National Environmental Science Program

1. Introduction

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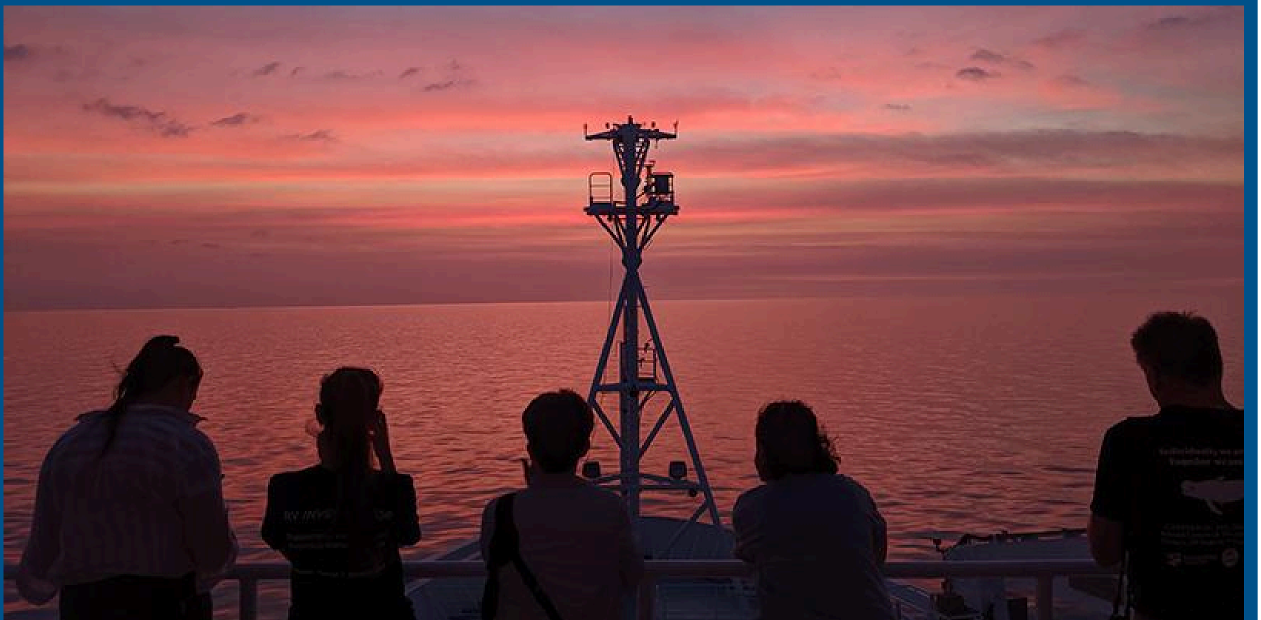

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Background

Australia has one of the world's largest marine estates that includes many vulnerable habitats and a high biodiversity, with many endemic species crossing a wide latitudinal range. The marine estate is used by a variety of industries including fishing, oil & gas, and shipping, in addition to traditional, cultural, scientific and recreational uses. The Commonwealth government manages the Australian Marine Parks (AMPs), the largest network of marine protected areas (MPAs) in the world (Cochrane 2016). These marine parks complement existing MPA networks in State and Territory waters.

Monitoring the impacts of these uses on the marine environment is a massive shared responsibility that can only be achieved by making the best use of all the information that is collected. Australia has a number of significant long-term marine monitoring and observing programs (Hedge et al. 2021, see Table 1 for ecological and biological programs), as well as a national ocean data network (aodn.org.au). Without some common and agreed standards, information collected may not be comparable with other areas or sectors. This may reduce its value to regional and national management, while the individual project or survey may lose the opportunity to interpret results in a regional or national context.

Australia is uniquely placed to develop standardised national approaches to monitor the marine environment. This objective integrates with one of the high-level recommendations identified by the National Marine Science Plan (2015-25): Recommendation 2 is to 'establish and support a national marine baselines and long-term monitoring program, to develop a comprehensive assessment of our estate, and to help manage Commonwealth and state marine reserves" (Hedge et al. 2021). Standardised national approaches will also contribute to the effective coordination across the marine science and observing community (including industry and citizen scientists). Such coordination has been recognised as integral to a governance system for sustained and effective monitoring in Australia's marine environment (Hayes et al. 2015) and yet was identified as highly variable and frequently inadequate in the 2016 State of the Environment Report (Evans et al. 2017). A 2019-20 audit of marine baselines and monitoring programs identified 371 programs (Hedge et al. 2021), with the sheer number of such programs making it challenging to coordinate among programs and apply consistent methods. In order to facilitate objective and robust conclusions about the status and trends of the marine ecosystems, it is crucial that sampling methods are as consistent as possible while still allowing for practical differences among equipment, vessels, and weather conditions. This need for consistent methodology has been identified in several reports on regional and national marine monitoring frameworks (Hedge et al. 2013, Bowden et al. 2015, Hayes et al. 2015, Hedge et al. 2021), and its contribution to supporting a blue economy is also recognised (Golden et al. 2017).

Although many biological monitoring programs focus on single elements of the marine environment (e.g. Wraith et al. 2013), several large-scale marine monitoring programs that include multiple areas are currently under development or implementation in Australian waters. Table 1 lists some of these programs, as well as the associated indicators to be measured or sampling platforms if specified. Standardised marine monitoring has been done successfully in Australian waters for shallow waters (e.g. underwater visual census in Reef Life Survey) and pelagic animals (e.g. acoustic tagging in IMOS Animal Tracking Facility), but prior to the development of Version 1 of these SOPs, it had not been developed, implemented, and adopted at a national scale for most other biological sampling platforms.

Table 1: Some of the large-scale biological or ecological monitoring programs currently operating or under development in Australia as of Dec 2023. UVC = underwater visual census, DOV = diver-operated video, ROV = remotely operated vehicle, AUV = autonomous underwater vehicle, BRUV = baited remote underwater video, MBES = multibeam echosounder.

	Program	Region	Indicator	Sampling Platforms	Example Reference
PELAGIC	Continuous Plankton Recorder (CPR)	Global	Plankton assemblages, colour index	CPR	Hosie et al. 2003
	IMOS Animal Tracking Facility	National	Marine megafauna movement	Acoustic telemetry, satellite tracking	Taylor et al. 2017
	IMOS Ships of Opportunity	National	Temperature, salinity, water column backscatter, biochemistry	Bathythermograph, echosounder, biogeochemical and meteorological sensors	Alory et al. 2007
	IMOS National Mooring Network	National	Nutrients, microbes, phytoplankton, zooplankton, environmental factors	Moored sensors, water sampling	Sloyan and O'Kane 2015
	Aquawatch	National	Various	Satellites, water sampling	https://www.csiro.au/en/about/challenges-missions/aquawatch
	Australian Microbiome Initiative	National	Microbial and zooplankton DNA	water sampling	van de Kamp 2019
BENTHIC & DEMERSAL	Reef 2050 Integrated Monitoring and Reporting Program	GBR	Various	Various	GBRMPA 2015
	Marine Integrated Monitoring Program	NSW	Various	Aerial imagery, UVC, BRUVs, AUVs, towed imagery, grabs, DOVs, ROVs	Aither 2022
	WAMSI estuary science program	WA	Various	Various	Thomson et al. 2017
	RedMap**	National	Fish, invertebrates	UVC, observations	Pecl et al. 2019
	Reef Life Survey**	Global	Demersal fish and benthic invertebrate assemblages	UVC	Stuart-Smith et al. 2017
	Long-Term Monitoring Program (AIMS)	GBR and NW Australia	Fish and benthic invertebrate assemblage, coral health and cover	UVC, DOV, Towed imagery	De'ath et al. 2012
	VIC Signs of Healthy Parks monitoring program	VIC	Various	UVC, drone/UAV, AUV, BRUVS, ROV, towed video, aerial photography	Parks Victoria's Technical Series
	WA marine monitoring program	WA	Various	Various	Dept Biodiv Conserv Attractions 2017
	NESP field manual package*	National	Various	MBES, AUV, BRUV, Towed camera, Sled/trawls, Grab/corer, ROV, microplastics, drop camera, socioeconomic survey	Current study

* Primarily benthic and demersal platforms, but also includes an emergent pelagic method (Pelagic BRUVs)
** Citizen science program

Due to the large geographic area, diverse flora and fauna, and range of environmental conditions represented by the Australian Marine estate, a single method of sampling is neither practical nor desirable (Bouchet et al. 2018, Przeslawski et al. 2018). For this reason, we present a standard approach for each of eight key marine benthic sampling platforms that were identified based on frequency of use in previous open water sampling and monitoring programs:

- Multibeam sonar (MBES),
- Autonomous Underwater Vehicles (AUVs),
- Benthic Baited Remote Underwater Video (BRUVs),
- Towed imagery,
- Grabs and box corers,
- Sleds and trawls,
- Remotely operated vehicles (ROVs), and
- Wide-field stereo drop cameras (drop cam).

