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水産海洋研究

Estimation of Distribution Boundary between Two Sandfish *Arctoscopus japonicus* Stocks in the Sea of Japan off Honshu, Japan Using Density Indices

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It has been known that there are two main spawning grounds of sandfish *Arctoscopus japonicus* in the Sea of Japan off Honshu, Japan, and the Korea Peninsula: one located off the coast of Akita Prefecture, Honshu, Japan, and the other located on the east coast of Korea. This paper investigated the distribution of these two stocks originating from the two spawning grounds using catches, density indices in 13 areas in the Sea of Japan based on catch per unit effort (CPUE) data and length frequency distributions of female in the offing of Akita Prefecture. The results were as follows: (1) in the offing of Akita Prefecture, monthly CPUE showed two peaks in April and October and very low values in summer; (2) the density indices showed that fish were concentrated near the spawning grounds in October to December; (3) in the offing of Akita Prefecture, the length frequency distributions indicated that 1-year old fish recruited from March to April; and (4) principal component analysis for the annual fluctuation in the density indices in each area indicated that the stock originating in Akita was distributed from the offing of Akita Prefecture to the offing of Wakasa, and the stock originating in Korea was distributed from the east coast of Korea to the offing of Noto.

Key words: *Arctoscopus japonicus*, density index, Korea, migration, principal component analysis, sandfish, Sea of Japan, stock

Introduction

It has been known that there are two main spawning grounds for sandfish *Arctoscopus japonicus* in the area from the Sea of Japan off Honshu, Japan and Korea Peninsula, one being along the coast of Akita Prefecture off Honshu, Japan, and the other being on the east coast of Korea (Okiyama, 1970; Choi *et al.*, 1983) (Fig. 1).

The migration pattern of sandfish from the spawning grounds off Akita Prefecture is as follows: In the spawning season from November to December, the adult fish migrate to coastal waters, spawn eggs on Fucales in shallow waters and then return to the offshore waters (Sugiyama, 1991). In the spawning areas, the eggs hatch from February to March and the juveniles remain in waters with depths of about 10 m until April or May (Okiyama, 1988; Minami and Tanaka, 1985). Adult fish are found in waters with depths of 200 to 300 m in the Sea of Japan off Honshu. In the waters off Korea, they distribute in waters with depths of 100 to 250 m.

Some papers have reported the stock identification and migration of the sandfish in the Sea of Japan off Honshu, Japan using isozymes (Fujino and Amita, 1984), morphological approaches and tag release-recapture methods (Okiyama, 1970; Tanaka, 1987; Sugiyama, 1991). Fujino and Amita (1984) reported that sandfish in Akita were genetically different from those in Korea. Okiyama (1970) and Sugiyama (1991) showed that many fish released in the waters off Akita Prefecture were recaptured in nearby waters where fish were released and the waters off the spawning grounds in Akita. According to Fujino and Amita (1984) and Okiyama (1970), sandfish originating from the two spawning areas probably are independent stocks, respectively. Small spawning grounds and eggs of sandfish are observed in other areas such as Toyama Bay and Sado Island (Minami *et al.*, 1989; Kitami *et al.*, 1974). However, it is considered that fish spawned in these areas are not independent stock because the spawning grounds is very small compared to those in Akita.

For managing the stocks, it is necessary to clarify the distribution boundary between these two stocks. Therefore, to investigate the stock boundary is important and urgent subject to determine allowable biological catches (ABC) for each stock. The purpose of this study is to determine the distribution boundary mainly using the catch and CPUE

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data.

Materials and Methods

Experimental harvesting survey in offing of Akita Prefecture

The Akita Prefectural Fisheries Promotion Center has conducted experimental harvesting surveys at water depths ranging from 100 to 300 m in the offing of Akita (Fig. 1). The survey has been conducted by operating about 20 hauls per month using Danish seine net (Sasao, 1999). They recorded the number of hauls and the frequency distribution of the body lengths sampled. Using this data, we calculated the catch per unit effort $U_{t,m}$ (CPUE; number of individuals/haul) by month m and year t and calculated the mean CPUE $\bar{U}_m$ per month from 1990 to 1998 except for 1992 when data were not collected. Here, the mean CPUE in May was not used because Akita Prefecture did not conduct the survey in May from 1990 to 1996. In order to clarify the seasonal migrations at each age, we defined the female density index $IF_{t,m,i}$ in length classes i ($i=1,\cdots,43$) for month m of year t by

$$IF_{t,m,i}=r_F\cdot U_{t,m}\cdot v_{t,m,i} \quad (1)$$

where r_F denotes the sex ratio of female and is assumed constant at 0.5 (Kato and Ohuchi, 1956) because the above survey did not collect the number of individuals by sex. Additionally, $v_{t,m,i}$ is the frequency of females in each length class i for month m of year t where the class width was 5 mm. In this study, we did not employ mixed length frequency of male and female because mean body length of male by age are smaller than that of female (Ikehata, 1988). We also investigated monthly density indices in length class of male by age. However, these monthly trends were not different by sex. Therefore, in this study we showed the density index in length class only for female.

