INTER-AMERICAN TROPICAL TUNA COMMISSION
COMISION INTERAMERICANA DEL ATUN TROPICAL

INTERNAL REPORT--INFORME INTERNO

No. 22

A COMPARATIVE STUDY OF YELLOWFIN TUNA IN THE EASTERN PACIFIC AND IN THE EASTERN ATLANTIC

by

Alain Fonteneau
Centre de Recherches Océanographiques de Dakar-Thiaroye

La Jolla, California

1992

PREFACE

The Internal Report series is produced primarily for the convenience of staff members of the Inter-American Tropical Tuna Commission. It contains reports of various types. Some will eventually be modified and published in the Commission's Bulletin series or in outside journals. Others are methodological reports of limited interest or reports of research which yielded negative or inconclusive results.

These reports are not to be considered as publications. Because they are in some cases preliminary, and because they are subjected to less intensive editorial scrutiny than contributions to the Commission's Bulletin series, it is requested that they not be cited without permission from the Inter-American Tropical Tuna Commission.

PREFACIO

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Estos informes no deben considerarse como publicaciones, debido a que en algunos casos son datos preliminares, y porque están sometidos a un escrutinio editorial menos intenso que las contribuciones hechas en la serie Boletines de la Comisión; por lo tanto, se ruega que no sean citados sin permiso de la Comisión Interamericana del Atún Tropical.

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TABLE OF CONTENTS

A COMPARATIVE STUDY OF YELLOWFIN TUNA IN THE EASTERN PACIFIC AND IN THE EASTERN ATLANTIC

BY

ALAIN FONTENEAU[1]

SUMMARY

This paper presents a comparative study of yellowfin tuna in the Eastern Atlantic and Eastern Pacific, based on past data and scientific analysis conducted by IATTC and ICCAT scientists. The fisheries are first compared: catch trends, fishing zones, size caugth and seasonal pattern of the fisheries. A wider geographical area and more important catches are observed in the Pacific. The sizes caugth by the two fisheries are different: they are bimodal in the Atlantic (with very few yellowfin caugth at intermediate sizes), but not in the Pacific. The environment of the two fisheries is analyzed: the thermocline and oxygen structures, seasonal and interannual variability of the environment are described. The seasonal variability is dominant in the Atlantic, when the interannual anomalies, El Niño, are dominant in the Pacific. The growth of yellowfin is limited to a comparison at a global pluriannual and ocean scale, based on recoveries of tags. The results suggest a possible slower growth in both oceans, 0.50 mm per day in the Atlantic and 0.68 mm per day in the Pacific. The growth of large fishes is similar in the two oceans, at approximately 1mm/day. However, the growth from otolith readings in the Pacific give faster growth rates at all sizes. Possible bias from the recoveries results in the two growth studies are discussed. The analysis of sex ratio is conducted and indicates that females are dominant between 126 and 156 cm in the Atlantic, at sizes where males are already dominant in the Pacific. For sizes greater than 156 cm, the sex ratio is similar in both areas. The spawning activities are studied by a comparison of the seasonality of gonad index. This seasonality is different in the two oceans: high gonad indices are seasonal in the Atlantic, when they are observed all year round in the Pacific. The association between yellowfin tuna and other species is studied: there is a similarity between the two areas, but two major differences are noticed: small bigeye tuna is seldom associated with yellowfin in the Pacific and often associated in the Atlantic ; porpoise

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are commonly associated with schools of large yellowfin in the Pacific, but rarely in the Atlantic. Those observations need to be better evaluated quantitatively and to be explained biologically.

Recommendations to conduct further coordinated researches in the two oceans are developped.

I. INTRODUCTION

This study has been conducted during a limited amount of time in the IATTC laboratory and its goal were limited to conduct a broad preliminary comparison of some parameters related to yellowfin tuna in the Eastern Pacific and the Eastern Atlantic oceans.

Two major types of comparison were conducted : first a comparison of the fisheries exploiting those two stocks in relation with environmental factors, and second a comparison of some biological parameters of the species in those two areas.

The present study has been conducted using the data available on the Atlantic and Pacific yellowfin tunas, and some scientific work published upon those two stocks.

The data from the Eastern Pacific are those collected by the IATTC (Inter American Tropical Tuna Commission). Most of the data from the longline fisheries are from the Far Seas Laboratory in Shimizu, Japan. Most of the scientific work conducted in this Eastern Pacific stock has been conducted by scientists from the IATTC or by Japanese scientists from the Far Seas Laboratory in Shimizu.

The Atlantic data are those collected by several national research agencies under the coordination of the International Commission for the Conservation of Atlantic Tunas (ICCAT) for recent years (since 1970). This Atlantic data base is the one which is operational in the CRODT (Centre de Recherches Oceanographiques de Dakar Thiaroye) in Senegal. The researches conducted on the Atlantic stock have been conducted by several national research institutions, especially from France, Spain, United States, Senegal, Ivory Coast, Ghana, etc... Most of them have been published for recent years in the ICCAT publications.

All the available data have been installed in the IATTC VAX computer, and subsequently converted to the same format in order to allow their comparison. Both sets of data are similar in nature and quality, and they cover fairly well, and for many years, both the detailed statistical characteristics of all the major fisheries, and the major biological characteristics of the two yellowfin tuna stocks.

The two Atlantic and Pacific stocks are of similar level of quantitative importance, and the past researches upon them have covered during the last 40 or 50 years a wide range of research fields. Those two geographical areas under study, Eastern Atlantic and Eastern Pacific are probably the only two areas in the world where all those extensive statistical and biological data and analysis, are presently available.

The goal of this study is to compare some existing data and analysis. This comparison will be done for practical reasons only at a global level . The final purpose of this work is to identify some specific parameters or phenomenon of major interest upon which further more detailed comparative studies should be developed.

The following elements will be reviewed in the present study :

-Chapter 2 : A general comparison of the yellowfin fisheries in the two areas : a comparison of fishing zones by gear and a comparison of the catches by sizes in each area (present and past fisheries).

-Chapter 3 : An overview of some oceanographical parameters estimated to be important for tunas in the two areas, and of their global relationship with the fisheries (longline and surface).

-Chapter 4 : A detailed comparison of the yellowfin tuna growth in the two areas, especially conducted on the recoveries of tagged fishes, but using other informations such as the readings of otoliths and modal progression analysis. The tagging and recovery data are of special interest to be compared, as they can provide direct biological evidence on growth, important parameter which seems to be, from existing studies, surprisingly different in the two oceans.

-Chapter 5 : A comparative review of some other major biological parameters, such as sex-ratio by sizes and seasonal fluctuations of gonad indices.

-Chapter 6 : The association of the yellowfin tunas with other tuna species, with mammals and with floating objects will be briefly reviewed and compared.

In each of those five chapters, a brief comparative review of the data and scientific analysis in the two oceans will be conducted.

The conclusion of this study will leads to research recommendations concerning some problems shown by the present comparative analysis of the two stocks.

2. OVERVIEW OF THE FISHERIES

2.1.OVERALL

The comparison between the eastern Atlantic and eastern Pacific fisheries will be primarily conducted during recent years, period 1980 to 1988. Unfortunately this recent period is heterogeneous in both areas, as many major changes have been observed during those recent years: El Niño anomalies, exodus of purse seiners to the Indian ocean and western Pacific, dramatic changes in the levels of stock abundances, etc. Consequently, the fishery parameters which are described may be the consequence of this heterogeneity and may need some further careful interpretation; as often as possible, some comparison will be done to the historical fisheries of both oceans in order to evaluate better the potential peculiarities of the recent period.

2.2. CATCHES :

The yearly catches by gear (purse seine, baitboat and longline) are given in table 1 and figure 1 for the areas east of 30° West for the Atlantic, and east of 150° West for the Pacific ocean. Those two geographical units are generally considered as unit stocks, even if the yellowfin tunas inhabiting those two geographical units are mixing with individuals from the corresponding adjacent area in the west This mixing of adults is clearly observed in the Atlantic from tagging results and from cpue data (Fonteneau 1992); this mixing of adults is also suggested by the cpue data in the Pacific (Suzuki et al. 1978), but not by the tagging data.

Those data show that the total yellowfin catches has always been greater in the Pacific Ocean than in the Atlantic : present average yellowfin catches for the period 1980 to 1988 in the Eastern Pacific are approximately 190000 tons, and 110000 tons in the Eastern Atlantic.

It can also be noticed that the development of the eastern Pacific fisheries has been observed earlier than in the Atlantic : the Eastern Pacific fishery was already catching an average 65000 tons of yellowfin yearly between 1949 and 1954, when the Atlantic yellowfin stock was still unexploited.

During the most recent years, the catches in the eastern Pacific are reaching record high levels of an average 250000 tons since 1985, when the average eastern Atlantic catches are levelling off at a 100000 tons level since 1984, because of reduced fishing effort by purse seiners.

Skipjack tuna is a major by catch species in the two fisheries : however the average relative importance of this species in the two fisheries is not equivalent. The total skipjack catches are presently at a level of 100000 tons in the Atlantic (1980-1988), nearly reaching the yellowfin catches (in weight), when the skipjack catches amount for only 89000 tons in the Pacific (less than half the yellowfin catches) during the same period. It can be noticed that the percentages of skipjack tuna in the catch from the two fisheries are highly variable from one year to the other, especially in the Pacific ocean. This species has been during certain years a very important species in the Eastern Pacific purse seine fishery : for instance, during 1978, 1980 or 1982, the skipjack catches where nearly equivalent to the yellowfin catches, when they are limited to an average 25 % of the yellowfin catches since 1985. Those changes are probably due to a combination of biological factors (abundance and availability of skipjack) and of economical parameters (relative landing value of skipjack, fishing nations, etc...).

2.3. FISHING ZONES :

The characteristics of the fisheries are interesting to analyze and to compare, even if they may not represent the distributions of the fish populations, but primarily the fishery operations themselves.

The present fishing zones for yellowfin tuna in the eastern Atlantic and Pacific oceans are shown in figure 2 . The two fishing maps are drawn at the same scale for fishing areas and for catches, in order to facilitate the comparison of the two fisheries.

Those two maps show well the general similarity and differences between the two fisheries : the two fisheries have in common an inshore component with a limited number of major coastal fishing zones, and an offshore component, more scattered in wide offshore areas. The major difference between the two fisheries is clearly the latitude of the major offshore fisheries which are located around the Equator in the Eastern Atlantic, and at the 10° North in the Eastern Pacific.

The figure 3 shows (at the same scale) maps for the historical fisheries (period 1969-1974 for the Atlantic and 1960-1970 for the Pacific). From an historical point of view, the offshore expansion of the fisheries took place during the late sixties in the Eastern Pacific, and in the middle seventies in the Atlantic. Those early yellowfin fisheries in both oceans were coastal, as it is clearly shown by this figure 3.

The present average fishing zones of the longline japanese fisheries are shown in figure 4 (yellowfin) and figure 5 (bigeye) for the Pacific ocean and the Atlantic, in comparison with the distribution of the longline efforts (the fishing maps of bigeye tuna are given because this species is presently the major target species of longliners in both oceans in the tropical areas).

The geographical distributions of yellowfin catches by longliners appears to be different in the two oceans : the major Atlantic fisheries are located between 10° North and 5° South, in the same range of equatorial latitudes as the purse seine fishery. In the Eastern Pacific, the longline yellowfin fisheries appears to be much more scattered between 20° North and 20° South, the major catches being caugth in the south (associated with bigeye), in an area opposite to the purse seine fishery.

A comparison of the fishing zones of large or small yellowfin taken by purse seiners in the two oceans is interesting: the figures 6 and 7 show for the Atlantic and Pacific fisheries this average (1980-1988) of the geographical distribution of yellowfin catches by purse seiners (Atlantic) or purse seiners and longliners combined (Pacific) classified in two categories : the large yellowfin, more than 30 kg, and the small ones, less than 30 kg. This figure shows well that in both oceans the small yellowfin are predominantly taken in the inshore areas, when the large ones are predominantly, but not exclusively, from the offshore area.

The figure 8 gives the fishing zones of the main secondary species in the surface fisheries, skipjack tuna, during recent years (1980-1988) and for both areas at the same scale. Those two maps show well that skipjack tuna is predominantly taken in coastal areas in the two oceans, in the same area that small yellowfin. The skipjack catches in the offshore areas are rare in both zones.

The table 2 gives a statistics of the total numbers of one degree squares fished in the two areas during recent years, with a classification of the numbers of one degree squares based on their average productivity of yellowfin and skipjack tunas. The figures 9 and 10 show the average yellowfin and skipjack catches by one degree squares, ranked by decreasing average importance, in the Eastern Atlantic and Pacific.

The number of 1 degree squares with an average significant catch of more than 10 tons of yellowfin is 3.0 times greater in the Eastern Pacific (1140 versus 385 squares). However, the number of highly productive one degree squares is similar in the two areas : 65 one degree squares produced an average of more than 500 tons in the Eastern Pacific (total catches in those squares = 51 000 tons), when 57 squares were in the same range of average catches in the Eastern Atlantic (total catches 44 000 tons) (figure 9).

The situation is different for skipjack tuna : the Eastern Atlantic fishery, with its higher total catches during recent years, is exploiting a greater number of highly productive squares, 20 squares producing on the average more than 1000 tons. This average level was never observed in the Eastern Pacific during recent years, as the maximum average skipjack catch per one degree square was only 860 tons (figure 10). However a different situation was observed in the historical fishery : during the average period 1960-1970 the fishing area of Equador produced an average catch of 23000 tons per year in only eight one degree squares (yearly average of 2300 tons per 1º square).

The different situation of the skipjack Atlantic fishery may be partly explained by the important Atlantic baitboat fishery based in Tema, which primarily targets on skipjack in a limited area off Ghana (24000 tons of average yearly skipjack catches between 1980 and 1988) ; however in the two fishing areas of Senegal and Cap Lopez, the important catch of skipjack shown by figure 9 was taken entirely by purse seiners.

Another interesting comparison to conduct between the two areas is related to their geographical sizes : it is obvious to notice that the Eastern Pacific fishing zone is much more greater than the Atlantic one; the distances between the most distant major fishing locations are much more greater in the Pacific than in the Atlantic: this is well shown for instance taking as a reference point the southern fishing zone of Congo in the Atlantic, and the southern Peru fishing zone in the Pacific, both located at 5 º South, near the southern limit of the exploited stock (figure 11). The distances between this reference area and the northern fishing zone are almost identical : 2500 nautical miles for the Pacific (Southern California) and the Atlantic (Senegal). Between the same southern geographical reference area and the more western fishing areas, the distances are approximately 3600 nautical miles in the Pacific (140° W), but only 2000 miles in the Atlantic (20° W).

- The area explored by the purse seine fisheries was on the average (1980-1988) 2.4 times greater (1840 versus 770 1º squares) in the Pacific than in the Atlantic.

2.4. SIZES OF YELLOWFIN CAUGHT

The estimations of the sizes caught by fisheries are based upon sampling schemes conducted at landing places. The sampling rates have been variable from year to year and between Atlantic and Pacific, but have been both conducted on a systematic and intensive way. The number of yellowfin sampled in both areas is shown by the table 3 which gives the numbers of yellowfin sampled for sizes during recent years in each ocean. A major difference between the two sampling scheme for sizes, is that the Pacific tuna sampling targets only at estimating the size composition of the catches, when the Atlantic sampling aims simultaneously (since 1980) at two goals, sizes and species composition of the catches. All the species composition given in the Atlantic log books have been thereafter corrected by this sampling.

The statistical methods employed in order to extrapolate the size samples to the total catches are different in the two areas. The extrapolations methods are based on a carefull analysis of the time and space heterogeneity of sizes in both fisheries.

The average total numbers of yellowfin estimated to be caugth by the two fisheries are given in table 4 in numbers, and in weight in table 5, by 2 cm class intervals, and shown (in weight) for recent years in figure 12 (average 1975-1988) and in figure 13 (1985-1989). The same results are given for the two historical fisheries in figure 14.

The average weight of yellowfin taken on both stocks during recent years (1975-1988) is similar, the average individual weight being 30 % less in the Pacific :

- 8.3 kg for the Eastern Pacific
- 11.9 kg for the Eastern Atlantic

However, the average weight of the yellowfin taken during the last five years (1985 to 1989) in the Eastern Pacific is reaching an average 11.2 kg, which is similar to the Atlantic average (figure 13); this change is due to changes in the fishing pattern of the purse seine fishery and to changes in the recruitment level in this stock. It can also be noticed that:

- the sizes at recruitment are similar in the two fisheries.

- the catches by size in weight in the Atlantic are always bimodal : the group of smaller fishes between 35 and 65 cm contributed, on the average, to a large number of fishes caught (6.6 millions of individuals yearly), but only to a minor proportion of the catches, 15.5 % of the fishes caught in weight. The group of intermediate sizes (from 65 to 110 cm) was also of minor relative importance, and contributed to only a 14.7 % of the average catches. The group of large fishes (more than 110 cm) is allways dominant in weight, and contributing to a 69.8 % of the total catches. This group of large fishes was predominantly taken by purse seiners (91 %), but also by longliners (9 %).

- the average catches by weight classes showed in the Pacific a flat curve, with a more or less constant contribution of each 2 cm class between 50 and 140 cm (figure 12). The group of small fishes (less than 65 cm) contributed to an average 21.6 % of the catch, when the intermediate group amount for 39.5 % of the catch. Those two values are higher than the corresponding Atlantic percentages. The group of large fishes (+110 cm) was only 38.9 % of the total catches in the Eastern Pacific, much less than the 69.8 % from the Atlantic.

- the largest yellowfin commonly taken in the Eastern Atlantic are much more larger than in the Pacific : fishes larger than 140 cm contributed to an average 40 % of the Atlantic catches, but only to a 9 % of the Eastern Pacific catches during the period 1975 to 1988. Even during recent years when the Eastern Pacific fishery is catching a larger average size of yellowfin (for instance during the period 1985-1989) (figure 13), the contribution of fishes greater than 140 cm in the Eastern Pacific was only 10 % of the total catches, compared to the average 70 % of the Atlantic (1975-1988).

- those interesting differences in maximum sizes taken significantly by the two fisheries and the characteristic size structure of the catches in both oceans were also already noticeable in the catch by sizes of the historical fisheries, as it is well shown by figure 14.

Further detailed analysis of the catch at size figures (in numbers) which have been observed in the two oceans should be undertaken, in relation to growth and natural mortality. This work which could be conducted throught ad hoc simulations, should provide some interesting global estimates on the changes of fishing patterns and fishing mortalities by size and age in the two oceans, in conjunction with the usual sequential population analysis presently done on both stocks. Especially the Atlantic bimodal catch at size should be analyzed more in depth, because of its various biological implications. This reduced catch at intermediate sizes can be explained by two major phenomenons :

(1) a decreased availability to the fisheries because of migrations or because of changes in the fish behaviour, reducing their catchability to the purse seiners in the present fishing zone.

(2) the increased growth rate (see chapter 4) between juvenile and adult stages which could explain a reduced number of fishes in this group of the population at intermediate ages.

2.5. SEASONALITY OF FISHERIES

One important parameter in the tuna fisheries is the seasonality of the abundance and catches of tuna by fishing seasons and fishing zones.

In order to compare the seasonalities of the two fisheries, the average monthly catches of yellowfin in selected areas has been calculated for both oceans (average period 1980 to 1988, figure 15). The areas selected in each ocean were taken from previous analysis done by scientists in the two oceans (PUNSLY 1987, FONTENEAU 1991).

This figure shows well the greatest seasonality in the Atlantic ocean fisheries, where most of the fishing zones show clearly an average alternance between periods of high catches, followed by periods of low catches.

In the Pacific ocean, only the southern area of Peru and the offshore fishing area at 10° North West of 120° West, show such a marked average seasonality. A low variability of average catches between months is observed in most of the other areas.

The seasonality of catches in the offshore area may be linked to spawning activity, as in both oceans this offshore area show high gonad indices during this fishing season (ALBARET 1976 ; CAPISANO et FONTENEAU 1991 and KNUDSEN 1977).

2.6 CONCLUSION ON FISHERIES

Only the large scale and major average characteristics of each of the two fisheries has been reviewed and compared in the present study. This comparison shows some major similarities and differences which should be further analyzed and explained, taking better into account the peculiarities of the recent period upon which the present analysis is based.

Also some interesting small scale changes in the fisheries, which are common in the two fisheries, have not been examined and should be further studied; for instance some important changes in the local species composition or abundances have been observed in both oceans . Those changes which may be very important for local fisheries, should also deserve in the future, some comprehensive study.

3. ENVIRONMENT

3.1. OVERALL

Environmental factors are considered to be an important component to determine the geographical distributions and movements of both tuna species and tuna fisheries ; this factor is also playing an important role in the dynamics of the tuna stocks and fisheries, as it is a key factor in controlling, among other factors, the variations of recruitment levels and of the stocks catchabilities to fishing gears.

In the present study, it is consequently of major interest to review the major environmental characteristics in the two areas and their variability, especially for those parameters which can explain the differences observed between the two stocks and fisheries.

The major parameters which will be reviewed and compared in the two areas are the followings :

- the distribution of highly productive areas
- the major surface and subsurface currents
- the temperature structure of the upper layers of the ocean and the seasonal and interannual variability of this parameter.
- the average oxygen structure in the upper layers.

3.2. AREAS OF HIGH PRODUCTIVITY :

It is difficult to evaluate the ocean productivity, especially in the oligotropic offshore areas where most of the primary productivity is probably based upon nanophytoplancton which was not measured by productivists until recent years. Taking into account those uncertainties, two maps of the average ocean productivity were taken from BERGER et al. 1988 :

- the first one (figure 16) gives the traditional image of the primary productivity based upon direct measurement at sea.

- the second one (figure 17) is based upon indirect calculations of primary productivity from phosphates concentrations at the 100 meters depth ; this method provides results only at a minimum distance of 100 km from the continental shelf. This method is expected to provide a more realistic estimate of the oceanic productivity.

One can make the following observations on those maps :

In the Eastern Atlantic ocean, the two maps show a general good correlation. The areas which are considered to be highly productive, which consequently should lead to tuna concentrations, are more apparent on the figure 16. In this figure the three major coastal fisheries of Senegal, Ghana and Cape Lopez are clearly associated with high primary productivity (upwellings). Those areas are either seasonaly or permanently productive ; the same comment applies for the equatorial area which is a productive area. On the average, there is a quite good agreement between areas of high productivity and areas rich in tunas. However in several cases, localized discrepancies between tuna and plancton productivities are observed. Those discrepancies should be further analyzed.

In the Eastern Pacific, there is a striking difference between the traditional and the more recent estimates of primary productivity (figures 16 and 17). In the coastal areas, both figures provides estimates of high primary productivity, which fits well with the locations of the major coastal tuna fishing zones. However, the offshore productivity estimated by the traditionnal and by the more recent methods are in contradiction, especially in the major offshore fishing zone centered at 10° North (on the north equatorial convergency). This area is now estimated to be highly productive, this conclusion being in agreement with the location of the purse seine fishery.

As a general conclusion, the general geographical distribution of the major tuna fisheries follows well in both oceans the distribution of higher primary productivity, but this global average observation would need to be further analyzed in a more detailed and comprehensive way.

3.3. SURFACE AND SUBSURFACE CIRCULATIONS

It is important to compare the surface and subsurface movements of the two oceans, as this parameter may play an important rôle on the distribution, the migrations and the concentrations of tunas.

The major surface and subsurface currents in the two areas are shown in figure 18. At a very global level, it appears that the general framework of currents is similar in the two areas, each current from one ocean having its symetrical counterpart in the other ocean, in both the surface and subsurface layers.

Some specific oceanographical features which may be important for tunas are link with those currents ; for instance:

- In the Atlantic : the equatorial divergency located in the equatorial circulation between 20-25° W and the African coast, the Guinea Dome at 10° North, the North Equatorial convergency at 3º North.

- In the Pacific : the convergency located at 10° North between the North Equatorial current and the North Equatorial countercurrent and the Costa Rica dome centered also at 10° North.

3.4. SEA SURFACE TEMPERATURE AND THERMOCLINE STRUCTURE IN THE TWO AREAS :

The average sea surface temperatures in the two zones under study are shown in figure 19.

The average thermocline structure in the two areas is shown in figure 20 a and b. This last figure shows well the major similarities and minor differences in the thermocline structure in the two areas:

-In both oceans the shallower thermoclines are located near 10º North and along the Equator. The shallow thermoclines cover a similar geographical range in the equatorial areas of the two oceans: for instance the 20º isotherm is reaching a depth of 80 meters at the same distance of 2700 miles from the coast line in both oceans.

-The thermocline pattern is different at 10° North: in the Pacific ocean the shallow thermocline covers a wider geographical area than in the Atlantic; for instance in the Pacific the 20º isotherm is reaching a depth of 80 meters at a distance of 3700 miles from the american coast, when this distance is only 1900 miles from Africa in the Atlantic (at 8º North).

Those distances must be considered taking into account the relative shape of the two ocean basins and of the two continents.

Another important parameter to consider is the interannual and seasonal variabilities of the environmental conditions :

The interannual variability in the Pacific Ocean is a well studyied event, characterized by the El Niño anomalies. Those El Niño anomalies are well shown by a diagram of the monthly thermocline depth in the Eastern Pacific (figure 21).

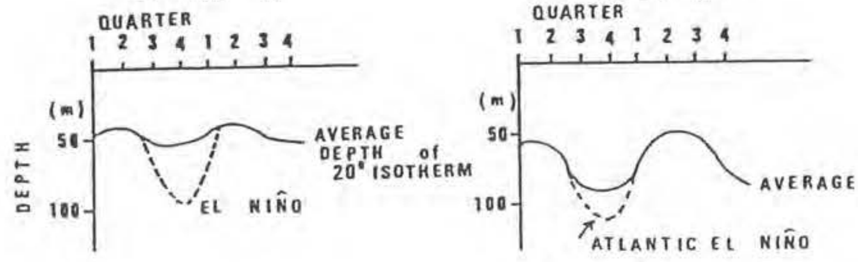
The major characteristic of the El Niño phenomenon in the area is an important deepening of the thermocline, with an excess of warm waters in the surface.

Those El Niño anomalies are also observed in the tropical Atlantic, to a lesser degree and with a certain time lag following the Pacific events. A good example is shown by the 1982-1983 Pacific El Niño, which has been also observed to a lesser degree in the Atlantic Ocean during 1984. During those Atlantic El Niño, a deepening of the thermocline similar to the Pacific is observed (figure 22).

Those El Niño interannual anomalies have very significant effects on the fisheries, especially because of the change in catchability due to the changes of thermocline depth.

The seasonality of the oceanographical conditions is well shown in the two areas by maps of the sea surface temperatures during selected periods, in winter and in summer time (figure 23). Those figures show well the large amplitude of the seasonal sea surface temperature fluctuations observed in the Atlantic, and their reduced importance in the Eastern Pacific.

This major difference between the environments in two oceans can be summarized by the following figure which shows the relative order of magnitude of both the seasonnal and interannual thermocline depth variability in both oceans :



Those differences in the thermocline structure variability can well explain some significant differences observed in the seasonal and year to year variability of the fisheries.

3.5. OXYGEN STRUCTURE IN THE TWO AREAS :

An important factor to consider in the tuna-environment relationship is the depth distribution of the low levels of dissolved oxygen in the sea water. This parameter is important because the physiological studies conducted on tunas have well shown that each species and age of tuna requires specific minimal levels of oxygen.

The average concentrations of dissolved oxygen in the two areas at a 150 meters depth are shown by figure 24. The vertical tropical structure of the oxygen concentration is also well shown by results of North-South oceanographical cruises done in the two areas. Such results are given in a simplified manner by the figure 25. Those two figures show well the differences in oxygen concentrations between the two oceans :

- The surface waters of the Eastern Pacific have commonly very low levels of oxygen, less than 1 ml/litre at 150 meters, in most of the fishing areas. Between 5° South and 10° North, low levels of 2 ml/l of oxygen are commonly observed above 100 meters (figure 25).

- The Eastern Atlantic shows similar low levels of oxygen (2 ml/l) in its upper layer only in two small coastal areas centered off 15° North and 15° South (figure 24) ; most of the fishing areas are located in areas with high oxygen concentration in the upper layers.

Those important differences in the vertical oxygen concentrations may explain several of the differences observed between the two fisheries. This point would need further comprehensive analysis.

3.6. GENERAL DISCUSSION OF THE GLOBAL TUNA - ENVIRONMENT RELATIONSHIP IN THE TWO AREAS :

The two Atlantic and Pacific fisheries show similarities or significant differences in their geographical distribution (surface and longline fisheries) and in their seasonal and interannual variability of catches. Those characteristics are probably well explained by the differences in the environmental conditions between the two areas.

The latitudes of shallower thermocline (Equator in the Atlantic, 10° North in the Pacific) correspond well to the major fishing areas of purse seiners.

The marked seasonality of the time and area fishing patterns in the Atlantic (figure 15) is probably linked to the stronger seasonal variability of the environmental conditions.

The effects of the El Niño on the fisheries of the two oceans are clearly apparent : in both oceans this environmental anomaly affects the availability and vulnerability of tunas to the fisheries. Those effects are less obvious in the Atlantic, because of the smaller importance of the El Niño events, as compared to the marked seasonal variability. However the important anomaly of cpue observed for large yellowfin in the Atlantic in 1984 has shown the potential importance of those anomalies upon the fisheries (Fonteneau 1991).

An other effect of the El Niño anomalies on tunas, is the effect on the recruitment level : it has been shown in the Eastern Pacific that the El Niño anomalies correspond to the highest year classes which enter in the purse seine fisheries (IATTC 1989). On the contrary, it has been shown in the Atlantic that the lowest yellowfin year classes were born during periods of Atlantic El Niño events : the two low year classes recruited during recent years in the Atlantic were those born during the first quarters of 1968 and 1984, both years well known in this area for their environmental anomalies.

This difference of biological effects of the El Niño anomaly on the recruitment levels should be better evaluated and further studied and understood biologically.

The differences in the yellowfin longline and surface fishing zones in the two oceans are obvious and probably explained by environmental parameters :

- in the Atlantic, the longline fishery obtains its better yellowfin catch rates in the same area (between 10° north and 5° south) where the purse seiners obtain their highest catches of large yellowfin.

- on the contrary, the yellowfin fishing zone of longliners in the Eastern Pacific covers a wide area between 20° South and 25° North, and very little longline effort is exerted by longliners in the purse seine fishing areas, especially in the major purse seine area centered at 10° North. This situation may be due to the shallow thermocline, typical in this area (SUDA et al. 1969, MIYABE and BAYLIFF 1987), and to the very low levels of oxygen in the infrathermoclinal waters in this area. It must however be noticed that in the historical longline fishery, the area centered at 9° North and 95° West, west of the Costa Rica dome (which is also heavily fished by purse seiners) showed seasonally very high yellowfin catch rates in an area with shallow thermocline and very low oxygen levels under the thermocline. This unexplained localized seasonal fishery is no more apparent in the present fishery (since the early seventies), probably in relation with the increased use of deep longlining targetting on bigeye.

As a conclusion, this preliminary global overview of the tuna environment relationship in the Atlantic and Pacific ocean shows several interesting features. However, further in depth studies are necessary to obtain a better understanding of the phenomenons happening in the two oceans.

The recommended further studies should conduct more detailed analysis between the data from the fisheries and from the environment in the two oceans which should be conducted an a statistical basis using data well stratified in time and area. The new computerized oceanographical data bases recently developped by oceanographers on a world wide scale should facilitate those comparisons.

Another problem which has not been examined and which should deserve some investigations, is the potential existence of a global warming in the surface layers of the intertropical oceans during recent years, as this trend suggested by some authors (Among others CITEAU et al. 1991) could have a dramatic impact in the stocks and fisheries trends.

4. COMPARISON OF YELLOWFIN GROWTH IN THE EASTERN ATLANTIC AND PACIFIC

4.1. OVERALL

The recovery of tagged fishes provides one of the most direct and strongest evidence in the field of fish growth.

Following this general goal, several tagging programs have been conducted for many years in both oceans, and have provided many direct and valuable informations on the growth of yellowfin tuna. Those tagging results have already been analysed independently in both oceans by several authors, among others BAYLIFF 1988 for the Pacific, FONTENEAU 1981 and BARD et al. 1991 for the Atlantic.

