Policy Brief: Strengthening Biodiversity Conservation through Key Indicator Species in East Asia

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Introduction:

The workshop titled "Key Indicator Species and Habitats for Marine Biodiversity Change in East Asia," convened in Jeju, Republic of Korea, from 28th to 30th November 2022, facilitated the exchange of research on key indicator species among scientists from China, Japan, the Republic of Korea, Russia, and Southeast Asian countries. This policy brief presents key findings on key indicator species, ecosystem types, and pathways leading to marine biodiversity changes in East Asia. It aims to provide policymakers with actionable recommendations to enhance biodiversity conservation in the region.

Background and Context:

Marine biological communities in East Asia face formidable threats, including habitat destruction, pollution, non-indigenous invasive species, over-fishing, and climate change. These factors have resulted in substantial changes in marine biodiversity, necessitating urgent conservation efforts. The workshop, sponsored by the Asia-Pacific Network for Global Change Research (APN) and organized by Jeju National University in collaboration with the Northwest Pacific Action Plan (NOWPAP), facilitated knowledge sharing among experts in the field.

Key Findings:

I. Marine Biodiversity Indicators:

1. Scleractinian Corals in Jeju Island

- Jeju Island in the Republic of Korea hosts a thriving population of scleractinian corals, despite being located in a high-latitude region not typically associated with coral reefs. This unique biodiversity of corals highlights the adaptability of corals to marginal environments. However, the presence of these corals has negatively impacted subtidal kelp populations on Jeju Island. Increased abundance of *A. japonica* may contribute to the decline of brown macroalgae in Jeju. Understanding the biodiversity and ecology of these high-latitude corals is crucial for effective conservation and management strategies.

2. Biogeography of the Mollusks of Jeju Island

- Jeju Island boasts a rich mollusk fauna influenced by the warm Tsushima Current, exhibiting zonal-geographical affinities with subtropical and tropical-subtropical species. Since 2007, approximately three dozen new species have been recorded, indicating an increasing influence of warming ocean currents on the island's fauna.
- Climate change, driven by global warming, has led to the expansion of marine organisms' habitats, potentially contributing to the addition of new mollusk species on Jeju Island. The region around Jeju Island has experienced significant temperature increases over the past century. Coastal development, particularly port development, has caused habitat loss, while overcollection of edible species and tourist pressure have resulted in biodiversity loss.

3. Diversity and distribution of corals in Korea

- A total of 170 coral species have been reported in Korean waters, including 80 species of soft corals, 35 species of hard corals, 30 species of sea anemones, and 12 species of black corals. Jeju Island stands out as having the highest diversity of coral species, while the Yellow Sea has the lowest diversity.

- Most coral species in Korea are found along the Kuroshio Current, a warm ocean current that influences the region. Jeju Island, in particular, exhibits a unique soft coral community and harbors the highest number of coral species.

- Scleractinian corals, also known as hard corals, are particularly sensitive to climate change due to their symbiotic relationship with zooxanthellae. These corals are crucial indicators of environmental changes in Korean waters. As sea temperatures rise, the distribution of zooxanthellate scleractinian corals is expanding northward. *Montipora efflorescens*, a dominant species expanding from the southern to northern parts of Jeju Island, holds particular importance as an indicator species for monitoring climate change impacts.

4. Climate-change driven range shifts of exploitable chub mackerel

- The strengthening of the Tsushima warm current in the Korea Strait and the Japan/East Sea (JES) will likely result in the northward migration of young-of-the-year mackerel biomass to the JES and adult mackerel biomass to the Yellow Sea.

5. Monstrilloid phylogeny and evolution

- The molecular phylogenomic analysis revealed a monophyletic grouping of *Monstrilloida* and identified a closer relationship between *Monstrilloida* and *Harpacticoida* (*Oligoarthra*) than with *Siphonostomatoida*. These findings challenged previous morphological-based hypotheses that placed Monstrilloida as a sister group of *Siphonostomatoida* or as a subgroup within it. The statistical tests supported the new phylogenetic hypothesis as the most likely one, rejecting the previously proposed relationships.

