INTER-AMERICAN TROPICAL TUNA COMMISSION
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INTERNAL REPORT - INFORME INTERNO

No. 16

DOLPHINS AND THE PURSE SEINE FISHERY FOR YELLOWFIN TUNA

By

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La Jolla, California

1981

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CONTENTS

Introduction

In the eastern Pacific ocean yellowfin tuna (Thunnus albacares) often associate with some species of dolphins (principally Stenella and Delphinus species). The reason for the association is not understood but fishermen have taken advantage of it by using dolphins as a cue to find yellowfin tuna, and to assist in capturing them. When tunas were caught primarily by baitboats using the pole and line method dolphins were not often involved and only occasionally injured. However, following the increasing use of purse seining in the late 1950's large numbers of dolphins were entangled in the nets and drowned in the process of catching tuna. In this paper I shall discuss the impact of the fishery on dolphin populations and the current management of tunas and dolphins.

In general quantities of tuna are measured by weight and those of dolphin by number. Unless otherwise noted this practice is followed in the paper.

Acknowledgements

Patrick Tomlinson and Richard Punsley provided assistance in the preparation and interpretation of much of the data used in this study. Thanks are also due to colleagues at the Inter-American Tropical Tuna Commission and the Southwest Fisheries Center who gave helpful advice and criticism.

The Fishery

The purse seine fishery for yellowfin and other tunas covers a large area of the eastern Pacific Ocean shown in Figure 1. Fishermen are able to catch tuna because they aggregate in schools which can be seen at the surface, or else in association with floating objects, commonly called logs, or in the case of yellowfin tuna, with schools of dolphins. In general, unassociated schools and schools associated with logs contain smaller yellowfin (Figure 2) and tend to be found closer to the shore than those which are associated with dolphin schools (Figure 3). Although the amount of each type of fishing varies from year to year, on average about one half of the total catch of yellowfin tuna is taken from schools associated with dolphins (Table 1).

TABLE 1. Estimated purse-seine catch (thousands of tons) of yellowfin, eastern Pacific east of 150°W.

Year	% of catch on dolphins	Total yellowfin catch
1966	59	82
1967	44	80
1968	46	103
1969	80	132
1970	68	161
1971	66	126
1972	79	186
1973	69	220
1974	54	220
1975	62	215
1976	56	256
1977	55	217
1978	35	191
1979	45	203
1980	48*	174*

* 1980 figures are provisional

Aggregations of yellowfin tuna and dolphins are often accompanied by birds and it is normally either the activity of birds or splashes made by the dolphins which attract the attention of the fishermen. As well as providing a cue for the fishermen to locate a school of tuna the dolphins serve as a target for the seiner to chase, round up, and eventually encircle with the net. During this activity the tuna remain very close to the dolphins and are also captured. Once the fish are securely encircled by the net the fishermen attempt to release the dolphins by carrying out a maneuver called "backdown". This involves retrieving about two-thirds of the net from the water, then moving the seiner slowly astern. The net is forced into a long channel and when the seiner reaches a certain speed the water flowing through the seine webbing causes the end section of the net to sink, allowing the dolphins to escape over the top. In effect the net is pulled out from underneath the school. During this maneuver it is usual for some of the crew to assist the dolphins to escape by disentangling animals which get caught in the webbing, and to help others over the corkline. For this operation one man may be in a small inflatable raft inside the net, and one or two others in speedboats which are tied to the net. Despite the efforts at ensuring that dolphins are released unharmed there are, on average, a few killed for each set made on tuna associated with dolphin schools.

Dolphin species involved in the fishery

The three species most commonly involved in the fishery are spotted dolphin (*Stenella attenuata*), spinner dolphin (*Stenella longirostris*), and common dolphin (*Delphinus delphis*). In addition several other species including striped dolphin (*S. coeruleoalba*), bottlenosed dolphin (*Tursiops truncatus*), and others are occasionally involved in the fishery. The three major species are widely distributed in the tropical waters (Rice, 1977) which are also inhabited by yellowfin tuna (Cole, 1981), but only in the eastern Pacific is there a large scale fishery based on the association of yellowfin tuna and dolphins.

In the eastern tropical Pacific several geographical forms of each of the three major species have been recognised (Perrin 1975, Perrin et al 1979, Evans 1975). Based on these forms the National Marine Fisheries Service (NMFS) has established management units for dolphins. The current boundaries of these management units for the three major species (Smith, 1979) are shown together with the distribution of sightings made by technicians aboard purse seiners from 1977-1979 in Figures 4-6. In some cases, for example eastern and whitebelly spinners, the geographical forms are sufficiently distinct and well known to make identification in the field possible. In this case the distributions of the stocks overlap. In other cases, either the forms cannot readily be identified in the field, or insufficient data are available to show ranges of the forms. In these cases management units are based on geographical areas within which a particular form appears to be most common.

Estimates of mortality

The Inter-American Tropical Tuna Commission (IATTC), the NMFS, and the Instituto Nacional de Pesca of Mexico have programs involving the placement of biologists on a sample of the seiners which fish for tuna associated with dolphins. These biologists collect data which are used to estimate abundance and incidental mortality of dolphins, and biological samples which are used for life history studies.

