SPC/Fisheries 18/WP.1
5 June 1986

ORIGINAL : ENGLISH

SOUTH PACIFIC COMMISSION

EIGHTEENTH REGIONAL TECHNICAL MEETING ON FISHERIES
(Noumea, New Caledonia, 4-8 August 1986)

TUNA STOCKS OF THE SOUTHWEST PACIFIC*

by
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South Pacific Commission
Noumea, New Caledonia

Abstract

The high seas fisheries for tuna in the southwest Pacific have rapidly become one of the world's major fisheries. This paper reviews in a general way the distribution of, and recent trends in fisheries for the principal tuna species: skipjack, yellowfin, bigeye and albacore. The general conclusion is that skipjack stocks are lightly exploited and could support increased exploitation. Yellowfin stocks are relatively more heavily exploited and increased exploitation should be conducted with caution. Bigeye stocks also appear to be in good condition. Longline fisheries for albacore appear to be fully exploited but there is possibility for expansion in more southerly surface fisheries.

The migratory behaviour of some of these species is discussed in relationship to the general concept of international tuna management and research organisations. It is concluded that the extent to which different species are "highly migratory" must be evaluated in relationship to the known movements of that species and magnitude of the relevant economic zones.

* Paper presented at INFOFISH Tuna Trade Conference held in Bangkok, Thailand, 25-27 February 1986.

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INTRODUCTION

The warm equatorial waters of the western and central Pacific Ocean nourish large populations of tropical tuna. These populations are the base of an artisanal fishery by Pacific Islanders which for centuries has provided not only food but also central cultural elements for many oceanic peoples. These populations have become the target of a steadily expanding and very valuable commercial fishery by industrial countries, the distant-water fishing nations (DWFNs). In addition, some DWFNs have found it advantageous to base fisheries for non tropical tuna species, such as albacore, in the same region. The landed value of the tuna caught in all of these fisheries approached US$500 million in 1984 according to estimates by the Forum Fisheries Agency (FFA 1985).

The countries and territories of the region, that is the 22 island members of the South Pacific Commission (SPC), are seeking ways to increase economic benefits from resources harvested in their waters. Fisheries officials from these countries have recognized the need for information, which is both reliable and accessible, on the stocks which support these valuable fisheries. In 1977, the SPC began a major survey of skipjack resources of the SPC region through its Skipjack Survey and Assessment Programme. The area surveyed included the entire SPC region from Pitcairn Island in the east to Palau in the west and from New Zealand in the south to Northern Marianas in the north. The responsibilities of the Skipjack Programme were expanded at the conclusion of the survey in 1980 to include billfish and all species of tuna, and it was renamed the Tuna and Billfish Assessment Programme. It was further given a broad mandate by the countries of the SPC to conduct biological research on tuna stocks. The highest priority of the Tuna Programme is compilation of a regional data base of statistics from the oceanic fisheries occurring in SPC countries and analysis of the effects of these fisheries on stocks.

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The purpose of this paper is to summarize information on the fisheries for four of the more important tuna stocks of the western central Pacific. In the course of this review, problem areas will be emphasized, such as lack of access to information and topics requiring additional research. No attempts will be made to provide formal, quantitative stock assessments for the fisheries involved. Such assessments invoke a potentially misleading sense of confidence not supported by the data. Rather, a broad qualitative review will be presented with particular attention to current conditions and prospects for further development. Such an approach may also be misleading, but it has the advantage of clarity.

The work summarized here is the result of a team effort by all members of the Tuna and Billfish Assessment Programme. In particular, the contributions of Tom Polacheck, Ray Hilborn, and Dave Fournier deserve special recognition.

SOURCES OF INFORMATION

The SPC uses several sources of data. One source is the published summaries prepared by some DWFNs. These documents provide valuable historical perspective on the development of the fisheries, but are not generally suitable for detailed analysis. They are usually published too long after the fact to be useful for assessment of current situations, and data contained are often aggregated over too broad a geographic area and over more than one size of fishing vessel. Furthermore, since the advent of the United Nations Convention on the Law of the Sea, some countries appear to consider fisheries information to be a negotiable commodity and have ceased publication and general distribution of fisheries summaries.

The most useful available source of information for scientific purposes is the logsheets of daily fishing activities by vessels licensed to fish in the EEZs (Exclusive Economic Zone) of SPC members. Logsheets are provided to the SPC as a condition of access to the EEZs. They contain very detailed information and often reach the SPC within a few months of the fishing activity reported. The earliest logsheets available to the SPC date from 1978, and coverage improves with time up to the present. Unfortunately, only fishing activity within the EEZs of the region is reported and significant gaps occur for the high seas areas. There are also important gaps during periods for which there were no fisheries agreements. Information on daily fishing activities is also obtained through bilateral agreements between the SPC and fishing associations. All logsheet information, whether obtained through access agreements or by other means, is treated as confidential and it is the expressed policy of the SPC not to release such information to a third party without the written authority of the organization which supplied it.

Reports from on-board fisheries observers are extremely useful in evaluating the information reported on logsheets. Observers are also able to gather information not normally included on the logsheet forms such as sizes of fish caught and species composition of bycatch. Information from other agencies in the form of published reports and analyses can often be brought to bear on the problems addressed by the SPC.

MAJOR TUNA SPECIES

Current knowledge of the stocks of the more important tuna species are presented below. These summaries are based primarily on information supplied to the SPC in the form of daily catch records, although some published summaries have also been included. In most cases, data have been aggregated over geographic area and nationality of fishing vessel to emphasize conditions of stocks in general rather than local conditions or the performance of a particular fleet.

Skipjack

Skipjack (Katsuwonus pelamis) are harvested commercially by two principal methods: pole-and-line (or live-bait boats) and purse-seine. Pole-and-line fishing for skipjack has gone through several episodes of expansion. The first of these occurred in the 1920s and 1930s when the Japanese distant-water fleet began fishing in the Mariana Islands and western Micronesia. These efforts were halted by the war, but resumed in the late 1940s and 1950s when newly developed techniques for holding and transporting bait enabled vessels to fish in more remote locations. In the 1970s, high prices for tuna stimulated efforts towards development, often through joint ventures, of locally based pole-and-line fleets in several island countries. Some of these fisheries have prospered while others have suffered. The major biological factors determining the success of pole-and-line fisheries have been availability of bait and seasonal variability in skipjack abundance. The historical development and future prospects of skipjack fisheries in countries of the SPC region are documented in a series of 20 different reports on individual countries which can be obtained from SPC headquarters.

The distribution of total pole-and-line skipjack catch for the years 1982-85 is shown in Figure 1. This figure is based primarily on data from distant-water fleets. Some data from locally based fisheries are included but some important local fisheries are missing. The continuing importance of the Micronesian fishery is particularly clear.

Purse-seine fishing for skipjack began in the late 1970s and expanded to a total annual harvest of over 300,000 tonnes in 1984. This harvest is almost entirely taken in large scale fishing operations by distant-water fleets, but there are also some successful intermediate scale, locally based, purse-seine operations.

The distribution of total purse-seine skipjack catch as reported to the SPC for the years 1982-85 is shown in Figure 2. This figure is also based primarily on data from distant-water fleets, but includes data from some locally based fisheries as well. The purse-seine fishery is less dispersed than the pole-and-line fishery, and a very large portion of the catch is taken in a relatively. small area of western Micronesia and northern Papua New Guinea.

Days searched plus days fished is a convenient measure of fishing effort for both pole-and-line and purse-seine fleets. Recent trends in this measure of fishing effort and in skipjack catch in the area between 1000°N and 1500°S latitude and 14000°E and 18000°W longitude can be seen in Figures 3 and 4. The rapid growth of purse-seine fishing relative to pole-and-line fishing is clearly evident. In 1982, fishing effort and catch by purse-seiners surpassed effort and catch by pole-and-liners.

Changes in fishing success for skipjack are shown in Figure 5. Catch per unit of fishing effort (CPUE) for the pole-and-line fleet has remained relatively constant during recent years in spite of the intense development of the purse-seine fishery. Catch curves, relating catch to fishing effort, for skipjack fisheries are shown in Figure 6. For both purse-seine and pole-and-line fishing, catch is roughly proportional to effort suggesting that skipjack stocks have been relatively lightly affected by fishing.

One of the major conclusions of the SPC skipjack survey was that fisheries at the time (1980) were harvesting only a small fraction of the potential yield of the region. Recent increases in skipjack harvests have not increased this fraction significantly, and prospects for continued expansion of skipjack harvests would therefore be rated as good in general.

The South Pacific Commission tagged and released over 150,000 skipjack between 1977 and 1980. Over 6,000 tags were recaptured and returned and provide an important data base for the analysis of skipjack migration. Figure 7 shows the resulting net movement pattern. There is no doubt that skipjack make long migrations. Closer examination, however, reveals an important qualification. In the interest of maintaining the clarity of the figure, only a single arrow has been drawn in each direction between any pair of ten degree geographic squares. Thus, the shorter arrows may represent many tags moving from point of release to point of recapture.

The proportion of fish moving different distances over different periods of time is presented in Figure 8. From this figure, it is clear that most of the tags were recovered within a few hundred miles of the point of release. The distance covered obviously depends on time, but the high mortality rate (about 18% per month) of skipjack reduces the number of fish which actually undertake long migrations.

Since most of the skipjack were recovered within one or two hundred miles of the point of release, the small scale movements should be examined in some detail. Figure 9 presents the mean squared distance travelled for tagged skipjack recaptured within 200 miles of the point of release. There is a roughly linear relation between mean squared distance travelled and time suggesting diffusive behaviour in contrast to a more directed migration.

Considerable caution must be exercised in interpreting results from a tagging programme. The conclusions depend completely on tags returned. If there is no fishery in a particular area to recapture the tags, or if the recaptured tags are not returned, then the conclusion will be that fish do not migrate to that area. This problem can be corrected to a certain extent by considering the distribution of fishing effort in the interpretation of the tag returns. Unfortunately, such data are too often not available or not accessible, and the figures shown here have not been corrected for fishing effort.

Yellowfin tuna

Yellowfin tuna (Thunnus albacares) are harvested commercially by both longline and purse-seine fishing. These two methods exploit different aspects of the fish's behaviour and their catches are sold to different markets. Of the two, longline fishing has the longest history in the western Pacific, and reliable statistics are readily available dating back prior to 1960.

The distribution of total longline yellowfin catch for the years 1982-85 is shown in Figure 10. This figure is based primarily on data reported to the SPC by distant-water fleets since there are very few locally controlled longline fleets. Several important features are evident. There are areas which, in the midst of plenty, would seem to have low catches. These are the so-called "high seas" areas for which the SPC does not have access to the necessary data. The importance of the equatorial oceanographic circulation system is evident. Otherwise, longline yellowfin harvests have a relatively uniform distribution in the tropical ocean.

The distribution of total purse-seine yellowfin catch for the years 1982-85 is shown in Figure 11. This figure is based on the same data as Figure 2, and as with skipjack, a very large portion of the catch is taken in the waters of western Micronesia and northern Papua New Guinea. The relatively concentrated purse-seine fishery is a marked contrast to the relatively broad distribution of the longline fishery.

Longline fishing effort is generally expressed as some multiple of number of hooks set. As above, days searched plus days fished is used to express purse-seine fishing effort. Recent trends in longline and purse-seine fishing effort and in yellowfin catch in the area between 1000°N and 1500°S latitude and 14000°E and 18000°W longitude can be seen in Figures 12 and 13. The rapid growth of purse-seine fishing is again clearly evident, and in 1982, yellowfin catch by purse-seiners surpassed catch by longliners.

Changes in fishing success for yellowfin are shown in Figure 14. Catch per unit of fishing effort for the longline fleet has declined by almost a factor of two since 1962, a decline which was well advanced prior to the inauguration of the purse-seine fishery. Catch curves, relating yellowfin catch to fishing effort on both a monthly and an annual basis, are shown in Figure 15. For the longline fishery (Figure 15), the monthly points show a wide scatter, and annual averages fall broadly between hooking rates of 0.5 and 3 fish per 100 hooks. There is a tendency for catches at high effort to be no higher than catches at moderate effort. The corresponding figure for purse-seine catch and effort (Figure 16) also exhibits month to month variability, but little tendency for catches to be low at high effort. The monthly points do show in some cases large changes in catch at constant effort. These changes are far too great to be indicative of changes in population abundance. A catch of 10,000 tonnes would not be expected to cause a decrease in the size of the population by a factor of two. More thorough analyses of the status of the yellowfin fishery in the western Pacific have been presented by SPC (1985) and Suzuki (1985).

There has been considerable discussion of the problem of potential interaction between purse-seine fisheries and longline fisheries for yellowfin. Purse-seiners catch younger surface schooling fish whereas longliners catch older deep-dwelling fish. Presumably, if the younger fish were not caught by purse-seiners, they would grow, and after about a year, become vulnerable to longline fishing. Predictions of interaction based on a simple model of a common shared stock indicate a high potential for extremely adverse impacts on the longline fishery. These impacts have not yet been detected, and there is considerable uncertainty about interaction between these two types of fishing. More complete catch data, further information on sizes of fish in the two fisheries, and analysis of stock movements are required to reach a more definitive conclusion.

The prospects for continued expansion of yellowfin harvests are difficult to state clearly. Average catch rates for the purse-seine fishery are relatively constant, but the disturbing month to month variation indicates that the population may be experiencing localized depletions as a consequence of the relatively dense concentrations of fishing effort. The longline catch rates continue to decline and are near the lowest ever recorded. Since yellowfin and skipjack catches by purse-seiners are highly correlated (Figure 17), it is nearly certain that fishing pressure on yellowfin will increase. The much higher market value of longline-caught fish would encourage the protection of this fishery, and intensification of purse-seine efforts should be tempered by this consideration. Therefore, it is absolutely essential that increased yellowfin harvests be carefully monitored in order to detect early signs of overfishing.

