Report on improving the effectiveness and impacts of Ecological Restoration project in the Yellow Sea

1. The status and problem of ecosystem servers and biodiversity of the Yellow Sea

The Yellow Sea (YS) is located between continental North China and the Korean Peninsula. It is separated from the West Pacific Ocean by the East China Sea in the south, and is linked with the Bohai Sea, an arm of the Yellow Sea in the north. It covers an area of about 400,000 km^2, with a mean depth of 44m. Most of the Sea is shallower than 80m. The central part of the sea, traditionally called the Yellow Sea Basin, ranges in depth from 70m to a maximum of 140m.

The general circulation of the Yellow Sea LME is a basin-wide cyclonic gyre comprised of the Yellow Sea Coastal Current and the Yellow Sea Warm Current. The Yellow Sea Warm Current, a branch of the Tsushima Warm Current from the Kuroshio Region in the East China Sea, carries water of relatively high salinity (> 33) and high temperature (> 12°C) in winter. Below 50m, the Yellow Sea Cold Water Mass forms seasonally and is characterized by low temperature with the bottom temperature lower than 7°C in its central part. All rivers into the Yellow Sea LME have peak runoff in summer and minimum discharge in winter, which has important effects on salinity of the coastal waters.

The YS lies in the warm temperate zone, and its communities are composed of species with various ecotypes. The YS is highly productive and supports a large population of fish, birds, mammals and invertebrates. Its intertidal flats are important habitats for millions of migrant birds. Its biodiversity is comparatively high with about 340 species of fish, 170 of molluscs, and 100 of crustaceans.

The YS has a very important ecological service function for surrounding countries. These services include provision of capture fisheries resources and mariculture, the supports of wildlife, provision of bathing beaches and tourism, and its capacity to absorb nutrients and other pollutants. With rapid economic development and climate changes, many problems have occurred in the ecosystem of the YS, such as rapid growth in fishing and economic decline in fish stocks, increasing discharge of pollutants, increases in jellyfish and harmful algal blooms, habitat loss, and immediate threats of climate change. The TDA and the associated cause chain analysis identified nine major problems: pollution and contaminants, eutrophication, plankton community changes, overfishing; unsustainable mariculture; habitat lass and degradation, jellyfish blooms, and climate change relate issues. To respond to these problems, the UNDP/GEF YSLME project was launched in July 2017 and aimed to achieve adaptive ecosystem-based management of the Yellow Sea Large Marine Ecosystem bordered by China, RO Korea and DPR Korea by fostering long-term sustainable institutional, policy and financial arrangements for effective ecosystem-based management of the Yellow Sea in accordance with the YSLME SAP.

2. Concept and main types of restoration

Restoration is described as returning an ecosystem to a close approximation of its condition prior to disturbance (NRC, 1992). According to Elliott et al. (2007)'s review, Ecological restoration can be divided into four categories: Natural recovery from a natural or anthropogenic change (whether adverse or otherwise); Anthropogenic interventions in response to a degraded or anthropogenically changed environment; Anthropogenic responses to a single stressor; Habitat enhancement or creation. The ultimate goal of restoration is to create a self-supporting ecosystem that is resilient to perturbation without further assistance (SER 2004).

The restoration activities in the estuarine, coastal and marine ecosystems are different among the different areas. The mainly activities are summarized in PEIS (2015) as below:

- Wetland Restoration: adding or removing substrate to achieve the proper elevation for wetland plant growth, or protecting or restoring transition zones such as tidal shorelines through shoreline stabilization methods.

- Coral Reef Restoration: reducing or eliminating land-based sources of pollution, reef recovery from disturbance/impacts, promoting recruitment and recovery through enhancement and protection of existing populations and natural systems, or controlling overgrowth of invasive species to enhance recruitment.

- Debris Removal: removing debris (solid, man-made items) from the coastal and marine environment, including removal of derelict fishing gear, and other persistent debris from coastal habitats.

- Beach and Dune Restoration: providing clean sediment for beaches that have been degraded from man-made injuries (e.g., oil spill or release of hazardous substance) or washed away due to natural processes or acute natural events.

- Signage and Access Management: installing signs, fences, or other barriers to prevent or discourage access to recovering habitat.

