Marine Ecological Capital Assessment: Methods and Applications

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Outline

1. Basic concepts
2. Identification of Marine Ecological Capital
3. Assessment methods
4. Application in China seas

1. Basic concepts

--Marine ecological capital(MEC)

Marine ecological resources which have direct or indirect contribution to social and economic production and provide benefits for human beings.

--Marine ecological capital value

The monetized benefits for humans from marine ecological capital, including the stock value of marine ecological resource and the value of marine ecosystem services.

1. Basic concepts

--The stock value of marine ecological resources

Includes 2 elements: the standing stock value of marine living resources and their habitat resources. Here habitat consists of sea water and surface seabed.

--Marine ecosystem service(MES)

Benefits which human beings obtained from marine ecosystem， which include any products and services, in any mass and non-mass forms, in any visible and non-visible forms. Including 4 groups: provisioning, regulating, cultural and supporting services.

1. Basic concepts

---Provisioning services

Material products provided by marine ecosystem, e.g. food, raw material, oxygen production.

--- Regulating services

The benefits obtained from the regulation of ecological processes. e.g. climate regulation.

--- Cultural services

The nonphysical benefits obtained from ecosystems. E.g. tour, leisure, R&D.

--- Supporting services

Those that are necessary to support all above ecosystem services. E. g. provide C, N, P, energy to ecosystem's running.

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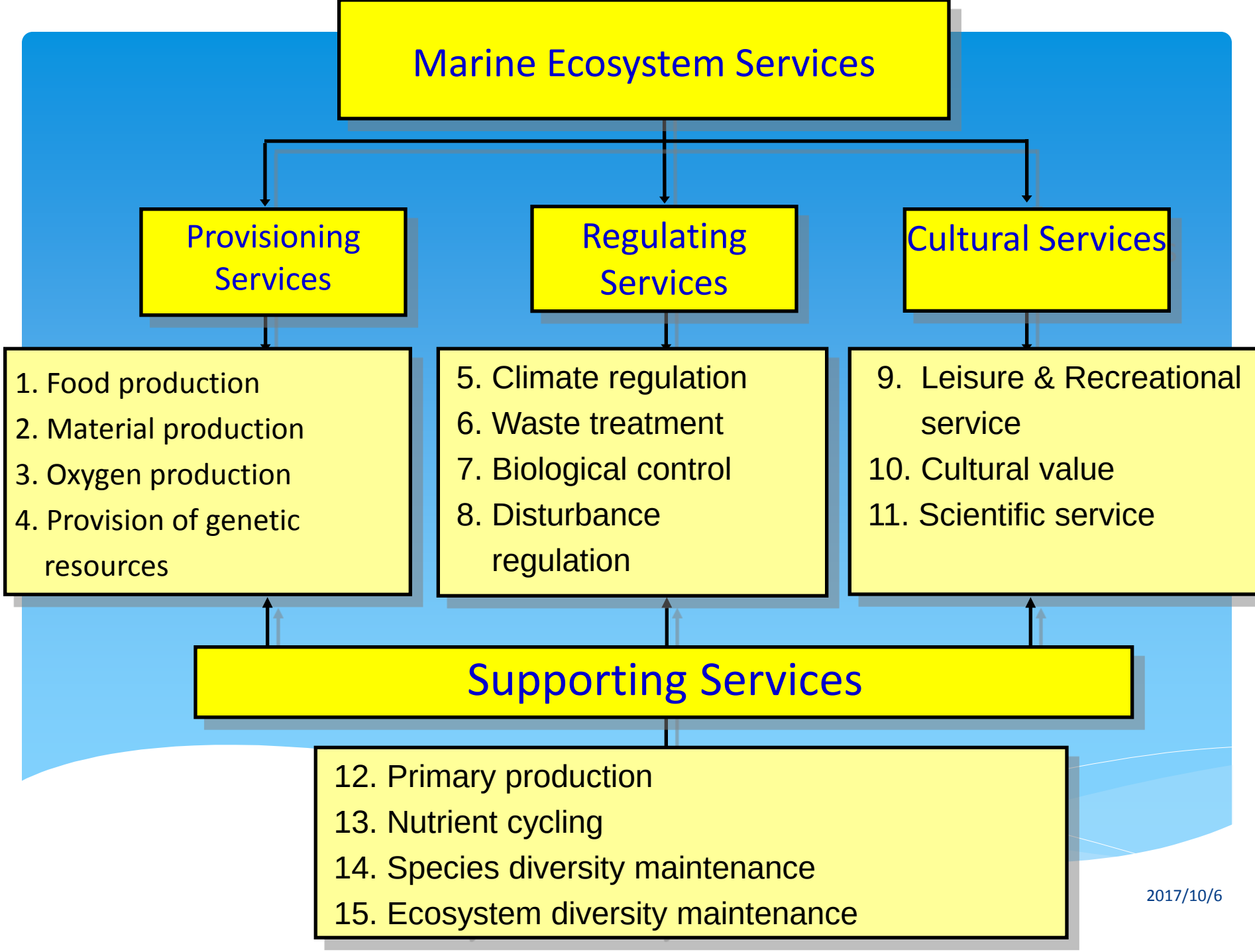
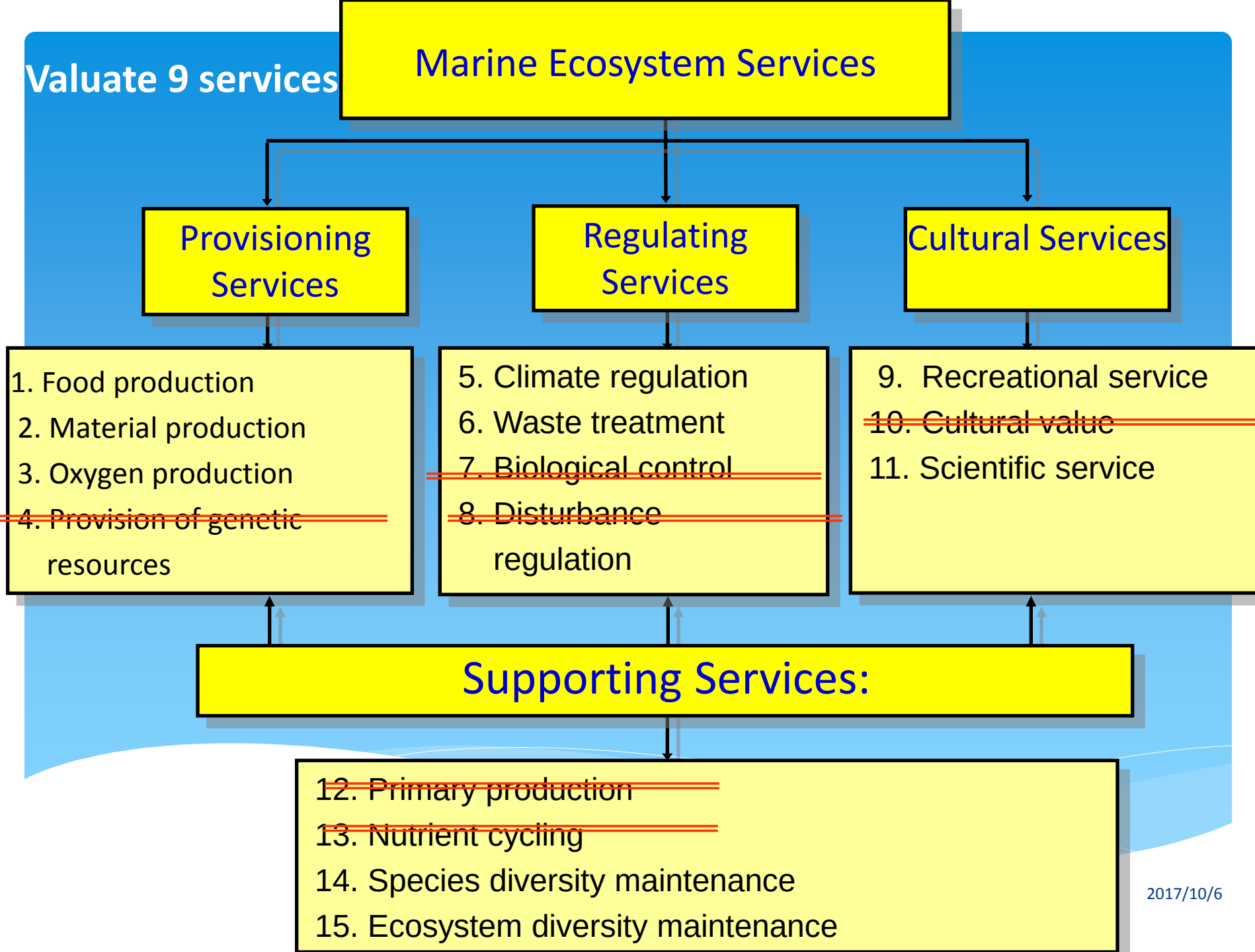
Identification

Marine Ecological capital value

- marine ecological resource stock value
- marine ecosystem service value


Marine Ecosystem Services
Provisioning Services
Regulating Services
Cultural Services
1. Food production
2. Material production
3. Oxygen production
4. Provision of genetic resources
5. Climate regulation
6. Waste treatment
7. Biological control
8. Disturbance regulation
9. Leisure & Recreational service
10. Cultural value
11. Scientific service
Supporting Services
12. Primary production
13. Nutrient cycling
14. Species diversity maintenance
15. Ecosystem diversity maintenance


