International Institute of Fisheries Economics and Trade (IIFET) Conference 2016

An integrated model for marine fishery management: Linking ecosystem and socio-economic system

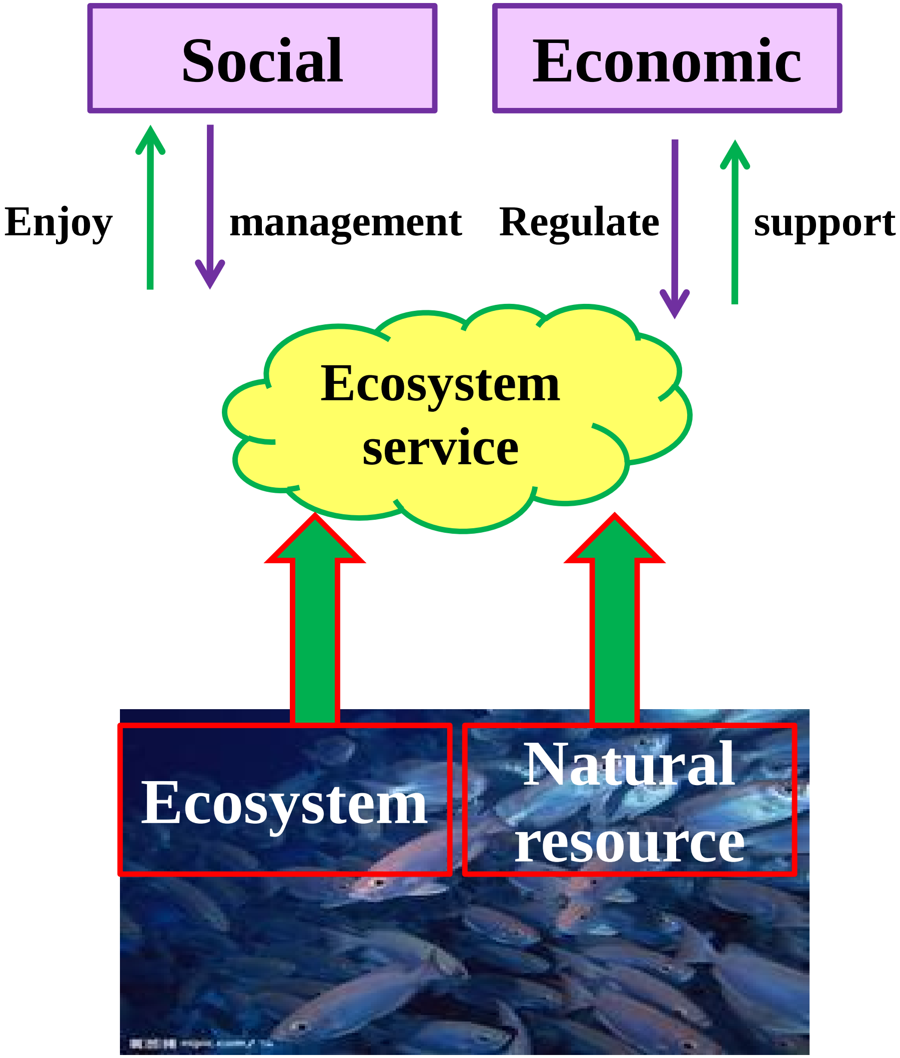
July, 2016, Aberdeen, Scotland, UK

Dr. Ying Wang

School of Economics and Management

Zhejiang Sci-tech University, Hangzhou, China

1. Introduction



Economists and ecologists are increasingly recognizing that the relationships among **ecological, economic and social objectives** should be considered in fisheries management and ecological conservation.

1. Introduction

- ✓ An integrated ecological-economics-social framework is put forward to assess the implementation of ecosystem-based fisheries management in the Pearl River Delta (PRD) fishery of China.

- ✓ In particular, we developed an integrated model by linking a regional economics system model-social accounting matrix (SAM) to an ecosystem model constructed by Ecopath with Ecosim (EwE) software.

