



LIFE MAPPER

MAPPING, PROTECTING, AND RESTORING MARINE ECOSYSTEMS



LIFE24-PRE-IT-LIFE-MAPPER

Guidelines for **MAP**ping, **ProtE**cting, and **R**estoring Marine Ecosystems

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Deliverable description

Deliverable 4.1 is the Marine Restoration Cost Database contained in the Excel spreadsheet. The database contains marine ecosystem restoration cost values from past research that can be used for cost effectiveness analysis or cost benefit analysis. The database presents previous study findings broken down by marine ecosystem type, value, and other study characteristics. For ease of use, the cost estimates are reported in 2024 international US Dollars and 2024 Euro per hectare values. Estimates are adjusted from the original studies based on exchange rates, inflation and purchasing power parity. This document provides a summary of the database and the cost estimates. Within the studies reported, marine restoration costs differ widely depending on ecosystem type, restoration methods, and location. The data are consistently right-skewed, meaning average (mean) costs are often notably higher than median values. Because of this skew, the median provides a more reliable benchmark for planning and investment decisions. Among ecosystems, cold-water coral restoration stands out as the most expensive per hectare. In contrast, mangrove restoration—especially in community-driven, labour-intensive projects in Southeast Asia—are associated with the lowest costs per hectare. Many of the cost estimates from the studies only capture upfront capital costs. As a result, the figures presented likely underestimate the true full lifecycle cost of restoration.



The Marine Restoration Cost Database

1. Introduction

Marine and coastal ecosystems are among the most productive and economically valuable ecosystems. They provide food security, coastal protection, carbon sequestration, and biodiversity habitat to hundreds of millions of people (Bayraktarov et al., 2016). However, they face unprecedented rates of degradation driven by climate change, coastal development, overexploitation, pollution, and physical disturbance (Beck et al., 2011). Where natural recovery is insufficient or too slow, active ecological restoration has emerged as a necessary management intervention. Ecological restoration is the process of *assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed* (Society for Ecological Restoration, n.d). The UN Decade on Ecosystem Restoration (2021–2030), the Kunming-Montreal Global Biodiversity Framework's Target 2, and the EU Nature Restoration Regulation's mandate to restore 20% of degraded marine ecosystems by 2030 have achieved the transition of restoration from a solely scientific pursuit to a global policy priority (Duarte et al., 2020; Hynes et al., 2022).

Understanding the costs of marine restoration (i.e., in monetary terms) to restore a hectare of reef, mangrove, seagrass, or saltmarsh, is more than an academic question. It is central to investment planning, to the design of payment-for-ecosystem-services mechanisms, to blue carbon markets, and to the triage decisions that conservation practitioners face when resources are limited. The seminal synthesis by Bayraktarov et al. (2016), which draws on studies across five coastal ecosystem types, established that the median cost of restoring one hectare of marine habitat was around US\$80,000 (2010 as base year), while mean values reached US\$1.6 million. Bayraktarov et al. (2016) highlight the feature of the right-skewed, highly variable cost distributions that characterise this field. The present report updates and extends that evidence base.



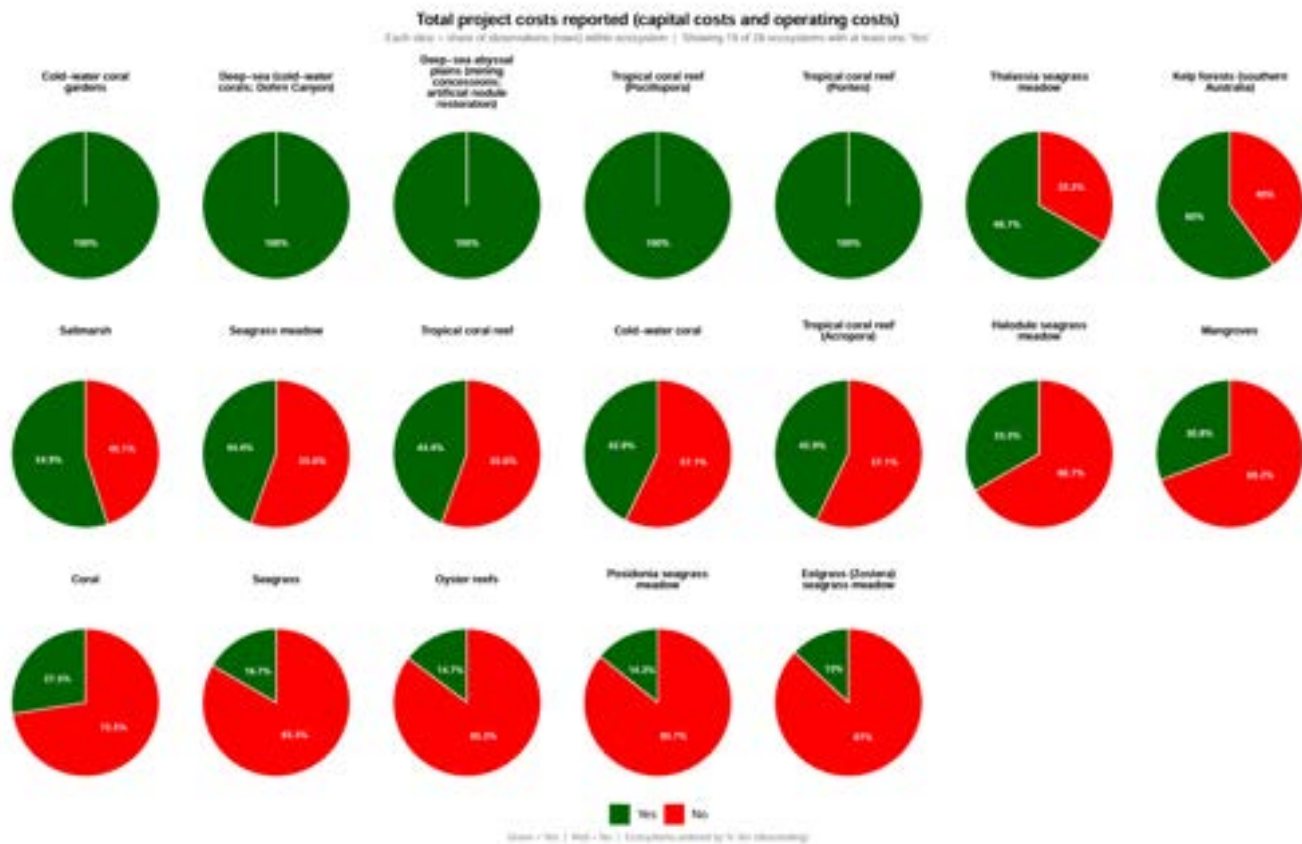
This report synthesises the 171 studies included in the Excel file deliverable¹. The report builds on Bayraktarov et al. (2016) and EU projects such as Climarest, REDRESS and MERCES. It draws its information from peer-reviewed journals, technical reports, conference proceedings, book chapters, and *grey* literature and the data collected spans between 1974 and 2025 (i.e., year of publication of the studies). Moreover, we organise the studies across twelve ecosystem categories, which consolidate the original 28 ecosystem classifications in the excel database into ecologically coherent groups. All costs reported here are expressed in international dollars per hectare at a 2024 base, adjusted using GDP (PPP) conversion, unless otherwise stated. The geographic coverage is global but heavily weighted towards the United States, Australia, Southeast Asia and Western Europe. Appendix A provided the list of the variables contained in the dataset with a brief description of each. This list is also in the second worksheet (Variable_Keys) of the database.