Estimates of total mortality have been made using data giving the numbers of dolphins killed during sampled trips and the total number of sets made on dolphin schools from IATTC logbook information. The estimates are made using ratio estimators and are subject to two sources of error. First, there are sampling errors in estimating average kill rate, and second, there are errors in the estimates of the total number of sets made on dolphins. From 1959 to 1972 there were only 21 observed trips on tuna seiners for which data are available and thus sampling errors are likely to be severe. The problem is aggravated by the uncertainty in how often the backdown procedure was used in the first few years of the fishery. This then gives rise to doubts about how well the sampled trips, all of which were made after 1963, represent all trips during the period. The total number of sets made on dolphins is not known exactly because fishermen do not always provide data on whether a set is made on dolphins or not. In these instances the number of sets made on dolphins is estimated. In the early years of the purse seine fishing set type had to be estimated for slightly more than 50% of all sets on yellowfin while in the years 1977-1979 set type was estimated for about 18% of all sets on yellowfin.

There have been several estimates of historical kills reported in unpublished documents (for example Anonymous, 1976; Smith, 1979; Alverson, MS). These estimates have been made using different procedures and interpretations of the data and consequently differ substantially, particularly for the years 1959-1961 which are most affected by the uncertainty about whether or not backdown was used. In general terms annual mortality was estimated to be in the range of 200,000 to 500,000 for most years in the period 1959-1972. In 1973 and later years the estimates are more reliable because of the increased number of trips sampled. Estimates of mortality by species for this period are shown in Figure 7. For the years 1973-78 these estimates are taken from Smith (1979), and for 1979-1980 from Anonymous (1981).

Impact on populations.

Estimates of the mortality in the 1960's were as high as half a million animals per year. This mortality undoubtedly had a large effect on the dolphin populations. To measure this effect it is necessary to have estimates of the size of the populations, the net reproductive rates, and estimates of incidental mortality.

In recent years the NMFS has conducted several aerial and research ship surveys of the stocks. Based on these, and on data collected by observers on seiners, several estimates of population sizes have been made. These estimates have been made using line transect methods which depend on several assumptions. The most important of these are that all dolphin schools on the line of search are seen, that the distance to the line of search at the time of first sighting can be measured for those not directly ahead, and that the path searched is independent of population density. Without going into details it is clear that all these assumptions might be violated, (Hammond, MS) and thus estimates of the population sizes should be treated with caution. Table 2 shows two sets of estimates of population size in 1979 based on different methods of estimating proportions of species composition for the three major species (Smith, 1979). These estimates are of the order of millions compared to kills of tens of thousands.

Attempts to measure net reproductive rates for dolphins in the eastern Pacific have not been successful. There are no direct estimates of natural mortality. Smith (1979) assumed that for unexploited stocks the gross reproductive rate would be close to the natural mortality rate. Net reproductive rates were then estimated for exploited stocks by subtracting gross reproductive rates for unexploited stocks from those for the exploited stocks. However, the differences found were generally not significant at the 95% confidence level. Thus, estimates of the dynamics of exploited populations have had to be made using assumed values of net reproductive rates which have most commonly been in the range of 0 to 0.06.

The estimates of all the components (population size, mortality, reproductive rates) necessary to assess the impact of incidental mortality are subject to errors which have not been fully assessed. Nevertheless, it seems clear that large kills that have been sustained in the past had a serious impact on some stocks. The most recent assessment of this impact (Smith, 1979) was that eastern spinner dolphins were at about 20% of their pre-exploitation population size, northern offshore spotted dolphins were around 40-50% of pre-exploitation size, and that other stocks were above 60% of their pre-exploitation population sizes.

Management of the tuna-dolphin complex

TABLE 2. Two sets of estimates of 1979 population size using alternative methods of calculation for offshore spotted, spinner, and commmon dolphins in the eastern tropical Pacific Ocean. Numbers in millions.

Offshore spotted dolphin	3.3	2.9
Eastern spinner dolphin	0.3	0.3
Whitebelly spinner dolphin	0.6	0.5
Common dolphin	1.3	3.1

Management responsibilities for the yellowfin tuna and dolphin populations are spread over government agencies of many of the countries involved in the fishery. However the most important management actions have been taken by the IATTC and the NMFS.

The IATTC was established by a convention between Costa Rica and U.S.A. which was implemented in 1950, to carry out research and to make recommendations to member governments for the management of the tuna and associated bait fisheries of the eastern tropical Pacific Ocean. The present members of the Commission are Canada, France, Japan, Nicaragua, Panama and U.S.A. The IATTC management goal for tuna stocks is "...designed to keep populations of fishes at those levels of abundance which will permit the maximum sustained catch". In 1966, in response to IATTC recommendations a quota management system for yellowfin tuna was instituted within the Commission's yellowfin regulatory area (CYRA), and was in effect every year from then until 1979. Although quotas were agreed to by the Commission for 1980 and 1981, member and cooperating governments have been unable to agree on means for implementing them. Thus there was no closed season within the CYRA in 1980, and so far none in 1981.

In 1976 the Commission agreed that it should concern itself with the problems arising from the involvement of dolphins in the purse seine fishery for yellowfin. As its objectives it was agreed that, "(1) the Commission should strive to maintain a high level of tuna production and (2) also to maintain porpoise stocks at or above levels that assure their survival in perpetuity, (3) with every reasonable effort being made to avoid needless or careless killing of porpoise". So far the IATTC involvement has mainly been concerned with carrying out research. Recommendations, principally concerning fishing gear and procedures, have been made by the Commission's staff but these have not yet been responsible for any management actions.

