



Title	Feeding interrelation between two species of Pleuronectes in Mutsu Bay, Aomori Prefecture
Author(s)	Takahashi, Toyomi; Maeda, Tatsuaki
Citation	日本水産学会誌, 55(10), 1727-1739 https://doi.org/10.2331/suisan.55.1727
Issue Date	1989
Doc URL	http://hdl.handle.net/2115/38663
Rights	© 1989 公益社団法人日本水産学会; © 1989 The Japanese Society of Fisheries Science
Type	article
File Information	takahashi1-16.pdf



[Instructions for use](#)

Feeding Interrelation between Two Species of *Pleuronectes* in Mutsu Bay, Aomori Prefecture

Toyomi Takahashi* and Tatsuaki Maeda*

(Received April 24, 1989)

Feeding interrelation between *Pleuronectes herzensteini* and *Pleuronectes yokohamae* was studied in Mutsu Bay. Catches in experimental seines and trawls conducted between 1977 and 1986 showed that in general, both species did not differ very much in biomass. Comparisons of the stomach contents indicated that the food segregation between these two species was insignificant during spring and was relatively large during summer. In addition, considering that they exhibit a similar diel and seasonal rhythms of feeding except in winter, an intense potential for competitive interaction of food between these two species was expected, especially in spring. However, from spring to autumn, distinct habitat segregation was found between *P. herzensteini* and *P. yokohamae*, and such an ecological segregation reduces their competition for food.

In spring and summer, unlike the *P. yokohamae*, the CPUE of *P. herzensteini* were inversely related to the prey biomass, because they were concentrated in West Bay where the prey biomass was less than in East Bay. No particular change from year to year was found in the space utilization pattern of *P. herzensteini*, despite the fact that the *P. yokohamae* biomass declined largely after 1983, indicating that the habitat segregation between these two species is basically affected by the physical or chemical conditions of the sea water.

Pleuronectes herzensteini and *Pleuronectes yokohamae* are important fishery resources in the coastal waters of Japan. Because these two species often live in the same areas and utilize a common food, chiefly polychaete annelids, particular attention has been given to interspecific competition for food.¹⁻³⁾

Interspecific competition according to Odum⁴⁾ is "any interaction between two or more species populations which adversely affects their growth and survival". However, in marine fish there are few examples of such a situation.^{5,6)} There are some problems in demonstrating the existence and degree of interspecific competition in the field. One of the largest problems is that it is difficult to distinguish between the effect of coaction and that of fishing, though the growth rates and population densities of highly exploited stocks, such as most demersal fishes in the coast of Japan, are probably affected to a varying extent by fishing pressure.

However, of the populations which demand a similar food resource in a particular environment, differences in the kind and size of the diets and the space and time of feeding are

sometimes found.⁶⁾ Such differences are undoubtedly important means by which ecologically similar populations reduce competition for food⁶⁾ and therefore become useful clues for detecting resource partitioning or interspecific competition.

In the previous paper,³⁾ as a result of analyzing diet composition and food selectivities of *P. herzensteini* and *P. yokohamae* in Mutsu Bay, it was suggested that they were potential competitors for food and habitat, but the details have not been examined. The objective of this paper is to know the feeding interrelationship between these two species. Diet compositions of major components in the demersal fish community, relative abundance, and space and food utilization patterns of *P. herzensteini* and *P. yokohamae* in the bay were investigated.

As a result of tagging experiments conducted between 1977 and 1982,³⁾ it was confirmed that both of these species in Mutsu Bay rarely migrate outside the bay.

Materials and Methods

The field work was carried out chiefly in

* Faculty of Fisheries, Hokkaido University, Hakodate 041, Japan (高橋豊美, 前田辰昭: 北海道大学水産学部).

areas with depths of 30–70 m in Mutsu Bay (see Takahashi *et al.*³⁾) between August 1977 and November 1986. Fish were caught with a 52.2 m Danish seine (cod end stretched mesh of 66 mm or 43 mm) and a 24 m otter trawl (cod end liner of 12 mm mesh). Additional sampling was conducted with a 16 m beam trawl using a 1 m × 6 m frame (cod end mesh of 43 mm). Trawl nets were usually towed for 30 min at speeds of about 3 knots on the bottom, and Danish seine nets were towed after settling to the bottom. All fish caught were separated by species (except in the case of dragonets), counted, and weighed. When possible, individual fish of fifty to one hundred per species were sampled at random from each tow and were frozen. The collection of demersal fish other than *P. herzensteini* and *P. yokohamae*, however, was conducted chiefly in November 1981, May and August–September 1982, and February 1983.

The relative efficiency of the two principal fishing gears, Danish seine and otter trawls for demersal fish was examined at six different sites in the bay from August 31 to September 3 in 1982. As a result, although no significant correlation was found between the catch per unit effort (CPUE=weight/haul) for Danish seine and the CPUE (weight/h) for otter trawl ($r=0.588$, $df=4$, $P>0.05$), the demersal fish species compositions (by weight) obtained from the two fishing gears were quite similar at all sites (Morisita's similarity index⁷⁾: $C_{(2)w}=0.78\sim 0.97$). For this reason, the fish species composition was calculated from data collected by combining catches using these two gears.

To examine the effects of food organisms on the distributions of *P. herzensteini* and *P. yokohamae*, in May and August–September of 1982 benthic invertebrates were taken with a grab sampler (0.069 m²), developed by Tamura,⁸⁾ at both ends and the median point of the tow lines after trawling (sampling times: four per point). These grab samples were washed onto a 1 mm aperture sieve screen, and invertebrate samples were preserved in 10% formalin solution within 10 min of collection for later examination.

Water temperature and salinity at about 3 m above the bottom were measured using reversing thermometers mounted within the Nansen bottles and an induction salinometer respectively. In 1986, however, the temperature and

salinity were measured with a Neil Brown CTD system. Water samples for investigating dissolved oxygen and pH at about 0.3 m above the bottom were collected using Van Dorn bottles and were measured by the Winkler-Carpenter method and a pH meter (Model TP-101; Toko chemical Lab.), respectively.

In the laboratory, invertebrates from the grab sampler were sorted into major taxa, and identified to species whenever possible. Each organism item was counted and damp weights were determined to an accuracy of 1 mg using a Shimadzu electrobalance. Only the smaller macrobenthos of less than 1 g were used to estimate the food biomass where the otter trawl net was operated. Weights of tubed polychaetes were recorded after the tubes were removed. Bivalves and gastropods, however, were weighed with shells. Fish were measured to the nearest 1 mm in total length and weighed to the nearest 1 g after defrosting. Stomachs were removed and fixed immediately in 10% formalin. Each prey item in the stomachs were counted and wet weighed in the same manner as the grab samples.

To examine the prey size of *P. herzensteini* and *P. yokohamae*, body weights of prey organisms in their stomachs, when available, were recorded to 0.1 mg using a Mettler electrobalance. When major prey items were damaged or partially digested, body weights at the time of ingestion were estimated from body widths using the following width-weight regression equations⁹⁾ calculated from the grab sample:

$$\text{Lumbrineridae: } \log Wt = -1.564$$

$$+ 3.034 \log W_5, r=0.970$$

$$\text{Paraprionospio pinnata: } \log Wt = -2.393$$

$$+ 3.548 \log W_5, r=0.980$$

$$\text{Maldane sarsi: } \log Wt = -1.632 + 3.030 \log W_2, \\ r=0.988$$

$$\text{Ophiura kinbergi: } \log Wt = -2.257$$

$$+ 2.912 \log D, r=0.999.$$

Where Wt is body weight (mg), W_2 and W_5 are the body width (mm) at the second and the fifth segments respectively, and D is the disk diameter (mm).

