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Transboundary Diagnostic Analysis for the Yellow Sea Large Marine Ecosystem (2020)

gef UNOPS YSLME UNDP/GEF Yellow Sea Large Marine Ecosystem

Implementing the Strategic Action Programme for the Yellow Sea Large Marine Ecosystem: Restoring Ecosystem Goods and Services and Consolidation of a Long-term Regional Environmental Governance Framework (UNDP/GEF YSLME Phase II Project)

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Foreword

Oceans and seas contribute approximately $3-6 trillion annually to the global economy in terms of the market value of goods and services including fisheries, energy, shipping, tourism, recreational, and mining sectors, as well as non-market ecosystem services such as climate regulation, nutrient cycling and carbon sequestration. Yet, the integrity of these ocean values and services is at significant risk due to a range of ocean management policy and market failures leading to fisheries overexploitation, pollution (especially nutrients and plastics), invasive species, habitat loss and ocean acidification. These are primarily resulting from anthropogenic factors that require transformational change in governance at various levels – local, national, regional and global.

In the Yellow Sea Large Marine Ecosystem (YSLME), since 2002 UNDP has been facilitating cooperation between PR China and RO Korea to identify environmental priorities and agree upon governance reforms and investments to address these challenges through the Transboundary Diagnostic Analysis (TDA) and Strategic Action Program (SAP) processes. These actions are consistent with the UNDP 2014-2017 Strategic Plan for the effective maintenance and protection of natural capital and the 2018-2021 Strategic Plans to address complex and interconnected challenges such as shocks from crises, economic stagnation, inequality and poverty, and climate change through nature-based solutions for a sustainable planet.

In the past decade, the proposed actions outlined in the YSLME SAP finalized in 2009 have been undertaken at regional (LME-wide), national, subnational and local or community level with substantial ecological, social and economic benefits. Good practices and on-the-ground results are demonstrated in reducing fishing efforts measured by decrease in the number of fishing vessels and increase in body sizes of capture fisheries landings, successful scaling up of integrated multitrophic aquaculture (IMTA), and increase in number and expansion in areas of marine protected areas, among others. YSLME SAP has also proven to be a very useful platform for enabling a wide range of innovative partnerships across government, UN agencies, business associations, non-government organizations (NGOs) and academia.

This update of the TDA in 2020 reflects the strong commitments of PR China and RO Korea and other partners in sustaining the science-based LME approach and joint signature solutions in support of the achievement of SDG 14 targets - Conserve and sustainably use the oceans, seas and marine resources for sustainable development. I welcome the commitment of both countries to using the concrete scientific findings of the TDA to inform their discussions towards the update of the SAP that will outline joint efforts towards achieving the sustainable management of the YSLME.

I wish to extend my heartfelt congratulations to the Ministry of Foreign Affairs (MOFA) and Ministry of Oceans and Fisheries (MOF) of RO Korea and the Ministry of Natural Resources (MNR), Ministry of Ecology and Environment (MEE), Ministry of Agriculture and Rural Affairs (MARA) and National Forestry and Grassland Administration (NFGA) of PR China for their joint efforts in improving the governance of the YSLME and its sustainability. The YSLME TDA/SAP updates being delivered for the benefits of the peoples of the YSLME provide tangible example of the utility of this science-based strategic planning approach to LME management and governance, as supported by the Global Environment Facility, not only in Asia but globally.

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Preface

The Yellow Sea Large Marine Ecosystem (YSLME) is one of the world's 66 LMEs—relatively large areas of coastal ocean space of 200,000 km^2 or greater delineated on the ecological criteria of bathymetry, hydrography, productivity and trophic linkages. It is one of the 22 LMEs that the Global Environment Facility (GEF) supported to assess and manage coastal and marine resources. In light of the LME approach, PR China and RO Korea developed the transboundary diagnostic analysis (TDA) of YSLME in 2007, adopted the strategic action programme (SAP) of the YSLME in 2009 and has been implementing the SAP from 2014-2020 with support of the GEF and the UNDP through a two-phased YSLME Project serviced by the UNOPS.

Updating the TDA and the adoption of the updated SAP of the YSLME as a subsidiary document of the Memorandum of Understanding between PR China and RO Korea on the post-YSLME Project arrangement are the two ambitious targets agreed at the inception period of the second phase of the YSLME Project. These are also essential instruments in sustaining regional governance of the YSLME in the coming decade.

The TDA update process started in 2017 and was completed in May 2020. The 1st Meetings of the Management, Science and Technical Panel (MSTP) and Interim YSLME Commission Council (ICC), held on July 11-13, 2017 in Seoul, RO Korea, agreed to initiate the process with an evaluation of the progress of the implementation of the National Strategic Action Plan (2009-2020) (NSAP). The 1st Meeting of the Regional Working Group on Governance (RWG-G), held on December 14-15, 2017 in Seoul, RO Korea, endorsed the terms of reference of the NSAP review. The review reports of NSAP implementation in the two countries were presented at the 3rd Meetings of the MSTP and ICC on March 12-14, 2019.

The six Regional Working Groups (RWGs) consisting of eminent experts from both PR China and RO Korea in the areas of assessment and monitoring, habitats, fish stocks, governance, pollution reduction and sustainable mariculture were fully engaged in the update process of TDA (2007) and SAP (2009-2020). National Marine Hazard Mitigation Service (NMHMS) of the Ministry of Natural Resources (MNR) of PR China and the Korea Marine Environment Management Corporation (KOEM) of the Ministry of Oceans and Fisheries (MOF) of RO Korea facilitated the consultation and coordination at the national level, while the Project Management Office organized a series of regional consultations to help reach consensus on the final conclusions and recommendations of the TDA update, including engagement of an international consultant to consolidate the NSAP reviews by the two countries. The revisions to the updated TDA were finalized during the YSLME 4th ICC meeting held in Jeju, RO Korea in November 2019.

Interventions made in the past years in implementation of the YSLME SAP have also bore fruit on several aspects. Some notable developments include:

- Improvement in capture fisheries as a result of reduction of commercial fishing fleets, and setting of location and season limitations for commercial fishing on the Yellow Sea both by PR China and RO Korea.
- Successful and sustainable implementation of maricultural practices introduced by the YSLME Phase II Project (Integrated Multi-trophic Aquaculture, recirculating aquaculture systems, and detection and response systems to control diseases).
- Reduction in point sources of pollution through regulation of emitters and promotion of cleaner production.
- Reduction in shore-based marine litter through various initiatives both in PR China and RO Korea (monitoring, clean-up, buyback programs, public awareness, and regulations).
- Designation of coastal zones and restoration of critical habitats helped protect key aquatic species, migratory birds, and zones for nutrient recycling.
- Increase in number of MPAs in the Yellow Sea (52 MPAs in PR China side and 28 MPAs in RO Korea side).
- Positive trajectory in controlling invasive alien species in ballast water through use of portable detection devices, design of land- and sea-based ballast water exchange facilities, and treatment facilities.

In assessing the primary transboundary issues in the region, it was found that challenges identified in the original TDA remain to be crucial in the coming years. These include fishing effort exceeding ecosystem carrying capacity; unsustainable mariculture; pollution and contaminants; eutrophication; change in ecosystem structure; habitat loss and degradation; and climate change. The TDA 2020 highlights microplastics, seasonal ocean acidification, broader range of climate change impacts, and changes in patterns of harmful algal blooms, possible increase in frequency of toxic algal blooms, and drifting macroalgae *Sargassum* as emerging issues to the YSLME that the updated SAP will need to respond in the next decade.

The TDA 2020 document is not comprehensive in terms of the state of knowledge of the YSLME, but does reflect the current understanding of priority problems in the system and their causes. As such, it can be used as a reference for planning any future interventions at either national or regional level.

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The update of the YSLME Transboundary Diagnostic Analysis (TDA) was supported by the UNDP/GEF YSLME Phase II Project and the Governments of PR China and RO Korea under the overall coordination of the Project Management Office led by the Project Manager, Yinfeng Guo, and Environmental Economist, Sangjin Lee, with technical assistance of Professor Paul Gremillion from Northern Arizona University, United States of America. The process commenced with review of the implementation of the National YSLME Strategic Action Plan by National Working Groups (NWGs) of PR China and RO Korea, followed with a series of consultations in particular at four side events at the 3rd YSLME Science Conference held in July 2019 in Qingdao, PR China, and a dedicated workshop in Jeju, RO Korea, in November 2019. The current version was based on the review reports of NSAP implementation in PR China and RO Korea and results of consultations consolidated by Professor Paul Gremillion.

Special thanks are extended to these colleagues for professionally leading the national review of the NSAP and updated TDA report: Bin Wang, Director General of National Marine Hazard Mitigation Service (NMHMS) of the Ministry of Natural Resources of PR China; Zhifeng Zhang, Deputy Director General of National Marine Environmental Monitoring Center (NMEMC) of the Ministry of Ecology and Environment of PR China; Jae Ryoung Oh, National Coordinator of the YSLME Phase II Project of RO Korea and Adviser of Korea Institute of Ocean Science and Technology (KIOST) and Hyun Hee Ju, Principal Research Specialist of Ocean Policy Institute, KIOST of RO Korea.

Contributions from below experts are acknowledged in the NSAP review and TDA update: **PR China** (in alphabetical order): Xiaodong Bian; Jinghui Fang; Jianguang Fang; Jiangchun Guan; Hao Guo; Chuan Jia; Xianshi Jin; Chaolun Li; Shenghao Liu; Ping Qi; Fangyuan Qu; Xiujuan Shan; Juying Wang; Lijun Wang; Shouqiang Wang; Xiaocheng Wang; Yan Wang; Quan Wen; Shanshan Wu; Fan Yang; Ziwei Yao; Dan Yi; Limin Yu; Ming Yu; Weiwei Zhang; Zhaohui Zhang; Zhendong Zhang; Linlin Zhao; and **RO Korea** (in alphabetical order): Joon Young Chang; Junghee Cho; Keun-Hyung Choi; Sun Wook Hong; Yang Jae Im; Se-Jong Ju; Jung Hoon Kang; Hyung Chul Kim; Kyung Shin Kim; Bong Oh Kwon; Hyun Jeong Lim; Gyung Soo Park; Mi-seon Park; and Wonduk Yoon.

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Acronyms and Abbreviations

CAC	–	Codex Alimentarius Commission
CCA	–	Causal Chain Analysis
CPUE	–	Catch per unit effort
DIN	–	Dissolved Inorganic Nitrogen
DDT	–	Dichlorodiphenyltrichloroethane (Pesticide)
DVI	–	Difference Vegetation Index
DPZ	–	Development Prohibited Zone
DRZ	–	Development Restricted Zone
EAAF	–	East Asian – Australasian Flyway
ECC	–	Ecosystem Carrying Capacity
FAO	–	UN Food and Agricultural Organization
GEF	–	Global Environment Facility
HAB	–	Harmful Algal Bloom
IMTA	–	Integrated Multi-Trophic Aquaculture
IUCN	–	International Union for Conservation of Nature
KIOST	–	Korea Institute of Ocean Science and Technology
KOEM	–	Korea Marine Environment Management Corporation
MALI	–	Marine Litter Information System (Republic of Korea)
MARPOL	–	International Convention for the Prevention of Pollution from Ships
MEIS	–	Marine Environment Information System (Republic of Korea)
MODIS	–	Moderate Resolution Imaging Spectroradiometer
MPA	–	Marine Protected Area
N:P	–	Ratio of Nitrogen to Phosphorus
NGO	–	Non-governmental Organization
NbS	–	Nature-based Solutions
NIFS	–	National Institute of Fisheries Science (Republic of Korea)
NIP	–	National Implementation Plan (People’s Republic of China)
NSAP	–	National Strategic Action Plan
OPRC	–	International Convention on Oil Pollution Preparedness, Response, and Cooperation
OPRC-HNS	–	Protocol on Preparedness, Response, and Co-operation to Pollution Incidents by Hazardous and Noxious Substances
PCB	–	Polychlorinated Biphenyl
POP	–	Persistent Organic Pollutant
PM2.5	–	Particulate Matter <2.5 microns in size
PRC	–	People’s Republic of China
ROK	–	Republic of Korea
RWG	–	Regional Working Group
SAP	–	Strategic Action Programme
Si:P		Ratio of Silicon to Phosphorus
SST		Sea-Surface Temperature
TAC		Total Allowable Catch
TDA		Transboundary Diagnostic Analysis
UNFCCC		UN Framework Convention on Climate Change
YS		Yellow Sea
YSLME		Yellow Sea Large Marine Ecosystem
WHO		UN World Health Organization
WWF		World Wildlife Fund for Nature

Executive Summary

This project builds upon regional cooperation for the sustainable use of the Yellow Sea Large Marine Ecosystem (YSLME) put in place by People's Republic of China and the Republic of Korea, supported by the Democratic People's Republic of Korea, the Yellow Sea Partnership and the Global Environment Facility (GEF) with an objective to foster a long-term sustainable institutional, policy, and financial arrangements for effective ecosystem-based management for the Yellow Sea (YS). In the strategic planning process, the participating countries will jointly undertake to prepare a regional Transboundary Diagnostic Analysis (TDA) and a regional Strategic Action Programme (SAP), the implementation of which is normally operationalized by the National Strategic Action Plan (NSAP).

The original TDA and SAP for the YSLME were developed during the YSLME Phase I Project (2005-2009). The current YSLME Phase II project (2014-2020) implements the Phase I SAP. During this concluding year of the Phase II project, one of the final activities is to update the TDA and SAP documents. These updates reflect the current state of knowledge of the ecosystem, and a revised set of priorities for sustainable management of the YSLME. The process for updating the TDA was conducted by the Secretariat, the Regional Working Groups (RWGs), national experts, and an international consultant. The major steps in updating the TDA were:

1. Development of a draft TDA update document. This document summarizes the state of scientific knowledge of the YSLME and was based primarily on two documents: the summary reports of the NSAPs for each country. These documents were the "Interim Review Report on the Progress of Implementation of the National Strategic Action Plan for YSLME 2009-2020 of the People's Republic of China" (C-NSAP) and, "An Analytical Study on the Implementation of the National Strategic Action Plan (NSAP) for the Yellow Sea Large Marine Ecosystem (YSLME) of the Republic of Korea" (K-NSAP).
2. The draft report was reviewed by the Secretariat, the RWGs, and other relevant stakeholders.
3. Update of the Causal Chain Analysis (CCA) and Priority Transboundary Problems. A workshop on the TDA and SAP updates was conducted at the 3rd YSLME Science Conference in Qingdao on July 17-18, 2019. This included an examination of the causal chain for priority problems in the YSLME and an assessment of emerging problems.
4. National meetings to review the TDA. Separate national meetings were held in August 2019 in Seoul, RO Korea and Wuhan, PR China. Comments from RWGs, NWGs, and other stakeholders were provided regarding the TDA in general and the CCA in particular.
5. TDA validation. Revisions to the TDA were discussed and finalized at the 4th Interim Commission Council (ICC) meeting in Jeju, RO Korea in November 2019.

The finalized TDA Update document is not comprehensive in terms of the state of knowledge of the YSLME, but does reflect the current understanding of priority problems in the system and their causes. As such, it can be used as a planning instrument for future interventions.

The key findings of the updated TDA can be summarized in terms of recent trends in fisheries, mariculture, pollution, ecosystems, and biodiversity. Additionally, emerging issues in the YSLME are addressed, priority transboundary issues are reviewed, and recommendations are provided.

FISHERIES

Management actions undertaken to improve fisheries in the Yellow Sea consisted of strategies to reduce fishing pressure and encouraging a re-balancing of the ecosystem. These management actions include buy-back programs for commercial fishing vessels, restrictions on the type of equipment used for commercial fishing, restrictions on the season and locations for commercial fishing, and programs to enhance fish stocks.

So far, PR China is on track to reduce its commercial fishing fleet on the Yellow Sea by 13 percent. RO Korea has reduced its Yellow Sea fishing fleet by 25 percent. Both countries have implemented limitations on locations and seasons for commercial fishing. In PR China there is now a comprehensive fishing ban for four months north of Latitude 35°N and four and a half months south of Latitude 35°N. RO Korea implemented a comprehensive fishing ban from April 1 to October 31 in certain locations.

There is no doubt that interventions implemented to improve capture fisheries have reduced stress on fisheries. However, detecting the actual recovery of fisheries through monitoring programs may require a longer timeframe than is captured by current data. For example, as of 2015, fish species distributions favored demersal, low-valued species. It is possible that the trajectory will be toward a return to demersal, high-valued species. Similarly, trends in catch per unit effort (CPUE) are equivocal. Increases in CPUE in recent years in the PR China waters of the Yellow Sea have been observed, along with increases in RO Korean waters between 2004 and 2011. However, the RO Korea data show a decline in recent years. Other measures of ecosystem health have indicated positive trends. For example, from 2016 to 2017 the average body length of two commercially important fish species (small yellow croaker and largehead hairtail) increased in the PR China waters of the Yellow Sea. Continued monitoring will be necessary to detect and understand longer term changes in ecosystem responses to management actions undertaken in the YSLME Phase II project.

MARICULTURE

The YSLME Phase I project recognized the adverse environmental impacts of high-density monoculture farming of finfish, crustaceans and seaweed in the Yellow Sea and shore-based aquaculture systems. Additionally, the high density of organisms is conducive to the spread of diseases.

The YSLME Phase II project promoted three initiatives to reduce environmental stress related to mariculture and aquaculture: Encourage Integrated Multi-trophic Aquaculture (IMTA) systems, improve technologies for recirculating aquaculture systems, and develop detection and response strategies to control diseases. IMTA systems mimic natural ecosystems by including organisms that occupy a range of trophic levels. Waste produced at one trophic level becomes available as a resource for another trophic level. Demonstration projects produced promising results and have produced data to support commercial scale expansion of IMTA approaches. Similarly, the Phase II project worked to reduce the environmental impact of shore-based aquaculture systems by supporting research and development projects aimed at developing environmentally friendly feed stocks and implementing recirculating systems using biofilters to purify aquaculture water. Finally, monitoring for and prevention of diseases in mariculture organisms was addressed through projects oriented around epidemic prevention.

With regard to trajectory, maricultural practices in the Yellow Sea have progressed towards ecological, efficient and environmentally friendly path during the Phase II project. The project developed and tested more sustainable practices applicable to the environmental conditions and organisms of the Yellow Sea. With financial and regulatory support, these can be scaled up and implemented at commercial levels.

POLLUTION

The YSLME Phase I project identified nitrogen and phosphorus, agricultural and urban sewage, heavy metals and organic contaminants, and marine litter as the major pollution problems in the Yellow Sea. The Phase II project addressed these pollutants through management actions divided in the categories of water and sediment quality, marine litter, and contaminants.

Water and Sediment Quality

Monitoring networks were developed to detect spatial and temporal changes in the water quality in near-shore and open-water areas, pathogens and harmful marine organisms of bathing beaches and recreational areas, and point and non-point sources of pollution. In western Yellow Sea, monitoring results indicate a decrease in polluted sea areas from 2012 to 2018, with inorganic nitrogen, active phosphate and oil as the main pollutants. Marine sediment analyses indicated overall low pollutant burdens and improving conditions from 2007 to 2017. The trend of COD in eastern Yellow Sea appears to be stable from 2010 to 2016.

Point and non-point sources of pollutants were addressed not only through monitoring, but also through implementation of load-reduction strategies and measures. In both PR China and RO Korea, point sources of pollution have been reduced through regulation of emitters and promotion of cleaner production. Both countries have implemented programs to increase the level of treatment of wastewater and reduce the total pollutant loading into the Yellow Sea. Non-point sources of pollution, atmospheric deposition and release of agricultural runoff, have been addressed through implementation of regulatory strategies and mitigation measures.

Marine Litter

Marine litter in the Yellow Sea consists primarily of plastic debris with both marine and shore-based origins. A range of initiatives has been undertaken in the Phase II project to address shore-based litter. These include increasing public awareness, restrictions on the use of plastic bags, beach cleaning events and marine litter monitoring. Initiatives for controlling marine litter include port cleanup events, buy-back programs for litter recovered during fishing operations, and the systematic replacement of styrofoam buoys with biodegradable buoys. Overall density of beach litter in monitored sites in both countries has shown a downward trend.

Contaminants

Both PR China and RO Korea are signatories to Stockholm Convention, Minamata Convention on Mercury, MARPOL and other conventions and international standards related with discharge of toxic pollutants and have actively supported their implementation. Examples include PR China's measures to eliminate the production of a large number of POPs, and prohibition on the production, circulation, use, and import or export of DDT, chlordane, and mirex. Another example is RO Korea's adoption of two protocols related to toxic discharges at sea: the International Convention on Oil Pollution Preparedness, Response, and Co-operation (OPRC) and the Protocol on Preparedness, Response, and Co-operation to Pollution Incidents by Hazardous and Noxious Substances (OPRC-HNS).

Trends

Monitoring studies indicate that the trends in pollutants are toward improvement and better water and sediment quality, reduction in marine litter, and decreased releases of contaminants from marine sources.

ECOSYSTEMS

Blooms of Nuisance Species

Blooms of jellyfish and harmful algae are indicators of ecosystem change and are themselves the cause of economic and health problems. The occurrence of jellyfish blooms has been increasing in frequency and geographic range. In response, both PR China and RO Korea have implemented monitoring programs to collect the data necessary to determine the controlling factors, key processes, and driving mechanisms in jellyfish blooms.

Harmful algal blooms (HABs) manifest themselves in the Yellow Sea as several different types of occurrences. Green tides are typically blooms of the phytoplankton *Ulva* or *Enteromorpha*. Red tides are generally blooms of dinoflagellate algae. Golden tides are typically blooms of the brown macro-algae *Sargassum*. The impacts of HABs include depletion of oxygen in water, release of toxins that cause health risks to marine organisms and humans, and interference with seaweed farming operations. HABs can be triggered by eutrophication and imbalances in nutrient ratios.

Advances during the Phase II project include development of monitoring programs, including remote sensing surveillance, that enable high resolution spatial and temporal analysis of trends in jellyfish and HAB blooms. With regard to trends, the drivers for blooms, nutrient imbalances and climate change, both are on a trajectory toward improving conditions.

Climate Change Effects

Climate change has profound effects on ecosystems, either as a direct driver or through indirect mechanisms. The Phase II project directly addressed climate change impacts specifically on lower trophic levels of the Yellow Sea ecosystems, and generally in the prediction of long-term changes in Yellow Sea ecosystems. Concerns related to climate change include rising sea-surface temperatures and sea levels and ocean acidification. These abiotic changes can cause diverse impacts on ecosystems, including northward distributions of warm-water species, trends of occurrences of HABs, and alterations of trophic structures.

Interventions in the Phase II project were oriented toward research to better assess the impacts of climate change. For example modeling studies conducted by PR China predict a northward movement in the economically important Japanese anchovy over the next three decades. RO Korea has conducted mesocosm experiments to evaluate the effect of changing CO_2 concentrations on marine ecosystems.

Adaptation measures include planning for prevention and mitigation of the effects of sea-level rise and increased intensity of storms. Coastal wetlands protection measures, already in place for habitat restoration, are anticipated to act as mitigation barriers for coastal erosion.

In terms of trends, the impacts of climate change are expected to worsen. CO_2 concentrations and sea-surface temperatures will continue increasing predictably. Work to understand ecosystem impacts due to these changes has provided information that can support adaptation planning.

BIODIVERSITY

Habitat loss, including degradation and fragmentation, is the most important cause of biodiversity loss globally. Reducing the rate of habitat loss, and eventually halting it, is essential to protect biodiversity and to maintain the ecosystem functions essential to supporting human livelihoods.

Coastal Wetlands

Preserving and restoring coastal wetlands are essential elements in the protection of Yellow Sea Ecosystems. Wetlands are nurseries for key aquatic species in the Yellow sea, are critical habitats for migratory water birds, and are intense zones of nutrient recycling. The coastal habitats in the Yellow Sea consist primary of mudflats and wetlands. Both have been vulnerable to urban and industrial development. Coastal management plans in PR China and RO Korea have been implemented to decrease or reverse the loss of coastal wetlands to development. These include designation of coastal zones where development is restricted or prohibited and other efforts to actively restore critical habitats.

Priority Endangered and Threatened Migratory Species

The ecosystems of the Yellow Sea support a variety of endangered and threatened migratory species, including migratory waterbirds, spotted seals, and sea turtles. Efforts to protect these species include preserving and restoring habitats as described above and expanding Marine Protected Areas, as described below. Additional efforts include sea-turtle rescue programs, protection programs for Spotted Seals, and overall efforts to increase public awareness.

Marine Protected Areas

Marine Protected Areas (MPAs) provide the refuges necessary for the conservation of wetlands and other critical habitats for rare and endangered species and other important marine organisms. PR China and RO Korea have undertaken systematic efforts to expand and manage MPAs and establish networks of MPAs. From 2007 to 2016, Yellow Sea MPAs in PR China increased from 22 to 52 in number and from 4,582 km^2 to 7,383 km^2 in area. From 2011 to 2017, MPAs along the entire RO Korean peninsula increased from 15 to 28 in number and from 289 km^2 to 586 km^2. The MPAs in both PR China and RO Korea represent less than 3 percent of the Yellow Sea, which is far below the 10 percent Aichi Target.

Invasive Alien Species

Invasion of alien species is one of the main causes of biodiversity loss. Marine systems are particularly vulnerable to invasive species released in the ballast water of ships, but also through accidental or intentional transportation through other means. Efforts over the past decade have been oriented toward detecting and controlling introduction of invasive alien species in ballast water. Advances include development of portable detection devices, design of land-based and sea-based ballast water exchange facilities, and treatment facilities for ballast water.

Trends

Interventions such as protecting coastal wetlands, increasing the area of MPAs, and controlling invasive alien species show a positive trajectory in the past decade. Quantitative measures of biodiversity, such as populations in vulnerable birds, sea turtles, and marine mammals, are also increasing and show a positive trajectory.

EMERGING ISSUES

Since the start of the Phase II project, several emerging issues have been recognized. With regard to pollution, microplastics, and seasonal acidification have emerged as threats that either did not exist at the start of the project, or will have more severe impacts than previously thought. Microplastics, for example, were known to exist, but the degree to which they affect all trophic levels of the ecosystem had not been anticipated. Similarly, many of the effects of climate change were known, but the degree to which atmospheric CO_2 increases have caused ocean acidification were not well understood.

With regard to ecosystem changes, emerging issues include a broadening range of impacts of climate change, and changes in the patterns of HABs. There is now greater recognition that climate change will place coastal wetlands and mudflats at greater risk of erosion and inundation. And while the occurrence of HABs may decrease with climate change, the frequency of toxic algae blooms may increase. Drifting macroalgae *Sargassum* is also as an emerging issue with evidenced direct impact on mariculture farming in north Jiangsu coasts and tourism in Jeju Island. Various environmental factors, such as seawater temperature, light availability, water circulation and nutrients, could regulate or influence the blooming dynamics.