Management of dolphins by NMFS is mandated by the Marine Mammal Protection Act of 1972. The goal of the act is that marine mammals "... should be protected and encouraged to develop to the greatest extent feasible commensurate with sound policies of resource management..." Management actions have been taken to place restrictions on gear and fishing techniques to reduce mortality of dolphins which have been encircled by a purse seine, and to place quotas on some stocks and to prohibit intentional setting of nets on others. The quotas and prohibition of intentional sets on eastern spinner dolphins and other stocks of minor importance to the fishery were implemented in 1977. The NMFS regulations apply directly to seiners under the U.S.A. flag, and indirectly, through the means of import restrictions of yellowfin tuna taken in a manner prohibited for U.S. fisherman, to parts of the international fleet.

Thus the management of the tuna-dolphin complex is being carried out mainly by two agencies with different goals, one to maximize the harvest of one part of the ecosystem and the other with the goal of providing the maximum protection for another part. Furthermore the management has been carried out so far as if the two groups of animals did not interact.

There are two types of interaction that may be considered in the management of yellowfin and dolphins. The first is that yellowfin schools associated with dolphins tend to be composed of larger fish than others. Consequently, fishing for yellowfin in association with dolphins produces a higher yield per recruit than fishing for yellowfin not associated with dolphins. The second type concerns ecological interactions between tuna and dolphins.

Considering only the size composition of the yellowfin catch, the policies of protecting dolphins by reducing the number of sets on dolphins and the management of tuna to maintain catches at maximum levels are not compatible. Figure 8 shows the estimated yield per recruit as a function of fishing effort for two age - specific catchability coefficients. One set corresponds to the age composition of the 1979-1980 yellowfin catches taken in association with dolphins, and the other to the age composition of yellowfin not taken in association with dolphins in the same period. This shows that for low fishing effort the yield per recruit behaves in much the same way for both sets of coefficients, but that for high values of fishing effort the yield per recruit of dolphin-associated fish is higher than that of fish not associated with dolphins. To complete the analysis recruitment should also be considered. Up to now, cohort analysis has not shown any relation between stock and recruitment, but if stocks were to decline a policy of fishing older fish is less likely to cause recruitment problems than one of fishing incoming year classes. These considerations are further complicated by the fact that small yellowfin tuna are often taken in association with skipjack tuna (Katsuwonus pelamis), and that any attempt to move effort from small yellowfin would to some extent reduce the catch of skipjack.

In the late 1960's the purse seine fleet began to fish further offshore and apparently found previously unexploited stocks of yellowfin. To evaluate the impact of this offshore fishery on the yield the IATTC began a policy of setting quotas that exceeded the estimated sustained yields. The rationale was that by overfishing it would be possible to observe a wide range of stock sizes and the parameters of the models then employed could be validated. As a result of this program the stock is estimated to be capable of producing around 175,000 tons per year. Because of the difficulty in achieving agreement on management measures in 1978 and 1979, and the lack of an agreement in 1980 and so far 1981, yellowfin stocks have been reduced below the level at which they could produce the maximum yield. To achieve the IATTC management goals it is thus necessary to allow the stock to recover, either by reducing the total catch or by increasing the yield per recruit.

The management implications of the ecological relation between yellowfin tuna and dolphins can only be speculated about because the nature of the interactions between the two groups are largely unknown. The most obvious explanation for the association, mentioned by several authors, is the possibility that it is based on feeding, for example yellowfin tuna may be following dolphins to take advantage of their presumably superior food finding abilities.

There have been several studies of the diet of both yellowfin tuna and dolphins based on stomach contents. Alverson (1963) examined the stomach contents of yellowfin tuna and reported the average content by volume to be fish 47%, crustaceans 45%, and cephalopods 8%. The fish Alverson examined were mostly captured by baitboats and were all taken close to the coast of Central and South America during the period 1957 to 1959. A more recent study by R.J. Olson of yellowfin tuna captured by purse seiners in 1970 and 1971 (Anonymous 1979) showed fish making up 90% by volume of stomach contents. In particular *Auxis* species which made up less than 6% in Alverson's samples made up about 50% of the stomach contents in the later samples. These differences may be due to the different areas sampled, as the latter study involved yellowfin from offshore areas in which dolphins and yellowfin frequently associate.

