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OCEANOGRAPHY AND TUNA FISHERIES IN THE INTER-TROPICAL WESTERN PACIFIC

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SUMMARY

In the western and central tropical Pacific, sea surface temperature has a rather weak seasonal variability, much less than its inter-annual variability due to the ENSO (El Nino Southern Oscillation) phenomenon. However, previous studies show the prominent role on tuna fisheries of the major currents pattern and the 35‰ isohaline, a good indicator of the equatorial upwelling.

At ORSTOM's laboratory in Nouméa, oceanographers are working on three topics related to oceanography, biological production and fisheries.

- The SURTROPAC team manage the XBT Ships of Opportunity Programme in the western Pacific, which gives a good semi-real time description of the main oceanographical events (seasonal and interannual variability) in the region; furthermore, good results were obtained on ocean modelling from wind and sea level information in collaboration with US scientists.

- PROPPAC is another major programme, aimed at evaluating the relationships between hydrological structures and the planctonic biomass and production in the western Pacific.

- Lastly, the TUNA-ENVIRONMENT programme investigates the impact of environmental variability (seasonal and inter-annual) on the distribution and availability of tunas to the different surface fishing gears, using the data bases available at ORSTOM (oceanography) and at the Tuna and Billfish Assessment Programme of the South Pacific Commission (tuna fisheries statistics); this is a collaborative effort between these two organisations. Some preliminary results of this study are presented hereafter.

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1- INTRODUCTION

For oceanic pelagic species such as tunas, information on the variations of oceanographical parameters is as important as the one on their average value: whereas parameters are generally related to fish behaviour (availability and/or catchability) or fluctuations not related to the fishery itself (recruitment for example), their average values may explain their general ecology (area of distribution, migration ...).

Firstly, we will present the main open-sea related programmes conducted in Nouméa by ORSTOM scientists. This will be followed by a brief description of the general oceanic features in the southwest Pacific. Lastly, the TUNA-ENVIRONMENT programme is described, and preliminary results presented.

2- HIGH SEAS OCEANOGRAPHICAL RESEARCH IN NOUMEA

In ORSTOM's laboratory in Nouméa, oceanographers are working on three topics related to the open-ocean: oceanography (SURTROPAC), biological production (PROPPAC) and fisheries (TUNA-ENVIRONMENT).

SURTROPAC:

Since 1969, the SURTROPAC (SURvey of TROpical PACific) Group has gathered surface data (sea surface temperature and salinity, meteorological information) from Ships of Opportunity in the western tropical Pacific. Starting in 1979, this collection was extended to XBT data (in collaboration with the Scripps Institution of Oceanography) and surface chlorophyll content (DANDONNEAU, 1988); the programme became fully operational in September 1980 between 20°N-20°S, and routinely provides data along four main shipping lines: New Caledonia-Japan, New Caledonia-California, New Caledonia-Tahiti-Panama, Tahiti-California (DONGUY, 1985).

At the end of 1985, as part of a cooperative french-US programme, this set of data was augmented with supplementary data from several other national agencies; this allowed the volume of data available to more than quadruple in size. The corresponding 1979-85 XBT coverage in the inter-tropical Pacific is shown in Fig. 1 (PICAUT *et al*, 1988). This work was aimed at quantitatively evaluating the accuracy of a wind-driven oceanic model of the seasonal (BUSALACCHI and O'BRIEN, 1981) and inter-annual (BUSALACCHI *et al*, 1983) variations of surface dynamic heights and sea levels. Relatively good results were obtained (McPHADEN *et al*, 1988a, 1988b), even if some limitations were due to the spatial distribution of the data (wind fields, XBT).

In January 1984, as part of the TOGA programme, ORSTOM's oceanographers initiated a series of bi-annual cruises (January and July, 1.000 m deep hydrographic and current sections) along the 165°E meridian, from 20°S to 10°N. This allowed a more precise definition of the main oceanographical events, in addition to the Ship of Opportunity Programme (DELCROIX *et al*, 1987). A detailed description of the results from the 10 cruises conducted from January 1984 to June 1988 is reported in ELDIN (1989). An atlas of data available in the southwest Pacific (10-24°S, 160°E-140°W) was also produced by the SURTROPAC group (DELCROIX and HENIN, 1989) with the SPREP's support.

PROPPAC:

This second major programme, which began in 1987, is described in LE BORGNE (1985). Its purpose is to estimate the influence of climatic variations, through the hydrological structure, on the open ocean pelagic production in the western tropical Pacific . Two goals are pursued: estimating empirical relationships between hydrology and biomass, and studying the mecanisms of the planctonic production in open-seas. As hydrographical parameters are easier to monitor on long time periods than the biological ones, the study is focused on the evaluation of the relationships between the vertical distribution of hydrological and chemical parameters and the biomass and production of the first levels of the trophic network (phyto and zooplancton). In addition to their specific participation to the SURTROPAC cruises (by adding them a biological component), two additionnal annual cruises are done (April and September, along 165°E from 20°S to 5°N, including a one week stationnary station at the equator). Some preliminary results showing the differences between ENSO and "non-ENSO" periods of oceanographic features as well as in the resulting biological production will be presented in a separate Information Paper at the 21th Regional Technical Meeting on Fisheries.

TUNA-ENVIRONMENT:

This third programme is carried out in collaboration between ORSTOM's "Environment and High Seas Resources" Research Unit in Nouméa and the Tuna and Billfish Assessment Programme (TBAP) of the South Pacific Commission. It consists of a study to gauge the impact of the environmental variability (seasonal as well as inter-annual) on the distribution and availability of tunas to the different fishing gears, using ORSTOM's (oceanography) and TBAP's (tuna fisheries statistics) data bases. Some preliminary results of this study are presented below.

3- THE GENERAL OCEANOGRAPHIC SITUATION IN THE SOUTH WEST PACIFIC.

The general climatology and circulation in the inter-tropical western Pacific is now relatively well known (DONGUY, 1985; DELCROIX *et al*, 1987; INOUE *et al*, 1987; TOOLE *et al*, 1987). The circulation is characterised by a well developed system of currents and countercurrents. From 20°N to 20°S, one can successively find:

-the North Tropical Countercurrent (NTCC): flowing eastward, north of 16°N;
-the North Equatorial Current (NEC): flowing westward between 8 and 16°N, at a mean maximum speed of 10 cm/s, 150 m thick;
-the North Equatorial Countercurrent (NECC): flowing eastward between 2 and 8°N, at a mean maximum speed of 30 cm/s, 150 m thick;
-the northern branch of the South Equatorial Current (SECN): flowing westward between 2°N and 6°S, at a mean maximum speed of 30 cm/s, 200 m thick, surmounting the Equatorial Under Current (EUC), flowing eastward between 3°N and 3°S at a mean maximum speed exceeding 50 cm/s, from 150 to 300 m deep;
-the South Equatorial Countercurrent (SECC): flowing eastward between 6 and 11°S, at a mean maximum speed of 10 cm/s, 50-100 m thick;
-the southern branch of the South Equatorial Current (SECS): flowing westward between 11 and 15°S, at a mean maximum speed of 5 cm/s, 200 m thick;
-the South Tropical Countercurrent (STCC): flowing eastward, south of 15°S.

A latitudinal section of this mean characteristic upper-layers circulation (as estimated from XBT computed geostrophic currents) during the "non-ENSO" period, from 20°N to 20°S, is exhibited in Fig. 3 (from TOURNIER, 1989); a more detailed description can be found in DELCROIX *et al*, 1987. This system is subject to seasonal variations on a semi-annual basis, as can be observed in Fig. 4.

The ENSO phenomenon (El Nino Southern Oscillation) is an anomalous event which takes place at irregular intervals of two to seven years (four on the mean), and lasting 18-24 months. It results in major perturbations in both worldwide climate and ocean surface and sub-surface structures and parameters of the equatorial Pacific: considerable warming of the upper layer, rising of the thermocline in the west and lowering in the east, strong variations (and even reversal) in the intensity of the main currents, low tradewinds with frequent westerlies, high precipitations on the dateline and drought in the western Pacific. Two ENSO events occurred during the period in which the study took place: the first in 1982-83 (the strongest ever observed) and the second in 1986-87 (relatively moderate, but significant in the western Pacific); an aborted ENSO was also noticed in 1980. Since mid 1988, a strong anti-El Nino (sometimes called La Nina) event developed across the entire equatorial Pacific, characterised by an intense equatorial upwelling. The influence of this phenomenon on the tuna fisheries will be investigated as soon as the fisheries and oceanographical data are available.

