THE DYNAMIC RESPONSE RELATIONSHIP BETWEEN FISHING ACTIVITY AND FISHERY RESOURCES CARRYING CAPACITY IN CHANGSHAN ISLANDS, CHINA

CAO, W. W.[1*] – SUN, C. Z.[2] – YANG, X. Y.[2]

[1]*College of Land and Tourism, Luoyang Normal University, Luoyang 471022, China*

[2]*Institute of Marine Sustainable Development, Liaoning Normal University, Dalian 116029, China*

**Corresponding author*
e-mail: cwwjy5032@163.com

(Received 9th Nov 2022; accepted 20th Jan 2023)

Abstract. Human who is subject to the bounded rationality will also improve fishing activity to restore the piscatorial resource that already ebbed. We evaluate the relationship between fishery resources carrying capacity and fishing activity of the Changshan Islands, China, by vector auto-regression model. It demonstrates that there is a remarkable negative correlation between fishery resources carrying capacity and major fish species catch. Overfishing leads to a decline in carrying capacity, the results of which can be seen quickly by the size and Mean Trophic Level of the catch. However, there is a dynamic balance between the intensity of fishing activity and the carrying capacity of the fishery ecosystem. The reduction of fishery resources limited the fishing activities of fishermen, which forced them to shift fishing areas or switch to mariculture, so that the ecosystem can be restored. The relationship of dynamic *balance* between fishing activity and fishery resources carrying capacity proves that the fishery ecosystem has the function of self-stabilizing, and human beings are rational in limiting fishing activities.
Keywords: *fishing activity, fishery resources carrying capacity, interaction, dynamic balance, mean trophic level, vector auto regression model*

Introduction

The oceans are huge resource banks where humans acquire protein by withdrawing living marine resources (Langton and Auster, 1999), and the world fish food supply has grown significantly during the last few years due to its nutritional qualities and the techniques of capture, storage and transport, which have been improved (Leo et al., 2014). Global fisheries statistics as disseminated by *Sea Around Us* (*www.seaaroundus.org*) indicated that the total global marine fisheries catches peaked in the mid-1990s, and continued to decline in the following twenty years (Zeller et al., 2018).

In recent years, research has increased about the depletion of marine resources caused by the overexploitation of fisheries and the degradation of ecosystems (Malcolm et al., 2021; Guan et al., 2021; Coro et al., 2021). Impacts of human activity on the sustainable development of marine fisheries have been considerably concerned, and the carrying capacity with theoretic and practical meanings has become a focused area over the past two decades (Huang et al., 2022). Anthropogenic activity, especially fishing activity, is a highly prominent inducement to change the marine ecosystem (Newton et al., 2007; Ding et al., 2017). The scientific literature unequivocally supports that fisheries affect an ecosystem by altering the flow of ecological capital (Langton et al., 1999), and these effects are most readily identified in those areas that experience infrequent natural disturbance (Jennings et al., 1998). According to Halpern et al.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

(2008), except for polar regions of earth, no area is unaffected by human influence in the oceans of the world, and 41% fraction is heavily affected. The exploitation of marine fishery resources has intensified to satisfy burgeoning human populations for food (Agardy, 2000), so that marine fishes of higher trophic level in the food web are being caught, and the changes of fishing in marine ecosystems will contribute to the significant reduction in primary consumers, and then lead to decreasing the prey for higher trophic level organisms (Jennings et al., 1998). As fishing activity selectively removes organisms from the marine food web, the trophic level and size structure of the marine ecosystem will be altered. (Pauly et al., 1998).

Consequently, the large, long-lived fish at or near the top of aquatic (especially marine) food webs, when exploited by multispecies fisheries faster than smaller, short-lived fishes with lower trophic levels, the mean trophic level of catches tends to decline in the exploited ecosystem. This process is termed as “fishing down marine food webs” (Christensen, 1996; Pauly et al., 1998). It has now been established that fishing activity leads to a global reduction in the carrying capacity of fishery resources, but this is not an overall converse phenomenon. Humans adapt their behavior to changes in the environment when they encounter ecological confinement. Marine ecosystems, just like the cultivated land with a long history of farming, the dramatic and apparently compensatory shifts in the biomass of different species exert an indispensable role in maintaining ecological balance by human self-regulation (Caddy, 1993). For a given the region, especially where industrial fisheries appear, if there were an ecosystem in which the stock was overexploited or the large catches of the higher trophic level fishes decreased, the fishing fleet would expand to an adjacent area (Kleisner et al., 2014). As part of the initiative of resource environmental enforcement, management authorities will establish legal and policy measures to prevent catastrophic losses and facilitate the recovery of already depleted fishery resources by limiting the number of marine fishing vessels and gear and introducing fishing moratoriums. Several studies have argued that the degradation of marine ecosystems suffering from overfishing is not a constant process in this regard the natural systems were considered resilient and stable (Holling, 1973). Marine ecosystems can avoid collapse due to over-exploitation, and depleted fishery resources can be restored through strict ecological management of marine areas (Kleisner et al., 2013; Worm et al., 2009). There was a negative and significant relationship between fishing gears and fishery resources and a positive correlation was observed between fishing regulation and fishery resources (Ajagbe et al., 2020).

From the above, considerable effort has been allocated to understanding the effects of fishing on marine ecosystems, but relatively little attention has been paid to understanding the changing processes of interaction between humans and marine ecosystems. As fisheries need to be managed in the context of the ecosystems in which they are embedded (Pikitch et al., 2004), attention should be paid to both identifications of pressure from marine fishing activity and quantification of fishery resources carrying capacity, basing ecological management, and more, profound and correct recognition of response relationship between fishing activity and carrying capacity, especially in tiny scale and typical offshore waters where human activity is the most intense.

The waters off the Changshan Islands are within China’s Haiyang fishing zone, a major fishing area in the country. With abundant fishing resources and a long history of human fishing activities, it has had an influential impact on the development of China’s marine fisheries (Han et al., 2008). Offshore and coastal fishing is a traditional sector of the Changshan Islands. The total offshore and coastal catches accounted for more than

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

75 percent of the total marine aquatic yield before the early 1980s, which results in an unhealthy status of fishery ecosystem due to perennial overfishing in the Changshan Islands, and fishery resources stock has been caused obvious changes, especially regarding dominant species in this water (Song et al., 2010).

In light of this debate, we investigated the maritime space of the Changshan Islands, a typical maritime area in China, to study the relationship between humans and marine ecosystems. Here we strive to demonstrate the interaction between marine fishing activity and fishery resources carrying capacity. Thus, in the remainder of this paper, first we attempt to examine the structural shifts in catches from different trophic levels of fish. We then estimated the maximum available biomass of these waters by coupling the data on the mean trophic level of the catch with scientific stock assessments. Last but not least, we explore the response of carrying capacity to the impact of fishing intensity and catch on the impact of available biomass. We specifically aimed to: (1) characterize the temporal variation of catch structure, (2) identify the carrying capacity of over the past more fifty years, and (3) figure out the response relationship between fishing activity and fishery resources carrying capacity.

Materials and methods

Study area

The study was conducted in the Changshan Islands maritime area, which is located in the northern waters of the Yellow Sea and the eastern side of the Liaodong Peninsula in China. The Islands have a pattern with a cluster of archipelagoes, including the Changshan Islands group, the Guanglu Islands group, the Shicheng Islands group, the Haiyang Islands group, and the Zhangzi Islands group (*Fig. 1*), with a land area of 142 km^2 and a sea area of 10324 km^2 (Wang, 2013). In order to exploit the advantages of space resources in the offshore and coastal areas of the Changshan Islands, as well as the reduction of marine biological resources due to overfishing, marine agriculture has been developed on a large scale. The proportion of mariculture production in marine fishery output exceeds that of marine catches among which marine catches 49.54%, mariculture 50.46% after 1987 (*Fig. 2*). However, the catches still have a significant impact on the marine biological resource system.