The report is organised as follows: Section 2 describes the availability of cost information per ecosystem service in the studies analysed in this project. Section 3 details the global distribution by country of the restoration studies, and Section 4 comprehensively describes the characteristics of the restoration studies and their associated costs. The final section offers concluding remarks.

2. Costs per ecosystem category

In Figure 1 (*Panels a to d*), we present the available cost data from the studies (i.e., total, capital, operating, and monitoring costs, respectively) in pie charts for each marine ecosystem in the 28 categories available in the Excel file, using a binary "yes" or "no" format. The panels only show the marine ecosystem categories that report at least one "yes" for each cost.

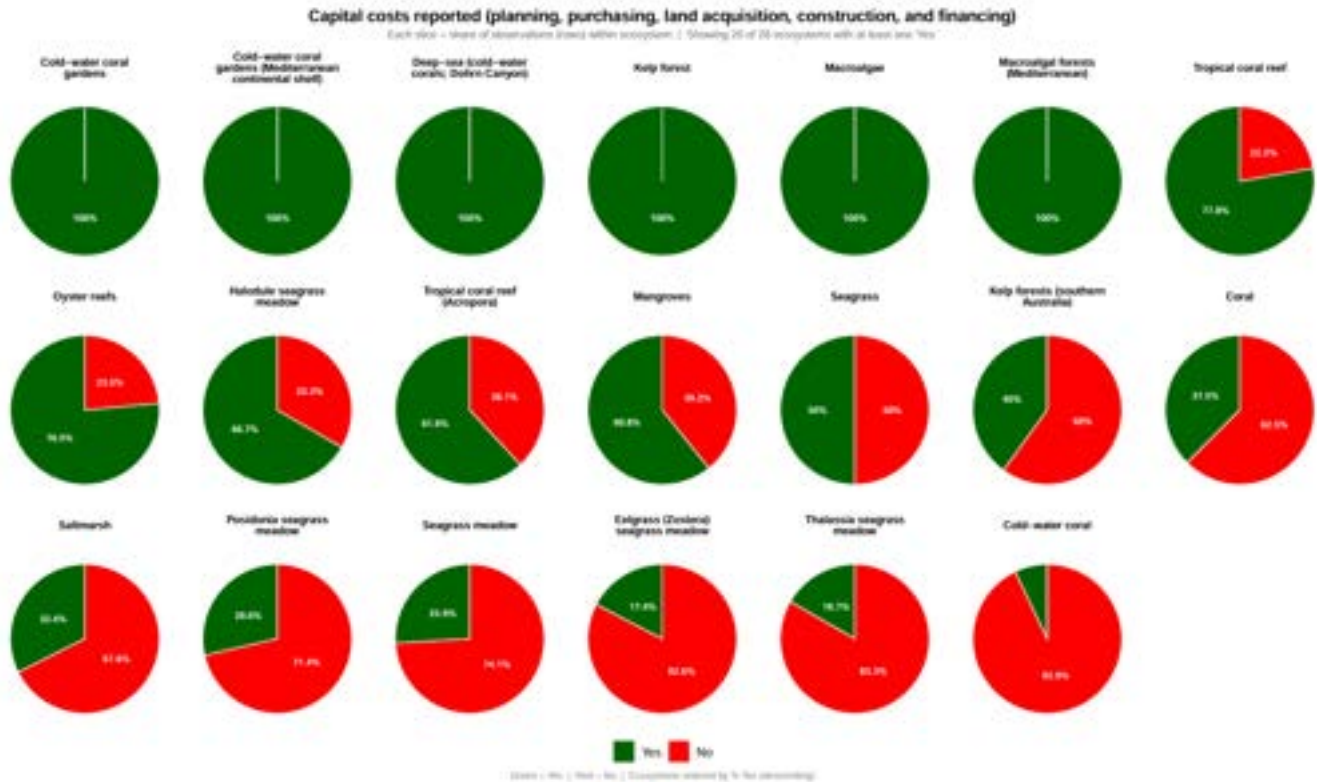
¹ Within the database there can be multiple rows for individual studies that report multiple costs. Each row represents a separately reported cost estimate.

