Overview on Scientific Issues for advancing Ecosystem-Based Management of YSLME

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Main Contents

• **I. EBM for sustainable YSLME**

• **II. Main scientific issues on YSLME trends and threats**

• **III. Conclusions and Perspectives**
1.1 Targets of YSLME SAP in 2009

- Sustainable ECC: A living sea, which is vital, productive and healthy

(Source: Jilan Su, 2001)
• **Ecosystem services of YSLME**
  
  – **Trend**: Great loss of ecosystem services value (-37%) of the coastal wetlands (tidal flats) from 1980s to 2010s
  
  – **Most important component**: the regulating services, such as carbon sequestration and waste treatment (Immaterial value)
  
  – **Main cause**: huge historical loss of tidal flats directly linked to coastal reclamation

<table>
<thead>
<tr>
<th>Region</th>
<th>Total ecosystem services</th>
<th>Provisioning</th>
<th>Regulating</th>
<th>Supporting</th>
<th>Cultural</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>12416</td>
<td>7543</td>
<td>3104</td>
<td>1886</td>
<td>7419</td>
</tr>
<tr>
<td>South Korea</td>
<td>5156</td>
<td>3298</td>
<td>1475</td>
<td>943</td>
<td>2697</td>
</tr>
<tr>
<td>North Korea</td>
<td>3798</td>
<td>2713</td>
<td>1086</td>
<td>776</td>
<td>1987</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>21370</td>
<td>13554</td>
<td>5665</td>
<td>3605</td>
<td>12103</td>
</tr>
</tbody>
</table>

(Source: Jongseo Yim et.al, 2018)
1.2 EBM: strategy for sustainable ECC

- EBM: integrates all components of an ecosystem, including humans, into the decision-making process

Continuum of transitioning from traditional single-species management to multisector comprehensive EBM

5 modules of spatial and temporal indicators of ecosystem (i) productivity, (ii) fish and fisheries, (iii) pollution and ecosystem health, (iv) socioeconomics and (v) governance

http://www.noaa.gov/iea
Scientific research needs for advancing EBM of YSLME

- Building consensus and more complete understanding of the ecosystem
- Building a network of interdisciplinary scientists
- Explicitly considering all components of the ecosystem including humans
- Identifying trade-offs to make decisions that result in the most desired outcome
- Supporting transition to ecosystem-based management

The NOAA IEA Approach

- Define EBM Goals & Targets
- Define Ecosystem Management Goals & Targets
- Develop Ecosystem Indicators
- Develop Indicators
- Assess Ecosystem
- Assess Ecosystem Indicators
- Taking, Monitoring, and Assessing Action
- Based on the IEA, an action is selected and implemented. Monitoring of indicators is important to determine if the action is successful. If yes, the status, trends, and risks to the indicators are updated and analyzed for incremental change; otherwise, as part of adaptive management, the outcomes need to be assessed and evaluated to refine goals and targets or indicators towards achieving objectives.

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2.1 Climate change implications in YSLME

• **2.1.1 Rising sea surface temperature (SST)**
  
  – From 1980 to 2018, the SST of China’s coastal waters increased by 0.23°C per ten years
  
  – Rising SST in Bohai Sea and Yellow Sea are most significant

(Sources: China Sea Level Bulletin 2018)
2.1.2 Intensified marine acidification

- Intensified acidification esp. for the bottom water of YS

Marine acidification will affect biocalcification rate, primary productivity, nitrogen fixation and reproduction, esp. for the shell formation process of calcareous organisms

(Source: X. Xu, H. Zhao, W. Zhai et al, 2018)
2.1.3 sea level rise and environmental impacts

• Rate of sea level rise
  – In 2018, the sea level of YS was 28 mm higher than annual average.
  – It was predicted that the sea level of YS will rise for 70~165 mm in the following 30 years

• Environmental impacts
  – Coastline erosion rate up to 35 m/yr
  – Saline intrusion distance up to 20-30 km

<table>
<thead>
<tr>
<th>Region</th>
<th>Coastline erosion</th>
<th>Saline intrusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dalian</td>
<td>0.8 m/yr</td>
<td>0.3 km</td>
</tr>
<tr>
<td>Weihai</td>
<td>0.7 m/yr</td>
<td>2.03 km</td>
</tr>
<tr>
<td>Nantong</td>
<td>35 m/yr</td>
<td>21.30 km</td>
</tr>
</tbody>
</table>
2.1.4 Northward distribution of warm water species

Abundance of *S. enflata* in northern YS

*S. enflata* as warm water species have never been found in northern YS before 1959 in winter, which were found widely distributed in this region since 2009.