The goal of the present study was to conduct a common analysis of the pooled data in order to evaluate better their common features and differences.

The analysis of apparent growth from tagged and recovered fishes must also be compared with results obtained by other methods, such as modal progression analysis and direct reading of hard parts. In the Atlantic, only the first type of analysis has been conducted, when results from both modal progressions and reading of hard parts are available for the Pacific yellowfin.

4.2. TAGGING AND RECOVERY DATA IN TWO AREAS :

The numbers of yellowfin tagged and recovered at a known size and date after more than 30 days at sea (this duration is often considered to be a reasonable minimum for growth studies), are the following :

- In the Eastern Atlantic, 479 individuals were recovered following those two constraints. The sizes at tagging and sizes at recovery of those fishes are given in figures 26 and 27, in comparison with the Eastern Pacific figures.

A reexamination of this set of data will show that certain critical errors remains in those tagging and recovery files. Those obvious errors will be eliminated, following the method described in chapter 4.3. This correction of errors will reduce the number of useful recoveries to 470 individuals.

. In the Eastern Pacific the original number of usable recoveries was 1 865 individuals. The sizes at tagging and sizes at recovery of those fishes are given in figures 26 and 27 in comparison to the Eastern Atlantic figures. The data set used previously by BAYLIFF 1988 to conduct his growth study, used only 1483 of those recoveries, because the recoveries between 30 and 60 days at liberty were eliminated. This limit at 60 days of liberty is clearly better than a 30 days limit, but is still somehow artificial; in order to increase the number of usable recoveries, the present comparison will use all recoveries for more than one month at sea in the two oceans, adding 382 individuals, corresponding to durations at sea between 30 and 60 days, to the BAYLIFF's original sample. This choice is based upon the hypothesis that the growth of fishes recovered after 30 days of liberty have not been affected by the tagging (even if the variance in the growth rates is higher for the short durations of liberty). As for the Atlantic, a correction of obvious errors has been made in the Pacific data set and reduced the number of tags used to 1818 individuals (47 tags estimated to be in error) (see chapter 4.3).

The figure 26 shows well the sizes of tagged fishes in each of the two oceans :

. Small yellowfin, for instance less than 50 cm at tagging, have similar absolute numbers of tagged and recovered fishes in both oceans: 173 fishes recovered in the Atlantic versus 445 in the Pacific.

. The larger fishes tagged and recovered, for instance tagged at size greater than 50 cm, are much more numerous in the Eastern Pacific data set (1818 recoveries) than in the Eastern Atlantic one (297 recoveries).

The durations at sea for the two Atlantic and Pacific samples are given on figure 28. Most of the recoveries are observed between 30 days and one year at sea : only 12.5 % of the Atlantic recoveries and 4.3 % of the Pacific recoveries stayed at sea for more than one year.

4.3. ERROR CHECKING AND CORRECTIONS DONE :

Any tag and recovery file contains errors due to :
- errors in the exact size at tagging
- errors in the size at recovery
- errors in the duration at sea

All fishes with negative apparent growth have been kept in the sample under study, because their elimination would obviously introduce a bias in the growth study, as the symetrical errors in excessive growth cannot be detected nor corrected. In order to eliminate the worst errors from the two data sets, the growth rate of each individual fish (in mm/day) was compared to the theoretical models accepted for each ocean. Those two model are the following :

. for the Atlantic ocean, a linear growth of 5 mm/day for sizes less than 65 cm, FONTENEAU 1981 followed by a VON BERTALANFFY type growth curve with the LE GUEN and SAKAGAWA 1972 parameters (table 6).

. for the Pacific, the RICHARDS function (RICHARDS 1959 based on otoliths readings proposed by WILD 1986 (table 6).

When the calculated average growth rates and expected ones differed by more than + or - 2 mm per day, the recovery has been eliminated. This selection rate is arbitry selected to eliminate the excessive positive or negative apparent growth. The percentage of recovered tags eliminated using this criterion was 1.9 % in the Atlantic and 2.5 % in the Pacific.

4.4. GROWTH RATES BY SIZE CATEGORIES :

The present analysis has been conducted grouping the recoveries into two categories of fishes :

- Fishes tagged at less than 60 cm ("small fishes") and after a limited time of less than 90 days at sea. This choice is done in order to estimate the growth rates of the small individuals, as this category of fishes has shown in many areas, for instance in the Eastern Atlantic, slower than expected growth rates

- Fishes tagged at sizes greater than 65 cm or "large fishes", for all durations at sea.

The results of this global analysis can be summarized as follows :

	Atlantic	Pacific
"Small fishes" numbers	224	452
Growth rates(mm/day)	.49	.68
Standard Dev.	.49	.66
S.D. of Average	.03	.03
"Large fishes" numbers	57	795
Growth rates(mm/day)	.97	.89
Standard Dev.	.64	.56
S.D. of average	.13	.03

Those results indicate that the recovered fishes showed the following characteristics :

(1) Large variance are observed in both oceans for growth rates obtained from recoveries. This variability is probably in majority due to a cumulative effect of errors in the size measurement at both tagging and recovery. This large variance does not necessarily correspond to a bias, as both types of errors are probably randomly distributed (positive or negative).

(2) The group of the "small fishes" has a significantly slower growth rate than the group of large fishes in both oceans.

(3) The growth of the "small fishes" tagged and recovered in the Eastern Atlantic is significantly slower that the growth of the same category of fishes in the Pacific.

(4) The growth rates of the "large fishes" are faster than the growth rates of the "small fishes" in both oceans ; the growth rates of large fishes seems very similar in the Atlantic and in the Pacific : 0.89 mm per day (+/- 0.03 mm) in the Pacific, versus an average rate of 0.97 per day (+/- 0.13 mm) in the Atlantic.

4.5. PRESENT ANALYSIS COMPARED TO EXISTING MODELS :

(a) Goal and method of the study :

The present study is limited to a comparison between the growth rates calculated from the tagging and recovery files and some growth models presently accepted by scientists for each stock. For practicle reasons the study is limited to a broad scale comparison mixing all areas and all available periods; furthermore several working hypothesis have been used without strict validations, for instance concerning the size ranges of tagged fishes, the durations at liberty, the growth models, etc..Those serious limitations may hamper the validity of the results of this preliminar and quick comparison.

In order to conduct this comparison, the following growth models have been selected :

For the Atlantic ocean :

(1) The model assuming a linear growth from 35 to 65 cm at a daily rate of 0.5 mm per day, followed by a VON BERTALANFFY growth curve with the parameters given by LE GUEN and SAKAGAWA 1972 (table 6). This composite model is based upon modal progression and tagging results.

(2) The model proposed recently to ICCAT by BARD et al. 1991 using a RICHARD growth function with the parameters given in table 4.1. This model is based only on recoveries and on the same sample of recovered tags,

For the Pacific ocean, the model based on the RICHARDS growth function proposed by WILD 1986 (table 6), from otoliths readings was used.

The following calculations were done :

In each case, the distribution of the growth rates of recovered fishes was calculated and compared to the distributions of theoretical expectations calculated from each growth model.

This comparison has been done using two types of figures, for each group of fishes (small or large) :

1. histograms of expected growth rates (theoretical from the growth model) compared to growth rates observed from tagging and recoveries.

2. theoretical average growth curve, compared to a drawing for all individual recoveries, of the apparent growth versus the numbers of days at sea. In this figure the date of tagging is fixed at the theoretical relative age corresponding to the curve.

The same general comparison of theoretical curve and expected apparent growth of recovered fishes has been also shown in figure 34 for the Atlantic and 35 for the Pacific.

The main results from this analysis are shown in figure 29 to 33. The main conclusions from this analysis are the following :

(a)in the Atlantic :

. for the "small fishes", a good fit is observed with the two stanza model (linear and VON BERTALANFFY) (figure 29) and a poor fit with the RICHARDS models proposed by BARD et al 1991 (figure 30), those recoveries showing slower than expected growth rates.

. for "large size", the two stanza model and the growth rates from recoveries are in reasonably good agreement (figure 32) (the growth of those large fishes in this model was estimated only from modal progressions). The small number of large yellowfin tagged and recovered (57 individuals only) is such that this figure has little significance. However the two stanza model seems in better agreement with the recovery data when all the recoveries are taken into account, adding 198 recoveries, most of them in the group of the large fishes (figure 34).

(b)in the eastern Pacific:

. for the group of "small fishes", a quite poor agreement between the RICHARDS function and the observed growth rates from recoveries was observed (figure 31) : the sample of small fishes should have a theoretical average growth rate of .99 mm/day, when its average observed growth is only 0.68 mm/day (Standard deviation of this average = 0.03).

. for the "large fishes", the average difference between observed and expected growth rates is smaller, an average rate of 1.00 +/-0.3 mm perday was observed, versus an expectation of 1.15 mm perday ; the observed growth of tagged fishes was also slower than the growth expected from the model (figure 33).

Those results need further consideration.

The theoretical distribution of growth rates have always a smaller variance that the observed ones, primarily because of the errors in the tagging/recovery files, but also because of the variability of growth rates between individuals. This last factor is probably an important one, but was not taken into account by the present growth comparison. However, a reasonable agreement should be expected between observed and theoretical growth rates, and the two distributions should have the same mode and average, if the model is correct and if the growth of recovered fishes is representative of the population growth.

This question is of key importance :

. On one side, it appears that several biases may affect the growth rates calculated from recoveries. Among other factors, we can list the following from causes of potential bias :

(1) tagged fishes grow slower than untagged fishes, because they carry a tag and may have subsequently more difficulties in their daily life (scooling, feeding, etc...).

(2) tagged fishes grow faster than untagged fishes because only the individual in good shape, which may have a faster growth, survive to tagging.

(3) the growth calculated on recovered fishes may depend of the fraction of the population which has been tagged : when fishes are tagged in a feeding and growth phase of their biological cycle, they will possibly grow much more faster than fishes at a similar size staying in unproductive and poor waters. Time and area variability of growth is clearly an important factor for tunas and for yellowfin (BAYLIFF 1988, BARD and ANTOINE 1986). The most difficult variability to sample is probably the time variability, as both the seasonal or the interannual levels may show differences in growth. If tagging is not covering randomly, and with enough tagged individuals, the entire population proportional to the importance of each fraction of biomass, some unexpected bias may occur, which may be positive or negative. Those bias would depend of the time and area variability of growth and of the coverage of tagging (in time and area).

(4) Size specific changes of catchability of the tagged fishes : in the Atlantic the catch at size figure (figure 12) showed a decreased catchability of yellowfin between 60 cm and 100 cm. There is clearly in such case a potential bias that the fast growing fraction of the small fishes tagged becomes first unavailable to the fishery, when only the slowest growing tagged fishes are still caught and recovered by the fishery. This bias could lead to underestimate the growth rates of juveniles estimated from tagging.

. Another alternate hypothesis is that the two first bias may be considered as potentially minor ones and that the growth calculated from recoveries provides a good measure of the growth of the group of fish tagged (in given conditions of tagged sizes, time, area and environment).

The third and fourth bias are probably much more critical and would need further careful analysis, especially the fourth one in the Atlantic which has not yet been analyzed.

However, as the tagging presently done in both oceans had covered a long period and were conducted within several time and area strata, the third type of potential bias may converge favourably towards a null bias (this would not be the case with a small number of tagging cruises). On the contrary, the fourth one is independent of the number of tagging done.

Concerning the reduced growth rates calculated on small fishes from recoveries for both Atlantic and Pacific oceans (.49 mm/day or .68 mm/day) it can be noticed that this slow growth was already constantly suggested by the slow modal progressions of the recruited fishes. This slow apparent displacement of the small yellowfin modes was for instance well shown by HENNEMUTH 1961 or DAVIDOFF 1963 for the Pacific, or by FONTENEAU 1981 in the Atlantic (figure 36 a and b).

The apparent growth rate of those yellowfin during their recruitment phase is observed at similar sizes and similar rates in both oceans : approximately .42 mm/day in the Pacific (average estimated on the cohorts x53, x56, x57 and x59) and .44 mm/day in the Atlantic between 35 and 60 cm..

The apparent inflexion points at which the modes start moving as expected from the growth models, is similar in both oceans : 65 cm on the average.

It has been generally assumed, at least in the Pacific ocean, that this slow modal progression was due entirely to a selectivity bias, only the oldest fraction of each recruited cohort being available to the fishing gear.

However FONTENEAU 1981, noticed for the Atlantic three important factors :

(1) the small yellowfin taken by baitboat and purse seiners show always the same apparent modal progressions, even if the size selectivity of those two gears is not identical.

(2) the apparent modal progression is slow, but always identical from one year to the other.

(3) the fact that small yellowfin are fished all year around in the eastern Atlantic is incompatible, when a fast growth hypothesis is accepted. with the spawning season which is limited in time (first quarter predominantly).

Based on those three observations, it is presently admitted for the Atlantic yellowfin that the slow modal progression of juvenile modes is related to two combined factors : a slow growth stanza and the selectivity bias. This selectivity bias could explain the difference between growth from recoveries (.50 mm/day) and from modal progression (.44 mm/day).

The same hypothesis may possibly apply to the Eastern Pacific, the apparent slow progression of juveniles modes at approximately .42 mm/day, being due partly to a selectivity bias, partly to a real slow growth stanza (at about .68 mm/day).

Interesting results on the growth of yellowfin tuna have also been obtained in the Pacific by WILD (1986) using the reading of daily rings of otoliths. This analysis was based upon a limited number of 196 individuals, this small number being due to the time consuming process linked with this otolith preparation and readings. The results from this study were obtained in a large range of sizes, 30 to 170 cm. They allowed WILD to calculate the parameters of the RICHARDS growth function given in table 6.

The daily increment technique seems highly reliable and well validated for yellowfin tuna, at least for small and medium size individuals.

The major possible bias in the technique would be if the so called daily rings are not deposited every day, which could underestimate the growth rates (which may be the case for large yellowfin). Another potential bias in the present otolith readings may be linked, not to the technique itself, but to the small sample size, which could not be representative of the real biological time and space heterogeneity of the growth parameter in the population (as for tagging).

It is presently difficult to decide which of the two results, growth rates from tagging or from otoliths readings, provides the better estimate of the population growth. Taking into account the importance of the growth parameter and the observed differences between the results obtained by the two methods, this

The first step in those investigations could be a reanalysis of the tagging and recovery data :

(1) using some weighting of the recoveries based on the quantitative importance of the underlying fraction of the population in each time and area strata where the tagging and/or recovery occurred.

(2) using a selection for the recovered tags which have been controlled by a technician or a scientist for size at recapture and duration at liberty tags.

(3) Investigate the changes of catchability of tagged fishes and their possible effect on estimated recovery growth rates.

5. SOME OTHER PARAMETERS RELATED TO SEX :

5.1. DATA

A lot of data have already been collected in the two oceans upon this important biological parameter which has a considerable potential impact on the stock assessment work and on the rational management of the resource.

The study has used all the data collected on yellowfin tuna taken by the surface fisheries in each area.

The available data consisted in the following samples :

- Atlantic : 11 937 individuals with known sex and 3 246 females with a known gonad weight are available. All those samples are in the range between 80 and 170 cm (1975-1987), with a maximum number of samples in the range 130 to 150 cm.

Those samples have are primarily been collected in Abidjan by the CRO (Ivory Coast) and they cover all the Eastern Atlantic.

- Pacific : 42195 individuals were sexed, and in this sample the gonad weigth is known for 17415 females. This sample collected by the IATTC technicians has been collected since the early fifties and covers all the purse seine fishing areas, but predominantly the inshore traditional fishing zone.

Several detailed analysis have been already conducted on those data in both oceans. The present study will be limited to a global comparison of the cumulated results.

5.2. SEX RATIO BY SIZES :

The global cumulated sex ratio by sizes in the two oceans are plotted in percentage in figure 37. ; the numbers sampled by sex and size are given in table 7. Most of the sex ratio by size have been collected using a predorsal measure of the fishes length. Those sex ratio by classes of predorsal length have been converted to a fork length scale for each class of predorsal length using the relationship of CAVERIVIERE 1976. This figure covers only the size range between 110 cm and 170 cm, because this range is biologically the more interesting and because fishes smaller than 110 cm have been poorly sampled in the Atlantic. Without questioning the validity and significancy of this global results, this figure suggests several facts :

(1) the sex ratio seems to be 50/50 and identical in the two oceans between 110 cm and 126 cm.

(2) the sex ratio appears to be different in the two oceans for larger fishes between 126 and 156 cm :

- in the Atlantic the females are slightly, but constantly, dominant for all sizes between 126 and 148 cm (53 to 57 % of those samples). The males start after 150 cm to be more and more dominant in the catch.

- at the same sizes in the Pacific samples, the males are sligthly dominant between 125 cm and 140 cm, and then increase their dominant percentage in the catch, starting at 140 cm towards nearly 100 % of males at 165 cm

(3) at sizes greater than 156 cm, the proportion of each sex in the sample is surprisingly fluctuating at similar levels in both Oceans with an increasing domination of males.

The significancy of those observations is difficult to test, because this aggregated set of data corresponds, in each ocean, to a mixture of data from heterogeneous time and area strata.

However, it is possible to accept the hypothesis that the present results are significant, and correspond to real biological characteristics and differences in the two stocks and fisheries.

In this hypothesis, the dominance of females in the catches at intermediate sizes in the Atlantic could support the hypothesis of a differential growth between the two sexes (especially a smaller L Ø for females). This hypothesis was suggested by the absence of large females in the catches of both oceans. This differential growth of females is also shown by the otoliths readings of WILD 1986 who founded a L Ø for females 10 cm smaller than the L Ø for the males.

However it must be noted that this dominance of females at intermediate sizes is not observed in the Pacific samples.

The present figures of pooled sex ratio by sizes has also been used to calculate the average proportion of each sex in the catches of both fisheries : this calculation has been done multiplying the average catches by sizes, by the corresponding average sex ratio (for each ocean).

The result of this calculation indicates that the relative importance of each sex in the catches of the two oceans is similar :

- 54 % of the total weigth of the landings were males and 46 % females in the Pacific (1975-1988).

- 57 % of the total weigth of the landings were males and 43 % females in the Atlantic (1975-1988).

More studies are necessary in both oceans :

(1) to calculate a pooled sex ratio is each ocean representative of the underlying population, calculated for instance weighting each sample by the estimated corresponding population in each time and area strata.

(2) to understand exactly the significances of sex ratio by sizes and the mechanism which determine them. More specifically, further simulation studies integrating growth, natural mortality and fishing mortality should be conducted in parallel in the two areas.

5.3. SEASONALITY OF GONAD INDEX

The gonad index (Gonad weight/fork length ^{3}) have been used in both oceans used to follow the time and space variability of gonad maturation, especially for females. This index does not provide a detailed information on the physiological status of the tunas, but is still useful to indicate if the females are in reproductive stage or not, at least for yellowfin taken by purse seiners (gonad index of yellowfin taken by the longliners are, most of the time, low and difficult to interpret). A gonad index of 30 is often considered to indicate a female in a reproductive stage (ALBARET 1976). The pooled monthly gonad index of females have been consequently calculated for both oceans. They are given in figure 38 in percentages, and in table 7 for the sampled numbers.

Those results indicate that on the average :

- The Atlantic gonad index data show a seasonnal cycle :

. high gonad indices are more frequently observed during the first quarter and at the end of the year.

. Low gonad indices are observed during summer.

- The Pacific pooled data show no clear seasonnality : high and low gonad index can be observed in similar proportions in any month of the year.

Those two general patterns have already been extensively analyzed in both oceans (ALBARET 1976 for the Atlantic, or ORANGE 1961 and KNUDSEN 1977 for the Pacific).

This difference between the spawning activities in the two areas under study corresponds well to the seasonality of sizes caugth observed in the two oceans, which appear to be much more complex and variable in the Eastern Pacific than in the Eastern Atlantic .

As a consequence, all the analytical work done in the Pacific has been conducted assuming traditionaly two yearly cohorts entering into the fishery (the X and Y cohorts), when only one predominant cohort (born during the first quarter and recruited during the third quarter) was observed in the Eastern Atlantic yellowfin fisheries. This average seasonal pattern of sizes taken in the Atlantic is apparent in the average quarterly sizes caugth, where the recruited cohorts can easily been followed by eye during their first two or three years of exploitation.

6. ASSOCIATION OF YELLOWFIN TUNAS

6.1. OVERALL

Yellowfin tuna live in association with other marine species and with various floating objects. Those ecological associations are of certain interest for both the scientists and the fishermen, and it is interesting to compare them in the two areas under study.

Yellowfin tuna are commonly fished in mixed schools with other tuna species in both oceans. As for other biological parameters, such as growth or sex ratio, it is often difficult, or impossible to evaluate the average mixing of species in the population, because this parameter seems highly variable in time and space. Subsequently the average species composition by school is very difficult to sample.

The mixing of tuna species within schools can be classified in both oceans according to several parameters :

- the size of fishes :

Large yellowfin tunas are not often associated with other tuna species, neither in the Atlantic nor in the Pacific. The same large yellowfin are often associated with porpoise in the Pacific, when this association seems to be incidental and rare in the Atlantic ; this difference will be further analyzed.

Small yellowfin are often associated with other tuna species, such as skipjack (in both oceans) or skipjack and bigeye (in the Atlantic).

- the type of schools :

The schools associated with floating objects show on the average a larger mixing of species, tunas and others, than free swimming schools (in both oceans).

The two major differences between Eastern Atlantic and Eastern Pacific are :

(1) A frequent association of small yellowfin with small bigeye in the Atlantic.
(2) A frequent association of large yellowfin with several species of porpoise in the Pacific.

6.2. THE MIXED SCHOOLS OF SMALL TUNAS :

In the central part of the Gulf of Guinea, the average species composition (estimated by sampling) of the catches of small size tunas (less than 55 cm) taken by purse seiners is the following (from FONTENEAU 1987) :

Yellowfin	24.0 %
Skipjack	70.7 %
Bigeye	5.3 %

This average species composition seems to be very stable from year to year, and also seems to correspond to the average species composition of the schools.

Two important factors must be noticed :

(1) the three species are more or less in the same size range, the average length of each species being approximately 45 or 50 cm (figure 39).
(2) the small bigeye tunas, less than 60 cm for instance, are most of the time ignored in the log books of all fleets (french, spanish, japanese, ghanean or USA purse seiners). The problem of small bigeye being misidentified as yellowfin was first raised in the Atlantic by FONTENEAU 1975. The proportion of bigeye in the catches has been obtained in the Atlantic since 1980 using a species composition sampling scheme conducted by technicians specially trained, in order to identify small frozen bigeye tunas (CAYRE 1984). The fishing areas for bigeye tunas by purse seiners in the Atlantic are shown in figure 40. ; those fishing zones are similar to the areas where small yellowfin are caugth (figure 6).

On the contrary, small bigeye tunas seem to be absent from the Eastern Pacific, and consequently this species does not appear to mix significantly with yellowfin. Only medium size bigeye (figure 39) are taken in the Pacific, and only in specific areas (figure 40) which are different from the areas where small yellowfin are usually caught (figure 7).

This situation may be real; in this case, the bigeye spawning zones and nurseries could be located outside the surface fishery area of the eastern Pacific. However KIKAWA 1966 noticed that the bigeye spawning seemed to occur predominantly in the eastern Pacific.

This situation observed in the eastern Pacific surface fisheries may also be due to some misidentification of the small bigeye and small yellowfin which are very difficult to distinguish at small sizes when they are frozen. Only a species sampling program conducted by technicians trained in this species identification, could clarify this question and confirm the absence of small bigeye in the Eastern Pacific catch of small yellowfin.

An experiment easy to realise would be to conduct in the canneries a check of species composition from the livers, as this technique provides an immediate identification without risk of misclassification. This sampling should be done on small yellowfin tunas, especially in the range of sizes 35 to 55 cm.

The problem may also be of some importance for stock assesment of both yellowfin and bigeye, especially in analytical models, as a species identification error of that type would affect the catch at age tables of the two species. As an example, in the eastern Atlantic ocean, the estimated yearly number of bigeye tunas less than 3.2 kg taken on the average is approximately 1.5 millions of fishes, versus 7.5 millions of yellowfin tunas. This misidentification of the Atlantic bigeye as yellowfin could mistakenly increase the yellowfin figures to 9 millions, and decrease the bigeye catch to nearly zero.

6.3. LARGE YELLOWFIN AND PORPOISE :

An extensive bibliography exists concerning this association in the Eastern Pacific. Most of the catches of large yellowfin in the Eastern Pacific are presently taken in association with porpoise, and using actively this association to catch yellowfin tuna. This association is observed in all the fishing areas, both offshore and inshore (figure 41) and it raises serious ecological problems for the tuna fishery. This association has been scientifically observed in details by the IATTC technicians for thousands of sets.

In the Atlantic (or in other areas such as the Indian Ocean), this association seems to be very rare : from past published work in the Atlantic based on log books, only 1.4 % of the schools on which the purse seiners setted, were noticed to be associated with porpoise. This low rate is also confirmed by a small number of scientific observer cruises. It seems clear that if some porpoise accidental mortalities may have occured in the Atlantic, this fishing mode of catching large yellowfin associated with porpoise, as it is practised in the eastern Pacific, was not a usual way of fishing.

In opposition, most of the large yellowfin taken in the eastern Atlantic are usually caught by purse seiners during the spawning season (when such spawning concentrations seem to be seldom found in the Pacific).

This rare association between tuna and porpoise in the Atlantic should first be verified by a more intensive and especially design scientific sampling scheme conducted by observers on the purse seine fishery. It must also be noticed that very few investigations have been conducted until now on the Atlantic tropical porpoises. Consequently, both the biology of most species or their population sizes remain unknown.

If this lack of association between Atlantic tunas and porpoise is confirmed, it would be of great interest to study and to understand the ecological or ethological reasons of this difference in the porpoise and/or tuna behavior between the two oceans. In the longer term, a good understanding of this bevahioral difference could, if confirmed, help to solve the problem of accidental porpoise mortalities in the Eastern Pacific yellowfin fishery.

6.4. TUNAS AND FLOATING LOGS :

Tunas in general, including yellowfin tuna, are often caugth in association with natural floating logs in both the eastern Atlantic and eastern Pacific oceans:

The informations published upon this topic (HALL and al. 1992, ARIZ et al.1992) allow to summarize the major characteristics of this association in the two oceans.

- A mixture of different sizes and species of fishes, including several species of tunas, are often taken in association with logs. This mixed species composition seems to be very similar in both areas. Skipjack tuna is always the dominant species under logs (approximately 58% of the catches in the eastern Pacific and 74% of the eastern Atlantic), but yellowfin tuna is significant and contributed to 39 % of the log catches in the Pacific purse seine catches, versus 20% in the Atlantic.

- The relative importance of this log fishery was similar in both oceans: 8% of the purse seiners catches being taken under floating logs was yellowfin.

- Those floating logs may be from natural or from human origin; those natural logs were predominantly concentrated near the inshore areas and were more abundant during the rainy seasons.

- The sizes of the yellowfin taken under logs were predominantly small in the two oceans, average weigth being 5 to 8 kg for the Atlantic and Pacific. A mixture of sizes is often observed under logs, large yellowfin being often taken in association with small individuals (in about 50% of the Atlantic log sets).

This association between logs and tunas and the development of this fishery on floating logs raises several questions:

- in term of stock assesment: how to calculate abundance indices from cpues in a log fishery where the searching time has not the same significancy as in a free school fishery?.

- in term of stock management: as the yellowfin taken under logs are usually small, the yield per recruit in a log fishery may significantly be altered in comparison to a free swimming school fishery (depending of the overall exploitation rate and the relative importance of the log fishery).

- in term of ecology: the association between tunas and logs remains a strange and poorly explained phenomenon. Furthermore many species of small tunas and other fishes are caught in this mode of fishing and further dumped at sea. Those dumpings may rise in the future some ecological problems.

All the investigations under this topic should usefully be developped in a coordinated manner between Eastern Atlantic and Pacific, and should also include other oceans where similar phenomenon are often observed.

7. CONCLUSION

The present comparison of yellowfin tuna in the Eastern Atlantic and Pacific allowed some provisional but interesting observations, conclusions on the similarities and dissimilarities of this species, its oceanographical environment and the fisheries exploiting this resource in the two areas under study.

This paper provides only a first and preliminar review of some major similarities and dissimilarities between the two areas :

Some are basic facts, such as sizes of fishes taken or area fished, which could be developped using more detailed time and area strata.

Many elements of the present comparison show facts which raise new questions or hypothesis, and would need more analysis or new research in order to solve the problems. Several potentialy interesting problems, have not yet been examined.

Those new research operations or programs should be usefully developped :

- either located in one ocean in order to answer to a local uncertainty: for instance small bigeye possibly caught in the Eastern Pacific, or porpoise abundance and its association with tunas in the Atlantic,

- or conducted in a coordinated way between the two oceans, for instance further tunas-environment studies, further comparative analysis of growth, of sex ratio by size, of stock structure and migrations.

Those comparisons between oceans have been neglected in the past, being mostly limited to partial crossed references taken from the litterature. This limitation is clearly a consequence of some excessive isolation between the work conducted by the Atlantic and Pacific tuna commissions, ICCAT and IATTC.

For instance there is a major interest to compare in much more details, and to understand better:

-How the different tuna species adapted themselves to the different environment structures and variabilities they found in the world oceans?,

-How the tunas react in the short term to environment changes?,

-How does fisheries operate in the different environments of the world oceans?.

Following this idea, a more active cooperation between research institutions active on tunas would be very useful, first in order to better analyse the existing data, and second to develop new coordinated research programs which could help to solve pending problems in each geographical or scientific area. There is also for the same reasons a similar interest to develop those comparisons to a wider geographical scale, for instance to the Indian Ocean and to the Western Pacific.

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Table 1 : Yearly catches of yellowfin tuna in the Eastern Atlantic and the Eastern Pacific oceans

	ATLANTIC					
YEAR	YFT	SKJ	BET	YFT	SKJ	BET
50	1	0	0	112	64	0
51	1	0	0	92	61	0
52	3	0	0	96	45	0
53	4	0	0	69	66	0
54	3	0	0	69	87	0
55	4	0	0	70	64	0
56	6	0	0	88	75	0
57	20	0	0	81	64	0
58	24	4	0	75	82	0
59	39	4	1	74	80	0
60	52	1	2	70	87	0
61	51	6	10	115	75	0
62	28	7	11	87	78	0
63	42	15	10	72	105	0
64	47	10	8	101	65	0
65	54	17	16	90	86	0
66	43	16	8	91	67	0
67	53	17	9	90	132	2
68	74	46	10	115	78	3
69	80	27	17	146	65	1
70	59	48	23	173	61	1
71	57	76	24	136	115	3
72	78	74	27	198	36	2
73	80	75	21	227	48	2
74	92	113	27	232	87	1
75	108	52	22	224	137	4
76	109	65	36	262	139	11
77	115	105	26	220	95	8
78	116	99	27	200	187	13
79	112	82	31	210	145	8
80	112	96	36	176	143	17
81	135	106	39	201	132	11
82	134	120	42	139	109	5
83	123	101	34	105	64	4
84	75	91	40	160	66	6
85	113	78	43	240	54	5
86	105	90	34	296	70	2
87	107	95	28	302	69	1
88	94	122	34	317	94	1

Tableau 2.- Number of one degree squares explored and fished with different level of average catches by surface fisheries in the Eastern Atlantic and Eastern Pacific oceans, for yellowfin and skipjack tunas.

		ATLANTIC		PACIFIC	
		NUMBERs	CUMULATIVE CATCH (%)	NUMBERs	CUMULATIVE CATCH (%)
EXPLORED		769	100.0	1841	100.0
Yellowfin	+ 1t	481	100.0	1408	100.0
	+ 10t	385	99.6	1140	99.4
	+ 75t	270	95.6	630	90.1
	+500t	57	45.2	65	27.4
Skipjack	+ 1t	475	100 %	1088	100
	+ 10t	381	99.5	732	99.2
	+ 75t	226	93.8	230	73.5
	+500t	52	56.1	11	12.6

Tableau 3.- : Numbers of yellowfin sampled for sizes in the two areas during recent years.

YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988
ATLANT.	37203	32891	37492	28678	18225	37087	32741	76127	39516
PACIF.	31572	32230	25944	21353	27538	29816	36411	45422	37590

Tableau 4.- : Average catches in numbers by 2 cm of fork length, by all the fisheries, during recent years (period 1975-1988) in the Eastern Atlantic and Eastern Pacific (1000 individuals).

PACIFIC

	QUARTER				
F.L.	1	2	3	4	TOTAL
30	15.9	6.3	8.1	14.7	53.1
32	17.4	18.4	5.9	21.5	84.1
34	44.8	56.8	15.1	37.4	202.1
36	76.2	137.4	37.1	45.6	348.2
38	71.4	179.0	89.7	94.2	524.0
40	159.4	337.7	238.0	220.7	965.1
42	250.8	456.3	323.4	258.7	1205.8
44	407.9	556.8	434.1	373.6	1380.8
46	429.3	592.8	529.0	442.3	1469.2
48	389.4	501.6	581.9	515.8	1475.1
50	294.6	509.1	509.3	619.3	1431.3
52	221.1	581.6	487.5	653.1	1442.8
54	174.7	416.9	482.1	524.2	1281.0
56	141.5	226.2	345.9	487.5	1071.0
58	96.8	129.6	235.3	447.6	912.7
60	93.8	129.8	204.9	414.1	852.4
62	101.2	106.4	169.3	347.7	776.9
64	105.0	123.9	164.9	261.8	728.5
66	115.1	125.5	140.6	213.7	670.8
68	110.3	125.6	131.8	175.2	608.9
70	130.8	144.1	152.6	177.6	586.3
72	183.2	130.3	144.7	170.8	556.6
74	171.0	141.9	138.6	149.6	497.8
76	134.2	156.3	128.7	126.5	428.2
78	113.4	140.9	112.9	96.6	345.3
80	74.7	126.1	114.6	104.9	308.6
82	61.2	113.4	115.8	111.3	293.6
84	51.7	105.1	119.4	106.3	268.5
86	61.0	95.0	104.0	98.8	253.0
88	44.2	76.5	89.3	99.6	226.8
90	50.0	69.5	77.0	84.9	216.2
92	47.8	59.6	69.3	79.2	208.5
94	45.3	57.9	75.6	67.5	201.4
96	51.8	46.1	68.0	62.0	191.2
98	45.4	42.1	70.9	59.8	190.5
100	40.8	47.4	65.5	50.0	182.3
102	40.2	40.5	65.5	52.0	181.8
104	37.7	43.6	65.9	51.2	171.0
106	33.6	40.2	58.0	48.5	164.8
108	33.6	34.5	51.4	38.1	155.7
110	29.0	32.3	46.9	41.1	147.6
112	31.9	31.7	38.6	38.7	145.6
114	26.8	29.7	32.9	30.1	127.5
116	25.5	25.8	31.4	27.5	123.8
118	24.7	23.8	25.6	21.0	110.7

ATLANTIC

	QUARTER				
F.L.	1	2	3	4	TOTAL
30	0.1	0.2	0.4	0.1	1.0
32	0.3	1.2	14.5	0.7	16.9
34	3.4	10.0	28.5	3.4	45.4
36	9.7	33.4	66.1	32.0	141.3
38	23.1	53.1	123.2	73.2	272.7
40	38.5	61.5	182.5	150.3	432.9
42	60.4	55.1	208.7	232.9	557.2
44	76.1	53.1	211.3	256.8	597.5
46	209.9	123.9	217.2	311.4	862.4
48	254.6	149.8	171.8	243.1	819.4
50	152.6	123.6	110.4	110.3	497.0
52	118.0	133.5	111.4	73.4	436.5
54	56.7	117.6	148.4	59.0	381.9
56	43.1	99.1	207.9	78.6	428.8
58	34.5	67.6	193.9	98.8	394.4
60	31.7	49.6	150.0	102.0	333.5
62	30.4	25.1	87.6	120.0	263.3
64	26.4	15.4	50.7	96.0	188.7
66	14.6	12.2	31.8	56.5	115.3
68	12.6	8.2	15.9	35.2	72.1
70	15.2	9.8	13.6	34.9	73.7
72	16.5	10.0	11.7	27.0	65.3
74	15.7	9.5	8.1	20.1	53.5
76	13.7	9.5	7.5	15.9	46.7
78	12.5	10.7	6.6	12.6	42.6
80	10.9	9.4	6.6	8.7	35.7
82	9.5	10.9	6.6	7.7	34.8
84	9.2	12.6	8.4	6.8	37.1
86	10.3	15.3	9.2	7.8	42.7
88	9.1	13.7	11.0	6.3	40.3
90	9.9	15.0	12.0	7.1	44.1
92	9.1	15.2	11.9	7.5	43.9
94	8.7	15.4	13.6	6.3	44.2
96	8.2	15.3	16.4	7.0	47.0
98	7.6	15.6	17.0	6.9	47.2
100	7.3	16.2	18.0	7.3	48.9
102	6.2	14.5	18.0	7.6	46.5
104	7.0	14.2	21.1	8.8	51.2
106	6.8	12.1	21.6	9.1	49.8
108	6.4	11.7	22.4	10.0	50.7
110	6.8	10.6	21.5	10.8	49.9
112	5.3	9.3	19.0	9.2	42.9
114	5.8	7.2	16.8	9.9	39.9
116	5.4	6.6	15.2	9.5	36.7
118	7.8	7.3	14.4	10.7	40.3

Table 4 : end

PACIFIC

QUARTER					
F.L.	1	2	3	4	TOTAL
120	24.2	22.6	25.4	18.9	102.8
122	26.0	22.1	21.9	22.6	102.2
124	24.9	24.1	24.3	19.3	100.9
126	23.3	20.6	18.6	21.3	96.8
128	23.0	19.1	18.1	18.4	88.9
130	22.1	20.7	18.0	19.5	89.4
132	20.2	20.6	19.0	17.9	84.0
134	23.6	20.9	18.6	19.0	84.8
136	21.1	18.2	16.9	13.6	72.5
138	22.5	16.4	14.4	15.0	66.2
140	18.6	12.1	13.4	11.8	56.0
142	16.5	11.3	10.7	9.0	48.8
144	14.2	8.0	9.4	8.2	41.3
146	10.3	8.3	8.4	6.2	36.4
148	8.7	6.7	7.1	5.8	29.5
150	6.6	5.5	5.5	4.3	23.6
152	7.4	5.0	6.5	3.1	21.8
154	5.7	3.4	5.1	2.3	17.7
156	4.5	3.1	3.3	1.9	14.0
158	3.8	3.6	3.1	1.2	11.4
160	2.6	1.7	1.7	0.7	8.1
162	2.1	1.4	1.5	0.4	5.5
164	1.4	0.7	1.0	0.7	4.0
166	0.8	0.5	0.6	0.4	2.2
168	0.5	0.4	0.3	0.4	1.4
170	0.6	0.2	0.2	0.0	0.9
172	0.2	0.1	0.3	0.1	0.5
174	0.0	0.3	0.1	0.0	0.3
176	0.0	0.0	0.0	0.0	0.1
178	0.0	0.0	0.0	0.0	0.0
180	0.0	0.0	0.0	0.0	0.0

ATLANTIC

QUARTER					
F.L.	1	2	3	4	TOTAL
120	10.5	8.5	14.6	11.5	45.2
122	11.3	9.1	13.7	10.9	45.2
124	14.5	11.0	16.2	12.0	53.8
126	12.9	10.3	11.4	10.1	44.9
128	15.7	11.5	12.6	10.2	50.2
130	16.9	11.6	12.0	9.9	50.5
132	21.8	13.7	13.0	11.9	60.5
134	23.8	13.6	13.6	12.3	63.5
136	28.6	14.2	14.1	15.0	72.0
138	30.3	14.2	16.2	16.8	77.5
140	31.4	13.3	15.9	16.8	77.6
142	32.9	13.0	14.2	17.6	77.7
144	29.2	11.1	10.9	15.8	67.1
146	30.1	11.3	10.4	15.9	67.8
148	31.6	12.3	11.2	16.9	72.1
150	34.1	13.8	11.9	18.2	78.1
152	29.9	12.4	10.4	16.1	69.0
154	23.3	10.4	8.4	12.6	54.8
156	18.4	8.3	6.8	10.2	43.8
158	13.6	6.5	5.1	7.7	32.9
160	9.2	4.6	3.8	5.1	22.9
162	7.3	3.7	2.9	4.3	18.3
164	5.1	2.9	2.3	3.3	13.8
166	4.7	2.7	1.9	3.2	12.6
168	3.2	2.0	1.5	2.4	9.2
170	2.2	1.4	1.2	1.6	6.6
172	1.2	1.0	0.8	1.0	4.2
174	0.6	0.5	0.6	0.5	2.4
176	0.2	0.2	0.3	0.2	1.1
178	0.1	0.1	0.1	0.1	0.6
180	0.1	0.0	0.0	0.0	0.3

Table 5.- : Average catches in weight by 2 cm of fork length, by all the fisheries, during recent years (period 1975-1988) in the Eastern Atlantice and Eastern Pacific (1000 tons)

PACIFIC

QUARTER					
FL	1	2	3	4	TOTAL
30	8.	4	4.	8.	29.7
32	12.	14.	4.	15.	60.2
34	37.	49.	13.	32.	171.3
36	75.	139.	38.	46.	349.7
38	83.	212.	108.	112.	614.9
40	218.	469.	332.	302.	1318.5
42	393.	735.	526.	414.	1889.9
44	733.	1023.	805.	683.	2431.8
46	878.	1235.	1117.	926.	2900.3
48	917.	1191.	1391.	1228.	3358.4
50	776.	1366.	1389.	1665.	3766.3
52	655.	1747.	1514.	1979.	4280.3
54	579.	1387.	1684.	1804.	4270.2
56	520.	840.	1329.	1876.	3970.1
58	396.	533.	989.	1897.	3782.4
60	427.	590.	964.	1905.	3890.1
62	507.	533.	878.	1747.	3901.6
64	579.	681.	924.	1441.	4016.1
66	692.	758.	861.	1282.	4053.3
68	724.	825.	877.	1150.	4023.9
70	936.	1030.	1101.	1270.	4215.6
72	1421.	1016.	1130.	1335.	4345.9
74	1419.	1200.	1173.	1270.	4216.8
76	1208.	1432.	1182.	1162.	3941.1
78	1099.	1394.	1123.	955.	3433.8
80	790.	1342.	1229.	1118.	3324.5
82	690.	1294.	1340.	1278.	3422.7
84	629.	1294.	1484.	1315.	3389.1
86	805.	1263.	1383.	1313.	3411.7
88	624.	1088.	1268.	1408.	3243.1
90	755.	1057.	1170.	1287.	3287.1
92	756.	969.	1127.	1282.	3386.1
94	775.	999.	1313.	1166.	3475.2
96	959.	852.	1254.	1143.	3510.6
98	886	827.	1391.	1169.	3725.6
100	853.	988.	1364.	1040.	3789.1
102	888.	896.	1449.	1157.	4011.7
104	883.	1023.	1552.	1215	4001.4
106	832.	998.	1445.	1220.	4082.8
108	878.	903.	1347.	1018.	4075.7
110	802.	897.	1298.	1165.	4091.1
112	932.	927.	1119.	1144.	4254.1
114	825.	917.	1009.	958.	3932.1
116	822.	837.	1012.	906.	4016.2
118	839.	810.	866.	728.	3768.1

ATLANTIC

QUARTER					
FL	1	2	3	4	TOTAL
30	0.	0.	0.	0.	0.6
32	0.	0.	10.	0.	12.0
34	2.	8.	24.	2.	38.5
36	9.	33.	66.	32.	141.3
48	27.	62.	144.	85.	318.9
40	52.	83.	247.	204.	587.5
42	94.	86.	326.	364.	871.5
44	136.	95.	378.	459.	1069.9
46	427	252.	442.	634.	1757.4
48	587.	345.	396.	560.	1890.3
50	396.	321.	286.	286.	1291.5
52	344.	389.	324.	213.	1271.9
54	184.	382.	482.	192.	1242.3
56	156.	358.	752.	284.	1551.7
58	138.	271.	777.	396.	1583.2
60	140.	219.	664.	451.	1476.7
62	148.	122.	427.	585.	1283.4
64	141.	82.	271.	513.	1009.3
66	85.	71.	186.	331.	675.1
78	80.	52.	101.	225.	460.6
70	106.	68.	95.	242.	512.6
72	125.	75.	88.	204.	493.4
74	129.	78.	66.	164.	438.5
76	121.	84.	67.	140.	414.2
78	120.	103.	63.	121.	407.9
80	112.	97.	68.	90.	368.2
82	105.	120.	73.	86.	385.3
84	109.	150.	100.	81.	441.4
86	131.	195.	117.	100.	544.1
88	125.	187.	150.	86.	549.6
90	144.	218.	175.	104.	643.2
92	141.	236.	185.	117.	682.2
94	145.	255.	225.	105.	731.4
96	145.	270.	289.	123.	828.9
98	143.	292.	318.	130.	883.7
100	146.	321.	357.	145.	971.8
102	132.	305.	380.	160.	978.6
104	157.	317.	470.	196.	1141.9
106	161.	286.	510.	216.	1174.5
108	160.	291.	560.	251.	1264.4
110	179.	281.	566.	285.	1312.3
112	148.	260.	528.	255.	1192.0
114	171.	213.	492.	289.	1166.9
116	165.	202.	469.	292.	1130.9
128	254.	238.	467.	346.	1306.0

Table 5 : end

PACIFIC

QUARTER					
FL	1	2	3	4	TOTAL
120	871.	814.	905.	680.	3686.3
122	985.	834.	822.	848.	3838.3
124	995.	960.	962.	763.	3979.2
126	973.	863.	766.	881.	3995.8
128	1002.	834.	780.	797.	3839.4
130	1016.	944.	816.	884.	4058.9
132	976.	993.	901.	848.	3993.6
134	1180.	1054.	930.	944.	4218.6
136	1111.	971.	880.	709.	3776.6
138	1237.	919.	786.	829.	3605.5
140	1071.	709.	763.	670.	3179.9
142	998.	701.	637.	532.	2910.8
144	888.	527.	583.	512.	2559.3
146	668.	542.	547.	400.	2346.9
148	590	460.	482.	387.	1978.9
150	468.	388.	391.	304.	1654.8
152	536.	370.	476.	229.	1587.9
154	435.	263.	393.	177.	1344.4
156	353.	247.	260.	150.	1107.1
158	316.	300.	256.	102.	935.1
160	224.	148.	151.	65.	685.9
162	184.	129.	138.	37.	489.9
164	134.	72.	100.	65.	368.4
166	76.	53.	60.	39.	211.3
168	49.	44.	30.	40.	140.1
170	68.	29.	21.	7.	99.3
172	26.	19.	35.	15.	56.1
174	7.	37.	15.	3.	40.8
176	8.	1.	0.	2.	20.1
178	0.	0.	0.	0.	2.3
180	0.	0.	0	0.	0.0

ATLANTIC

QUARTER					
FL	1	2	3	4	TOTAL
120	356.	290.	496.	393.	1536.9
122	403.	325.	492.	391.	1613.3
124	543.	413.	607.	451.	2016.3
126	507.	407.	449.	399.	1764.2
138	648.	476.	519.	420.	2064.7
130	728.	502.	517.	426.	2174.6
132	983.	617.	586.	538.	2725.6
134	1121.	644.	644.	579.	2989.7
136	1407.	702.	696.	739.	3545.2
840	1556.	729.	833.	863.	3983.0
140	1682.	716.	856.	902	4159.1
142	1840.	726.	788.	987.	4343.4
144	1704.	647.	636.	922.	3910.0
146	1825.	688.	636.	967.	4118.0
158	1997.	782.	709.	1067.	4556.1
150	2244.	907.	786.	1195.	5133.3
152	2043.	851.	715.	1105	4717.2
146	1656.	740.	597.	901.	3895.8
156	1359.	613.	503.	754.	3232.5
168	1044.	499.	392.	589.	2526.6
160	736.	370.	303.	412.	1823.1
162	604.	311.	240.	357.	1513.2
164	441.	251.	203.	284.	1181.0
166	417.	245.	172.	284.	1120.2
168	298.	184.	142.	222.	847.6
170	214.	140.	123.	151.	630.0
172	126.	98.	86.	106.	418.9
174	68.	57.	62.	58.	246.2
176	23.	28.	34.	29.	115.8
178	17.	14.	21.	15.	68.8
180	17	5.	6.	5.	35.1

Table 6.- : Growth of yellowfin tunas from 40 cm of fork length following the three growth curves compared in the present study. The calculated size, is the size reached after a given number of days after an initial recruitment at 40 cm.

RELATIVE AGE (DAYS)	CALCULATED FORK LENTH		
	2 STANZA	BARD 90	WILD 86
1	40	40	40
183	49	51	58
365	58	65	78
547	71	82	98
729	95	101	117
911	113	120	134
1093	129	138	148
1275	141	153	158
1457	151	163	166
1639	159	170	173
1821	166	174	177
2003	171	177	180
2185	176	178	182
2367	179	179	184
2549	182	179	185
2731	184	179	186
2913	186	179	186
3095	188	179	187
3277	189	179	187
3459	190	179	187
3641	191	179	187

Table 7.- : Number of yellowfin tunas, by sex and fork length, sampled in the Eastern Atlantic and Pacific.

7(a) PACIFIC

F.L	% MAL.	% FEM.	Nb MAL.	Nb FEM.	Nb. TOT
51	59.3	40.7	264	181	445
53	54.5	45.5	390	326	716
55	52.1	47.9	449	412	861
57	50.8	49.2	461	446	907
59	49.7	50.3	460	466	926
61	50.5	49.5	461	452	913
63	49.7	50.3	445	450	895
65	47.7	52.3	350	384	734
67	48.1	51.9	334	361	695
69	53.3	47.0	950	844	1794
71	50.8	49.2	881	853	1734
73	50.4	49.6	852	838	1690
75	49.8	50.2	828	836	1664
77	52.0	48.0	825	761	1586
79	48.8	51.2	867	910	1777
81	50.9	49.1	823	794	1617
83	49.3	50.7	771	793	1564
85	51.4	48.6	721	681	1402
87	49.1	50.9	634	657	1291
89	49.3	50.7	635	654	1289
91	50.2	49.8	616	610	1226
93	48.1	51.9	607	656	1263
95	51.5	48.5	617	582	1199
97	52.0	48.0	585	539	1124
99	49.6	50.4	552	560	1112
101	52.0	48.0	553	511	1064
103	53.4	46.6	533	466	999
105	51.0	49.0	454	437	891
107	50.9	49.1	417	402	819
109	48.6	51.4	357	378	735
111	52.5	47.5	345	312	657
113	51.8	48.2	298	277	575
115	51.3	48.7	274	260	534
117	45.3	54.7	224	270	494
119	57.6	42.4	276	203	479
121	49.7	50.3	237	240	477
123	48.4	51.6	213	227	440
125	50.1	49.9	211	210	421
127	53.8	46.2	193	166	359
129	54.5	45.5	199	166	365
131	55.3	44.7	166	134	300
133	54.8	45.2	138	114	252
135	56.7	43.3	123	94	217
137	56.6	43.4	98	75	173
139	60.9	39.1	106	68	174

7(b) ATLANTIC

F.L	% MAL.	% FEM.	Nb FEM.	Nb MAL.	Nb TOTAL
98	33.5	66.5	93	47	140
102	57.9	42.1	37	51	88
106	55.0	45.0	54	66	120
110	50.4	49.6	67	68	135
114	53.7	46.3	68	79	147
118	49.4	50.6	130	127	257
123	51.6	48.4	211	225	436
126	46.9	53.1	274	242	516
128	47.6	52.4	246	223	469
130	46.8	53.2	333	293	626
132	43.2	56.8	326	248	574
134	43.3	56.7	464	355	819
136	44.8	55.2	448	364	812
139	43.9	56.1	670	524	1194
141	46.3	53.7	562	484	1046
143	48.2	51.8	569	613	1272
145	49.3	50.7	473	460	933
147	57.4	42.6	461	621	1082
149	61.5	38.5	283	452	735
151	68.8	33.2	246	494	740
154	74.4	25.6	112	325	437
156	79.1	20.9	90	341	431
158	82.9	17.1	46	223	269
160	70.5	29.5	85	203	288
162	77.3	22.7	17	92	119
164	92.3	7.7	7	84	91
170	89.7	10.3	12	104	116

Table 7(a) : end

7(a) PACIFIC

F.L	% MAL.	% FEM.	Nb MAL.	Nb FEM.	Nb. TOT
141	66.2	33.8	98	50	148
143	69.3	30.7	97	43	140
145	71.8	28.2	74	29	103
147	83.0	17.0	83	17	100
149	81.6	18.4	80	18	98
151	73.6	26.4	53	19	72
153	83.1	16.9	49	10	59
155	76.1	23.9	35	11	46
157	84.8	15.2	39	7	46
159	91.9	8.1	34	3	37
161	66.7	33.3	34	17	51
163	88.5	11.5	23	3	26
165	93.9	6.1	31	2	33
167	91.4	8.6	32	3	35
169	100.0	0.0	20	0	20

Table 8.- : Monthly observed frequencies of sampled gonad indices, calculated on females larger than 95 cm taken by purse seiners, in the eastern Atlantic, and corresponding percentages (given per 1000).

8 (a) : Numbers of females sampled

CLASS OF G.I		MONTH											
		1	2	3	4	5	6	7	8	9	10	11	12
0- 5	1	2	4	6	7	4	1	8	1	2	6	6	3
5-10	2	3	25	19	24	15	32	30	21	8	11	42	8
10-15	3	25	36	28	44	17	24	16	18	24	5	57	12
15-10	4	25	54	77	48	23	14	7	3	10	1	38	15
20-25	5	50	60	83	46	28	11	1	4	5	10	18	18
25-30	6	38	58	63	39	23	7	5	5	1	7	12	15
30-35	7	45	60	64	29	17	11	3	1	5	6	18	19
35-40	8	33	37	49	20	9	6	2	5	1	5	9	18
40-45	9	27	31	33	9	13	3	0	2	1	5	11	12
45-50	10	20	22	13	10	4	5	1	4	0	9	7	14
50-55	11	16	11	11	4	2	0	0	2	1	4	3	9
55-60	12	5	3	8	2	2	2	0	0	0	1	1	3
60-65	13	9	1	3	0	1	1	0	0	0	1	1	3
65-70	14	6	3	0	0	0	0	0	0	0	1	0	1
70-75	15	4	3	2	0	0	0	0	0	0	0	0	0
75+	16	3	4	1	0	0	0	0	0	0	1	0	0

8 (b) : per 1000

CLASS OF G.I		MONTH											
		1	2	3	4	5	6	7	8	9	10	11	12
0- 5	1	6	9	13	24	8	8	109	15	34	82	26	20
5-10	2	9	60	41	85	273	273	410	318	137	150	188	53
10-15	3	80	87	60	156	205	205	219	272	413	68	255	80
15-10	4	80	131	167	170	119	119	95	45	172	13	170	100
20-25	5	160	145	180	163	94	94	13	60	86	136	80	120
25-30	6	122	140	136	138	59	59	68	75	17	95	53	100
30-35	7	144	145	139	102	94	94	41	15	86	82	80	126
35-40	8	106	89	106	70	51	51	27	75	17	68	40	120
40-45	9	86	75	71	31	25	25	0	30	17	68	49	80
45-50	10	64	53	28	35	42	42	13	60	0	123	31	93
50-55	11	51	26	23	14	0	0	0	30	17	54	13	60
55-60	12	16	7	17	7	17	17	0	0	0	13	4	20
60-65	13	28	2	6	0	8	8	0	0	0	13	4	20
65-70	14	19	7	0	0	0	0	0	0	0	13	0	6
70-75	15	12	7	4	0	0	0	0	0	0	0	0	0
75+	16	9	9	2	0	0	0	0	0	0	13	0	0

Table 9.- : Monthly observed frequencies of sampled gonad indices, calculated on females larger than 95 cm taken by purse seiners, in the eastern Pacific and corresponding corresponding percentages (given per 1000)

(a) Numbers of females sampled

CLASS OF G.I	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
0. 5	5	7	7	5	5	3	17	30	16	16	47	10
5.10	97	106	88	83	78	62	91	161	95	165	238	140
10.15	115	128	126	141	144	98	77	77	83	140	199	127
15.20	59	51	35	59	69	58	43	31	48	52	73	38
20.25	25	33	31	43	36	33	43	49	32	39	40	19
25.30	23	46	43	47	39	30	45	43	25	38	22	17
30.35	34	33	48	44	35	39	56	43	37	42	15	22
35.40	26	34	49	49	40	21	41	48	22	38	11	18
40.45	23	30	50	22	29	22	35	50	16	27	5	10
45.50	19	19	29	18	31	23	22	31	7	19	3	7
50.55	9	9	22	16	23	4	10	28	6	20	4	6
55.60	9	10	12	8	12	8	9	18	6	3	2	1
60.65	5	7	7	6	8	2	3	9	2	6	4	1
65.70	2	1	2	6	10	2	4	5	4	4	4	0
70.75	0	0	3	1	3	4	0	4	1	0	9	0
75+	0	8	2	6	7	5	3	5	3	6	14	1

(b) per 1000

CLASS OF G.I	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
0. 5	11	13	12	9	8	7	34	47	39	26	68	23
5.10	215	203	158	149	137	149	182	254	235	268	344	335
10.15	254	245	227	254	253	236	154	121	205	227	288	304
15.20	130	97	63	106	121	140	86	49	119	84	105	91
20.25	55	63	55	77	63	79	86	77	79	63	57	45
25.30	50	88	77	84	68	72	90	68	62	61	31	40
30.35	75	63	86	79	61	94	112	68	91	68	21	52
35.40	57	65	88	88	70	50	82	75	54	61	15	43
40.45	50	57	90	39	50	53	70	79	39	43	7	23
45.50	42	36	52	32	54	55	44	49	17	30	4	16
50.55	19	17	39	28	40	9	20	44	14	32	5	14
55.60	19	19	21	14	21	19	18	28	14	4	2	2
60.65	11	13	12	10	14	4	6	14	4	9	5	2
65.70	4	1	3	10	17	4	8	7	9	6	5	0
70.75	0	0	5	1	5	9	0	6	2	0	13	0
75+	0	15	3	10	12	12	6	7	7	9	20	2

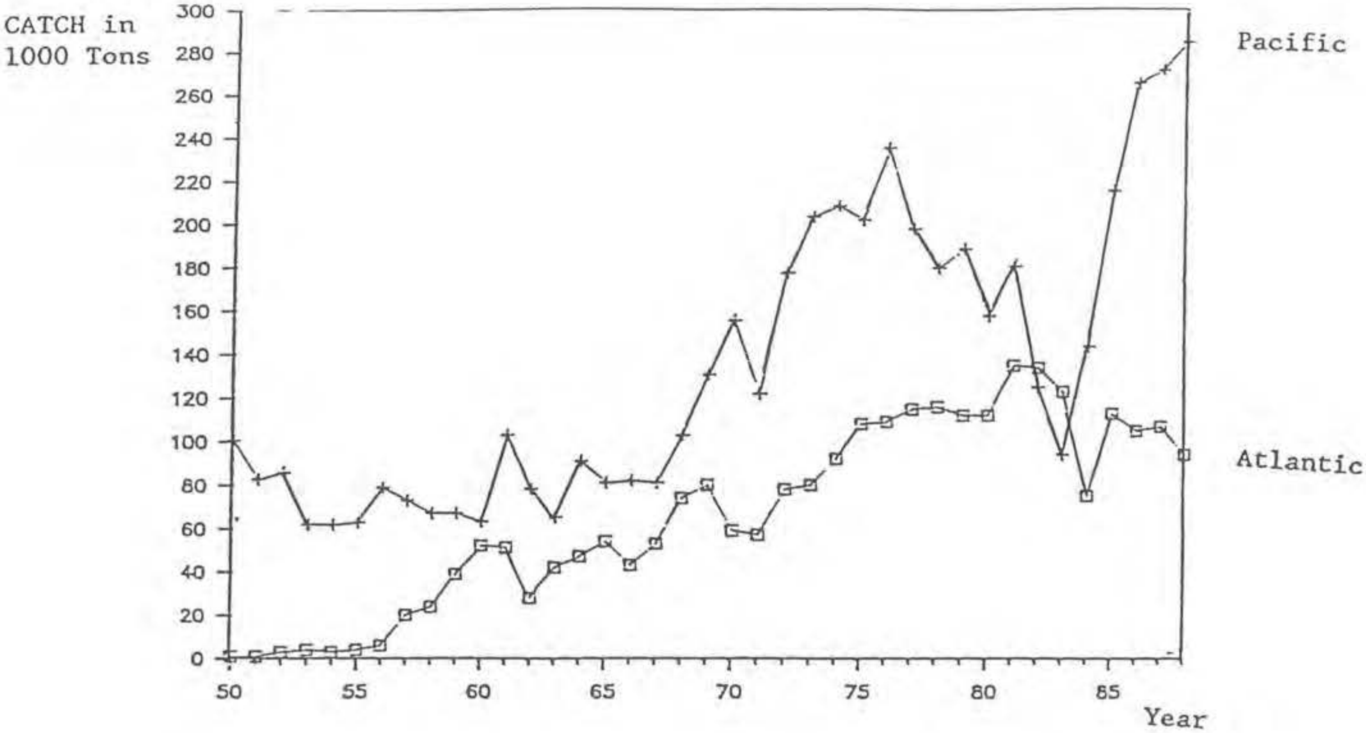
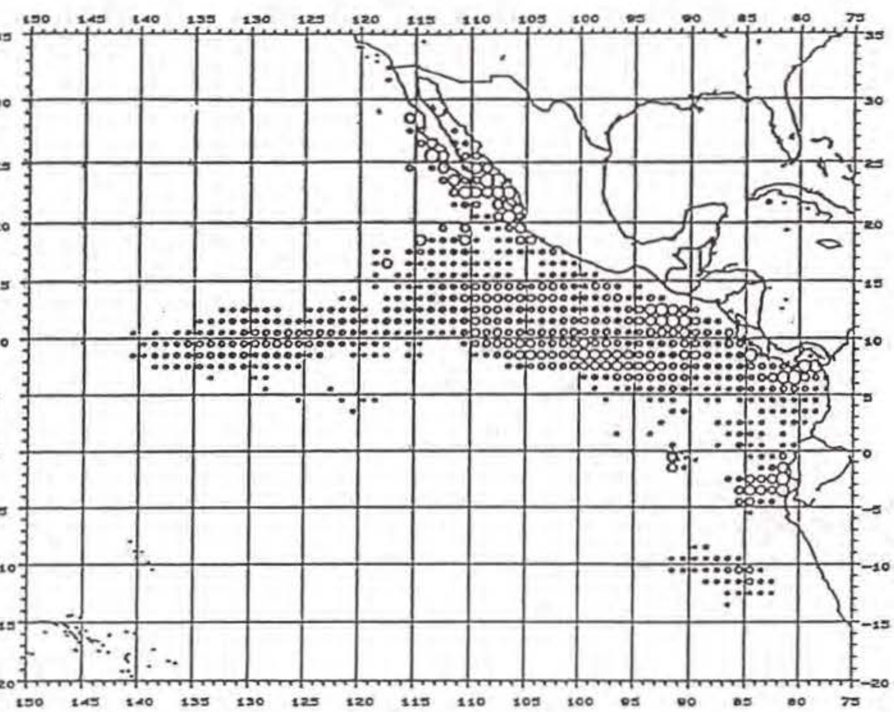
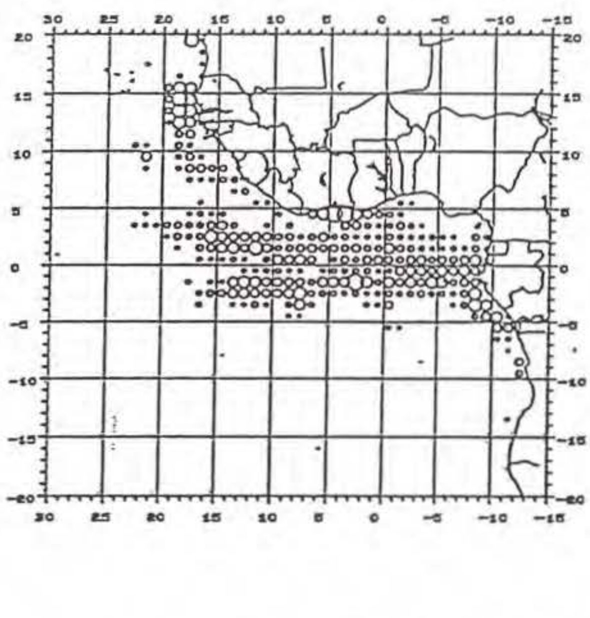


Figure 1.- : Yearly catches of yellowfin tuna in the Eastern Atlantic and Pacific oceans.





o 1000 t.

