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Phenomenon on Fishing Down Marine Food Web in East Coast Gulf of Thailand

Methee Juntaropakorn[1] and Amararatne Yakupitiyage[2]

[1]*Faculty of Science at Sriracha, Kasetsart University Sriracha Campus, 199 Moo 6 Sukhumvit Rd., Sriracha, Chonburi, Thailand.*
[2]*Aquaculture and Aquatic Resources Management, School of Environment, Resources and Development, Asian Institute of Technology, Klongluang, Pathumthani, 12120, Thailand.*
Coresponding author e-mail address : amara@ait.ac.th

Abstract— Several studies presented the occurrence of fishing down the marine food web in different part of the world including Thailand. Some data from Gulf of Thailand were conducted from 1966-1982 and 1977-1997 which showed a decline in the mean trophic level but did not determined the subsequence trends. Therefore, this study was focus on the analyzing of trend in trophic level and fishing-in-balance index to determine the effect of fishing and other factors. The data of trawl survey from 1988-2007 and the data of fish landing from 1990-2007 which used in this study derived from the Department of Fisheries, Thailand. Base on number of species or groups composition, hierarchical cluster was analyzed using 10 trawl stations resulted in two main clusters covered provinces of Rayong, Chanthaburi and Trad. The data indicated that from 1988 to 2007, mean trophic level decreased from 3.28 to 3.10 (decline ~0.09/decade) in cluster 1 and 3.27 to 3.13 (decline ~0.07/decade) in cluster 2. The fishing-in-balance index was above zero in the early 1990s but later on values were mostly below zero. The significantly decrease of mean trophic level, catch per unit effort (CPUE) and total landing in cluster 1 supported the fishing down marine food web phenomenon in the East Coast Gulf of Thailand. Data analysed indicated that it was fishing down marine food web in the East Coast Gulf Thailand was consistent with the trend has been reported. By the concept of fishing down marine food web, 4 phases were classified; phase 1 was high catch of species with high mean trophic level (TLm), phase 2 was low catch of species with high TLm, phase 3 was high catch of species with low TLm and phase 4 was low catch of species with low TLm. The analyzed data were evaluated that fishery in the East Coast Gulf of Thailand was classified in phase 3 and eventually reach phase 4 in the near future. Overfishing, particularly of species high level in the food chain was the main cause for significantly decreased in observed mean trophic levels.

Keywords— ***Fishing down; Gulf of Thailand; Trawl survey***

INTRODUCTION

Coastal and marine resources are important for humans in all countries. Natural resources located along the coast are used for development of the country. Fisheries resources from the sea is the main source of the food supply that serve the population in each country. The increasing trend in world the fisheries impact on ecosystems (Goni, 1998; Hall, 1999; Hollingworth, 2000; Pauly, 2003) the failure in traditional stock assessment and management and the economic subsidies of fisheries lead to overfishing of marine resources, and, in some cases, to stock collapse. Pauly et al. predicted further decreasing trends in world catches and vast effects on marine biodiversity(Pauly, 2002; Pauly, 2003; Botsford, 1997).

The mean trophic level of fisheries catches was introduced by Pauly et al. as an indicator of fishing impact on aquatic ecosystems. The rationale of this indicator, which quantifies a process now widely known as 'fishing down marine food webs' is that fisheries, upon depletion of the large, high trophic level species they initially target, shift to small, low trophic level species. Pauly et al. proposed the mean trophic level of catch (TLm) to reflect the declining fisheries production with the assumption that a decline in the mean trophic level of catch (TLm) is generally due to high fishing mortality that reduce both biomass and biodiversity of top predators. Usually, TLm declines as the result of fishing pressure being focused on the higher trophic levels at the start of fishery, which is then

replaced by pressure on the lower as the abundance of high trophic level species declines (Pauly, 1998 ; Kleisner, 2011).