Fitch and Brownell (1968) studied feeding habits of five spinner dolphins and three spotted dolphins which had been taken in association with yellowfin tuna in the eastern Pacific. On the basis of the stomach contents they concluded that the spinner dolphins had been feeding at 250 m or more below the surface, and that the spotted dolphins had been feeding within 30 m of the surface. Perrin et al (1973) examined the stomach contents of spotted dolphins, spinner dolphins, and yellowfin tuna which had been taken in twelve purse seine sets during the period 1968-1970. The overlap of species in the stomach contents was greatest between yellowfin tuna and spotted dolphins which both included ommastrephid squids, *Auxis* sp., and epipelagic exocoetids as frequent items in their stomachs. Ommastrephid squid were also common in stomachs of spinner dolphins. Mesopelagic fish were frequently found in the spinner dolphin stomachs but were not frequent in the stomachs of either yellowfin tuna or spotted dolphins. Crustacea were a frequent item in yellowfin stomachs but were not found in the dolphin stomachs. Among the fish species frequently found in the stomachs of spinner dolphins but rarely in spotted dolphins by both Perrin et al (1973) and Fitch and Brownell (1968), was a mesopelagic gonostomatid, Vinciguerria sp. which was also at times common in yellowfin stomachs sampled in 1970 and 1971 (R.J. Olson, unpublished data) Yellowfin are taken by longliners in the eastern Pacific at depths of 100 m (Suzuki et al. 1968) and thus there is the potential for an overlap in consumption of mesopelagic fauna by spinner dolphins and yellowfin. The relative proportion of empty stomachs among the three species taken in the same set indicated that spinner dolphins did not feed at the same time as spotted dolphins and yellowfin tuna. This is consistent with the observation by Norris and Dohl (1980) that spinner dolphins feed at night, and by Schaefer et al. (1963) that yellowfin tuna feed during the day. However, apparent night time feeding behavior in spotted dolphins in the eastern Pacific (Leatherwood and Ljunblad, 1979) and off Hawaii (Shomura and Hida, 1965; Scott and Wussow, MS) has been reported.

There have been reports of dolphins eating yellowfin tuna in the Atlantic Ocean. (Le Guen, unpublished data; Savini, unpublished manuscript). This is not known for the species involved in the fishery in the eastern Pacific.

In summary there is some overlap in the diets of yellowfin tuna and both spotted and spinner dolphins. However, because yellowfin and dolphins are opportunistic feeders the dietary overlap could be a result of their association rather than a cause. The feeding association alone does not provide decisive evidence for either competition or facilitation among the species. Feeding competition would only be important if food were a limiting resource for one or more of the species. Furthermore, if local abundance of prey were critical competition might be avoided by using different feeding strategies, for example feeding on different sized prey as noted by Perrin et al. (1973). Sharp and Francis (1976) speculated that large yellowfin tuna (>40 cm) are not food limited based on the results of energetic modelling of yellowfin tunas and the observed density of potential prey organisms.

An alternative view of the relation between yellowfin tuna and dolphins is that it is similar to the relation that exists between yellowfin tuna and floating objects. Floating objects such as trees, dead whales, buoys and small pieces of rope at times have schools of yellowfin and other fishes associated with them, and in fact this association is important for a substantial part of the catch of both yellowfin and skipjack tunas. Again the reasons for the association are unknown, but in this case the potential interactions clearly would not include competition.

If there are strong ecological interactions between yellowfin tuna and dolphins these should be considered in setting and implementing management goals for future changes in population sizes. Figure 9 shows the recent history of offshore spotted dolphin and yellowfin tuna population sizes as estimated by Smith (1979) and Anonymous (1981).

The yellowfin fishery was confined to within a few hundred miles of the coast prior to 1966, and subsequently expanded offshore reaching the edge of the CYRA in 1969. Thus estimates of the abundance of stocks which are currently exploited based on catch rates or cohort analysis cannot be made for the early years of the purse seine fishery. The estimates in Figure 9 were made using cohort analysis and show biomass both of large yellowfin which form the bulk of the fish associated with dolphins, and all yellowfin. Both estimates show much the same changes which reflect fluctuations in year class strength and removals by the fishery. In particular, the 1974 year class was large and was followed by poor recruitment in 1976 and 1977. Overall the estimates show a decline in stock size caused by the increased catches during the period.

The population estimates for offshore spotted dolphin are inferred from estimates of 1979 population sizes and the history of mortality. In making the estimates shown here it was assumed that there was only one stock. However, very high mortalities in the early years only involved animals close to the coast, and consequently the pattern of decline was probably more severe in inshore water than offshore. To quantify this difference it would be necessary to estimate the rate of mixing of dolphins from different areas.

The present management goals are to maintain dolphin populations at or above the levels which allow maximum net reproduction (NMFS) and for the yellowfin population to grow only slightly from the current size (IATTC). If the dolphin species and yellowfin are in competition the growth of dolphin populations would be detrimental to the yellowfin stocks whereas if dolphins assisted yellowfin to locate food the growth of dolphin populations may be beneficial for yellowfin. Similar arguments relate the effect of yellowfin management upon the achievement of the goals of dolphin management.

What does our present knowledge about the relation between yellowfin tuna and dolphins contribute to the management of the yellowfin-dolphin complex? The question of the relation between the yield per recruit of yellowfin and fishing yellowfin either associated with, or not associated with dolphins is simply a matter of how societies value protecting dolphins compared to catching tuna as an industry. Roughly one dolphin is killed for each three tons of yellowfin taken on dolphins. Purse seining on yellowfin not associated with dolphins at most produces 84% of the yield per recruit that could be taken from fishing yellowfin associated with dolphins. This latter comparison of course ignores the question of whether the fisheries are interchangeable and the contribution of skipjack to the fishery.

The question of the effect of ecological interaction on management must, because of lack of knowledge, remain open. In the absence of information about the effect of any species upon another in the complex, there seems to be no good reason to modify existing management plans to try to take account of interactions. However this should be done recognizing our ignorance, rather than by assuming that such interactions are unimportant. Research directed towards answering questions about possible effects of interactions should be actively pursued with the goal of producing more certain management.

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Figure captions

Figure 1. Catches of yellowfin tuna in the eastern Pacific Ocean in 1980 by 1 degree squares for all trips for which usable logbook data were obtained.

