WP. SC7B2 7.

# OCEANOGRAPHY AND TUNA FISHERIES

# IN THE INTERTROPICAL WESTERN PACIFIC

R. PIANET, Centre ORSTOM de Nouméa


## SUMMARY.

In the western and central tropical Pacific, SST has a rather weak seasonal variability, much less than its interannual variability due to the ENSO (El Niño Southern Oscillation) phenomenon. However, previous studies showed the prominent roles on tuna fisheries of the major currents pattern and the 35%. isohaline, a good indicator of the equatorial upwelling.

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

- -The SURTROPAC team manage the XBT Ships of Opportunity Program 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 in collaboration with US scientists on ocean modelling from wind and sea level information.

- -PROPPAC is another major program, aimed to estimate the relationships between hydrological structures and the planctonic biomass and production in the western Pacific.

- -Last, the TUNA-ENVIRONMENT program studies the impact of the environmental variability (seasonal and interannual) on the distribution and availability of tunas to the differents fishing gears, using the data bases available at ORSTOM (oceanography) and at the Tunas and Billfishes Assessment Programme of the South Pacific Commission (tuna fisheries statistics); it is going ahead in collaboration between both organisations. Some preliminary results of this study are presented hereafter.


## 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 ...).

First, we will present the main open-sea related programs conducted in Nouméa by ORSTOM's scientist. Then follows a brief description of the general oceanic features in the southwest Pacific. Last, the TUNA-ENVIRONMENT 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 gathers 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 programm, this set of data was augmented with supplementary data from several other national Agencies; this allowed to more than quadrupled the volume of data available. The corresponding 1979-85 XBT coverage in the intertropical Pacific is shown on Fig. 1 (PICAUT *et al*, 1988). This work aimed at quantitatively evaluate the accuracy of a wind driven oceanic model of the seasonnal (BUSALACCHI and O'BRIEN, 1981) and interannual (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).

Within the TOGA program, the oceanographers of Nouméa also initiated in January 1984 a serie 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 allows a more precise definition of the main oceanographical events, in complement 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 datas availables in the south-west Pacific (10-24°S, 160°E-140°W) was also carried out by the SURTROPAC group (DELCROIX and HENIN, 1989) with the SPREP support.

PROPPAC:

This second major programme in Nouméa, 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 focussed 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, and includind a one week stationnary station at the equator). Some preliminary results showing the differences in oceanographic features as well as biological resulting production between ENSO and "non-ENSO" periods 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 consist in a study of the impact of the environmental variability (seasonal as well as interannual) 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 further.

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

The general climatology and circulation in the intertropical 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 developped 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 estward 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 on 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 it can be observed on Fig. 4.

The ENSO phenomenon (El Niño 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: important 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 drough in the western Pacific. Two ENSO events occured during the period on which the study takes 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 Niño (sometimes called La Niña) event developped across all the 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 datas will be 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 were pointing 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 occured 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 hydroclimatics phenomenons and biological information to assess the spatiotemporal 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 differents oceanographic parameters availables in order to identify the more pertinents. 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 in six sub-areas (Fig. 2) based on the mean latitudinal current system distribution shown on 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:

Oceanography:

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 datas from January 1979 were used. Anomalies (*i.e* standardized deviations from the whole period mean) were computed in the six subareas for the following parameters: sea surface temperature (SST), salinity (SSS) and chlorophyll content (SSC), depth of the isotherms 27°C (Z27, an estimate of the upper mixed layer thickness) 24° and 20°C (Z24 and Z20, 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 on Fig. 4 (from TOURNIER, 1989). Fig. 5 exhibits the 27, 24 and 20 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 members countries; until now, most of the other data are either unavailable, scarce or unreliable, and thus were not usable for this work.

The **pole-and-line fishery** is quite exclusively japanese, its catch -almost entirely skipjack- ranging from 25-50 000 tons, in SPC area (source SPC). The number of pole-and-line 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 some 30-40% of the estimated total catch in the western Pacific. The fishery is highly seasonal, most of the pole-and-line 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 on 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 at a less 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 usually reported to SPC amount 100-150 000 tons these last years (reaching 220-320 000 tonnes 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 some 25-35% of the total yield. Two substantially different seining methods are used: log sets (done on floatsam, and catching a mixture of skipjack and young yellowfin) and school sets (done on free swimming schools, catching more yellowfin of larger sizes); both methods were distinguished for the analysis. The mean quarterly effort distribution of purse-seine (1984-87) is reported on 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 estiimated to be fishing more east. The seasonnality is less pronounced than for pole-and-line, 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) is not taken in 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 in a first step as representative of the fishery. The resource being assumed to be 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 representatives 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, areas 21, 31 and 41) where both pole-and-line and purse-seine fisheries are present. As said previously, they are characterized by their currents, respectively the NEC (area 21), the NECC (area 31) and the SECN/EUC system (area 41). Fig 8, 9 and 10 exhibits the standardized anomalies of sea surface temperatures (SST), sea surface salinities (SSS), surface chlorophyll content (SSC), mixed layed depth (Z27), thermocline depth (Z20), geostrophic current intensity, pole-and-line and purse-seine (logs and schools sets separated) skipjack cpues respectively in areas 21, 31 and 41. Total catches (in metric tons) and efforts (fishing + searching days) by areas from pole-and-line and purse-seine are reported on Table 1 and 2.

### Area 21 (Fig 5a and 8):

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 highly, 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 between 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 firt quarter of 83; for the 86/87 event, the phenomenon is shorter and less intense. The NEC shows a weak seasonnality (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 exclusively done by pole-and-line vessels, with a scarce effort from purse-seiners. The effort is strongly seasonnal (February-April), and was low in 82, with an eastward shift (area 22) in early 83; skipjack catches reflect the effort distribution, generally increasing the anomalies. Skipjack cpues are also strongly seasonnal, 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 (Fig 5b and 9):

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 highly with no marked seasonal pattern, and exhibit a strong positive anomaly from mid 82 to mid 83, as it was evidenced by DANDONNEAU (1986, 1988); 84 is also relatively high, as it was for area 21. The variations of Z27, Z24 and Z20 are synchroneous, 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 seasonnal (maximum in July-October), and showed a marked positive anomaly in the second half of 82, followed by a strong negative anomaly in 83, and remained at a low level in 84.

Both pole-and-line and purse seine vessels are operating in this area. Their effort is strongly seasonnal, more for pole-and-liners (November-May, peak in February-April) than for purse-seiners (April-August). The pole-and-lines 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 because the low effort exerted before 84. Catches still reflect the effort distribution. Skipjack cpue are strongly seasonnal for both gears: maximum in January-May and minimum in June-October for pole-and-line, while for purse-seine, 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 cpues 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 (Fig 5c and 10):

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 synchroneous, and reflect well the 82/83 (+50m rising) and 86/87 (+40m rising) ENSO events. The SEC is quite strongly seasonnal (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 seasonnal (maximum in June-August, minimum in October-April), opposite to the SEC; this maximum was weaker than usual in 82/83, stronger in 84.