Figure 2.- : Average fishing zones of surface fisheries for yellowfin tunas during recent years (1980-1988) in the Eastern Pacific (a) and the Eastern Atlantic oceans (b). Only the 1 degree squares with an average catch of 75 tons are represented in those two maps, in order to show better the more important fishing zone ; those squares with a catch greater than 75 tons contributed in both oceans to more than 90 % of the total catches.

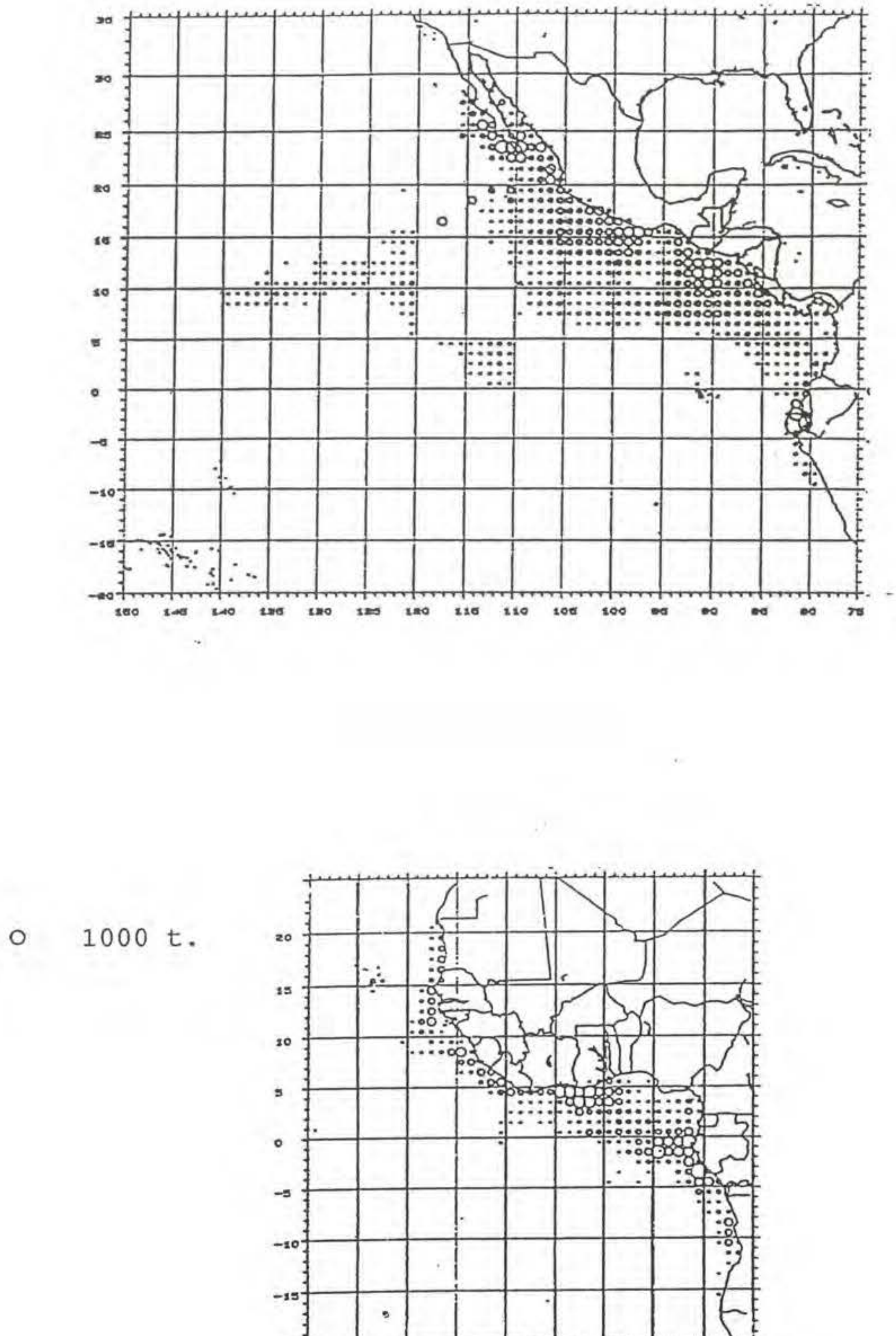
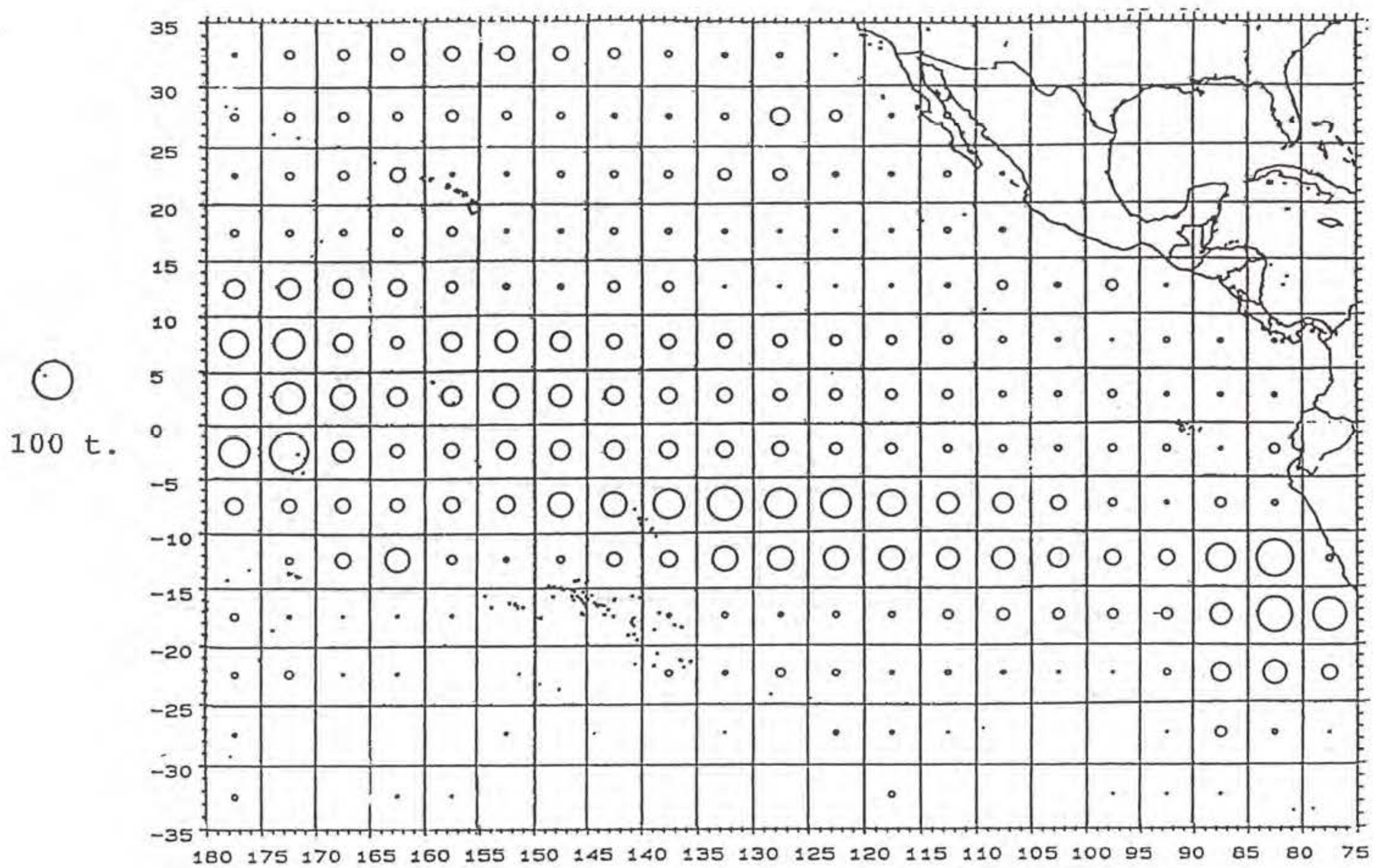


Figure 3.- : Average fishing zones of surface fisheries for yellowfin tunas during the historical fisheries, 1960-1970 in the Eastern Pacific (a) and 1969-1974 in the Eastern Atlantic (b).



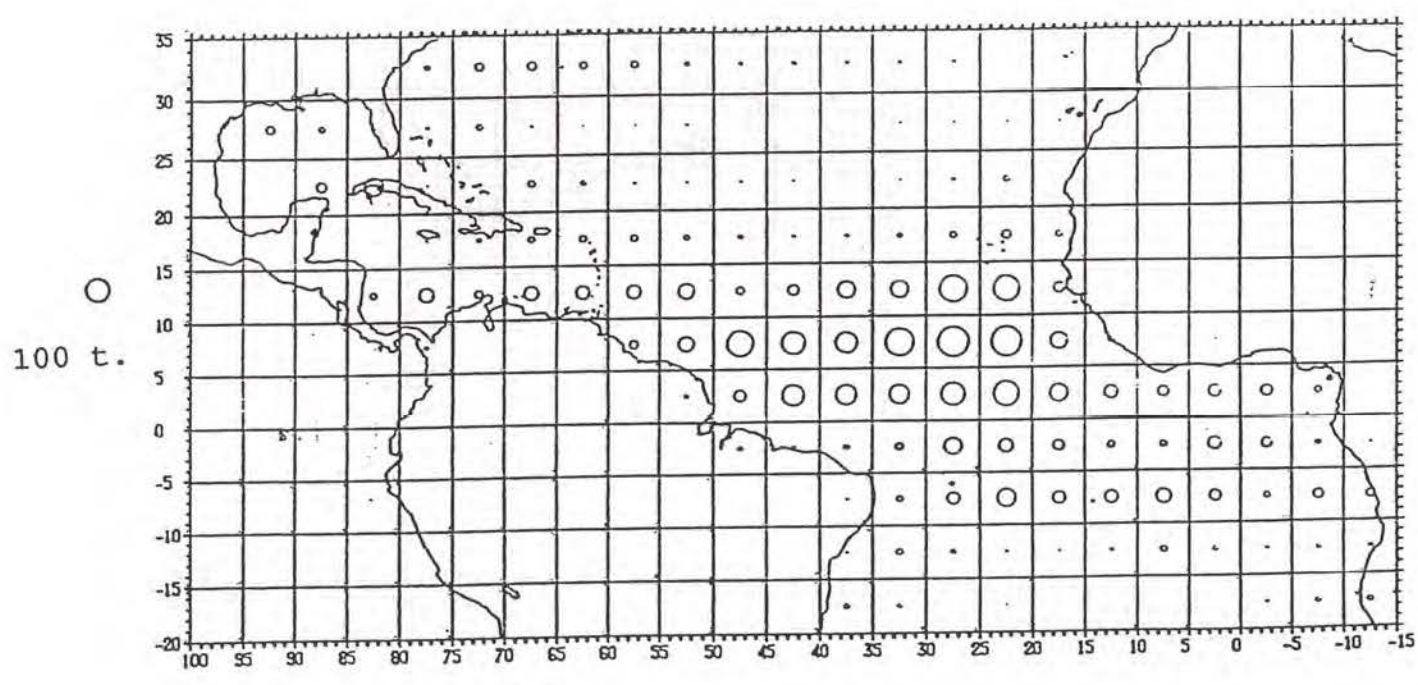
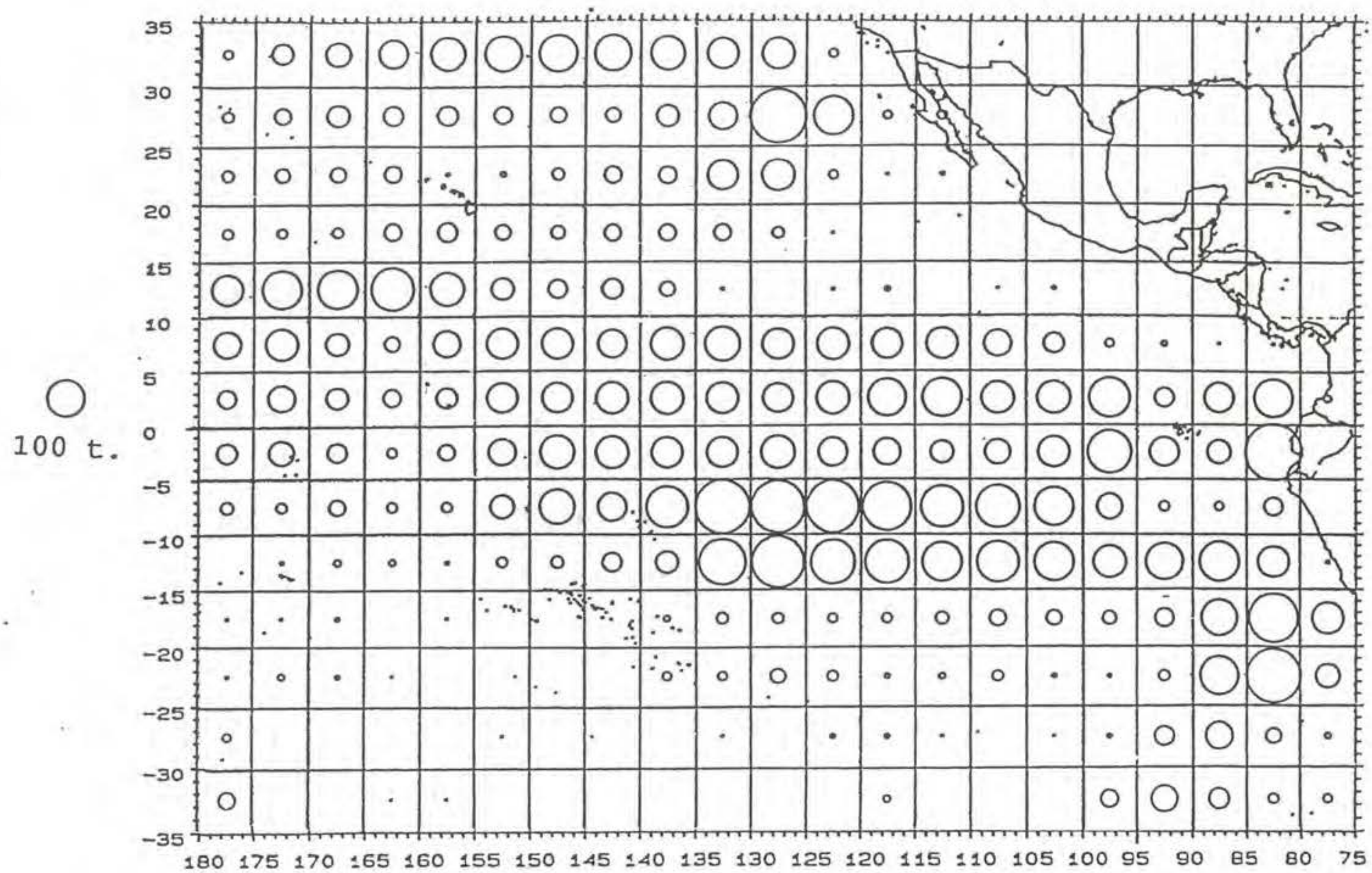


Figure 4.- : Average 1978-1988 fishing zones of the japanese longline fishery for yellowfin in the Eastern Pacific and for all the longline fisheries in the Atlantic (average 1980-1987).



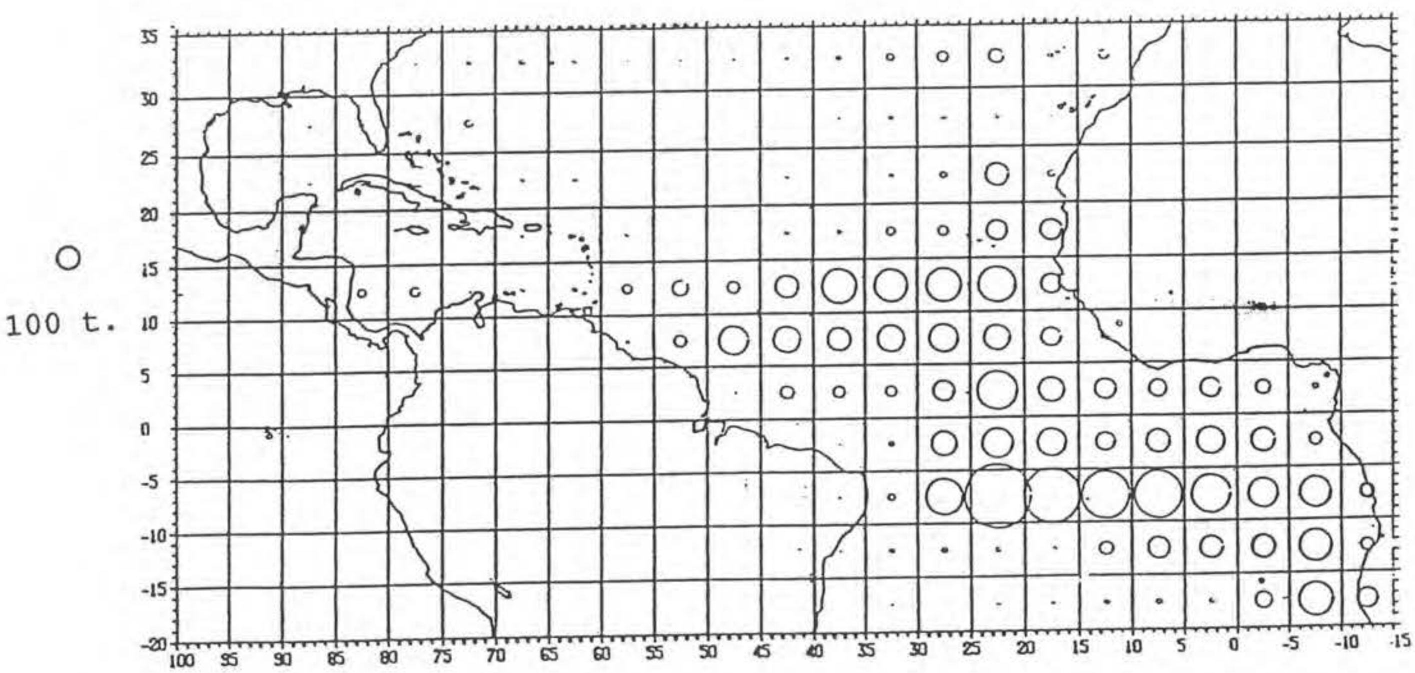


Figure 5.- : Average 1978-1988 quarterly fishing zones of the japanese longline fishery for bigeye in the Eastern Pacific and for all the longline fisheries in the Atlantic (average 1980-1987).

(b) Yellowfin more than 30 kg

O 1000 t.

(a) Yellowfin less than 30 kg

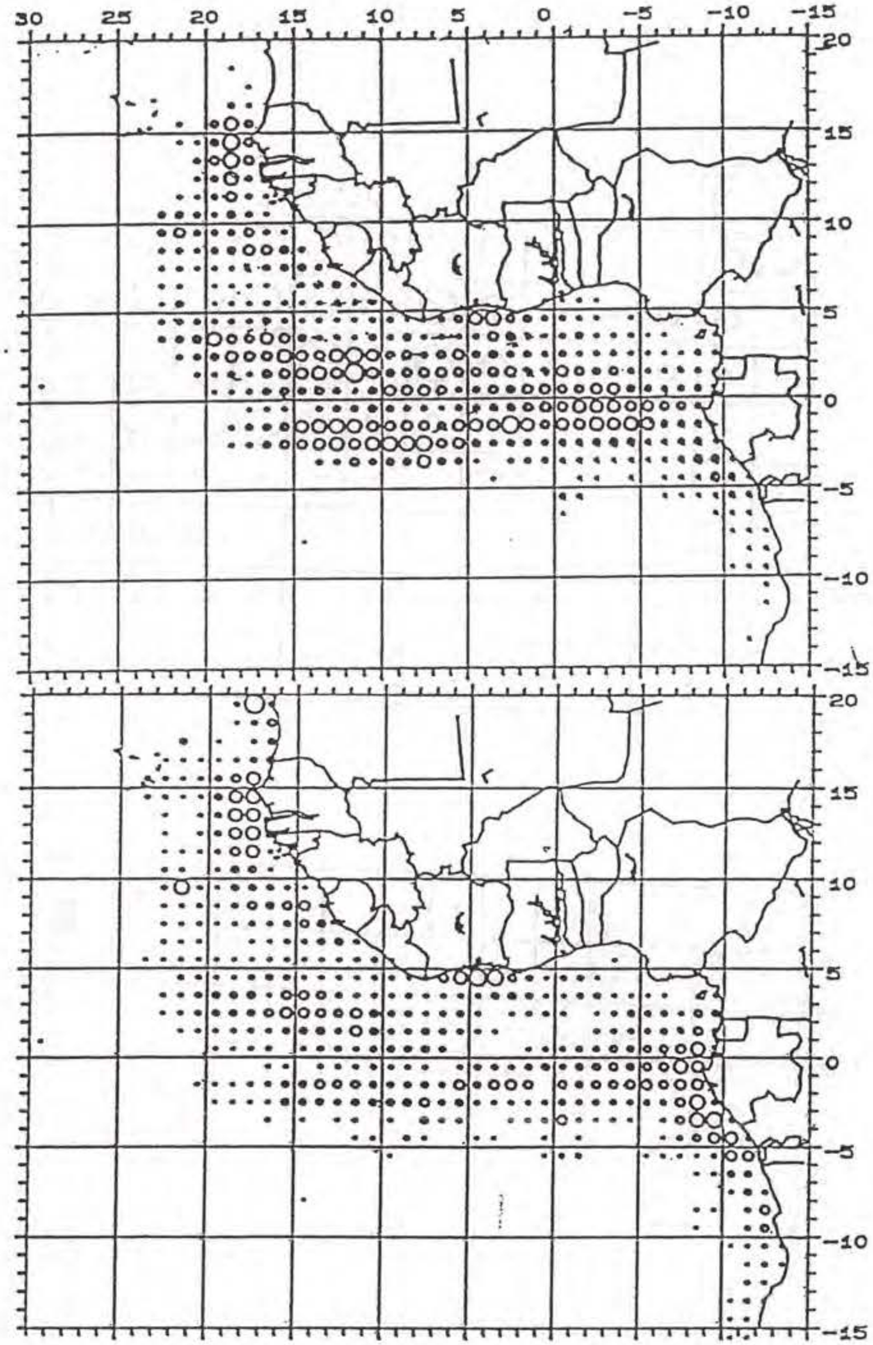
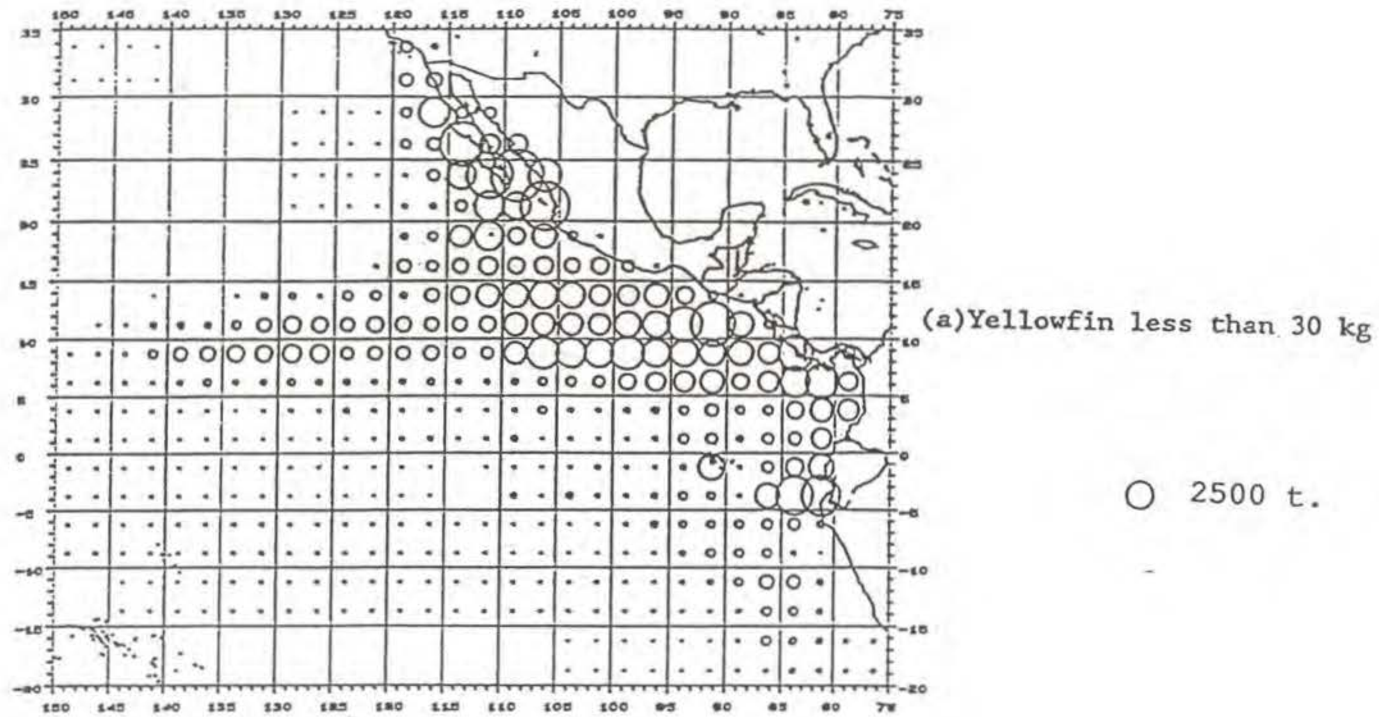


Figure 6.- : Average fishing zones of purse seine fisheries for yellowfin less (b) and more (a) than 30 kg during recent years (1980-1988) in the Eastern Atlantic ocean.



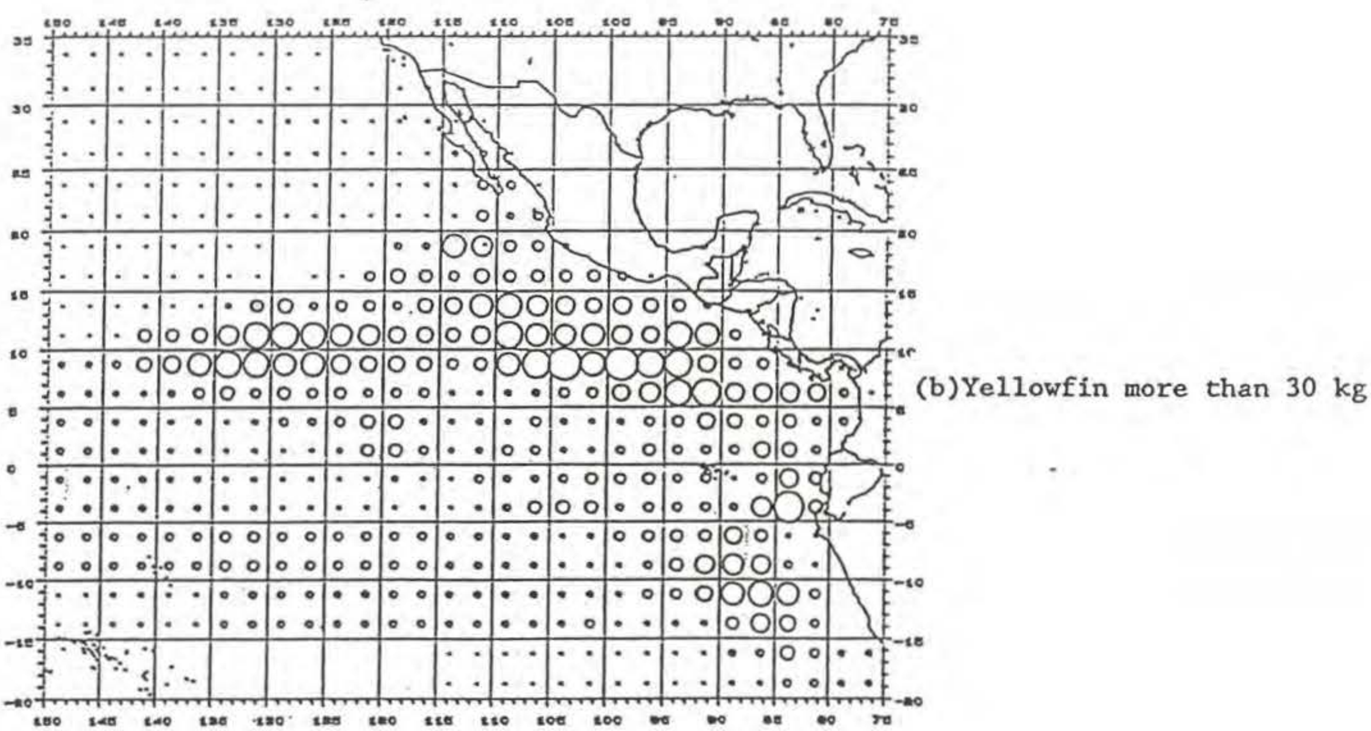
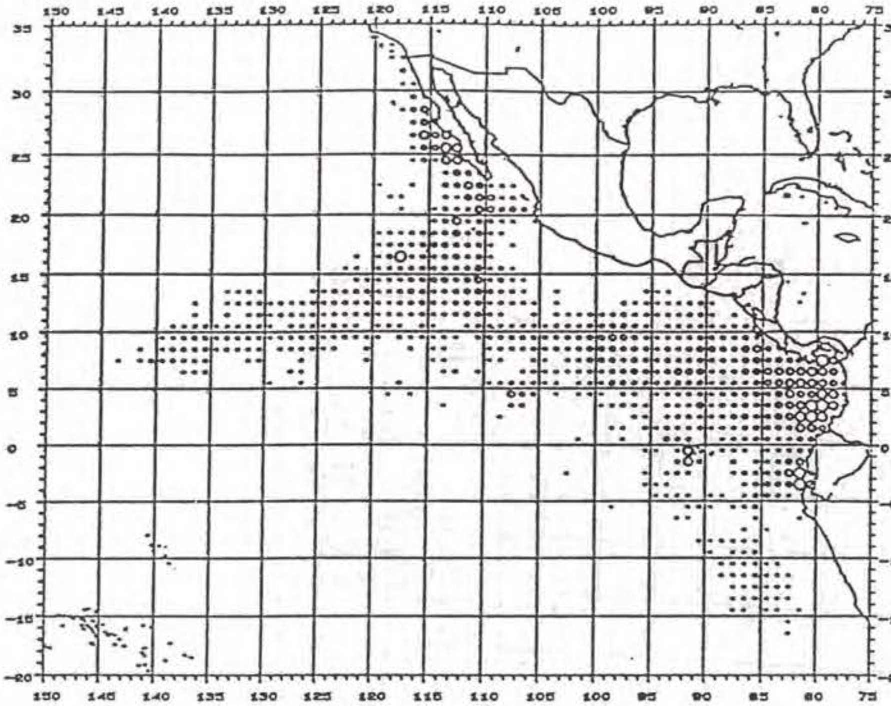


Figure 7.- : Average fishing zones for all fisheries (surface and longline) in the Eastern Pacific by 2.5 degree squares, average period 1980 to 1986, for large yellowfin (larger than 30 kg), and small yellowfin (less than 30 kg)



○ 1000 t.