Figure 1. Project costs per ecosystem category in the studies
Panel A. Total project costs


Panel A reports the share of studies that include total project costs across the 19 ecosystem categories for which at least one study records a "Yes". Cold-water coral gardens, the deep-sea cold-water coral site in Dohrn Canyon, and the two less-common tropical coral morphotypes (*Pocillopora* and *Porites*) show 100% reporting, though each is represented by only one or two studies. Among the larger, better-populated categories, salt marsh leads at 54.9% (39 of 71 observations), followed by tropical coral reefs at 44.4% and Acropora-dominated reefs at 42.9%. Reporting is substantially lower for mangroves, where only 30.8% of observations include total project costs, and lowest for oyster reefs (14.7%), Posidonia seagrass meadows (14.3%), and eelgrass (13.0%).



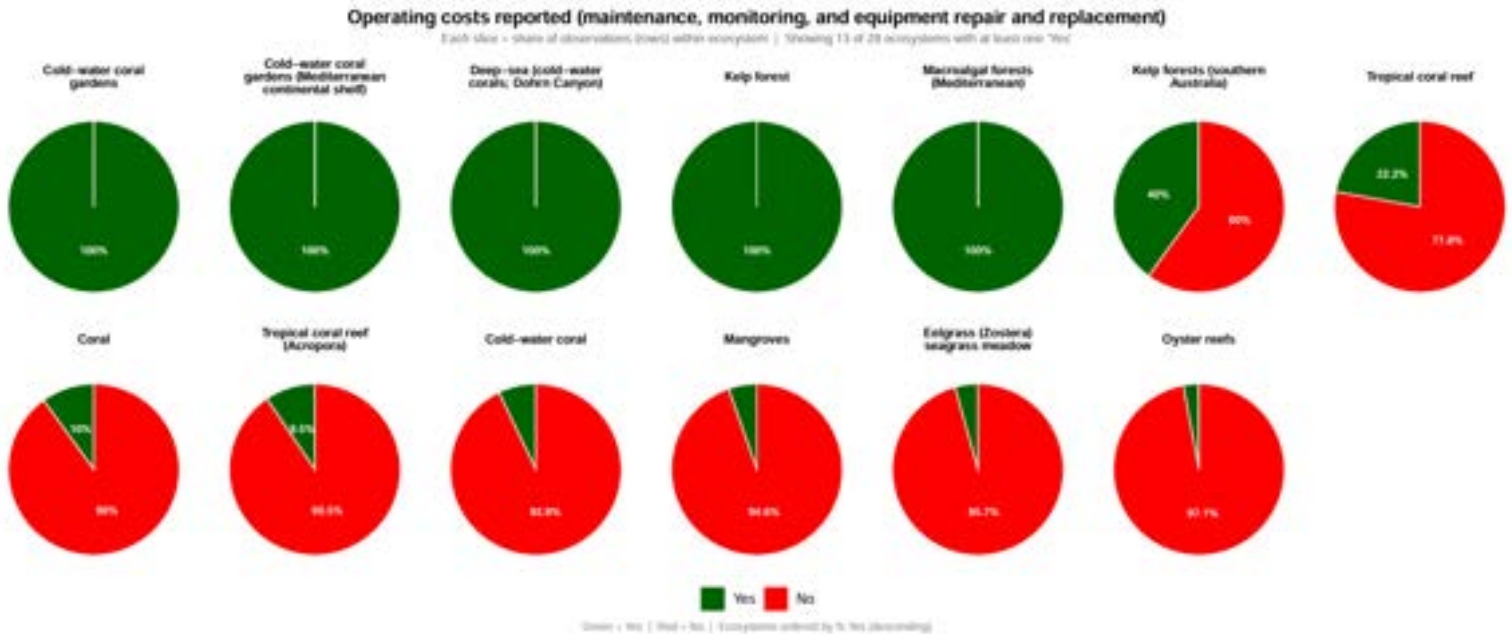
Panel B. Capital costs



Panel B shows capital cost reporting across 20 ecosystem categories. Oyster reefs report capital costs in 76.5% of observations, tropical coral reefs in 77.8%, and Acropora reefs in 61.9%. Mangroves, despite their low total cost reporting rate in Panel a, report a 60.8% rate, suggesting that planting and construction expenditures are more routinely captured than operating costs. Deep-sea and cold-water coral entries are again at 100%. Saltmarsh (32.4%) and eelgrass (17.4%) report relatively poorly, while cold-water corals, excluding the deep-sea entries, report 7.1%.