PRIORITY TRANSBOUNDARY ISSUES

The summary state of scientific knowledge of the YSLME provided by the NSAP reports prepared by PR China (C-NSAP) and RO Korea (K-NSAP) were reviewed in regional meetings to determine the priority transboundary issues and to develop an analysis of the primary, intermediate, and root causes for these problems. This analysis will form the basis for the updated SAP document. The primary transboundary issues for the updated TDA differ only slightly from the original transboundary issues identified in the original TDA. These are:

1. Fishing effort exceeding ecosystem carrying capacity
2. Unsustainable mariculture
3. Pollution and contaminants
4. Eutrophication
5. Change in ecosystem structure
6. Habitat loss and degradation
7. Climate change

RECOMMENDATIONS

The 2009 SAP was organized around the concept of ecosystem carrying capacity and ecosystem services, with four separate service types (Provisioning, Regulating, Cultural, and Supporting) addressing the 11 targets identified. The next phase in managing the YSLME can build on the success of these approaches by:

- Retaining the orientation toward the ecosystem services
- Incorporating integrated ecosystem management approaches
- Applying concepts in nature-based solutions

The SAP Update should build on the primary transboundary problems identified in the updated TDA and on the Causal Chain Analysis (CCA) conducted as part of the TDA Update.

Recommendations for targets and management actions include:

Capture Fishery and Mariculture

1. Implement input control management together with output control, improve the existing input control management system and introduce advanced output control management system;
2. To effectively manage the license system, conduct scientific survey and evaluations to have a comprehensive and accurate understanding of fishery resources in a collaborative manner;
3. Conduct joint conservation on the fish species of the Yellow Sea region;
4. Establish mariculture carrying capacity management for important species and typical aquaculture areas;
5. Require that mariculture waste water comply with industrial standards; and
6. Standardize mariculture and promote mechanized aquaculture. This can result in 30 percent-50 percent improvement in production efficiency.

Pollution Reduction

1. Control the release of nutrients and contaminants from point and non-point terrestrial sources, from the atmospheric deposition, and from ships and harbors to protect ecosystems and human health.
2. Reduce the exposure to microbial and viral pathogens, toxins from certain types of algae blooms, and pharmaceutical products that are acutely dangerous to human health.
3. Strengthen marine microplastics monitoring to provide scientific data support for pollution prevention and control, and put forward effective strategy and management measures for marine microplastics.
4. Control the input of "raw" plastic debris from land-based source, such as decreasing or eliminating the usage of disposable plastic products and encouraging the recycle usage industries of plastic, to prevent the plastic debris from moving to sea through rivers and estuaries.

Biodiversity and Ecosystems

1. Monitor and assess changes in ecosystem structure and apply integrated management of ecosystems to reduce the occurrence of HABs and jellyfish blooms
2. Preserve, protect and conserve the wellbeing of threatened and endangered marine mammals and migratory birds and their habitats through MPA networks and other area-based measures.
3. Enhance the disaster prevention and reduction function of marine ecosystems and reduce the losses caused by natural disasters.
4. Conduct surveillance and control programs necessary to prevent the introduction and spread of invasive species.
5. Develop and implement effective and timely adaptation strategy to monitor, assess, prepare and respond to impacts of climate change.

1 Introduction

The Yellow Sea Large Marine Ecosystem (YSLME) Phase II Project builds on a decade of regional cooperation between PR China and RO Korea in the management of the Yellow Sea ecosystem and the services it provides. This transboundary cooperation was achieved using an approach developed by the Global Environment Facility (GEF) to coordinate the interrelated science and policy activities necessary for effective ecosystem management. This approach involves first developing a comprehensive assessment of the scientific knowledge of the ecosystem, and includes an evaluation of the primary problems and threats to the ecosystem. This information is presented as the Transboundary Diagnostic Analysis (TDA) and reflects the joint efforts of the nations involved. The TDA thus provides an agreed-upon set of information on which to develop management strategies.

The second part of the GEF approach is to take the results of the TDA and develop a set of ecosystem quality objectives for the sustainable management of the ecosystem. These objectives are realized through the further development of management actions with measurable outcomes. These efforts result in a Strategic Action Programme (SAP). The SAP is a politically negotiated document that provides a blueprint for attaining a sustainable ecosystem.

The original TDA and SAP for the YSLME were developed during the YSLME Phase I Project (2005-2009). The current YSLME Phase II project (2014-2020) implements the Phase I SAP. During this concluding year of the Phase II project, one of the final activities is to update the TDA and SAP documents. These updates reflect the current state of knowledge of the ecosystem, and a revised set of priorities for sustainable management of the YSLME.

1.1 Project History

1.1.1 YSLME Phase I: TDA and SAP Development

The UNDP / GEF project, “Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem”, was commissioned by the UNDP as Implementing Agency and UNOPS as the Executing Agency. The project was initiated in 2005 and concluded in 2010. The original four objectives of the project were:

1. Develop regional strategies for sustainable management of fisheries and mariculture;
2. Propose and implement effective regional initiatives of biodiversity protection;

3. Propose and implement actions to reduce stress to the ecosystem, improve water quality, and protect human health; and
4. Develop and pilot regional institutional capacity building initiatives.

An innovative feature of the project was a focus on ecosystem-based management based on the concept of ecological carrying capacity (ECC). The project strategy involved work in three fundamental areas: assessment, planning for stress reduction, and demonstration projects. Assessment activities consisted of collating and reviewing information about the ecosystem, and targeted efforts to fill in gaps by gathering new information, and by assessing this information to identify the causes of problems and options for remedial actions.

The Transboundary Diagnostic Analysis (TDA) was a key component of this phase. The TDA provided a summary of the scientific knowledge of the YSLME relevant to pollution, fisheries, ecosystems, and biodiversity. These data were analyzed to develop a list of the most pressing environmental and ecological problems in the ecosystems. The TDA identified nine primary transboundary problems (**Table 1**).

Table 1. Primary Transboundary Problems in the YSLME.

Fisheries	1. Fishing effort exceeding ecosystem carrying capacity 2. Mariculture facing unsustainable problems
Pollution	3. Pollution and contaminants
Ecosystem Changes	4. Eutrophication 5. Jellyfish blooms 6. Harmful algal blooms (HABs) 7. Change in ecosystem structure 8. Climate change-related issues
Biodiversity	9. Habitat loss and degradation

These problems were further analyzed to evaluate the immediate, underlying, and root causes of the problems through the process of Causal Chain Analysis (CCA). This listing of causes provided the basic information necessary for the next phase of the project, development of the Strategic Action Programme (SAP).

The regional TDA document was produced in 2007 (UNDP/GEF 2007). The SAP document was produced in 2009 and proposed a set of regional management actions to address the environmental problems identified in the TDA. The SAP was structured along an ecosystem services model, whereby management actions were framed in terms of Provisioning Services (fisheries), Regulating Services (nutrients and ocean pollutants), Cultural Services (marine litter and beach contamination), and Supporting Services (protection of ecosystems, habitats, and biodiversity). Within these service areas, 11 targets were developed, to be implemented through 32 management actions (**Table 2**).

Table 2. Targets and Management Actions from the 2009 SAP.

Provisioning Services	
Target 1: 25-30% reduction in fishing effort	
Action 1-1	Control fishing boat numbers
Action 1-2	Stop fishing in certain areas/seasons
Action 1-3	Monitor and assess stock fluctuations
Target 2: Rebuilding of over-exploited marine living resource	
Action 2-1	Increase mesh size
Action 2-2	Enhance stocks
Action 2-3	Improve fisheries management
Target 3: Improvement of mariculture techniques to reduce environmental stress	
Action 3-1	Develop environment-friendly mariculture methods and technology
Action 3-2	Reduce nutrient discharge
Action 3-3	Control diseases effectively
Regulating Services	
Target 4: Meeting international requirements on contaminants	
Action 4-1	Conduct intensive monitoring and assessment
Action 4-2	Control contaminants discharge with reference to Codex alimentarius and Stockholm Convention
Action 4-3	Implementing MARPOL 1973/78 effectively
Target 5: Reduction of total loading of nutrients from 2006 levels	
Action 5-1	Control total loading from point sources
Action 5-2	Control total loading from non-point sources and sea-based sources
Action 5-3	Apply new approaches for nutrient treatment
Cultural Services	
Target 6: Reduced standing stock of marine litter from current level	
Action 6-1	Control source of litters and solid wastes
Action 6-2	Improve removal of marine litter
Action 6-3	Increase public awareness of marine litter
Target 7: Reduce contaminants, particularly in bathing beaches and other marine recreational waters, to nationally acceptable levels	
Action 7-1	Conduct regular monitoring, assessment and information dissemination particularly in bathing beaches and other recreational waters
Action 7-2	Control pollution in bathing beaches and other marine recreational waters
Supporting Services	
Target 8: Better understanding and prediction of ecosystem changes for adaptive management	
Action 8-1	Assess and monitor the impacts of N/P/Si ratio change
Action 8-2	Assess and monitor the impacts of climate change
Action 8-3	Forecast ecosystem changes in the long-term scale
Action 8-4	Monitor the transboundary impact of jellyfish blooms
Action 8-5	Monitor HAB occurrences
Target 9: Maintenance and improvement of current populations/distributions and genetic diversity of the living organisms including endangered and endemic species	
Action 9-1	Establish and implement regional conservation plan to preserve biodiversity
Target 10: Maintenance of habitats according to standards and regulations of 2007	
Action 10-1	Develop regional guidelines for coastal habitat management
Action 10-2	Establish network of MPAs
Action 10-3	Control new coastal reclamation
Action 10-4	Promote public awareness of the benefits of biodiversity conservation
Target 11: Reduction of the risk of introduced species	
Action 11-1	Control and monitor ballast water discharge
Action 11-2	Introduce precautionary approach and strict control of introduction of non-native species

In addition to the TDA and SAP documents, an important outcome of the Phase I project was the development of institutional frameworks that could be carried forward to future projects. The ultimate goal of sustained ecosystem management in the Yellow Sea was the development of a YSLME Commission. The objectives of the commission were better coordination of national ecosystem management efforts and more effective regional management efforts, within the context of a non-legally binding and cooperation-based institution. To support these efforts, an Interim Commission Council (ICC) was proposed.

Other institutional bodies were also created to manage technical and governance aspects of ecosystem management in the YSLME. Regional Working Groups (RWGs) with related National Working Groups (NWGs) were established within the disciplinary areas of fisheries, mariculture, habitat, pollution, monitoring and assessment, and governance. A Management, Science, and Technical Panel (MSTP) was developed to provide guidance to the RWGs.

The Phase I project was concluded in 2010, with the expectation that a second phase project would be launched to implement the SAP and continue work toward establishing the YSLME Commission.

1.1.2 YSLME Phase II: SAP Implementation

The YSLME Phase II project, "Implementation of the Yellow Sea LME Strategic Action Programme for Adaptive Ecosystem-Based Management", was launched in 2014 to implement the Phase I SAP. This project has a mid-2020 date for completion of technical activities and a December 2020 full completion date. As with the Phase I project, UNDP is the Implementing Agency and UNOPS is the Executing Agency. The project objective is to:

> *Restore the ecosystem goods and services of the Yellow Sea and secure the establishment of an effective long-term regional environmental governance mechanism through the YSLME Commission[1].*

Project design is consistent with the ECC approach defined in the 2009 SAP and is designed for implementation through four components, three of which are associated with the four ecosystem services of provision, regulation, cultural, and supporting services (**Table 3**).

[1] http://www.yslmep.org/?page_id=43

Table 3. Components and Outcomes of the YSLME Phase II Project.

Component	Outcome	
Component 1. Ensuring sustainable regional and national cooperation for ecosystem based management, based on strengthened institutional structures and improved knowledge for decision making	1.1	Regional governance structure, the YSLME Commission established and functional, based on strengthened partnerships & regional co-ordination; wider stakeholder participation and enhanced public awareness.
	1.2	Improved inter-sectoral coordination and collaboration at the national level, based on more effective Inter-Ministry Coordinating Committees.
	1.3	Wider participation in SAP implementation fostered through capacity building and public awareness, based on strengthened Yellow Sea Partnership and wider stakeholder participation; improved environmental awareness; enhanced capacity to implement ecosystem-based management.
	1.4	Improved compliance with regional and international treaties, agreements, and guidelines.
	1.5	Sustainable financing for regional collaboration on ecosystem-based management secured, based on cost-efficient and ecologically effective actions.
Component 2. Improving Ecosystem Carrying Capacity with Respect to Provisioning Services	2.1	Recovery of depleted fish stocks as shown by increasing mean trophic level.
	2.2	Enhanced fish stocks through re-stocking and habitat improvement.
	2.3	Enhanced and sustainable mariculture production, by increasing production per unit area as means to ease pressure on capture fisheries.
Component 3. Improving Ecosystem Carrying Regulating and Cultural Services	3.1	Ecosystem health improved through a reduction in pollutant discharge (e.g., nutrients) from land-based sources.
	3.2	Wider application of pollution reduction techniques piloted at demonstration sites.
	3.3	Strengthened legal and regulatory processes to control pollution.
	3.4	Marine litter controlled at selected locations.
Component 4. Improving Ecosystem Carrying Capacity with Respect to Supporting Services	4.1	Maintenance of current habitats and the monitoring and mitigation of the impacts of reclamation.
	4.2	MPA Network strengthened in the Yellow Sea.
	4.3	Adaptive Management mainstreamed to enhance the resilience of the YSLME and reduce the vulnerability of coastal communities to climate change impacts on ecosystem processes and other threats identified in the TDA and SAP.
	4.4	Application of ecosystem-based community management (EBCM) preparing risk management plans to address climate variability and coastal disasters.

To implement the SAP, China and Korea each developed National Strategic Action Plans (NSAPs) which were designed to be consistent with both the regional SAP developed in the Phase I project and national priorities identified by relevant ministries and stakeholders. The institutional bodies developed in the Phase I project were continued in the Phase II project and consist of:

- Management, Science, and Technical Panel (MSTP)
- Regional Working Groups (RWGs)
- Inter-Ministry Coordinating Committee (IMCC)
- National Coordinator (NC)
- National Working Groups (NWGs)
- Commission Secretariat

Activities to implement the SAP have been diverse and comprehensive, but can be categorized generally as:

- Legal, institutional, and governance reform & regional governance mechanisms
- Demonstration projects & scientific studies
- Technical capacity building and training
- Public awareness and education programmes
- Regional monitoring and data management networks
- Expansion of marine protected areas

Among the activities during the final year of the Phase II project are updates for the TDA and SAP documents, which are newly added in response to the project extension to 2020 and interest of PR China and RO Korea. These updates are intended to capture the progress made in understanding the ecosystem, perspectives on the management of the ecosystem, and governance changes that have occurred since the original TDA and SAP documents were produced. This document (TDA Update 2020) focuses on new knowledge obtained since the original TDA document in 2007.

Much of this information was collected as a direct result of SAP implementation. The SAP Update document to follow (SAP Update 2020) provides an analysis of the impact and relevance of the targets and management actions undertaken in the YSLME Phase II project. The key output of the SAP update is a revised set of targets and management actions intended to guide policy development in the next steps in the management of the YSLME.

1.2 Methodology

1.2.1 Scope

The 2007 TDA laid the groundwork for SAP development and implementation through a thorough process of identifying priority problems, defining working groups to address the problems, and undertaking a CCA to determine immediate, underlying, and root causes for the problems. TDA documents commonly also include national and regional reports on legal and institutional frameworks and stakeholder, governance, and socioeconomic analysis. To some extent these components were addressed in the 2009 SAP and in YSLME Phase II activities. This TDA Update will summarize activities undertaken in these areas and make recommendations for further action beyond 2020 or in the next project phase.

1.2.2 Information Sources

The primary information sources for this TDA update are progress reports prepared in 2018 by PR China and RO Korea on implementation of each country's NSAPs, namely "Interim Review Report on the Progress of Implementation of the National Strategic Action Plan for YSLME 2009-2020 of the People's Republic of China, September 2018" (C-NSAP) and "An Analytical Study on the Implementation of the National Strategic Action Plan (NSAP) for the Yellow Sea Large Marine Ecosystem (YSLME) of the Republic of Korea, June 2019" (K-NSAP). Other data sources were used as needed and available. These are cited in the text and listed in Section 7 References.

1.2.3 Approach

Using GEF methodologies, the TDA provides the mutually agreed factual basis for the policy instruments that are proposed in the SAP document. The structures of TDAs vary across projects. The 2007 YSLME TDA had several key features:

- Background information on the TDA/SAP process
- Geographic and disciplinary scope for the YSLME project
- A summary of scientific data relevant to the ecosystem and its problems
- A CCA and description of root causes
- Chapters describing transboundary versus domestic problems, options for interventions, considerations for SAP preparation, and conclusions.

These features were preserved in this TDA update. The update process included the following information gathering, validation, and revision steps:

1. Development of a draft TDA update document. This document summarizes the state of scientific knowledge of the YSLME and was based primarily on two documents: the summary reports of the NSAPs for each country.
2. The draft report was reviewed by the Secretariat, the RWGs, and other relevant stakeholders.
3. Update of the CCA and Priority Transboundary Problems. A workshop on the TDA and SAP updates was conducted at the 3rd YSLME Science Conference in Qingdao on July 17-18, 2019. This included an examination of the causal chain for priority problems in the YSLME and an assessment of emerging problems.
4. National meetings to review the TDA. Separate national meetings were held in August 2019 in Seoul, RO Korea and Wuhan, PR China. Comments from RWGs, NWGs, and other stakeholders were provided regarding the TDA in general and the causal chain analysis in particular.
5. TDA validation. Revisions to the TDA were discussed and finalized at the 4th Interim Commission Council (ICC) meeting in Jeju, RO Korea in November 2019.

The finalized TDA Update document is not comprehensive in terms of the state of knowledge of the YSLME, but does reflect the current understanding of priority problems in the system and their causes. As such, it can be used as a planning instrument for future interventions.

1.3 The Geography of the Yellow Sea

The Yellow Sea is defined by the Chinese mainland to the west and the Korean Peninsula to the east (**Figure 1**). The Bohai Sea to the north drains into the Yellow Sea and to the south, the Yellow Sea connects to the East China Sea. For the purposes of defining boundaries, the northwestern project extent is a line drawn in a northeasterly direction from Penglai on the Shandong Peninsula, to Lushun. The Bohai Sea is excluded from the project area. The southern boundary is defined by a line drawn from the north bank of the Yangtze River (Chang Jiang) estuary to the south side of Jeju island and from there north to the Korean mainland (TDA, p 15 – 16).

The project area covers about 400,000 km^2 and measures about 1,000 km along the north-south axis and about 700 km maximum width. The floor of the Yellow Sea is post-glacially submerged portion of the continental shelf, characterized by shallow depths (44 m average depth and 100 m maximum depth), and a gently sloping seafloor within the project area. The major rivers flowing into the Yellow Sea are the Yangtze, Yellow, Han, Datung, Yalu, Guang, and Sheyang Rivers.
These rivers deliver more than 1.6 billion tons of sediment to the Yellow Sea annually, with the Yellow and Yangtze providing most of the sediment load (TDA, p 15).

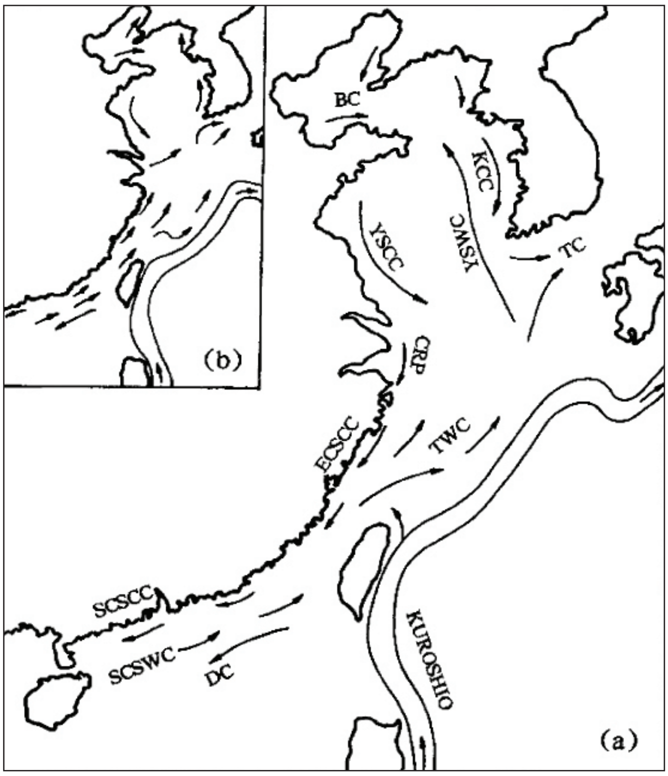
Figure 1. Boundaries of the YSLME covered by the YSLME Phase II Project.

Source: http://www.yslmep.org/?page_id=43

The open connections with the Bohai Sea to the north and the East China Sea to the south form a continuous circulation pattern, which varies seasonally. Water circulation in the Yellow Sea is primarily driven by winter cooling and summer heating, freshwater discharge from rivers, and perhaps the inflow of warm saline waters in a branch of the Kuroshio. The Kuroshio is a warm current that flows northeasterly off the coast of Japan, into the northern Pacific Ocean. Wind forcing and freshwater runoff are also influenced by the cold and dry northerly winter monsoon and the warm, humid southerly summer monsoon. The major water masses of the Yellow Sea are the Yellow Sea Cold Water, the Yellow Sea Warm Current Water and Yangtze River mixed water. The Yellow Sea Cold Water is formed during winter cooling and occupies the lower layer of the basin. This water mass survives throughout the summer. The Yellow Sea Warm Current Water is relatively saline and flows northwestward between Sokotra Rock and Jeju Island, into the Jeju Strait and the eastern Yellow Sea. The predominant direction of outflow from the Yangtze is to the south, consistent with geostrophy, but, in the summer, Yangtze River mixed water extends northeastward toward Jeju Island and lowers the salinity of waters west of Jeju Island (TDA, p 17).

Current speeds in the eastern part of the Yellow Sea are usually less than 0.2 knots except for areas near Huksan and Jeju Islands, where stronger currents are observed. In summer, the circulation of the Yellow Sea is characterized by southward flowing Yellow Sea Coastal Current (Chinese coastal water), northward flowing Yellow Sea Warm Current, influenced by the Kuroshio to the east, and the northeastward movement of water from the East China Sea, with a central cyclonic gyre (Su, 1998). In winter, the central cyclonic gyre is not as pronounced, but apart from the southward coastal flow along the Korean Peninsula, the overall circulation of the Yellow Sea remains essentially cyclonic (**Figure 2**, Su, 1998).

Figure 2. (a) Winter and (b) summer circulation features for the China Seas, from Su (1998).



The current features identified are the Bohai Coastal Current (BC), the Yellow Sea Coastal Current (YSCC), the Changjiang River Plume (CRP), the East China Sea Coastal Current (ECSCC), the Taiwan Warm Current (TWC), the Tsushima Current (TC), the Yellow Sea Warm Current (YSWC), the Korean Coastal Current (KCC), the South China Sea Coastal Current (SCSCC), the South China Sea Warm Current (SCSWC), and the Dongsha Current (DC).

The surface sediments of the Yellow Sea are mostly terrigenous, carried by rivers and winds from the surrounding lands. The annual input of fine-grained detritus to the Bohai Sea was, until recently, about one billion tonnes per year. Over 90 percent of this sediment load has been delivered historically by the Yellow River, but this has already decreased and projections made in 2006 estimated that by 2019 sediment loads from the Yellow River would decrease to about 300 million tonnes per year as a result of engineering works on the Yellow River. Excluding the Yangtze River, about 50 million tonnes of sediment are discharged by rivers directly into the Yellow Sea proper, including a considerable amount of coarse-grained material from rivers draining the Korean Peninsula. According to 2018 Yellow River Sediment Bulletin, the sediment load of Lijing Station in 2018 was 297 million tonnes, which was much lower than the average value from 1952 to 2015 (674 million tonnes).

Unconsolidated surface sediments are distributed by tidal currents, longshore currents, waves, and the Yellow Sea Warm Current. Fine sediment is deposited where current and wave actions are the lowest. As a result, fine-grained surficial sediments are found in the central region of the Yellow Sea, on the Chinese coast, and on the southwest and southern coasts of Korea. Sandy sedimentary faeces exist in the eastern central portion of the Yellow Sea and central and northern coastal areas of the Korean Peninsula. (TDA, p 17).

Yellow Sea Ecosystems 2

2.1 Fisheries

During the first phase of YSLME Project, the Regional Working Group on Fisheries (RWG-F) identified two priority problems related to fisheries: Declines in landings in commercial fisheries, and unsustainable maricultural practices (TDA, 2007).

2.1.1 Capture Fisheries

A significant growth in commercial fisheries in the Yellow Sea over the past several decades has been a positive socioeconomic force, but has resulted in overexploitation of the fishery and changes to the species composition of fisheries. Management actions in the 2009 SAP have been oriented toward reducing the level of fishing efforts and rebuilding marine living resources (**Table 4**).

Table 4. Management Actions Related to Commercial Fisheries.

Action 1.1	Reduce the number of fishing vessels and maintain a proper mid/long-term level of fishing efforts in consideration of the fish stock.
Action 1.2	Designate the closed areas and seasons for protection of spawning and recruitment stock resources.
Action 1.3	Monitor and assess fish stocks.
Action 2.1	Increase Mesh Size.
Action 2.2	Enhance Fish Stocks.
Action 2.3	Improve Fishery Management.

A combination of management actions implemented since the 2007 TDA have been taken to improve fisheries in the Yellow Sea. Fishing pressure was relieved on fish stocks through vessel buy-back programs (Action 1.1), seasonal closure of commercial fisheries (Action 1.2), and regulations on fishing practices, including specifications on allowable mesh sizes for nets (Action 2.1).

The goal of the management action of the vessel buy-back program (Action 1.1) is to maintain fishing efforts at a moderate level in the mid- to long-term in order to protect and secure the stability of the fishery resources of the Yellow Sea. The indicators used to assess the implementation of this management action was the number of fishing vessels, which is the most commonly used to measure fishing efforts.

In PR China, measures to reduce fishing boat numbers predate the 2009 SAP. In 2003, a control system for the period 2003–2010 was implemented. During that period 30,000 fishing vessels were decommissioned in PR China through a governmental buy-back program. This program was renewed for the period 2015–2020 and is anticipated to meet the target of 20,000 additional vessels removed from service in PR China. Based on the data from China Fisheries Yearbook, the number of motored fishing vessels has been reduced from 54,068 in 2015 to 42,182 in 2018, with a total reduction of 11,886 vessels in the provinces of Liaoning, Shandong and Jiangsu, representing a reduction of 22%.

As of 2017, RO Korea has reduced the number of fishing vessels by 25 percent compared to 2009. In RO Korea, under the Five-Year Plan for Reducing Fishing Vessels in Littoral Seas, 4,413 vessels will be reduced by 2023, with a reduction of 2,315 vessels in phase I (2014-2018). From 2013 to 2017, the number of fishing vessels operating in the Yellow Sea was reduced from 25,229 to 21,929, with a reduction of 3,300 vessels (K-NSAP, Table 3.4, p 13).

