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Database for marine and coastal restoration projects in Australia and New Zealand

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Summary The United Nations has declared 2021–2030 as the Decade on Ecosystem Restoration and the Decade of Ocean Science for Sustainable Development. These declarations emphasise the importance of restoring degraded marine and coastal ecosystems and supporting research and knowledge. The number and scale of marine and coastal restoration projects have been increasing in Australia and New Zealand over the past 40 years. However, the lack of a central repository of projects and their results limits opportunities to share knowledge to improve effectiveness. To address this gap, we developed the Australian and New Zealand Marine and Coastal Restoration Database. Information for this database was gathered from publicly available documents (peer-reviewed journal articles and technical reports) and discussions with key organisations that lead projects in Australia and New Zealand. For each project, we recorded the start date, duration, spatial scale, location, details on monitoring, and success criteria. The database includes information up until 1 June 2020. It is available online via the Australian Coastal Restoration Network website.

Key words: *central repository, coastal, database, restoration, success.*

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Introduction

Marine and coastal ecosystems, which include coral reefs, kelp forests, mangroves, salt marsh, seagrass and shellfish reefs, provide essential ecosystem services, such as carbon drawdown, fisheries nurseries and feeding grounds, coastline protection and nutrient cycling (Duarte *et al*. 2020), along with recreational and cultural services. Decades of anthropogenic impacts on the world's marine and coastal environments have resulted in widespread degradation, including in Australia and New Zealand. As the impacts of climate change and biodiversity loss become more apparent, increased efforts to reverse the loss of these ecosystems and restore or rehabilitate impacted areas are being employed (Saunders *et al*. 2020; Murray *et al*. 2022).

Ecological Management & Restoration *Linking science and practice*

Implications for Managers

- Provide a source of available literature on marine and coastal restoration in Australia and New Zealand for managers to enable continued knowledge sharing.
- Develop a body of work for specific ecosystems and the impact of restoration on their conservation status.
- Use lessons learnt from earlier, similar projects to inform the development of new projects.
- Use the strengths and weaknesses of previous projects to ensure the continued improvement of project design and implementation.

There is a global need to restore coastal and marine ecosystems (Abelson *et al*. 2020). The United Nations (UN) declared 2021–2030 as the UN Decade on Ecosystem Restoration. The declaration is a global call for action to hasten the restoration of degraded ecosystems to battle the climate crisis, increase food security, improve clean water provision and safeguard biodiversity (Waltham *et al*. 2020). This declaration focuses on restoration, anticipating that the number of restoration projects globally will continue to significantly increase (Saunders *et al*. 2020). Restoration, however, is not always successful and there are lessons learned in every project (Bayraktarov *et al*. 2016, Boström-Einarsson *et al*. 2020). Common reasons that coastal restoration often does not succeed have been identified as:

- not establishing effective, scalable restoration tools;
- not establishing clear criteria for success;
- site selection issues, and
- inadequate funding for monitoring (Abelson *et al*. 2020).

Furthermore, where project completion schedules are shorter than the actual recovery timeframe and no long-term monitoring is implemented, it is not possible to determine whether restoration has been successful (Prach *et al*. 2019). The sharing of information related to species, scale, methods and monitoring is valuable for future restoration projects to continue to improve, succeed and be fit for purpose (Gerovasileiou *et al*. 2019).

Australia and New Zealand comprise diverse marine and coastal habitats because of their geography. The region encompasses a significant portion of the southern hemisphere, with the most northern tip of Australia (Cape York) occurring just below 10° S and the southern tip of New Zealand at 47° S. The oceanic position of the two countries also drives the climate variations and sea temperatures across the region, allowing for tropical, temperate, sub-Antarctic and desert marine and coastal ecosystems to exist. However, marine and coastal ecosystems are particularly at risk from climate change impacts, such as rising sea levels and ocean warming (Oppenheimer *et al*. 2019). Coupled with water pollution from intensive land use and other anthropogenic stressors (including urbanisation and development), coastal ecosystems have become degraded in many areas of both Australia and New Zealand, resulting in conservation listings of coastal ecosystems and ecological communities as Vulnerable, Endangered, or Critically Endangered (Rogers *et al*. 2016; Gillies *et al*. 2020). In Australia, all marine ecosystems are protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Under the EPBC Act, Matters of National Environmental Significance (MNES) identify ecological communities, species (flora and fauna), Ramsar-listed wetlands, World Heritage Sites, and other areas unique to Australia's environment and cultural heritage that are of national significance and potentially threatened. Marine ecosystems and the species of flora and fauna that they support are considered MNES (McLeod *et al*. 2018). In New Zealand, the *Environment Act 1986* sets out requirements for protecting and managing natural resources, including ecosystem values and sustainability. This Act was further strengthened through the establishment of the *Resource Management Act 1991*, which specifically focuses on the sustainable management of land and water, the prevention of pollution and the conservation of the coastal marine environment (Seaman 2018).

