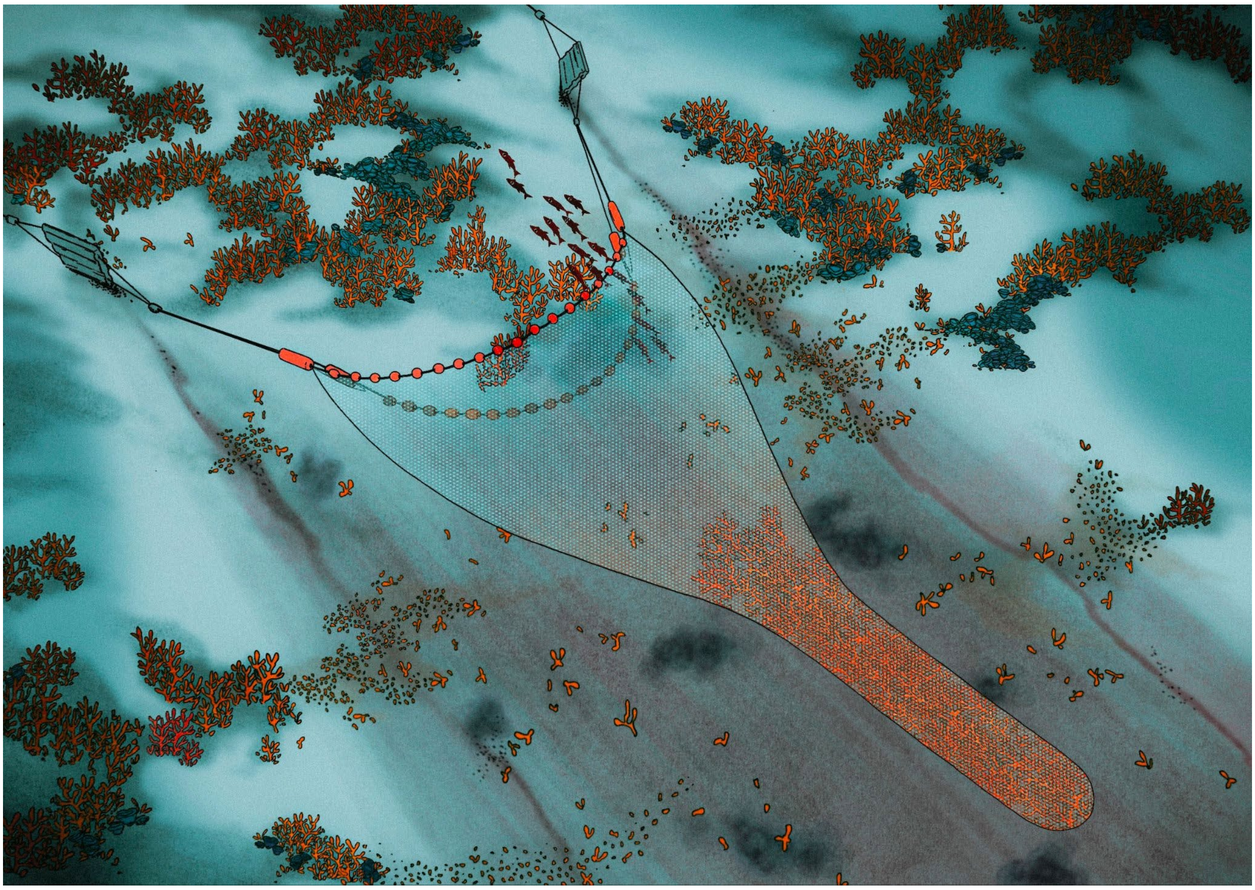


Figure 7. Issues with the encounter protocol and trawl surveys when estimating VME locations and potential impacts. The bottom trawling gear retains only a part of the VME biomass and indicator taxa, largely underestimating the VME communities on the seafloor. Figure not to scale. Illustrated by Anni Kaikkonen.

Limitations of incorporating uncertainty

Most of the IAs did not communicate the uncertainties associated with the various analyses contained within them. This issue ranges from omitting discussion on data gaps to not considering the impacts of the uncertainties in the final assessment. While RAs are mentioned in the FAO Guidelines as an element to be included in the IA, many IAs were completely lacking an RA or did not include the basic elements of even simple RAs. While some of the IAs included a subsection titled Risk Assessments, it is questionable under what premises an RA with no data, expert assessment, nor any information of the sources of the assessments could in fact be considered an RA.

While the best described source of uncertainty was in IAs that discussed the model uncertainty for estimating VME indicator taxa occurrence, the most common data gaps mentioned were related to the location of potential VMEs. Consequently, a major source of uncertainty in the assessments stems from how the risk from fishing activities interacts with the equally uncertain estimates of the VME occurrence. As most IAs only consider areas with confirmed potential VMEs based on bycatch taxa, these IAs overlook areas where VMEs are likely to occur as opposed to where they are known to occur.

This uncertainty could partly be addressed by developing metrics for the confidence given to the potential VME location and fishing activities to illustrate what is the level of precaution applied in cases of more or less certain VME occurrence. Unfortunately, the reviewed IAs show little effort to overcome these challenges by not including confidence estimates in the IAs or by complementing missing data with robust expert assessments.