Each of these platforms targets a discrete data type (bathymetry, imagery, samples) within particular environments (consolidated, unconsolidated substrates) (Table 2), with specific advantages (Table 3).

We also provide four additional field manuals:

- Survey design to provide guidance on robust sampling design to underpin most of the other field manuals (see Survey Planning section below),
- Pelagic BRUVs as a concept sampling method in pelagic ecosystems due to its similarity to benthic BRUVs,
- Knowledge, attitude and practice (KAP) surveys to account for the importance of considering social and cultural values in marine monitoring, and
- Microplastics, a field manual based on the collected data rather than the sampling platforms.

Importantly, the inclusion of these sampling platforms and data in the current version is not an assessment of their value but instead an indication of their frequency of use and suitability for national monitoring (e.g. established methods, dedicated users, integration with existing national programs).

One of the main challenges in assessing marine biodiversity is the lack of standardised approaches for monitoring it (Duffy et al. 2013, Teixeira et al. 2016). As such, the overarching goal of these field manuals is to reduce the bias and variance in data from differences in sampling procedures, thereby ensuring that patterns in data are due to patterns in the community rather than patterns of how or when the community was sampled. If the measured ecological variable and the variation in sampling techniques are confounded, it is challenging if not impossible to objectively determine if observed changes are due to real ecological change or sampling technique. If variability is sufficiently high, real changes that would trigger appropriate management may not be detected in time, if at all.

Importantly, many state marine monitoring programs use their own standard operating protocols (SOPs) relevant for wetland, estuarine, embayment, or intertidal habitats (Table 1). The current package of field manuals is not meant to replace them, but rather to complement them for deeper waters and national monitoring purposes. At the same time, we hope that individual state marine monitoring programs will also identify opportunities to adjust current practices to increase national consistency and that the SOPs will provide an opportunity for industry and industry consultants to contribute to national monitoring through standardising their ongoing activities (Teytelman 2018). To that end, marine managers from all states and territories in Australia were engaged in the process of developing these field manuals. This ensured that methods were similar whenever possible and differences were clearly explained in relation to marine monitoring in Commonwealth waters.

Table 2: Summary of prioritised benthic sampling platforms and their acquisition targets. See text above for definition of abbreviations and acronyms.

	Data Type	Data Target	Spatial coverage	Environment	Chapter
MBES	Bathymetry, backscatter	Seafloor	Continuous	All	3
AUV	Imagery	Epifauna, habitat	Continuous	All	4
BRUV	Imagery	Demersal fish, habitat	Point (qualitative)	All	5
Towed	Imagery	Epifauna,habitat	Transect	All	7
Grab/Boxcore	Biological and sediment samples	Macrofauna, infauna	Point	Unconsolidated substrate	8
Sled/Trawl	Biological and sediment samples	Megafauna, epifauna	Transect (qualitative)	Consolidated substrate	9
ROV	Imagery*	Epifauna, habitat	Transect	All	10
Drop cam	Imagery	Epifauna, habitat	Point (qualitative)	All	11
Survey design	n/a, this field manual is not based on a benthic sampling platform				2
Pelagic BRUV	n/a, this field manual is not based on a benthic sampling platform				6
KAP surveys	n/a, this field manual is not based on a benthic sampling platform				12
Microplastics	n/a, this field manual is not based on a benthic sampling platform				13

* ROVs can collect biological and geological samples, but the focus of the manual in this package is on imagery.

Table 3: Advantages of prioritised benthic sampling platforms.

	MBES	AUV	BRUV	Towed	Grab/Boxcorer	Sled/Trawl	ROV	Drop Cam
Continuous (i.e. grid) broad-scale spatial coverage	X							
Continuous (i.e. grid) fine-scale spatial coverage		X						
Non-extractive	X	X	X	X			X	X
Able to revisit exact sites (repeatability)	X	X					X	
Able to sample over variety of environments	X	X	X	X			X	X
Species-level identifications[1]					X	X	X[2]	
Genetic, morphological etc analysis possible					X	X	X[2]	
Behaviour observed			X	X			X	X
Cryptofauna included					X	X		
Quantitative	X	X	X	X	X		X	X
Concurrent physical and biological data		X	X	X	X		X	X

Minimal technical expertise			X	X	X	X	X[3]	X
Vessel flexibility			X	X	X		X[3]	

[1] Refers to identifications able to be made with unknown or cryptic species (i.e. well-known, distinctive species can be identified via imagery)
[2] Only possible when the ROV is equipped with sampling capability. This is outside the focus on the ROV manual
[3] This only applies to small off-the-shelf ROVs, Working class ROVs require technical expertise and specific vessel specifications

Scope

This field manual package aims to provide a standardised national methodology for the acquisition of marine data from a prioritised set of frequently-used sampling platforms (below diver depths) so that data are directly comparable in time and through space. This will then facilitate national monitoring programs in Australian open waters and contribute to the design of an ongoing monitoring program for AMPs. The long-term goal is to produce a set of manuals that is applicable to a broad range of users and to be prescriptive enough that all data are collected without unnecessary technical variation.

Survey planning

We strongly advise that survey design should be considered at all levels of planning (Figure 1), as it is essential to ensure sampling provides efficient and representative information to inform management (Hayes et al., 2019). If information is lacking, then evidence-based decision frameworks, e.g. a Monitoring Evaluation, Reporting and Improvement (MERI) framework, cannot proceed without being compromised. Chapter 2 of this field manual package provides details of sampling design considerations and how they can be navigated, as well as example code and data for implementing a spatially-balanced design, as outlined in Foster et al. (2017) and Foster et al. (2019). Chapter 2 also emphasises the foundational role of seafloor data from sonar (Chapter 3), which can facilitate the production of base maps covering tens or hundreds of square kilometres, with accurate geo-location. These maps can form the input needed to generate an efficient spatial survey design. Where no seafloor data exists, the principles in Chapter 2 can also be used to design efficient and representative sonar surveys.

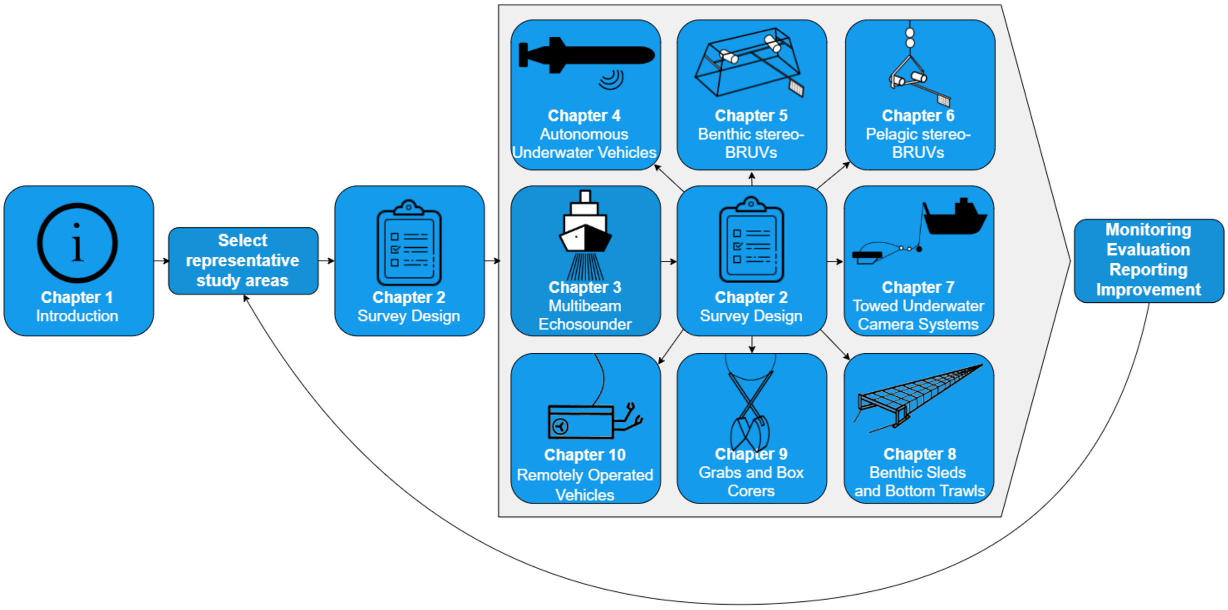

Figure 1: Recommended role of Survey Design (Chapter 2) in Survey Planning, including the foundational role of seafloor data from multibeam sonar (Chapter 3), to inform sampling (Chapters 4-11) and management frameworks (e.g. a Monitoring Evaluation, Reporting and Improvement framework).

