Tennenbaum Marine Observatories Network and MarineGEO Program Science Strategy

2026-2035

MarineGEO
THE TENNENBAUM
MARINE OBSERVATORIES NETWORK

Smithsonian Institution

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The Marine Global Earth Observatory (MarineGEO) network, made possible by a generous founding gift from Michael Tennenbaum, provides an unparalleled platform to scale coordinated ecological monitoring and collaborative experimentation through standardized protocols applied across diverse nearshore systems. As environmental change and human pressures accelerate, there is an urgent need to detect, explain, and anticipate how these ecosystems are changing, reorganizing, and adapting. MarineGEO's geographic reach and disciplinary breadth allow the network to link local observations to regional and global patterns, enabling cross-site comparisons and broader-scale insights.

This Science Strategy defines a shared vision to focus and align the network's monitoring and research efforts around ecological processes, connectivity, and environmental change across spatial and temporal scales. MarineGEO produces long-term, comparable baselines that enable trend detection, attribution of environmental and anthropogenic drivers, and assessment of ecosystem resilience and vulnerability. The network advances mechanistic understanding of ecosystem responses to multiple stressors in nearshore environments through coordinated analyses, cross-site syntheses, and experimental integrations. The strategy promotes an integrated, seascape-scale approach that spans multiple habitats and supports the selective inclusion of socio-economic dimensions, strengthening the relevance of MarineGEO science for conservation, management, and policy. By demonstrating the value of sustained, standardized monitoring, the strategy helps translate scientific insight into actionable knowledge.

Finally, the Science Strategy emphasizes adaptive implementation, enabling MarineGEO to update research questions, methods, and analytical approaches as environmental conditions change, scientific understanding advances, and decision-making needs evolve. The research themes, activities, and implementation framework leverage the shared strengths of the MarineGEO network and directly supports delivery of the MarineGEO Strategic Plan, with emphasis on our strategic priorities.

Our Vision

To be a global leader in monitoring and investigating nearshore marine ecosystems to advance science, inform decision-making, and sustain coastal systems.

Our Mission

To build a global network of partner organizations that fosters the next generation of marine scientists who advance our understanding of nearshore marine ecosystems at local, regional, and global scales through standardized, accessible monitoring to inform science-based decision making.

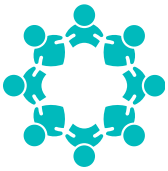
Our Guiding Principles

Advance scientific understanding of how nearshore marine habitats are changing using standardized, user-friendly, low-cost monitoring protocols combined with coordinated projects.

Strengthen capacity across career stages, institutions, and geographies through hands-on training, mentorship, and sustained engagement.

Foster diverse, cross-disciplinary and international partnerships that integrate long-term monitoring and experimental research into science-based decision-making.

Increase data usability and impact by committing to open, standardized, and well-curated datasets that translate data into knowledge that supports science-based solutions and conservation strategies.

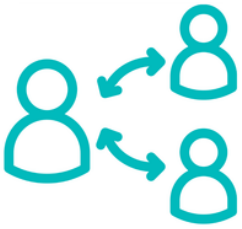


Build an inclusive community of practice that lowers barriers to participation, strengthens long-term monitoring, enhances institutional capacity, and creates meaningful opportunities for collaboration and growth.

Our Framework

Monitoring implementation

- Lead and support the co-development and implementation of standardized global monitoring protocols.
- Develop undergraduate field course modules that include MarineGEO protocols through the *Connecting Coastlines to Campuses* program.
- Host training workshops for new members, professors, and other stakeholders in MarineGEO monitoring protocols and data carpentry.
- Host refresher training workshops to ensure compliance with MarineGEO protocols.



Reporting and sharing results

- Share key findings through peer-reviewed publications and high-level conferences.
- Increase our social media presence through the creation of online content and the joint posting of partner content.
- Produce a regular MarineGEO newsletter and annual report.
- Host Working Group meetings and seminars.
- Co-host side events at major international conferences and policy forums.

