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Changes in the Community Structure of the Laizhou Bay

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Abstract

The properties of the community structure of the Laizhou Bay were described based on the surveys in May, the main spawning season. The spawning stocks of fishery species have dramatically declined to a very low level and shift of dominant species had been observed. The slope from size spectrum analysis that is inversely proportional to the overall fishing effort could be an indicator of fishing mortality. The diversity and evenness index decreased from 1959 to 1993 and then increased in 1998. It is concluded that changes in the community structure are attributed to the anthropogenic activities, including direct high fishing pressure and marine pollution mainly from the drainage of waste waters.

Introduction

The continuous increase in fishing activities and changes in the environment had affected the fishing community structure along the Chinese coastal waters, such as the Yellow Sea and the Bohai Sea (Jin 1996). Fishery management has been focusing towards the community levels. The Laizhou Bay is an important spawning and feeding area for many commercially important fishery species in the Yellow Sea and the Bohai Sea. The main spawning season occurs in May for most of the fishery species. Located in the southern part of the Bohai Sea, Laizhou Bay is directly discharged by the Yellow River and is a typical estuary ecosystem. Many high valued species that are distributed in the bay are also important for enhancement and aquaculture.

This paper analyzes the community dynamics over time, including changes in biomass composition, shift in dominant species, size spectrum and species diversity with regard to the Laizhou Bay fishery species during the month of May.

Materials and Methods

Data source

The data were obtained from bottom trawl surveys of the Laizhou Bay (south of 38º 20'N, west of 120º 30'E) in May 1959, 1982, 1993, and 1998 with predetermined sampling stations of 19, 19, 17 and 20 respectively (Fig.1). Pair trawlers (around 200 horse power vessels) were used with the same net mesh size of 6.3 cm for the opening and a cod end mesh size of 2 cm. The opening height was measured at 5 to 6 m, and the trawling speed was around 2.6 knots.

Analysis

The catches were sorted and weighed in the laboratory on shore. Rays, sharks and *Fugu* with few specimens that were not easily identified into species have been treated as one species. All fish and fishable invertebrates have been used in the analysis. For each survey, the catch data were first analyzed by the Detrended Correspondence Analysis (DCA), using the computer program CANOCO (ter Braak 1988, 1990). Since the length gradients from DCA were less than 3 SD units, the Laizhou Bay has been considered as one community in the following analysis. A dominance curve as suggested by Clarke (1990), which is a plot of percentage cumulative biomass against the species rank was used to investigate changes in species biomass over time.

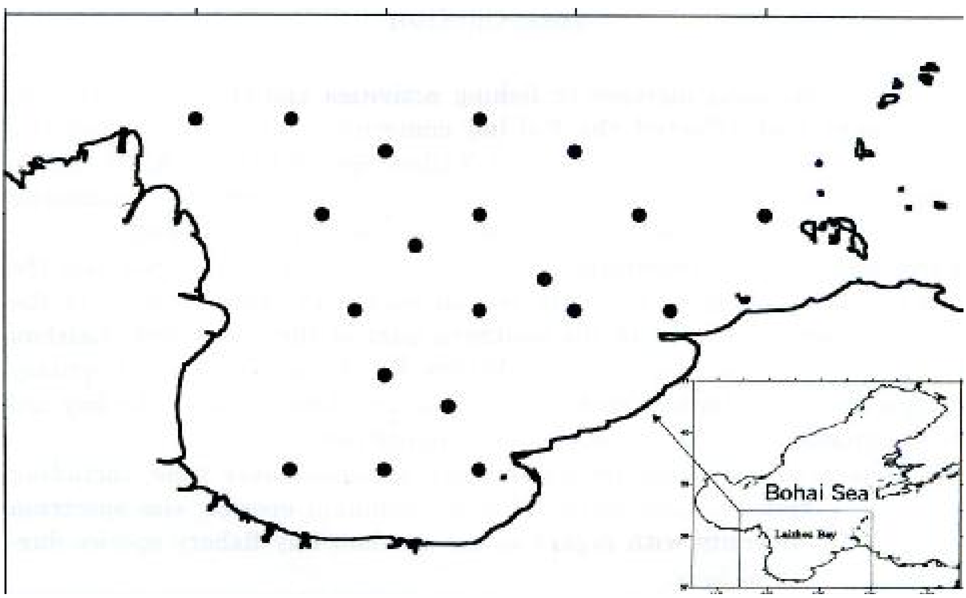

Fig. 1. Survey station in the Laizhou Bay.