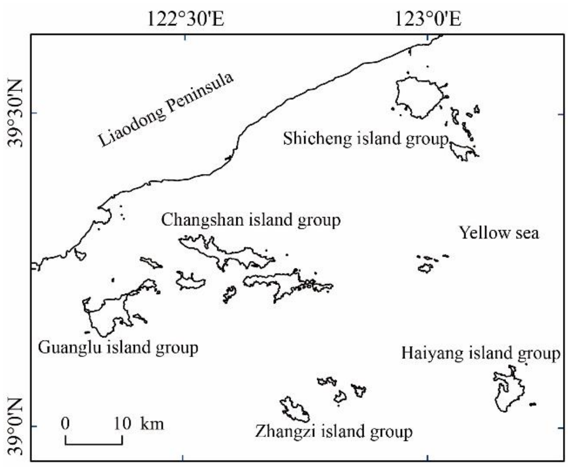

Figure 1. *Spatial pattern of the Changshan Islands sea area*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

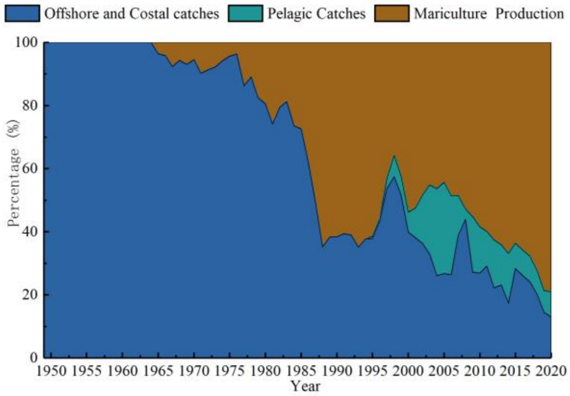

Figure 2. *Proportion of Marine fishery output the Changshan Islands 1950-2020. Data sources: Compiled from the Changhai Yearbook over the years*

The trajectories of offshore and coastal catches in the Changshan Islands maritime area are similar to those of the whole nation. There is a growing tendency of total catches in the Changshan Islands, from 2.3×10^4 tons in 1965 to 22.50×10^4 tons in 2016, an increase of 8.02 times. We use methods of linear regression to further analyze its trend. The results prove that the linear slope is 0.394, it means that the catch has increased by 0.394×10^4 tons per year over 52 years (*Fig. 3*).

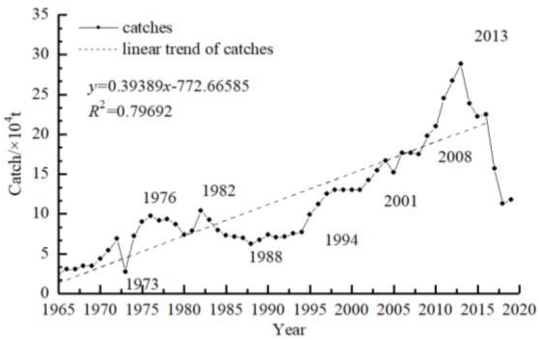

Figure 3. *Interannual variation of catches in the Changshan Islands from 1965 to 2020. Data sources: Compiled from the Changhai Yearbook over the years*

Analytical procedure

For the purpose of this study, we first used a simplified index Mean Trophic Level (MTL) of catch which reflects the state of fishery resources stock from one aspect, to assess the temporal variation of catch structure. We then employed the trophic dynamic model to estimate the fishing carrying capacity. Finally, we observe the response relationship between fishing activity and fishery resources carrying capacity quantitatively using the Vector Autoregressive Model (*VAR*).

Assessment of catch structure

The stock of marine biological resources determines the size and structure of the catch. As such, catch-based indicators are best considered as indicators of pressure rather than the state (Degnbol et al., 2004). In this study, we employ the MTL of catches

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

from 1965 to 2016 to verify the effect of fishing on the structure of fishery resources. Trophic level (TL) is used to indicate the position of an organism in a food web, reflects the species pattern and structural composition of the ecosystem (Ding et al., 2016). For marine ecosystem, trophic levels reflect not only the food relationships among species in the marine food web but also the dynamics of marine biodiversity and fisheries status in fisheries ecosystem research and management (Pauly et al., 2001). Furthermore, the concept of MTL was proposed to evaluate the impact of fishing activity on the environment of fishery resources (Pauly et al., 2000). Therefore, it is believed that the MTL of catches could be used as an indicator of the sustainability of developed marine ecosystems (Pauly et al., 2002), and to evaluate the impact of fishing activity on the trophic structure of marine ecosystem, and to estimate the level of primary productivity to maintain the sustainable development of fisheries (Pauly et al., 2005). The MTL of organisms in the fishery landing was calculated for each year from:

$$MTL_i = \frac{\sum_{ij} TL_j \times Y_{ij}}{\sum Y_{ij}} \quad \text{(Eq.1)}$$

where Y_{ij} is the landings of species j in year i and TL_j is its TL. The declining of MTL of catches is well known as *Fishing Down Food Webs*, it reflects a transition from long-lived, high trophic level, piscivorous bottom fish toward short-lived, low trophic level invertebrates and planktivorous pelagic fish, which denote that present exploitation patterns are unsustainable (Pauly et al., 1998). We calculate MTL and TL using the Microsoft excel software.

Estimation of fishing carrying capacity

Based on equilibrium ecology theory, we estimate the catch carrying capacity of the marine ecosystem of the Changshan Islands from 1965 to 2016 using a trophic dynamic model using:

$$C_i = PP \times E^{MTL_i} \quad \text{(Eq.2)}$$

Here C_i is the carrying capacity of the water in year i, and PP is the Primary Production of the marine ecosystem. According to the survey of the National Marine Environmental Monitoring Center China, the primary productivity of the sea area of the Changshan Islands is 85.13 mg C/(m^2·d) in spring, 1201.13 mgC/(m^2·d) in summer, 247.17 mgC/(m^2·d) in autumn, 92 mgC/(m^2·d) in winter, it covers a marine area of about 10324 km^2. Thus, the Primary Production is calculated as 1.56×10^6 tC/a. E denoting ecological transfer efficiency, referring to previous research results, the value is 15% (Ning et al., 1995; Wang and Chao, 2017). MTL_i is the Mean Trophic Level of catch in year *i*. C_i is calculated using the Microsoft excel software.

