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Safeguarding South-East Asia's Marine Ecosystems from Ocean Acidification Threats

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Highlights

The increasing carbon dioxide emissions from human activities are being absorbed by the oceans, leading to a decrease in seawater pH levels worldwide. South-East Asia is particularly vulnerable to this problem, as the projected trend of ocean acidification severely threatens marine life in the region, as well as marine industry productivity and food safety. Urgent action must be taken by the Association of Southeast Asian Nations (ASEAN) Secretariat and its Member States to sustain coastal populations' livelihoods and economic prosperity.

Recommendations:
- Improve marine protected areas (MPAs) by applying science-based design and grass-roots community participation
- Establish a regional task force and collaborative funding
- Increase public awareness and implement marine educational programmes through curriculum integration

Ocean Acidification in South-East Asia

The industrial era has steadily increased carbon dioxide (CO2) emissions, primarily due to human activities like burning fossil fuels, land use changes and deforestation. Annually, around 26% of anthropogenic CO2 emissions (10.5 Gt) are absorbed by the ocean, aiding in mitigating the greenhouse effect (Friedlingstein et al. 2022). However, this phenomenon also contributes to the acidification of ocean water, reducing pH levels by approximately 30% (Ingrosso et al. 2017). This significantly impacts marine ecosystems, particularly in South-East Asia (SEA). Nine of the 10 Member States of the Association of Southeast Asian Nations (ASEAN) are coastal states, and approximately 90% of SEA's population depend significantly on marine resources for sustenance (Asian Development Bank 2021). The combined impacts of ocean acidification, warming sea surfaces and unpredictable ocean conditions adversely affect local well-being, including the ability of marine industries to develop and maintain socio-economic stability. This accelerating threat is disrupting the intricate balance of marine ecosystems in SEA, with profound implications for both natural and human systems. Coral degradation caused by ocean acidification, for example, weakens biodiversity and diminishes habitats that are essential to many marine species. Additionally, rising sea temperatures significantly contribute

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to coral bleaching, making coral reefs more vulnerable. At the same time, rising mortality of fish and shellfish undermines the food security and economic well-being of coastal populations that depend on these resources. Given the region's ecological diversity and economic importance, it is crucial to address the multifaceted impacts of ocean acidification. Effective action will safeguard the environmental health of marine ecosystems and the economic stability and food security of SEA's coastal populations, ensuring the region's resilience against future environmental and economic challenges.

Environmental and Socio-Economic Impacts

SEA's Coral Triangle (CT) is an outstanding hub of marine biodiversity, hosting a diverse range of reef-associated organisms. It contains more than three-quarters of the world's reef-building coral species, around 37% of the world's reef fish, 50% of razor clams and the largest mangrove forest worldwide, making it an essential player in maintaining marine ecosystems (Asaad et al. 2018). Coral reefs protect marine ecosystems and coastal communities from natural disasters such as storms, tsunamis and coastal erosion. They also contribute significantly to the community's economic growth, with an annual catch of 3.7 million tons, providing income and a source of food for coastal residents and contributing around USD 11 billion annually to the region's economy (Lam et al. 2019). In addition, other groups of species, such as molluscs, including clams, oysters and scallops, are important commodities in the region's food chain, amounting to nearly 1 million tons and contributing approximately USD 1 billion in 2019 (SEAFDEC 2022).

In some SEA countries, fish and shellfish play a critical role in food security, providing more than half of the total dietary intake. For instance, per-capita fish consumption in Malaysia is 56 kg per year (Khusun et al. 2022), which is double the global average. High acidity in water disrupts the ability of coral reefs and shellfish to form and maintain their calcium carbonate skeletons, which are vital for their survival. As acidity increases, the availability of carbonate ions diminishes, resulting in weaker organisms that are more prone to damage. Without proactive interventions by governments, coral reefs in the CT region will be marginalized by 2050 (Hoegh-Guldberg et al. 2017), and the potential catch of fish and other marine resources is expected to decline by about 3 million metric tons for each degree Celsius of global warming (Cheung, Reygondeau and Frölicher 2016). This reduction may therefore triple with a temperature rise of 3.5°C by the end of the twenty-first century.

Despite the high reliance of SEA on coral reef ecosystems, there remains a considerable lack of robust data on ocean acidification, which has the potential to negatively impact the nutritional composition of seafood, influence marine food webs, and jeopardize the sustainability of coastal populations, further exacerbating existing issues of food insecurity and malnutrition. Timely and targeted action is essential to safeguard these communities and preserve the marine resources on which they depend for their livelihoods and long-term viability.

Policy Recommendations

A holistic approach that encompasses multiple sectors can effectively mitigate the negative impacts of ocean acidification in the short and long term. The following recommendations are offered for policymakers and key stakeholders including fisheries associations, local communities, non-governmental and regional organizations such as the Asian Fishers Society the Southeast Asian Fisheries Development Center, and international partners such as WorldFish. They aim to ensure that no ASEAN Member States are left behind in efforts to address this pressing issue.

