SCRS/1998/033 Col.Vol.Sci.Pap. ICCAT, 49 (1) : 387-394 (1999)

PRELIMINARY ANALYSIS ON THE SPATIAL AND TEMPORAL VARIABILITY IN THE SEX RATIO AT SIZE OF THE SWORDFISH IN THE PACIFIC OCEAN BASED ON THE DATA COLLECTED BY JAPANESE LONGLINE TRAINING AND RESEARCH VESSELS

Kotaro Yokawa[1]

SUMMARY

A total of 31,843 sexed size data collected by Japanese longline training and research vessels from 1970 to 1996 were analyzed to see whether the spatial and temporal variability in the sex ratio at size recently reported in the Atlantic also exist in the Pacific. The number of females was higher than males in the second quarter when it was considered to be the spawning season. The ratio of females was higher in the 1970s than in the 1980s and the 1990s at size classes less than 140 cm EFL during the first and fourth quarters in the spawning grounds of the north Pacific. This difference among the decades might be attributed to the historical change in the gear configuration from regular to deep line.

RÉSUMÉ

Des données de taille sur 31.843 poissons capturés par les navires japonais de formation et de recherche entre 1970 et 1996, et dont le sexe avait été déterminé, ont été analysées pour déterminer si la variabilité spatiale et temporelle du sex-ratio par taille signalée dernièrement pour l'Atlantique existait aussi dans le Pacifique. Les femelles étaient plus nombreuses que les mâles pendant le deuxième trimestre, dont on pense qu'il serait la saison de ponte. Le ratio des femelles était plus élevé pendant les années 1970 que pendant les années 1980 ou 1990 pour les classes inférieures à 140 cm de EFL pendant les premier et quatrième trimestres dans les zones de frai du Pacifique Nord. Les différences entre les décennies pourraient être attribuées à l'évolution historique des engins, de la ligne ordinaire à la ligne de profondeur.

RESUMEN

Se analizó un total de 31.843 datos de sexo de pez espada capturado con barcos palangreros japoneses de capacitación e investigación durante 1970 y 1996, para conocer si la variabilidad espacial y temporal del sex ratio por clases de talla recientemente comunicados para el Atlántico también tienen lugar en el Pacífico. El número de hembras fue superior al de machos en el segundo semestre, cuando se sugirió que ésa podría ser la estación de reproducción. El ratio de las hembras fue superior en los años 70 que en los 80 y 90 en las clases de talla inferiores a 140 cm EFL, y en el 1er y 4° trimestre en el caladero del Pacífico norte. Esta diferencia entre las décadas podría atribuirse al cambio histórico en la configuración del arte, de liña tradicional a liña profunda.

1 National Research Institute of Far Seas Fisheries, 5-7-1 Orido, Shimizu, Shizuoka 424, Japan.

Introduction

Spatial and temporal variability in the sex ratio at size has been one of the major issue of the swordfish stock assessment in the Atlantic. Hoey (1986) suggested a difference in migratory pattern between sexes which he called "size-temperate mediated sexual segregation". Turner et al. (1996) revealed the fishing area factor had large effects on observed sex ratio at size. Turner et al. (1997) indicated the effect of year and year*area interactions were significant in the analysis by means of the General Additive Model. Turner et al.. (1996) and Turner et al.. (1997) also pointed out that the temporal effects such as quarters and half year were minor. Mejuto et al.. (1995) reported abnomaly high male ratio in the tropical and subtropical area in the southwest Atlantic and Mejuto et al.. (1997) suggested that this characteristic high male ratio could be considered as an indirect indicator of the area for reproductive activity.

The present paper reviewed the sexed size data collected by Japanese longline training and research vessels in the period between 1970 and 1996 to see whether the above findings about the spatial and temporal variability in the sex ratio at size in the Atlantic would be the case in the Pacific.

Materials and Methods

Sexed size data of swordfish caught by Japanese longline training and research vessels operated in the Pacific were used in this study. All samples measured by eye-fork length to nearest 5cm. Total of 31,843 sexed size data were available since 1970 up to 1996 mainly collected by the Japanese training vessels and some were from the research vessels. All training vessels belong to the high school of fishery science and they collected size data of swordfish during their training cruise of longline. As only a few sexed size data collected by the commercial boat were available, these data were not used in this study.

Results

Data distribution

The data was collected about ten thousands per each decade (Table 1). They were summed up into 5° x 10° rectangle areas and plotted on the map by decade (Fig.1). Through the period between the 1970's to 1990's, most of the data were concentrated in the tropical and sub-tropical areas where the training vessels mainly operated.

Spatial variability of sex ratio

To see the spatial variability of sex ratio, all size data were split into two groups, one is that of fishes larger than 105cm EFL and the other of fishes less than 110cm EFL. The EFL of 110cm was roughly corresponding to the reported size-at-maturity of male.

Figure 2 shows the sex ratio (male/total) of fishes larger than 105cm EFL by each 5° x 10° rectangle area and by quarter. All data of fishes over 105cm EFL between 1970 and 1996 were used. Following Mejuto et al., (1997) who reported that the concentration of male into the area where reproductive activity occurred, the sex ratio at each 5° x 10° rectangle area were expressed by the ratio of the number of male to the total to see the distribution of male.