3- THE TUNA-ENVIRONMENT STUDY

3.1- PRESENTATION:

Numerous studies have shown the prominent role of oceanography on the distribution and availability of pelagic fishes -including tunas- for which a comprehensive review was carried out by SUND *et al*, 1981. In the tropical Pacific, the extensive roles of the major current patterns and water types (YAMANAKA *et al*, 1969; TANAKA and YAO, 1980) as well as the 35‰ isohaline, considered as a good indicator of the equatorial upwelling (DONGUY *et al*, 1978), were evidenced.

These analyses pointed out the role played by the equatorial upwelling and the general oceanic circulation on the size distribution and catch of the Japanese baitboats. However, since these studies, important changes have occurred in the fishery (dramatic increase of the purse-seine fishery, implementation of the new Law of the Sea) as well as in oceanographic surveillance (XBT from Ships of Opportunity, large scale studies such as the TOGA Programme).

The target of this programme is to use the knowledge of hydroclimatic phenomena and biological information to assess the spatio-temporal distribution of tunas, their behaviour and their disponibility to the different fishing gears. The first step will be to correlate the monthly catches and raw catch per unit of effort (cpue) by elementary rectangles (2° latitude x 5° longitude) with the different oceanographic parameters available in order to identify the more relevant. In a second step, an attempt of modelling will be undertaken by applying the model used in the Atlantic Ocean during the International Skipjack Year (MENDELSSHON and ROY, 1986), including parameters related to the thermal structure and using geographical strata based on the currents-countercurrents or convergence-divergence systems in the western Pacific.

In a first instance, this study was limited to the western part (135-180°E) of the tropical Pacific, from 6°S to 16°N, according to the distribution of fisheries data. Following Tanaka's hypothesis about the relationship between pole-and-line catch rates and the major currents, this area was divided into six sub-areas (Fig. 2) based on the mean latitudinal current system distribution shown in Fig. 3: three in latitude (6°S-2°N: northern branch of the South Equatorial Current and Equatorial Under Current, SECN and EUC; 2-8°N: North Equatorial Counter Current, NECC; 8-16°N: North Equatorial Current, NEC), and two in longitude (135-160°E, 160-180°E). The time series of the different parameters were estimated as standardised anomalies from the 1979-1987 period.

3.2- THE DATA USED:

<u>Oceanography:</u>

Surface and extended thermal structure data bases issued from the Ships of Opportunity Programme from 30°N to 30°S, 120 to 180°W were used; they consist in surface data from 1969 (namely 6 parameters: temperature, salinity, sea status, cloudiness, wind direction and stress) and the extended XBT database and sea surface chlorophyll content from 1979; only data from January 1979 were used. Anomalies (*i.e* standardised deviations from the whole period mean) were computed in the six subareas for the following parameters: sea surface temperatures, salinities and chlorophyll contents, depth of the isotherms 27°C (an estimate of the upper mixed layer thickness) 24° and 20°C (as indicators of the thermocline depth and gradient). The mean monthly intensity of the geostrophic currents computed from the XBT data base (1979-85) are reported in Fig. 4 (from TOURNIER, 1989); Fig. 5 exhibits the 27, 24 and 20°C isotherms depth in the western part of the studied area (21, 31 and 41).

Tuna fisheries:

The bulk of the statistics comes from Japan, through access agreements with SPC member countries. Until now, most of the other data were either unavailable, scarce or unreliable, and thus could not be taken in account for this work.

The **pole-and-line fishery** is quite exclusively Japanese, its catch -almost entirely skipjack- ranging from 25 to 50.000 tons in the SPC area (source SPC). The number of pole-and-line vessels declined from more than 200 in 1980 to some 100 in 1987, although the total yield remained at a comparable level. Nevertheless, it must be emphasized that SPC statistics cover only 30-40% of the estimated total catch in the western Pacific. The fishery is highly seasonal, most of the pole-and-line vessels leaving the area from May to October to fish in international waters more north and east. Their mean quarterly effort distribution (1984-87) is reported in Fig. 6 (HAMPTON, 1988). The bulk of the effort is concentrated in the Micronesian area (Federated States of Micronesia, Marshall Islands and the western part of Kiribati) and, to a lesser extent, in Papua New Guinea, Solomon Islands and Fiji.

The **purse-seine fishery** is carried out by some 120 vessels from more than 10 countries (Japan, Korea, Taïwan, USA, ...) and catches reported to SPC over recent years have amounted to 100-150.000 tons these last years (reaching 220-320 000 tons in 1984-85 when US statistics were made available); SPC statistics are estimated to cover about 50% of the real western Pacific catch. Yellowfin catch is quite important, reaching 25-35% of the total yield. Two substantially different seining methods are used: log sets (carried out on flotsam, and catching a mixture of skipjack and young yellowfin) and school sets (carried out on free-swimming schools, catching mainly yellowfin of larger sizes); both methods were separated for the analysis. The mean quarterly effort distribution of purse-seine vessels (1984-87) is reported in Fig. 7 (HAMPTON, 1988). Most of the effort is concentrated in the western Pacific (Federated States of Micronesia, Papua New Guinea and Kiribati), but US purse-seiners are estimated to be fishing further east. The seasonality is less pronounced than for pole-and-liners, with some north-south shifting and discrepancies between logs and schools fishing.

The **longline fishery**, although important (some 600 vessels, mainly from Japan, Korea and Taïwan) was not taken into account in this study. Studies on the impact of the environment on this fishery were recently carried out in Japan (SUZUKI, 1988; MIYABE *et al*, 1988 in press).

In order to have a sufficiently homogeneous set of catch and effort data, only Japanese baitboats of 200-300 tons and purse-seiners of 200-500 tons from 1979 to 1988 were retained initially as being representative of the fishery. Assuming that the resource has been exploited quite recently (at least regarding the surface fishery) and at a relatively low level (SIBERT, 1986; HAMPTON, 1988), the stock abundance will be considered as stable and the monthly raw cpue computed representative of the catchability of the different gears.

3.3- PRELIMINARY RESULTS:

The results presented are limited to the western part of the area (west of 160°W, sub-areas 21, 31 and 41) where both pole-and-line and purse-seine fisheries are present. As previously mentioned, they are characterized by their currents, respectively the NEC (area 21), the NECC (area 31) and the SECN/EUC system (area 41). Figs 8, 9 and 10 exhibit the standardized anomalies of sea surface temperatures (SST), salinities (SSS) and chlorophyll contents (SSC), mixed layer depth (Z27), thermocline depth (Z20), geostrophic currents intensities, pole-and-line and purse-seine (logs and schools sets separated) skipjack cpues, respectively in areas 21, 31 and 41. Total catch (in metric tons) and effort (fishing and searching days pooled) by areas by pole-and-line and purse-seine vessels are reported in Tables 1 and 2.

Area 21 (Figs 5a and 8, NEC):

SST shows a seasonal pattern (27-31°C), with no evident anomaly due to the 82/83 ENSO event; SSS were high in 81, with a relatively strong negative anomaly in 82; SSC vary greatly, with strong values at the end of 83 and for the second half of 84. XBTs reflect quite well the 82/83 episode, with some discrepancies in the variations of the Z27 and Z20 depth. They show a marked rise of the thermocline and a thin upper mixed layer, the 27°C isotherm reaching the surface during the first quarter of 83; for the 86/87 event, the phenomenon is shorter and less intense. The NEC shows a weak seasonality (maximum in October-January) and a strong negative anomaly in the second quarter of 83, followed by a higher intensity in the third quarter of 84.

In this area, fishing is carried out exclusively by pole-and-line vessels, with a small effort from purse-seiners. The effort is strongly seasonal (February-April), and was low in 82, with an eastward shift (towards area 22) in early 83; skipjack catches reflect the effort distribution, generally increasing the anomalies. Skipjack cpues are also strongly seasonal, with a maximum in January-May and a minimum in June-October; they were particularly high during the second quarter of 83 and 86.

Area 31 (Figs 5b and 9, NECC):

SST shows no clear seasonal pattern (28-31°C), and the 82/83 ENSO event is more evident, with relatively high SST in 81-early 82, followed by low SST in 83. SSS are more seasonal (maximum during the first half-year, in connection with the equatorial upwelling), with a negative anomaly in 82 followed by high values in the first half of 83. SSC vary greatly with no marked seasonal pattern, and exhibit a strong positive anomaly from mid 82 to mid 83, as evidenced by DANDONNEAU (1986, 1988); 84 SSC anomalies are also relatively high, as they were in area 21. The variations of Z27, Z24 and Z20 are synchronous, and reflect well the 82/83 (+40m rising) and 86/87 (+30m rising) ENSO events; the aborted 80 warm episode is also apparent. The NECC is rather seasonal (maximum in July-October), and showed a marked positive anomaly in the second half of 82, followed by a strong negative anomaly in 83; it remained at a low level in 84.