Observation on relationship between fishing and fishery resources carrying capacity

There is an interaction between fishing and fishery resources carrying capacity that, when overfishing occurs, the carrying capacity of Marine fishery resources are destroyed, and fishing activity is restricted when the carrying capacity of marine fishery resources declines, but further research is needed to understand the quantitative process that response relationship changes in the relationship between fishing and fishery resources

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

carrying capacity. Therefore, *VAR* (Vector Autoregressive Model) is introduced here for analyzing quantitatively the mechanism of interaction between fishing and fishery resources carrying capacity. The Model is commonly used to predict interconnected time series systems and to analyze the dynamical effects of stochastic perturbations on variable systems, thereby revealing the impact of various factor shocks on variable formation. In this paper, we introduce a generalized impulse response function based on the *VAR* to measure the response relationship between the carrying capacity of marine fishery resources and fishing activity, and analyze the dynamic relationship and degree of response of these two variables over time. The *VAR* is stated as follows:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} \cdots + A_p y_{t-p} + \varepsilon_t \quad t = 1, 2, \ldots, n \qquad \text{(Eq.3)}$$

where y_t is the endogenous variable of k dimensions, y_{t-i} (i = 1, 2, …, p) is the lagged endogenous variable vector; n is the number of samples, A_p is the matrix of $k \times k$ dimensions; ε_t is the random disturbance column vector of k dimensions. In order to observe the relationship between fishery resources carrying capacity (*CA*) and fishing (*F*) in the Changshan Islands, the study converted the raw data into natural logarithms to reduce the impact of raw data fluctuations, and the corresponding indicators were named *lnCA* and *lnF*, so, y_t can be defined as $\{lnCA, lnF\}$. The entire calculation was performed with the software Eviews 8.0.

Data sources

The data collected in this study, such as the total catch, yield of all kinds of catches, number and tonnage of motor fishing boats in the sea area of the Changshan Islands, were compiled and obtained from historical data and statistical Changhai yearbooks 1965 to 2020 which were provided by Changhai county statistics bureau. Since the range of our study is the area of the Changshan Islands, deep-sea fishing yields are subtracted from the total catch data, aquatic plants, whales, seals, and other aquatic mammals, shellfish, jellyfish, sea cucumbers, and miscellaneous aquatic animals with unknown taxonomic status were removed for data continuity and availability, and 26 catch species were eventually retained. The trophic level data of main catches are available from Fishbase (*http://www.fishbase.org*), and other trophic level data adopted from the results of Tian Jia-Shen et al. (2018) and Wang Luo et al. (2017) on mean trophic leave of fish in the Yellow Sea and Bohai Sea, especially in Dalian sea area (Wang et al., 2017; Tian et al., 2018). The trophic level of the family to which the species belongs shall be used for those parts of the species which do not correspond accurately to the trophic level. According to the research of Deng et al. (1986) and Li et al. (2017), the catches were separated into low trophic level catches (below 2.89), middle trophic level catches (2.90~3.49), and high trophic level catches (above 3.50) (*Table 1*).

Results

Variation of catches and mean trophic level

Composition changes of different trophic level catches

The increase in the total catch suggests that humans are intensifying the relentless assault on the fishery resources of the Changshan Islands marine area, but it is not clear

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

how the fishing species have changed. Therefore, based on the classification of trophic levels, we furthermore investigate the changes in the composition of catches at different trophic levels, counting the proportions in the structures from 1965 to 2016, respectively, and analyzing the tendency of the annual variability over 52 years. As shown in *Figure 4*, the catches at the low, middle and high trophic levels all increase progressively. In 1965, the catch was 4600 tons at low trophic level, 2200 tons at middle trophic level, and 18100 tons at high trophic level. And, in 2016, that figure has reached 8,900 tons, 3,800 tons and 1,200 tons respectively.

Table 1. *Trophic level type of main catches in the Changshan Islands*

Trophic level type	Catch species		Trophic level	St dev
	English name	Scientific name		
Fishes in low trophic level	Grey mullet	*Mugil soiuy*	2.49	0.19
	Anchovy	*Engraulis japonicus*	2.56	0.22
	Spottail mantis squillid	*Squilla mantis*	2.6	0.3
	Gazami crab	*Portunus trituberculatus*	2.6	0.3
	Filefishes nei	*Cantherhines spp*	2.7	0.4
	Akiami paste shrimp	*Acetes japonicus*	2.7	0.35
	Fleshy prawn	*Penaeus chinensis*	2.7	0.35
	Southern rough shrimp	*Trachypenaeus curvirostris*	2.7	0.35
	Sardine	*Sardinella spp*	2.82	0.09
Fishes in middle trophic level	Chub mackerel	*Scomber japonicus*	3.09	0.43
	Pacific sandlance	*Ammodytes personatus*	3.1	0.28
	Indo-Pacific swamp crab	*Scylla serrata*	3.1	0.3
	Silver pomfret	*Pampus argenteus*	3.12	0.37
	Cuttlefish	*Sepiolidae*	3.2	0.14
	Seabream	*Sparidae*	3.4	0.05
	Japanese jack mackerel	*Trachurus japonicus*	3.4	0.45
	Common squids nei	*Loligo spp*	3.5	0.37
Fishes in high trophic level	Flatfishes nei	*Pleuronectiformes*	3.51	0.02
	Common octopus	*Octopus vulgaris*	3.55	0.73
	Yellow croaker	*Larimichthys polyactis*	3.64	0.63
	Large yellow croaker	*Larimichthys croceus*	3.72	0.56
	Elongate ilisha	*Ilisha elongata*	3.79	0.61
	Groupers nei	*Epinephelus spp*	3.9	0.02
	Daggertooth pike conger	*Muraenesox cinereus*	4.07	0.66
	Largehead hairtail	*Trichiurus lepturus*	4.45	0.77
	Japanese Spanish mackerel	*Scomberomorus niphonius*	4.5	0.8

Figure 5 illustrates the rate at which the fraction of catches at each trophic level appears unstable to large amplitude fluctuations from 1965 to 2016. (1) From 1965 to 1976, the proportion of low trophic level catches decreased from 18.57% to 1.47%, middle trophic level catches increased from 8.88% to 20.74%, and high trophic level catches increased from 72.55% to 77.79%. (2) From 1977 to 1993, the proportion of low trophic level catches increased from 8.56% to 22.41%, and peaked at 52.7% in 1985. The proportion of catches at middle trophic level decreased from 24.92% to 11.78%, and even in 1988 dropped to 1.29%, close to a 52 years low. The proportion catches at high trophic level was 66.52% at the beginning and 65.81% at the end of the

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

period, while the range of variation was large, with a minimum of 44.68% in 1979 and a maximum of 81.16% in 1990. (3) From 1994 to 2006, the proportion of low trophic level catches decreased from 11.62% to 7.46%, and the lowest was only 0.25% in 1999. The proportion of catches at the middle trophic level decreased from 47.96% to 29.47%. The proportion of catches at the high trophic level increased from 40.42% to 63.08%, reaching a high of 69.44% in 1998. (4) From 2007 to 2016, the proportion of low trophic level catches increased from 2.99% to 35.95%, middle trophic level catches decreased from 41.1% to 14.13%, and high trophic level catches decreased from 55.91% to 49.92%. Overall, the study revealed that, on average, low trophic level accounted for 18.55% of catches, middle trophic level accounted for 23.44%, and high trophic level accounted for 58.01%.