Coordinating data analyses and syntheses

- Set key benchmarks and baselines for ecosystems using suites of indicators, based on the Essential Ocean Variables (EOV) and Key Performance Indicator (KPI) frameworks.
- Coordinate Working Groups and/or workshops to lead data analyses and drafting of manuscripts.
- Co-develop open-source and open-access data portals to facilitate the integration of scientific data into management and policy.

Co-developing and defining research questions

- Convene Working Groups to co-develop and refine research questions for monitoring data and network projects.
- Facilitate workshops with stakeholders to co-develop solutions, using available information to predict their impact and feasibility.
- Implement scientific research that investigates drivers of change and supports effective management.

Research Themes

The research themes outlined below identify a set of priorities supporting the MarineGEO network's mission over the next decade. Central to these themes are the network's two complementary approaches: standardized monitoring, and coordinated network experiments. Together, these efforts advance our understanding of the nearshore marine environment through biodiversity assessments, tracking trends in habitat condition and seascape-level change, and forecasting ecological responses to stressors and drivers of change.

Theme 1: Biodiversity assessments

Establishing robust ecological baselines through annual monitoring enables the detection of change over time, supports evaluations of ecosystem health, and provides critical information for effective conservation, management, and policy decision-making.

Objective 1.1: Conduct regular monitoring using MarineGEO protocols to document biodiversity and assess foundational species extent and condition.

Objective 1.2: Develop standardized indicators of ecosystem health for nearshore habitats, using the EOV framework.

Objective 1.3: Synthesize data to identify emergent patterns across regional and global gradients, including species of concern (threatened, endangered), non-indigenous species, and geographic range extensions.

Objective 1.4: Assess the potential of current and cutting-edge technologies, such as environmental DNA (eDNA) and telemetry, to complement traditional monitoring methods.

Objective 1.5: Link synthesis with national and international agreements (e.g., Global Biodiversity Framework) to ensure MarineGEO data remains action oriented.

Theme 2: Drivers of ecosystem change

In an era of unprecedented environmental change, understanding how ecosystems respond to threats is critical for building solutions that promote biological conservation at local, regional, and global scales. Robust, large-scale field experiments maximize our power to reliably assess status and trends of biodiversity, to articulate associated uncertainty, and to compare results across space and time.

Objective 2.1: Integrate multi-scale observations by combining monitoring data with network experiments and remote sensing products to understand responses in habitat condition and biological diversity at local to global scales.

Objective 2.2: Design coordinated experiments to test hypotheses on fundamental ecological processes, mechanistic drivers of change, and ecosystem vulnerability and resilience.

Objective 2.3: Conduct experiments to evaluate the effects of management, conservation, and restoration practices on biodiversity, ecosystem services, and ecological processes to inform marine spatial planning.

Theme 3: Seascape connectivity

Monitoring across multiple ecosystems enables a seascape-level understanding of nearshore ecosystems and represents a distinctive strength of MarineGEO. The ocean is continuous; marine organisms are highly connected with ecological interactions occurring at multiple scales. Understanding how connectivity across different habitats can reduce or increase vulnerability is vital for building resilient ecosystems. When combined with understanding the needs and dependence of coastal communities on nearshore marine resources, this can help foster effective management and stewardship.

Objective 3.1: Analyze food-web and trophic interactions across habitat mosaics to better understand the linkages between connected ecosystems.

Objective 3.2: Map the spatial configuration and extent of interconnected habitats to assess responses to different stressors to evaluate how connectivity influences ecosystem-level resilience.

Objective 3.3: Assess the potential for the integration of social indicators in combination with environmental indicators to provide a socio-ecological assessment of coastal resilience.

Theme 4: Future predictions and scenario planning

Future predictions and scenario planning are essential for anticipating how ecosystems may respond to environmental change. Projecting ecosystem impacts across multiple forecasting scenarios can reveal key risks and tipping points, opportunities, and trade-offs and support a foundation for more informed and adaptive management decisions.