Both pole-and-line and purse seine vessels are operating in this area. Their effort is strongly seasonal, more with respect to pole-and-liners (November-May, peak in February-April) than purse-seiners (April-August). Pole-and-line effort, which is generally higher in area 32 than in area 31, showed a strong eastward shift during 82-83, which was not observed in 86-87; on the contrary, purse-seine effort shows no anomaly, probably due to the low effort exerted before 84. Catches still reflect the distribution of effort. Skipjack cpue is strongly seasonal for both gears: maximum in January-May and minimum in June-October for pole-and-liners, while for purse-seiners the situation is somewhat different regarding the fishing method (maximum in October-February for school sets, December-May for log sets); for yellowfin, the seasonal pattern is similar but less marked. High cpue anomalies were observed in the second quarter of 83 and 86 for pole-and-line and log sets, and the first quarter of 88 for all purse-seiners.

Area 41 (Figs 5c and 10, SECN-EUC):

In this area, SST has a weak seasonal pattern (27-31°C), but the 82/83 ENSO warming is clear, with high SST in 81-early 82, followed by low to normal SST up to 86. SSS are also weakly seasonal (maximum in October-January), with a strong positive anomaly in 81. SSC are higher and less variable than in the other areas, with a weak seasonal pattern (maximum November-February).

Z27, Z24 and Z20 variations are synchronous, and reflect well the 82/83 (+50m rising) and 86/87 (+40m rising) ENSO events. The SEC is quite strongly seasonal (maximum in February-April, minimum in June-August), but remained very weak from mid 82 to the end of 83; in fact, a strong reversal of this current was observed during this period, as it was during the 86/87 event (cf reports of SURTROPAC cruises). The EUC is also strongly seasonal (maximum in June-August, minimum in October-April), opposite of the SEC; this maximum was weaker than usual in 82/83, stronger in 84.

Pole-and-line effort is relatively low (higher in area 42 than in area 41), with a strong seasonality (no fishery from May to August), while the purse seine effort is high with no evident seasonality; catches still reflect the effort distribution. Skipjack cpue is strongly seasonal for pole-and-line (as the effort was); for purse-seine, the seasonality is not very high, more marked for school sets (maximum March-May) than for log sets (maximum April-May). The seasonal pattern for yellowfin is rather weak. Positive cpue anomalies were observed in the third quarter of 83 (for the three gears), the first quarter of 86 (pole-and-line and log sets) and from October 86 to January 87 (purse-seine).

3.4- RELATIONSHIPS BETWEEN CPUE AND OCEANOGRAPHY:

A raw attempt was made to estimate the relationships between geostrophics currents as well as the thermocline (Z20) and mixed layer (Z27) depths and the pole-and-line and purse-seine (log and school sets) skipjack cpues. The principal results are reported in the table below:

Area	Parameter	Pole-and-line		Purse-seine Log sets		Purse-seine School sets	
21	NEC	-0.26	(+)	-		-	
	Z20	0.03	(NS)	-		-	
22	NEC	-0.44	(+++)	-		-	
	Z20	0.29	(++)	-		-	
31	NECC	-0.47	(+++)	-0.19	(NS)	-0.24	(NS)
	Z20	0.03	(NS)	0.40	(+++)	0.04	(NS)
	Z27	0.36	(+++)	0.19	(NS)	0.06	(NS)
32	NECC	-0.36	(+++)	-		-	
	Z20	0.33	(++)	-		-	
	Z27	0.25	(+)	-		-	
41	SEC	0.05	(NS)	0.28	(++)	-0.17	(NS)
	EUC	-0.22	(NS)	-0.39	(+++)	0.12	(NS)
	Z20	-0.27	(NS)	0.12	(NS)	-0.17	(NS)
	Z27	-0.25	(NS)	-0.03	(NS)	-0.14	(NS)

NS : not significant; + : significant at 10%;
++ : significant at 5%; +++: significant at 1%

Pole-and-line cpues generally show a relatively good correlation with the geostrophic current intensity estimate, in all areas except 21 and 41, possibly because of the more scarce data in those areas. This result confirms Tanaka's hypothesis (TANAKA and YAO, 1980; MARCILLE and BOUR, 1981) regarding the important role of currents, but with a negative relationship instead of a positive one; nevertheless, it must be emphasised that these observations were based on observed instantaneous currents and not on the general circulation (*i.e* water masses transports), and that no catch data were available from the NTCC area; another possible interpretation may be a bias related to the extremely strong 82/83 ENSO event. A relationship is also observed with the thermocline depth (area 22) and the warm mixed layer thickness (areas 31 and 32), although less significant..

Purse-seine results are more ambiguous: surprisingly, no effect could be found regarding school sets, even with the thermocline depth; for log sets, the SECN and EUC have an effect on skipjack cpues (positive for the former, negative for the latter, probably increased because of their opposite variations); the thermocline depth is also positively significant in area 31. On a general basis, results regarding this general lack of relationships between purse-seine catches and thermocline depth may have several explanations: 1) the relative scarcity of the catch data; 2) the period in which the study was carried out, highly affected by two ENSO warm episodes with no marked cold episode between them; and 3) the area stratification and extent used (based on current considerations), which are not homogeneous regarding thermocline depth.

Regarding a general ENSO effect, warm events had a positive effect on pole-and-line catches, during the beginning and first part of the peak period of the 82/83 event, somewhat sooner for the 86/87 event; the result is less evident for purse-seiners (few data in 82/83, low to medium results in area 31 and 41 in 86/87).

These results are in accordance with information from Japanese papers (Suisan Taushin, 12 March 1987; Katsuo-Maguro Tsushin, 13 October 1987) reported in the FFA News Digest (January 1988).

CONCLUSION

These results are preliminary, and have to be put into perspective because of the shortness of the time series, particularly for the currents estimates. Further work must be achieved, particularly by taking into account the 1969-78 period and including data from the US and other distant water fishing nations for the more recent period as soon as they are made available.

New techniques involving wind driven oceanic modelisation of the seasonal and inter-annual variations of surface dynamic heights and sea levels may give reasonable results, despite some limitations due to the spatial distribution of the data (wind fields, XBT), and offer large possibilities to environment related studies. Preliminary results obtained by oceanographers from GEOSAT altimetry data are very promising. Knowledge of the relationships between tuna fisheries and the oceanographical structure (such as convergence-divergence system, currents pattern, thermocline role, biological productivity) may greatly benefit from the combined efforts of these studies which can give a strong enhancement to tunas fisheries related oceanography.

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Table 1: Total effort and catch by area (see Fig. 2) from 200-300 TJB Japanese pole-and-line (Source: SPC).

Fishing effort (searching and fishing days combined):

Year	Area	21	Area	22	Area	31	Area	32	Area	41	Area	42	TOTAL
79	2 341	40.5%	4	0.1%	2 384	41.3%	613	10.6%	216	3.7%	221	3.8%	5 779
80	845	12.8%	9	0.1%	2 702	40.9%	2 415	36.6%	151	2.3%	480	7.3%	6 602
81	810	15.7%	569	11.0%	1 141	22.1%	1 298	25.2%	179	3.5%	1 156	22.4%	5 153
82	342	8.5%	1 234	30.6%	251	6.2%	1 963	48.7%	50	1.2%	188	4.7%	4 028
83	1 023	17.5%	0	0.0%	496	8.5%	4 038	69.0%	180	3.1%	116	2.0%	5 853
84	478	8.0%	0	0.0%	3 187	53.1%	2 088	34.8%	77	1.3%	170	2.8%	6 000
85	471	12.8%	0	0.0%	1 036	28.1%	1 603	43.5%	108	2.9%	466	12.6%	3 684
86	1 150	24.7%	252	5.4%	2 087	44.8%	1 006	21.6%	34	0.7%	127	2.7%	4 656
87	479	24.3%	506	25.7%	195	9.9%	555	28.2%	7	0.4%	229	11.6%	1 971
88	434	52.6%	85	10.3%	125	15.2%	165	20.0%	0	0.0%	16	1.9%	825
Mean	837	18.8%	266	6.0%	1 360	30.5%	1 574	35.3%	100	2.2%	317	7.1%	4 455

Total catch (metric tons. all species combined):