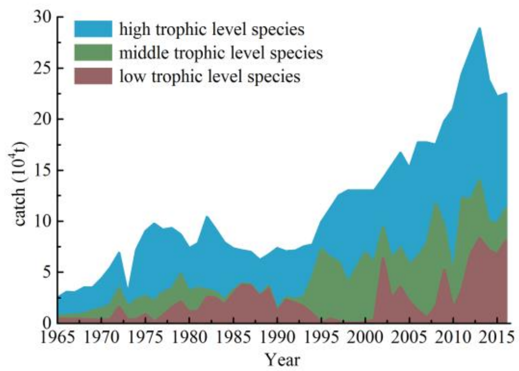

Figure 4. *The catch of each trophic level species*

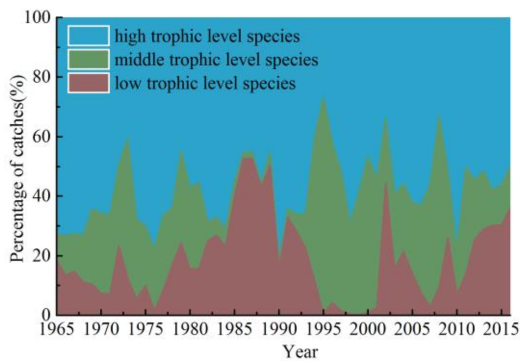

Figure 5. *The percentage of catch at each trophic level species*

Changes of mean trophic

According to *Equation 1*, annual MTL of coastal and offshore catches is calculated from 1965 to 2016. The result indicates that MTL fluctuates between 3.12 and 3.85, the 52 years average of MTL is 3.48 (*Fig. 6*), and it is implied that the regional trends of MTL variations become increasingly evident under the intervention of long-term predatory fishing activity of mankind. Especially after the 1990s, the frequency and amplitude of fluctuations increased significantly, indicating that the stability of the fishery resource ecosystem declined and vulnerability increased. More specifically, (1) the MTL showed a small-scope fluctuation after maintaining a certain level of stability

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

in 1965-1984. (2) The average fluctuation range of MTL widened to 0.11 and the fluctuation frequency increased from 1977 to 1993. (3) The MTL remains substantially concussion and the average fluctuation range was further enlarged to 0.17 from 1994 to 2006. (4) The fluctuation range of MTL narrowed, and the average shrank to 0.10 from 2007 to 2016. What will be particularly interesting to watch is the trend, which has plummeted since 2010, and what it means for the catch of high trophic level species to be replaced by low trophic level species in future years.

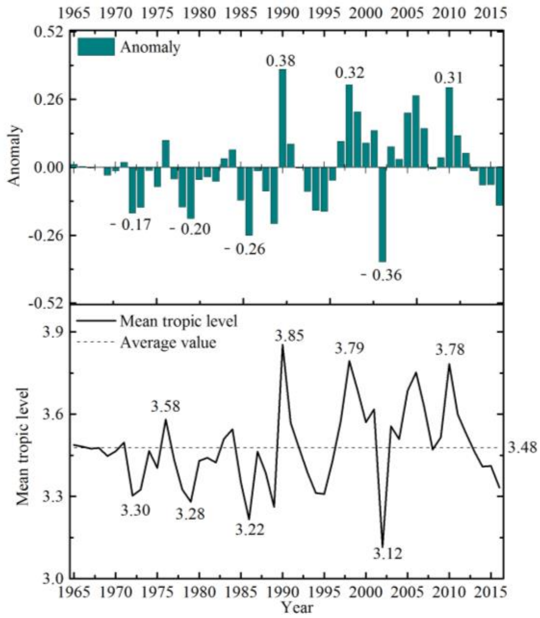

Figure 6. *Interannual variation in mean trophic level and anomaly in the the Changshan Islands from 1965 to 2016*

Evaluation of fishery resources carrying capacity and major fish species catch

In this study, we get the fishery resources carrying capacity of the Changshan Islands sea area based on *Equation 2*, as shown by the calculated results, the carrying capacity fluctuates between 22908.16 tons and 63572.61 tons from 1965 to 2016. The carrying capacity of per unit area is 2.22-6.16 tons per square kilometer. We selected 26 major catch species to assess human exploitation of fisheries ecosystems in order to assess the relationship between fishing and the carrying capacity of fishery resources based on statistics. Then, the function of nonlinear curve fitting in *OriginPro 9.0* software was utilized to fit the two observed value curves of fishery resources carrying capacity and major fish species catch (*Fig. 7*). The fit curves of fishery resources carrying capacity and major fish species catch in *Figure 7* illustrate changes in the marine fishery ecosystem and fishing activity, among them, the observed value and fit curves of fishery resources carrying capacity which exhibit a state of fluctuating denoting that fishery resources carrying capacity kept within a certain range affected by various factors. The observed values and the fitted curves for the catch of the main fish species illustrate that the catch of the main fish species rose substantially in the undulations. The fitted curves make it clear that there is a significant negative correlation between the carrying capacity of the fishery resources and the catch of the main fish species. Concretely, before the mid-1970s, the carrying capacity remained predominantly stable, although

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

catches continued to grow, and there was no overfishing in terms of catches. The fishery ecosystem then reached a state of instability, with the carrying capacity fluctuating due to overfishing during the mid-1970s and since the early 1980s. In this case, major species fishing was declining throughout the 1980s and early 1990s. At the same time, the ecosystem had a chance to recover and the carrying capacity enhanced, which means that biomass also increased. As a result, the catch grew by 24.68% per year between 1993 and 2005, driven by demand from economic development and advances in fishing technology, but the catch experienced sharp fluctuations between 2005 and 2016. Conversely, from 1993 to 2010 there was another drop in carrying capacity, and from 2010 to 2016 there was a slight increase, but not as dramatic as the increase in catches.

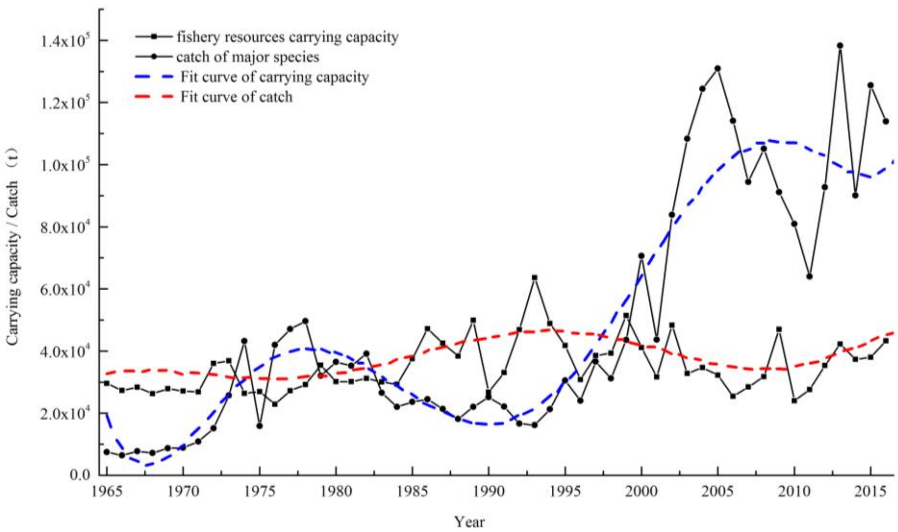

Figure 7. *Observed value and fit curves of fishery resources carrying capacity and major fish species catch*

The response relationship between fishing activity and fishery resources carrying capacity

Above that, we learn from the time series under investigation on the two fitted curves that there is a strong negative correlation between the carrying capacity of the fishery resources and the catch of the main fish species. Therefore, we utilize the *VAR* model to further evaluate the response relationship between the two. Therefore, this paper evaluates how fishing activity and fishery resources carrying capacity interacted from 1965 to 2016 using analytical tools as *VAR* model. The *VAR* operation has four phases: First, the stationarity of the time series is analyzed prior to learning; second, the determination of the lag length; thirdly, co-integration test; finally, the impulse response analysis. All this was done with the software *Eviews 8.0*.