Based on recorded bottom water temperatures, data were pooled for the four seasons, winter (February–March), spring (April–May), summer (July–September), and autumn (October–December). January and June samples are not included in this paper.

Results

Relative Abundance

Catches in experimental Danish seines and otter trawls showed that in general *P. herzensteini* had the greatest biomass next to *Lepidotrigla microptera* throughout all seasons (Table 1). *P. yokohamae* were third in biomass in spring and autumn, but in summer its proportion was smaller than that of *Gymnocanthus intermedius* and *Mustelus manazo*. Although few fishings were conducted, the remarkably low percentage (1.6%) for *P. yokohamae* in winter

does not represent their movement towards the coastal waters of the bay or its outside. The main reason for this is that the samplings for winter were made only in 1983 and 1986 when the abundance of *P. yokohamae* was very low, as is explained below.

Diet Compositions

Fig. 1 shows the gravimetric diet compositions of major demersal fishes in each season. In order to compare the data by body size, the samples were divided into three length groups respectively. Throughout all seasons the princi-

Table 1. Species composition (% by weight), of demersal fish, by seasons, obtained by Danish seine and otter trawl, in Mutsu Bay. Calculated on data between 1977 and 1986 (except 1984). Winter comprises February and March; spring, April and May; summer, July, August, and September; autumn, October and November

Species	Winter* ¹	Spring* ²	Summer* ³	Autumn* ⁴
<i>Scyliorhinus torazame</i>	0	0.2	2.6	0.6
<i>Mustelus manazo</i>	0.3	0.7	7.6	7.1
<i>Gadus macrocephalus</i>	1.5	+	0.2	+
<i>Lophius litulon</i>	0	0.7	0.4	0.7
<i>Sphyræna pinguis</i>	0	0	+	0.5
<i>Eynnys japonica</i>	0	+	+	0.2
<i>Pagrus major</i>	0	+	0.1	1.9
<i>Neoditrema ransonneti</i>	0.3	0.6	0	+
<i>Enedrias nebulosa</i>	0	0.3	0.4	0.1
<i>Sebastes schlegeli</i>	0	+	0.3	+
<i>Sebastes vulpes</i>	0.1	0.7	+	+
<i>Hexagrammos otakii</i>	10.7	7.6	2.4	3.4
<i>Pleurogrammus azonus</i>	3.3	1.1	1.1	+
<i>Hemitripterus villosus</i>	0.6	0.8	0.1	+
<i>Gymnocanthus intermedius</i>	0.9	3.9	9.4	3.8
<i>Lepidotrigla microptera</i>	54.1	45.2	33.4	43.3
<i>Liparis agassizii</i>	0	0.2	1.5	1.2
Callionymidae	0.3	1.3	1.3	1.7
<i>Paralichthys olivaceus</i>	0.9	1.1	0.8	1.2
<i>Hippoglossoides pinetorum</i>	0.5	2.6	2.2	0.5
<i>Eopsetta grigorjewi</i>	0	0.7	0.4	1.0
<i>Pleuronichthys cornutus</i>	0	0.2	+	0.1
<i>Pleuronectes mochigarei</i>	0.6	1.5	0.6	0.3
<i>Pleuronectes punctatissima</i>	+	+	0.2	0.1
<i>Pleuronectes herzensteini</i>	23.2	15.0	27.5	19.6
<i>Pleuronectes yokohamae</i>	1.6	9.4	5.2	8.5
<i>Kareius bicoloratus</i>	0.1	2.8	0.2	1.9
<i>Tanakius kitaharai</i>	0.5	0.2	0.5	0.4
<i>Microstomus achne</i>	0	2.5	+	+
<i>Thamnaconus modestus</i>	0	+	0.9	1.1
Other fishes	0.5	0.4	0.5	0.6
No. of fishing	11	54	71	69

*¹ Sampled 1983 and 1986.

*² Sampled 1978–1980, 1982, and 1986.

*³ Sampled 1977–1978, 1981–1983, and 1985–1986.

*⁴ Sampled 1977–1981 and 1986.

+ : Less than 0.1%.