Year	Area	21	Area	22	Area	31	Area	32	Area	41	Area	42	TOTAL
79	10 312	40.4%	10	0.0%	9 853	38.6%	3 357	13.2%	937	3.7%	1 035	4.1%	2 5504
80	3 022	9.1%	60	0.2%	12 915	38.8%	13 875	41.7%	569	1.7%	2 815	8.5%	33 256
81	3 401	11.7%	4 578	15.8%	4 264	14.7%	7 020	24.2%	1 235	4.3%	8 547	29.4%	29 045
82	1 078	7.4%	3 381	23.4%	1 183	8.2%	7 686	53.1%	283	2.0%	866	6.0%	14 477
83	6 692	12.9%	0	0.0%	4 267	8.2%	38 716	74.5%	1 630	3.1%	656	1.3%	51 961
84	2 044	5.2%	0	0.0%	20 916	52.7%	14 885	37.5%	371	0.9%	1 465	3.7%	39 681
85	1 384	8.2%	0	0.0%	3 988	23.5%	8 076	47.6%	294	1.7%	3 231	19.0%	16 973
86	8 240	21.0%	2 469	6.3%	18 660	47.5%	8 537	21.7%	252	0.6%	1 141	2.9%	39 299
87	2 957	19.6%	6 204	41.1%	918	6.1%	3 483	23.1%	13	0.1%	1 534	10.2%	15 109
88	2 744	45.2%	722	11.9%	771	12.7%	1 773	29.2%	0	0.0%	56	0.9%	6 066
Mean	4 187	15.4%	1 742	6.4%	7 774	28.6%	10 741	39.6%	558	2.1%	2 135	7.9%	27 137

Table 2: Total effort and catch by area (see Fig. 2) from 200-500 TJB Japanese purse-seiners (Source: SPC).

Fishing effort (searching and fishing days combined):

Year	Area	31	Area	32	Area	41	Area	42	Area	51	TOTAL
79	0	0.0%	0	0.0%	257	76.5%	0	0.0%	0	0.0%	336
80	0	0.0%	0	0.0%	108	57.4%	0	0.0%	0	0.0%	188
81	6	0.9%	0	0.0%	526	82.6%	22	3.5%	2	0.3%	637
82	5	0.8%	0	0.0%	518	85.5%	1	0.2%	0	0.0%	606
83	26	3.7%	0	0.0%	586	84.2%	0	0.0%	1	0.1%	696
84	193	9.7%	0	0.0%	1 706	86.0%	0	0.0%	0	0.0%	1 983
85	1 206	31.7%	30	0.8%	2 449	64.4%	30	0.8%	0	0.0%	3 800
86	1 975	49.7%	40	1.0%	1 830	46.1%	40	1.0%	0	0.0%	3 971
87	2 593	62.6%	44	1.1%	1 369	33.1%	42	1.0%	5	0.1%	4 140
88	708	58.5%	1	0.1%	414	34.2%	0	0.0%	0	0.0%	1 211
Mean	671	38.2%	12	0.7%	976	55.5%	14	0.8%	1	0.1%	1 757

Total catch (metric tons. all species combined):

Year	Area	31	Area	32	Area	41	Area	42	Area	51	TOTAL
79	0	0.0%	0	0.0%	4 596	98.3%	0	0.0%	0	0.0%	4 675
80	0	0.0%	0	0.0%	3 107	97.5%	0	0.0%	0	0.0%	3 187
81	1	0.0%	0	0.0%	8 934	94.8%	390	4.1%	20	0.2%	9 426
82	0	0.0%	0	0.0%	9 305	98.7%	45	0.5%	0	0.0%	9 432
83	474	4.2%	0	0.0%	10 859	95.1%	0	0.0%	0	0.0%	11 416
84	2 650	6.6%	0	0.0%	37 147	93.1%	0	0.0%	0	0.0%	39 881
85	24 255	32.9%	857	1.2%	47 773	64.7%	857	1.2%	0	0.0%	73 827
86	51 588	50.0%	967	0.9%	49 538	48.0%	967	0.9%	0	0.0%	103 146
87	55 592	62.4%	810	0.9%	31 706	35.6%	810	0.9%	90	0.1%	89 095
88	19 052	65.3%	15	0.1%	10 020	34.3%	0	0.0%	0	0.0%	29 175
Mean	15 361	41.2%	265	0.7%	21 299	57.1%	307	0.8%	11	0.0%	37 326

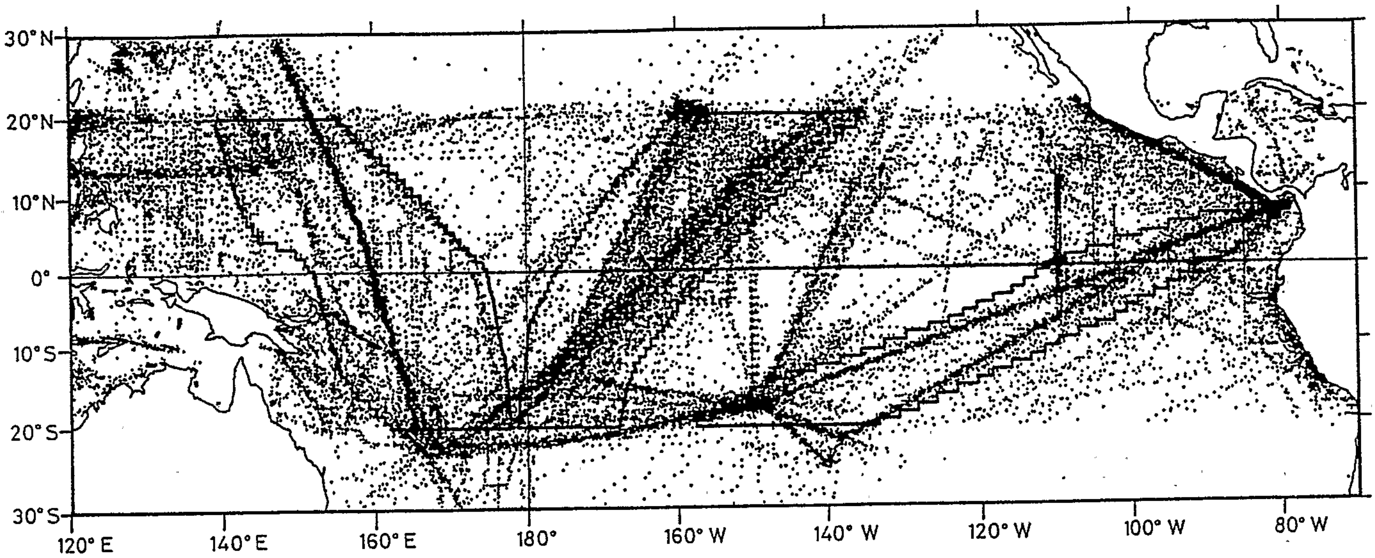


Fig 1: XBT coverage in the intertropical Pacific, 1979-1985 (from PICAUT *et al*, 1988).