The 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 seasonnality; catches still reflect the effort distribution. Skipjack cpues are strongly seasonnal for pole-and-lines (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). Yellowfin's seasonal pattern is rather weak. Positive cpues 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 tentative was done 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 datas in those areas. This result confirms Tanaka's hypothesis (TANAKA and YAO, 1980; MARCILLE et 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, (may be because of the relative scarcity of the catch datas) 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. Regarding a general ENSO effect, warm events had a positive effect on pole-and-line catches, during the begining 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 datas 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 relativised because of the shortness of the time serie, particularly for the currents estimates. Further work must be achieved, particularly by taking in account the 1969-78 period and including US and others distant waters fishing nations (DWFN) datas as soon as they will be available.

New techniques involving wind driven oceanic modelisation of the seasonnal and interannual variations of surface dynamic heights and sea levels may give reasonable results, despite of if 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 datas 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 of the combined efforts of these studies which can give a strong enhancement to tunas fisheries related oceanography.

## BIBLIOGRAPHIE


ANONYME, 1988. Investigations on Western Pacific Yellowfin Fishery Interactions Using Catch and Effort Data. SPC/Fisheries 20/WP 17, July 1988: 13p.

BUSALACCHI A.J. and O'BRIEN J.J., 1980. The seasonnal variability in a model of the tropical Pacific. J. Phys. Oceanogr.,vol 10: 1929-51.

BUSALACCHI A.J., TAKEUCHI K. and O'BRIEN J.J., 1983. Interannual variability of the Equatorial Pacific-Revisited. J. Geophys. Res., vol88 (12): 7551-62.

DANDONNEAU Y., 1986. Monitoring the sea surface chlorophyll concentration in the tropical Pacific: consequences of the 1982-83 El Niño. Fish. Bull., vol 84(3): 687-695.

DANDONNEAU Y., 1988. La chlorophylle dans le Pacifique: un essai d'océanographie à partir de mesures à la surface de l'océan. Thèse présentée à l'Université d'Aix-Marseille II, Faculté des Sciences de Luminy: 68p et 10 annexes.

DELCROIX T et HENIN C., 1989. Atlas océanographique du Pacifique tropical sud-ouest. ORSTOM/NOUMEA, Série Conventions Sciences de la Mer, Océanographie physique, n° 2, 68p.

DELCROIX T., ELDIN G. and HENIN C., 1987. Upper Ocean Water Masses and Transports in the Western Tropical Pacific (165°E). J. Phys. Oceanogr.,vol 17: 2248-2262.

DONGUY J.R., 1985. Contribution à la connaissance des variations climatiques de l'océan Pacifique tropical. Thèse présentée à l'Université de Bordeaux, N° 838, 13 Mai 1987.

DONGUY J.R., BOUR W., GALENON P. et GUEREDRAT J.-A., 1978. Les conditions océanographiques et la pêche de la bonite (*Katsuwonus pelamis*) dans le Pacifique occidental. Cah. ORSTOM, sér. Océanogr., vol XVI(3-4): 309-317.

ELDIN G., 1989. Coupes verticales des structures océaniques physique à 165°E observées au cours de dix campagnes SURTROPAC, 1984-1988. ORSTOM/NOUMEA, Rapport Scientifique et Technique, Sciences de la Mer, Océanographie physique n° 1, 130p.

HAMPTON J., 1988. Status of Tuna Fisheries in the Western and Central Pacific. Second Southeast Asian Tuna Conference, 3rd Meeting of Tuna Research Group, Kuala Terengganu (Malaysia), 22-25 august 1988: 23p.

INOUE M., O'BRIEN J.J., WHITE W.B. and PAZAN S.E., 1987. Interannual Variability in the Tropical Pacific for the Period 1979-1982. J. Geophys. Res., vol 92, n° C11: 11671-679.

LE BORGNE R., 1985. Etude de l'influence des conditions hydrologiques sur la Production Pélagique dans la zone occidentale du Pacifique: Programme PROPPAC. Doc. interne du Centre ORSTOM de Nouméa: 22p.

McPHADEN M.J., BUSALACCHI A.J., PICAUT J. and RAYMOND G., 1988a. A Model Study of Potential Sampling Errors Due to Data Scatter Around Expendable Bathythermograph Transects in the Tropical Pacific. J. Geophys. Res., vol 93, N° C7: 8119-30.

McPHADEN M.J., BUSALACCHI A.J. and PICAUT J., 1988b. Observations and Wind-Forced Model Simulation of the Mean Seasonnal Cycle in Tropical Pacific Sea Surface Topography. J. Geophys. Res., vol 93, N° C7: 8131-46.

MARCILLE J. et BOUR W., 1981. La pêche des thons à la senne et à la canne dans l'océan Pacifique tropical: situation actuelle et perspectives de développement. Travaux et Documents de l'ORSTOM, N° 134: 259p.

MENDELSSOHN R. and ROY C., 1986. Environmental influences on the French, Ivory Coast, Senegalese and Morrocan Tuna Catches in the Gulf of Guinea. Proceedings of the ICCAT Conference on the International Skipjack Year Program, ICCAT, 1986: 170-188

MIYABE N., YUKINAWA M. and MIZUNO K., 1988. Effect of El Niño events upon Reproduction and Distribution of Tunas II: Effect on the Bigeye Tuna Stock in the Tropical Pacific. In press.

PICAUT J., TOURNIER R. et FABRE V, 1988. Champs mensuels 1979-1985 de températures, hauteurs dynamiques et courants géostrophiques, déduits de mesures XBT 0-400 m le long de trois rails moyens de navigation dans le Pacifique Tropical. Groupe SURTROPAC, ORSTOM/Nouméa, document provisoire: 30p.

SIBERT J., 1986. Tuna Stocks of the Southwest Pacific. SPC/Fisheries 18/WP1, May 1986:33p. In Infofish Tuna Trade Conference, Bangkok (Thailand), 25-27 february 1986.

SUND P.N., BLACKBURN M. and WILLIAMS F., 1981. Tunas and their environment in the Pacific Ocean: a review. Oceanogr. Mar Biol. Ann. Rev.,1981, vol 19: 443-512.

SUZUKI Z., 1988. Study of interactions between longline and purse seine fisheries on yellowfin tuna, *Thunnus albacares* (Bonnaterre). Bull. Far Seas Fish. Res. Lab., N° 25, march 1988: 73-145.

TANAKA T. and YAO M., 1980. Catch relationships in four different skipjack areas in the western Equatorial Pacific. SPC/Fisheries 12 /WP 16. Translation of Suisan Sekai, 29(3)/58-63.

TOOLE J.M., ZOU E. and MILLARD R.C., 1987. On the Circulation of the Upper Waters in the Western Equatorial Pacific Ocean. Woods Hole Oceanographic Contribution Number 6553: 51p.