Data on the migration of yellowfin tuna in the western Pacific are not as extensive as for skipjack. Figure 18 shows migrations made by yellowfin tagged incidentally by the SPC during the skipjack survey. Some further comparisons with results from studies conducted by the IATTC and ORSTOM are instructive. Schaeffer et al. (1961) have analysed the results of yellowfin tagging in the eastern Pacific and concluded that there is little evidence for strongly directed movement and have noted a similar linear relationship between mean squared distance travelled and time at liberty as noted for skipjack above. Cayre et al. (1974) report that tagged yellowfin in the eastern Atlantic migrate seasonally but the total distance travelled is less than 300 miles. Yellowfin may thus also be tuna which do not exhibit a high degree of directed migration, but further tagging studies in the western Pacific are required.

Bigeye

Bigeye tuna (Thunnus obesus) are harvested principally by longline fisheries as both bycatch and targetted catch. Cannery managers and observers on board purse-seine vessels informally report that sets containing yellowfin may also contain bigeye. The proportion of bigeye in yellowfin catches is not known with any precision but may range from about 2% (Gillett 1985) to as high as 30%. At the size that these two species are caught in purse-seines, it is difficult to distinguish between them, and fishermen in the western Pacific have no good reason to make the distinction. Therefore, purse-seine catches of bigeye are generally reported to the SPC as yellowfin.

The distribution of total longline bigeye catch reported to the SPC for the years 1982-85 is shown in Figure 19. This figure is based on the same data as Figure 10 for yellowfin catches. As with yellowfin catch, the distribution of bigeye catch is relatively uniform except for gaps due to incomplete data.

The trends in longline fishing effort and bigeye catch in the area between 1000°N and 1500°S latitude and 14000°E and 18000°W longitude can be seen in Figures 20 and 21. Catches increased in the late 1970s in spite of relatively constant effort, probably reflecting improvements in fishing technology (ie. bathythermographs) and efforts to target on bigeye through the use of so-called "deep" longlines. The trend can be more easily seen in Figures 22 and 23 showing a gradual increase in hooking rate for the same period. Similar trends were noted previously by Calkins (1980).

From the scanty data available, it would appear that the longline fishery for bigeye is viable at the present levels of exploitation and could probably sustain higher catches.

Southern Albacore

Southern stocks of albacore (Thunnus alalunga) are harvested principally by longline fisheries operating in more southerly latitudes. The distribution of longline catch of southern albacore reported to the SPC for the years 1982-85 is shown in Figure 24 which indicates that albacore are caught in the more sub-tropical areas of the South Pacific. Also, the distribution of catch is much less uniform. Data on the longline fishery for albacore is not as complete as for other species and it is not clear whether this uneven distribution is a reflection of missing data or a real phenomenon.

Prior to the mid 1970s, there was an active Japanese longline fishery for southern albacore, but currently most of the catch is taken by Korean and Taiwanese longliners based in American Samoa (Wetherall and Yong 1984). Unfortunately, data from these fleets are not available to the SPC in sufficient detail to be included in this analysis. Albacore are taken by some locally controlled longline fisheries and also as bycatch in longline fisheries targetting on bigeye, southern bluefin and blue marlin.

Trends in the longline fishery for albacore in the area between 0500°S and 3000°S latitude and 14500°E and 18000°W longitude can be seen in Figures 25 through 28. The data on which these figures are based are not complete and any conclusion based on them would be unwarranted. They have been included in the interest of completeness.

There is growing interest in troll fisheries for surface dwelling populations of albacore in the vicinity of the sub-tropical convergence. Since the troll fishery catches smaller (and presumably younger) fish, there is potential for the troll fishery to have an adverse impact on the longline fishery in an interaction analogous to that predicted by yellowfin. The New Zealand domestic troll fishery currently lands about 3,000 tonnes annually. In 1982, French scientists conducted an oceanographic survey of the sub-tropical convergence in relation to abundance of surface populations of albacore with promising results (Hallier and LeGall 1983). In February 1986, exploratory fishing is to be conducted in the same region in conjunction with an oceanographic survey by an international group of American, French and New Zealand scientists. The SPC is sponsoring a workshop on southern albacore to be hosted by the New Zealand Ministry of Agriculture and Fisheries in June of this year. Thus, our understanding of southern albacore will likely improve in the next few years.

The prospects for the future of the albacore fishery are also difficult to predict. The most recent analysis of the southern albacore longline fishery by Wetherall and Yong (1984) concludes that little increase in catch can be achieved by increases in effort. The potential for an expanded troll fishery may be good if problems of surface and longline interaction prove not to be severe.

Very little work has been conducted on the migratory behaviour of southern albacore stocks, but northern albacore make apparently regular, trans-Pacific migrations (Rothschild and Yong 1970). The small scale movements of albacore relative to oceanographic conditions have received considerable attention. Good fishing for albacore is found in association with oceanic fronts, areas where two water masses join (Laurs et al. 1984).

MIGRATORY BEHAVIOUR AND MANAGEMENT

The United Nations Convention on the Law of the Sea encourages the formation of international fisheries organisations for the management of highly migratory fisheries resources. Most of the important tuna species are included in a list of highly migratory species in an Annex to the Convention.

The motivation to promote the formation of such organisations appears to rest on the assumption that only an international body can effectively manage fisheries for stocks of fish whose ranges span the boundaries of more than one coastal state. This assumption in turn contains within it three constituent assumptions: 1) that curtailment of fishing effort is inevitably required to conserve the stock; 2) that individual states cannot apply effective measures within their own national jursidictions; 3) that fishing activities in one state affect fishing success in another. The validity of these assumptions may not be universal and must depend on the goals of the particular management plan, the nature of the fishing fleet, the characteristics of the coastal state, and the species of tuna involved.

The economic structure of fisheries for tropical tuna appears to differ from fisheries for other species in other parts of the world. The profit margin of tuna fisheries is low and it becomes unprofitable to fish for tuna before the stocks become depressed to really low levels. This characteristic is in sharp contrast to other types of fisheries, such as North Sea herring, where it is profitable to fish at very low population levels thus seriously endangering the stock. The departure of purse-seine vessels from the eastern Pacific since 1982 could be sighted as an example of how economic forces may act to conserve a stock. Thus statutory effort curtailment to conserve stocks is not inevitable.

Individual states are well capable of instituting fisheries management plans for tuna and many do so. Management plans may have many purposes such as to maximize employment in the fishery, maximize employment in fish processing, stimulate local markets, or increase revenues from access fees. Coastal states issue licences to fish for many species of fish, including tuna, in their EEZs with cost of access a function of catch value. Quotas may be set on both catch and numbers of licences. If costs are too high or quotas too low, fishermen may fish elsewhere. Coastal states can apply management measures within their own national jurisdiction which not only serve national priorities, but can also have the effect of stock conservation.

The effect of fishing activities in one area on fishing success in another depends on several factors. Obviously, the mobility of the fish is important. Equally important is the distance between the two areas and their relative size. A third factor is the mortality rate of the fish. Tuna are certainly mobile fish, but different species of tuna move in different fashions. Albacore and bluefin are long-lived and appear to make regular transoceanic migrations. Yellowfin and skipjack are short-lived and often remain in a relatively small area. If the EEZs are large, as they are in the South Pacific, it is doubtful that they migrate frequently among several countries. The term "highly migratory" therefore should be put in a relative context. At this stage of our knowledge of tuna biology we can apply no absolute scale. These fish are only "highly migratory" if their range of migration, as constrained by their movement and mortality rates, is large in relation to the size of the EEZ.

International fisheries organizations for tuna can have many legitimate functions and their importance will grow as tuna fisheries expand. There are sound economic, political and biological reasons to form these organizations which depend on both the species under consideration and the local geopolitical situation. If the organizations are to be successful, it is important that they are founded for sound reasons. The assertion that tuna are "highly migratory" hides the important qualification that there are biological differences between tuna species and the implications of migratory behaviour depend on the geographical characteristics of the region in question. Indeed the global mobility of tuna fleets, and the ability to fish in many different EEZs, are perhaps more valid motivations for forming international tuna fisheries organizations.

CONCLUSIONS

The major tuna resources in the western Pacific Ocean appear to be in good condition and the fisheries for them viable from a biological point of view. The skipjack stock has so far been only lightly exploited and could sustain much higher yields. The yellowfin stock also appears to be in good condition, although there are suggestions from both the longline and purse-seine fisheries that the population is beginning to respond to fishing pressure. The longline fishery for bigeye continues to show high catch rates and the prospects are good for this fishery. The longline fishery for albacore appears to be fully saturated, but there is the possibility of increased yields from the southern surface troll fishery.

CAUTIONS

The above optimistic conclusions must be tempered by some cautious qualifications:

1. The lack of information for international waters and about the activities of certain fleets severely restricts the validity of any conclusions and prohibits application of scientifically rigorous analyses.

2. Both purse-seine and pole-and-line vessels operate in concentrated areas. The purse-seine fishery takes most of its catch in the areas shown in Figure 2. The pole-and-line fisheries often operate close to shore in localized fishing grounds. In both of these cases there is a strong possibility for local transient stock depletions which are not detectable in the kind of cursory analysis presented above.

3. The large scale purse-seine fishery depends on the presence of logs and other flotsam to attract schools of tuna. Traditional methods of relating fishing success to stock size do not have their traditional interpretation: catch per day indicates abundance of flotsam and catch per set indicates school size. Considerable research is necessary to determine the relationship between stock size and recruitment of schools to flotsam.

4. The extent to which surface and longline fisheries, for both yellowfin and albacore, exploit a common stock is unknown. The relationship is critical for determining the potential for interaction between different fisheries.

5. Fisheries in areas adjacent to the SPC region, in particular countries to the west, may have an impact on the fisheries discussed. The SPC does not have access to data from these areas in sufficient detail.

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Figure 1. Distribution of pole-and-line skipjack catch for the years 1982 through 1985. The "?" symbols indicate area where data coverage is incomplete.

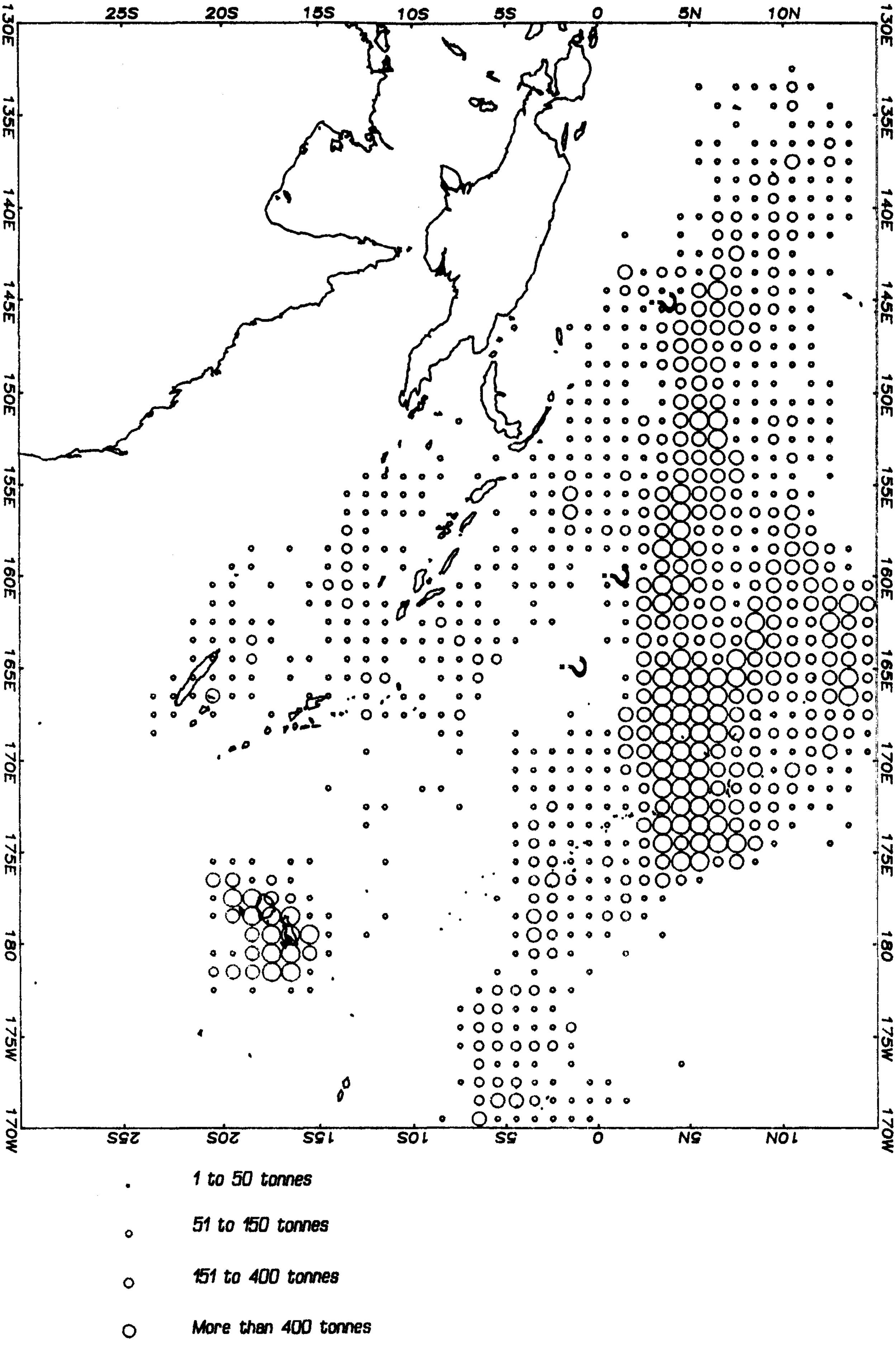


Figure 2. Distribution of purse-seine skipjack catch for the years 1982 through 1985. The "?" symbols indicate area where data coverage is incomplete.