Since the Bray and Curtis (1957) measure is dominated by the abundant species, rare species add very little to the value of the coefficient. The dissimilarity (B) in species composition between surveys in different years was measured by the method:

$$B = \frac{\sum_{i=1}^{S} \left| X_{ij} - X_{im} \right|}{\sum_{i=1}^{S} \left(X_{ij} + X_{im} \right)}$$

where X_{ij}, X_{im} = average catch per haul per hour in species *i* in *j* and *m* surveys.

S = number of species

The species richness (R) was estimated by means of a nonparametric approach, the jackknife method (Heltsche and Forrester 1983):

$$R = S + \left(\frac{n-1}{n} \right)^{k}$$

variance of this estimate is:

$$\mathrm{var}(R) = \left(\frac{n-1}{n} \right) \left[\sum_{i=1}^{S} \left(i^2 f_i \right) - \frac{k^2}{n} \right]$$

and confidence limit is given by:

$$R \pm t_{\alpha} \sqrt{\mathrm{var}(R)}$$

where:

R = Jackknife estimate of species richness
S = Observed total number of species present in *n* stations
n = Total number of stations sampled
k = Number of unique species
var(R) = Variance of jackknife estimate of species richness
f_i = Number of stations containing *i* unique species (*i* = 1, 2, 3, ...,S)
t_{α} = Student's t value for *n*-1 degrees of freedom for the appropriate value of α .

Shannon-Wiener function was used for the calculation of species diversity index (H') and the species evenness index (J') was estimated by the Pielou (1975) function both by biomass and abundance. They are:

$$H' = \sum_{i=1}^{S} (p_i)(\mathrm{Ln}\, p_i)$$

$$J' = \frac{H'}{\mathrm{Ln}(S)}$$

where:

S = number of species
p_i = proportion of total samples belonging to *i*th species

Results

Changes in catches composition and dominant species

The biomass of fishery species in the Laizhou Bay has largely varied during the surveys (Fig. 2). The average catch per haul has decreased from 423.6 kg·hour^{-1} in 1959 to 4.7 kg·hour^{-1} in 1998. Fish absolutely dominate the total biomass, accounting for more than 72%, a lower proportion in 1998. The fishery biomass of invertebrate also showed a small increase from 1959 to 1993 and a decrease in 1998.

During the surveys, a few species dominated the catches. The top five species in biomass are given in table 1. All were bottom fish in 1959 and the

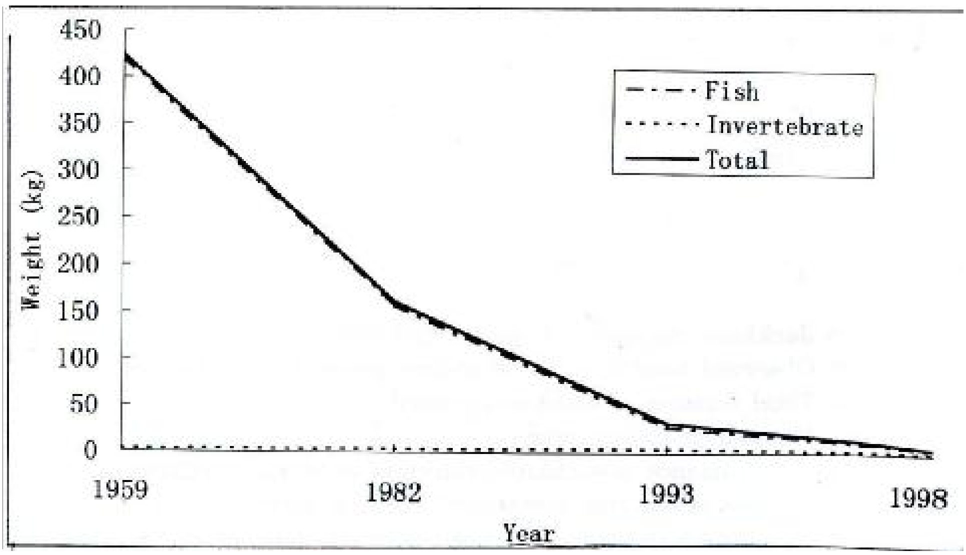

Fig. 2. Average catch per haul (kg/hour) in the Laizhou Bay in May from 1959 to 1998.