1. Introduction

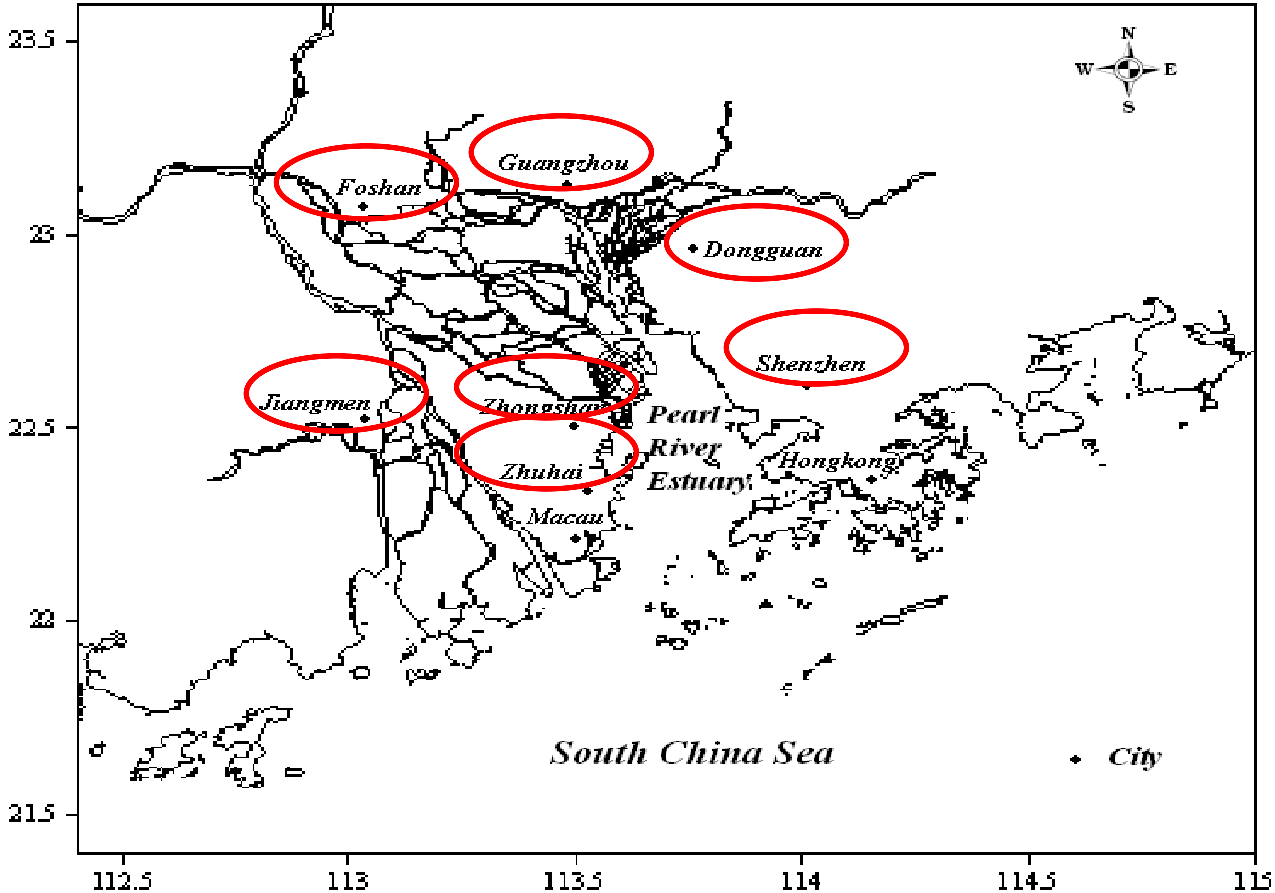


Fig.1.1 Geographical scope of the study

- The Pearl River Estuary is an important fishing ground in China.
- The study area is associated with six cities, including Guangzhou, Foshan, Zhongshan, Dongguan, Shenzhen and Jiangmen.

2 Integrated model for marine fishery management

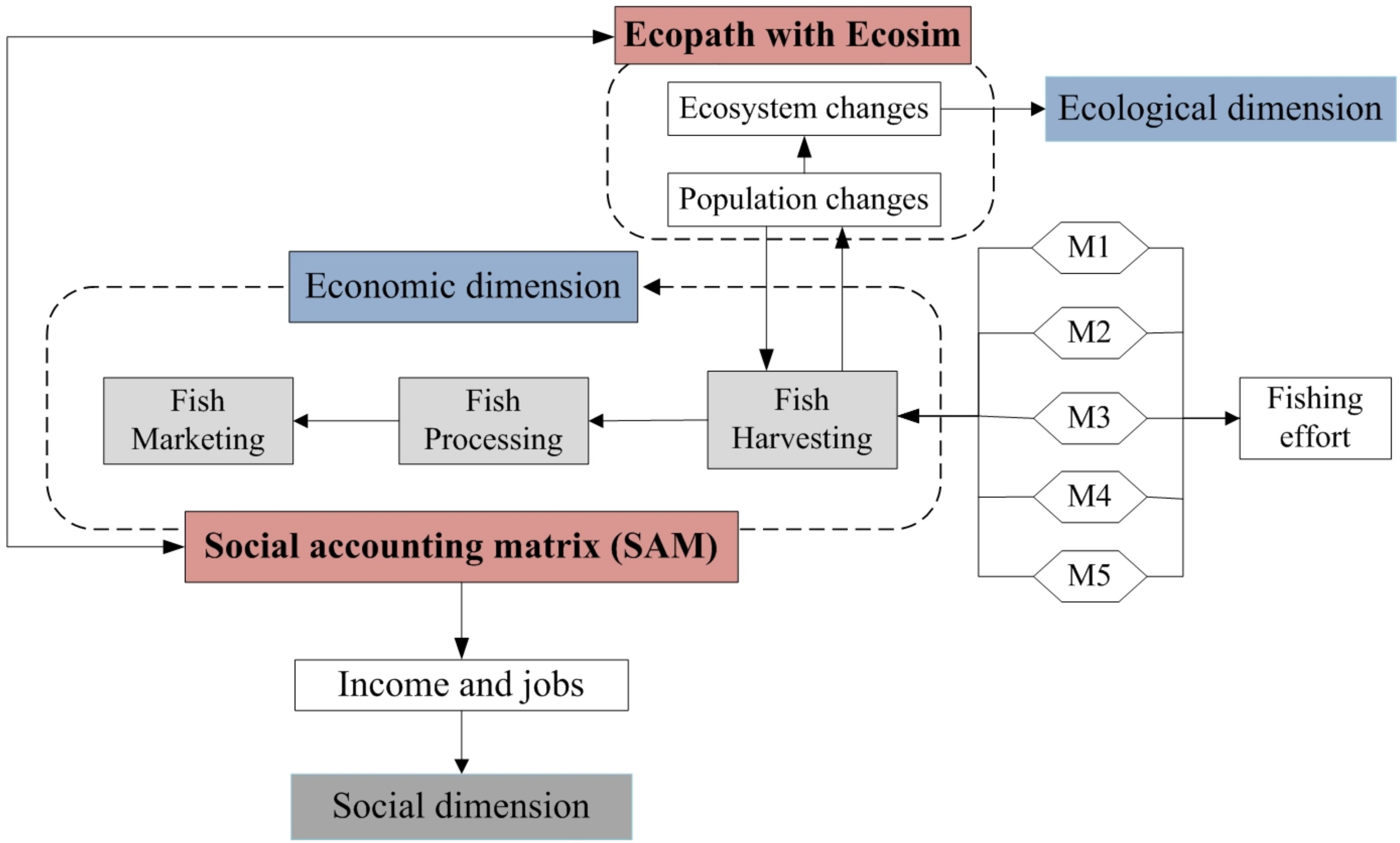
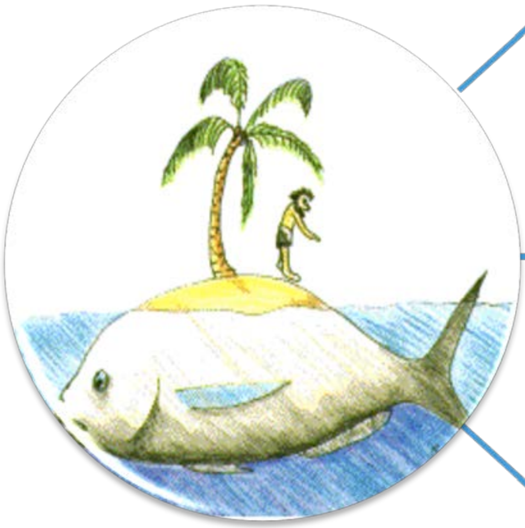