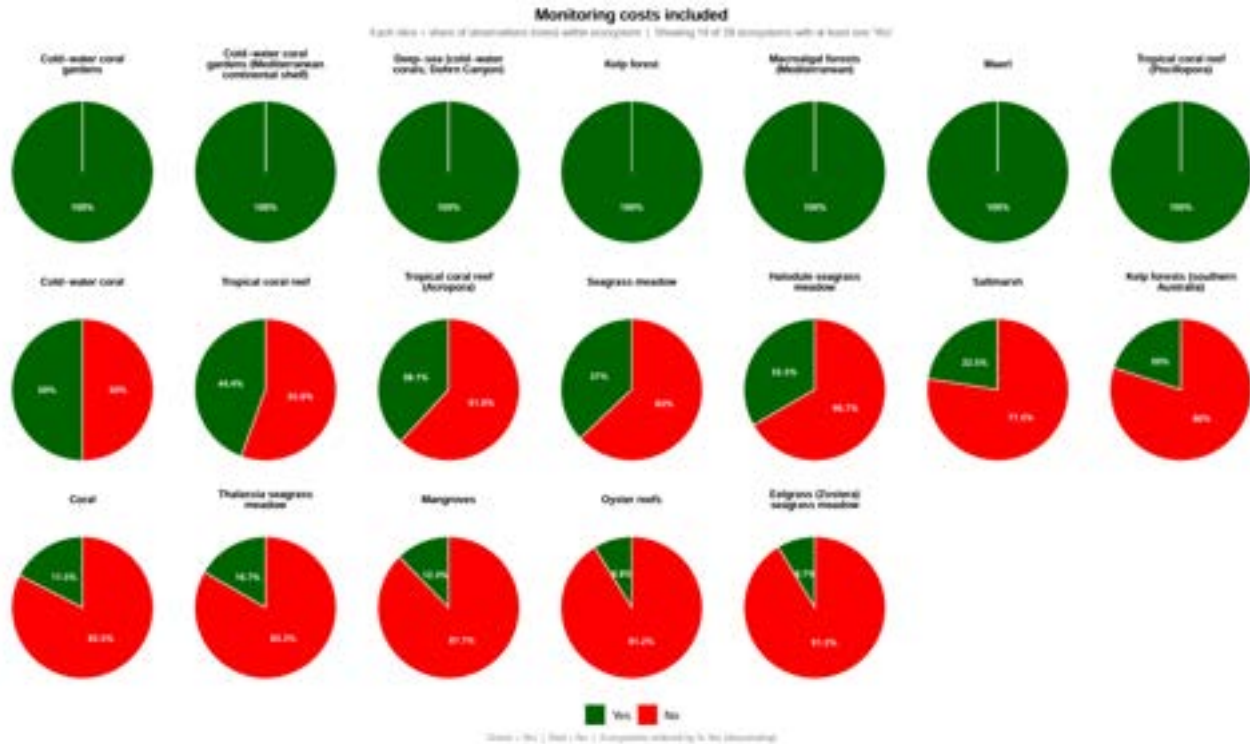


Panel C. Operating costs



Panel C reports the availability of operating cost data across the 171 studies. Operating costs are reported in only 13 of the 28 original ecosystem categories. Among the major ecosystems, tropical coral reefs account for 22.2%, coral (generic) for 10.0%, and Acropora reefs for 9.5%. Mangroves, with 130 observations, report operating costs in only 5.4% of cases, and oyster reefs in just 2.9%. Eelgrass reaches 4.3%.

Panel D. Monitoring costs.



Panel D presents the inclusion of monitoring costs across 19 ecosystem categories. Cold-water coral gardens, Dohrn Canyon, Pocillopora reefs, maerl, macroalgal forests, and kelp forests all record 100%. Cold-water corals (50.0%), tropical coral reefs (44.4%), and Acropora reefs (38.1%) show the highest rates. Seagrass meadows (tropical and temperate) reach 37.0%. By contrast, mangroves (12.3%), oyster reefs (8.8%), and eelgrass (8.7%) report monitoring costs in fewer than one in ten observations. Saltmarsh reaches only 22.5%, despite containing a larger sample of studies.

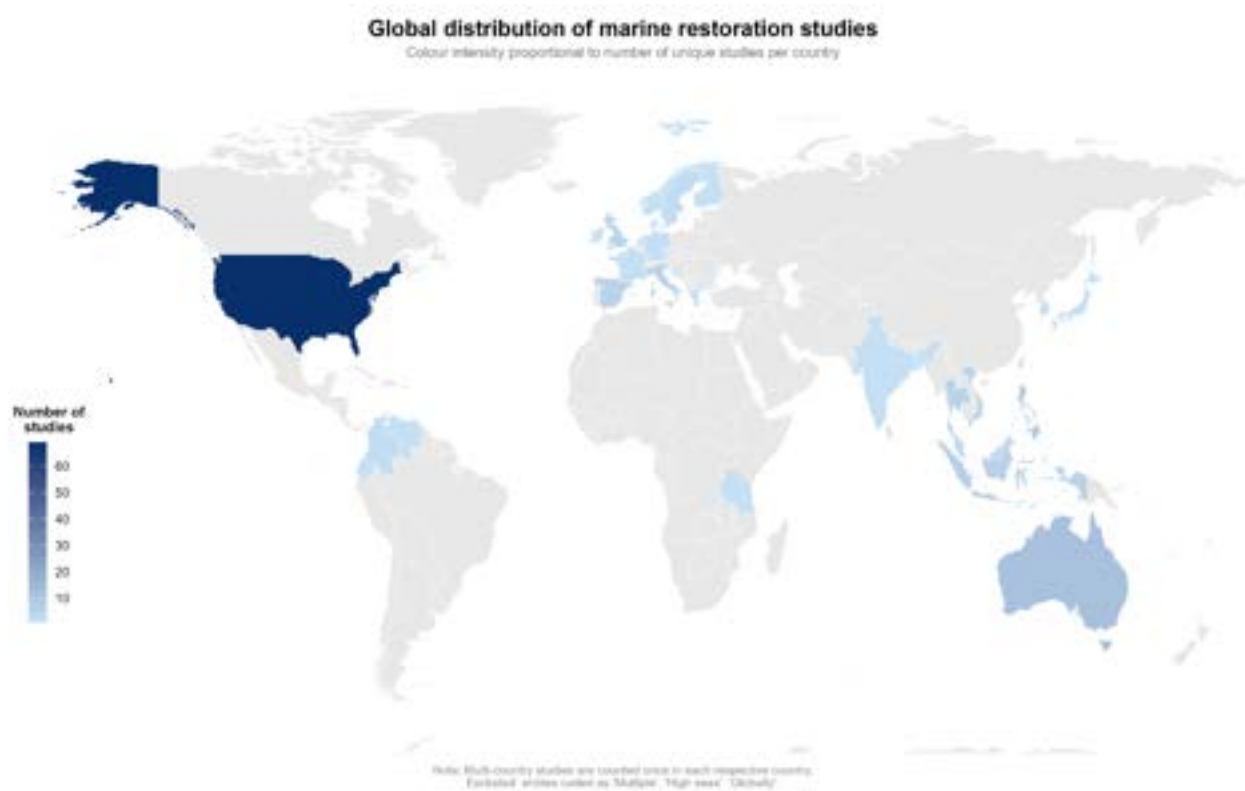
Overall, the four panels in Figure 1 suggest a systematic gap in cost reporting across the marine restoration literature. Operating costs are rarely documented, absent in more than 90% of observations across most ecosystems, meaning that the cost estimates available in this

database and in the broader literature may predominantly reflect upfront capital expenditure rather than the full lifecycle cost of restoration.