In 2015, the National Environmental Science Program (of the Australian Government) Marine Biodiversity Hub funded a project titled 'The role of restoration in conserving matters of national environmental significance' to explore the capability of conservation and restoration efforts to reduce risks to marine MNES and advance restoration in critical habitats in the coastal and marine environment in Australia (NESP 2020).

Restoration of marine and coastal ecosystems has been occurring in Australia and New Zealand since the mid-1970s (McLeod *et al*. 2018). This relatively long history of restoration, coupled with some of the largest and most diverse marine ecosystems globally (such as the Great Barrier Reef), has placed the region at the forefront of restoration research. However, restoration has been relatively small-scale (less than one hectare) and the findings and outcomes are generally restricted to peer-reviewed journal articles, research and consultancy reports, and practitioner-retained knowledge. In the last decade, the number of restoration projects across a range of marine and coastal ecosystems has increased (McLeod *et al*. 2018). As part of the formation of the Australian Coastal Restoration Network (McLeod *et al*. 2018), it was agreed that there was a need to develop a central repository for project information. The central repository was to take the form of a database with an associated visualisation tool that would house information about coastal and marine restoration projects conducted in Australia and New Zealand.

There is a need to better understand the failings of conservation and restoration projects to learn from mistakes and improve on the potential for securing successful outcomes (Dailianis *et al*. 2018;

Fraschetti *et al.* 2021). Catalano *et al.* (2019) report in a study that reviewed published conservation projects that acknowledged failures, that failings are rarely published in the literature. Learning from these failures is critical to scientific development in conservation and restoration and the sharing of learnings, including failures can enable future projects to adopt approaches that have a greater chance of success (Catalano *et al.* 2018). Furthermore, the sharing of assessment methodologies is also important, not only to enable the continued development of scientific methods, but also to enable researchers and practitioners to identify methods that may or may not be appropriate for their projects (Knight *et al.* 2006). Based on these insights, the need to develop the database based on publicly available documents with subcategories appropriate for the ecosystem type, species, methodologies, and learnings, was identified. The marine and coastal restoration database (hereinafter 'database') sought to identify the number of restoration projects in the marine and coastal environment in Australia and New Zealand, details about the restoration projects (including the location, scale, methods, and monitoring, if any), and provide a repository of information specific to those projects that demonstrated that restoration in Australia and New Zealand is planned and spatially varied.

Methods

Scoping and definition

The database required scoping and defining, including accepted exclusions and inclusions, the format and system requirements, and key audiences and stakeholders. Scoping activities included identifying the ecosystem types to include in the definition of 'coastal ecosystems' (i.e., anything in the tidal zone), the ecosystems to be excluded (i.e., terrestrial and freshwater), the format for the database (MS Excel versus more bespoke databasing softwares), the user interface (for example, Power BI or Tableau), and the target audience to determine the appropriate level of detail and language. Furthermore, the project required a specific start and end date to dictate the data that would be included, noting that funding was limited with a hard end date to the overarching project (NESP Project E5) of April 2021. The database was limited to projects that were publicly available (via project websites, Google Scholar searches, Scopus, and ISI Web of Knowledge databases) or projects led by organisations conducting large programs of restoration research or on-ground activity in Australia and New Zealand. The restoration database included projects that focus on coral and shellfish reefs, mangrove forests, habitats formed by kelp and other macroalgae, seagrass meadows, salt marsh and intertidal wetlands. These ecosystems were selected as they represent the majority of coastal and marine wetland types in Australia and New Zealand that occur in the tidal and subtidal zones. We used Google Sheets for the database to allow online multi-user functionality, facilitate stakeholders' review and input, enable a live connection with the online visualisation tool (Tableau), and for embedding within the Australian Coastal Restoration Network website. Through a review of data criteria and inclusions, the restoration database includes over 40 different fields of data. These comprised information on the data source, habitat type, project metadata, details of the methods, monitoring design, results and conclusions. It includes restoration projects identified up until 1 June 2020 when the project and associated funding concluded.

