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A comparative assessment of the evolution of the recent trends in the fisheries in East Asian Delta (The Mekong and the Pearl River)

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Abstract

Fishing activity has been increasing drastically during the last 20 years on the East Asian littoral zones, particularly near the delta of important rivers which are, in addition, submitted to high human pressure due to the rapid development of large cities. In the past decade, the Mekong delta fisheries sector has achieved considerable growth. However, the sector suffers from many problems that need to be resolved to ensure their sustainable development. In China, the Pearl River is the second largest river (2,200 km) in terms of water discharge, after the Yangtze. The annual variation in discharge is significant and depends on the amount of rainfall that the catchment receives. Currently, the coastal region is a significantly and quickly developing economic zone in China. The high population density and rapid development of industry and agriculture have resulted in severe stress to the aquatic environment. A great deal of waste, excessive reclamation, over fishing and frequent oil spills etc. greatly influenced the water-related environmental quality in the PRE. The aim of this paper is to analyze the recent trends of evolution of catch/ fishing effort in The Pearl River Estuary (PRE) in China and in the Mekong Delta (Viet Nam) by reconstructing the past recent years on a comparative basis, in order to try to understand to which extent fisheries and other human pressure are responsible of the current situation The Ecopath package which includes Ecosim and Ecospace was in a first step utilized to balance the trophic structure of the food web in the two ecosystems. (References to be given in the full paper) In addition to balancing the model, we attempted to fit time series data on catch and effort for the recent year by using the Ecosim sub routine which make possible predictions of the future of these fisheries under various management scheme. Time series data were made available from data collected during a Mekong Delta survey from 2000 to 2008 and during a PRE survey at the same time.

Keywords: Asian Deltas, Mekong, Pearl River, China, Viet Nam, fitting Time series data

1. Introduction

Fishing activity has been increasing drastically during the last 20 years on the East Asian littoral zones, particularly near the deltas of important rivers which are, in addition, submitted to high human pressure due to the rapid development of large cities.

In the past decade, the Mekong delta fisheries sector has achieved considerable growth. However, the sector suffers from several problems that need to be resolved to ensure their sustainable development. The Government of Viet Nam encouraged investing more to off-shore fishing from 1998 after Linda Storm, which has contributed to an increasing number of fishing boats and fishing effort. This situation has increased competition in coastal fishing. Therefore, the Mekong Delta experiences problems including over-fishing in the coastal area, degradation of the marine environment and coastal resources, underdeveloped infrastructure, and lack of effective resource management.

In China, the Pearl River is the second largest river (2 200 km) in terms of water discharge, after the Yangtze. The annual variation in discharge is significant and depends on the amount of rainfall that the catchment receives. The Pearl River Estuary (PRE) is located in Chinese south province of Guangdong. Currently, the coastal region of the PRE is a significantly and quickly developing economic zone in China (Chau, 2005 in Duan *et al.*, 2009). As a result of rapid economic development in recent decades, the whole region has experienced rapid industrialization and urbanization. The high population density and rapid development of industry and agriculture have resulted in severe stress to the aquatic environment. A great deal of waste, excessive reclamation, over fishing and frequent oil spills etc. greatly influenced the water-related environmental quality in the PRE (Pang and Li, 2001; Lu and Chen, 2006 in Duan *et al.*, 2009).

The aim of this paper is to analyse the recent trends of evolution of catch/fishing effort in these two regions by reconstructing the past 10 years on a comparative basis, in order to try to understand to which extent fisheries and other human pressures are responsible of the current situation

1.1. Location

1.1.1. The Mékong Delta

The littoral marine zone near the Mekong Delta is 4286.41 km2 and extends from 105°46 E to 106°18E 8°55 N to 9°21 N. has a 700 km coastline and a sea territory of 360,000 km^2

The Mekong delta is characterized by intense urbanisation and associated developing human activities. Fishermen are operating hot only in the Mekong River itself and in its delta but also in the marine littoral zones (the continental shelve). The Mekong Delta experiences a typical monsoon climate leading to a seasonal increase of salinity in the lower part of the river. The hydrological pattern is also, and to some extent mostly, under the strong influence of the huge quantity of water coming every year from Lake Tonle Sap (Cambodia). Numerous fishing gears are used: littoral trawls targeting benthic fish and crustaceans, pelagic trawl for pelagic small Clupeids, gill nets for pelagic species in general, and drags for crustaceans. Fish biodiversity is high as recorded in other areas in the region but it is clearly threatened by the increasing fishing pressure and other deteriorations of the habitat (Van *et al.,* 2009).