TOURNIER R., 1989. Variabilité de la structure thermique et des courants à l'Ouest et au Centre de l'Océan Pacifique Tropical de 1979 à 1985. Thèse de Doctorat de l'Université Paris VI: 160p, 64 fig.

YAMANAKA H., MORITA J. and ANRAKU N., 1969. Relations between the distribution of tunas and water types of the north and south Pacific oceans. Bull. Far Seas Fish. Res. Lab., N° 2: 257-273.

TABLE 1: Total efforts and catches by areas (see Fig. 2) from 200-300 TJB japanese pole-and-line (Source: SPC).

Fishing effort (searching + fishing days):

| Year | Area 21 | Area 22 | Area 31 | Area 32 | Area 41 | Area 42 | Total |
|---|---|---|---|---|---|---|---|
| 79 | 2.341 | 4 | 2.384 | 613 | 216 | 221 | 5.779 |
| 80 | 845 | 9 | 2.702 | 2.415 | 151 | 480 | 6.602 |
| 81 | 810 | 569 | 1.141 | 1.298 | 179 | 1.156 | 5.153 |
| 82 | 342 | 1.234 | 251 | 1.963 | 50 | 188 | 4.028 |
| 83 | 1.023 | 0 | 496 | 4.038 | 180 | 116 | 5.853 |
| 84 | 478 | 0 | 3.187 | 2.088 | 77 | 170 | 6.000 |
| 85 | 471 | 0 | 1.036 | 1.603 | 108 | 466 | 3.684 |
| 86 | 1.150 | 252 | 2.087 | 1.006 | 34 | 127 | 4.656 |
| 87 | 479 | 506 | 195 | 555 | 7 | 229 | 1.971 |
| 88 | 434 | 85 | 125 | 165 | 0 | 16 | 825 |
| Mean | 837 | 266 | 1.360 | 1.574 | 100 | 317 | 4.455 |
| % | 18,8 | 6,0 | 30,5 | 35,3 | 2,2 | 7,1 | 100,0 |

Total catches (metric tons, all species combined):

| Year | Area 21 | Area 22 | Area 31 | Area 32 | Area 41 | Area 42 | Total |
|---|---|---|---|---|---|---|---|
| 79 | 10.312 | 10 | 9.853 | 3.357 | 937 | 1.035 | 25.504 |
| 80 | 3.022 | 60 | 12.915 | 13.875 | 569 | 2.815 | 33.256 |
| 81 | 3.401 | 4.578 | 4.264 | 7.020 | 1.235 | 8.547 | 29.045 |
| 82 | 1.078 | 3.381 | 1.183 | 7.686 | 283 | 866 | 14.477 |
| 83 | 6.692 | 0 | 4.267 | 38.716 | 1.630 | 656 | 51.961 |
| 84 | 2.044 | 0 | 20.916 | 14.885 | 371 | 1.465 | 39.681 |
| 85 | 1.384 | 0 | 3.988 | 8.076 | 294 | 3.231 | 16.973 |
| 86 | 8.240 | 2.469 | 18.660 | 8.537 | 252 | 1.141 | 39.299 |
| 87 | 2.957 | 6.204 | 918 | 3.483 | 13 | 1.534 | 15.109 |
| 88 | 2.744 | 722 | 771 | 1.773 | 0 | 56 | 6.066 |
| Mean | 4.187 | 1.742 | 7.774 | 10.741 | 558 | 2.135 | 27.137 |
| % | 15,4 | 6,4 | 28,6 | 39,6 | 2,1 | 7,9 | 100,0 |

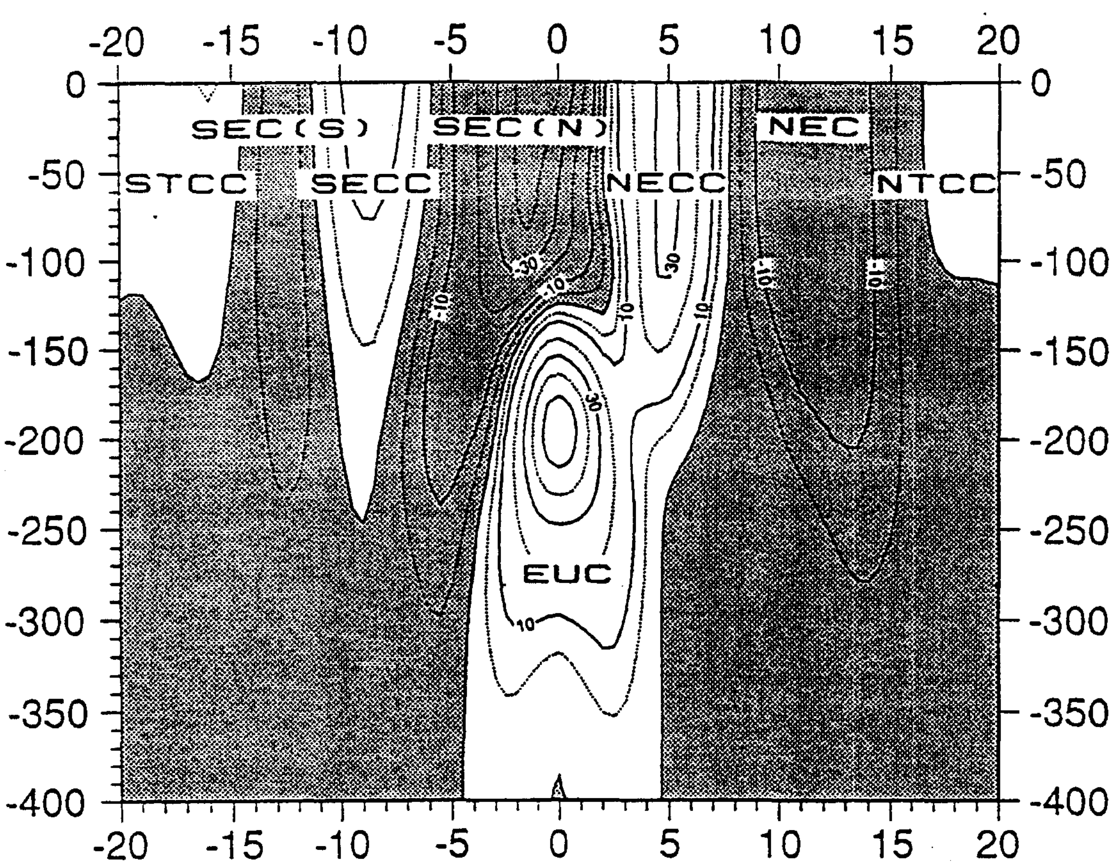
TABLE 2: Total efforts and catches by areas (see Fig. 2) from 200-500 TJB japanese purse-seiners (Source: SPC).