Sampling platforms

We generally limit our field manuals to benthic biological sampling, with a few exceptions described above for Chapters 6, 12, and 13. These field manuals focus on data acquisition and post-processing including data management, particularly as applied to marine monitoring. Standardisation of sampling design is important to ensure rigor and reproducibility (National Academies of Sciences, Engineering, and Medicine 2019) and is addressed accordingly in Chapter 2. Data analysis and reporting are generally not included in the field manuals, although we direct users to useful methods or resources within each field manual.

For most field manuals, a scope specific to that particular sampling gear and data type is presented in a separate section. Overall, these field manuals are meant to cover basics and important considerations, with agency- and gear-specific SOPs supplemented as needed by individual researchers. Detailed and gear-specific SOPs are outside the scope of this field manual package due to the large number of existing SOPs and the variety of gear currently employed by researchers. It is impractical that researchers would agree on detailed SOPs (and associated gear). Rather, we have developed these field manuals to find consensus about as many issues as possible, while noting the differences. These differences can then be assessed in the future (e.g. they may not correspond to large amounts of variation in data), and addressed if need be. Wherever possible, however, we have mandated or recommended specifications (e.g. imagery resolution) that should be used in future equipment upgrades or purchases.

This field manual package does not describe the decision to use a particular sampling platform, supporting previous recognition that a top-down, one-size-fits-all approach to monitoring is unlikely to be effective in systems with large environmental variability (Fancy et al. 2009). In some instances, multiple platforms will yield higher observed diversity (e.g. BRUVS + a transect-based imagery platform), while data collected among other platforms are comparable (e.g. ROV, diver-operated video, towed video, Schramm et al 2019). For a more detailed review of each sampling platform, as well as a comparative assessment among them, we refer readers to our companion reports on benthic (Przeslawski et al. 2018) and pelagic (Bouchet et al. 2018) sampling methods used in marine monitoring. These reports also relate marine sampling platforms to Essential Ocean Variables (Miloslavich et al. 2018, Muller-Karger et al. 2018). After the decision to use an appropriate sampling platform has been made, using the appropriate field manuals will help ensure that the collected data can be compared with data collected previously and in the future, thus contributing to national marine monitoring and reporting.

Format

In order to maximise uptake, methods in each field manual are usually presented as simple steps. All steps listed are considered essential unless they are clearly marked with brackets and italics as recommended (e.g. Use netsonde or bottom contact sensor to ensure sled or trawl is suitably deployed along the seafloor *[Recommended]*)

The field manual package is designed to be separated into its component chapters representing discrete sampling platforms, as needed. The component chapters themselves fit together into a cohesive whole (Figure 2). For this reason, the package can be downloaded in its entirety as a single pdf, or as standalone chapters representing discrete field manuals (Figure 2). References are listed accordingly at the end of each chapter.

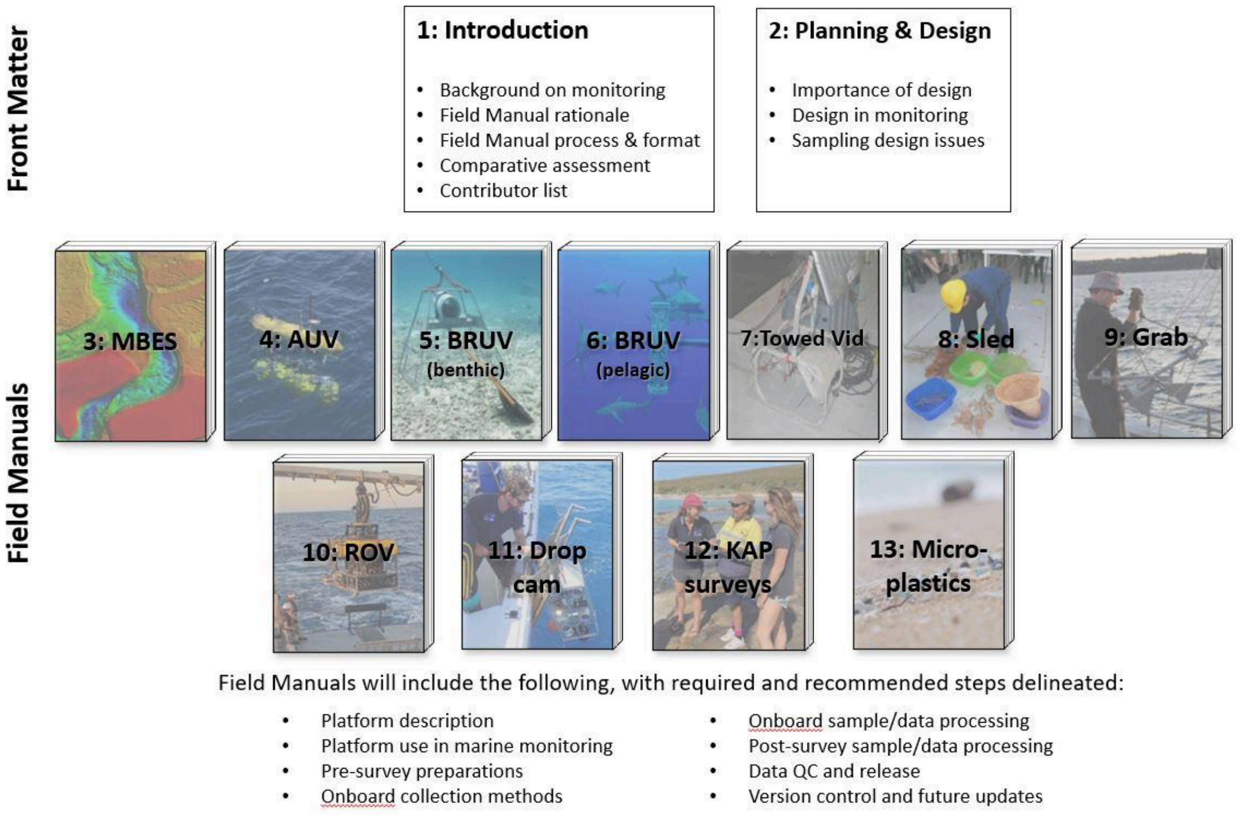

Figure 2: The structure and general contents of the NESP field manual package (version 3) with numbers indicating respective chapters.

Development of Field Manuals

The process of developing these field manuals has been detailed in Przeslawski et al (2019a) and Przeslawski et al. (2023).

The main challenge in the development of these manuals was to find a balance between being overly prescriptive (such that people prefer to follow their own protocol and ignore the manuals) and overly flexible (such that data are not consistent and therefore not comparable). A collaborative approach was therefore paramount to their development.