Catch and effort data

Immature and mature sandfish are caught in offshore of Japan and Korea by Danish seine, small-scale Danish seine and bottom trawl boats. The Japan Sea National Fisheries Research Institute have collected fishing data of Danish seine fishery in small areas defined by a 10 min. grid (Anonymous, 1978). Hereafter, we call this "small area". The institute also investigated the 11 medium-sized fishing areas (Fig. 1) composed of the small areas (Anonymous, 1978). The 11 areas are located north of Oga Peninsula (hereafter, area B); south of Oga Peninsula (area C); the offing of Niigata (area D); the offing of Noto (area E); the offing of Kaga (area F); the offing of Wakasa (area G); the offing of Tajima (area H); north of Oki Island (area I); the area around Oki Island (area J); the offing of Hamada (area K); and south of Yong-il (area L). In this study, we additionally defined areas A and M, which are the spawning areas off Akita Prefecture and the waters off eastern Korea, respectively.

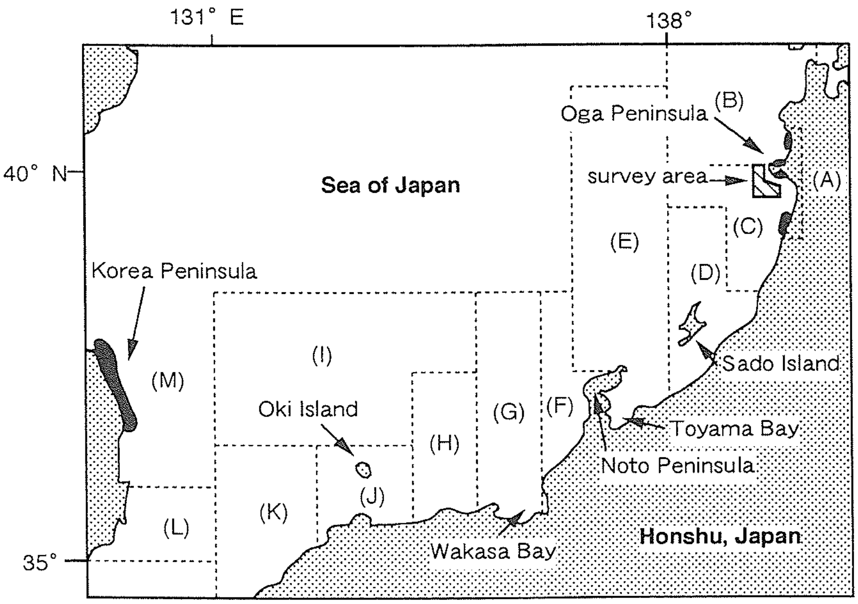

Figure 1. Location of the spawning grounds (dark areas) where are corresponding to two stocks of sandfish and the area (slash area) where Akita Prefecture has conducted experimental harvesting survey. The alphabet in parentheses denote the waters or the medium-sized areas as follows; (A), The spawning areas off Akita Prefecture; (B), North of Oga Peninsula; (C), South of Oga Peninsula; (D), The offing of Niigata; (E), The offing of Noto; (F), The offing of Kaga; (G), The offing of Wakasa; (H), The offing of Tajima; (I), North of Oki Island; (J), The area around Oki Island; (K), The offing of Hamada; (L), South of Yong-il; (M) Korea.

We used the number of hauls $x_{t,m,j}$ and the catch $y_{t,m,j}$ (kg) of Danish seine fishery by month m of year t in small area j. The institute calculated the monthly density indices $P_{t,m,h}$ of the medium-sized areas h of year t and the yearly density indices $P_{t,h}$ as follows (Anonymous, 1978):

$$P_{t,m,h} = \sum_{j} \frac{y_{t,m,j}}{x_{t,m,j}}, \quad (2)$$

$$P_{t,h} = \sum_{m=Jan.}^{Dec.} P_{t,m,h}. \quad (3)$$

We defined the mean monthly density index $\bar{Q}_{m,h}$ in the medium-sized areas over the period of 1978 to 2000 as

$$\bar{Q}_{m,h} = \frac{1}{23} \sum_{t=1978}^{2000} P_{t,m,h}. \quad (4)$$

In the waters located at east of Wakasa Bay, the Danish seine fishery is closed in July and August. While, in the waters located at west of Wakasa Bay, it is closed from June to August. Therefore, we neglected density indices during these periods.

For fishing areas where CPUE and density index data can not be collected, we used the catch data as a density index. In area A (spawning area off Akita Prefecture), we used the coastal catch $C_t(t)$ of Akita Prefecture in year t that is harvested by set and gill nets as a density index of the spawning areas off Akita Prefecture. These fishing gears are passive harvesting method compared with, for instance, Danish seine fisheries, and we considered that catch in area A can be used as the real density of shoal spawning.

Chun (2002) indicated the annual trend of catch in Korea, which is harvested as by-catch by the walleye pollock fisheries, coincided with that of the density index calculated in the Korean waters from the 1960s to 1990s. However, the density index is not available because the data are not publicized. Therefore, in the case of area M, we used catch data in Korea as a density index (Anonymous, 1965). K_t and $\bar{K}_m$ denote the catch (t) in Korea (area M) of year t; and the mean monthly sandfish catch (t) for the years 1965 to 1998 except for 1968, respectively.

