Biofouling in the Seas of East Asia

A regional action plan to tackle causes and impacts

January 2024

This report is made possible with technical support from the Regional Task Force on Biofouling Management and IMO GloFouling Project Management Unit and financial assistance from KIOST and the UNDP/GEF/IMO GloFouling Partnerships Project.

1. Introduction

The spread of invasive species is one of the most prominent global ecological threats. Impacts from bio-invasions affect the environment, ecosystem services, and human societies. Invasive species cause ecological and economic harm, disrupting ecosystems, threatening the survival of other species to the point of extinction, and impacting wider ecological structures and their associated ecosystem services.

Invasive species range from microorganisms to large vertebrates. Typically, they are alien species transported intentionally or unintentionally from their native range. Aquatic environments and coastal habitats are among those sensitive to bio-invasions. Once an invasive species has become established, it is often impossible to eliminate it from affected ecosystems. Prevention is thus a key component of managing risk.

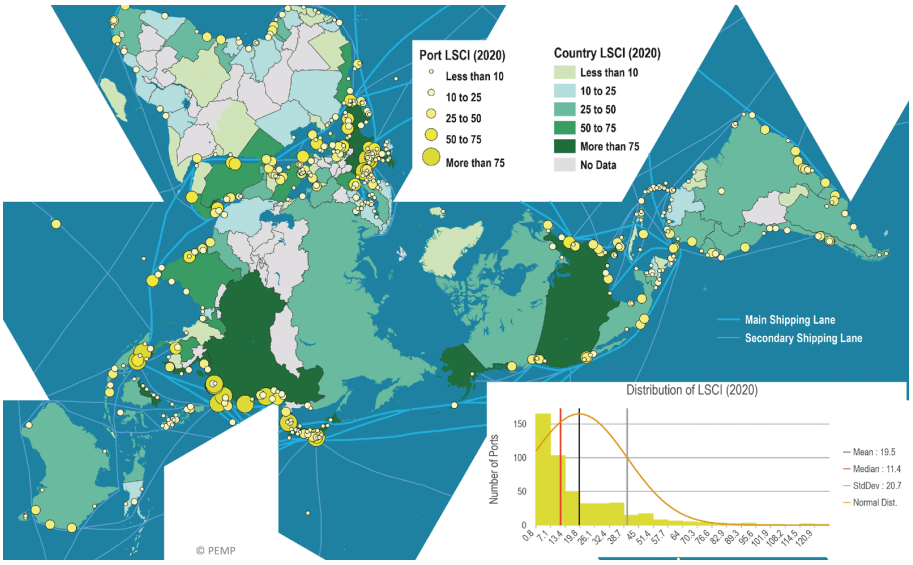
Links With Shipping and the Wider Economy

Coastal invasions are more extensive than often recorded, and invasive species can spread rapidly after their initial incursion (Grosholz 2022). This secondary spread can occur passively through natural connectivity between aquatic environments (Stuer-Lauridsen et al. 2018), but much like the initial invasion, it can be facilitated and exacerbated by human-mediated activities (Gollasch et al. 2007). Species that end up in ports can spread naturally to nearby areas, or even get picked up by other boats and transferred further afield.

The spread of invasive species is closely linked with economic factors (Perrings et al. 2002). Shipping, which develops in response to as well as furthering economic growth, has a long history of serving as a vector for the transfer of invasive species. Shipping is responsible for the spread of well-known and widely visible destructive species such as *Rattus norvegicus*. Around two-thirds of historical aquatic bio-invasions have been mediated by shipping (Gollasch 2007).

Almost all marine ecoregions already host invasive species, with shipping being the biggest vector of their transport (Molnar et al. 2008). The seas of East Asia are a hotspot for shipping, both regional and global. The region contains 9 of the world's 10 busiest container ports (WSC 2021), and the four most connected economies. There is more intra-Asian trade than in any other region, and such trade has continued to increase and become a significant part global trade flow already dominated by shipping to and from the region to elsewhere (UNCTAD 2023).

As shipping activities increase the risks of species transfer is expected to continue rising absent appropriate and effective management (Drillet 2016). The most prominent current shipping-related biofouling vectors are ballast water, sediments, and biofouling (Hewitt & Campbell 2010). Shipping in the seas of East Asia is expected to intensify, as populations and economies in the region continue to grow, expanded trade volume and trade traffic. While data remains limited, it is known that new invasive species continue to spread, and that existing invasive species are continuing to spread within the region.



Global shipping connectivity is largest in the seas of East Asia (visualization by UNCTAD 2022)

The impact of shipping on exposed ecosystems can be seen in the communities of biofouling organisms in harbor areas. Biofouling is the attachment of biological material to artificial surfaces, such as ship hulls. These attachments can include living organisms, which can establish themselves at new locations through this transfer vector. One shipping hub in the region is the Manila South Harbor, where a number of invasive species have established themselves and can breed and foul new material, despite the pollution in the waters. These species include *Perna viridis*, which spread within the region before becoming an invasive species in other areas of the world. Others, such as the *Chthamalus stellatus* barnacle, come from Europe, implying they have spread from the opposite end of the globe (Nacorda et al., 2018).

While this is the most internationally pressing issue relating to biofouling, the phenomenon also creates a number of other persistent challenges for human societies in coastal areas. Biofouling on ships creates more friction between ships and water, resulting in drag that reduces fuel efficiency. Depending on conditions, biofouling can increase fuel consumption by up to 55% (GloFouling 2022), creating economic costs as well as climate change costs. Over the global fleet, biofouling may have a huge cumulative impact on greenhouse gas emissions.

Ecological and Economic Impacts in the Seas of East Asia

While the threat and impact are often less immediately visible than in terrestrial ecosystems, invasive species have a significant impact on aquatic ecosystems and generate substantial ecological and economic impacts (Vilà et al. 2010), sometimes to the point of effectively becoming ecosystem engineers (Wallentinus & Nyberg 2007). Native species are displaced by resulting habitat and community structure changes, reducing their populations and genetic diversity. Such changes also impact ecosystem services, affecting human health and potentially livelihoods. As it has on land, human activity has allowed aquatic species to shift across natural geographic barriers that have previously defined species' habitats.

The *Mytella Sallei* mussel has spread via shipping throughout the region. Its appearance in Yundang Lagoon in Xiamen, China, significantly altered the ecological community in its brackish waters. In seasons where *M. Sallei* proliferated, the presence of other species which inhabit similar niches was reduced. The introduced mussel not only directly competed with native species, but appeared to directly impact the environmental health of the lagoon's water (Cai, et al. 2014).

Travelling species also bring other organisms with them. The spread of pathogens such as *Vibrio parahaemolyticus* and *Enterocytozoon hepatopenaei* has caused billions of dollars of damage to shrimp aquaculture in Southeast Asia (Shinn et al. 2018).

