National **Environmental Science** Programme

1. INTRODUCTION

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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 has recently established the Australian Marine Parks (AMPs), the largest network of marine protected areas in the world, complementing existing networks in State and Territory waters (Cochrane 2016).

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. It now has a number of significant long-term marine monitoring and observing programs (Table 1.1), as well as a national ocean data network (aodn.org.au). Without some common and agreed standards, much of the information collected will 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 now uniquely placed to develop standardised national approaches to monitor the marine environment. This objective integrates with one of the eight high-level priorities identified by the National Marine Science Plan (2015-25): the establishment of national baselines and long-term monitoring. This 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 currently highly variable and frequently inadequate in the 2016 State of the Environment Report (Evans et al. 2017). 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 in marine monitoring 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), 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 1.1 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 it has yet to be developed, implemented, and adopted at a national scale for most other biological sampling platforms (but see IMOS AUV Facility in Table 1.1).

Table 1.1 Large-scale biological or ecological monitoring programs currently operating or under development in Australia as of Dec 2017. 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 Reference Stations	National	Nutrients, microbes, phytoplankton, zooplankton, environmental factors	Moored sensors, water sampling	Sloyan and O'Kane 2015
	Benthic/Demersal	RIMREP	GBR	Various	Various (TBC)	GBRMPA 2015
		Marine Integrated Monitoring Program	NSW	Various (TBC)	Aerial imagery, UVC, BRUVs, AUVs, towed imagery, grabs, DOVs, ROVs	NSW Government 2017
		WAMSI estuary science program	WA	Various (TBC)	Various (TBC)	Thomson et al. 2017
		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
		IMOS AUV Facility	National	Benthic invertebrate assemblages	AUV	Perkins et al. 2017
		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	Current study

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

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 six 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 video, grabs and box cores, and sleds and trawls. Each of these platforms targets a discrete data type (bathymetry, imagery, biological and sediment samples) in particular environments (consolidated, unconsolidated substrates) (Table 1.2), with specific advantages (Table 1.3). In addition, we provide a field manual for pelagic BRUVs as a concept sampling method in pelagic ecosystems due to its similarity to benthic BRUVs. Importantly, the inclusion of these sampling platforms 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 1.1). 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. 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 1.2: Summary of prioritised benthic sampling platforms and their acquisition targets

	Data Type	Data Target	Spatial coverage	Environment	Chapter
MBES	Bathymetry, backscatter	Seafloor	Continuous	All	3
AUV	Imagery	Epifauna	Continuous	All	4
BRUV	Imagery	Demersal fish	Point (qualitative)	All	5
Towed	Imagery	Epifauna	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

Table 1.3: Advantages of prioritised benthic sampling platforms.

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

[1] Refers to identifications able to be made with unknown or cryptic species (i.e. well-known, distinctive species can be identified via imagery)

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 is 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.

We generally limit these platforms to benthic biological sampling, with a few exceptions (e.g. pelagic BRUVs included as a proof-of-concept due to its similarity to benthic BRUVs; water column, sedimentology, and geochemistry data included for comprehensiveness related to the relevant platform). These Marine Sampling Field Manuals focus on data acquisition and post-processing including data management, particularly as applied to marine monitoring. Standardisation of sampling design is important 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 each field manual, a scope specific to that particular 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. In this first version of the field manuals, 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). Ultimately, the decision to use particular marine sampling platforms depends on a variety of factors, including depth (e.g. reef vs slope), substrate (e.g. hard vs soft), purpose (e.g. voyage of discovery vs impact assessment), and resources (e.g. minimal expertise vs technologically complex). For a more detailed review of each sampling platform, as well as a comparative assessment among them, we refer readers to our companion report (Przeslawski 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 (i.e. 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. For this reason, the package can be downloaded in its entirety as a single pdf, or as standalone chapters representing discrete field manuals (Figure 1.1). References will be listed accordingly at the end of each chapter.

