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Technical guideline on coastal ecological rehabilitation for hazard mitigation —

Part 5:

Seagrass bed

海岸带生态减灾修复技术导则 第5部分：海草床

（English Translation）

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Contents

Foreword

The T/CAOE 21 *Technical guideline on coastal ecological rehabilitation for hazard mitigation* consists of the following eleven parts:

——*Part 1: General;*

——*Part 2: Mangroves;*

——*Part 3: Salt marshes;*

——*Part 4: Coral reefs;*

——*Part 5: Seagrass bed;*

——*Part 6: Oyster reef;*

——*Part 7: Sandy coast;*

——*Part 8: Technical guide for the ecological construction of sea walls (trial);*

——*Part 9: Renovation of island-connecting sea wall and coastal engineering;*

——*Part 10: Directives for sea dike ecological construction of sea reclamation and enclosure project;*

——*Part 11: Supervising and monitoring.*

This is part 5 of T/CAOE 21, which is used together with Part 1.

This part is drafted in accordance with the rules given in the GB/T 1.1-2009.

This part was proposed by *the Marine Early Warning and Monitoring Division, Ministry of Natural Resources.*

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Technical guideline on coastal ecological rehabilitation for hazard mitigation—
Part 5: Seagrass bed

1 Scope

This part of T / CAOE 21 stipulates the work flow, data collection and investigation, suitability evaluation, implementation plan preparation, ecological hazard mitigation and restoration technology, tracking monitoring and effect evaluation, quality control, and results and archiving of ecological hazard mitigation and restoration of seaweed beds.

This part is suitable for ecological hazard mitigation and restoration of seaweed bed in coastal zone protection and restoration project, and other seagrass bed restoration work can be used as reference.

2 Normative references

The following documents are indispensable for the application of this document. For dated reference documents, only the dated version applies to this document. For undated references, the latest version (including all amendments) applies to this document.

GB 3097 *Sea water quality standard*

GB/T 12763.2 *The specification for oceanographic survey- Part 2: Marine hydrographic observation*

T/CAOE 20.6 *Technical guidelines for survey and assessment of coastal ecosystem status-Part 6:Seagrass bed*

T/CAOE 21.1 *Technical guidelines for coastal ecological disaster reduction and restoration-Part 1: General*

3 Terms and definitions

The following terms and definitions apply to this section.

3.1

seagrass bed

seagrass community composed of one or more seagrass species.

Note: rewrite HY/T 083-2005, definition 3.1.

3.2

reproductive shoot

seagrass shoot with flowers or seeds.

3.3

ramet

a new plant produced by clonal growth, consisting of stems, branches, rhizomes and roots.

3.4

propagule

any plant material that can be used for reproduction, including ramets, seeds, etc.

3.5

ramet transplantation

a method of collecting well-growing ramets from the natural seagrass bed and transplanting them in the sea to be restored.

3.6

planting unit

the basic unit of seagrass transplantation.

3.7

seed bank

the general term for viable seeds in the substrate.

4 Work procedure

The work process is executed in accordance with the requirements specified in Chapter 6 of T/CAOE 21.1.

5 Data collection and investigation

5.1 Data requirements

The background information that should be collected and investigated in the ecological restoration project area of marine grass bed ecological hazard mitigation (see Table 1) includes:

——Overview of the project area: regional location, scope, climate, beach elevation;

——Ecological conditions of the project area: seagrass bed, biome (macrobenthos, macroalgae), water environment, sediment environment, etc.;

——Marine dynamics in the engineering area: characteristics of regional waves, currents, tide levels, etc.;

——Marine disasters in the engineering area: frequency and level of storm surge, typhoon, and wave disasters in the area;

——Human activities in the engineering area: fishery activities, marine engineering, land-based pollution, etc.

Table 1—Data collection and investigation content of the seagrass bed ecological hazard mitigation and restoration engineering area

Investigation contents	Investigation elements	Investigation methods
Project area overview	Natural conditions: climate, etc.	Data collection
	Geographical attributes: specific location and geographic coordinates	Data collection
	Terrain : beach elevation	Site investigation
	Policies and regulations: laws and regulations, planning	Data collection
Seagrass bed	Area, type, coverage, density of stems and branches, height of stems and branches, width of vegetation zone	Site investigation
Biotic community	Macrobenthos: species, density, biomass	Site investigation
	Macroalgae: coverage, type	Site investigation
Environmental factors	Water environment: transparency, water temperature, salinity, dissolved oxygen, suspended matter, inorganic nitrogen, active phosphate	Data collection, Site investigation
	Sediment environment: sediment type, particle size,	Site investigation

	organic carbon, sulfide	
	Hydrodynamic environment: wave、ocean current、tide level	Site investigation or Data collection
Threat factors	Natural factors: storm surge、typhoon、invasion of alien species, etc.	Data collection, Site investigation, Social survey etc.
	Artificial activity: fishery fishing, benthic organism harvesting, mariculture, marine engineering, land source pollution, etc.	Data collection, Site investigation, Social survey etc.

