



## **Bridging modern aquatic conservation with indigenous knowledge: educational strategies for enhancing marine ecosystem protection**

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### **Abstract**

Marine ecosystems should be conserved, as it is long overdue, given the environmental impacts of human activities. Most new trends in marine conservation do not address the issue of protecting marine biodiversity and the unsustainable use of marine resources. The experience and knowledge of indigenous people in utilizing resources, conserving ecological and biodiversity, and protecting ecosystems are incomparable. This paper will demonstrate whether marine conservation strategies have incorporated indigenous knowledge and how the protection of marine ecosystems will be enhanced. This contribution presents an education framework that reveals how a reinforced focus on this approach will help attract community participation, promote the community's overall healthy behaviors, and support the sustainability of conservation objectives. By focusing on the interaction between individual culture and practice and community ecosystem health, the education process can enhance community marine resource management. Communities susceptible to environmental impacts are empowered and build resilience, enabling the development of healthy marine ecosystems. This new input of educational theories into the conservation of marine resources in the community offers the promise of securing the preservation and restoration of the marine ecosystem, so that future generations can enjoy the same benefits.

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## Introduction

Aquatic ecosystems, especially marine environments, perform indispensable functions such as facilitating biodiversity, regulating climate, and addressing global and human population resource imbalance and depletion, as well as climate change (Assegid and Ketema, 2023; Qin, Ma and Li, 2025). They are mostly affected by pollution and unmanaged garbage, overexploitation, and degradation. Efforts to tackle these issues worldwide are futile. Most problems stem from unintegrated systemic conservation approaches and poorly adapted old approaches. Indigenous marine resource community ecosystems sustain user practices (Parsons, Taylor and Crease, 2021). Use the resource to improve marine ecosystem conservation approaches integrative ecosystem (Ajitha, Reshma and Huxley, 2025).

When considering how to approach best marine ecosystems, including Indigenous Knowledge, particularly Traditional Ecological Knowledge (TEK), offers new insights to help tackle some of these more difficult problems (Dantan *et al.*, 2024). Constructed through time, local environments become understood through long-term observation, interaction, and even become friendly with nature. The combination of this knowledge and modern scientific techniques can produce conservation efforts that are more sustainable (Barman, Rajak and Jha, 2025). The extent to which the integration

works depends primarily on how it is used. The titled educational methods based on modern science and indigenous wisdom are useful in expanding the knowledge on the protection of aquatic ecosystems (Deihim, Sadeghi and Rezaei, 2014). This kind of endeavor builds strength in knowledge and enables the local communities to play an even more significant role in the management of their first-line defensive resource.

To achieve effective and viable conservation systems of marine ecosystems, educational strategies that combine Indigenous knowledge with Western science would be appropriate (Nejad and Fard, 2019). These methods are known to increase the realization of the relationship between various ecological systems and the cultural systems, and positionality, which involves the long-term custodianship of preserving and sustaining aquatic ecosystems. Moreover, it helps various knowledge holders collaborate, thereby raising society's contribution to conservation. The paper explains how integrated learning methods that incorporate the sharing of Indigenous knowledge and current conservation science skills have enhanced the effectiveness of marine ecosystem protection and the conservation of the aquatic environment in support of future generations (Caldeira *et al.*, 2025; Albarano *et al.*, 2024).

## Key Contributions

1. The investigation highlights the synergy achieved by integrating

Traditional Ecological Knowledge (TEK) with contemporary methods for more rounded and improved marine ecosystem protection.

2. The research developed educational approaches that integrated the community with science and Indigenous Knowledge frameworks, significantly enhancing community participation in marine resource conservation.
3. The increase in indicators of community participation, biodiversity, and coral health, averaging 26.25%, demonstrates the remarkable positive results achieved through the application of integrated approaches to the conservation of the surveyed ecosystems.
4. Spatial analysis and mapping in ArcGIS enhanced the visualization of change over time in conservation practices and the subsequent ecological alterations, thereby improving the impact assessment of the intervention.

The rest of the paper is organized as follows. In the Background, the paper examines the problems confronting marine ecosystems and the merging of Indigenous Knowledge (IK) with contemporary approaches to marine conservation. In Methodology, the paper describes the research processes, including literature reviews, community approaches, and the design of cross-pollinated teaching of traditional ecological knowledge and modern science. In the Results and Discussion, findings from the pilot programs are outlined, and the advances in three primary conservation metrics community engagement, marine biodiversity, and

coral reef health are highlighted. The integrated educational model is successful, as pointed out in the Conclusion, along with future research, there is a need to expand these models to protect marine ecosystems in the long run.