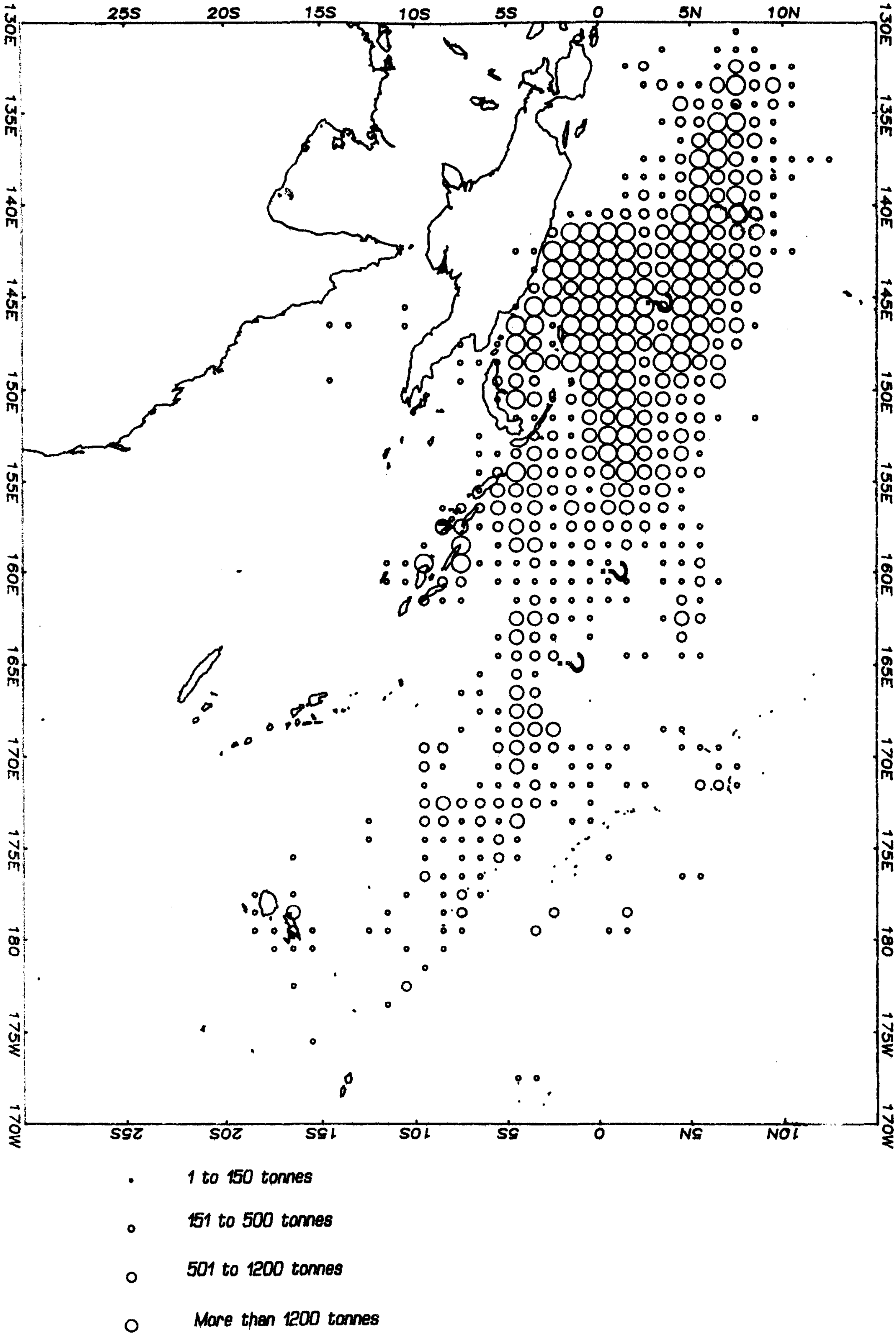


Figure 3. Trends in pole-and-line (dotted line) and purse-seine (solid line) fishing effort in the area between 1000°N and 1500°S and 14000°E and 18000°W. Effort is expressed as the sum of boat-days fished and boat-days searched.

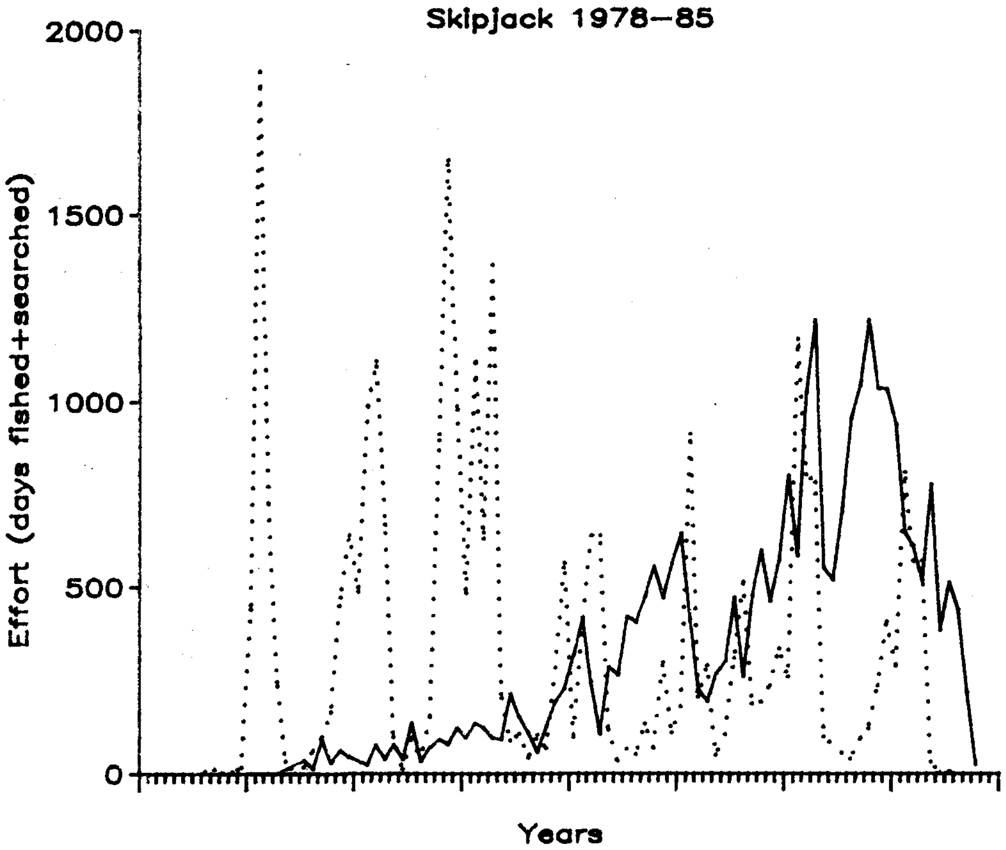


Figure 4. Trends in pole-and-line (dotted line) and purse-seine (solid line) skipjack catch in the area between 1000°N and 1500°S and 14000°E and 18000°W.

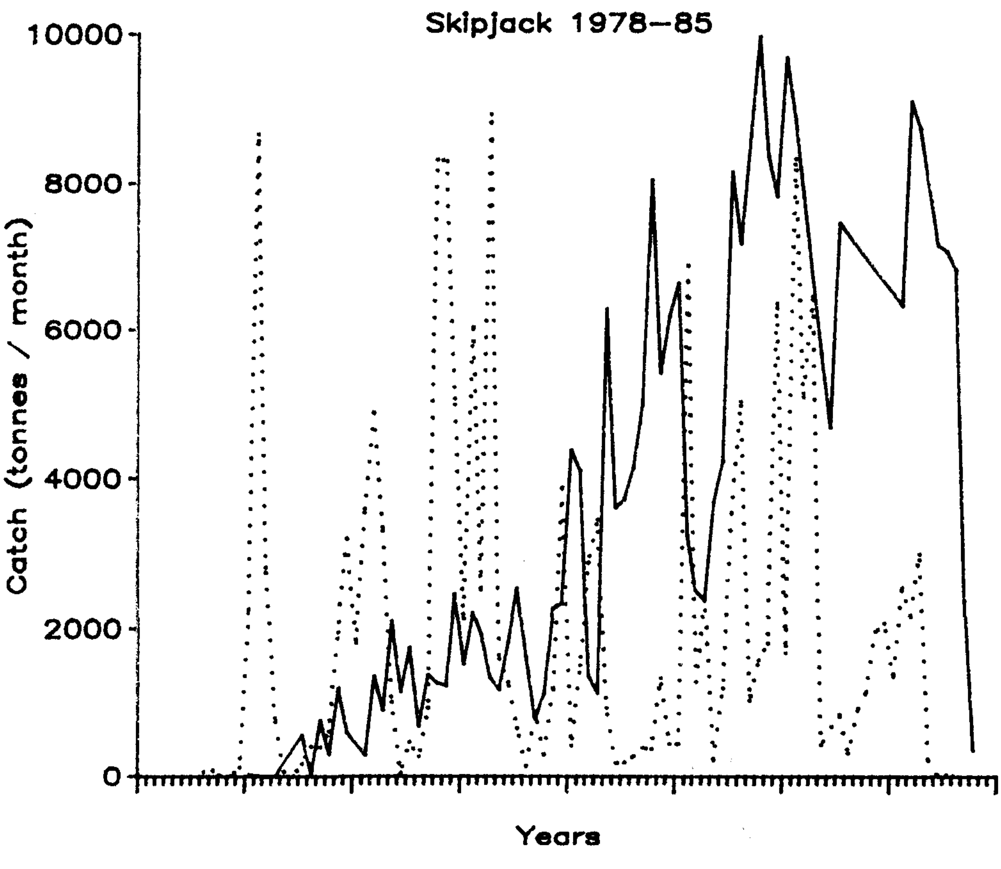


Figure 5. Trends in catch per unit of effort for skipjack by pole-and-line (dotted line) and purse-seine (solid line) vessels in the area between 1000°N and 1500°S and 14000°E and 18000°W. Effort is expressed as the sum of boat-days fished and boat-days searched. Individual symbols indicate average over year.

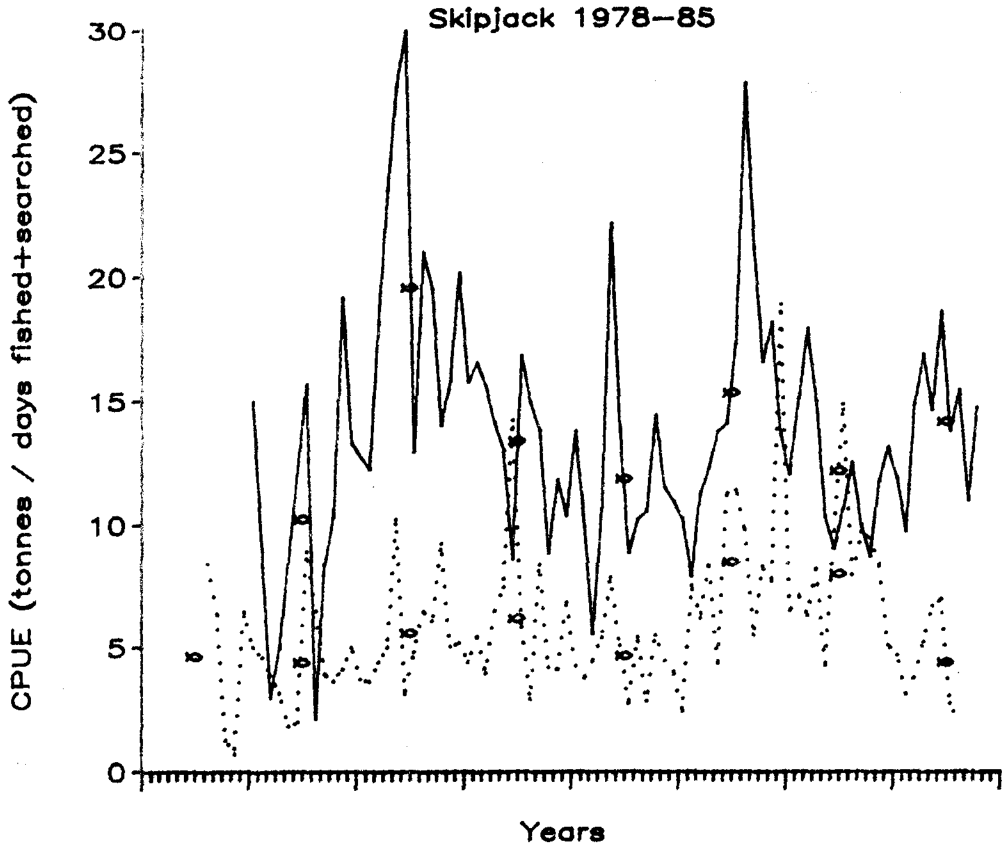


Figure 6. Relationship between skipjack catch and effort for purse-seine vessels (+) and pole-and-line vessels (o) in the area between 1000°N and 1500°S and 14000°E and 18000°W. Straight lines indicate average CPUE.

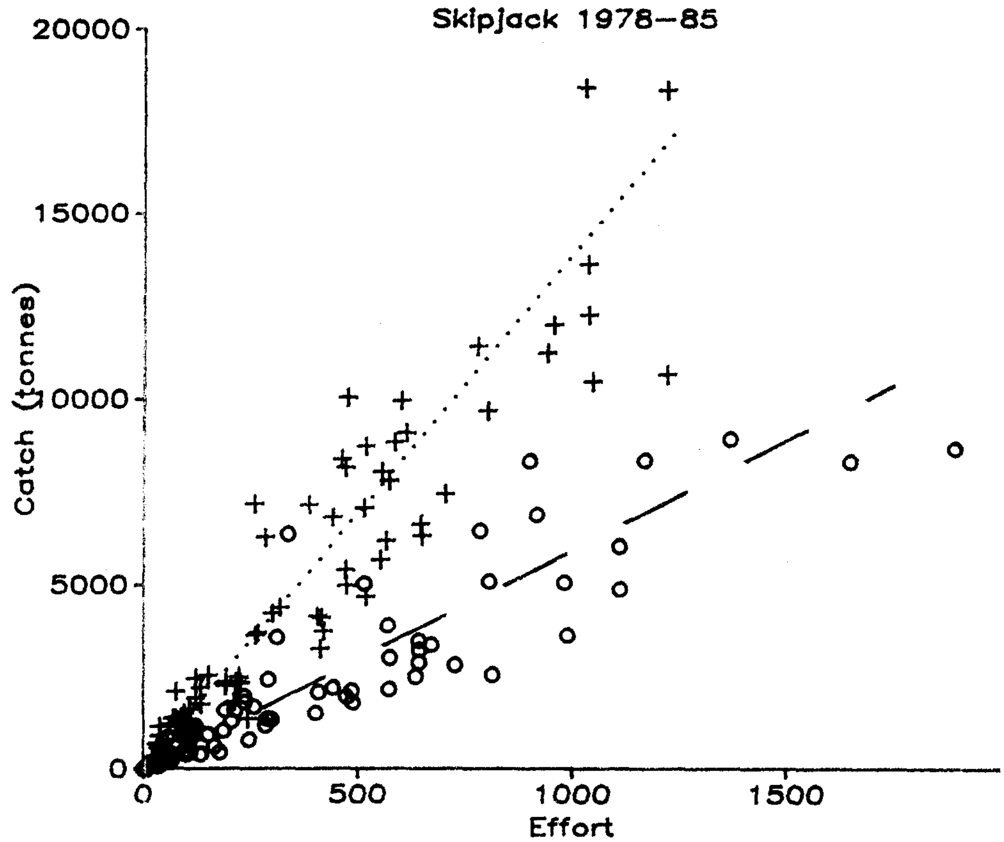


Figure 7. Straight line representations of movements of skipjack tagged by the Skipjack Programme and subsequently recovered. Movements plotted have been selected to show no more than two examples between any pair of ten degree squares, one in each direction, and no more than two examples of movement wholly within any ten degree square. Tick marks on the arrows represent time-at-large with one tick mark per 90-day interval (from Kearney 1983).