The number of female was higher than male at the tropical area in the west Pacific and at the tropical and subtropical area in the central Pacific in the 2nd quarter (Fig. 2). The tropical and subtropical areas in the central-east Pacific were suggested to be a spawning ground and the 2nd quarter was suggested to be main spawning season in the northwest Pacific (Yabe et al.. 1959, Uchiyama and Shomura 1974, Nishikawa and Ueyanagi 1974). The number of male seemed to be higher than female in the tropical area in the south central and southeast Pacific in 4th quarter than in other quarters.

Figure 3 shows the sex ratio of fishes less than 110cm EFL by 5° x 10° square and by quarter. High male ratios were observed in almost all areas and quarters.

Spatial variability of sex ratio at size

Yabe et al. (1959) suggested that the Pacific swordfish spawn in February to August at the northwest Pacific (west of 170° E, south of the subtropical convergence). Uchiyama and Shomura (1974) noted that the spawning in Hawaiian waters extended from April through July. In the eastern Pacific, main spawning season was suggested to be from March through July in north hemisphere and to be around January in south hemisphere (Kume and Joseph, 1969).

Based on these information above, one broad spawning ground was hypothesized in the north Pacific (Fig. 4). Although one broad spawning ground, however, were suggested in the tropical area in the south Pacific (Yabe et al. 1959), two separate spawning grounds were set in the south Pacific (Fig. 4) for the analysis of the spatial variability of sex ratio at size because quite a few size data were available in area between two designated spawning ground.

The sex ratio at 10cm length class in each area and quarter was expressed by the number of female to the total followed by the standard way in the ICCAT swordfish working group. Size data in the area outside of the designated spawning ground were only 5% in the north Pacific and 30% in the south Pacific. Because the number of size data outside the designated spawning area were not enough to draw graphs of the sex ratio at size for the transition and feeding areas in both of the north and south Pacific, these data were omitted from the analysis.

Figures 5 shows the sex ratio (female/total) at 10cm EFL classes by quarter at the spawning ground in the north and south Pacific. Data in the period between 1970 and 1996 were used. Data in the two designated spawning grounds in the south Pacific were combined into one because Yabe et al. (1959) suggested one broad spawning ground in the tropical area in the south Pacific. There were no apparent variability observed among quarters in both of north and south Pacific.

Figure 6 shows comparison of the sex ratio at size between two designated spawning areas in the south Pacific. Because of the shortage of the number of data, specific periods which have enough data chosen for the quarterly comparison. The ratio of female at the length class smaller than 180cm in the western spawning ground tended to be higher than that in the eastern spawning ground throughout the year.

Figure 7 shows the sex ratio at 10cm EFL classes by quarter and by decade in the spawning area in the north Pacific. The ratio of female was higher in the 1970's than in the other two decades at the length glasses smaller than 150cm.

Figure 8 shows the comparison of the sex ratio at size between the 1970's and 1990's in both of two spawning areas in the south Pacific. Only the data in 4th quarter in the southwestern spawning area and 3rd quarter in the southeastern spawning ground had enough amounts for comparison. High female ratio under 160cm length classes were observed at 1970's in the 4th quarter in southwestern spawning area while no apparent difference was observed between 1970's and 1990's in the 3rd quarter in the southeastern spawning ground.

Discussion

Quarterly analysis of the sex ratio for fishes larger than 105cm EFL (Fig. 2) suggested that females were concentrating in the spawning area in the north Pacific in 2nd quarter when estimated to be major spawning season by Yabe et al. (1959). On the other hand, the sex ratios at size were similar among quarters in the spawning area in the north Pacific (Fig. 5). These two phenomena indicate that the proportion of the number of catch of large sized female to the total become higher in 2nd quarter than in other quarters. Yokawa and Uozumi (1997) reported that the proportion of the number of catch of large sized female (>150cm EFL) became highest in 2nd quarter of the year in the tropical area in the northwest Pacific. Concentration of mature female in the spawning ground at the spawning season might be the migration pattern of the swordfish stock in the north Pacific.

Observed high male ratio for the fishes less than 110cm EFL irrespective of seasons (Fig. 3) might be result of misunderstanding of sex. All the Japanese training vessels have been identified the sex of swordfish by naked eye observation and the sex of slender and immature gonad of small sized swordfish is very difficult to identify (Uozumi, personal comm.). Investigation by interview to captains of the training vessels would clarify this matter.

The ratio of male seemed to be higher in 1970's than in other decades at the length classes smaller than 140cm in 1st and 4th quarters in the spawning ground in the north Pacific (Fig. 8). One of the possible reasons of this is the historical change in the gear configuration of the training vessels. If daily vertical migration pattern of swordfishes in the spawning area in the north Pacific were different by sex, then change in the number of lines per basket, which has directly effect on the attainment depth of the gear, would cause the change in catchability of gear on each sex. All the training vessels changed their number of lines pér basket from some 5 of 7 lines to more than 10 line around the end of the 1970's (Suzuki, personal comm.). More detailed study with data of the number of lines per basket for each cruise of each training vessel is necessary for the estimation of sex ratio at size by different configuration.