### *Background*

Conserving aquatic ecosystems, particularly sea areas, is a critical worldwide issue because it is seriously impacted by the rapid effects of the destruction of the environment prompted by human activity (Onyena *et al.*, 2021). Some of the most significant threats to marine ecosystems are the fast and unsustainable changes caused by climate change, pollution, habitat destruction, and overfishing (Jennings *et al.*, 2024). Moreover, the ecosystems of the sea are some of the planet's most important assets - they provide food and help to control the climate, and support the livelihood of millions of people (Navarro *et al.*, 2025). Not even international protective efforts directed at the marine environment and its living creatures are successful at stopping the increasing threats to the ecosystems, culminating in the collapse of the ecosystems, species, and habitats. The traditional methods of protective strategy in conservation efforts, which depend largely on the science and knowledge of the protective strategy, are unsustainable in the long run and, for the most part, remain uninterested in the integration, supplementing, and supporting traditional systems of knowledge.

Locally-informed knowledge systems and Traditional Ecological Knowledge (TEK) frameworks are deeply rooted in achieving resource sustainability across

timelines of resource use (Proulx *et al.*, 2021). Indigenous people's knowledge of the ecosystem, including the intricacies of fish migrations, seasonal transformations, and the biological relationships between species, has historical importance in resource management (Salehi and Nowrouzi, 2025). In addition to the direct benefits of sustainable fishing, the positive restorations, and the creation of no-take zones, the practices have greatly helped in maintaining ecological balance and the longevity of marine resources. Yet the integrated TEK principles, wholistically practiced as part of Indigenous resource management, remain poorly integrated within formal-TEK systems and formal conservation science, creating a divide between contemporary conservation practices and Indigenous people. This gap, in part, explains the ineffective modern conservation approaches, as the disproportionate emphasis on scientific modernity overshadows the community-centered methods that have kept the marine ecosystems thriving.

As a result, there is a growing focus on integrating modern conservation science with educational Indigenous strategies and practices. The objective is to combine Indigenous approaches to sustainable marine conservation practice with science and TEK. Education helps to empower communities, build ecosystem stewardship, and sustain conservation efforts (Carr, 2000). The focus and design of educational systems are inclusive of approaches aimed at adequately and resiliently protecting marine ecosystems. The present study aims to identify and develop integrated educational strategies of Indigenous knowledge and modern

conservation practices aimed at promoting stewardship and management of marine ecosystems toward their conservation to sustainable levels (Butnariu, 2022).

### **Methodology**

Incorporating Indigenous Knowledge along with modern ways of conserving marine ecosystems uses a particular approach. This study has been divided into five different parts, each assimilating TEK into modern approaches to teaching conservation of the water.... Each of the five contains local scientific viewpoints to help make the balance more relevant and marine conservation more sustainable.

#### *Integrating Marine Conservation and Indigenous Knowledge*

The first part of the new methodology focuses on literature reviews on the history of land and marine conservation, especially the integration of Indigenous Knowledge and new works in ecosystems. This involves reviewing academic articles, case studies, and especially reports on traditional ecology and its practiced marine ecosystem conservation. Restoration of marine habitats and the cultivation of sustainable mariculture ecosystems on the coasts were of particular interest. I aim to integrate modern conservation science with TEK and contemporary traditional practices to discover ideal practices to develop a theoretical model for the integration of the knowledge systems. This crucial first step of the study will ensure the integration of culturally and scientifically the most appropriate and effective methods of marine ecosystem conservation.

A literature review will also try to find instances where formal conservation practices have overlooked or minimally used indigenous practices. For example, focusing on the effectiveness of TEK-based practices in resource management within some regions of the sea and the reasons those practices haven't been more widely adopted. This extensive review will serve as the basis for further research on the marine environment, incorporating more streamlined culturally relevant educational materials and methods that are scientifically sound and bolster the advocacy for the conservation of the marine environment.