In January 2017, Bureau of Fisheries of the Ministry of Agriculture and Rural Affairs (MARA) of PR China issued the most strict fishing closure system in history for the mid-summer fishing closures in the Bohai Sea and the Yellow Sea. For waters of the Bohai Sea and the Yellow Sea north of 35°N, fishing closure starts from May 1 at 12 pm to September 1 at 12 pm; and for waters south of 35°N, the closure starts from May 1 at 12 pm to September 16 at 12 pm. According to a study supported by the YSLME Phase II Project, the abundance index of fish resources (CPUE) increased from 40.95kg/h in August 2016 to 48.51 kg/h in August 2017, an increase of 18.4%. Compared with 2016, the abundance of resources for some major economic species also had increase trends in 2017.

In RO Korea, closed areas have been designated for each type of fishery by laws to protect the spawning stock and recruitment resources of the Yellow Sea. By legally designating closed seasons and water depth for all fishery resources and specific fishery resources, RO Korea has established an environment that is conducive to the protection of fishery resources in consideration of the number of target fish species and the marine environment of the seas. A comprehensive no-fishing season for all fishery resources is put into effect from April 1 to October 31 in certain seas, such as Gunsan and Buan in Jeollabuk-do. Fishery resources are divided into fish species (such as cod and salmon), other crustaceans (such as swimming crab), shellfish, seaweed, and other organisms. For each category, the government defines the period and depth of water in which fishing is prohibited. In addition, pursuant to the National Land Planning and Utilization Act and Fishery Resources Management Act, public waters and neighboring lands have been designated as fishery resource protection zones in order to protect and foster fishery resources. As of the end of 2017, a total of 30 areas, including the surface waters of 10 bays and 20 inland bodies of water (approximately 3,172 km^2), have been designated as fishery resource protection zones (K-NSAP, p 17 Table 3.5, p 19 Table 3.6).

Efforts to enhance fish stocks (Action 2.2) include re-stocking programs and the development of artificial reefs, marine forests, and marine ranching. PR China has undertaken a restocking program for more than 100 species, including freshwater species and endangered species (C-NSAP, p 15-16). The China NSAP review reports that extensive studies on the effects of stock enhancement have been conducted, including consideration of the genetic and ecological risks. A series of innovative studies were used to guide the conservation of fishery resources. Since 2018, China–Korea joint stock enhancement program has been conducted every year, with longer term cooperation anticipated (C-NSAP, p15-16).

In RO Korea, various fishery resource recovery projects have been carried out, and most of the current projects show sustainable and stable operation. The installation of artificial reefs, release of fry, marine forest, marine ranching, and various other fishery resource creation projects have been carried out. In particular, the size, budget, and target area of related projects have been continuously expanded, showing that management activities have been actively carried out. From 2011 to 2016, 2.9 ha of artificial reefs have been installed. With regard to marine forests, the goal was to create over 54,000 ha of marine forests from 2009 to 2030. As of 2017, 15,242 hectares of marine forest have been created. Also, RO Korea has planned to establish 50 coastal marine ranches from 2006 to 2022. As of 2017, 45 have been created (K-NSAP, p 25–26).

Improvement in fisheries management (Action 2.3) includes the activities described above, with additional activities. PR China has implemented a series of control strategies oriented toward limiting access to fish harvesting. These include establishing fishery genetic resource protection areas; requiring fishing licenses; setting limits on catchable fish sizes and the proportion of juvenile fish; requiring a sea area utilization fee for stock protection and enhancement activities; and reductions in fuel subsidies (C-NSAP, p16 - 17).

Other fisheries management activities in RO Korea include managing use of fishing gear, limiting the use of fishing gear, voluntary management of fishing, and total allowable catch (TAC). After the implementation of the TAC system, the number of species under the system increased to 18 by 2017. Starting with four species in 1999, the number increased to 18, including sailfin sandfish, swimming crab, whiparm octopus, and variously colored abalone (K-NSAP, p 27–30). Since 2011 the TAC exhaustion rate has gradually decreased, meaning that fishery catches have not been exceeding the allowable catch. In 2011, the exhaustion rate was over 80 percent, but that figure fell to about 46 percent by 2017. These measures have a regulatory basis in the revision of the Fisheries Act (1995), revision of the Fishery Resources Protection Decree (1996), and the enactment of the Regulations on the Management of the Total Allowable Catch (1998) (K-NSAP, p 27-30).

Cooperation with neighboring countries to establish and promote various plans is critical, particularly migratory fisheries resources in the Yellow Sea, shared by RO Korea and PR China. In reality, Korean swimming crabs and small yellow croakers are the same as the Chinese ones. Hence, it is difficult to effectively restore the fisheries resources with the efforts without bilateral cooperation. Recently, the Chinese government has also implemented its pilot TAC programs. The Korean government also plans to promote the TAC system as the main management measure for the coastal and offshore fisheries.

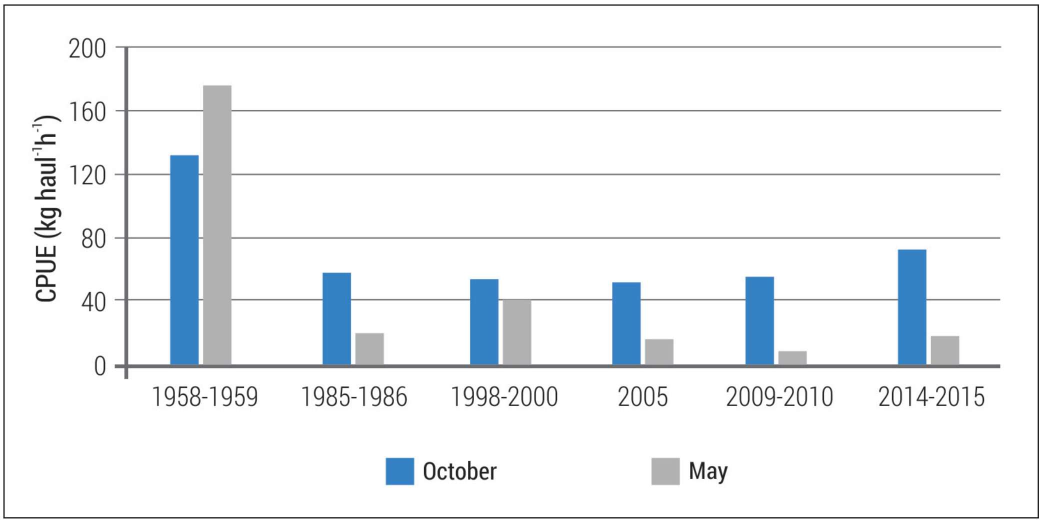
Ecosystem Responses to Capture Fisheries Interventions

Over the past several decades, the combined coastal areas of PR China and RO Korea have supported a significant proportion of global fish production. The species being captured have shifted over the years, with cycles of abundance stimulating increased fishing intensity. As catch intensity overtook recruitment, declines in the catch of one species resulted in increased fishing pressure for another. In the decades since the 1950s, the fisheries of the YSLME underwent two fundamental transitions. From the late 1950s to the late 1990s, the fisheries shifted from demersal, high-valued species to pelagic, low-valued species. Then from the late 1990s to 2014-2015, the fisheries shifted from pelagic, low-valued, to demersal, low-valued species (C-NSAP, P 10-12).

Two mechanisms are likely responsible for these shifts in species dominance, with implications for both stock decline and recovery. The first is known as *systematic replacement*. This occurs when a dominant species declines in abundance, either naturally or through overfishing. Another competitive species takes advantage of the surplus food and vacant space to increase its abundance. The second mechanism is *ecological replacement*. This occurs when environmental changes gradually restructure the ecosystem, resulting in changes in stock abundance. In the long term, these two drivers may be intermingled (Tang 1993, 2014). Once fisheries restoration measures have been implemented, stock recovery may be slow due to both of these ecological phenomena (C-NSAP, p 13).

The effectiveness of management actions can be evaluated by examining long-term changes in *Catch per Unit Effort* (CPUE). Changes in CPUE in the Chinese waters of the Yellow Sea are well described in **Figure 3**, showing high values in the 1958-1959 compared to the ones after that period which could be ascribed into the overfishing (Tang, 1989 and 1993). Overall biomass of fishery respires in the YSLME showed relatively stable pattern in last 30 years.

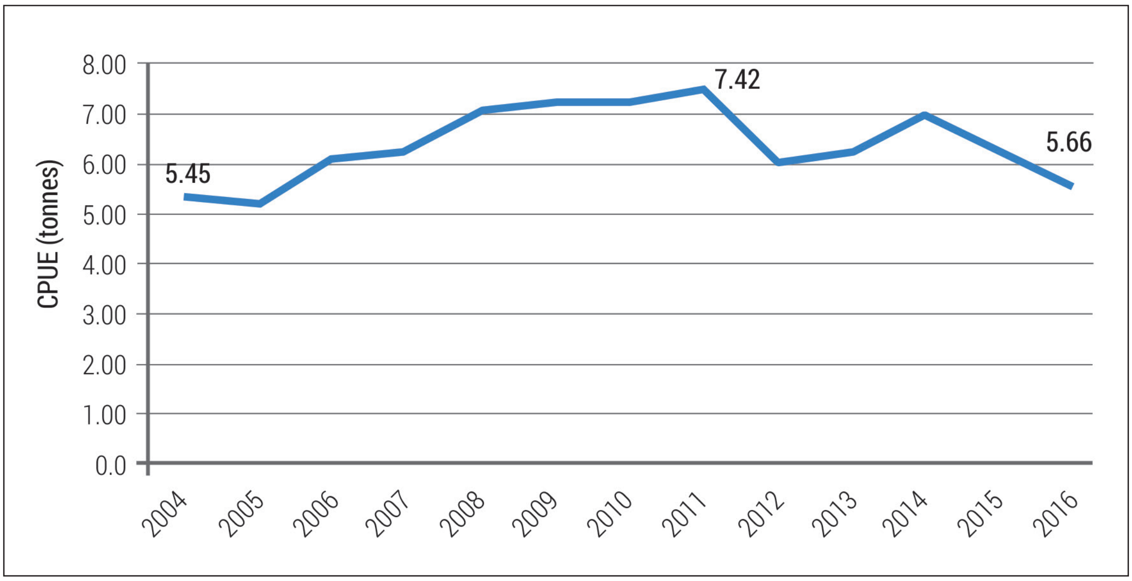
Figure 3. Long-term Catch Per Unit Effort (CPUE) changes of fishery resources in the Chinese Waters of the Yellow Sea.



Source: C-NSAP p 10, Figure 2.3

Based on the number of fishing vessels in RO Korea, CPUE in the RO Korea waters of the Yellow Sea showed a pattern of increasing steadily from 5.5 metric tons in 2004 to 7.4 metric tons in 2010. However, it dropped to 6.1 tonnes in the following year and fluctuated with a value of 5.7 tonnes recorded in 2016. Considering the tonnage (MT) of fishing vessels, CPUE showed a pattern of continuous increasing for five years from 1.6 tonnes in 2004 to 2.2 tonnes in 2009. After showing a pattern of continuous decline, it reached 1.4 tonnes in 2016. It is noticeable that this figure is lower than 1.6 tons of 2004 as well as the record low of CPUE over the entire analysis period (**Figure 4**).

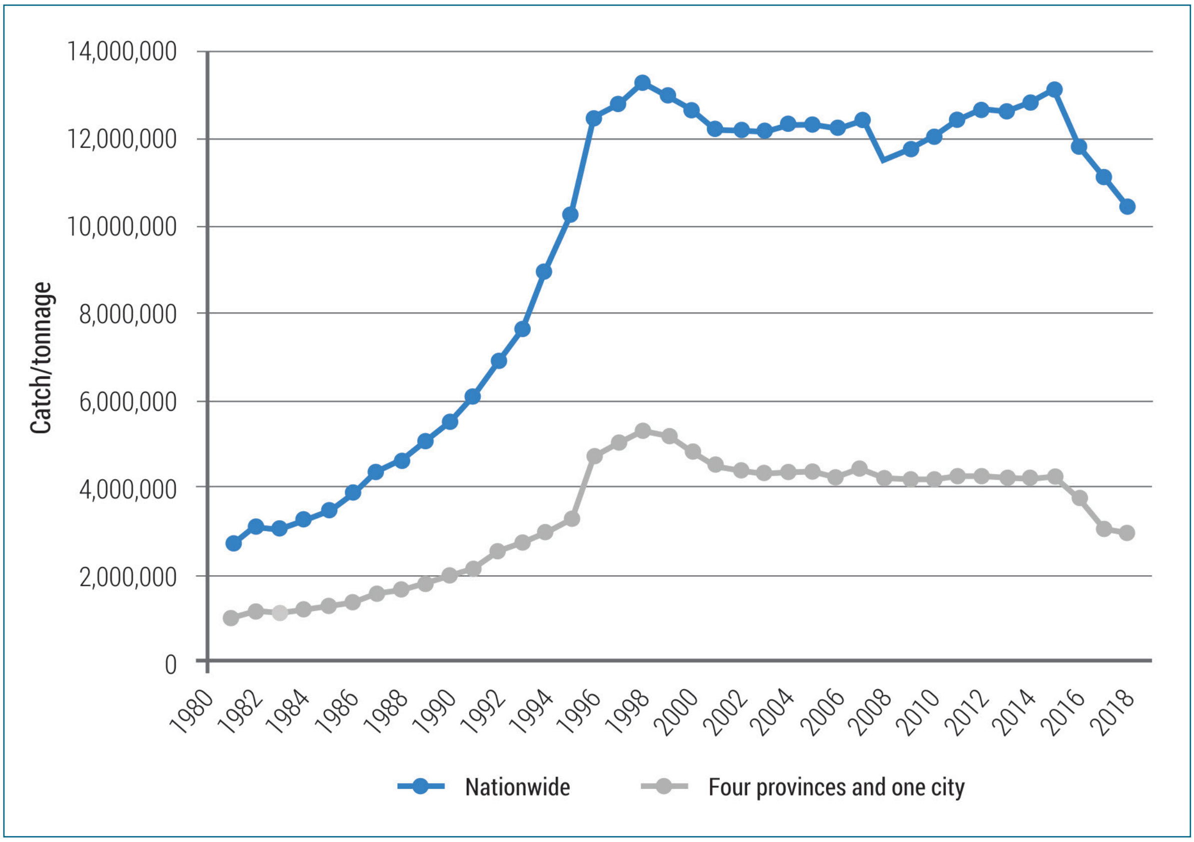
Figure 4. Patterns of Catch Per Unit Effort in the RO Korea waters of the Yellow Sea.



Source: Kim, D. 2019.

Another measure of the fishery is the total annual catch in tonnes. In PR China, catches in the four provinces of Liaoning, Shandong, Jiangsu and Zhejiang and the City of Tianjin in the Yellow Sea are shown in **Figure 5**). The catch increased steadily before 1995, and suddenly increased in 1996, and decreased slightly in 1998 and two years after, and kept stable in the following 14 years, and then decreased again. (Shan & Jin, 2019)

Figure 5. Total marine catch of four provinces and one city in the PR China waters of the Yellow Sea.



Source: Shan, X & Jin, Y. 2019. YSLME

According to the summary report on "Implementation of the fishing vessel buyback program in the Yellow Sea of Korea and its effectiveness analysis" authored by Dohoon KMI of RO Korea in 2019, catches of the coastal and offshore fisheries in the Yellow Sea of RO Korea has been shown with a pattern of constant declining over the past 40 years. After marking a record high of 646,000 metric tons in 1986, the catch amount has been decreased gradually until 2017. It is noticeable that the catch in 2017 was equivalent to 58 percent of that in 1986 and also was decreased by 2 percent per year on average between 1986 and 2017. It was found that the proportion of the fishery production in the coastal and offshore waters has been decreasing. The catch in the Yellow Sea, which had accounted for 40 percent of the country's total coastal and offshore fishery production in 1986, fell to 23 percent of the total in 2015. The decreasing proportion of the Yellow Sea catches in the country's total catches which are also on the decline indicates a faster reduction in the catch in the coastal and offshore waters of the Yellow Sea than the catch observed in the overall coastal and offshore waters of the country.

A third measure of fishery health is the distribution of body length for commercially important fish species. Average body length of small yellow croaker and largehead hairtail in the PR China waters of the Yellow Sea increased from 2016 to 2017. Additionally, recruitment stock biomass increased and population structure went from simple to complex (C-NSAP, p 8-9).

There is no doubt that interventions implemented to improve capture fisheries have reduced stress on fisheries. However detecting the actual recovery of fisheries through monitoring programs may require a longer timeframe than is captured by current data For example, as of 2015, fish species distributions favored demersal, low-valued species. It is possible that the trajectory will be toward a return to demersal, high-valued species. Similarly, trends in CPUE are equivocal. Increases in CPUE in recent years in the PR China waters of the Yellow Sea have been observed, along with increases in RO Korean waters between 2004 and 2011. However, the RO Korea data show a decline in recent years. Other measures of ecosystem health have indicated positive trends. An example is the 2016–2017 comparison of average body length of commercially important fish species mentioned above. Continued monitoring will be necessary to detect and understand longer term changes in ecosystem responses to management actions undertaken in the YSLME Phase II project.

2.1.2 Mariculture

The YSLME Phase I Regional Working Group on Fisheries (RWG-F) identified as a priority issue the rapid expansion of mariculture without adequate understanding of the consequences. Over the period from 1995 to 1997 alone, Yellow Sea maricultural production increased from 400,000 tonnes per year to about almost 4 million tonnes per year (TDA, 2007, P 46). Concerns related to mariculture are based on the high density of organisms and include the sedimentation of organic matter, transmission of diseases, and nutrient releases.

Traditional maricultural practices involved growing monocultures of finfish, crustaceans, molluscs, or seaweed in marine enclosures open to circulation from coastal waters. These waters provide nutrients to grow the organisms and flush away waste products. Land-based aquaculture systems operate on the same principle, recirculating nearby seawater to serve the same purposes of nutrition and waste removal.

It is known that mariculture also leads to negative impacts on environmental quality. During the breeding process, emission of nutrients (N, P) and organic matters (feces, residual feed) as metabolic wastes of culturing organisms and residual feed to the marine environment, beyond the nearshore marine environment capacity and self-purification ability, as a result of eutrophication and the ecological marine environment deterioration.

Management actions related to mariculture (**Table 5**) were designed to reduce the risks and environmental impacts associated with mariculture through three strategies: implementing a more advanced system for marine systems (Action 3.1), improving the technology of land-based systems (Action 3.2), and developing detection and response strategies to control diseases (Action 3.3).

Table 5. Management Actions Related to Mariculture.

Action 3.1	Reduce water-borne pollution and enhance the health of farmed organisms through Integrated Multi-Trophic Aquaculture (IMTA)
Action 3.2	Improve the technology for land-based aquaculture systems
Action 3.3	Developing detection and response strategies to control diseases

A relatively new approach in mariculture is Integrated Multi-trophic Aquaculture (IMTA). Rather than to farm one marine species, IMTA systems mimic ecosystems by including organisms that occupy a range of trophic levels. The organic or inorganic substances such as feed, feces, and nutrients produced by feeding units (such as fish and shrimp), become the feed for other types of cultured units in trophic levels (e.g., filter feeders and deposit feeders) in the system. An IMTA system using seaweed, shellfish, and echinoderm demonstrated the feasibility of this concept. Through photosynthesis and metabolic processes, kelp were net producers of oxygen, while removing carbon, nitrogen, and phosphorus. This nitrogen uptake offsets the nitrogen excretion by other culturing organisms in trophic levels such as shellfish and etc. If echinoderm (e.g., sea cucumber) are introduced into the system, particulate matters excreted by fish and shellfish are consumed in significant quantities. (C-NSAP, p 5-7).

IMTA systems have been implemented in RO Korea in small-scale projects conducted by the National Institute of Fisheries Science (NIFS) from 2011 to 2018. Through at least three demonstration projects, IMTA facilities and techniques were demonstrated and proven at the pilot scale, but have not yet been launched at commercial scales and Korean government making efforts to expand this technology in fisheries industry (K-NSAP, p 31).

Land-based aquaculture systems are essentially point-sources of nutrient loading to coastal areas and can be pathogen sources as well. Activities related to Action 3.2 were focused on minimizing the impact of aquaculture facilities by treating and recycling water and introducing environment-friendly feed sources (C-NSAP, p 6). Research and development projects in RO Korea focused on alternative feeds using alternative feed sources and developing bio-filtration systems to improve water quality. These projects, like those related to IMTA, develop technology that can make commercial-scale facilities possible (K-NSAP, p 33).

The demonstration of land-based IMTA showed significantly improvement in water quality. The N, P and organic particles were reduced by an IMTA pond out of the indoor fish aquaculture area. The government is organizing the experts to release the official industry standard for aquaculture wastewater. The land-based IMTA gives the farms very good solution to comply the coming standard. The demonstration of land-based IMTA is forward-looking.

With regard to trajectory, maricultural practices in the Yellow Sea have progressed towards ecological, efficient and environmentally friendly path during the Phase II project. The project developed and tested more sustainable practices applicable to the environmental conditions and organisms of the Yellow Sea. With financial and regulatory support, these can be scaled up and implemented at commercial levels.

2.2 Pollution

Nutrients, heavy metals and organic contaminants, and marine litter are the major pollution problems in the Yellow Sea (K-NSAP & C-NSAP, p 21). The Phase II YSLME SAP Implementation project addressed these pollutants in ten management actions, which fall into the general categories of water and sediment quality, marine litter, and contaminants.

2.2.1 Water and Sediment Quality

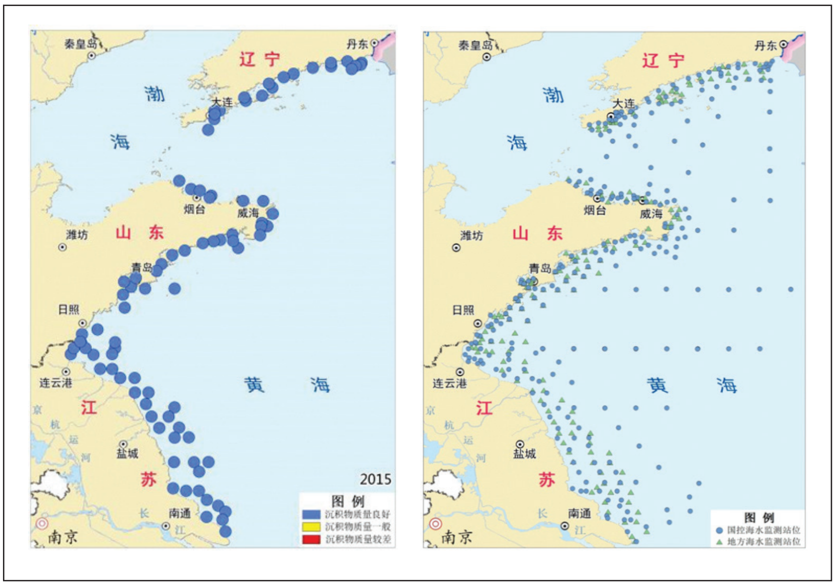
Water and sediment quality have been addressed in SAP implementation in terms of monitoring and assessment (Actions 4.1 and 7.1), strategies to control point (Action 5.1) and non-point sources (Action 5.2) of pollution to the Yellow Sea, and introduction of new technologies to decrease nutrient loading to the Yellow Sea (Action 5.3) (**Table 6**).

Table 6. Management Actions Related to Water and Sediment Quality.

Action 4.1	Intensive pollution monitoring and assessment.
Action 5.1	Manage land-based point source pollution loads.
Action 5.2	Manage land-based non-point source pollution loads.
Action 5.3	Introduce new technology to reduce nutrients (nitrogen and phosphorus)
Action 7.1	Conduct regular monitoring and assessment and disseminate information, particularly in bathing beaches and other recreational waters.

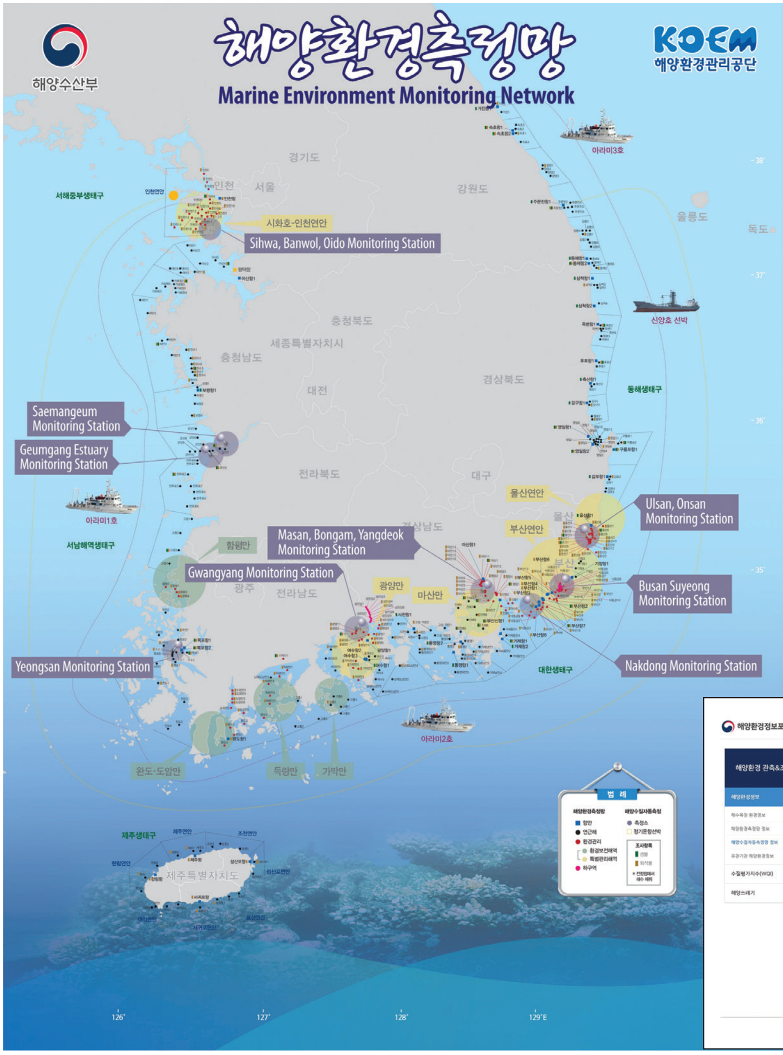
Monitoring networks have been established on the Chinese (**Figure 6**, C-NSAP, Figure 2.8 p 23) and Korean (**Figure 7**, K- NSAP, p 39) sites of the Yellow Sea for routine monitoring of seawater, marine organisms, and marine sediment. The monitoring grid includes sampling in both near-shore and open water-areas of the Yellow Sea. As a result, data are presented in spatial terms.

Figure 6. PR China monitoring sites in the Yellow Sea.