Objective 4.1: Develop and refine predictive models that forecast ecosystem-level responses to environmental change under multiple future scenarios.

Objective 4.2: Develop species distribution models to assess habitat range shifts under different climate scenarios and the potential impacts to marine biodiversity.

Objective 4.3: Develop prioritization tools that incorporate future climate predictions and habitat conditions for forward looking management, conservation, and restoration strategies.

Diffusion of Knowledge

Theme 5: Science communication

Science communication will serve as a cross-cutting function across all research themes, ensuring that findings are translated into clear, accessible, and actionable messages for diverse audiences. Integrated throughout the research lifecycle, from design to dissemination, it will support consistent messaging, strengthen partner engagement, and enhance public awareness. By communicating complex ideas accurately and accessibly, it builds trust in science, counters misinformation, and supports evidence-based decision-making in management and policy. Ultimately, science communication connects researchers, stakeholders, and the wider public to maximize the reach, relevance, and real-world impact of the research.

Objective 5.1: Maintain the scientific reputation of the network through the production of high-impact peer-reviewed publications and presentations at scientific conferences.

Objective 5.2: Establish interoperable data management and visualization tools that synthesize monitoring results across habitats, geographies, and time scales to support timely evidence-based management decisions.

Objective 5.3: Support adaptive management and conservation strategies through the translation of ecological understanding into guidance for ecosystem management, restoration, and policy decisions.

Objective 5.4: Facilitate peer and public engagement through profiling MarineGEO activities, partner organizations, and people through various outlets (e.g., social media, story maps).

Metrics of Success

To effectively monitor and evaluate our efforts in achieving the goals and objectives set out in the Science Strategy we have compiled a total of 59 Specific, Measurable, Achievable, Realistic, and Time-bound (SMART) indicators. Measurable outputs include the publication of peer-reviewed manuscripts, the initiation and implementation of new projects, and the hosting or assistance in workshops and training sessions.

Themes	Objectives	SMART indicators
1. Biodiversity assessments	*1.1: Conduct regular monitoring*	*1.1A:* All observatory and monitoring partners conduct annual monitoring and provide data in a timely manner.
		1.1B: Develop and implement 2 (two) new protocols utilizing the *Connecting Coastlines to Campuses* program framework.
		1.1C: Train at least 5 (five) professors in MarineGEO protocols and data carpentry through the *Connecting Coastlines to Campuses* program framework, each year.
		1.1D: Conduct training of at least 30 (thirty) people in each MarineGEO protocol every 2 (two) years.
	1.2: Develop standardized indicators	*1.2A:* Utilize the EOVs to ensure existing and future monitoring protocols align with this framework, by 2028.
		1.2B: Publish peer-reviewed papers validating standardized indicators across MarineGEO habitats, 3 (three) by 2030 and 6 (six) by 2035.
	1.3: Synthesize data to identify emergent patterns	*1.3A:* Conduct 4 (four) network-wide data syntheses identifying emergent biodiversity patterns, by 2035.
		1.3B: Maintain and update network-wide database(s) of biodiversity trends, biogeographic range extensions, and NIS species records.
		1.3C: Produce 4 (four) synthesis peer-reviewed publications documenting biodiversity trends across regional and global gradients, by 2035.