Although the FAO Guidelines allow the "best available" evidence to be used for IAs, rather than specifying a level of necessary evidence, the resulting uncertainty from weaker data and analysis is not reflected in the fishing practices allowed. In the absence of detailed data on VME locations in the fishing area, a precautionary approach to avoiding all of their likely locations should be implemented until appropriate scientific data are available, rather than only avoiding areas where VME indicators are seen in trawl catches (para. 74 in the FAO Guidelines).

Overall, assessment of uncertainties and their communication is essential in supporting fisheries management, as higher uncertainties should reflect a greater precautionary approach in management decisions.

Inadequate consideration of impacts from fishing

The difficulties in defining what constitutes a SAI in the context of the fishing activity being evaluated is another major impediment to the effectiveness of the IAs. In the IAs, SAIs are not explicitly defined, with the exception of NAFO IA. This lack of an explicit definition is surprising since the FAO Guidelines establish a detailed set of criteria to assess SAIs, and these criteria could be modified or adapted for the areas and VMEs assessed. Considering the longevity of VME taxa, the 5–20-year time period defined in the FAO Guidelines (see Box 4) is relatively short and most impacts on VME taxa would thus be considered SAIs on the basis of recovery being unlikely in under 20 years (Fig. 8).

VME taxa are long-lived and their recovery from disturbance often takes longer than the 20 years limit for SAI

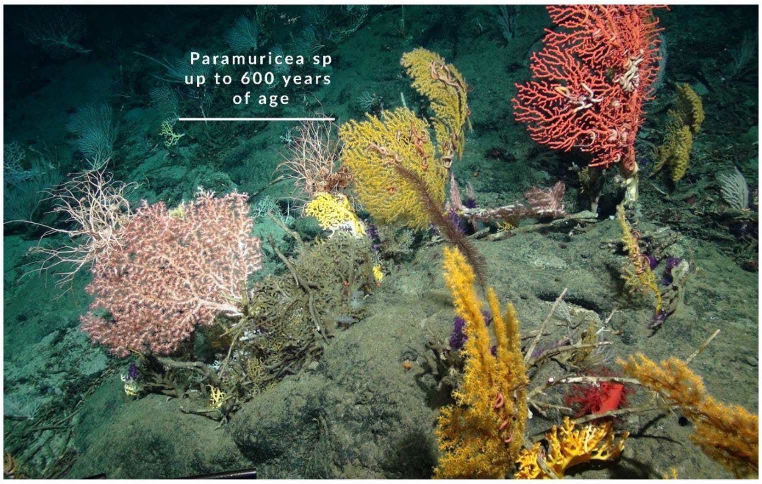


Figure 8. Many VME taxa are long-lived and their recovery from disturbance often takes longer than the 20 years limit for SAI. For example, individuals in the genus *Paramuricea* may live up to 600 years old (Prouty 2016). Image courtesy of TROPICS, JC094.

Consideration of impacts to other ecosystem components apart from VMEs was missing from most reviewed IAs, with especially pelagic organisms left unaddressed. In addition to assessing the potential risks to VMEs, according to the FAO Guidelines, the IAs should also include the target species and other ecosystem components (“low-productivity fishery resources', i.e., most of the deep-sea fish present). When reporting potential bycatch, only a few species and taxonomic groups were specifically mentioned in the IAs, despite the fact that impacts on "low productivity fishery resources" are to be assessed under the Guidelines and SAIs prevented. Furthermore, pelagic ecosystem components, including pelagic micronekton and zooplankton, are often the food supply for the target species (Drazen and Sutton 2017).

In most regions the risks from fishing remain unquantified beyond consideration of the benthic ecosystem. Furthermore, indirect impacts from fishing (such as increased turbidity, sediment plumes, and release of toxic substances from the sediment) are not considered directly, including their likely spatial or temporal extent. When indirect impacts (either on the seafloor or on the water column) are not considered, it is not feasible to estimate the sustainability of fishing and its impact on the overall ecosystem integrity.

Only three of the reviewed IAs considered cumulative impacts of the fishing activities (Australia-NZ for SPRFMO, NAFO, and Japan for SIOFA). Although cumulative impacts are explicitly required to be included, these three IAs considered cumulative effects only from past fishing activities. Paragraph 67 of the FAO Guidelines requires that "States and RFMO/As should have an appropriate protocol identified in advance for how fishing vessels in DSFs [deep-sea fisheries] should respond to encounters in the course of fishing operations with a VME". Regardless, even this consideration of past fishing, especially with regards to fishing conducted by other States, is limited in the IAs. The other types of impacts the IAs should consider, in addition to direct impact from fishing to the seafloor, include secondary impacts (e.g., sediment plumes and release of toxic substances form the sediment), other activities (e.g., seabed mineral exploration), and offshore pollution. In addition, while impacts of climate change on deep-ocean communities are still poorly known, the expected changes in the environment and e.g., food supply, are likely to reduce the resilience of species and communities, and hence, higher levels of precaution should be applied when considering other human-induced pressures (fishing) on these ecosystems.