5.2 Investigation on ecosystem status

5.2.1 Investigation elements

The investigation elements are detailed in Table 1.

5.2.2 Investigation method

The survey methods of seagrass beds, biological communities (macrobenthos, macroalgae), water environment, sediment environment, beach elevation, human activities and other related indicators are implemented in accordance with T / CAOE 20.6. The hydrodynamic environment data should include continuous observation data in the past five years and not less than one time, and the specific investigation method should be implemented in accordance with GB12763.2.

5.2.3 Investigation time

Conduct an investigation before and after the ecological hazard mitigation and restoration of seagrass beds, and the investigation time should be arranged in the same season. During the storm surge disaster, the on-site investigation should be carried out within 10 days after the disaster to investigate the status of the ecosystem.

5.3 Field observation of hazard mitigation function

5.3.1 Selection of measuring section and measuring point

The hazard mitigation function of seagrass bed is observed on site by setting section. The cross section should be parallel to the wave direction as far as possible, and the stem and branch density and vegetation belt width of seagrass should be able to better reflect the situation of seagrass bed in the whole region. 1 - 2 sections were set when the distribution characteristics of seagrass beds were uniform; when the distribution characteristics of seagrass beds are significantly different, more than three sections should be selected. There are no less than three measuring points in each section, two of which are located in the seaward side (seaward point) and the landward side (landward point) of seagrass vegetation area.

5.3.2 Observation elements and methods

The field observation elements of hazard mitigation function include wave height and tidal level towards sea point and land point. Observation methods for wave elements and tidal levels such as wave height and period shall be implemented in accordance with the relevant provisions of GB / T 12763.2.

5.3.3 Time of observation

The field observation period of hazard mitigation function should include the whole storm surge influence period (from 1d ~ 3d before storm surge warning to storm surge warning relief).

6 Suitability evaluation

6.1 Evaluation content

Before the ecological hazard mitigation and restoration of seagrass beds, a suitability evaluation should be carried out and a suitability evaluation report should be prepared. The assessment content includes ecological status assessment, hazard mitigation function assessment, restoration suitability assessment, etc.; if there is no seagrass bed distribution in the area, no hazard mitigation function assessment is required.

6.2 Ecological status assessment

The ecological status assessment is carried out in accordance with the provisions of T/CAOE 20.6.

6.3 Assessment of hazard mitigation function

6.3.1 Evaluation content

Evaluate the effect of seagrass beds on reducing storm surges and waves.

6.3.2 Evaluation index

Wave height attenuation rate is calculated according to formula (1).

$$R_{wL} = \frac{H_0 - H_L}{H_0} \times 100\% \quad \cdots\cdots (1)$$

Where:

R_{wL}——The percentage of the wave height attenuation (H_0-H_L) to the original wave height H_0 after the wave passes through the seagrass bed vegetation with vegetation width L during the storm surge;

H_0——The effective wave height of the seagrass bed vegetation area facing the sea (the sea point), in meters(m);

H_L——The effective wave height to the land side (land point) of the seagrass bed vegetation zone, in meters(m).

6.3.3 Evaluation method

See Annex A.

6.3.4 Evaluation results

According to the evaluation result, the hazard mitigation function can be divided into four grades: excellent, good, medium and poor according to the wave height attenuation rate, as shown in Table 2.

Table 2—Level table of wave height attenuation rate of seagrass bed vegetation

Wave height attenuation rate	Hazard mitigation function level
≥25%	excellent
≥15%～<25%	good
≥5%～<15%	moderate
<5%	poor

6.4 Evaluation of restoration suitability

6.4.1 Evaluation index

The degraded seagrass bed (total score of current assessment <60 points) is selected as the main object of ecological restoration suitability evaluation. The environmental conditions of the degraded area should meet the relevant requirements for the biological growth of seagrass, mainly including:

a) The velocity of the ocean current is relatively flat, and should not exceed 1.5m/s;

b) The salinity of the water body is relatively stable, not less than 20;

c) There is no source of a large amount of suspended sediment, high light transmittance;

d) The sulfide content in the sediment is not more than 500μg/g;

e) The bottom surface layer is clay silt, silty sand or fine sand (the seaweed of the genus shrimp is the bottom of the rock);

f) There is less human interference such as seawater pollution and fishery activities, and the seawater meets the water quality standards of Class 3 or more specified in GB 3097.