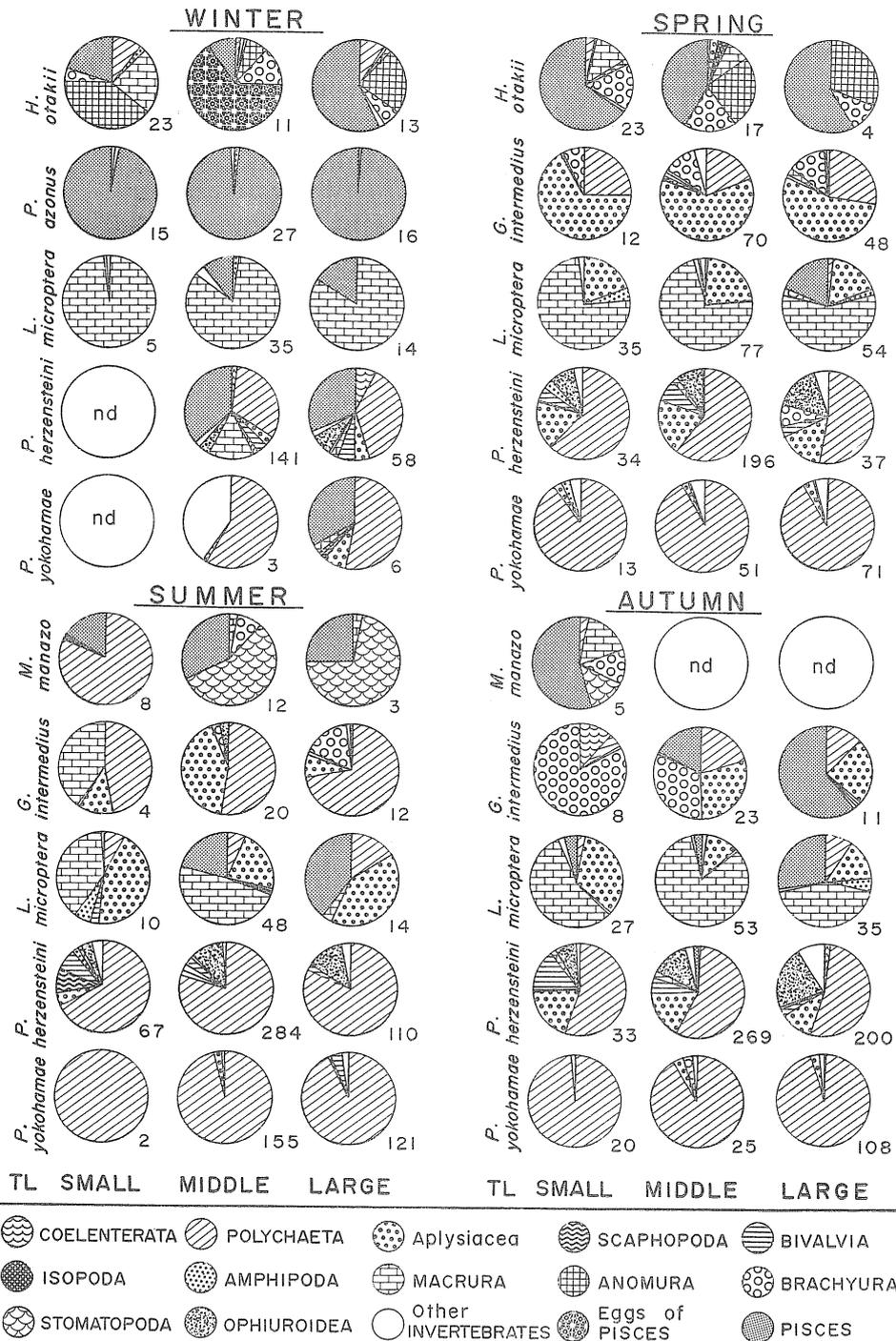


Fig. 1. Diet composition (% by wet weight) in stomachs of main demersal fishes during each season, by size of fish, in Mutsu Bay (area combined). Based on samples from November 1981, May and August-September 1982, and February 1983, except for a few cases; Summer data for *Mustelus manazo* and winter data for *Hexagrammos otakii*, *Pleurogrammus azonus*, and *Pleuronectes yokohamae* contain the samples of 1983-1986. Length groups of fish: *M. manazo*, -500 mm (small), 501-900 mm (middle), 901 mm- (large); *H. otakii*, -200 mm, 201-300 mm, 301 mm-; *P. azonus*, -240 mm, 241-280 mm, 281 mm-; *Gymnocanthus intermedius*, -120 mm, 121-160 mm, 161 mm-; *Lepidotrigla microptera*, -180 mm, 181-240 mm, 241 mm-; *Pleuronectes herzensteini* and *P. yokohamae*, -120 mm, 121-200 mm, 201 mm-. Figures are number of stomachs examined containing food. nd: no data.

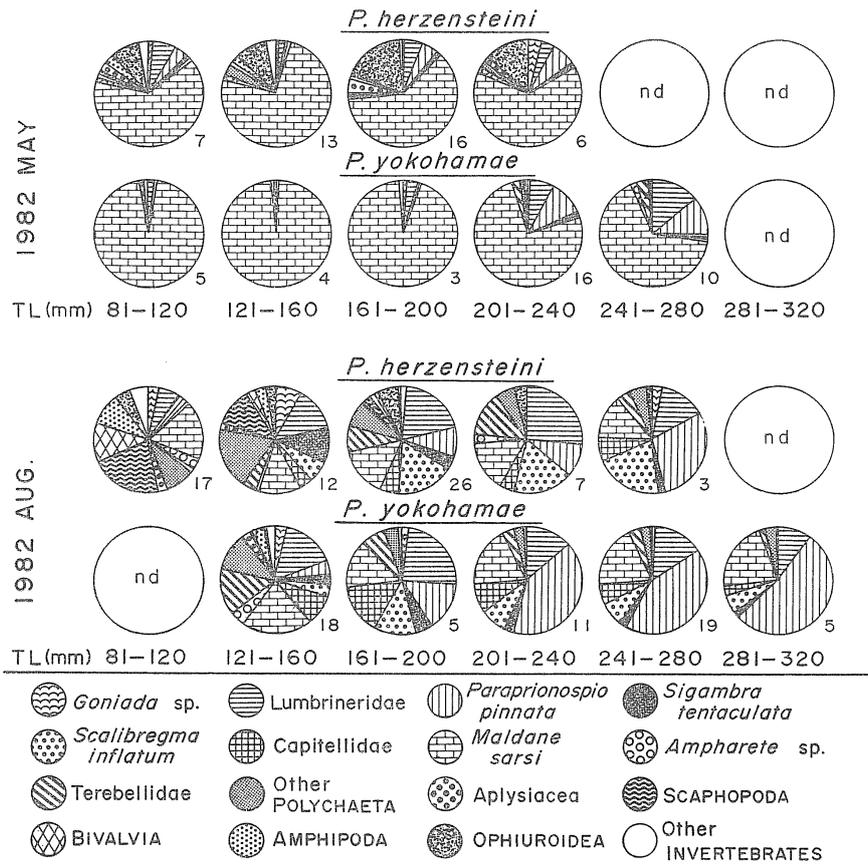


Fig. 2. Diet composition (% by number) of *Pleuronectes herzensteini* and *P. yokohamae*, by size of fish, collected simultaneously off Wakinosawa in Mutsu Bay on May 16 and August 31, 1982. Figures are number of stomachs examined containing food. nd: no data.

Table 2. Similarity indices (C_x) for the diet composition (by number) of *Pleuronectes herzensteini* (PH) and *P. yokohamae* (PY), subdivided into size groups, collected simultaneously in Mutsu Bay on May 16 and August 31, 1982

May									
PH 121-160	0.985								
PH 161-200	0.987	0.968							
PH 201-240	0.992	0.980	0.991						
PY 81-120	0.918	0.965	0.883	0.911					
PY 121-160	0.906	0.958	0.871	0.900	0.999				
PY 161-200	0.922	0.967	0.887	0.916	0.999	0.998			
PY 201-241	0.974	0.979	0.941	0.968	0.963	0.955	0.967		
PY 241-280	0.976	0.957	0.944	0.965	0.918	0.905	0.924	0.987	
	PH	PH	PH	PH	PY	PY	PY	PY	
	81-120	121-160	161-200	201-240	81-120	121-160	161-200	201-240	
August									
PH 121-160	0.744								
PH 161-200	0.481	0.762							
PH 201-240	0.382	0.635	0.951						
PH 241-280	0.290	0.467	0.809	0.790					
PY 121-160	0.530	0.741	0.824	0.831	0.593				
PY 161-200	0.364	0.658	0.919	0.918	0.848	0.832			
PY 201-240	0.270	0.348	0.630	0.639	0.916	0.549	0.765		
PY 241-280	0.271	0.337	0.619	0.638	0.907	0.534	0.746	0.996	
PY 281-320	0.222	0.230	0.477	0.496	0.826	0.404	0.598	0.961	0.973
	PH	PH	PH	PH	PH	PY	PY	PY	PY
	81-120	121-160	161-200	201-240	241-280	121-160	161-200	201-240	241-280