Limited application of mitigation and management measures

VME encounter protocols and ‘move-on’ rules were often the only measures to protect potential VMEs. Some regions, such as the Southwest Atlantic where no RFMO/A is in place, lack even these basic regulations (with the exception of the measures, including a move-on rule, established by Spain in response to an EU regulation adopted for the implementation of UNGA resolution 61/105 in areas where no RFMO exists or is under negotiation (Regulation (EC) 734/2008)). Encounter protocols have been used in fisheries management for nearly three decades (Shotton and Patchell, 2008). Although better than nothing, move-on rules are not precautionary, since they are primarily a reactive measure that aims to prevent further impacts in future in the same exact location once VMEs have already been damaged by fishing, rather than to avoid impacts (ICES WGDEC 2010).

Move-on rules may have utility where confidence in regional distribution of potential VMEs remains low (e.g., Australia-NZ SPRFMO). However, in many RFMO/As move-on thresholds can be so high that observer programmes are not deemed meaningful, as the likelihood of catching over the permitted quantity of the VME indicator taxa is very low for most fishing operations, even in areas of widespread VME indicator taxa. Threshold values for encounter rules are generally poorly informed and, in some cases, transferred between regions without a clear ecological justification. For instance, SEAFO uses encounter thresholds developed by NAFO for trawls, and by CCAMLR for longlines, despite the many and substantial differences in productivity, species composition, and habitat availability between the areas. In NAFO, trawling occurs in a large, contiguous continental shelf region, in a highly productive area of the Northwest Atlantic.

SEAFO fisheries by comparison exclusively occur upon isolated seamounts in less productive regions and so are likely to respond differently to disturbance. In contrast, encounter threshold values for the SPRFMO area were identified by statistical analysis of regional data (Geange et al. 2020). However, the Australia-NZ IA states that the development of VME thresholds used for the move-on rule from historic bycatch data suffers from poorly understood catchability, limited historical identification of taxa, and limited spatial extent of samples, and that it is clear that bottom trawls are inefficient at sampling fragile organisms such as corals and retain only a small proportion of the benthos impacted. The lack of monitoring compromises evaluation of the effectiveness of the proposed mitigation measures and IAs in terms of whether deep-sea fisheries can or are being managed to prevent SAIs on VMEs.

5) Recommendations to improve the effectiveness of high seas bottom fisheries impact assessments

The severe data gaps and other deficiencies in the IAs, could be improved in many ways: first and foremost, by collecting the information as called for in the Guidelines, such as mapping areas where VMEs are known or likely to occur using non-intrusive or destructive methods such as video surveys of the seabed to do so. Other deficiencies could be improved by being clear about the data sources, making data available to support claims about the impacts, improved explanations for why key data are not shown, and detailing which methods have been used to reach conclusions on SAIs. In addition to these simple improvements, the major issues discussed above could be first addressed by making the IA criteria in the FAO Guidelines more prescriptive and stringent about the information required. Furthermore, the IA criteria could be supported with technical guidance documents about how best to collect and report the required information. The following section outlines solutions to the key shortcomings in the IAs identified in this review.

Standardise the content of the IAs

The deficiencies in the reviewed IAs with respect to FAO Guideline criteria stem from the IAs not including all of the required elements, or only partially considering these criteria. To comply with the IA criteria in the FAO Guidelines, it is therefore recommended to standardise IA content to include the elements of the seven criteria. This can be achieved by structuring the IAs to answer each of the seven criteria established in paragraph 47 of the FAO Guidelines and by making FAO Guidelines more prescriptive to operationalise the IA requirements. Furthermore, the data sources used and how to access these data need to be clearly stated in the IAs to ensure transparency.

Standardising the content of the IAs not only ensures that the IAs meet the criteria set out in the FAO Guidelines, but also allows for better comparison of IAs against each other and to understand impacts and mitigation strategies across ocean regions. In addition to improving the comparability and ease of evaluation across RFMO/As and States, the creation of a standardised template and assessment methodologies for IAs is likely to facilitate the IA process for the organisations or States preparing the assessments. This could include standardised RA procedures to identify the key impacts in a given area and optimise the information needed to assess the impacts of the fishing activity. The development of common standards for IAs could draw on existing IA templates from RFMO/As that have bottom fishery impact assessment standards (e.g., SPRFMO).

Improve baseline information of the environment

A cost-efficient option to improve the baseline information on the environment that is potentially affected by fishing, would be to use publicly available deep-ocean data (see e.g., Levin et al. 2019). For example, the General Bathymetric Chart of the Oceans (GEBCO) Seabed 2030 Project is developing a range of bathymetric data sets and data products, with the aim of making the data publicly available (Mayer et al. 2018). Data from Ocean Biodiversity Information System (OBIS) could be applied to develop SDMs to identify potential VMEs. Data from such data sources can also be potentially used to provide information on the historical status of ecosystems before they were fished. Such information is useful for providing a quantitative assessment of SAIs, and for monitoring of mitigation strategies aimed at restoration and recovery. Furthermore, there already exists various useful outputs from global datasets that can be used to provide some relevant ecological information for IAs. For example, information on the distribution of biogeographic provinces can be used to contextualise the potential effects of fishing in a broader ecological context (see e.g., benthic and meso-pelagic bioregionalisation of Watling et al. 2013 and Sutton et al. 2017).

While the use of existing data is not an impediment to comprehensive IAs, the sources of data must be better described in the IAs in order to justify statements on the risk or severity of impacts and to ensure transparency and replicability of the assessment. Improving description of the methods and data sources used, especially with respect to the use of expert assessment in the final assessment, would increase transparency in the IAs. Future effort should focus on improving the quality of VME and fisheries data (e.g., from VMS, observers and cameras), developing objective approaches to quantify the confidence in assessments (including data layers used in the analyses), and investigating methods to assess the risk to VMEs from human activities and cumulative effects, including their potential for recovery.