6.4.2 Suitability zone

The suitability zoning can be divided into suitable restoration areas, reformable restoration areas and unsuitable restoration areas, which are specifically defined according to the following requirements:

a) All the conditions in 6.4.1 are satisfied, which is the suitable restoration area.

b) The degraded seagrass bed that basically meets the conditions of 6.4.1, but is mainly disturbed by human activities such as seawater pollution and fishery production, can be improved by controlling human activities and other artificial measures, which is a reformable restoration area.

c) The area that does not meet the growth conditions of seagrass in 6.4.1, and the habitat improvement is not feasible, or conflicts with the local planning, is not suitable for restoration.

7 Implementation program establishment

The implementation plan was prepared according to the requirements specified in 7.3 in T / CAOE 21.1.

8 Ecological Restoration Technology of Seagrass Bed

8.1 Species choice

Priority is given to the selection of medium or large marine grass species with certain disaster mitigation functions in the locality, as detailed in Table 3 and Annex B .

Table 3—Main species for ecological restoration of seagrass beds

	Chinese name (Latin name)	Restoration methods	Restoration time	Seed collection time	density of crop
Temperate zone Seagrass	*Zostera marina*	Sub-plant transplantation method	May – June or Mid-September-October	July-August	150,000 grain /hectare
		seed-mediated method	Mid-September - early-October		
	Zostera japonica	Sub-plant transplantation method	May-June	September-October	300,000 grain /hectare
		seed-mediated method	October-November		
	Phyllospadix iwatensis	Sub-plant transplantation method	October-November	-	-
Subtropical -Tropical Seagrass	*Enhalus acoroides*	Sub-plant transplantation method	April-June	September-December	100,000 grain /hectare
		seed-mediated method	September-December		
	Zostera japonica	Grass transplantation	November-January next year	-	-

		method			
	Thalassia hemprichii	Grass transplantation method	April-June	-	-
	Cymodocea rotundata	Subplant transplantation method	April-June	-	-

8.2 Source of materials

Source of materials for ecological restoration of seagrass beds should follow the following principles:

——Seagrass beds with vigorous growth, high coverage and continuous distribution were selected as the provenance.

——The environmental conditions of the provenance were similar to the restoration area.

8.3 Seagrass bed Restoration method

See Annex C.

8.4 Maintenance

——The seagrass bed restoration area needs to be managed and protected regularly within 2 years. Specific measures include:

——cleaning up large areas of algae and sea drift repair garbage, etc.;

——timely planting unit dead or swept away by the waves to replant;

——cleaning up the pests in the restoration area (sea anemone etc.);

——Avoiding the interference of human activities in the restoration of seagrass, and prohibiting fishing activities that destroy seagrass beds such as trawling and shellfish harvesting in the restoration area and the surrounding sea areas;

——Setting up a sign warning monument near the restoration area, indicating the restoration, protection and management information of seagrass bed;

——Formulating a sound emergency plan for typhoons, storm surges and other disasters;

——Strengthening social participation and raise public awareness of protection.

9 Tracking monitoring and ecological evaluation

9.1 Tracking and monitoring

9.1.1 Frequency of monitoring

Seagrass bed restoration should be monitored once from 1 week to 2 weeks (in the first year), when the survival rate of seagrass to be transplanted tends to be stable, seagrass bed restoration is monitored once every 2-3 months. After the second year, the monitoring was carried out once a year in summer, and the continuous monitoring was not less than 3 years.

9.1.2 Monitoring content

The monitoring contents in the first year were mainly seagrass beds, and the monitoring indexes included survival rate, coverage, stem height, stem density, etc. The contents and indicators for follow-up monitoring in the second year are shown in table 4 and the survey monitoring methodology is implemented in accordance with T / CAOE 20.6.

9.2 Effect evaluation

9.2.1 Evaluation of hazard mitigation effects

Follow the method specified in 6.3.

9.2.2 Ecological effect assessment

9.2.2.1 Select reference system

The condition of seagrass bed before ecological hazard mitigation and restoration was used as the reference system to evaluate the effect of seagrass restoration. The evaluation method shall be implemented in accordance with T/CAOE 20.6.

9.2.2.2 Evaluation indicators and assignment

A comprehensive evaluation of the restoration effect will be carried out in the third year of seagrass bed restoration. The evaluation indicators include seagrass beds, biological communities, and environmental elements. Refer to Table 4 for the classification and assignment of indicators.