Stationarity test of time series

In order to avoid the *pseudo*-regression phenomenon of the model and ensure its effectiveness, the stationarity test was conducted on the data of carrying capacity (*CA*) and fishing (*F*) from 1965 to 2016 using the Augmented Dickey-Fuller (ADF) stationary test of unit root. The results of the obtained tests are listed in *Table 2*. As can be seen from *Table 2*, the null hypothesis that the variable *lnCA* and the first difference

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

ΔlnCA have unit roots are both rejected at the 1% significance level. It suggests that the time series of the variable *lnCA* and the first difference *ΔlnCA* are stationary. The null hypothesis that the variable *lnF* has a unit root is true and the null hypothesis of the first difference *ΔlnF* is rejected, which indicates that time series of the first difference *ΔlnF* is stationary. In this way, the VAR model is built using the first difference time series of the carrying capacity and the fishing activity.

Table 2. *The test results of augmented Dickey-Fuller (ADF) stationarity of unit root for variables*

Variable	**Test type (c, t, p)**	**ADF test statistic**	**Test critical values**			**Prob.**	**Stationarity**
			1% level	**5% level**	**10% level**		
lnCA	(c, t, 0)	-4.5973	4.1446	3.4987	3.1786	0.0028	Stationary
ΔlnCA	(c, t, 2)	-6.6339	4.1567	3.5043	3.1818	0.0000	Stationary
lnF	(c, t, 0)	-2.6803	4.1446	3.4987	-0.1786	0.2487	Unstationary
ΔlnF	(c, t, 0)	-9.0222	4.1485	3.5005	3.1796	0.0000	Stationary

Among the test type, the c and t represent terms with constants and trends, and k means the lag length considering Akaike Information Criterion. *Δ* denotes first difference

Lag length judge

An important issue in the *VAR* model is the judge of the lag length. When choosing the lag length p, the lag length should be large enough to fully reflect the dynamic characteristics of the constructed model. However, at the same time, the larger the lag length, the more parameters need to be estimated and the model has less freedom. So, when making a choice, it is necessary to fully consider that there should be a sufficient lag length and degrees of freedom. Therefore, we integrated several evaluation statistical indicators and utilized *Eviews 8.0* to judge the maximum lag length of the *VAR* model. *Table 3* shows the judge of lag length, which indicates four indicators (LR, FPE, AIC, HQ) among five from *VAR* model chose 1 as a lag order. Based on this, the optimal lag length for the *VAR* model is determined to be the first lag.

Table 3. *The judge of lag length*

Lag	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	NA	0.000238	-2.665563	-2.587596*	-2.636099*
1	10.11681*	0.000225*	-2.723714*	-2.489814	-2.635323
2	5.300955	0.000235	-2.680325	-2.290492	-2.533007
3	6.014173	0.000241	-2.660346	-2.114579	-2.4541
4	6.422284	0.000242	-2.658353	-1.956653	-2.393179

*Lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

Johansen co-integration test

Before constructing the *VAR* model, it is necessary to confirm whether there is a long-term and stable co-integration relation between *lnCA* and *lnF*. This paper adopts the method of Johansen co-integration test, which is the most common method for

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

multi-variable analysis and it is judged by calculating Trace Statistics and max-eigenvalue statistics (Johansen, 1991). The results are presented in *Table 4*, and from the Trace Statistic results, all Trace Statistics are larger than the critical value at the significance level of 5%. This indicates that the test results reject the null hypothesis that there is a long-term co-integration relation between the carrying capacity of fishery resources and the amount of fishing at the 0.05 level.

Table 4. *Results of Johansen co-integration test*

Hypothesized no. of cointegration equation(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
None *	0.521982224	48.01107648	15.49471288	2.71E-07
At most 1 *	0.214716538	11.84381591	3.841465501	0.000577942

Trace test indicates 2 co-integrating eqn(s) at the 0.05 level. *Rejection of the hypothesis at the 0.05 level. **MacKinnon-Haug-Michelis (1999) p-values

Impulse response analysis

The impulse response function can be used to investigate the dynamic interactive relationship between variables as a mainly analytic tool of *VAR* model, and by an application of the function, the figure of impulse response function between carrying capacity and fishing has been drawn (*Fig. 8*). In the diagram, impulse response denotes the response of a variable to another one with one standard deviation (S.D.) innovations. *Figure 8* illustrates that the response with one S.D. innovation oscillates between positive and negative values with a clear decay after the middle term and becomes negligible at later times. *Figure 8a* and *d* show carrying capacity and fishing activity have responded immediately to its own impulse of one standard deviation innovations. The response was significantly positive in the first phase, and dropped to the lowest point in the second phase, then it began to recede gradually after the third phase. *Figure 8b* indicates the response of carrying capacity to fishing, it made no response until the second period that started to obvious negative response, and wended from negative to positive in phase 4. The transition process revealed that there is a temporal hysteresis in the response of the fishery resource carrying capacity to fishing activity, and the negative impact of fishing on the fishery ecosystem emerges as a one-period lag. *Figure 8c* suggests that the response of fishing activity to the carrying capacity is positive in the first two phases, negative in the third phase, and positive in the fourth phase. The process showed that fishing responded quickly to positive changes in carrying capacity, and was slow to respond to negative changes until the third phase. The trend of the responses in *Figure* 8 shows that all of them tend to stabilize after the fifth phase.

Discussion

Catch is a visual indicator that reflects the development of marine fisheries and is susceptible to fluctuations caused by factors such as stocks of fishery resources in marine areas, fishing vessels and fisheries management policies. In particular, fishing fleets and fisheries management policies are direct agents. For instance, the number of primarily motorized fishing vessels and the tonnage of fishing vessels indicate fishing

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

effort, which are important indicators of catching capability. Fisheries management policies show the attitude of local administrators towards marine fisheries. More stringent regulations would constrain fishing activity and conserve fish stocks, whereas lenient policies would allow fishermen to wreak havoc on fishing ecosystems and reduce stocks of fishery resources. *Figure 9* illustrates that the dominance of motorized fishing vessels in the catch was not always the case, with the weight of landed catches not rising, or even a decreasing with increasing ship tonnage. For example, the marine fishery of the Changshan Islands experienced a leap forward development like most of the country from 1965 to 1976. There was a big increase in fishing fleets and yields, which had a great influence on fishery resources stock (Tong and Zhang, 2015).