Figure 2. Length frequencies of yellowfin tuna from sets made in association with dolphins and sets not in association with dolphins, 1976-1980.

Figure 3. Areas of the eastern Pacific Ocean where fishing has been primarily for yelowfin associated with dolphin (hatchet) and yellowfin not associated with dolphins striped, 1976-1980.

Figure 4. The distribution of sightings of spotted dolphins by technicians on purse seines, 1977-1979.

Figure 5. The distribution of sightings of spotted dolphins by technicians on purse seiners, 1977-1979.

Figure 6. The distribution of sightings of common dolphins by technicians on purse seiners, 1977-1979.

Figure 7. Estimates of dolphin mortality incidental to purse seining, 1973-1980.

Figure 8. Yield per recruit of yellowfin for two age specific catchability vectors ( ) typical of fishing in association with dolphins, ( ) typical of fishing schools not associated with dolphins.

Figure 9. Estimated changes in population size of spotted dolphins and yellowfin tuna over the perid 1959-1980.

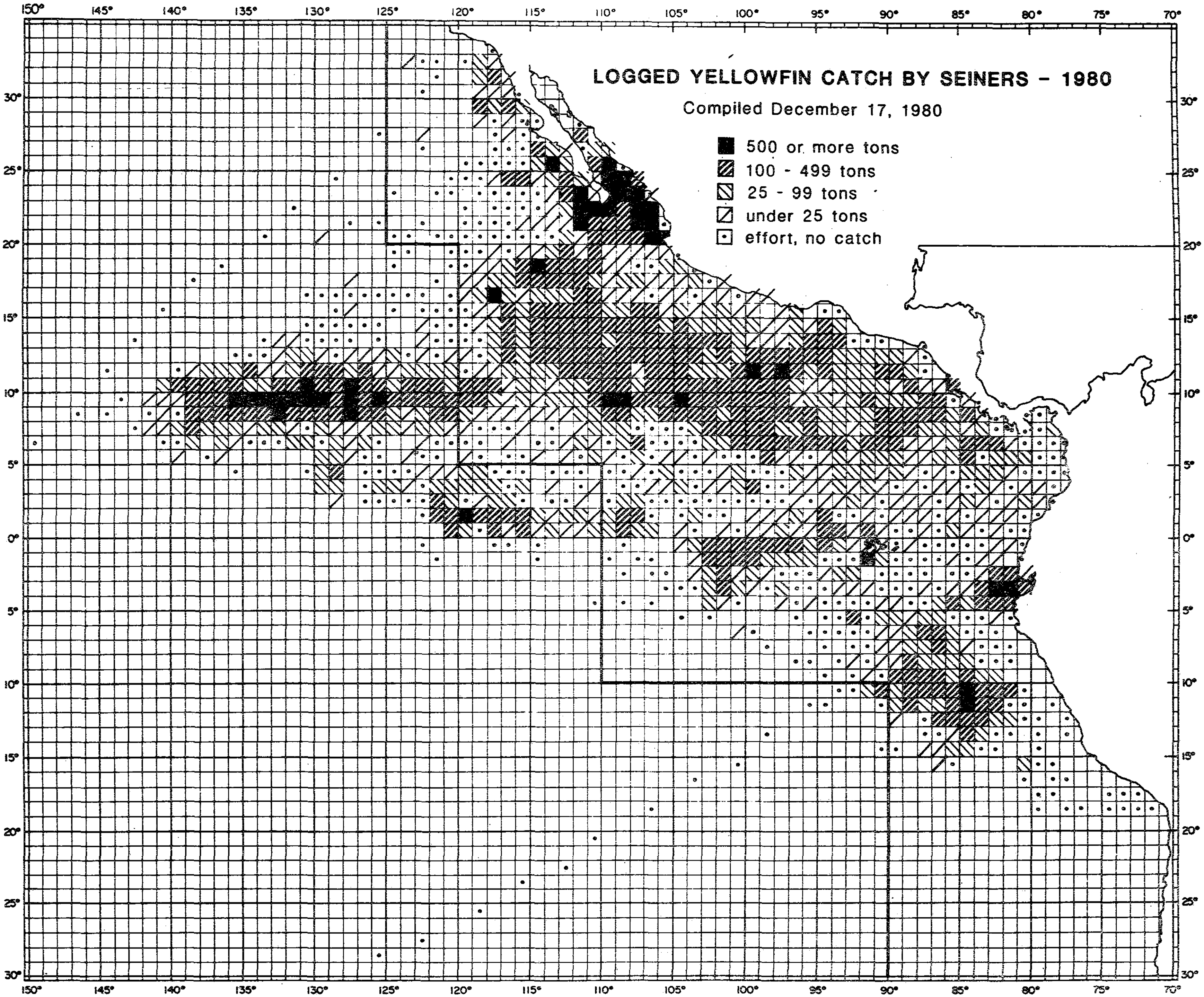

FIGURE 1. Catches of yellowfin tuna in the eastern Pacific Ocean in 1980 by 1 degree squares for all trips for which usable logbook data were obtained. The Commission's Yellowfin Regulatory Area (CYRA) is east of the heavy black line.