Table 4—Evaluation Index, Classification and Evaluation

Seagrass bed	Index	I	II	III
1	seagrass bed area increase	＞15%	≥5%~≤15%	＜5%
2	coverage increase	＞15%	≥5%~≤15%	＜5%
3	shoot density increase	＞15%	≥5%~≤15%	＜5%
Assignment		50	30	10
Biological community	Index	I	II	III
1	Coverage of large algae	≤15%	＞15%~≤30%	＞30%
2	Macrobenthos biomass increase	＞10%	＞5%~≤10%	≤5%
Evaluation		25	15	5
Water environment	Index	I	II	III
1	dissolved oxygen (mg/L)	＞6	＞5~≤6	≤5
2	suspended matter (mg/L)	≤10	＞10~≤50	＞50
3	inorganic nitrogen (μg/L)	≤200	＞200~≤300	＞300
4	active phosphate (μg/L)	≤15	＞15~≤30	＞30
Evaluation		15	10	5
Sediment environment	Index	I	II	III
1	organic carbon content	≤2.0%	＞2.0%~≤3.0%	＞3.0%
2	sulfide contents (μg/g)	≤300	＞300~≤500	＞500
Evaluation		10	5	1

9.2.2.3 Index calculation method

See Annex D.

9.2.2.4 Comprehensive assessment method

The comprehensive assessment index of the ecological status of the seagrass bed after restoration is calculated according to Formula (2).

$$I_{RSG} = I_{RV} + I_{RB} + I_{RW} + I_{RS} \quad \cdots\cdots (2)$$

Where:

I_{RSG}——comprehensive assessment index of seagrass bed ecological status after restoration;

I_{RV}——seagrass bed status index;

I_{RB}——biocommunity status index;

I_{RW}——water environment condition index;

I_{RS}——sediment environment index.

When the comprehensive evaluation seagrass ecosystems index $I_{RSG}\geqslant 80$, the ecological restoration effect is significantly improved; when $60\leqslant I_{RSG}<80$, the raw state repair effect is improved; when $I_{RSG}<60$, the ecological restoration effect is basically unchanged.

10 Quality control

Quality control is implemented in accordance with the requirements specified in Chapter 8 of T/CAOE 21.1.

11 Results and archives

The results and archives are implemented in accordance with the requirements specified in Chapter 9 of T/CAOE 21.1

Annex A
(annex normative)
Evaluation method of seagrass bed disaster mitigation function

A.1 Field observation method

A.1.1 Applicability of field observation methods

The field observation method is suitable for areas to be assessed that are frequently affected by disasters and economic conditions permit. In the year when the seagrass bed marine disaster mitigation function assessment is carried out, at least one storm surge should have a significant impact on the assessment area.

A.1.2 Observation data analysis and calculation method

The most unfavorable period (the maximum effective wave height) (the time length can be taken as 30 min) is selected from the effective wave height series observed in the field (see Fig. 5.3). The effective wave height H_0 and H_L of the measuring points before and after the observation section is brought into Formula (1) (see Fig. 6.3.2) to calculate the wave height attenuation rate R_{wL}.

A.2 Physical model test method

A.2.1 Applicability of the physical model test method

In cases where the frequency of regional marine disasters is low (there is no storm surge affecting the area to be assessed during the assessment year or the observation conditions are restricted and the on-site observation cannot be performed, physical model test methods can be used. Compared with the empirical formula, the advantage in that the physical model experiment can be to assess having a complicated shape, the uneven distribution of marine seagrass beds and mitigation effect with complex features.

A.2.2 Technical method

A.2.2.1 Model selection

The physical model needs to select the plant model of seagrass bed vegetation area, according to the structure characteristics of seagrass plants, according to the length similarity criterion to determine the size of the model. The length similarity scale is shown by the Formula (A.1).

$$\lambda_L = \frac{L_p}{L_m} \qquad \text{(A.1)}$$

Where:

L_p——characteristic length of the prototype, in meter (m);

L_m——characteristic length model, in meter (m).

A.2.2.2 model objects layout

The model objects are arranged according to the actual seagrass distribution characteristics. Model Plant arrangement density N_m and vegetation width L_m can be calculated through the length similar scale, according to the Formula (A.2) and (A.3).

$$N_m = N_p {\lambda_L}^2 \qquad \text{(A.2)}$$

$$L_{vm} = \frac{L_{vp}}{\lambda_L} \qquad \text{(A.3)}$$

Where:

N_p——the characteristic density of prototype;

N_m——the characteristic density of the model;

L_{vp}——the characteristic width of the prototype vegetation belt, in meter (m);
L_{vm}—characteristic width of model vegetation zone, in meter (m).