small pelagic fish (mainly *Engraulidae*) became the major species since the surveys of 1982. In 1998, four of them were small pelagic and one was a small crustacean (*Oratosquilla oratoria*). The largehead hairtail (*Trichiurus haumela*), the most abundant species in 1959, was not caught in 1982 and 1998, and only three specimens in 1993. The percent dissimilarities in species composition between surveys are very high (Table 2), with higher values occurring in the longer intervals between surveys, especially between 1959 and 1998.

For each survey, the fishery species were ranked by relative biomass, and the cumulative percentage of the total number of individuals belonging to each species was plotted against species rank (Fig.3). It shows that the dominance of fishery species in biomass has generally decreased. There was also an increase from 1982 to 1993 for the most abundant species. Actually in 1959, the Laizhou Bay was dominated by a single species, that is the largehead hairtail (Table 1), while more species dominated the community in recent years.

Changes in size spectrum

The size spectra of all fishery species in the Laizhou Bay showed a decreasing trend between 30 cm and 70 cm from 1959 to 1998 (Fig. 4). Small size species (less than 30 cm in 1959 and less than 20 cm in other surveys) were excluded in the linear regression due to gear selectivity and uncertain species identification (Fig. 4). The length range continuously decreased during the surveys from 1982 to 1998, which was also indicated by the slopes of the regressions.

Table 3 shows the linear regression slopes and intercepts from figure 4 and the fishing effort index from 1959 to 1998. A linear regression produces a correlation coefficient of -0.946, indicating that the slope is inversely proportional to the overall fishing effort.

Table 1. Top five species and their percentages in biomass during the surveys in May from 1959 to 1998.

1959		1982		1993		1998	
Species	%	Species	%	Species	%	Species	%
Trichiurus haumela	77.9	*Setipinna taty*	41.7	*Engraulis japonicus*	57.6	*Thrissa kammalensis*	25.5
Pseudosciaena polyactis	15.4	*Engraulis japonicus*	25.2	*Loligo beka*	9.5	*Oratosquilla oratoria*	23.7
Cynoglossus semilaevis	1.9	*Nibea albiflora*	10.4	*Thrissa kammalensis*	8.7	*Engraulis japonicus*	12.9
Fugu	0.8	*Harengula zunasi*	4.2	*Setipinna taty*	5.9	*Setipinna taty*	12.1
Platycephalus indicus	0.8	*Lateolabrax japonicus*	4.1	*Raja*	3.4	*Clupanodon punctatus*	6.7

