Evaluation of Marine Ecosystem Intrinsic Value

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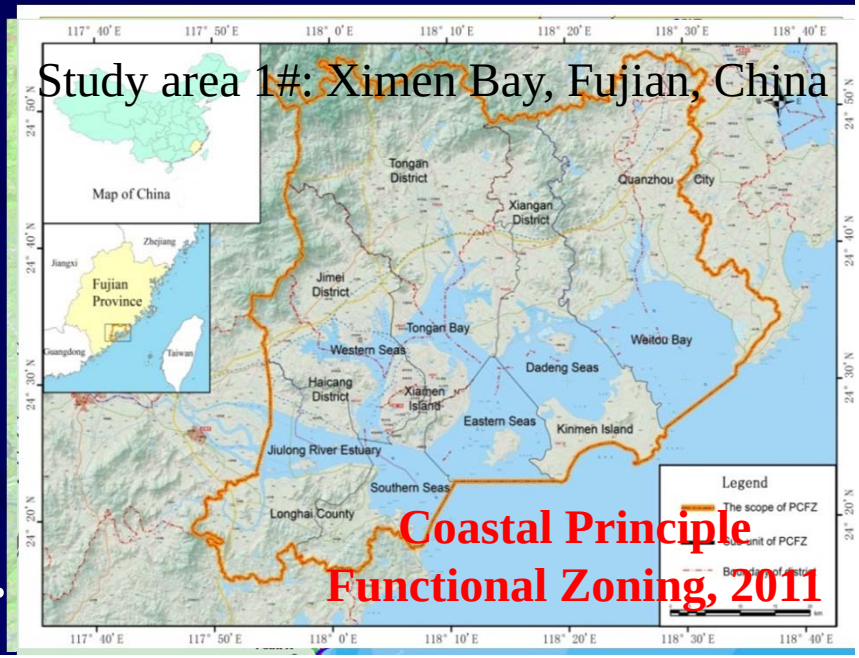
Introduction

- Ecosystem services (ES) was considered to bridge ecology, economy and social science.
- Definition of ES: the benefits human populations derive, directly or indirectly, from ecosystem functions, referring to ecosystem goods and services together (R. Costanza *et al.*, Nature, 1997).
- ES was grouped into 17 major categories, and their value (ESV) were calculated.
- But all losses of ESV were about 10% of the benefits of human activities.
- ESV may under-valuate the ecosystem value.
- Rethinking the value its due.



Argument of Ecosystem Value

- **View of economists: No use, no value;**

➢ ESV is based on the instrumental value of ecosystem;

➢ focused on the utility to human being from markets or willingness-to-pay (WTP) from human perspective;

➢ and related to ecosystem functions.

➢ So far, ESV is currently widely accepted and used to assess the value of ecosystem as the scientific basis of the support for decision-making processes.

- **View of environmental ethicists: Existence is value;**

➢ non-instrumental value: an end value, not a use value;

➢ non-relational value: not a function of ecosystem;

➢ objective value: not a functional or conscious valuing.

No existence, no function/service

ESV & EIV

- Ecosystem Service Value (ESV):

➢represents instrumental and utility value of ecosystem to human being, rather than full objective value of ecosystem;

➢ relates to ecosystem functions which only for human;

➢ bases on the utility from human perspective, not bases on ecosystem itself.

- Ecosystem intrinsic value (EIV) is:

➢ non-relationship with ecosystem functions, but in itself;

➢ non-instrumental value, but its existence;

➢ an objective value of the ecosystem itself.

Existence of ecosystem is the base; and ESV is only the working process of ecosystem functions to human being.

About EIV

- The issue of intrinsic values is helpful to reflect on the relationship between nature and humans. It proposes that nature has value in itself and is valued as an end in itself, independent of its usefulness to achieve some higher end (Millennium Ecosystem Assessment，MA, 2003; The Economics of Ecosystems and Biodiversity, TEEB, 2010).
- Acknowledging intrinsic values of nature acknowledges the fact that people are part of nature (TEEB, 2010).
- ESV is a utilitarian value (TEEB, 2010), and may result in a potential undervaluation to ecosystem value.
- The key is how to articulate value institutions, and how to evaluate EIV (TEEB, 2010).

Definition & Valuation of EIV

- Progress and practice of ecosystem value theory, the approaches and methods of ecosystem evaluation were reviewed.
- EIV concept and its connotation were defined.
- EIV is the objective value represented solely by ecosystem itself and its nature, and independent with man, man's will and preferences, i.e. human market.
- Identification: EIV includes the existence, structures, functions and processes of ecosystem, and is the sum of substance, energy and information of ecosystem.
- Approach & Methods for valuing EIV: Emergy and Eco-exergy were determined to express EIV by using energy approach.