A.2.2.3 Water level and wave conditions

According to the nearshore tide and wave characteristics of the vegetation area of the seagrass bed to be evaluated, the wave height and water level in the hydrodynamic parameters of the model can be calculated by the length scale, and the calculation formulas are shown in Formulas (A.4) and (A.5). The model test and prototype parameters should also conform to the gravity similarity criterion, that is, the prototype Freud number is equal to the model Freud number. According to the length scale and gravity similarity criterion, the relationship between wave period and real sea state period in the model is shown in Formula (A.6).

$$H_{0m} = \frac{H_{0p}}{\lambda_L} \quad \cdots\cdots (A.4)$$

$$\eta_m = \frac{\eta_p}{\lambda_L} \quad \cdots\cdots (A.5)$$

$$T_m = \frac{T_p}{\sqrt{\lambda_L}} \quad \cdots\cdots (A.6)$$

Where:
H_{0p}—— characteristic effective wave height of prototype hydrodynamic parameters, in meter (m);
H_{0m}——characteristic effective wave height of model hydrodynamic parameters, in meter (m);
η_p——characteristic water level of prototype hydrodynamic parameters, in meter (m);
η_m——characteristic water level of model hydrodynamic parameters, in meter (m);
T_p——characteristic effective wave period of prototype hydrodynamic parameters, in second (s);
T_m——characteristic effective wave period of model hydrodynamic parameters, in second (s).

A.2.2.4 Arrangement of flume and measuring instruments

A wave-making device with active wave-absorbing function should be arranged at the head of the experimental tank for physical model experiment. The model is arranged in the middle of the tank, a certain distance from the wave-making equipment. After the model area, after a certain distance, set up the wave suppression equipment. Measure the wave propagation attenuation in the vegetation area of seagrass bed by digital wave-height gauge, arranged the wave-height gauge in the vegetation area before and after, measuring point of the wave-height gauge is at least three (each one for the front, middle and rear edge of the vegetation areas)

A.2.3 Test data analysis and calculation

Based on the data obtained from the model test , the hydrodynamic parameters such as water level , wave height , period , and the width and height of the vegetation area in the test condition are calculated by Formulas (A.3) - (A.5) , and the wave height $H_0 = H_{0p}$ and $H_L = H_{Lvp}$ sum before and after the prototype vegetation on hazard mitigation area and the width of the vegetation area in the evaluation section $L = L_{vp}$ are brought into Formula (1) to calculate the wave height attenuation rate R_{wL}.

A.3 Numerical simulation method

A.3.1 Applicability of numerical simulation method

In the lower frequency region marine hazards (storm surge area to be evaluated does not occur within a year of evaluation)or economic and technical conditions were not taken during a field observation method, if the master region feature distribution area vegetation length, width, and vegetation the density of stems, height Laid time characteristic parameters, hydrodynamic conditions, mature and numerical simulation conditions, this method can be evaluated seagrass beds and mitigation function.

A.3.2 Numerical mode

There are two main types of existing numerical models for the interaction of plants and waves. One type is to directly add a plant force item to the ocean current and wave models to characterize the effect of plants, and to modify the relevant parameters of the model in the seagrass bed area. ; the other is the use of specialized seagrass bed zone wave current motion field model, this type of model has different processing methods, as will be considered as a porous medium plants derived obtain spatial averaging to wave and current movement of the fluid plants The governing equation. Specific numerical simulation can select a suitable numerical model according to actual requirements and computing capabilities. This guide gives the calculation method of the wave flow motion fluid governing equation in porous media, as follows:

The model plant vegetation considered porous media of N-S equations deduced spatial averaging, equations in Formula (A.7) and Formula (A.8). This model can better simulate the attenuation process of wave propagation in vegetation areas.

$$\frac{\partial \langle u_i \rangle}{\partial x_i} = 0 \quad \cdots\cdots (A.7)$$

$$\frac{\partial \langle u_i \rangle}{\partial t} + \langle u_j \rangle \frac{\partial \langle u_i \rangle}{\partial x_j} = -\frac{1}{\rho}\frac{\partial \langle P \rangle}{\partial x_i} + g_i + \nu \frac{\partial^2 \langle u_i \rangle}{\partial x_i \partial x_j} - \frac{\partial^2 \langle u_i' u_j' \rangle}{\partial x_j} - \langle f_i \rangle \quad \cdots\cdots (A.8)$$

Where:

$\langle u_i \rangle$——i (i=1, 2 in a two-dimensional problem; i=1, 2, 3 in a three-dimensional problem) the average velocity in space;

$\langle P \rangle$——space mean pressure;

ρ——fluid density in kilogram per cubic meter (kg/m^3);

g_i——gravitational acceleration in the i direction;

ν——fluid kinematic viscosity;

$\langle u_i' u_j' \rangle$—— Spatial average Reynolds stress, which can be solved by k-e turbulence model;