Baseline data regarding both VME locations and potential impacts on other ecosystem components, such as non-target fish species, and deep-water sharks and skates could be achieved through establishing thorough and rigorous data collection programmes. One solution to this issue is to develop more standardised observer programmes for bycatch monitoring. Such improved and coordinated data collection programmes are particularly valuable in areas where ecological data are particularly sparse, and could be combined with iterative and responsive management strategies. Observing standards have been made available via national research institutes, such as NOAA (**https://www.fisheries.noaa.gov/topic/fishery-observers**) which could be taken up by RFMO/As without rigorous observer programmes, or used to potentially improve the existing observer programmes of RFMO/As. It is acknowledged that some RFMO/As or States have training programmes for their observers, that include support from scientific institutes, as well has highly structured reporting forms and VME indicator taxa identification guides that are reviewed periodically to improve the quality of baseline data from observer monitoring (e.g., New Zealand for SPRFMO).

Apply diverse methods for VME identification

No single existing sensing or sampling method accurately assesses the full gamut of ecological components that render a marine ecosystem as vulnerable, particularly in deep ecosystems where attributes of resilience are poorly known for much of the fauna. One method that has proved effective for collecting information on VMEs is high-resolution underwater imagery (e.g., using Remotely Operated Vehicles – ROV, towed cameras) (Morato et al. 2018). Underwater imagery allows qualitative description of community composition and associated fauna, determination of the extent of the associated habitat, and the damage caused by particular fishing gears (e.g., Ardron et al. 2014). This has been done in most RFMOs (e.g., CCAMLR, NAFO, NEAFC, SEAFO), to varying degrees. However, because of the high cost of operations associated with in situ surveys, direct observations of VMEs are only available for a fraction of the area of the deep seabed (Morato et al. 2018). The best compromise is to use detailed multi-approach study sites to identify good proxies for biodiversity and ecosystem functions.

Simpler broad-scale approaches that can measure these proxies in a standardised way could then be applied across RFMO/A areas.

In areas where data on the distribution of VMEs or VME indicator taxa are available, SDMs and HSMs may be used to predict where potential VMEs are likely to occur (as recognised in UNGA resolution 71/123 (UNGA 71/123, para 181)). These approaches are useful when data are limited, and where environmental data enable robust predictions. The use of such modelling tools, however, requires the validation of the model outputs and consideration of the uncertainties in the predictions to better translate the confidence of the estimate to management purposes (Bowden et al. 2021). In the absence of VME/VME indicator taxa data, environmental data can be used to identify areas where VMEs are likely to occur. For example, Relative Environmental Suitability modelling techniques that rely on expert input can be used (Kaschner et al. 2006), or bathymetric data can be used to identify features (e.g., seamounts) that might potentially support VMEs (Dunstan et al. 2009, Watling and Auster 2017).

In addition, the Australian-NZ IA for SPRFMO highlighted uncertainties associated with lack of information on connectivity amongst VME "populations". Lack of knowledge of the connectivity amongst populations of species associated with VMEs on seamounts and other underwater features has been highlighted as a major impediment to assessing the efficacy of VME protection measures (Koslow et al. 2015). Further research should thus target both the improved identification of VMEs and the connectivity of protected areas (as done e.g., in the NAFO IA).

Broader consideration of impacts from fishing

As the reviewed IAs considered primarily only the direct impacts of fishing gear on seafloor communities, expanding the range of impacts arising from the fishing activity is needed to comprehensively evaluate the impacts of the fishing on marine ecosystems. This expansion should include impacts to adjacent non-fished areas as well as the water column above fished areas of the seafloor.

While the IAs may be correct in assuming low impacts for certain types of fishing, they need to include the data and rationale to back up the conclusions. Improved rationale can, to a large extent, be solved by improving the information on the data sources used. The IAs could further be strengthened by improving the description of the fishing activity and detailing the different types of impacts that potentially arise from it, even if unlikely (through the RA process). Even when relatively broad categories for describing the risks are used, it would help clarify what impacts are expected and how they can be avoided.

To better understand the overall impacts the fishing activities are having, it is essential to comprehensively survey any new fishing areas before fishing has taken place. These surveys should ideally include control sites so that ongoing monitoring can better determine impact and allow for estimates of recovery time where fishing in the area has ceased. Data on the production/regeneration times for the fauna are severely lacking for much of the fauna impacted by fishing.

Expanding the definition of cumulative impacts and how they are addressed in the overall impact assessment would significantly improve the IAs. In addition to the historical fishing that is considered in most of the IAs that mention cumulative impacts, the effects of climate change on the environment, food availability, and available habitat need to be included in the IAs to anticipate future dynamics. Climate change is expected to have major impacts on overall water column productivity, fish habitat, fish and fisheries that should be assessed as cumulative impacts alongside past fishing activities (FAO 2019). While there is still limited information about effects of climate change on communities at depth, climate-induced changes in the environment will make the evaluation of impacts of fishing increasingly uncertain and affect the risk associated with management decisions (Roux et al. 2022).