- Fish Passage: installing fish ladders, bypass channels, nature-like fishways, dam removals, eel passes, and fish-friendly tide gates, and culvert removal and modification or replacement.

- Fish, Wildlife, and Vegetation Management: control/removal of localized populations, re-establishing native species, monitoring for newly established species.

- Levee and Culvert Removal, Modification, and Set-Back: berm breaching; culvert removal/replacement to allow tidal or natural flooding of wetlands; removal of fill, levees, and dikes or other impediments to historic/natural tidal flow or hydrology.

• Shellfish Reef Restoration: creating, restoring, or rehabilitating shellfish populations and shellfish habitats.

• Subtidal Planting: planting submerged aquatic vegetation (SAV) or marine algae.

• Conservation Transactions: purchasing or transferring ownership, usage rights, or access to water or land; or purchasing or transferring conservation credits.

3. General process of Restoration project

SERA (2017) proposed six key principles of ecological restoration practice.

- Principle-1: Ecological restoration practice is based on an appropriate local indigenous reference ecosystem. A reference ecosystem is a model adopted to identify the particular ecosystem that is the target of the restoration project. This involves describing the specific compositional, structural and functional ecosystem attributes requiring reinstatement before the desired outcome (the restored state) can be said to have been achieved.
- Principle-2: Restoration inputs will be dictated by level of resilience and degradation. This means that where human-induced impacts are low (or where sufficient time frames and nearby populations exist for effective recolonisation) recovery may be able to occur without assistance, but in sites of somewhat higher impact, at least some intervention is likely to be needed to initiate recovery. Where impacts are substantially higher or sufficient recovery time or populations are not available, correspondingly higher levels of restoration inputs and interventions are likely to be needed.
- Principle-3: Recovery of ecosystem attributes is facilitated by identifying clear targets, goals and objectives. Each ecosystem has different biomes and different sites, which mean that each project will have site-specific targets, goals and objectives aligned with specific attributes. Clearly defined targets and goals and measurable objectives, which can be used to monitor progress over time, will improve the chance of success.
- Principle-4: The goal of ecological restoration is full recovery, insofar as possible, even if outcomes take long timeframes or involve high inputs. A restoration project is not qualified by its duration or funding. It is important that the intent to achieve the highest and best level of recovery possible. It also need to set the standards which offer a tool for progressively assessing and ranking degree of recovery over time.
- Principle-5: Restoration science and practice are synergistic. Ecological restoration is a rapidly emerging practice that often relies upon processes of trial and error, with monitoring increasingly being informed by scientific approaches. Formal field experiments can also be incorporated into restoration practice, generating new findings to both inform adaptive management and provide valuable insights for the natural sciences.
- Principle-6: Social aspects are critical to successful ecological restoration. Restoration is carried out to satisfy not only conservation values but also socioeconomic values,

including cultural ones. Social engagement is essential components of a restoration project and need to be planned and resourced alongside the physical or biological project components. The restoration project can be sustained and successful only when the public understands the significance and value of restoration.

Restoration projects need to adopt appropriate processes of planning, implementation, monitoring and evaluation to improve the chances of achieving the desired restoration outcomes.

Planning and design: Project planning, feasibility studies, engineering and design studies, and permitting activities are conducted before implementing restoration projects to characterize the environment, determine the best restoration approach from an engineering standpoint, and predict and compare results and conditions with the project and without it. In this phase, the projects need identify and describe the appropriate local native reference ecosystem(s), actual or compiled from historical or predictive records. The projects also need clearly state its targets, goals and objectives.

Implementation: Ecological restoration included restoration, rehabilitation, remediation and reclamation (Perrow and Davy 2002). Methodologies of restoration include active restoration and passive restoration. Active restoration requires humans to control and intervene at regular basis in order to restore, recreate or improve the community structure and ecosystem processes (Wagner et al., 2008). In a salt marsh restoration program in the New England region of the United States, hydroperiod adjustment through tidal flow restoration proved effective (Burdick et al., 1996). A large restoration project has been conducted in a degraded coastal *Phragmites australis* wetland in the Nature Reserve of the Yellow River Delta (in China) since 2001. The restoration measures involved building dams and embankments, freshwater collection and water diversion from the Yellow River. This project has proved to be successful with an expanded area of *Phragmites australis* wetland, increased biota species richness and habitat quantity and desalination of the soil (Tang et al., 2006). Passive restoration means elimination of influencing factors that lead to degradation or destruction and restoring degraded ecosystems to a healthy state under natural conditions (Wagner et al., 2008). For example, the enhancement of ecohydrological processes rebuild the hydrogeomorphology for wetland self-restoration (Mitsch and Wang, 2000; Hunter et al., 2008; Jarzemsky et al., 2013).