Valuate 9 services
Marine Ecosystem Services
Provisioning Services
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1. Food production
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Supporting Services:
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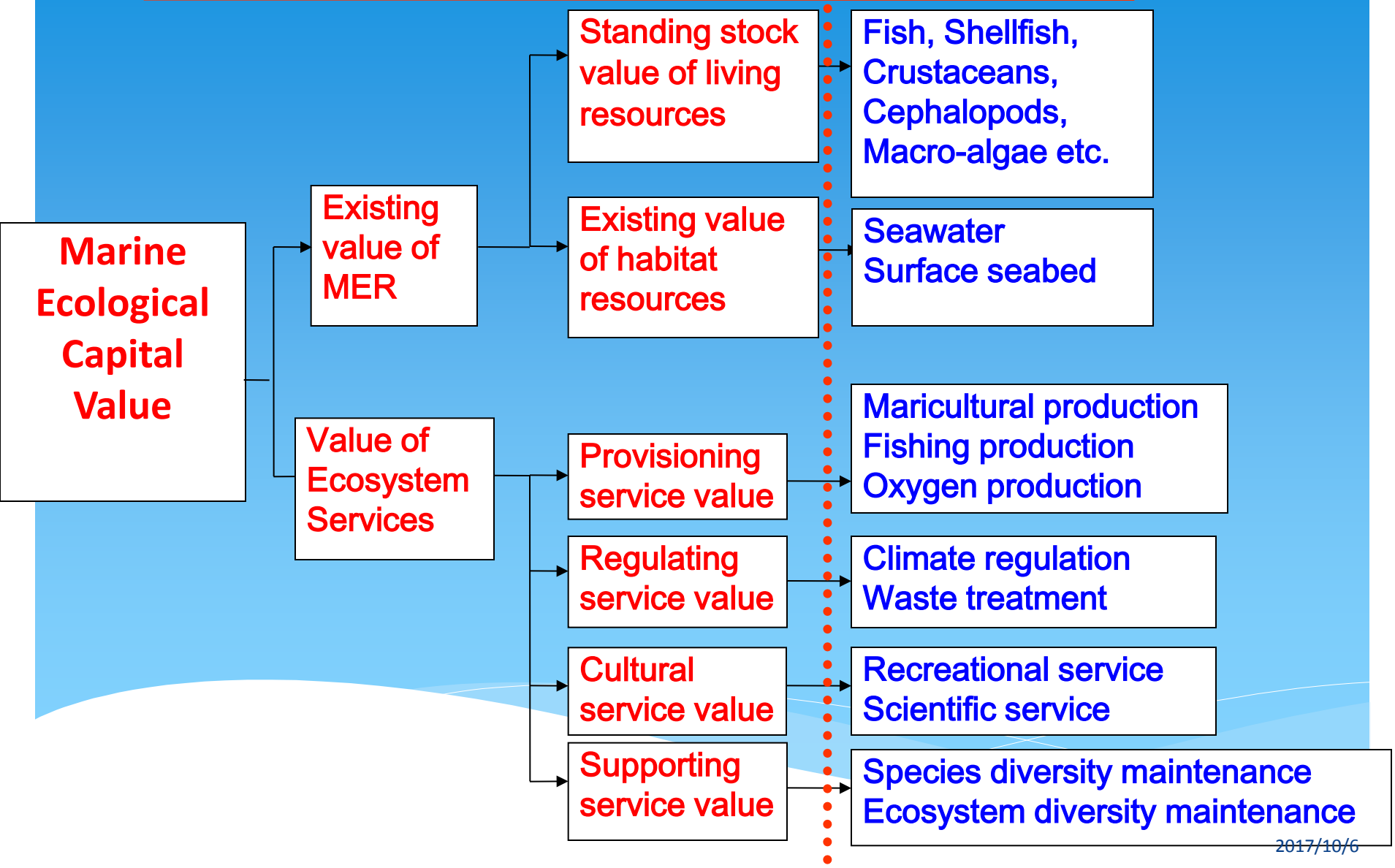
14. Species diversity maintenance
15. Ecosystem diversity maintenance

MEC value: constituent elements

Assessment index



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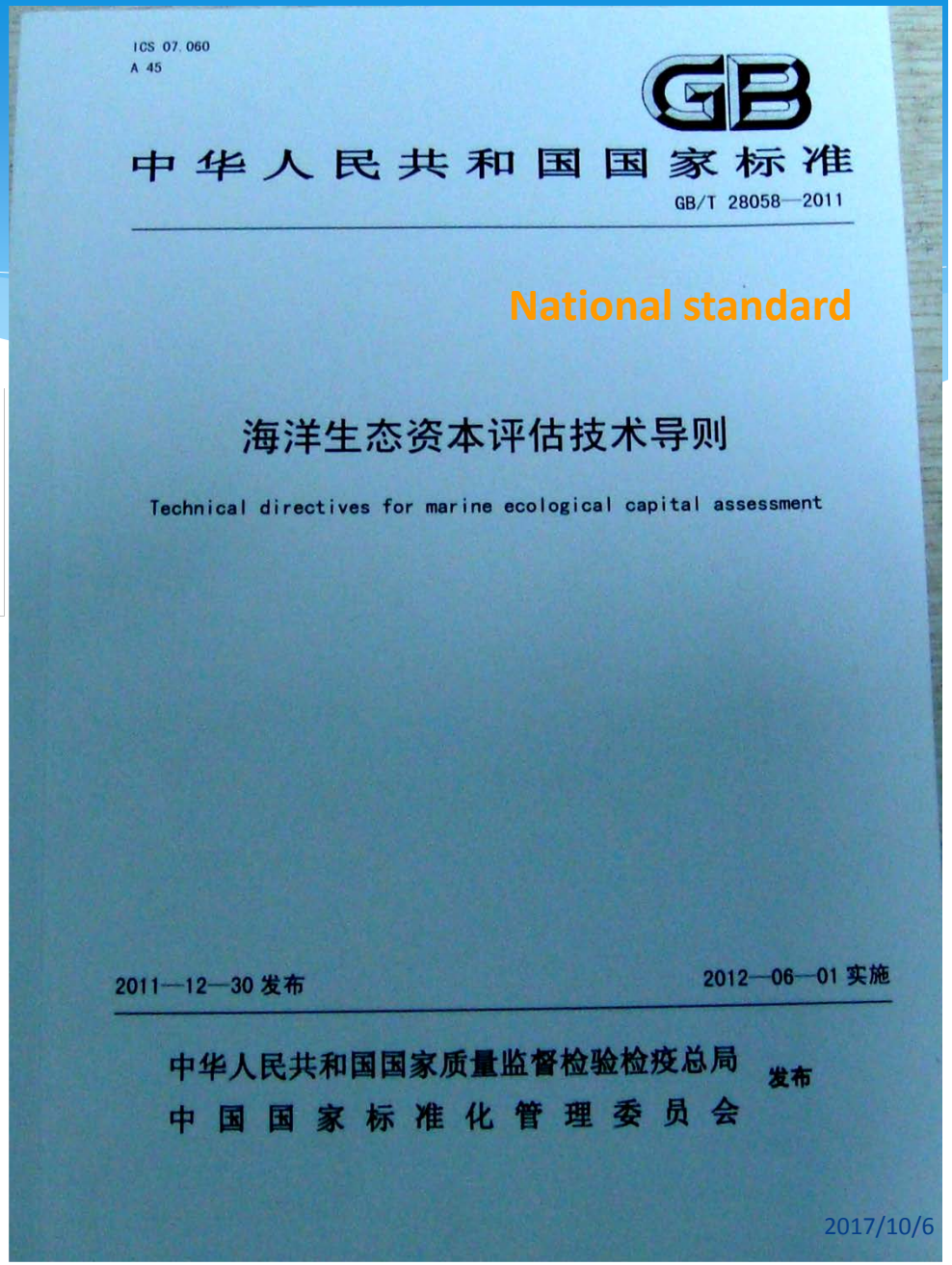
Technical Directives for Marine Ecological Capital Assessment



3.1 standing stock of marine living resources

--Quantification

The standing stock of six kinds marine living resources were assessed, including **fish, shellfish, crustaceans(crabs, shrimps), cephalopods(octopus, squid), macro-algae(kelp) and the others**.

Table 1 **value of standing stock of marine living resources**

	Kinds	**Quantity**/ ton	Price/ CNY per kg	**Value**/ $\times 10^4$ CNY
1	Fish			
2	Shellfish			
3	Curstacean			
4	Ephalopods			
5	Macro-algae			
6	The others			

--Valuation

The **market-price method** is recommended to calculate the standing stock value of marine living resources, refer to formula 1:

$$V_L = \sum (Q_{Li} \times P_{Li}) \times 10^{-1} \quad \text{..... (1)}$$

in which：

V_L —Standing stock value of marine living resources. Unit: $\times 10^4$CNY ；

Q_{li} —the production of marine living resources. Unit: ton；i=1，2，3，4，5，6 refers to fish, shellfish, crustaceans, cephalopods, macro-algae & the others；

P_{li} —the price of ith marine living resources. Unit: CNY/kg

3.2 Evaluation of marine ecosystem services

3.2.1 Provisioning Services

3.2.1.1 Maricultural production

-- Quantification

Five kinds: fish , shellfish, crustaceans, macro-algae and the others.

Table2 Value of maricultural production

	Kinds	Quantity/ Ton	Price/ CNY per kg	Value/ $\times 10^4$ CNY
1	Fish			
2	Shellfish			
3	Crustacean			
4	Macro-algae			
5	The others			

--Valuation

The **market-price method** is recommended to calculate the maricultural production, refer to formula 2:

$$V_{SM} = \sum (Q_{SMi} \times P_{Mi}) \times 10^{-1} \qquad \cdots\cdots\cdots\cdots\cdots\cdots (2)$$

in which：

V_{SM} ——the value of maricultural production. Unit: $\times 10^4$CNY per year；

Q_{SMi}——the production of mariculture production. Unit: Ton per year；i=1，2，3，4，5，6 refers to fish, shellfish, crustaceans, macro-algae and the others；

P_{Mi} ——the average price of ith kind of species. Unit: CNY/kg.