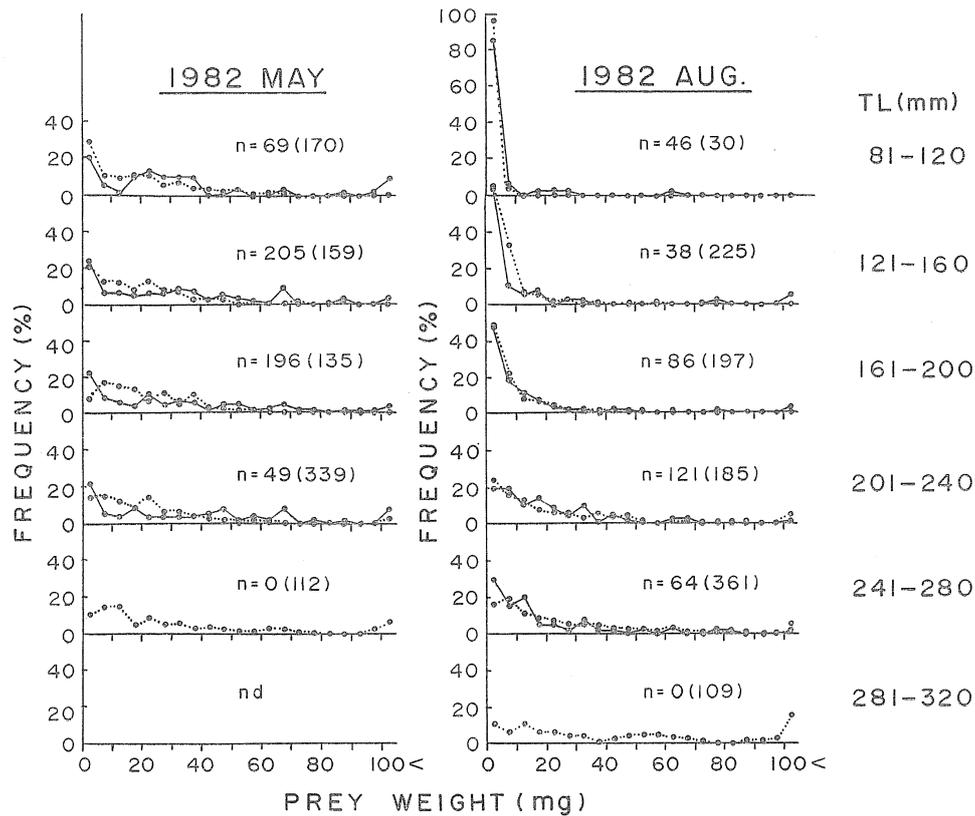


Fig. 3. Body weight frequency distribution of prey in stomachs of *Pleuronectes herzensteini* (solid line) and *P. yokohamae* (dotted line), by size of fish, collected simultaneously off Wakinosawa in Mutsu Bay on May 16 and August 31, 1982. n and (n) indicate number of prey measured for *P. herzensteini* and *P. yokohamae*, respectively. nd: no data (modified Takahashi *et al.*⁹⁾).

pal food item of *P. herzensteini* and *P. yokohamae* was polychaetes regardless of their body length, though in winter, fish also became important in their diet. *M. manazo* less than 500 mm in length and all length groups of *G. intermedius* in summer also consumed polychaetes in greater proportion. The other fishes, however, fed chiefly on fish, crustaceans such as shrimps (*Macrura*), pagurians (*Anomura*), crabs (*Brachyura*), and squillas (*Stomatopoda*), or sea-hares (*Aplysiacea*).

The numerical diet compositions, by fish size (40 mm intervals), of *P. herzensteini* and *P. yokohamae* caught simultaneously off Wakinosawa in May and August 1982 are shown in Fig. 2. In the May sample, the polychaete *Maldane sarsi* were prominent in the diets of all length groups of *P. herzensteini* and *P. yokohamae*, accounting for 60.9~74.4% and 65.7~97.5% of the total number, respectively. Brittle stars (Ophiuroidea: almost *O. kinbergi*) were the numerically next important food of *P. herzensteini* (9.3~18.6%), but were hardly eaten by *P. yokohamae* (less than 0.3% of the total).

On the other hand, the August sample was dominated by several species of polychaetes such as Lumbrineridae, *P. pinnata*, *Scalibregma inflatum*, and *M. sarsi* as a rule, moreover, there were considerable variations in diet composition according to the length of the fish. Namely, *P. pinnata* increased in number with an increase in the length of *P. herzensteini* and *P. yokohamae*. Conversely scaphopods *Episiphon makiyamai*, bivalves (chiefly *Clinscardium californiense* and *Alvenius ojanus*), and amphipods (chiefly *Caprella acanthogaster*, *Anonyx ampuloides*, and *Pontocrates altamarinus*) decreased in number with an increase in the length of *P. herzensteini*.

To estimate the similarity in diet composition of *P. herzensteini* and *P. yokohamae*, a Kimoto's C_{π} index¹⁰⁾ was computed on the basis of 23 taxonomic categories of prey organisms for the May sample and 38 for the August sample (Table 2). For the May sample, the C_{π} values between species were great in all cases (0.87~0.98) as well as those between the different length groups within species (0.96~1.00 for *P.*

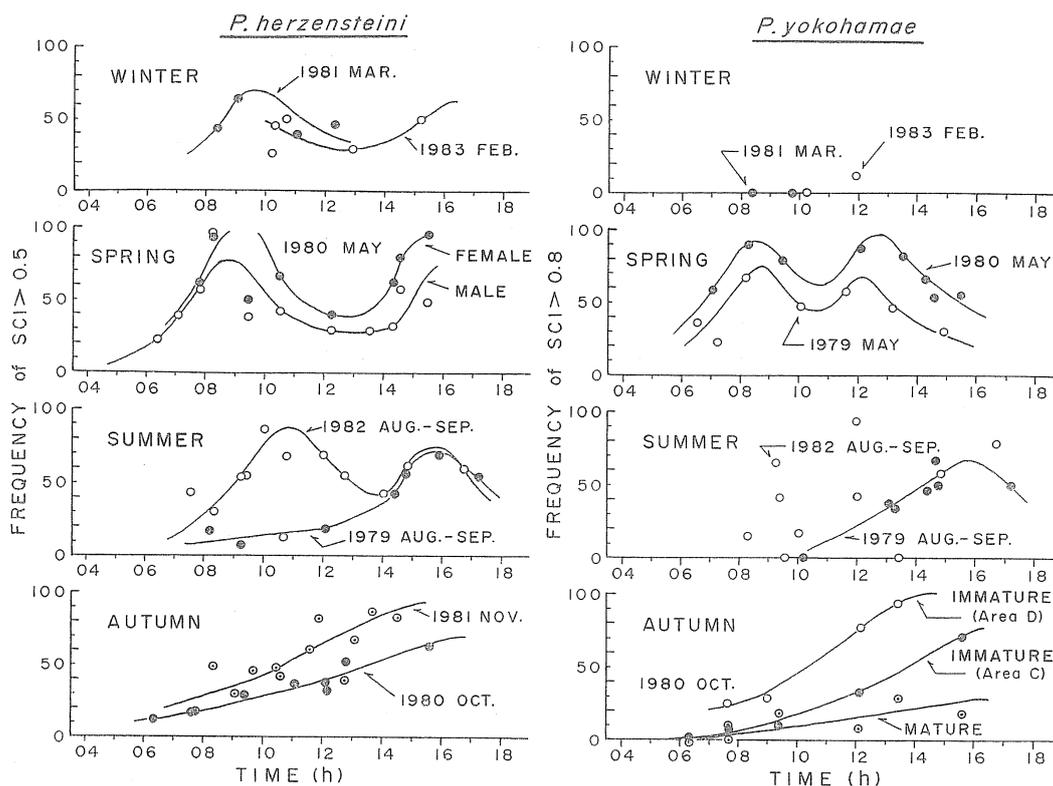


Fig. 4. Diel changes in percent occurrence of *Pleuronectes herzensteini* with SCI (stomach contents weight $\times 10^2$ /body weight) > 0.5 and *P. yokohamae* with SCI > 0.8 in each season in Mutsu Bay. Percentages for *P. herzensteini* in spring differed by sex, and those for *P. yokohamae* in autumn differed by gonad maturation and sea area, and therefore are shown separately. Area C: western part of East Bay, Area D: eastern part of East Bay (partly, Takahashi *et al.*^{11,12}).