References

Kume, S. and J. Joseph, 1969. Size composition and sexual maturity of billfishes caught by the Japanese longline fishery in the eastern Pacific Ocean east of 130° W. Far Seas Fish. Res. Lab. Bull. 2: 115-162.

Hoey, J.J., 1986. A review of sex ratio by size data for western north Atlantic swordfish. Swordfish workgroup working paper 86/10. NMFS, Miami.

Mejuto, J., J.M. De la Serna and B. Garcia, 1995. An overview of the sex-ratio at size of the swordfish (*Xiphias gladius*) around the world: similarity between different strata. ICCAT Col. Vol. Sci. Pap. Vol. XLIV(3): 197-205.

Mejuto, J., J.M. De la Serna and B. Garcia, 1997. Some considerations on the spatial and temporal variability in the sex ratio at size of the swordfish (*Xiphias gladius* L.). ICCAT SCRS Doc. 97/32. 30pp.

Nishikawa, Y. and S. Ueyanagi, 1974. The distribution of the larvae of swordfish, *Xiphias gladius*, in the Indian and Pacific Oceans. *In* Shomura, R.S. and F. Williams (eds.), Proc. Internat. Billfish Symp. Kailua-Kona, Hawaii, 9-12 August 1972. Part 2. Review and Contributed Papers. U.S. Dep. Comm., NOAA Tech. Rep. NMSF SSRF-675, p. 261-264.

Turner, S.C., F. Arocha, and G.P. Scott, 1996. U.S. swordfish catch at size and catch at age by sex. ICCAT. Col. Vol. Sci. Pap. Vol. XLV(2): 373-378.

Turner, S.C., V.R. Resptrepo and F. Arocha, 1997. Swordfish catch at size and catch at age by sex for the United States. ICCAT SCRS Doc. 95/150. In press.

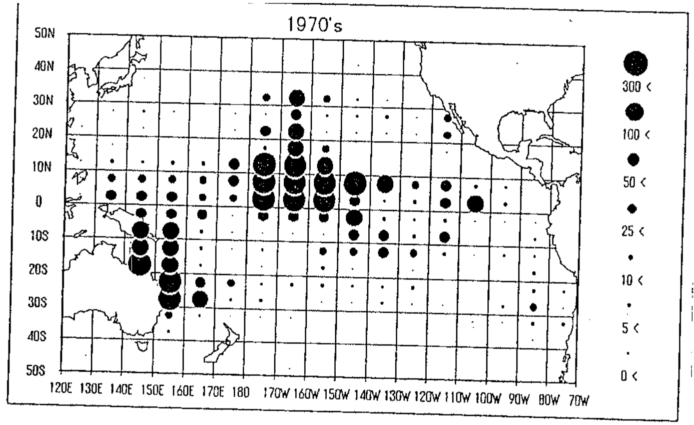
Uchiyama J.H. and R.S. Shomura, 1974. Maturation and fecundity of Swordfish, *Xiphias gladius*, from Hawaiian waters. *In* Shomura, R.S. and F. Williams (eds.), Proc. Internat. Billfish Symp. Kailua-Kona, Hawaii, 9-12 August 1972. Part 2. Review and Contributed Papers. U.S. Dep. Comm., NOAA Tech. Rep. NMSF SSRF-675, p. 142-148.

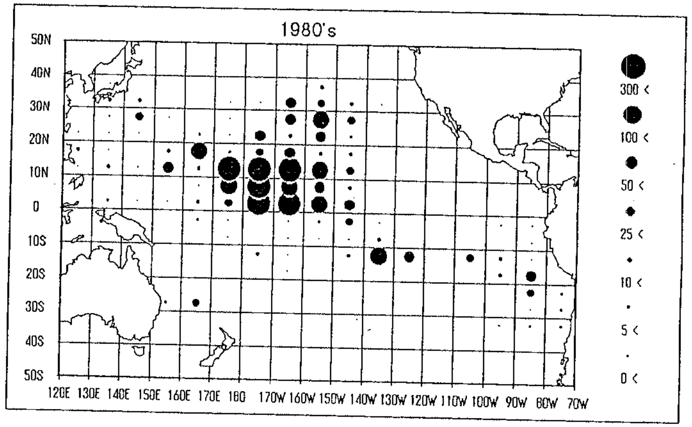
Yabe, H., S. Ueyanagi, S. Kikawa and H. Watanabe, 1959. Study on the life history of the swordfish, *Xiphias gladius* Linnaeus. [In Jap., Engl. summ.] Rep. Nanakai Reg. Fish. Res. Lab. 10: 107-150.