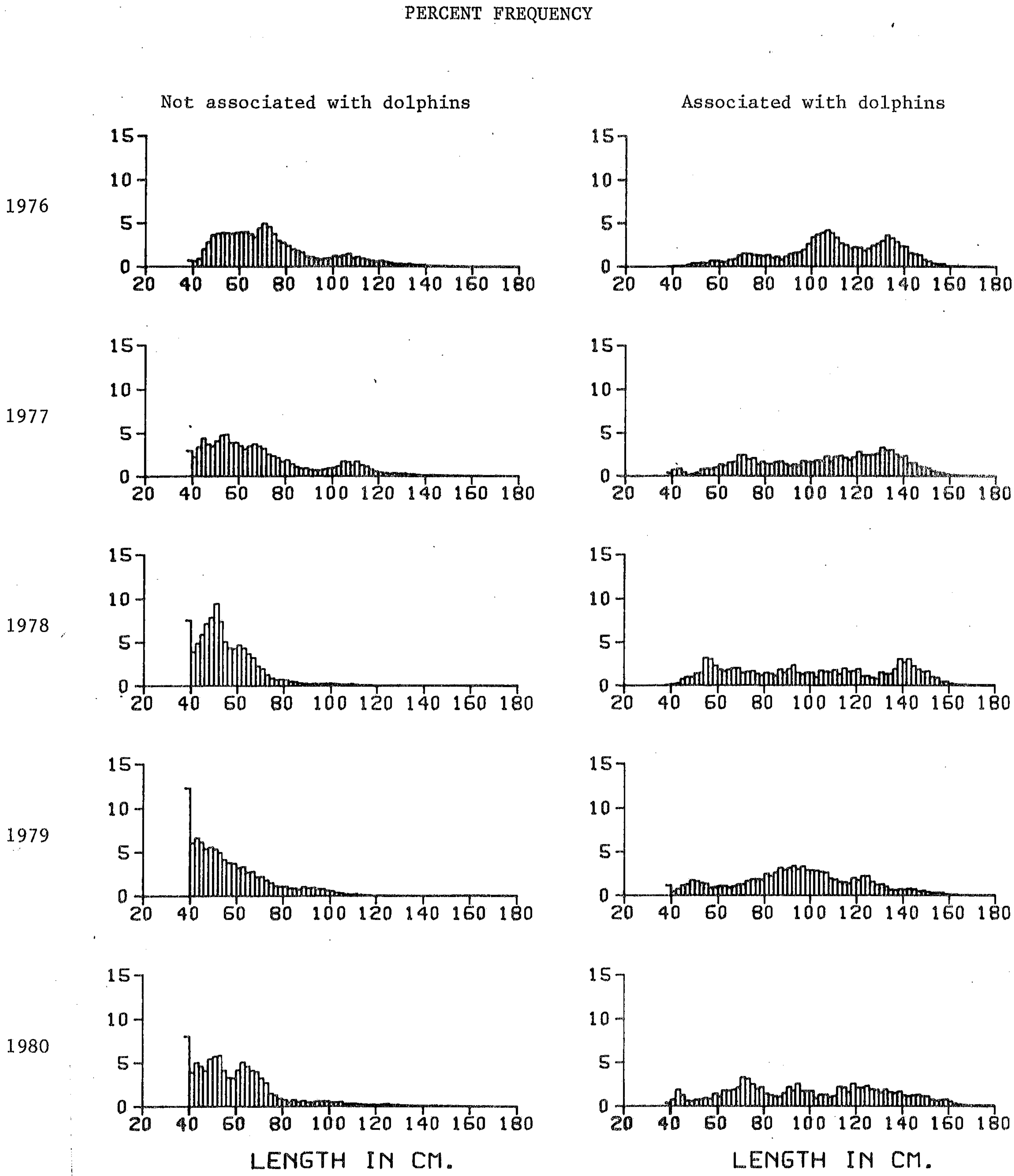

FIGURE 2. Length frequency of samples of yellowfin tuna taken by purse seiners either in association with or not in association with dolphins.