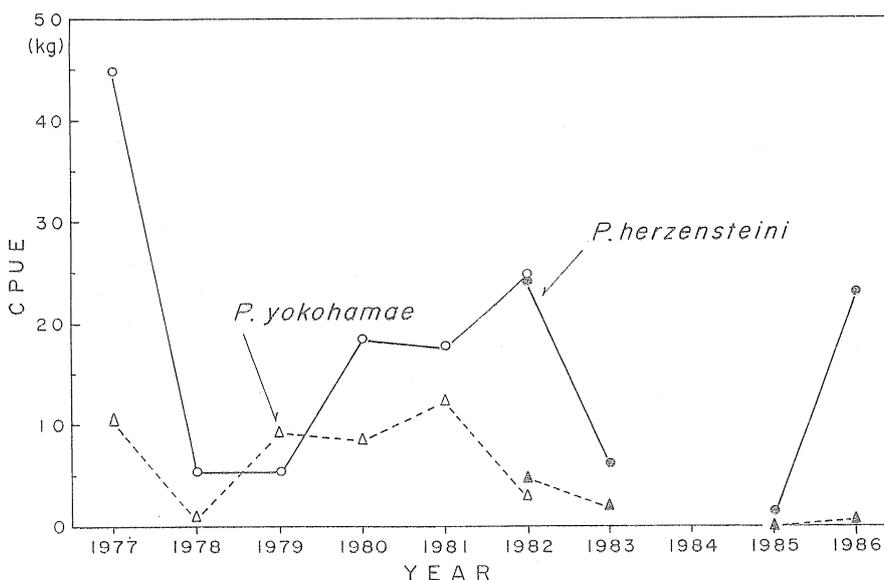


Fig. 5. Mean catch per unit effort (CPUE) of *Pleuronectes herzensteini* (circles and solid line) and *P. yokohamae* (triangles and broken line) in late July-late October during 1977-1986 (except 1984) in Mutsu Bay. CPUE for Danish seine (open marks) means catch per haul, and CPUE for otter trawl (closed marks) means catch per h at 3 kt.

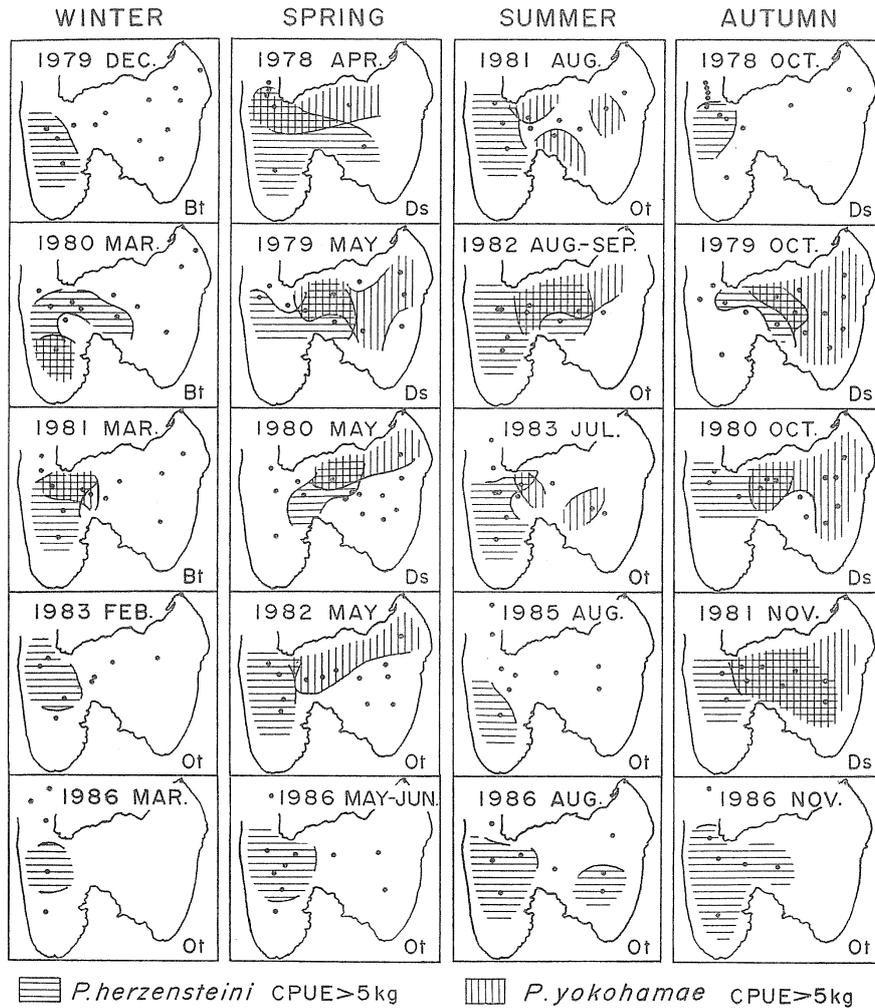


Fig. 6. Comparison of distributions of *Pleuronectes herzensteini* and *P. yokohamae* in each season between April 1978 and November 1986. CPUE for beam trawl (Bt) and otter trawl (Ot) means catch per h at 3 kt, and CPUE for Danish seine (Ds) means catch per haul (partly, Takahashi *et al.*³⁾).

herzensteini; 0.90~1.00 for *P. yokohamae*). On the other hand, the C_r values for the August sample ranged widely in both within (0.29~1.00) and between species (0.22~0.92), and most of the larger values were found between the pairs of equivalent or adjacent length groups.

Fig. 3 shows the prey size (body weight) distributions for the same samples as above. In both species, the prey size distributions for the May sample were roughly independent of fish length, and the overlap of prey size between species was evidently great even between the smallest and the largest fish. In contrast, the prey size for the August sample became larger with an increase in fish length, and the overlap between species was great only between equivalent or adjacent length groups.

Diel Feeding Periodicity

The diel feeding periodicities of *P. herzensteini* and *P. yokohamae* in this study area varied seasonally.¹¹⁾ However, the details have not been clarified. For this reason, the percent occurrences of SCI (stomach contents weight $\times 10^2$ /body weight) > 0.5 for *P. herzensteini* and SCI > 0.8 for *P. yokohamae* were calculated on the samples obtained in each season. As in Fig. 4, the diel feeding periodicities of both species were similar except in winter. In winter (February-March), *P. herzensteini* appeared to have two peaks in their feeding activity, one during forenoon and the other in the afternoon, though *P. yokohamae* intook very little food. In spring (May), both species had two remarkable peaks of feeding per day. However, in autumn (October-November) they

fed on food chiefly from about noon to evening, though mature *P. yokohamae* ate very little food. The feeding pattern in summer (August-September) varied by year. Namely, in 1979 both species had one peak of feeding per day, and in 1982 *P. herzensteini* had two peaks of feeding per day and no trend was found in *P. yokohamae*, showing that the shift from the "Spring type (two peaks)" of feeding to the "Autumn type (one peak)" of feeding takes place probably from August to September.

Annual Changes in Fish Biomass and Space Utilization

Experimental seine and trawl catches indicated that the biomass of *P. herzensteini* and *P. yokohamae* in the bay changed remarkably from year to year (Fig. 5). The CPUE of *P. herzensteini* ranged from 44.7 to 5.4 kg/haul during 1977-1982 and 24.1~1.5 kg/h during 1982-1986 (except in 1984) with no regular trend. The CPUE of *P. yokohamae* also fluctuated greatly during 1977-1982 (12.4~0.8 kg/haul), and thereafter remained low (less than 2.0 kg/h). When comparing the CPUE of both species, remarkable differences were not ob-

served except in 1977, 1982, and 1986 when the biomass of *P. herzensteini* was very great.

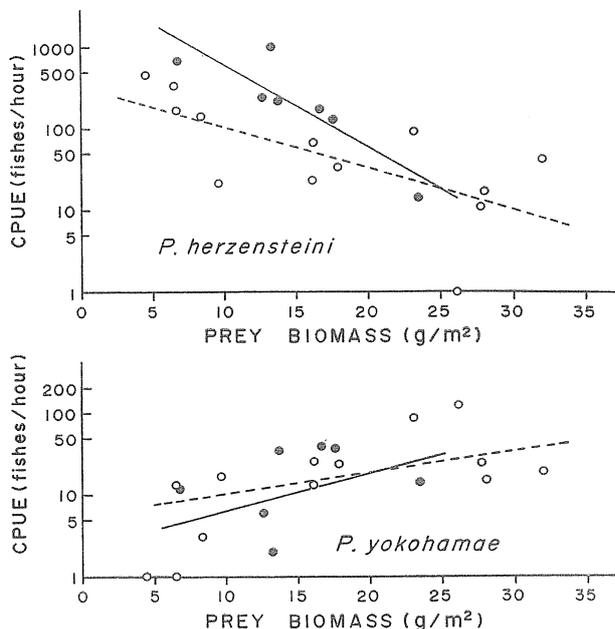


Fig. 7. Semi-logarithm regressions of CPUE (fishes/h) of *Pleuronectes herzensteini* (upper) and *P. yokohamae* (lower) on biomass (g/m²) of prey in Mutsu Bay in May (open circles) and August-September (closed circles) 1982.