$\langle f_i \rangle$——space averaging plant force

Force of vegetation area f_i can be reduced to drag and inertia terms. For a single cylinder, the Formula (A.9) and (A.10) can be used to calculate the drag force and inertia force of the water body .

$$f_D = \frac{1}{2}\rho C_D D u |u| \quad \cdots\cdots (A.9)$$

$$f_I = \rho C_m \frac{\pi D^2}{4}\frac{\partial u}{\partial t} \quad \cdots\cdots (A.10)$$

Where:

f_D——Drag force;

f_I——Inertia force;

C_D——Drag coefficient (According to the specific characteristics of rigidity and flexibility of different seagrass species to determine);

C_m——Inertia coefficient (According to the specific characteristics of rigidity and flexibility of different seagrass species to determine);

ρ——The density of the fluid, in kilograms per cubic meter (kg/m^3);

D——Diameter of plant, in meter (m);

u——Water velocity, per second in meter (m/s).

A.3.3 Analysis and Calculation of Numerical Simulation Results

When using the numerical simulation method to evaluate the function of hazard mitigation, the real scale should be used to simulate and calculate, and the wave height H_0 and H_L before and after the simulation of the vegetation area to be evaluated and brought into the formula (1), the wave height attenuation rate R_{wL} can be calculated.

A.4 Selection of Evaluation Methods

The selection of evaluation method should be combined with the site conditions, economic conditions, technical equipment and experimental conditions. When conditions permit, first of all, the field observation method should be considered to directly measure and calculate the wave height reduction rate of seagrass bed during storm surge. When the conditions are limited, such as no storm surge impact assessment area in recent years, cannot be carried out during the storm surge disaster field observation, can use other methods ; If the physical model experiment conditions allow, the physical model can be used to evaluate, to ensure that the prototype plant parameters and marine hydrodynamic parameters are true and reliable ; When the numerical simulation method is used for evaluation, it should be noted that reliable numerical models should be selected to ensure the reasonable and accurate parameterization of grass plant characteristics.

Annex B
(annex informative)
Pictures of Main Species for Ecological Restoration of Seagrass Bed

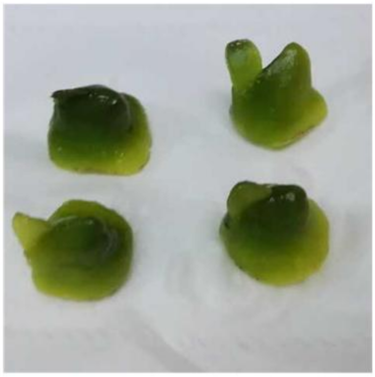
Zostera marina

Zostera marina's seed

Phyllospadix iwatensis

Enhalus acoroides

Enhalus acodoides' fruit



Enhalus acodoides' seed

Thalassia hemprichii

Cymodocea rotundata

Zostera japonica

Annex C
(annex normative)
Methods for Restoration Seagrass Bed

C.1 transplant method

C.1.1 transplanting time

Different species of seagrass have different restoration times. See Table 3.

C.1.2 Transplant unit collection

The commonly used transplantation units include grass and clone ramets, which were collected in the provenance according to the following methods. In order to reduce the damage to the seagrass bed, the transplantation unit should be collected from different areas of the seagrass bed

——Grass block: Using the diameter (about 20cm ~ 30cm) of PVC pipe or iron shovel and other tools to dig grass block with a certain shape (cylinder, cuboid) in the seagrass bed root zone substrate. For the convenience of transportation, the length and width of the grass were both less than 30 cm, and the depth of the grass was determined by the development degree of different seagrass roots. The spacing of the collected grass is not less than 0.5 m.

——Plants: First collect the grass (method above), then wash the attached substrate locally, as far as possible to 2 ~ 5 plants connected fragments as a transplant unit. Enhalus acoroides can be planted by single plant.

C.1.3 Transplant unit temporary maintenance and transportation

After the transplantation unit was collected, thickening plastic finishing box or temporary maintenance in the pool could be used. The oxygen can be filled by air pump in temporary maintenance. When the transplant unit is transported to the repair area, the plant must be moist and fresh, and ice bags can be added if necessary to keep fresh. Seagrass plants are easy to rot, and should be transplanted as soon as possible (within 2d–3d) after transplantation unit collection .

C.1.4 Transplant unit colonization

Different transplant units have different ways of fixing them to the substrate. Specific as follows:

——Grass: Dug out a pit slightly larger than the transplant unit in the repair area, place the grass in and compact it. Spacing of grass graft does not exceed 50 cm.