3. Global distribution of studies

Figure 2 presents the geographic distribution of the 171 studies worldwide, with colour intensity proportional to the number of unique studies per country.

Figure 2. Global distribution of marine restoration studies



The United States accounts for 70 studies which represents more than 40% of all studies in the database. Australia holds 12 studies, followed by the Philippines (10), Indonesia (7), Spain (5),



Italy (5), the United Kingdom (5), Thailand (5), and Vietnam (5). Israel (4), the Netherlands (3), and Malaysia (3) are also represented.

4. The Group Categories of marine ecosystems

Table 1 presents the consolidation of the 28 original ecosystem classifications in the database into 12 ecologically coherent group categories. The rationale for each cluster is described in the third column of the table.

Table 1. Group Categories of ecosystem services

Number	New Category	Previous categories included in excel database	Rationale
1	Saltmarsh	Saltmarsh	Same category
2	Mangroves	Mangroves	Same category
3	Oyster reefs	Oyster reefs	Same category
4	Tropical coral reefs	Tropical coral reef; Coral; Tropical coral reef (Acropora); Tropical coral reef (Porites); Tropical coral reef (Pocillopora)	Species-level coral distinctions (Acropora, Porites, Pocillopora) reflect biological variation but not systematically different cost structures in the literature.
5	Seagrass meadows (tropical & temperate)	Seagrass meadow; Seagrass; Thalassia seagrass meadow; Halodule seagrass meadow	Generic and tropical seagrass entries. Thalassia and Halodule are tropical genera with similar restoration approaches Zostera and Posidonia are slow-growing cool-temperate species with substantially higher restoration costs and longer recovery times. This distinction is empirically supported in Unsworth et al. (2019) and Bayraktarov et al. (2016)
6	Seagrass meadows (cool-temperate)	Eelgrass (Zostera) seagrass meadow; Posidonia seagrass meadow	



7	Kelp forests	Kelp forests (southern Australia); Kelp Forest	Biogeographic qualifier (southern Australia) is a study-level detail, not a category-level distinction.
8	Macroalgal habitats	Macroalgal forests (Mediterranean); Macroalgae; Maerl	Maerl (coralline algae) is structurally distinct but we grouped them here given the few observations they have in the database.
9	Cold-water corals	Cold-water coral; Deep-sea (cold-water corals; Dohrn Canyon); Cold-water coral gardens (Mediterranean continental shelf); Cold-water coral gardens	All refer to azooxanthellate deep-water scleractinian corals.
10	Deep-sea abyssal plains	Abyssal plains; Deep-sea abyssal plains (mining concessions; artificial nodule restoration); Deep-sea nodule field	Mining-disturbed nodule fields are functionally the same ecosystem type, the "mining concessions" qualifier describes the stressor, not the ecosystem
11	Mixed deep sea	Mixed deep sea	Same category
12	Mixed/unclassified seabed	mixed seabed	Same category

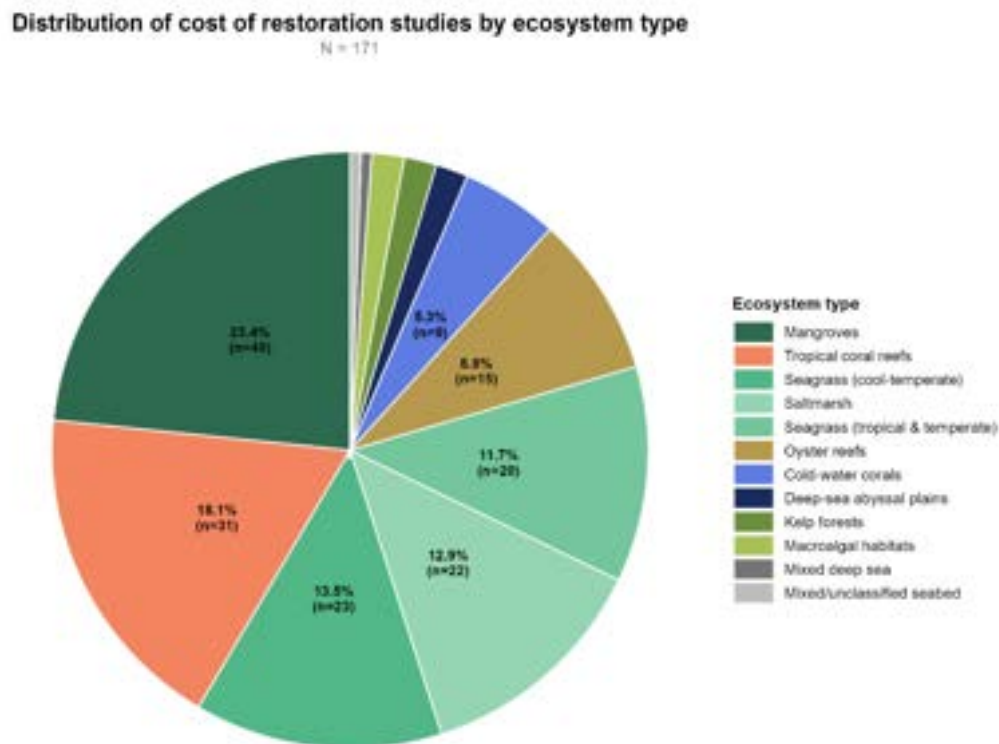
Source: Excel database Marine Restoration Cost