The Mekong delta is known for its abundant potential in marine resources. Marine fisheries production consists mainly of pelagic and demersal fish, which contribute 80 to 90% of fisheries yield (Thuoc and Long 1997 in Van *et al.,* 2009). The remaining 10 to 20% is contributed by valuable invertebrates such as penaeid and acetes shrimps, crabs, lobsters, cuttlefish, squids and molluscs. Among these, penaeid shrimps and cuttlefish are the most important species for export (Son and Thuoc, 2003).

1.1.2. The Pearl River Estuary

The coastal ecosystem of the Pear River Estuary in our study, extends from 112°30′E to 115°30′E, 21°00′N to 23°00′N, is a typical ecosystem of China's coastal sea with 72 600 km^2 (Figure 2). The coastal ecosystem covers the shelf from the coast to approximately 100m depth with the characteristics of estuarine coastal waters driven by gradients due to the combined influence of river flow and sea. The PRE waters are subjected to the influence of three water sources: the Pearl River discharge, the oceanic waters from the South China Sea and the coastal waters from the South China Coastal Current (Yin, 2004 in Duan *et al.,* 2009). The resultant nutrient-enriched waters provide large biological productivity and sustain the most important commercial fisheries (Li *et al*., 2000; Wang and Lin, 2006, in Duan *et al.,* 2009). They play a role of natural refuge and nursery area for hundreds of species, including some local and endangered species. It is also an important fishing ground in the SCS. The whole system has distinct productivity, strong fishing activity and complicated relationship of food web.

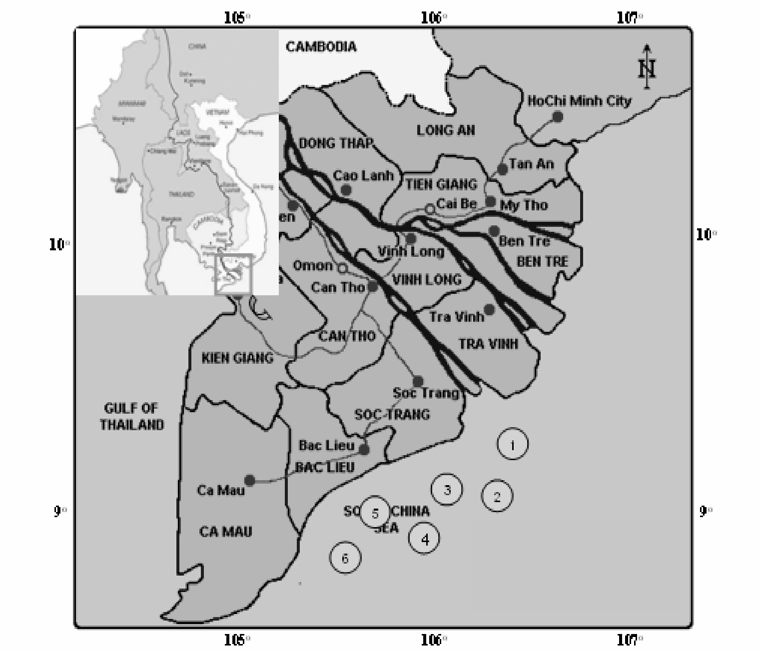

Figure 1: The Coastal areas in the Mekong Delta (Viet Nam).