—— Branching: In order to avoid being washed away by the sea, the fixation of the transplant unit needs the help of other objects. Specific methods are:

(a) Rhizome-binding method: The rhizomes of the ramets were bound to the stones with hemp rope or plastic banding (which can be recycled after the survival of the planting unit), and then buried or thrown in the repair area.

(b) Pinning method: The rhizomes are fixed on U-shaped and V-shaped pegs (similar to staple needle) with rope or tie, and then fixed to the sea bottom . Enumeration inserts the length of the substrate about 15 cm, transplant unit evenly distributed.

(c)Grid method: rhizomes are fixed on the mesh or grid frame with hemp rope or tie, and then fixed on the repair area. The distance between the cloned fragments on the grid was about 10 cm ~ 20 cm; The distance between grid frames is less than 1m.

C.2 seed method

C.2.1 seed collection

The seed maturity of different species is different, and the collection time is shown in Table 2. Seed collection methods are as follows:

——Reproductive branch collection: In the seagrass seed mature season, collecting reproductive branch, put into the net bag in the seawater pond or fixed in the sea area . When the seeds mature and fall off, remove the stems and leaves, collect seeds. This method was mainly applied to *Zostera marina* and *Zostera japonica*.

——Seed bank collection: if the seed setting rate of seagrass was low or the reproductive branch was missed in the current year, the sediment of about 10 cm in the surface layer could be excavated in the provenance, and the seeds could be picked after screening (the aperture was not more than the short diameter of the seeds) . This method is mainly applied to species with seed bank, such as *Zostera marina* and *Zostera japonica*, etc.

——Fruit collection: The mature fruit of *Enhalus acoroides* was collected from September to December each year, and then put into a net bag and temporarily reared in a seawater pond or fixed in the sea area . When the fruit bursts, collect the seeds.

C.2.2 Seed Preservation and Transportation

Seeds need to be preserved in a seawater pond with warm salt conditions similar to natural seawater. Seeds of *Zostera marina* and *Zostera japonica* can be stored at 0 - 4℃ (soaked in seawater) ; *Enhalus acoroides* should be preserved at room temperature (soaked in seawater) . When sowing, the seeds were taken out and transported to the repair area in a foam box (with ice). *Enhalus acoroides* seeds were sowed as soon as possible after release to prevent seed decay (3d ~ 5d).

C.2.3 Sowing time and density

The sowing time of different species is shown in table 3.

Sowing density of different species is different. Planting density of *Zostera marina* is not less than 150,000 seeds / hectare, planting density of *Zostera japonica* is not less than 300,000 seeds /hectare, planting density of *Enhalus acoroides* is 100,000 seeds /hectare.

C.2.4 seeding method

Mainly includes direct seeding method, mud block seeding method, net bag seeding method, mechanical seeding method, transplant seedling method, etc.

——Direct seeding: Direct seeding of seeds in the restoration area at low tide. This method is low cost, but the seed loss is serious. Suitable for species with abundant seeds.

——Slurry seeding method : the fine sand and clay water mixed evenly, using the diameter of 7cm ~ 10cm,height of 3cm ~ 5cm PVC pipe as a mold made of mud, and the seeds (10~15) placed in the mud . After drying for 1d - 2d, the mud was thrown in the seagrass restoration area. This method is suitable for Zostera marina.

——Seeding method of net bag : The seeds of seagrass are mixed with sediment and put into a net bag(mesh size should be less than the short diameter of seeds) made of cotton (or hemp, etc. .) . The net bag is spread in the sea area of restoration, and the thickness is not more than 5 cm.

——Mechanical seeding method: Seagrass seeds are planted in the sea area by seagrass seeding machinery.

——Seedling method: The collected seeds were germinated and cultivated into seedlings, and then transplanted to the repair sea area. It is suitable for most seagrass.

Annex D
(annex normative)
Evaluation Index of Seagrass Bed Restoration Effect

D.1 Seagrass bed index

a) The increase rate of seagrass bed area is calculated by formula (D.1):

$$V_1 = \frac{A-A_0}{A_0} \times 100\% \quad \cdots\cdots (D.1)$$

Where:

V_1——Area increase rate of seagrass bed, the unit is percentage (%);

A——Repaired area per hectare, the unit is hectare (hm2);

A_0——Initial planting area, the unit is hectare (hm2).

Note: The boundary of seagrass bed area is defined as coverage ≥ 5 %.

b) Seagrass coverage index is calculated by formula(D.2):

$$\bar{C} = \frac{\sum_1^N C_i}{N} \quad \cdots\cdots (D.2)$$

Where:

$\bar{C}$——Average coverage of seagrass after restoration, the unit is percentage (%);

C_i——The coverage value of the i^th quadrat, the unit is percentage (%);

N——Total number of regional samples assessed.