Fig. 3.1 Links between the PRD economy, social and the PRE ecosystem

2.1 Ecological model of the PRE ecosystem



Ecopath

- A static, mass-balanced snapshot of the system.

Mass balance model

Ecosim

- A time dynamic simulation model for policy exploration.

Time dynamic simulation

Ecospace

- A spatial and temporal dynamic module for exploring impact of protected areas.

Spatial simulation

Model input and output

No	Group name	TL	B($t \cdot km^{-2}$)	P/B($year^{-1}$)	Q/B($year^{-1}$)	EE	P/Q
1	Benthic producers	**1.0**	153.000	11.885	-	**0.01**	-
2	Phytoplankton	**1.0**	13.000	231.000	-	**0.47**	-
3	Zooplankton	**2.0**	10.400	32.000	192.000	**0.31**	**0.167**
4	Jellyfish	**3.1**	1.075	5.011	25.040	**0.74**	**0.200**
5	Polychaeta	**2.0**	0.800	6.750	22.500	**0.89**	**0.300**
6	Mollusks	**2.2**	0.700	3.500	11.700	**0.86**	**0.299**
7	Echinoderms	**2.3**	0.240	1.200	3.580	**0.88**	**0.335**
8	Benthic crustaceans	**2.2**	0.560	5.650	26.900	**0.84**	**0.210**
9	Other zoobenthos	**2.6**	1.690	1.000	9.000	**0.74**	**0.111**
10	Shrimps	**2.3**	**2.220**	3.080	16.352	0.95	**0.188**
11	Crabs	**2.5**	**0.506**	3.790	12.500	0.95	**0.303**
12	Cephalopods	**3.2**	1.475	3.100	8.000	**0.95**	**0.388**
13	Psenopsis anomala	**3.0**	0.101	2.410	24.000	**0.97**	**0.100**
14	Stromateids	**3.4**	0.393	3.030	**15.150**	**0.93**	0.200
15	Upeneus bensasi	**3.1**	**0.018**	2.098	10.280	0.95	**0.204**
16	Pneumatophorus japonicus	**2.8**	0.045	2.625	8.800	**0.97**	**0.298**
17	Argyrosomus argentatus	**3.4**	0.034	3.550	7.710	**0.96**	**0.460**
18	Collichthys lucidus	**3.3**	0.060	7.360	29.160	**0.96**	**0.252**
19	Saurida tumbil	**3.3**	0.020	4.260	7.120	**0.93**	**0.598**
20	Trachurus japonicus	**3.5**	0.412	2.150	7.860	**0.90**	**0.274**
21	Nemipterus virgatus	**3.1**	0.486	2.070	7.250	**0.93**	**0.286**
22	Priacanthids	**3.4**	0.216	2.940	8.000	**0.92**	**0.368**
23	Decapterus maruadsi	**3.1**	0.461	1.870	11.080	**0.92**	**0.169**
24	Trichiuridae	**3.8**	1.200	3.020	6.207	**0.91**	**0.487**
25	Small pelagic fish(-)	**2.8**	1.772	4.260	17.040	**0.97**	**0.250**
26	Large pelagic fish(+)	**3.1**	0.368	4.260	6.270	**0.96**	**0.679**
27	Benthopelagic fish	**2.8**	0.922	3.080	15.420	**0.91**	**0.200**
28	Small demersal fish(-)	**2.6**	**0.764**	4.700	23.500	0.95	**0.200**
29	Large demersal fish(+)	**3.0**	0.164	3.500	6.207	**0.94**	**0.564**
30	Sharks	**3.8**	0.005	0.200	4.130	**0.10**	**0.048**
31	Seabirds	**3.4**	0.003	0.060	66.098	**0.06**	**0.001**
32	Turtles	**2.9**	0.000	0.100	2.500	**0.10**	**0.040**
33	Marine Mammals	**4.0**	0.009	0.045	14.768	**0.05**	**0.003**
34	Detritus	**1.0**	200.000	-	-	**0.16**	