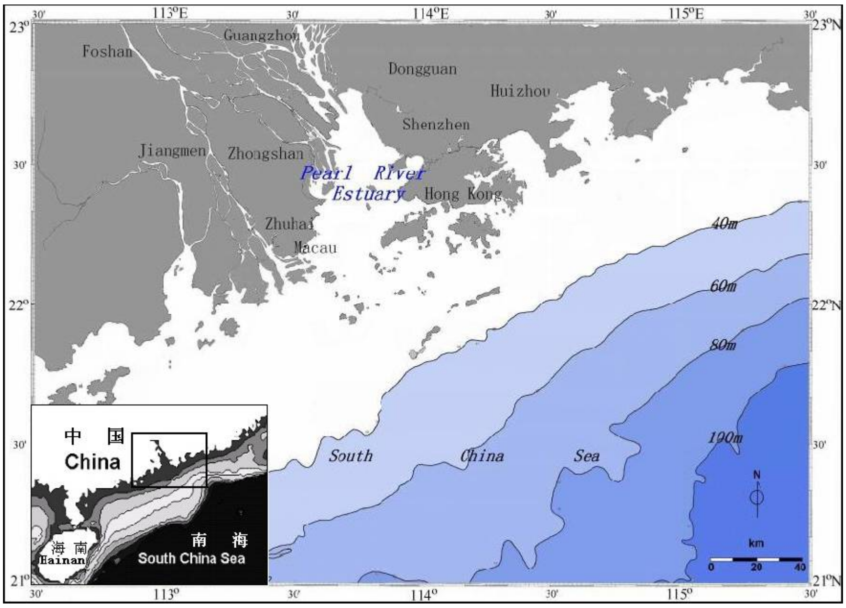

Figure 2: The Coastal areas near the Pearl River Estuary

In terms of utilisation of energy it can be expressed as $Q = \boldsymbol{P} + \boldsymbol{R} + \boldsymbol{U}$, where *Q* is consumption, *P* production, *R* respiration, and *U* unassimilated food.

In terms of utilisation of production the implication of a steady state will be expressed as follows for an arbitrary time period and for each element *i* of an ecosystem:

$$B_i * (P/B)_i * EE_i = \sum_{j=1}^{n} Bj * (Q/B)_j * DC_{ij} + EX_i$$

Where

Bi is the biomass of function group *i* during the period covered (usually, a year);

$(P/B)_i$ the production/biomass ratio;

EE_i the ecotrophic efficiency, i.e., the fraction of the production that is utilized within the system by predators or exported , mostly by the fishery; $(Q/B)_i$, the relative food consumption of *i*; and DC_{ij} is the fraction of prey *i* in the diet of predator *j*;

EX_i represents what is exported from the ecosystem, mostly through fisheries. The simultaneous linear equations using in Ecopath model states that the production and consumption of any group are balanced within an ecosystem.

The Ecopath model allows construction of a snap-shot of the ecosystem under mass-balance situation. The aim/purpose of the model is not only to verify the previously published biomass estimates, but also to identify the capacity of the ecosystem to adapt to various pressures including anthropic ones (Villanueva *et al.*, 2006). Constructing an Ecopath model consists mainly of the following steps:

i) Identification of the area and period for which the model will be constructed on an ecosystem;

ii) Definition of all functional groups (boxes), from primary producers to top predators, to be included;

iii) Setting values for the parameters such as production/biomass ratio *(P/B)*, consumption ratio *(Q/B)*, biomass *(B)* and ecotrophic efficiency *(EE)* for each functional group. However, for each group, one of them will remain unknown.

iv) Entry of the catches (including discards when they are known and important compared to the amount of fish which are disembarked) for every fishing species and, when possible, for each of the various fishing gears in use in the area;

v) Entry of diet consumption matrix *(DC)* expressing the diet fraction of predator/prey relationship in the model;

vi) Ensuring the balance of the models (mass input equals output for each box).

In addition to balancing the model, we attempted to fit time series data on catch and effort for the recent year by using the Ecosim sub routine (Walter *et al.*, 1997). The purpose of Ecosim was to make possible prediction of the future of these fisheries under various management schemes after a proper calibration of Ecosim (see Christensen *et al.*, 2005, for this approach).

3. Results

Two models originated from this work. It results in preliminarily contributions by Van *et al.* (2009) and Duan *et al.* (2009).

The important results of these preliminary works are the identification of key groups in the ecosystems (pelagic and demersal fish populations including predators. The trophic structure of the ecosystem can be summarized as in Figure 3 (Viet Nam) and Figure 4 China)

Time series data were made available from data collected during a Mekong Delta survey from 2000 to 2008 as shown on Table 1, thanks to the Department of Fisheries (unpublished data and personal communication) and also through our surveys.