3.2.1.2 Fishing production

-- Quantitication

Six kinds: fish , shellfish, crustaceans, cephalopods, macro-algae and the others.

Table 3 Value of fishing production

	Kinds	Quantity/ ton	Price/ CNY per kg	Value/ $\times 10^4$ CNY
1	Fish			
2	Shellfish			
3	Crustacean			
4	Cephalopods			
5	Macro-algae			
6	The others			

--Valuation

The **market-price method** is recommended to valuate the fishing production , refer to formula 3:

$$V_{SC} = \sum (Q_{SCi} \times P_{Ci}) \times 10^{-1} \quad \text{.....(3)}$$

in which：

V_{SC}——the value of the fishing production , the unit is ($\times 10^4$) CNY per year；

Q_{SCi}——the production of fishing. the unit is ton per year；i=1，2，3，4，5，6 refers to fish , shellfish, crustaceans, cephalopods, macro-algae and the others ；

P_{Ci} ——the average price of ith kind of the fishing production ， the unit is CNY/kg.

3.2.1.3 Oxygen production

--Quantification

The oxygen products provided from phytoplankton and macro-algae.

…… (4)

$$Q_{O_2} = Q'_{O_2} \times S \times 365 \times 10^{-3} + Q''_{O_2}$$

in which：

Q_{O_2}——oxygen production. Unit: ton per year(t/a)；

Q'_{O_2}——oxygen produced by phytoplankton. Unit: milligram per day per square meter (mg/m^2·d)；

S ——the water area be evaluated. Unit:square kilometers(km^2)；

Q''_{O_2}——the oxygen produced by macro-algae. Unit: ton per year(t/a).

- The oxygen production by phytoplankton, refers to formula 5：

$$Q'_{O_2} = 2.67 \times Q_{PP} \quad \text{……(5)}$$

in which：

Q'_{O_2}—the oxygen production by phytoplankton. Unit: mg/m^2·d；

Q_{PP}—**primary productivity** of phytoplankton. Unit: mg C/m^2·d.

- The oxygen production by macro-algae, refers to formula 6：

$$Q''_{O_2} = 1.19 \times Q_A \quad \text{……(6)}$$

in which：

Q''_{O_2} —oxygen production by macro-algae. Unit: t/a；

Q_A—the **dry weight of macro-algae biomass**. Unit: ton per year(t/a).

3.2.1.3 Oxygen production

--Valuation

The **replacement-cost method** is recommended to valuate the oxygen production. refer to formula (7) :

$$V_{O_2} = Q_{O_2} \times P_{O_2} \times 10^{-4} \quad \text{..... (7)}$$

in which：

V_{O_2}——the value of oxygen production. The unit is ($\times 10^4$) CNY per year；

Q_{O_2}——the oxygen production. Unit: ton per year(t/a)；

P_{O_2}——the **cost of oxygen production by liquification of air in steel-making factory**. Unit: CNY per ton.

3.2.2 Regulating Services

3.2.2.1 Climate regulation

--Quantification

Based on the fixation of carbon dioxide by marine plants.

$$Q_{CO_2} = Q'_{CO_2} \times S \times 365 \times 10^{-3} + Q''_{CO_2} \quad \cdots\cdots\cdots\cdots\cdots\cdots (8)$$

in which：

Q_{CO_2}—total quantity of fixed CO2. Unit: ton per year(t/a)；

Q'_{CO_2}—carbon dioxide fixed by phytoplankton. Unit: mg/m^2·d；

S ——the water area be evaluated. Unit: km^2；

Q''_{CO_2} ——carbon dioxide fixed by macro-algae. Unit: t/a.

- Carbon dioxide fixed by phytoplankton.

$$Q'_{CO_2} = 3.67 \times Q_{PP} \quad \cdots\cdots\cdots\cdots\cdots\cdots (9)$$

in which：

Q'_{CO_2}—the CO_2 fixed by phytoplankton. Unit: mg/m^2·d；

Q_{PP}—**primary productivity** of phytoplankton. Unit: mgC/m^2·d.

Carbon dioxide fixed by macro-algae：

$$Q''_{CO_2} = 1.63 \times Q_A \quad \cdots\cdots\cdots\cdots\cdots\cdots (10)$$

in which：

Q''_{CO_2}—the carbon dioxide fixed by macro-algae. Unit: t/a；

Q_A—the **dry weight of macro-algae**. Unit: ton per year(t/a)

6.2.1 Climate regulation

--Valuation

The **replacement-cost method** was recommended to valuate the oxygen production, refer to formula （11） ：

$$V_{CO_2} = Q_{CO_2} \times P_{CO_2} \times 10^{-4} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (11)$$

In which：

V_{CO_2}—the value of climate regulation. Unit:$\times 10^4$CNY per year；

Q_{CO_2}—the climate regulation. Unit: ton per year(t/a)；

P_{CO_2}—the market transaction price of carbon dioxide emission right, the unit is CNY per ton.

3.2.2.2 Waste treatment --Quantification

Two methods are recommended to quantify the waste treatment:

A. If the environmental carrying capacity of the assessed waters is known. The **environmental carrying capacity** of COD, N or P is used as the waste treatment quantity.

B. If the environmental carrying capacity of the assessed waters is unknown. The **waste discharge into sea** is used as the waste treatment quantity. Here the waster discharge means waste water, COD, N, and P.

3.2.2.2 Waste treatment --Quantification

(1) Based on the waste water into the sea.

$$Q_{SWT} = Q_{WW} - Q_{WW} \times w \times 20\% \quad \cdots\cdots\cdots\cdots\cdots\cdots (12)$$

in which：

Q_{SWT}—waste treatment quantity in sea. Unit: ton per year(t/a)；

Q_{WW}—industrial & domestic sewage. Unit: t/a；

w —mass fraction of solid pollutants in industrial & domestic sewage, %；

$Q_{WW\times}w$ — Total solid pollutants in industrial & domestic sewage. Unit: t/a；

$Q_{WW\times}\ w\times 20\%$ —Total solid pollutants sedimentated in the bottom of river and channel into sea. Unit: t/a.

The sedimentation rate is supposed as 20%.

3.2.2.2 Waste treatment --Quantification

(2) Based on waste pollutants(e.g COD, nitrogen, phosphorus) into the sea. refers to formula （13）：

$$Q_{SWT} = Q_{WW} \times w \times (1 - 20\%) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots （13）$$

in which：

Q_{SWT} ——waste treatment quantity. Unit: ton per year(t/a)；

Q_{WW} ——industrial & domestic sewage. Unit: t/a；

w ——mass fraction of ith pollutant in industrial & domestic sewage, %；

（1 - 20%）show the rate of pollutant into the sea.

3.2.2.2 Waste treatment

--Valuation

The **replacement-cost method** is recommended to valuate the waste treatment, refer to formula （14）：

$$V_{SW} = Q_{SWT} \times P_W \times 10^{-4} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (14)$$

in which：

V_{SW} ——the value of waste treatment. Unit:$\times 10^4$CNY per year；

Q_{SWT}——the waste treatment quantity. Unit: ton per year(t/a) ；

P_W ——the **cost of artificial wastewater treatment**. Unit: CNY per ton.

3.2.3 Cultural Services

3.2.3.1 Leisure & Recreational service

--Quantification

The leisure and recreational service mainly considers natural and slightly artificial marine scenic spot. The amount of tourist is the important quantification indicators for this service.

--Valuation

a) If the number of tourism spots in the assessed waters are less than 8, the **zonal travel-cost method(ZTCM) or individual travel-cost method (ITCM)** is recommended.

b) If >8, economic income of coastal tourism industry is recommended to valuate this service.

Zonal travel cost method：

$$V_{ST} = \sum \int_0^Q F(Q) \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (15)$$

in which：

V_{ST}——the value of leisure and recreational service, the unit is ($\times 10^4$) CNY per year；

$F(Q)$ is the **travel demand function based on the questionnaire survey** .

Individual travel cost method (ITCM):

$$V_{ST} = (\overline{TC} + CS) \times P \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (16)$$

in which：

V_{ST}——the value of leisure and recreational service. Unit: $\times 10^4$ CNY per year；

$\overline{TC}$—the **average travel cost of single tourist**, Unit: CNY per person；

CS —**consumer surplus of single tourist**. Unit: CNY per person ；

P —the total number of tourist into the specific tourism spot. the unit is $\times 10^4$ persons per year .

3.2.3.1 Leisure and Recreational service

The valuation of based on economic income of marine tourism industry :

$$V_{ST} = \sum_{j}^{m} \sum_{i}^{n} (V_{Tj} \times F_{ji}) \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (17)$$

in which：

V_{ST}—the value of leisure and recreational service. Unit:$\times 10^4$CNY per year；

V_{Tj} —the marine tourism income from the assessed waters, the unit is ($\times 10^4$) CNY per year；

F_{ji}—the **adjustment coefficient of the specific tourism spot**;

m —the number of cities around the assessed waters；

n —the number of marine tourism spots in the assessed waters.

F_{ji} is composed of P_{ji} *and* Q_{ji} .

$$F_{ji} = \frac{P_{ji} + Q_{ji}}{2} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (18)$$

in which：

F_{ji} ——the **adjustment coefficient** of the specific marine tourism spot;

P_{ji} ——the **coastaline length coefficient** of specific marine tourism spot ；

Q_{ji} ——the **grade coefficient** of specific marine tourism spot.

P_{ji} refers to formula （19）：

$$P_{ji} = \frac{L_i}{\sum_i L_{ji}} \qquad \text{……（19）}$$

In which：

P_{ji}——the coastaline coefficient of specific marine tourism spot;

L_i ——the coastaline length of specific marine tourism spot.

Unit: km；

$\sum_i L_{ji}$ ——the total length of all marine tourism sport coastline in the assessed waters.