Ultimately, over 228 individuals from at least 76 organisations contributed to versions 1, 2 or 3 of the field manual package (see Collaborators section in this introductory chapter). The increase in collaborators from Version 1 to Version 2 is due primarily to i) the new ROV manual, ii) expansion of the BRUV authors based on preparation of an associated manuscript to a journal, and iii) the merger of the V1 NESP field manual with AusSeabed's *Australian Multibeam Guidelines*. The increase in collaborators from Version 2 to Version 3 is due additional authors of the three new SOPs (KAP surveys, drop cams, microplastics. By engaging researchers, managers, and technicians from multiple agencies with a variety of experience, sea time, and subject matter expertise, we strove to ensure the field manuals represented the broader marine science community of Australia including real-world context, diversity of experiences, and candid acknowledgement of limitations and challenges. This not only improved the content but also increased the potential for adoption of the SOPs across multiple agencies and monitoring programs. After the release of the first version, input from additional stakeholders was actively sought and incorporated into the subsequent versions (see the sections on 'Updates and Revisions' later in this chapter).

The process used to develop each field manual included in this package is shown in Figure 3, and the steps are listed below:

1. For each field manual, a working group was formed in which known users of the given sampling platform were invited. To be as inclusive as possible, we also extended more general invitations through email lists (e.g. Australian Coral Reef Society, Australian Marine Science Association (AMSA), NESP) and presentations (e.g. AMSA conferences). Each working group was led by a coordinator(s) to develop content. Coordinators were identified as experts in their particular sampling platform and took on the role of lead author(s) for their respective field manual (Table 4).

2. Content was developed by the coordinators based on meetings with the working group and associated input, including existing SOPs.

3. A draft field manual was distributed to the working group as a strawman for further discussion and refinement.

4. A complete field manual was submitted for internal review and approval by the editors, NESP, and other lead project institutions (e.g. Geoscience Australia, IMOS).

5. A complete field manual was submitted to an external reviewer who was not previously associated with the project.

6. A final revised field manual package was released as Version 1 on the Ocean Best Practice Repository (www.oceanbestpractices.net) and the website (www.nespmarine.edu.au).

7. Feedback was solicited through a questionnaire, particularly geared towards field testers. This was used to assess outcomes and impacts (Przeslawski et al 2021) and to inform future versions (Steps 8-9).

8. Content of field manuals was revised based on feedback and new developments (e.g. data discoverability and accessibility). This was incorporated into Version 2 in 2020, with the exception of the ROV manual which was a new addition to the Version 2 field package and thus had not yet been through a process of stakeholder feedback after release.

9. Content of field manuals was updated with minor revisions to ensure currency as part of Version 3 in 2024. In addition, three new field manuals were developed using Steps 1-5 and released as part of Version 3.

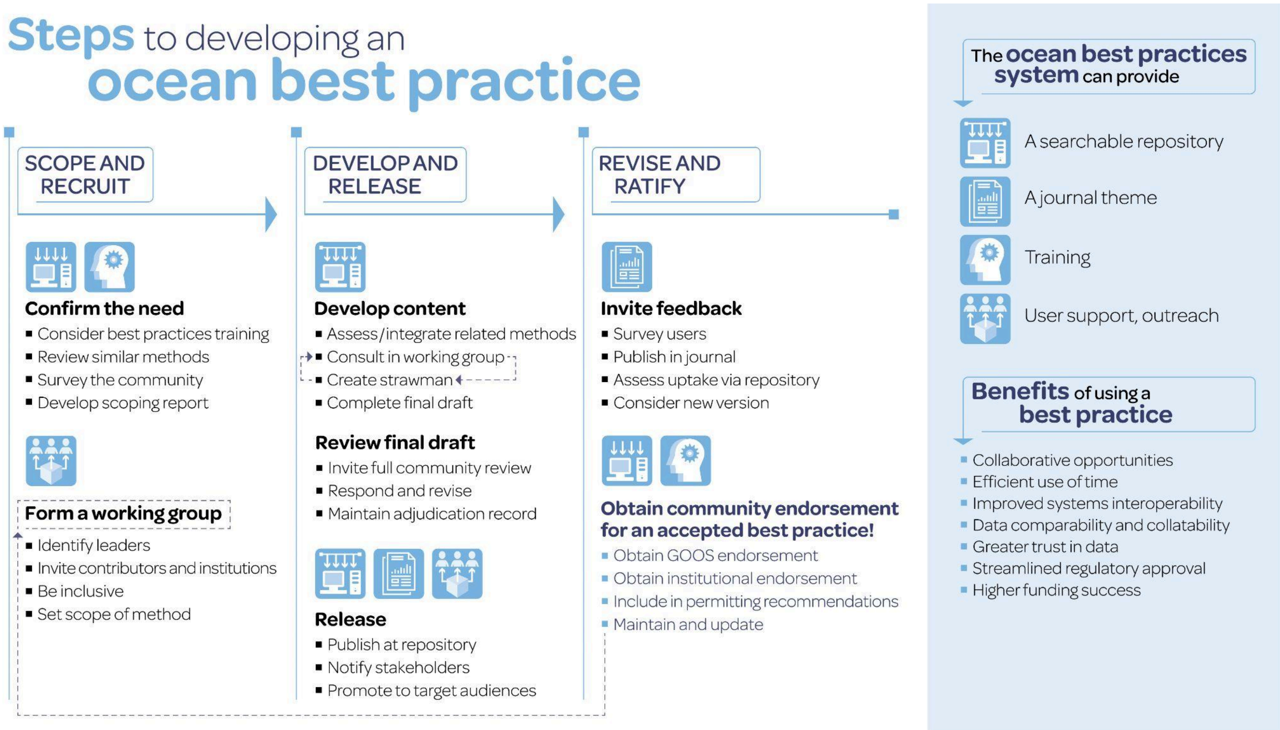

Figure 3: Flow chart showing the iterative process used in the initial development of this field manual package, including links to the international Ocean Best Practices System program (www.oceanbestpractices.org) (Przeslawski et al. 2023).

Table 4: Working groups responsible for the development of the marine sampling field manuals. Working group members are listed in a table at the end of this chapter as authors or collaborators. Green indicates activity on a given field manual during a new version, while grey indicates no development or changes.

Field Manual	Working Group Lead(s)	V1 (2018)	V2 (2020)	V3 (2024)
Survey design	Scott Foster			

Multibeam	Vanessa Lucieer, Kim Picard, Aero Leplastrier			
AUV	Jac Monk, Neville Barrett			
BRUV (benthic)	Tim Langlois, Joel Williams, Jac Monk			
BRUV (pelagic)	Phil Bouchet			
Towed imagery	Andrew Carroll			
Sled and trawl	Rachel Przeslawski			
Grab and box corer	Rachel Przeslawski			
ROV	Jac Monk			
Drop cam	Jac Monk, Tim Langlois			
KAP survey	Matt Navarro, Nicole Hamre			
Microplastics	Nina Wootten, Patrick Reis Santos			

Universal Protocols

In this section, we generally describe some of the protocols that span most field manuals. Further detail on each of these is also provided in each chapter, as it is specifically relevant to a given sampling platform or method.

Sampling design

There are several overarching issues related to sampling design across all field manuals (e.g. randomisation, efficient designs, and uncertainty). We strongly encourage users of any field manual contained in this package to read Chapter 2 to familiarise themselves with these issues.

Permits

Prior to undertaking any marine survey, researchers are responsible for ensuring appropriate applications for permission are lodged, with subsequent relevant approvals obtained and documented. More information regarding legislation and permitting can be found on the AusSeabed website (www.ausseabed.gov.au/resources/permit).

Risk assessments

Risk assessments not only help quantify potential risks associated with planning and field activities, they can help make fieldwork safer and reduce costs. They may also be a requirement for some organisations. It is recommended that a risk assessment is completed during the survey planning phase and again prior to the commencement of fieldwork for any of the sampling platforms included in this manual:

- Planning risk assessment. The assessment during the planning phase identifies risks and mitigation strategies associated with attaining appropriate equipment, staff, finances and other resources. In addition, it should include potential reasons survey objectives may not be met. This provides an opportunity to develop contingency plans and prioritise objectives.

- Fieldwork risk assessment. This assessment identifies risks associated with onboard activities, including safety hazards, equipment damage or loss, inclement weather, and any other aspect that may compromise budget, survey objectives, or crew health and safety. There will be some overlap with the risks identified in the planning phase, but this risk assessment should explicitly address onboard risks. This provides an opportunity to ensure the survey is compliant with workplace health and safety issues, as well as optimising the potential for successful data acquisition.