Fishing effort (searching + fishing days):

| Year | Area 31 | Area 32 | Area 41 | Area 42 | Area 51 | Total |
|---|---|---|---|---|---|---|
| 79 | 0 | 0 | 257 | 0 | 0 | 336 |
| 80 | 0 | 0 | 108 | 0 | 0 | 188 |
| 81 | 6 | 0 | 526 | 22 | 2 | 637 |
| 82 | 5 | 0 | 518 | 1 | 0 | 606 |
| 83 | 26 | 0 | 586 | 0 | 1 | 696 |
| 84 | 193 | 0 | 1.706 | 0 | 0 | 1.983 |
| 85 | 1.206 | 30 | 2.449 | 30 | 0 | 3.800 |
| 86 | 1.975 | 40 | 1.830 | 40 | 0 | 3.971 |
| 87 | 2.593 | 44 | 1.369 | 42 | 5 | 4.140 |
| 88 | 708 | 1 | 414 | 0 | 0 | 1.211 |
| Mean | 671 | 12 | 976 | 14 | 1 | 1.757 |
| % | 38,2 | 0,7 | 55,6 | 0,8 | 0,0 | 100,0 |

Total catches (metric tons, all species combined):

| Year | Area 31 | Area 32 | Area 41 | Area 42 | Area 51 | Total |
|---|---|---|---|---|---|---|
| 79 | 0 | 0 | 4.596 | 0 | 0 | 4.675 |
| 80 | 0 | 0 | 3.107 | 0 | 0 | 3.187 |
| 81 | 1 | 0 | 8.934 | 390 | 20 | 9.426 |
| 82 | 0 | 0 | 9.305 | 45 | 0 | 9.432 |
| 83 | 474 | 0 | 10.859 | 0 | 0 | 11.416 |
| 84 | 2.650 | 0 | 37.147 | 0 | 0 | 39.881 |
| 85 | 24.255 | 857 | 47.773 | 857 | 0 | 73.827 |
| 86 | 51.588 | 967 | 49.538 | 967 | 0 | 103.146 |
| 87 | 55.592 | 810 | 31.706 | 810 | 90 | 89.095 |
| 88 | 19.052 | 15 | 10.020 | 0 | 0 | 29.175 |
| Mean | 15.361 | 265 | 21.299 | 307 | 11 | 37.326 |
| % | 41,2 | 0,7 | 57,1 | 0,8 | 0,0 | 100,0 |




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 3: Mean vertical currents section in the western Pacific along the Nouméa-Japan line in a "Pre-ENSO" situation (from PICAUT et al, 1988).

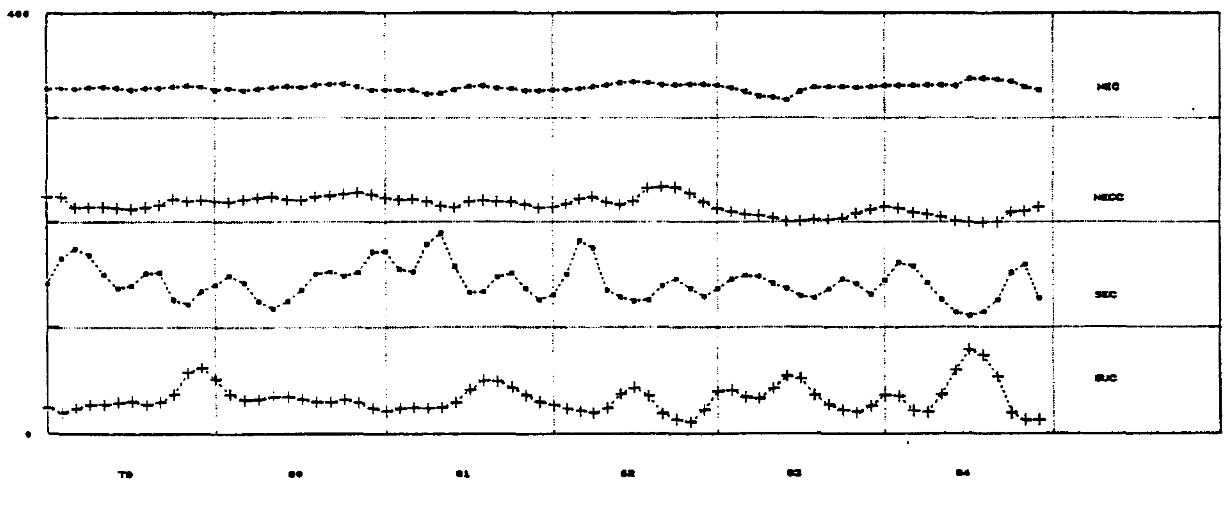


Fig 4: Monthly intensity ($10^6$ $m^3/s$) of the geostrophic currents along the Nouméa-Japan line, 1979-1984 (from PICAUT et al, 1988).

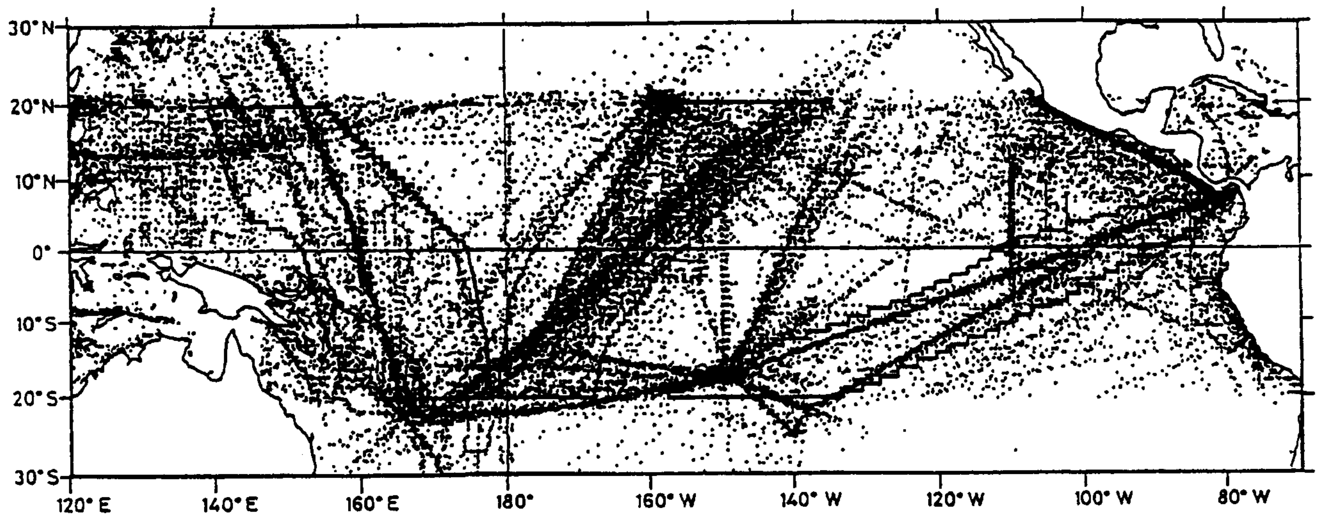



Fig 1: XBT coverage in the intertropical Pacific, 1979-1985 (from PICAUT et al, 1988).