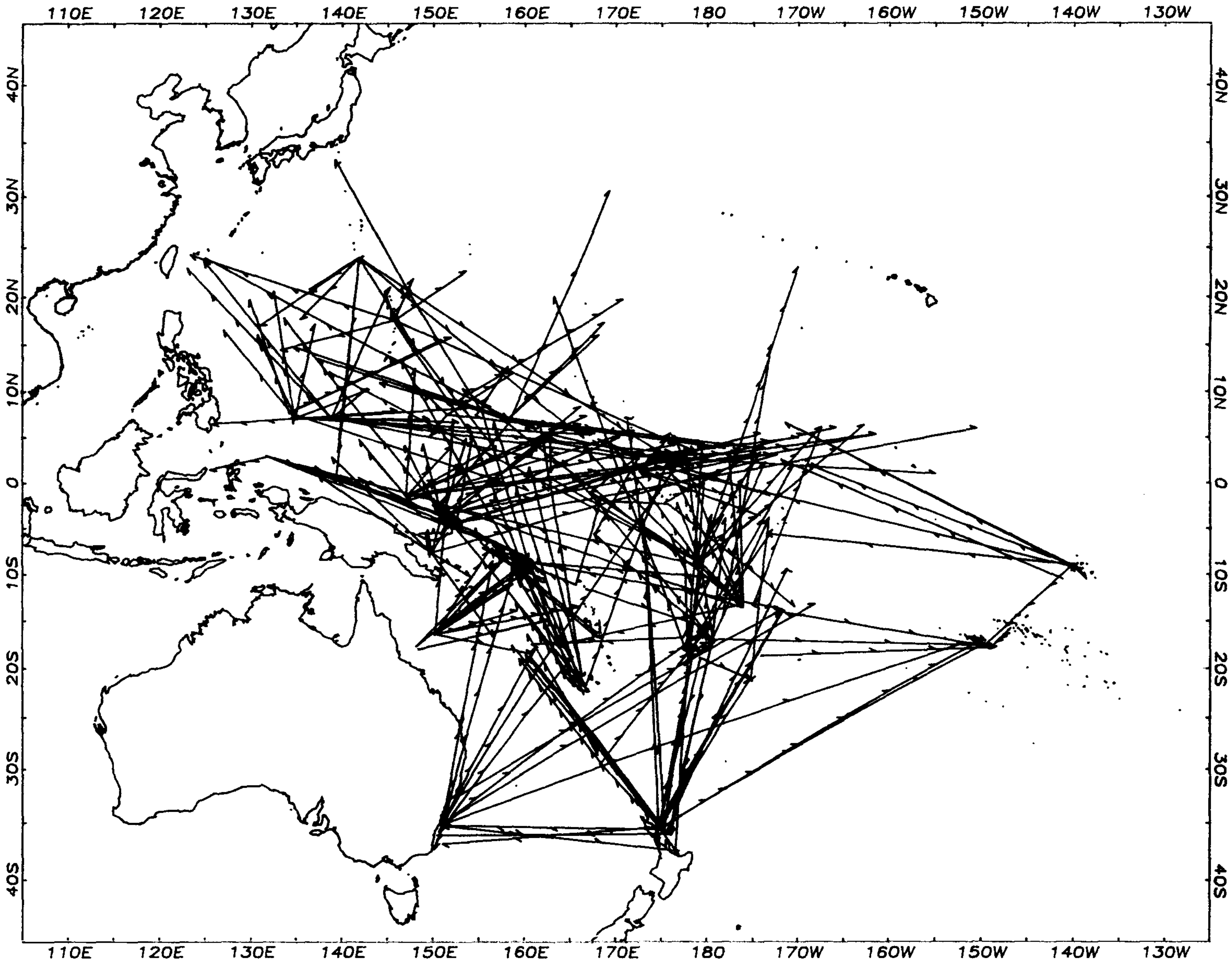


Figure 8. Numbers of tagged skipjack recovered at different distances from point of release (from Kearney 1983).

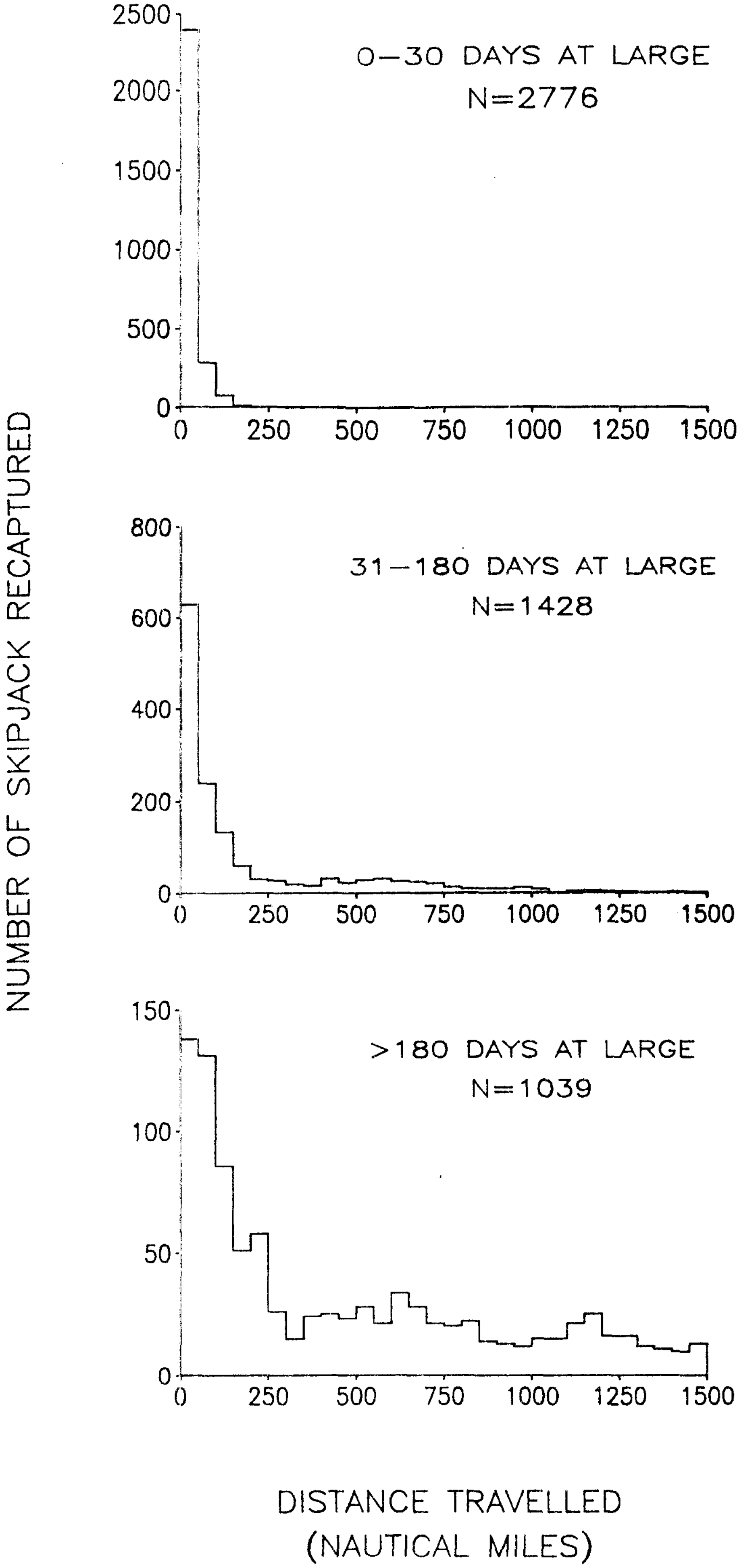


Figure 9. Mean square of distance travelled (nautical miles) for tagged skipjack at liberty for different periods of time. Only fish moving less than 200 nmi have been included. Error bars indicate two standard errors on each side of the mean.

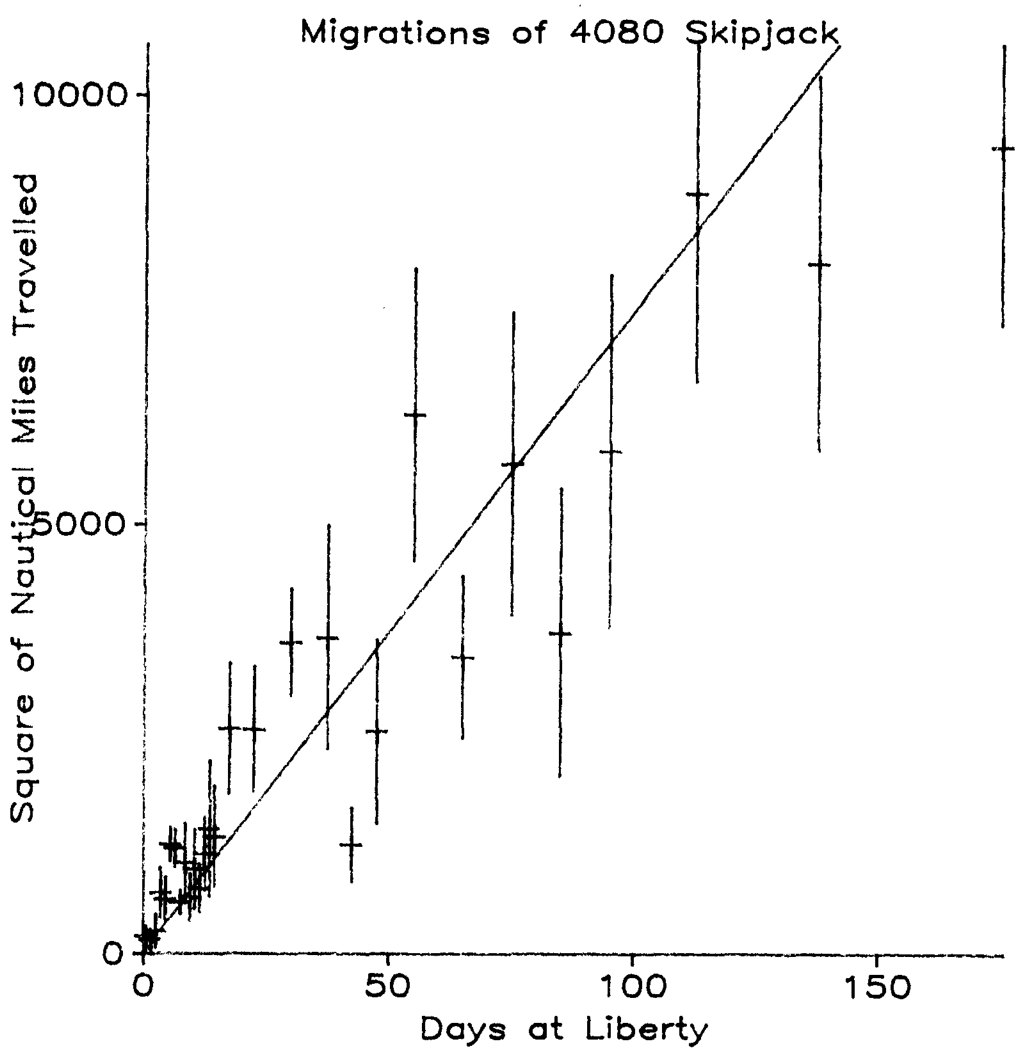


Figure 10. Distribution of longline yellowfin catch for the years 1982 through 1985. The "?" symbols indicate area where data coverage is incomplete.