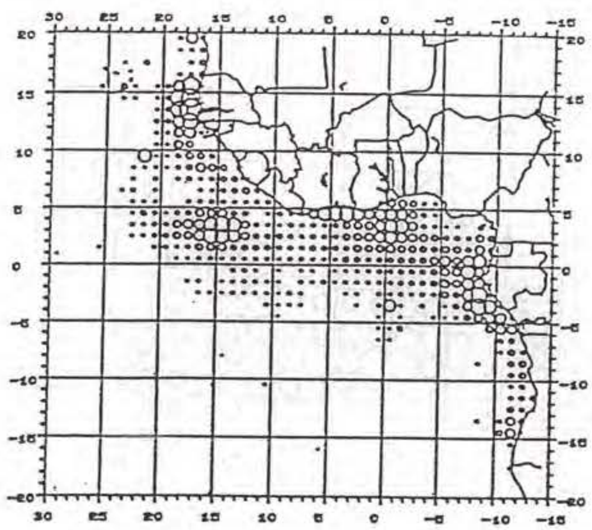


Figure 8.- : Average fishing zones of skipjack fisheries during recent years (1980-1988) in the Eastern Pacific (a) and the Eastern Atlantic oceans (b) (only the 1 degree squares whith a catch greater than 10 tons are shown in this map).

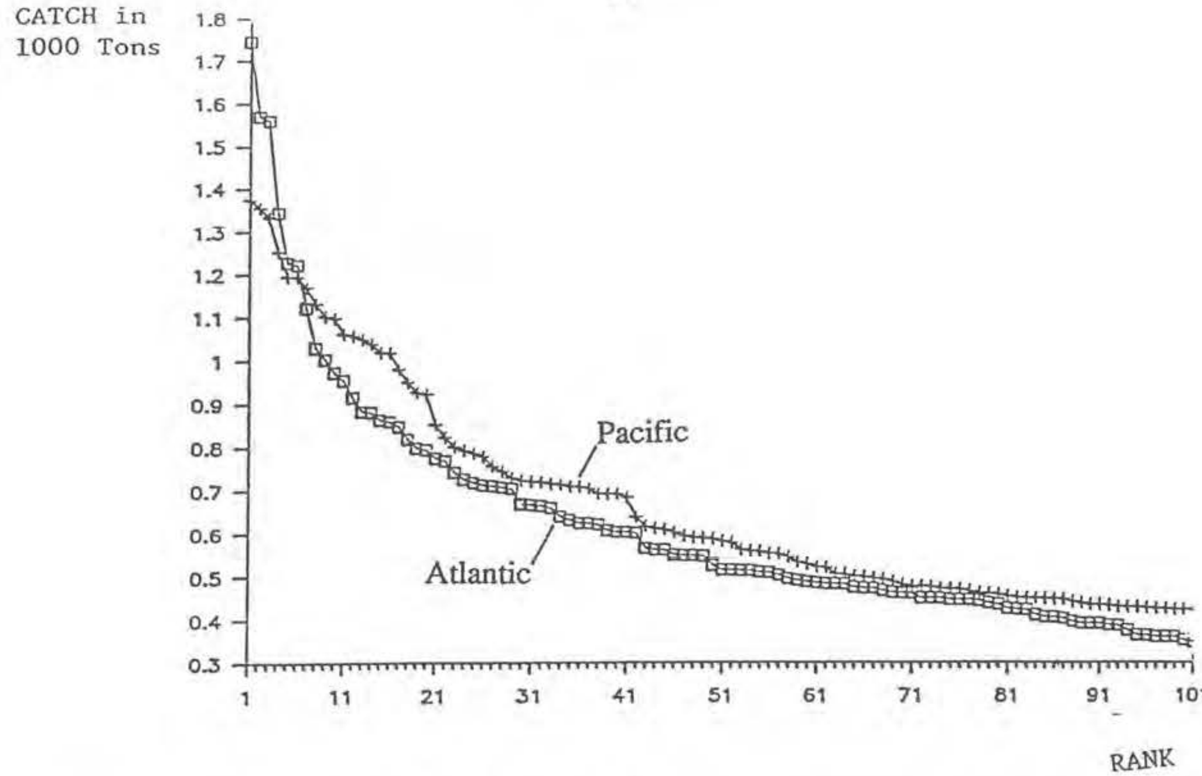


Figure 9.- : Average yellowfin catches by 1 degree squares for the Eastern Atlantic and Pacific surface fisheries ranked by decreasing level (period 1980-1988).

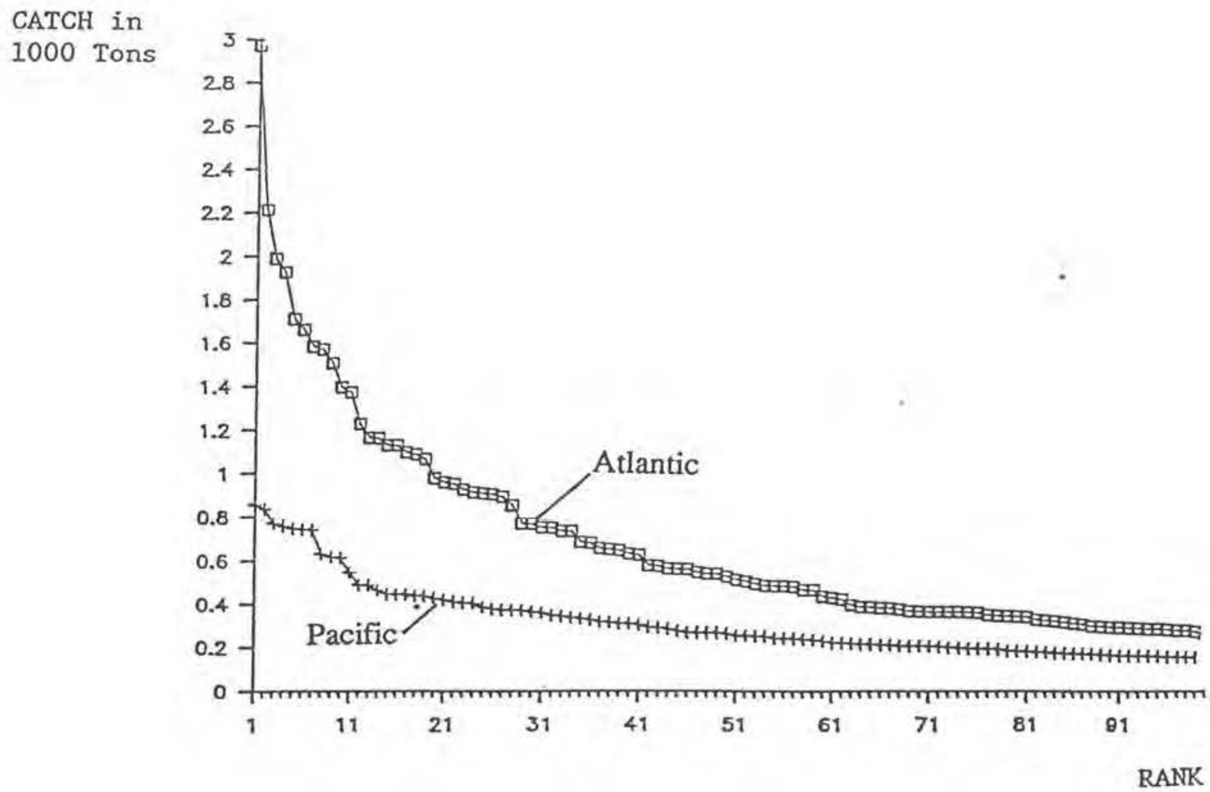


Figure 10.- : Average skipjack catches by 1 degree squares for the Eastern Atlantic and Pacific surface fisheries ranked by decreasing levels (period 1980-1988).

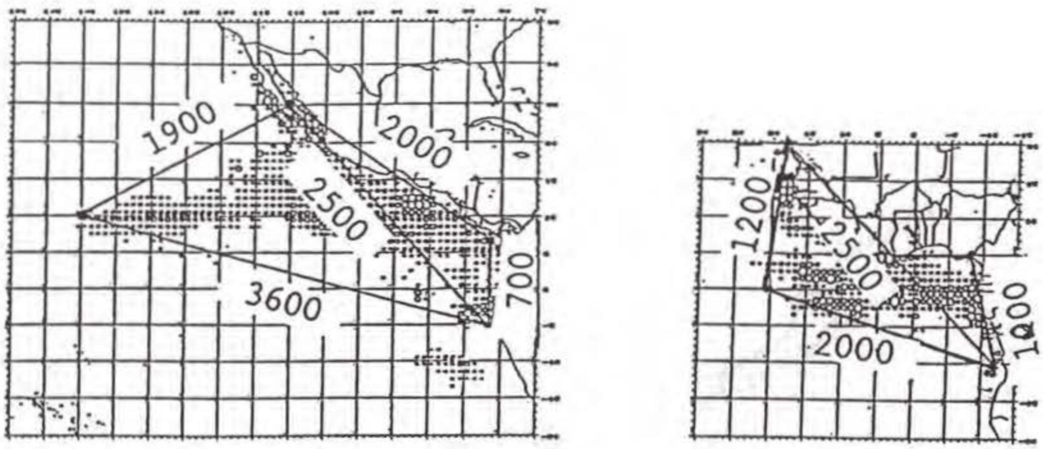


Figure 11.- : Schematical representation of the two fishing areas with distances between the major components of the fisheries (in nautical miles).

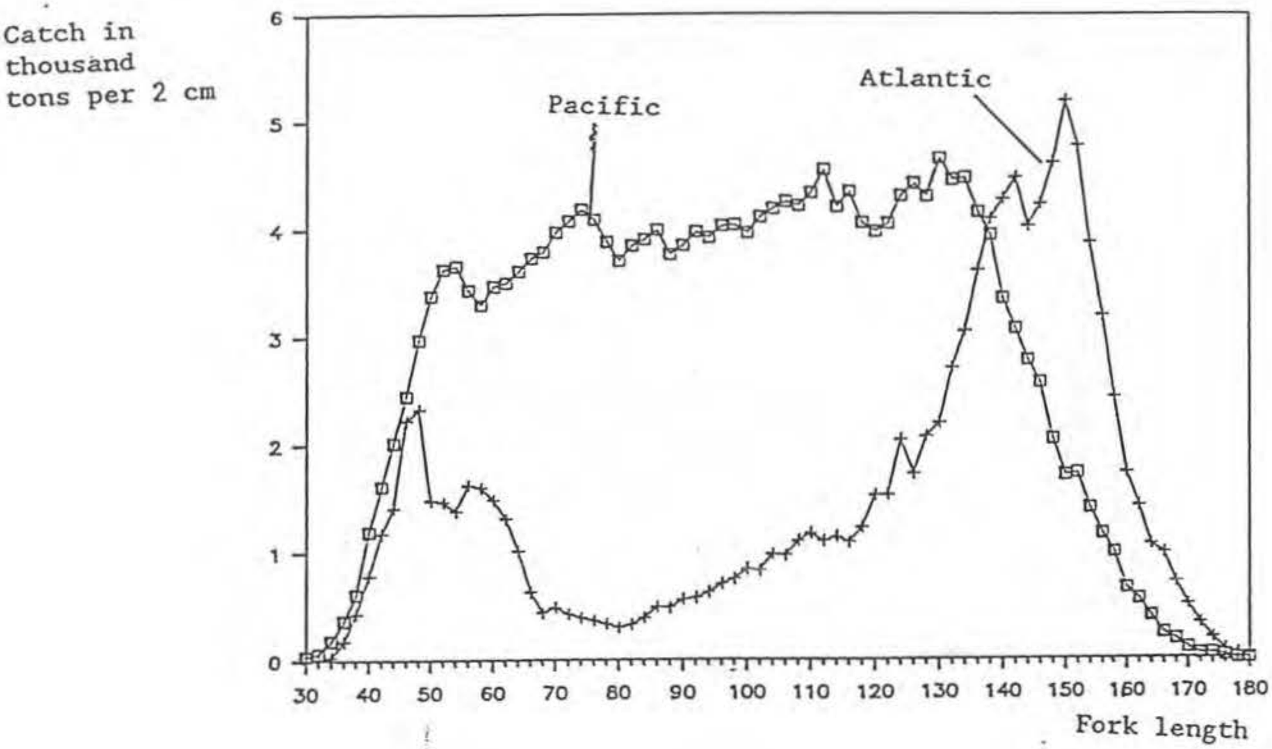


Figure 12.- : Average sizes of yellowfin tunas caught (2 cm intervals) by the Eastern Atlantic and Eastern Pacific fisheries during the period 1975-1988.

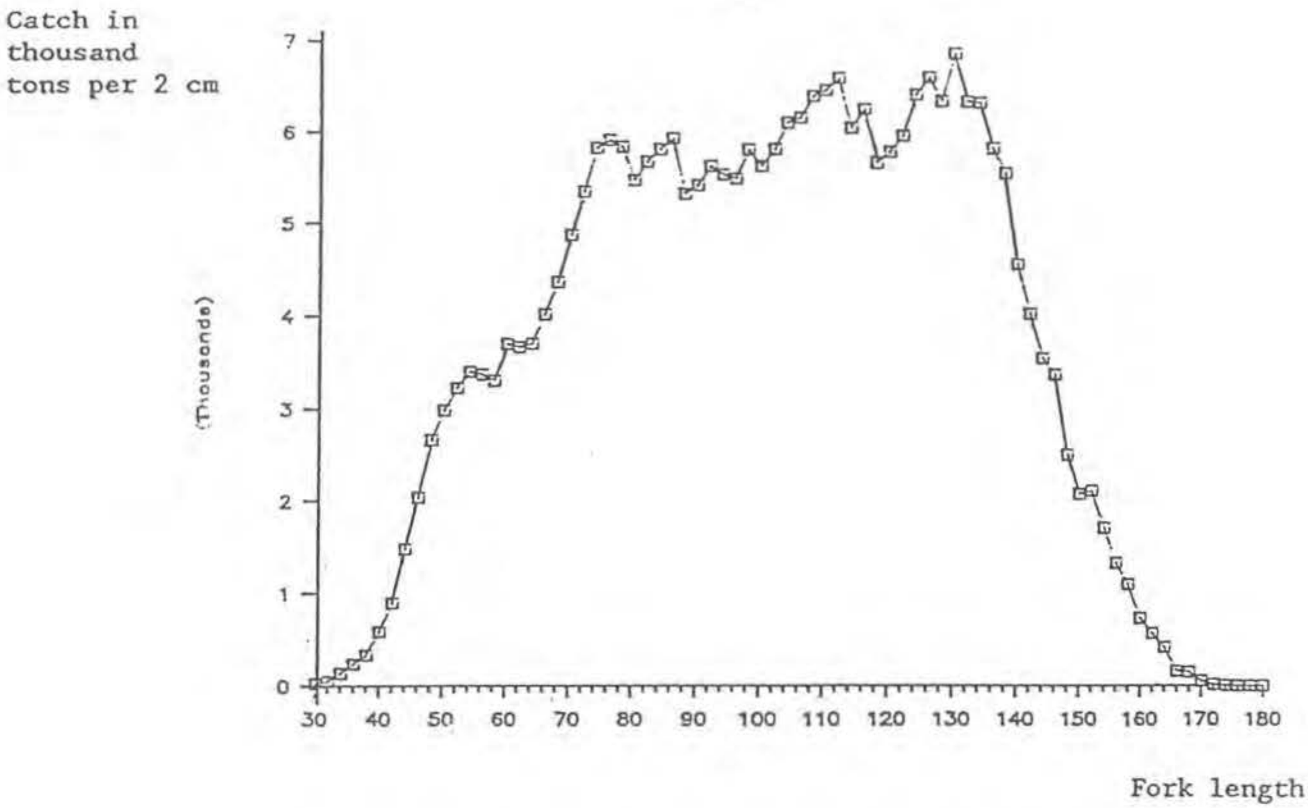


Figure 13.- : Average sizes of yellowfin tunas caught (by 2 cm intervals) by the Eastern Pacific fishery during the period 1985-1989.

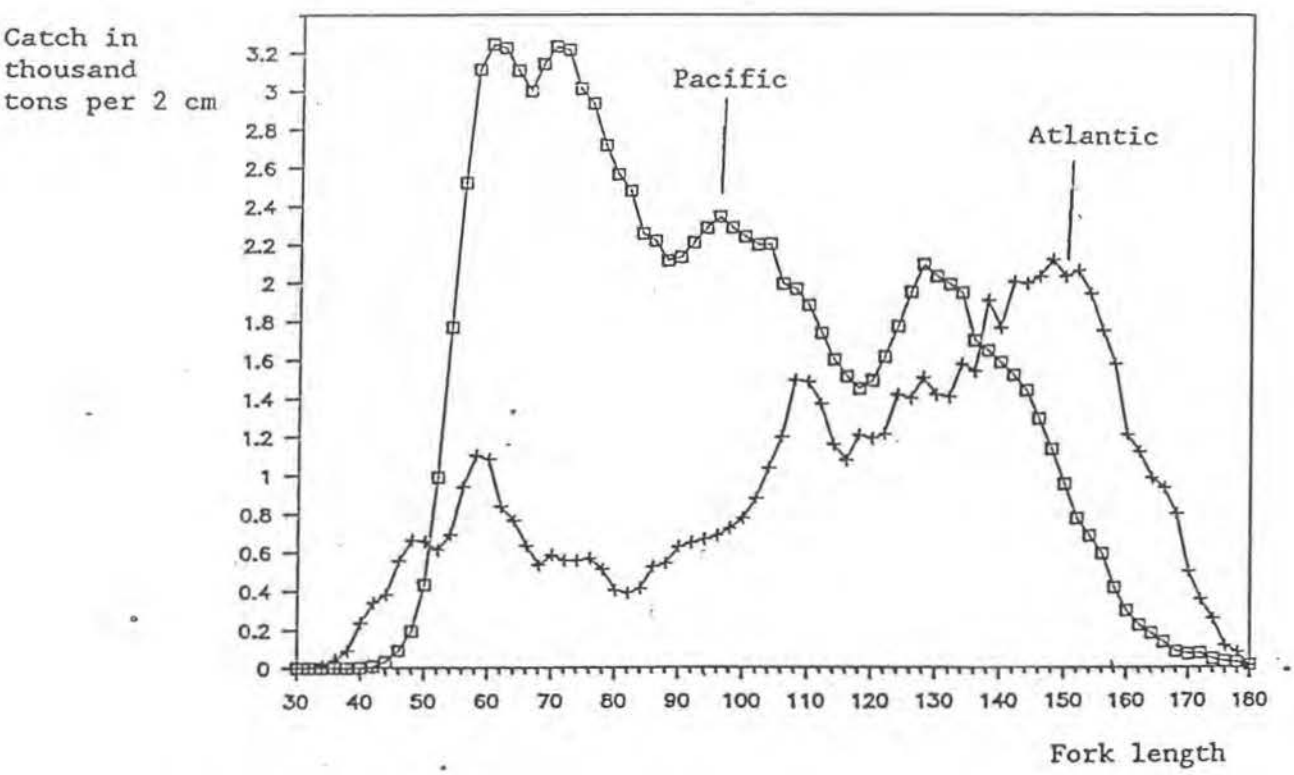


Figure 14.- : Average sizes of yellowgin tunas caught (2 cm intervals) by the Eastern Atlantic and Eastern Pacific fisheries during the historical period (1960-1970) for the Pacific and for the Atlantic oceans (1965-1974).

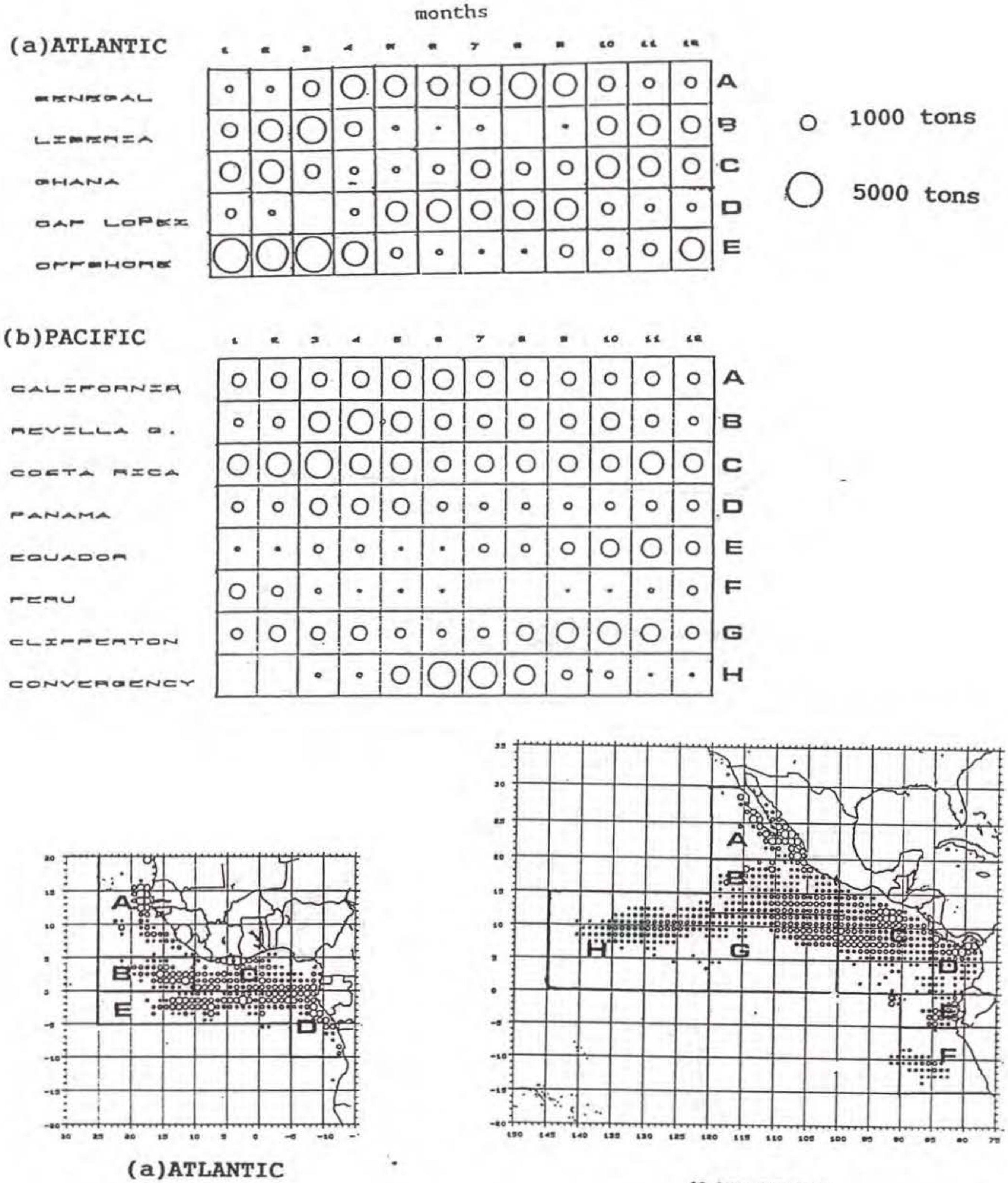


Figure 15.- : Average monthly catches of yellowfin tuna (period 1980-1988) by area (areas shown in the bottom).

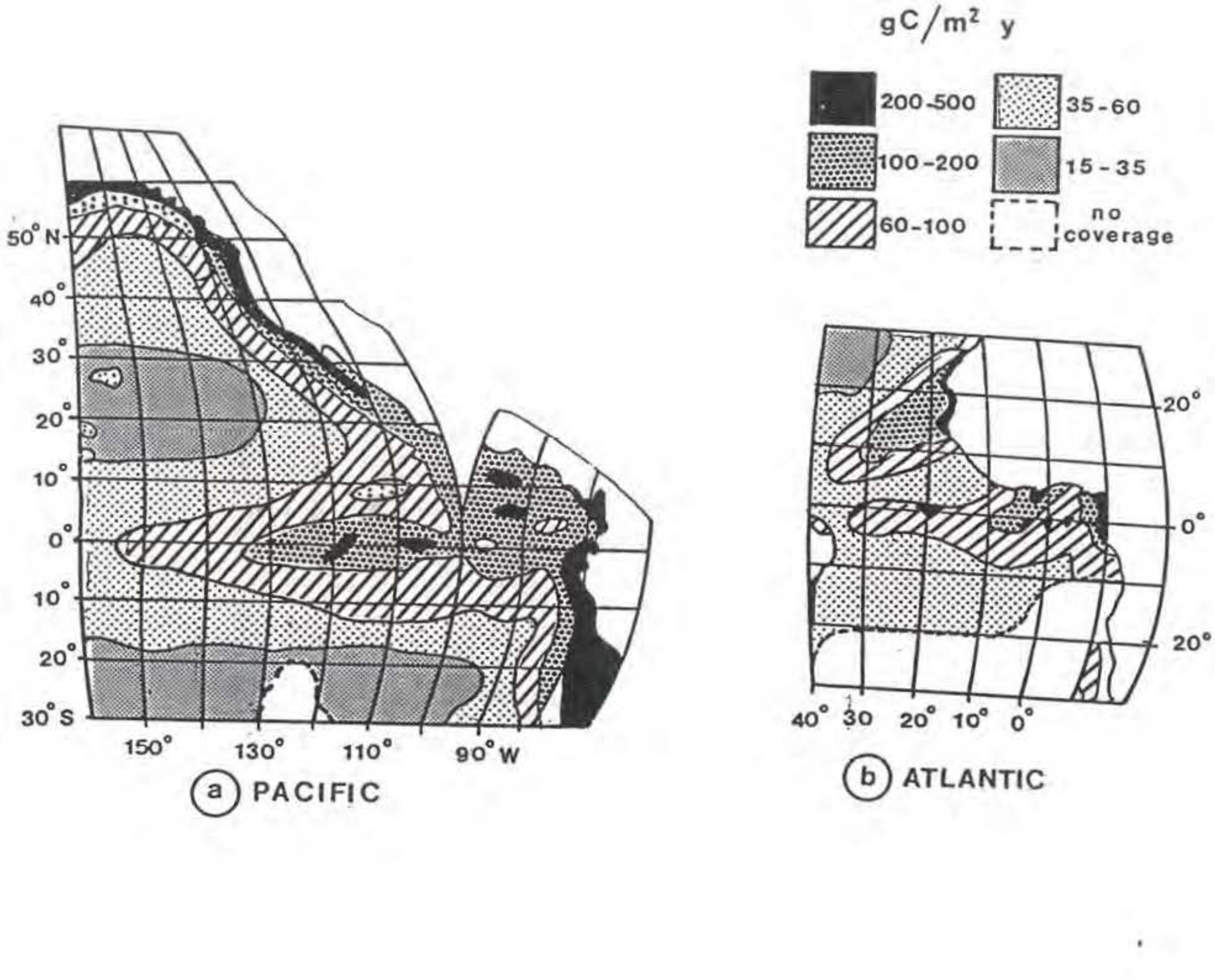


Figure 16.- : Primary productivity in the Eastern tropical Atlantic and Pacific based on direct radiocarbon measurements from the litterature (from Berger et al. 1988).

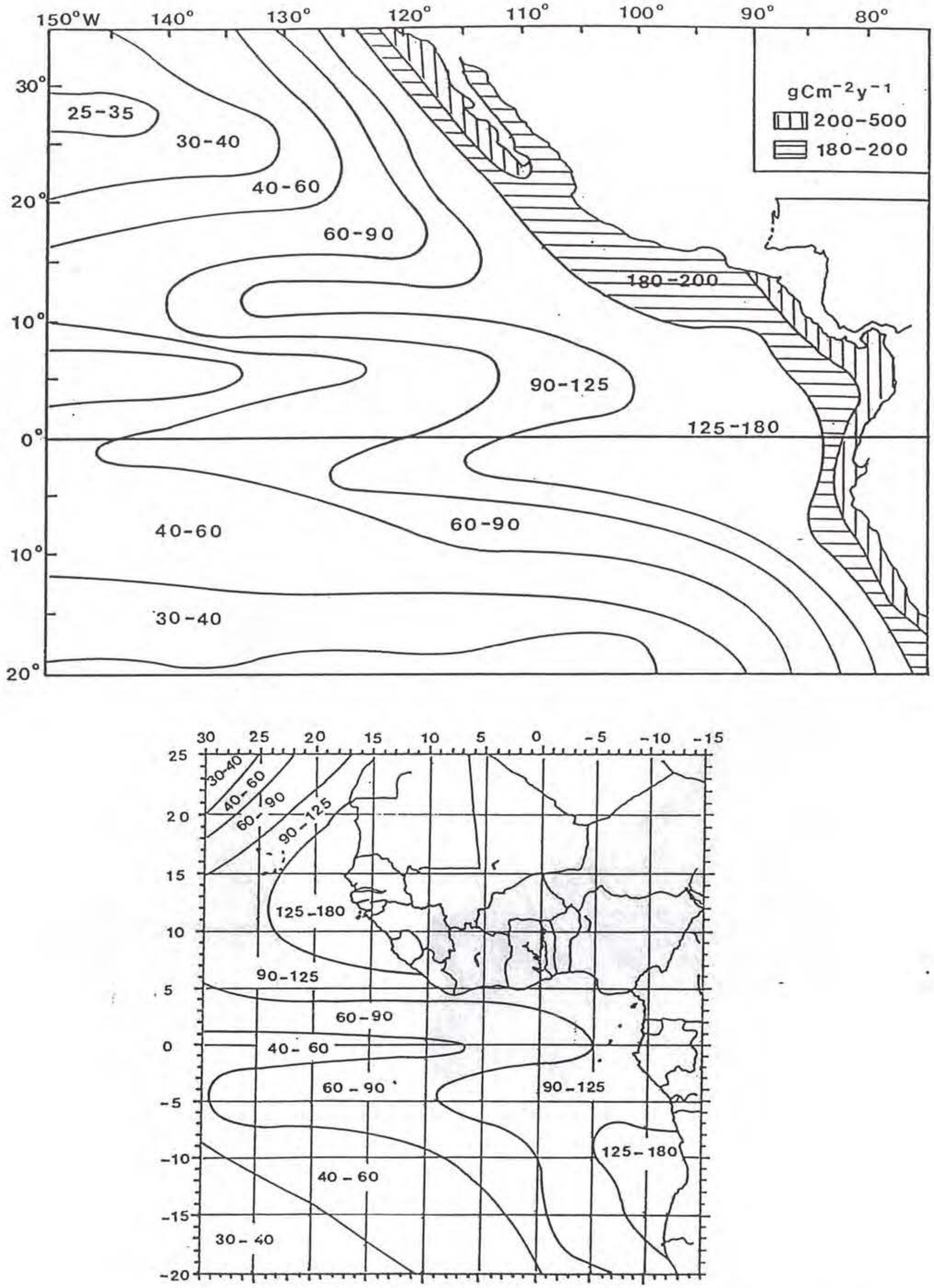


Figure 17.- : Primary productivity in the Eastern tropical Atlantic (a) and Pacific (b) as calculated from phosphates distribution (only the areas at more than 100 miles from the shore are estimated) (Redrawn from Berger et al. 1988).

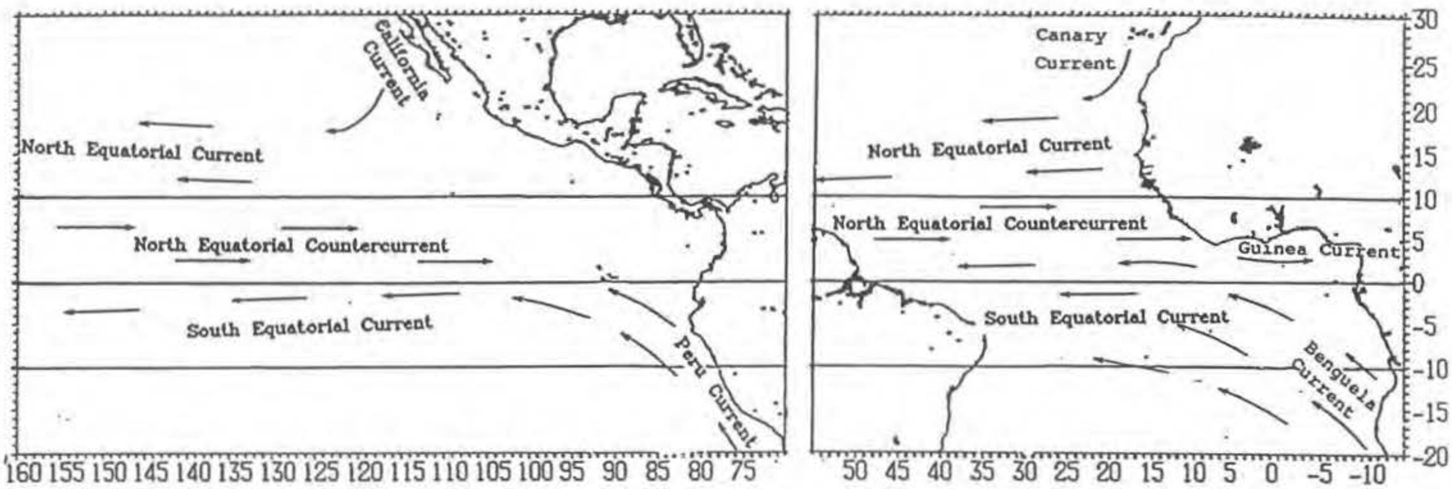


Figure 18.- : Simplified map of the major currents in the two fishing areas.