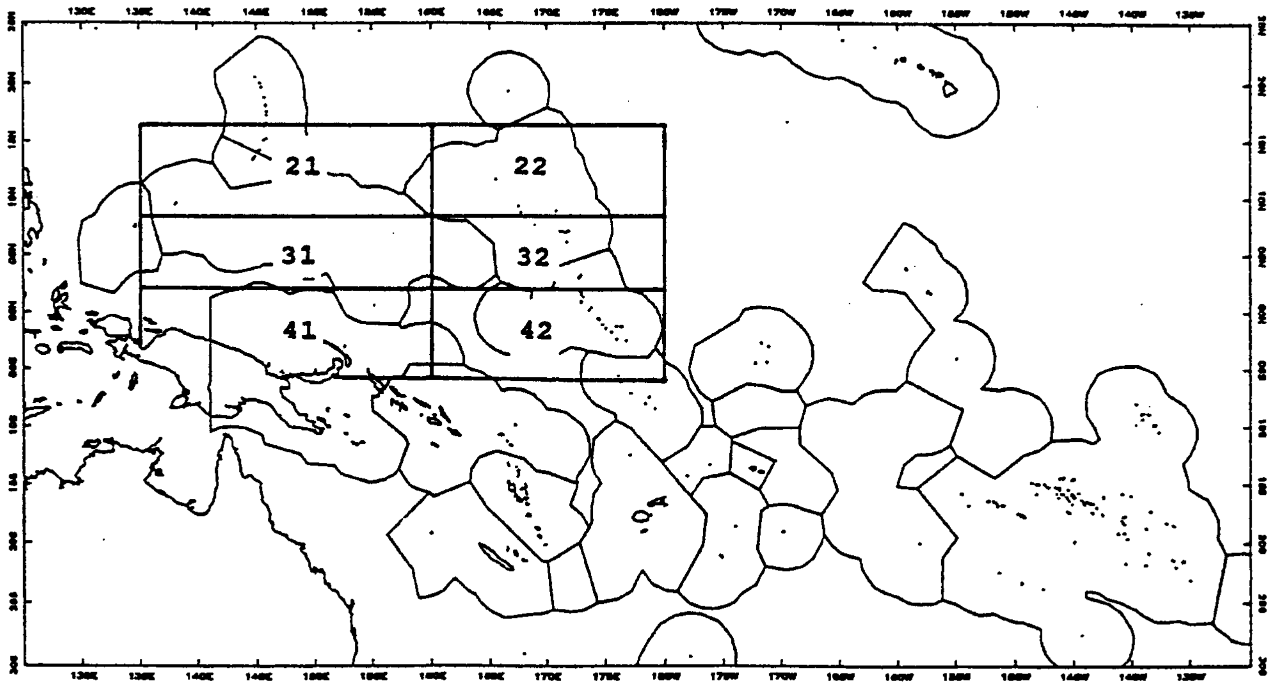



Fig 2: The South Pacific Commission Area and countries EEZ and the studied areas.

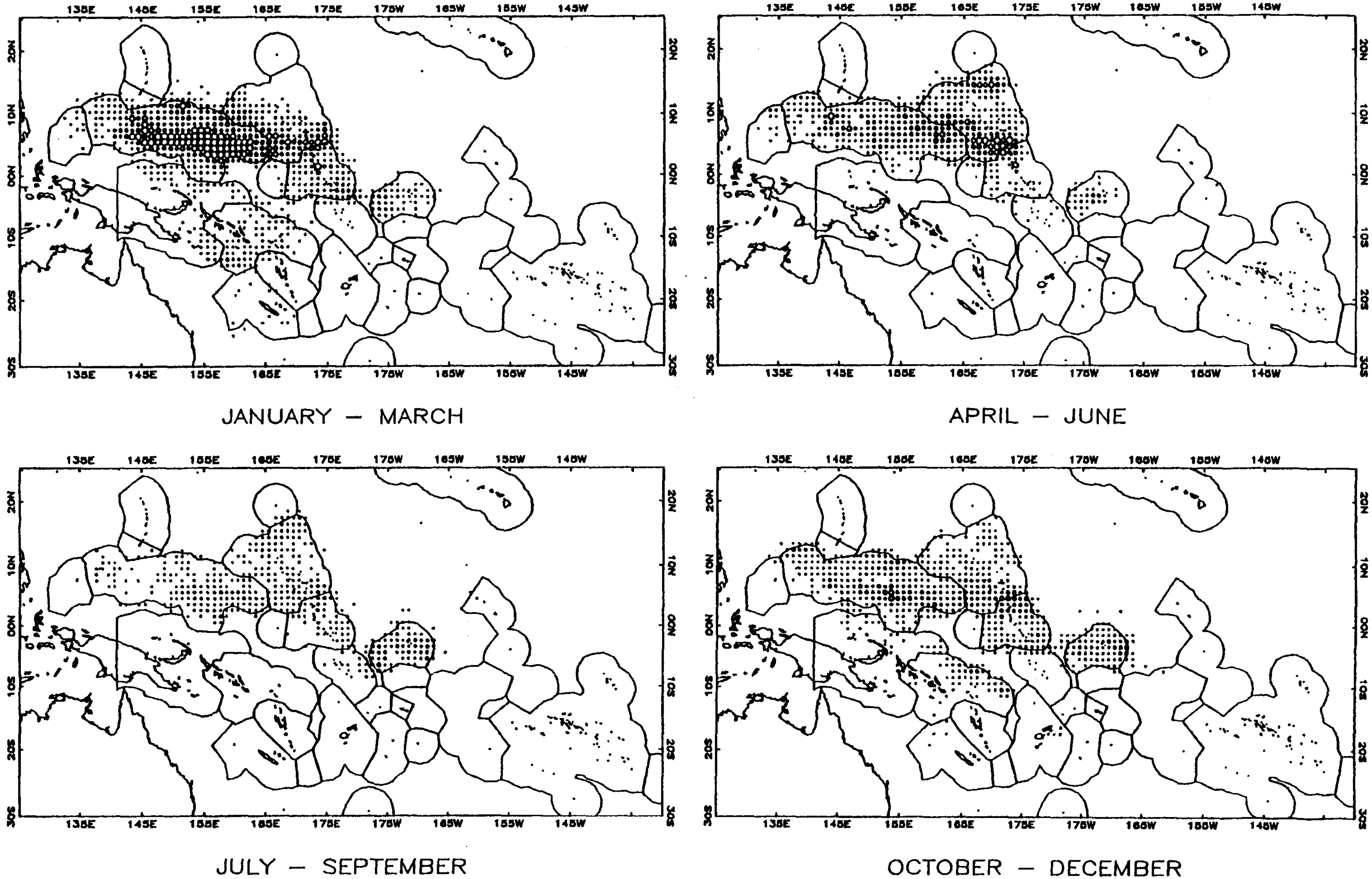



Fig 6: Mean quarterly effort distribution of pole-and-lines in SPC area (1984-87).