Q_{ji} refers to formula （18） ：

$$Q_{ji} = \frac{D_i}{\sum_i D_{ji}} \qquad \text{.....（18）}$$

In which：

Q_{ji} ——the grade coefficient of the specific tourism spot ;

D_i ——the grade of the specific tourism spot ;

$\sum_i D_{ji}$ ——the total grade number of all tourism spots in the assessed waters.

3.2.3.2 Scientific service

--Quantification

Scientific invest cost method was developed to assess scientific service. Scientific service quantity is measured the number of scientific papers on the assessed waters.

--Valuation

Direct-Costing method is recommended.

$$V_{SR} = Q_{SR} \times P_R \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (19)$$

V_{SR}—the value of scientific service. Unit: $\times 10^4$ CNY per year；

Q_{SR}—the **number of scientific papers on the assessed waters** published in a year;

P_R—scientific project investment per paper.

3.2.4 Supporting Services

3.2.4.1 Maintenance of species diversity

--Quantification

Maintenance of species diversity in quantity is reflected by the number of the **protected species or other species with importance value in science, culture, religion or potential commercial aspects**.

--Valuation

The **contingent valuation method** is recommended to valuate the maintenance of species diversity. The questionnaire survey on **willingness-to-pay of local residents for maintaining marine species forever**. refers to formula (20)

$$V_{SSD} = \sum WTP_j \times \frac{P_j}{H_j} \times \eta \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (20)$$

in which：

V_{SSD}——the value of maintenance of species diversity. Unit: $\times 10^4$ CNY per year；

WTP_j——**willingness-to-pay for maintaining marine species forever**, the unit is CNY per person；

P_j ——the population of urban and/or countryside region；

H_j ——the average persons of one family members；

η ——the payment rate of local residents.

3.2.4.2 Ecosystem diversity

--Quantification

The maintenance of ecosystem diversity mainly be reflected by the number of **marine key habitats, e.g nature reserve, special protection area, aquatic germplasm resources conservation zones** in the assessed waters.

--Value assessment

The value of ecosystem diversity maintenance method is recommended to valuate the maintenance of ecosystem diversity. The questionnaire survey on **willingness-to-pay of local residents for maintaining marine protected area forever**. refers to formula (21).

$$V_{SED} = \sum WTP_j \times \frac{P_j}{H_j} \times \eta \qquad \cdots\cdots\cdots\cdots (21)$$

in which：

V_{SED} ——the value of ecosystem diversity maintenance, the unit is ($\times 10^4$) CNY per year；

WTP_j——willingness-to-pay for maintaining protected area forever, the unit is CNY per person；

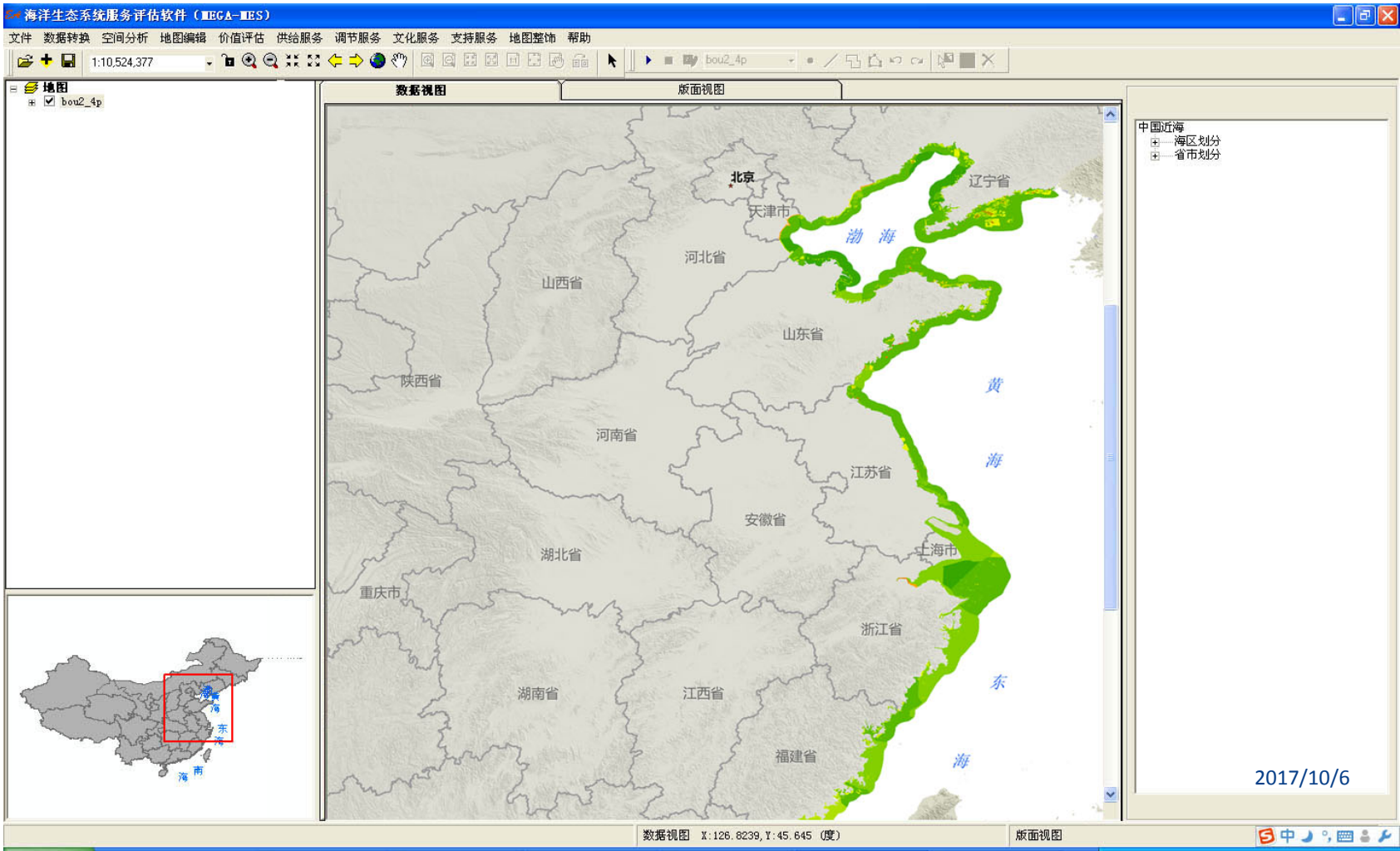
P_j——the population of urban and/or countriside region；

H_j——the average persons of one family members；

η——the payment rate of local residents.

Assessment software

Mapping by MEGA-MES V1.0 based on Arc GIS



2017/10/6

Outline

1. Basic concepts
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4. Ecosystem service value of China coastal seas

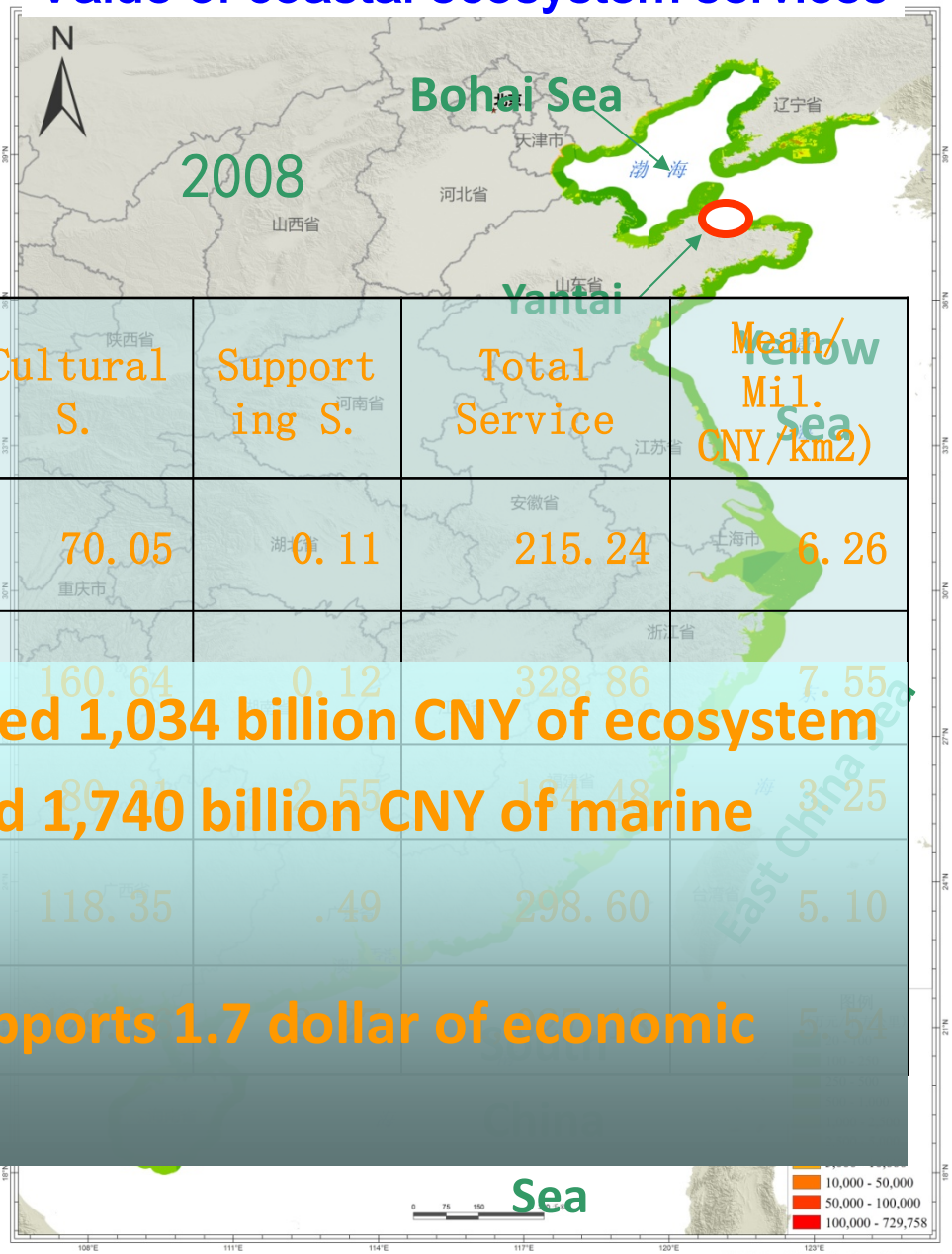
* National-scale（全国尺度、海盆）：100 000 km^2
* Provincial-scale（省尺度）：10 000 km^2
* County-scale（县尺度、海湾）：100 km^2
* Assess area: 12 nautical miles from coastal line