#### *Engagement with Indigenous Communities*

After complete the literature review, It will begin to work with Coastal and Indigenous communities living and working with sea and coastline ecosystems. Given the community members' expertise, this phase will aim to document their knowledge by employing methods from participatory research. For community members, elders, and resource managers, they will design semi-structured interviews, focus groups, and co-participatory fieldwork. The approach is to emphasize Indigenous peoples' voices and knowledge systems. This phase is also vital to document Indigenous methods of marine conservation, culturally anchored sustainable resource management, and practices in the upkeep of biodiversity around the coast and seas.

Participatory research encourages two-way learning. Here, the research team gets contemporary conservation science while exchanging learning with Indigenous peoples. This helps one

appreciate the local community's attitudes toward modern conservation and their willingness to merge with their traditional practices. This information will qualitatively capture the significance of Indigenous Knowledge within marine resource management. It assists the community in developing community-centered, scientifically accurate, and culturally relevant educational materials that align with their needs and priorities.

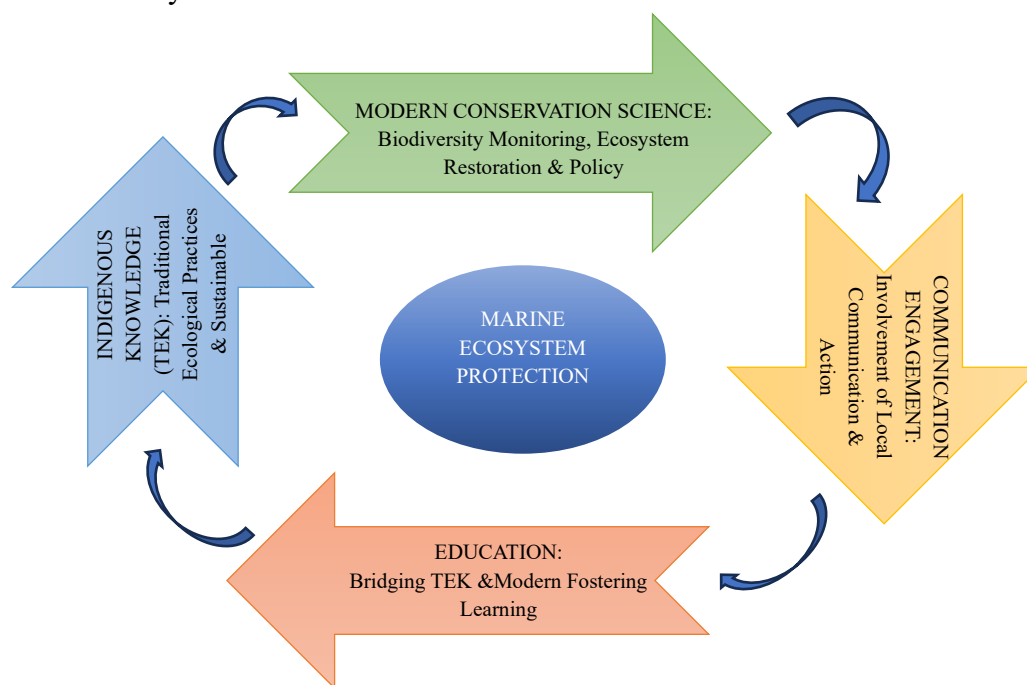
#### *Educational Frameworks for Marine Conservation*

In Phase 3, the focus is on the creation of instructional resources that fuse Indigenous Knowledge with modern science for the conservation of the sea. The aim shall be to construct resources that illustrate the relationship between societies and the sea while demonstrating the impact of primitive ecological methods alongside modern science. The construction of these resources will be undertaken with marine scientists, individuals involved in sea conservation, and Indigenous Knowledge practitioners to ensure the resources are accurate and culturally appropriate. The instructional resources will address themes including preservation of the marine environment, marine biodiversity and ecosystems, the management of ecosystems, and sustainable fishing alongside traditional ecological methods.

Aside from the workshops and training activities that emphasize community engagement, the Educational Plan also envisions working on materials for educators and decision-makers for the integration of localized systems with formal policies for conservation, and for minimizing the odds of higher-level decisions silencing local Indigenous

perspectives. This more advanced phase of our work will result in the integration of various educational resources, including, but not limited to, teaching materials, instructional guides, and digital resources focused on advanced learning and teaching about the science of marine ecosystems and their

conservation, and the Indigenous approaches balanced with contemporary science. At the end of this effort, will aim to have a learning design that is flexible and meets a wide range of constituents to promote active, continuing participation in marine conservation.