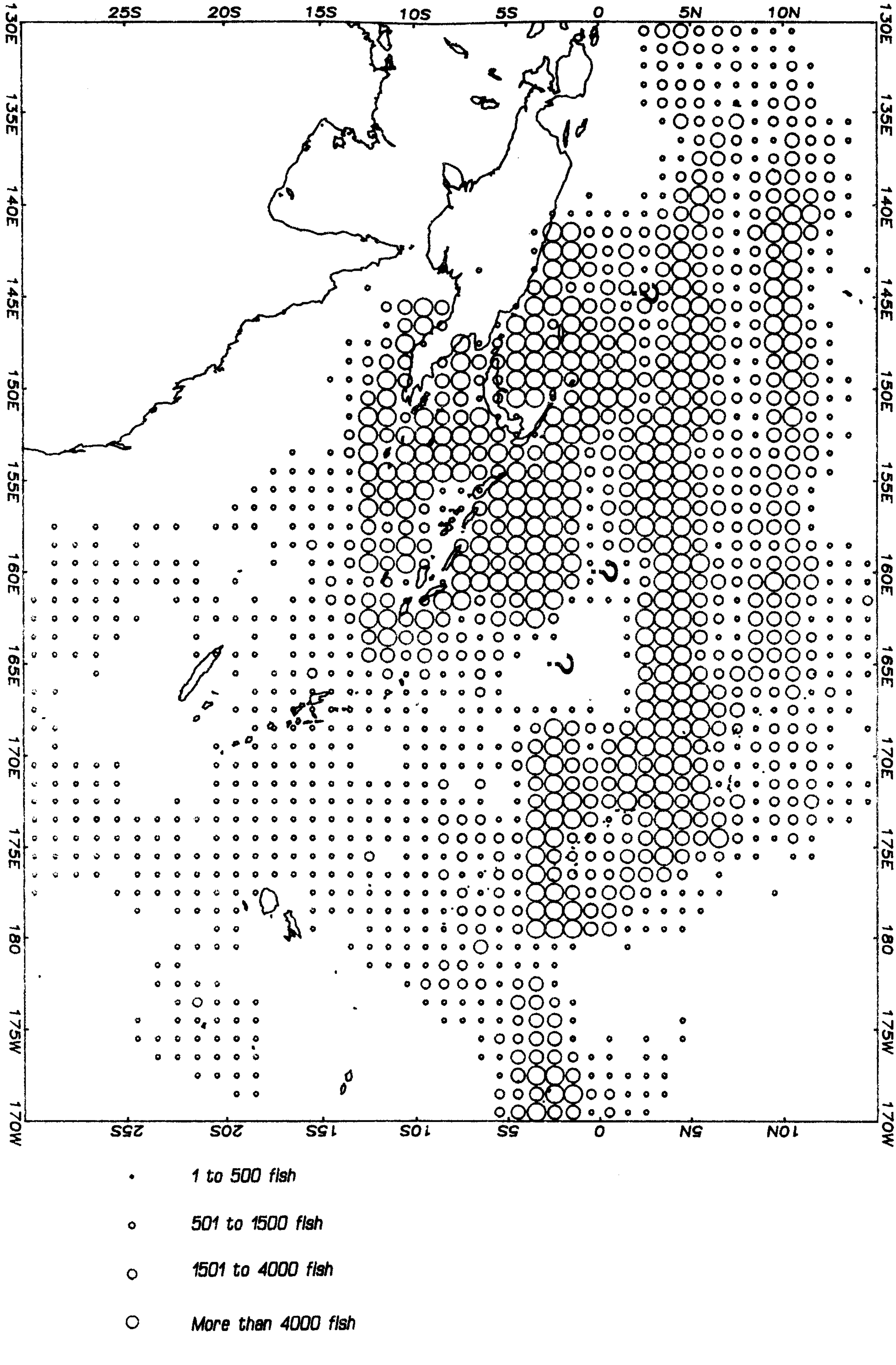
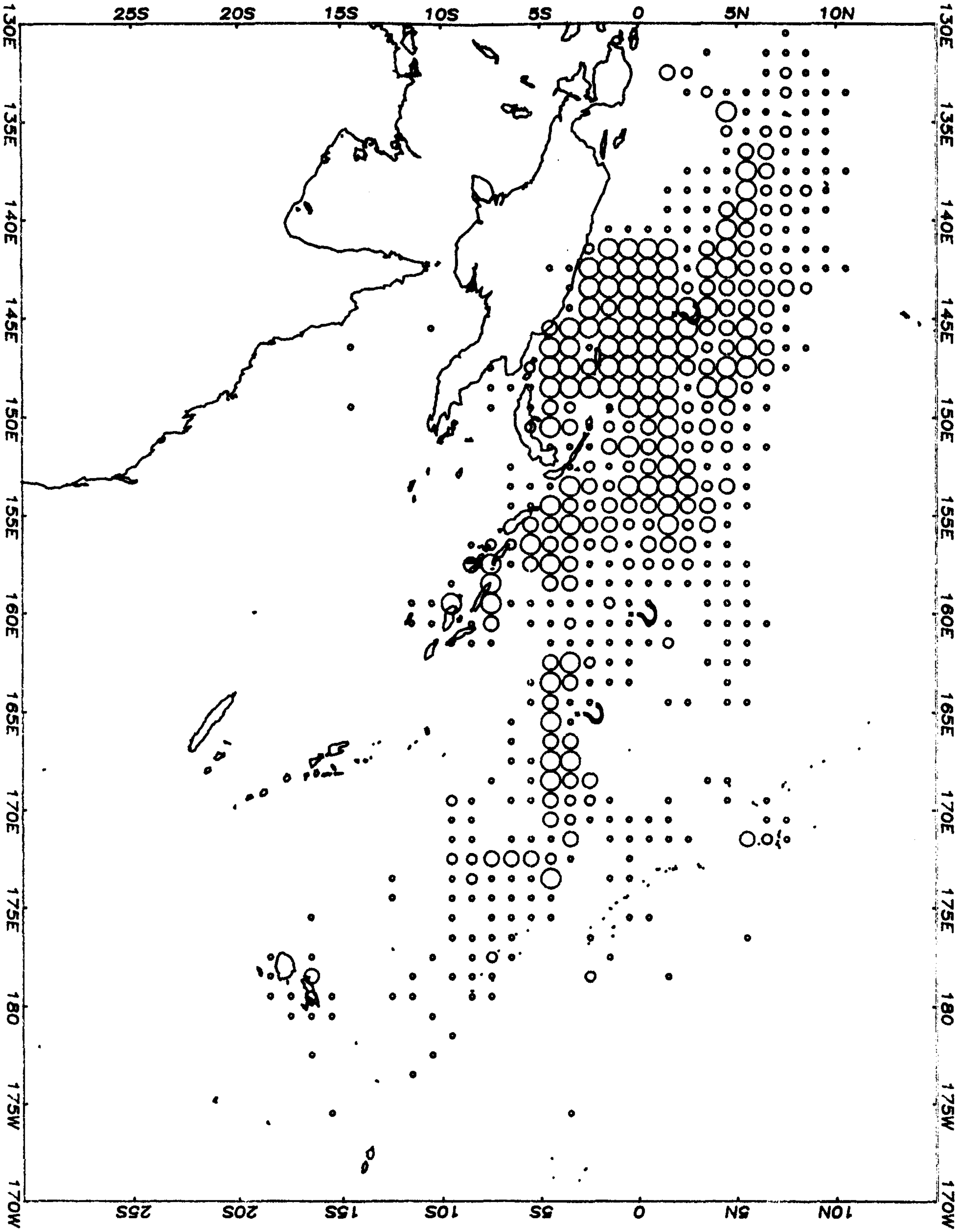


Figure 11. Distribution of purse-seine yellowfin catch for the years 1982 through 1985. The "?" symbols indicate area where data coverage is incomplete.



• 1 to 100 tonnes

∘ 101 200 tonnes

○ 201 to 400 tonnes

◯ More than 400 tonnes

Figure 12. Trends in longline (dotted line) and purse-seine (solid line) fishing effort in the area between 1000°N and 1500°S and 14000°E and 18000°W. Purse-seine effort is expressed as ten times the sum of boat-days fished and boat-days searched; longline effort is expressed in 1000's of hooks set.

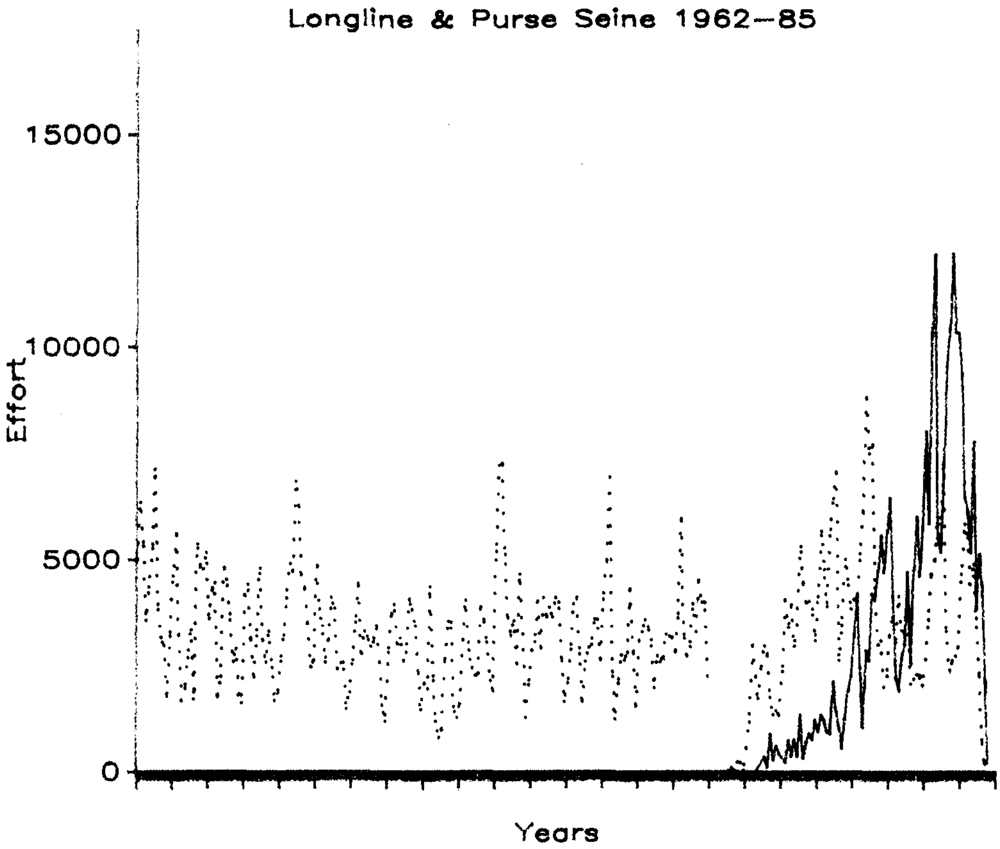


Figure 13. Trends in longline and purse-seine yellowfin catch in the area between 1000°N and 1500°S and 14000°E and 18000°W. Longline catches are reported in pieces and for the purpose of this figure an approximate average weight of 25 kilograms has been assumed to convert reported catches to weight.

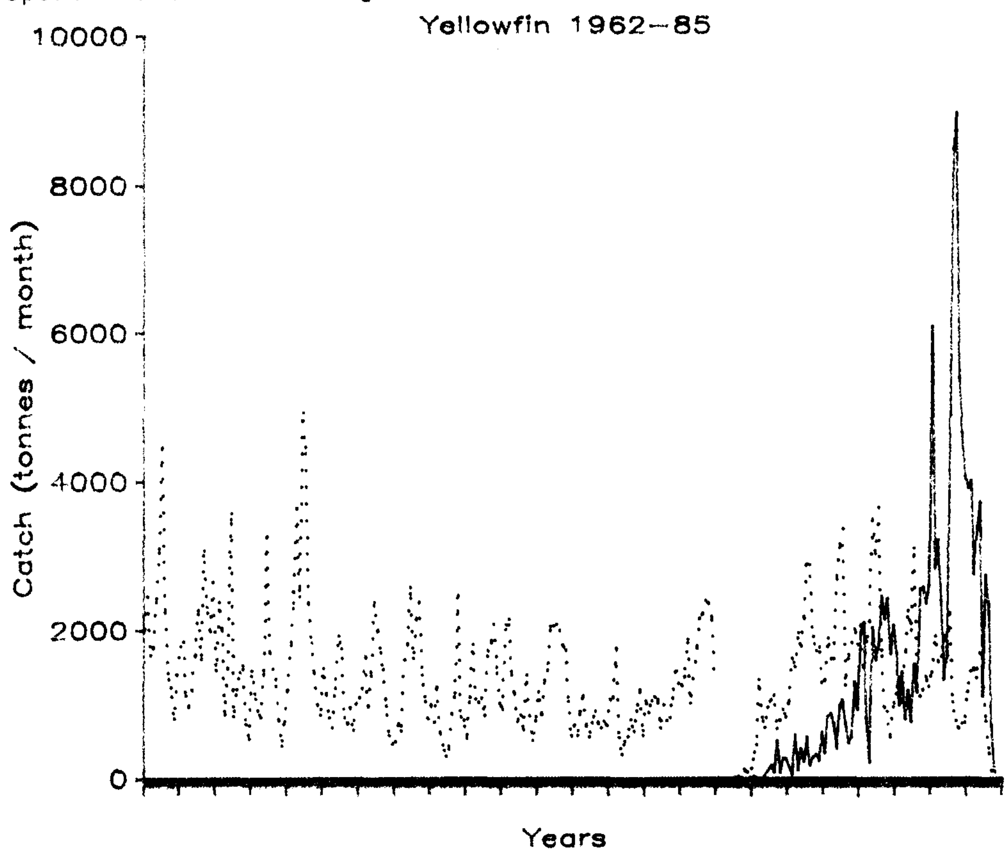


Figure 14. Trends in catch per unit of effort for yellowfin by purse-seine (solid line) and longline (dotted line) vessels in the area between 1000°N and 1500°S and 14000°E and 18000°W. CPUE is expressed in tonnes per day for purse-seine and fish/100 hooks for longline. Individual symbols represent average over year.

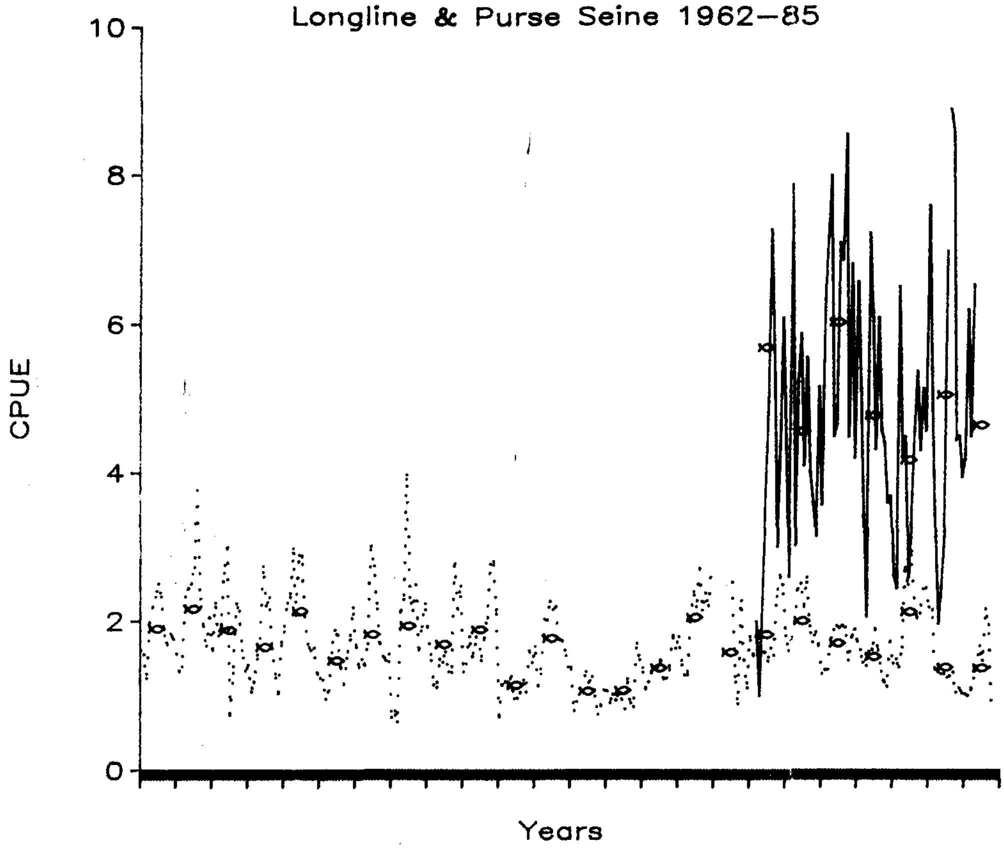


Figure 15. Relationship between yellowfin catch and effort for purse-seine vessels in the area between 1000°N and 1500°S and 14000°E and 18000°W.