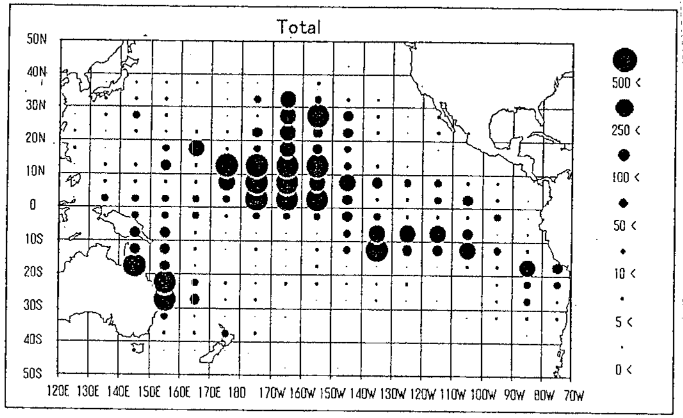
Yokawa, K. and Y. Uozumi, 1997. Evaluation and preliminary analysis of size data of swordfish caught by Japanese longliners during 1970-1994. Working document in 2nd International Pacific Swordfish Symposium, Kahuku, Hawaii, 3-6 March 1997, NMSF, Honolulu.

Table 1. Number of size data used in this study.

	Male	Female	All
1970's	5468	6786	12254
1980's	4792	4188	8980
1990's	6283	4326	10609
Total	16543	15300	31843







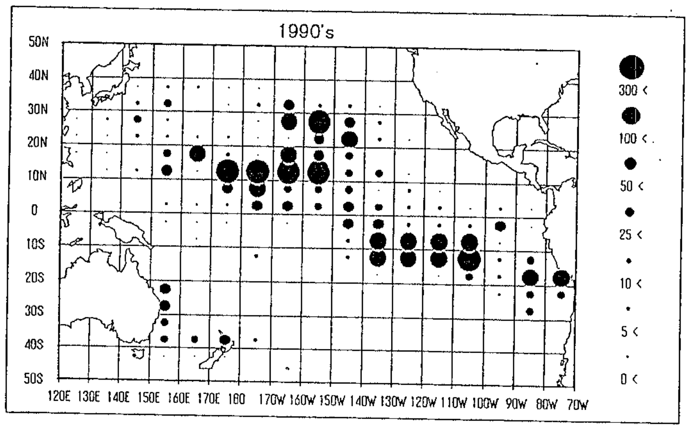


Fig. 1. Distributions of the number of size data used in this study.