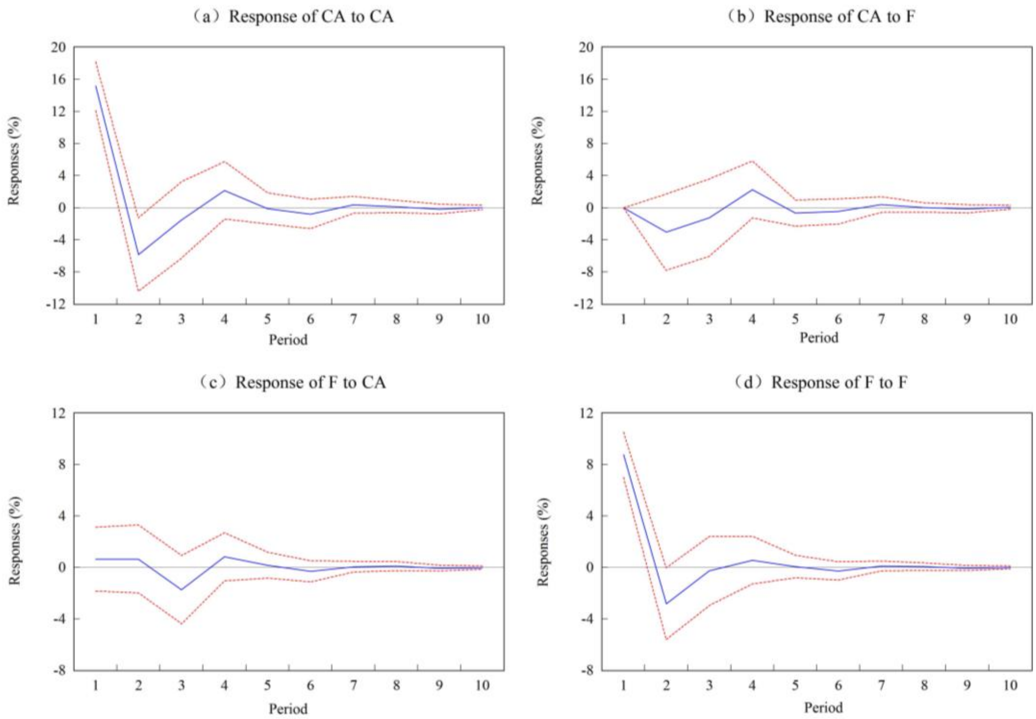

Figure 8. *Response to Cholesky One S.D. Innovations ± 2 S.E. CA is carrying capacity and F is fishing activity. The four diagrams illustrate (a) response of carrying capacity to itself, (b) response of carrying capacity to fishing activity, (c) response of fishing activity to itself, (d) response of fishing activity to carrying capacity. The numbers on the left axis indicate the impulse response, the bottom axis reflects the periods of impulse, the solid line is the trend after the variable is impulse, and the dotted lines on both sides are curves of plus or minus two standard deviations of the trend*

Correspondingly, from 1977 to 1993, the tonnage of motor fishing vessels increased by 105.56%, while fishing output decreased by 15.95%. Moreover, in the same period, the national Marine catch was growing rapidly (Xu, 2013), which resulted in fishery resources stock suffering from the shift of the marine ecosystem in this sea area of the Changshan Islands. Although there was no significant increase in motorized fishing vessels, fishing production increased rapidly from 1994 to 1998. The main causes lie in the upgrading of fishing techniques and the reform policies and development of marine fisheries. The rapid development of the marine fishing industry in the past five years has caused great damage to fishery resources. Therefore, in 1999, the Chinese government proposed the “zero growth” of fishing output and restricted fishing activity (Liu and Long, 2014). As a result, although the tonnage of motorized fishing vessels increased on a large scale from 1999 to 2007, catches were slow to increase. After that, the Changshan Islands intensified its development and established a development strategy of marine ranching. In particular, the opening up of the Changshan Islands to the outside world in 2009 ushered in a period of massive development, with the fishing output maintaining a rapid growth rate.

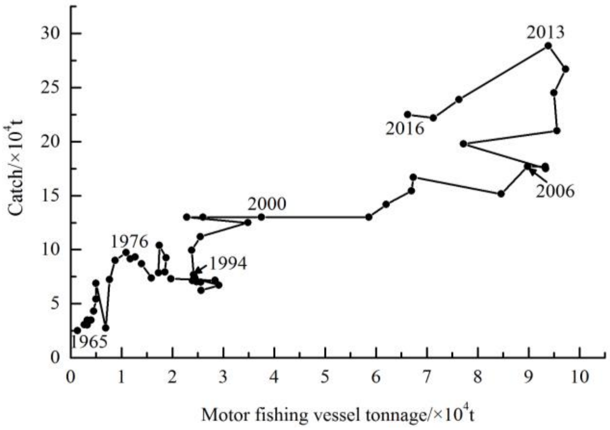

Figure 9. *Relationship between tonnage of motor fishing vessel and catch*

It can be seen that overfishing has a significant impact on the MTL. Overfishing directly reduces the species and abundance of large fish in the community and affects the non-fishing species through the food web. It reduces the diversity, ability to counter interference, and stability of the community. Also, the structure and function of the community are greatly affected (Crowder et al., 2008). For instance, the MTL shows three phases of variation between 1994 and 2013. Phase I saw a dramatic increase in catches, with the proportion of high nutrient grade catches in the total catch increasing from 40.42% to 69.44% and MTL increasing significantly from 1994 - 1998 with large-scale investment in fishing vessels. In the second phase, catches struggled to rise, and the proportion of high-trophic catches fell significantly due to overfishing, to 33.87% in 2002, even though the tonnage of fishing vessels was still growing rapidly from 1999 to 2002. In the third phase, the MTL was promoted to increase rapidly from 2003 to 2013 by further intensifying fishing and expanding or shifting fishing areas. However, it is important to note that after 2013 MTL, fishing yields and tonnage of fishing vessels declined significantly due to the damage to the fishing ecosystem. If the amount of fishing is increased too much, individual fish will tend to be taken before their potential growth is realized, and the total yield will be reduced. The longer-term impact of overfishing is in the destruction of the structure of the fishery resources. If the amount of catch is increased too much, individual fish will tend to be caught before their potential growth is realized, and the total yield will be reduced. Studies on the Yellow Sea by scholars have proven that the Yellow Sea fishery resources have undergone great changes in the past 50 years along with the replacement of dominant species composition, the miniaturization of resource individuals and the reduction of mean trophic level (Jin, 2003; Xu et al., 2005). Other studies suggest that the community structure of fishery resources in the Yellow Sea is declining, the main catch was small

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

low-quality fish, economic invertebrates and economic larvae, and the individual catches are relatively small (Li, 2010). The summer fishing moratorium was implemented in the Yellow Sea and Bohai Sea since 1995, which has mitigated the decline of fishery resources to some extent, but it was not fundamentally restored, especially species of fish stock, and the structure of economic fish in the nearby sea was lower in quality compared with the 1980s (Lu et al., 2011). The mean trophic level had declined by an average of 0.24 per decade between 1985 and 2010, particularly in the northern Yellow Sea, where is the main area in which the Changshan Islands are located (Zhang et al., 2004, 2007, 2011).

However, we should also recognize that the fishery ecosystem has the function of being self-stabilizing, just as it has a certain ability to self-heal. As shown in *Figure 7*, the carrying capacity fluctuates only within a certain range. In the extreme scenario, due to the resilience of the fishery ecosystem, which has not suffered an endless decline in response to high-intensity overfishing, and humans can simultaneously treat nature rationally, although some of this rationality is limited. This can also be reflected in the study of MTL fluctuations. The recent research shows that MTL of catches in the Changshan Islands sea area has a cyclical fluctuation with the intervention of human activity, and it fluctuates periodically in 15~19 years and 24~34 years (Sun et al., 2019). The main reason is that when the catch MTL declines, humans dominated by bounded rationality will adopt some positive measures, such as implementing summer fishing moratoriums, shifting fishing areas, and controlling fishing intensity, etc., to reduce the pressure of fishing on fishery resources ecosystem to a certain extent in order to achieve the purpose of restoring the carrying capacity of the fishery resource ecosystem. Specifically, rational fishermen will reduce or even abandon fishing if they cannot get enough or target fish in the area.

Moreover, overfishing and its effect on the fish community may have some hysteresis or difficulty to be detected (Jackson et al., 2001). *Figure 8* illustrates that there is a time lag between the fishing activity and fishery resources carrying capacity in the Changshan Islands, and only when a variable changes significantly after a change has occurred, the dependent variable changes accordingly, and the effect gradually weakens and eventually approaches zero as time progresses. This also indicates that there is a long-term dynamic and stable relationship between fishing activity and fishery resources carrying capacity. Although the response degree of carrying capacity is not as drastic as that of fishing activity, it has a long response time. Comparing *Figure 8b* and *c* indicates marine ecosystem has more vulnerability than human system and human system has more resilience as it is better able to adapt to vary of carrying capacity with quick response and flexibility.