The results of the fitting attempts with Ecosim as displayed by Ecosim appear below Figure 5. (two possible pattern of variation of the fishing effort were considered

For the Pearl River Estuary, the time series data made available are summarized on Table 2 below and two attempts of fitting were carried out one over the last 18 years and another over the last 10 years. The results of the fitting attempts with Ecosim as displayed by Ecosim appear below Figure 6

For the Mekong Delta, by referring to the recorded fishing effort (on the left of Figure 3), strong correlations could be observed with the variations of the fishing effort for some exploited groups: shrimps and squids, and to a lesser extend, trash fish and demersals. For other groups, the increase of catch seem to appear independently of the increase of the fishing effort: predators, benthic feeders small pelagic, mackerel and crabs

With the simulated fishing effort (right) the catch of several groups tend to increase: benthic feeders, demersal, squids, crabs. After an increase, catch is decreasing for other groups: trash fish and shrimps. For two groups, the recorded catch increase is much higher than the increase of the fishing effort: mackerel and top predators.

In the estuary of the Pearl River, the general trend is a slow increase of the catch in relationship with the increase of the fishing effort. A slight decrease could be fitted for the most recent years (*Nemipterus* sp, *Decapterus* and Cephalopods (Figure 4 right) with a smoothed trend of increase of the fishing effort. However, again, the increasing of the catch of some group could not be fitted properly (*Trichurius* sp and jelly fish).

Table 1: The time serie of catch/effort data made available for Vietnam (Note that fishing effort is expressed as a relative variation from the value for 2000. *Groups in italics are specifically targeted with gill nets,* other ones with trawls

Year	Fishing effort	Trash fish	Predators	Benthic feeders	Demersal	*Small pelagics*	*Mackerel*	squids	Shrimps	Crabs
2000	1.000	0.580	0.060	0.200	1.040	*0.070*	*0.020*	0.620	1.600	0.180
2001	1.061	0.490	0.100	0.320	1.290	*0.080*	*0.030*	0.470	1.410	0.130
2002	0.968	0.290	0.110	0.470	1.530	*0.110*	*0.040*	0.980	1.620	0.410
2003	0.952	0.300	0.150	0.500	1.200	*0.160*	*0.110*	0.850	1.590	0.440
2004	1.221	0.400	0.190	0.370	1.560	*0.220*	*0.130*	0.670	1.410	0.440
2005	1.230	0.510	0.233	0.411	1.738	*0.249*	*0.157*	0.928	1.762	0.511
2006	1.237	0.512	0.233	0.412	1.745	*0.250*	*0.158*	0.931	1.769	0.513
2007	1.220	0.602	0.274	0.484	2.050	*0.294*	*0.186*	1.094	2.078	0.603
2008	1.397	0.581	0.265	0.468	1.981	*0.284*	*0.179*	1.057	2.008	0.582

Table 2: The time series of catch/effort data made available for the Pearl River Estuary, China (Note that fishing effort is expressed as a relative variation from the value for 1998

Year	fishing	Other pelagics	Decapterus	Trichurius	Nemipterus	Prianchatus	Crustaceans	Mollusks	Cephalopods	Jelly fish
1998	1	1.572	0.017	0.021	0.018	0.029	0.457	0.379	0.175	0.027
1999	1.02	1.853	0.015	0.028	0.017	0.032	0.451	0.239	0.167	0.027
2000	0.98	2.056	0.013	0.024	0.017	0.027	0.459	0.228	0.218	0.025
2001	1.05	1.962	0.014	0.028	0.017	0.029	0.478	0.213	0.197	0.037
2002	1.05	2.449	0.013	0.03	0.016	0.036	0.478	0.187	0.229	0.046
2003	1.07	2.043	0.018	0.032	0.016	0.035	0.445	0.221	0.246	0.047
2004	1.12	1.692	0.016	0.035	0.013	0.038	0.467	0.219	0.141	0.058
2005	1.11	1.678	0.014	0.035	0.013	0.039	0.465	0.207	0.137	0.069
2006	1.1	1.424	0.013	0.034	0.013	0.03	0.465	0.207	0.173	0.07
2007	1.1	1.424	0.013	0.034	0.013	0.03	0.465	0.207	0.173	0.07