Emergy

- *Emergy* is a type of available energy, embodied energy, in a system that is consumed in direct and indirect transformations needed to make a product or service, accounts for a measure of quality differences between different forms of energy, and could supports environmental decision making (Odum, 1996).
- Emergy is measured in units of *emjoules*, a unit referring to the available energy of one kind consumed in transformations.
- Emergy analysis: Data → transformation → monetization:

  Emergy (sej) = Available Energy (J) × Transformity (sej/J)

  Monetized by $Em\$=Em/Em_R$ (Em_R: emergy/dollar ratio)

  Emergy value embodies the existence value of ecosystem.

Eco-exergy

- In thermodynamics, the **exergy** of a system is the **maximum useful work possible** during a process that brings the system into equilibrium with a heat reservoir, ***available energy to work***.
- **Eco-exergy** is a potential, available and maximum useful work of an ecosystem, a **work capacity** (Jørgensen, 2007).
- **Eco-exergy analysis:** data→Ex-density→Ex_{total}→monetization:

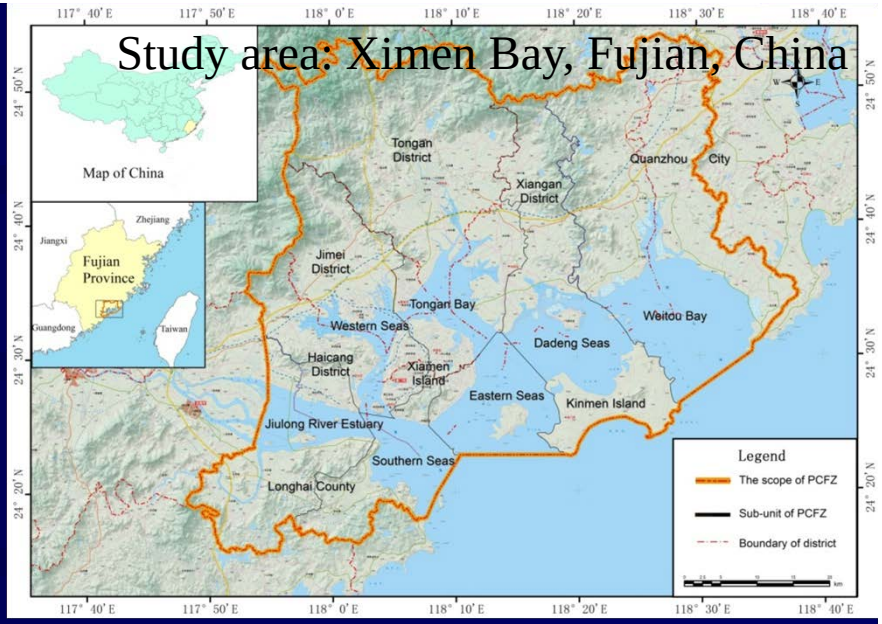
Eco-exergy density: $Ex_d = \sum \beta_i C_i$; total eco-exergy: $Ex_{Total} = \sum \beta_i C_i RS$

β: weight of component, Jørgensen *et al.* (2005) proposed best β values for main species; C: concentration of a component; R: turnover rate of species; S: area.

Monetized by $Ex\$=Ex_{total}/Ex_R$ (Ex_R: exergy/dollar ratio)

Eco-exergy value embodies the **potential work capacity** of ecosystem, **a creative value** of ecosystem intrinsic value.

Case Study in the Coastal Area of Xiamen Bay



- **Scope:** Following ecosystem-based management (EBM);
- **Profile:** A semi-enclosed Bay with sea area 984 km^2 including 2 bays, 4 channels and an estuary.
- **Assumption:** Marine ecosystem in Xiamen Bay was in dynamic equilibrium within a year, such as 2010.
- **Data collection**: All abiotic data and biotic data in Xiamen Bay area were collected, most of them more than 10 years, and some more than 20 years;
- **Retrospective assessment** were done to understand the status and the trends of the ecosystem;
- **Emergy & Eco-exergy analysis** were conducted according to the approaches and methods from references.