The impact of human activity on the carrying capacity of nature is a relatively slow process. There is a time lag in the response of productive capacity properties to the effects of human activity, and productivity can take pressure from human activity within certain limits. However, excessive activity destroys the ecosystem and productivity gradually declines. When humans perceive a decline in the fishery resources carrying capacity, they may respond in two distinct ways. One is to increase the intensity of fishing activities in order to obtain sufficient desired resources. The other is to limit and reduce the intensity of activities in order to protect the sustainability of natural ecosystems. It illustrates the mutual response from the fishing activities in the Changshan Islands. In the 60s-70s of the 20th century, fishery resource carrying capacity gradually decreased as fishing intensity increased, destroying the fishery ecosystem. Correspondingly, fishermen have had to reduce the intensity of their fishing or shift catch areas to restore the fishery ecosystem. However, they returned to fishing, and once fishery resources were restored, larger vessels and more advanced fishing techniques were introduced. Fortunately, the intensity of fishing has decreased in recent years, and the carrying capacity has gradually recovered as awareness of ecological and environmental protection has increased and the government's fishing ban policy and fishing control policy have been implemented.

Conclusion

In this paper, we use the MTL Index, fishery resources carrying capacity model, and vector autoregressive model to study the state of fishery ecosystem affected by fishing activity and explore the response relationship between fishing activity intensity and fishery resource ecosystem.

Our results demonstrate that there is a dynamic balance between the intensity of fishing activity and the carrying capacity of the fishery ecosystem. When stocks in the fishery ecosystem are abundant, human fishing activity will be enhanced by improving fishing techniques and increasing the input from motorized fishing boats. The consequence of this continued increase in fishing intensity is that the structure of the fishery resources is altered and the mean trophic level decreases. Ultimately, overfishing results in a decrease in carrying capacity, and a decrease in the fishery resources carrying capacity will constrain the intensity of fishing activity. There are remarkable responses of the dependent variables fishery resources carrying capacity and fishing activity by impulsing from each other in earlier stage, and trend of both them tend to be stable for long-term development, which means that they influence each other significantly in the initial stage, but it tends to be balanced in the long-time series.

There is a temporal hysteresis in the response of fishing activity to fishery resources carrying capacity, the decline of carrying capacity results from overfishing will be revealed after a period of time. On the contrary, carrying capacity responded quickly to fishing, the effect of the decline in the fishery resources carrying capacity immediately manifested through the catch.

Through the periodical change of MTL and fishing activity of observation, we also found that the strengthening of human fishing activity is not infinite, human beings would reduce the stress of fishing on fishery ecosystem to a certain extent to restore the carrying capacity of fishery ecosystem by implementation of summer fishing moratorium, transferring of fishing area and the control of fishing intensity. In addition, the reciprocity relation between the carrying capacity of the fishery resources and the fishing activity can also demonstrate that the fishery ecosystem has a self-stabilizing function. However, this self-stabilization presupposes self-restrained fishing activity. Of course, in addition to human activity, environmental changes also have important effects on fish communities in coastal waters (Olsson et al., 2012; Bergström et al., 2016).

By summarizing the mutual response law of human fishing activity and fishery resources carrying capacity, we can understand the reaction of fishery ecosystem under the impulse of fishing, and then constrain the intensity of fishing, so as to maintain the healthy and sustainable development of fishery ecosystems. However, due to the lack of relevant data, this study only discusses the interaction between human fishing activities and fishery resources carrying capacity. and neglects the relevant influencing factors and mechanisms. It is necessary to strengthen this research in the future.

Acknowledgement. Data of trophic level of some fishes were obtained from Sea Around Us for which we are grateful. We also appreciate that Professor Yuezhen Li who works at Liaoning Normal University provided data of the Changshan Islands for this study.

REFERENCES

[1] Agardy, T. (2000): Effects of fisheries on marine ecosystems: a conservationist's perspective. – ICES Journal of Marine Science 57(3): 761-765.
[2] Ajagbe, S. O., Ajagbe, R. O., Ariwoola, O. S. (2020): Effect of fishing activities on fishery resources in Ikere-Gorge, Iseyin, Oyo State, Nigeria. – Nigerian Agricultural Journal 51(1): 79-86.
[3] Bergström, L., Heikinheimo, O., Svirgsden, R., Kruze, E., Ložys, L., Lappalainen, A., Saks, L., Minde, A., Dainys, J., Jakubavičiūtė, E., Ådjers, K., Olsson, J. (2016): Long term chanes in the status of coastal fish in the Baltic Sea. – Estuarine, Coastal and Shelf Science 169: 74-84.
[4] Caddy, J. (1993): Toward a comparative evaluation of human impacts on fishery ecosystems of enclosed and semi-enclosed seas. – Reviews in Fisheries Science 1(1): 57-95.
[5] Christensen, V. (1996): Managing fisheries involving predator and prey species. – Reviews in Fish Biology and Fisheries 6(4): 417-442.
[6] Coro, G., Ellenbroek, A., Pagano, P. (2021): An Open Science approach to infer fishing activity pressure on stocks and biodiversity from vessel tracking data. – Ecological Informatics 64: 101384.
[7] Crowder, L., Hazen, E., Avissar, N., Bjorkland, R., Latanich, C., Ogburn, M. (2008): The impacts of fisheries on marine ecosystems and the transition to ecosystem-based management. – Annual Review of Ecology, Evolution, and Systematics 39: 259-278.
[8] Degnbol, P., Jarre, A. (2004): Review of indicators in fisheries management-a development perspective. – African Journal of Marine Science 26(1): 303-326.
[9] Deng, J., Meng, T., Ren, S. (1986): Food web of fishes in Bohai Sea. – Acta Ecologica Sinica 6(4): 356-364.
[10] Ding, Q., Chen, X., Li, G., Fang, Z. (2016): Research progress in application of mean trophic level of catch in assessing fishery sustainability. – Marine Fisheries 38(1): 88-97.
[11] Ding, Q., Wang, Y., Chen, X., Chen, Y. (2017): Effects of economics and demographics on global fisheries sustainability. – Conservation Biology 31(4): 799-808.
[12] Guan, Y., Zhang, J., Zhang, X., Li, Z., Meng, J., Liu, G., Bao, M., Cao, C. (2021): identification of fishing vessel types and analysis of seasonal activities in the northern South China Sea based on AIS data: a case study of 2018. – Remote Sensing 13: 1952.
[13] Halpern, B., Walbridge, S., Selkoe, K., Kappel, C., Micheli, F., D'agrosa, C., Bruno, J., Casey, K., Ebert, C., Fox, H., Fujita, R., Heineman, D. (2008): A global map of human impact on marine ecosystems. – Science 319(5865): 948-952.
[14] Han, Z., Guo, J., Liu, K. (2008): Research on the ecological footprint of the island region and it's sustainable development. – Ecological Economy 2: 63-67: 86.
[15] Holling, C. (1973): Resilience and stability of ecological systems. – Annual Review of Ecology and Systematics 4: 1-23.
[16] Huang, H., Wang, Z., Li, Y., Zhao, X., Wang, Z., Cheng, X. (2022): Fishery resources, ecological environment carrying capacity evaluation and coupling coordination analysis: the case of the Dachen Islands, East China Sea. – Frontiers in Marine Science 9: 876284.
[17] Jackson, J., Kirby, M., Berger, W., Bjorndal, K., Botsford, L., Bourque, B., Bradbury, R., Cooke, R., Erlandson, J., Estes, J., Hughes, T., Kidwell, S., Lange, C., Lenihan, H., Pandolfi, J., Peterson, C., Steneck, R., Tegner, M., Warner, R. (2001): Historical overfishing and the recent collapse of coastal ecosystems. – Science 293(5530): 629-637.