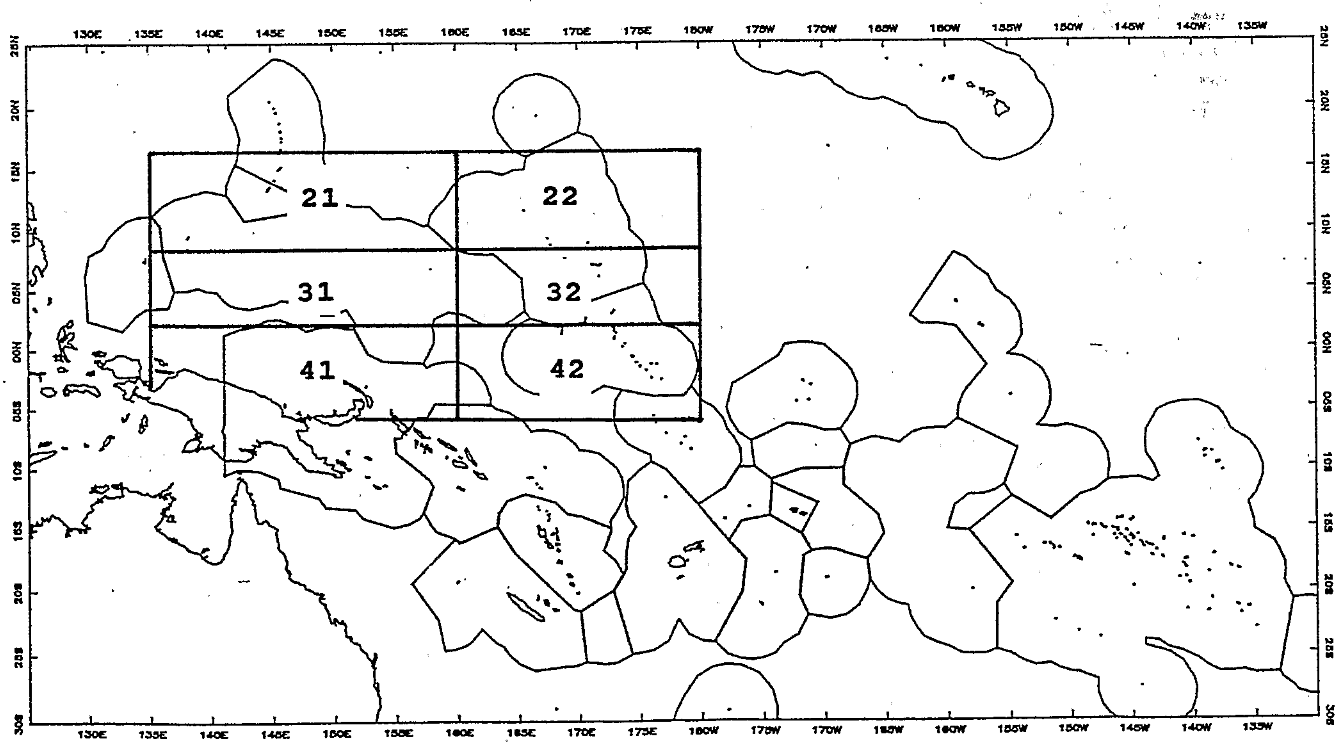


Fig 2: The South Pacific Commission Area, countries' EEZ and the study area.

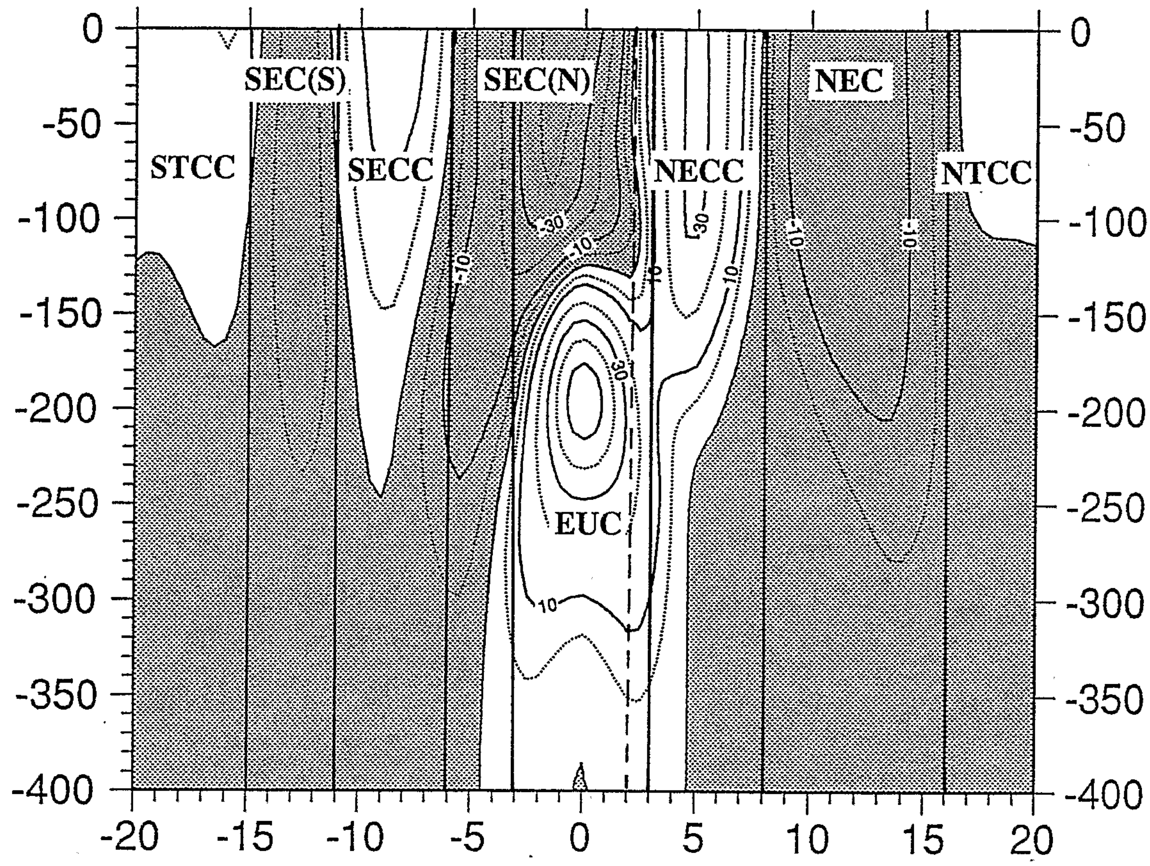


Fig 3: Mean vertical currents section in the western Pacific along the Nouméa-Japan line in a "Pre-ENSO" situation (from TOURNIER, 1989).

NTCC	: North Tropical Counter-Current
NEC	: North Equatorial Current
NECC	: North Equatorial Counter-Current
SEC(N)	: Northern branch of the South Equatorial Current
SEC(S)	: Southern branch of the South Equatorial Current
SECC	: South Equatorial Counter-Current
STCC	: South Tropical Counter-Current
EUC	: Equatorial Under Current

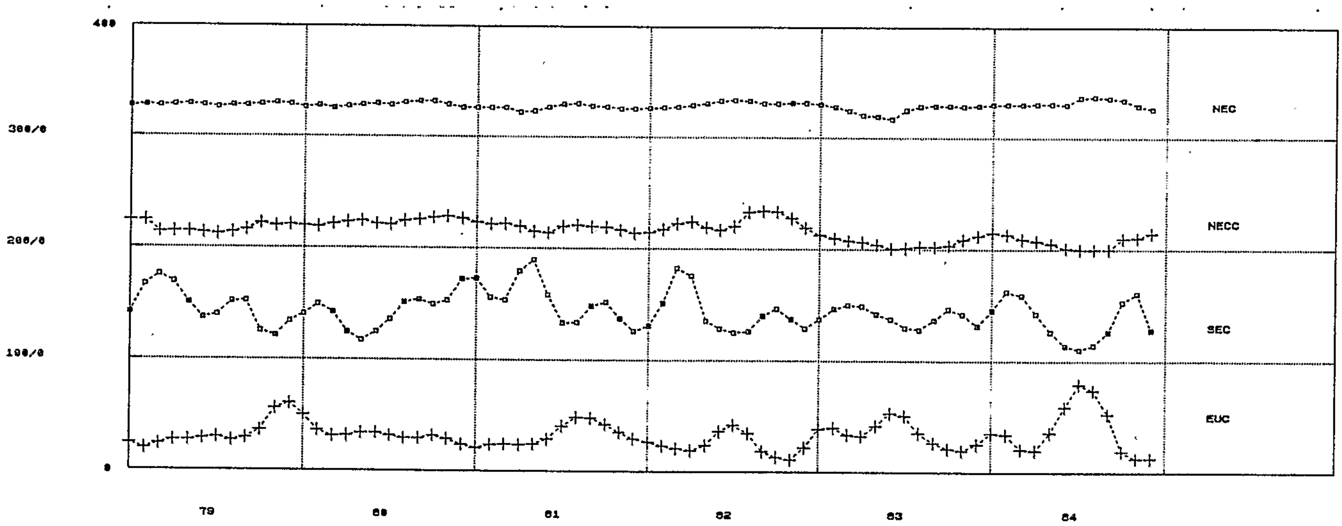
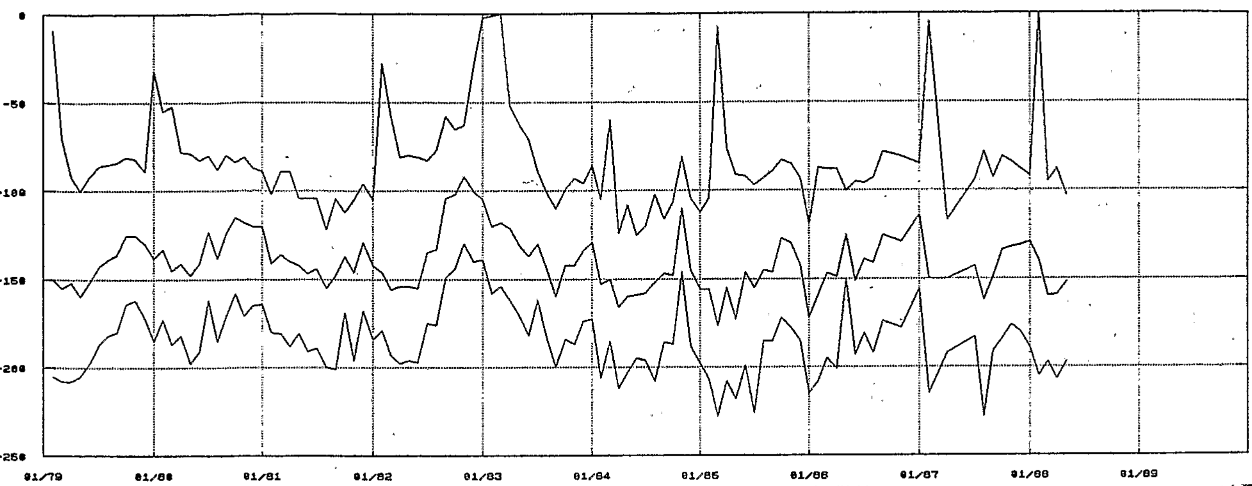
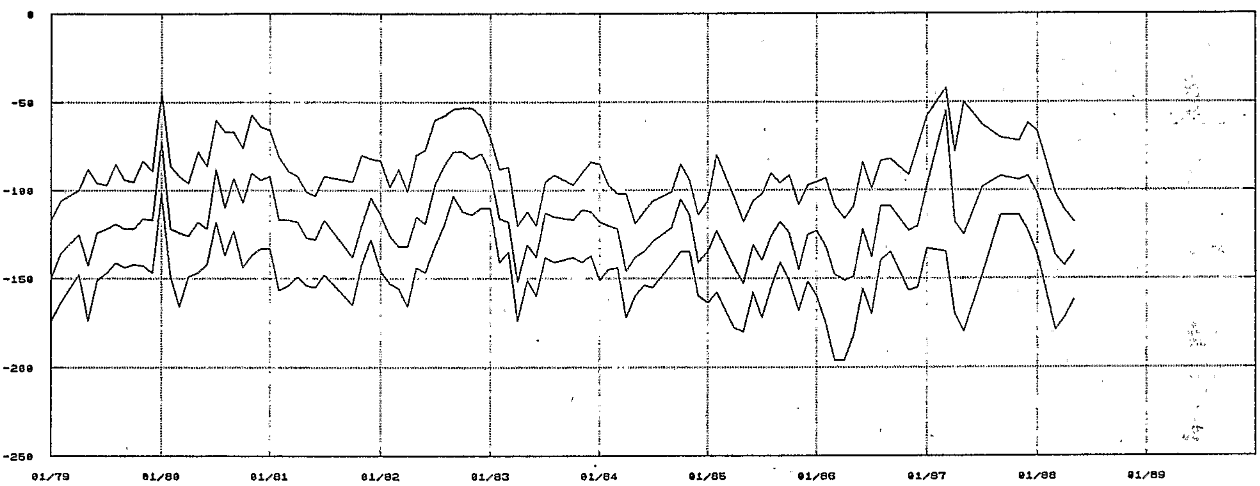