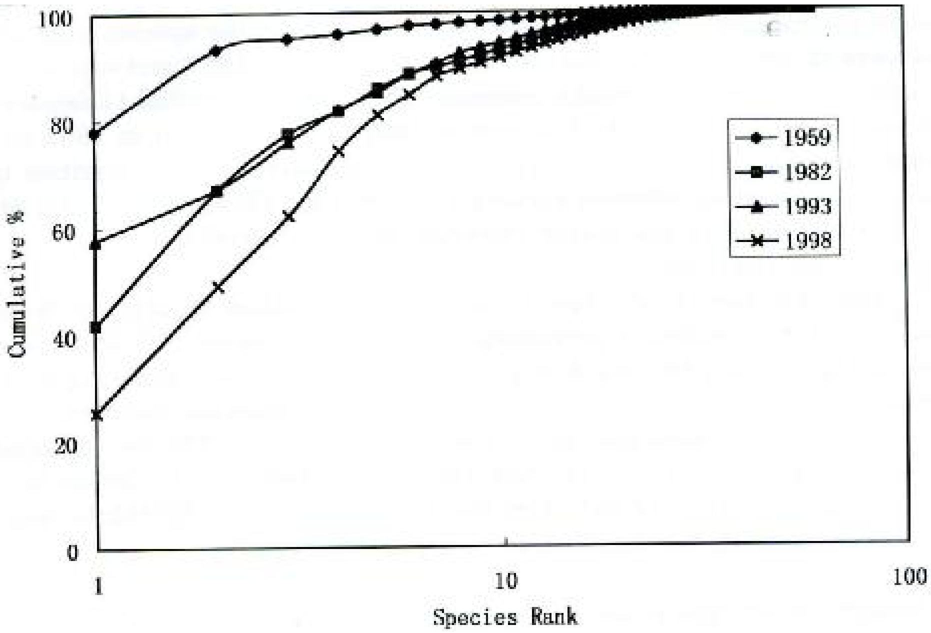

Fig. 3. Dominance curves by biomass from the Laizhou Bay in May.

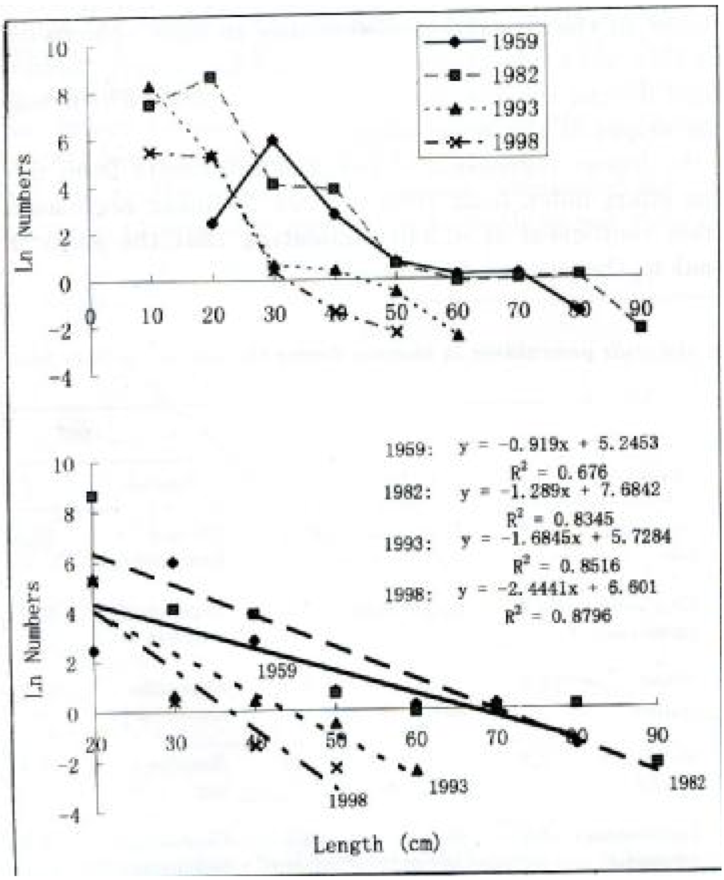

Fig. 4. Size spectrum in the Laizhou Bay in May. Ln of overall average numbers per haul versus length (above), and linear regression between Ln numbers and length (below).

Species diversity

Species richness estimated by the jackknife method shows that the highest number of species occurred in 1982, while the lowest was in 1993 (Fig. 5). However, the number of species caught was highest in 1982 and lowest in 1959 (Fig. 6), since the estimate from the jackknife method is based on the observed frequency of rare species in the community. The difference between figures 5 and 6 in the species richness is due to the relatively high number of unique species in 1959 and low in 1993. Species diversity and evenness indices by abundance show a similar trend (Fig. 6), decreasing from 1959 to 1993, and then increasing in 1998.

Discussion

Fisheries usually target the larger sized predators. When these species at higher trophic levels are removed, the community structure is disrupted. Any perturbation affecting top predators can be expected to have ramifications on the whole ecosystem (Schindler 1987). The spawning stocks of fishery species in the Laizhou Bay have dramatically declined to a very low level and the dominant species have varied in the different periods of surveys (Table 1, Figs. 2 and 3). Larger sized species have been more intensively exploited and this has caused the average size of the species, shown by the size spectrum analysis, which continuously decreased from 1959 to 1998 (Fig. 4). Therefore, the community structure in the Laizhou Bay has changed (Table 2).