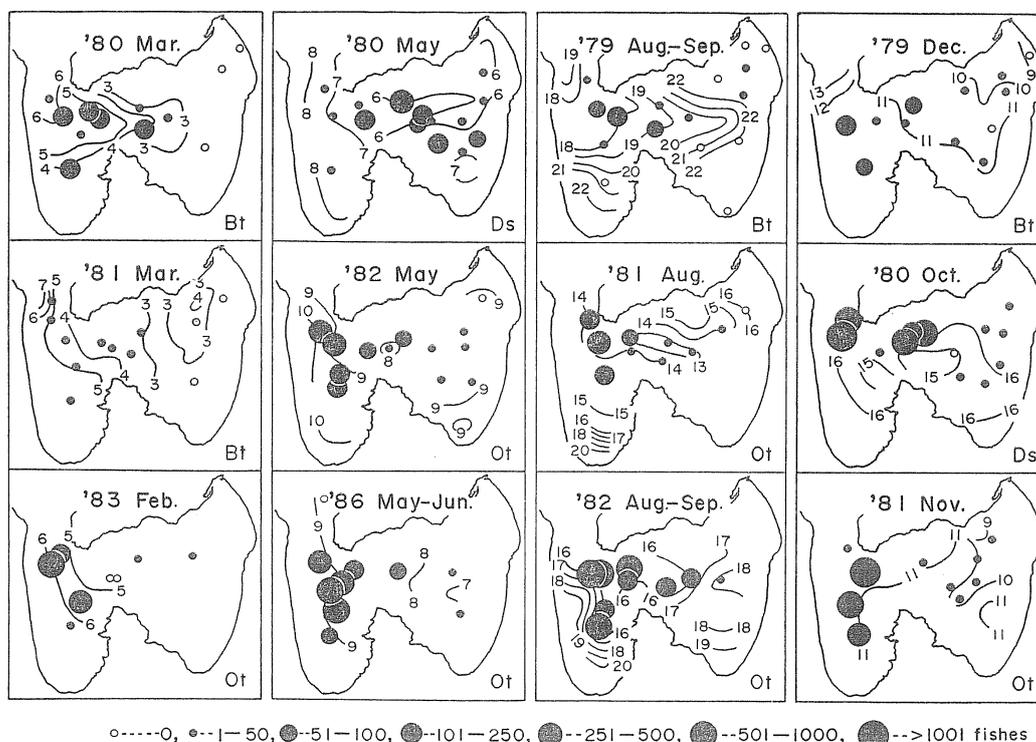


Fig. 8. Distribution of CPUE of *Pleuronectes herzensteini* in each season. Contours of bottom water temperature (°C) are superimposed. CPUE for beam trawl (Bt) and otter trawl (Ot) means number of catch per h at 3 kt, and CPUE for Danish seine (Ds) means number of catch per haul.

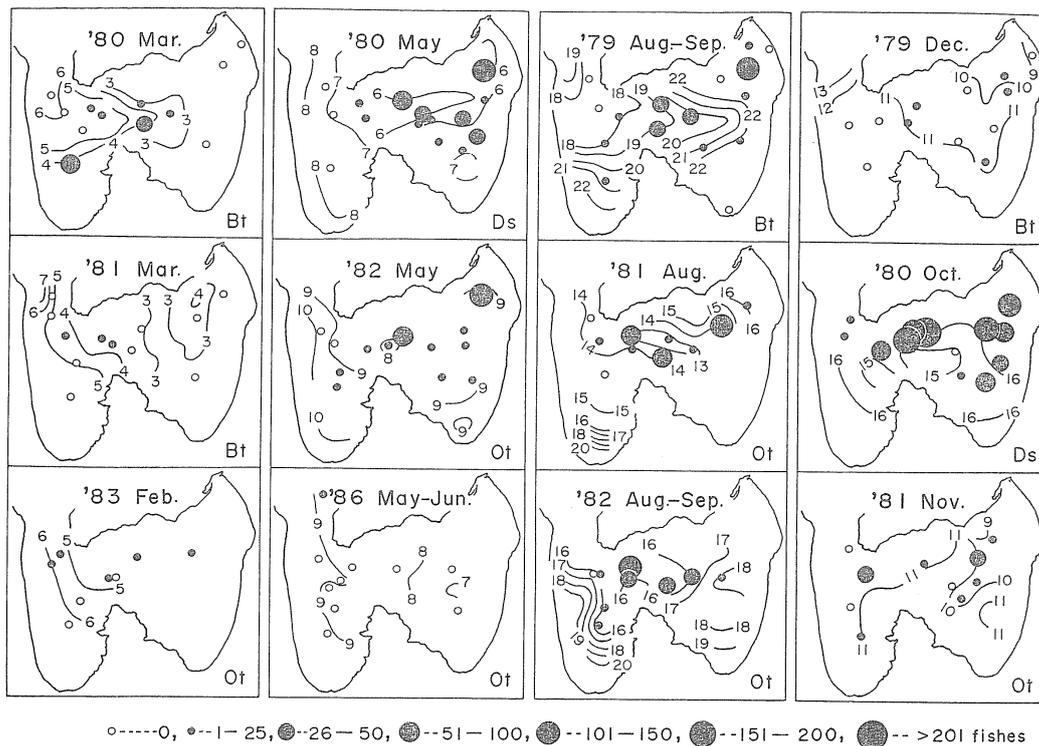


Fig. 9. Distribution of CPUE of *Pleuronectes yokohamae* in each season. Contours of bottom water temperature ($^{\circ}\text{C}$) are superimposed. Details as in Fig. 8.

Features of space utilization by *P. herzensteini* and *P. yokohamae* are shown in Fig. 6. *P. herzensteini* were concentrated in the West Bay or the western part of the East Bay, or both in all seasons. A somewhat different trend, i.e. expansion to the eastern area of East Bay, was seen in November 1981 and August 1986 when their biomass was larger (Fig. 5). However, the CPUE (8.4 kg/haul for 1981 and 6.5 kg/h for 1986) of *P. herzensteini* in the eastern area of East Bay was considerably low as compared with the CPUE (19.7 kg/haul, 53.9 kg/h) in West Bay. Thus, the main habitat of *P. herzensteini* was consistently in the West Bay and/or western part of East Bay, regardless of their abundance. On the other hand, in *P. yokohamae* the area of CPUE > 5 kg was not found after 1985 because of a reduction in the biomass (Fig. 5). Before 1983, however, their concentration was found in the West Bay in winter and in the East Bay from spring to autumn with few exceptions.

Relation between Fish Density and Prey Biomass

Relations between the CPUE of *P. herzensteini* or *P. yokohamae* and the biomass of prey in May and August-September 1982 are

shown in Fig. 7. Organisms which are hardly eaten by each species are not included in the calculation. The regression of CPUE(C) on prey biomass (B) is as follows;

P. herzensteini:

$$\ln(C+1) = 5.763 - 0.115B, n=13; \text{ May}$$

$$\ln C = 8.720 - 0.233B, n=7;$$

August-September

P. yokohamae:

$$\ln(C+1) = 0.757 + 0.107B, n=13; \text{ May}$$

$$\ln C = 1.716 + 0.061B, n=7;$$

August-September.