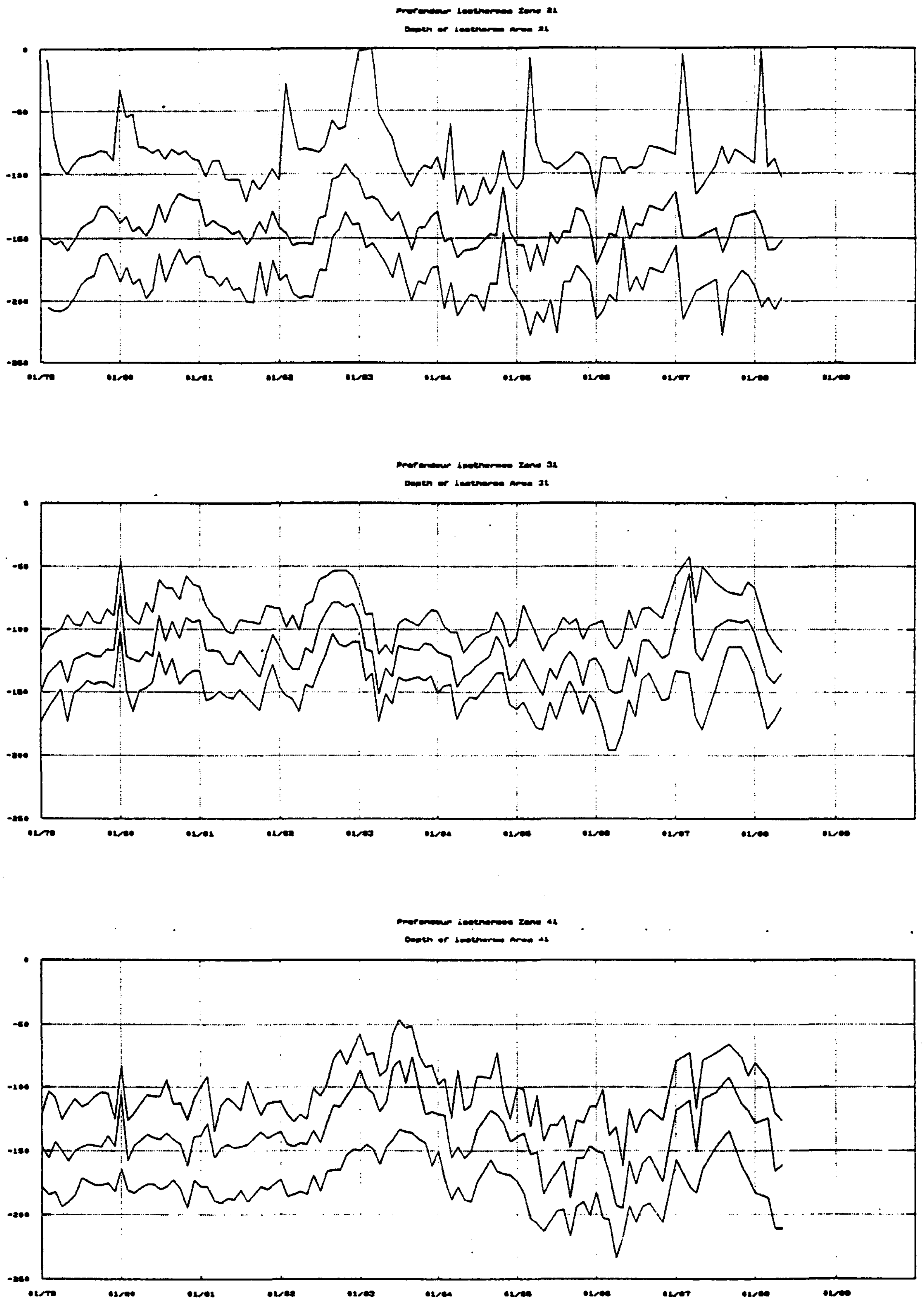


Fig 5: Depth of 27, 24 and 20°C isotherms in areas 21 (upper), 31 (center) and 41.(lower).