National assessment

Value of coastal ecosystem services

Billion CNY, 2008

Sea	Area/km2	Provisioning S.	Regulating S.	Cultural S.	Supporting S.	Total Service	Mean/ Mil. CNY/km2)
Bohai Sea	34,359.77	135.18	9.90	70.05	0.11	215.24	6.26
Yellow Sea	43,541.11	162.05	6.06	160.64	0.12	328.86	7.55
East China Sea	56	210.00	71.19	30.58	2.55	184.48	3.25
South China Sea		7.04	12.72	118.35	.49	298.60	5.10
Total							

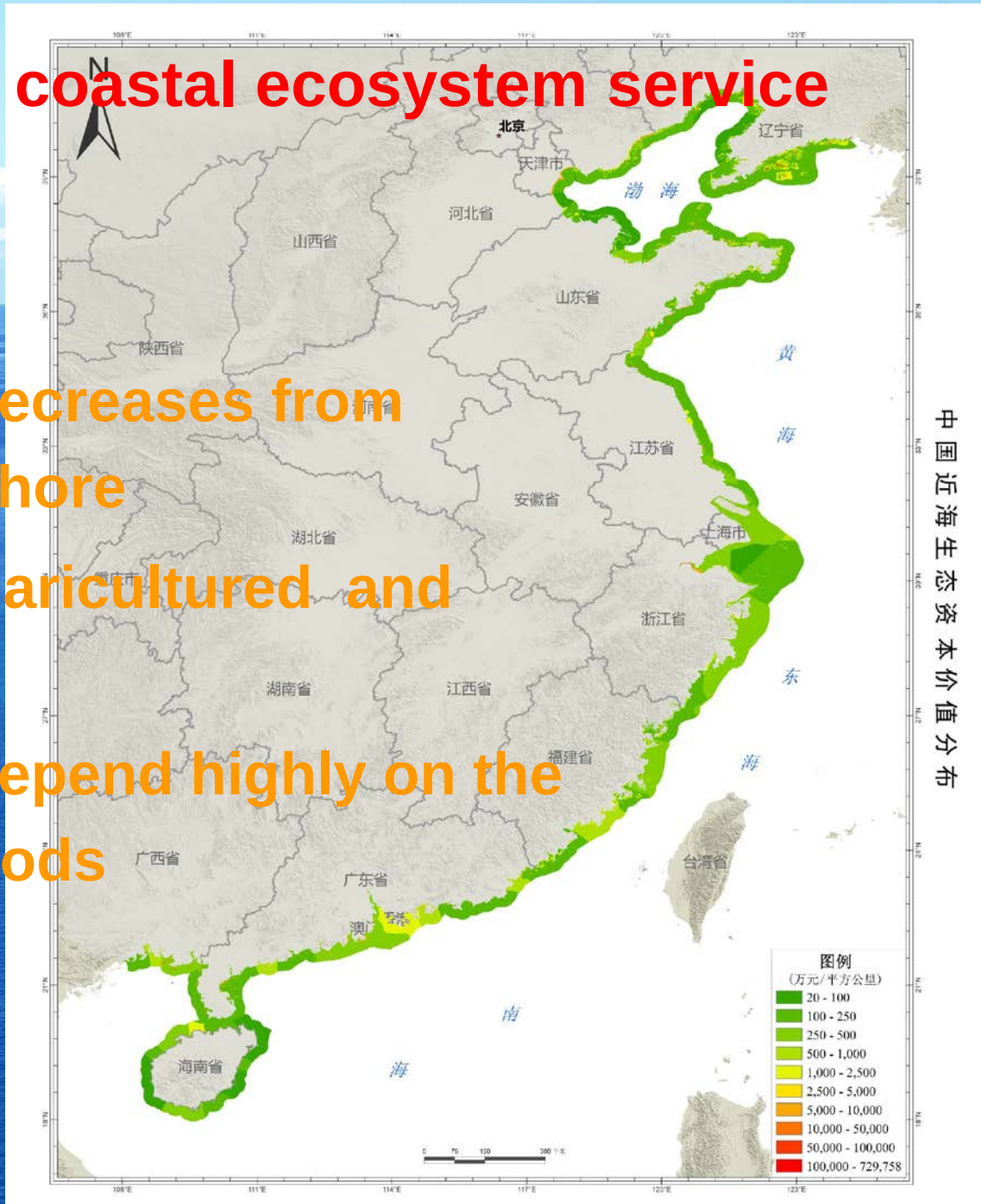


China's coastal ecosystem provided 1,034 billion CNY of ecosystem services in 2008, which supported 1,740 billion CNY of marine industrial products

One dollar of ecological value supports 1.7 dollar of economic output

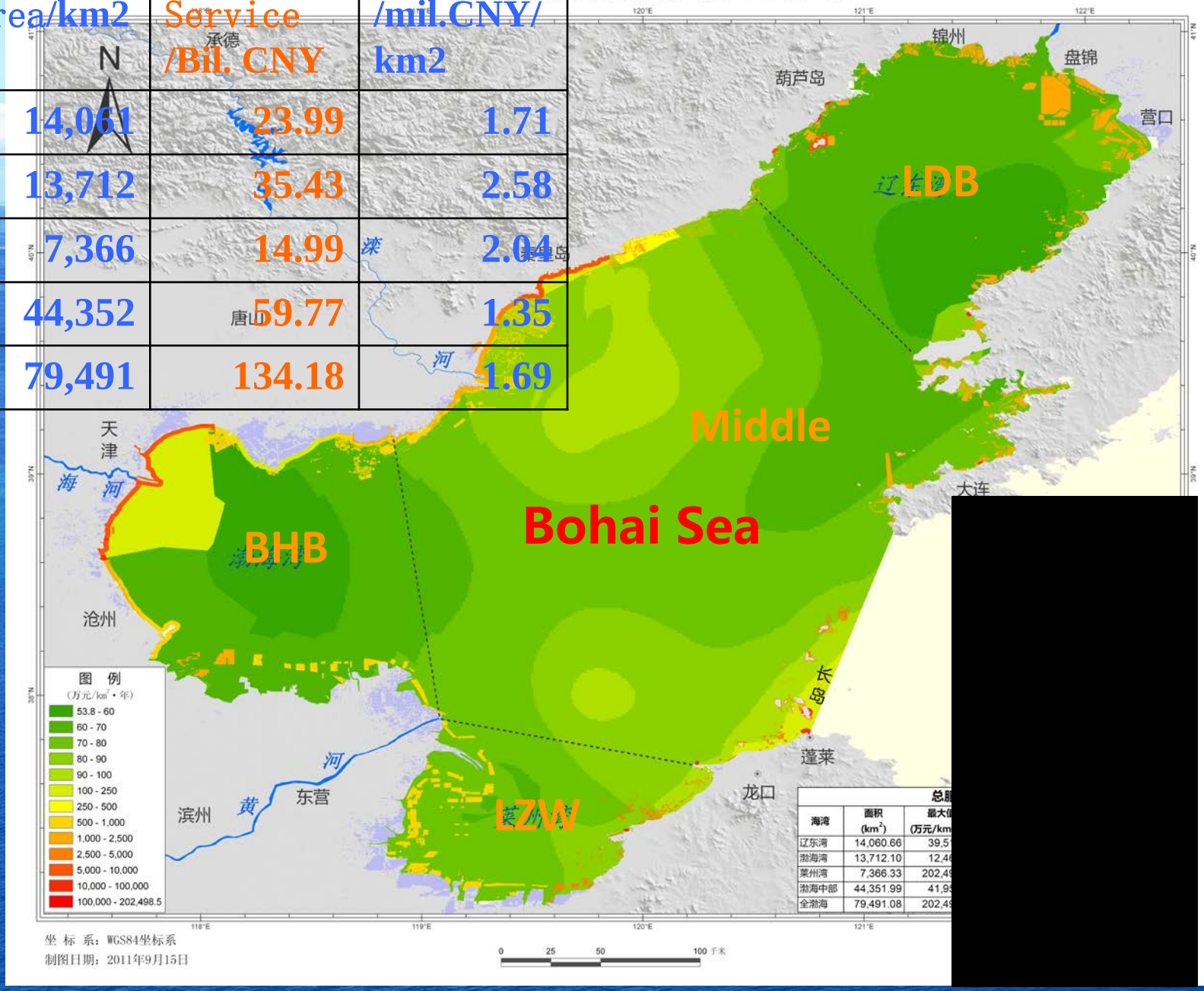
Spatial patterns of coastal ecosystem service value

1. Service value decreases from onshore to offshore
2. High value in maricultured and tourism areas
3. Service value depend highly on the utilization methods



Total Service Value

Region	Area/km2	Total Service /Bil. CNY	Mean /mil.CNY/ km2
LDB	14,061	23.99	1.71
BHB	13,712	35.43	2.58
LZW	7,366	14.99	2.04
Middle	44,352	59.77	1.35
Total	79,491	134.18	1.69