In order to clarify the distribution areas and migration patterns, we examined the monthly fluctuations of density indices $\bar{Q}_{m,h}$ and $\bar{K}_m$. We also examined the similarities among the fluctuations in the annual patterns of $P_{t,h}$, C_t and K_t using principal component analysis (PCA). PCA has frequently been performed to examine the characteristic variations in time series data consisting of many variables (Koslow, 1984; Nakamura and Yamagata, 1997; Tanimoto *et al.*, 1993; Nemoto and Shimizu, 1997). We used the natural logarithm values of $P_{t,h}$, C_t and K_t and performed PCA

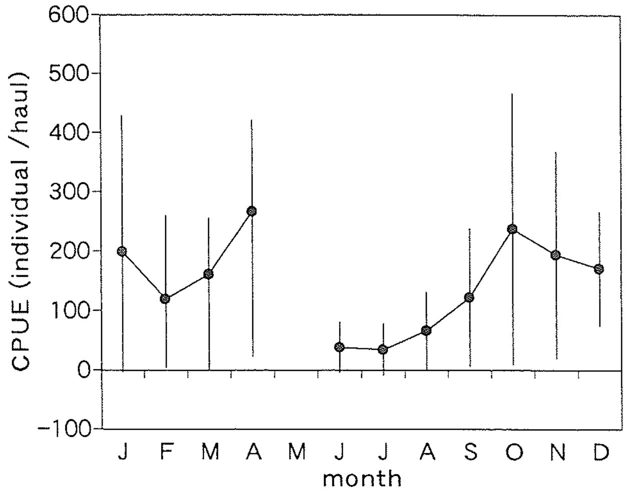

Figure 2. The mean monthly CPUE (individual number /haul) obtained by survey conducted in the offing of Akita Prefecture from 1990 to 1998. Closed circle and bar indicate the mean and the twice standard deviation, respectively.

using Excel Statistics that is add-in program of Microsoft Excel.

Results

Monthly fluctuations of CPUE, density indices and catch

Figure 2 shows the mean monthly CPUE $\bar{U}_m$ obtained by the survey. $\bar{U}_m$ shows seasonal variation with two peaks: $\bar{U}_m$ gradually increases from a low in February to an apparent peak in April and then gradually increases from very low levels in June and July to a second peak in October.

Figure 3 shows the mean monthly density indices (kg/haul) for the 11 medium-sized areas, $\bar{Q}_{m,h}$, calculated by equation (4) and the mean sandfish catches, $\bar{K}_m$ for the east coast of Korea. The density indices of the medium-sized areas could be classified into two groups based on the values: areas B, C, D, E, F and G had low values (at most 100 kg/haul) while areas H, I, J, K and L had very high values (at most 500 to 1000 kg/haul). $\bar{Q}_{m,h}$ should be standardized with the size of area where it is calculated. However, the size of the medium-sized area does not so different in each other. Therefore, for simplicity in this study, we did not standardize the $\bar{Q}_{m,h}$ with the size of the area.

The monthly trends in the medium-sized areas can be summarized as follows. In areas B and C, $\bar{Q}_{m,h}$ showed an increasing pattern from September to December. In areas D, E and F, $\bar{Q}_{m,h}$ increased from January to February and gradually decreased from September. The $\bar{Q}_{m,h}$ in area G showed the high values from January to May and then sharply declined. In areas H, I, J and K, $\bar{Q}_{m,h}$ gradually increased from January to May and gradually decreased from September to December. In area L, $\bar{Q}_{m,h}$ showed the high