15 commercial exploited species are analyzed in integrated model

Fitting the PRD Ecological model with time-series catches data

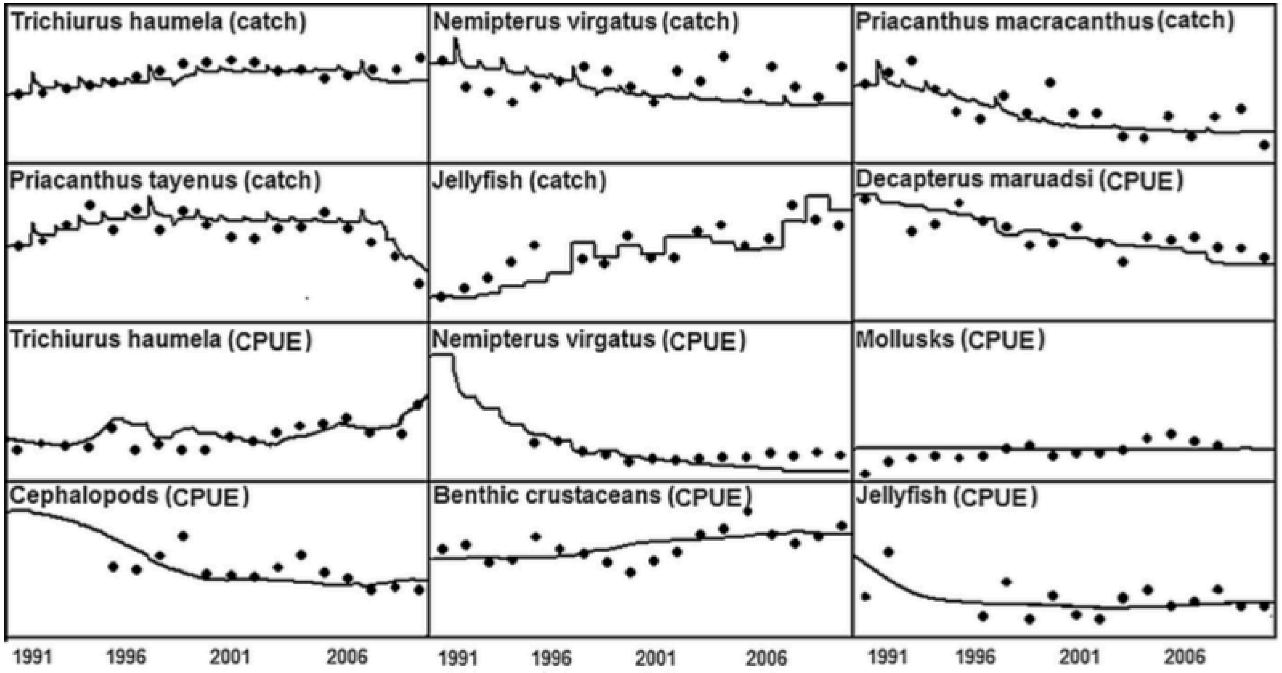


Fig. 4. Best fits obtained for 12 sets of times series data regarding catch and relative abundance for seven groups via dynamic simulations using Ecosim.

The total sum of square error (SS) was decreased from 24.25 to 18.31 after altering the vulnerability (V) factor.

2.2 An SAM model for the PRE coastal economic system

- The matrix of direct coefficient in SAM model, denoted S, is derived as :

$$S = \begin{bmatrix} A & 0 & C \\ V & 0 & 0 \\ 0 & Y & H \end{bmatrix}$$

- The supply and demand balance equations can then be written as :

$$\begin{bmatrix} x \\ v \\ y \end{bmatrix} = S \begin{bmatrix} x \\ v \\ y \end{bmatrix} + \begin{bmatrix} ex \\ \\ ey \end{bmatrix}$$

- To estimate the economic linkages of a sector, the multipliers obtained from the SAM's inverse coefficients can be given by the following:

$$\begin{bmatrix} x \\ v \\ y \end{bmatrix} = (I - S)^{-1} \begin{bmatrix} ex \\ \\ ey \end{bmatrix}$$

2.2 An SAM model for the PRD coastal economic system

Table 2
Social accounting matrix (SAM) of Guangdong province for the PRE's coastal economy in 2010.

($ in million, $1 = ¥6.8)			Activities			Commodities			Factors		Institutions						
			FISH 1	PROC 2	OTHER 3	FISH 4	PROC 5	OTHER 6	LAB 7	CAP 8	HH 9	GOV 10	ENTR 11	CAPEXP 12	INVENT 13	ROW/EX 14	TOTAL 15
Activities	FISH	1				11234.1											**11234.1**
	PROC	2					3055.9										**3055.9**
	OTHER	3						2059807.5									**2059807.5**
Commodities	FISH	4		658.8	7453.0						2893.1					378.6	**11383.5**
	PROC	5		104.9	2723.2						787.0					103.0	**3718.1**
	OTHER	6	7425.7	747.9	1393825.7						256648.6	70273.0		313034.6	20055.9	342495.0	**2404506.2**
Factors	LAB	7	3748.4	443.7	296578.0												**300770.0**
	CAP	8	60.0	1100.6	359227.5												**360388.2**
Institutions	HH	9							300770.0	36229.1		797.3					**337796.4**
	GOV	10									4224.4		51709.0	96.0	15040.9		**71070.2**
	ENTR	11								194691.8							**194691.8**
	CAPEXP	12								129467.4	73243.3		142982.8			2533.8	**348227.3**
	INVENT	13												35096.7			**35096.7**
	ROW/IM	14				149.4	662.2	344698.8									**345510.4**
	Total	**15**	**11234.1**	**3055.9**	**2059807.5**	**11383.5**	**3718.1**	**2404506.2**	**300770.0**	**360388.2**	**337796.4**	**71070.2**	**194691.8**	**348227.3**	**35096.7**	**345510.4**	**337796.4**

Note: FISH – fishing, PROC – processing, OTHER – other, LAB – labour input, CAP – capital input, HH – households, GOV – governments, INVENT – investments, SAV – savings, ROW – rest of world, IM – import, EX – export.