The coast of Thailand was productive fisheries area. Thailand, ranked among the top ten fishing nations of the world, had a total marine fisheries production of 2.63 million tons in 2004, which accounted for ninety per cent of total fish production of the country. This catch, which worth 61.80 billion Thai Baht (US$.1.82 billion), was harvested from the Gulf of Thailand (1.8 million tons) and from the Indian Ocean (0.83 million ton) (DoF, 2006). Thai fisheries production exceeded 2 million ton for the first time in 1977, there after declined. Production regained in 1983 and it further increased up to 3.6 million ton in 1995 probably due to increased fishing pressure. Department of Fisheries (Dof, 1999) reported that the catch-per-unit effort (CPUE) has been declined from 298 kg/hr in 1961 to around 20 kg/hr in 1990. Various studies concerning on the demersal, pelagic and invertebrate resources in the Gulf of Thailand have indicated problems associated with over-exploitation (Boonyubol, 1982; Chullasorn, 1998; DFWG, 1995; Hongskul, 1972; PFGW, 1995; Supongpan, 1988; Supongpan, 1993; Vibhasiri, 1987). It has been noted a change in catch composition towards small and less valuable species. Gayanilo and Pauly based on the Thompson and Bell's method estimated MSY and MEY of five dominant species in the trawl catch (i.e. *Priacanthus tayenus*, *Nemipterus hexodon*, *Saurida undosquamis*, *Saurida elongate* and, *Metapenaeus affinis*) and claimed that those species were over-exploited (Pauly, 1997). However, overfishing caused resources decline and probably also caused the loss of biodiversity of the fisheries resources.

In the past, the trend in fishing the marine food web along the Gulf of Thailand coast during 1965 to 1997 has been analyzed, but no further study has been conducted. This study was aimed to assess the effect of fishing on the mean trophic level and CPUE in the three provinces of Eastern Gulf of Thailand (Rayong, Chanthaburi and Trad) to further demonstrate the concept of fishing down the marine food web. The analysis would be useful for researchers and fishery managers not just in Thailand but also in other countries experiencing the same problem.

MATERIAL AND METHODS

Trawl survey data.

The marine resource survey was conducted by the Eastern Marine Fisheries Research and Development Center, Department of Fisheries (DoF), Thailand using an otter board trawler along the eastern Gulf of Thailand from 1988 to 2007 (except in 2001). Ten shore trawl stations were selected along the coast of Rayong, Chanthaburi and Trad provinces of Thailand (Fig. 1). Hierarchical cluster analysis of the 10 trawl stations based on number of species or groups composition produced two main clusters: Cluster 1 covering stations 18, 19, 20, 21 (Rayong and Chanthaburi provinces) and Cluster 2 covering stations 31, 32, 42, 43, 44 and 58 (Trad province).

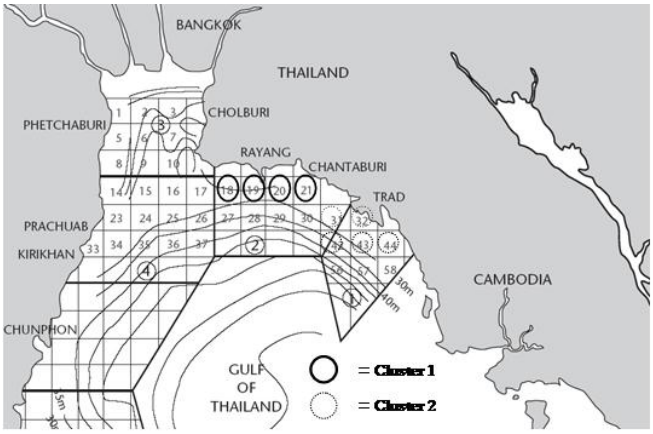

Fig 1 Trawl survey stations in Eastern Gulf of Thailand

Data on fish catch from trawling in stations 18 to 58 in the Eastern Gulf of Thailand were ranked by quantity. To understand the trends in fishing and marine food web, the two cluster data sets were analyzed as follows:

The trophic level of the top 10 species or groups (based on catch quantity) in each station each year was calculated using the formula:

$$TL_i = 1 + \sum_{j=1}^{n} DC_{ij} TL_j \quad (1)$$

where DC_{ij} represents its diet composition, j is the prey, and TL_j is its trophic level. Estimates of TL_j were based on information on the diet of each species, as complied in Freire et al., complemented with data from FishBase and Pauly and Christensen.

The mean trophic level of each of the top 10 species or groups for the years1988-2007 was estimated using the following formula:

$$\overline{TL} = \frac{\sum_{i=1}^{10} X_i TLi}{\sum_{i=1}^{10} X_i} \quad (2)$$

where X_i is the percentage of catch of species *i*

The observed trends were interpreted by plotting the mean trophic level against landings. This interpretation facilitated analysis of the relationship between the landings and the fishing of the food web.

A fair evaluation of the impacts of a fishery should not be based on an index of mean trophic level, which simply declines as the fishery moves down the food web. Rather, it should be based on an index that should decline only when catches do not increase as expected. The Fishing-in-balance (FIB) index can be an indicator of a trophic level balance objective in fishery management, assessing whether fisheries are ecologically balanced.