(Source: J.F. Fan et al. 2010)

Distribution of anchovy stock under climate change

These 4 scenarios representing the low, relative low, modest and the highest emission scenarios. The wintering anchovy stock shows the obvious northward trend, reaching as much as to 2.5-2.7 degree in the next 30 years.

➢ Time-series monitoring and scientific research are expected!
2.2 Significant shifts of nutrient distribution and sources

- **2.2.1 Nutrient contents and distribution shifts**
  - P-limited eutrophication: N:P ratio = (18-22):1
  - Varied distribution pattern in the bottom water of south YS

(Source: NMEMC)
2.2.2 Transboundary input of nutrients by Green Tide

- **Amounts of transboundary nutrient inputs**
  - In 2012, total amount of 4 million tons of *Enteromorpha Prolifera* containing 22500 tons of nitrogen and 400 tons of phosphorus were transported from Changjiang Estuary to south YS.

- **Effects on the nitrogen contents in seawater**
  - The macro algae completely decomposed within 80 days, leading to the contents of organic nitrogen increased from 25% to >90% of the total nitrogen in bottom seawater of south YS.

<table>
<thead>
<tr>
<th>Nutrient inputs for YS (1000 t/yr)</th>
<th>literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>N</td>
</tr>
<tr>
<td>Transboundary inputs by Green Tide</td>
<td>22.5</td>
</tr>
<tr>
<td>Inputs from Direct Discharge Outlets</td>
<td>9.96</td>
</tr>
<tr>
<td>Inputs from Yellow River</td>
<td>21.1</td>
</tr>
</tbody>
</table>

*China Marine Ecological Environment Bulletin, 2017-2018*
2.2.3 Increased input of nutrients from mariculture

- **Increased contribution** of nutrients by increased yields
- **Main components:** particulate nutrients (mostly organics)

(Source: Y. Cui, et al, 2005)  
(Source: X. Yuan et al, 2015)
• Monitoring and research gaps for organic nutrients
  – Organic nitrogen: key factor inducing the outbreak of pico-plankton blooms (*Aureococcus anophagefferens*) in YS and BS since 2009.
  – Organic nutrients are neither included in the *National Seawater Quality Criteria of China*, nor included in annually monitoring projects. Related researches were also rare.

Nitrogen components before Brown Tide
- 72% DON
- 8% NO₂-N
- 8% NO₃-N
- 7% NH₃-N

Nitrogen components during Brown Tide
- TN
- DON
- DIN

(Source: S. Lv et al, 2013)
2.3 Multiple threats of plankton blooms to YSLME

- 2.3.1 Decline of Red Tide events, with increased proportion of toxic species

  - Decline of Red Tide events, mainly found in estuaries and bays.
2.3.1 Decline of Red Tide events, with increased proportion of toxic species

- Increased proportion of HABs caused by toxic species

Proportion of HABs caused by *Dinoflagellate* and *Flagellates* *Pigmentosa* in China’s coastal area 2001-2017

Reported algae toxins in YS region (1994-2005)
2.3.2 Macroalgae bloom with widening spatio-temporal scope

- **Green Tide bloomed continuously since 2008**
  - Species: *Enteromorpha Prolifera*
  - Time: April to August
  - Spatial distribution: Mainly in coastal area
  - Transportation: south → north

![Graph showing coverage and distribution over years](chart.png)
• **Golden Tide (Sargassum)** bloom lasted all year long
  
  – Time: Oct. 2016 to Nov. 2018
  
  – Spatial distribution □ From offshore to coastal area
  
  – Transportation □ north → south

April to June 2017, co-occurrence of green tide, golden tide, and red tides
2.3.3 Jellyfish bloom from episodically to continuously

- Jellyfish bloomed continuously from 2003 to 2009
  - Dominant species: *N. nomurai* and *A. aurita*. *N. nomurai*
  - Time: episodically in 1920, 1950 and 1995 (Kawahara et al., 2006), and continuously in 2003-2009 (Yoon et al., 2014)
  - Spatial distribution: appearance all over the YS region

- Where is the source of jellyfish outbreak?
- How to predict jellyfish bloom event and its possible impacts?