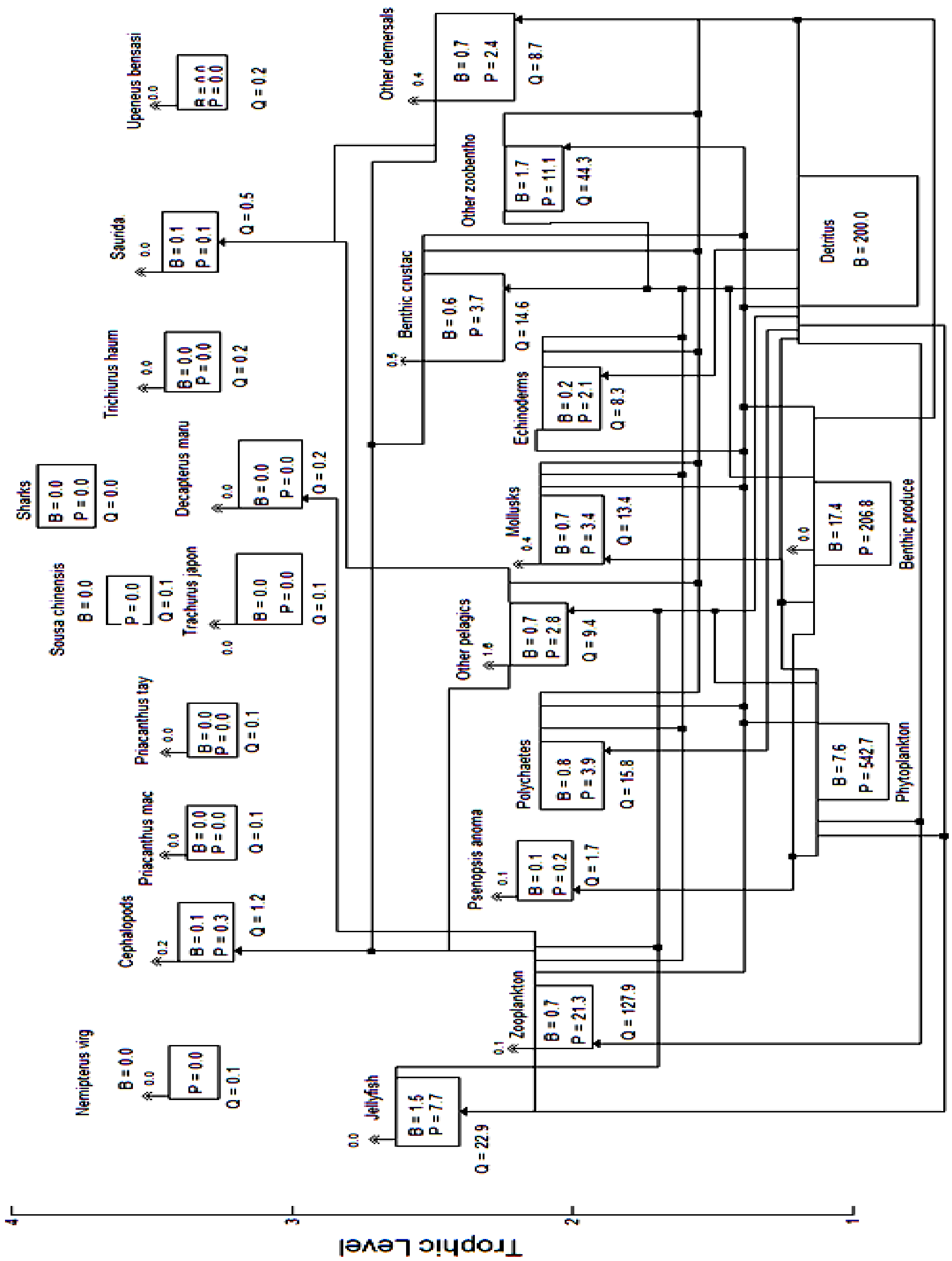

Figure 3: The trophic structure of the Mekong Delta ecosystem as established with the Ecopath model and software.