Fig 4: Monthly intensity (10^6 m^3/s) of the geostrophic currents along the Nouméa-Japan line, 1979-1984 (from Tournier, 1989).

AREA 21



AREA 31



AREA 41

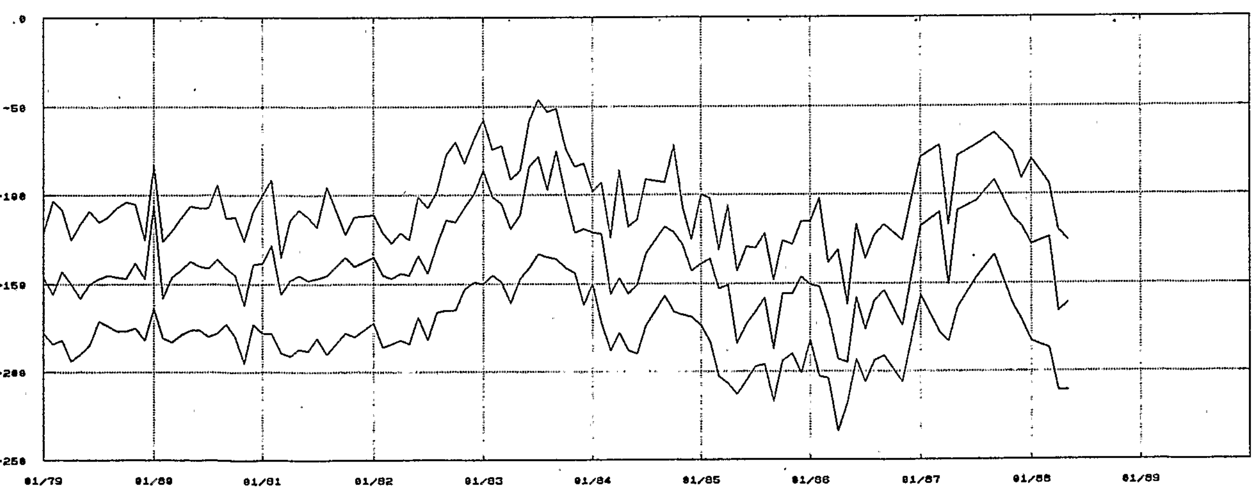


Fig 5: Depth of 27, 24 and 20°C isotherms in areas 21 (upper), 31 (centre) and 41(lower).

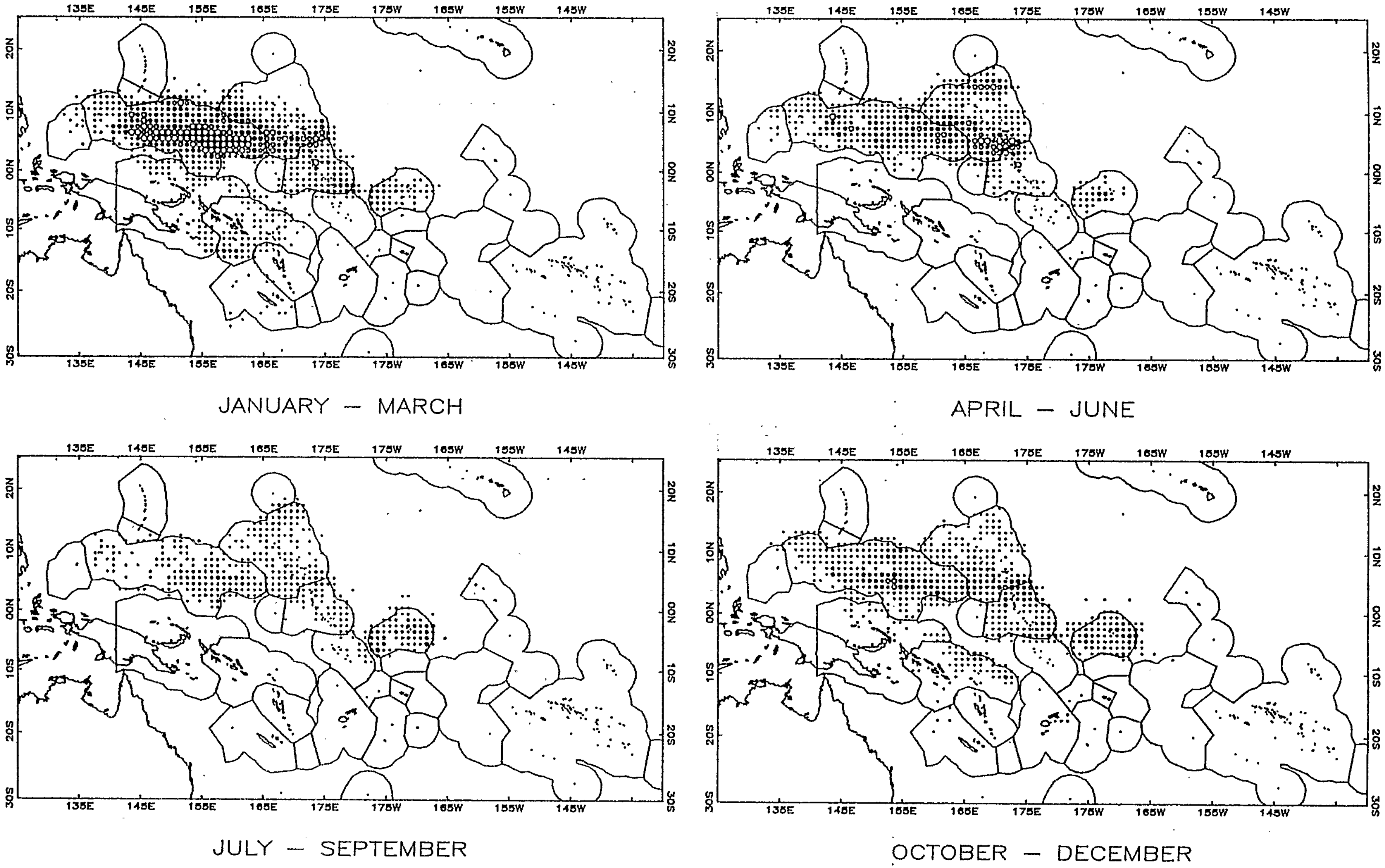


Fig 6: Mean quarterly effort distribution of pole-and-lines vessels in the SPC area (1984-87).