Mytella strigata (also *M. charruana*) is native to the Americas (CC BY-NC-SA WoRMS via the Smithsonian)

Respondents to a survey carried out by PEMSEA and the GloFouling project that focused on government officials in the region (Factuar, 2021) saw significant concern being raised by these respondents was the potential impact of invasive species on fisheries and aquaculture. This reflects similar results from previous studies (Drillet et al. 2016). For example, significant concerns were raised regarding the potential for Cyprinus carpio carp to infect shrimp aquaculture with white spot disease. The need for more research regarding this and other impacts of invasive species was also widely acknowledged.

International Policies

There are multiple international agreements and treaties that create a basis for the global management of invasive species. The web of international agreements under which states have committed to addressing invasive-species related biofouling issues includes the United Nations Convention on the Law of the Sea (UNCLOS), the Convention on Biological Diversity (CBD) (most recently expressed through the Kunming-Montreal Global Biodiversity Framework) and the International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS). Biofouling is also a topic touched upon by some UNEP Regional Seas Conventions, such as the Barcelona Convention for the Protection of the Mediterranean Sea Against Pollution. Managing biofouling will also be needed to meet UN SDG 14 Life Below Water, and the goals of the Paris Climate Agreement.

There are specific agreements to target some vectors of spread. Ballast water for example was addressed by the IMO through the adoption in 2004 of the International Convention for the Control and Management of Ships' Ballast Water and Sediments, which entered into force in 2017. It specific regulations, monitoring needs, and enforcement processes, and is considered an effective risk management tool (Baumler et al. 2021).

Ballast water has already established international management guidelines (SGS, Société Générale de Surveillance)

Due to its impacts on shipping activities, such as on speed and fuel consumption, the management of biofouling has received proactive management efforts by vessel operators for centuries. The 2001 International Convention on the Control of Harmful Anti-fouling Systems on Ships was developed to regulate the types of biocides that anti-fouling systems make use of in an effort to protect the environment from secondary chemical pollutions. However, the AFS convention does not cater directly for risks of bio-invasions.

For this reason, in 2011 IMO Resolution MEPC.207(62) was adopted, and the IMO published "The Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species" (the 2011 Biofouling Guidelines). In 2012, IMO adopted "The Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft" focusing on ships smaller than 24m (MEPC.1/Circ.792). The original 2011 Biofouling Guidelines were revised and the updated version was adopted in July 2023.

Under IMO guidelines, shipping vessels are recommended to have an established Biofouling Management Plan, carried on the ship alongside a Biofouling Record Book that tracks biofouling management operations and any relevant inspections. Relevant practices to be tracked include in-water inspections, cleaning activities that remove accumulated biomatter, the application or re-application of anti-fouling coatings, and the installing or monitoring of marine growth prevention systems (MGPS).

To build upon growing consensus on the need to tackle biofouling, the IMO in collaboration with the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) initiated the GloFouling Partnerships Project in 2019. This follows the model of the 2000-2017 GloBallast Programme, which was seen as having successfully spurred not only domestic improvements in the target countries, but wide international awareness and action on the problem.

Shipping sees ships from throughout the world interact, necessitating international responses (SGS, Société Générale de Surveillance)

A Coordinated Regional Approach

The UNDP/GEF/IMO GloFouling Partnerships Project seeks to create resources and guidance tools that can enhance the capabilities of developing nations in implementing the IMO Biofouling Guidelines. Its key initiatives include raising awareness about biofouling and the consequences it can have, not only relating to the impact of invasive species on coastal and marine biodiversity and ecosystem services, but also to other socioeconomic and climate change-related impacts. To achieve a consistent and comprehensive approach, the project advocates for a regional approach aligned with the IMO Biofouling Guidelines.

PEMSEA (Partnerships in Environmental Management for the Seas of East Asia) serves as a regional platform and coordinating mechanism for the countries that share the seas of East Asia. The partnership includes 11 country partners and 21 non country partners. It's network includes local governments, learning centers, and regional and international organizations. It is a regional coordinating organization (RCO) within the GloFouling Partnerships Project.

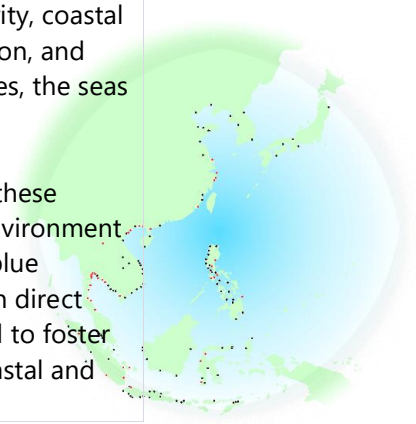
In September 2023, a regional taskforce meeting saw the adoption of the Regional Strategy on Biofouling Management. This strategy is designed to provide guidance to countries around the seas of East Asia in enhancing their national biofouling strategies, to provide a common framework that would allow national strategies to complement each other, and to provide specific assistance in implementing anti-biofouling strategic action. This regional strategy is now being incorporated into plans shaping the regional response to biofouling.

East Asian Seas Region

The East Asian Seas (EAS) region is a dynamic and growing economic and demographic global center. Its shared seas are surrounded by communities ranging from coastal metropolises to rural villages. Such communities share a relationship with the ocean, which have long served as a conduit connecting the countries of the region.

The seas of the region are highly productive, containing the Coral Triangle and numerous other biodiversity hotspots. These rich coastal and marine ecosystems provide essential services, including fisheries that contribute to food security, coastal protection against natural hazards, opportunities for eco-tourism, recreation, and cultural significance. In addition to their direct value to nearby communities, the seas play a role in global challenges such as climate change.

The collective efforts of the region focus on safeguarding and enhancing these ecosystem services, recognizing their critical role in sustaining both the environment and the livelihoods of both coastal communities and the wider region. A blue economy framework recognizes the economic role these seas play, both in direct economic output and in ecosystem services. A holistic approach is needed to foster socio-economic growth while ensuring the responsible stewardship of coastal and marine environments.



2. The Regional Strategy on Biofouling Management

The challenges posed by biofouling require responses at local, national, and regional levels. The link to international shipping is crucially important, especially so in East Asia, which is already the global hotspot for shipping despite continuing advances in its economies. The development of the GloFouling Partnerships' Regional Strategy on Biofouling Management was a response to this need.

The development of the strategy saw significant inputs from both regional and international expertise, and saw input and involvement from national governments in the region. Its approval and adoption is a crucial step to address biofouling in the region, as well as to have an impact on global biofouling routes. The strategy is designed to work with the IMO's Biofouling Guidelines, linking it to a global approach.

The commitment to a coordinated regional response, coupled with the support for national and local initiatives, is a significant signal of the regional intent to address this challenge, and produce healthier marine ecosystems and ecosystem services.

Activities of PEMSEA and the GloFouling Partnerships Project

Regional Coordinating Organizations (RCOs) within the Glofouling Partnerships project work on biofouling management at the regional level, working on capacity building while establishing regional strategies and action plans.