Monitoring and evaluating: Monitoring activities evaluate implementation quality and the effectiveness of completed or in-progress habitat restoration projects. Monitoring is defined as systematic data collection to assess whether a directed restoration action was carried out as designed and, as appropriate, to determine whether the restoration action is providing a basic level of effectiveness. Examples of monitoring parameters may include as-built topography/bathymetry (e.g., width, depth, slope, height, elevation, etc.), other ecosystem structure components (e.g., survival of planted species, water stage, etc.), and/or presence/absence of target biota species (Table 1).

Table 1. Categories of recommended parameters to be monitored and related terms

Category/Term	Definition
Metric	A measurement used to quantify a characteristic of a habitat
Variable	A physical or environmental factor that is subject to change and may impact the area of study.
Universal metrics	Metrics that should be sampled for every restoration project, regardless of its restoration goal.
Universal environmental variables	Variables that will aid in data interpretation and should be measured for every restoration project.
Restoration goal-based metrics	Metrics that are specific to ecosystem service-based restoration goals and are not sampled for every project. They may be considered for projects citing a particular restoration goal.
Ancillary monitoring considerations	Optional metrics that may be monitored to obtain additional beneficial information associated with restoration performance.

(Baggett et al., 2015).

Currently, there is no professional consensus on the choice of ecological metrics to assess restoration success. A meta-analysis of oyster restoration projects in the Chesapeake Bay examined the available datasets from 1990 to 2007, analyzing over 78,0000 records from 1035 sites (Kramer and Sellner 2009, Kennedy et al. 2011). The analysis found that relatively few of the restoration activities were monitored, and that the restoration goals of many of the projects were not well-defined, with only 43% of the datasets including both a restoration and monitoring component. To achieving the stated ecosystem-based restoration goals, it is important to implement all oyster restoration projects using experimental designs with robust sample size replication and quantitative pre- and post-restoration monitoring. The recommended a set of Universal Metrics (Table 2) that should be monitored for all oyster restoration projects (Baggett et al., 2014).

Table 2. Universal metrics. dGPS=differential Global Positioning System.

Metric	Methods	Units	Frequency	Performance Criteria
Reef areal dimension				
Project footprint	Measure maximal aerial extent of reef using dGPS, surveyor's measuring wheel or transect tape, or aerial imagery; subtidal, use sonar or SCUBA.	m2	Preconstruction, within 3 months postconstruction, minimum 1–2 years postconstruction; preferably 4–6 years. After events that could alter reef area.	None
Reef area	Measure area of each patch reef dGPS,	m2	Preconstruction, within 3 months postconstruction, minimum 1–2	None

	surveyor's measuring wheel or transect tape, or aerial imagery; subtidal, use sonar or depth finder with ground truthing. Sum all patches to get total reef area.		years postconstruction; preferably 4–6 years. After events that could alter reef area.	
Reef height	Measure using graduated rod and transit, or survey equipment; subtidal, use sonar or depth finder.	m	Preconstruction, within 3 months postconstruction, minimum 1–2 years postconstruction; preferably 4–6 years. After events that could alter reef area.	Positive or neutral change
Oyster density	Utilize quadrats. Collect substrate to depth necessary to obtain all live oysters within quadrat, and enumerate live oysters, including recruits. If project involved the use of seed oysters, enumerate all seed oysters present in quadrat.	ind/m2	Immediately after deployment if using seed oysters. Otherwise, annually at the end of oyster growing season (will vary by region), 1–2 years at minimum; preferably 4–6 years.	Based on short- and long-term goals developed using available regional and project-type data, as well as current and/or historical local/regional densities.
Size–frequency distribution	Measure shell height of at least 50 live oysters per oyster density sample.	mm (size), number or % per bin (size dist.)	Annually at the end of oyster growing season (will vary by region) in conjunction with oyster density sampling, at a minimum.	None