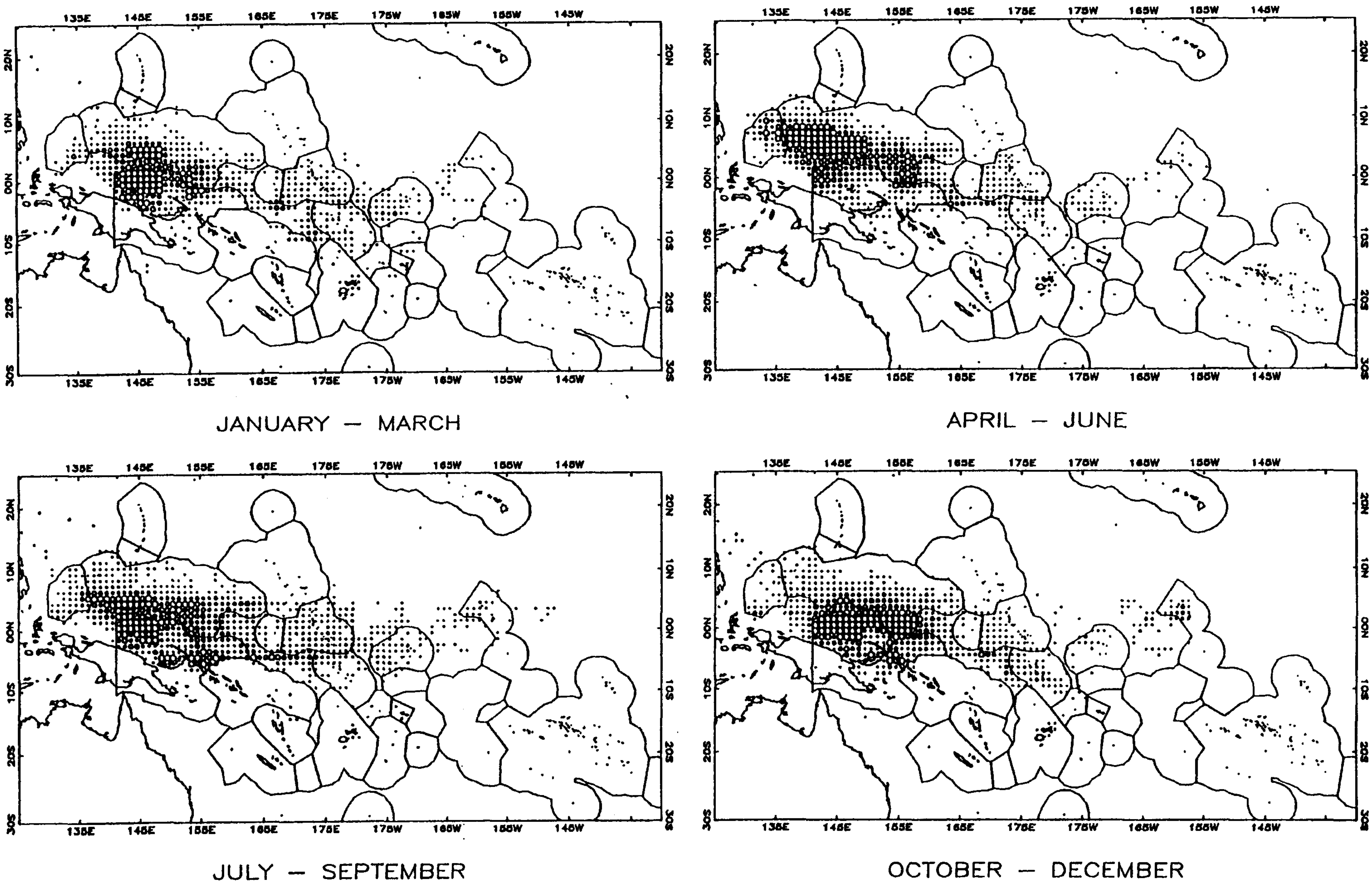



Fig 7: Mean quarterly effort distribution of purse seine in SPC area (1984-87).

## ANOMALIES AREA/ZONE 21

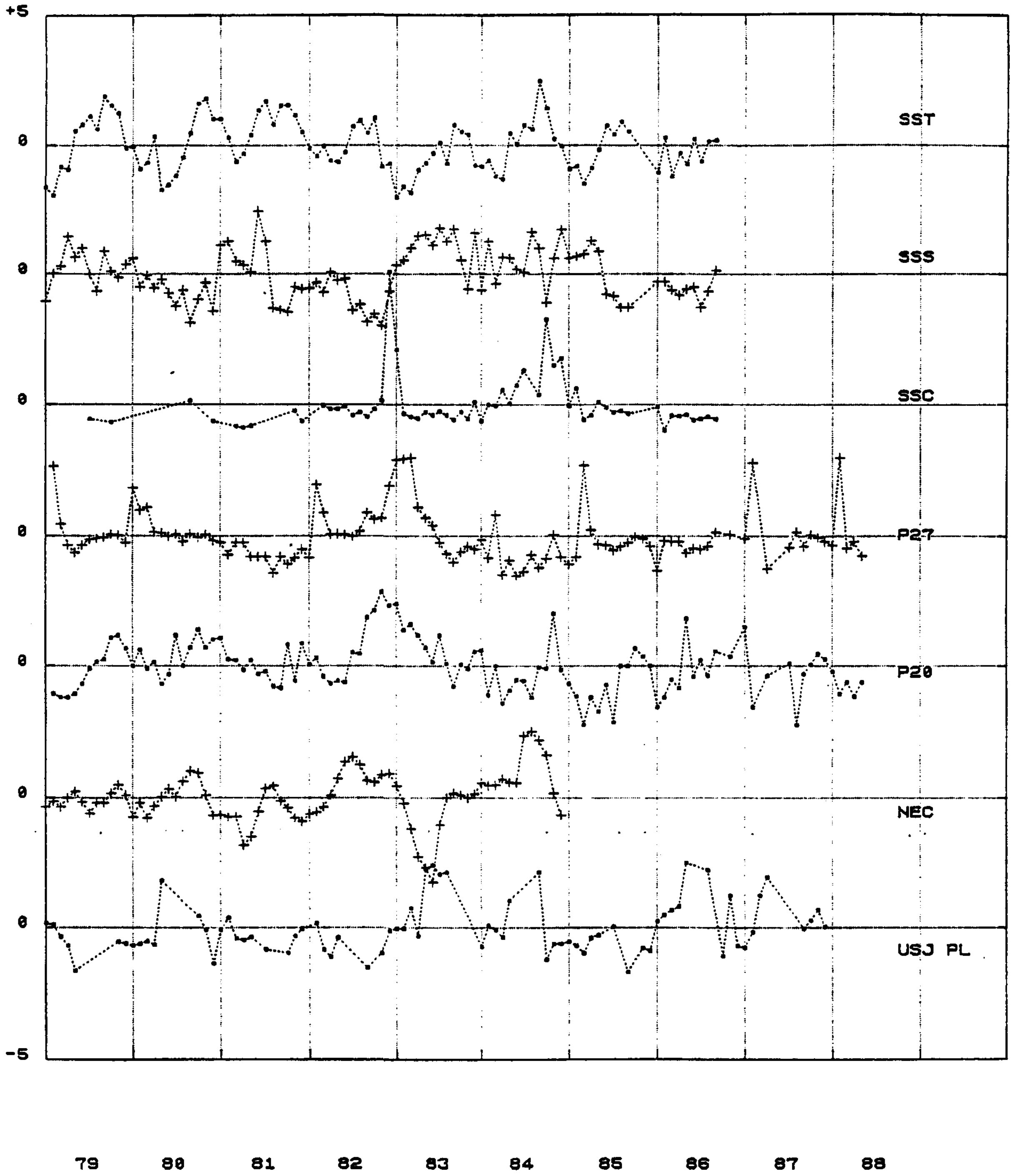



Fig 8: Standardized anomalies of sea surface temperatures (SST), salinities (SSS), chlorophyll contents (SSC), mixed layer (P27) and thermocline (P20) depth , North Equatorial Current intensity (NEC) and pole-and-line skipjack cpues (USJ PL) in area 21.