Development of the regional strategies began in November 2021, when a draft Regional Strategy Template was adopted by the GloFouling Partnerships Project and its RCOs. Turning these into specifically-focused documents was the expected responsibility of a Regional Task Force (RTF) created in line with a Terms of Reference defining its responsibilities. The RTF include representatives from all countries in the region. The RTF will also be responsible for overseeing the strategy's implementation and updating it as necessary.

KEY EVENTS:

JUNE 2021: *REGIONAL SEMINAR ON BIOFOULING MANAGEMENT AND INVASIVE AQUATIC SPECIES*

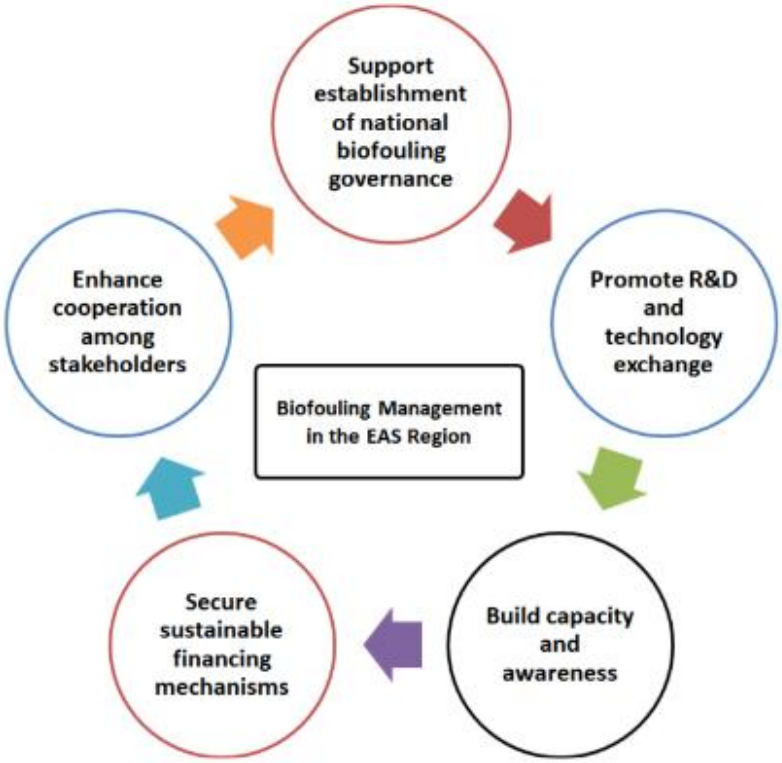
APRIL 2022: *FIRST MEETING OF THE REGIONAL TASK FORCE ON BIOFOULING MANAGEMENT IN THE EAST ASIAN SEAS REGION*

DECEMBER 2022: *SECOND MEETING OF THE REGIONAL TASK FORCE ON BIOFOULING MANAGEMENT AND INVASIVE AQUATIC SPECIES*

SEPTEMBER 2023: *THIRD MEETING OF THE REGIONAL TASK FORCE AND ADOPTION OF THE REGIONAL STRATEGY ON BIOFOULING MANAGEMENT*

Vision	Harmonized biofouling management practices across the EAS region to maintain healthy marine ecosystems, free from disruption of Invasive Aquatic Species, and to enhance the energy-efficient operation of ships
Mission	To protect and maintain healthy marine ecosystems and reduce greenhouse gas emissions from ships through integrated efforts and a systematic implementation of the IMO recommendations on biofouling management across the region

The overall strategic objectives to achieve this vision and mission are to build capacity at the national governance level and to promote collaboration among countries in the region to ensure that the complex and multi-sectoral issues related to biofouling can be managed in a concerted and integrated fashion. This overall goal is supported by five strategic objections.



The 5 strategic objectives of biofouling management in the ASEAN Region.

Strategic Objective 1: Support Establishment of National Biofouling Governance in the EAS Region

As with the international guidelines, national guidelines and procedures are often in early stages of development. Detailed understanding, capacity, and policies remain needed at national levels, including with the EAS region. Even with a potential understanding in place, the multi-sectoral cause and impact of biofouling means that it is a difficult challenge for any one particular government agency to tackle.

Effectively tackling biofouling thus requires a cross-sectoral legal and institutional foundation, with an overarching strategy under which specific monitoring and action plans can be developed and implemented. A coordination mechanism to ensure inter-agency cooperation is a key factor for the success of these interlocking policies.

The regional strategy seeks to support the establishment of national biofouling governance through the creation of legal, institutional, and coordinating mechanisms and arrangements. This will allow international and regional strategy to be translated to the national level, and provide focal points for transboundary cooperation.

Strategic Objective 2: Promote Research and Development (R&D) and Technology Exchange in the EAS Region

The widely acknowledged lack of a detailed understanding of not only biofouling's impacts, but the extent to which such impacts have spread within the region and within individual states. Carrying out such research faces significant challenges due to the complex interrelation of biofouling with environmental and socioeconomic activities, which fluctuate throughout the year and between different locations, making extrapolation from particularly local studies and comparisons between studies in different locations difficult. Uncertain knowledge about local ecosystems and how to measure and evaluate the value of ecosystem services means even when information on biofouling is available, quantifying its impact presents a further challenge.

Obtaining an understanding of biofouling's spread and impacts remains only an initial step, with research being further needed in prevention and treatment. Practices to continue to monitor biofouling incursions and impacts, to reduce or eliminate biofouling, and to repair damaged ecosystems and ecosystem services are also essential to managing relevant challenges.

In addition to research, new technologies will also have a substantial impact. Examples that have already seen development include novel materials and strategies to reduce the ability of fouling species to attach to artificial surfaces, and methods to clean ship hulls using in-water remotely operated vehicles (ROVs). These have seen improvements in efficiency, impact, and cost-effectiveness.

At a broad scale, research and development (R&D) for biofouling management might be classified into two areas: i) research on the specific spread and impact of invasive aquatic species, and ii) technology and methodological development on biofouling control. The first will require R&D communities that research marine ecosystems throughout the EAS Region to collaborate more closely on studies such as those that identify the baseline of indigenous species in the region and that identify and track the appearance and spread of invasive species at local and regional scales. The second area will require broad cooperation between researchers, governments, and the private sector. Technologies to prevent and remove biofouling will need to be developed, commercialized, and spread.

Considering the differences in technological development levels between countries in the region, the promotion of technology transfer and exchange will help reduce potential gaps in the

regional response that would undermine biofouling management efforts. Improvements in technology efficiency and applicability would expand their potential use throughout localities in the seas of East Asia.

Strategic Objective 3: Build Capacity and Awareness on Biofouling Management in the EAS Region.

