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Trophic controls of jellyfish blooms and links with fisheries in the East China Sea

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ABSTRACT

Large jellyfish blooms have occurred in the East China Sea (ECS) during the last decade, a period also characterized by increasing fishing pressure, eutrophication, and changing climatic conditions. As large jellyfish blooms may have detrimental effects on fishery resources and ecosystem functioning it is desirable to understand the factors leading to jellyfish blooms. Therefore an Ecopath model covering the whole territorial waters of the ECS has been developed to address a number of questions about the impact and control mechanism of large jellyfish blooms on trophic structure and energy flows in the ECS. Model data collection for the ECS is based on records from 1997 to 2000. Forty-five functional groups are defined in the model including 32 fish (19 single species and 10 multispecies), 2 benthic and 1 for each of the following: mammals, sea birds, sea turtles, primary producers, large jellyfish, cephalopods, shrimp, crabs, zooplankton, heterotrophic bacteria and detritus. The average trophic level of fishery catch in the ECS ecosystem for the period 1997–2000 was 2.71 while the mean value for all groups was 2.87. Analysis of the trophic interactions has identified a possible positive pelagic feedback loop allowing large jellyfish blooms to develop as a result of mutual competition and predation between large jellyfish and Stromateoidae. This could be initiated by exploitation of Stromatidae. The pelagic pathway of the ecosystem will be disrupted at the initial stage of a large jellyfish bloom.

1. Introduction

Jellyfish abundance is increasing in numerous marine ecosystems worldwide. In the Bering Sea, jellyfish biomass had been dramatically increased over the eastern Bering Sea shelf since the early 1990s (Brodeur et al., 2002), and the catch of jellyfish during the summer survey in 2000 was the highest recorded. Other examples include the Gulf of Mexico (Graham, 2001), Sea of Japan (Eczema, 2005), North Sea (Christopher et al., 2005), German Bight (Greve, 1994) and also the East China Sea (ECS) (Yan et al., 2004a; Cheng et al., 2005). The great increase in jellyfish biomass that has occurred over the past decade in both the ECS and Yellow Sea occurred simultaneously with a decline in fishery resources. Survey data conducted by Fishery Resources Dynamic and Monitor Net of the ECS Region during 1990–2003 have shown that the biomass of large jellyfish in recent years was much greater than that during the early 1990s and the dominant species were *Cyanea* spp. and *Stomolophus* spp.

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As large jellyfish blooms have detriment impacts on fishery resources and ecosystem functioning it is desirable to understand the factors leading to jellyfish blooms. Nevertheless, very few long-term datasets exist to help determine why jellyfish populations are on the increase. In some areas, over-fishing has altered community structure suggesting that trophic controls may have allowed jellyfish blooms, whereas in other areas recent shifts in climate and ocean condition may have driven these unprecedented increases in jellyfish abundance (Purcell, 2005; Xian et al., 2005).

The wide continental shelf waters of the ECS provide large fishery resource for China, Japan and South Korea. Heavy fishing pressure has resulted in a significant change in resource composition in the past few decades (Yan et al., 2004b). Stocks of high value and low-volume species have been fished heavily leading to low landings. Some high volume and low-value species has also been heavily fished (e.g. green filefish) although some species (e.g. hairtail) are still producing high landings (Chen et al., 1997a). The mean trophic level of the catch has decreased from 3.5 in 1965 to 2.8 in 1990 (Chao et al., 2005) and the catches have come to be smaller, and are mainly composed of younger and premature individuals for some species such as hairtail (Chen et al., 1997b; Yan et al., 2004a).

Ecopath is a comprehensive and practical method to represent trophic structure of an ecosystem providing basic information for fishery resource management with multiple trophic levels. Large-scale fishery resources investigation of the ECS had been done during 1973–1977, 1980–1981 and 1997–2000 (Zheng et al., 2003). The survey data show the declining abundance of some fishery resources and changes in species catch composition in terms of biomass and value. The purpose of this study is to construct a mass-balanced trophic model using the ECOPATH 5.1 approach (Christensen and Pauly, 1992) to examine possible mechanisms leading to jellyfish blooms and the impact of these blooms on fishery resources.