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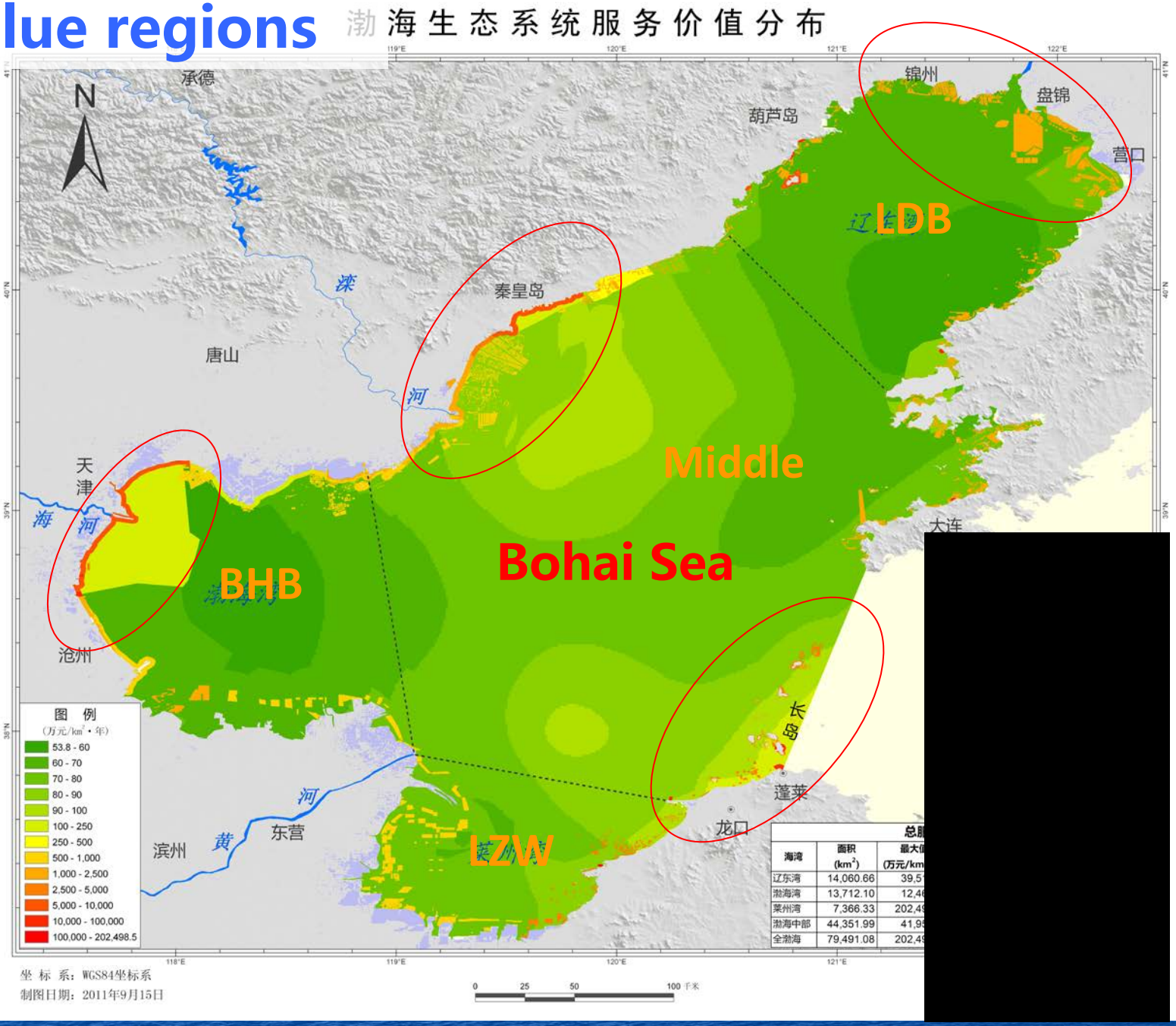
High value regions



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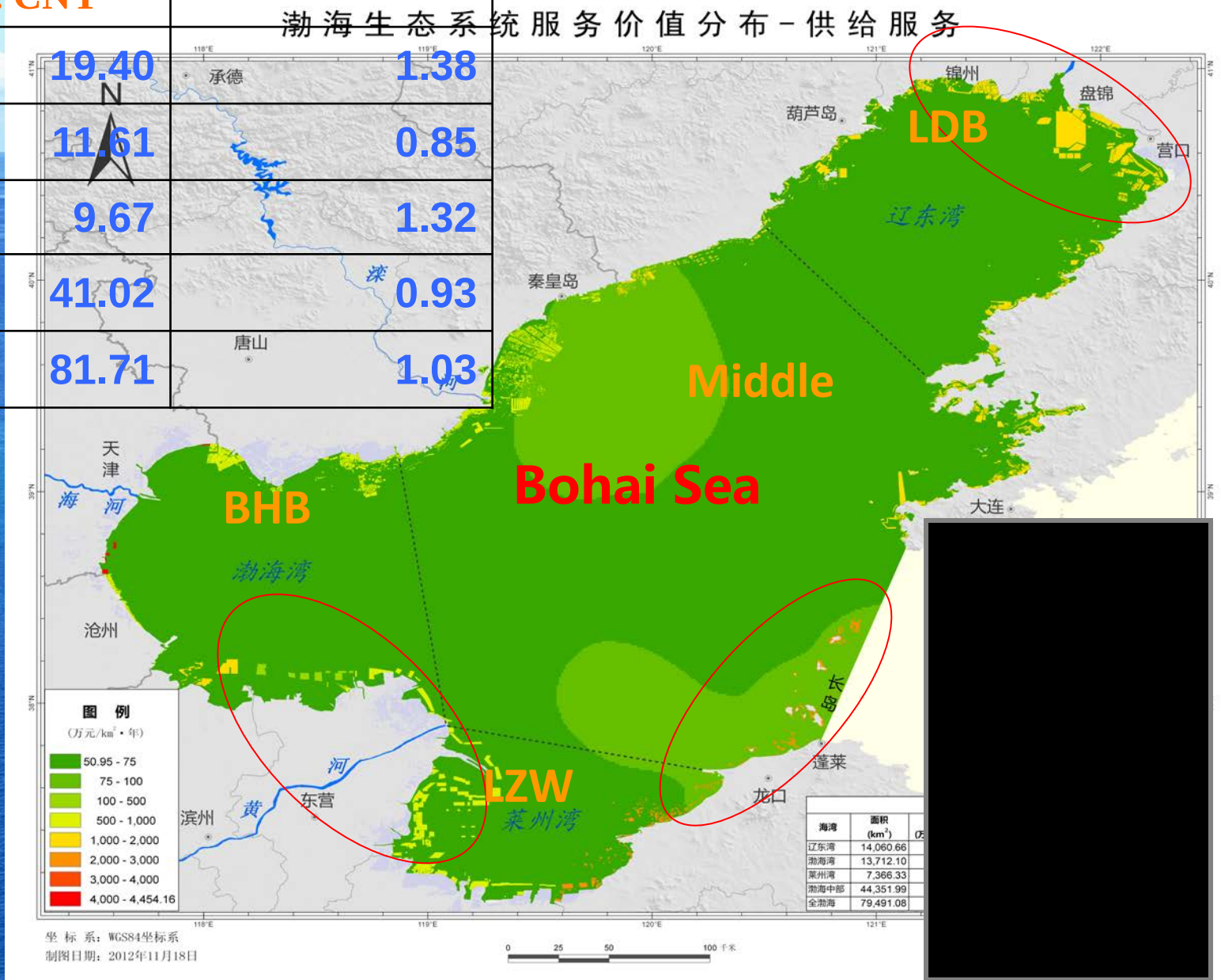
Provisional Service

Region	Provisional Service /Bil. CNY	Mean /mil.CNY/km2
LDB	19.40	1.38
BHB	11.61	0.85
LZW	9.67	1.32
Middle	41.02	0.93
Total	81.71	1.03



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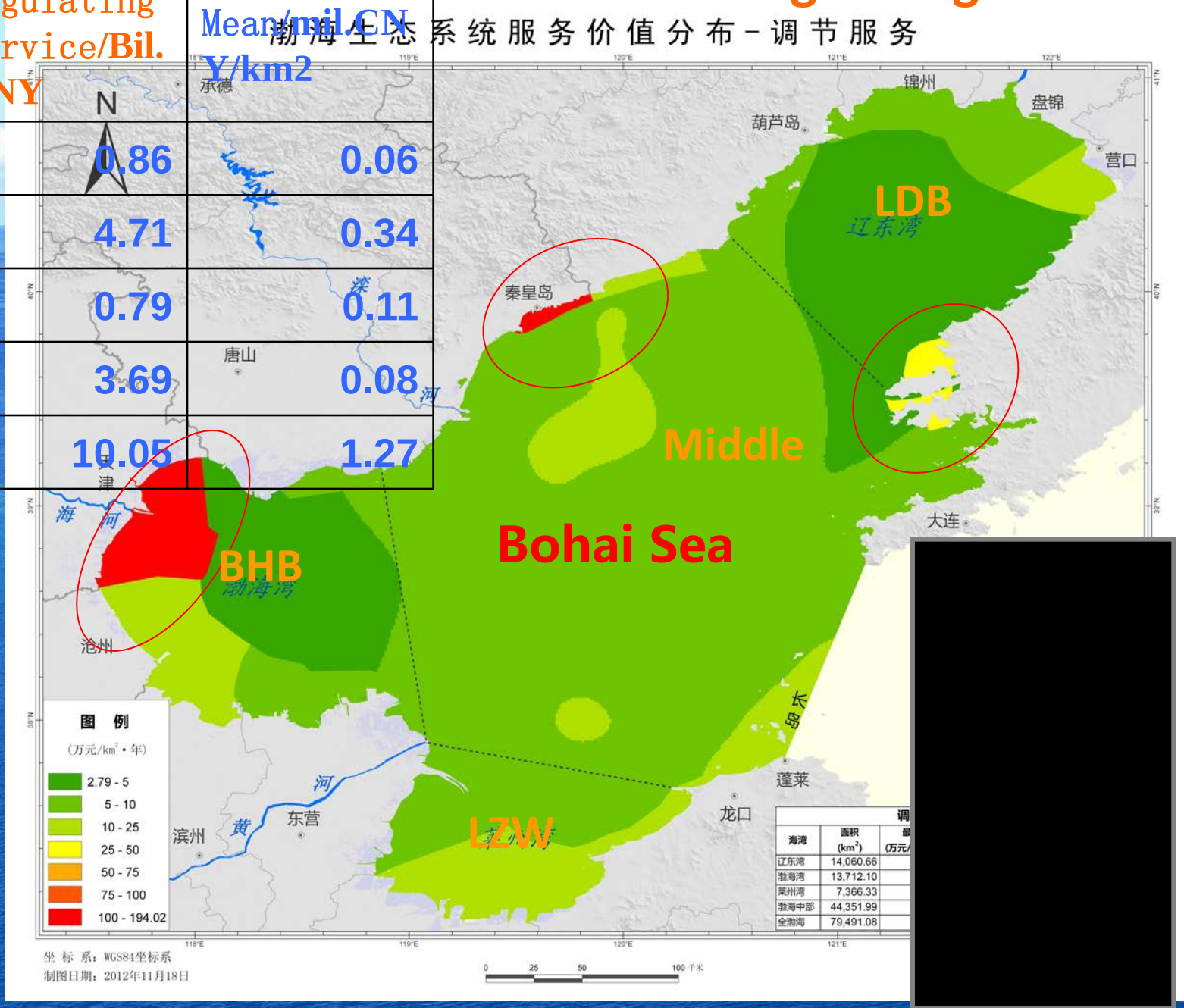
Regulating service