Managing biofouling requires the cooperation of a wide range of stakeholders. Awareness of the wide range of impacts of biofouling remain not widely known among many stakeholders, who are thus unable to implement measures to address biofouling challenges. Stakeholders involved in international and domestic shipping, port activities, marine and coastal fisheries, and aquaculture are crucial to ensuring any biofouling measures are effective.

Increasing awareness of biofouling is therefore needed for local and national capacity to meet the ambitions that drive the regional strategy. Capacity and awareness building activities may include media outreach, regional training, and knowledge exchange. The establishment of data centers to provide national hubs for biofouling data and information might be supported through the establishment of a regional center, bringing together efforts throughout the region.

Strategic Objective 4: Secure Sustainable Financing Mechanisms within National and Regional Levels.

Tackling biofouling is a long-term and likely continuous challenge that will require sustained resourcing and backing throughout the region. Research, policy development, policy implementation, and monitoring and evaluation will all require reliable financial support to ensure their success.

The Regional Strategy will support the mainstreaming of biofouling measures within local and national budgets, complementing the wider institutionalization of biofouling measures. It will also seek to facilitate access to financial assistance, such as through Official development assistance (ODA) or through multilateral development banks (MDBs). Biofouling's cross-cutting nature, impacting the environment, the blue economy, and climate change, provides the potential for wide financing as well as broad positive impacts from any progress to address its challenges, making it a valuable target for impact investing.

Strategic Objective 5: Enhance Cooperation Among Stakeholders.

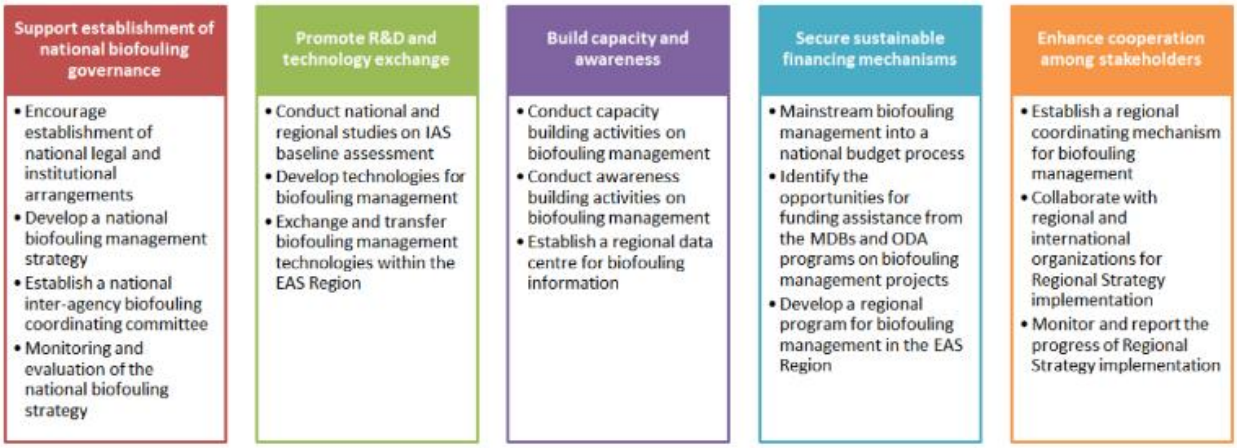
The interlinked and widespread causes and effects of biofouling across different sectors and regions means that cooperation between different stakeholders will be crucial to addressing any biofouling-related issue. Different actions will need cooperation from a different range of local, regional, and international stakeholders, including academe, governments and regulators, private sector bodies, civil society organizations, and individuals in coastal communities throughout the region.

Even within government, biofouling actions require cooperation from environmental ministries, ministries that handle fisheries and aquaculture, energy and transport ministries, port authorities and others involved in maritime administration, customs departments and bodies involved in

international shipping, local administrations, and even bodies relating to natural resources, health and wellbeing, and socioeconomic management.

A number of regional organizations can play a role in enhancing biofouling cooperation. These include existing research communities, shipbuilding and shipping associations such as the Global Industry Alliance (GIA), international organizations such as the IMO, multilateral development banks and bodies, regional actors such as PEMSEA, and regional institutions such as ASEAN, Coral Triangle Initiative on Coral Reefs and Food Security (CTI) and the ASEAN Biodiversity Centre. Organizations and institutions involved in meeting existing targets and goals such as those cooperating on ballast water may have key lessons and input to managing biofouling (eg. Global TestNet).

Strategic Actions



Key strategic actions for the five strategic objectives

Under the Regional Strategy, the overall objectives are supported by a number of strategic actions. These are tangible and complementary initiatives covering different timescales, ranging from:

- Immediate: Actions envisioned to be completed within a year
- Short-term: Actions expected to take 2-5 years
- Medium-term: Actions which encompass 5-10 years
- Long-term: Actions which may extend for up to two decades

Each action has specific targets and indicators, along with the key stakeholder who is best-placed to ensure the objectives and actions are achieved.

Strategic Objective	Actions / Activities	Targets and Indicators	Timeframe	Responsible entity(ies)
Support the establishment of national biofouling governance in the EAS countries	Encourage the establishment of national legal and institutional arrangements on biofouling management	• Relevant national policy established in	Medium-term	EAS countries
		• Laws and regulations on biofouling management enacted	Long-term	EAS countries
		• Guidance for institutionalization and the creation of legal mandates for national biofouling management developed	Long-term	EAS countries
	Develop a national biofouling management strategy	• A national biofouling management strategy developed • An implementation plan for the national strategy developed and implemented	Short-term	EAS countries
	Establish a national inter-agency biofouling coordinating committee	• An inter-agency coordinating committee established • National Task Force (NTF) established and/or biofouling coordination and management is tackled in relevant existing committees in countries (see page 16)	Immediate	EAS countries RCO

	Monitoring and evaluation of the national biofouling strategy	• Framework and guidance for monitoring and reporting established • Annual monitoring plans developed as part of national strategies	Medium-term	EAS countries, RCO
Promote R&D and technology exchange in the EAS Region	Conduct national and regional studies on IAS baseline assessment	• National and regional studies on IAS baseline assessment conducted • Guidelines for a long-term monitoring system prepared	Medium-term	EAS countries, RCO
	Develop technologies for biofouling prevention and management	• Public and private companies involved in developing biofouling removal technologies; • Risk assessment procedure and requirements of removed biofouling debris developed	Medium-term	EAS countries
	Exchange and transfer biofouling management technologies within the EAS Region	• Advanced technologies for removing biofouling introduced in the country • Joint demonstration of technologies and tech-exchange fairs conducted	Medium-term	EAS countries, RCO Biofouling industries
Build capacity and awareness on biofouling	Conduct capacity building activities on biofouling management	• A capacity building needs assessment conducted; • National and regional trainings on biofouling and AFS management tools conducted; • A regional training hub for capacity-building and training of personnel involved in risk assessment control monitoring in ports ships and other coastal facilities established	Short-term	EAS countries, RCO