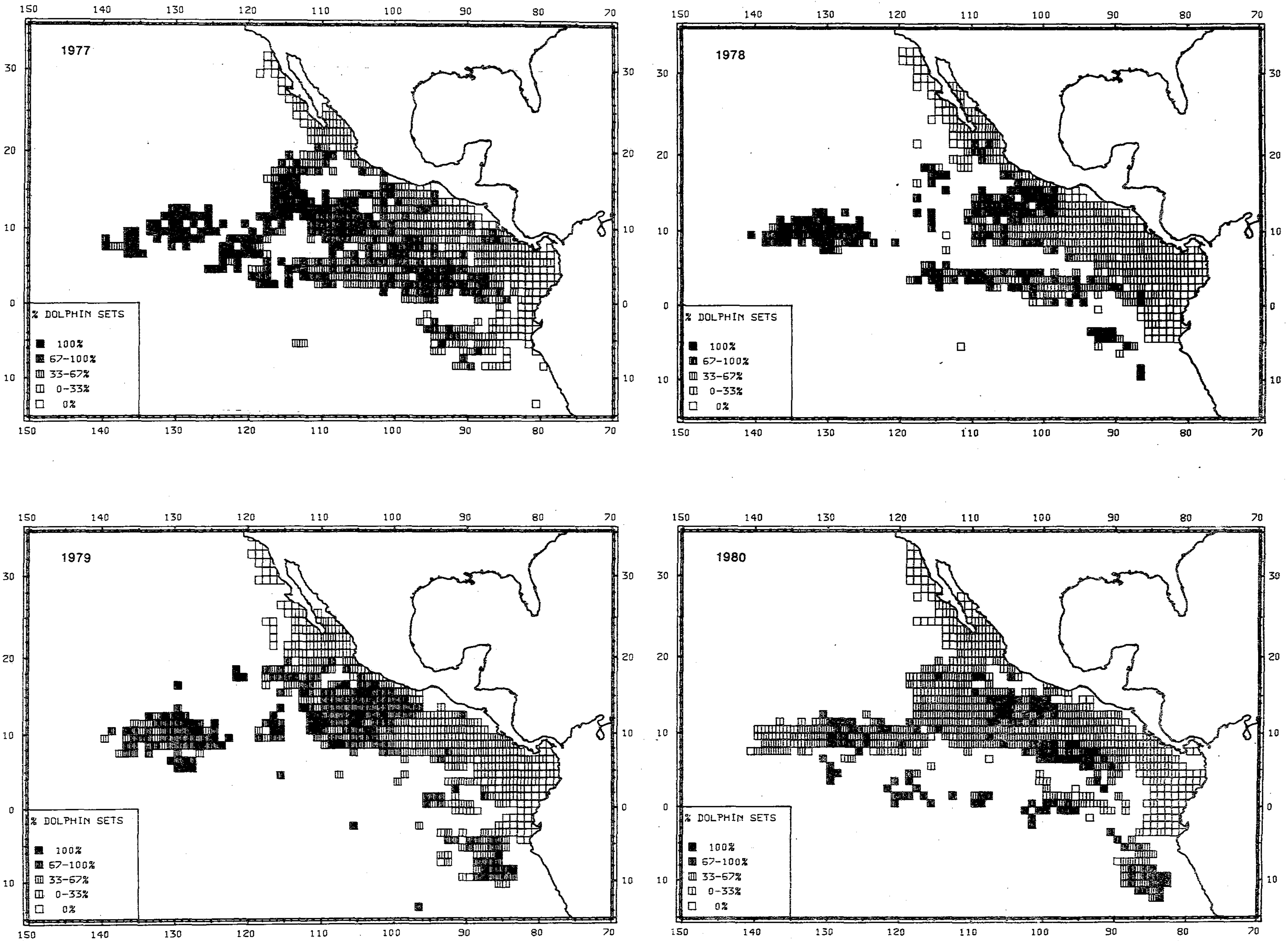

FIGURE 3. Proportions of purse seine sets which were made on dolphin schools, 1977-1980.