Region	Regulating Service/Bil. CNY	Mean/mil.CNY/km2
LDB	0.86	0.06
BHB	4.71	0.34
LZW	0.79	0.11
Middle	3.69	0.08
Total	10.05	1.27



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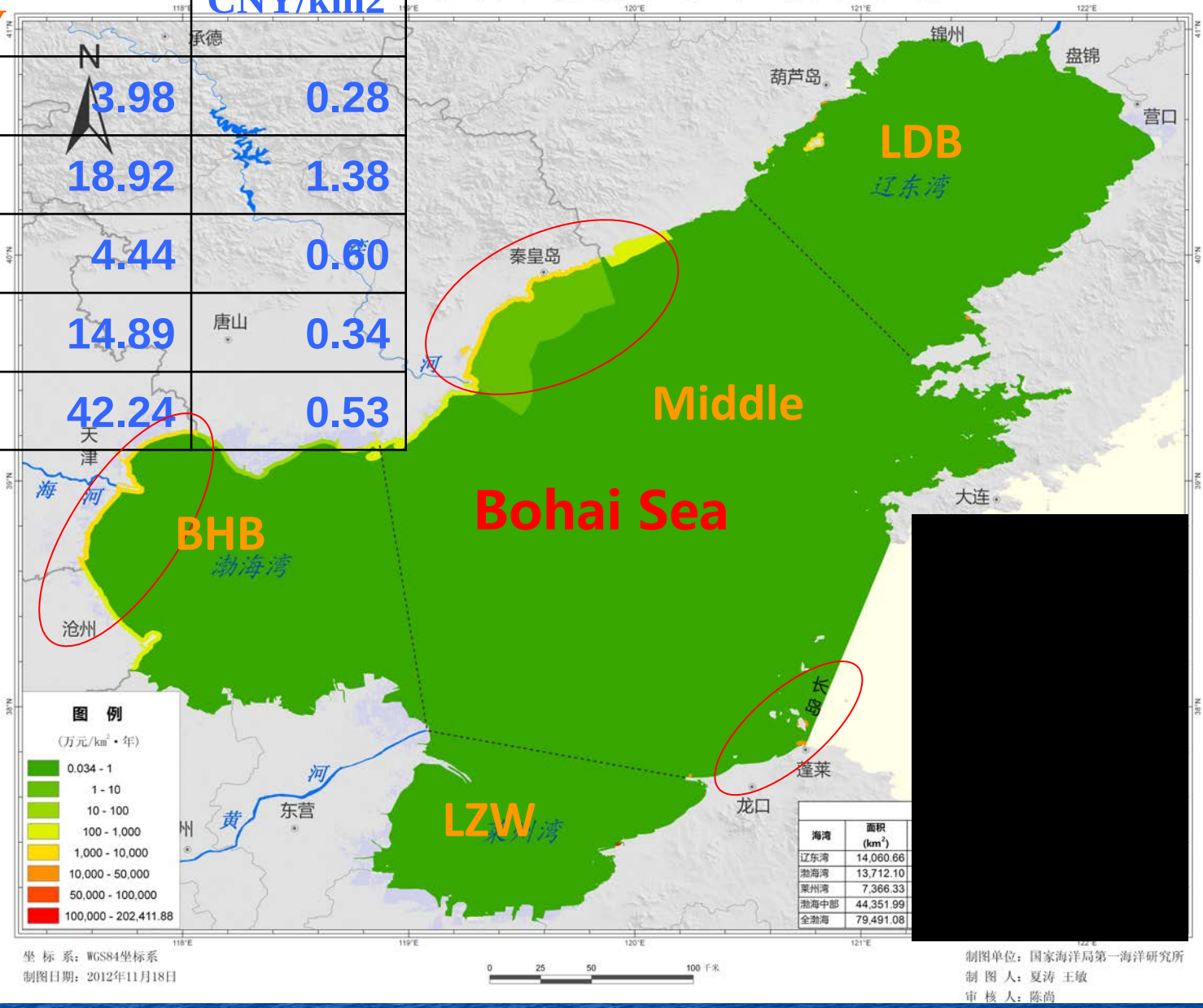
Cultural service

Region	Cultural Service/Bil. CNY	Mean/mil. CNY/km2
LDB	3.98	0.28
BHB	18.92	1.38
LZW	4.44	0.60
Middle	14.89	0.34
Total	42.24	0.53



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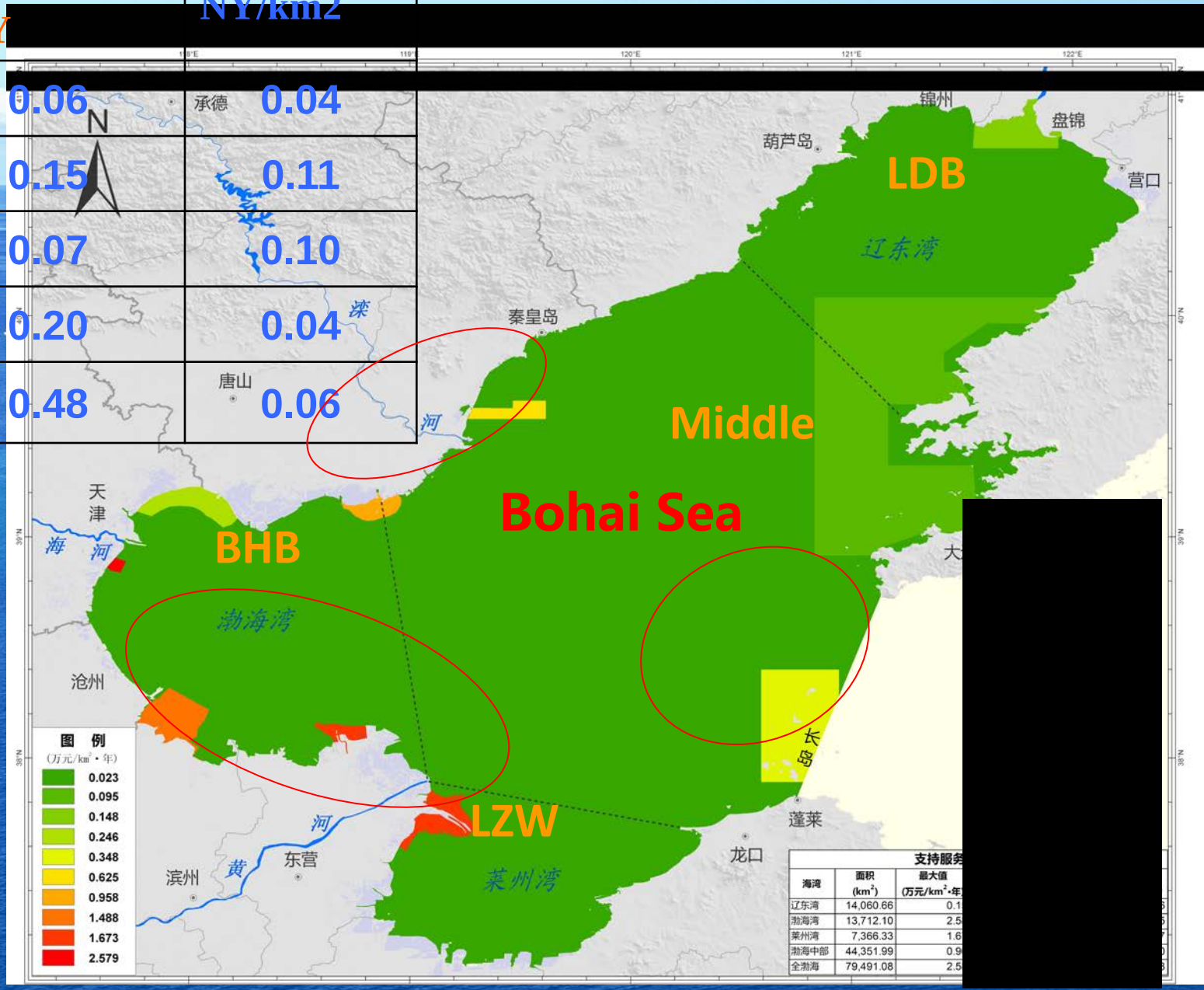
Supporting service