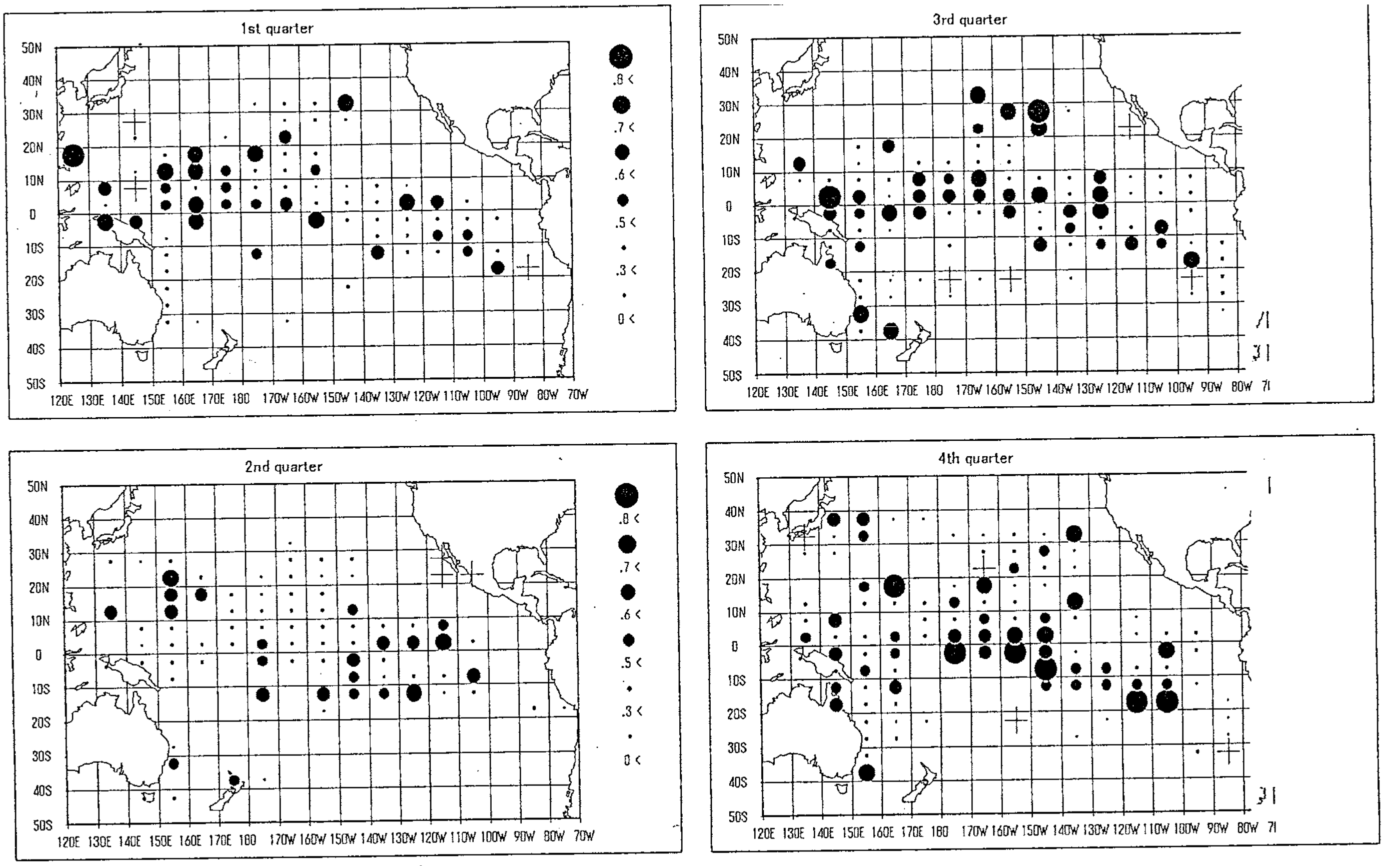


Fig. 2. The sex ratio (male/total) for the fish over 105cm EFL by 5° x 10° square and by quarter. Data in the period between 1970 and 1996 were used.

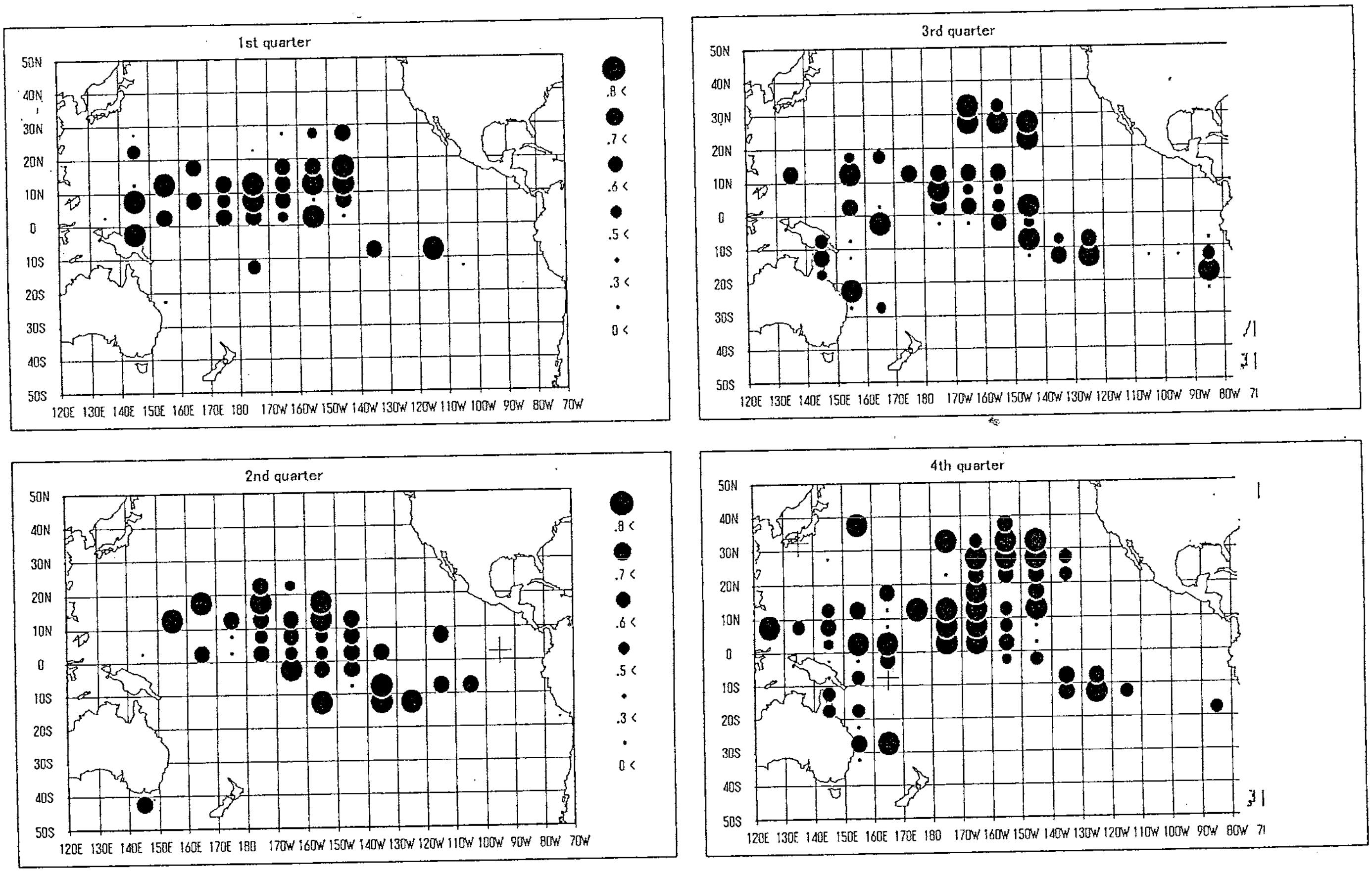


Fig. 3. The sex ratio (male/total) for the fish less than 110cm EFL by 5° x 10° square and by quarter. Data in the perioc between 1970 and 1996 were used.