	Conduct awareness building activities on biofouling management	• A set of policy briefs aimed at policymakers published • Best practices of biofouling management in the EAS Region published • A regular regional biofouling conference organized • Awareness building meetings and events organized	Immediate / Short-term	EAS countries, RCO Regional and international organizations
	Establish a regional data center for biofouling information	• A regional data center similar to the Global Invasive Species Database for linking sharing and collecting data and information and database established, linked to existing knowledge platforms; • A mechanism for sharing national and regional data and information on biofouling and IAS established	Medium-term	RCO/IMO
Secure sustainable financing mechanisms within national and region levels	Mainstream biofouling management into a national budget process	• National biofouling finance needs assessment and finance plan developed • Biofouling management budget included in the regular national budget • Biofouling management included in the national blue economy strategy	Short-term	EAS countries
	Identify the opportunities for funding assistance from the MDBs and ODA programs on biofouling projects	• Bankable project proposals for the MDBs such as ASEAN Catalytic Green Finance Facility (ACGFF) ADB Blue Finance and Blue Bond and World Bank Group's Blue Initiative etc.	Short-term	EAS countries

		developed and submitted; • Project proposals for ODA funding opportunities in the EAS Region such as JICA, KOICA, USAID, EU fund etc. developed and submitted		
	Develop a regional program for biofouling management in the EAS Region	• Financial needs assessment and planning conducted; • A regional project document on biofouling management for resource mobilization in the EAS Region developed and submitted	Short-term	RCO
Enhance cooperation among stakeholders	Establish a regional coordinating mechanism for biofouling management	• A Regional Coordinating Committee and a Regional Task Force (RTF) formed; • A regional coordinating office with staff established; • A Regional Strategy implementation plan developed and implemented	Short-term	EAS countries, RCO, Regional and international organizations
	Collaborate with regional and international organizations for Regional Strategy implementation	Activities of National Strategies and Regional Strategy jointly conducted with regional organizations such as PEMSEA, CTI, ACB, IMO, CBD, AFS, BWM, GIA, etc.	Short-term	EAS countries, RCO, Regional and international organizations
	Monitor and report the progress of Regional Strategy implementation	A regional monitoring and reporting system established in RCO for assessing and reporting of the progress of Regional Strategy implementation	Short-term	RCO

4. Existing Actions and Commitments Within the Region

The Regional Strategy builds upon existing national and international commitments to topics such as biodiversity and climate change. For example, all states in the EAS region are party to the Convention on Biological Diversity (CBD), which directly addresses invasive species. The Aichi Biodiversity Targets, established as part of the Strategic Plan for Biodiversity 2011–2020 under the CBD, while not directly addressing biofouling serve as a global framework for action to safeguard biodiversity, for example through the development of national targets and actions as part of National Biodiversity Strategies and Action Plans (NBSAPs). The Kunming/Montreal Biodiversity Summit (COP15) saw the agreement of a new set of goals and targets within the Kunming-Montreal Global Biodiversity Framework (GBF). This agreement is aimed at halting and reversing biodiversity loss by the end of the decade, and improving sustainability further before 2050.

Aichi Biodiversity Target 9

> By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

Kunming-Montreal Global Biodiversity Framework Target 6

> Eliminate, minimize, reduce and or mitigate the impacts of invasive alien species on biodiversity and ecosystem services by identifying and managing pathways of the introduction of alien species, preventing the introduction and establishment of priority invasive alien species, reducing the rates of introduction and establishment of other known or potential invasive alien species by at least 50 per cent, by 2030, eradicating or controlling invasive alien species especially in priority sites, such as islands.

Through the GBF, countries have agreed to actively report on, review, and enhance their biodiversity conservation efforts. The management of invasive aquatic species that arrive through biofouling will be a key global challenge for biodiversity conservation.

The Paris Agreement is a legally binding treaty on climate change that has been ratified by all EAS states. This agreement through its Article 4 requires the submission of Nationally determined contributions (NDCs), which should include plans to meet the ambitious goals of the Paris Agreement regarding climate change mitigation and reduction. Separately to these national targets, the International Maritime Organization has developed the 2023 *IMO Strategy on Reduction of GHG Emissions from Ships*. For both NDCs and the IMO Strategy, reducing biofouling may make a noticeable contribution to the business-as-usual emissions from shipping.

Paris Agreement Article 4

1. In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

2. Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.

2023 IMO Strategy on Reduction of GHG Emissions from Ships

To reduce the total annual GHG emissions from international shipping by at least 20%, striving for 30%, by 2030, compared to 2008; and to reduce the total annual GHG emissions from international shipping by at least 70%, striving for 80%, by 2040, compared to 2008.

The IMO Ballast Water Management Convention is a comparable example to envisioned regional and international action on biofouling, given its targeting of another vector for invasive species dispersal through maritime shipping. China, Indonesia, RO Korea and Singapore have translated the BWM Convention into domestic law. Japan, Indonesia, Malaysia, and the Philippines have also joined the convention. This convention is separate to the International Convention for the Prevention of Pollution from Ships (MARPOL), which regulates different aspects of pollution that might originate from maritime shipping.

International Convention for the Control and Management of Ships' Ballast Water and Sediments

Each Party shall, with due regard to its particular conditions and capabilities, develop national policies, strategies or programmes for Ballast Water Management in its ports and waters under its jurisdiction that accord with, and promote the attainment of the objectives of this Convention.

The Sustainable Development Strategy for the Seas of East Asia (SDS-SEA) was ratified by a group of East Asian countries including Brunei Darussalam, Cambodia, China, DPR Korea, Indonesia, Japan, Malaysia, Philippines, RO Korea, Singapore, Thailand, Vietnam, and later joined by Lao PDR and Timor-Leste. This strategy targets key environmental issues in maritime regions. Though SDS-SEA does not specifically address biofouling, its comprehensive approach to marine and coastal environmental challenges indirectly encompasses aspects related to biofouling.

Sustainable Development Strategy for the Seas of East Asia Objective 3

Prevention of adverse impacts from sea-based human activities
Action Programmes
1. Prevent operational and accidental pollution of marine waters from shipping activities by:
   a. Implementing the requirements of MARPOL 73/78;
   b. Instituting navigational safety and traffic management measures, especially in areas of congested traffic and/or of marine protected areas and for PSSAs in accordance with relevant IMO guidelines, standards and criteria;
   c. Developing and strengthening capacity for at-sea multisectoral law enforcement and maritime surveillance while ensuring maritime safety and facilitating marine environmental protection;
   d. Requiring the use of environmentally friendly, anti-fouling compounds on ships' hulls and marine equipment

At national levels, there is still action required to meet existing IMO Biofouling Guidelines, and there is a need for the overarching national institutional plans that the Regional Strategy is set up to support. However, this does not mean that no action has taken place, with many countries having policies and regulations in place that deal with aspects of biofouling, and experience with the institutionalization needed to tackle similar problems such as ballast water. In some countries various regulatory agencies have already been established that are able to coordinate government bodies for either biodiversity or maritime affairs.