Variation of seagrass coverage by formula (D.3):

$$V_2 = \frac{\bar{C}-C_0}{C_0} \times 100\% \quad \cdots\cdots (D.3)$$

Where:

V_2——Rate of change seagrass coverage, the unit is percentage (%);

$\bar{C}$——Average coverage of seagrass after restoration;

C_0——Initial planting coverage.

c) Calculation of stem and branch density of seagrass by formula (D.4):

$$\overline{D} = \frac{\sum_1^N D_i}{N} \quad \cdots\cdots (D.4)$$

Where:

$\overline{D}$——Stem and branch density monitoring average, the unit is seeds / m2;

D_i——Stem branch density of the i^th quadrat, the unit is seeds /m2;

N——Total number of regional samples assessed.

The variation of stem and branch density of seagrass was calculated by formula (D.5):

$$V_3 = \frac{\overline{D}-D_0}{D_0} \times 100\% \quad \cdots\cdots (D.5)$$

Where:

V_3——The change rate of stem density, the unit is percentage (%);

$\overline{D}$——Average value of stem density after restoration;

D_0——Stem and branch density of initial planting.

d) The evaluation index of restoration seagrass bed was calculated by formula (D.6):

$$I_{RV} = \frac{\sum_1^q V_i}{q} \quad \cdots\cdots (D.6)$$

Where:

I_{RV}—— The evaluation index of restoration seagrass bed;

V_i——the i-th seagrass bed evaluation index assignment (see Table 4);

q——Total number of seagrass bed evaluation indexes.

D.2 Biocommunity indicators

a) Average Coverage of Macroalgae by Formula(D.7):

$$B_1 = \frac{\sum_1^N MA_i}{N} \quad \cdots\cdots (D.7)$$

Where:

B_1——The average coverage of macroalgae after restoration in percentage (%);

MA_i——Coverage of large algae of quadrat I in percentage(%);

N——Total number of regional samples assessed.

b) Biomass of macrobenthos by formula (D.8):

$$\overline{BA} = \frac{\sum_1^N BA_i}{N} \quad \cdots\cdots (D.8)$$

Where:

$\overline{BA}$——Average biomass of macrobenthos after restoration in unit of g / m2;

BA_i——Macrobenthos biomass of quadrat I in unit of g / m2;

N——Total number of regional samples assessed.

c)The change rate of macrobenthos biomass is calculated by formula(D.9):

$$B_2 = \frac{\overline{BA} - BA_0}{BA_0} \times 100\% \quad \cdots\cdots (D.9)$$

Where:

B_2——The change rate of macrobenthos biomass in unit of percentage(%);

$\overline{BA}$——Average biomass of macrobenthos after restoration in unit of g;

BA_0——Biomass of macrobenthos before restoration.

d)Status index of biological community in restored seagrass bed()by formula(D.10):

$$I_{RB} = \frac{\sum_1^q B_i}{q} \quad \cdots\cdots (D.10)$$

Where:

I_{RB}——Status index of biological community in restored seagrass bed;

B_i——The assignment of the ith biological community evaluation index (see Table 4) ;

q——Total biological community assessment indicators.

D.3 Water environment indicator

Water environmental assessment is calculated as follows.

a)Assignment of each indicator of the water environment by formula(D.11):

$$W_q = \frac{\sum_1^n W_i}{n} \quad \cdots\cdots (D.11)$$

Where:

W_q——The qth evaluation index;

W_i——The qth evaluation index assignment of the ith station (see Table4);

n——Assessment of regional stations.

b) Water environment index by formula (D.12):

$$I_{RW} = \frac{\sum_1^m W_q}{m} \quad \cdots\cdots (D.12)$$

Where:

I_{RW}——Water Environment Index after restoration;

W_q——The qth evaluation indicator (see table 4);

m——Total number of regional evaluation indicators.

D.4 Substrate environmental indicators

a) Assessment assignments for the sediment environment are calculated by formula (D. 13):

$$S_q = \frac{\sum_1^n S_i}{n} \quad \cdots\cdots (D.13)$$

Where:

S_q—— The qth evaluation index assignment of the substrate environment;

S_i——The qth evaluation index assignment of the ith station in the substrate environment (see table 4);

n—— The number of stations in the Areas assessed.

b) The substrate environment condition index is calculated by (D.14):

$$I_{RS} = \frac{\sum_1^q S_q}{q} \quad \text{(D.14)}$$

Where:

I_{RS}——Environmental Condition Index of Repaired Substrate;

S_q——Assignment of the q^th evaluation index;

q——Total number of regional evaluation indicators.

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