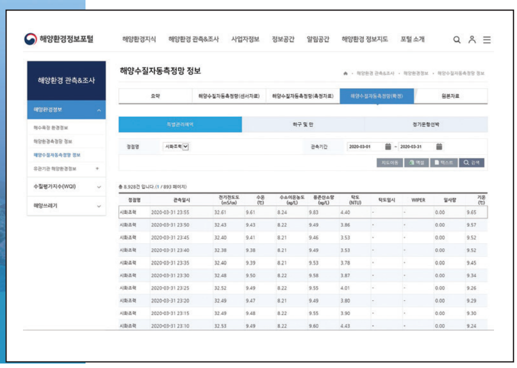


Source: C-NSAP Figure 2.8 p 23.

Figure 7. Map of survey areas for the ROK Marine Environment Monitoring Network and screenshot of the Marine Environment Information System (MEIS).



Source: K-NSAP Figure 3.8p 39.



PR China publishes the national marine environment status bulletin every year. As for seawater, the areas polluted in the Yellow Sea has been fluctuating between 2001 and 2018. In 2018, the average areas of seawater that had not reached the 1st grade of seawater quality standard was about 26,090 km^2, the most polluted sea area stands at 1,980 km^2. It is also noticeable that the main pollutants of the seawater in the Yellow Sea were inorganic nitrogen, active phosphate and oil (**Figure 8**). In this bulletin, the sediment quality monitoring result was also published. The monitoring indicators include heavy metals, PCBs, sulfide, organic carbon and petroleum. For marine sediment, in 2007, about 91.7 percent of marine sediment sites met comprehensive quality grade I (good quality), in 2017, the ratio increased to 100 percent. **Figure 9** showed the marine sediment quality distribution trend in the last 10 years. The marine sediment quality of the Yellow Sea was good and annual variations were not significant.

Figure 8. Annual change of seawater quality in the Yellow Sea (2001-2018).

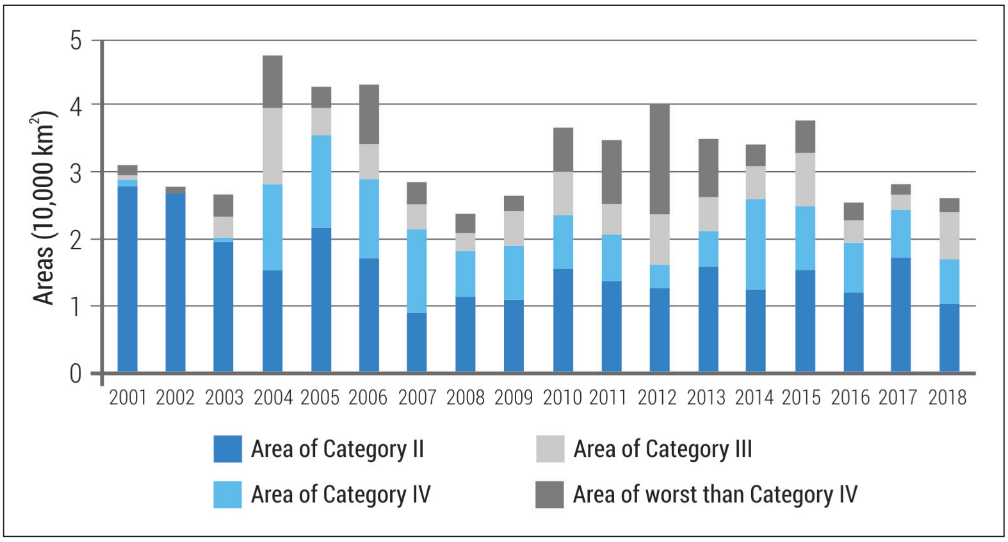
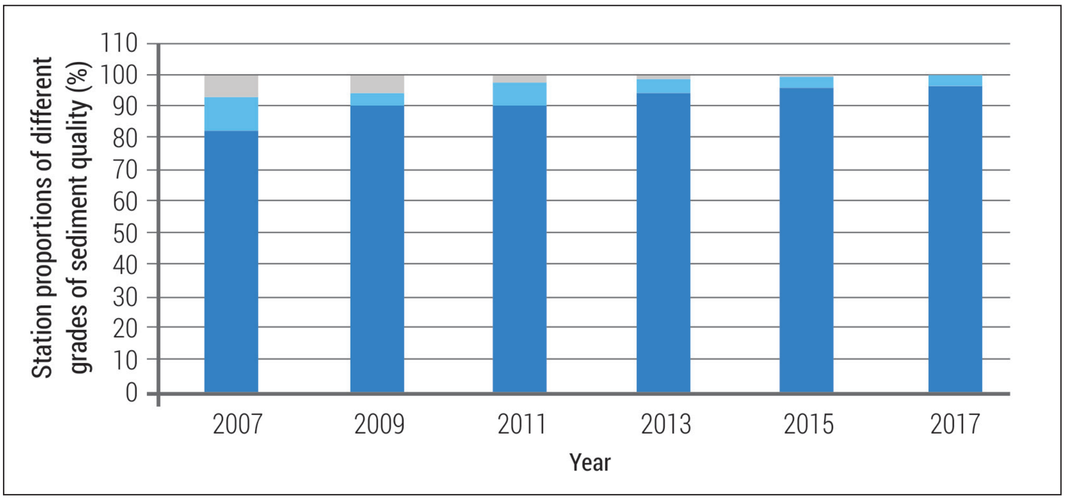


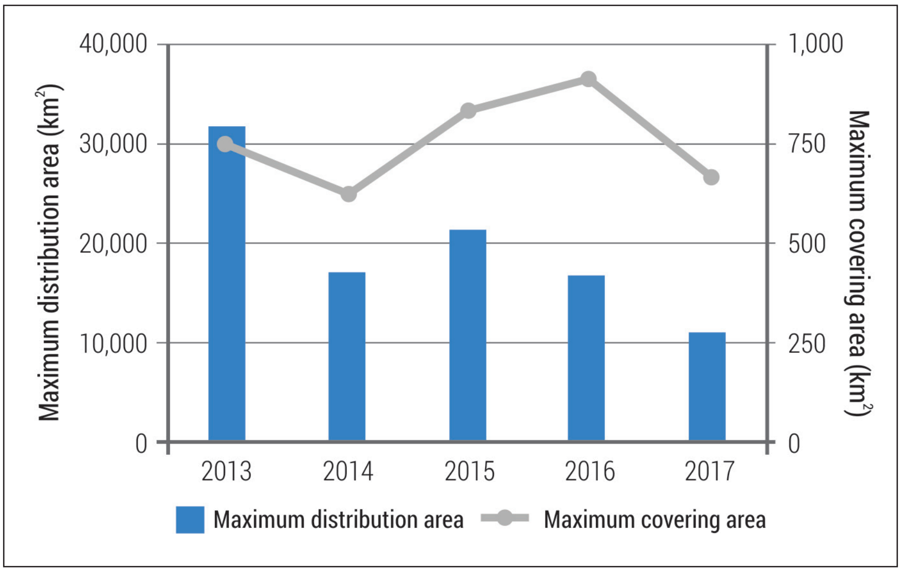
Figure 9. Annual variation of integrated quality of sediments of the YS (2006-2017).



Blue = Good, Light blue = Neutral, Grey = Bad.
Source: C-NSAP , Figure 2.11p 25.

A second monitoring network is focused at bathing beaches and other recreational areas with similar monitoring and dissemination programs in PR China (C-NSAP, p 37-39) and RO Korea (K-NSAP, p 76–81), This monitoring program is intended to provide up-to-date information, disseminated through web pages and other means, on beach and near-shore weather, pathogens, and biological hazards (e.g., jellyfish). The occurrence of jellyfish blooms has been increasing in frequency and in geographical range, influencing the maritime economy in many ways, causing significant economic losses. Both PR China and RO Korea suffered from the influence brought by the jellyfish bloom, so there was long-term international cooperation between two countries. In 2007, the first large scale green tide caused by Ulva broke out in Qingdao coast, and it recurred every subsequent year as shown in **Figure 10**.

Figure 10. The maximum distribution area and maximum covering area of green tide from 2013 to 2017 in Shandong Province, PR China.



Source: C-NSAP, p 48 Figure 2.28.

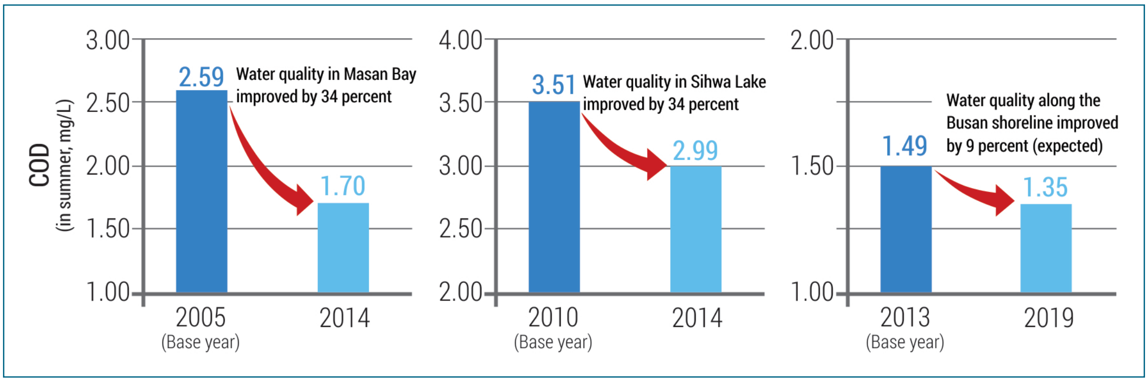
The primary point sources of discharge into the Yellow Sea from both PR China and RO Korea are industrial and municipal wastewater from urban areas. In China, the Yellow Sea provinces of Liaoning, Shandong, and Jiangsu are major commercial zones in eastern China and have undergone massive urbanization and industrialization. Municipal and industrial discharges from this region have severely deteriorated water quality. With regard to point source pollution control, emphasis was placed on the regulation of heavy pollution enterprises and the promotion of cleaner production. Local governments have made significant progress. For example, all chemical parks in Jiangsu Province installed automated on-line monitoring devices for wastewater. By the end of 2019, the sewage treatment rates of cities and counties will reach 95 percent and 85 percent respectively (C-NSAP, p 31).

RO Korea has worked to control point-sources of pollution by constructing new wastewater treatment facilities, assuring that new sewage collection systems collect stormwater and wastewater separately (separated systems), and converting combined systems to separated systems. Since 2012, RO Korea has installed 173 facilities in the Han, Geum and Yeongsan River basins, representing an 8 percent increase in capacity (K-NSAP, p 48-52).

Non-point sources of pollution to the Yellow Sea consist primarily of atmospheric deposition and release of pollutants from agricultural areas. Marine atmospheric monitoring stations have been established in China (C-NSAP, p 31) and RO Korea (K-NSAP, p 52 and p 57-58) and are currently operational. To improve the quality of atmospheric environment, PR China revised the law on *Prevention and Control of Atmospheric Pollution* in 2018. By the beginning of 2019, China achieved ultra-low emission of coal generating units of about 810 million KW, accounting for 80 percent of the total installed capacity of coal-fired power plants. The proportion of excellent days in 338 cities was 79.3 percent, an increase of 1.3 percent over the same period the previous year, and the PM2.5 concentration was 39 mg/m^3, down 9.3 percent from the same period the previous year. Agricultural runoff is the primary non-point source of pollution to the Yellow Sea and releases fertilizers, sediments, herbicides, and pesticides into surface waters. China has a high application rate of fertilizers (22 kg/acre), far in excess of the world average (8 kg/acre), due to limited arable conditions of the soil. The strategy for China is to control the annual growth rate in the use of fertilizer over the period from 2015 to 2020, with the objective of zero growth by 2020 (C-NSAP, p 33).

The approach in RO Korea for managing non-point sources has been to establish a Total Water Pollutant Load Management System for the river basins contributing to the Yellow Sea. Under this system, the aggregate pollutant load from all non-point sources are considered and managed collectively. Pollutant concentrations themselves are not regulated. Rather, the party for each pollutant source is allocated a quota for the total allowable mass of pollutants that may be discharged over a specified period of time. The technologies used to achieve these requirements include vegetated swales or buffer strips, wetlands, infiltration trenches, ecological ponds, and detention facilities. After implementation of this management system, the water quality (chemical oxygen demand, COD) improved by 9 percent to 34 percent in the three locations monitored (**Figure 11**, K-NSAP, Figure 2.13, p 55) (K-NSAP, p 53 - 56).

Figure 11. Improvement in water quality in three areas of coastal RO Korea. (target expected to be achieved in Busan coastal area)



Source: K-NSAP, Figure 3.13, p 55.

New approaches to nutrient treatment (Action 5.3) consist primarily of upgrading existing industrial and municipal wastewater treatment facilities for more effective nutrient removal and constructing new facilities with these capabilities. These approaches are known as advanced wastewater treatment or tertiary treatment. Technologies include the biological processes of nitrification-denitrification, and biological phosphorus removal, and physico-chemical processes including coagulation, contact phosphorus removal, reverse osmosis, and selective ion exchange resin removal. The proportion of advanced wastewater treatment facilities in Korea has increased steadily since 2012. Facilities including municipal, industrial, agricultural, livestock and septic systems are included in these upgrades and as of 2016, 74 percent of all wastewater facilities in Korea apply advanced treatment (K-NSAP, Table 3.40, p 60).

2.2.2 Marine Litter

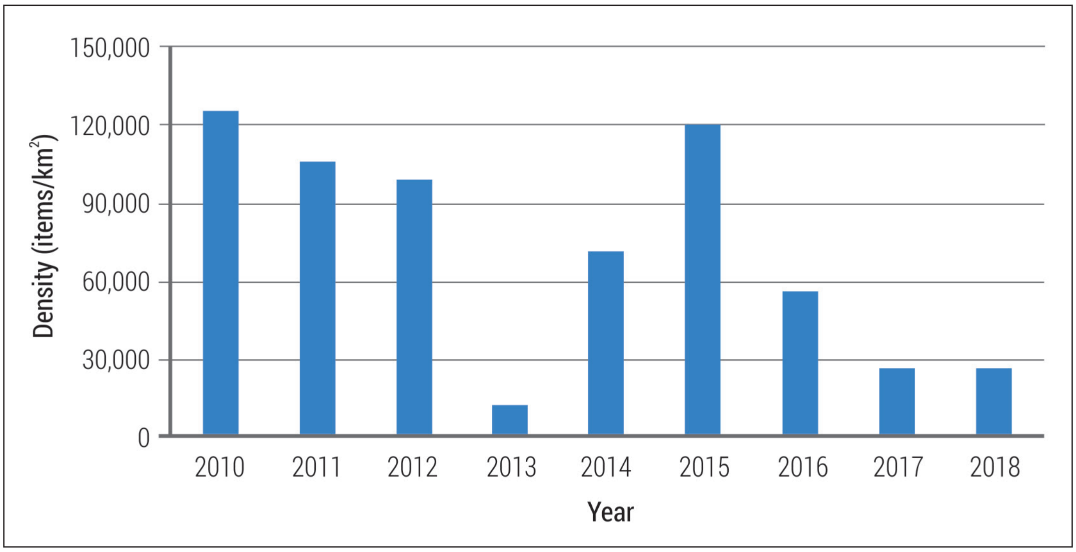
Marine litter can be found on both beaches and in open waters, and has both terrestrial and marine sources. Management actions relevant to marine litter are to minimize generation of marine litter (Action 6.1), improve collection and treatment of marine litter (Action 6-2), and establish a management system for litter (Action 6.3) (**Table 7**).

Table 7. Management Actions Related to Marine Litter.

Action 6.1	Minimize generation of marine litter through the management of original sources of marine litter and solid waste materials.
Action 6.2	Strengthen capacities to collect and treat marine litter.
Action 6.3	Establish management system for litter.

PR China has been monitoring marine litter on beaches and floating in open water since 2010. Concentrations have fluctuated, however the overall density of marine litter in 2018 was lower than in previous years (**Figure 12**, Zhang, 2019). The composition of marine litter in the Yellow Sea is mostly plastic and while individual pieces can range widely in size, the most common plastic litter consists of expanded polystyrene foam, plastic bags, plastic bottles and cigarette filters (C-NSAP, p 35.)

Figure 12. Beach litter density along the coasts of Yellow Sea of PR China (2010-2018).



Source: Zhang, 2019.

In 2008, PR China issued a plastic restriction order to limit the use of disposable plastic bags. To reduce plastic waste input to the environment from source, PR China issued the "Implementation Plan of Domestic Waste Classification System" and launched in 46 pilot cities (Action 6.1). Local governments actively carry out river rubbish disposal, establish garbage inspection system, and clean up marine floating garbage (Action 6.3).

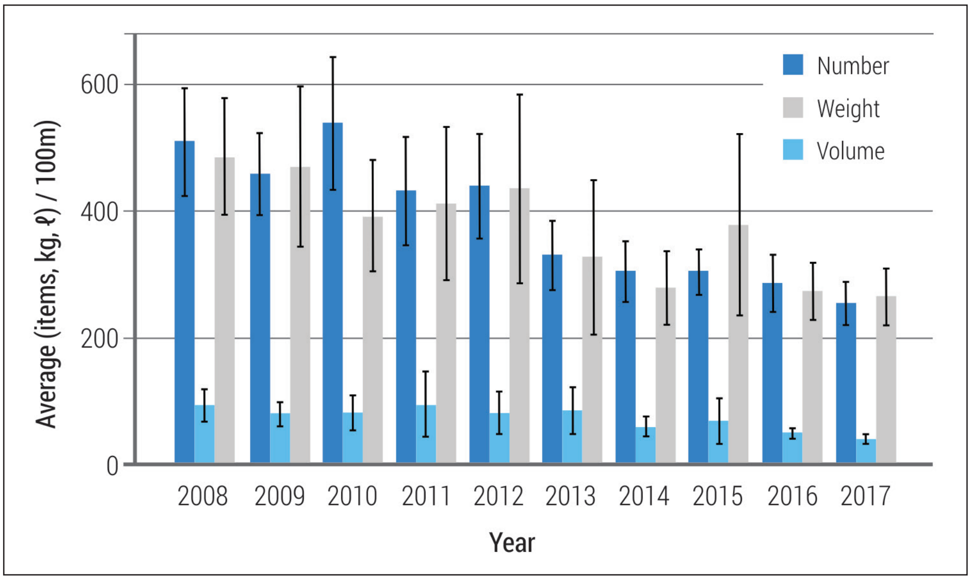
PR China actively encourages local governments and NGOs to organize activities for cleaner beaches. Environmental awareness and outreach and education events are held to observe World Environment Day, Earth Day, World Oceans Day, and International Coastal Clean-up Day, among others (Action 6.2).

The Korean government has implemented a series of measures to minimize (Action 6.1) the occurrence of marine litter, such as the establishment of long-term plans for marine litter management and supply of compactors to minimize generation of solid waste (K-NSAP, p 62). Since 2008, the country has been establishing and implementing a basic plan for marine litter management every five years (K-NSAP, p 62). The Ministry of Oceans and Fisheries (MOF) provided support for the installation of floating marine litter collection platforms (Action 6.2), on which marine litter generated during marine activities can be temporarily stored. To improve implementation, the platform locations, manufacturing, installation, and other details have been stipulated in the Guidelines for the Installation, Manufacturing, and Operation of Floating Marine Litter Collection Platforms. (K-NSAP, p 68).

RO Korea has begun replacing EPS buoys with biodegradable eco-friendly buoys. As of 2017, 386 eco-friendly buoy products have been developed and released by 38 companies (K-NSAP, p 63). In 2011, RO Korea established a Marine Litter Information System and Marine Litter Management Center (MALI Center) to collect and analyze information on overall marine litter management (Action 6.3) and propose research and policy measures (K-NSAP, p 72–73).

Temporal trend of distribution of litter on the monitored beaches indicates that the number, weight and volume decreased significantly in the waters of Korean Peninsula in the 10-year period based on Korean National Marine Debris Monitoring Program (KNMDMP). (Hong et al, 2018) (**Figure 13**).

Figure 13. Temporal distribution trend of litter for 2008-2017 in RO Korea.



Source: Hong et al., 2018.

2.2.3 Contaminants

The discharge of toxic pollutants in the marine environment can result in the violation of one or more international standards or conventions (**Table 8**).

Table 8. Management Actions Related to Contaminants.

Action 4.2	Comply with international standards for regulating toxic organic pollutants.
Action 4.3	Implement international agreements regarding regulations on oil and hazardous and noxious substances (HNS).

PR China and RO Korea both have aligned with the Codex Alimentarius and the Stockholm Convention. The Codex Alimentarius Commission (CAC) was established in 1963, by the United Nations Food and Agricultural Organization (FAO) and the World Health Organization (WHO), to establish a set of international standards for contaminants in food. PR China formally joined the CAC in 1984 and RO Korea[2] joined the CAC in 1971. The Stockholm Convention on Persistent Organic Pollutants requires signatory countries to reduce or eliminate persistent organic pollutants (POPs) in the environment.

PR China signed the convention in 2001 (Entry into Force in 2004) and RO Korea signed[3] the convention in 2007 (Entry into Force in 2007) (C-NSAP, p 26 – 29; K-NSAP, p 41).

Since entering into the Stockholm Convention, PR China has undertaken a wide range of activities, including elimination of production of a large number of POPs, developed alternative technologies, and prohibited the production, circulation, use, and import or export of DDT, chlordane, and mirex except for vector control and emergency use. In April 2007, the State Council of PR China approved the "National Implementation Plan" (NIP) of China. Since the NIP was carried out, PR China has made progress and solved a number of environmental hazards of POPs that seriously threaten human health and safety. Firstly, the production, use, import and export of the initial group of intentionally produced POPs has been stopped, the content level of which in the environmental and biological samples has an overall downward trend. Secondly, the emission intensity of dioxins in key sectors such as iron ore sintering, secondary non-ferrous metal smelting, and waste incineration has decreased by more than 15 percent. Thirdly, over 50,000 tons POPs-containing legacy waste has been cleaned up and disposed. In December 2018, PR China updated the NIP, specifically for the Convention implementation of the 11 new POPs, and submitted to Secretary of the Convention (C-NSAP, p 26-29).

RO Korea has adopted the criteria proposed in the Stockholm Convention into the POPs Control Act and Marine Environment Management Act to provide the basis for POPs management efforts. In addition, RO Korea has comprehensively identified the status and trends of POPs pollution in the environment (atmosphere, soil, water, and sediment) through the establishment and operation of POPs monitoring networks for each environmental medium across RO Korea in accordance with the Plan for the Establishment and Operation of POPs Monitoring Network and secured the data necessary for establishing POPs policies. Furthermore, the Korean government is working to reduce emissions by designating a national dioxin emission rate, based on studies of POPs emission sources and amounts, and strengthening the management of POPs-emitting facilities. RO Korea

2 http://www.fao.org/fao-who-codexalimentarius/about-codex/members/en/
3 http://www.pops.int/Countries/StatusofRatifications/PartiesandSignatoires/tabid/4500/Default.aspx

has reformed its domestic laws regarding POPs in order to comply with international criteria and strengthened national regulations, such as the addition of new POPs subject to the Stockholm Convention. (K-NSAP, p 41 - 43).

Pollutant discharges from ships are regulated by the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78). The objective of this Convention is to eliminate pollution by oil and other harmful substances and to minimize accidental spillage of such substances. To comply with MARPOL 73/78, PR China adopted several regulations to control discharge of ballast waters and other emissions from ships (C-NSAP, p 29- 31).

RO Korea adopted two protocols related to toxic discharges at sea: the International Convention on Oil Pollution Preparedness, Response, and Co-operation (OPRC) and the Protocol on Preparedness, Response, and Co-operation to Pollution Incidents by Hazardous and Noxious Substances (OPRC-HNS). Activities included providing contingency plans regarding oil pollution for vessels and marine facility, reports and notifications regarding oil spills, and national and regional systems to respond to and address oil spills (K-NSAP, p 44-47). Concurrently with the entry into effect of the Ballast Water Management Convention (September 2017), RO Korea enacted the Ballast Water Management Act to strengthen the regulations on ballast water management (K-NSAP, p 116).

2.2.4 Microplastics

In Yellow Sea, the distribution of microplastics in seawater is patchy, with high concentrations close to the coastal cities. They are also found in zooplankton, with high concentration near the adjacent waters of Yangtze estuary, and were detected in all 19 fish species sampled, ranging from 0.18 to 0.91 for different species with an average of 0.42 pieces/fish. (Sun et al., 2018). There is also widespread distribution of microplastics in sediments from the Yellow Sea. (Zhao, 2018)

Microplastics on beaches have been actively studied in Korea. OSEAN (2020) compared monitoring results of microplastics using Manta trawl and neuston nets with 250-505 μm mesh size. Results indicate that the abundance in Kyeonggi and Asan Bays of RO Korea showed the same order with those in Bohai Sea and Rudong offshore wind farms of PR China. The levels of microplastics were high in the Nakdong River Estuary and Soya Island where styrofoam buoys were used in huge quantities near the sampling sites. (Lee et al., 2013; Kim et al., 2015)

Comparison of the monitoring data with those of other published reports shows that the microplastic density in the Yellow Sea was in the lower-middle level. However, due to the limitation of monitoring capability, microplastic monitoring stations cannot cover the whole Yellow Sea area. In addition, there is still a lack of systematic research on the origin, flux into the sea, transmission path and ecological impact of marine microplastics in the Yellow Sea region.

2.3 Ecosystem Changes

From an ecological perspective, ecosystem changes can occur from both "top down" and "bottom up". As described previously, top-down changes occur, for example, when fishing pressure removes or depletes a particular species occupying a high trophic level, and other competing species replace it. Bottom-up changes can occur when supplies of nutrients change and the structure of primary producers is altered. Both processes occur simultaneously in the Yellow Sea and the ecosystem is additionally affected by other driving forces, which include climate change impacts. Management Goal 8 of YSLME SAP calls for *better understanding and prediction of ecosystem changes for adaptive management*.

2.3.1 Nutrient Ratios

Water quality monitoring programs described previously in Section 2.2.1 provide data on nutrient ratios in coastal and pelagic waters of the Yellow Sea (**Table 9**).