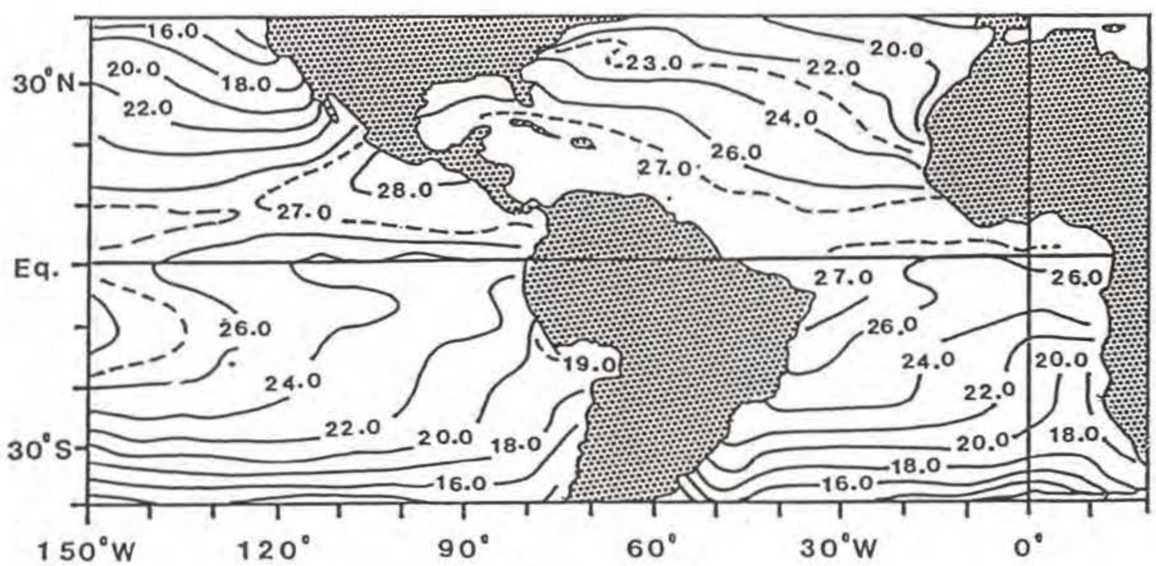
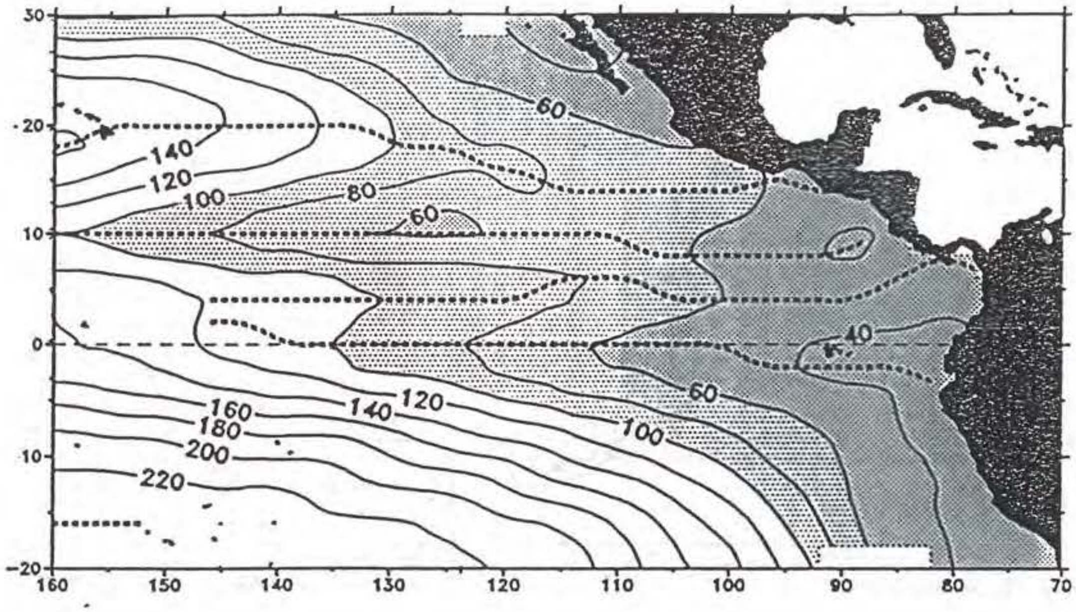


Figure 19.- : Average yearly sea surface temperature in the two areas under study (from Levitus 1982).



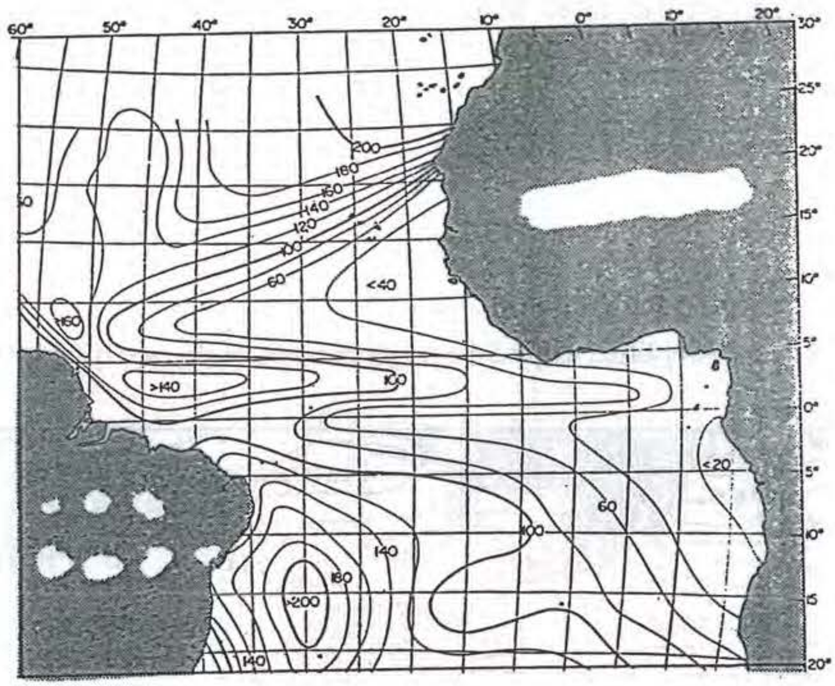


Figure 20-:Average depth of the thermocline in the two areas under study (Eastern Pacific: depth of the 20º isotherm (Pacific from Fiedler 1992 and Atlantic fron Defant 1961).

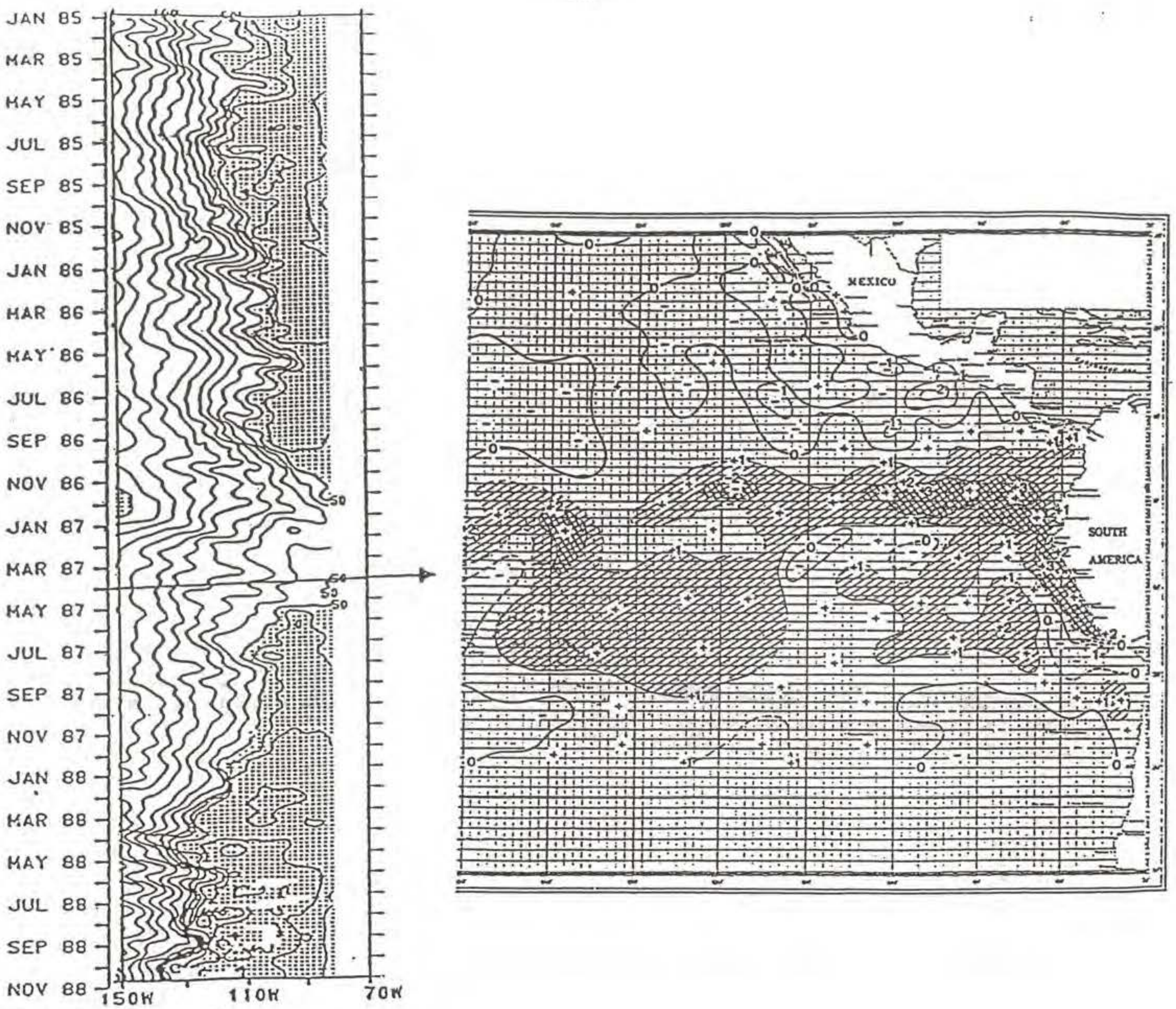


Figure 21.- : Depth of the 20° degree isotherm versus time and latitude (isocurbs by 10 meters intervals), in the Eastern Pacific. (from Climate Diagnostics Bull., NOAA, Nov. 1988) and departure of SSTs from the long term average during april 1987; the areas with SST from 1 to 3º C above normal are hatched) (from IATTC 1988).

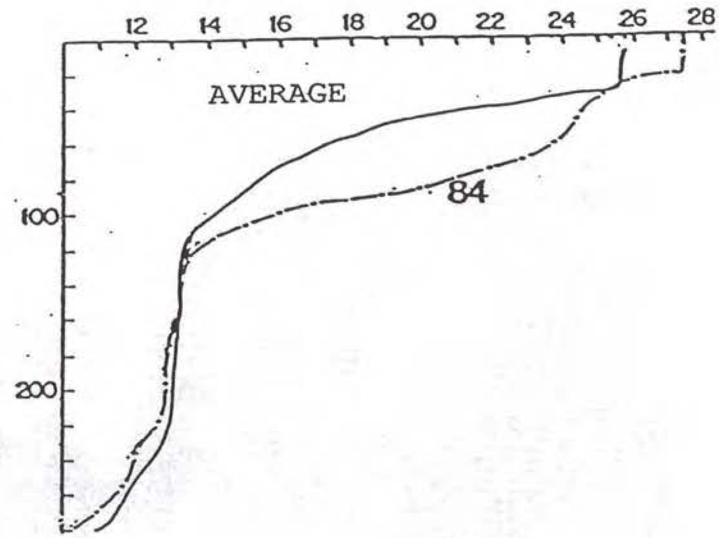


Figure 22.- : Thermocline structure in the equatorial Atlantic (at 4° West) under average oceanographical conditions, and during an Atlantic El Niño type anomaly (first quarter of 1984) (From Hougton and Colin 1987).

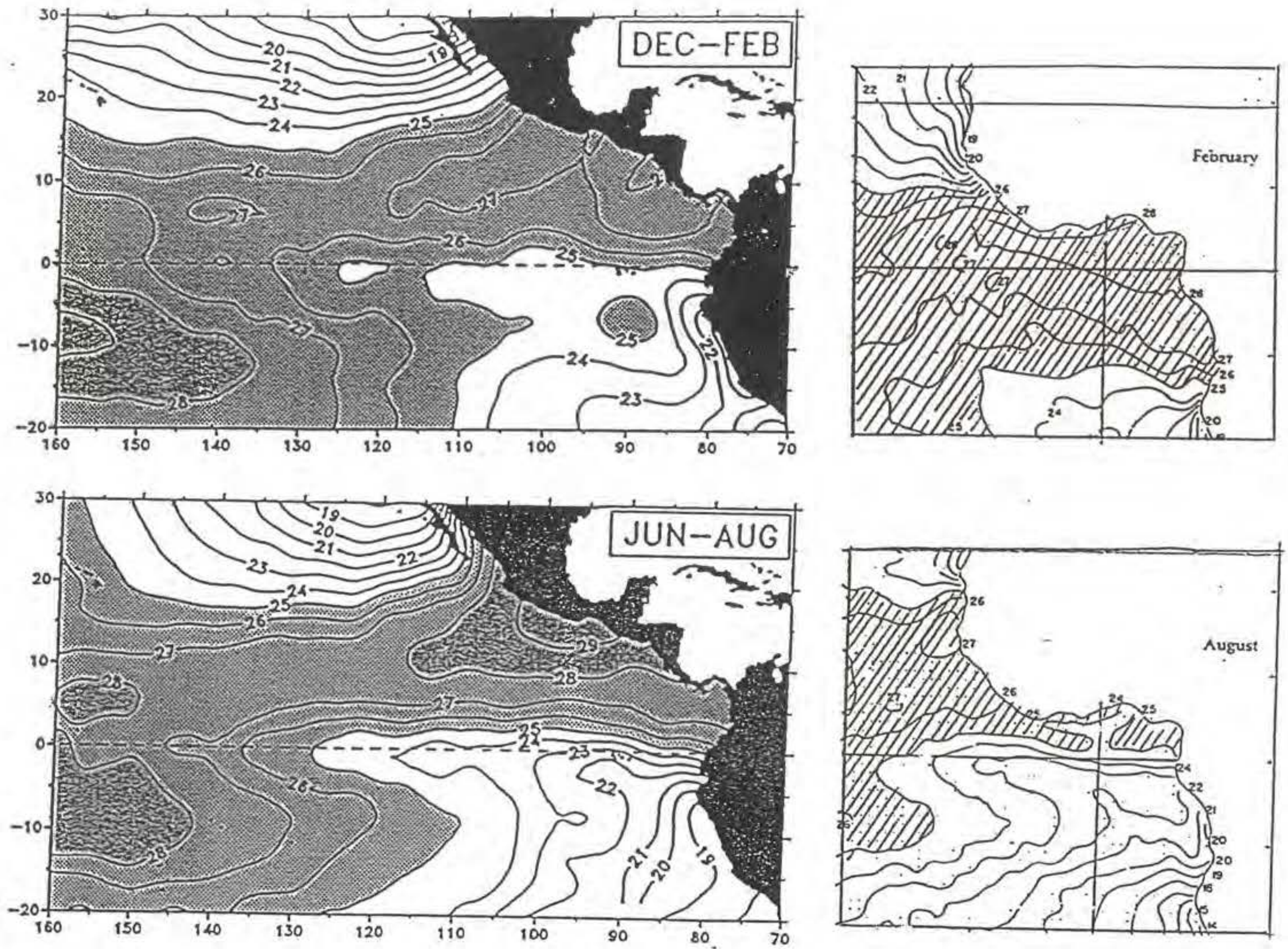


Figure 23.- : Seasonal average sea surface temperatures in the two areas under study : a winter season and a summer season. (Pacific figure taken from Fiedler 1992, Atlantic figures from Hastenrath and Lamb 1977).(The darker or shadded areas correspond to warm waters with an average temperature greater than 25º C).

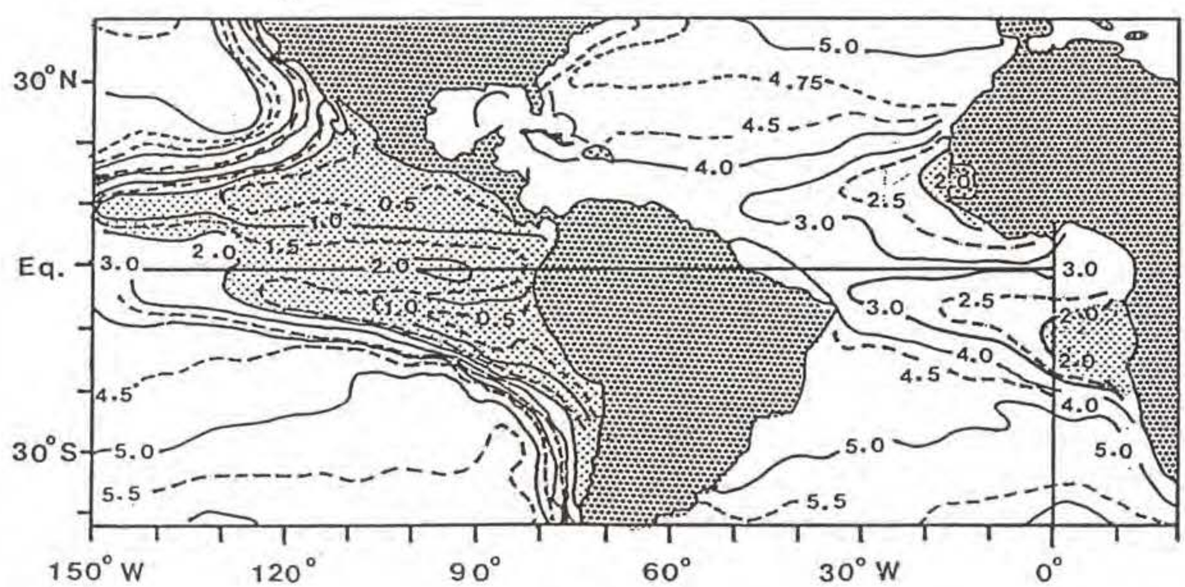


Figure 24.- : Average concentration of oxygen at a 150 meters depth in the two areas (from Levitus 1982).

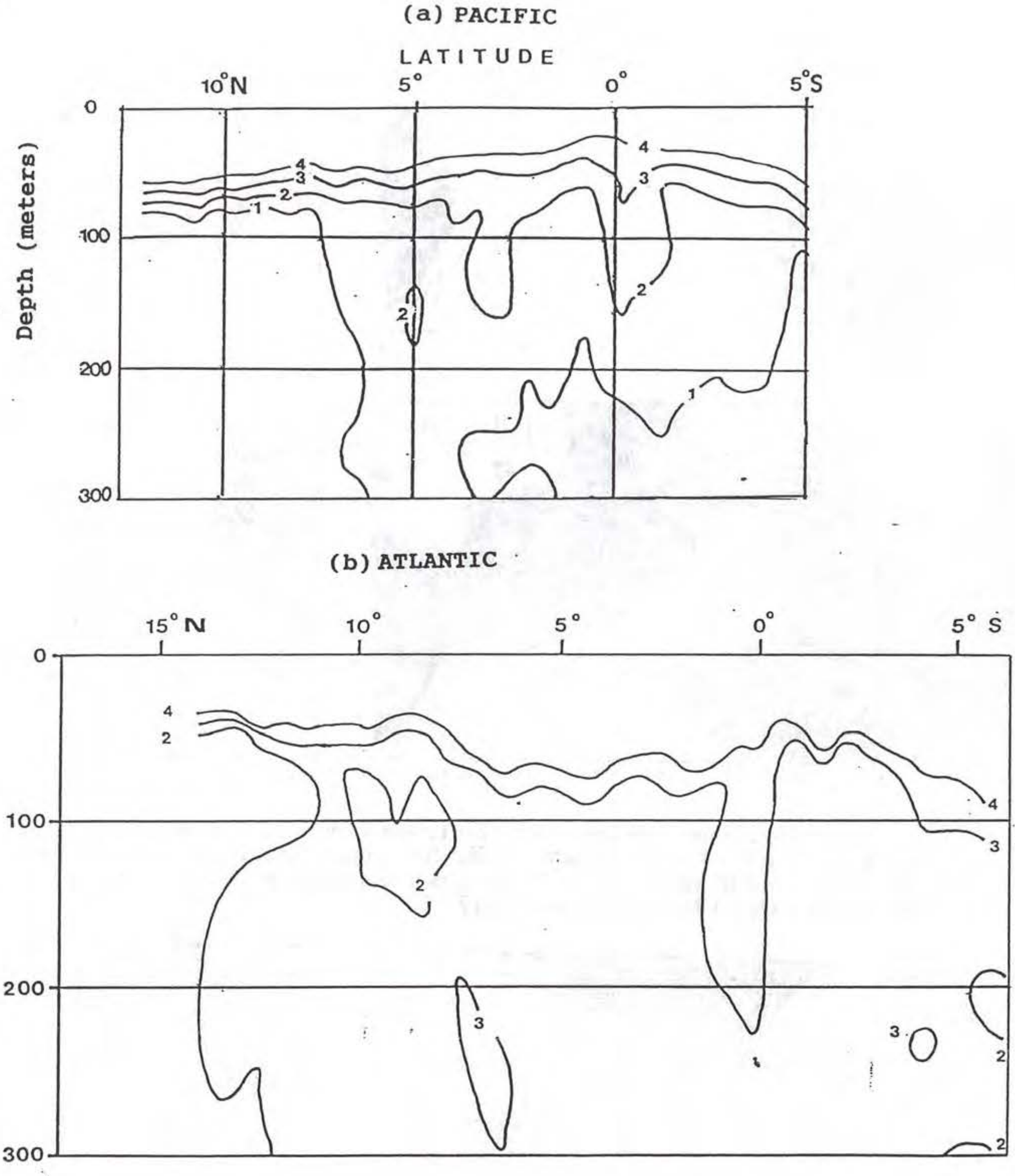


Figure 25.- : Typical North-South oxygen concentrations (ml/liter) observed in the Pacific and in the Atlantic ocean :

(a) Eastern Pacific : Eastropac cruise at 105° degrees West (February 1967)

(b) Eastern Atlantic : Focal cruise at 22° W (july 1982).

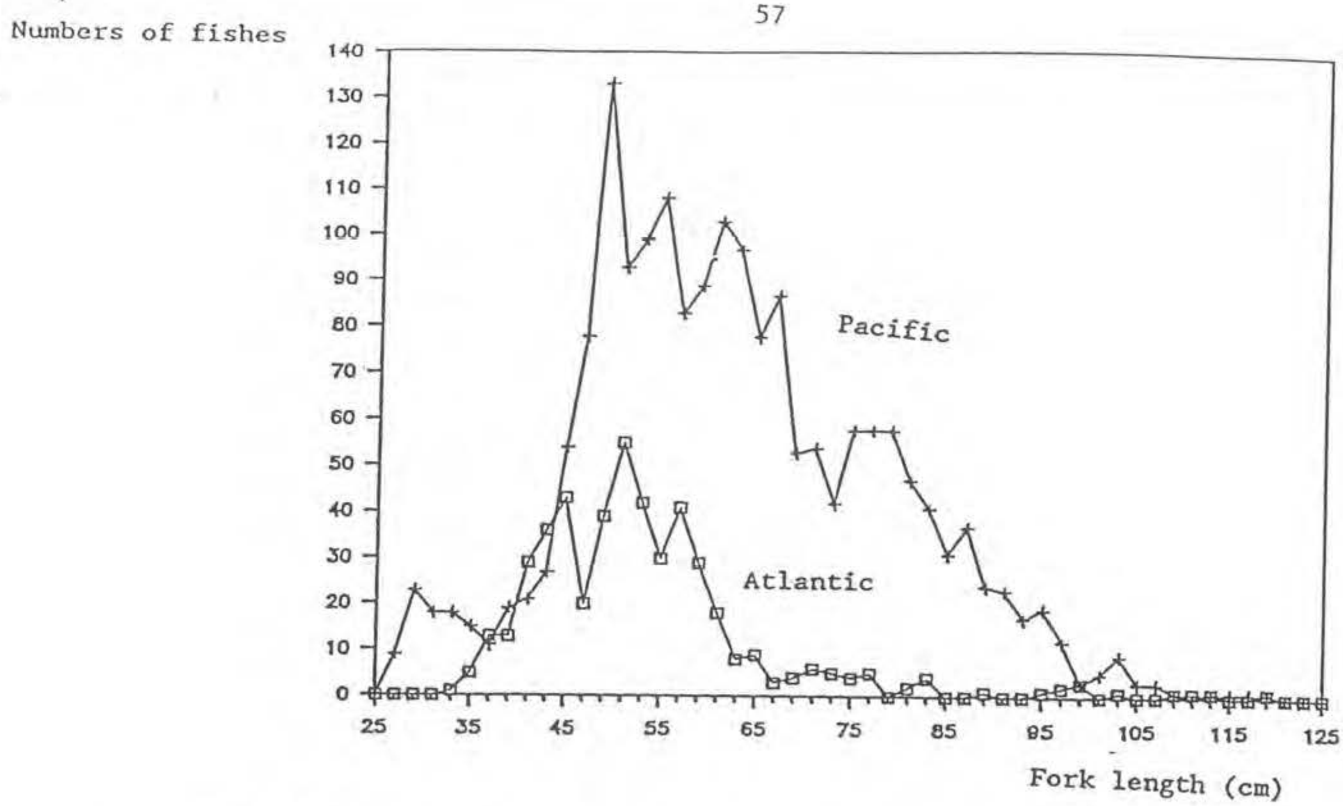


Figure 26.- : Sizes at release of the recovered tags in the Eastern Atlantic and Pacific data set.

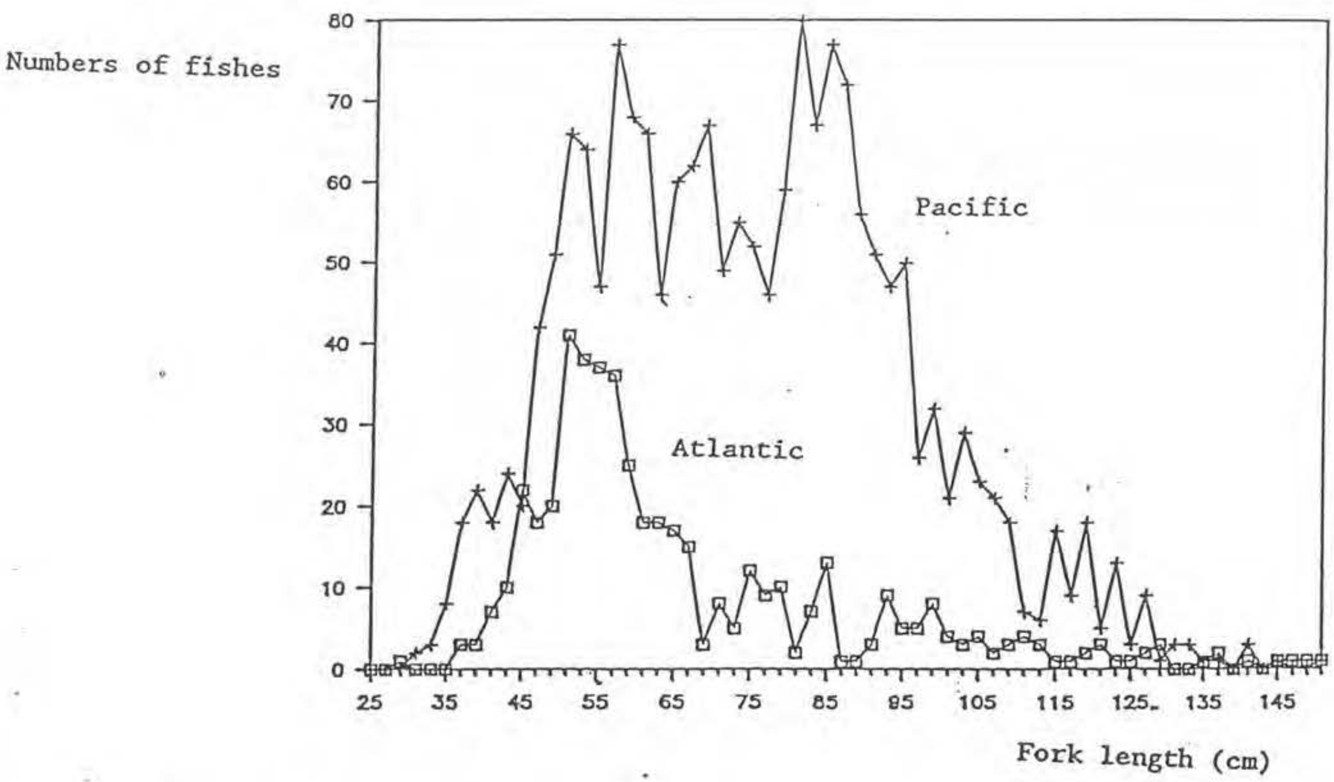


Figure 27.- : Sizes at recovery for the Eastern Atlantic and Pacific tagging data sets.