FIB index was estimated as follows:

$$FIB = \log\left(Yi\left(\frac{1}{TE}\right)^{TL_i}\right) - \log\left(Y_0\left(\frac{1}{TE}\right)^{TL_0}\right) \quad (3)$$

Where Yo and TLo are the percentage of each of the top 10 species/groups and mean TL of the first year of the series.

Yi is percentage of each of the top 10 species/groups at year i.

TLi the mean TL of each of the top 10 species/groups at year i.

TE is the mean transfer efficiency. Here TE is set at 0.10, as estimated as a reasonable average of marine systems by Pauly and Christensen on the basis of 48 published ecosystem models.

The FIB index, as defined with TE = 0.1, has the property of staying constant if catch increases by a factor of ten for each decline of 1 trophic level. This is due to the fact that, in the absence of geographic expansion or contraction, and with an ecosystem that has maintained its structural integrity, for the fisheries to be moving down the food web should result in increased catches (and conversely for increasing TL). Therefore, the FIB index will increase only if catches increase faster than TL declines and will decrease if increasing catches fail to compensate for a decrease in TL. If this is the case the FIB index will remain constant, and fishing can be deemed 'in balance'. Indications from previous studies are that catches do indeed increase as 'fishing down the food web' sets in, but only in the initial phases will the increase in catches balance with the decrease in its trophic level. The FIB index, which enables assessment whether the fishery is ecologically balanced or not, should decline when catches do not increase as expected. Values of FIB < 0 may be associated with unbalanced fisheries, a lower catch than the theoretical catch based on the productivity of the food web.

Regression model on trend over the years in the 2 clusters were analyzed by mean trophic level, fishing-in-balance (FIB) index, CPUE of fishery resources in each group and fishery resources quantity landing.

Fisheries resources landing data.

Data on fisheries resources at major landings in Rayong, Chanthaburi and Trad provinces were collected from the Annual Fisheries Statistics of Thailand during year 1990-2007. Based on cluster analysis of trawl survey stations along the Eastern coast, the quantity of fisheries resources at landing places data of cluster 1 cover Rayong and Chanthaburi provinces and cluster 2 cover Trad province.

RESULT AND DISCUSSION

Catch per unit effort (CPUE) and fish landings

The trawl survey data in terms of catch per unit effort (CPUE) along the Eastern coast of Thailand showed a substantial decline over time. There is a significant decrease in catch per unit effort (CPUE) of trawl fishing in clusters 1 and 2 from 1988-2007, with highest CPUE (63.39 kg/hr) in cluster 2 in 1994 and lowest CPUE (8.79 kg/hr) in cluster 1 in 2007 (Fig. 2).

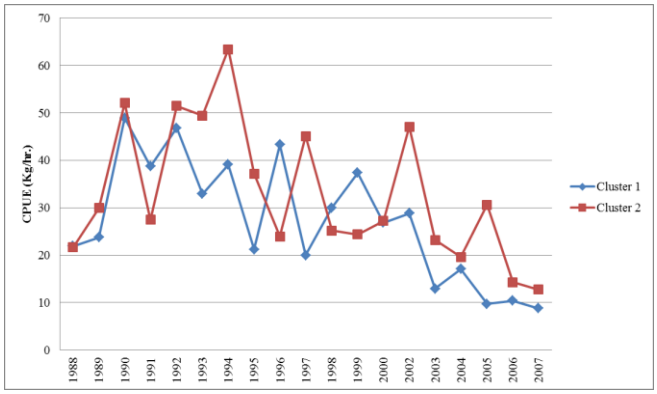

Fig. 2 CPUE from the Department of Fisheries (DoF) trawl survey in cluster 1 and cluster 2 from 1988 to 2007.

In the Gulf of Thailand, the catch rates from the research vessels shows a decreasing trend since 1966. In 1961, before the introduction of otter-board trawl to Thailand by the German technical assistance, the monthly catch rates from research vessel surveys were over 300 kg/hr. After 1966, the catch rate was 172.9 kg/hr and further declined to 75.1 kg/hr in 1976. The catch rate has continuously decreased and was about 18 kg/hr in 1998. Christensen study of the Gulf of Thailand showed increase in total catches for the demersal trawl fisheries and strong decline in the catch rate of demersal fishes based on trawl surveys in the Gulf.

The demersal fish and low value fish in the 2 clusters show similar rates of CPUE decline but regression trend over the years shows significant decline only in demersal fish group with $r = -0.751$, $P < 0.05$ in cluster 1 and $r = -0.51$, $P < 0.05$ in cluster2 (Fig. 3). However, in recent years (2002-2007), regression showed significant decline in both demersal fish ($r = -0.87$, $P < 0.05$) and low value fish ($r = -0.866$, $P < 0.05$). Cephalopod, especially squid, had a significant increase ($r = 0.821$, $P < 0.05$).They are thus able to build up population quickly in favorable conditions, but equally, population may crash suddenly with no reserves from different age classes [35].