Examples of interagency mechanisms in some states within the EAS region

Country	Interagency Mechanism	Description
China	National Committee for Biodiversity Conservation	This Committee brings together 23 departments under the State Council and is headed by a Vice Premier. It ensures communication and collaboration within the national government to coordinate biodiversity-related actions.
Malaysia	National Committee on Invasive Alien Species	This Committee meetings twice a year to bring together agencies responsible for different aspects of invasive species monitoring and management, such as those involved in research and monitoring, policy implementation and enforcement, and public awareness. It is chaired by the Director-General of the Department of Agriculture (DOA) Malaysia, with the Plant Biosecurity Division of DOA serving as the Secretariat. Malaysia has established an action plan to tackle invasive species, currently through the National Action Plan on IAS 2021-2025.

Philippines	Inter-Agency Coordinating Committee to Facilitate the Ratification and Accession to and Implementation of Maritime Conventions (ICCFRAIMC)	Originally the Inter-Agency Coordinating Committee on the Ratification and Implementation of Maritime Conventions (ICCRIMC), this interagency coordinating mechanism is chaired by the Department of Transportation with a vice-chair provided from the Department of Foreign Affairs. It is tasked with monitoring and implementing all maritime conventions to which the Philippines has become a party to. Its membership includes not only government departments, but representatives from academe.
Thailand	National Task Force for Biodiversity	Thailand has established a commitment to biodiversity through its actions towards the Convention on Biological Diversity (CBD). Under its National Reform Plan in Natural Resources and Environment, it aims to set up a National Task Force for Biodiversity that might include implementing the biofouling guideline within its remit.

Given biofouling's impact on biodiversity, a number of countries have included some measures relating to biofouling within strategies and action plans related to biodiversity. Factuar (2021) reported that its eight surveyed countries in the region had established such plans in line with the requirements of the Convention on Biological Diversity.

Sample of National Biodiversity Strategies and Action Plans in EAS Countries

Country	Document Title	Link
Cambodia	National Biodiversity Strategy and Action Plan (Feb 2016)	https://www.cbd.int/doc/world/kh/kh-nbsap-v2-en.pdf
China	China Biodiversity Conservation Strategy and Action Plan (2011-2030)	https://www.cbd.int/doc/world/cn/cn-nbsap-v2-en.pdf
Indonesia	Indonesian Biodiversity Strategy and Action Plan 2015-2020 *A new IBSAP is expected in 2024*	https://www.cbd.int/doc/world/id/id-nbsap-v3-en.pdf
Malaysia	National Action Plan on Invasive Alien Species 2021-2025	http://www.doa.gov.my/index/resources/aktiviti_sumber/sumber20_awam/penerbitan/buku/national_action_plan_on_invasive_alien_species_2021-2025.pdf
Philippines	Philippine Biodiversity Strategy and	https://www.cbd.int/doc/world/ph/ph-

	Action Plan 2015-2028	nbsap-v3-en.pdf
RO Korea	The Republic of Korea's Fourth National Biodiversity Strategy 2019–2023 *A Fifth NBS is expected to cover 2024-2028*	https://www.cbd.int/doc/world/kr/kr-nbsap-v4-en.pdf
Singapore	National Biodiversity Strategy and Action Plan (updated in May 2019 based on Aichi Biodiversity Target 2011-2020)	https://www.nparks.gov.sg/-/media/nparks-realcontent/biodiversity/national-plan/singapore_2009-nbsap_updated-may-2019
Thailand	The Master Plan for Integrated Biodiversity Management B.E. 2558-B.E. 2564	https://www.cbd.int/doc/world/th/th-nbsap-v4-en.pdf

Factuar (2021) also reported existing monitoring mechanisms for invasive aquatic species in some of the surveyed countries. China's Bulletin on the State of China's Ecology and Environment includes available information about invasive species. Malaysia tasks its Quarantine and Inspection Services, the Royal Malaysian Customs Department, and the Marine Department with the monitoring of biofouling. It has a Biodiversity Information System which includes material on invasive species. In Singapore, invasive aquatic species are recorded as part of wider habitat surveys. While RO Korea did not indicate that they undertook any specific biofouling monitoring, they maintain both a Marine Environment Information Website and an Information on Korean Alien Species database.

Case Studies in the seas of East Asia

Within the region, two countries are undertaking leading international roles as part of the GloFouling Partnerships Project. Indonesia and the Philippines are both archipelagic countries, with their thousands of islands interconnected by domestic shipping networks and linked into regional and international trade networks. Their native ecosystems have productive wild fisheries, which remain heavily relied upon for food and other ecosystem services. Both also have additional maritime sectors which interact with biofouling, such as offshore oil and gas, aquaculture, and recreational aquatic tourism. Both are thus heavily vulnerable to biofouling, and face heightened needs for it to be addressed both domestically and globally.

Biofouling in Indonesia

The Indonesian government has taken significant actions to generate actions limiting biofouling throughout its ports and coastlines. Domestic law requires both ships and port authorities to take action to prevent environmental pollution and damage. Some of these explicitly tackle biofouling, particularly barnacles. The Ministry of Transport through the Directorate of Shipping and Seafarers issues Anti Fouling System Control Certificates, which require details of biofouling paints and of survey plans (Utama 2021).

International shipping arrives directly at a number of ports spread throughout the country. Foreign ships over 24m or 400GT entering Indonesian waters are required to have anti-bioufling measures in place that meet international standards. If no antifouling certificate is provided, the ship is required to undergo inspection. Foreign vessels are required to submit a clear schedule of activities, and are barred from some maritime activities such as fishing (Utama 2021).

Domestic shipping is also tracked, with significant potential risk of secondary biofouling if an international invasive species is brought into a busy domestic port such as Tanjung Priok and Tanjung Perak near Jakarta. Fishery vessels are restricted to specific Fisheries Management Areas, which in addition to other potential impacts reduces the risk of biofouling between these zones (Utama 2021).

A number of invasive aquatic species have become established in ports throughout Indonesia. In particular, bivalves that affect local mollusc species are common. Some species are more well established in the more populated and economically active western parts of the country, with domestic shipping having been found as a vector of their spread eastwards (Utama 2021).

National coordination on biofouling is an area of focus. The responsibility for biofouling inspection and enforcement lies with harbormasters and other port authorities, which may differ in enforcement capacity. There are no regulations to prevent the potential spread of invasive species from ship cleaning facilities. These gaps are a key focus of the Indonesian government, which is working with nearby partners such as Australia and Singapore to further develop its biofouling management capabilities (Utama 2021).