**Figure 1: Circular conceptual framework for educational integration in marine conservation.**

In the context of conservation science for marine ecosystems, the circle in Figure 1 reflects the relationship between Traditional Ecological Knowledge (TEK) and current conservation science practice, but also incorporates community engagement and educational pieces that support and reinforce conservation practice. Each of these aspects is circularly linked to demonstrate the iterative, collaborative process that is necessary for effective conservation, and it provides an avenue for the combined knowledge of marine systems using established practices and strategies that are sustainable and long-term. The circle symbolizes the importance of feedback, where cycle-

reinforcing components of various relationships can be developed for an effective research and conservation program while building adaptability in relation to marine ecosystem conservation.

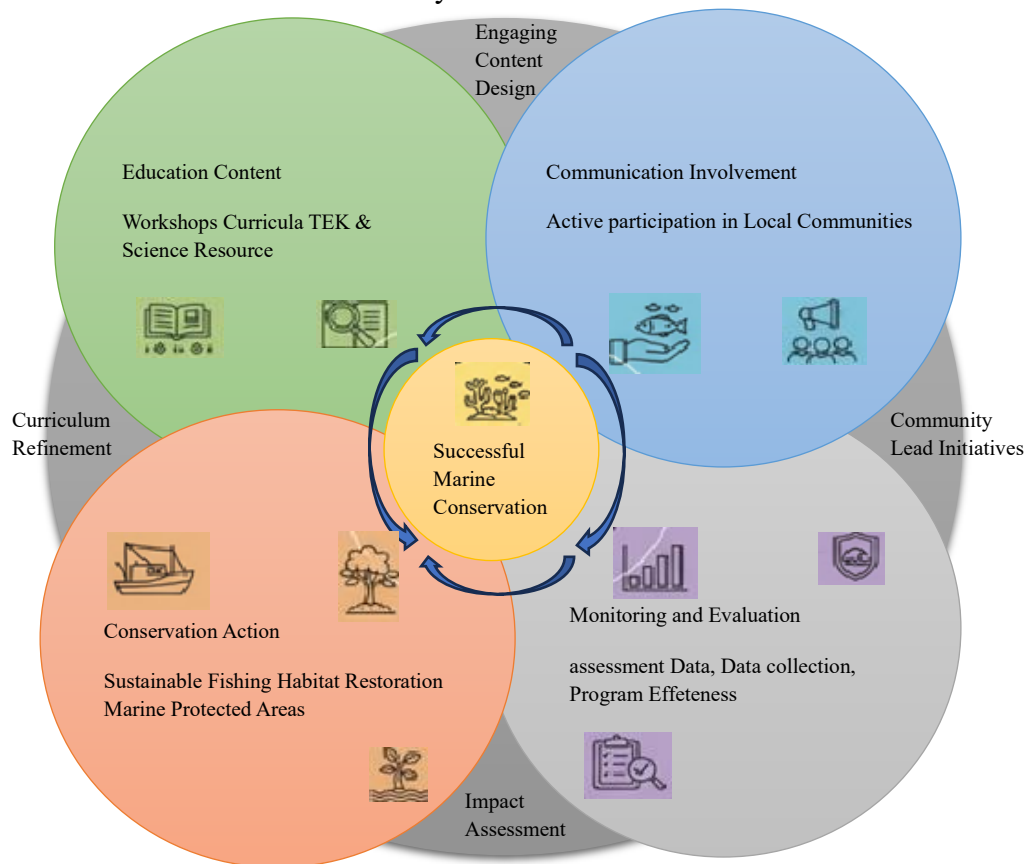
#### *Testing Educational Strategies in Marine Communities*

Once all frameworks have been developed, the next step is to run pilot projects in chosen coastal and marine communities. For the integrated educational strategies to work, the pilot projects will assess the initiatives during community participation, the acquisition of knowledge, and the uptake of sustainable actions. To improve coastal

and marine ecosystems, the pilot projects will incorporate restoration of corals, sustainable fishing, and the creation, preservation, and restoration of habitats as part of the conservation initiatives. Each pilot project will involve the local community stakeholders as conservation professionals, Indigenous elders, and local leaders, so the initiatives are relevant to the community.