2.2 An SAM model for the PRD coastal economic system

Table 3
Fish production of Guangdong province in the PRE (2010).

Fish production value ($ in million, $1 = ¥6.8)	*Decapterus maruadsi*	*Trachurus japonicus*	*Engraulis japonicus*	*stromateids*	*Pneumatophorus japonicus*	*Argyrosomus argentatus*	*Collichthys lucidus*	*Saurida tumbil*	*Nemipterus virgatus*	*Sparidae*	*Trichiurids*	Shrimp	Crab	Cephalopods	**Other species**	**Marine capture the region**	**Other fishing**	**Total raw fish**
Stern and pair trawling	25.74	2.41	9.94	30.58	2.08	17.87	0.65	0.21	122.21	96.02	154.59	44.57	35.26	47.30	1.92	591.34		591.34
Gill net fishery	0.69	0.02	0.81	2.87	0.00	0.00	0.38	0.26	2.37	1.96	3.06	320.49	88.14	7.51	11.51	440.06		440.06
Purse seine	0.00	0.33	1.68	34.13	0.27	12.43	1.11	2.84	26.47	21.70	40.33	0.00	37.11	0.00	16.55	194.95		194.95
Hook and line	0.00	0.00	0.00	9.03	0.00	0.39	0.23	0.00	17.33	14.20	5.13	0.00	0.00	10.02	3.91	60.25		60.25
Other fishing	7.89	3.43	5.04	13.72	5.68	0.39	1.46	0.70	6.55	5.41	11.61	12.63	15.51	21.05	6.72	117.79		117.79
Marine capture	34.32	6.18	17.47	90.33	8.03	31.08	3.84	4.00	174.93	139.29	214.72	377.69	176.01	85.88	40.61	1404.39		1404.39
Other fishing																	9829.71	9829.71
Fishery economic	34.32	6.18	17.47	90.33	8.03	31.08	3.84	4.00	174.93	139.29	214.72	377.69	176.01	85.88	40.61	1404.39	9829.71	11234.10

Note: 1. Other fishing refers to mariculture, freshwater aquaculture and freshwater capture.
2. Data are sourced from Aquatic Products Yearbook of Guangdong Province (2010) and field survey data from Xiangzhou Fishing Port, Wanshan Island, Guishan Island, Dong'ao Island of Zhuhai City, and Nansha Fishing Port of Guangzhou City.

2.3 Linkages between SAM and EwE models

- The economic value of ecosystem is defined on the basis of its relevant ecological features, and its economic value is equivalent to the net present value of goods and services that flow from "uses" and "non-uses" of the resource.
- We focus only on the commercial fishing industry harvests fish from the ecosystem. The coastal ecosystem model is connected with the economic SAM model using the classical harvest function:

$$h = qEx \qquad \text{(Eq.6)}$$

- According to Eq.6, for fixed catchable coefficient and a given level of fishing effort, the harvest is proportional to stock size. That is the marine capture fishery output in economics model is proportional to biomass in the ecological model.

2.4 PRE fishery management scenarios

- **S1 or status quo:** this scenario predicts the performance of the existing levels of harvest including the fishing license system, closed seasons and closed areas, minimum mesh sizes, and prohibition of some types of fishing gear and fishing methods.
- **S2 or fishing effort reduction:** S2 applies this suggestion; fishing efforts of all fishing gear types are reduced by an annual rate of 5% for 30 years from 1981 to 2010 *.

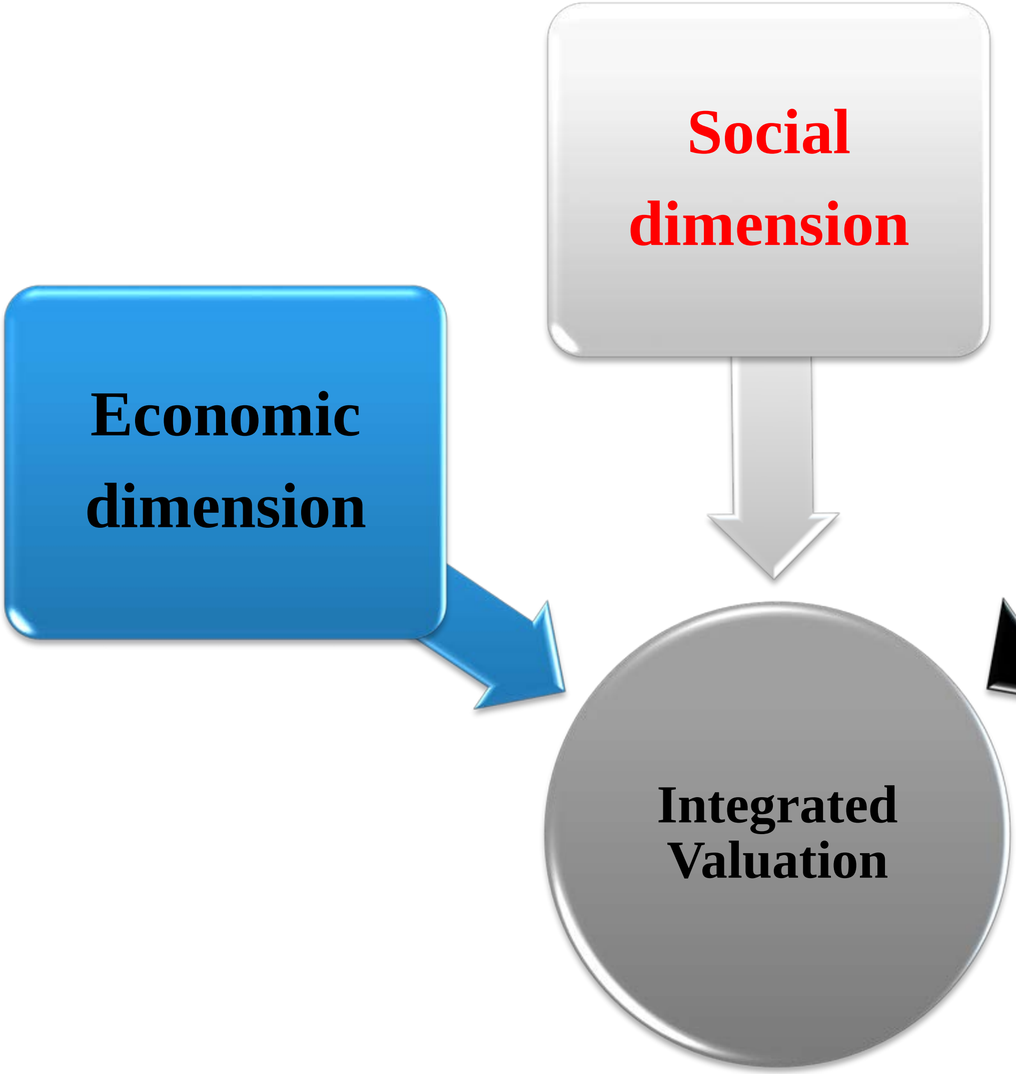
> * Previous studies suggest that the Northern SCS (north of 12°N) ecosystem could be restored by reducing fishing effort by an annual rate of 5% for 30 years.