Region	Supporting Service/Bil. CNY	Mean/mil.CNY/km2
LDB	0.06	0.04
BHB	0.15	0.11
LZW	0.07	0.10
Middle	0.20	0.04
Total	0.48	0.06



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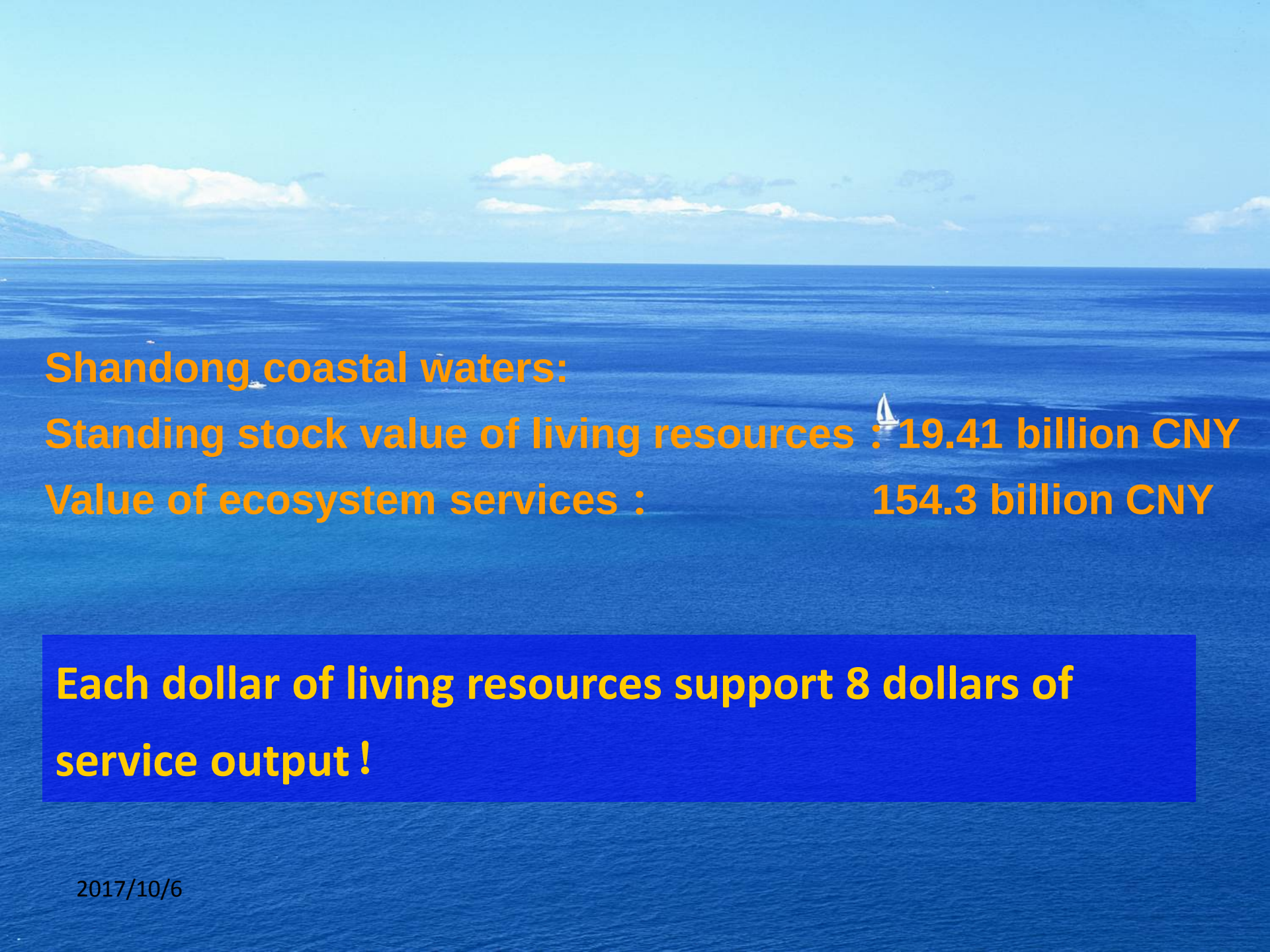
Ecosystem service: 3 kinds of utilization model

- **Provisioning service-dominated utilization model** deeply depends on marine ecological resources
- **Cultural service-dominated utilization model** depends on marine environmental quality
- **Provisioning-cultural service dominated utilization model** depends on marine eco. resources and evrionmental quality.



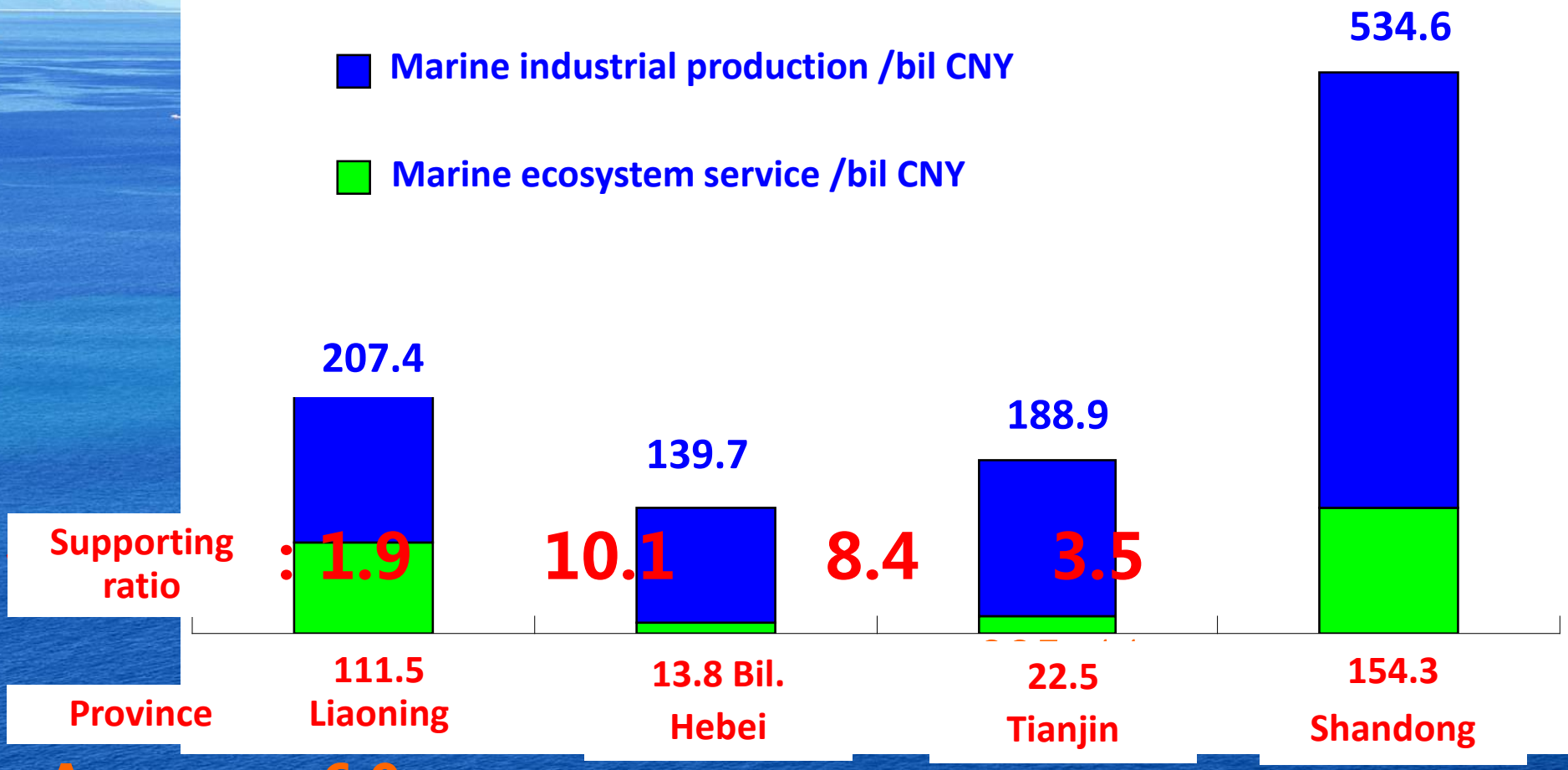
Shandong coastal waters:

Standing stock value of living resources : 19.41 billion CNY

Value of ecosystem services : 154.3 billion CNY

Each dollar of living resources support 8 dollars of service output !

Supporting ratio of marine ecosystem service to marine industrial production



Average : 6.0

Applications of MES theory

As one of principles to make function zoning and marine development planning

- **Setup ecological red line: no-reclamation**
- **Setup Protected Area**

As assessment indicators of marine management effectiveness & blue economic policy

- **Increases in both economic value and MES**

As baseline of eco-compensati or payment for ecosystem service policy

- **Baseline value-> damaged value->compensation amount**

Take-home messages

1. The China coastal waters provided 1,034 billion CNY of services in 2008，average 5.57 mil. CNY/(km2.a). One dollar of ecological value supports 1.7 dollar of economic output
2. Spatial trends of ecosystem services:
   - Value decreases from onshore to offshore
   - High eco-value in maricultural and recreational area
3. There are 3 kinds of ecological utilization model: P, PC and B models in China coastal waters
4. Ecological capital theory is a sound, useful and SMART tool to optimize marine spatial zoning, management effectiveness assessment and to establish the eco-compensation policy.

Acknowledgement

SOA 908 program(2005-2010)
Ocean & Fisheries Dept of Shandong Province
Ocean & Fisheries Dept of Fujian Province
NSFC of China
S & T Dept of Shandong Province
UNDP/GEF/YSLME


Thank You!