Climate-induced changes could include lower phytoplankton productivity, alteration of species distributions (e.g., via thermal or oxygen tolerances), changes in recruitment, growth rates, calcification, behaviour or reproductive rates, changes in genetic connectivity, and altered availability of critical habitat, breeding grounds, prey or predators (Sweetman et al. 2017). Spatial representation of historical or projected changes in climate parameters and time of emergence (exceeding natural variability) can help identify areas that may serve as climate refugia and vulnerability hotspots in the near future (Levin et al. 2020).

Enhance cooperation between organisations

To better assess cumulative impacts from past fishing activities as described above, there is a need for improved coordination between the RFMO/As and States preparing the IAs to manage cumulative effects of different countries' fisheries.

IAs could be amended by using standardised methods for assessing impacts from the fishing activity. For instance, the scale-intensity consequence analysis (SICA) developed by the Marine Stewardship council (MSC 2010) provides a widely used tool for qualitative impact assessment for data-poor fisheries. The use of standardised tools facilitates comparison of the impacts of fisheries operating in different contexts, and further allows for improvements in the IAs practices to be implemented more efficiently. Additional resources have been developed and collated by the FAO to support implementation of fisheries management (Fletcher et al. 2014), including tools for risk and impact assessment.

Explicitly consider uncertainty and improve risk assessment

The scale and range of issues to be considered in the IAs pose a challenge to impact assessments, especially with scarce data, all of which cannot be addressed at the same level of detail as for target species. To accommodate for the uncertainties, risk-based assessment methods have been used increasingly as a part of impact assessments. By summarising information on the different outcomes, RAs can play a significant role in dealing with uncertainty as a part of the IAs (Burgman 2005). The fundamental purpose of the RA process is to find optimal management actions under uncertainty. In its simplest form, an RA includes the stages of risk identification, risk analysis (the quantification of risks), and risk evaluation (consideration and comparison of risk reduction measures).

The consequences and likelihood for each of the risks (e.g., in the context of fisheries, the risk of SAI on VMEs) should be evaluated separately. While quantitative RAs are often deemed the preferred method, data-deficient fisheries and those in areas with limited knowledge of ecological interactions, a qualitative risk assessment is often the most cost-efficient solution. Regardless of the type of RA applied, the metrics used may be chosen to accommodate the extent of available data and must be well justified (e.g., definition of low and high risk should be included in the assessment).

The paucity of data underpinning the assessment of fisheries impacts call for better assessment of uncertainties and their communication to support management. To support more transparent and robust assessment of risks in the IAs, it is essential to undertake comprehensive RAs as a part of the IAs, and levels of precaution should be directly related to the level of uncertainty.

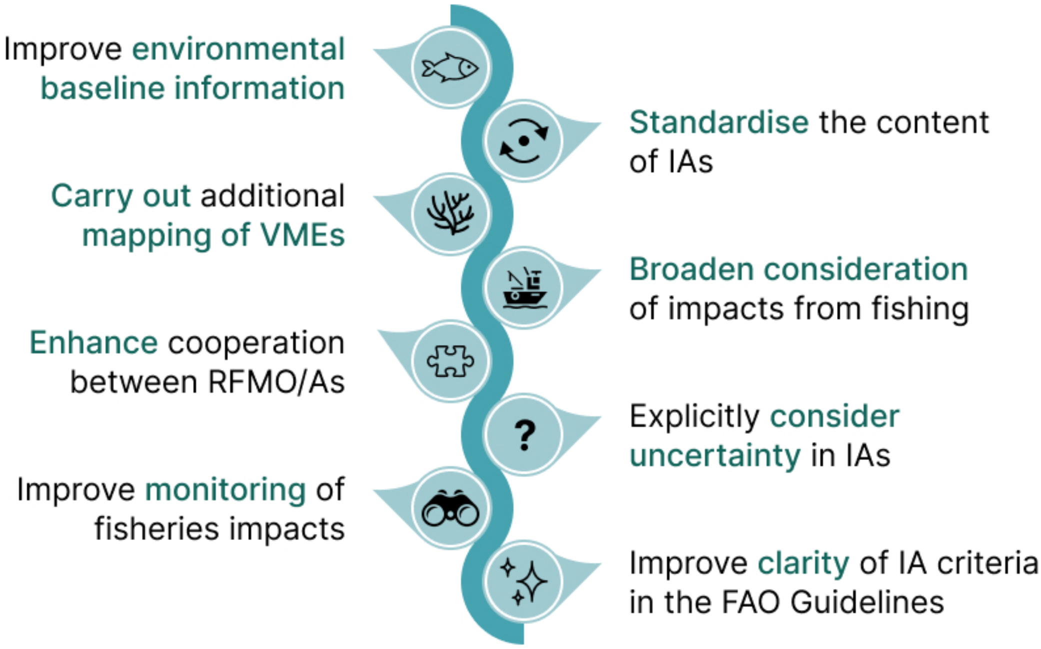


Figure 9. Recommendations to improve the efficiency of IAs for deep-sea fisheries on the high seas.