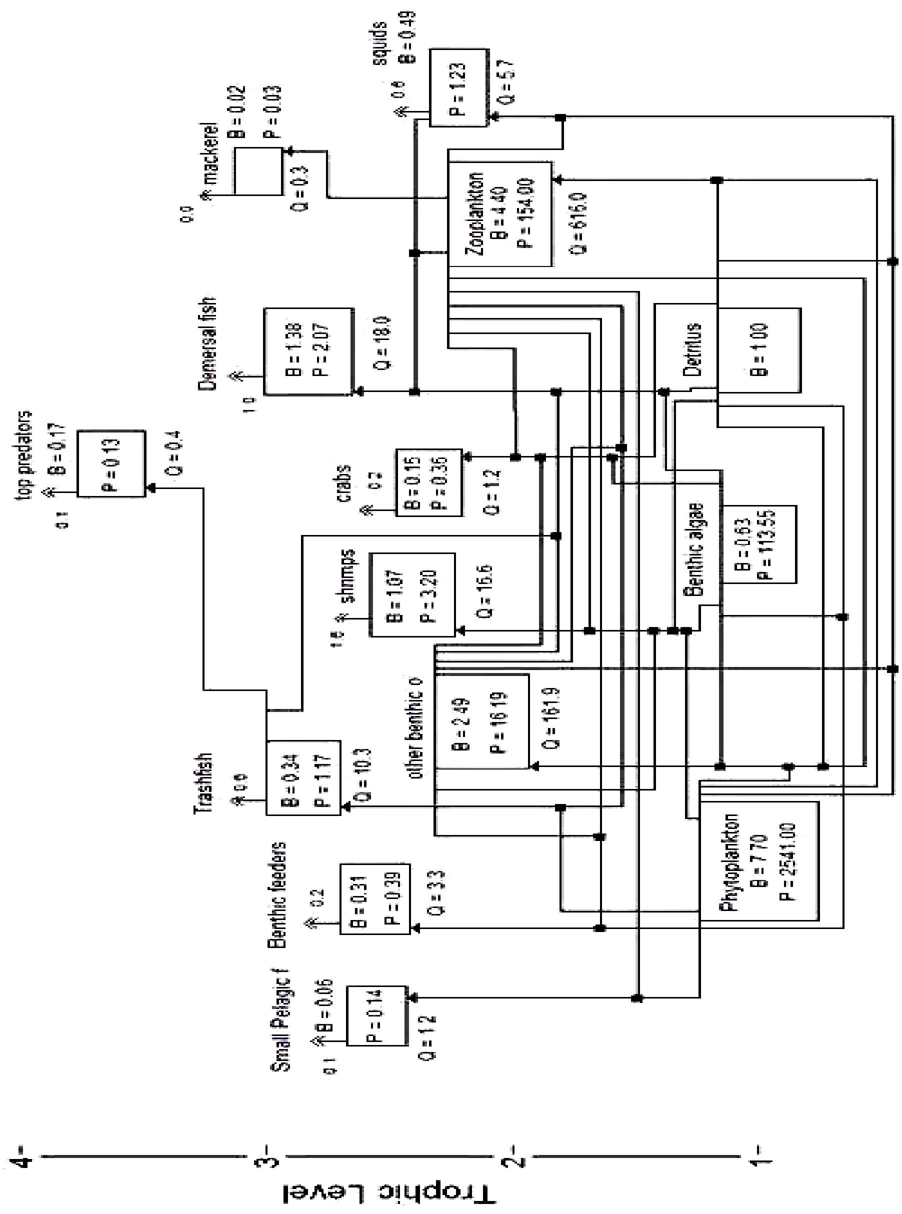

Figure 4: The trophic structure of the Pearl River Estuary ecosystem as established with the Ecopath model and software.