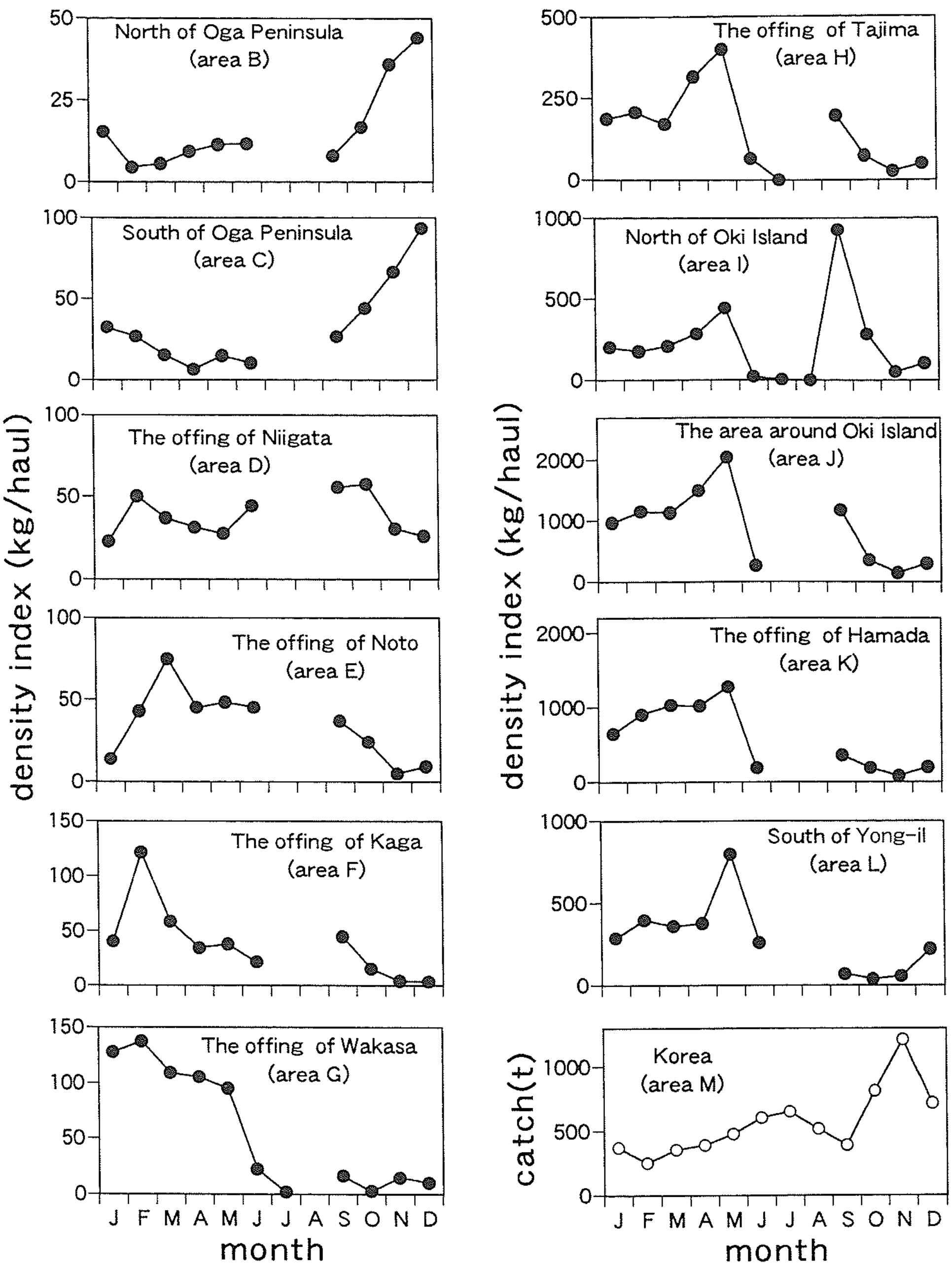

Figure 3. The mean monthly density indices (kg/haul) for the 11 medium-sized areas from 1978 to 2000 and the mean monthly sandfish catches (t) for the east coast of Korea from 1965 to 1998 except for 1968.

value in May and were the low values from September to November, and then increased slightly in December. In the coastal area of Korea (area M), $\bar{K}_m$ increased slightly from February to July and was rather stable through the year at around 500 ton, however it was very high from October to December at almost two times the level of the catch recorded from January to September.

Monthly fluctuations of female density indices

Figure 4 shows the monthly female density indices $IF_{t,m,i}$ obtained in the surveys. Here, we assumed that the distributions could be broken down into unimodal distributions by each age of which modes correspond to the mean body length by age reported by Ikehata (1988). In January, two peaks were identified in the 16–17 and 20–22 cm corresponding to 2-year-old, and 3-year-old and older fish, respectively. From March to April, recruitment of 1-year old fish with lengths from 8 to 12 cm was observed. In addition, from March to December, the monthly variations of unimodal distributions showed almost the same pattern that is very low in summer and gradually high from autumn.

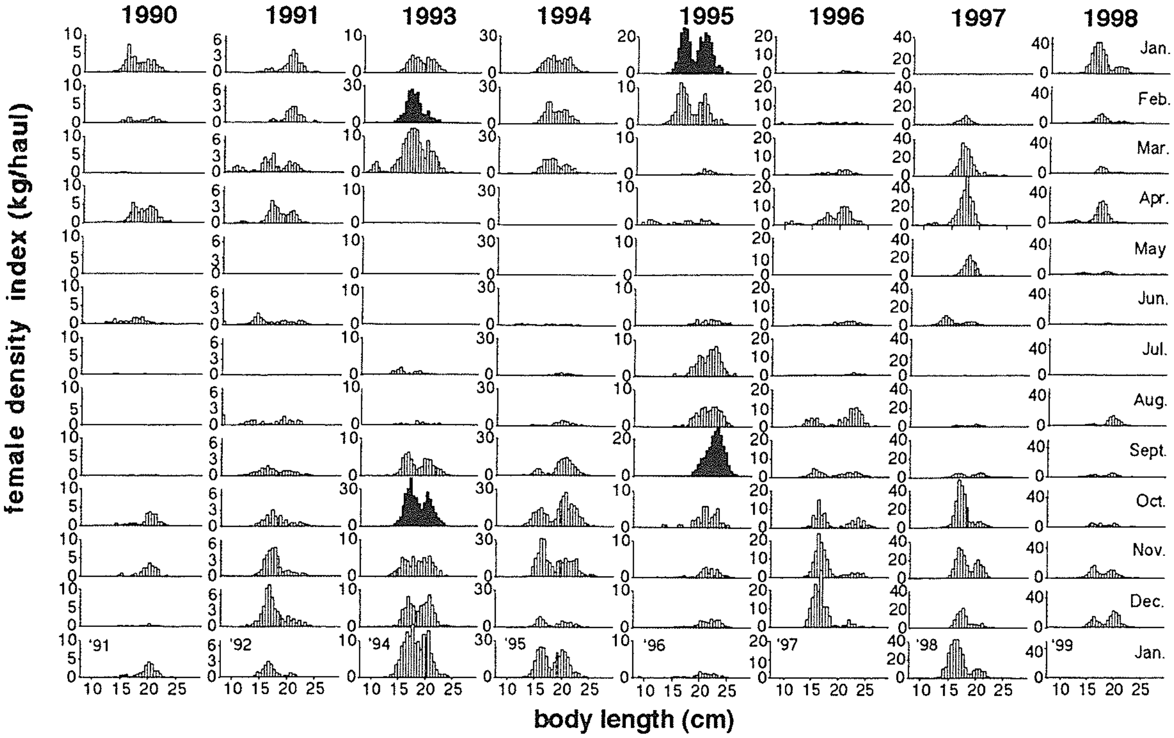

Figure 4. The monthly female density indices obtained by survey of the offing of Akita Prefecture in the year from 1990 to 1998 except for 1992. The scale of the y-axis is different in February and October of 1993 and in January and September of 1995 compare to the other month in the year (closed histograms).