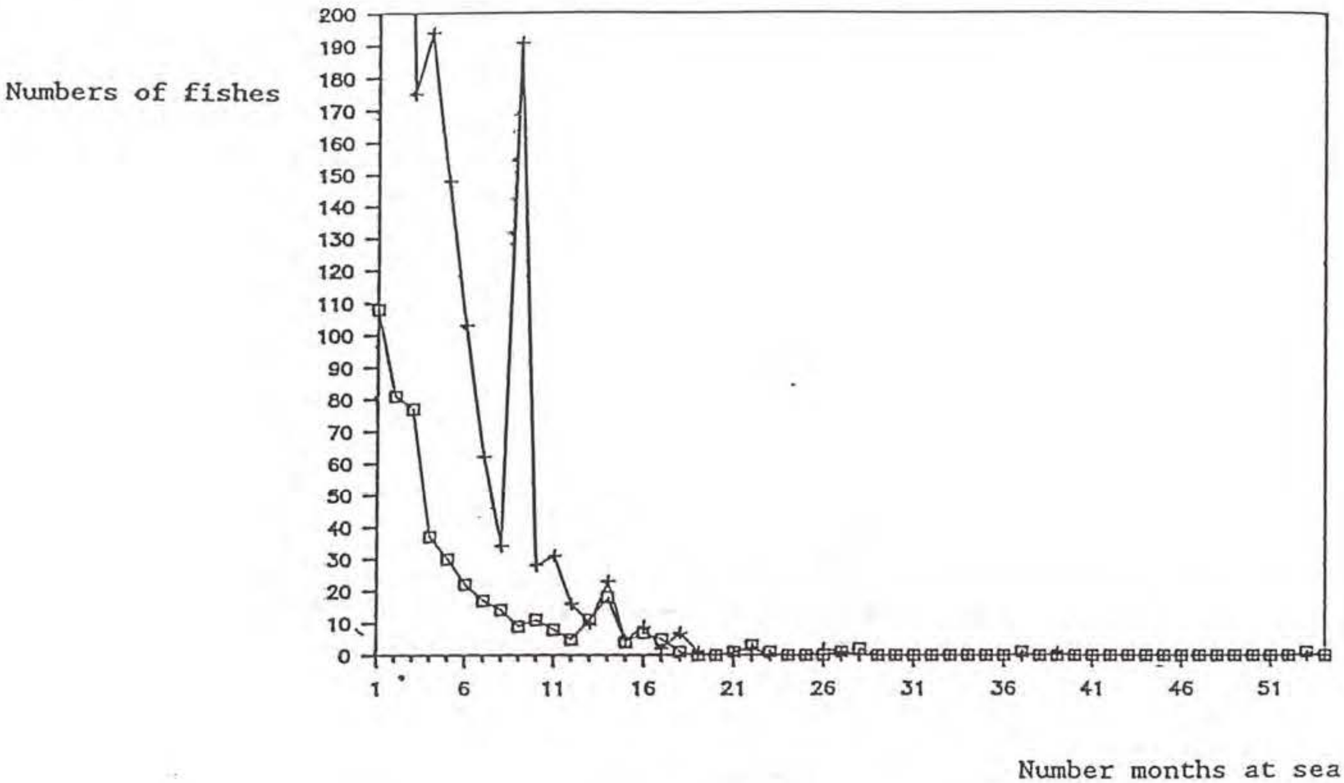
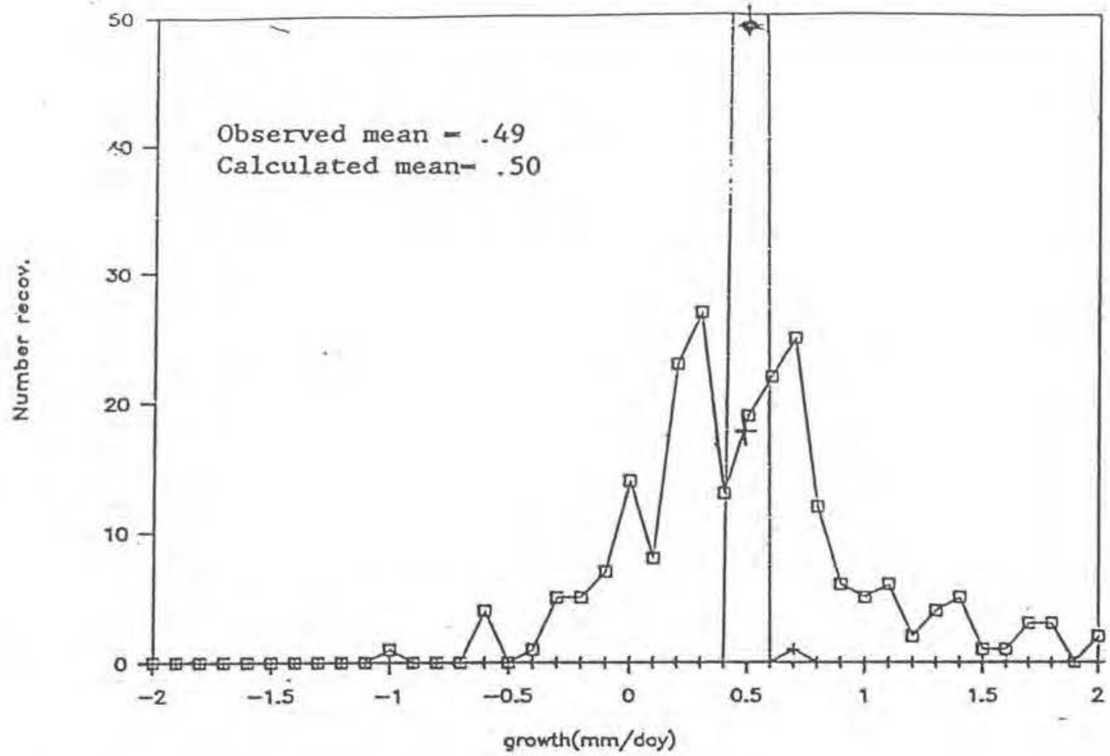
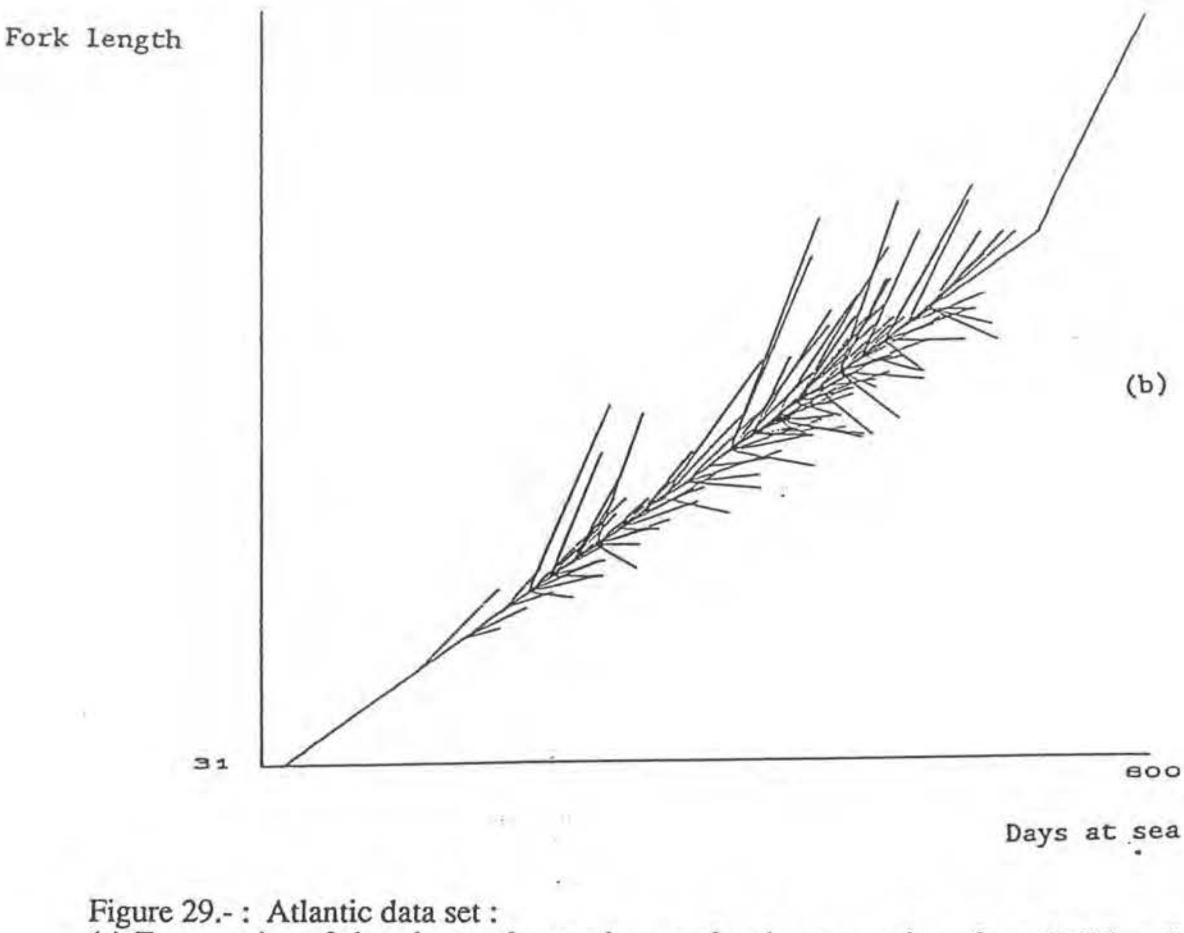


Figure 28.- : Duration of liberty of recovered tags in the Atlantic and Pacific data sets.



(a)

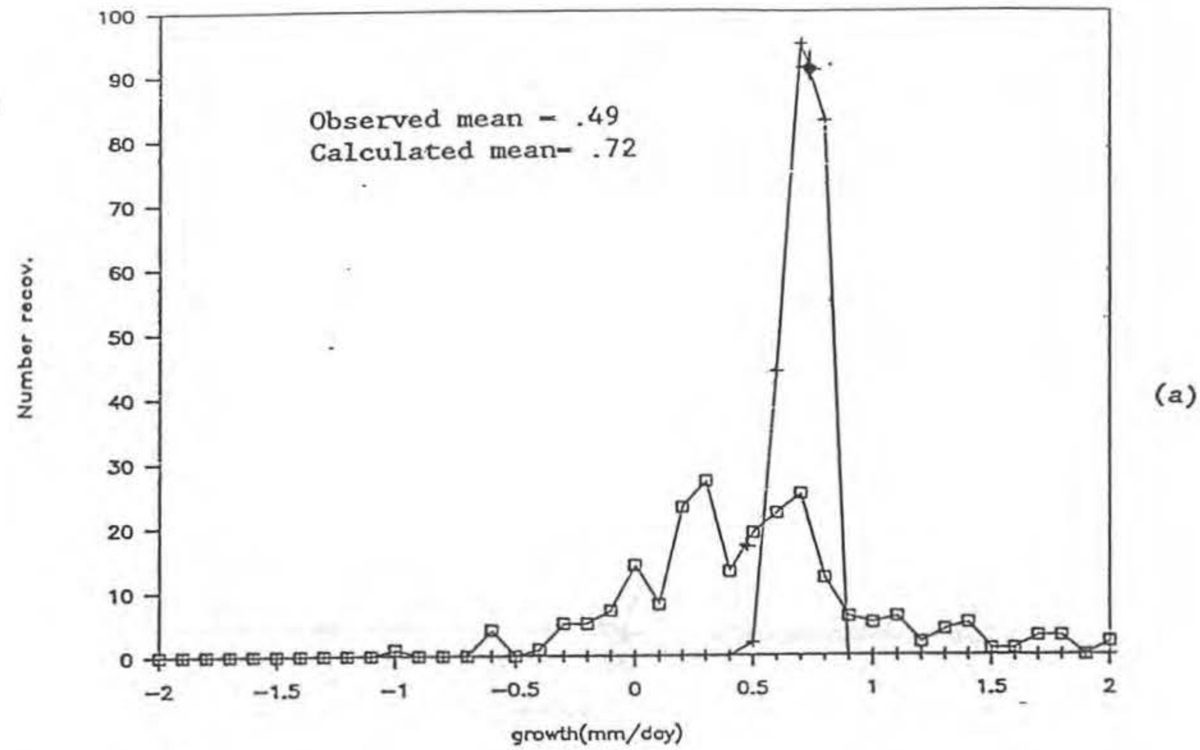


(b)

Figure 29.- : Atlantic data set :

(a) Frequencies of the observed growth rates for the recoveries of small fishes (less than 60 cm and 30 to 90 days at sea), compared to the expected growth rates calculated with the two stanza growth curve.

(b) Theoretical growth curve, versus observed recovery pattern.



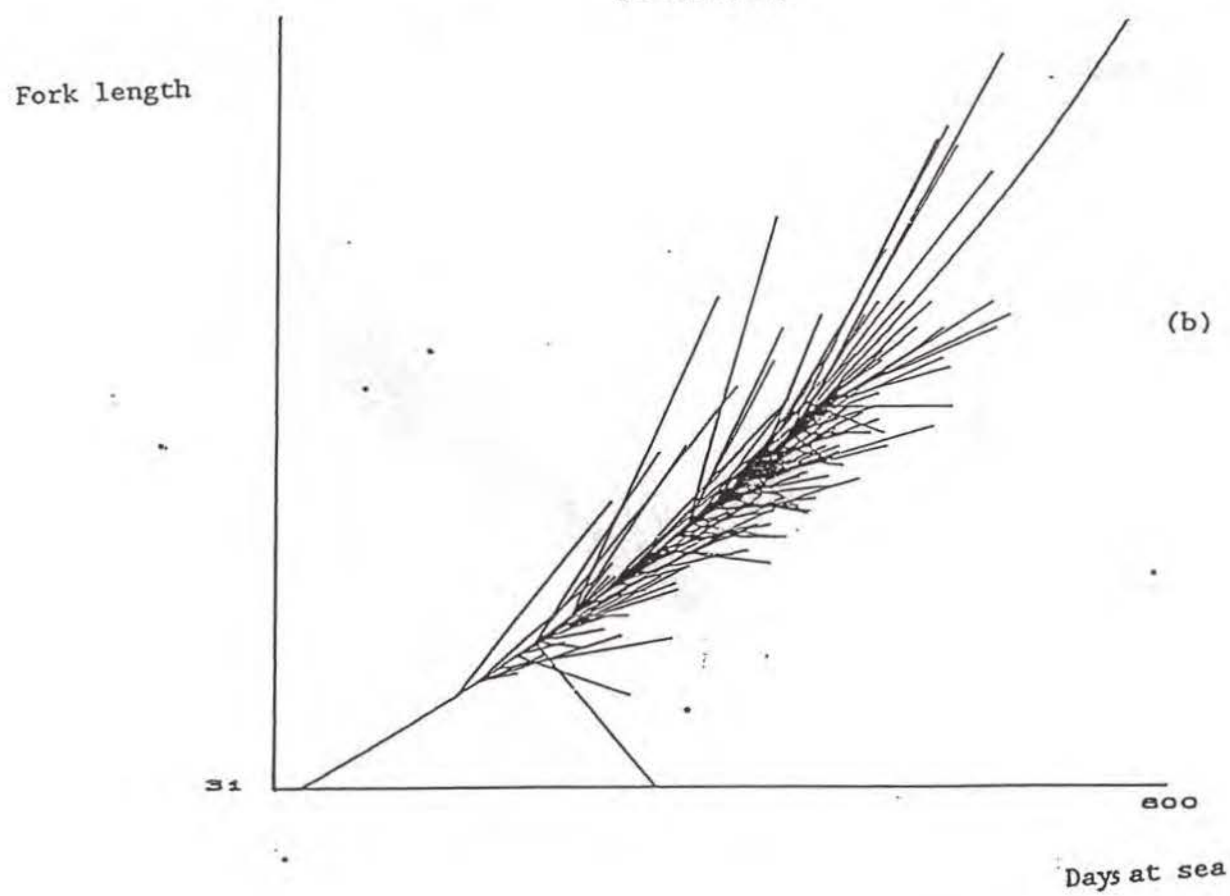
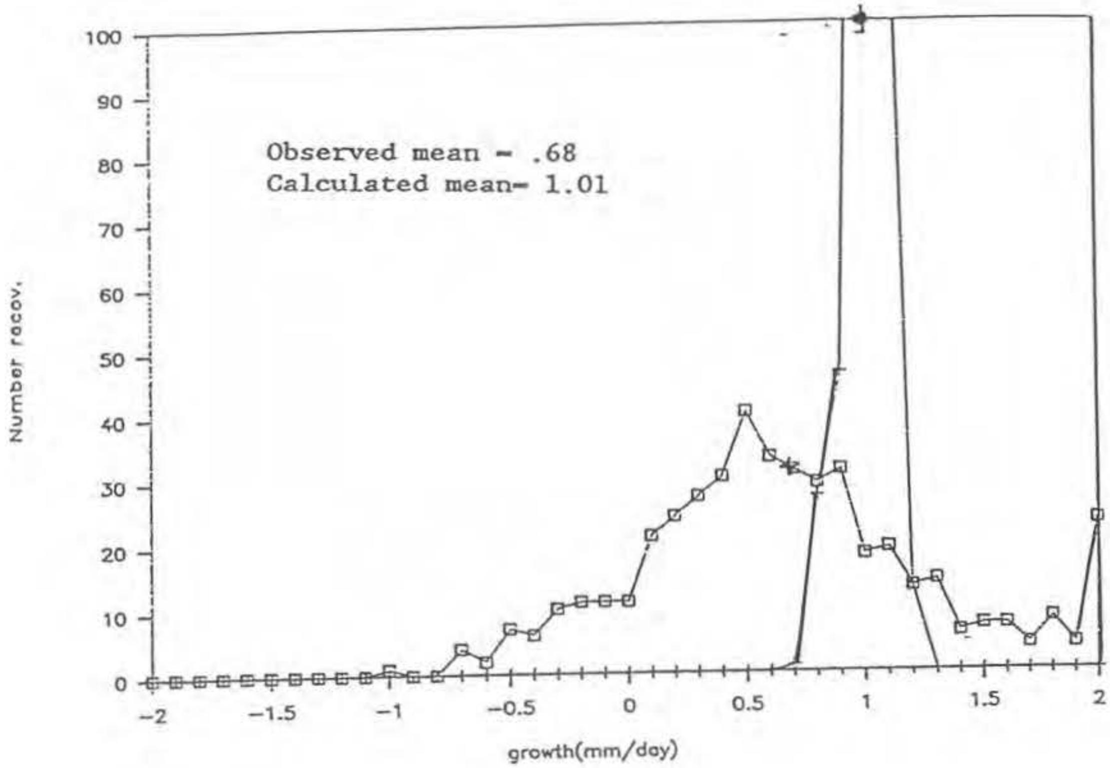


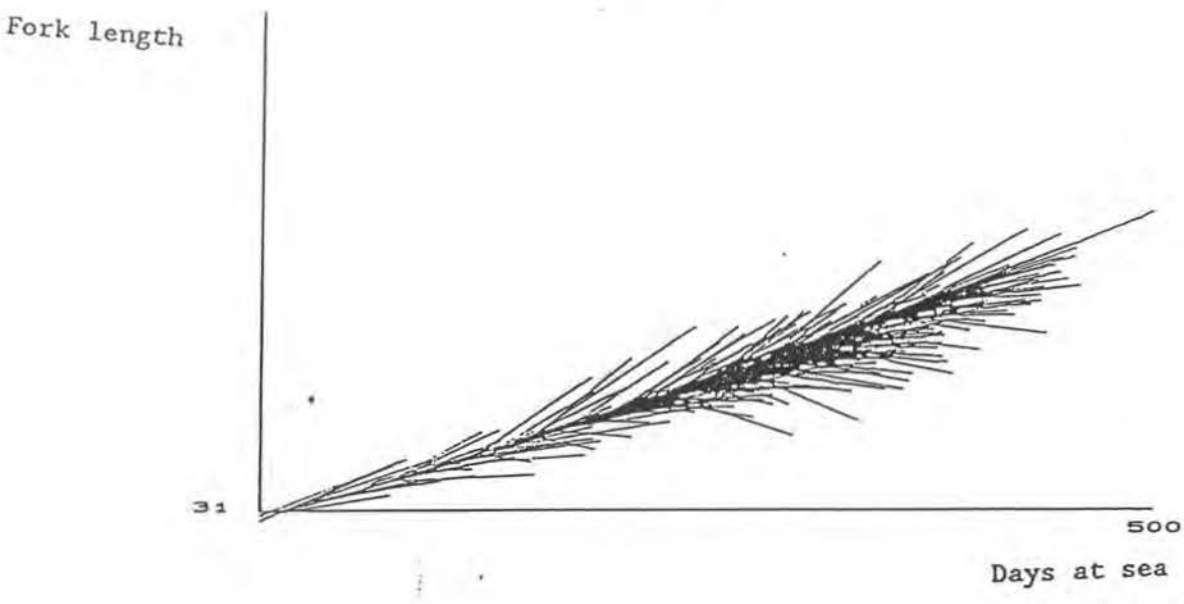
Figure 30.- : Atlantic data set :

(a) Frequencies of the observed growth rates for the recoveries of small fishes (less than 60 cm and 30 to 90 days at sea), compared to the expected growth rates calculated with the Atlantic Richards function of Bard.

(b) Theoretical growth curve, versus observed recovery pattern.



(a)

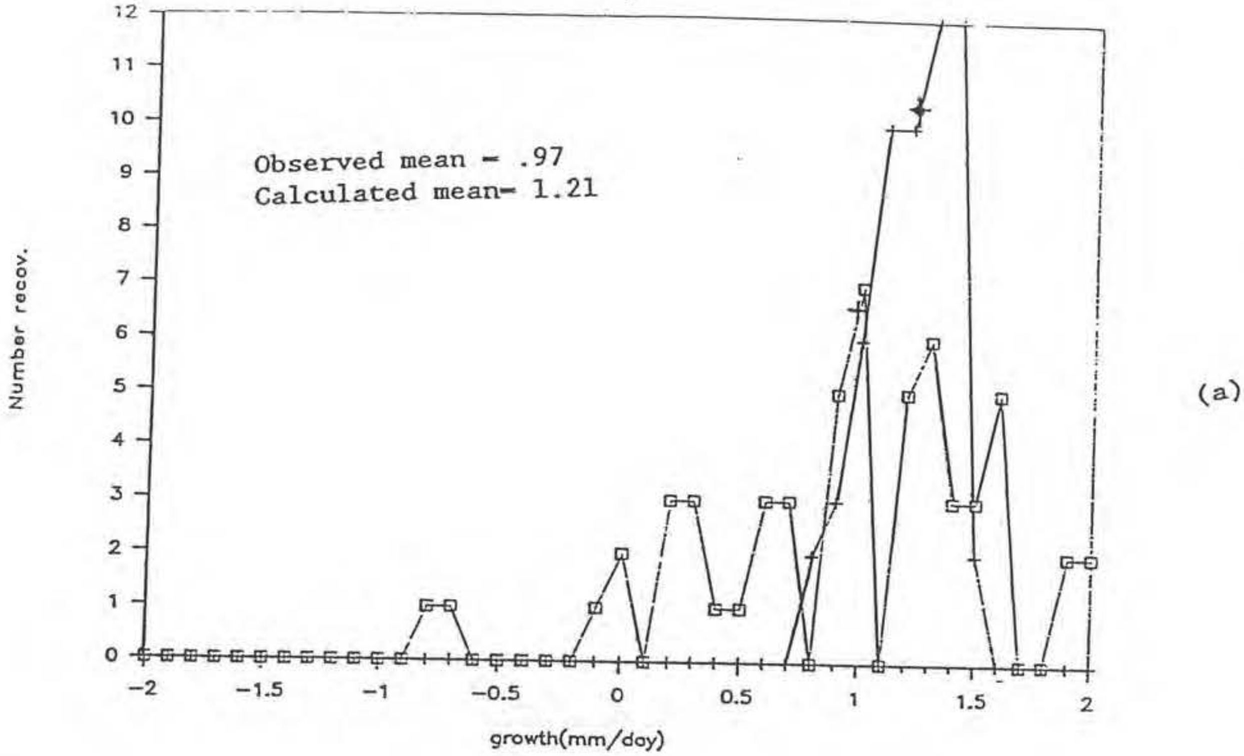


(b)

Figure 31.- : Pacific data set :

(a) Frequencies of observed growth rates for the recoveries of small fishes (less than 60 cm and 30 to 90 days at sea) compared to the expected growth rates calculated with the Richards growth function of Wild.

(b) Theoretical growth curve, versus observed recovery pattern.



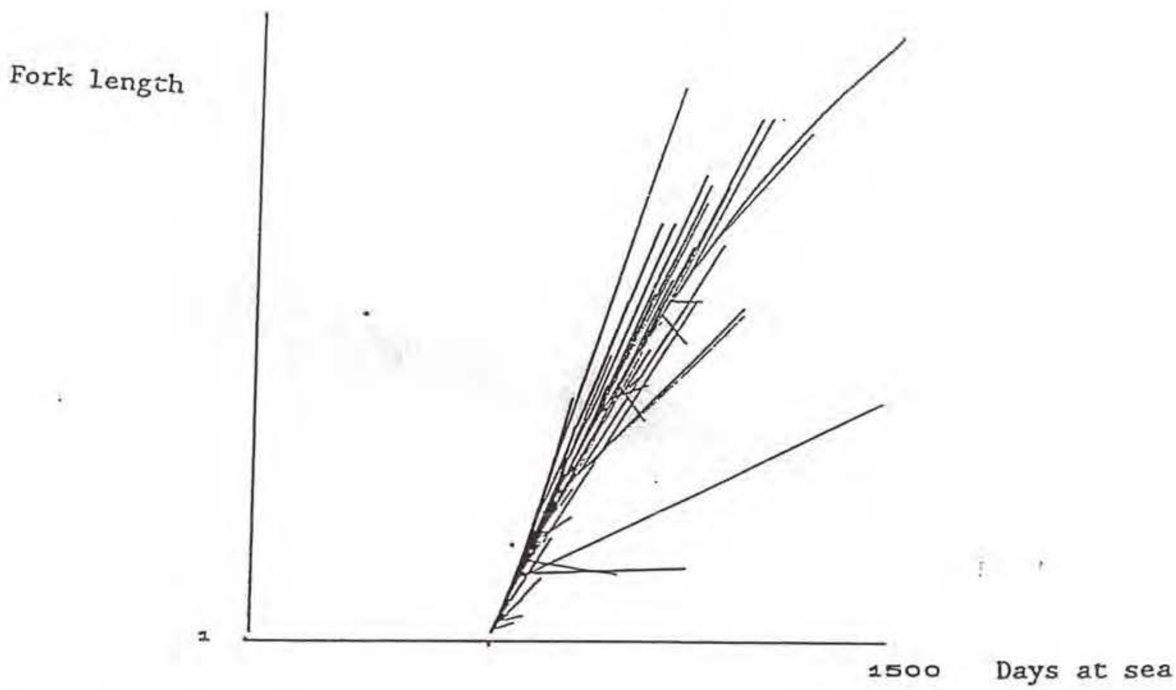
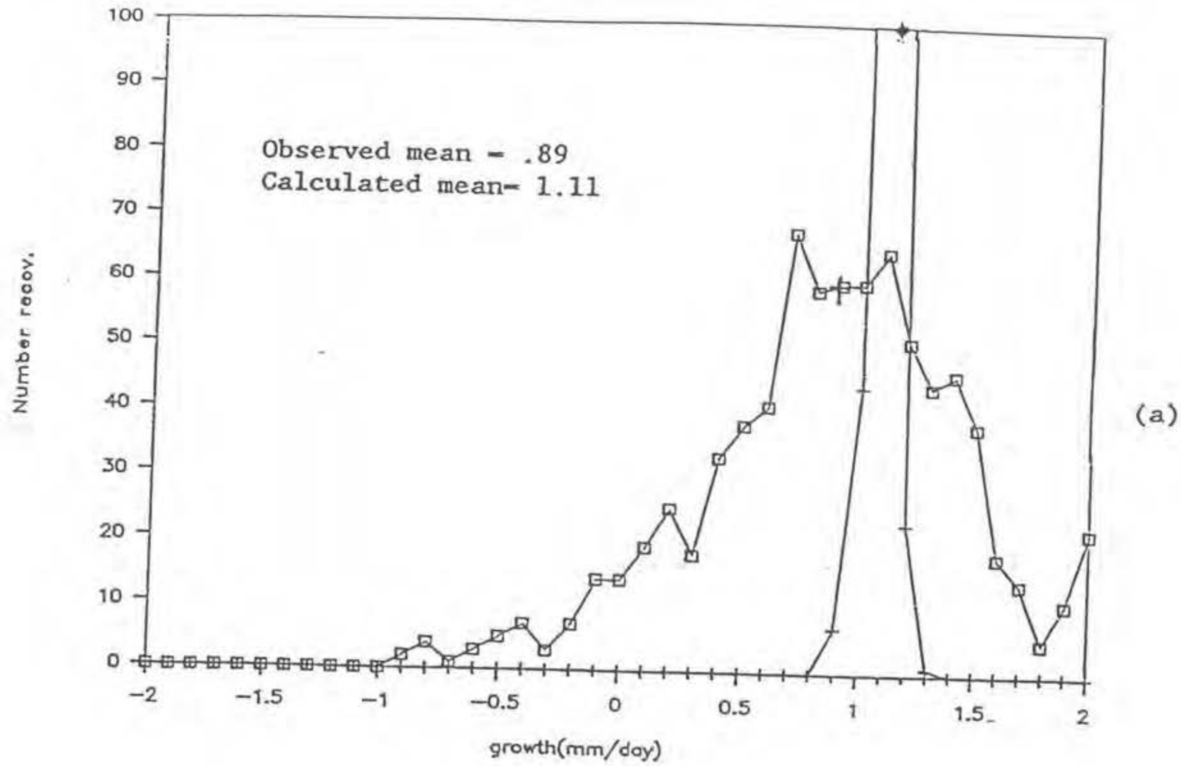


Figure 32.- : Atlantic data set :

(a) Frequencies of the observed growth rates for the recoveries of large fishes (more than 60 cm at tagging), compared to the expected growth rates calculated with the Atlantic two stanza growth curve.

(b) Theoretical growth curve, versus observed recovery pattern.



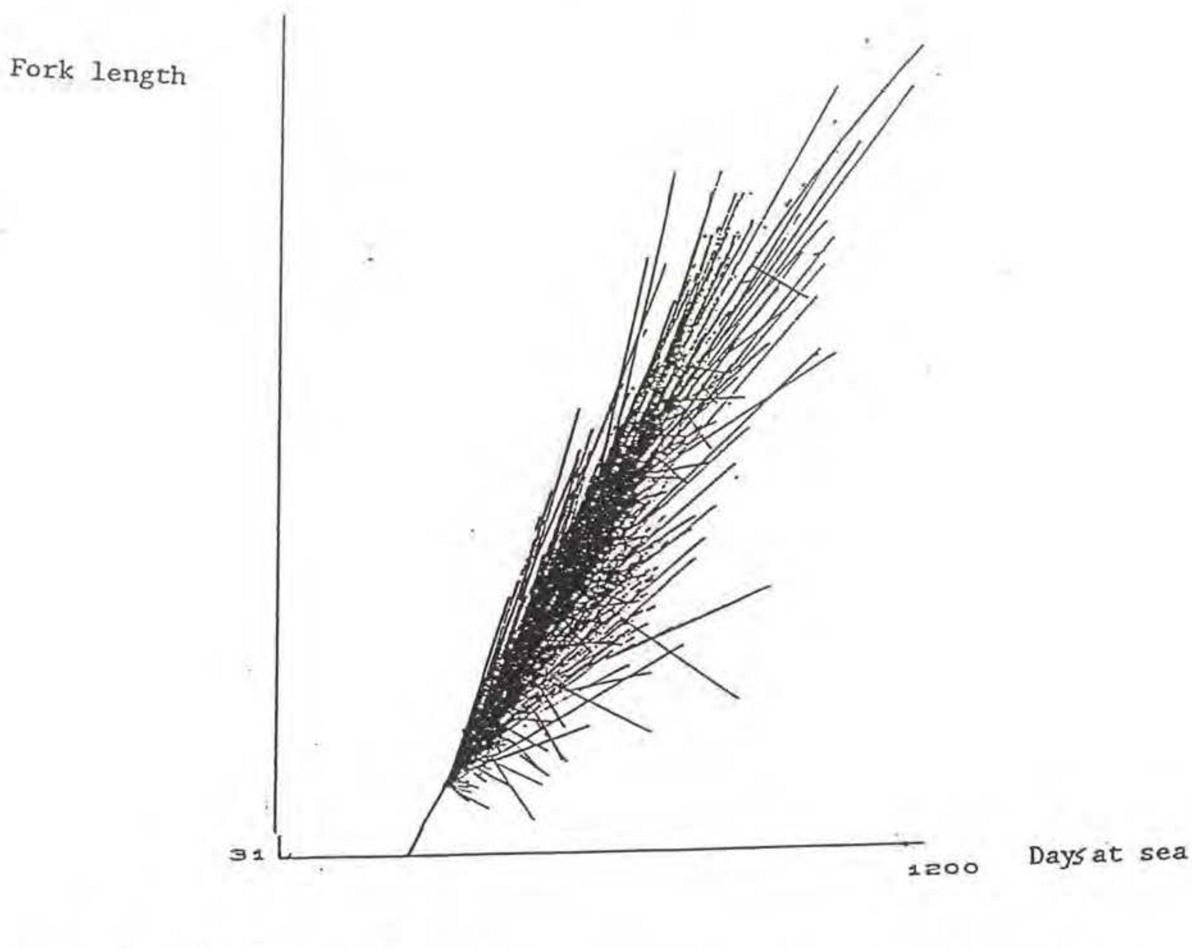


Figure 33.- :Pacific data set :

(a) observed growth rates for the recoveries of large fishes (more than 60 cm at tagging), compared to the expected growth rates calculated with the Pacific Richards function of Wild.

(b) Theoretical growth curve, versus observed recovery pattern.