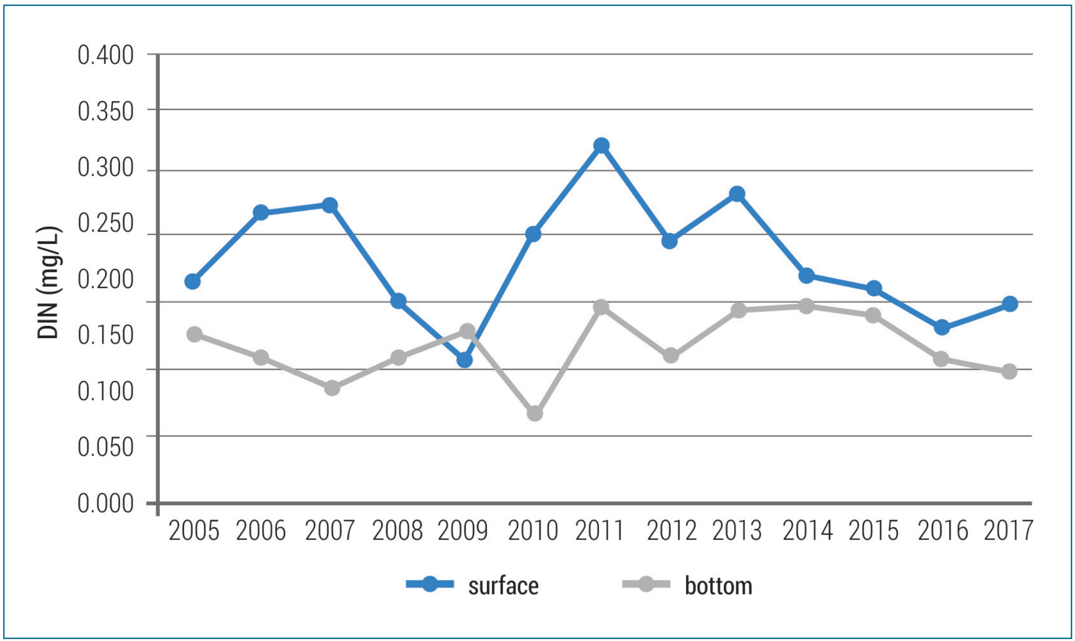
Table 9. Management Actions Related to Nutrient Ratios.

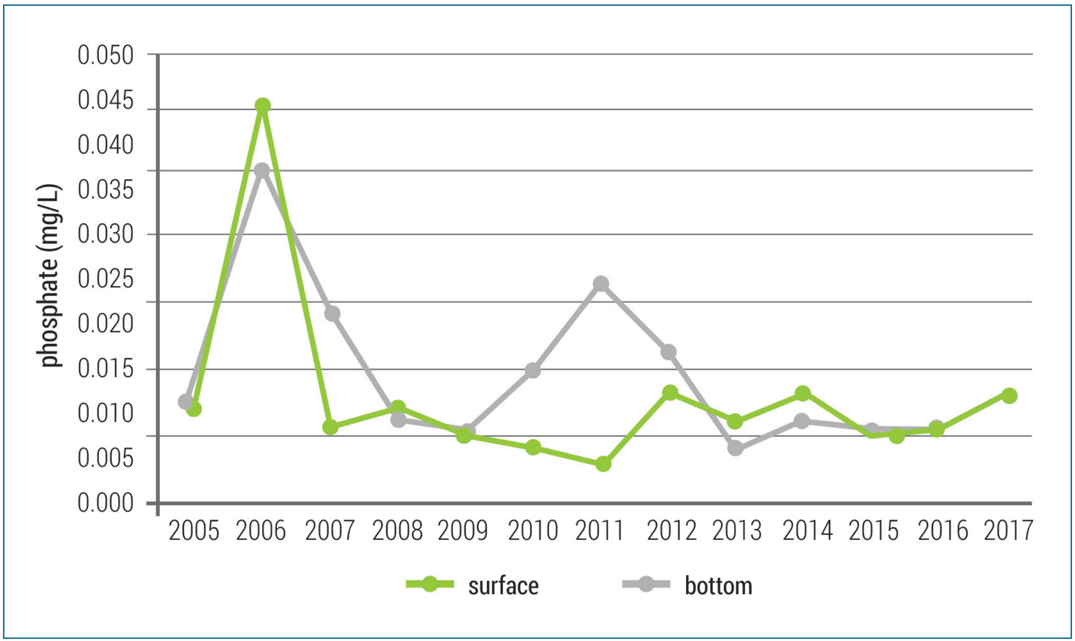
Action 8.1	Monitor and evaluate the effects of the ratios of nitrogen, phosphorus, and silica.

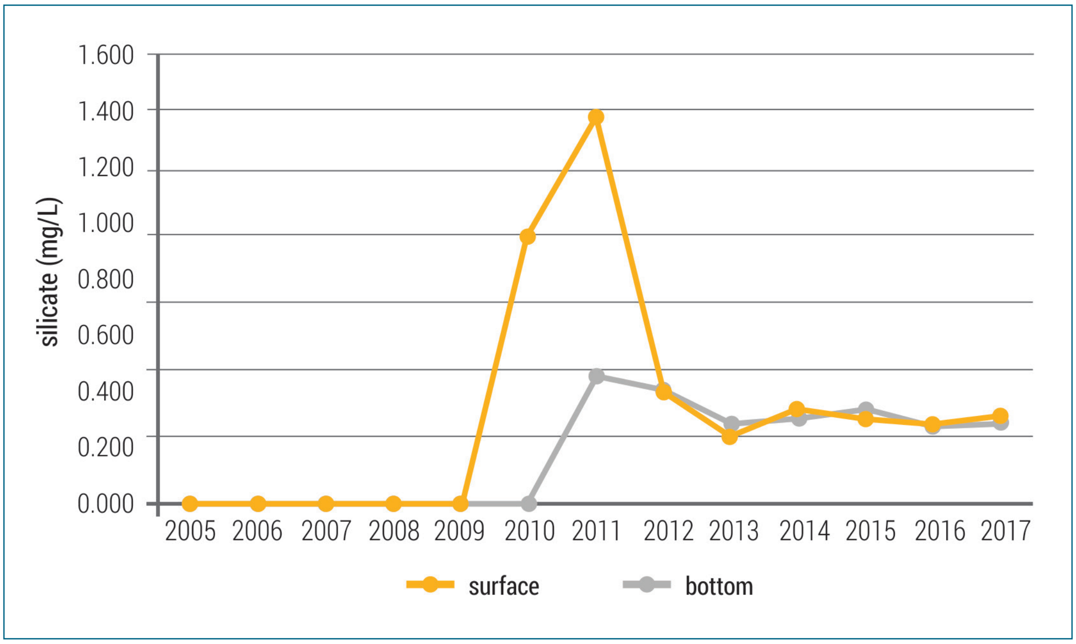
Concentrations and ratios of three key nutrients: nitrogen, phosphorus, and silica, have a strong influence on the abundance and diversity of primary producers (phytoplankton, zooplankton, and macro-algae) that form the base of the food chain. Ecosystems that are considered healthy, have a higher relative abundance of diatoms. These single-celled plankton have skeleton-like internal structures, and therefore require certain amounts of dissolved silica in their environment. Concentrations and ratios of nitrogen and phosphorus can govern whether or not harmful algae blooms will occur.

Figure 14, (C-NSAP, Figure 2.2 – 2.4 p 41) shows changes in Yellow Sea nutrient concentrations from 2005 to 2017. **Figure 15**, (K-NSAP, Figure 3.25 p 85) for example, shows systematic decline in the ratios of both N:P and Si:P in the eastern Yellow Sea, due to river discharge effects. It is not yet known if these changes are part of a long-term trend, or instead are a temporary fluctuation. However, these changes may be expected to drive higher trophic-level ecosystem changes.

Figure 14. Inter-annual changes of dissolved inorganic nitrogen (DIN), phosphate, and silicate in YS both surface and sediment.

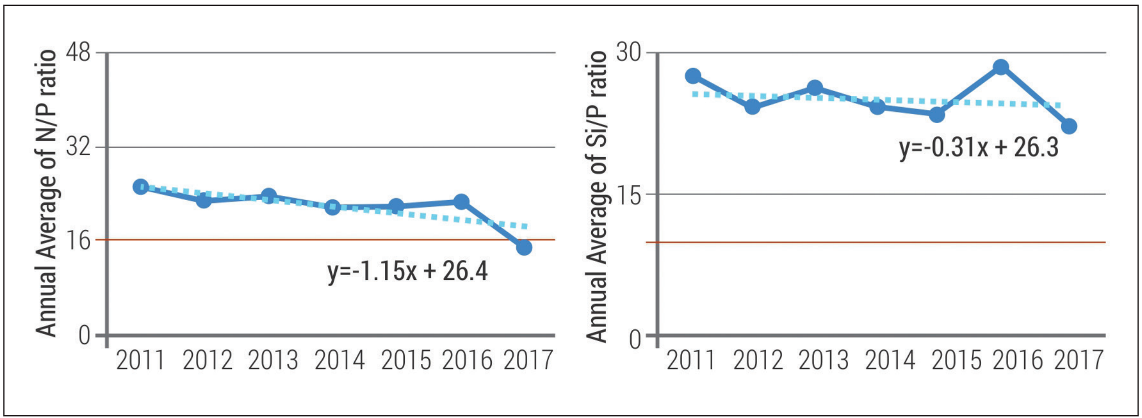






Source: C-NSAP, Figures 2.2 – 2.4 p 41

Figure 15. Inter-annual variation of N:P ratios (left) and Si:P ratios (right) in the eastern YSLME.



Source: K-NSAP, Figure 3.25.

2.3.2 Blooms of Nuisance Species

Blooms of jellyfish and harmful algae are indicators of ecosystem change and are themselves the cause of economic and health problems. Monitoring and evaluating the extent of these blooms are the objectives of Actions 8.4 and 8.5 (**Table 10**).

Table 10. Management Actions Related to Blooms of Nuisance Species.

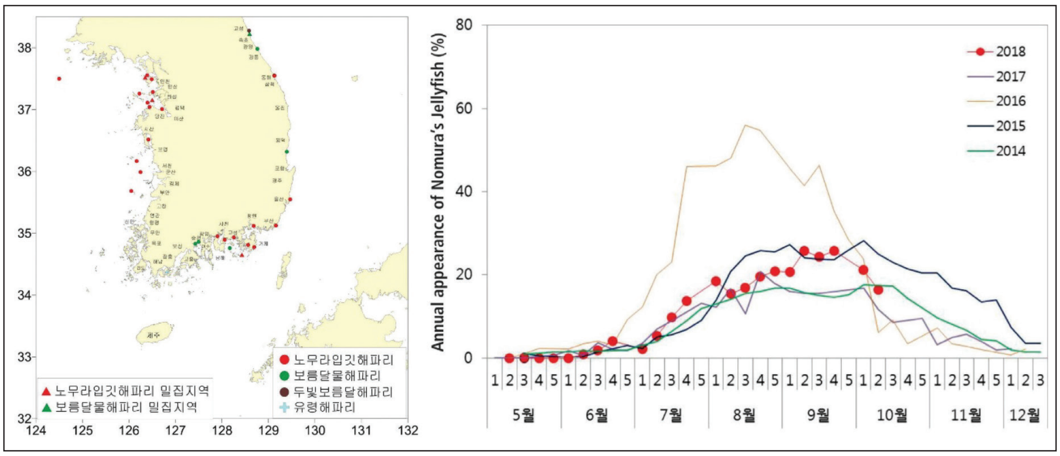
Action 8.4	Monitor and evaluate the transboundary impact of jellyfish blooms.
Action 8.5	Monitor the appearance of harmful algae blooms (HABs).

The occurrence of jellyfish blooms has been increasing in frequency and geographical range, influencing the maritime economy in many ways. Jellyfish blooms cause huge economic damages in fisheries activities, venomous jellyfish sting summer beachgoers, which adversely affect coastal tourism, leading to regional economic losses. Jellyfish block cooling water intake systems in nuclear power plants, causing reduction in electric power production, also leading to significant economic loss. At the ecosystem level, jellyfish blooms can alter the function of marine ecosystems and structure of marine food web that may induce "non-productive or unsustainable marine ecosystem. This altered ecosystem may be vulnerable to global warming (regime shifts) and to marine pollution (C-NSAP, p 46–47).

To monitor jellyfish populations and evaluate their impact on the Yellow Sea, PR China undertook the National Basic Research Program on Giant Jellyfish Blooms in Chinese Seas, from 2011 to 2015. The main tasks of the project were to understand the controlling factors, key processes, and driving mechanisms in jellyfish blooms in Chinese coastal waters; to discover how jellyfish blooms influence the marine ecosystem and their mechanisms of causing harm; and evaluating ecological disasters and how to put into place mitigating measures (C-NSAP, p 46-47).

In RO Korea, the NIFS and the Korea Marine Environment Management Corporation (KOEM) have been developing measures to reduce damage caused by jellyfish blooms through the Study on the Causes of and Countermeasures against Jellyfish Blooms (by NIFS) and polyps' habitat mapping and removal undertaking (by KOEM). In addition, NIFS has established a system for monitoring the annual appearance of Nomura's jellyfish in waters around Korean peninsula (**Figure 16**).

Figure 16. Weekly appearance of Nomura's jellyfish (red dot), Moon jellyfish (green dot) and other (left) and annual variation of appearance rate (%) of Nomura's jellyfish in 2014-2018 (right).



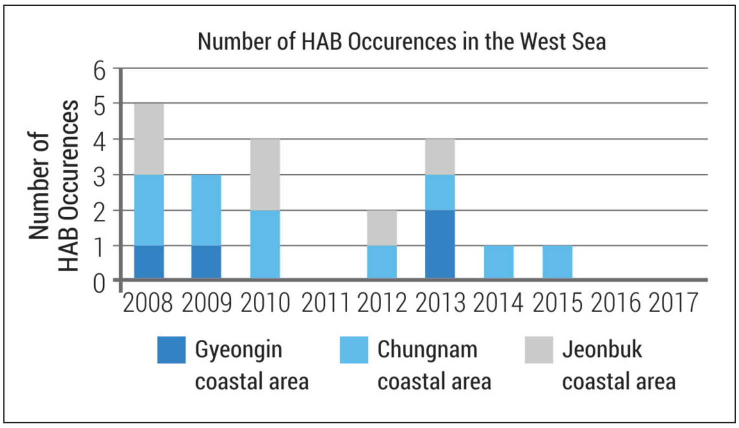
Source: K-NSAP, Figure 3.30.

Common forms of HAB are known variously as green tide (e.g., *Ulva* or *Enteromorpha* blooms), gold tide (floating *Sargassum*), and red tide (generally, blooms of dinoflagellate algae, but species can vary). In 2007, the first large scale bloom of *Ulva* broke out along the Qingdao coast. From then on, green tide affected this area annually. The causes of harmful algal blooms are complex, but necessary preconditions include nutrient enrichment and change in N/P/Si ratios. Recent reports alarmed massive seaweed farming of *Poryphyra yezoensis* for green tide occurrence, in the case of the Yellow Sea, relatively low silica concentrations that favour harmful algae over diatoms. Adverse effects include the nuisance presence of the algae, local oxygen depletion, and the release of toxins that can be fatal to wildlife and humans.

The occurrence and distribution of HABs have changed over the last decade. Green tides consisting of *Enteromorpha prolifera* have bloomed continuously on the west coast of the YSLME. It is anticipated that the increased primary productivity associated with green tides will result in an overall increase in organic nitrogen in the YSLME. Red tides have been observed to decline in frequency, but to have an increased proportion of toxic species.

As of 2017, there were 82 HAB monitoring stations in the eastern Yellow Sea, and nine surveys have been conducted. Monitoring in the coastal waters of the eastern Yellow Sea indicates that the number of occurrences of HABs began declining after 2014 and no red tides occurred in 2016 and 2017 (**Figure 17**) (K- NSAP, p 94–96).

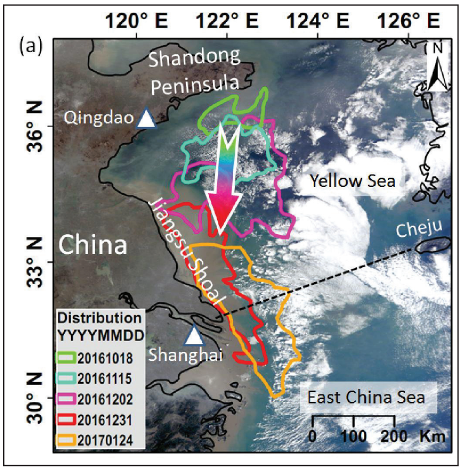
Figure 17. Number of HAB occurrences (right) in the eastern YSLME (2008-2017).



Source: K-NSAP Figure 3.33 p 96.

Field surveys and remote sensing analysis indicated that the pelagic *Sargassum* biomass increasingly occurred in East China Sea and western Yellow Sea. Genetic screening confirmed the pelagic *Sargassum* biomass in East China Sea and Yellow Sea comprised a single species *S. horneri*, and could be derived from four discrete benthic populations identified along the coasts of Liaoning, Shandong and Zhejiang provinces. Two distinct blooms were detected. The winter bloom was initiated from the southeastern coast of Shandong Province, drifted southward and reached the southeastern coast of Jiangsu Province (**Figure 18**).

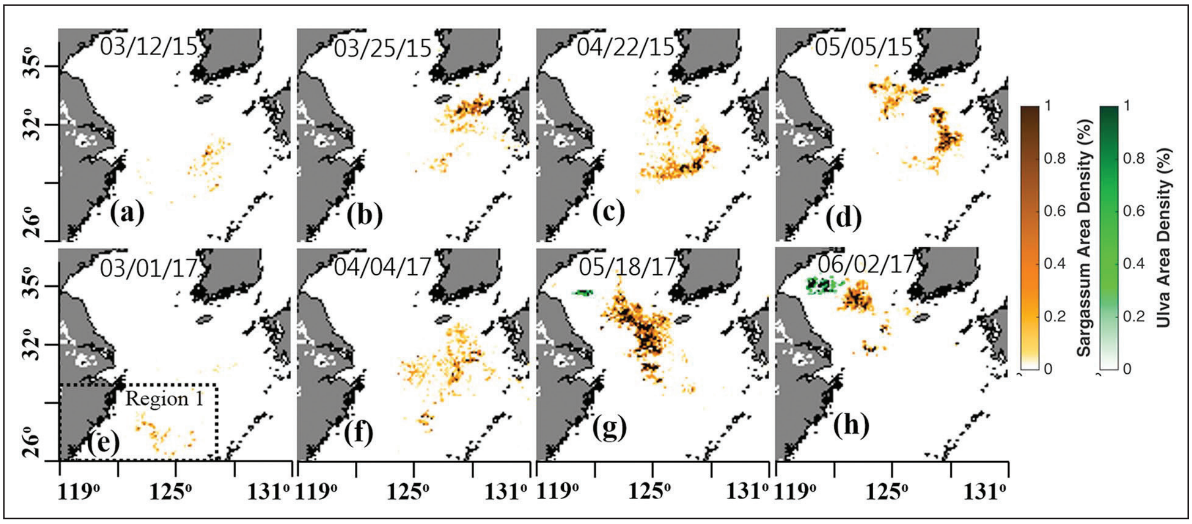
Figure 18. Southward drifting of *Sargassum* from October 2016 to January 2017.



Source: Xing et al., 2017.

The spring bloom was initiated along the coasts of Zhejiang Province, drifted offshore and northward, and intruded into the Yellow Sea (**Figure 19**). Of economic importance, in December 2016, a seaweed farming area of *Poryphyra yezoensis* in the Jiangsu Shoal of the western Yellow Sea was severely affected by *S. horneri*. At the sites severely affected by drifting *Sargassum*, the *Poryphyra* aquaculture facilities were taken over by *Sargassum* and collapsed. This caused the largest direct economic loss by floating *Sargassum* in PR China, with estimated losses of 500 million CNY (about USD $73 million) (C-NSAP, p 49). And various environmental factors, such as seawater temperature, light availability, water circulation and nutrients, could regulate or influence the blooming dynamics. Whereas, further research is needed to identify the exact biomass source for the winter *Sargassum* bloom and clarify the outbreak mechanism of both winter and spring blooms.

Figure 19. Northward drifting of *Sargassum* in 2015 and 2017 (Qi et al., 2017). Yellow to brown colors represent the floating *Sargassum*, while green color indicates the floating *Ulva*.



2.3.3 Climate Change Effects

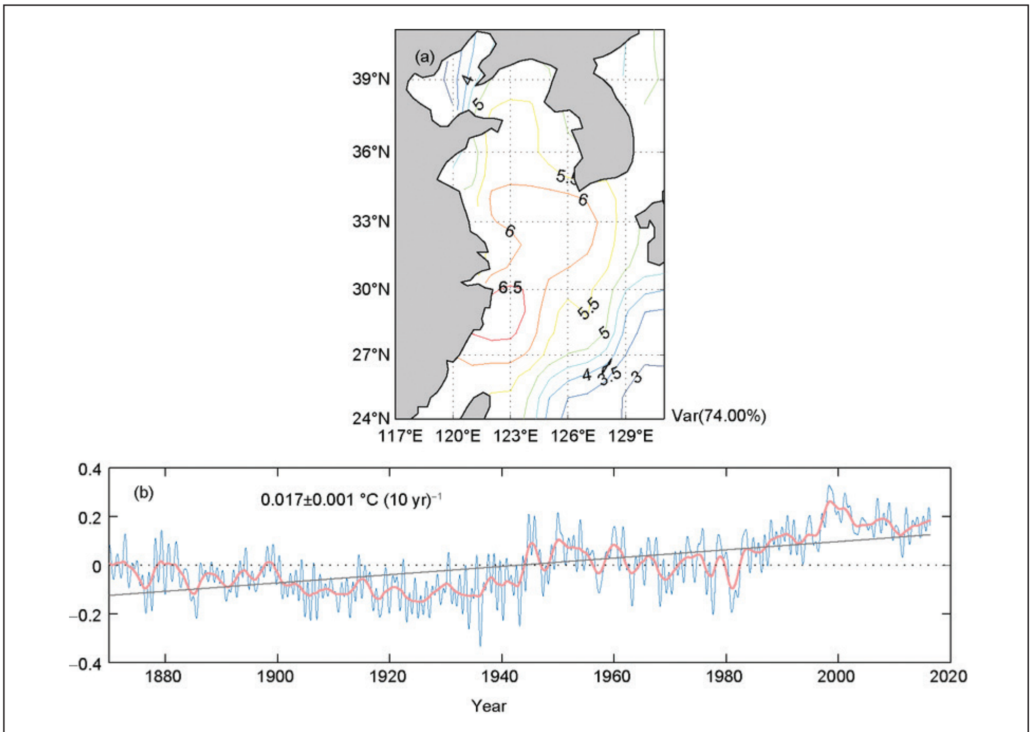
Climate change has profound effects on ecosystems, either as a direct driver or through indirect mechanisms. The YSLME Phase II SAP implementation project directly addressed climate change impacts specifically on lower trophic levels of the Yellow Sea ecosystems (Action 8.2), and generally in the prediction of long-term changes in Yellow Sea ecosystems (Action 8.3) (**Table 11**). Concerns related to climate change include rising sea-surface temperatures and sea levels, and ocean acidification. These abiotic changes can cause diverse impacts on ecosystems, including northward distributions of warm-water species, trends of decreasing occurrence of HABs (e.g., Zeng et al., 2019), and alterations of trophic structures.

Table 11. Management Actions Related to Climate Change Effects.

Action 8.2	Monitor and evaluate the lower trophic level effects of climate change.
Action 8.3	Predict long-term changes of the Yellow Sea's ecosystem due to climate change.

Sea-surface temperatures have been increasing in the Yellow Sea in recent decades. **Figure 20** shows mean annual sea-surface temperature (SST) anomalies in coastal China from 1870 to 2017 (Pei, et al., 2017).

Figure 20. Sea-surface temperature (SST) anomalies in the Yellow Sea and East China Sea.

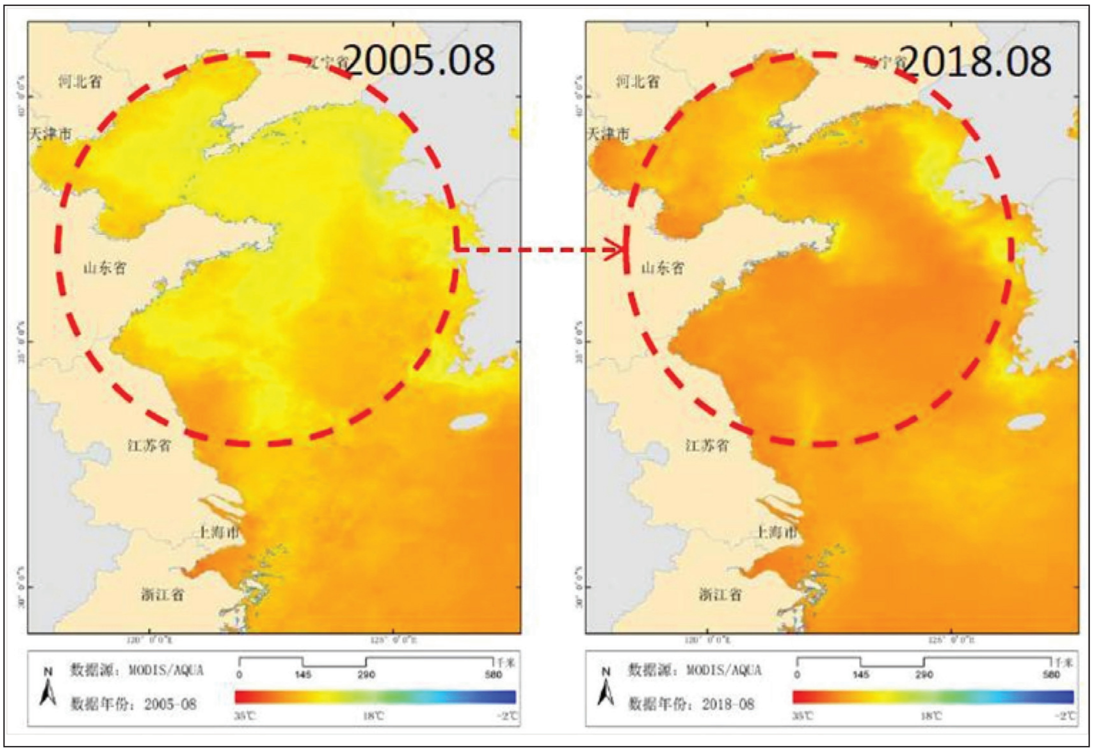


(a) spatial and (b) temporal. The bold pink curve in (b) indicates the 2-year moving average and the grey line indicates the trend. The Y-axis in (b) is degrees Celsius and the equation in (b) indicates the average increase in SST for the period of record (1980–2018), plus or minus the 95 percent statistical confidence interval.

Source: Pei et al., 2017.

This trend of increasing sea-surface temperatures (SSTs) can be seen in the spatial increase in the water temperatures of the YSLME. **Figure 21** shows increases in water temperatures during the month of August in 2005 compared with 2018 in the northern YSLME and the Bohai Sea. The China Sea Level Bulletin (2018) reports that from 1980 to 2018, the sea surface temperatures of China's coastal waters increase by 0.23°C over the ten-year period.

Figure 21. Spatial distribution of sea-surface temperatures in the Bohai Sea and upper YSLME.

