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Ecological conversion efficiency and its influencers in twelve species of fish in the Yellow Sea Ecosystem

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Abstract

The ecological conversion efficiencies in twelve species of fish in the Yellow Sea Ecosystem, i.e., anchovy (*Engraulis japonicus*), rednose anchovy (*Thrissa kammalensis*), chub mackerel (*Scomber japonicus*), halfbeak (*Hyporhamphus sajori*), gizzard shad (*Konosirus punctatus*), sand lance (*Ammodytes personatus*), red seabream (*Pagrus major*), black porgy (*Acanthopagrus schlegeli*), black rockfish (*Sebastes schlegeli*), finespot goby (*Chaeturichthys stigmatias*), tiger puffer (*Takifugu rubripes*), and fat greenling (*Hexagrammos otakii*), were estimated through experiments conducted either *in situ* or in a laboratory. The ecological conversion efficiencies were significantly different among these species. As indicated, the food conversion efficiencies and the energy conversion efficiencies varied from 12.9% to 42.1% and from 12.7% to 43.0%, respectively. Water temperature and ration level are the main factors influencing the ecological conversion efficiencies of marine fish. The higher conversion efficiency of a given species in a natural ecosystem is acquired only under the moderate environment conditions. A negative relationship between ecological conversion efficiency and trophic level among ten species was observed. Such a relationship indicates that the ecological efficiency in the upper trophic levels would increase after fishing down marine food web in the Yellow Sea ecosystem.

Keywords: Ecological conversion efficiency; Fish; Influencers; Relationship between ecological conversion efficiency and trophic level; Yellow Sea

1. Introduction

The trophodynamics in a marine food web is one of the important subjects in the Global Ocean Ecosystem Dynamics (GLOBEC), and one of the primary goals in studies on coastal oceans. Trophodynamics study is to analyze the quantitative relations among preys and predators in the food web of the ecosystem from the angle of energy transfer, to understand the function of bottom up and top down control on the ecosystem productivity and finally to reveal species shifts and stock recruitment mechanism of those dominant species (Anonymous, 1999; Tang and Su, 2000). Clearly, the study of ecological efficiency (Kozlovsky, 1968) at different trophic levels is indispensable for comprehending the trophodynamics of the bottom-to-top food web in an ecosystem. As we know, the ecological efficiency at a trophic level depends on the ecological conversion efficiencies (i.e., the ratio of body growth to food consumption of a living organism in a given period of time under specific ecological conditions) of all the living organisms at the same level. In the past decades,

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many studies have been carried out in this field (e.g., Eggers, 1977; Elliott and Persson, 1978; Jobling, 1988; Smith et al., 1988; Cui and Liu, 1990; Xie and Sun, 1992; Hansen et al., 1993; Boisclair and Sirois, 1993; Li et al., 1995; Hop et al., 1997), but it was confined to few species, and especially rare for marine fishes. Therefore, it is worth to further quantifying species-specific ecological conversion efficiencies to realize the perspective of ecological efficiency in marine food webs.

Based on the concept of a simplified food web (Steele, 1974; Christensen and Pauly, 1992; Tang, 1999), twelve species of marine fish, including anchovy (*Engraulis japonicus*), rednose anchovy (*Thrissa kammalensis*), chub mackerel (*Scomber japonicus*), halfbeak (*Hyporhamphus sajori*), gizzard shad (*Konosirus punctatus*), sand lance (*Ammodytes personatus*), red seabream (*Pagrus major*), black porgy (*Acanthopagrus schlegeli*), black rockfish (*Sebastes schlegeli*), finespot goby (*Chaeturichthys stigmatias*), tiger puffer (*Takifugu rubripes*), and fat greenling (*Hexagrammos otakii*), were selected to investigate the ecological conversion efficiency (including food conversion efficiency and energy conversion efficiency) and the influencing factors with methodology comparison. These selected species are not only economically important fishes widely distributed in the Yellow Sea and the Bohai Sea (typical coastal ocean), but also dominant species ranked in the upper trophic levels of the ecosystems. Furthermore anchovy, rednose anchovy, chub mackerel, halfbeak, gizzard shad and sand lance are pelagic fish and the others belong to demersal fish. The aim of this study is to reveal the features of the ecological conversion efficiency in these important species and provide parameters and fundamental access to the studies of food web trophodynamics and ecosystem-based management in coastal oceans.