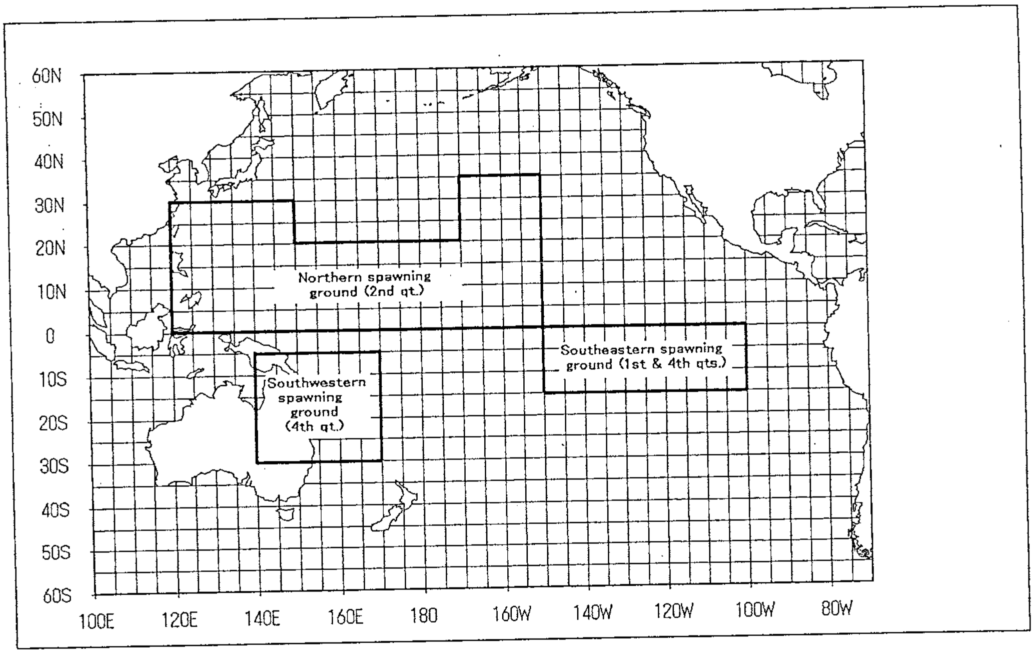


Fig. 4. Designated areas of spawning graound and their spawning seasons.

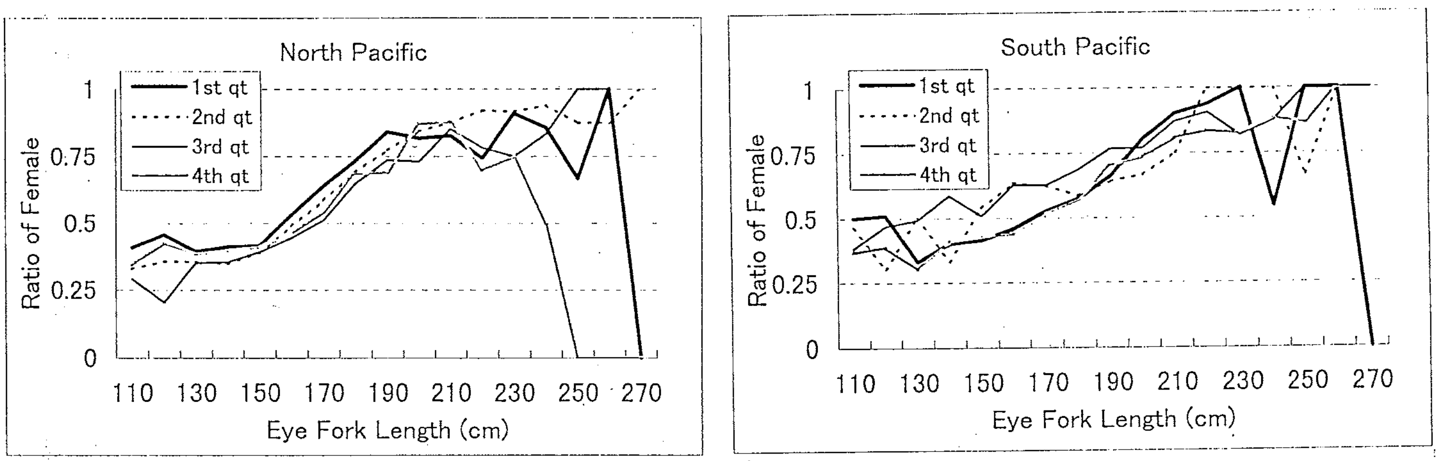


Fig. 5. Sex ratio (female/total) at 10cm length class by quarter in the spawning ground in the north (right) and south (left) Pacific