Database headings include:

- Project ID, Entry Number
- Project URL
- Habitat Type
- Restoration Technique/Methodology
- Country, Location, Geocode, Latitude and Longitude
- Project Work Start (commencement date)
- Method Specifics
- Species
- Author/Practitioner Main Results/Conclusions
- Full Reference, Source Type, Publication URL

At the commencement of the project (January 2019), several key audiences were identified to help guide the development of the database (Table 1).

Stakeholders were identified based on their existing role and involvement in marine and coastal restoration in Australia and New Zealand. Since the legislation specific to restoration is in its infancy, we relied on the authors' knowledge of the project process (from inception to monitoring and delivery) to identify the various external touchpoints applicable to most projects. We anticipated that these stakeholders would use the restoration database to inform future restoration projects, determine strategies and planning for restoration, contribute to policy amendment and reform, and provide a conduit for new project teams to engage with experienced researchers and practitioners on specific restoration methods.

In addition to the literature and online search, we specifically targeted organisations that are currently conducting several restoration projects and engaged with their teams to assist in populating the database. These team members have been included as co-authors on this paper and contributors to the database:

- The Nature Conservancy Australia
- The Nature Conservancy New Zealand
- Blue Carbon Lab, Deakin University
- EcoCommons, Griffith University
- Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER), James Cook University
- Centre for Sustainable Tropical Fisheries and Aquaculture, James Cook University
- Centre for Marine Science and Innovation, University of New South Wales
- University of Auckland

Table 1. Key audiences, stakeholders and contributors identified for the database compiled by the Marine Biodiversity Hub of the Australian National Environmental Science Program, along with the type of stakeholder, and their role in a project

Contributor/Stakeholder	Type	Role in project
Department of Agriculture, Water and Environment (now the Department of Climate Change, Energy, the Environment and Water)	Commonwealth Government	Stakeholder/ potential user
State and Territory Environment and Planning departments	State and Territory level governments	Stakeholder/ potential user
Researchers	Government Research Organisations (e.g., Australian Institute of Marine Science, Bureau of Meteorology, Commonwealth Scientific and Industrial Research Organisation) Universities	Stakeholders/ potential users
Tertiary students	Education	Stakeholders/ potential users
Not for Profits Non-Government Organisations Citizen Science Groups	Charities, Independent Organisations, Philanthropic Organisations, Community Organisations	Stakeholders/ potential users
Natural Resource Management Groups	Government-funded organisations	Stakeholders/users

Data extraction and entry

Publicly available documents were systematically reviewed to extract information into the relevant fields of the restoration database. It quickly became apparent that there were gaps where the information did not provide complete details of a project, such as defined success criteria, geographic coordinates and monitoring information. Where data could not be determined from reviewing the documentation, these criteria were entered as 'Not reported' unless the document specifically noted that an aspect (such as baseline monitoring) was not conducted. In such cases, the entry was 'no'. No interpretation of data was conducted as part of the database entry process. If a document alluded to a method or practice but did not properly describe or explain it, it was not interpreted but either entered verbatim or noted as 'not reported'.

Once data was entered to the restoration database, it became clear that the definition of a 'project' needed to be further refined. In many cases, a restoration project comprised numerous restoration sites across different geographic locations. In some cases, projects encompassed a single geographic reference but with multiple restoration plots established at different times and spatial scales. Following consultation with the contributing organisations and the development team, we decided that, in such cases, each defined area would have a separate row entry in the database. As such, there are multiple entries for the same project in the restoration database, with different criteria relating to the date of establishment, spatial scale, project phase or method specifics.

This approach was also applied to entries that were provided by the contributing organisations. In these cases, each organisation was provided with a blank version of the database to populate with their projects. Several online meetings and working sessions were held with each organisation where necessary to assist in populating the database, and particularly to troubleshoot any situations where project information was not available for some criteria. Once complete, the organisation-specific databases were amalgamated with the master restoration database in Google Sheets.

Quality assurance and verification

We developed two versions of the database: (i) a version suitable for connection to the visualisation software, which was limited to information that could be visualised, and (ii) a full version. The visualisation version of the database went through a more rigorous verification and assurance process. This step involved two members of the team that were not involved in the data entry process systematically reviewing each entry for accuracy, completeness and consistency. Each entry was checked with the corresponding documentation or reference to ensure no available data was missing, that 'not reported' was entered in fields accurately, and that any blanks were addressed. Both versions of the database are currently stored by the Australian Coastal Restoration Network, with the visualisation tool and access to the reduced database publicly available via the Network's website (www.acrn.org.au/database).