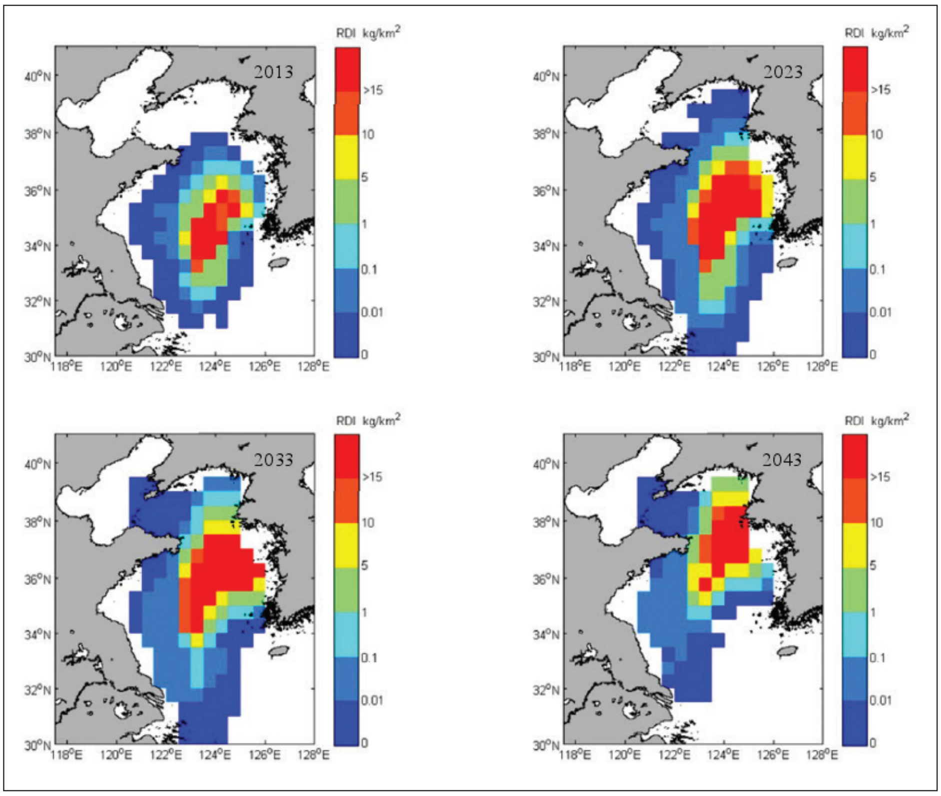


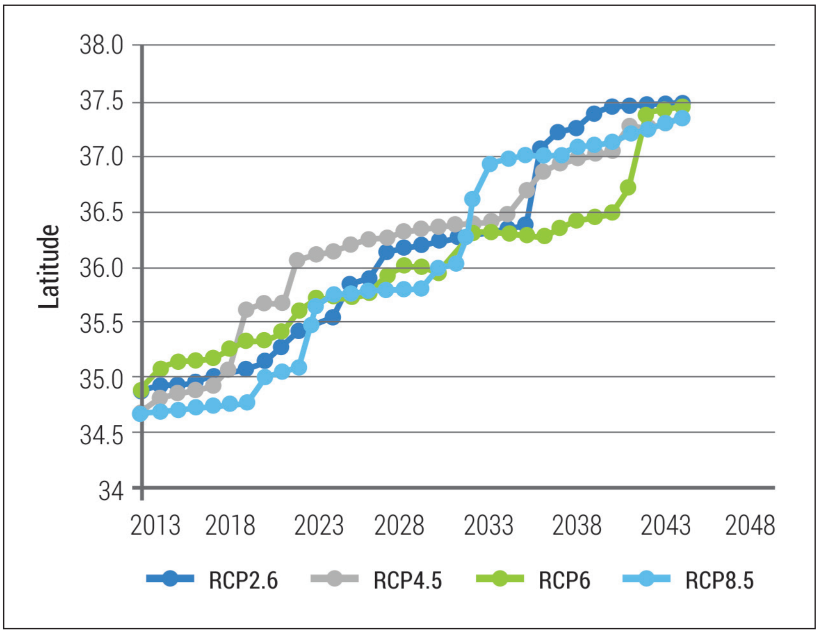
Source: SOA. 2018.

Increased atmospheric CO_2 levels is being observed to cause a loss of alkalinity in ocean waters worldwide. Marine acidification affects bio-calcification rates, primary productivity, nitrogen fixation, and species reproduction, especially for the shell formation process of calcareous organisms. Increased acidification in the waters of the YSLME has been modelled to the year 2100. In a modelling study of marine acidification, Zhai (2018) predicted spatial patterns of decreased alkalinity, particularly in the bottom waters of the YSLME.

Recent observational and modelling studies attribute ecosystem changes to climate change. According to research conducted in the northern Yellow Sea, the plankton structure has greatly changed from 1959 to 2011. Some warm water species, such as *Sagitta enflata* and *Doliolum denticatum*, which were distributed in the south of Yellow Sea in 1959, are now distributed in the northern Yellow Sea and became the dominant species (Zou et al, 2013) (C-NSAP, p 51). Separately, a 2014 modelling study predicted changes in the abundance and distribution of Japanese anchovy in response to climate change. Chen (2014) modelled the inter-annual variations in resource density, and distribution of the anchovy, a key species in the food web of the Yellow Sea. Under four climate-change scenarios with varying assumptions on atmospheric CO_2 concentrations, the wintering anchovy stock showed a clear northward trend, by as much as 2.7 degrees latitude in the next 30 years (**Figure 22**).

Figure 22. Predictions of redistributions of wintering anchovy from 2013 to 2043 under different scenarios. Top: spatial distributions. Bottom: temporal distributions.

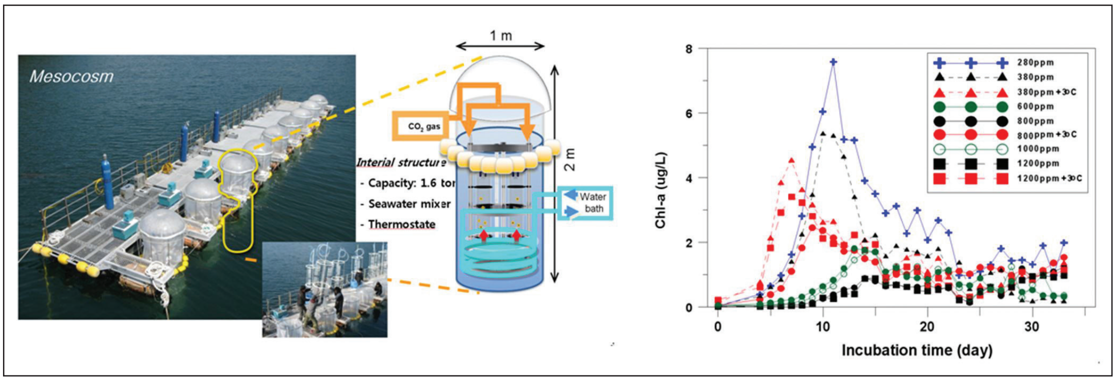




Source: Chen 2014; C-NSAP Figures 2.24 and 2.25 p 43 – 44.

Ecosystems are sufficiently complex that predictions of changes in trophic structures due to climate change are not possible with numerical models alone. Korea Institute of Ocean Science and Technology (KIOST) has undertaken mesocosm experiments to assess the impact of climate change on marine ecosystems. An example of the results of an experiment in which algal growth rates are monitored under different CO_2 concentration levels is shown in **Figure 23**.

Figure 23. A photo and specification of KIOST self-produced Mesocosm system. Left: Photo and diagram of system. Right: Chart of algal growth versus incubation time for varying CO_2 concentrations.



Source: K-NSAP, Figure 3.27.

Climate Change and Marine Disasters

Marine disasters in the coastal region of the Yellow Sea are mainly caused by storm surge (including near-shore waves), ocean waves, sea ice, green tide and red tide as well as coastal erosion. Saltwater intrusion, soil salinization and sea level rise related to climate change can also induce varying degrees of disasters. Climate change can also induce negative impacts on coastal and marine systems in the Yellow Sea. For example, salt marshes and seagrass beds may decline unless they can move inland, while coastal marshes will be vulnerable to saltwater intrusion with rising sea levels. Overall, in the influence of climate change, marine hazards seriously threaten the lives and property safety of residents in the coastal areas of the Yellow Sea and also obstruct the development of an ecological civilization of this region, becoming one of the restrictions to the economic and social development of the coastal region.

To address climate change, PR China has established the marine disaster prevention and mitigation operational system for the entire coastal region of the Yellow Sea, including the operational observing and monitoring network, the warning and monitoring system for marine ecosystems, marine environmental warning and forecasting integration as well as marine hazard mitigation and hazard risk prevention. Moreover, China is now exploring applications and practices in marine disaster emergency management, ocean-related spatial planning "multi-regulation", integrated marine management, and community disaster reduction, to mitigate and adapt to climate change. However, the function of coastal ecosystems on mitigating marine hazards is still insufficiently considered in the present work for marine disaster prevention and mitigation. Climate change impacts on coastal ecosystems in the Yellow Sea are still poorly understood, particularly for the damage to ecosystems caused by tropical and extratropical cyclones and storm surges.

Previous studies have suggested that coastal ecosystems, such as coastal wetlands, salt marshes and sandy coasts, can potentially play an important role in coastal defence, disaster risk reduction and carbon fixation, to mitigate and adapt to climate change. Therefore, it is recommended to implement coastal ecosystem protection and restoration projects, aiming at preserving and restoring coastal habitats for building natural infrastructure to increase resilience and biodiversity of the coastal habitats to reduce marine disasters. For some coastal areas in the Yellow Sea, hybrid living shorelines with traditional, hard infrastructure and nature-based defenses are also recommended to implement to reduce ecological and economic losses by mitigating storm, erosion and rising sea level risk associated with climate change.

To cope with climate change in the ocean, the Ministry of Ocean and Fisheries of RO Korea is working on a "comprehensive plan and responding to climate change in the ocean" in 2016. Climate change is accelerating rising sea temperatures, rising sea levels, and ocean acidification.

Over the past 47 years (1968-2014), the surface sea temperature of the Korean waters has risen by about 1.18 °C, and it is expected to rise 2-3 °C in 2050 and 4-5 °C in 2100. Rising sea temperatures are expected to widen the incubation and dead zone due to stratification in the sea, which poses the risk of loss of indigenous life, including the reduction of marine resource habitat, increased harmful red tide and the advantage of exotic species. Also, the marine ecosystem is expected to change due to the decrease in animal plankton due to the rise in water temperature, the increase in subspecies, and the reduction of cold-water fish such as salmon. In the past 40 years, sea levels have risen about 2.48 mm on the Korea Coast, higher than the global average of 1.7 mm during the same period. By the end of the 21st century, sea levels on the south and west coasts are expected to rise 65 cm. Due to rising sea levels, erosion and flooding of coastal and island areas are expected.

Seasonal Acidification

As a sink of atmospheric CO_2, oceans absorb about 25 percent of anthropogenic atmospheric CO^2 emissions annually, progressively lowering levels of seawater pH and aragonite saturation state (Ω_{arag}), a process referred to as ocean acidification. It affects the growth, reproduction, metabolism and survival of marine organisms, which affects the balance of marine ecosystems and the service functions to humans. However, ocean acidification in coastal regions is more complex as these areas are impacted by multiple natural and anthropogenic processes other than CO_2 uptake.

The Yellow Sea, a semi-enclosed shallow sea of the northwest Pacific, forms a major marine zone in China with increasing sensitivity to ocean acidification. The seriously acidified seawaters with Ω_{arag} of less than 1.5 occupied one third of surveyed Yellow Sea in summer and autumn, while subsurface water Ω_{arag} was generally lower than 1.0 in the central area in autumn. It also revealed that sea surface water with Ω_{arag} values above 2.0 will disappear for the whole Yellow Sea by the year 2100. Notably, bottom water Ω_{arag} will drop to 0.8–1.9 and most subsurface water will develop substantial aragonite under saturation in the central areas. Thus, the Yellow Sea might represent a system highly vulnerable to the potential negative effects of ocean acidification, where should be considered as a priority region for further research on ocean acidification and its synergistic effects on marine mammals and ecosystem structures.

2.4 Biodiversity

Habitat loss, including degradation and fragmentation, is the most important cause of biodiversity loss globally. Natural habitats in most parts of the world continue to decline in extent and integrity, although there has been significant progress to reduce this trend in some regions and habitats. Reducing the rate of habitat loss, and eventually halting it, are essential to protect biodiversity and to maintain the ecosystem functions essential to supporting human livelihoods.

2.4.1 Coastal Wetlands and Reclamation

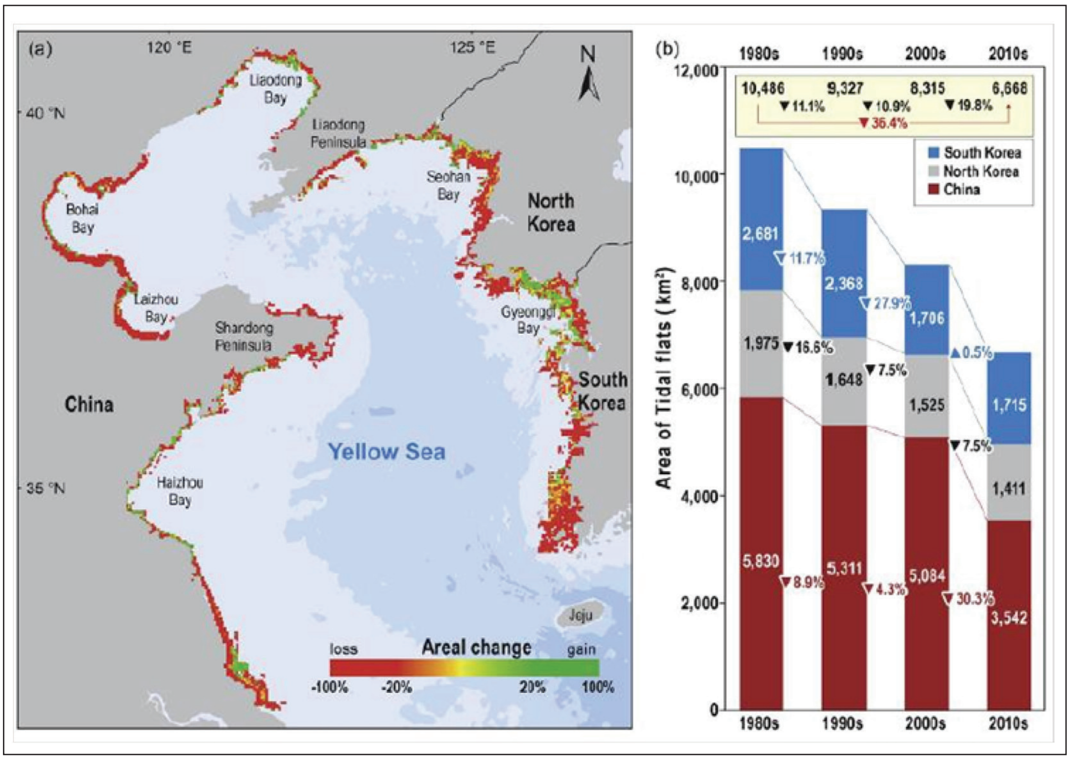
Preserving and restoring coastal wetlands are essential elements in the protection of Yellow Sea ecosystems. Wetlands are nurseries for key aquatic species in the Yellow Sea, are critical habitats for migratory water birds, and are intense zones of nutrient cycling. Located at the interface between land and sea, these wetlands also compete with human interests for development, and therefore are on the front lines of reclamation projects. Management actions in the YSLME Phase II SAP implementation project related to coastal wetlands involve developing management plans for the preservation of coastal habitats (Action 10.1) and for controlling reclamation demand (Action 10.3) in the coastal areas of the Yellow Sea (**Table 12**).

Table 12. Management Actions Related to Coastal Wetlands.

Action 10.1	Supplement and effectively implement plans for coastal management areas and develop guidelines for the preservation of coastal habitats.
Action 10.3	Control new coastal reclamation demand and implement proper management strategies.

Intensifying human activities, primary reclamation projects, have resulted in severe wetland loss. Compared with the 1980s, the YSLME lost 9,700 km^2 of sea area, with 40 percent of total natural tidal flats lost (Yim, et al., 2018) (**Figure 24**).

Figure 24. Areal change in the tidal mudflats from the 1980s to the 2010s.



Source: Yim et al., 2018.

PR China and RO Korea are both taking action to preserve and restore these critical habitats. According to China's Second National Wetland Survey, the coastal areas of the Yellow Sea account for just over 11 percent of the total wetlands in PR China. Of the 49 wetlands in PR China designated as International Important Wetlands, two are in the Yellow Sea region: The National Nature Reserve for Rare Birds in Yancheng, Jiangsu and the National Nature Reserve for Père David's Deer in Dafeng, Jiangsu (C-NSAP, p 55–56).

PR China has launched several wetlands conservation projects to mitigate the impact of reclamation and prevent habitat loss. According to the ecological redline policy, over 19,000 km^2 of coastal area in Liaoning, Shandong and Jiangsu provinces were designated as Development Restricted Zones (DRZs) or Development Prohibited Zones (DPZs). All construction activities are banned in DRZ areas, and construction is strictly controlled and reclamation is prohibited in DRZ areas.

There is an increasing number of protected wetlands in the Yellow Sea coastal area of China. Prior to 2007 there were three protected wetlands occupying 3,870 km^2. As of 2017, that number had grown to nine wetlands occupying 4,220 km^2 (C-NSAP, p 55-57). And finally, China's moratorium on coastal reclamation went into effect in 2018. The moratorium is intended to demolish illegally reclaimed land and to stop approving general reclamation projects.

Article 6 of Korea's Coast Management Act requires a national integrated coastal management plan every ten years at the national level (Article 6) and at the local government levels (Article 8). Management goals associate with the national plan include systematic management of all natural shores, mudflats, and coastal habitats. Mudflats, like coastal wetlands, are key habitats for shellfish, invertebrates, and migratory waterbirds along East Asian – Australasian Flyway (EAAF).

Monitoring efforts from 2003 to 2013 by local governments indicate that of the eight local regions participating in the monitoring study, half reported net gains in mudflat areas and half reported losses. In terms of total areas, though, there was a decisive gain in total mudflat area (19.0 km^2), compared with losses (5.5 km^2) (K-NSAP, p 104).

2.4.2 Priority Endangered and Threatened Migratory Species

The coastal wetlands and mudflats described previously are some of the key habitats for priority endangered and threatened species in the YSLME. It is additionally essential to protect endemic species and marine organisms (Action 9.1) in the Yellow Sea (**Table 13**).

Table 13. Management Actions Related to Priority Endangered and Threatened Migratory Species.

Action 9.1	Conserve the genetic diversity and population of endemic species and marine organisms under protection and develop regional management guidelines.

The wetlands of the Yellow Sea are critical to the survival of many migratory waterbirds using the EAAF, by providing staging and over-wintering habitats. The China Yellow (Bohai) Sea migratory bird habitat in Yancheng, Jiangsu Province has been recently listed as a UNESCO World Heritage site at the 43rd session of the World Heritage Committee. The Yancheng wetland is critical to the survival of many migratory waterbird species using the EAAF, by providing staging and over-wintering habitats for migratory waterbirds. During early winter, thousands of birds can be found in Yancheng area, either low flying or searching for food in great numbers.

A total of 3,941 Black-faced Spoonbills were recorded in the 2018 Global Black-faced Spoonbills Census, which was coordinated by the Hong Kong Bird Watching Association. The number of Black-faced Spoonbills in mainland China reached 744, an increase of 187 percent compared with 2017. China became the second largest habitat in the world for this species. (Source: SINA. http://news.sina.com.cn/o/2018-03-28/doc-ifyssrri4817579.html).

The Xiaoyangkou, Jiangsu wetland is one or the most important habitats for waterbirds in the Yellow Sea, according to a 2016 study of the Institute of Geographical Sciences and Natural Resource Research of the Chinese Academy of Sciences. It is critical to the survival of many migratory waterbird species using the EAAF. It is the staging and over-wintering habitats for migratory waterbirds, and home to about 370 species of birds recorded in this area. Some critically endangered species like the Spoon-billed Sandpiper, Baer's Pochard and White Crane, can be found in the area, too, according to the International Union for Conservation of Nature Red List of Threatened Species 2015 (C-NSAP, p 58).

Through the efforts of the Korean Ministry of Oceans and Fisheries, the Korean Ministry of Environment, NGOs, and other relevant organizations, projects have been undertaken to protect endangered marine organisms. These include rescuing sea turtles; securing the basis for marine life to reproduce indoors; protecting the habitat, and restoring the populations, of marine species under protection; and raising public awareness of the protection and management of marine life (K- NSAP, p 97-101).

A total of 202,360 sea birds of 87 species were observed in 2018 at 34 major coastal wetlands in RO Korea. The largest number of species was identified in Suncheonman Bay in Jeolla Province with 56 species and the largest population was observed in Biin/ Janghang in Chungnam Province with 53,860 individuals. Seaside birds observed in the above two regions accounted for the highest proportion with 64 percent of the total species and 27 percent of the population.

Suncheonman Bay is currently designated and managed as a Ramsar wetland and wetland protection area and is under constant protection management by the central and local governments. Suncheonman Bay's vast mudflats and farmland are considered the most important areas for the wintering duck and wild goose[4].

Other efforts undertaken by both PR China and RO Korea involve protecting the Bohai and Yellow Sea populations of Spotted Seal, which as adults inhabit the ice floes of the north Pacific Ocean and adjacent seas. However, Liaodong Bay in the upper reaches of the Yellow Sea serves as a breeding area for this population of Spotted Seal. Historically this population of Spotted Seals was abundant, with more than 8,000 in the 1940s. Over-hunting and wetland loss resulted in a dramatic decrease in populations. PR China listed this population as a second-class protected species and the National Nature Reserve for Spotted Seal in Dalian was designated in 1992. By 2007, the number of Bohai and Yellow Sea populations of Spotted Seal was 890. Conservation efforts have resulted in an increase in numbers, with 2,000 individuals counted in 2015 (C-NSAP, p 58-61).

4 http://www.ecosea.go.kr/ecbs_synreport/datacenter/doc/datacenter08Detail.do

Korean surveys of the same populations have been underway since at least 2002. In 2006, a survey of the habitat conditions of the Bohai and Yellow Sea populations of spotted seals in Baengneyong Island (Ministry of Oceans and Fisheries), and a survey of the habitat conditions by the Han River Basin Environmental Office (Ministry of Environment) were conducted. In addition to reports of annual populations, a service proving real-time video of the spotted seal habitat on Baengneyong Island was launched (**Figure 25**).

Figure 25. Real-time video service of the spotted seal habitat on Baengneyong Island.

Source: K-NSAP Figure 3.34 p 100.

2.4.3 Marine Protected Areas

Marine Protected Areas (MPAs) provide the refuges necessary for the conservation of wetlands and other critical habitats for rare and endangered species and other important marine organisms. PR China and RO Korea have undertaken systematic efforts to expand and manage MPAs and establish networks of MPAs (Action 10.2, **Table 14, Figure 26**).

Table 14. Management Actions Related to Marine Protected Areas.

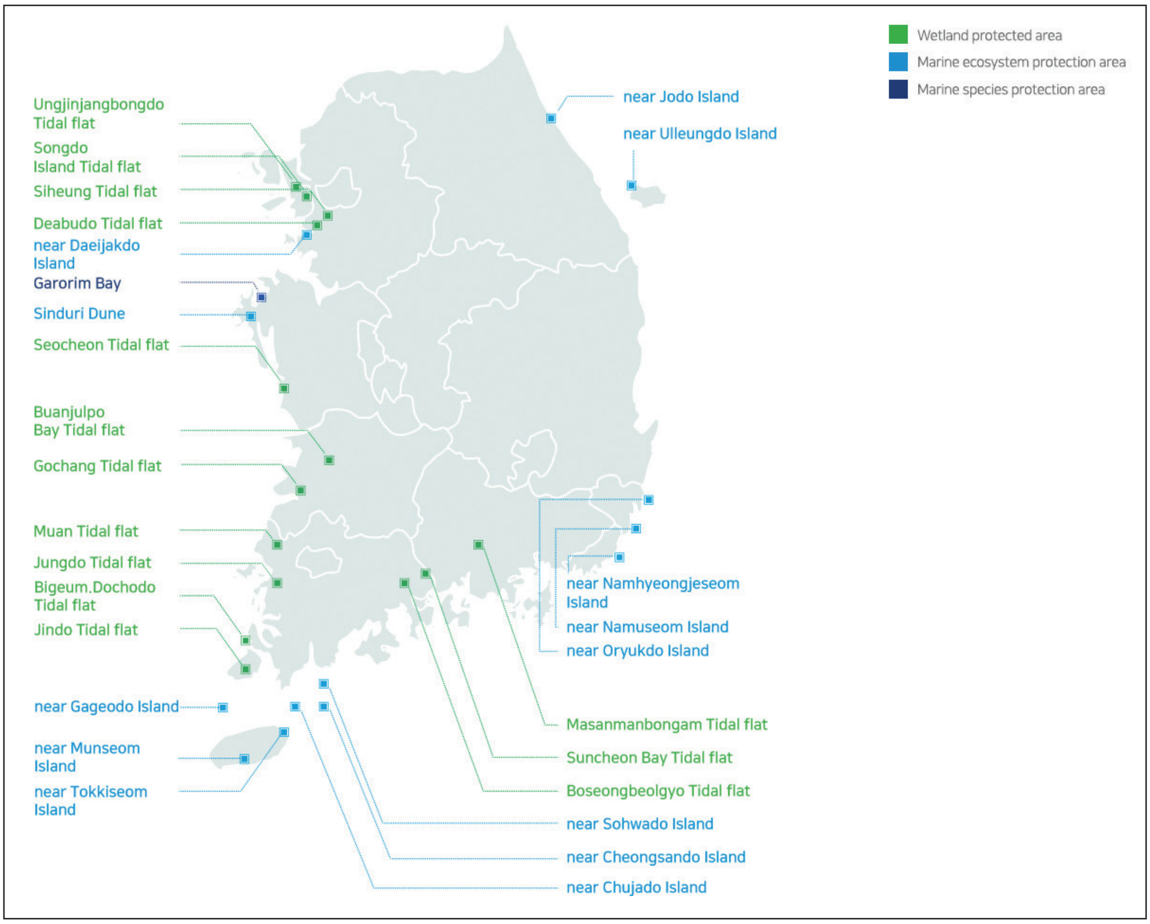
Action 10.2	Expand and effectively manage marine protected areas (MPAs) and establish a network of MPAs.

PR China has steadily increased the number of MPAs. More critical habitats have been protected through designation as MPAs after 2007 in YSLME region, including Bohai Sea. From 2007 to 2016, Yellow Sea MPAs in PR China increased from 22 to 52 in number and from 4,582 km^2 to 7,383 km^2 in area. By 2017, there were 31 national-level MPAs in the Yellow Sea area (C-NSAP, P 61).