6. Use of seaweeds as bioindicators

Seaweeds have been widely used as bioindicators for various environmental assessments:

- Bioindicators for Assessing Water Quality: Some seaweed species are sensitive to changes in nutrient levels, making them valuable indicators of excess nutrients in coastal waters. Additionally, they can also accumulate heavy metals, allowing them to monitor metal pollution in marine environments.
- Bioindicators of Climate Change: Seaweeds' sensitivity to changes in environmental conditions, such as temperature, salinity, pH, and nutrient availability, makes them potential bioindicators of climate change. Monitoring changes in seaweed populations can provide insights into the effects of climate change on marine ecosystems.
- Bioindicators of Habitat Loss: Certain species of seaweed are highly specialized and grow in specific habitats. Changes in the abundance or diversity of these species can indicate shifts in the ecosystem's composition and highlight the presence of environmental stressors.
- Bioindicators of Invasive Species: Seaweeds can serve as indicators of invasive species due to their role as primary producers and their sensitivity to changes in ecological conditions. Monitoring seaweed abundance and diversity can help detect the presence of invasive species and their impacts on marine ecosystems.
- Commonly Used Seaweed Species as Bioindicators: Several species of seaweeds have been commonly used as bioindicators in specific environmental assessments. For example, the green seaweeds *Ulva spp.* have been used for nutrient pollution assessment, the brown seaweeds *Fucus spp.* for changes in water quality, and the red seaweeds *Corallina spp.* for ocean acidification.

II. Marine Biodiversity Changes

1. Changes in the Plankton Functional Groups in Jiaozhou Bay, Yellow Sea

Long-term monitoring in Jiaozhou Bay reveals several key changes:

- Long-term Changes of Physical-Chemical Parameters: Seawater temperature has been increasing, consistent with global warming trends. Salinity shows a slight decreasing trend, possibly due to increased precipitation. Dissolved inorganic nitrogen and phosphates exhibited an initial increase from 2006 to 2010, followed by a continuous decrease. Silicate concentrations followed a similar trend. Dissolved oxygen levels remained good, with no hypoxia events recorded.

- Changes in Warm-water Plankton Species: Warm-water phytoplankton and zooplankton species have increased in Jiaozhou Bay. These changes are likely linked to the warming of water temperature in the bay and the expansion of the warm-water species' biogeographic range.
- Changes in Composition of Phytoplankton: While diatoms remain dominant, the abundance of dinoflagellates has gradually increased, resulting in an increase in the dinoflagellate/diatom ratio. The high N/P ratio in the water may contribute to the competitive advantage of dinoflagellates over diatoms.
- Changes in Gelatinous zooplankton: Gelatinous zooplankton, including small jellyfish, has increased in Jiaozhou Bay. The abundance of small jellyfish has shown a significant increase, and the dominant species of jellyfish have changed over time. This shift in gelatinous zooplankton dynamics may have ecological implications for the bay.
- Changes in size of zooplankton: The size of zooplankton in Jiaozhou Bay has decreased over time. Several zooplankton groups have exhibited a decrease in biovolume. Conversely, the abundance of microzooplankton *Noctiluca scintillans* has increased.
- Long-term Change on Ecosystem Health: Based on the trends observed in plankton functional groups and key environmental factors, an ecosystem health assessment system was established for Jiaozhou Bay. The overall health of the bay has shown an increasing trend, indicating improving water quality. However, further research is needed to better understand the health conditions of the biota.

2. Marine Environment and Ecology Monitoring and Assessment in China

- In 2021, China conducted seawater quality monitoring at 1,350 national monitoring sites, 193 riverine sections flowing into the sea, 442 sewage outlets with daily discharge volume exceeding 100 tons, and 31 bathing beaches. The overall quality of marine water in China has shown improvement, with 96.8% of the marine water meeting the Seawater Quality Standard Grade Ⅰ. Specifically, 77.4% of coastal areas exhibited Excellent or Good water quality, representing a 0.8% increase compared to the previous year. However, several regions, including Liaodong Bay, Yellow River Estuary, Jiangsu Coast, Yangtze River Estuary, Hangzhou Bay, Zhejiang Coast, and Pearl River Estuary, still face pollution challenges. The primary indicators failing to meet the Seawater Quality Standard were inorganic nitrogen and active phosphate.
- China assessed marine sediment quality at 540 national monitoring sites and found overall stability in the ecological status of typical marine ecosystems. The water quality of sea-entering

rivers remained slightly polluted, with no significant change compared to the previous year. Furthermore, the environmental quality of ocean dumping zones and oil/gas exploration zones generally complied with the environmental protection requirements for marine functional zones. Marine fishery areas demonstrated good environmental quality, and there was a slight decrease in both the frequency and cumulative area of recorded red tides compared to the previous year.