6) Conclusions

This report concludes that the reviewed IAs are likely not in compliance with paragraph 47 of the FAO International Guidelines for the Management of Deep-Sea Fisheries in the High Seas adopted in 2009, as the IAs do not robustly demonstrate that deep-sea fishing activities on the high seas can prevent SAIs on VMES and that fishing is conducted in a sustainable manner. Even the most comprehensive IAs, despite covering certain topics in more detail, are not fully compliant with the FAO Guidelines. It is the responsibility of RFMO/As and fishing States to demonstrate that their fisheries are sustainable and can be, or are being, managed to prevent SAIs as a condition of being able to exploit these resources (UNGA resolution 61/105 para. 83; UNGA resolution 64/72 paras. 119 & 120). If exploitation of deep-sea resources is allowed to continue, the shortcomings illustrated by the reviewed IAs should be addressed.

The shortcomings identified across the reviewed IAs (but not necessarily common to all) include incomplete description of the proposed fishing activities, inadequate baseline data, lack of risk assessments, limited consideration of the impacts of fishing, including no assessment of indirect impacts of fishing, and insufficient consideration of uncertainties in the assessment. In order to improve the effectiveness of the IAs in demonstrating the kind of impacts deep-sea fishing activities are likely to pose to marine ecosystems, this report identifies several ways to strengthen the IA process. These recommendations include improved collection of baseline data and VME identification, assessment of impacts on broader range of species associated with VMEs or otherwise potentially impacted by deep-sea fishing, enhanced cooperation between RFMO/As and more streamlined IA processes, as well as better consideration of different types of impacts from fishing and the uncertainty of the risk estimates. Fisheries management should explicitly reflect the uncertainty in the evidence for sustainability and impact on the ecosystem, and where necessary apply a precautionary approach to fishing. Conducting robust IAs for deep-sea fisheries is required for the implementation of international commitments and legal obligations for the conservation of fish stocks and also sets a precedent for managing other human activities in the high seas. Ultimately, conducting IAs that are in full compliance with the FAO Guidelines is crucial for protecting the deep sea from the harmful impacts of bottom fishing and for conserving biodiversity.

Annex 1: Detailed Review Results

Detailed review results can be accessed here: **https://www.dosi-project.org/wp-content/uploads/Fishery-Report-Annex-2022.pdf**

How to Cite: DOSI (2022). A Review of Impact Assessments for Deep-Sea Fisheries on the High Seas against the FAO Deep-Sea Fisheries Guidelines. Deep Ocean Stewardship Initiative Report. **https://www.dosi-project.org/fisheries-review-2022/**

About DOSI

The Deep-Ocean Stewardship Initiative seeks to integrate science, technology, policy, law and economics to advise on ecosystem-based management of resource use in the deep ocean and strategies to maintain the integrity of deep-ocean ecosystems within and beyond national jurisdiction.

Contact us: **DOSIcomms@gmail.com**

References

Althaus, F., Williams, A., Schlacher, T. A., Kloser, R. J., Green, M. A., Barker, B. A., et al. 2009. Impacts of bottom trawling on deep-coral ecosystems of seamounts are long-lasting. Mar. Ecol. Prog. Ser. 397, 279–294. doi:10.3354/meps08248.

Ardron, J.A., Clark, M.R., Penney, A.J., Hourigan, T.F., Rowden, A.A., Dunstan, P.K., Watling, L., Shank, T.M., Tracey, D.M., Dunn, M.R. and Parker, S.J., 2014. A systematic approach towards the identification and protection of vulnerable marine ecosystems. Marine Policy, 49, 146-154.

Auster, P.J., Gjerde, K., Heupel, E., Watling, L., Grehan, A. and Rogers, A.D., 2011. Definition and detection of vulnerable marine ecosystems on the high seas: problems with the “move-on” rule. ICES Journal of Marine Science, 68(2), 254-264.

Baco, A.R., Roark, E.B. and Morgan, N.B., 2019. Amid fields of rubble, scars, and lost gear, signs of recovery observed on seamounts on 30-to 40-year time scales. Science advances, 5(8), p.eaaw4513.

Bailey, D. M., Collins, M. A., Gordon, J. D., Zuur, A. F., & Priede, I. G. 2009. Long-term changes in deep-water fish populations in the northeast Atlantic: a deeper reaching effect of fisheries? Proceedings of the Royal Society B: Biological Sciences, 276(1664), 1965-1969.

Baker, K.D., Devine, J.A. and Haedrich, R.L., 2009. Deep-sea fishes in Canada’s Atlantic: population declines and predicted recovery times. Environmental biology of fishes, 85(1), 79-88.

Burgman, M., 2005. Risks and decisions for conservation and environmental management. Cambridge University Press.

Bowden, D.A., Anderson, O.F., Rowden, A.A., Stephenson, F. and Clark, M.R., 2021. Assessing habitat suitability models for the deep sea: is our ability to predict the distributions of seafloor fauna improving? Frontiers in Marine Science, 8, 632389.

Cailliet, G. M., Andrews, A. H., Burton, E. J., Watters, D. L., Kline, D. E., and Ferry-Graham, L. A. 2001. Age determination and validation studies of marine fishes: Do deep-dwellers live longer? Exp. Gerontol. 36, 739–764.

Clark, M. R., Althaus, F., Schlacher, T. A., Williams, A., Bowden, D. A., & Rowden, A. A. 2016. The impacts of deep-sea fisheries on benthic communities: a review. ICES Journal of Marine Science, 73(suppl_1), i51-i69.