But, for example, some methods, such as the index of biological integrity (IBI), the habitat evaluation procedure (HEP), the hydrogeomorphic approach (HGM) and the rapid assessment of wetland functions are widely applied to assess the success of wetland restoration (Findlay, 2002; Li and Liu, 2007). Griffith et al. (2005) noted that multiple biological communities can be taken into account for the IBI method. An assessment of tidal restoration of salt marshes uses hydrology, soil and sediments, vegetation, nekton and birds as success indicators (Neckles et al., 2002). Both vegetation (i.e., leaf area index and aboveground biomass) and soil characteristics (i.e., soil organic matter, total nitrogen and redox potential) have been adopted as success indicators to assess restored mangrove wetlands (Salmo III et al., 2013). Alligators (hole abundance and occupancy rate) were chosen as indicators for Everglades restoration in 2009 and 2012 (Mazzotti et al., 2009; Fujisaki et al., 2012). Moreover, the microbial metrics (i.e., enzyme activities and bioenergetic parameters, fungal abundance) were used to indicate the progress in the restoration of salt marshes (Duarte et al., 2012; Salmo III et al., 2013).

To develop a success indicator system for monitoring restoration activities, the following steps should be used. First, restoration goals should be identified to ensure that the selected success indicators are more reasonable (Wang, 2006). Then, restoration practitioners should investigate ecosystem structure (e.g., landscape or community composition, distribution, and evolution), function (i.e., productivity and ecological service functions) and disturbance (e.g., reclamation, drainage and intensity, range and frequency of disturbance) (Cui and Yang, 2002). After that, much more attention should be paid to dynamic changes at different space and time scales, as these selected success indicators are more sensitive to spatial and temporal changes. Moreover, the developed success indicator system should represent the hierarchy of the target ecosystem at multiple scales (Wu, 1991). In addition, some important social attributes should be included in the indicator system, as the success evaluation of restored ecosystem might be based on subjective human evaluation of the attributes and characteristics of restored ecosystem under some condition (Meyer,1997).

Evaluation is essential to the restoration projects. The evaluation of a restoration plan can be divided into three aspects. Many standards have been established for the quality of the Marine environment. When the environmental quality meets the relevant standards, the restoration project is successful. Before implementation, the projects identify and describe the appropriate local native reference ecosystem(s). The results of restoration activities can be evaluated by comparing the restoration area with the reference area. In addition, the outcomes of restoration can be evaluated by comparing the changes before and after restoration. So, we need carry out effectiveness monitoring as systematic data collection to assess the effectiveness of restoration actions and to assess progress toward the desired goals and outcomes of a given project.

Effectiveness monitoring typically addresses the development, enhancement, or testing of coastal habitat restoration techniques; improves the understanding of trophic relationships within coastal habitats; and improves habitat restoration monitoring and evaluation methods. Effectiveness monitoring and evaluation address ecological and/or technique effectiveness questions and thus advances the understanding of the efficacy of habitat restoration actions. Effectiveness monitoring data analyses and dissemination of results inform future priorities, project selection, and implementation activities and improve restoration programs and advance restoration practice (SERA, 2017).

The Society of Ecological Restoration International (SER) (2004) has also issued a primer illustrating nine ecosystem attributes such as diversity, vegetation structure, ecological functions and ecological processes (e.g., nutrient cycling and biological interactions) that should be taken into account and adopted when assessing the success of eco-logical restoration. The nine attributes can be grouped into the four categories of species composition, ecosystem function, ecosystem stability, and landscape context (Shackelford et al., 2013). However, no studies on ecological restoration measured all metrics proposed by SER (2004).

Ruiz-Jaén and Aide (2005b) reviewed a large number of published studies regarding restoration ecology and categorized the success indicators into diversity, vegetation structure, and eco-logical processes. In addition, the vegetation structure recovery has been a focus in the success evaluation of many restoration projects (Young, 2000). However, it is proposed that both diversity and abundance are most commonly used in restoration assessments (Wortley et al., 2013; Zhang et al., 2015).