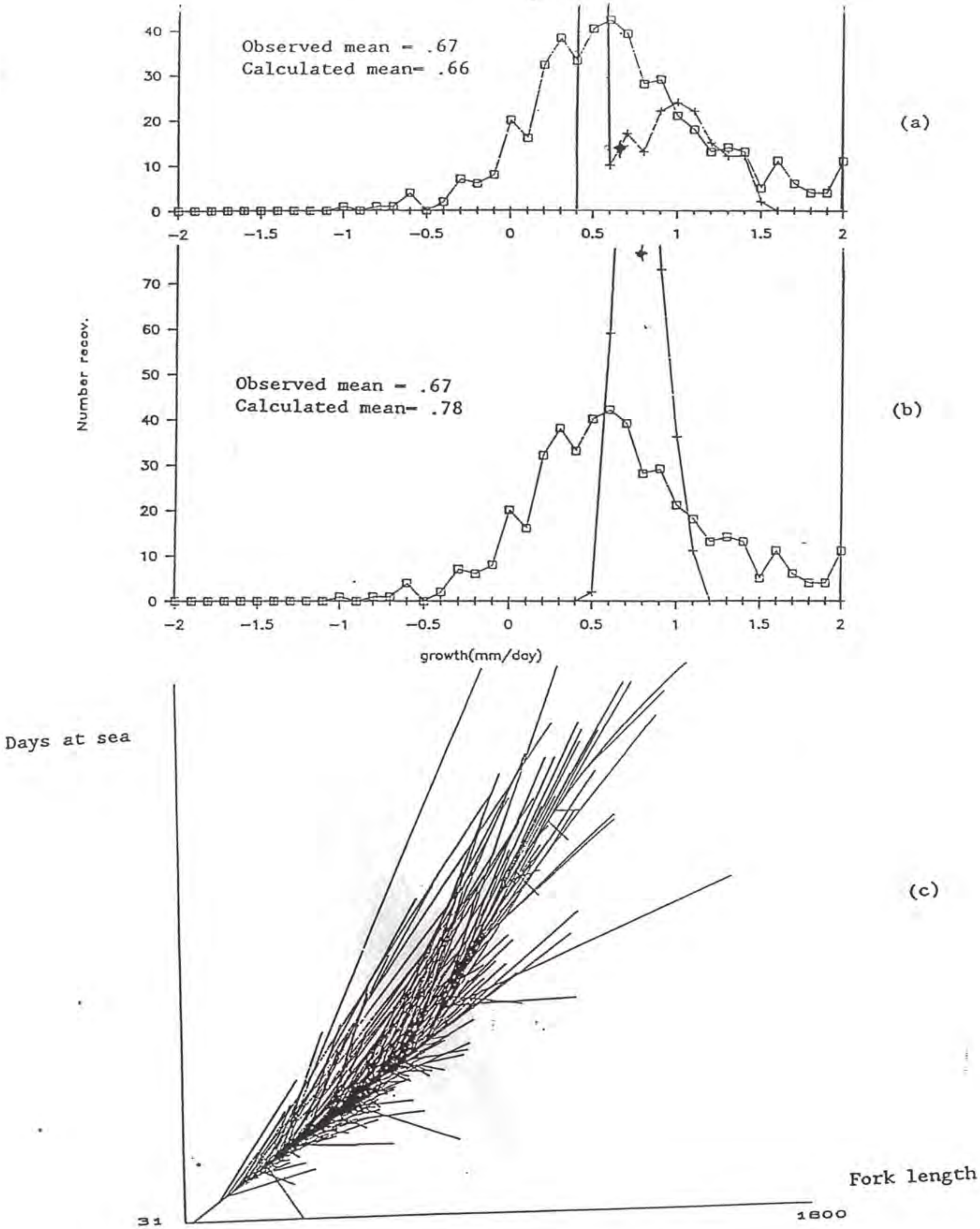


Figure 34.- : Atlantic data set, all recoveries :

(a) Frequencies of the observed growth rates of the recoveries, compared to the expected growth rates calculated with the Atlantic two stanza growth model.

(b) Idem with the Richards function of Bard 1989.

(c) Theoretical growth curve versus observed recovery pattern.

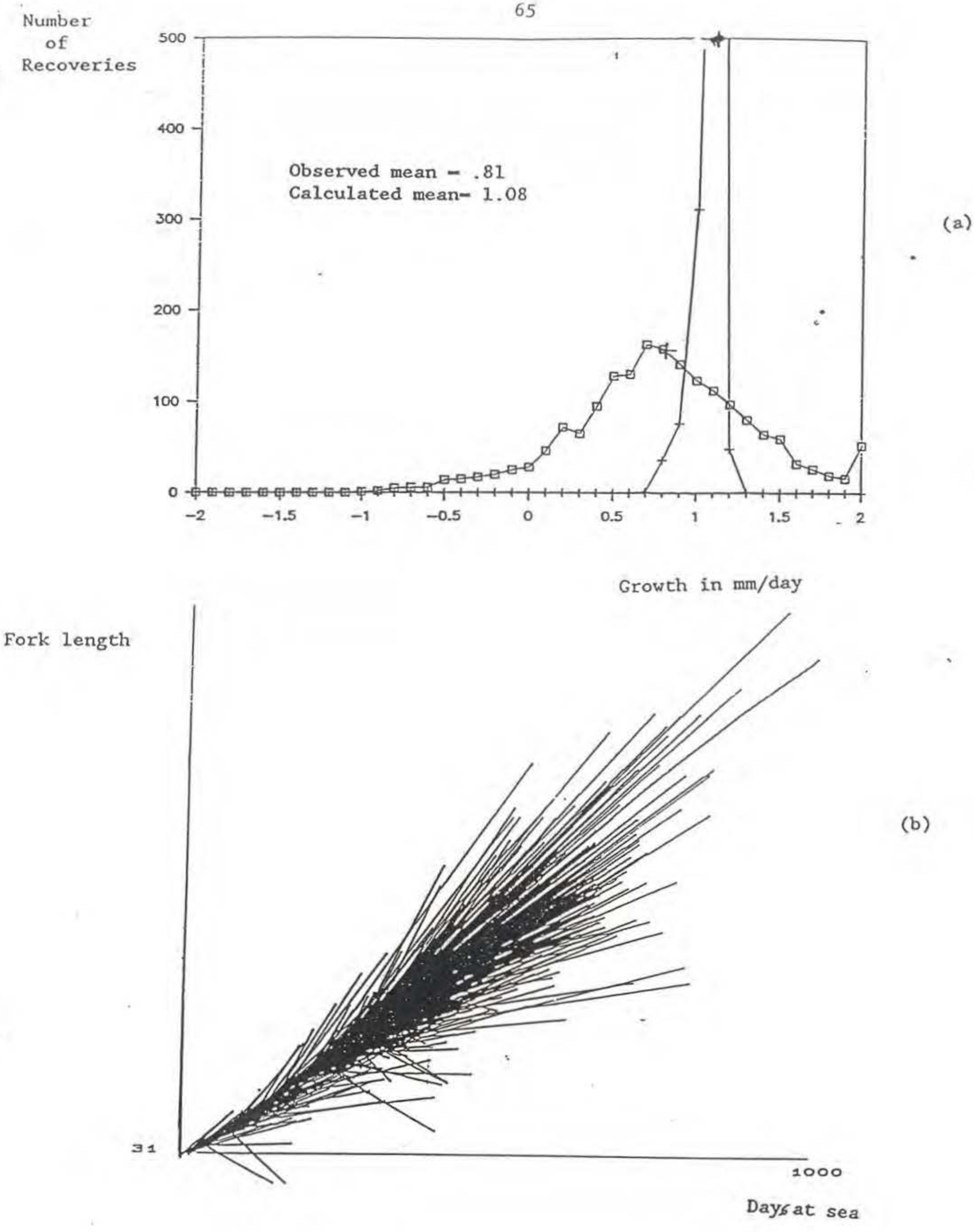
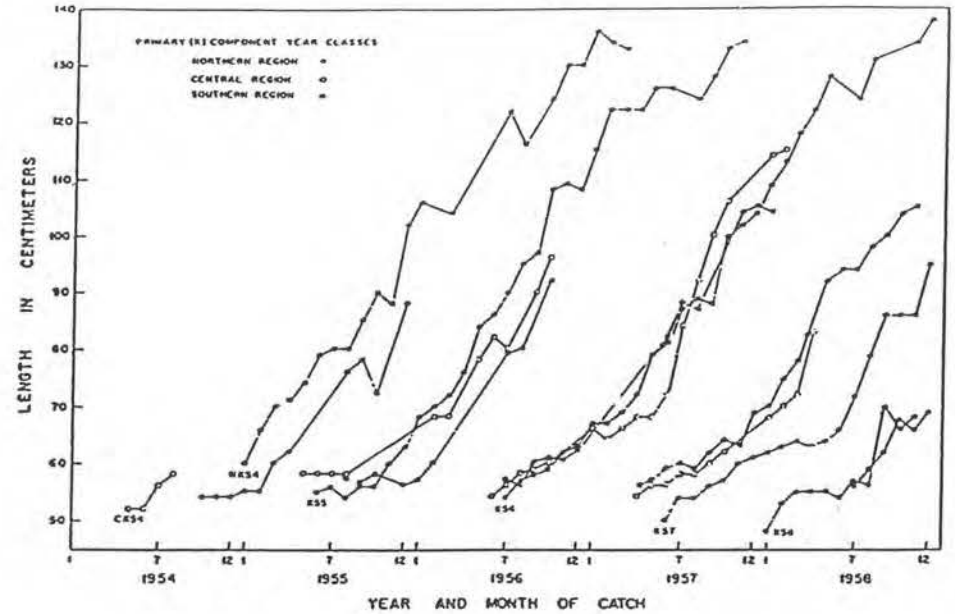


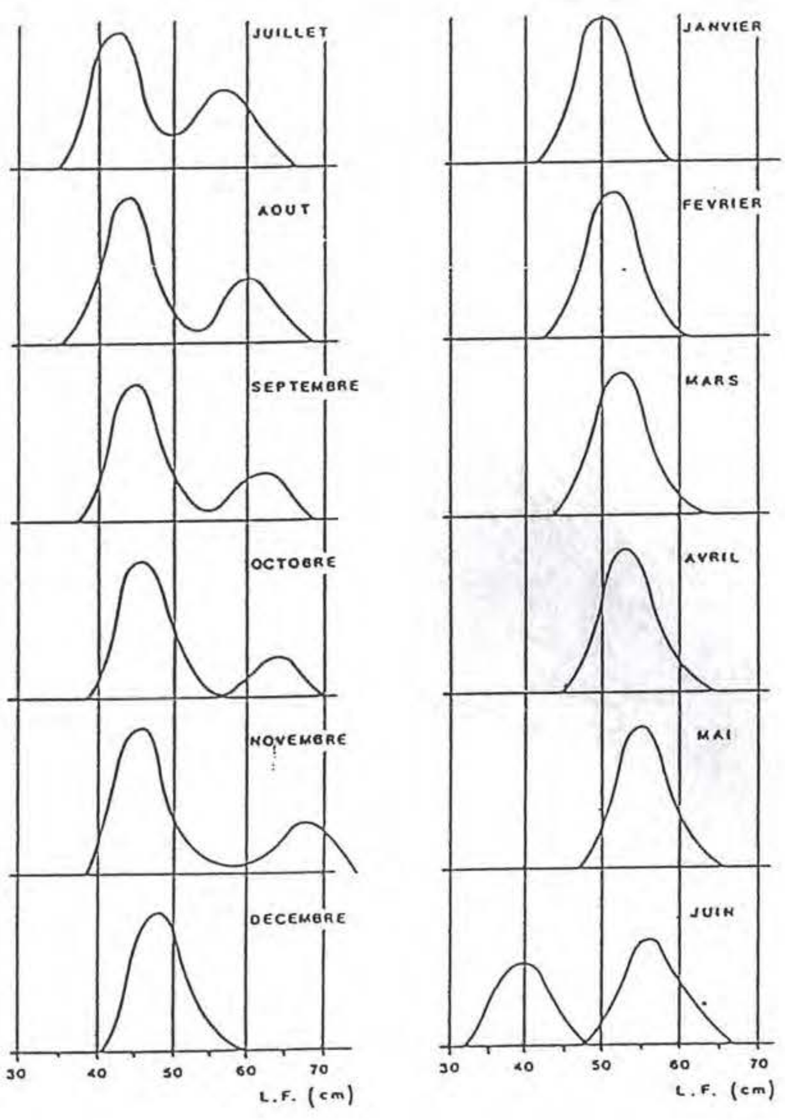
Figure 35.- : Pacific data set, all recoveries :

(a) Observed growth rates and expected growth rates calculated with the Pacific Richards function of Wild 1986.

(b) Theoretical Richards growth curve, versus observed recovery pattern.



(a) PACIFIC



(b) ATLANTIC

Figure 36.- : Exemple ofslow apparent modal progressions observed in the eastern Pacific by HENNEMUTH 1961 (36 a)and in the Atlantic by FONTENEAU 1981 (36 b).

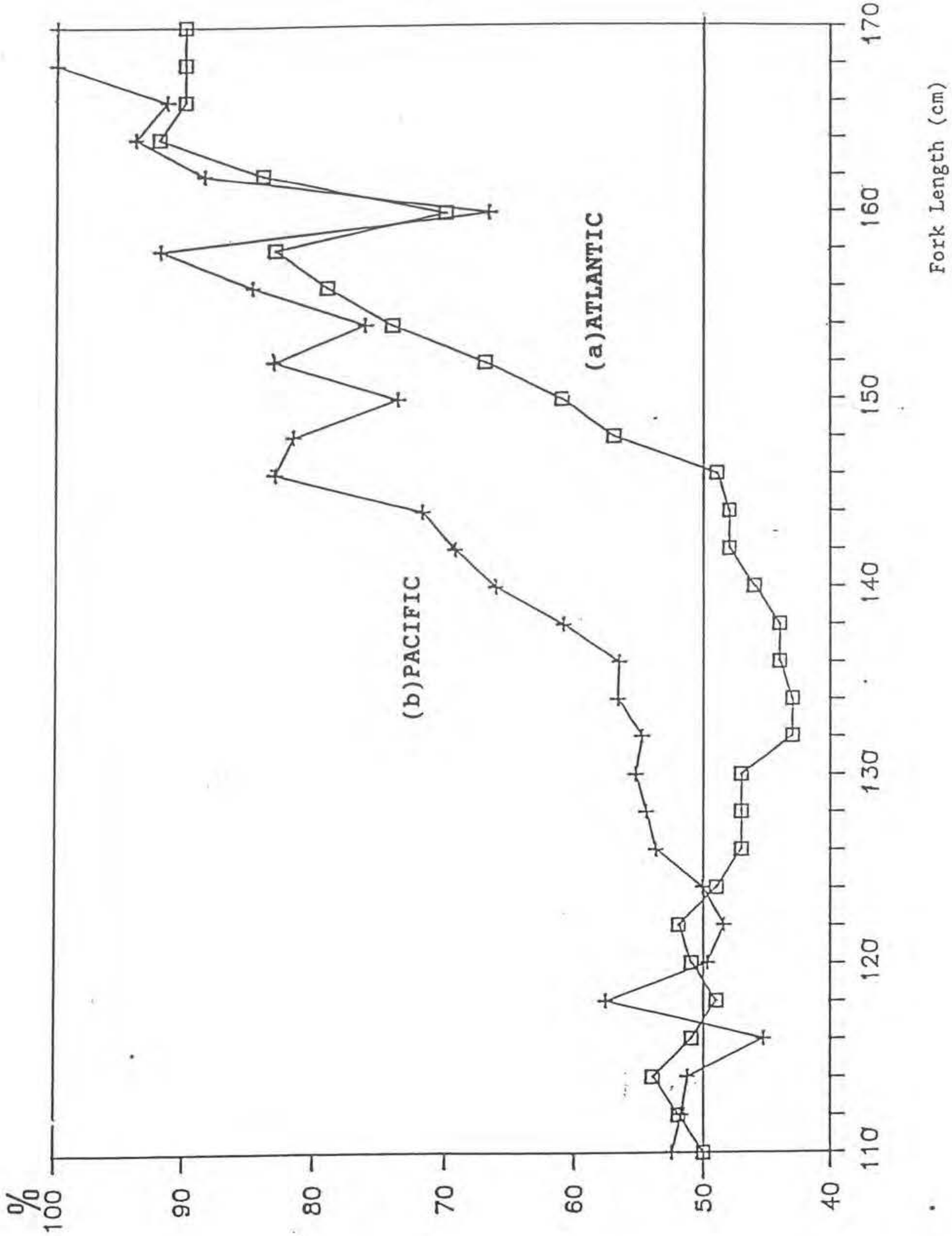


Figure 37.- : Average percentage of males in the sampled catches of yellowfin tunas in the eastern Atlantic and Pacific (surface fisheries).

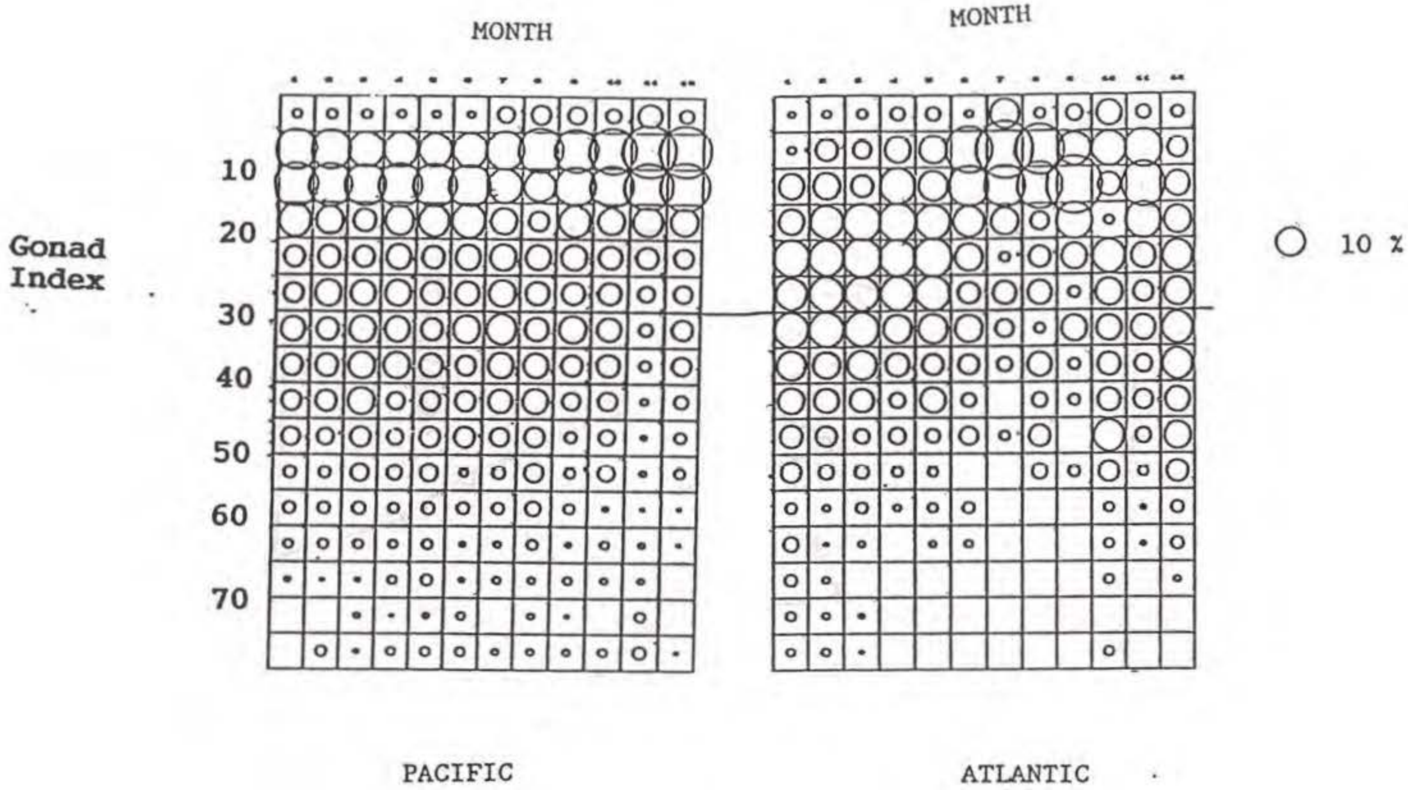
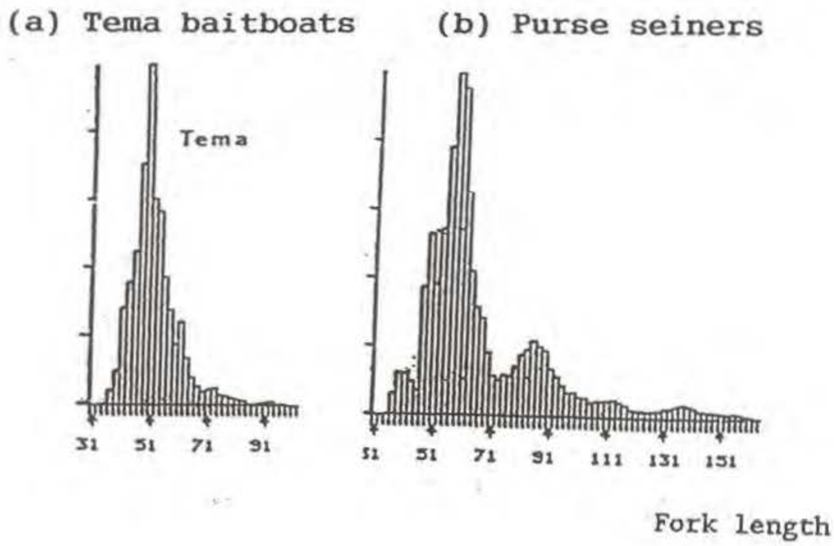
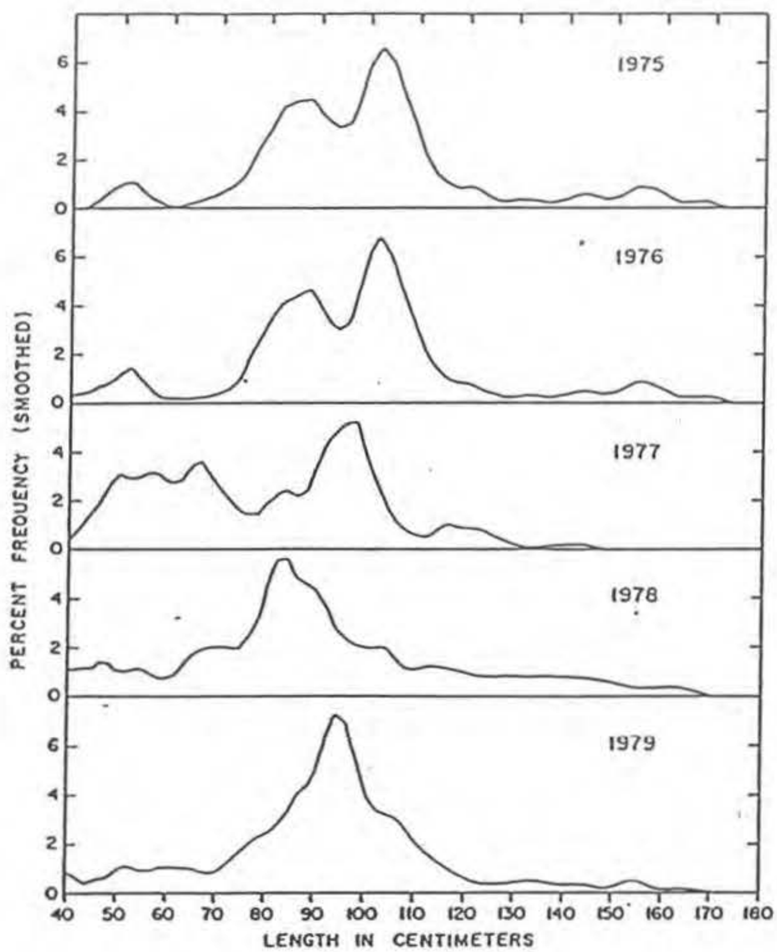


Figure 38.- : Monthly frequency of females gonad indices, in percentages, sampled on purse seiners catches in the Eastern Atlantic and Pacific ; a gonad index greater than 30 is assumed to correspond to a spawning activity.



ATLANTIC



PACIFIC

Figure 39.- : Exemples of bigeye size distributions taken in the Atlantic (Tema baitboat (a) and purse seiners (b), average 1972-1982) and in the eastern Pacific (by purse seiners).

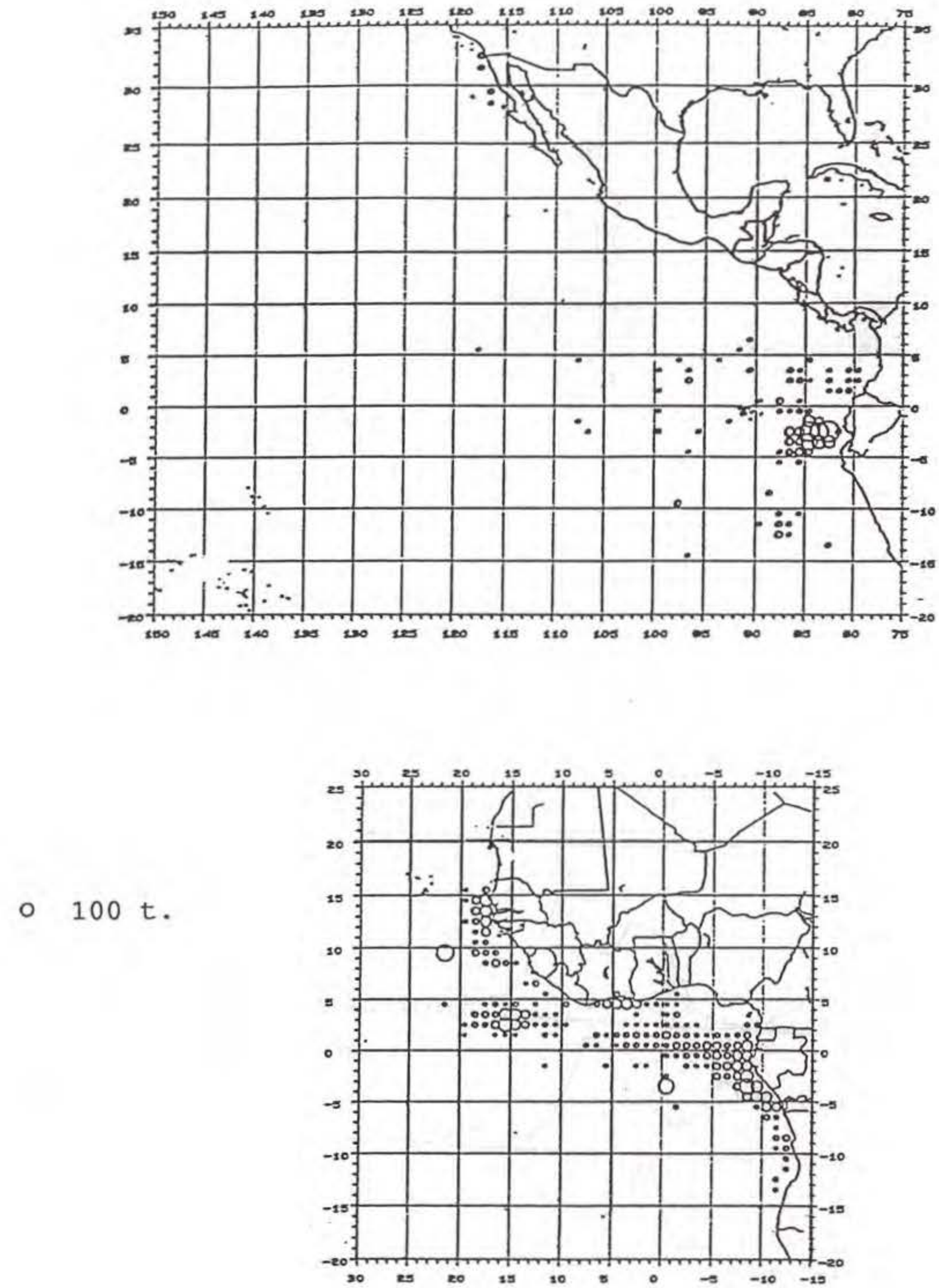


Figure 40.- : Fishing zone of bigeye tunas by purse seiners in the Eastern Atlantic and Eastern Pacific (average period 1980-1988).

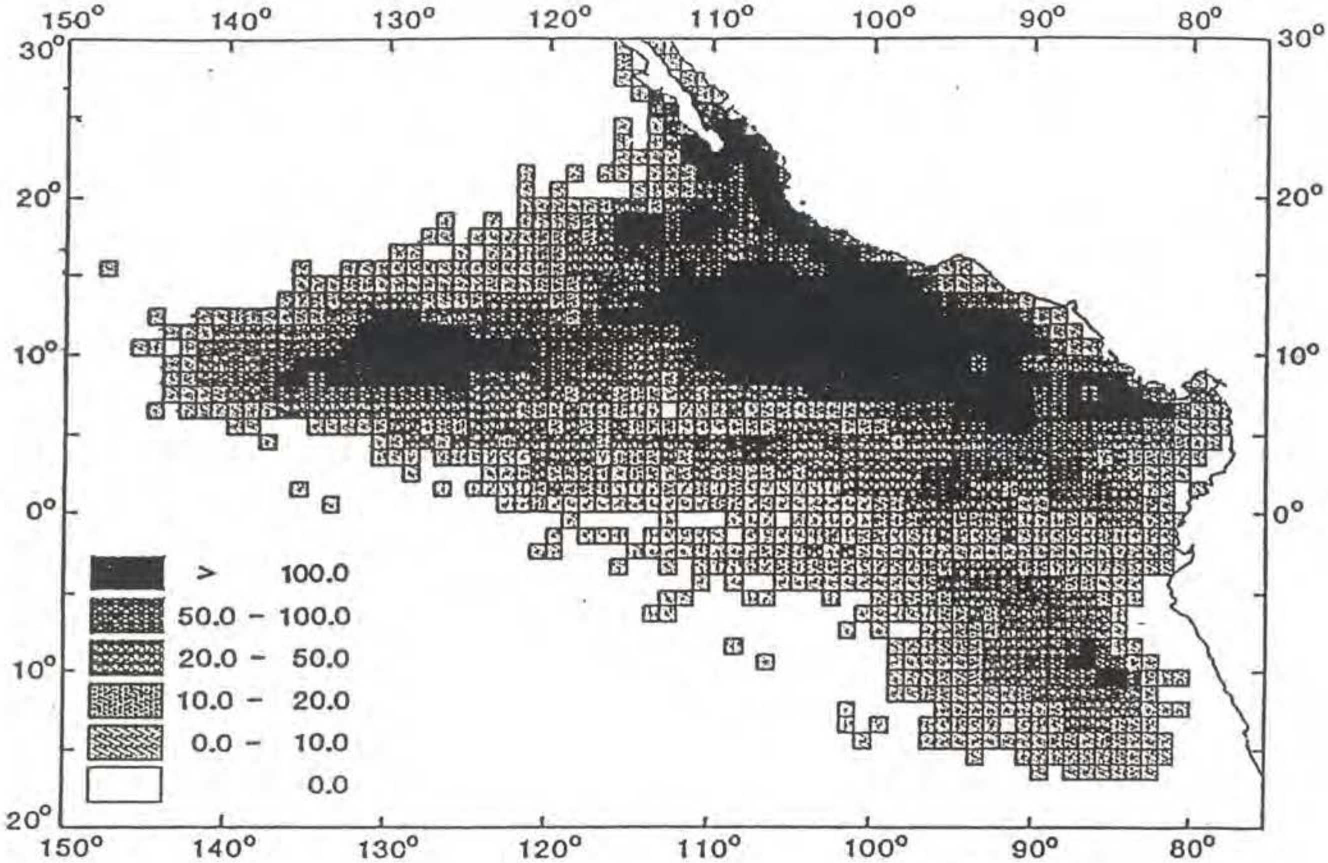


Figure 41.- : Geographical distribution of the porpoise sets in the Eastern Pacific (From IATTC Annual Report 1988).