3. Moonlight and coral reef organisms in Okinawa

- Many fish species inhabiting coral reefs in Okinawa exhibit synchronization of reproductive events with lunar phases. Studies have shown that moonlight exposure at midnight during full and new moon phases leads to a significant decrease in plasma melatonin levels, which inhibits the initiation of gonadal development. This suggests that moonlight plays a vital role in the induction and phase-setting of reproductive processes in coral reef fish.
- Artificial Light at Night (ALAN), including nighttime light pollution, has been found to have negative effects on marine organisms. In territorial fish species, ALAN disrupted hatching processes. Crustaceans and invertebrates experienced suppressed activity, reduced food consumption, growth rate, and disrupted reproduction under ALAN conditions. These findings indicate that ALAN can interfere with the ecological and reproductive activities of organisms in coral reef ecosystems.

4. Environmental DNA to Detect Fish Biodiversity in the Open Ocean

- The Arctic ecosystem is experiencing substantial changes due to warming and rapid sea ice reduction. eDNA analysis has the potential to improve our understanding of the Arctic ecosystem by reducing the constraints associated with conventional surveys. It provides a less laborious and non-invasive approach to assess the distributional shift of Arctic fish species, which is crucial for monitoring ecological changes and their impacts on local communities.
- eDNA metabarcoding analysis revealed clear compositional differences in fish communities across multiple biogeographic zones in the open ocean. The taxonomic richness showed a latitudinal cline, with notable boundaries in transition zones. Fish communities in each region were distinguishable and closely aligned with conventional biogeographic classifications. This demonstrates the capability of eDNA to depict latitudinal transitions in fish communities.
- Using species-specific eDNA detection, the distribution of polar cod (*Boreogadus saida*), a key species in the Arctic ecosystem, was examined. The results indicated that polar cod eDNA was primarily detected in surface waters of the central Chukchi Sea shelf and northernmost observation areas, including the marginal ice zone. This suggests that eDNA can reliably track

the range shift of Arctic fish associated with climate change, providing a baseline for understanding the impacts of environmental changes.

5. Monitor Changes in The Marine Biodiversity in Jeju

- The Autonomous Reef Monitoring Structures (ARMS) method was developed as a low-cost, non-destructive, and effective means of studying the biodiversity of coral reef waters. It has been successfully applied in various marine biodiversity research programs worldwide, providing quantitative assessments and allowing for the comparison of monitoring results across different water bodies.
- The Marine Global Earth Observatory (MarineGEO) Program, initiated in 2013, aims to investigate marine biodiversity and ecosystem structures in different countries. ARMS installations are used to assess biodiversity changes due to climate change, pollution impacts on ecosystem function, and restoration efforts. The program has expanded to Asian countries, including South Korea.
- Implementing ARMS monitoring in Jeju allows for the detection of climate refugees, species that have newly extended their range due to climate change. It also aids in identifying new species in understudied taxa. Monitoring these changes is essential to prevent disruptions to marine ecosystems as these species may compete with indigenous organisms.
- Monitoring the marine environment is crucial for effective marine management and decision-making. By understanding natural changes and evaluating the costs and benefits of marine monitoring, policymakers can make informed decisions to protect marine biodiversity. Jeju Island, with its high biodiversity and the recent influx of subtropical/tropical organisms due to climate change, requires continuous monitoring to prepare for potential shifts in fisheries resources.

6. Identifying patterns in the multitrophic community and food-web structure of a low-turbidity temperate estuarine bay

- Estuarine ecosystems are dynamic and complex, characterized by transitional zones where rivers meet the sea. Understanding the structure and dynamics of estuarine food webs is crucial for managing and conserving these important ecological systems.
- The study revealed distinct community structures between the estuarine channel and the deep bay, indicating spatial variations in community compositions.
- While seasonal differences were observed in plankton patterns, the macrobenthos and nekton communities showed less seasonal variation.
- Phytoplankton were found to play a prominent role as the primary basal resource in both pelagic

and prevalent-detrital benthic pathways.

- The study demonstrated that food-web topologies persisted across seasons in respective areas, suggesting stability in trophic interactions within the ecosystem.