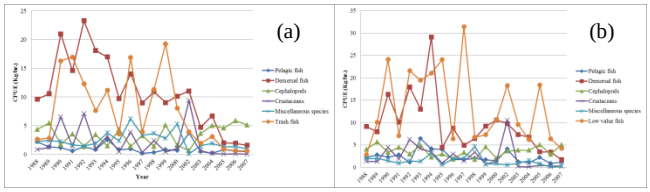

Fig. 3 CPUE of fish groups in cluster 1(a) and cluster 2 (b) from 1988 to 2007.

In the cluster 2 from the year 2002 to 2007, statistical test result showed a significant negative regression only in demersal fish group with $r = -0.976$, $P < 0.001$. There is a significant decrease in fish landing in cluster 1 ($r = -0.739$, $P < 0.001$) but it is not significant in cluster 2 ($r = 0.087$, $P > 0.05$) from 1990-2007 but from 2003 to 2007, the decrease is significant in both 2 clusters (cluster 1; $r = -0.986$, $P < 0.01$ and cluster 2; $r = -0.987$, $P<0.01$) (Fig. 4).The trend over the years with CPUE data from trawl survey and landings also showed a decline from 1994 in the 2 clusters (Fig. 5).

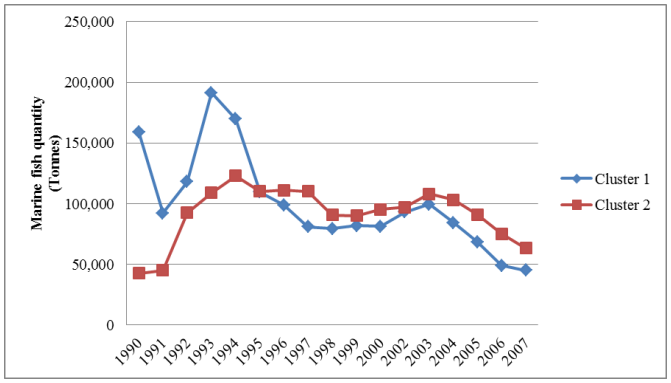

Fig. 4 Annual landings in cluster 1 and cluster 2 in the Eastern Gulf of Thailand from 1990 to 2007.

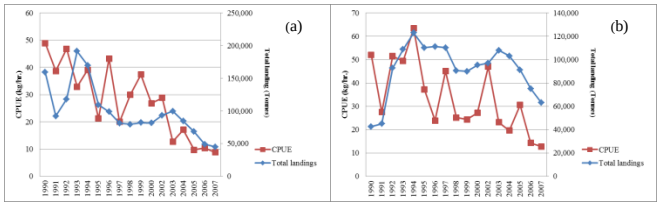

Fig. 5 CPUE versus landings in cluster 1(a) and cluster 2 (b) in the Eastern Gulf of Thailand from 1990 to 2007.

Mean trophic level.

There is a significant decrease in the mean trophic level of fish catch in cluster 1 from 1988 to 2007 (r= -0.551, P< 0.05) (Fig. 6). In cluster 2, the mean trophic level goes up and down with the highest in 1991 and lowest in 1998. From 1988 to 2007, the mean trophic level decreased from 3.28 to 3.10 (decline ~0.09/decade) in cluster 1 and 3.27 to 3.13(decline ~0.07/decade) in cluster 2. This constitutes a rate slightly lower than the overall decline rate (0.10 per decade) estimated at the global level by Pauly et al. and 0.28 per decade in Uruguayan water of AUCFZ but higher than the southeast coast of India that decrease 0.04 per decade. Unselective fishing such as trawling aimed at maximizing total catch tend to reduce the average trophic level in a system's food web. Also, this reflects the mean trophic level of aggregate fisheries catch from a given area.

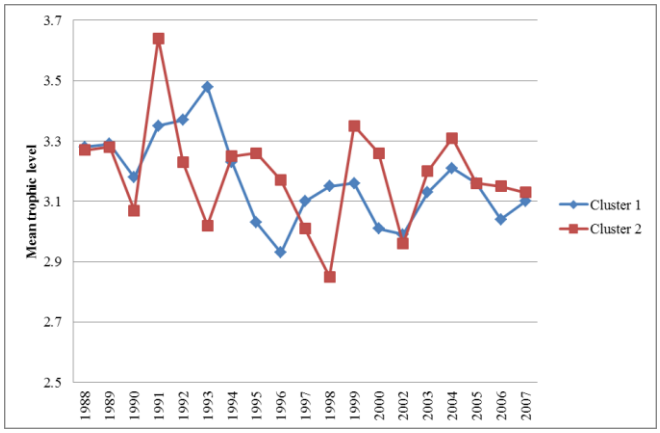

Fig. 6 Mean trophic level of major species or groups in cluster 1 and cluster 2 in the Eastern Gulf of Thailand from 1988 to 2007.