# ANOMALIES AREA/ZONE 31

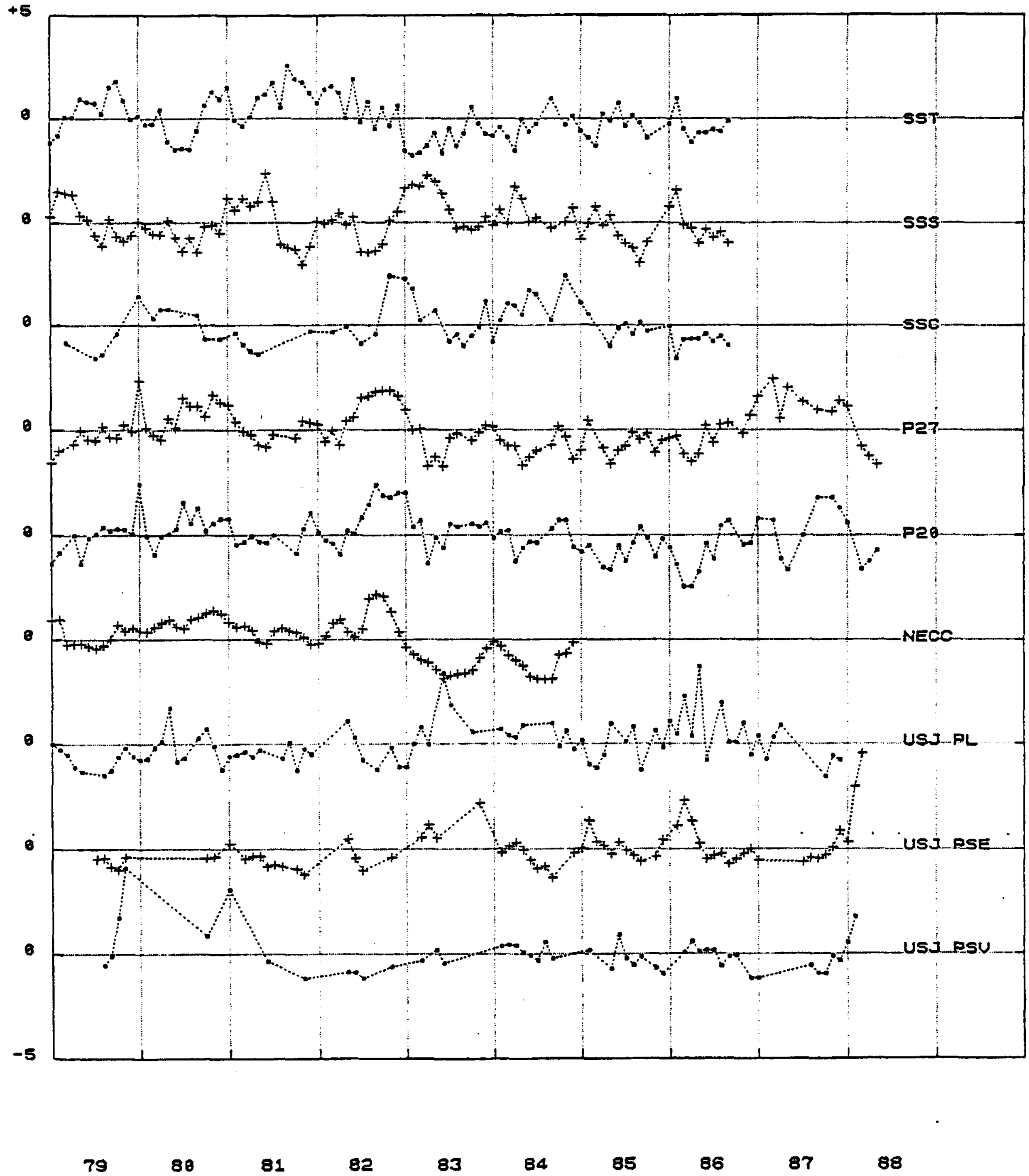



Fig 9: Standardized anomalies of sea surface temperatures (SST), salinities (SSS), chlorophyll contents (SSC), mixed layer (P27) and thermocline (P20) depth, North Equatorial Counter-Current intensity (NECC), pole-and-line (USJ PL), purse seine log (USJ PSE) and school (USJ PSV) sets skipjack cpues in area 31.

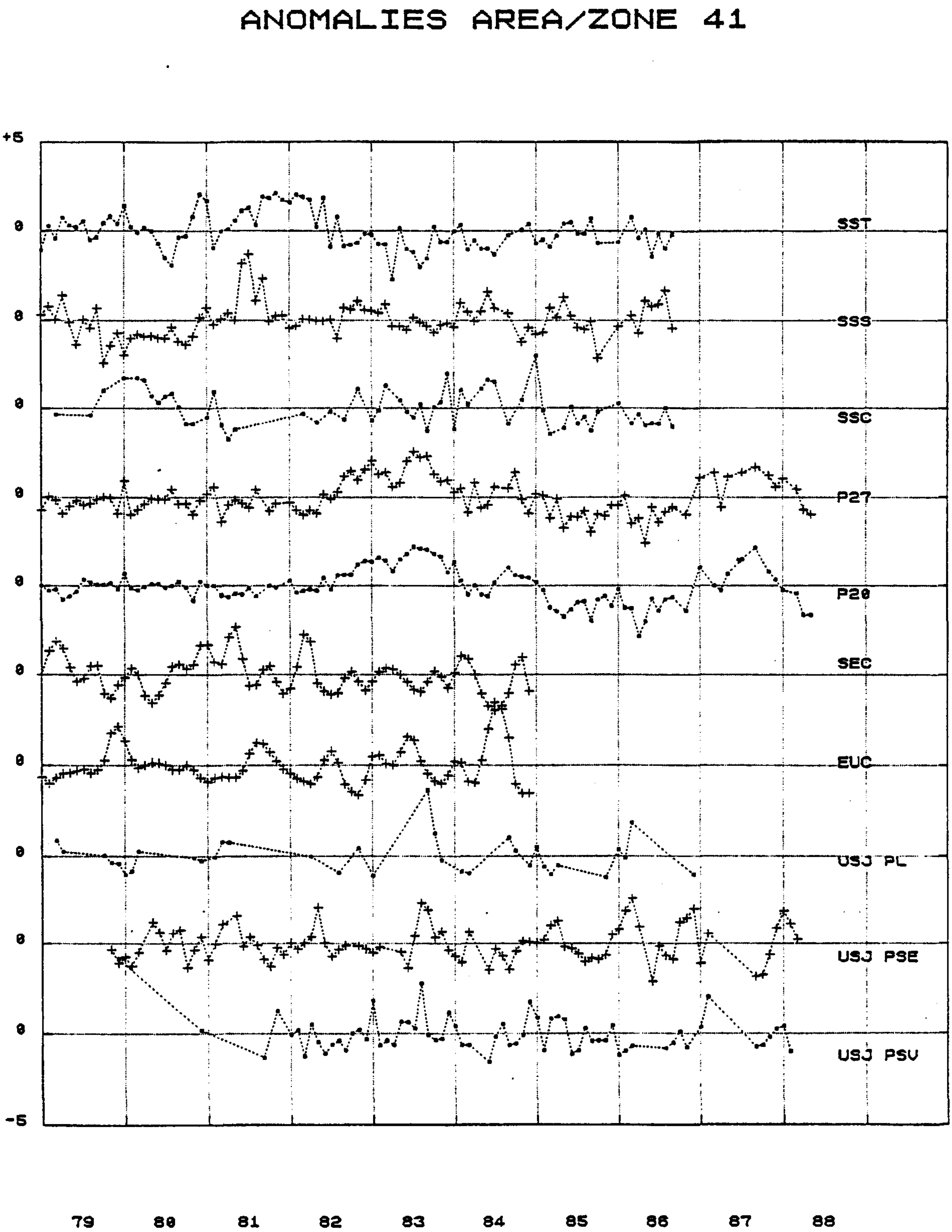



Fig 10: Standardized anomalies of sea surface temperatures (SST), salinities (SSS), chlorophyll contents (SSC), mixed layer (P27) and thermocline (P20) depth, northern branch of the South Equatorial Current (SEC) and Equatorial Under Current (EUC) intensity, pole-and-line (USJ PL), purse seine log (USJ PSE) and school (USJ PSV) sets skipjack cpues in area 41.