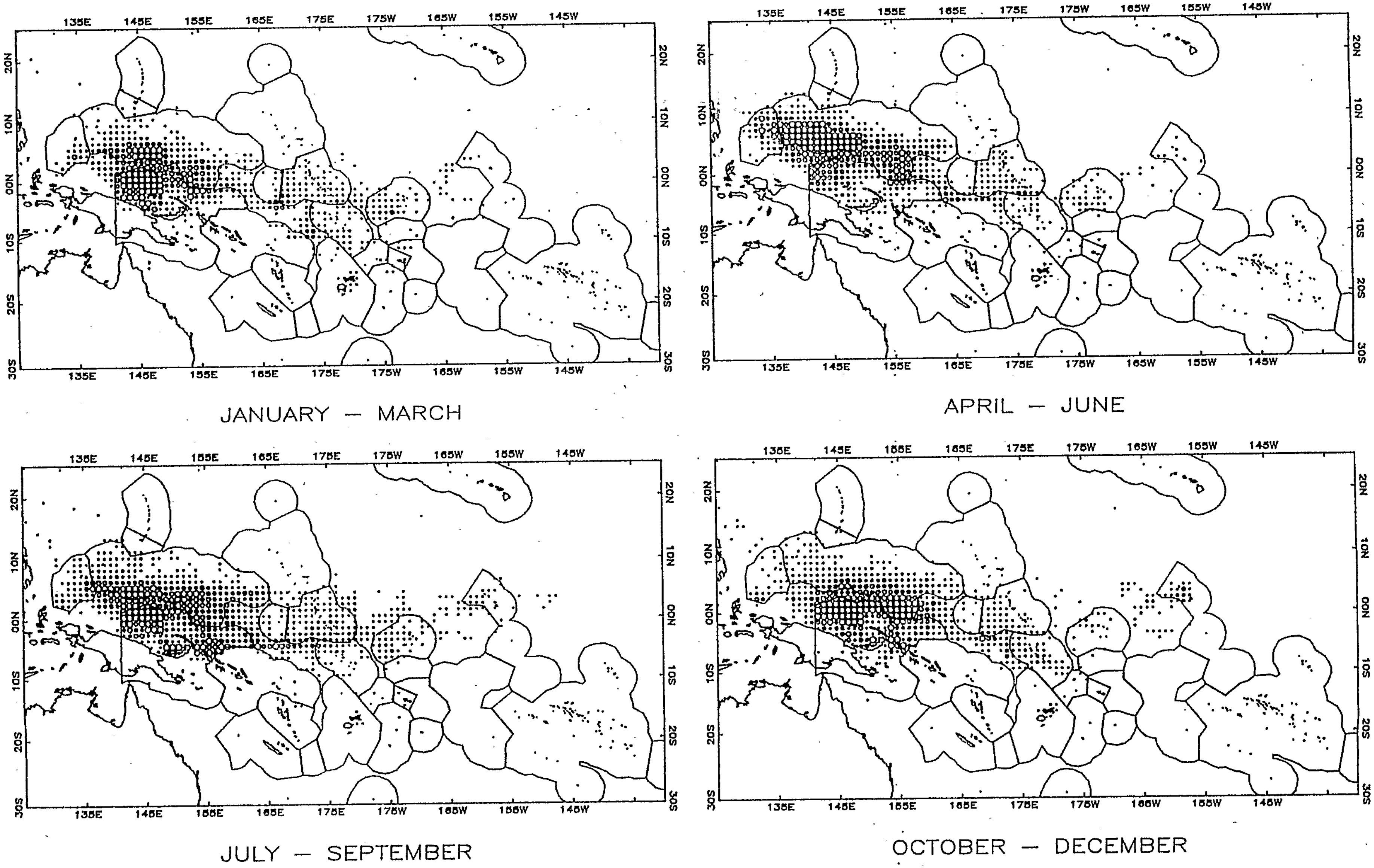


Fig 7: Mean quarterly effort distribution of purse-seine vessels in the SPC area (1984- 87).

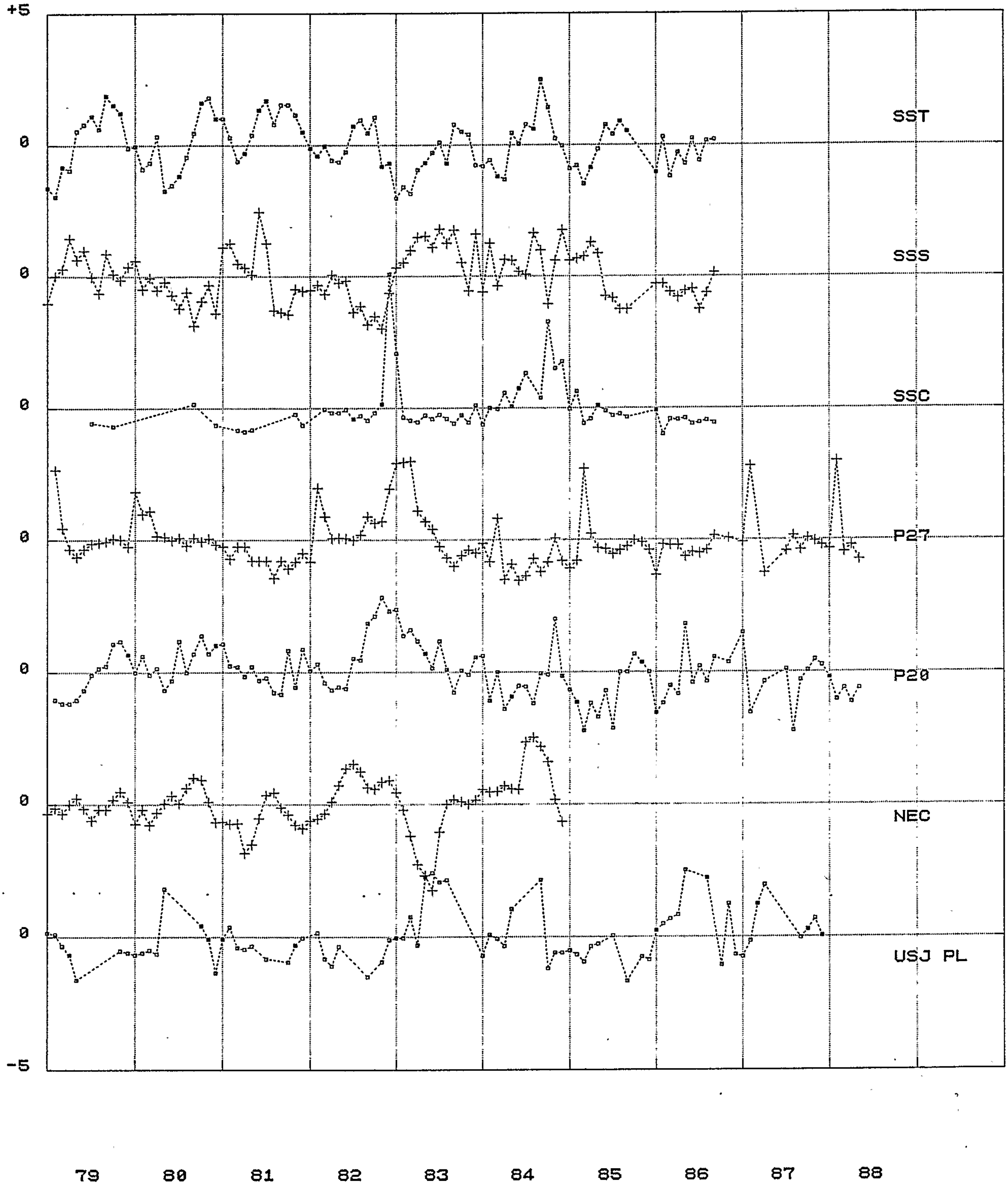


Fig 8: Standardized anomalies of sea surface temperatures (SST), salinities (SSS), chlorophyll contents (SSC), mixed layer (Z27) and thermocline (Z20) depth, North Equatorial Current intensity (NEC) and pole-and-line skipjack cpues (USJ PL) in area 21.