Calculative Results

Table 1 Emergy analysis of marine ecosystem in Xiamen Bay

Components	Area	Dry weight	Total energy	Emergy transformity	Emergy	Emergy dollar
	(km^2)	(g/m^2)	(10^{13} J)	(10^5 sej/unit)	(10^{17} sej)	(10^9 RMB)
Abiotic component					**213839**	**16.8**
Solar energy	**984**		**481000**	**0.00001**	**48.1**	**0.0038**
Wind energy	**984**		**305**	**0.00663**	**20.2**	**0.0016**
Rainfall (Chemical energy)	**984**		**681**	**0.15444**	**1051**	**0.083**
Tidal energy	**984**		**5580**	**0.23564**	**13149**	**1.03**
Wave energy	**984**		**7200**	**0.3055**	**21996**	**1.73**
Sediment	**984**		**23500**	**0.74**	**174000**	**13.66**
Seawater	**984**		**3054**	**0.048**	**1466**	**0.115**
Inorganic nutrients (N, P)	**984**				**230**	**0.018**
Biodetritus	**984**	**1037**	**1709**	**0.11**	**1879**	**0.168**
Bio-components					**54183**	**4.25**
Phytoplankton	**984**	**3.36**	**5.5**	**0.047**	**2.60**	**0.0002**
Mangroves	**2**	**48890**	**172**	**0.047**	**81.1**	**0.0064**
Zooplankton	**984**	**0.11**	**0.21**	**1.68**	**3.50**	**0.0003**
Macrobenthos	**856**	**7.52**	**11**	**130**	**14012**	**1.1**
Macrobenthos (Intertidal)	**129**	**138**	**30**	**130**	**38531**	**3.0**
Meiofauna	**984**	**0.046**	**0.076**	**130**	**98.5**	**0.0077**
Fish	**984**	**0.14**	**0.33**	**310**	**1011**	**0.079**
Siphonopods	**984**	**0.0074**	**0.012**	**310**	**37.8**	**0.003**
Crustacea	**984**	**0.045**	**0.074**	**310**	**229**	**0.018**
Chinese white dolphin	**984**	**0.0023**	**0.0038**	**642**	**24.1**	**0.0019**
Birds	**984**	**0.0089**	**0.015**	**1030**	**152**	**0.012**
Bacteria	**984**	**0.16**	**0.27**	**0.11**	**0.30**	**0.000023**
Biodiversity	**984**	**5713 species**		**2.43×10^{14}**	**1.39×10^{6}**	**109**
Toatal					**1.66×10^{6}**	**130**

Calculative Results

Table 2 Eco-exergy analysis of marine ecosystem in Xiamen Bay

Components	Area	Dry weight	Turnover rates	Weight β	Ex	Ex dollar
	(km^2)	(g/m^2)	(annual)		(10^{10} kJ/a)	(10^9 RMB/a)
Biodetritus	984	1037	1	1	1908	1.82
Phytoplankton	984	3.36	230	20	28440	27.2
Mangroves	2	48890	0.03	393	2313	2.21
Zooplankton	984	0.11	32	210	1310	1.25
Macrobenthos	856	7.52	6.5	200	15649	15
Macrobenthos (Intertidal)	129	138	6.5	200	43032	41
Meiofauna	984	0.046	6.57	133	74.0	0.071
Fish	984	0.14	2	499	264	0.253
Siphonopods	984	0.0074	3.1	310	13.1	0.013
Crustacea	984	0.045	5	232	95.6	0.091
Chinese white dolphin	984	0.0023	0.045	2127	0.40	0.00038
Birds	984	0.0089	0.06	980	0.97	0.00092
Bacteria	984	0.16	1400	8.5	3591	3.43
Total					96955	92.4

Results & Discussion

- **Results in Xiamen Bay (984 km^2) in 2010:**
  - Emergy: 1.66 × 10^{23} sej; *Em$*: 130 billion RMB;
  - Eco-exergy: 9.70 × 10^{14} kJ; *Ex$*: 92.4 billion RMB;
  - Total EIV: 222 billion RMB;
  - EIV in unit area is 226×10^6 RMB/km^2·yr = 36×10^6 $/$km^2$·yr.
- **Comparison:**
  - Total EIV is 30 and 9 times of ESV and the GDP of Xiamen marine industry in 2010, respectively;
  - Ex of EIV is about 13 and 3.7 times of ESV and the GDP of Xiamen marine industry in 2010, respectively;
  - EIV in unit area is 10 times of the highest ESV of World average estuaries - 22832 $/ha·yr (1994, Costanza *et al.* 1997) = 3.23×10^6 $/$km^2$·yr (2010) by discount, a potential undervaluation of ESV.

EIV (2010) (10^9 RMB/a)	ESV (2010) (Cai *et al.*, 2013) (10^9 RMB/a)	GDP of Xiamen marine industry (2010) (10^9 RMB/a)
Total EIV=Em+Ex: 222 Ex: 92.4	7.27	24.7

Conclusion

- Concept & connotation of ecosystem intrinsic value (EIV): an objective value represented solely by ecosystem itself, and independent with man, man's will and preferences, and valued as an end in itself to achieve higher end.
- EIV includes the existence, structures, functions and processes of ecosystem as a whole, is the sum of its substance, energy and information, and consists of existence value and work capacity, a creative value, the representation of stock and flow of EIV.
- Evaluation of EIV uses energy approach, Emergy & Eco-exergy methods to express EIV for existence value and work capacity.
- Case study showed: EIV in Xiamen Bay is much higher than ESV and marine industry GDP, a rational value.
- It implies a potential undervaluation to ecosystem value by ESV, and may mislead decision-making process.

EIV is an objective value of ecosystem, can just conserve ecosystem and support environmental decision-making towards sustainability.


Thank you for your attention!