7. Using eDNA to detect the presence of marine invasive species in ports and harbors

- Marine biological invasion through the maritime industry poses a significant threat to marine biodiversity. Ballast water discharge and biofouling of ship hulls are major vectors for introducing invasive species into ports and harbors worldwide. The International Maritime Organization (IMO) has implemented conventions to mitigate this risk, including the Ballast Water Management Convention (BWMC) and the Antifouling Systems Convention (AFS).
- Biofouling is a more significant vector of biological invasion than ballast water release in several port ecosystems. Current ecological counting methods for compliance assessment are time-consuming and limited in coverage.
- eDNA metabarcoding offers a rapid and cost-effective approach for monitoring invasive species in ballast water and port environments. The use of eDNA can improve the early detection of exotic species and complement traditional ecological methods.
- However, limitations include insufficient sequence information in DNA databases and challenges in primer design. Technical aspects of eDNA techniques need to be effectively communicated to maritime industry stakeholders, flag state authorities, and coast guards.

8. Artificial drivers of jellyfish blooms and transport of non-native species

- Jellyfish populations have been increasing globally, and this phenomenon is often associated with ocean degradation. Various human activities, such as overfishing, marine construction, eutrophication, and global warming, have been identified as potential contributors to the rise of jellyfish populations. However, the perception of a worldwide trend toward increased jellyfish abundance remains unsupported due to limited evidence and exaggerated information.
- The rise of *Aurelia coerulea*, a frequent blooming species, is primarily attributed to the increase in coastal development and construction. Underwater artificial structures serve as crucial habitats for the polyps of *Aurelia coerulea*.
- Blackfordia virginica, a non-indigenous hydromedusa, has been found in Shihwa Lake and

Seomjin River mouth. The species blooms annually in Shihwa Lake, leading to the depletion of zooplankton prey. B. virginica and B. polytentaculata were newly discovered in the Seomjin River mouth, near an international trading port.

- Monitoring efforts should focus on identifying the dispersion and invasion patterns of *Blackfordia* species in brackish waters.
- *Carybdea brevipedalia*, a venomous box jellyfish, displays agile swimming and voracious nocturnal feeding behavior. The species primarily preys on larger zooplankton, including decapod and fish larvae, mysids, and swimming polychaetes.
- *Carybdea brevipedalia* exhibits passive hunting behavior and relies on tentacle elongation and agile swimming to capture faster prey.
- The impact of artificial light on the species' productivity and feeding rate requires further investigation.
- Recent evidence suggests a northward shift in the distribution of *Carybdea brevipedalia* onto the eastern coast of Korea.

Policy Recommendations:

Based on the workshop findings, the following recommendations are proposed:

1. Enhanced Monitoring and Research:

a. Support research and monitoring of key indicator species to track changes in distribution patterns, assess the impacts of climate change and habitat loss, and identify potential conservation priorities.

b. Encourage collaboration between research institutions, government agencies, and independent researchers to share data and enhance knowledge on marine biodiversity changes, with a focus on vulnerable ecosystems and species. Facilitate evidence-based decision-making through joint efforts.

c. Prioritize research on the impacts of Scleractinian corals on other benthic communities in Jeju Island and study the resilience and adaptability of corals like *M. millepora* to understand their survival mechanisms under environmental stressors.

d. Invest in research and collaboration to expand the catalog of available markers in reference databases. Prioritize taxonomically verified sequences to ensure accurate species identification and assessment.

e. Allocate resources to support genomic and transcriptomic research initiatives focused on understudied groups, such as *Monstrilloida*, to enhance our understanding of their biology, ecology, and conservation needs.

f. Encourage taxonomists and researchers to consider the revised phylogenetic relationships when revising the taxonomy and classification of copepod species, particularly within the *Monstrilloida* order.

g. Promote the integration of molecular phylogenomic techniques alongside morphological analyses to improve the accuracy of phylogenetic inference and enhance our understanding of the evolutionary relationships among different taxa.

2. Strengthen Monitoring Programs:

a. Expand the monitoring and assessment to cover a wider range of marine ecosystems and include long-term monitoring of key indicators to track changes in species populations, including shifts in distribution, abundance, and size structure.

b. Regularly assess the impact of climate change on key indicator species, considering both environmental factors and socio-economic aspects.

c. Strengthen monitoring efforts to detect and respond to the spread of non-indigenous species.

d. Identify and select appropriate seaweed species as bioindicators to enable better monitoring and management of marine ecosystems.

e. Establish long-term monitoring programs to assess changes in community structures and food-web dynamics in response to natural and anthropogenic influences, enabling informed decision-making and adaptive management strategies.