In PR China, Aquatic Germplasm Resources Conservation Zone (AGRCZ) at national or provincial level is important to conservation of spawning, feeding, wintering grounds and migration corridors of key fishery resources with high economic value or areas with aquatic ecosystem with ecological or scientific research value. Up to 2017, 25 AGRCZs are designated in Yellow Sea region (excluding Bohai Sea), covering the sea area of 14,580 square kilometers. Within the conservation zones, land reclamation and building of new sewage outlets inside conservation zones are prohibited, according to the Interim Measures for the Administration of Aquatic Germplasm Resources Protected Zones issued in 2011 by the Ministry of Agriculture (now known as Ministry of Agriculture and Rural Affairs).

From 2011 to 2017, MPAs along the entire RO Korean peninsula increased from 15 to 28 in number and from 289 km^2 to 586 km^2 (**Figure 26**) (K-NSAP, Table 3.69, p 106). Pursuant to the National Land Planning and Utilization Act and Fishery Resources Management Act, 30 areas with 3,172 km^2, including the surface waters of 10 bays and 20 inland water bodies, have been designated as fishery resource protection zones at the end of 2017. (K-NSAP, p19)

Figure 26. Designated marine protected areas in Korea, as of 2018.

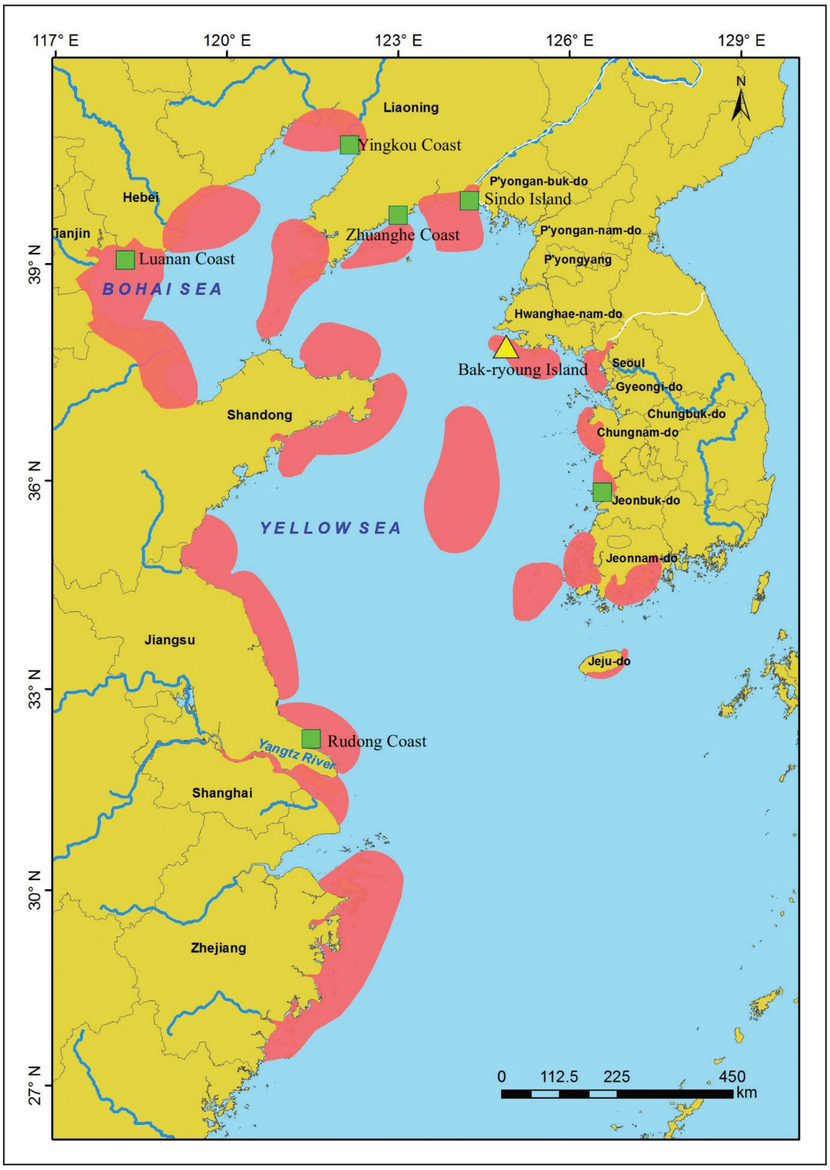


Source: K-NSAP Figure 3.37 p 105.

RO Korea has also led efforts to establish a domestic and international network of MPAs. The KOEM has been working to expand the domestic Mudflat Center Network more broadly to a Regional MPA Network. Further expansion of these efforts is anticipated to include the conservation and restoration of MPAs, establishment of a foundation for sustainable use and management of MPAs by strengthening domestic and international networks, and improvement of the brand value of MPAs by raising public awareness of MPAs (K-NSAP, p 105-106).

While progress has been made in creating MPAs, the areas available for rare, endangered, and protected species, though enlarged, are inadequate. Through support of YSLME Phase II Project, Liao et al (2019) reviewed the population and habitats, designation of MPAs and conservation gaps of Spotted Seals, Finless Porpoises and whales. Using the data of synchronized counting surveys conducted in PR China in 2016 and 2017, the results of survey conducted in DPR Korea in 2018, and the public information in Birds Korea and EAAFP, conservation gaps of waterbirds and their habitats in YSLME were also analyzed. Based on the review and field studies, six sites (i.e., Rudong Coast, Luannan Coast, Yingkou Coast, Zhuanghe Coast in PR China, Sindo Island in DPR Korea) were identified as spatial gaps for conservation of endangered waterbirds and their habitats. One site (i.e., Bak-ryoung Island) was identified as spatial gap for conservation of spotted seals and their habitat. (**Figure 27**).

Figure 27. Spatial gaps of endangered mammals and waterbirds and their habitats in YSLME.



Note: Green rectangles represent the spatial gaps of endangered waterbirds and their habitats; the yellow triangle represent the spatial gaps of endangered mammals and their habitats.
Source: Liao, G.X. & W, L., 2019.

2.4.4 Invasive Alien Species

Invasion of alien species is one of the main causes of biodiversity loss. YSLME Phase II SAP implementation project is addressing invasive species through the control and monitoring of the inflow (Action 11.1) and the prevention of new introductions (Action 11.2) of non-native species (**Table 15**).

Table 15. Management Actions Related to Invasive Alien Species.

Action 11.1	Control and monitor the inflow of non-native species by discharge of ship ballast water.
Action 11.2	Control non-native species efficiently with precautionary approaches.

Invasive species can be introduced inadvertently or intentionally. Marine systems are particularly vulnerable to invasive species released in the ballast water of ships, but also through accidental transportation through other means. According to Bai & Ma (2015), the number of marine invasive species in the YSLME was 120, of which, six species were microbes, 45 species were animals, and 69 were plants (C-NSAP, p 63).

Invasive species can also be introduced intentionally, because of their superior ability to perform some function in designed systems. The rooted wetland plant, *Spartina*, was introduced intentionally to PR China from USA in 1979 for ecological restoration projects. Due to its strong adaptability and high reproduction, it spread extensively along the coast of PR China, displacing native wetland species, resulting in significant impact on wetland ecosystem health. Studies conducted in the Yancheng National Nature Reserve from 2006 to 2015 observed an expansion rate for *Spartina* of 1.35 km^2/year (C- NSAP, p 63 – 64).

RO Korea has been extensively engaged in ballast water management. Their efforts include development of portable devices to detect the presence of microalgae in ballast water; developing land-based and movable water treatment facilities for ballast water, including strategies for exchange and disposal of ballast water; tightening regulatory requirements for reporting ballast water operations; and expanding the infrastructure and support for national research and development for ballast water management. Korea's activities also include conducting an international forum on ballast water and expert training (K-NSAP, p 112–119).

Korea's activities to control non-native species with precautionary approaches include revision of the regulation on and management system for the introduction of the introduced non-native species, conducting epidemiological and damage studies for non-native species and the creation of an information management system, a project to eliminate harmful marine organisms, and efforts to raise public awareness of and draw attention to the introduction of introduced species (K-NSAP, p 120-125).

Primary Problems and Root Causes

3

The 2007 TDA analysed primary problems in the YSLME, categorized by the four scientific components for which Regional Working Groups (RWGs) were formed. These were fisheries, pollution, ecosystems, and biodiversity (TDA 2007, Section 6). These problem areas were examined more deeply through causal chain analysis (CCA) exercises (TDA 2007, Section 7). For each problem, its fundamental problem, or driver, was identified. From there, the primary cause was determined, followed by intermediate causes, and finally a root cause was listed. Multiple causes may be attributed to problems. For example, the 2007 TDA listed six primary causes and 11 root causes for the problem of Eutrophication and Harmful Algal Blooms.

This detailed analysis of problems and their causes at the TDA level sets the stage for interventions that can be proposed at the SAP level. The hierarchy of primary, intermediate, and root causes allows for flexibility in the design of interventions. Primary causes, such as, "Sewage discharge into seas and rivers," can be more readily addressed through interventions, but do not address more fundamental causes of problems. Root causes, such as, "Limited influence of environmental constituency on government policies," address the most fundamental drivers of problems, but are difficult (or impossible) to solve through SAP interventions. Nonetheless, identifying root causes is essential for both understanding the ultimate drivers of priority problems, and to set courses to obtain aspirational goals.

The 2008 SAP translated the primary problems and causal chain analysis into a set of nine environmental problems and causes. In the process of updating the TDA, the primary problems were re-evaluated and a new causal chain analysis was conducted. Analysis of the data collected since 2007, and presented in Section 2 of this document, combined with the causal chain analysis exercise, indicates that the original nine priority problems still exist, but their relative impact on the YSLME has changed somewhat. These changes are reflected in the revised CCA, to be discussed below. Through consultations conducted as part of the TDA update process, national experts also concluded that the list of nine priority problems could be made more concise, while still capturing all of the relevant environmental and ecosystem concerns in the YSLME. The list was revised to the seven priority transboundary problems shown in **Table 16**.

Table 16. Primary Problems in the YSLME.

Fisheries	1. Fishing effort exceeding ecosystem carrying capacity 2. Mariculture facing unsustainable problems
Pollution	3. Pollution and contaminants
Ecosystem Changes	4. Eutrophication (combines jellyfish blooms and HABs) 5. Change in ecosystem structure 6. Climate change-related issues
Biodiversity	7. Habitat loss and degradation

The CCA in the 2007 TDA has been re-examined and updated through a process that started with the SAP Workshop conducted at the YSLME 3rd Science Conference in Qingdao, PR China, in July 2019. Subsequently the RWGs and other stakeholders have reviewed and updated the CCA. The updated CCA was validated at the YSLME 4th Interim Commission Council meeting in Jeju, RO Korea, in November 2019. These revisions provide the basis for examining the causes associated with the primary problems and for revising management actions in the SAP update. This section addresses the primary problems and their causes, as developed by the YSLME Phase I project, and re-evaluates them based on the findings of the YSLME Phase II project.

3.1 Fisheries

The Regional Working Group on Fish Stock (RWG-F) addressed problems associated with commercial fisheries and the Regional Working Group on Sustainable Mariculture (RWG-M) addressed problems associated with nutrients from mariculture in the YSLME phase II project.

3.1.1 Description of the Problem

The situation with regard to capture fisheries at the end of the YSLME Phase I project was dominated with problems of commercial overfishing. The capture production in the Yellow Sea grew at an explosive rate from 400,000 tonnes in 1986 to almost 2.5 million tonnes in 2004. This well exceeded the carrying capacity of the system, with commercial and ecosystem consequences. The composition of catches shifted to lower-value species, and ecosystem structures changed (SAP, p 4).

In this same period, the mariculture production in PR China grew to 13.84 million tonnes in 2005, thereby supplying 73.2 percent of the world's total demand for farmed marine organisms. The environmental impacts of this growth include increased release of organic wastes, and competition for food resources among cultivated organisms. These factors all increase stress and lower the growth and survival rates of cultured organisms, thus reducing productivity (SAP, p 5).

3.1.2 Progress in Addressing the Problem

The YSLME Phase II project addressed capture fisheries and mariculture in a series of separate management actions (Tables 3.1 and 3.2). With regard to capture fisheries, management actions associated with buy-back programs for fishing vessels (Action 1.1) and closure of fishing areas and season (Action 1.2), had immediate and significant positive impact on fisheries in the Yellow Sea. Management actions calling for increased mesh size (Action 2.1) and fish restocking (Action 2.2) also contributed to recovery of the YSLME fisheries. While the recovery of fisheries is being observed, continued efforts to decrease fishing pressure and improve capture fishing practices are necessary.

A key vulnerability in mariculture is the growth and transmission of diseases, due to the high density of organisms. Important progress has been made during the YSLME Phase II project on developing early warning diagnosis systems for detecting and responding to disease outbreaks.

Maricultural practices in the Yellow Sea have progressed towards ecological, efficient and environmentally friendly path during the Phase II project. Project activities have investigated and promoted Integrated Multi-trophic Aquaculture (IMTA) and improved technology for seawater recirculating aquaculture systems (RASs). These promising advancements may appeal to commercial interests through improved productivity, but ultimately will require regulatory pressures to be implemented at large scales in the YSLME.

3.1.3 Emerging Problems

Emerging problems related to capture fisheries and mariculture include:

- Hidden risks from lack of assessment of marine ranching to the marine environment as a part of the management actions
- Re-employment of displaced fishers remains top on the agenda of both governments
- Increasing impact of extreme climate and heatwave to the mariculture

With regard to the last problem, climate change impacts oceans, coastal and inland waters. It is believed that coastal systems and lower-lying areas will face increasing risks of flooding, seawater intrusion, coastal erosion and saltwater intrusion. Coastal systems face the most serious risks. For example, predictions of elevated carbon dioxide concentrations in seawater and the resulting acidification problems will have a physiological impact on the growth and reproduction of bivalves, which may affect the quality of the shell. However, climate warming will also increase the rate of attachment and growth of shellfish and expand the latitude of aquaculture, so climate change may also bring benefits.

3.1.4 Causal Chain Analysis

The updated causal chain analysis for fisheries is provided in the Annex 2. Compared with the Causal Chain Analysis from the 2007 TDA, concerns regarding overfishing have been decreased, but vigilance is still necessary for recovery of the capture fishery, particularly species of greatest commercial interest. Overexploitation of target fish species and over-capacity of fishing fleets remain primary and intermediate causes for unsustainable fishing practices in the YSLME. While retraining programs have been underway, inadequate alternative livelihoods remains as an underlying cause. Increased reliance on mariculture has the potential to create greater pollution impacts on the YSLME. The primary cause for unsustainable mariculture practices was identified as maricultural development exceeding ecosystem carrying capacity, with resulting negative environmental impacts. Underlying and root causes pointed to insufficient understanding of ecosystem carrying capacities, a lack of awareness of sustainable mariculture practices, and a poor understanding of ecosystem-based mariculture practices.

3.1.5 Preliminary Recommendations to Guide SAP Update

Capture fisheries:

1. Implement and improve the existing input control management system and introduce advanced output control management system;
2. To effectively manage the license system, conduct scientific survey and evaluations to have a comprehensive and accurate understanding of fishery resources in a collaborative manner;
3. Conduct joint conservation on the fish species of the Yellow Sea region.

Mariculture:

1. Establish aquaculture carrying capacity management for important species and typical aquaculture areas.
2. Require that aquaculture waste water comply with industrial standards.
3. Standardize aquaculture and promote mechanized aquaculture. This can result in 30 percent to 50 percent improvement in production efficiency.

3.2 Pollution

The 2009 SAP initially identified pollution and contaminants under the heading, "pollution." In the YSLME Phase II project, the Regional Working Group on Pollution Reduction (RWG-P) added microplastics as a pollutant. Other concerns are increases in atmospheric deposition of particulate matter (PM10 and PM2.5) associated with industrial emissions, and emerging contaminants associated with wastewater discharges.

3.2.1 Description of the Problem

Pollutants entering the YSLME have both land-based and marine origins. Land-based pollutants consist primarily of nutrients, sewage, heavy metals, organic contaminants and marine litter released from agricultural, municipal, and industrial sources. Marine pollutants can include nutrients and pathogens, but are primarily oil, persistent organic pollutants (POPs) and other toxic contaminants released from marine vessels. Marine litter, consisting primarily of plastic waste, can have terrestrial and marine origins. In the Yellow Sea, a significant source of marine litter is the decomposition of EPS buoys.

3.2.2 Progress in Addressing the Problem

An important area of progress in the YSLME Phase II project has been to develop coordinated monitoring programmes. Water, sediment, and atmospheric quality monitoring programs have long been extant, but the Phase II project has enabled reliable baseline information to be collected, against which future changes can be evaluated (Actions 4.1 and 7.1). With regard to actions for reducing the quantity of land-based pollutants, both point sources of municipal and industrial waste (Action 5.1) and non-point sources of agricultural runoff (Action 5.2) have been targeted for reduction through facility upgrades, construction of new facilities, and implementation of best practices. Additionally, new regulatory approaches oriented toward limiting the total allowable amounts of pollution discharge from specific regions or water systems is being implemented (Action 5.3). In western Yellow Sea, monitoring results indicate a decrease in polluted sea areas from 2012 to 2018, with inorganic nitrogen, active phosphate and oil as the main pollutants. Marine sediment data indicated overall low pollutant burdens and improving conditions from 2007 to 2017. The trend of COD in eastern Yellow Sea appears to be stable from 2010 to 2016.

Marine litter and contaminants are the other major pollutants. Progress in decreasing marine litter have focused on reducing the amount of litter generated such as port cleanup, buy-back programs for litter recovered during fishing operations and the systematic replacement of EPS buoys with biodegradable buoys (Action 6.1), strengthening capacities to collect and treat marine litter (Action 6.2), and developing information management systems and increasing public awareness for litter (Action 6.3).

Progress toward resolving problems of marine contaminants has been oriented toward complying with international conventions (Actions 4.2 and 4.3). Both PR China and RO Korea are signatories to Stockholm Convention, Minamata Convention on Mercury, MARPOL and other conventions and international standards related with discharge of toxic pollutants and have actively supported their implementation. Examples include PR China's measures to eliminate the production of a large quantity of POPs, and prohibition on the production, circulation, use, and import or export of DDT, chlordane, and mirex. Another example is RO Korea's adoption of two protocols related to toxic discharges at sea: the International Convention on Oil Pollution Preparedness, Response, and Co-operation (OPRC) and the Incidents Protocol on Preparedness, Response, and Co-operation to Pollution Incidents by Hazardous and Noxious Substances (OPRC-HNS).

3.2.3 Emerging Problems

The 2019 CCA exercises also identified several emerging issues, all of which were considered to be on a trend toward worsening conditions.

- Increase in atmospheric particulate matter (PM10 and PM2.5).
- Microplastics prevalent in all trophic levels of the ecosystem.
- Contaminants of emerging concern including pharmaceuticals

3.2.4 Causal Chain Analysis

The 2019 CCA exercises for pollution confirmed that the issues and primary concerns identified in the 2007 TDA still existed, but with trends of improving conditions. Fundamental problems carried over from the 2007 CCA consisted of nitrogen enrichment, heavy metal and hazardous organic pollutants, and marine litter. The causes for nitrogen enrichment included domestic, industrial, agricultural, and airborne terrestrial sources, as well as the aquatic source of maricultural activities. Intermediate causes for these sources generally consisted of a lack of investment in prevention and control technologies, or a lack of expertise and understanding on applying best practices for pollution control. Progress has been made in relieving these stresses through investments in infrastructure improvements, as indicated above. Root causes included economic development, population growth, and limited influence of environmental constituencies on government policies.

The causes for pollution from hazardous organic pollutants and heavy metals included terrestrial sources delivered as atmospheric pollution and in runoff. These were associated with power generation, oil refining, heavy industry, vehicle traffic, and solid waste incineration. Atmospheric sources also included long-range transport. Marine sources included shipping emissions and oil spills. Intermediate causes included increased demand associated with population and economic growth, inadequate application of prevention and control technologies, and inadequate recognition of the magnitude of the environmental impacts of these releases. Root causes included inadequate regulatory and compliance mechanisms, and limited compliance with international conventions (i.e., MARPOL, Stockholm Convention, OPRC, and OPRC-HNS).

The primary causes for marine litter continue to be primarily plastic wastes from terrestrial sources and Styrofoam wastes from marine sources (buoys). Intermediate causes include inadequate containment of terrestrial litter, inadequacies in management of land, and lack of public awareness. Root causes include lack of financial resources and inadequacies in public policies and regulations.

Primary and intermediate causes for emerging PM10 and PM2.5, microplastics and contaminants of emerging concern included increased industrialization, overuse of plastics, inadequate prevention and controls, and inadequate treatment of domestic sewage. Root causes included limited or inadequate regulatory mechanisms and limited influence of environmental constituencies on the development of governmental policies.

3.2.5 Preliminary Recommendations to Guide SAP Update

In order to improve the prevention and control of nutrients, contaminants and marine plastics in the Yellow Sea region, it is suggested to carry out the following actions in SAP:

1. Control the release of nutrients and contaminants from point and non-point terrestrial sources, from the atmosphere, and from ships and harbors to protect human health and ecosystem.
2. Reduce the exposure to microbial and viral pathogens, toxins from certain types of algae blooms, and pharmaceutical products that are acutely dangerous to human health.
3. Strengthen marine microplastics monitoring to provide scientific data support for pollution prevention and control, and put forward effective strategy and management measures for marine microplastics.
4. Control the input of "raw" plastic debris from land-based source, such as decreasing or eliminating the usage of disposable plastic products and encouraging the recycle usage industries of plastic, to prevent the plastic debris from moving to sea through rivers and estuaries.

3.3 Ecosystem Changes

In the CCA, the Regional Working Group on Assessment and Monitoring (RWG-A) found that the ecosystems of the YSLME responded to the primary drivers of change: nutrient and pollutant loading, which first affects the lowest trophic levels of the ecosystem in a "bottom up" fashion, and commercial fishing pressure, which first affects the highest trophic levels of the ecosystem in a "top down" fashion. Therefore, while pollution and fishing are issues and concerns in other areas of this work, they are fundamental drivers or primary causes with respect to ecosystem changes.

3.3.1 Description of the Problem

The main problems addressed are nutrient over-enrichment or imbalance (eutrophication), resulting blooms of harmful algae (HABs) and jellyfish, and overall changes in ecosystem structure. Climate change impacts can affect any of the trophic levels individually, but collectively add to the overall changes in ecosystem structure. Monitoring programs described previously in "Pollution" were used to evaluate nutrient ratios, primarily the elemental ratios of nitrogen to phosphorus and nitrogen to silicate. These ratios can indicate over-enrichment of nitrogen, which can lead to a dominance in undesirable algae over diatoms. Decreases in the dominance of diatoms can lead to harmful algal blooms and lead to changes in ecosystem structure that favor lower-valued fish species.

Blooms of harmful algae and jellyfish are themselves a nuisance. In the case of HABs, the release of toxins can result. In the case of jellyfish, this can result in human health risks through stings and consequently impact tourism. A direct impact of climate change on ecosystems is the shift in the location and abundance of temperature-sensitive species as a result of warming.

3.3.2 Progress in Addressing the Problem

The Phase II YSLME project has established baseline monitoring for nutrient ratios; the presence, duration, and extent of nuisance blooms; and measures of climate change. These data are being used in predictive modelling studies to anticipate changes in ecosystem structure. Examples of the results of these efforts include observed decreases in the ratios of nitrogen to phosphorus and nitrogen to silicate in the Korean waters of the YSLME. This is an early indication that diatoms may be able to compete for dominance in that ecosystem. Another example is a modelling student to understand the impact of climate warming on the distribution of the economically important Japanese anchovy. Preliminary results indicate a northward shift in the abundance of this species.

3.3.3 Emerging Problems

1. Greater recognition of the extent of indirect and direct climate change impacts, including changing terrestrial erosion patterns and sea-level change impacts on coastal zones (mudflats and wetlands).
2. *Sargassum spp* outbreaks and impact to tourism in RO Korea and mariculture in northern coast of Jiangsu.
3. Declining frequency of HABs, with increased proportion of toxic species.
4. Decreased alkalinity at the bottom waters of the YSLME and vulnerability to potential negative effects of ocean acidification.

3.3.4 Causal Chain Analysis

The 2019 CCA exercise for ecosystem impacts confirmed that the primary issues consisted of changes in biomass, changes in both water column and benthic species composition, toxic algae blooms, and loss of benthic habitat in coastal areas. Trends for most of these sources were determined to be toward worsening conditions, due primarily to climate change effects. Primary and intermediate causes included eutrophication, overfishing, climate change, and development in coastal zones. Root causes include climate change and economic development without adequate consideration of marine environmental consequences.

Two new issues and concerns were identified in the 2019 CCA. First, the concern of Toxic Algae Blooms was re-identified as Harmful Algal Blooms. Harmful Algal Blooms were considered to be greater threats than in the previous CCA. HABs were connected to both poorly controlled nutrient management and greater threats to human and ecosystem health. Second, the lack of ecosystem resilience to withstand disasters and climate change was identified as an issue/concern. The fundamental problem/driver associated with this lack of resilience was that ecosystems are becoming more vulnerable to damage and impairment of functions due to human impacts.

3.3.5 Preliminary Recommendations to Guide SAP Update

Management actions from the 2008 SAP continue to be relevant to improve the state of YSLME ecosystems. The following management actions are recommended:

1. Monitor and assess changes in ecosystem structure and apply integrated management of ecosystems to reduce the occurrence of HABs and jellyfish blooms
2. Enhance the disaster prevention and reduction function of marine ecosystems and reduce the losses caused by natural disasters.
3. Develop and implement effective and timely adaptation strategy to monitor, assess, prepare and respond to impacts of climate change.

3.4 Biodiversity

Preserving coastal habitats is at the core of protecting biodiversity in the YSLME, concluded in the CCA process conducted by the Regional Working Group on Habitat (RWG-H). The 2008 SAP reports that, "Habitat has been lost at a staggering rate, with almost 40 percent of coastal wetlands being converted to other uses" (SAP p 5). China's moratorium on reclamation and regional efforts to expand MPAs are improving the habitats that can support increases in biodiversity.

3.4.1 Description of the Problem

Biodiversity can be threatened in the YSLME through the destruction or degradation of habitats and through the introduction and continued spread of invasive alien species. Coastal wetlands and mudflats are important habitats for shellfish fisheries, culture, and many of the commercially important fish species use these areas as nursery or feeding grounds at some stage in their life cycle. Additionally, many endangered bird species depend on these coastal areas as staging, feeding and breeding grounds on the migration routes. In addition, wetlands perform important biogeochemical functions, such as sediment retention, carbon sequestration, nutrient cycling, prevention of saltwater intrusion, and coastline stabilization (SAP, p 5).

Invasive alien species create problems in both coastal and open-water areas. The introduction of non-native wetland plants, notably spartina (*S. alterniflora*), has resulted in the loss of abundance and diversity of native species of wetland plants. The introduction of non-native planktonic species through uncontrolled releases of ballast water has threatened YSLME ecosystems with imbalances in ecosystem structure. *S. alterniflora* is included on the first batch of PR China invasive species list. It was originally distributed in the coast of American Atlantic. It was introduced into China from the U.S. in 1979 for its ability in ecological restoration. But, due to its strong adaptability and high reproduction, it spread extensively in the coast of China, especially in Jiangsu coastal wetland, resulting in significant impact on wetland ecosystem health and safety.