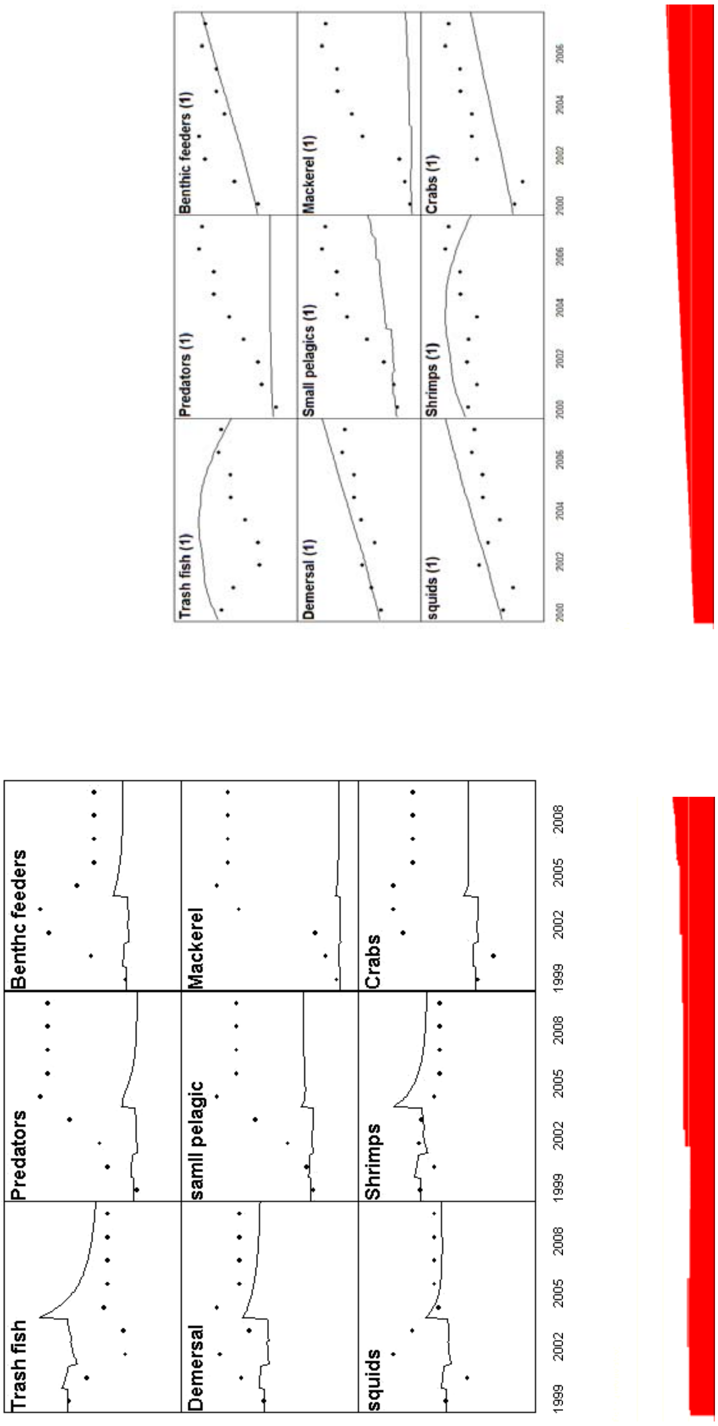

Figure 5: Attempts in fitting time series data with two different patterns of the fishing activity for the Mekong Delta., The patterns of variations of (t) the fishing effort are displayed below in grey.