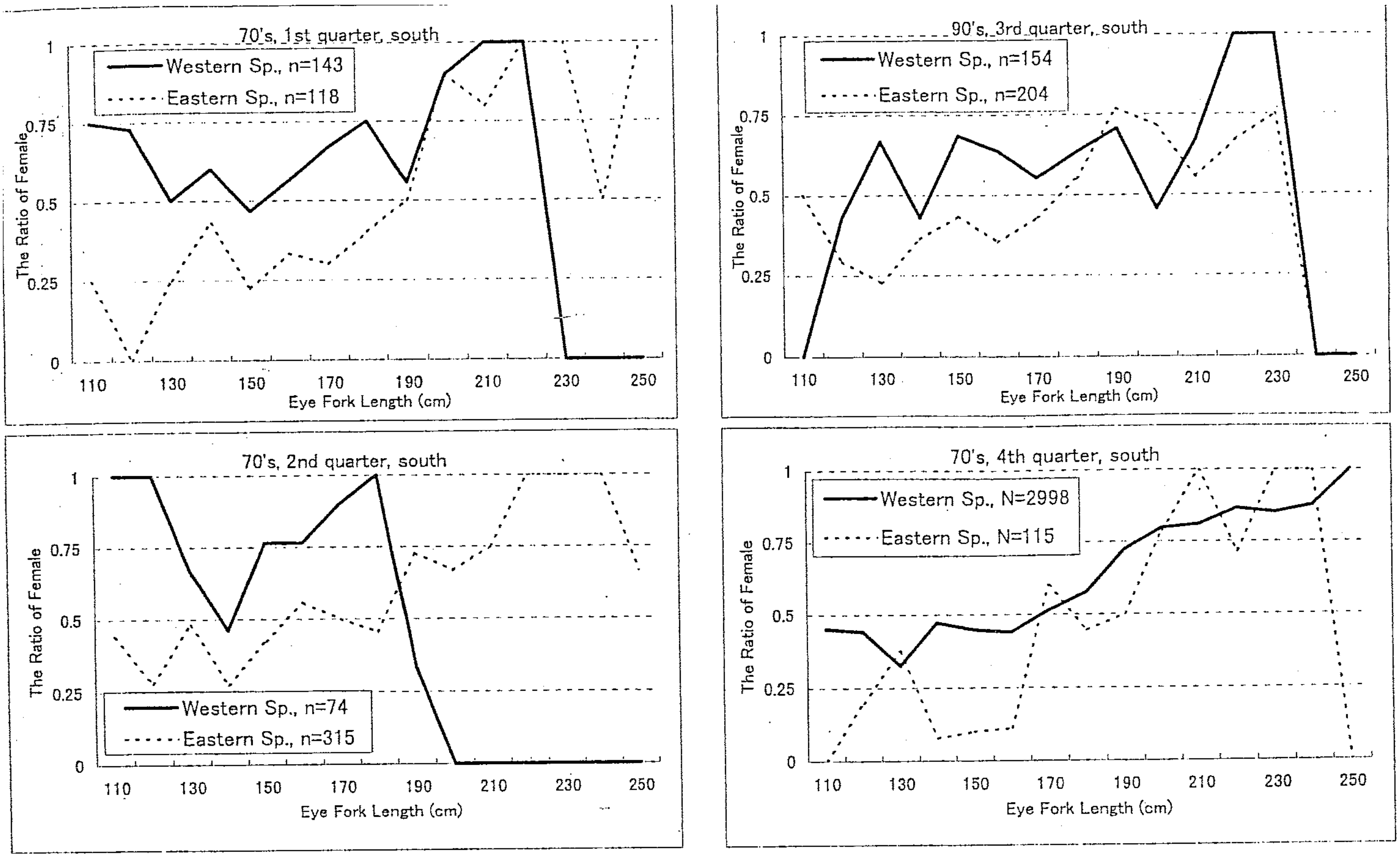


Fig. 6. Comparisom of the sex ratio (female/total) at size between the southwestern and southeastern spawning grounds. Data used were 1970's in 1st quarter (left–top), 1970's in 2nd quarter (left–bottom), 1990's in 3rd quarter (right–top) and 1970's in 4th quarter (right–bottom).