Development of the visualisation tool

We used the online visualisation software Tableau to develop a data visualisation dashboard (Desktop Professional Edition, version 10.5, Fig. 1). The following criteria were included in the visualisation: project ID and entry number, project URL, habitat type, restoration technique and methodology, country location with geocode and latitude/longitude, project work start (commencement date), method specifics, species, author/practitioner main results/-conclusions, and full reference with source type and a URL to the publication.

Results

In total, 232 coastal restoration sites were included in the database across eight habitat types (coral reefs, kelp forests, mangroves, salt marsh, seagrass, estuary, wetlands, and shellfish reefs). Thirty-three sites were located in New Zealand and 198 in Australia. The first project started in 1978, with the number of projects increasing each decade since then (Table 2).

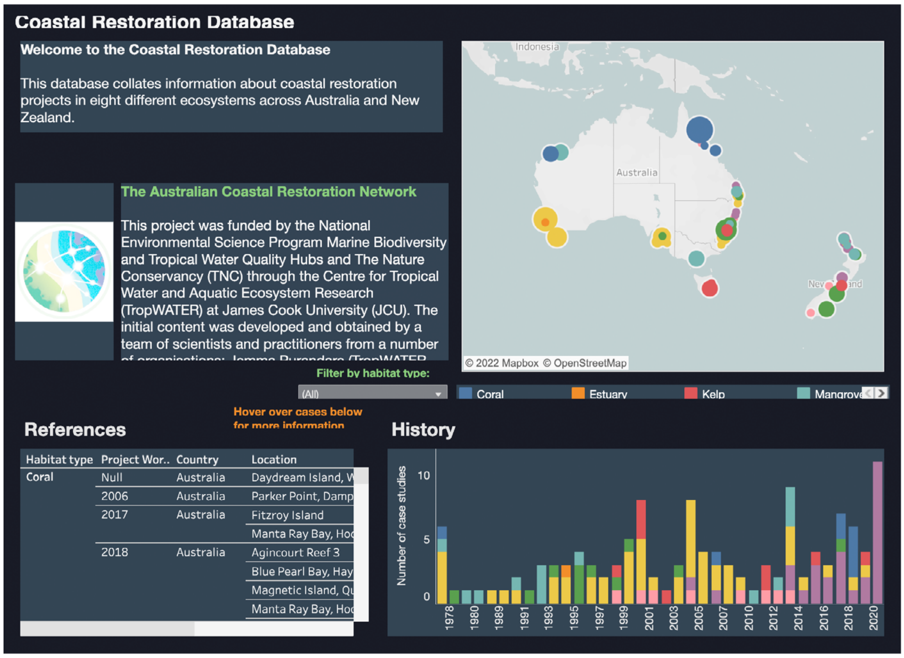

Figure 1. Screenshot showing the interactive visualisation dashboard used to support the database compiled by the Marine Biodiversity Hub of the Australian National Environmental Science Program). The visualisation is spatial and displays information on restoration sites when a location symbol is clicked. It is available at https://www.acrn.org.au/database.

Table 2. Summary of restoration projects according to commencement decade (year), as compiled in the Marine Biodiversity Hub of the Australian National Environmental Science Program

Years	Projects
1970–1979	5
1980–1989	14
1990–1999	61
2000–2009	65
2010–2019	70
2020 (January to June)	11
No date reported	6

These projects were further sub-divided into the ecosystem type and are summarised in Table 3. In many cases, one site (geographic location) consisted of numerous restoration projects over varying timeframes, and this has also been captured to represent the information available.

Seagrass projects were, overall, the most reported ecosystem with 92 projects across 49 sites. However, it is important to consider that these data are based on projects that have been documented and made publicly available but may not be representative of the total number of projects or sites delivered per ecosystem. Furthermore, there is the potential for certain categories to have cross-over or duplication (e.g., wetlands and salt marsh, or estuary and known estuarine ecosystems). In grouping the data, the description of the project and site was key to how it was classified, and the classification was driven by the project reporting.