Indigenous leadership and collaboration

Aboriginal and Torres Strait Islanders have a long and enduring connection to Sea Country and should play a greater role in the delivery of marine science and management (Fischer et al 2022). The different perspectives of Indigenous Knowledge and Western science will give the strongest foundation to understand marine ecosystems and inform modern marine management decisions (Reid et al 2020). Considering both perspectives also expands our ecological and cultural knowledge, as well as increasing the capability, capacity and geographic reach of Traditional Owners' marine activities. The marine science community must actively embrace Indigenous Knowledge and make space for it in our current research frameworks (Hedge et al 2020), as well as exploring new and innovative ways to share knowledge and encourage the next generation of Indigenous scientists.

As such, we encourage researchers and Indigenous practitioners operating in this space (.e.g Indigenous rangers) to partner and engage with each other whenever possible, including supporting Indigenous-led research which may require locally adapted versions of these field manuals. Cross-cultural partnerships need to be built on trust and personal relationships. This can take considerable time and often falls outside the typical western approach of stakeholder engagement.

Researchers and Indigenous practitioners operating in this space should be guided by the *Code of Ethics for Aboriginal and Torres Strait Islander Research* (AIATSIS 2020) wherever possible when planning and implementing research in collaboration with Indigenous people, including obtaining relevant permissions where required. More specifically, they should apply the CARE principles for Indigenous data governance (Carroll et al. 2020). These principles describe how data should be treated to ensure that Indigenous governance over the data and its use are respected. They include the following aspects:

- Collective benefits, in which data management should be designed and function in ways that enable Indigenous peoples to derive benefit from the data;
- Authority to control, in which Indigenous peoples' rights and interests in Indigenous data must be recognised and their authority to control such data be empowered;

- Responsibility, in which those working with Indigenous data have a responsibility to share how those data are used to support Indigenous peoples' self-determination and collective benefit; and
- Ethics, in which Indigenous peoples' rights and wellbeing should be the primary concern at all stages of the data life cycle and across the data ecosystem.

Quality assurance and control

These field manuals define quality assurance (QA) as measures adopted before and during data acquisition, while quality control (QC) are measures adopted after data acquisition. Specifically QA represents the processes necessary to support the generation of high quality data and QC represents the follow-on steps that support the delivery of high-quality data, requiring both automation and human intervention. The documentation of the QA/QC process is arguably just as important as data acquisition itself. The QA/QC process can affect data analysis and interpretation (e.g. observer bias in marine imagery in Durden et al. 2016b) , and it is thus an integral part of standardisation to facilitate comparisons between datasets (Lara-Lopez et al. 2017). The appropriate methods for QA/QC depends on the data type (e.g. multibeam, underwater imagery, biological specimen). As such, further details on QA/QC are included in each field manual in the Data Release sections.

Data discoverability and accessibility

Only 30 per cent of Australia's marine baselines and monitoring data is open access, while 50 per cent is either restricted or confidential (Hedge et al. 2021). This hinders large-scale monitoring and research programs. Reasons for not making data open access vary and include lack of suitable data repositories, insufficient cloud storage, poorly defined workflows, time-poor researchers, poor understanding of why open access data are important, researcher or institutional competition, confidentiality clauses, and industry embargoes.

Notwithstanding all of those reasons, all marine metadata and data should be publicly released so that it is discoverable and accessible to the public, unless circumstances require otherwise (e.g. confidentiality clause or embargo for commercial work). Even in situations when data cannot be shared, the metadata should be made available so that future surveys are based on informed decisions about existing sampling locations. Refer to Stocks et al. (2016) for further information on appropriate information management including useful advice on data quality control and data sharing. Data can be licensed with the Creative Commons BY license which attributes the author but allows for free use of the data, including commercial applications. Some agencies may prefer to restrict commercial applications based on their data in which case Creative Commons BY-NC should be used.

Discoverable and accessible data contribute the following potential benefits to scientific, commercial, environmental, and social endeavours:

- Increased citations, media attention, and public engagement opportunities for researchers (McKiernan et al. 2016);
- More collaboration, funding, and job opportunities for researchers (Popkin et al. 2019);

- Larger and more useful datasets to address regional, national, and international issues (e.g. Cinner et al. 2020);
- Faster and more accurate development of analytical tools to inform important and emerging scientific and management questions (Zipkin 2019);
- Enabling artificial intelligence developments to improve the cost-efficiency of biodiversity monitoring (Katija et al 2022).
- Stronger capability to monitor environmental changes and develop appropriate management plans, including expedited capacity to appropriately respond to natural disasters (Donner et al. 2017);
- Increased potential for industry and commercial application of data products and information (e.g. Carroll et al. 2012);

All field manuals, excluding the manual on survey design, include a section titled "Data Release," which describes ways to ensure public discoverability and accessibility of collected data, thereby abiding by the FAIR (findable, accessible, interoperable, reusable) principles (Wilkinson et al., 2016). In the first version of the field manuals, these sections did not provide a clear national standard and instead refer to anticipated improvements in subsequent versions. This vagueness was due to the current lack of established national data infrastructure able to incorporate appropriate or comprehensive information produced from the sampling platforms.

To meet these challenges related to data discoverability and accessibility, a series of workshops were held in the months following the field manuals release (July – September 2018, July 2019), including focused workshops on bathymetry data, marine imagery, and biological specimen data. The bathymetry data release protocols subsequently eventuated as part of digital infrastructure developed as part of the AusSeabed program (www.ausseabed.gov.au). In contrast, marine imagery and biological specimen data were linked to existing digital platforms (Squidle+, GlobalArchive, OBIS Australia, Atlas of Living Australia) so priorities were to establish appropriate workflows linking these platforms with the data collection phase, and to find the resources needed to ensure they can be developed and maintained. Further recommendations about the discoverability of marine imagery and biological specimen data can be found in the relevant workshop reports (Przeslawski et al. 2019c,d).

Regardless of the challenges described above, the appropriate methods for release of marine data depend on the data type (e.g. multibeam, underwater imagery, biological specimen). As such, further details on data management (including accessibility and discoverability) are included in each field manual in the Data Release sections.

Post-survey report

A post-survey report is highly recommended within a year of survey completion. Such a report is valuable documentation of the survey objectives, methods, and preliminary results. It is especially important because it is a single resource describing the multiple methods and data often acquired from a given survey, and it provides overarching context to a survey that is not found in the associated metadata or data. Many agencies have their own post-survey report template, and we have also included such a template with suggested headings and content.

Outreach and Maintenance

After the release of the Version 1 of the field manual package in early 2018, efforts were focussed on outreach to increase the adoption of the field manuals by the broader marine science community in Australia, as well as industry, regulators, and policymakers. This was done initially through conference presentations and face-to-face meetings, with follow-up meetings and questionnaires to gauge the success of adoption. Outreach and engagement efforts were focussed on establishing institutional uptake of the field manuals, rather than just individual uptake. This ensures the continuity and long-term applicability of the SOPs even if advocating individuals leave an agency. Ultimately, institutional uptake will maximise the comparability of datasets from various surveys, thus increasing the amount of comparable data able to be applied to national products and syntheses.

The field manuals are not just applicable to the Australian community; they are also valuable to the international community, both regarding their content and the process used to develop them. The latter was addressed in two scientific journal papers (Przeslawski et al 2019a, Przeslawski et al 2023), while the content is available through the international searchable Ocean Best Practice Repository (www.oceanbestpractices.org) (Pearlman et al 2019).

Following community consultation and input, support was available to develop a Version 2 of this field manual package in 2020 and a Version 3 in 2024.. There will be a need to develop subsequent versions for the following reasons:

- Keeping up with technological advances to ensure uniformity of data acquisition across multiple agencies over time is a challenge for some platforms, particularly those that are based on rapidly advancing technology (e.g. AUV, MBES, microplastics). In order to ensure that field manuals include relevant advances, they should be periodically checked and revised, lest they become superseded or obsolete.
- Over time, opportunities may arise for increasing the amount of standardisation between research providers. This may come from the acquisition of new sampling gear, changes in research staff, or development of new projects and monitoring programmes.
- The way in which the data are stored in aggregated databases will evolve over time. Currently, for many platforms, there is a competitive environment within this area. Competition is a force for change, and so change is likely to occur. The 'Data Release' sections of each manual will almost certainly need to be updated again by 2028 to account for these developments and provide clearer and more definitive instructions (e.g. Przeslawski et al 2019d).
- Each field manual has a sub-section on uses of the sampling platform in marine monitoring. This will need to be periodically updated to include new research and monitoring outcomes.
- One of the strengths of this field manual package is the collaborative approach taken to ensure representation of a range of organisations and disciplines. As time passes, this representation will become increasingly outdated, and new and different researchers should be given the opportunity to contribute.