Jellyfish appearance in Korean waters in August of 2007

High risks of plankton bloom to seawater utilization engineering
May to Sept.

Macroalgae bloom

- **Enteromorpha linza**
  - Name: 绿藻
  - Characteristics: 10-50cm, high可达30cm, 形态变化大
  - Distribution: 生长在海水内

- **Ulva lactuca**
  - Name: 海带
  - Characteristics: 10-40cm, 形态变化大
  - Distribution: 生长在海水内

- **Pantocarpus laevifolius**
  - Name: 大海带
  - Characteristics: 10-16cm, 高可达60cm
  - Distribution: 生长在海水内

- **Sargassum pallidum**
  - Name: 棕藻
  - Characteristics: 高可达80cm
  - Distribution: 生长在海水内

Jellyfish bloom

- **Aurelia aurita**
  - Name: 欧洲海月
  - Characteristics: 直径10-30cm
  - Distribution: 生长在海水内

- **Nemopilema nomurai**
  - Name: 水母
  - Characteristics: 体长20-30cm
  - Distribution: 生长在海水内

- **Rhopilema esculentum**
  - Name: 海蜇
  - Characteristics: 体长10-20cm
  - Distribution: 生长在海水内

- **Pleurobrachia globosa**
  - Name: 海球
  - Characteristics: 体长2-5cm
  - Distribution: 生长在海水内
2.4 Multiple pressures on sustainable fishery

• 2.4.1 Changes in fishery species composition and trophic level

Two different species shift of fishery species composition in the YS

– 1) from demersal, high-valued species to pelagic, low-valued species during 1958 - 2000
– 2) from pelagic, low-valued species to demersal, low-valued species since 2000

(Source: Q. Wu, 2019)
2.4.2 Impacts of overfishing down the food chain

- Declined fishing catch production, with declined catch value
  
  ![Graph showing production of various fish products](chart1.png)

- Production of low-valued fish also downscaled greatly
  
  ![Graph showing catch rate of anchovy](chart2.png)

Production of Anchovy in YS Based on catch data
(Source: Steven Martell et al, 2013)

(Source: Q. Wang et al, 2016)
2.4.3 Impacts of plankton bloom on fishery trophic level

- **Declined trophic level of fishery species**: the living space of other species being squeezed out by jellyfish blooms
- **Heightened volatility** of fishery resource composition after jellyfish bloom
- Severe impacts on the **habitat environment** esp. for demersal and benthic species

Time-series of average trophic levels of main fishery species in southern YS
(Source: Y. Liu et al, 2015)
Production of prawn could not recover after 1990s because of multiple pressures

Time-series production of BS prawn

(Source: J. Su et al, 2008)
2.5 Degradation of wetlands for keystone species

- Coastal wetlands in the Yellow Sea are critical to the survival of many **migratory waterbird species**
- The nearshore waters in Yellow Sea are also critical habitats for the **marine mammals** (e.g. spotted seal, finless porpoise, whales)

23 potential priority areas in the Yellow Sea Eco-region for keystone species and their habitats
- Marine mammals
- Migratory waterbirds
- Valuable fishes
- Mollusk
- Vegetation
- Algae...

(Source: WWF, 2003)
2.5.1 Defective MPA network

- Existing MPAs of China and Korea could not cover all the priority areas, esp. nearshore waters
- Some of the keystone species were not included as protecting objects of MPAs
- Lack of ecosystem-based regional MPA network weakened the protection efforts and results.