We keep three categories unchanged (i.e., salt marshes, mangroves, and oyster reefs). We collapse Tropical coral reefs into five entries: the generic "Coral" and "Tropical coral reef" classifications, alongside the three species-specific entries (*Acropora*, *Porites*, *Pocillopora*). The literature does not support systematically different cost structures across these morphotypes as a basis for separate reporting categories. The two seagrass categories are kept distinct precisely because the cost evidence does support separation. *Zostera* and *Posidonia* are slow-growing cool-temperate species with substantially higher restoration costs and longer recovery timescales than their tropical and warm-temperate counterparts (Bayraktarov et al., 2016;

Unsworth et al., 2019). Maerl is grouped with macroalgal habitats due to the very limited number of observations in the database. We consolidate the four cold-water coral entries, as they all refer to azooxanthellate deep-sea Scleractinia corals, and the site-specific qualifiers (Dohrn Canyon, Mediterranean continental shelf) describe location rather than a distinct ecosystem type.

Figure 3 below presents the distribution of the 171 unique studies across the 12 ecosystem group categories as a pie chart.

Figure 3. Distribution of cost restoration studies by ecosystem group



Mangroves are the most studied ecosystem by a clear margin, accounting for 40 studies (23.4% of the total), followed by tropical coral reefs (31 studies, 18.1%). The two seagrass categories



together account for 25.2% of studies: 23 for cool-temperate seagrasses (13.5%) and 20 for tropical and temperate seagrasses (11.7%), making seagrasses the second-most-studied ecosystem type in the database. Saltmarsh contributes 22 studies (12.9%) and oyster reefs 15 (8.8%). Cold-water corals, deep-sea abyssal plains, macroalgal habitats, and kelp forests each account for three or fewer studies. The two residual categories (mixed deep sea and mixed/unclassified seabed) each represent a single study.

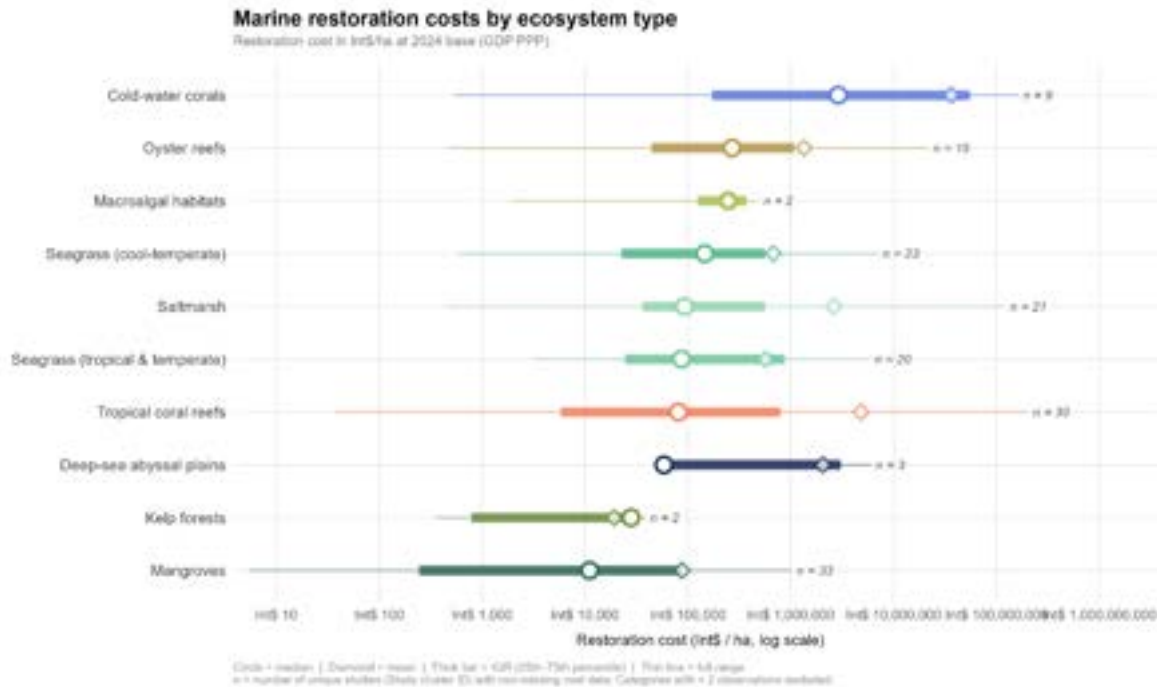
In Table 2 and Figure 4 we present restoration costs across ten ecosystem group categories described in Table 1 for which at least two cost observations are available. Each category is represented by a circle (median), a thick bar (interquartile range), and a thin line (full range), with a diamond indicating the mean.

Table 2. Descriptive statistics of marine restoration costs per hectare by ecosystem type

Ecosystem type	N	Studies	Median	Mean	Min	Max
Cold-water corals	18	9	2,895,276	36,131,405	537	163,311,619
Oyster reefs	34	15	268,849	1,346,138	458	21,307,270
Macroalgal habitats	2	2	246,987	246,987	1,990	491,985
Seagrass (cool-temperate)	30	23	145,726	679,060	604	6,882,595
Saltmarsh	70	21	92,624	2,612,439	451	119,173,643
Seagrass (tropical & temperate)	42	20	86,747	567,700	3,069	5,746,002
Tropical coral reefs	66	30	80,830	4,812,905	38	199,649,323
Deep-sea abyssal plains	3	3	58,453	2,048,756	56,366	6,031,448
Kelp forests	5	2	28,047	19,186	353	38,694
Mangroves	112	33	11,099	87,496	5	1,004,246

Note: Values are USD \$ per ha (Base year = 2024). Thirteen studies were excluded due to being outliers to the cost distribution.