[18] Jennings, S., Kaise, M. (1998): The effects of fishing on marine ecosystems. – Advances in Marine Biology 34: 201-352.
[19] Jin, X. (2003): The change of community structure of nekton in the waters off southern Shandong Peninsula in spring. – Journal of Fisheries of China 27(1): 19-24.
[20] Johansen, S. (1991): Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. – Econometrica 59(6): 1551-1580.
[21] Kleisner, K., Zeller, D., Froese, R., Pauly, D. (2013): Using global catch data for inferences on the world's marine fisheries. – Fish and Fisheries 14(3): 293-311.
[22] Kleisner, K., Mansour, H., Pauly, D. (2014): Region based MTI resolving geographic expansion in the Marine Trophic Index. – Marine Ecology Progress Series 512: 185-199.
[23] Langton, R., Auster, P. (1999): Marine fishery and habitat interactions: to what extent are fisheries and habitat interdependent? – Fisheries 24(6): 14-21.
[24] Leo, F., Miglietta, P., Pavlinović, S. (2014): Marine ecological footprint of Italian Mediterranean fisheries. – Sustainability 6(11): 7482-7495.
[25] Li, T. (2010): Preliminary study on community structure of fishery resources in north yellow sea and coastal waters of southern Shandong Peninsular. – Master Thesis, Ocean University of China.
[26] Li, J., Cao, K., Ding, F., Yang, W., Shen, G., Li, Y. (2017): Changes in trophic-level structure of the main fish species caught by China and their relationship with fishing method. – Journal of Fishery Sciences of China 24(1): 113-123.
[27] Liu, J., Long, W. (2014): Study on China's marine fishing policy transformation direction. – Chinese Fisheries Economics 32(2): 29-34.
[28] Lu, Z., Xu, B., Li, F., Song, M., Zhang, H., Liu, Y. (2011): Structure and distribution of fish resources in the Yellow Sea off Shandong during spring and autumn 2006. – Journal of Fishery Sciences of China 18(6): 1335-1342.
[29] Malcolm, C. D., Olivas, M. L. B., Dagostino, R. M. C. (2021): Reported capture, fishery perceptions, and attitudes toward fisheries management of urban and rural artisanal, small-scale fishers along the Bahía de Banderas coast, Mexico. – Environmental Challenges 4: 100110.
[30] Newton, K., Côté, I., Pilling, G., Jennings, S., Dulvy, N. (2007): Current and future sustainability of island coral reef fisheries. – Current Biology 17(7): 655-658.
[31] Ning, X., Liu, Z., Shi, J. (1995): Assessment of primary productivity and potential fishery production in the Bohai sea, Yellow Sea and East Sea, China. – Acta Oceanologica Sinica 17(3): 72-84.
[32] Olsson, J., Bergstrom, L., Gardmark, A. (2012): Abiotic drivers of coastal fish community change during four decades in the Baltic Sea. – ICES Journal of Marine Science 69(6): 961-970.
[33] Pauly, D., Watson, R. (2005): Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity. – Philosophical Transactions of the Royal Society B: Biological Sciences 360(1454): 415-423.
[34] Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., Torres, F., Torres, J. (1998): Fishing down marine food webs. – Science 279(5352): 860-863.
[35] Pauly, D., Christensen, V., Walters, C. (2000): Ecopath, Ecosim, and Ecospace as tools for evaluating ecosystem impact of fisheries. – ICES Journal of Marine Science 57(3): 697-706.
[36] Pauly, D., Palomares, M., Froese, R., Sa-a, P., Vakily, M., Preikshot, D., Wallace, S. (2001): Fishing down Canadian aquatic food webs. – Canadian Journal of Fisheries and Aquatic Sciences 58(1): 51-62.
[37] Pauly, D. Christensen, V., Guénette, S., Pitcher, T., Sumaila, U., Walters, C., Watson, R., Zeller, D. (2002): Towards sustainability in world fisheries. – Nature 418(6898): 689-695.
[38] Pikitch, E., Santora, C., Babcock, E., Bakun, A., Bonfil, R., Conover, D., Dayton, P., Doukakis, P., Fluharty, D., Heneman, B., Houde, E., Link, J., Livingston, P., Mangel, M.,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427

Mcallister, M., Pope, J., Sainsbury, K. (2004): Ecosystem-based fishery management. – Science 305(5682): 346-347.
[39] Sun, C., Cao, W., Xiao, C. (2019): Characteristics of variation in mean trophic level of marine fishery resources in Changshan Archipelago. – Marine Science Bulletin 38(1): 87-95.
[40] Tian, J., Han, J., Lu, Z., Ma, Z., Li, D., Wang, B., Liu, Y. (2018): The continuous trophic spectrum of food web in Dalian marine area, China. – Chinese Journal of Applied Ecology 29(1): 300-308.
[41] Tong, C., Zhang, S. (2015): The study of the history of Chinese marine fishery ecological policies (1949-1986). – Journal of Guangdong Ocean University 35(2): 39-44.
[42] Wang, Y. (2013): China's Marine Geography. – Science Press, Beijing, pp. 558-568.
[43] Wang, Z., Chao, M. (2017): Simulation of the marine ecological footprint of Jiangsu coastal waters using STELLA model. – Journal of Fishery Sciences of China 24(3): 576-586.
[44] Wang, L., Du, S., Yang, T., Chang, Y. (2017): Using stable isotopes to evaluate food web structure in Dalian coastal water. – Chinese Journal of Ecology 36(5): 1452-1457.
[45] Worm, B., Hilborn, R., Baum, J., Branch, T., Collie, J., Costello, C., Fogarty, M., Fulton, E., Hutchings, J., Jennings, S., Jensen, O., Lotze, H., Mace, P., Mcclanahan, T., Minto, C., Palumb, I., Parma, A., Ricard, D., Rosenberg, A., Watson, R., Zeller, D. (2009): Rebuilding global fisheries. – Science 325(5940): 578-585.
[46] Xu, B., Jin, X. (2005): Variations in fish community structure during winter in the southern Yellow Sea over the period 1985–2002. – Fisheries Research 71(1): 79-91.
[47] Zeller, D., Cashion, T., Palomares, M., Pauly, D. (2018): Global marine fisheries discards: a synthesis of reconstructed data. – Fish and Fisheries 19: 30-39.
[48] Zhang, B., Tang, Q. (2004): Study on trophic level of important resources species at high trophic levels in the Bohai Sea, Yellow Sea and east China Sea. – Advances in Marine Science 22(4): 393-404.
[49] Zhang, B., Tang, Q., Jin, X. (2007): Decadal-scale variations of trophic levels at high trophic levels in the Yellow Sea and the Bohai Sea ecosystem. – Journal of Marine Systems 67(3): 304-311.
[50] Zhang, B., Wu, Q., Niu, M., Jin, X. (2011): Variation in feeding ecology within the fish community in the north Yellow Sea. – Journal of Fishery Sciences of China 18(6): 1343-1350.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_14091427