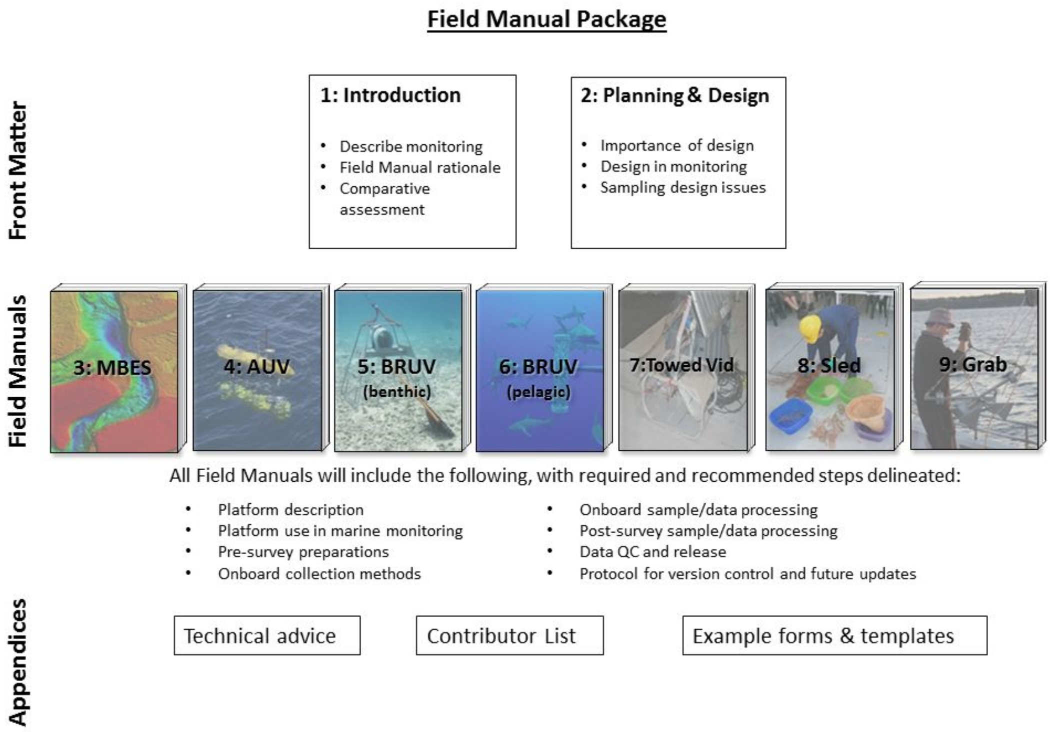

Figure 1.1 The structure of the NESP field manual package (version 1) with numbers indicating respective chapters

Development of Field Manuals

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 is not consistent and therefore not comparable).
A collaborative approach was therefore paramount to their development.

Ultimately, over 70 individuals from over 30 organisations contributed to the field manual package. 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. This not only improved the content but also increased the potential for adoption of the SOPs across multiple agencies and monitoring programs. Input from additional stakeholders will be actively sought during the 2018 outreach program.

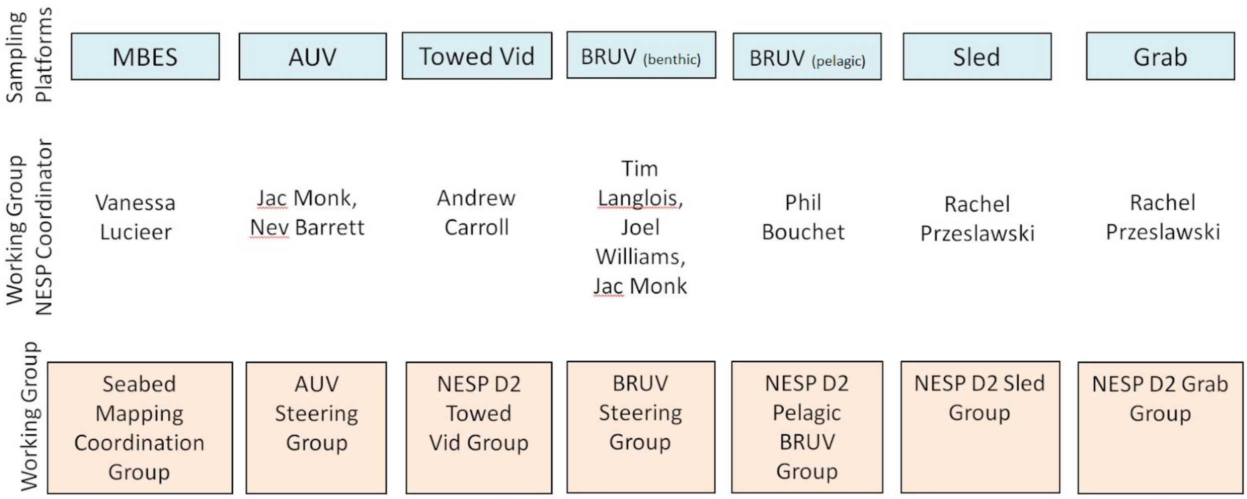

Figure 1.2 Collaborative network that developed the marine sampling field manuals. Working group members are listed in Appendix A as authors or collaborators.