2.4 PRE fishery management scenarios

- **S3, Gear switch policy:** switch 25% fishing effort from trawler to hook and line fishery in order to reduce the by-catch.
- **S4, Summer closure extend:** ban all fishing operations in the moratorium season， and extend the duration of the moratorium from 1 June to 1 September （extend 1 month）.

All of three simulation scenarios are assumed much stricter management regulations are implemented in the PRE coastal fishery.

3. Results



Social dimension
Economic dimension
Ecological dimension
Integrated Valuation

3.1 Ecological dimension

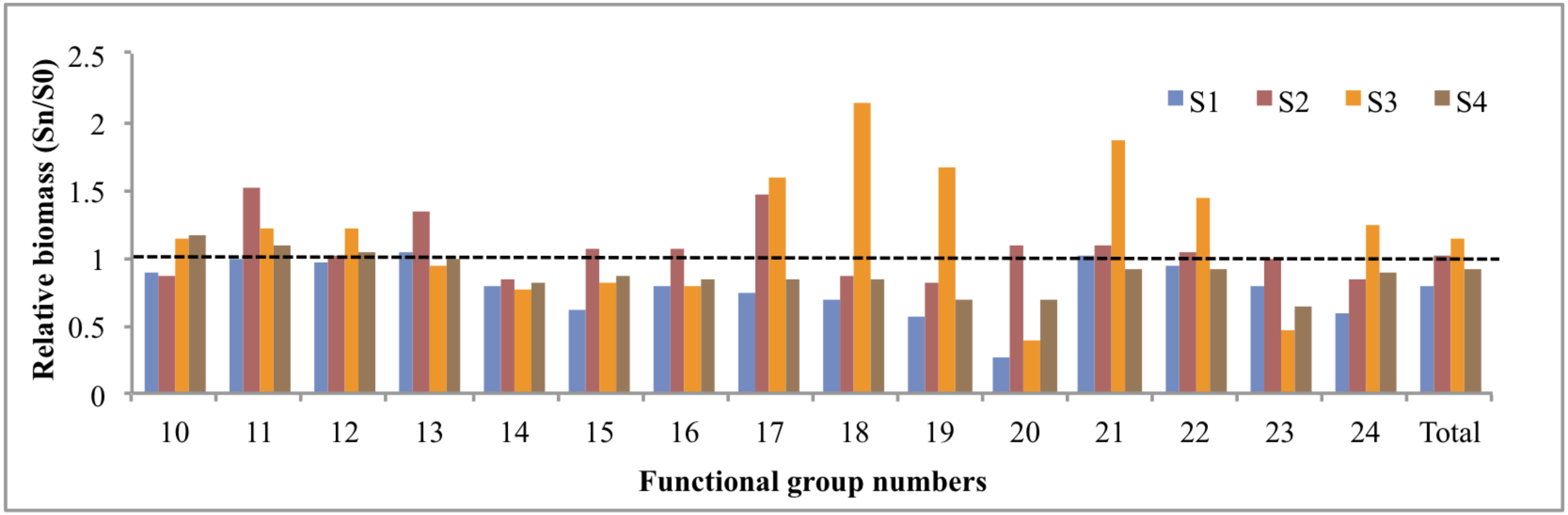
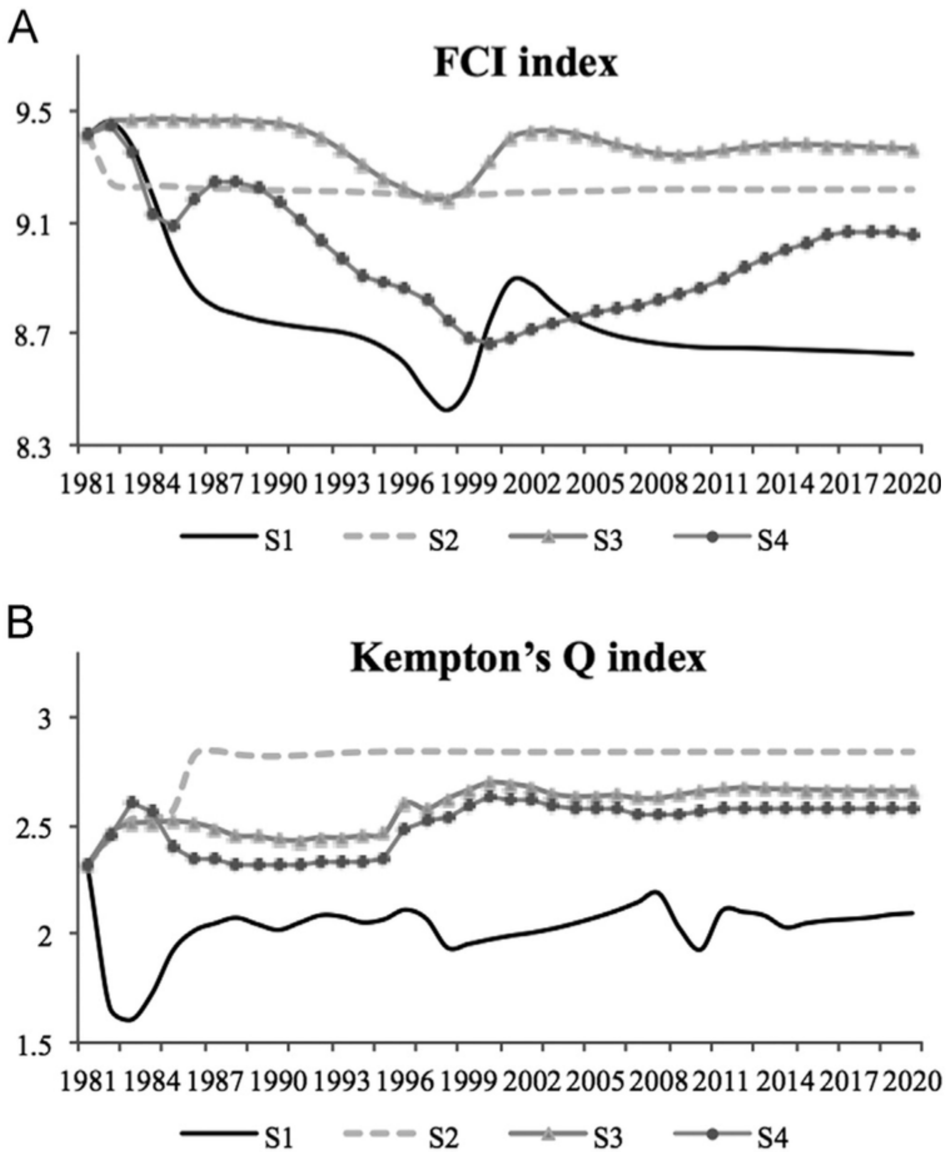