In *P. yokohamae*, a significant positive relationship ($r=0.70$, $P<0.01$) was found in May and the slope of this regression equation was significantly different from zero ($t=6.48$, $P<0.001$), though no significant relation was found in August-September ($r=0.29$, $P>0.05$). On the other hand, the CPUE of *P. herzensteini* were inversely related to the prey biomass. Namely, significant negative relationships were found in both May ($r=-0.67$, $P<0.05$) and August-September ($r=-0.88$, $P<0.01$), and the slopes of these two regression equations were significantly different from zero ($t=-2.50$, $P<0.05$; $t=-2.97$, $P<0.05$ respectively).

Relation between Fish density and Water Temperature

As can be seen in Fig. 8, *P. herzensteini* in winter (February-March) were concentrated in relatively warm waters and no catch was found in cold waters below 3°C. In the other seasons, no major trend was discerned between the CPUE and water temperature. However, in August-September 1979 when bottom temperatures were very high, above 19°C catches of *P. herzensteini* were poor. The concentration of the fish in warmer waters during winter was found also in *P. yokohamae* (Fig. 9). In the other seasons, no relation was found between the CPUE and temperature. Unlike *P. herzensteini*, however, in August-September 1979 the maximum abundance of *P. yokohamae* was observed at the highest temperature (22.3°C) during this period.

Discussion

Both *P. herzensteini* and *P. yokohamae* are in general the main components in the demersal fish community in Mutsu Bay (Table 1) and did not differ very much in biomass except in the case of a few years (Fig. 5). Moreover, an analysis of the food habit and food size suggests that both species in the bay require a similar food resource (Figs. 1, 2 and Table 2). Furthermore, they occupy more or less a common habitat (Fig. 6) and exhibit a similar diel feeding periodicity (Fig. 4) and seasonal pattern in feeding intensity from spring to autumn.¹²⁾ From these facts, an intense potential for competitive interaction of food between these two species was expected.

To elucidate the food competition between *P. herzensteini* and *P. yokohamae*, it is necessary to investigate whether or not their feeding activity is strongly affected by other species. The principal food item of *P. herzensteini* and *P. yokohamae* was polychaetes regardless of their body length throughout all seasons, and this food item also comprised the greater part of the diets of *M. manazo* less than 500 mm in length and all length groups of *G. intermedius* in summer, but not for the dominant *L. microptera* (Fig. 1). In addition, the polychaete ingested by *M. manazo* was exclusively larger *Aphrodita japonica* (2~27 g) and were hardly found in the stomachs of *P. herzensteini* and *P. yokohamae*. Similarly, a quite

large difference was observed in prey size between *G. intermedius* and both species of *Pleuronectes*. Namely, although a strict comparison cannot be made, when calculating the values of total weight/total number of all polychaetes found in the stomachs of the summer samples, the values for *G. intermedius* more than 121 mm in length comprising the greater part of the catches, ranged between 0.071~0.260 mg, while those for all length groups of *P. herzensteini* and *P. yokohamae* were 0.008~0.023 mg and 0.003~0.029 mg respectively. Therefore, it cannot be considered that strong competition for food occurs between both species of *Pleuronectes* and the other major demersal fishes. In winter, however, *P. herzensteini* fed considerably on fish (chiefly *Bregmaceros japonicus*) and shrimps (Fig. 1). Such a dietary shift to larger preys is probably dependent on the shortage of food supply, because the macrofaunal biomass in their habitat (West Bay) decreases remarkably in winter.¹³⁾ For this reason, it may be possible that competition between *P. herzensteini* and other fish feeders or shrimp feeders occurs during the winter.

Comparisons of the stomach contents of *P. herzensteini* and *P. yokohamae* taken simultaneously from the same site indicated that the food segregation between the two species was trifling during the spring and was relatively large during the summer (Figs. 2, 3 and Table 2). Such seasonal variation in food segregation is closely related to the intensity of food requirements in relation to their annual life period and food availability, because during the spring the food requirement of both species is very high but the available food biomass is scarce, and the reverse relation is true in summer.⁹⁾

These facts indicate that the competition for food between these two species was more intense in spring than in summer. But, as mentioned before there were distinct segregations in the habitat of both species from spring to autumn, so it can be considered that such a habitat utilization pattern reduces the interspecific competition for food between these two species.

During the major feeding season of both species (spring and summer),¹²⁾ positive relationships were found between the CPUE of *P. yokohamae* and available prey biomass. But, significant negative relationships were found

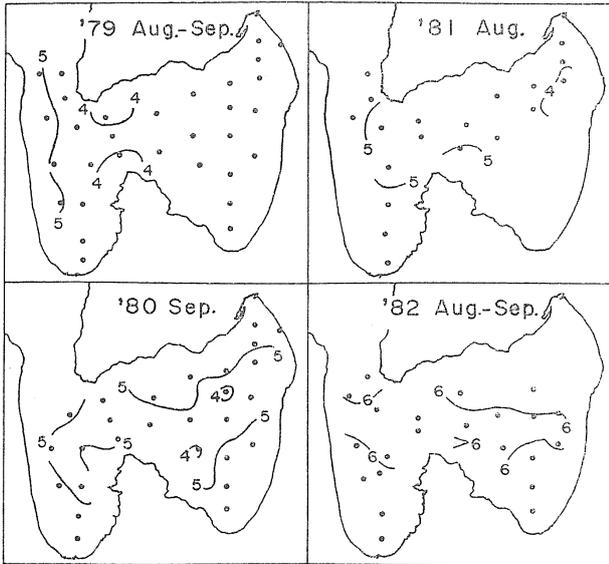


Fig. 10. Distribution of dissolved oxygen (ml/l) at about 0.3m above the bottom in August/September 1979, September 1980, August 1981, and August/September 1982.

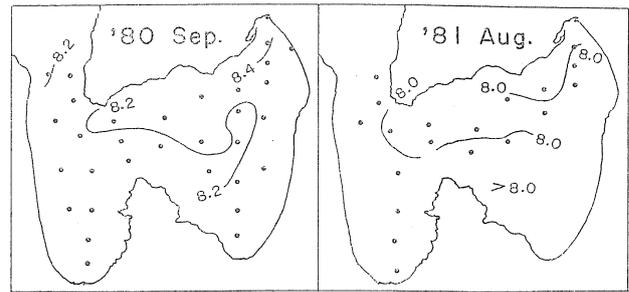


Fig. 11. Distribution of pH at about 0.3m above the bottom in September 1980 and August 1981.

summer.