- Suggestions about standard vocabularies for metadata are currently lacking, and there is an opportunity to help guide the AODN and other programs regarding controlled metadata vocabularies in future versions.

- The new online platform managed through GitHub Pages was chosen partly due to the inherent version control features. Nonetheless, an update or new system to host these field manuals may be required in the future.

A long-term plan and associated support for managing the field manuals has not yet been fully developed, with the exception of the multibeam field manual which will be overseen by AusSeabed. Efforts are still needed to establish a high-level oversight committee to develop and implement actions needed for future versions and to strengthen institutional uptake. At the time of writing this introduction, the most likely groups for this responsibility are the National Marine Science Committee's Monitoring and Environmental Baseline working group, the AODN and/or the NESP Marine and Coastal Hub.

Version 2 - Updates and Revisions

Version 1 of the field manual package was released in February 2018, and Version 2 was released two years later in July 2020.

All original chapters were updated in Version 2 with stakeholder feedback, corrections, and updates where applicable. The chapter 'Seafloor Mapping Field Manual for Multibeam Sonar' was substantially changed in Version 2 to amalgamate it with the *Australian Multibeam Guidelines* which were released in June 2018 by AusSeabed, a nationally seabed mapping coordination program. The unified multibeam manual in Version 2 addresses stakeholder concerns about maintaining two separate SOPs for multibeam sonar. In addition, a new manual on ROVs was developed for the Version 2 package. The ROV was chosen based on findings from a report titled Scoping of new field manuals for marine sampling in Australian waters (Przeslawski et al. 2019b).

All major changes related to a given sampling platform are logged in a version control table at the end of the relevant manual.

One of the most notable changes for Version 2 was the development of an online portal for the field manuals (https://marine-sampling-field-manual.github.io). While Version 1 was released as static pdfs through the NESP Marine Hub website, Version 2 was released through GitHub. This digital delivery system has the following benefits:

- The manuals are easily accessible in online or pdf formats, increasing the flexibility of user experiences and needs.

- The online system readily reflects minor corrections by harvesting through the source document maintained on Google docs.

- Updates and version control are easier to manage through permissions on GitHub and GoogleDocs.

- Analytics are easily generated to track downloads which can then be incorporated into impact assessments.

- A clearly documented user-friendly workflow (Figure 5) will help future contributors to maintain and update existing SOPs and to develop new ones.
- The online system has more flexibility to embed imagery and other media (e.g. video tutorials) in future versions, thereby taking a much more modern approach than only static pdfs allow.

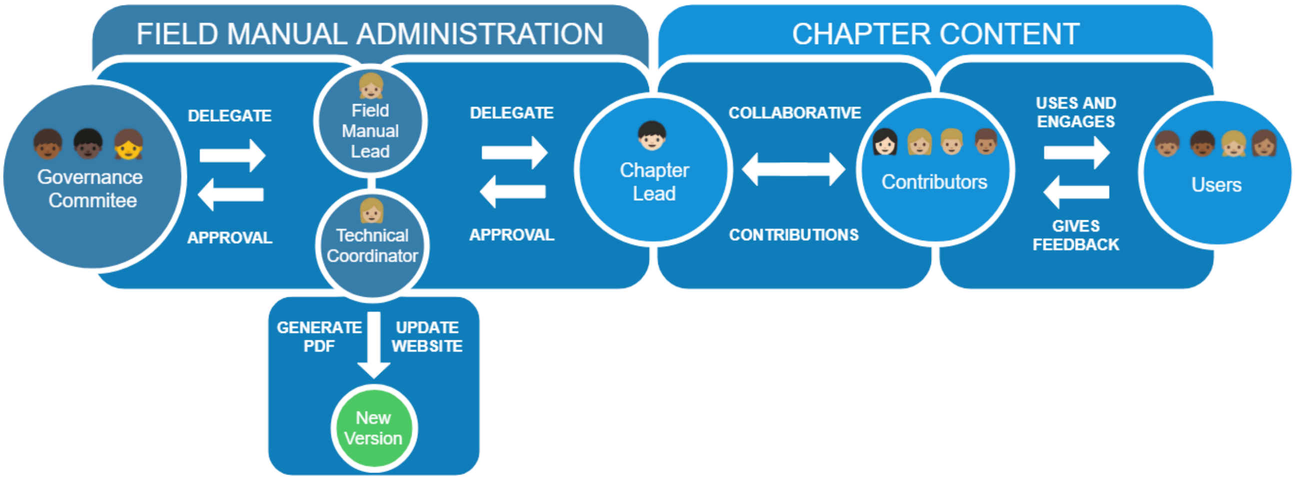

Figure 5: Workflow of version control and governance for the digital field manuals of Version 2 and future versions.

Version 3 - Updates and Revisions

Version 3 of the entire field manual package was released in March 2024. In addition to minor updates on most field manuals, three new field manuals were developed (see Table 4). The introductory chapter was also updated, including a new section on Indigenous partnerships and engagement. The website was revised to reflect all Version 3 updates including the expanded list of collaborators from the new field manuals.

Collaborators

All individuals that contributed to versions 1, 2 or 3 of this field manual package are listed below, with the following categories assigned based on their level of contribution:

- *Editors* oversaw production of the entire field manual package, ensuring fit-for-purpose content and consistent scope, style, and formatting throughout.
- *Lead authors* led working groups associated with discrete chapters or sampling platforms.
- *Authors* helped write chapters or provided crucial information to do so.
- *Contributors* participated in working group discussions.
- *Reviewers* provided assessments of draft chapters. In some cases, reviewers of Version 1 became co-authors of Version 2 due to their extensive contributions.

First name	Surname	Agency	Role	Chapter
Rachel	Przeslawski	Geoscience Australia, NSW DPI	Editor, Lead author	Various
Scott	Foster	CSIRO	Editor, Lead author	Various
Neville	Barrett	UTas	Lead author	AUV, ROV, MBES, Drop cam
Phil	Bouchet	UWA	Lead author	P_BRUV, BRUV
Andrew	Carroll	Geoscience Australia	Lead author	Towed Vid, AUV
Brooke	Gibbons	UWA	Lead author	BRUV, KAP, Drop cam, Website
Bronwyn	Gillanders	The University of Adelaide	Lead author	Microplastics
Nicole	Hamre	UWA	Lead author	KAP
Tim	Langlois	UWA	Lead author	BRUV, P_BRUV, KAP, Drop Cam
Aero	Leplastrier	Geoscience Australia	Lead author	MBES (V2)
Vanessa	Lucieer	UTas	Lead author	AUV, MBES (V1)
Jac	Monk	UTas	Lead author	ROV, AUV, BRUV, TowVid, Stats, Drop Cam
Matt	Navarro	UWA	Lead author	KAP, Drop cam
Kim	Picard	Geoscience Australia	Lead author	MBES (V2)
Patrick	Reis-Santos	The University of Adelaide	Lead author	Microplastics
Claude	Spencer	UWA	Lead author	Drop Cam
Joel	Williams	NSW DPI	Lead author	BRUV, ROV, Drop cam
Nina	Wootton	The University of Adelaide	Lead author	Microplastics
Rene	Abesamis	Silliman University	Author	BRUV
Vanessa	Adams	UTas	Author	KAP
Kye	Adams	WA Department of Biodiversity, Conservation and Attractions (DBCA)	Author	Drop Cam
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Jacob	Asher	NOAA	Author	BRUV
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Ashlee	Bastiaansen	UTas	Author	Drop Cam
Nic	Bax	UTas	Reviewer	All (V1)
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Robin	Beaman	James Cook University	Author, Contributor	TowVid, MBES
Penny	Berents	Australian Museum	Author	Grab
Nicole	Bergersen	Acoustic Imaging	Contributor	MBES
Douglas	Bergersen	Acoustic Imaging	Contributor	MBES
Anthony	Bernard	South African Institute for Aquatic Biodiversity	Author	BRUV, Drop cam
Brian	Bett	University of Southampton	Reviewer	AUV
Matthew	Birt	AIMS	Author	BRUV
Michelle	Blewitt	AUSMAP	Author	Microplastics
Todd	Bond	UWA	Author	ROV, Drop cam
Matt	Boyd	CSIRO	Contributor	MBES
Brett	Brace	RAN AHO	Contributor	MBES
Tom	Bridge	AIMS	Author	AUV
Brendan	Brooke	Geoscience Australia	Contributor	MBES
Simon	Bryars	SA Dept Env and Water	Author	KAP
Owen	Cantrill	QLD MSQ	Contributor	MBES
Mike	Cappo	AIMS	Author	BRUV
Genevieve	Carey	ENTAC	Author	Drop Cam, KAP
Mark	Case	AIMS	Contributor	MBES
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* An abridged version of the grab field manual was developed for the AHO for sedimentology, excluding geochemical and biological data.