Annual fluctuations of density indices and catches

Figure 5 shows the annual sandfish catches in area A and M, and the annual density indices from areas B to L. These fluctuations were roughly divided into three patterns. The first was recognized in the areas A, B, C, D, E, F and G, where the densities were very high from the late 1970s to the early 1980s. After the mid 1980s the values were very low although in areas B and G were not extremely low. After the late 1990s the values in these areas tended to increase. The second was observed in areas H, I, J and K where a slightly increasing trend was observed from the late 1970s to the 1980s and they were not very low in the 1990s. The third was observed in areas L and M, where the pattern was similar to the areas H to K from the late 1970s to the 1980s. After the 1990s, however, they were very low and did not show a recovery in the late 1990s.

Table 1 shows the eigen values, the factor loadings, the ratios of contribution and the cumulative ratios of contribution obtained from the principal component analysis (PCA). In PCA, the principal components with eigen value greater than unity are generally used to interpret the analysis (Okuno *et al.*, 1981). In this case, the eigen values of the first PC_1, the second PC_2, and the third principal component PC_3 were greater than unity and accumulated value reached by 77.4% of the total variance. In this study, however, we focused only on PC_1 and PC_2 because the contribution of each these two ratios was greater than 30%, while that of PC_3 was less than 10%. Figure 6 shows the factor loadings of PC_1 (f_1) and PC_2 (f_2) for each medium-sized area. Here, factor loadings f_a ($a=1,2$) denote the correlation coefficients between PC_a and variables such as $P_{t,h}$ (Okuno *et al.*, 1981). Areas A, B, C, D, E, F and G had relatively high and positive f_1 values while areas E, F, G, H, I, J, K, L and M had relatively high and positive f_2 values. In areas E, F and G, both f_1 and f_2 showed values between 0.50 and 0.60 (Table 1).

Discussion

Before discussing the migration patterns of sandfish using the mean monthly density indices, we must confirm that these indices are truly related to the actual density of fish shoal. In the western waters from area H, the Danish seine fishery is closed in June, July and August, and focus on harvesting snow crab, *Chionoecetes opilio*, in November and December (Kitazawa and Oaku, 1982; Anonymous, 1989). Therefore, this could affect the monthly density indices. However, in the survey using an otter-trawl net in Tottori Prefecture (area J), CPUE (individual number/haul) showed a peak from July to September (Anonymous, 1989).

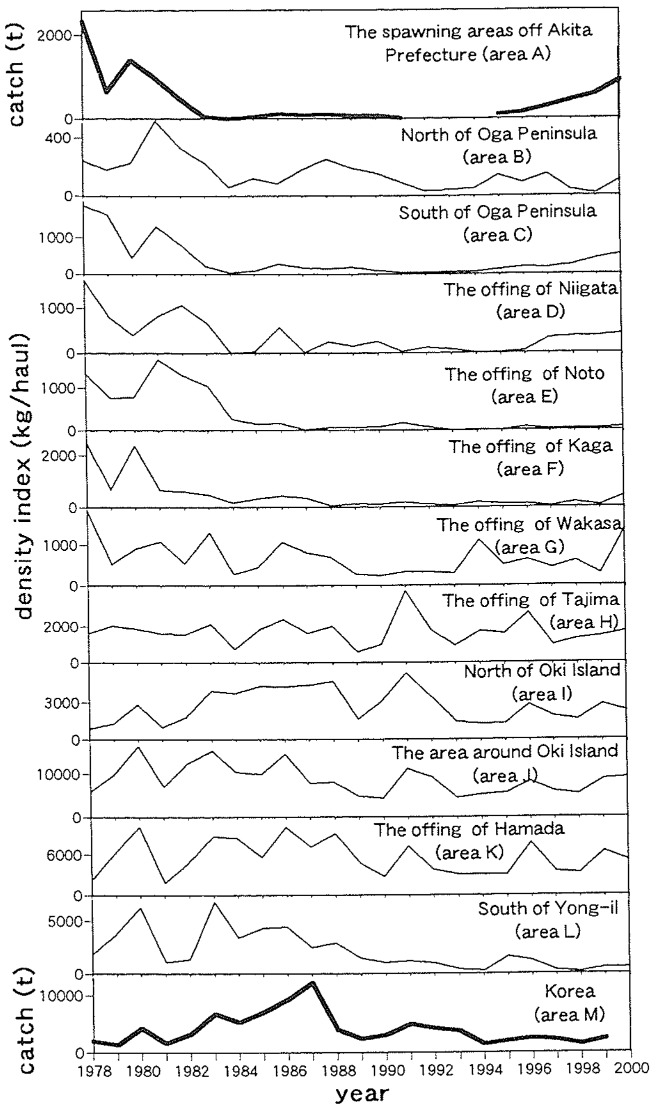

Figure 5. The annual sandfish catches in the spawning areas off Akita Prefecture and Korea, and the annual density indices in the medium-sized areas.