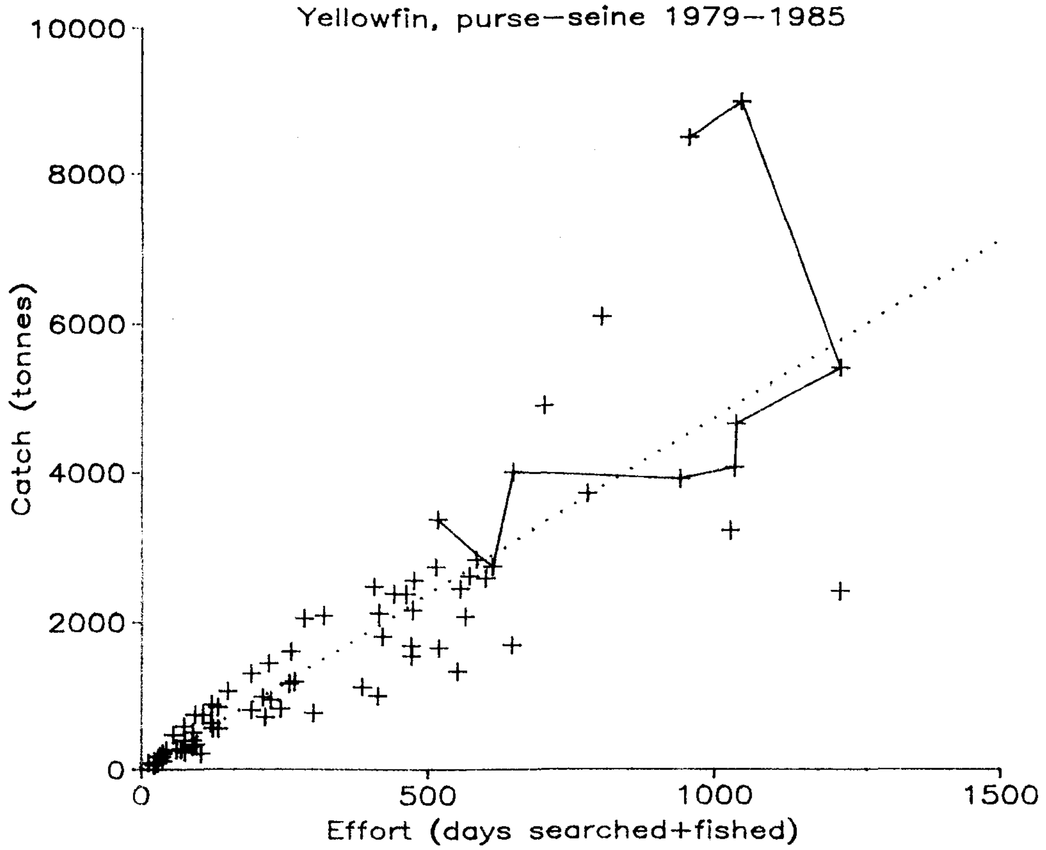


Figure 16. Relationship between yellowfin catch and effort for longline vessels in the area between 1000°N and 1500°S and 14000°E and 18000°W.

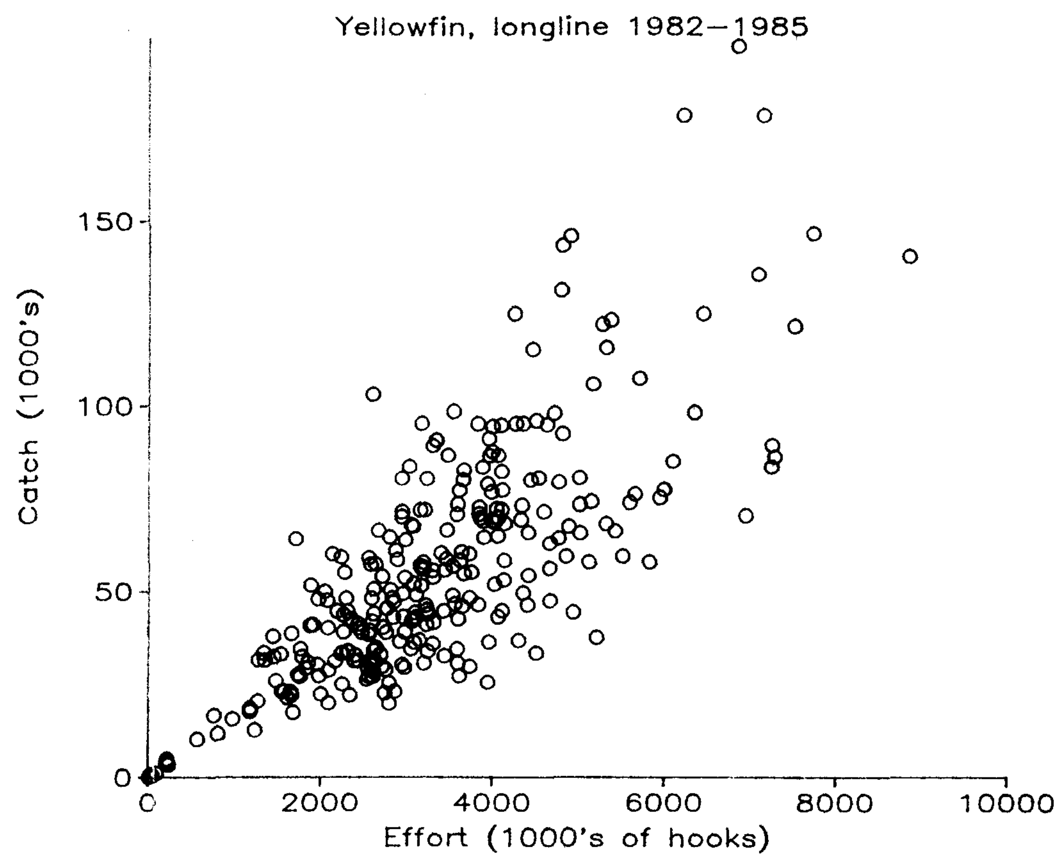


Figure 17. Yellowfin catch by purse-seiners as a function of skipjack catch in the area between 1000°N and 1500°S and 14000°E and 18000°W.

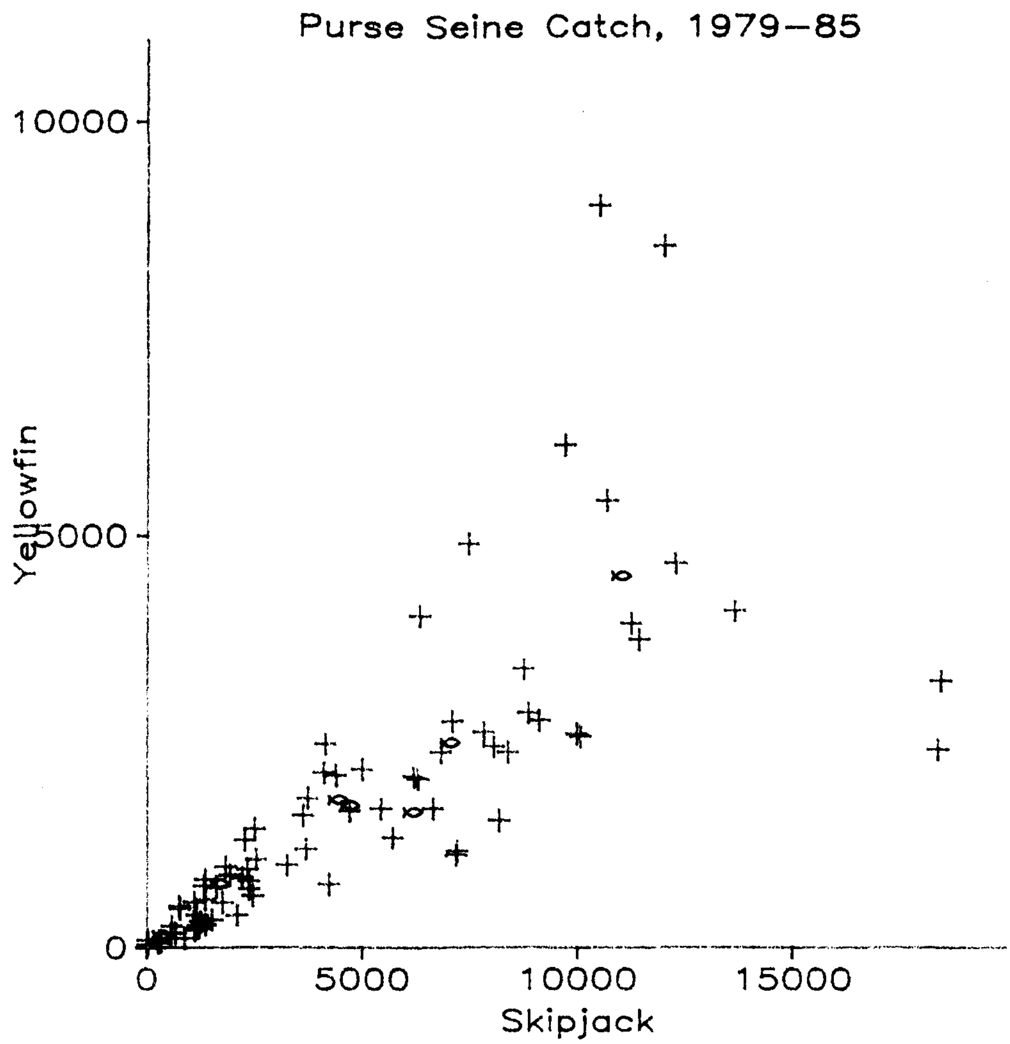


Figure 18. Straight line representations of movements of yellowfin tagged by the Skipjack Programme and subsequently recovered. Movements plotted have been selected to show no more than two examples between any pair of two degree squares, one in each direction. Tick marks on the arrows represent time-at-large with one tick mark per 30-day interval.

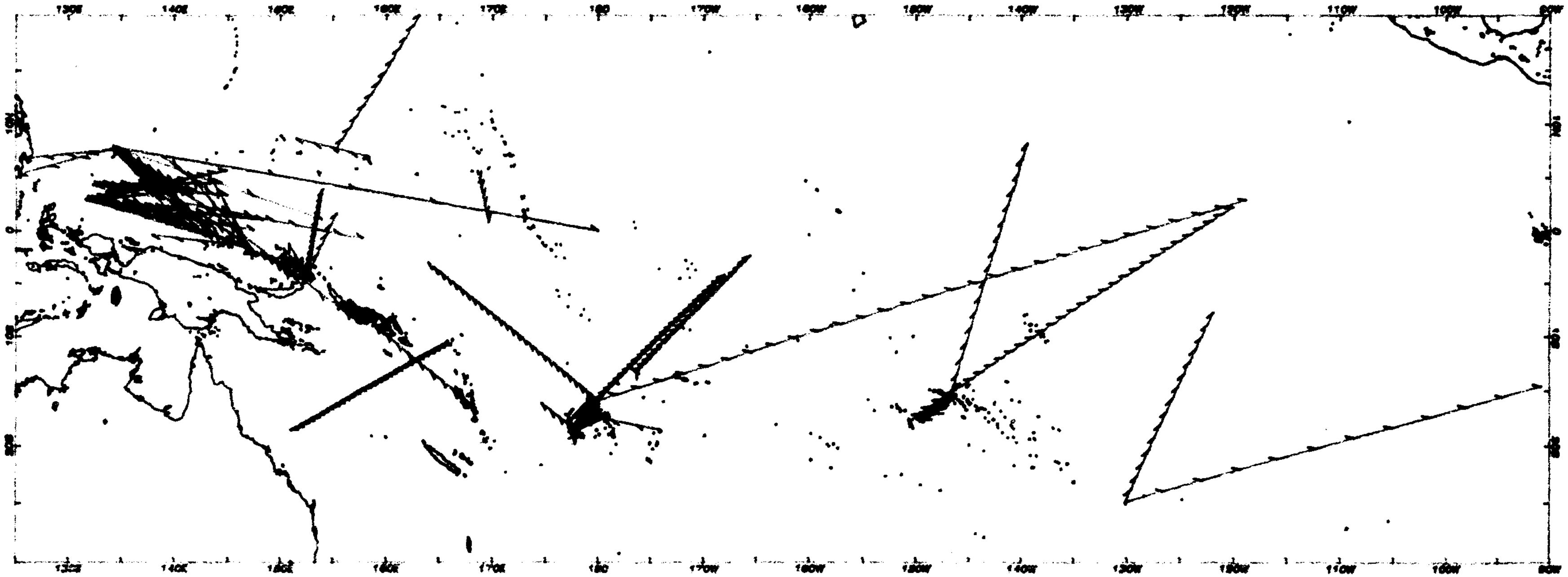


Figure 19. Distribution of longline bigeye catch for the years 1982 through 1985 based on the same information as Figure 10. The "?" symbols indicate area where data coverage is incomplete.