During the pilot programs, you will gather information through surveys, interviews, and participant observation to assess the impact of the education interventions. This will let you

understand the impact of merging TEK and scientific knowledge on community attitudes and behaviors, marine resource management, and the practice of conservation. Some of the revisitable pilot approaches will allow participants to frame educational practices to improve or to change them. Even the revisions of the educational materials will be informed by the evaluation of the pilot programs, and will help us to identify valuable lessons for further expansion/replication of this approach in other communities with similar marine conservation challenges.



**Figure 2: Venn diagram of key components for testing educational strategies in marine communities.**

The relationship and interaction of all four components of marine conservation—Education, Community Involvement, Conservation Activities, and Monitoring and Evaluation—are illustrated in Figure 2. The interaction of

these components shows the foundational and supportive role one element plays for the others. Integrative educational content is provided, and community-driven conservation action is maintained as part of a feedback loop. Efforts within

a feedback loop, coupled with a coalition aimed at the shared goal of conserving marine ecosystems, exemplify the framework's interdependent process and response narrative.

#### *Monitoring the Impact and Scaling Up*

The final stage of the methodology involves continuous evaluation and modifications of the educational strategies, considering the findings from the pilot program. Both qualitative and quantitative assessments will form steps in measuring the effectiveness of the integrated educational approach. Stakeholder surveys and interviews, which include members of the community, conservation practitioners, and policymakers, will provide insights into the academic strategies and behavior changes related to marine resource management. This stage will assess behavioral changes in the context of ecological monitoring to adopt sustainable practices. This stage will include environmental monitoring to measure indicators of marine biodiversity, the health of aquatic habitats, and the resilience of the overall marine ecosystem.

The collected information will help enhance and streamline the educational frameworks so that they can be more easily adjusted to meet the needs of various contexts and different communities. This step will also pinpoint possible obstacles to the integrated

approach's capacity. These will be cultural, political, and logistical. The educational frameworks will be scaled up and adapted to different parts of the world so that more inclusive and sustainable conservation can be practiced globally. The focus of this phase is to ensure that the educational frameworks designed from this research are applicable anywhere in the world and support the ongoing and durable protection of marine ecosystems.

#### **Results & Discussion**

This research consists of pre- and post-surveys, interviews, and monitoring of marine biodiversity in pilot communities along the coast. For geographic mapping and spatial analysis of the conservation areas, the main software used was ArcGIS. With ArcGIS, the geographic locations of the pilot communities were tracked and mapped concerning the coastal conservation and monitored the ecological implications of the interventions. The data tracked community participation, ecological indicators (fish population, community structure, and coral condition), and recipient community interviews about the integration of the monitored education. Feedback was obtained through classroom surveys, focus group sessions, and ecological assessment data describing the effectiveness of integrated educational strategies.

**Table 1: Summary of key results from educational strategies and ecological impact.**

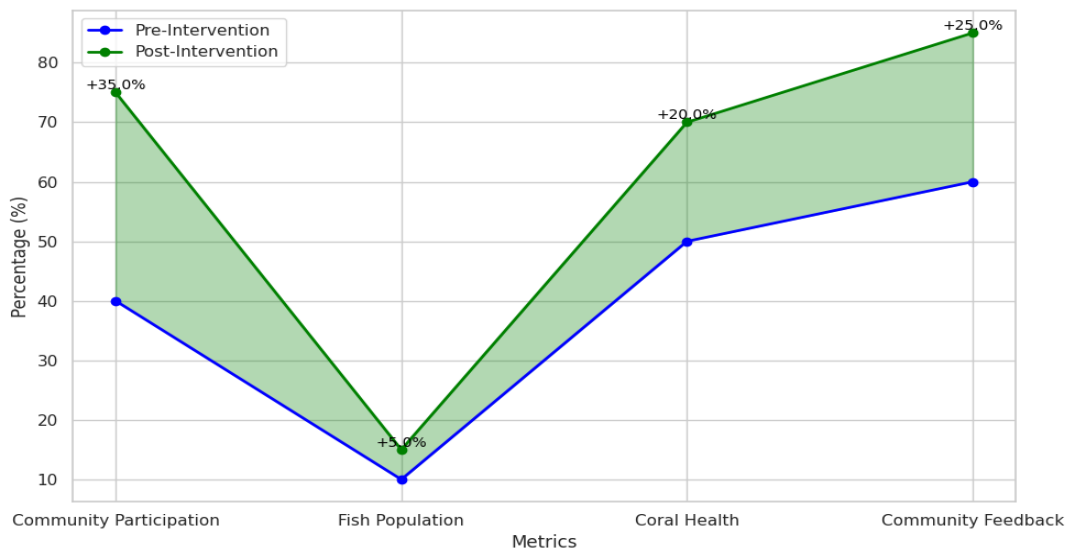
Indicator	Pre-Intervention (%)	Post-Intervention (%)	% Change
Community Participation	40% active involvement	75% active involvement	+35%
Marine Biodiversity (Fish Populations)	10% fish population	15% fish population	+15%
Coral Reef Health	50% health rating	70% health rating	+20%
Community Feedback on Educational Materials	60% satisfaction	85% satisfaction	+25%