As shown in Figure 3, the mean monthly density indices in the waters from area H to area J were similar to each other and coincided with the trend of CPUE obtained in Tottori Prefecture that is high from July to September. Thus, we considered that the mean monthly density indices from areas H to L roughly reflect the actual density of fish shoal in respective areas.

Some papers have reported that in Akita Prefecture mature sandfish after spawning migrate from the coastal to the offshore areas and then migrate to the southern areas. Sugiyama (1991) reported that tagged fish released from the coast off Akita in the spawning seasons were caught at Sado Island after 3–6 months. Cyubachi (1991) showed that tagged fish released in the southern part of area C migrated

Table 1. The eigen values, factor loadings, the ratios of contribution and the cumulative ratios of contribution which obtained from the principal component analysis for years from 1978 to 1999, except 1992 to 1994.

	Area	Factor loading f_1	f_2	f_3
A	The spawning areas off Akita Prefecture	0.868	−0.050	−0.310
B	North of Oga Peninsula	0.466	0.319	0.657
C	South of Oga Peninsula	0.924	0.118	−0.154
D	The offing of Niigata	0.789	0.114	−0.307
E	The offing of Noto	0.547	0.586	0.084
F	The offing of Kaga	0.591	0.633	0.206
G	The offing of Wakasa	0.570	0.562	0.002
H	The offing of Tajima	0.003	0.600	−0.452
I	North of Oki Island	−0.830	0.427	−0.140
J	The area around Oki Island	−0.140	0.881	−0.267
K	The offing of Hamada	−0.579	0.629	−0.297
L	South of Geijitsu	−0.117	0.831	0.350
M	Korea	−0.607	0.629	0.174
Eigen value		4.84	3.99	1.23
Ratio of contribution (%)		37.3	30.7	9.5
Cumulative ratio of contribution (%)		37.3	68.0	77.4

to south. Okiyama (1970) reported that a fish released in the southern coast of Akita Prefecture was recaptured in Toyama Bay (area E) after 77 days. He also showed that two fish tagged and released in Korea were caught in area H. During the spawning season in Korea, the fishing grounds are located in the waters around 38°N and then move to southern waters around 36–37°N from January to May (Kiyokawa, 1991). Figures 2 and 3 show that the density indices and catch in the areas B, C and M near the spawning grounds are high during October to December while the areas far from spawning grounds are very low during these months. Figures 2 and 4 also indicate that CPUE and the female density index in Akita from January to April were relatively higher than those in summer. These results indicated the mature sandfish migrate to their spawning grounds and stay there until spring.

As we discussed above, we could follow the migration patterns for spawning using the monthly CPUE but could not examine the distribution boundary in the two stocks. We used PCA of the fluctuation patterns on annual density indices to examine the boundary. When the age composition of fish harvested in different areas is quite different, it is not reasonable to compare the annual density indices. In

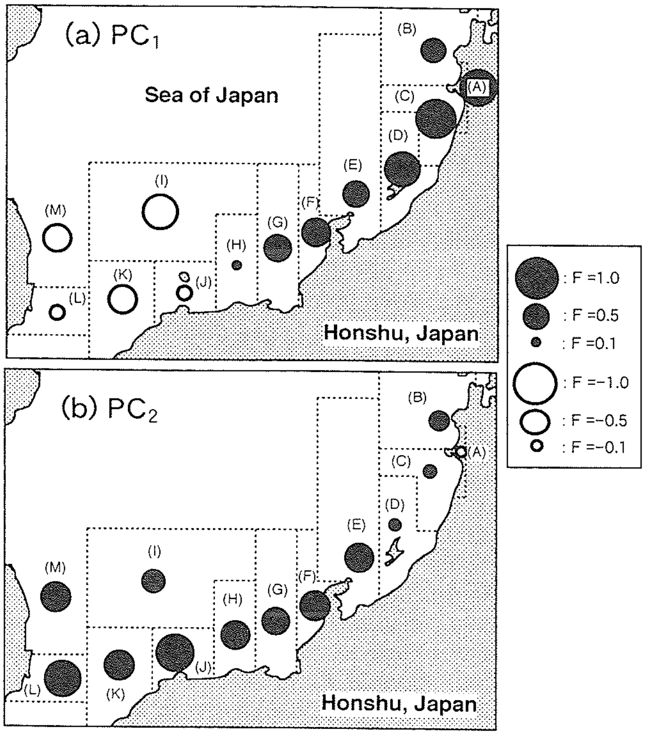

Figure 6. Results of principal component analysis. (a) The factor loading of first principal component, and (b) The factor loading of second principal component for each medium-sized area.

the offing of Akita Prefecture, 1-year-old fish recruited in March and April (Fig. 4). It has been reported that 1-year old fish in other areas are also observed in the same months based on length distributions of harvested fish (Katano, 1988; Yasuzawa, 1992; Kasuya, 1992; Kuranaga, 1987; Kiyokawa, 1991; Kitazawa and Yuki, 1982; Yamazaki *et al.*, 1981). There are a few observations about sandfish before recruiting. Sugiyama and Shibata (1989) reported that young sandfish with a body length of 5–6 cm, that is corresponding to 0-year old fish, were observed in waters with a depth of 372 m near the offing of Akita Prefecture in July. Yamazaki *et al.* (1981) reported that the sandfish with body lengths of about 8 cm were found at depths of 0–200 m in area J in January based on surveys by mid-water trawl net. These information along with the distribution imply that the sandfish before recruiting born in the two spawning grounds migrate widely in the Sea of Japan off Honshu and that the age composition of 1 and 2 years old fish constructed the main catch is almost uniform in all areas. Therefore, we consider that annual fluctuations of density indices in each area mainly reflect the real density of fish shoal including recruitment.