Clark, M.R., Bowden, D.A., Rowden, A.A. and Stewart, R., 2019. Little evidence of benthic community resilience to bottom trawling on seamounts after 15 years. Frontiers in Marine Science, 6, p.63.

Clark, M. R., and Koslow, J. A. 2007. Impacts of fisheries on seamounts. Seamounts Ecol. Fish. Conserv., 413–441.

Dunstan, P.K. Clark, M.R., Guinotte, J., O’Hara, T., Niklitschek, E., Rowden, A.A., Schlacher, T., Tsuchida, S., Watling, L., Williams, A. 2011. Identifying Ecologically and Biologically Significant Areas on Seamounts. Gland, Switzerland: IUCN.

Drazen, J.C. and Sutton, T.T., 2017. Dining in the deep: the feeding ecology of deep-sea fishes. Annu. Rev. Mar. Sci, 9(1), 337-366.

Gage, J.D., Roberts, J.M., Hartley, J.P. and Humphery, J.D., 2005, September. Potential impacts of deep-sea trawling on the benthic ecosystem along the northern European continental margin: a review. In Symposium on Effects of Fishing Activities on Benthic Habitats (503-517). American Fisheries Society.

Geange, S.W., Rowden, A.A., Cryer, M., Bock, T.D. 2019. SC7-DW13. A review of VME indicator taxa for the SPRFMO Convention Area South Pacific Regional Fisheries Management Organisation 7th Meeting of the Scientific Committee Havana, Cuba 7–12 October 2019

Geange, S.W., Rowden, A.A., Nicol, S., Bock, T. and Cryer, M., 2020. A data-informed approach for identifying move-on encounter thresholds for vulnerable marine ecosystem indicator taxa. Frontiers in Marine Science, 7, p.155.

Gianni, M., Fuller, S.D., Currie, D.E.J., Schleit, K., Goldsworthy, L., Pike, B., Weeber, B., Owen, S. and Friedman, A., 2016. How much longer will it take. A ten-year review of the implementation of United Nations General Assembly resolutions, 61(105), p.64.

ICES. 2010 Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC) 2010. Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC), 22–26 March 2010

ICES. 2021. Workshop on the Use of Predictive Habitat Models in ICES Advice (WKPHM). ICES Scientific Reports. 3:67. 100. http://doi.org/10.17895/ices.pub.8213

FAO. 2019. Deep-ocean climate change impacts on habitat, fish and fisheries, Lisa Levin, Maria Baker, and Anthony Thompson (eds). FAO Fisheries and Aquaculture Technical Paper No. 638. Rome, FAO. 186.

FAO. 2020. Worldwide review of bottom fisheries in the high seas in 2016. FAO Fisheries and Aquaculture Technical Paper No. 657. Rome. https://doi.org/10.4060/ca7692en

Fletcher, W.J. and Bianchi, G., 2014. The FAO–EAF toolbox: Making the ecosystem approach accessible to all fisheries. Ocean & Coastal Management, 90, 20-26.

Kaiser, M.J., 2019. Recent advances in understanding the environmental footprint of trawling on the seabed. Canadian Journal of Zoology, 97(9), 755-762.

Kaschner, K., Watson, R., Trites, A.W. and Pauly, D., 2006. Mapping world-wide distributions of marine mammal species using a relative environmental suitability (RES) model. Marine Ecology Progress Series, 316, 285-310.

Kenchington, E., Lirette, C., Murillo, F.J., Beazley, L. & Downie, A.-L. 2019. Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO Scientific Council Research Document 10/058, Serial No. N7030, 68 p. https://www.nafo.int/Portals/0/PDFs/sc/2019/scr19-058.pdf

Koslow, J.A., Auster, P., Bergstad, O.A., Roberts, J.M., Rogers, A., Vecchione, M., Harris, P.T., Rice, J. and Bernal, P., 2015. Biological communities on seamounts and other submarine features potentially threatened by disturbance. United Nations World Ocean Assessment.

Levin, L.A., Bett, B.J., Gates, A.R., Heimbach, P., Howe, B.M., Janssen, F., McCurdy, A., Ruhl, H.A., Snelgrove, P., Stocks, K.I. and Bailey, D., 2019. Global observing needs in the deep ocean. Frontiers in Marine Science, 6, p.241.

Levin, L.A., Wei, C.L., Dunn, D.C., Amon, D.J., Ashford, O.S., Cheung, W.W., Colaço, A., Dominguez-Carrió, C., Escobar, E.G., Harden-Davies, H.R. and Drazen, J.C., 2020. Climate change considerations are fundamental to management of deep-sea resource extraction. Global change biology, 26(9), 4664-4678.

Mayer, L., Jakobsson, M., Allen, G., Dorschel, B., Falconer, R., Ferrini, V., Lamarche, G., Snaith, H. and Weatherall, P., 2018. The Nippon Foundation—GEBCO seabed 2030 project: The quest to see the world's oceans completely mapped by 2030. Geosciences, 8(2), p.63.

Menegotto, A. and Rangel, T.F., 2018. Mapping knowledge gaps in marine diversity reveals a latitudinal gradient of missing species richness. Nature communications, 9(1), 1-6.

Morato, T., Pham, C.K., Pinto, C., Golding, N., Ardron, J.A., Duran Munoz, P. and Neat, F., 2018. A multi criteria assessment method for identifying Vulnerable Marine Ecosystems in the North-East Atlantic. Frontiers in Marine Science, 460.