2. Ecosystem definition and data sources

2.1. ECS ecosystem definition

The ECS is a vast, semi-enclosed marginal sea and part of the western Pacific Ocean bordered by China, South Korea, and Japan. It covers an area of 770 000 km^2 (Zheng et al., 2003). The average water depth of the ECS is approximately 370 m. The confluences of the longshore current, the Yellow Sea cold water mass and the Kuroshio Current provide good fishing grounds in the ECS. Large quantities of land-based nutrients and pollutants flow into the ECS along with large fresh water inputs, mainly from the Changjiang (Yangtze) riverine system. Such riverine inputs influence productivity of the ecosystem and affect the composition, distribution and dynamics of the phytoplankton community. The ECS ecosystem modelled in this study is defined as the area surveyed during 1997–2000 surveys (Zheng et al., 2003; Fig. 1).

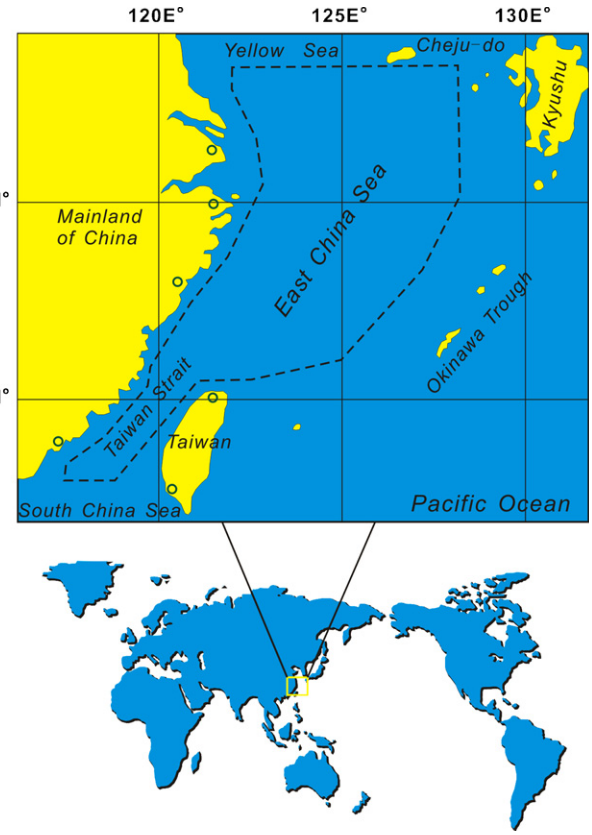

Fig. 1 – Area covered by the East China Sea Ecopath model.

2.2. Model construction

Forty-five functional groups were defined; some of them aggregate several species, whereas others represent only 1 genus or species. The selection of fish groups, and some invertebrate groups, was based on abundance and economic importance. Other invertebrate groups were selected due to their importance to consumers. One heterotrophic bacteria group, one primary producer group (phytoplankton) and one detritus group were also included in the model. Large jellyfish was specified as an individual group in order to test the relationship between jellyfish and other groups and to examine the impact of large jellyfish blooms to the ECS ecosystem. Six fleets were defined in the model. Five fleets (trawl, stow net, drift gill net, purse seine and shrimp trawl) represent the main fishing fleets in mainland of China. In addition a sixth fleet was incorporated to represent landings of the Taiwan district and Japan taken from the ECS. The fishery landings of South Korea from the ECS were not included in the model as it was not possible to disaggregate ECS landings from total landings.

The model was balanced following the procedure in Blanchard et al. (2002); first all parameters values were checked to see if they were within biologically plausible limits, then the diet composition data was modified to ensure ecotrophic efficiency (EE) values were less than 1. Once the manual balancing had ensured no EE value was significantly greater than 1 the automatic balancing routine was used to complete model balancing. After balancing, consistency of the model was checked using physiological criteria to ensure