If sandfish originating from two spawning areas widely distribute from Akita to Korea, we can not discuss the distribution using the annual density indices. As mentioned above, sandfish sampled in Akita were genetically different to those in Korea (Fujino and Amita, 1984). Fish migrating long-distance areas, for instance, from area A to M, was not observed (Sugiyama, 1991; Cyubachi, 1991; Kiyokawa, 1991). Therefore, we consider that almost all sandfish originating in a spawning area do not migrate in nearby other spawning area.

From the results that sandfish originating from the two spawning areas are independent stocks (Okiyama, 1970; Fujino and Amita, 1984) and the migration pattern mentioned above, we can interpret that PC_1 and PC_2 show the abundance fluctuations of the stocks originated in the spawning areas off Akita and Korea, respectively (Fig. 6 and Table 1). We concluded that the distributions of the two stocks are separated into two areas based on the annual fluctuations of density indices and catches, and monthly fluctuations of density indices in each medium-sized area. That is, the stock originating in Akita is distributed from areas A to G, and that of Korea is distributed from areas M to E. Based on isozyme analysis, Fujino and Amita (1984) reported that the fish in area G were genetically same as those in Akita Prefecture and the genetical difference were not detected in the fish in area M and J. However, they could not refer to mixing areas of stock distributions. Okiyama (1970) reported that fish in Akita Prefecture and Korea are independent stocks based on catch fluctuation, morphological approaches, and tag release-recapture methods, but he did not conclude about the distribution boundary. The distribution boundary could not be discussed from the studies using tag release-recapture methods because few fish migrating long-distance areas was observed (Sugiyama, 1991; Cyubachi, 1991; Kiyokawa, 1991). The range of stock distribution originated in Akita obtained by this study relatively corresponded to the results of Fujino and Amita (1984). However, that in Korea did not correspond to each other.

f_1 and f_2 in areas E, F and G were positive and high, and there were little difference between f_1 and f_2 (Fig. 6 and Table 1). This means that density indices in these areas have some relation to both stocks and it is showing that the two stocks are mixed in these areas. The annual density indices in areas E and F were very low from 1980s while that in area G was not (Fig. 5). This extreme decline would occur due to the destruction of stock abundance originating in Akita. Thus, the two stocks are probably distributed together in areas E, F and G, and the degree of mixture with the stock originating in Akita in the areas are probably larger than that in Korea.

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References

Anonymous (1965–2000) The annual statistics of Agriculture, Forestry and Fishery in Korea. Ministry of Affairs and Fisheries, Korea. (in Korean).

Anonymous (1989) Fishing conditions of sandfish in Tottori Prefecture. Report of Sandfish Ecology and Management, Akita, Yamagata, Tottori and Shimane Prefectural fishery experimental stations, 53–81. (in Japanese).

Anonymous (1978–2000) Statistics on offshore trawl fishery in areas off Japan Sea. Japan Sea National Fisheries Research Institute, Fisheries Research Agency. (in Japanese).

Choi, S. H., Y. Y. Chun, S. J. Son and H. K. Suh (1983) Age, growth and maturity of sandfish, *Arctoscopus japonicus* (STEINDACHNER) in the Eastern Sea of Korea. Bull. Fish. Res. Dev. Agency, **31**, 7–19.

Chum, Y. Y. (2002) Long-term fluctuations of the fisheries resources in the East Sea (Sea of Japan) off Korea. In Japan-Korea-China Joint symposium on the marine fisheries resources. Japan Sea National Fisheries Research Institute and Seikai National Fisheries Research Institute, Fisheries Research Agency, Niigata. (in Japanese).

Cyubachi, T. (1991) The characteristics of the distributions of sandfish in the offing of Yamagata Prefecture. Report of Sandfish Research Council, Japan Sea National Fisheries Research Institute, **4**, 11–16. (in Japanese).

Fujino, K. and Y. Amita (1984) Subpopulation identification of the sailfin sandfish from Waters Adjacent to Japan. Fish Gene. Breed. Sci., **9**, 31–39. (in Japanese).

Ikehata, M. (1988) The fundamental study in the otolith of sandfish. Report of Sandfish Research Council, Akita Prefectural fishery experimental station, **2**, 11–16. (in Japanese).

Kasuya, Y. (1992) Trend in sandfish catch at Fukui Prefecture in 1991. Report of Sandfish Research Council, Japan Sea National Fisheries Research Institute, **5**, 21–22. (in Japanese).

Katano, S. (1988) Trend in sandfish catches at Niigata Prefecture in 1988. Report of Sandfish Research Council, Akita Prefectural fishery experimental station, **3**, 11–13. (in Japanese).

Kato, G. and A. Ohuchi (1956) Fishery biological study of the commercially important fish. Bull. Jpn Sea Reg. Fish. Res. Lab., **4**, 197–215. (in Japanese).