Some comparative studies of size spectra from various areas have demonstrated that logarithmic numbers per size group are linearly correlated with the size of fish, and the slope of the relationship could be related to fishing intensity (Pope et al. 1987; Murawski and Idoine 1992; Gobert 1994; Rice and Gislason 1996). Since the linear function is presented between the fishing effort and the slope of size spectra in the Laizhou Bay (Table 3), the overall changes in the size composition of species assemblage with time may be used as an indicator to estimate the impact of fishing.

The reduced biomass of large sized species with time also indicates the shortening of the food chain in the Laizhou Bay. As Pauly et al. (1998) indicated, the trophic level of species in

Table 2. The Bray-Curtis dissimilarity index of biomass composition between different surveys.

Year	1982	1993	1998
1959	0.96	0.98	1
1982		0.74	0.96
1993			0.79

Table 3. The slopes and intercepts of size spectra and fishing effort index.

Year	Slope	Intercept	Fishing effort index
1959	-0.919	5.2453	100
1982	-1.289	7.6842	1,380
1993	-1.6845	5.7284	3,417
1998	-2.4441	6.601	4,170

landings has declined from long-lived high trophic level, piscivorous bottom fish toward short-lived, low trophic level invertebrates and planktivorous pelagic fish. The removal of the top predator in the community caused the dependence of fishery on the small pelagic species at lower trophic levels in the Laizhou Bay, while the biomass of bottom fishes have declined to a very low level such as largehead hairtail and croakers (*Sciaenidae*), which are negligible in recent catches. The decrease in biomass in the Laizhou Bay and in the entire Bohai Sea is mainly due to the decline of anchovy (*Engraulis japonicus*) stock, the most abundant species in 1993 (Table 1). The catch per unit effort during the spring surveys decreased from 40.7 kg/h in 1982 to 22.6 kg/h in 1993 and only 0.6 kg/h in 1998. The fishing intensity on the anchovy stock in the Yellow Sea and the Bohai Sea has considerably increased since the large-scale exploitation of this species in the late 1980's, furthermore, the stock has been the major fishery target in the northern part of China. Total catch was 21 x 10^4 tons in 1993 and 60 x 10^4 tons in 1996 over the maximum sustainable yield or MSY (half a million tons) estimated by the acoustic method (Iversen et al. 1993). The total catch reached a million tons in 1997 and overfishing on the stock has been recognized by a recent acoustic survey in the Yellow Sea. The variation of fishery stocks in the Yellow Sea highly affects the fishery biomass in the Bohai

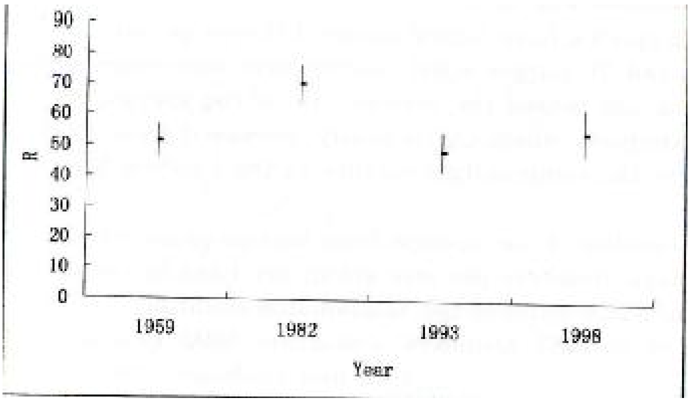

Fig. 5. Species richness (R) estimated by the jackknife method.