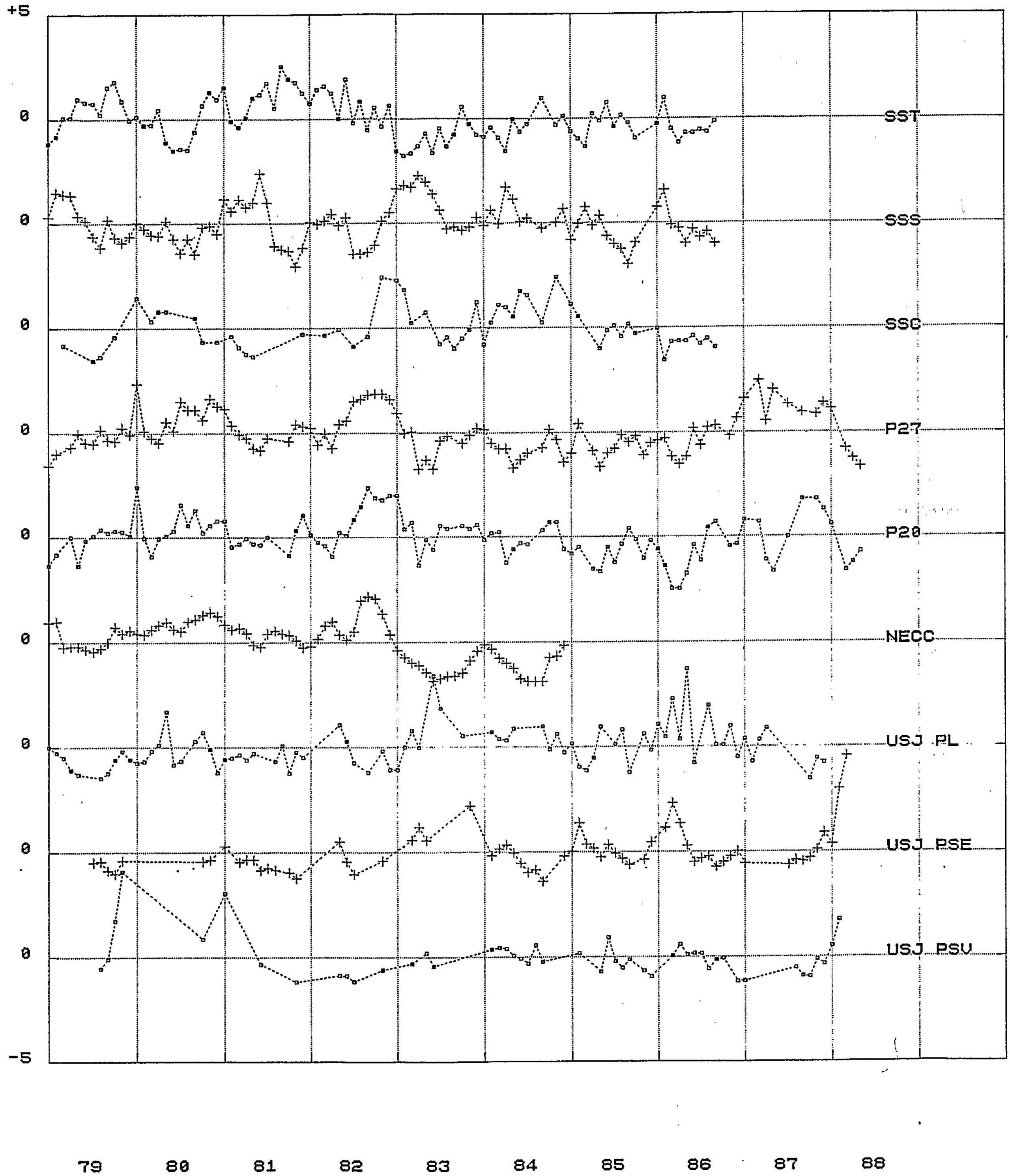


Fig 9: Standardized anomalies of sea surface temperatures (SST), salinities (SSS), chlorophyll contents (SSC), mixed layer (Z27) and thermocline (Z20) depth, North Equatorial Counter-Current intensity (NECC), and skipjack cpues of pole-and-line (USJ PL), purse-seine log (USJ PSE) and school (USJ PSV) sets in area 31.

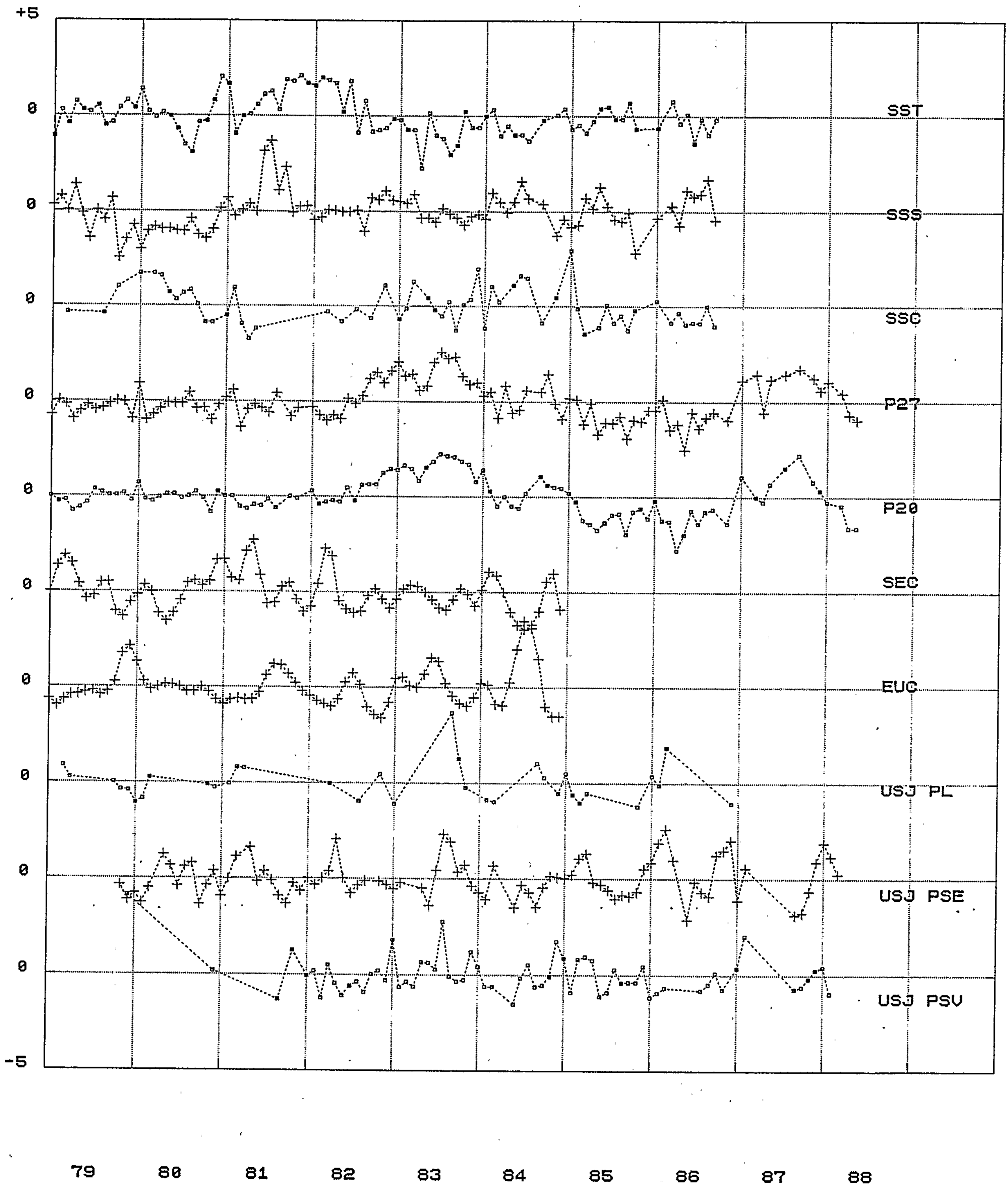


Fig10: Standardized anomalies of sea surface temperatures (SST), salinities (SSS), chlorophyll contents (SSC), mixed layer (Z27) and thermocline (Z20) depth, northern branch of the South Equatorial Current (SEC) and Equatorial Under Current (EUC) intensity, and skipjack cpues of pole-and-line (USJ PL), purse-seine log (USJ PSE) and school (USJ PSV) sets in area 41.