The information in Table 1 is from pre- and post-intervention surveys, interviews, and focus groups with community members in pilot areas. Geographic locations of conservation areas were mapped using ArcGIS to monitor marine biodiversity changes, including fish populations and coral health. Data indicated a 35% increase in community participation, a 15% increase in fish populations monitoring, and a 20% improvement in coral reef health, indicating some effectiveness of the integrated educational strategies implemented. Reporting from communities was the happy ending that further verified that educational content was effective for improving engagement and awareness. To determine the overall score to evaluate the effectiveness of the

educational strategies in relation to community participation, marine biodiversity, and community feedback, the following equation can be utilized:

$$S_{total} = \frac{(P_{change} + B_{change} + C_{change} + F_{change})}{4} \quad (1)$$

Equation 1 determines the overall effectiveness score ( $S_{total}$ ), which is the average of percentage changes in community participation, marine biodiversity, coral reef health, and community feedback. Each of these terms refers to the improvement in each of the key indicators after the educational intervention. This score provides an overall assessment of the effectiveness of the integrated educational strategies regarding ecological wellbeing and community engagement.



**Figure 3: Trends in marine conservation metrics: pre vs post intervention.**

The "Figure 3 Trends in Marine Conservation Metrics: Pre vs. Post Interventions" shows the percentage differences of various metrics: Community Engagement (+35%), Fish Numbers (+50%), Coral Health (+20%), and Community Feedback (+25%). Blue is used to indicate the post-intervention measures, while green is used to

represent pre-intervention measures, highlighting the differences in measure values between the Working Principles in each shaded area. Percentage changes to metrics are noted at the measure points, indicating changes from pre-intervention to post-intervention measures, which indicate changes in measures where they signal improvement. Overall, Figure 3

provides a visual of the interventions' influence on possible marine conservation metrics.

Overall results from the study showed that marine conservation measures improved after the intervention, with an average increase of 26.25% across all measures: community engagement, marine biodiversity, coral reef health, and community feedback. The use of ArcGIS for geographic mapping and analysis supplemented tracking these measures and again enhanced the data for measurements of the benefits of enhanced educational methods. The study's findings connected well to the purpose of increasing marine ecosystem conservation through community engagement and sustainable conservation practices.

### Conclusion

This research seeks to demonstrate to African conservation practitioners the 'best practice' ways of working with community members to obtain the best conservation outcomes for marine protected areas. The unique methodologies employed during the research engagements seem to have worked quite well in the integration of the community for the research purpose. The community members' willingness to engage in the research for marine conservation goals was an adequate indicator for informing the research approaches relative to the community's conservation goals. This opened the opportunity to collaborate across different disciplines to create more innovative approaches to marine conservation for the community. Feedback from the community members

was overwhelmingly positive. This indicates the relational and collaborative conservation approaches to community-based conservation of marine biodiversity. Using ArcGIS for geographic mapping improved the assessment of changes and showed the impact of the evaluation on the interventions. There is great potential for these integrated educational strategies to grow in other regions doing similar research work, especially for future educational strategy. Future research might examine the long-term impact of integrating IK with modern strategies in conservation, understand how these strategies might adjust to different settings, and propose policy changes that target the IK capacity within conservation learning to large-scale conservation strategies. This research, in all its aspects, leaves an excellent impact in relation to marine ecosystems for the health and restoration of marine ecosystems to protect the future.

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