Fig.4-1 Biomass ratios of the functional groups from beginning of 30-year simulations to the end of the simulations

- ✓ Compared with the baseline scenario 1, total annual production of 15 functional groups (and thus biomass) for scenarios 2, 3 and 4 is higher by 27.8%, 44.1% and 14.4%, respectively.
- ✓ The results showed the total biomass increased over all policy simulation scenarios, but increased the most when the 20% fishing effort switching from trawler to hook and line fishery.

3.1 The ecological dimension



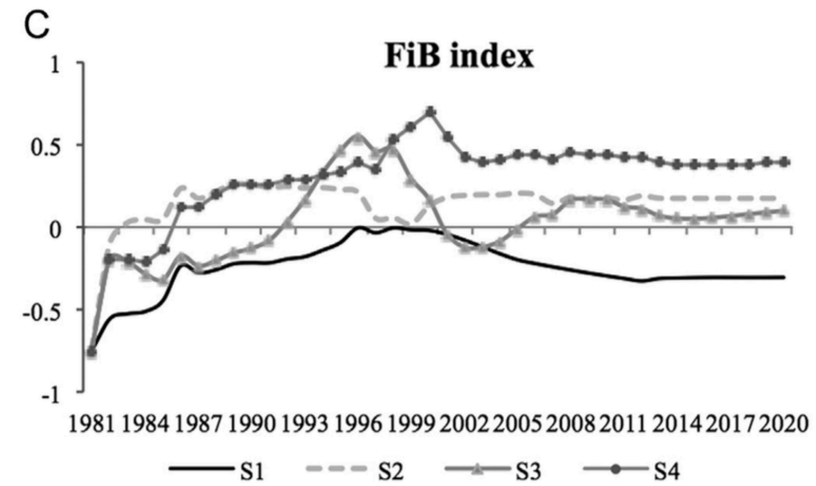


Fig. 4. The FCI, Kempton's Q (Q-90) index, and FiB index for the four scenarios between 1981 and 2020.

- The fishing effort reduction policy (S2), gear switch policy (S3), and the summer closure extension policy (S4) show positive effects on most ecological metrics, but none of them show the best performance across all the evaluated ecological metrics.