Figure 4. Marine restoration costs by ecosystem type



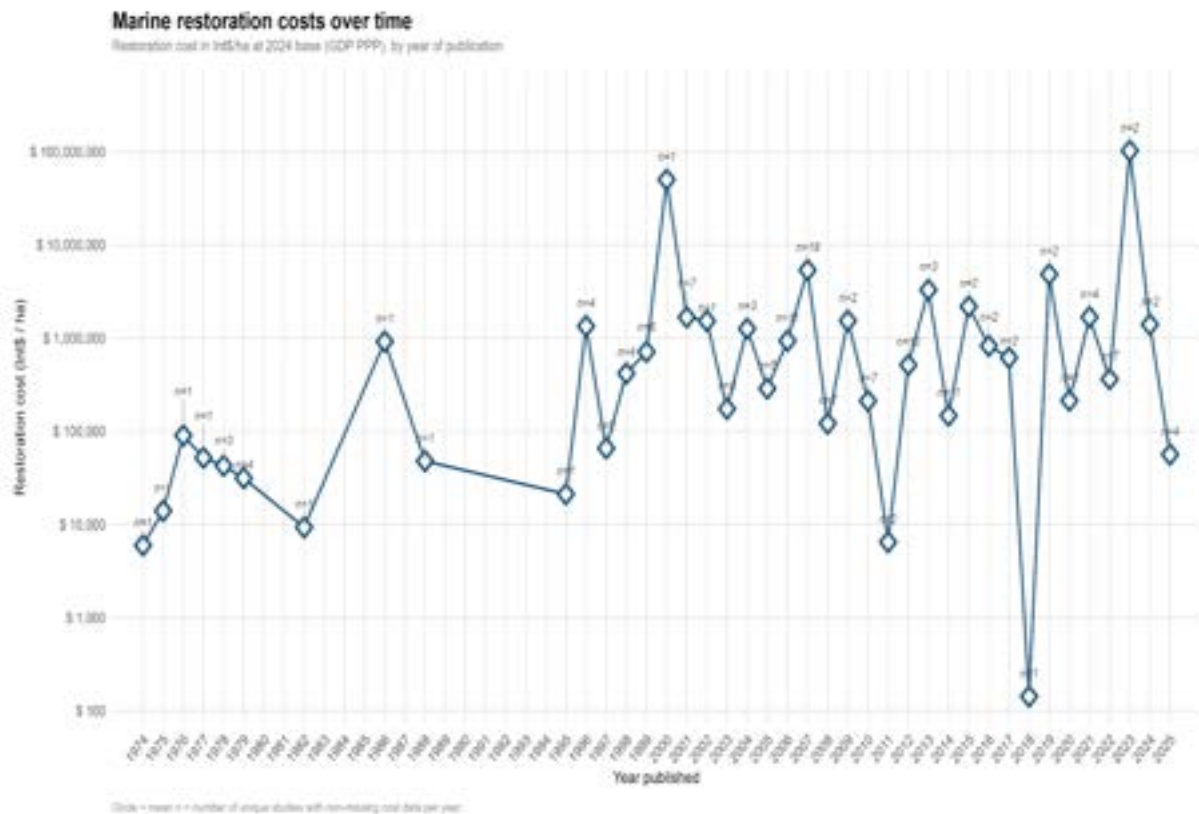
A common feature to the ecosystems in Table 2 and Figure 4 is a right skewed distribution. This right skewness might be due to the heterogeneity of restoration approaches, project scales, and geographic contexts in the analysed restoration studies included in the database.

Regarding specific ecosystems, cold-water corals are by far the most expensive ecosystem to restore, with a median of \$2,895,276 per hectare and a range from \$537 to \$163,311,619. Cool-temperate seagrasses (*Zostera and Posidonia*) rank second in median cost at \$145,726, consistent with their widely-documented difficulty in restoration. Oyster reefs (median \$268,849) occupy the third position, followed by macroalgal habitats (\$246,987) and saltmarsh (\$92,624). Seagrass meadows (tropical and temperate) and tropical coral reefs report median costs of \$86,747 and \$80,830, respectively. The difference between median and mean for tropical coral reefs (\$80,830 versus \$4,812,905) is the highest in the dataset, driven by a small number of projects combining artificial reef construction with large-scale outplanting that



push the upper tail of the cost distribution to approximately \$199,649,323 per hectare. Mangroves display the lowest median cost of any ecosystem with the largest amount of data (\$5,374 per hectare) though the mean reaches \$83,229, and the full range extends from as little as \$5 to over \$1,000,000 per hectare. Kelp forests appear at the bottom of the cost distribution, with a median of \$571 per hectare, but this figure should be interpreted with caution since only two studies with cost data exist in the database. Lastly, in Figure 5 we present the evolution of marine restoration costs over the period 1974–2025 in international dollars per hectare at a 2024 base (GDP PPP).

Figure 5. Timeline of average marine cost restoration values



Several insights can be drawn from Figure 5. First, the series displays volatility in restoration costs, consistent with the right-skewed cost distributions documented in Table 2 and Figure 4,



and driven by heterogeneity in ecosystems, techniques, and geographies across publication years. Also, there is no clear upward or downward persisting trend in real costs over the five decades covered. Third, the two most prominent spikes occur in 2000 and in 2023, where the mean is driven entirely by cold-water coral restoration cost scenarios from Strong et al. (2023), which report values between \$67,000,000 and \$163,000,000 per hectare. Fourth, the 2018 data point represents the lowest mean in the sample (\$143). Notably, this figure comes from a single mangrove study with atypically low reported costs, which illustrates the sensitivity of annual means to individual observations in years with few studies. Finally, the number of studies per year increases from the mid-1990s onwards, suggesting a growing global interest in marine ecosystem restoration.