The mean trophic level of the whole fishery in the Gulf of Thailand was estimated by Christensen and Pauly and Chuenpagdee to have declined from 1965 to 1997 at a rate in the range 0.05 to 0.09 per decade. In recent years, there is a low catch of species or groups with low TLm in cluster 1 while in cluster 2 (Fig. 7), there is high catch of species or groups with low TLm.

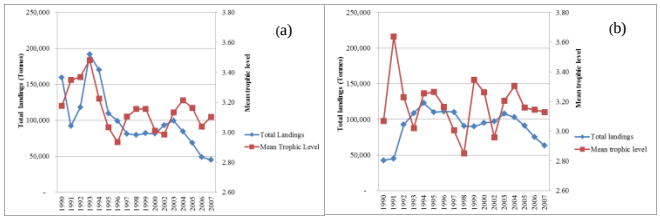

Fig. 7 Total landings and mean trophic level in cluster 1(a) and cluster 2 (b) in the Eastern Gulf of Thailand from 1990 to 2007.

Several studies using trophic level approaches have been carried out for a better understanding of the functioning of ecosystems. Mean trophic level proved to be a good indicator of the status of exploited fishing resources in a multispecies context. In marine ecosystems, they showed that the mean trophic level of fish community in a given ecosystem decreases when fishing activities are intense. The same trend was found to occur for the mean trophic level of the catches landed. The significant decrease of mean trophic level, CPUE and total landings in cluster 1 supports the fishing down marine food web phenomenon in the Eastern Gulf of Thailand. In the 'fishing down the marine food web' concept, the trend goes from high catch of species or groups with high TLm (phase 1), then low catch of species or groups with high TLm (phase 2), then high catch of species or groups with low TLm (phase 3), and finally low catch of species/groups with low TLm (Phase 4). The findings of our study indicate that the fishery in the Eastern Gulf of Thailand is now in phase 3 which would eventually result in phase 4. This should be of great concern to fishery managers.

Fishing-in-balance index.

The fishing-in-balance index in the Eastern Gulf of Thailand was above zero in the early 1990s but later on the values were mostly below zero, indicating an imbalance in the fishery (Fig. 8). Christensen estimated the FIB index in the Gulf of Thailand from 1966 to 1981 and showed that the index start out at 0 (log scale) and increased over the next two years (where the average trophic level shows no decline) and then remained at a level of 0.5 throughout the time series.

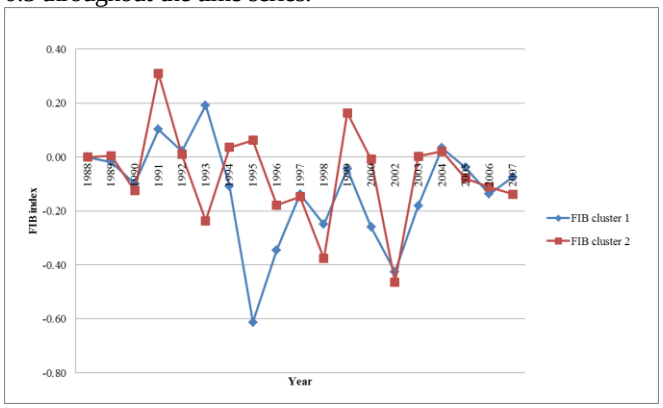

Fig. 8 Fishing-in-balance index of cluster 1 and cluster 2 in the Eastern Gulf of Thailand from 1988 to 2007.

Results of this study show fishery-induced impacts on the community structure of fish species in Eastern Gulf of Thailand. The trawl survey data in terms of catch per unit effort (CPUE) along the Eastern coast of Thailand showed a substantial decline over time. The fisheries show high catch of species with low mean trophic level eventually resulting in low catch of species with low mean trophic level. Overfishing has affected the community structure of the Eastern Gulf of Thailand as indicated by the significant decreasing trend in mean trophic level, which should be of great concern to fishery managers. We suggest the integration and implementation of ecosystem-based approaches to the governmental agency management programs in the Gulf of Thailand to reverse the negative impacts on the fishery.

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