References

Alory, G., S. Wijffels., G. Meyers. 2007. Observed trends in the Indian Ocean over 1960-1999 and associated mechanisms. Geophysical Research Letters 34, L02606.

Aither. 2022. Integrated Monitoring and Evaluation Framework for the Marine Integrated Monitoring Program A Live Framework prepared for NSW Department of Primary Industries and Environment.

AIATSIS 2020. AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research. Australian Institute of Aboriginal and Torres Strait Islander Studies.

Bouchet, P., Z. Huang, C. Phillips, J. Meeuwig, S. Foster, and R. Przeslawski. 2018. Comparative assessment of pelagic sampling platforms. University of Western Australia, Perth.

Bowden, D. A., M. R. Clark, J. E. Hewitt, A. A. Rowden, D. Leduc, and S. J. Baird. 2015. Designing a programme to monitor trends in deep-water benthic communities. Wellington.

Carroll, A.G., D.C. Jorgensen, P.J.W.,Siwabessy, L.E.A. Jones., M.J. Sexton, M. Tran, W.A. Nicholas, L.C. Radke, M.P. Carey, F.J.F. Howard, M.J. Stowar, A.J. Heyward, A. Potter, and Shipboard Party, 2012. Seabed environments and shallow geology of the Petrel Sub-Basin, northern Australia: SOL5463 (GA0335) - post survey report. Record 2012/66. Geoscience Australia: Canberra.

Carroll, S., Garbai, I., Figueroa-Rodriguez, O. et al. 2020. The CARE principle for Indigenous data governance. Data Science Journal 19.

Cinner, J.E., J. Zamborain-Mason, G.G. Gurney et al. 2020. Meeting fisheries, ecosystem funciton, and biodiveristy goals in a human-dominated world. Science 368 (6488): 307-311.

Cochrane, P. 2016. The marine protected area estate in Australian (Commonwealth) waters. Pages 45-63 *in* J. Fitzsimons and G. Westcott, editors. Big, Bold and Blue. CSIRO.

De'ath, G., K. E. Fabricius, H. Sweatman, and M. Puotinen. 2012. The 27–year decline of coral cover on the Great Barrier Reef and its causes. Proceedings of the National Academy of Sciences 109:17995-17999.

Department of Biodiversity Conservation and Attractions. 2017. Marine Conservation Research. Government of Western Australia. https://www.dpaw.wa.gov.au/about-us/science-and-research/marine-research

Donner, S.D., G.J.M. Rickbeil, and S.F. Heron. 2017 A new, high-resolution global mass coral bleaching database. PLoS ONE 12(4): e0175490. https://doi.org/10.1371/journal.pone.0175490

Duffy, J.E., L.A. Amaral-Zettler, D.G. Fautin, G. Paulay, T.A. Rynearson, H. M. Sosik, and J. J. Stachowicz. 2013. Envisioning a Marine Biodiversity Observation Network. BioScience 63:350-361.

Durden, J.M., B.J. Bett, T. Schoening, K.J. Morris, T.W. Nattkemper, and H.A. Ruhl. 2016. Comparison of image annotation data generated by multiple investigators for benthic ecology. Marine Ecology Progress Series 552:61-70.

Evans, K., N. Bax., and D. Smith. 2017. Australia state of the environment 2016: Marine Chapter. Independent report to the Australian Government Minister for Environment and Energy, Department of the Environment and Energy, Canberra.

Fancy, S., G.J.E. Gross, and S.L. Carter. 2009. Monitoring the condition of natural resources in US national parks. Environmental Monitoring and Assessment 151:161-174.

Fischer, M., Maxwell, K., Nuunoq, Pedersen, H., Greeno, D., Jingwas, N., Blair, J.G., Hugu, S., Mustonen, T., Murtomäki, E., and Mustonen, K. 2022. Empowering her guardians to nurture our Ocean's future. Review in Fish Biology and Fisheries 32:271-296.

Foster, S.D., Hosack, G.R., Monk, J., Lawrence, E., Barrett, N.S., Williams, A., Przeslawski, R. 2019. Spatially balanced designs for transect-based surveys. Methods in Ecology and Evolution 11:95-105.

Foster, S.D., Hosack, G.R., Lawrence, E., Przeslawski, R., Hedge, P., Caley, M.J., Barrett, N.S., Williams, A., Li, J., Lynch, T., Dambacher, J.M., Sweatman, .P.A., and Hayes, K. 2017. Spatially balanced designs that incorporate legacy sites. Methods in Ecology and Evolution 8:1433-1442.

GBRMPA. 2015. Reef 2050 Integrated Monitoring and Reporting Program Strategy. Great Barrier Reef Marine Park Authority & Queensland Government, Townsville.

Golden, J.S., J. Virdin, D. Nowacek, P. Halpin, L. Bennear, and P. G. Patil. 2017. Making sure the blue economy is green. Nature Ecology and Evolution 1:0017.

Hayes, K.R., J.M. Dambacher, P.T. Hedge, D. Watts, S. D. Foster, P.A. Thompson, G.R. Hosack, P.K. Dunstan, and N.J. Bax. 2015. Towards a blueprint for monitoring Key Ecological features in the Commonwealth Marine Area. NERP Marine Biodiversity Hub, Hobart.

Hayes, K.R., G.R. Hosack, E. Lawrence, P. Hedge, N. Barrett, R. Przeslawski, M.J. Caley, S.D. Foster. 2019. Designing Monitoring Programs for Marine Protected Areas Within an Evidence Based Decision Making Paradigm Frontiers in Marine Science 6: 746.

Hedge, P., Souter, D., Jordan, A., Trebilco, R., Ward, T., van Ruth, P., Cowlishaw, M., Lara-Lopez, A., Barrett, N., Thornborough, K., Nichol, S., Przeslawski, R., Parr, A., Kendrick, A., Holmes, T., Pattiaratchi, C., and Ferns, L. 2021. Establishing and supporting a national marine baselines and monitoring program. A report from the Baselines and Monitoring Working Group prepared for Australia's National Marine Science.

Hedge, P., van Putten, E.I., Hunter, C. and Fischer, M. 2020. Perceptions, motivations, and practices for Indigenous engagement in marine science in Australia. Frontiers in Marine Science 7.

Hedge, P., F. Molloy, H. Sweatman, K. Hayes, J. Dambacher, J. Chandler, M. Gooch, A. Chinn, N. Bax, and T. Walshe. 2013. An Integrated Monitoring Framework for the Great Barrier Reef World Heritage Area. Department of the Environment, Canberra.

Hosie, G. W., M. Fukuchi, and S. Kawaguchi. 2003. Development of the Southern Ocean Continuous Plankton Recorder survey. Progress in Oceanography 58:263-283.

Katija, K., Orenstein, E., Schlining, B., Lundsten, L., Barnard, K., Sainz, G., Boulais, O., Cromwell, M., Butler, E., Woodward, B., and Bell, K.L.C. FathomNet: A global image database for enabling artificial intelligence in the ocean. Scientific Reports 12.

Lara-Lopez, A., Moltmann, T., Mancini, S., Proctor, R., 2017. Quality Assurance and Quality Control by Variable. Integrated Marine Observing System, Hobart, 67 pp.