5. Concluding Remarks

Three main findings stand out from this report. First, restoration costs vary enormously across ecosystems, techniques, and geographic contexts, with distributions consistently right skewed, in which mean costs can exceed median costs by a non-trivial amount. This feature makes the median the most appropriate benchmark for planning and investment purposes. Second, cold-water corals are the most expensive ecosystem to restore per hectare, while mangroves, particularly in community-based, labour-intensive contexts in Southeast Asia, are the most affordable among ecosystems with sufficient data. Third, and perhaps most consequentially, the cost data available in this database predominantly reflect upfront capital expenditure. Operating, monitoring, and long-term maintenance costs are systematically underreported across almost all ecosystem types, meaning the figures presented here likely understate the true lifecycle cost of restoration.



References

- Bayraktarov, E., Saunders, M. I., Abdullah, S., Mills, M., Beher, J., Possingham, H. P., Mumby, P. J., & Lovelock, C. E. (2016). The cost and feasibility of marine coastal restoration. *Ecological Applications*, 26(4), 1055–1074. <https://doi.org/10.1890/15-1077>
- Beck, M. W., Brumbaugh, R. D., Airoidi, L., Carranza, A., Coen, L. D., Crawford, C., Defeo, O., Edgar, G. J., Hancock, B., Kay, M. C., Lenihan, H. S., Luckenbach, M. W., Toropova, C. L., Zhang, G., & Guo, X. (2011). Oyster reefs at risk and recommendations for conservation, restoration, and management. *BioScience*, 61(2), 107–116. <https://doi.org/10.1525/bio.2011.61.2.5>
- Duarte, C. M., Agusti, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J.-P., Fulweiler, R. W., Hughes, T. P., Knowlton, N., Lovelock, C. E., Lotze, H. K., Predragovic, M., Poloczanska, E., Roberts, C., & Worm, B. (2020). Rebuilding marine life. *Nature*, 580(7801), 39–51. <https://doi.org/10.1038/s41586-020-2146-7>
- Hynes, S., Chen, W., Dempsey, E., Norton, D., Doherty, E., Campbell, D., & Garrod, G. (2022). Public preferences for the restoration of marine habitats and species — the case of oyster reef restoration in Ireland. *Ecological Economics*, 194, 107349. <https://doi.org/10.1016/j.ecolecon.2022.107349>
- Society for Ecological Restoration. (n.d.). What is ecological restoration? <https://www.ser.org/page/MissionandVision>
- Strong, J. A., Piechaud, N., De Clippele, L. H., Bett, B. J., Horton, T., & Huvenne, V. A. I. (2023). Recovery and restoration potential of cold-water corals: Experience from a deep-sea marine protected area. *Restoration Ecology*, 31(8), e13970. <https://doi.org/10.1111/rec.13970>



Unsworth, R. K. F., McKenzie, L. J., Collier, C. J., Cullen-Unsworth, L. C., Duarte, C. M., Eklöf, J. S., Jarvis, J. C., Jones, B. L., & Nordlund, L. M. (2019). Global challenges for seagrass conservation. *Ambio*, 48(8), 801–815. <https://doi.org/10.1007/s13280-018-1115-y>

Appendix A

Variable name	Description / definition
Ecosystem	Specific ecosystem targeted by the restoration activity (e.g. kelp forest, oyster reef, seagrass meadow, cold-water coral reef). Broad categories avoided unless unavoidable.
Study (cluster)	Unique numeric identifier grouping all observations from the same underlying study or publication.
Reference	Full citation of the source study (authors, year, title, journal/report).
Publication type	Type of publication (peer-reviewed article, report, working paper, government document).
Year published	Year the study was published.
Year (data collection)	Year(s) during which restoration or cost data were collected.
\$ value reported based on year	Year to which originally reported monetary values correspond.
Type of source	Classification of the source of cost data (primary, modelled, mixed).
Action	General restoration action undertaken.
Specific technique	Detailed description of restoration technique used.
Species	Species or taxa targeted by the restoration if relevant.
Location	Specific site or regional location of the restoration project.
Country	Country where the restoration project took place.
Total project costs reported (capital costs and operating costs)	Whether total project costs are reported.
Capital costs reported (planning, purchasing, land acquisition, construction, and financing)	Whether capital costs are reported.
Operating costs reported (maintenance, monitoring, and equipment repair and replacement)	Whether operating costs are reported.
Monitoring costs included	Whether monitoring costs are included.
Construction costs included	Whether construction/installation costs are included.
In-kind costs (volunteers)	Whether volunteer or in-kind labour is included.
Funding: Government	Indicates government funding involvement.



Funding: NGO	Indicates NGO funding involvement.
Funding: volunteers	Indicates volunteer contributions.
Funding: private	Indicates private sector funding involvement.
Notes to funding	Additional notes describing funding structure if provided.
Project duration (year)	Duration of the restoration project if reported.
Spatial extent (ha)	Spatial extent of restoration activity if reported.
Restoration cost in (US\$ / ha)	Restoration cost per hectare in nominal USD in data collection year of original study.
Restoration cost in (Int\$ / ha) @2024 base, GDP (PPP)	CPI and PPP adjusted restoration cost per hectare in International 2024 US dollars
Restoration cost in (Euro / ha) @2024 base	Restoration cost per hectare in 2024 Euro, converted from cost per hectare (USD 2024)