The process used to develop each field manual included in this package is shown in Figure 1.3 and described 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 2017 conference). 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 (Figure 1.2).
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, Geoscience Australia, and 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.
8. Content of field manuals was revised based on feedback and new developments (e.g. data discoverability and accessibility). This will form the next version of the field manual package.

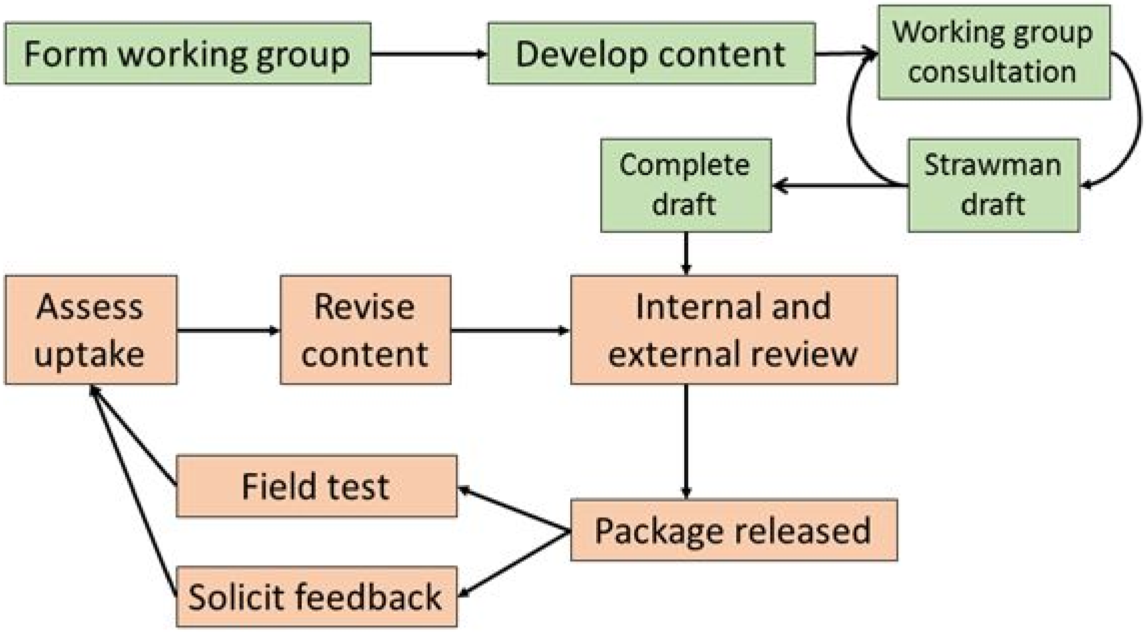

Figure 1.3 Flow chart showing the iterative process used in the development of this field manual package (version 1, orange and green), as well as subsequent future versions (orange only).

Contributors

All individuals that contributed to this field manual package are listed in Appendix A, with the following categories assigned based on their level of contribution:

- *Editors* oversaw production of the entire field manual package, ensuring 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.
- *Field testers* provided input based on their actual use of a manual in the field.

Universal Protocols

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

Sampling design

There are several overarching issues related to sampling design across all marine sampling platforms (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. A list of potential permissioning documents relevant to marine sampling in Commonwealth waters are listed in Appendix B.

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.

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.

Data discoverability and accessibility

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. 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.

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 restriction on commercial applications based on their data in which case Creative Commons BY-NC should be used.

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 one with suggested headings and content in Appendix C for reference.

Maintenance of Field Manuals

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). In order to ensure that field manuals include relevant advances, they should be periodically checked and revised, lest they become superseded or obsolete.

Resources are available to develop a Version 2 of this field manual package, due for completion in late 2018, following additional community consultation and input. As part of this version, a long-term plan for managing the field manuals will be developed, including maintenance, version control, and the scoping of further SOPs as new sampling platforms are ready for use in monitoring programs. Potential future SOPs include marine plastics and genomics. Shallow reef census methods are not included presently but a separate Marine Hub project has assessed the major national diver-based reef monitoring programs (Stuart-Smith et.al., 2017).

Outreach

After the release of the current field manual package (version 1), efforts will be focussed on outreach to increase the adoption of the field manuals by the broader marine science community, as well as industry, regulators, and policymakers. This will be done initially through conference presentations and face-to-face meetings, with follow-up meetings and questionnaires to gauge the success of adoption. Feedback on the current version, as well as suggestions for future versions and field manuals can be given here: www.surveymonkey.com/r/CQKC688.

In addition, there is a need to establish institutional uptake of the field manuals, rather than just individual uptake. This will ensure 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. Efforts are currently underway to establish a high-level oversight committee to develop and implement actions needed for this.

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