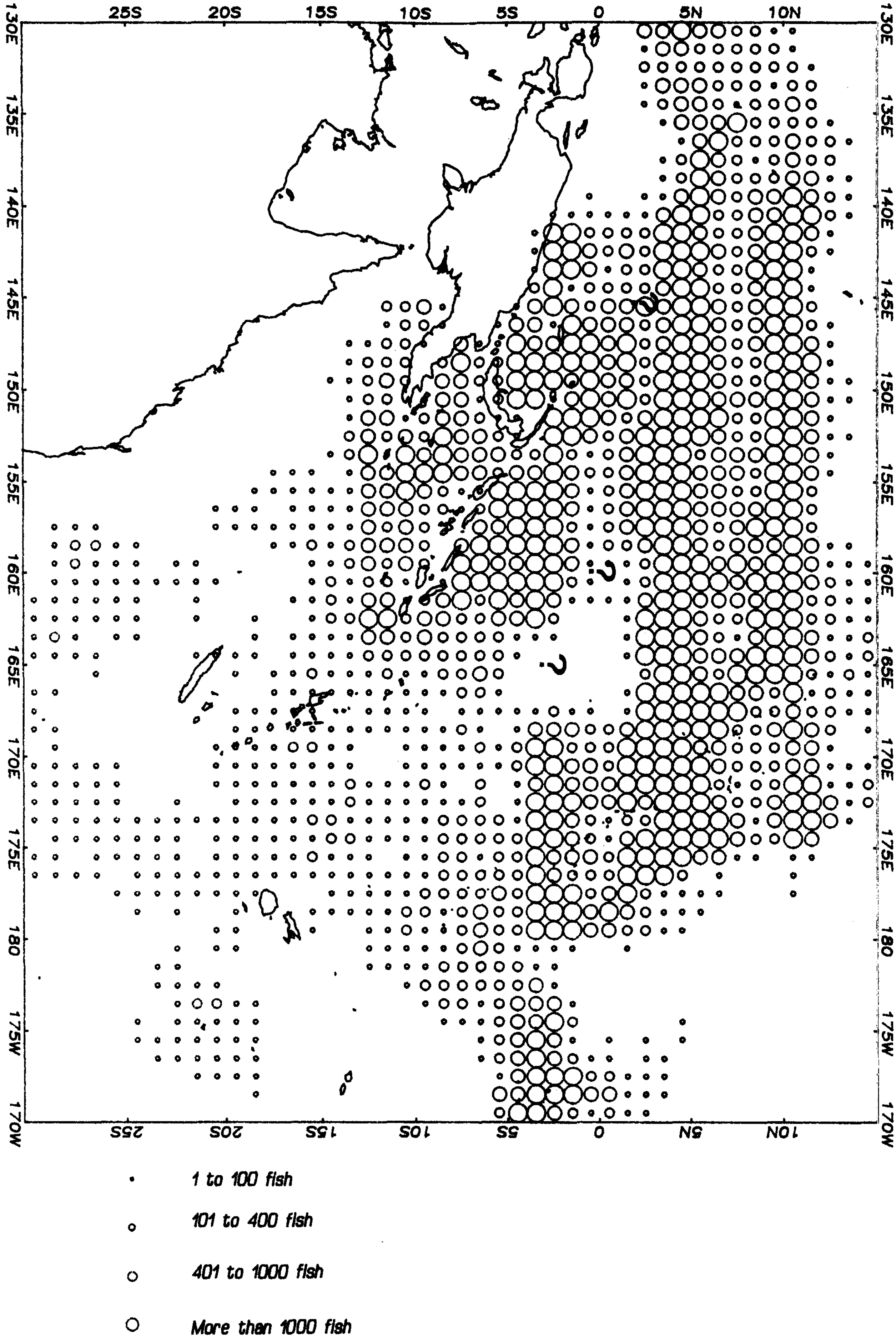


Figure 20. Trends in longline fishing effort in the area between 1000°N and 1500°S and 14000°E and 18000°W. Individual symbols represent average over year.

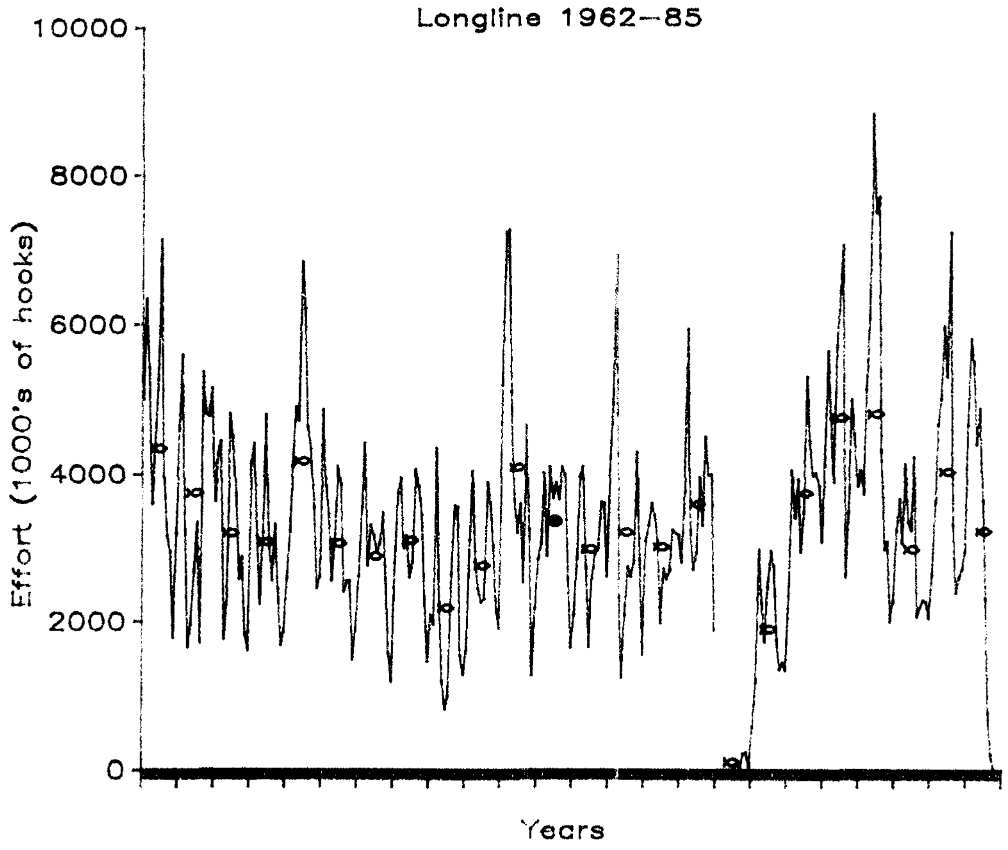


Figure 21. Trends in longline bigeye catch in the area between 1000°N and 1500°S and 14000°E and 18000°W. Individual symbols represent average over year.

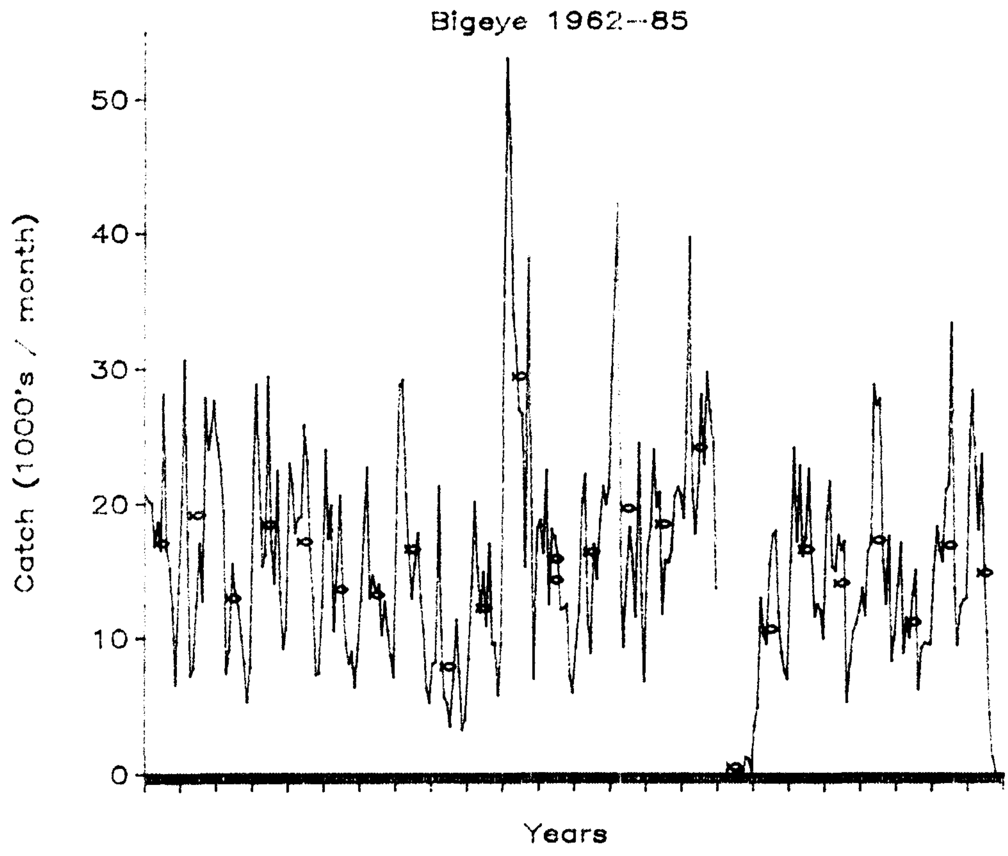


Figure 22. Trends in catch per unit of effort for bigeye by longline vessels in the area between 1000°N and 1500°S and 14000°E and 18000°W. Individual symbols represent average over year.

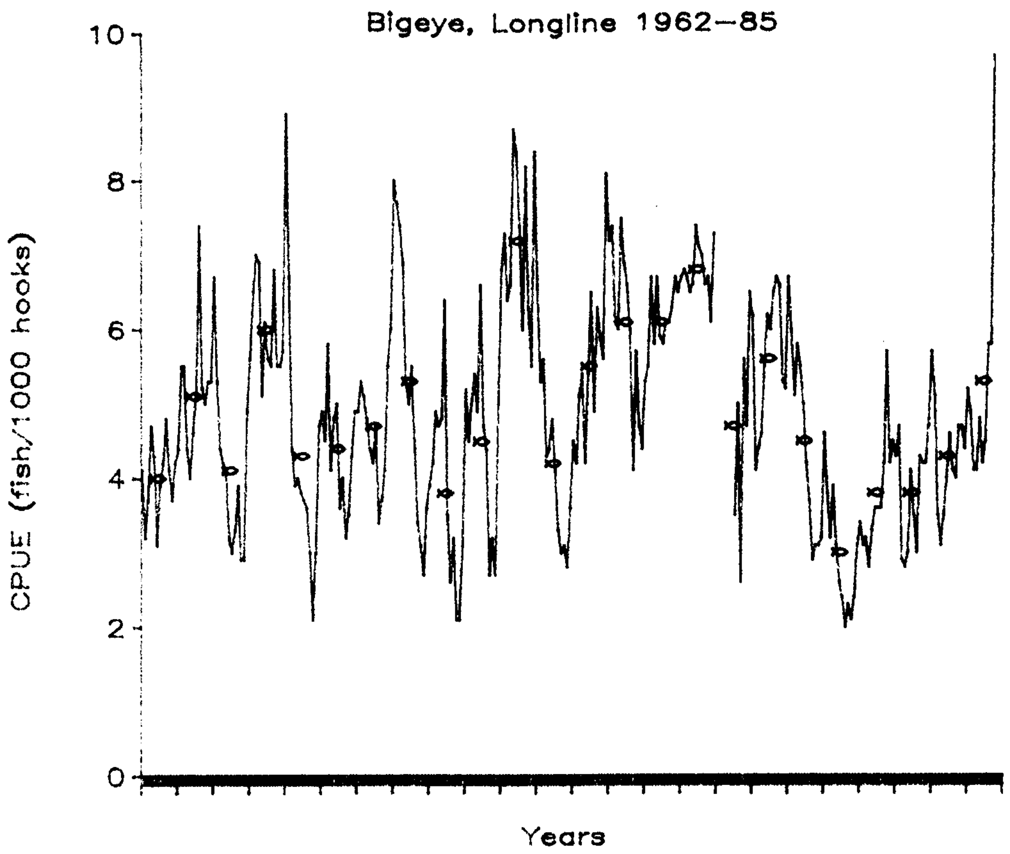


Figure 23. Relationship between bigeye catch and longline effort in the area between 1000°N and 1500°S and 14000°E and 18000°W. Straight line is the long-term average CPUE.