According to the previous thermal resistance experiments,¹⁴⁾ *P. herzensteini* is superior in cold resistance, but is inferior in heat resistance to *P. yokohamae*: The critical low temperature of feeding was about 1°C for *P. herzensteini* and 2°C for *P. yokohamae*, and the upper temperature limit for normal feeding was 18~19°C for *P. herzensteini* and 24°C for *P. yokohamae*. Considering these experimental results, the concentration of both species in the West Bay during the winter is evidently a behavior to escape the cold water in the East Bay (Figs. 8, 9). On the other hand, the fact that in the summer of 1979 *P. herzensteini* were concentrat-

for *P. herzensteini* (Fig. 7). The direct cause of this is that the main part of *P. herzensteini* was distributed in the West Bay where the prey biomass was less than in East Bay,¹⁸⁾ suggesting that food organisms do not strongly restrict the distribution of *P. herzensteini* in spring and

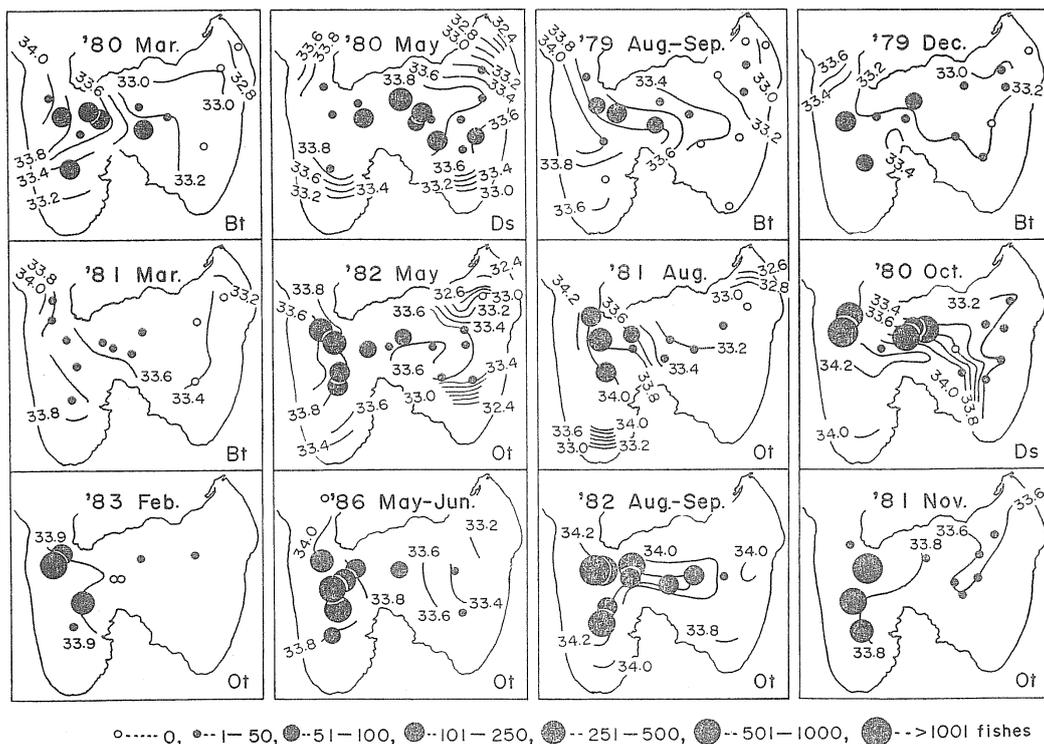


Fig. 12. Distribution of CPUE of *Pleuronectes herzensteini* in each season. Contours of bottom salinity (‰) are superimposed. Details as in Fig. 8.

ed in relatively cold waters (below 19°C) and *P. yokohamae* were concentrated in waters of highest temperature (22.3°C) is probably due to the difference in thermal resistance between these two species. However, it is rare that temperatures offshore of the bay rise to 18°C, and yet in spring and late autumn the difference in temperature between West Bay and East Bay was little. Therefore, it cannot be considered that temperature is the main reason for the habitat segregation between both species.

In addition, it seems that dissolved oxygen (Fig. 10), pH (Fig. 11), and bottom sediments (see Takahashi *et al.*¹⁸⁾) are also independent of the habitat segregation, because these abiotic factors do not differ very much between the West Bay and the East Bay.

The habitat segregation between *P. herzensteini* and *P. yokohamae* is also reported by Omori,²⁾ who stated that the occurrence of this phenomenon in Sendai Bay, Miyagi Prefecture, was caused by the coaction of both species. However, at least in Mutsu Bay it cannot be considered that habitat segregation between these two species is due to their interaction for food or habitat, because no particular change was found in the space utilization pattern of *P. herzensteini*, despite the fact that the biomass of *P. yokohamae* which occupy the vantage area for feeding declined extremely after 1983 (Fig. 5).

West Bay where *P. herzensteini* predominates is influenced by open sea waters, i.e. the Tsugaru Warm Water originating from the Kuroshio, so it has a consistently higher salinity than in East Bay.¹⁶⁾ Moreover, the distribution of *P. herzensteini* from spring to autumn appears to be connected with contours of salinities of 33.6‰ or 33.8‰ except in a few cases (Fig. 12).

From the above results, there seems no doubt that the habitat segregation between *P. herzensteini* and *P. yokohamae* is basically affected by the physical or chemical conditions of sea water.

Acknowledgements

Grateful acknowledgements is made to Prof. Emeritus M. Ueno, Prof. Emeritus S. Mishima,

and Prof. K. Kyushin, Faculty of Fisheries, Hokkaido University, for their helpful suggestions. The authors would like to express heartfelt thank to Instructor Dr. T. Nakatani and Messrs. Y. Tsuchiya, N. Yanagawa, M. Sasaki, O. Tominaga, S. Yokoyama, and T. Fujioka of our laboratory for field sampling. Thanks are also due to the captain and crews of R/V Seiho-Marui, Aomori Pref. Fish. Exp. Sta., and R/V Ushio-Marui, Hokkaido University, for their kind assistance.

References

- 1) M. Hatanaka, M. Kosaka, Y. Sato, K. Yamaki, and K. Fukui: *Tohoku J. Agr. Res.*, **5**, 177-189 (1954).
- 2) M. Omori: *Nippon Suisan Gakkaishi*, **40**, 1115-1126 (1974).
- 3) T. Takahashi, T. Maeda, Y. Tsuchiya, and T. Nakatani: *Nippon Suisan Gakkaishi*, **53**, 177-187 (1987).
- 4) E. P. Odum: *Fundamentals of Ecology II*, W. B. Saunders Company, Philadelphia, 1971, pp. 213-220.
- 5) T. Kikuchi: *Dobutsu no Shukan-Kankei, Seitai-gaku Koza*, **13**, Kyoritsu Shuppan, Tokyo, 1974, pp. 1-120.
- 6) M. Hanaoka: in "Umi no Seibutsu-Gunshu to Seisan" (ed. by S. Nishizawa, R. Ishida, and K. Kawasaki), Koseisha Koseikaku, Tokyo, 1977, pp. 311-364.
- 7) M. Morisita: *Mem. Fac. Sci. Kyushu Univ. Ser. E. (Biol.)*, **3**, 65-80 (1959).
- 8) T. Tamura: *Bull. Fac. Fish. Hokkaido Univ.*, **3**, 240-242 (1953).
- 9) T. Takahashi: *Nippon Suisan Gakkaishi*, **53**, 189-194 (1987).
- 10) S. Kimoto: *Dobutsu-Gunshu Kenkyuho I, Seitai-gaku Kenkyuho Koza*, **14**, Kyoritsu Shuppan, Tokyo, 1976, pp. 136-139.
- 11) T. Takahashi, T. Tominaga, T. Maeda, and M. Ueno: *Nippon Suisan Gakkaishi*, **48**, 1257-1264 (1982).
- 12) T. Takahashi, S. Saito, T. Maeda, and H. Kimura: *Nippon Suisan Gakkaishi*, **49**, 663-670 (1983).
- 13) T. Takahashi, T. Maeda, T. Nakatani, and N. Yanagawa: *Nippon Suisan Gakkaishi*, **52**, 1339-1349 (1986).
- 14) T. Takahashi, O. Tominaga, and T. Maeda: *Nippon Suisan Gakkaishi*, **53**, 1905-1911 (1987).
- 15) K. Otani and T. Terao: *Bull. Fac. Fish. Hokkaido Univ.*, **24**, 100-131 (1974).