3. Conservation Measures:

a. Implement and enforce effective conservation measures to protect critical habitats, particularly those at risk from habitat destruction and pollution.

b. Promote sustainable fishing practices and develop strategies to mitigate the impacts of overfishing.

c. Strengthen efforts to control non-indigenous invasive species through effective management and eradication programs.

d. Implement measures to conserve and restore diverse habitats, including rocky and sandy coastlines and coral ecosystems. This includes protecting important coastal areas and promoting sustainable fishing practices.

e. Establish more marine protected areas and enforce regulations to prevent destructive fishing practices, coral harvesting, and habitat destruction to conserve and protect coral ecosystems.

f. Incorporate ecological considerations into coastal development plans to minimize the impacts on key indicator species.

g. Tailor conservation and restoration efforts in estuarine ecosystems considering spatial and temporal variations in community structures. Address unique ecological dynamics in different areas within the estuary.

h. Focus on preserving water quality, reducing nutrient pollution, and managing phytoplankton blooms to maintain a healthy trophic base, given the significant role of phytoplankton as the primary energy source in estuarine food webs.

i. Protect and restore benthic habitats, minimizing disturbances and implementing sustainable management practices that maintain their functional roles within the food web.

j. Develop and enforce regulations to mitigate light pollution and its impact on coral reef ecosystems, regulating the type, intensity, and duration of artificial lighting near coral reefs to protect their ecological integrity.

4. Climate Change Adaptation:

a. Develop strategies to address the consequences of climate change on marine biodiversity, including the identification and protection of climate-sensitive species and habitats.

b. Support the development of climate-resilient marine ecosystems through restoration and conservation measures.

5. Sustainable Tourism:

a. Develop and enforce regulations to manage tourism activities effectively, ensuring they do not negatively impact the natural environment and fragile coastal ecosystems.

b. Implement measures to minimize the ecological footprint of tourism and promote sustainable practices.

6. Public Awareness and Education:

a. Promote public awareness and understanding of the importance of ecosystems and their vulnerability to climate change.

b. Develop educational programs to foster a sense of stewardship and encourage responsible behavior among local communities, tourists, and stakeholders.

c. Foster public awareness about key indicator species and their diverse ecological roles, emphasizing the importance of preserving biodiversity and understanding evolutionary relationships for effective ecosystem management.

d. Promote awareness and knowledge sharing among maritime industry stakeholders regarding the benefits and applications of eDNA technology.

e. Provide training and capacity-building programs to facilitate the adoption and implementation of eDNA techniques in port monitoring.

7. Stakeholder Engagement:

a. Promote stakeholder engagement and participation in decision-making processes related to key indicator management.

b. Encourage dialogue between scientists, policymakers, fishing communities, and other stakeholders to ensure the effective implementation of adaptation strategies and the equitable distribution of benefits.

c. Encourage the integration of eDNA monitoring into existing port management and biosecurity strategies.

8. International Collaboration:

a. Foster international cooperation and knowledge exchange among East Asian countries, sharing best practices and successful conservation strategies.

b. Collaborate with organizations such as NOWPAP, APN, and regional scientific institutions to promote joint actions and information sharing on marine biodiversity conservation.

c. Collaborate with international partners to develop early warning systems and control measures for non-indigenous species.

d. Develop guidelines and regulations based on scientific evidence to address the potential impacts of climate change and invasive species on marine ecosystems.

e. Foster international cooperation to establish consistent eDNA-based monitoring frameworks and regulations.

f. Encourage the IMO to incorporate eDNA approaches into ballast water compliance assessments and enforcement measures.

g. Establish international collaborations to share and update genomic databases regularly.

Conclusion:

The workshop on key indicator species highlighted the urgent need to address threats to marine biodiversity in East Asia. The policy recommendations provided in this brief emphasize the importance of enhanced monitoring, conservation measures, climate change adaptation, and international collaboration. NOWPAP, policymakers, and stakeholders are urged to prioritize these recommendations to safeguard the invaluable marine ecosystems and key indicator species in the region, ensuring a sustainable future for East Asia's biodiversity.