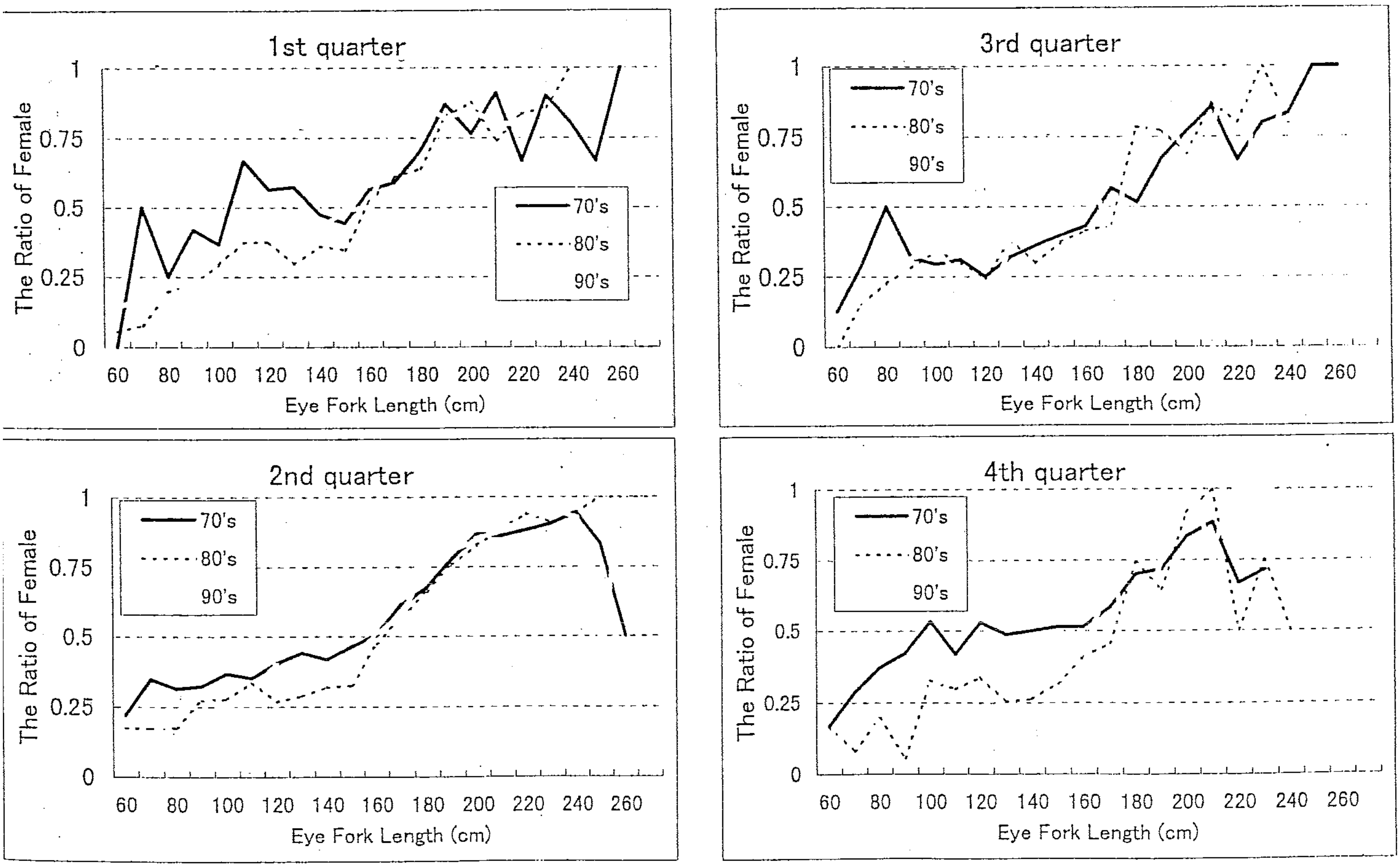
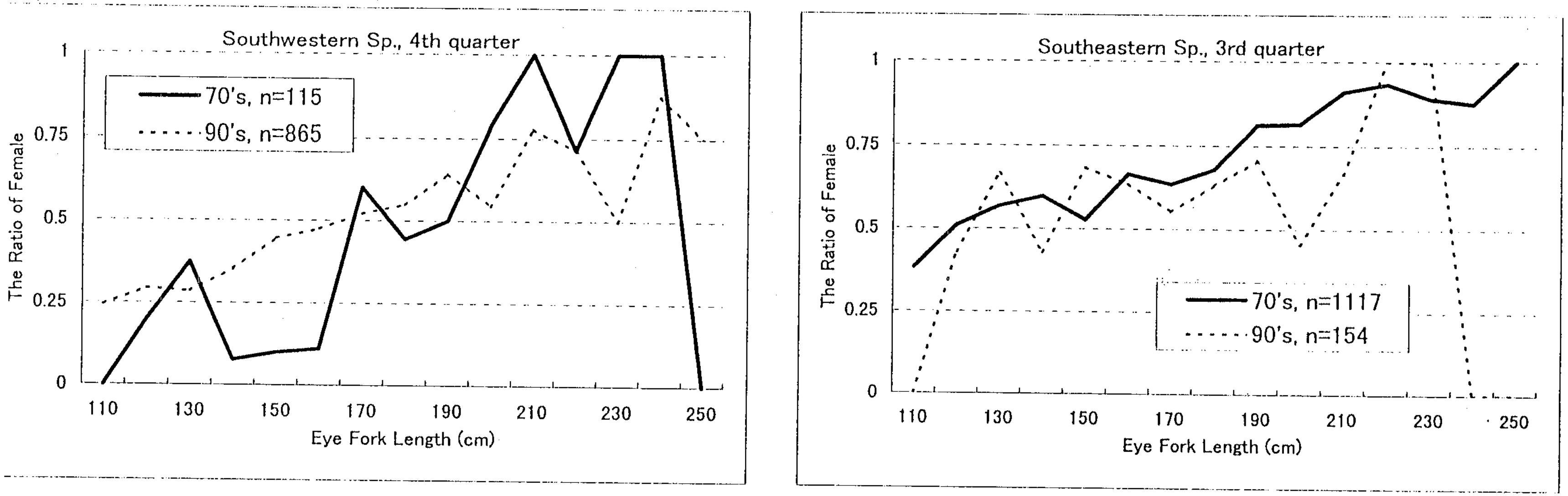


Fig. 7. Sex ratio (female/total) at 10cm length classes by quarter and by decade in the spawning area in the north Pacific.



ig. 8. Temporal variability in the sex ratio at size in the spawning are in the south Pacific. Data used were or comparisom were of 4th quarter in the southwestern spawning area (right) and of 3rd quarter in the outheastern spawning area (left).