Themes	Objectives	SMART indicators
1. Biodiversity assessments	*1.3: Synthesize data to identify emergent patterns*	*1.3D:* Engage Working Group members to contribute towards a protocol of peer-reviewed publication. Working Groups should meet monthly and aim to submit and/or publish 1 (one) paper every 2 (two) years.
	1.4: Assess the potential of current and cutting-edge technologies	*1.4A:* Develop at least 5 (five) projects that increase our data analysis capacities using novel technologies (e.g., scoring of photoquadrats with new AI tools) and implement where successful to promote the scaling of different monitoring protocols, over the course of 10 (ten) years.
		1.4B: Develop a soundscape monitoring strategy by the end of 2027 and implement in at least 5 (five) sites across a latitudinal gradient over the course of 10 (ten) years, if deemed viable.
		1.4C: Develop an environmental DNA (eDNA) monitoring strategy by the end of 2028 and implement in at least 10 (ten) sites across environmental gradients over the course of 10 (ten) years, if deemed viable.
		1.4D: Develop a seascape-scale telemetry monitoring strategy by the end of 2032 and implement in at least 5 (five) sites across a latitudinal gradient over the course of 10 (ten) years, if deemed viable.
		1.4E: Develop an approach for 3D structure monitoring and analysis using emergent technologies (e.g., AI), over the course of (ten) years.
		1.4F: Produce 3 (three) peer-reviewed publications utilizing or incorporating emerging technologies into monitoring or mechanistic experiments, by 2035.
		1.4G: Validate emerging technologies and integrate into standardized MarineGEO monitoring protocols, where deemed viable.
	1.5: Link synthesis with national and international agreements	*1.5A:* Contribute MarineGEO data to international biodiversity repositories (e.g., Ocean Biodiversity Information System), annually.
		1.5B: Determine where MarineGEO data can be used to support reporting on international agreements (e.g., Global Biodiversity Framework), by 2028.

Themes	Objectives	SMART indicators
2: Drivers of ecosystem change	*2.1: Integrate multi-scale observations*	*2.1A:* Integrate remote sensing data products with monitoring data across 6 (six) observatories to assess habitat condition and biodiversity change by 2030.
		2.1B: Publish 5 (five) synthesis peer-reviewed papers combining monitoring, experimental, and remote sensing data to assess ecosystem responses across multiple scales, by 2035.
	2.2: Design coordinated experiments	*2.2A:* Design and implement 3 (three) coordinated network experiments testing mechanistic drivers of ecosystem change, by 2035.
		2.2B: Publish 5 (five) peer-reviewed papers arising from coordinated network experiments.
		2.2C: Convene and maintain a Working Group for each habitat to co-develop question-driven projects. Working Groups should meet multiple times per year.
	2.3: Conduct experiments to evaluate the effects of management, conservation, and restoration practices	*2.3A:* Implement 3 (three) experiments evaluating the effectiveness of management, conservation, or restoration practices, by 2035.
		2.3B: Produce 2 (two) peer-reviewed publications translating experimental findings into actionable guidance for management.
		2.3C: Convene 10 (ten) workshops for management and/or conservation partners in the co-design or implementation of management-based projects by 2035.
3: Seascape connectivity	*3.1: Analyze food-web and trophic interactions*	*3.1A:* Conduct at least 2 (two) food-web or trophic interaction assessments across which include at least 5 (five) partner observatories and produce at least 2 (two) peer-reviewed publications, by 2030.
		3.1B: Publish at least 2 (two) peer-reviewed papers documenting trophic linkages and cross-habitat interactions by 2030.

Themes	Objectives	SMART indicators
3: Seascape connectivity	*3.2: Map the spatial configuration and extent of interconnected habitats*	*3.2A:* Produce comparable habitat maps for each TMON, Observatory, and Monitoring site, by 2030.
		3.2B: Evaluate how habitat configuration influences ecosystem responses to environmental or anthropogenic stressors, to produce 3 (three) peer-reviewed publications, by 2035.
	3.3: Assess the potential for the integration of social indicators	*3.3A:* Explore opportunities with the Smithsonian's Resiliency Imitative and other social science groups and networks, to understand how to integrate social indicators into MarineGEO data frameworks.
		3.3B: Co-develop a list of essential socio-ecological indicators that combine MarineGEO monitoring data with social and/or community-level metrics, by 2028.
4: Future predictions and scenario planning	*4.1: Develop and refine predictive models*	*4.1A:* Compile a dataset of relevant variables and remote sensing products to be used in modeling predictions to ensure standardization of MarineGEO analyses, by 2027.
		4.1B: Develop or refine predictive models forecasting ecosystem-level responses to environmental change utilizing MarineGEO monitoring data.
		4.1C: Publish 3 (three) peer-reviewed papers applying predictive models of ecosystem dynamics under future scenarios, by 2035.
	4.2: Develop species distribution models	*4.2A:* Develop species distribution models for priority or indicator species across different climate scenarios using MarineGEO monitoring data, resulting in 3 (three) peer-reviewed publications by 2035.
		4.2B: Publish at least 2 (two) peer-reviewed papers documenting projected species range shifts and biodiversity impacts under different climate trajectories.