1. Improve the Effectiveness of Marine Protected Areas (MPAs) by Integrating Science-Based Design and Grass-Roots Community Participation

MPAs have proven to be effective tools for mitigating the negative impacts of human and industrial activities on marine ecosystems. Under proper management, MPAs can provide ecological, social and economic benefits and support the recovery of certain species (Humphreys and Clark 2020). Unfortunately, inadequate management practices have rendered around 69% of MPA coverage areas in SEA ineffective (Lam et al. 2019). Moreover, the selection of MPAs within the CT has protected only 17.8% of its coral reefs, indicating a pressing need for strategic improvements (White et al. 2014). This ineffectiveness stems largely from the fragmented and scattered designation of protected zones. When strategically located in biodiversity hotspots and effectively managed, marine protected areas (MPAs) can safeguard specific marine species, but existing MPAs often overlook critical habitats and distribution points. Furthermore, low levels of community involvement undermine local ownership and diminish the collective responsibility needed to support effective MPA management. Maritime spatial planning and area monitoring should be integrated into the design process to assess and identify areas of high biodiversity and vulnerable species. This will help to determine areas for MPAs that will protect ecosystems and provide the most significant contributions to the socio-economic sustainability of the community. This principle can be applied to both existing and future MPAs.

It is essential to develop comprehensive and culturally sensitive management strategies that rely on collaboration with local communities, Indigenous groups and other relevant stakeholders. The MPAs of Hawaii, United States, are a remarkable example of how prioritizing community involvement can lead to sustainable and culturally harmonious outcomes. In Hawaii, local and indigenous voices were deeply integrated in the planning and designation of the MPAs, creating a sense of shared ownership. Authorities ensured inclusive decision-making by giving communities an active role in governance, valuing traditional ecological knowledge alongside scientific data and fostering trust through open forums and transparent information sharing (Boaventura et al. 2021). This approach aligned conservation strategies with proven cultural practices and encouraged long-term support by showing communities the benefits of healthier ecosystems and fisheries. When local inputs are prioritized, community members feel empowered and invested, leading to more resilient and collectively supported stewardship of natural resources.

2. Establish an ASEAN Regional Task Force and Collaborative Funding

Ocean acidification is inherently a transboundary problem that requires a coordinated global response. Addressing its complex, far-reaching impacts necessitates collaboration to develop effective mitigation and adaptation strategies. ASEAN should lead a targeted regional response by facilitating partnerships and promoting equitable resource-sharing. Specifically, it could establish a SEA ocean acidification task force comprising scientists, policymakers and other stakeholders from each Member State to coordinate regional research, monitoring and response strategies. This task force would establish standardized protocols for data collection, ensure uniform reporting methods and promote consistency across national monitoring initiatives. Furthermore, research on the local impacts of ocean acidification could be expanded to reflect the socio-cultural conditions of the region, allowing the task force to develop solutions suited to the community's needs. ASEAN could also partner with existing global bodies, such as the Global Ocean Acidification Observing Network (GOA-ON) and the Ocean Acidification International Coordination Centre (OA-ICC), to ensure that findings from SEA are integrated into global data. GOA-ON would provide technical training and capacity-building workshops for researchers in each Member State, enabling high-quality monitoring and analysis of local marine chemistry changes. These workshops could also be hosted at regional research institutions, such as the ASEAN Centre for Biodiversity in the Philippines, which focuses on biodiversity and ecosystem protection, establishing a shared knowledge base and fostering regional collaboration.

In addition, ASEAN should advocate for joint funding applications with international partners, such as the European Union (EU), the Group of 20 (G20) and the Asia-Pacific Economic Cooperation (APEC), creating a dedicated ocean acidification resilience fund for SEA to support research, equipment and technology exchange. This funding would ensure that Member States with fewer resources are included. Drawing from models like the EU Horizon 2020 programme, which funds collaborative research on climate impacts and resilience, ASEAN could establish a regional research grant to encourage projects aimed explicitly at ocean acidification, connecting experts in SEA with global scientists to foster innovation. The combined outcomes — a shared regional monitoring framework and joint research funded by international partners and centres of excellence — would lay the groundwork for ASEAN to develop cohesive, data-driven policies. These policies would address local impacts and align with global ocean acidification mitigation efforts, positioning SEA as a resilient and proactive participant in the worldwide response to this urgent environmental issue.

3. Increase Public Awareness and Implement Educational Programmes through Curriculum Integration

Two complementary approaches should be pursued to support social adaptation and enhance public understanding of ocean acidification in SEA. Firstly, ocean acidification should be included in national curriculums. This would involve designing age-appropriate modules, practical activities like field trips and hands-on experiments that allow students to observe marine ecosystems. In Okayama, Japan, students who participated in marine educational activities such as field trips exhibited a behavioural and attitudinal change in their responses to ocean-related issues and developed a sense of responsibility and connection with the ocean (Sakurai and Uehara 2020). A pilot programme should be launched in coastal regions to assess the curriculum's effectiveness before expanding nationally (for example in Indonesia, which has the largest coastal population in SEA).

Secondly, collaboration with local communities, including non-governmental organizations and student groups, is essential for building grass-roots awareness. This would benefit from direct involvement by schools, educators and community leaders who can organize and promote activities like community workshops, exhibitions and ocean-themed events. These workshops could cover topics such as the basics of ocean chemistry, the impacts of acidification on local fisheries and sustainable practices for protecting marine resources. Capacity-building initiatives should also focus on training community members to lead educational sessions, empowering them to act as local advocates for marine protection. To achieve this, ASEAN could establish a small grants programme that funds local organizations to develop public education projects on ocean acidification, particularly in coastal and fishing communities. This would align with the priorities of the ASEAN Maritime Outlook (ASEAN 2023). This multi-level engagement, from national education policy to community-based outreach, would promote widespread understanding of ocean acidification, fostering a collective commitment to safeguarding SEA's marine ecosystems.

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