Spatial protection gaps in the Yellow Sea Eco-region
(Source: WWF, 2003)

| Summary of the status protection for the habitats of four shorebird categories |
|-----------------------------------|---|---|---|---|
|                                   | Anatidae | Laridae | Waders | Stork and Crane |
| Protected                         | 6         | 5       | 4      | 17               |
| Unprotected                       | 24        | 25      | 28     | 0                |

(Source: Y. Liu et al, 2019)
2.5.2 Loss of habitats by historical reclamation

- Compared with 1980s, the Yellow Sea lost 9700 km² of the sea area, with 40% of total natural tidal flats lost.

Tidal Mudflats on the Periphery of the Yellow Sea
(Source: Jongseo Yim et al, 2018)
The location and range of Dalian Black-faced Spoonbill Municipal Nature Reserve

Black-faced Spoonbill and Chinese Egret roosting at Zhuanghe estuary

Fishing business for leisure around Zhuanghe estuary

Reclamation and infrastructure around Zhuanghe estuary
2.6 Emerging environmental issues and ecological risks

• 2.6.1 Marine microplastics
  - Contents of MPs in the surface water and sediment of YS were relatively low, compared with other sea areas worldwide
    • Source, transportation and distribution mechanism?
    • Total amount, density and composition?
    • Impacts on marine ecosystem?
    • Effects on human health?

(Source: J.Y. Wand et al, 2018)
2.6.2 Antibiotics Resistance Genes (ARGs)

- High-risk of ARGs transported from ridge to reef

Discharge Outlets  Surface Water  Estuary  Coast and Sea

Complex migration of antibiotic resistance in natural aquatic environments

(Source: H. Gao et al, 2018)
2.6.3 Combined pollution from accumulating POPs

(Source: L.X. Zeng et al, 2013)

(Source: Y. Wang et al, 2014)
2.6.4 Invasive species

- Research indicated the number of marine invasive species in YSLME was 120, in which, 6 species were microbes, 45 species were animals and 69 species were plants.

- *S. alterniflora* spread extensively in the coast of China, especially in Jiangsu coastal wetland, resulting in significant impact on wetland ecosystem health and safety. In 2012, the expansion of *S. alterniflora* was still increasing, with an area of 153.8 km².

![Invasive species in YSLME](image)

**The area of S. alterniflora in Yancheng, Jiangsu**

(Source: G.X. Liao et al, 2019)
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### 3.1 New trends or threats to sustainable YSLME

<table>
<thead>
<tr>
<th>Type of issue</th>
<th>TDA of YSLME phase I</th>
<th>New trends or threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollution</td>
<td>Nitrogen enrichment, mainly caused by land-based inputs</td>
<td>Organic nitrogen enrichment, mainly caused by transboundary Green Tide</td>
</tr>
<tr>
<td></td>
<td>Heavy metal, POPs, Marine litter</td>
<td>ARGs, Micro-plastics, emerging POPs</td>
</tr>
<tr>
<td>Ecosystem</td>
<td>Increased frequency of HABs</td>
<td>Decreased frequency of HABs, with increased proportion of toxic species; Widespread macroalgae and jellyfish blooms</td>
</tr>
<tr>
<td>fishery</td>
<td>Changes in fishery species composition and trophic level</td>
<td>Declined fishing catch production, with declined catch value, even for low-value species</td>
</tr>
<tr>
<td></td>
<td>Unsustainable mariculture practices</td>
<td>Increased input of nutrients from mariculture</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>Loss of benthic habitats, decline of endemic species</td>
<td>Loss of wetlands, degradation of habitats for prior species, defective MPA network</td>
</tr>
</tbody>
</table>
| Climate change        |                                                                                       | Increased risks related to climate change, such as acidification, coastline erosion and saline intrusion etc. | implications


Comprehensive impacts of Climate Change and Human Influence
3.2 Perspectives for scientific research interests

Proposed scientific research interests

- Source, fate and impacts of organic nutrients, MPs, ARGs and other pollutants
- Prediction of trends and risks of multiple plankton blooms
- Restoration of spawning, nursing, feeding grounds and other habitats for keystone species
- Evaluation and protection of immaterial values of YSLME
- Understanding of comprehensive impacts of climate change and anthropogenic influences
- Adaptive management strategy

(Revised from Ingram et al, 2018)
Thanks for listening