3.2 Economics dimension

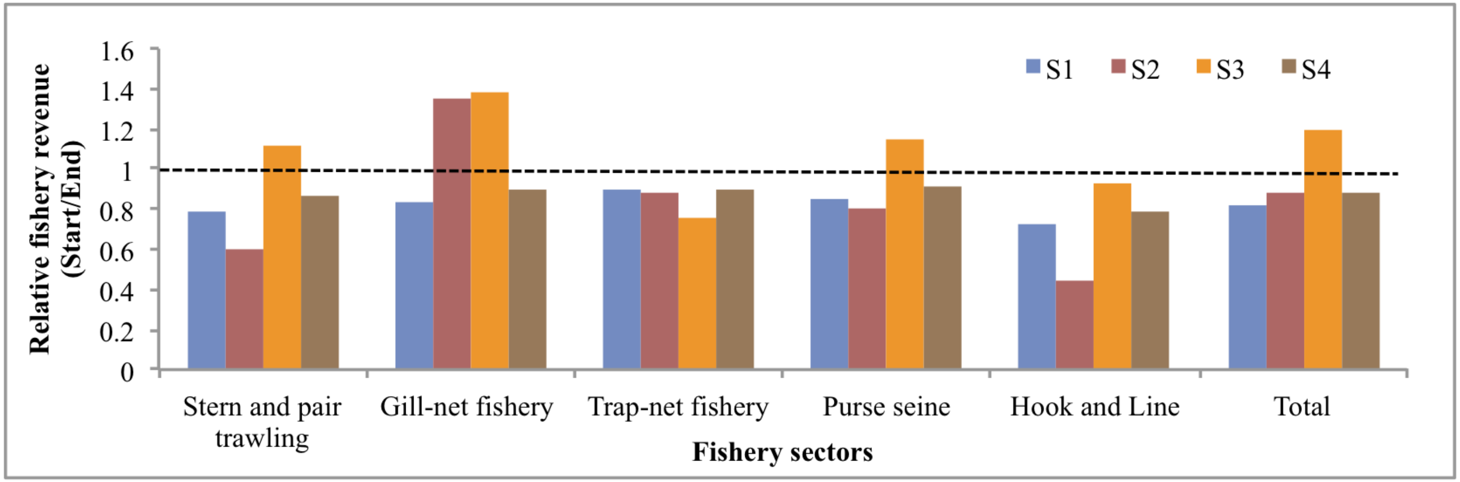


Fig. 4-3 Economic impact per fishery sector per scenario

- ✓ Simulated scenarios 3 effort switch policy was equivalent to a 4.3% revenue increase for total marine capture, from 1336.4 million to 1394.0 million in dockside value of the landings.
- ✓ However, the total landing revenues decrease 31.4%, 15.1%, and 8.4% in scenario 1, 2 , 4, respectively.

3.3 Social dimension

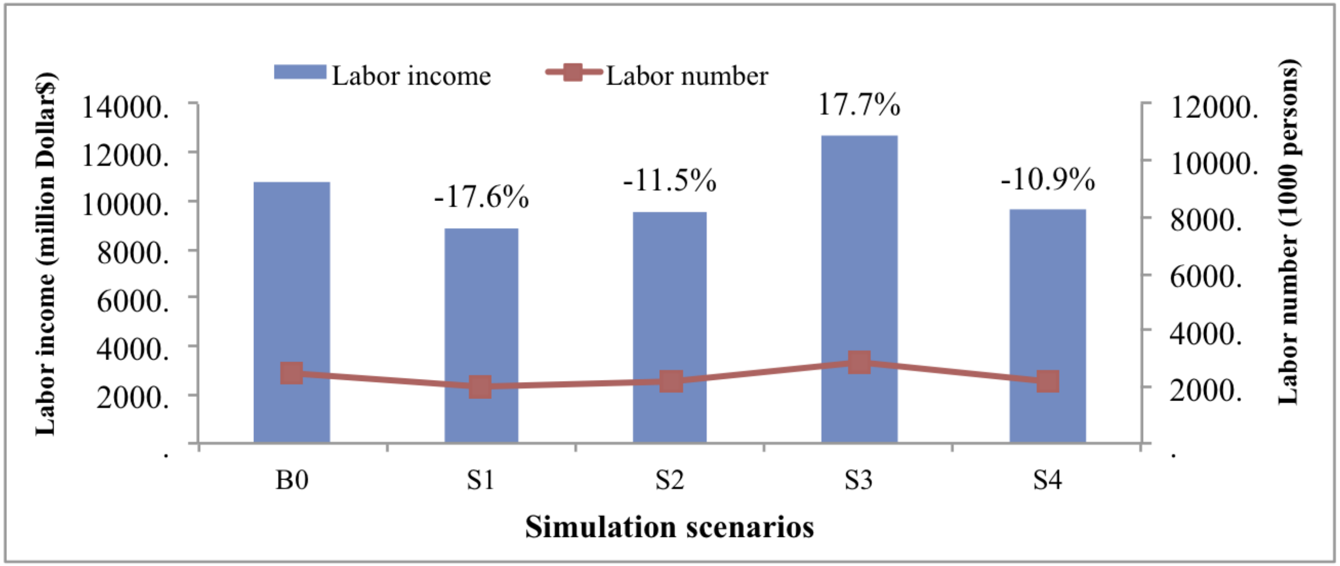


Figure 4-4 Changes in income and labor numbers for the PRE fishery sector in response to three fishery management simulation scenarios

- ✓ The main channel between social and economics in our model is income contribution. Employment effects mirrored the trends in economic impact.
- ✓ As observed in the graph, the social welfare of the five fishing methods follow similar trends to their economic revenue, which result from fishery household income being closely related to economic revenue.

3.4 Valuation from three dimensions

- The simulation results suggest that the status quo can be improved to optimal levels by reducing or switching fishing efforts.
- The gear switch scenarios was a compromise between economics and conservation metrics, and also outperformed other scenarios in terms of total biomass at the end of simulation year.
- The fishing effort reduction policy performed better than summer closure extend policy for the conservation metrics, but relatively poorly on the economic aspect.

4 . Conclusion

- Multi-objective management remains a great challenge for fisheries management and decision-making, as conflicts between socio-economic and ecological goals always exist.
- We believe that the integrated SAM-EwE model provides a useful approach to quantify the trade-offs between ecological and socioeconomic systems.

International Institute of Fisheries Economics and Trade (IIFET) Conference 2016

Thank You !