Biofouling in the Philippines

Biofouling management efforts in the Philippines have mostly occurred through the frame of biodiversity protection and fisheries management. It is not directly addressed by any particular legislative actions, although the principles of managing invasive species are included in other legislation on marine pollution and biosecurity that have been implemented per domestic initiative and to meet the responsibilities of relevant international treaties. Invasive aquatic species also are a prominent consideration in the national Biodiversity Strategy and Action Plan 2015-2028, and a separate National Invasive Species Strategy and Action Plan 2016-2026 has been developed. Some regional governments within the Philippines have taken their own measures relating to marine pollution and biodiversity protection (Vallejo 2021).

There are 10 ports with significant foreign shipping spread throughout the Philippines. All but one are located in estuarine areas, and a few are close to recognized biodiversity and tourism areas. Invasive species have been separately detected at a number of these ports. Monitoring in the busy South Harbor port has found a number of foreign species that persist at low levels, in addition to the more widespread and noticeably destructive species. This monitoring has increased the number of known species from 3 in 2006 to an estimated more than 30 (Vallejo 2021).

Secondary pathways are a significant risk, with cases being identified of invasive species spreading from the coast of Manila, the country's capital and largest city, to both nearby areas throughout Manila Bay and to domestic ports elsewhere in the archipelago. Invasive species have been specifically observed as being present on the small fishing boats that traverse the country, as well as on discarded floating fishing gear. Oil tankers traveling domestically are also suspected of spreading invasive species (Vallejo 2021).

The Philippines has identified invasive aquatic species not only in ports, but also in aquaculture farms. Some invasive species may have commercial applications if well-established, which may lead to further proliferation within Philippine waters. This is despite downsides. For example, while the South American mussel *Mytella strigata* is sometimes sold as cheap animal feed, it has damaged the harvest of mussels in Manila Bay, and even affected milkfish aquaculture ponds (Vallejo 2021).

One method that has been instituted to reduce biofouling is annual drydocking, recommended in a 2005 Domestic Shipping Development Plan. However, compliance among individual boat operators is patchy, including for the many wooden hulled vessels that move through Philippine waters, which are more prone to biofouling than steel-hulled vessels. Existing efforts among private operators to combat biofouling has had drawbacks. The toxic and banned tributyltin is still used in some antifouling paints, and the chemical is a common pollutant in Manila Bay (Vallejo 2021).

The regulation of some biofouling measures is undertaken by MARINA (Maritime Industry Authority). This body is responsible for issuing Antifouling System Certificates, which include the requirement that a ship owner has drydocking facilities. It also regulates antifouling measures, having banned the aforementioned tributylin. There are legislative initiatives within the Philippines to specifically address biofouling (alongside initiatives to address ballast water). Such initiatives seek to balance the different impacts of biofouling among the maritime transport sector, fisheries and aquaculture, and biodiversity management (Vallejo 2021).

Biofouling in RO Korea

The government of the Republic of Korea has undertaken heavy investment into solutions to the biofouling challenges facing its fleets. The country is heavily reliant on marine ships for both its fisheries and its imports and exports, so any changes to biofouling impacts on the level of an individual ship will have large multipliers. A Marine Environment Management Act was established in 2007 and has been amended regularly since then, which includes provisions on biofouling management (KLT, nd), and includes provisions to manage invasive species in its laws and policies regarding biodiversity. Research has found that biofouling is a serious issue for the country's marine fleet, bringing invasive species and contributing to ship inefficiency (Park *et al*., 2022).

In 2021 the government begun a five-year US$25 million research and development project. This includes environmental impact focused research, including the development of environmental risk assessment guidelines (PEMSEA 2022).

Development efforts include new research towards ship cleaning techniques and technology. Research developed in partnership with commercial companies is investigating how to efficiently and effectively undertake remote cleaning in situ. This requires remote vehicle able to operate in the rough waters of the ocean and nonetheless being able to clean ship hulls to a high standard at speed. Current remotely operated vehicles (ROVs) can reportedly clean up to 700m of hull in 6 hours (PEMSEA 2022).

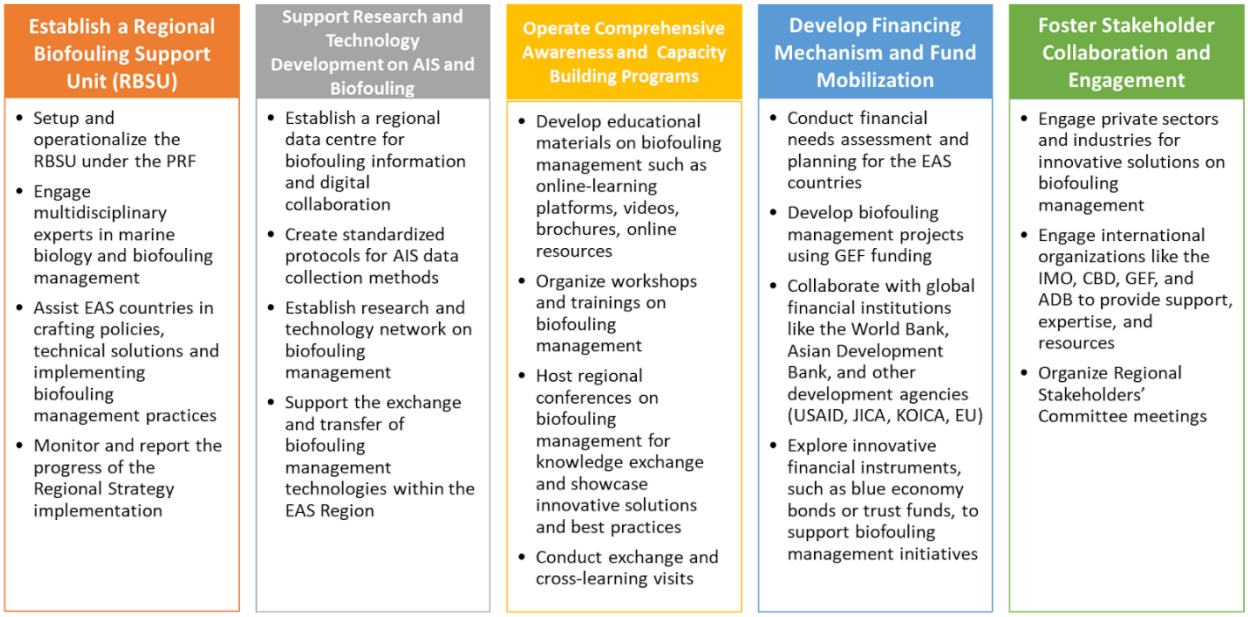
Current research on ship cleaning is looking at increasing the speed of cleaning, and reducing its environmental impact, for example through better capture of cleaning byproducts (currently it is stated that up to 99% of byproducts larger than 10µm are captured). There is also research into the possibility of making the ROVs function autonomously, and seeing how such vehicles would be complement continued manual cleaning of difficult to reach areas (PEMSEA 2022).