3.4.2 Progress in Addressing the Problem

Activities to protect biodiversity in the Phase II YSLME project are placed in the categories of coastal wetlands and reclamation, priority threatened and endangered migratory species, marine protected areas, and invasive alien species. Efforts to protect coastal habitats and the biodiversity they support include regulatory controls on development in coastal zones and establishment of new marine protected areas. Activities to prevent or control the spread of invasive alien species have been targeted to developing better technologies to detect planktonic invasive species and to better manage ballast water.

3.4.3 Emerging Problems

Two key emerging problems have been recognized: alterations in habitats for the spotted seal and critical vulnerability of migratory waterbirds due to a lack of MPAs. Identification and construction of MPA network is an effective way to protect biodiversity and adapt to impact of climate change. A better planned MPA network could bring more benefits to ecosystem than the total of every single member of this network. Currently, the MPA network construction is far from being completed. To better construct a YSLME MPA network, scientific tool for MPA planning was developed and conservation gap analysis was also conducted for mammals and migratory shorebirds with support of YSLME Phase II Project.

The spotted seal (*Phoca largha*) inhabits the ice and waters of North Pacific Ocean and adjacent seas, and Liaodong Bay in PR China is the southern-most of the eight putative breeding grounds. The population in Bohai and Yellow Sea of spotted seal is a national second-level protected wild animal in PR China. It is the only pinniped marine mammal that can breed in PR China's waters. It is an important flagship species for aquatic wildlife protection and has important ecological, cultural and social values. Spotted seals are mainly distributed in the Bohai Sea and the Yellow Sea. For protecting spotted seal, the governments of PR China and RO Korea have established MPAs in Yellow Sea and Bohai Sea. Meanwhile, spotted seal has high mobility with seasonal migratory in the distribution region. Many countries are located along its migratory route: PR China, RO Korea, Japan, DPR Korea, and Russia. The protection status of spotted seal may be different in these countries. To strengthen the protection of spotted seals, marine protected areas network should be established in their main habitats to form a complete marine protection network system.

The Yellow Sea coastal area is an important stop for migratory waterbirds on the East Asian-Australian Flyway. Many important wetlands that constitute the stopovers for these birds are irreplaceable, and coastal development and marine engineering encroach many intertidal zones, especially the high-tide zone. Shorebirds' main foraging areas are concentrated in the mid-tide and low-tide zones. When the tide rises, the shorebirds fly to the high tide zone, which provides safe and undisturbed areas. The absence of these high-tide zones will force shorebirds to fly further afield near ponds or other human structures, and will have to face more threats. Restoring or manually building some high tide zones for bird resting in the area can mitigate the impact of habitat loss on endangered shorebirds.

3.4.4 Causal Chain Analysis

Primary issues and concerns related to biodiversity overlapped to some extent with the CCA for ecosystems and included loss of biodiversity, changes in community structure, habitat loss and degradation, and changes in species abundance and diversity. While the ecosystems CCA showed trends of decreasing conditions, most of the fundamental problems related to biodiversity showed improving trends. In both the ecosystems and biodiversity CCAs, trends in decreasing quality were associated with climate change root causes. For the biodiversity CCA, nearly all of the fundamental problems were related to primary and intermediate causes that have either been addressed through management interventions, or for which environmental stress has been decreased through other means.

The main fundamental problems for biodiversity included habitat loss and modification, declines in anadromous and catadromous fisheries, and declines in threatened and endangered species, including birds, sea turtles, and marine mammals. Primary and intermediate causes included increased demands for coastal lands and seafood, increased damming of rivers, degradation and fragmentation of habitats, destruction of coastal habitats, and unsustainable egg harvesting and hunting. Root causes included economic and population growth without adequate consideration of the stresses placed on ecosystems, and development undertaken in the absence of comprehensive and coherent legislation for environmental and biodiversity protection.

3.4.5 Preliminary Recommendations to Guide SAP Update

1. Preserve, protect and conserve the wellbeing of threatened and endangered marine mammals and migratory birds and their habitats through MPA networks and other area-based measures.
2. Conduct surveillance and control programs necessary to prevent the introduction and spread of invasive species.
3. Carry out ecological protection, restoration and rehabilitation of degraded wetlands.

Conclusions and Recommendations 4

4.1 Conclusions

This TDA Update reflects new perspectives on the transboundary YSLME. These perspectives have been shaped by new scientific data collected in the YSLME; from the impacts of governance, legislative, and regulatory change put in place since 2007, and from changes in our awareness of the impacts of climate change and emerging pollutants. The activities of the YSLME Phase II project have been responsible for some of the developments that led to these new perspectives.

The key outcomes of the TDA Update process were the following:

1. Provide a summary of the state of the YSLME, with regard to fisheries, pollution, ecosystem changes, and biodiversity.
2. The nine priority problems (Table 15) identified in the 2007 TDA remain valid.
3. A set of primary, underlying, and root causes for these problems were reviewed and updated through a Causal Chain Analysis (CCA) exercise.
4. Emerging problems or concerns in the YSLME are identified.

Through regional validation meetings and deliberations among RWGs and national stakeholders, it was determined that the nine priority problems remain valid and that no additional primary problems need to be added. It was determined that some of the nine problems were similar enough that the list could be focused into the following seven primary transboundary problems:

1. Fishing effort exceeding ecosystem carrying capacity
2. Unsustainable mariculture
3. Pollution and contaminants
4. Eutrophication
5. Change in ecosystem structure
6. Habitat loss and biodegradation
7. Climate change

An updated causal chain analysis revealed that some of the issues, concerns, and primary drivers associated with primary problems have changed since 2007. The updated CCA also reflects changes in our understanding of primary, intermediate, and root causes for these concerns. Underlying and root causes often relate to governance, legislative, and regulatory limitations. Progress with governance and regulatory frameworks has addressed some of these problems. New concerns have also emerged and have been included in the CCA.

Emerging problems have also been identified in the updated TDA. These include:

- **Fisheries**
  - Lack of assessment of the impacts of marine ranching on the YSLME
  - Re-employment of displaced fishers
  - Increasing impacts of climate change on mariculture
- **Pollution**
  - Extent of microplastics pollution at all trophic levels.
  - Emerging contaminant including pharmaceuticals.
- **Ecosystems**
  - Direct and indirect effects of climate change on ecosystems
  - Changes in the patterns and frequency of harmful algal blooms and drifting macroalgae
  - Decreased alkalinity at the bottom waters of the YSLME and vulnerability to potential negative effects of ocean acidification
- **Biodiversity**
  - Increased migration of spotted seal away from the Bohai Sea and YSLME
  - Need to expand marine protected areas to protect threatened and endangered transboundary species with conservation gaps

The data and insights collected in the updated TDA will be directly applied to the process of updating the YSLME SAP. Targets and management actions will be reviewed based on the material gathered in Section 3 (Primary Problems and Root Causes) of this document and the CCA.

4.2 Recommendations for SAP Update

The 2009 SAP was organized around the concept of ecosystem carrying capacity and ecosystem services, with four separate service types (Provisioning, Regulating, Cultural, and Supporting) addressing the 11 targets identified in the SAP. An important advantage of applying the concepts of ecosystem carrying capacity and ecosystem services in the YSLME Phase II project was the recognition of the value that stable, resilient ecosystems can provide, both for the sustainability of the ecosystems and for human livelihoods themselves.

The next phase in managing the YSLME can build on the success of these approaches by:

- Retaining the orientation toward the ecosystem services
- Incorporating integrated ecosystem management approaches
- Applying concepts in nature-based solutions

Integrated ecosystem management applies a systemic thinking approach which recognizes the connectivity of ecosystems. For example, planning for MPAs should consider the importance of providing corridors for the safe movement of the marine organisms being protected. Therefore, planning for MPA networks, rather than considering MPAs to be isolated patches, results in more effective protection for marine ecosystems

Integrated ecosystem management concepts can be implemented through nature-based solutions (NBSs). In broad terms, NBSs are strategies to use natural or engineered ecosystems to assist in managing the effects of human disturbance, while also performing their natural functions as stable, resilient ecosystems. One example is the use of constructed wetlands to sequester land-based nutrient loads, while also serving as coastal protection barriers against waves, and serving as nursery habitats for migratory birds. The NBS approach augments ecosystem services approaches and permits broader, systemic approaches in ecosystem management.

The SAP Update should build on the primary transboundary problems identified in the updated TDA and on the Causal Chain Analysis (CCA) conducted as part of the TDA Update. These priority transboundary problems and the root causes and recommendations resulting from the CCA should form the basis for a set of ecosystem targets to be achieved or significantly addressed by 2030.

The targets will be operationalized through a set of management actions for each target. Management actions in the SAP may include regional coordination for monitoring programmes and data sharing, regional MPA networks, and legal and institutional mechanisms that benefit from bilateral cooperation. The targets identified in the SAP can be elaborated upon in NSAPs. These documents will use the SAP as a starting point and will operationalize the targets through the mutually agreed upon SAP management actions. These targets should also include nationally relevant management actions. This approach is identical to the NSAPs produced by each country for the YSLME Phase II Project.

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Annex

Causal Chain Analysis, 2020 Update

Causal Chain Analysis – Pollution

↑ Improving ↓ Getting worse

Issue/ Concern	Fundamental Problem/ Driver	Priority	Trend	Primary Cause	Secondary Cause	Tertiary Cause	Root Cause
Emerging issues	Air pollution: PM10 and PM2.5	High	↓	Emissions from industry	Limited technical solutions	Industrialization and urbanization	Inadequate legislative and regulatory controls
	Marine plastics	High	↓	Marine plastics from land and sea	Overuse of plastics		
					Inadequate control of terrestrial and marine litter		See "Marine Litter Contamination" below
	Contaminants of emerging concern	High	↓	Sewage discharge into waterways and sea	No tertiary sewage treatment		Limited application of research knowledge of assimilative capacity calculations
					Inadequate urban sewage treatment capacity		Limited influence of environmental constituency on governmental policies
					Inadequate understanding of the type and occurrence of emerging contaminants		Low awareness and knowledge of health risks of emerging contaminants
Eutrophication and harmful algae blooms	Nitrogen enrichment	High	↑	Sewage discharge (treated and untreated) into the rivers and sea.	No tertiary sewage treatment	Limited knowledge of capacity of system to absorb nitrogen	Limited application of research knowledge of assimilative capacity of ecosystem
					Limited investment in urban infrastructure	Rapidly increasing urban sewage and limited sewage treatment capacity	Limited influence of environmental constituency on government policies
					Inadequate separation of sewage and stormwater drainage systems	Cost of separating sewage and stormwater in long-established urban areas	Limited influence of environmental constituency on government policies
						Where such separation exists, it is frequently overwhelmed by major storm events	Limited influence of environmental constituency on government policies
				Toxic substance leakage from chemical industries			Irrational industrial distribution
				Residues released from mariculture	Density of mariculture (i.e., gages and ponds) exceeds capacity to absorb nitrogen (compounded by over-feeding of stock)	Lack of recognition of the assimilative capacity of YS system to absorb nutrient releases	Insufficient maricultural management (High density of localized mariculture)

Causal Chain Analysis – Pollution (cont.)

↑ Improving ↓ Getting worse

Issue/ Concern	Fundamental Problem/ Driver	Priority	Trend	Primary Cause	Secondary Cause	Tertiary Cause	Root Cause
				Agriculture - Arable farming runoff	Overuse of fertilizers and limited control of waste runoff from agricultural activities	No use of buffer zones for nutrient assimilation; inadequate recognition of problems at national levels	Inadequate balance between development and environment; insufficient application of good agricultural management practices
				Agriculture – Livestock runoff; nutrients into freshwaters	No use of buffer zones for nutrient assimilation.	Inadequate recognition of problem at national levels	Inadequate balance between development and environment
				Atmospheric deposition	Industrial and vehicle emissions	Substantial increase in standard of living	Large-scale economic development
Contaminants and Their Effects	Fecal bacterial contamination and associated risks to human health	Medium	↑	Discharge of domestic sewage	Inadequate urban sewage treatment capacity	Korea – Limited investment in urban infrastructure China – Rapidly increasing urban populations and limited investments in urban infrastructure	Limited attention to the problem in sewage treatment in relation to human health protection
	Chemical and pharmaceutical residues in farmed organisms.	High	↑	Untreated sewage loading from urban areas	Inadequate advanced treatment of domestic sewage	Limited investment in urban infrastructure; insufficient understanding of health effects of emerging contaminants	Limited attention to the problem in sewage treatment in relation to human health protection
Industry, Oil Spill, Transportation, and Chemicals.	PAH contamination	High	↑	Shipping emissions	Increase in the number and size of vessels	Increase in demand for marine transportation	Limited compliance with MARPOL Convention
					Ships are using inadequate fuels		Limited compliance with MARPOL Convention
				Power generation emissions.	Limited use of atmospheric scrubbers	Inadequate recognition of problem at national levels.	Limited development of emission controls on industry
					Power plants are using inadequate fuels (coal and oil)		Limited development of emission controls on industry
					Growth in demand for electrical power	Inadequate recognition of problem at national levels	Limited development of emission controls on industry

Causal Chain Analysis – Pollution (cont.)

↑ Improving ↓ Getting worse

Issue/ Concern	Fundamental Problem/ Driver	Priority	Trend	Primary Cause	Secondary Cause	Tertiary Cause	Root Cause
				Oil spills	Discharge of improperly treated bilge water		Limited compliance with OPRC & OPRC-HNS
					Inadequate spill prevention		Limited compliance with OPRC & OPRC-HNS
				Oil refinery emissions	Increased PAH released from refining activities & increased demand for refined oil products	Limited controls on PAH releases	Limited development of controls on emissions from industry
				Steel production emissions	Increased demand for steel	Limited controls on PAH releases	Limited development of controls on emissions from industry
				Home heating emissions	Limited use of renewable energy sources for home heating purposes	Limited incentives for renewable power generation	Absence of balanced energy policy based on the need to mitigate climate change and protect the environment
				Diesel engine emissions	Increased traffic due to economic growth		Regulatory infrastructure does not keep pace with economic growth
				Road paving emissions	Increased need for road paving due to economic growth		Regulatory infrastructure does not keep pace with economic growth
	Heavy metal contamination (Cd, Pb, Zn, Cu, Hg, Cr.)	Medium	↑	Release of metals from industry	Inadequate compliance with regulations	Limited compliance assurance infrastructure	Inadequate compliance enforcement
					Improper treatment of solid and liquid waste		Lack of technology and investment
				Release of metals from vehicles	Limited restrictions in metals releases from transport		Inadequate regulatory infrastructure or compliance
		Medium	↑	Long distance transport from other areas	Emissions to atmosphere in other regions of the world	No jurisdictional influence except through international conventions	NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention

Causal Chain Analysis – Pollution (cont.)

↑ Improving ↓ Getting worse

Issue/ Concern	Fundamental Problem/ Driver	Priority	Trend	Primary Cause	Secondary Cause	Tertiary Cause	Root Cause
				Release of used PCB- containing dielectric / coolant oils	Inadequate facilities for decommissioning transformers, capacitors, and other PCB- containing equipment in the electrical industry		NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention
		Medium		Incineration of solid wastes	Inadequate segregation of wastes	Poor regulation of solid waste management and recycling	NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention
	PCDD & PCDF Contamination	Medium	↑	Incineration of solid wastes	Inadequate segregation of wastes.	Poor regulation of solid waste management and recycling	NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention
				Emissions from the steel industry	Uncontrolled combustion without scrubbing	Limited implementation of release controls	NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention
				Emissions from the pulp and paper industry	Use of outdated pulping technologies and contaminated feedstock	Limited implementation of process and release controls	NB: Development and administration of regulations will be promulgated under NIPs for implementation of the Stockholm Convention
	Marine litter contamination	High	↑	Releases of anthropogenic wastes from land-based sources	Inadequate classification of solid waste management and treatment	Lack of appreciation that marine litter is a problem	Low awareness of impact of marine litter entering coastal waters
				Releases of anthropogenic wastes from sea-based sources	Usage of EPS buoys and fishing gear for aquaculture	Lack of public awareness	Lack of financial resources
				Transport of natural materials from land- based sources into the marine environment	Natural materials mobilized by floods and storms	Inadequacies in land management: forestry, agriculture, parks, and public spaces	Inadequacies in public policies, legislation, and regulations to address comprehensively land- based sources of marine pollution

Causal Chain Analysis – Ecosystem

↑ Improving ↓ Getting worse

Issue/ Concern	Fundamental Problem/ Driver	Priority	Trend	Primary Cause	Secondary Cause	Tertiary Cause	Root Cause
Changes in Biomass and Species Composition	Change in phytoplankton abundance and composition	Medium	↓	Eutrophication & overfishing of commercially valuable species	Regional climate change		NB: This is a global issue and relates to the implementation of the FCCC. Both countries are parties to the Kyoto Protocol. Human activities (Related with eutrophication's root causes.)
	Shift in the penology of phytoplankton & zooplankton biomass & composition	Medium		Regional climate change			NB: This is a global issue and relates to the implementation of the FCCC. Both countries are parties to the Kyoto Protocol
Changes in Species Composition	Decrease in ratio of diatoms to dinoflagellates (China)	High	↓	Changes in nutrient concentrations and ratios	Changes in nutrient fluxes	Rapid development of coastal zone	Inadequate controls on economic growth
	Jellyfish blooms	High		Coastal artificial structure.	Regional climate change and trophic structure changes	Climate change	Climate change, rapid development of coastal zone and inadequate controls on development
Change in Benthic Species Composition and Dominant Species	Cold water species inhabiting area (YSCWM) shrinks.	Medium	↓	Pollution and warming	Regional climate change		Lack of strict controls on pollution discharge and CO_2 emissions
							NB: This is a global issue and relates to the implementation of the FCCC. Both countries are parties to the Kyoto Protocol
Harmful Algae Blooms (HABs)	Human and ecosystem health and economic harm caused by HABs	High		Inadequate capabilities for prediction and control of HABs			
	Eutrophication driven by point and non-point loading of nutrients	High		Limited control and prevention of nutrient release to the Yellow Sea			
	Silicate depletion relative to N and P	High	↑	Retention of fixed silicate behind freshwater dams	Construction of dams on major rivers draining into the Bohai and Yellow Seas	Freshwater storage and power production to support economic development Limited development an imposition of coherent policies on the maintenance of nutrient balances	Economic development without adequate consideration of marine environmental consequences

Causal Chain Analysis – Ecosystem (cont.)

Improving (↑) Getting worse (↓)

Issue/ Concern	Fundamental Problem/ Driver	Priority	Trend	Primary Cause	Secondary Cause	Tertiary Cause	Root Cause
Loss of Benthic Habitat in Coastal Areas	(See Biodiversity causal chain)	High	↓				See Biodiversity causal chain
Lack of ecosystem resilience to withstand disasters / climate change	Ecosystem is vulnerable to damage and impairment of functions due to human impacts	High	↑	Inadequate ecosystem protection, restoration, and conservation measures in place	Lack of understanding of the vulnerabilities of ecosystem, human health and fisheries to the impact of climate change and ocean-based disasters	Weak integration of disaster preparedness and climate resilience into investment decision making	Degraded integrity and services of the Yellow Sea resulting from anthropogenic interferences Climate variations and extreme weather conditions
Decreased pH level	Behavior change of calcifying and non-calcifying marine organisms	High	↓	Inadequate understanding of how ocean acidification impacts food web and structure of marine ecosystems	Lack of sustained efforts to monitor ocean acidification and take preventive actions	Increase in concentration of carbon dioxide (CO_2) in the atmosphere	Higher intensity of anthropogenic activities

Causal Chain Analysis – Fisheries

↑ Improving ↓ Getting worse

Issue/ Concern	Fundamental Problem/ Driver	Priority	Trend	Primary Cause	Secondary Cause	Tertiary Cause	Root Cause
Decline in landings of commercially important species and increase in landings of low-value species (including changes in dominant species	Unsustainable natural resource exploitation practices	High	↑	Overexploitation of target fish species	Over-capacity of fishing fleets	Inadequate alternative livelihoods	Problem is being addressed through buy-back programs, but is not complete
						Insufficient monitoring and enforcement	Insufficient procedures to assure compliance
					Inadequate management of allowable catch	Inadequate organizational structure for catch management	Absence of inter-provincial and transboundary joint stock management programs for selected species and inadequate data sharing for adaptive management
				Inadequate management of fishery habitats	Insufficient knowledge of areas for conservation of fishery resources, spawning grounds and habitats	Inadequate capacity and lack of management programs to strengthen the management effectiveness of conservation areas of fishery resources, spawning grounds and habitats	Conservation needs of fishery resources and spawning grounds overridden by economic considerations in coastal development
				Type and use of fishing gear causing damage to ecosystem	Inadequate availability of environmentally friendly gear and practices	Lack of awareness of the economic costs and consequences of the fishing gears to navigation and marine organisms	Absence of incentive mechanism to recover abandoned fishing gears
				Climate change			See Ecosystem causal chain
Unsustainable maricultural practices	Unsustainable development of coastal zone	High	↑	Mariculture exceeding carrying capacity	Increased demand for seafood as a result of changing lifestyles	Insufficient knowledge of carrying capacity	Lack of mechanisms to internalize externalities from unsustainable mariculture; poor understanding of ecosystem-based mariculture concepts; lack of awareness of the value of sustainable mariculture
				Environmental consequences of releases of nutrients; bacterial, viral, and fecal matter; and food residues from mariculture	Overfeeding, inadequate effluent treatment, poor quality of feed	Insufficient application of environmentally friendly techniques and considerations of carrying capacity	Inadequate commitment to emerging best practices in mariculture

Causal Chain Analysis – Biodiversity

↑ Improving ↓ Getting worse

Issue/ Concern	Fundamental Problem/ Driver	Priority	Trend	Primary Cause	Secondary Cause	Tertiary Cause	Root Cause
Loss of biodiversity	Habitat loss	High	↑	Land reclamation	Increase in demand for coastal lands		Growth-driven economic policies
	Loss of wildlife	High	↑	By-catch, unsustainable use, invasive species, illegal catch			Inadequate regulatory infrastructure or enforcement
	Habitat modification	High	↑	Gaps in MPA planning / marine spatial planning			
				Aquaculture	Increase in demand for fishery products		Rising standard of living, population increase, decrease in natural and commercial species
				Reduced river flows	Increase in water use, damming	Water demand increase	Economic and population growth
				Construction of artificial structures	Increased demand for coastal infrastructure		Economic growth and tourism demand
					Coastal disaster prevention		Climate change results in increased coastal disasters
					Energy demand		Improved standard of living
					Sea level rise	Global warming	Fossil fuel consumption
	Changes in community structure (shift of ecosystem)	Medium	↑	Eutrophication	Increase in nutrient input	Urbanization, fertilizer use, deforestation	Inadequate controls on growth
				Introduced species	Ballast water		Inadequate enforcement
					Intentional introduction of alien species		Aquaculture, blue carbon, increased coastal development
				By-catch and accidental injuries			Decrease in profit margin, increase in demand, population growth
Habitat loss and degradation	Benthic habitat loss	High	↑	Littering of benthic habitat with wastes	Inappropriate solid waste disposal practices	Poor compliance with regulations, lack of public awareness	Development being undertaken with limited comprehensiveness and coherence in the legislative basis for environmental and biodiversity protection
	Coastal shore-land habitat loss	High	↑	Land reclamation	Rapid industrial and social development in the coastal zone	Development undertaken without full understanding of consequences, deficiencies in comprehensive development planning	
	Pollution	High	↑	Domestic and industrial waste discharges	Growth of extended urban areas and associated industry in the coastal zone		

Causal Chain Analysis – Biodiversity (cont.)

↑ Improving ↓ Getting worse

Issue/ Concern	Fundamental Problem/ Driver	Priority	Trend	Primary Cause	Secondary Cause	Tertiary Cause	Root Cause
	Loss of habitat in estuaries / deltas	High	↑	Reductions in river discharge resulting in lower sediment supply	River basin development (construction of dams for water impoundment and power generation)	Pressure for hinterland development, power production, irrigation, and improved water supplies; development undertaken without full understanding of consequences	
				Changes in locations and amounts of river discharge	River diversion schemes		
	Habitat conversion	High	↑	Reclamation for aquaculture ponds for shrimp, crab (recent years only), etc.	Increasing demand for seafood	Population growth and increased affluence	
					Demand for job opportunities, social development with increased personal aspirations		
				Reclamation for salt production	Increasing demand for edible salt		
	Habitat degradation	High	↑	Degradation and fragmentation of habitat due to natural change and human activities	Indiscriminant local and community development	Local development undertaken without full understanding of the consequences	
					Climate change		See Pollution causal chain
Changes in species abundance and diversity	Decline in vulnerable birds	High	↑	Overhunting and unsustainable egg harvests	Sustainability not considered by local harvesters	High demand for food including the continuation of traditional exploitation practices	Deficiencies in policy and regulation of traditional natural resource exploitation practices and inadequate public information
				Destruction of reproductive, resting, and feeding habitat, especially in coastal wetlands	Lack of consideration of species protection in social and economic development practices	Inadequate balance between developmental aspirations and the need to protect the environment and biodiversity	Development being undertaken in the absence of comprehensive and coherent legislation for environmental and biodiversity protection, combined with poor enforcement of existing legislation
				Climatic change			See Pollution causal chain

Causal Chain Analysis – Biodiversity (cont.)

↑ Improving ↓ Getting worse

Issue/ Concern	Fundamental Problem/ Driver	Priority	Trend	Primary Cause	Secondary Cause	Tertiary Cause	Root Cause
	Decline in sea turtles	High		Unsustainable egg harvest	Sustainability not considered by local harvesters	High demand for food including the continuation of traditional exploitation practices	Deficiencies in policy and regulation of traditional natural resource exploitation practices and inadequate public information
				Destruction of reproductive habitat	Lack of consideration of species protection in social and economic development practices	Inadequate balance between developmental aspirations and the need to protect the environment and biodiversity	Development being undertaken in the absence of comprehensive and coherent legislation for environmental and biodiversity protection, combined with poor enforcement of existing legislation
				Overexploitation	Sustainability not considered by local harvesters	Continuation of traditional practices without regard for consequences of increased production	Deficiencies in policy and regulation of traditional natural resource exploitation practices and inadequate public information
	Decline in anadromous and catadromous fish	High	↑	Spawning / migration blocked by dams	Construction of river barrages without adequate consideration of environmental and biodiversity consequences	Inadequate balance between development aspirations and the need to protect the environment and biodiversity	Development being undertaken in the absence of comprehensive and coherent legislation for environmental and biodiversity protection combined with poor enforcement of existing legislation
	Decline in marine mammals (spotted seal and finless porpoises)	High	↑	Accidental injury	Increased maritime transport		
				By-catch	Inappropriate fishing practices	Inadequate controls on fishing practices	Weak enforcement of controls on fishing activities

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