McKiernan, E.C., P.E. Bourne, C.T. Brown, S. Buck, A. Kenall, J. Lin, D. McDougall, B.A. Nosek, K. Ram, C.K. Soderberg, J.R. Spies, K. Thaney, A. Updegrove, K.H. Woo, and T. Yarkoni. 2016. How open science helps researchers succeed. eLife 5:e16800.

Miloslavich, P., N.J. Bax, S.E. Simmons, E. Klein, W. Appeltans, O. Aburto-Oropeza, M.A. Garcia, S.D. Batten, L. Benedetti-Cecchi, D.M. Checkley Jr., S. Chiba, J.E. Duffy, D.C.Dunn, A. Fischer, J. Gunn, R. Kudela, F. Marsac, F.E. Muller-Farger, D. Obura, Shin, Y-J. 2018. Essential ocean variables for global sustained observations of biodiversity and ecosystem changes. Global Change Biology 24(6): 2416-2433.

Muller-Karger, F., P. Miloslavich, N.J. Bax, et al. 2018. Advancing marine biological observations and data requirements of the complementary Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs) frameworks. Frontiers of Marine Science. doi.org/10.3389/fmars.2018.00211.

National Academies of Sciences, Engineering, and Medicine. 2019. Reproducibility and Replicability in Science. Washington, DC: The National Academies Press. https://doi.org/10.17226/25303.

Pecl, G.T., Stuart-Smith, J., Walsh, P., Bray, D.J., Kusetic, M., Burgess, M., Frusher, S.D., Gledhill, D.C., George, O., Jackson, G., Keane, J., Martin, V.Y., Nursey-Bray, M., Pender, A., Robinson, L.M., Rowling, K., Sheaves, M., and Moltschaniwskyj, N. 2019. Redmap Australia: Challenges and successes with a large-scale citizen science-based approach to ecological monitoring and community engagement on climate change. Frontiers of Marine Science 6.

Perkins, N. R., S.D. Foster, N.A. Hill, M.P. Marzloff, and N.S. Barrett. 2017. Temporal and spatial variability in the cover of deep reef species: Implications for monitoring. Ecological Indicators 77:337-347.

Pearlman J., M. Bushnell, L. Coppola, et al. Evolving and sustaining ocean best practices and standards for the next decade. Frontiers of Marine Science. 6: 277.

Popkin, G. 2019. Data sharing and how it can benefit your scientific career. Nature. 568: 445-447.

Przeslawski, R., S. Foster, and J. Monk. 2018. Comparative assessment of benthic sampling platforms. NESP Marine Hub.

Przeslawski, R., S. Foster, J. Monk, N. Barrett, P. Bouchet, A. Carroll, T. Langlois, V.,Lucieer, J. Williams, and N. Bax. 2019a. A Suite of Field Manuals for Marine Sampling to Monitor Australian Waters. Frontiers of Marine Science. 6:177

Przeslawski, R., L. Bodrossy, A. Carroll, A. Cheal, M. Depczynski, S. Foster, B.D. Hardesty, P. Hedge, T. Langlois, A. Lara-Lopez, A. Lepastrier, S. Mancini, K. Miller, J. Monk, M.Navarro, S. Nichol, S. Sagar, R. Stuart-Smith, J. van de Kamp, J. Williams. 2019b. Scoping of new field manuals for marine sampling in Australian waters. Report to the National Environmental Science Programme, Marine Biodiversity Hub. Geoscience Australia.

Przeslawski, R., I. Falkner, S. Foster, S. Mancini, S. Bainbridge, N. Bax, A. Carroll, E. Flukes, M. Gonzalez-Riviero, T. Langlois, K. Moore, M. Rehbein, K. Tattersall, D. Watts, A. Williams, M. Wyatt. 2019c. Data Discoverability and Accessibility: Report from Workshops on Marine Imagery and Biological Specimen Data. Report to the National Environmental Science Program, Marine Biodiversity Hub. Geoscience Australia.

Przeslawski, R., N. Barrett, N. Bax, A. Carroll, S. Foster, M. Heupel, J. Jansen, T. Langlois, T. Moltmann, J. Pocklington, R. Stuart-Smith, M. Wyatt. 2019d. Data Discoverability and Accessibility: Report from July 2019 Workshop on Marine Imagery. Report to the National Environmental Science Program, Marine Biodiversity Hub. Geoscience Australia.

Przeslawski, R., Foster, S., Gibbons, B., Langlois, T., and Monk, J. 2021. Impact and Outcomes of Marine Sampling Best Practices. Report to the National Environmental Science Program, Marine Biodiversity Hub. Geoscience Australia.

Przeslawski, R., Barrett, N., Carroll, A., Foster, S., Gibbons, B., Jordan, A., Monk, J., Langlois, T., Lara-Lopez, A., Pearlman, J., Picard, K., Pini-Fitzsimmons, J., van Ruth, P., Williams, J. 2023. Developing an ocean best practice: A case study of marine sampling practices from Australia. Frontiers in Marine Science 10.

Reid, A.J., Eckert, L.E., Lane, J-F., Young, N., Hinch, S.G., Darimont, C.T., Cooke, S.J., Ban, N.C. and Marshall, A. 2020. 'Two-Eyed Seeing': An Indigenous framework to transform fisheries research and management. Fish and Fisheries 22:243-261.

Schramm, K.D., E. Harvey, M.J. Travers, J. Goetze, B. Warnock, B.J. Sanders. 2020. A comparison of stereo-BRUV, diver operated and remote stereo-video transects for assessing reef fish assemblages. Journal of Experimental Marine Biology and Ecology 524: 151273.

Sloyan, B.M., T.J. O'Kane. 2015. Drivers of decadal variability in the Tasman Sea. Journal of Geophysical Research: Oceans 120, 3193-3210.

Stocks, K. I., N.J. Stout, and T.M. Shank. 2016. Information management strategies for deep-sea biology. Pages 368-385 Biological Sampling in the Deep Sea. Wiley Blackwell, West Sussex.

Stuart-Smith, R.D., et al. 2017. Assessing National Biodiversity Trends for Rocky and Coral Reefs through the Integration of Citizen Science and Scientific Monitoring Programs. BioScience 67(2): 134-146.

Taylor, M. D., R.C. Babcock, C.A. Simpfendorfer, and D.A. Crook. 2017. Where technology meets ecology: acoustic telemetry in contemporary Australian aquatic research and management. Marine and Freshwater Research 68:1397-1402.

Teixeira, H., T. Berg, L. Uusitalo, K. Fürhaupter, A.-S. Heiskanen, K. Mazik, C. P. Lynam, S. Neville, J. G. Rodriguez, N. Papadopoulou, S. Moncheva, T. Churilova, O. Kryvenko, D. Krause-Jensen, A. Zaiko, H. Veríssimo, M. Pantazi, S. Carvalho, J. Patrício, M. C. Uyarra, and À. Borja. 2016. A Catalogue of Marine Biodiversity Indicators. Frontiers in Marine Science 3.

Teytelman, L. 2018. No more excuses for non-reproducible methods. Nature 560: 411.

Thomson, C., Kilminister, K., Hallett, C., Valesini, F., Hipsey, M., Gaughan, D., Summers, R., Syme, G., P., S., 2017. Research and information priorities for estuary management in southwest Western Australia Western Australian Marine Science Institution, Perth, p. 87.

van de Kamp, J., Brown, M., Ostrowski, M., Seymour, J., Smith, M., Raes, E., Karsh, K., Holmes, B., Bodrossy, L., and Bissett, A. 2019. Australian Microbiome Initiative - towards microbial omics at the continental scale. Geophysical Research Abstracts 21.

Wilkinson, M.D., M. Dumontier, I.J. Aalbersberg, et al. 2016. The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data 3:160018

Wraith, J., T. Lynch, T.E. Minchinton, A. Broad, and A.R. Davis. 2013. Bait type affects fish assemblages and feeding guilds observed at baited remote underwater video stations. Marine Ecology Progress Series 477:189-199.

Zipkin, E.F., B.D. Inouye, and S.R. Beissinger. 2019.. Innovations in data integration for modeling populations Ecology 100: e02713