To help managers track progress towards project goals over time, NRSA (2017) develop a Standards to offer a tool (Progress evaluation 'recovery wheel', Figure 1) for progressively assessing and ranking degree of recovery over time. This tool is summarised in Table 3.

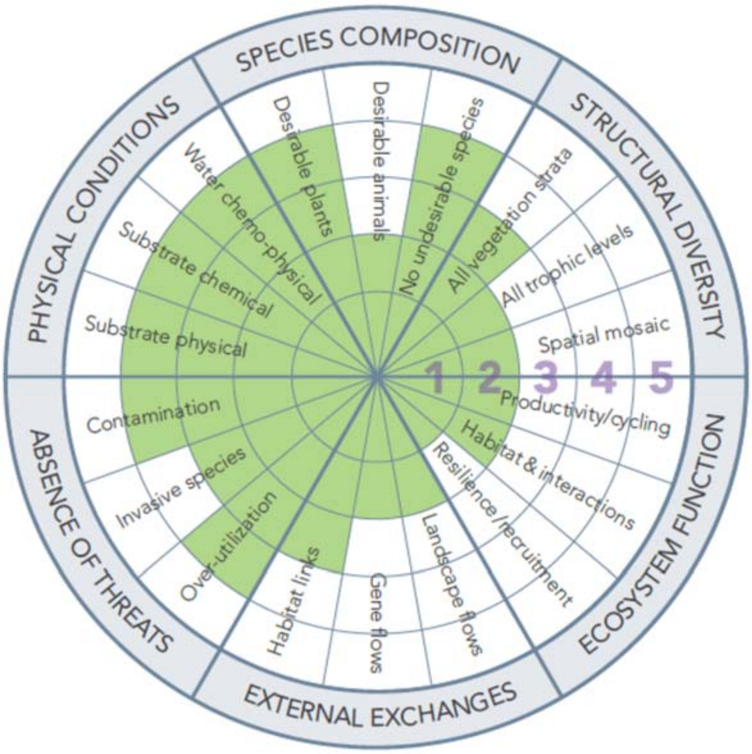

Figure 1 Progress evaluation 'recovery wheel' of SERA. Download the Recovery Wheel App for Android from Google Play or for IOS from Itunes. Interactive web-based or Excel versions are also available on the SERA website.

Table 3 Generic one-to-five-star recovery scale interpreted in the context of the six attributes used to measure progress towards a restored state. (Note: this five-star scale represents a gradient from very low to very high similarity to the reference ecosystem. It provides a generic framework only; requiring users to develop indicators and a metric specific to their system and ecosystem type.)

Attribute	One-star	Two-star	Three-star	Four-star	Five-star
Absence of threats	Further deterioration discontinued and site has tenure and management secured.	Threats from adjacent areas beginning to be managed or mitigated.	All adjacent threats being managed or mitigated to a low extent.	All adjacent threats starting to be managed or mitigated to an intermediate extent.	All threats managed or mitigated to high extent.
Physical	Gross physical and	Substrate chemical	Substrate	Substrate	Substrate exhibiting