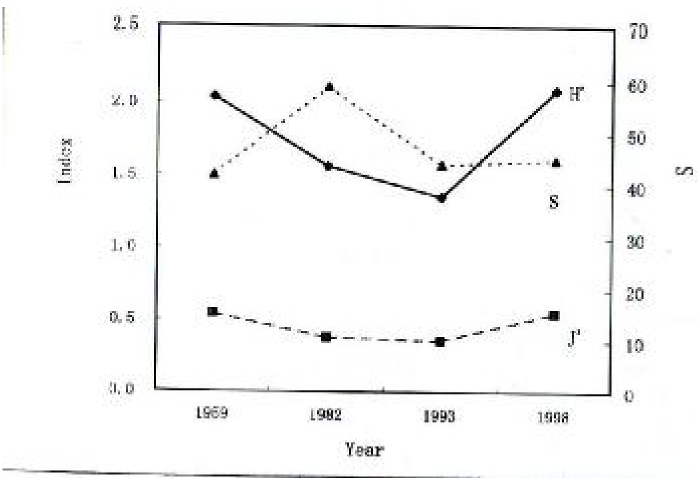

Fig. 6. Changes of diversity indices in the Laizhou Bay over time (H' - diversity index; S - no. of species observed; J'- evenness index).

Sea (Jin 1996). Although a similar number of species was caught based on recent surveys in the Laizhou Bay, the high exploitation of abundant species has caused an abundant distribution of fishery species even at a very low level as reflected in the lower dominance and high diversity indices (Figs. 3 and 6).

Changes in the community structure of the Laizhou Bay may also be due to changes in environmental factors. One important aspect is the eutrophication in the Bohai Sea. It is reported that red tide has occurred 20 times in the past seven years due to organic pollution, mainly from industrial and domestic sewage. According to the latest survey, phytoplankton biomass has been three times as that five years ago, and more than 200 times for the zooplankton. This is similar to the Gulf of Thailand Strategy illustrated by Pauly (1979) that is, fishing both the predators and the prey fishes, and the steady increase in fishing effort will result in the collapse of the prey and predator fish stocks, followed by an increase in biomass of the basic food animals. Since most of the small pelagic fishes prey on zooplankton, the low biomass of pelagic fishes has relaxed the predation on the zooplankton. Therefore, a large increase in zooplankton biomass was observed from the 1993 to 1998 surveys in the Laizhou Bay.

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References

Bray, T.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs. 27: 325-349.

Clarke, K.R. 1990. Comparisons of dominance curves. Journal of Experimental Marine Biology and Ecology 138: 143-157.

Gobert, B. 1994. Size structures of demersal catches in a multispecies multigear tropical fishery. Fisheries Research 19: 87-104.

Heltsche, J.F. and N.E. Forrester. 1983. Estimating species richness using the jackknife procedure. Biometrics 39: 1-11.

Iversen, S.A., D. Zhu, A. Johannessen and R. Toresen. 1993. Stock size, distribution and biology of anchovy in the Yellow Sea and East China Sea. Fisheries Research 16: 147-163.

Jin, X. 1996. Variations in fish community structure and ecology of major species in the Yellow/Bohai Sea. Dr. Sci. Thesis. University of Bergen. Norway.

Murawski, S.A. and J.S. Idoine. 1992. Multispecies size composition: a conservative property of exploited fishery system? Journal of Northwest Atlantic Fishery Science 24: 79-85.

Pauly, D. 1979. Theory and management of tropical multispecies stocks: a review, with emphasis on the Southeast Asian demersal fisheries. ICLARM Studies and Reviews No.1:1-35.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres Jr. 1998. Fishing down marine food webs. Science 279: 860-863

Pielou, E.C. 1975. Ecological diversity. Wiley, New York.

Pope, J.G., T.K. Stokes, S.A.Murawski and J.S. Idoine. 1987. A comparison of fish size-composition in the North Sea and on Georges Bank. In: Ecodynamics-contributions to theoretical ecology (ed. W. Wolff, C.J. Soeder and F.R. Drepper), pp.146-152. Springer-Verlag, Berlin.

Rice, J. and H. Gislason. 1996. Patterns of change in the size spectra of numbers and diversity of the North Sea fish assemblage, as reflected in surveys and models. ICES Journal of Marine Science 53: 1214-1225.

Schindler, D.W. 1987. Detecting ecosystem responses to anthropogenic stress. Canadian Journal of Fisheries and Aquatic Sciences 44(Suppl. 1): 6-25.

ter Braak, C.J.F. 1988. CANOCO- a FOTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis, principal components analysis and redundancy analysis (version 2.1). Agricultural Mathematics Group, Wageningen, 95 pp.

ter Braak, C.J.F. 1990. Update notes: CANOCO version 3.10. Agricultural Mathematics Group, Wageningen, 35 pp.

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