Table 3. Number of projects per site, and sites per ecosystem type, as compiled in the Marine Biodiversity Hub of the Australian National Environmental Science Program

Ecosystem	No. of sites (n = 126)	No. of projects (n = 232)
Coral	8	31
Estuary	1	1
Kelp	8	24
Mangrove	13	19
Salt marsh	11	27
Seagrass	49	92
Shellfish reef	28	30
Wetland	8	8

Discussion

The development of the database presented several challenges that can be used as opportunities to improve how the outcomes and progress of restoration projects are reported, and the way restoration projects are implemented.

Reporting findings

When the data entry team were reviewing documents for restoration data and information to input into the database, we found differences in the way projects and authors reported their data and findings. In many cases, certain key aspects of the project, such as why the restoration was required, whether the original stressors and reasons for the decline remained an issue, whether baseline monitoring had been conducted and what the project's definition of success was, were either omitted or skimmed over. In many cases, lessons learned from previous projects were not reported. This lack of reporting reduces the potential for knowledge transfer that can drive improvements in methodologies.

A similar issue was also encountered with several projects regarding the way in which geographical references were reported. In many cases, a location such as 'Port Phillip Bay' was reported but coordinates or a more specific location of the plots were not provided. Other crucial information such as the size of plots and/or scale of a restoration project were also often omitted from the reporting. This created an issue when translating the projects onto the data visualisation spatial platform and assumptions of scale had to be made to ensure the location pin represented the correct geographic area. A standardised approach to reporting would assist in communicating the outcomes and findings of restoration projects more effectively, particularly where such information might assist in obtaining further funding or planning for future projects (Eger *et al*. 2022).

Defining success and conducting monitoring

Many projects included in the database did not include criteria for, or definitions of, success. This violates Principle Five of the Society of Ecosystem Restoration International Principles and Standards for the Practice of Ecological Restoration which states that 'Ecosystem recovery is assessed against clear goals and objectives, using measurable indicators' (Gann *et al*. 2019). In more than half the documents reviewed, baseline monitoring was either not conducted or not reported. The frequency of monitoring varied greatly, with several projects monitoring only once or twice after establishment, and some monitoring at irregular intervals. Other important missing information included the duration of monitoring and whether any reference or control sites were monitored. These inconsistencies make it challenging to compare projects, particularly when trying to determine whether restoration success is linked to a specific methodology. Often the sparse monitoring regimes can be linked to limitations in funding or constraints around the duration of the project (Eger *et al*. 2022). For example, if the approved timeframe for a project, as linked to a grant or funding, is only one year, then the ability to monitor in a meaningful way once establishment has been completed is limited. Where failures are not reported, it is challenging for future projects to properly consider and actively improve and develop approaches that may improve the likelihood success. Often, the duration of a project was a limiting factor to identifying whether restoration was likely to be successful, which is a factor that has been identified in other studies as a limitation (Bekkby *et al*. 2020).

Concluding Remarks

The development of a database focused on marine and coastal restoration projects in Australia and New Zealand highlights a broad and rich field of ongoing research and management. While the preparation of the database presents progress in the field, it has also highlighted deficiencies in areas of reporting and monitoring that, if overcome, could increase progress. Section 3 of the International Restoration Standards published by the Society for Ecological Restoration (SER) notes that the specific standard practices to be used in designing and implementing restoration projects includes: (i) planning and design, (ii) implementation, (iii) monitoring and evaluation and (iv) maintenance of projects following completion (Gann *et al*. 2019). Best practice restoration projects should, therefore, incorporate monitoring and evaluation methods of a duration and type specific to tracking whether a project is likely to meet targets, goals and objectives, and whether adjustments are required, using an adaptive management framework (Gann *et al*. 2019).

The identified deficiencies include: (i) the need to better report findings and improve consistency in how findings are reported, (ii) the importance of monitoring projects in the medium- to long-term and the consistencies in monitoring methodologies, (iii) the importance of defining success and setting criteria for measuring success early, and (iv) the importance of reporting geographic locality in a consistent manner (i.e. using longitude and latitude rather than a broad area). It is also important to define failure in the context of a project where (i) failure may not be strictly the inverse of success, and (ii) having failure specifically defined, monitored, and evaluated will more likely result in the improvement of restoration methods in the future.

This database represents an opportunity to share knowledge and improve the effectiveness of coastal and marine restoration projects as we enter the UN Decade on Ecosystem Restoration and of Ocean Science for Sustainable Development. This research will be useful for policy-makers because it provides context and evidence about what has been completed so far.

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Conflict of Interest

The authors declare no conflicting interests.

Data Availability Statement

The data that support the findings of this study are openly available via the Australian Coastal Restoration Network at https://www.acrn.org.au.

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