The shipbuilding industry in RO Korea has already incorporated 2011's IMO Resolution MEPC.207(62) into their design and construction processes. Innovations in response have included changes to ship part design, new anti-fouling coats, and installing marine growth prevention systems (MGPSs). The industry is seeking to get ahead of national and international guidance, touting the economic advantages of fuel efficiency in addition to the environmental benefits (PEMSEA 2022).

6. PEMSEA Regional Action Plan on Biofouling Management

As part of the GloFouling Partnerships Project PEMSEA serves as a Regional Coordinating Organization (RCO), and is supporting efforts to combat biofouling throughout the seas of East Asia. In tandem with the development of the Regional Strategy on Biofouling Management, PEMSEA has developed a Regional Action Plan that incorporates its short- and long-term activities to support biofouling management efforts in the region.

This action plan incorporates multiple concurrent strategies. PEMSEA serves as a regional platform for maritime activities in the region, which will be leveraged to promote the regional sharing of knowledge and best practices. It will also support capacity development efforts throughout the region through direct engagement and through working with IMO to organize regional training. It will also promote regional and international collaboration on biofouling management, providing a supporting voice for the region.



The regional action plan contains five overarching components, each with individual actions to occur along different time frames. Throughout this, PEMSEA will support national governments in developing national biofouling governance and secure funding and support for further biofouling actions. As biofouling is a transboundary issue, PEMSEA will also continue to work with the IMO, country partners, multilateral development banks (MDBs), and other regional and international stakeholders on the implementation of the Regional Action Plan and Regional Strategy, and the development of further projects to enhance biofouling management. Research on the many aspects of biofouling will continue to be promoted at institutional and network levels.

The potential for a “GloFouling 2” project may help develop national strategies on invasive aquatic species, and biofouling management strategies at higher levels such as within ASEAN. Other avenues of stakeholder cooperation in the maritime industry and its ancillary sectors will continue to be pursued, including within wider missions such as addressing GESI issues, sustainable development, and climate change.

Component	Action	Timeframe	Indicators	Outcome
Establish a Regional Biofouling Support Unit (RBSU)	Setup and operationalize the RBSU under the PRF	Short-term	- Agreed mission, vision, and responsibilities - Stakeholder engagement plan - Initial operations commenced	A functional RBSU
	Engage multidisciplinary experts in marine biology and biofouling management	Short-term	- Key staff hired in identified roles - Effective secretariat staff - Network of experts formed	Capable staff positioned at RBSU
	Assist EAS countries in crafting policies (national strategy), technical solutions and implementing biofouling management practices	Medium-term	- Draft strategies developed with RBSU assistance - Implementation of strategies in EAS countries	National strategies
	Monitor and report the progress of the Regional Strategy implementation	Annual	- Annual progress report published and distributed - Stakeholders for annual meetings identified	Annual meeting and report
Support Research and Technology Development on AIS and Biofouling	Establish a regional data center for biofouling information and digital collaboration linked to IMO global database	Medium-term	- Data management and reporting system designed - Integration with other relevant databases	A data center established within the Sea Knowledge Bank of PEMSEA

			- Initial data collection undertaken	
	Create standardized protocols for AIS data collection methods	Long-term	- Development of draft protocols involving stakeholder consultation - Final protocol approved and adopted by relevant authorities - Training materials and guidelines for protocol implementation developed	A standard protocol
	Establish research and technology network on biofouling management	Medium-term	- Identification of key experts in the region - Potential meetings and workshops identified	Regional Task Force Roster of experts
	Support the exchange and transfer of biofouling management technologies within the EAS Region	Long-term	- Engagement of technology providers and users in the region - Stakeholders and hosts for tech fairs identified - Regular updates and showcases of new technologies - Feedback and impact assessment of technology adoption	Tech-exchange fairs Technology marketplace

Operate Comprehensive Awareness and Capacity Building Programs	Develop/adapt IMO educational materials on biofouling management such as online-learning platforms, videos, brochures, online resources	Medium-term	- Survey of existing materials carried out - New publications created to fill gaps - Educational videos produced and published	Online learning platform Publications Videos
	Organize workshops and trainings on biofouling management in collaboration with IMO/country partners	Annual	- Capacity gaps identified - Collaboration with key experts for workshop topics	Capacity building workshops Specialized workshops
	Host regional conferences on biofouling management for knowledge exchange and showcase innovative solutions and best practices	Medium-term	- Opportunities for conferences identified - Participation from regional and international stakeholders	Regional Conferences (EAS Congress, Maritime Week)
	Conduct exchange and cross-learning visits	Medium-term	- Hosts and visitors identified - Documentation and sharing of learnings from visits	Learning exchanges
Develop Financing Mechanism and Fund Mobilization	Conduct financial needs assessment and planning for the EAS countries	Short-term	- Cooperation established relevant with national bodies - Development of a financial mechanism model	Needs assessment conducted Financial mechanism established
	Develop biofouling management project proposals and submit to GEF	Short-term	- Initial project proposals developed alongside	PIF and Project Document

	funding and others		national stakeholders	
	Collaborate with global financial institutions like the World Bank, Asian Development Bank, and other development agencies (USAID, JICA, KOICA, EU)	Short-term	- Establishment of communication and partnerships with financial institutions - Existing funds identified - Agreements or MoUs signed with financial institutions	Project proposals submitted to MDBs and Aid institutes
Project proposals submitted to public/private financing institutes	Engage private sectors and industries for innovative solutions on biofouling management	Medium-term	- Identification of relevant private sector entities in the region - Private sector inclusion in the stakeholder engagement and management plans - Inclusion of private sector in meetings and workshops	Regional Industry Alliance on biofouling management
	Engage international organizations like the IMO, CBD, GEF, and ADB to provide support, expertise, and resources to the EAS countries	Short-term	- Inclusion of relevant organizations in stakeholder engagement - Roundtable participants identified	Regional Investors' Roundtable
	Organize Regional Stakeholders' Committee meetings around EAS congress	Every three years	- Integration of biofouling into the EAS Congress	Project steering committee meetings

7. A biofouling-free future for the region

While biofouling is a pressing problem, the coordinated development of a Regional Strategy with the cooperation of countries in the region, regional bodies, and international organizations demonstrates the commitment within the region towards addressing it. The next steps are clear, with research and capacity building required throughout the region. The following steps have been laid out, to be informed by evolving understanding at local, national, regional, and international levels.

The negative environmental and socioeconomic effects of biofouling are apparent. As further research allows them to be more effectively understood, mitigating actions and countermeasures can be put in place. An integrated information management system at national and regional levels will help provide comprehensive baseline information and map the impacts of invasive aquatic species, collating information from different government ministries, academic institutions, and private bodies.

The cross-cutting nature of biofouling will require the establishment of specific institutions, legislation, and policies. No single ministry or agency will be able to tackle biofouling on its own, and similarly no country will be able to manage biofouling without the cooperation of its neighbors and other partners further afield. Strategic action plans will be required to guide collaboration, and put forward a path towards a positive vision of healthier seas and oceans.

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