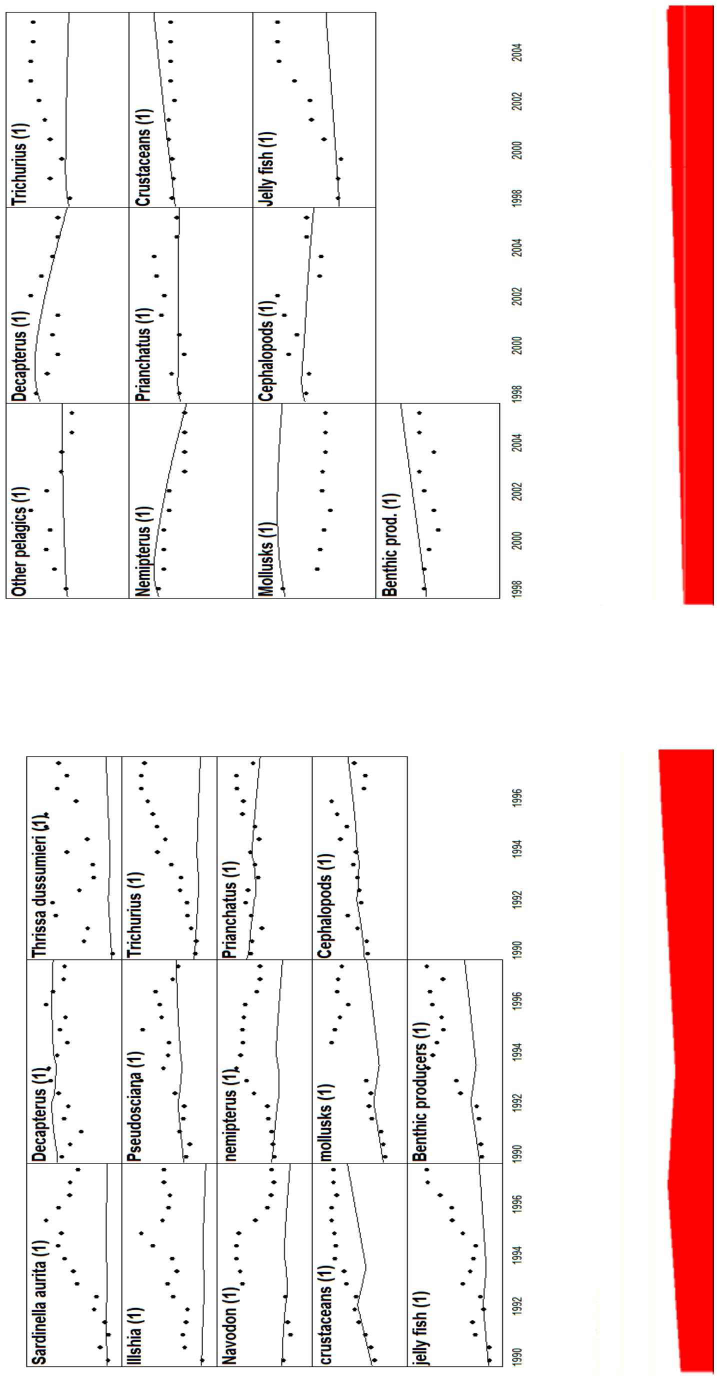

Figure 6: Attempts in fitting time series data with two different patterns of the fishing activity for the Mekong Delta.. The patterns of variations of the fishing effort are displayed below in grey.

4. Discussion and conclusion

Several points should be considered Ecosim simulations showed once more the necessity of consistent time series data on both fishing effort and catch for several years (at least ten). A proper setting of the vulnerability parameter of ecosim *sensu* Christensen *et al.,* (2005) helps, to some extend, to improve the quality of the fitting. Such a setting was operated for all the fitting However, the significance of this parameter has to be kept in mind: a bottom up control for the abundance of groups requesting low values of the vulnerability (less than 2) and on the opposite a top down control when the vulnerability index is more than 2. Such a hypothesis could be considered for groups which are under a strong predation pressure (fishing mortality lower than the predation mortality as computed by ecopath), the EE value of the group under consideration should also be taken into account. Generally, the vulnerability index was fixed at low values (between 1 and 2) for groups at high trophic levels and at much higher values (up to 10) to groups belonging to the lower trophic levels, including invertebrates. The vulnerability concept sensu Christensen et a (2005) is also in connection with the evaluation of the possible carrying capacity of the ecosystem as defined by Christensen and Pauly (1995).

From management point of view, it appears for several groups that the catch is quite constant or slightly decreasing displaying overfishing patterns.

In Viet Nam, for instance the Government encouraged to invest more to off-shore fishing from 1998 after Linda Storm, which has contributed to an increasing number of fishing boats and fishing effort. However, the lack of facilities, knowledge and experience for off-shore fishing has brought an inefficiency of many off-shore fishing boats. Some off-shore fishers sold their boats after some years of operation and they started to use smaller boats in association with new entrants of nears-shore fishers. As a result, it is difficult to assess the real evolution of the fishing effort. It appears however that this situation has increased competition in coastal fishing and will, most likely, cause deterioration of coastal fisheries resources. A better registration of fishing boats has recently started thanks to sector managers which will help to clarify the situation of numerous unregistered near-shore fishing boats. This might lead to a revision and updating of the recent variations of the fishing effort which could explain, at least partly, some high catch increases currently not properly documented.

Simultaneously, in the coastal ecosystem of the Pearl River Estuary（PRE, the resources exploitation has ever greatly contributed to the development of the fisheries and national economy. However, the status of fishery resources and the ecosystem structure have changed substantially due to over fishing. It appeared that the ecosystem had experienced large changes that switching from large-size and high-value demersal fishes dominated ecosystem to an ecosystem dominated by small-size and low-value pelagic species (Duan *et al* 2009). Fishery resources are depleted，the quality of the landings reduced，the value of marine capture are declined，the cost of fishing are increasing，so it is necessary to assess fisheries social, economic and ecological costs and benefit into an integrated framework for fisheries policy and decision-making.

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