conditions	chemical problems remediated (e.g. contamination, erosion, compaction).	and physical properties (e.g. pH, salinity) on track to stabilize within natural range.	stabilised within natural range and supporting growth of characteristic biota.	maintaining conditions suitable for ongoing growth and recruitment of characteristic biota.	physical and chemical characteristics highly similar to that of the reference ecosystem with evidence they can indefinitely sustain species and processes
Species compositio n	Colonising indigenous species (e.g. < 2% of the species of reference ecosystem). No threat to regeneration niches or future successions.	Genetic diversity of stock arranged and a small subset of characteristic Indigenous species establishing (e.g. 2 to 10% of reference). Low threat from exotic invasive or undesirable species.	A subset of key indigenous species (e.g. up to 25% of reference) establishing over substantial proportions of the site, with nil to low threat from undesirable species	Substantial diversity of characteristic biota (e.g. up to 60% of reference) present on the site and representing a wide diversity of species groups. No inhibition by undesirable species.	High diversity of characteristic species (e.g. > 80% of reference) across the site, with high similarity to the reference ecosystem; improved potential for colonisation of more species over time.
Structural diversity	One or fewer strata present and no spatial patterning or trophic complexity relative to reference ecosystem.	More strata present but low spatial patterning and trophic complexity, relative to reference ecosystem.	Most strata present and some spatial pattering and trophic complexity relative to reference site.	All strata present. Spatial pattering evident and substantial trophic complexity developing, relative to the reference ecosystem.	All strata present and spatial pattering and trophic complexity high. Further complexity and spatial pattering able to selforganise to highly resemble reference ecosystem.
Ecosystem function	Substrates and hydrology are at a foundational stage only, capable of future development of functions similar to the reference.	Substrates and hydrology show increased potential for a wider range of functions including nutrient cycling, and provision of habitats/resources for other species.	Evidence of functions commencing—e.g. nutrient cycling, water filtration and provision of habitat resources for a range of species.	Substantial evidence of key functions and processes commencing including reproduction, dispersal and recruitment of a species.	Considerable evidence of functions and processes on a secure trajectory towards reference and evidence of ecosystem resilience likely after reinstatement of appropriate disturbance regimes.
External exchanges	Potential identified for reinstating exchanges (e.g. of species, genes, water, fire) with	Connectivity for enhanced positive (and minimised negative) exchanges	Connectivity increasing and exchanges between site and external	High level of connectivity with other natural areas established, observing control	Evidence that potential for external exchanges is highly similar to reference and long term integrated

	surrounding landscape or aquatic environment.	arranged through cooperation with stakeholders and configuration of site.	environment starting to be evident (e.g. more species, flows etc)	of pest species and undesirable disturbances.	management arrangements with broader landscape in place and operative.

Public education and social communication: The public outreach project type includes implementation of projects to enhance and further public knowledge about the local environmental resources, the ecological importance of restoration activities, and the value of the environment to local communities. Education and engagement is often best achieved by actively involving adequately supervised stakeholders in paid or voluntary work—both having a positive effect in stakeholder communities. When public understand the benefit of the restoration, it can increase the level of practical collaboration, facilitating solutions best suited to local ecosystems and cultures.

4. Future challenges of the restoration project in YS

Countries bordering the yellow sea, China and RO Korea, have implemented ecological restoration activities to conserve and manage coastal and marine resources in YS. In China, restrictions on locations and seasons for commercial fishing extend to 4 months since 2017. Efforts to enhance fish stocks include re-stocking programs and the development of artificial reefs, marine forests, and coastal marine ranches were implemented at both sides of YS. China has launched several wetlands conservation projects to mitigate the impact of reclamation and prevent habitat loss. China and RO Korea have undertaken systematic efforts to expand and manage MPAs and establish networks of MPAs.

Although these restoration activities have produced positive results, the restoration of the YS ecosystem still faces many challenges. Compared with some successful cases of ecological restoration, there is still a lack of methodologies, standards and guidelines to ensure that restoration plans are implemented according to the set goals. Firstly, theories, technologies, monitoring and evaluation suitable for the implementation of the Yellow Sea ecosystem restoration projects need to be further improved, like 'recovery wheel' of SERA. Secondly, we need improve the conservation and compensation systems to ensure the restoration projects proceed smoothly. Third, as the basis for the implementation of ecological protection and restoration activities, relevant laws and regulations need to be further improved. Fouthly, because the government and enterprises are the main bodies of ecological restoration activities, enhancing the public ecosystem conservation awareness will increase the likelihood of restoration project success.

The Yellow Sea ecosystem is a whole. Close cooperation and joint efforts on ecological restoration between country and country, government and public are necessary. UNDP/GEF YSLME project provides a good international platform for the ecological restoration of the Yellow Sea. With the implementation of Phase I "Transboundary Diagnostic Analysis for the

YSLME" and Phase II "Implementing the Strategies Action Programme for the YSLME", the understanding of the changes of the Yellow Sea ecosystem and its causes has been deepened. China and RO Korea have taken a series of ecological restoration actions and achieved positive results. Nevertheless, restoration, protection and management of marine ecosystem is a long-term strategic task. It is hoped that this plan will continue in accordance with the established goals, so that the yellow sea ecosystem will become a successful model for the protection and restoration of Marine ecosystems under the influence of natural changes and human activities.

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