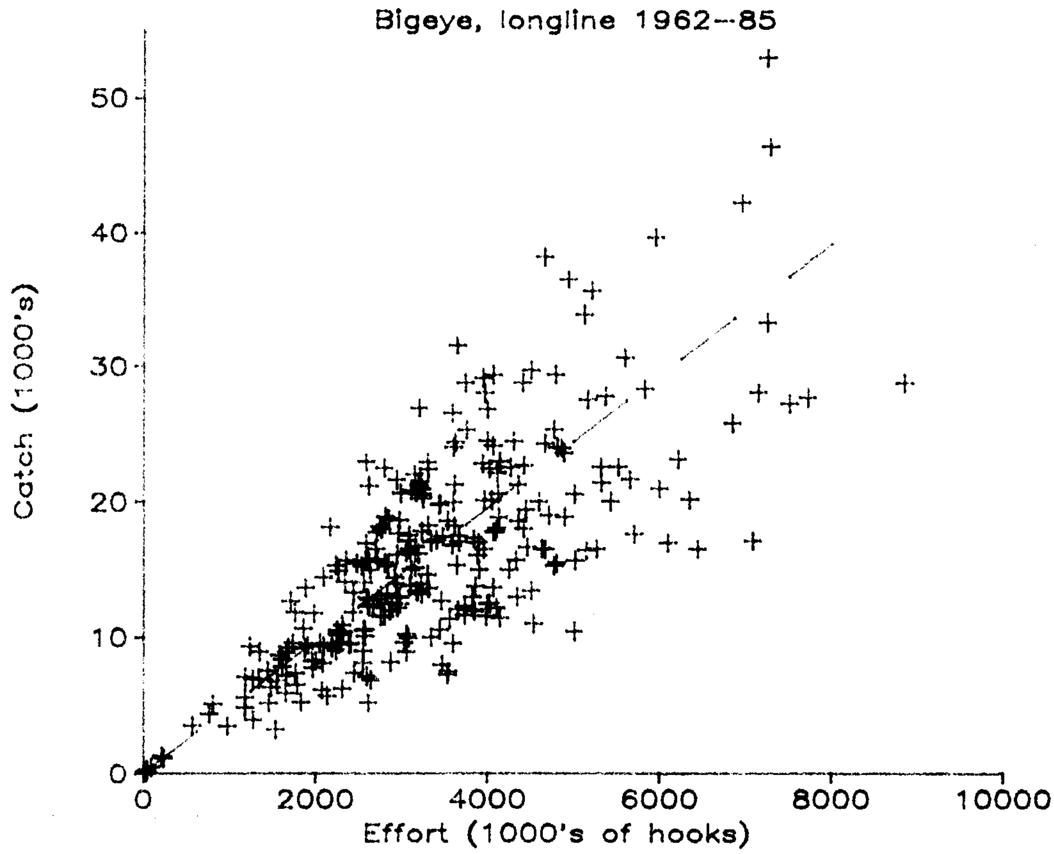


Figure 24. Distribution of longline southern albacore catch for the years 1982 through 1985.

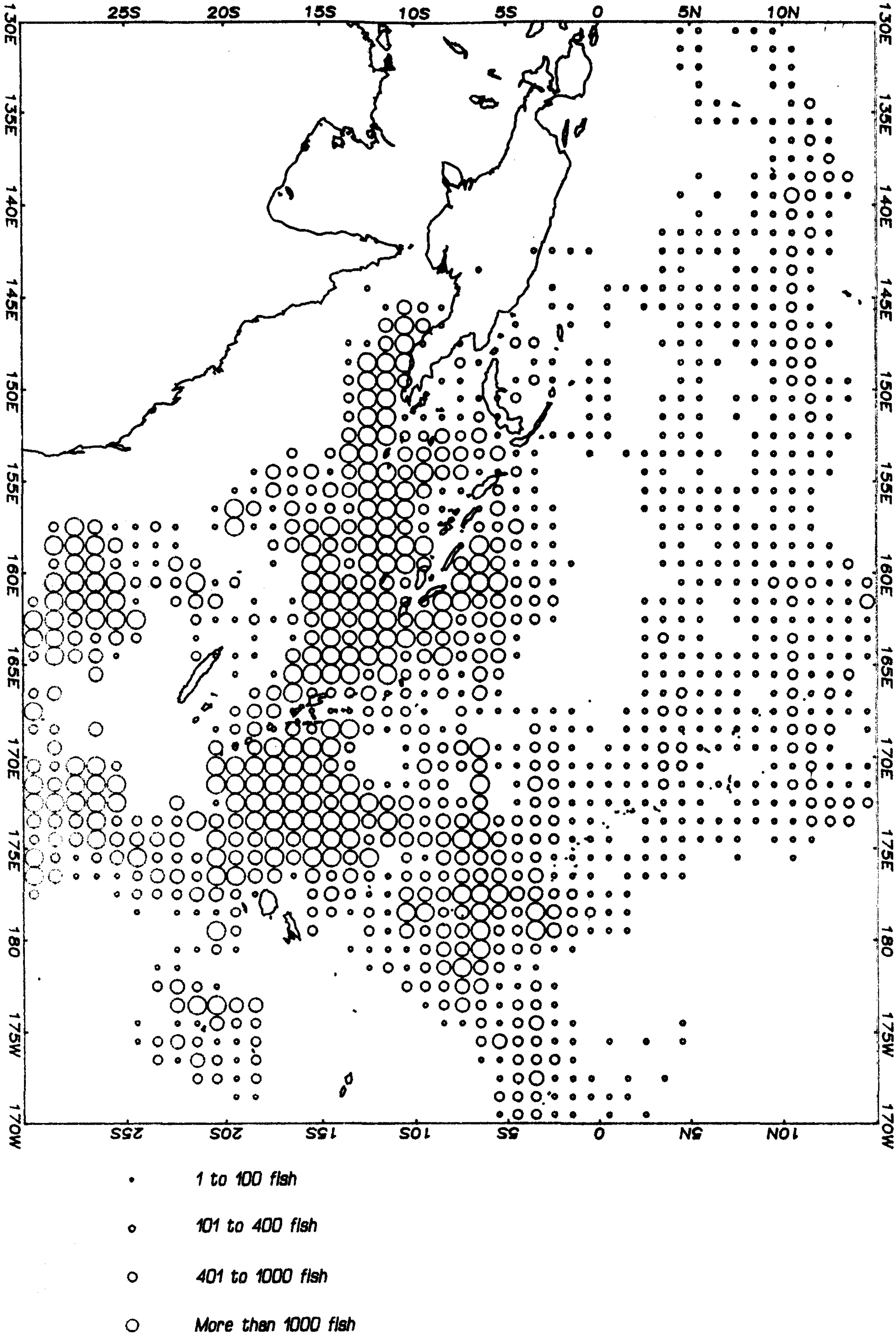


Figure 25. Trends in longline fishing effort in the area between 0500°S and 3000°S and 14500°E and 18000°W. Individual symbols represent average over year.

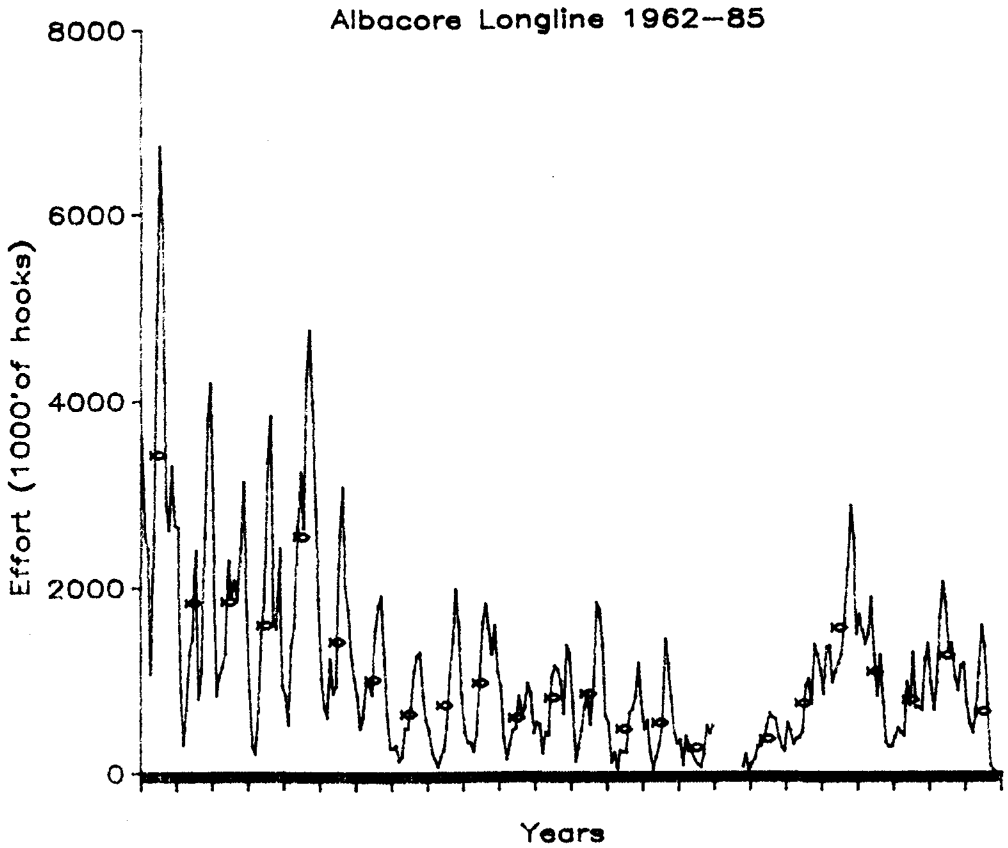


Figure 26. Trends in longline southern albacore catch in the area between 0500°S and 3000°S and 14500°E and 18000°W. Individual symbols represent average over year.

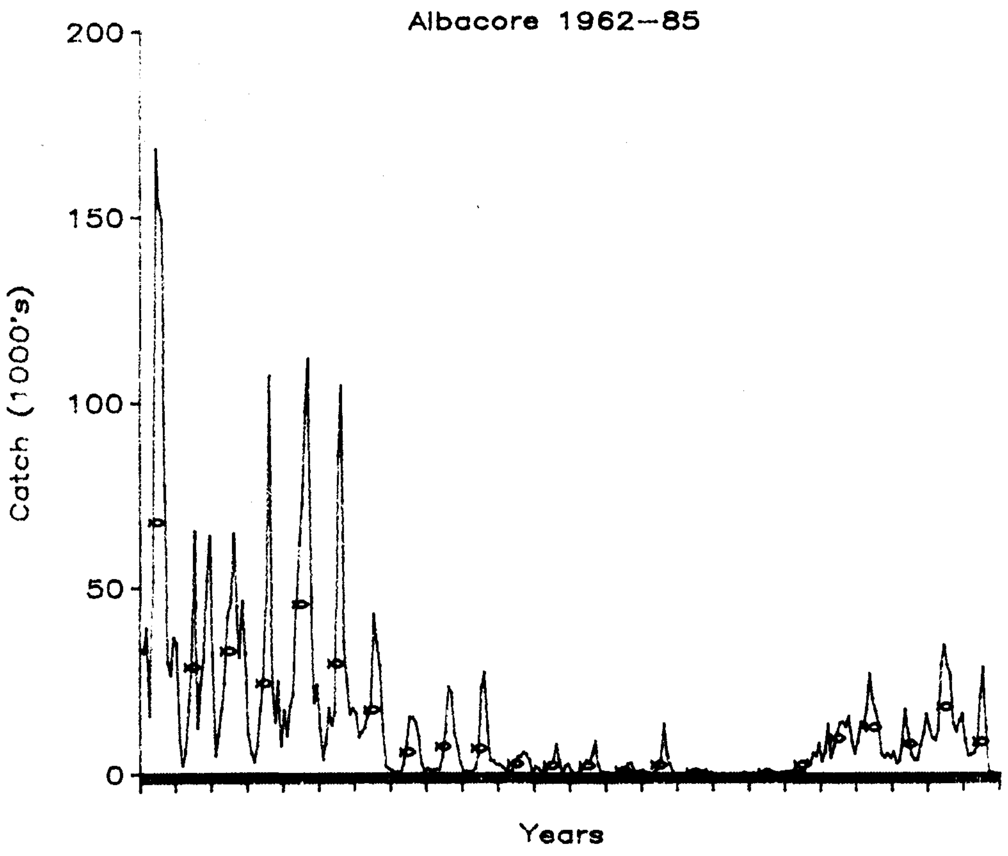


Figure 27. Trends in catch per unit of effort for southern albacore by longline vessels in the area between 0500°S and 3000°S and 14500°E and 18000°W. Individual symbols represent average over year.

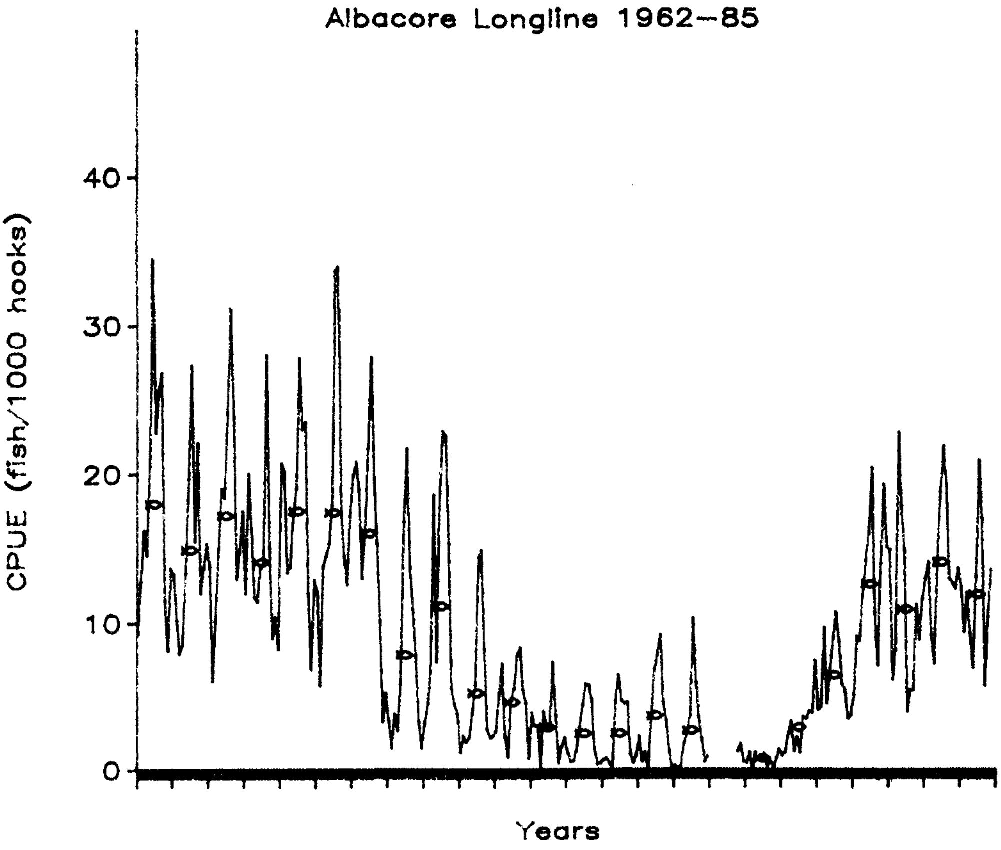


Figure 28. Relationship between southern albacore catch and longline effort in the area between 0500°S and 3000°S and 14500°E and 18000°W.