Kitami, T., Y. Honma and M. Okiyama (1974) Spawning habitat of sandfish in the coasts of Sado Island and Niigata area. Collecting and breeding, **6**, 126–129. (in Japanese).

Kitazawa, H and T. Oaku (1982) Study on the discards by the Danish seine fishery in western Wakasa Bay. Bull. Jpn. Sci. Fish., **48**, 1089–1093. (in Japanese).

Kitazawa, H and Y. Yuki (1982) The survey for the exploitation of offshore fishing grounds. Bull. Shimane Pref. Fish. Exp. Sta., 34–35. (in Japanese).

Kiyokawa, T. (1991) On the distribution and the migration of sandfish in the waters Western Sea of Japan. Rep. Exp. Res. Jpn. Sea, **21**, 51–66. (in Japanese).

Koslow, J. A. (1984) Recruitment patterns in Northwest Atlantic fish stocks. Can. J. Fish. Aquat. Sci., **41**, 1722–1729.

Kuranaga, R. (1987) On the sandfish caught in the offing of Tottori Prefecture. Report of Sandfish Research Council, Akita Prefectural fishery experimental station, **1**, 38–42. (in Japanese).

Minami, T and M. Tanaka (1985) Juvenile Japanese Sandfish, *Arctoscopus japonics* Caught by the "Akahige" fishery in the Shinamo River Estuary, Niigata Prefecture, the Japan Sea. Bull. Jpn. Sea Reg. Fish. Res. Lab., **35**, 1–10. (in Japanese).

Minami, T., K. Nashida and A. Imamura (1989) Spawning migration in sandfish, *Arctoscopus japonicus*, in Toyama Bay. Report of Sandfish Research Council, Akita Prefectural fishery experimental station, **3**, 42–44. (in Japanese).

Nakamura, H., G. Lin and T. Yamagata (1997) Decadal climate variability in the North Pacific during the recent decades. Bull. Am. Meteor. Soc., **78**, 2215–2225.

Nemoto, M. and M. Shimizu (1997) The catch characteristics of set-net fishing grounds in Seisyou region of Sagami Bay. Nippon Suisan Gakkaishi, **63**, 947–955. (in Japanese).

Okiyama, M. (1970) Studies on the population biology of the sandfish, *Arctoscopus japonicus* (STEINDACHNER) II, population analysis (preliminary report). Bull. Jpn. Sea Reg. Fish. Res. Lab., **22**, 59–69. (in Japanese).

Okiyama, M. (1988) On the early life history in sandfish. Report of Sandfish Research Council, Akita Prefectural fishery experimental station, **2**, 21–28. (in Japanese).

Okuno, T., H. Kume, T. Yoshiga and T. Yoshizawa (1981) Multivariate analysis. Nikkagiren Syuppansha, Tokyo, Japan, 430 pp. (in Japanese).

Sasao, K. (1999) The survey of fishery resource. Rep. Akita Pref. Fish. Prom. Cent., 65–100. (in Japanese).

Sugiyama, H. (1991) Construction of fishing grounds for sandfish in the waters northern Sea of Japan. Rep. Exp. Res. Jpn. Sea, **21**, 67–76. (in Japanese).

Sugiyama, H. and O. Shibata (1989) Ecological observation of the Japanese Sand Fish *Arctoscopus japonicus* off Akita Prefecture. Jamstectr Deepsea Research, 111–119. (in Japanese).

Tanaka, M. (1987) On the liberation of tagged fish and the subpopulation of sandfish. Report of Sandfish Research Council, Akita Prefectural fishery experimental station, **1**, 43–47. (in Japanese).

Tanimoto, Y., N. Iwasaki, K. Hanawa and Y. Toba (1993) Characteristic variations of surface temperature with multiple time scales in the North Pacific. Am. Meteor. Soc., **6**, 1153–1160.

Yamazaki, S., J. Adachi, N. Tanaka, Y. Yuuki and K. Ishida (1981) The survey for the exploitation of offshore fishing grounds. Rep. Shimane Pref. Fish. Exp. Sta., 34–35. (in Japanese).

Yasuzawa, Y. (1992) Trend in sandfish catch at Niigata Prefecture. Report of Sandfish Research Council, Japan Sea National Fisheries Research Institute, **5**, 17–18. (in Japanese).

密度指数による本州日本海におけるハタハタ2系群の分布境界域の推定

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本州日本海に分布するハタハタは，秋田沿岸と朝鮮半島東岸に主な産卵場を持つ2系群が知られている．本研究では，本州沖から韓国東岸までの日本海を13の海区に区分し，海区別のハタハタ漁獲量，CPUEから計算した密度指数および秋田県沖の体長組成を用い，上記2系群の分布について検討した．結果を以下に示した：(1) 秋田県沖のCPUEの季節変動は4月と10月にピークを持ち，夏季には低下する；(2) 産卵場に近い海区では10月から12月にかけて密度指数が高く，同時期の産卵場から離れた海区での密度指数は低い；(3) 秋田県沖の加入開始年令は1才で，加入時期は3月から4月である；(4)各海区の密度指数の年変動は主成分分析により地理的に2分される．以上の結果から，秋田沿岸を起源とする系群は秋田県沖から若狭沖まで分布し，朝鮮半島東岸を起源とする系群は韓国東岸から能登沖まで分布することが示唆された．

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