Themes	Objectives	SMART indicators
4: Future predictions and scenario planning	*4.3: Develop prioritization tools*	*4.3A:* Develop at least 2 (two) spatially explicit prioritization tools that integrate climate projections and habitat condition data for use in conservation or restoration planning by 2035.
		4.3B: Pilot prioritization tools with at least 2 (two) partners across different geographies by 2035.
5. Science communication	*5.1: Maintain the scientific reputation of the network*	*5.1A:* Submit at least 1 (one) peer-reviewed paper annually with contributions from at least 5 (five) observatory partners.
		5.1B: Present MarineGEO findings at 3 (three) national or international conferences, every year.
		5.1C: Host at least 1 (one) session at a high-level conference each year (e.g., World Conference on Marine Biodiversity).
		5.1D: Co-host 1 (one) side event at a major conference or high-level event, every other year.
	5.2: Establish interoperable data management and visualization tools	*5.2A:* Develop publicly available tools for quality assurance and quality control (QA/QC) of data collected with MarineGEO protocols.
		5.2B: Establish an access-controlled partner data portal (e.g., SharePoint site) by 2027, where all MarineGEO partners can view and download relevant monitoring and project data prior to public release.
		5.2C: Deliver data visualization reports to partners within a month post-data submission, barring data quality issues, for seagrass, oyster, and fouling protocols (by 2027) and coral reefs and sandy beach habitats (by 2028).

Themes	Objectives	SMART indicators
5. Science communication	*5.2: Establish interoperable data management and visualization tools*	*5.2E:* Launch an interactive dashboard integrating all MarineGEO monitoring programs, allowing users to explore where data has been collected and filter by site, habitat, year, and variable, with options for downloads in relevant formats, by 2028.
	5.3: Support adaptive management and conservation strategies	*5.3A:* Produce at least 5 (five) management briefs that translate MarineGEO research findings into actionable management recommendations by 2035.
		5.3B: Establish at least 4 (four) collaborations with management agencies, conservation organizations, or non-governmental organizations (NGOs) to co-develop evidence-based best practices by 2035.
		5.3C: Document at least 5 (five) instances where MarineGEO findings have directly informed management decisions by 2035.
		5.3.D: Provide service and advice to at least 3 (three) national or international committees.
	5.4: Facilitate peer and public engagement	*5.4A:* Foster strategic alliances within SI, e.g., Coastal Carbon Network, BRIDGE and external networks, e.g., RLS, MBON.
		5.4B: Engage at least 10 (ten) partner organizations in the creation of at least 4 (four) joint content creation or co-promotion of MarineGEO activities through social media or other public outlets, every year.
		5.4C: Achieve 800 followers on each social media platform by the end of 2027 and subsequently increase our social media following by at least 5% each month.
		5.4D: Create story maps for each habitat with the associated Working Group by 2027; update these as new outputs and outcomes arise.

Themes	Objectives	SMART indicators
5. Science communication	*5.4: Facilitate peer and public engagement*	*5.4E:* Host at least 1 (one) session at a high-level conference each year (e.g., World Conference on Marine Biodiversity).
		5.4F: Co-host 1 (one) side event at a major conference or high-level event, every other year.