2. Materials and methods

2.1. In situ studies

The ecological conversion efficiencies of five species of marine fish were estimated *in situ* using Eggers model (Eggers, 1977) or Elliott–Persson model (Elliott and Persson, 1978). The basic experimental conditions for the five species were listed in Table 1.

Daily food consumptions of rednose anchovy, halfbeak, chub mackerel and anchovy were estimated using Eggers model. Rednose anchovy were collected using a manual purse seine from stocks growing in an earthen pond (1.5 m depth and 15000 m^2 area) next to Laizhou Bay of the Bohai Sea. Halfbeak were captured using a small purse seine in the sea-cage area off Qingdao. Sampling (n_1) was performed once per 2–3 h within a sampling day ($n_1=9$ for rednose anchovy and $n_1=8$ for halfbeak, 24 h). Seventy-130 individuals of rednose anchovy and 20 individuals of halfbeak were sampled for each sampling. Sampling days (n_2) were scheduled at an interval of 2 days per 15 day period ($n_2=7$) for rednose anchovy and 7 days per 28 day period ($n_2=5$) for halfbeak. Rednose anchovy preferred to eat large copepods, ostracods and small gastropods growing in the pond, and halfbeak predominantly fed on zooplankton in the sea. Chub mackerel and anchovy were captured from a trap net in the north of Shanddong Peninsula and reared in a cage ($6\times6\times4.5$ m size and 10 mm mesh) near the shore. They were fed *ad libitum* twice daily at 7:30 and 16:30 with minced small yellow croaker for Chub mackerel and zooplankton reinforced by sand lance surimi for anchovy. Sampling method was similar to that of rednose anchovy and halfbeak ($n_1=8$, 24 h; $n_2=5$, 28 d; 10 ind. $haul^{-1}$). Body weight and fork length (FL) of each fish sampled were measured and the

Table 1
The basic experimental conditions for five marine fishes *in situ* studies

Species	Date of exp.	Temp. (°C)	IBW (g wet·ind.$^{-1}$)	FBW (g wet·ind.$^{-1}$)	Diet	Sampling
		Mean±SD	Mean±SD	Mean±SD		
Rednose anchovy	Sep. 4–28, 1998	25.2±2.9	0.52±0.37	2.19±0.75	Zooplankton	9 hauls 24 $h^{-1}\times7$, 70–130 ind. $haul^{-1}$
Halfbeak	Aug. 5–Sep. 1, 2000	26.1±0.7	1.69±0.14	3.92±0.40	Mainly zooplankton	8 hauls 24 $h^{-1}\times5$, 20 ind. $haul^{-1}$
Chub mackerel	Aug. 2–29, 2000	25.9±0.8	28.85±3.39	88.51± 9.26	Minced small yellow croaker	8 hauls 24 $h^{-1}\times5$, 10 ind. $haul^{-1}$
Anchovy	Sep.5–30, 2003	23.3±0.9	0.31±0.06	0.92±0.16	Zooplankton and minced sand lance	8 hauls 24 $h^{-1}\times5$, 10 ind. $haul^{-1}$
Gizzard shad	Sep. 4–28, 1998	25.6±2.9	6.70±2.19	10.29±3.62	Detritus	9 hauls 24 $h^{-1}\times7$, 10–20 ind. $haul^{-1}$

Notes: exp., experiment; Temp., temperature; IBW, initial body weight; FBW, finial body weight; ind., individual; SD, Standard deviation.