Nielsen, J., Hedeholm, R.B., Heinemeier, J., Bushnell, P.G., Christiansen, J.S., Olsen, J., Ramsey, C.B., Brill, R.W., Simon, M., Steffensen, K.F. and Steffensen, J.F., 2016. Eye lens radiocarbon reveals centuries of longevity in the Greenland shark (Somniosus microcephalus). Science, 353(6300), 702-704.

Pham, C.K., Diogo, H., Menezes, G., Porteiro, F., Braga-Henriques, A., Vandeperre, F. and Morato, T., 2014. Deep-water longline fishing has reduced impact on Vulnerable Marine Ecosystems. Scientific reports, 4(1), 1-6.

Portela, J., Acosta, J., Cristobo, J., Muñoz, A., Parra, S., Ibarrola, T., Del Río, J.L., Vilela, R., Ríos, P., Blanco, R. and Almón, B., 2012. Management strategies to limit the impact of bottom trawling on VMEs in the high seas of the SW Atlantic. Mar. Ecosystem, InTech, 199-228.

Probert, P. K., McKnight, D. G., and Grove, S. L. 1997. Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. Aquat. Conserv. Mar. Freshw. Ecosyst. 7, 27–40.

Prouty, N.G., Fisher, C.R., Demopoulos, A.W. and Druffel, E.R., 2016. Growth rates and ages of deep-sea corals impacted by the Deepwater Horizon oil spill. Deep Sea Research Part II: Topical Studies in Oceanography, 129, 196-212.

Roark, E. B., Guilderson, T. P., Dunbar, R. B., Fallon, S. J., and Mucciarone, D. A. (2009). Extreme longevity in proteinaceous deep-sea corals. Proc. Natl. Acad. Sci. 106, 5204–5208. doi:10.1073/pnas.0810875106.

Rogers, A.D., Gianni, M. 2010. The Implementation of UNGA Resolutions 61/105 and 64/72 in the Management of Deep-Sea Fisheries on the High Seas. Report prepared for the Deep-Sea Conservation Coalition. International Programme on the State of the Ocean, London, United Kingdom, 97.

Roux M.-J., Duplisea D.E., Hunter K.L. and Rice J. 2022. Consistent Risk Management in a Changing World: Risk Equivalence in Fisheries and Other Human Activities Affecting Marine Resources and Ecosystems. Front. Clim. 3:781559. doi: 10.3389/fclim.2021.781559

Sharp, B.R., Parker, S.J. and Smith, N., 2009. An impact assessment framework for bottom fishing methods in the CAMLR Convention Area. CCAMLR Science, 16, pp.195-210.

Shotton, R. and Patchell, G., 2008. The Proposed “5-Mile” Move-on-rule in Deep-sea Trawl Fisheries of the Southern Indian Ocean: An Analysis of its Origins and the Basis for the Requirement. SIODFA Tech. Rep. 08/02.

Simpfendorfer, C.A. & Kyne, P.M. 2009. Limited potential to recover from overfishing raises concerns for deep-sea sharks, rays and chimaeras. Environmental Conservation 36, 97–103.

Sutton, T.T., Clark, M.R., Dunn, D.C., Halpin, P.N., Rogers, A.D., Guinotte, J., Bograd, S.J., Angel, M.V., Perez, J.A.A., Wishner, K. and Haedrich, R.L., 2017. A global biogeographic classification of the mesopelagic zone. Deep Sea Research Part I: Oceanographic Research Papers, 126, 85-102.

Sweetman, A.K., Thurber, A.R., Smith, C.R., Levin, L.A., Mora, C., Wei, C.L., Gooday, A.J., Jones, D.O., Rex, M., Yasuhara, M. and Ingels, J., 2017. Major impacts of climate change on deep-sea benthic ecosystems. Elementa: Science of the Anthropocene, 5.

Watling, L., & Auster, P. J. 2021. Vulnerable Marine Ecosystems, Communities, and Indicator Species: Confusing Concepts for Conservation of Seamounts. Frontiers in Marine Science, 8, 622586.

Watling, L., Victorero, L., Drazen, J.C. and Gianni, M., 2020. Exploitation of deep-sea fishery resources. Natural Capital and Exploitation of the Deep Ocean, p.71.

Watling, L., Guinotte, J., Clark, M.R. and Smith, C.R., 2013. A proposed biogeography of the deep ocean floor. Progress in Oceanography, 111, 91-112.

Watling, L., France, S.C., Pante, E. and Simpson, A., 2011. Biology of deep-water octocorals. Advances in marine biology, 60, 41-122.

Weaver, P.P.E., Benn, A., Arana, P.M., Ardron, J.A., Bailey, D.M., Baker, K., Billett, D.S.M., Clark, M.R., Davies, A.J., Durán Muñoz, P. and Fuller, S.D., 2011. The impact of deep-sea fisheries and implementation of the UNGA Resolutions 61/105 and 64/72. Report of an international scientific workshop, National Oceanography Centre, Southampton, 45.

Zeller, D., Cashion, T., Palomares, M. and Pauly, D., 2018. Global marine fisheries discards: A synthesis of reconstructed data. Fish and Fisheries, 19(1), 30-39.