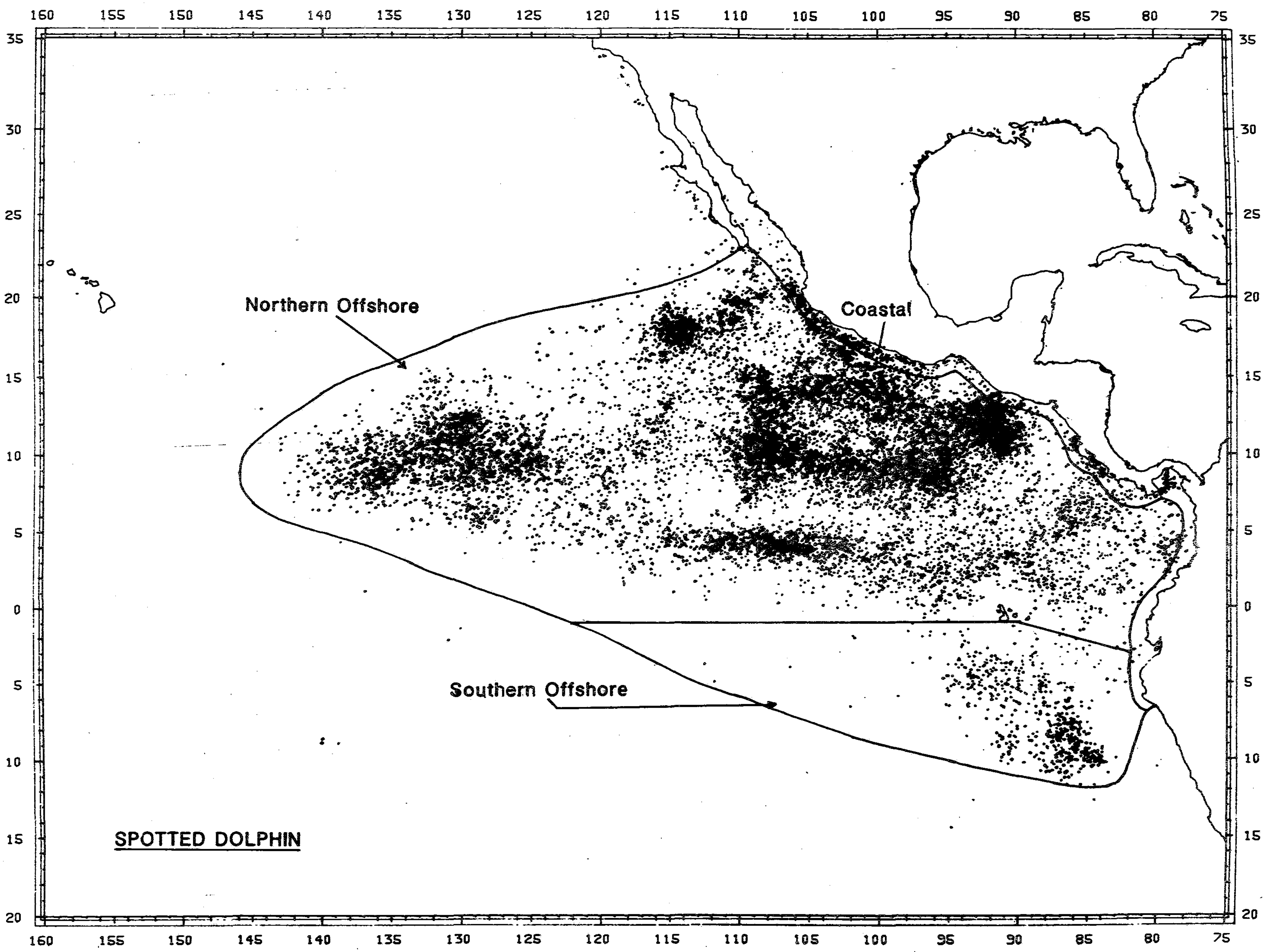

FIGURE 4. The distribution of sightings of spotted dolphins by technicians on purse seiners, 1977-1979.

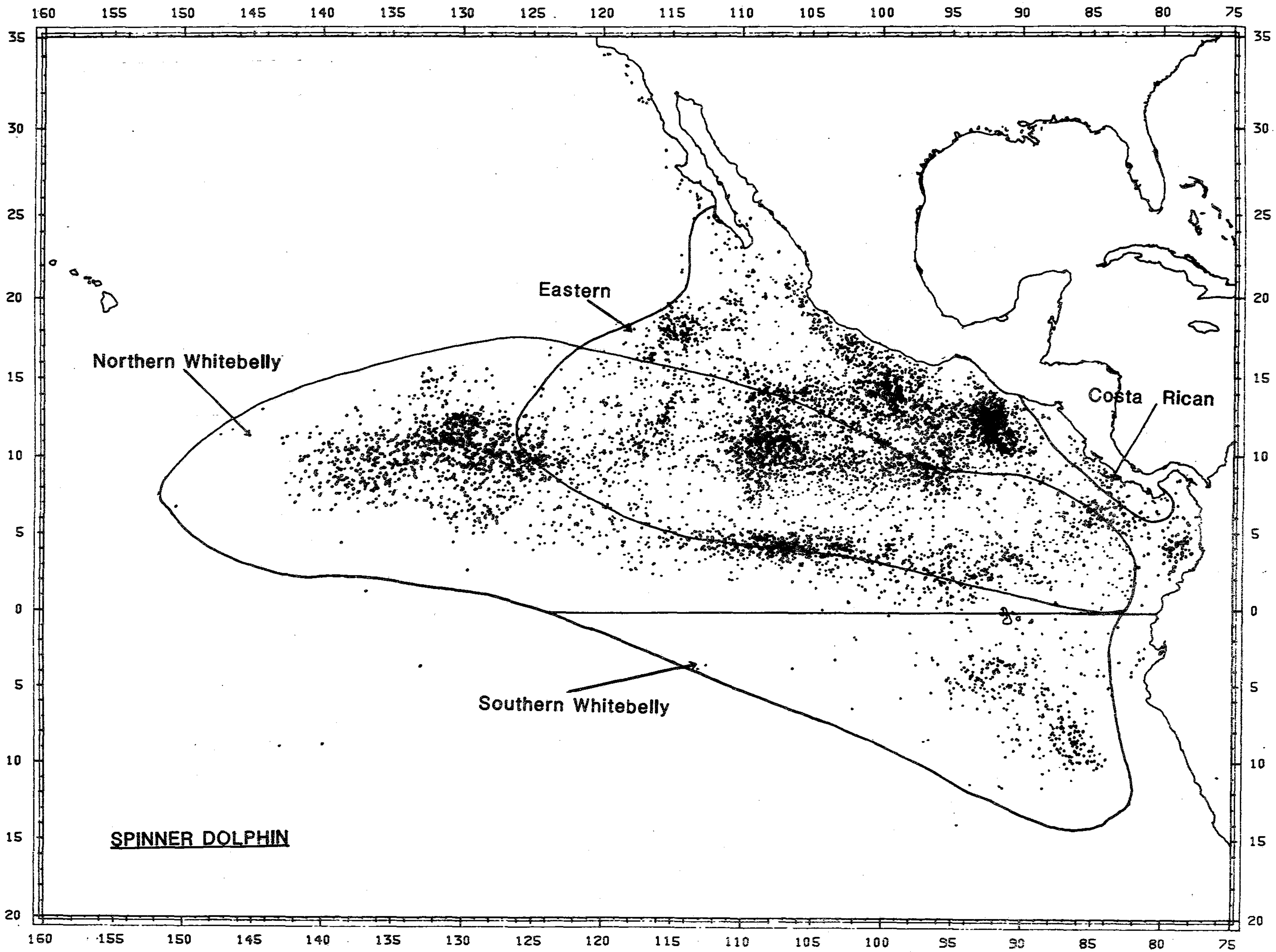

FIGURE 5. The distribution of sightings of spinner dolphins by technicians on purse seiners, 1977-1979.

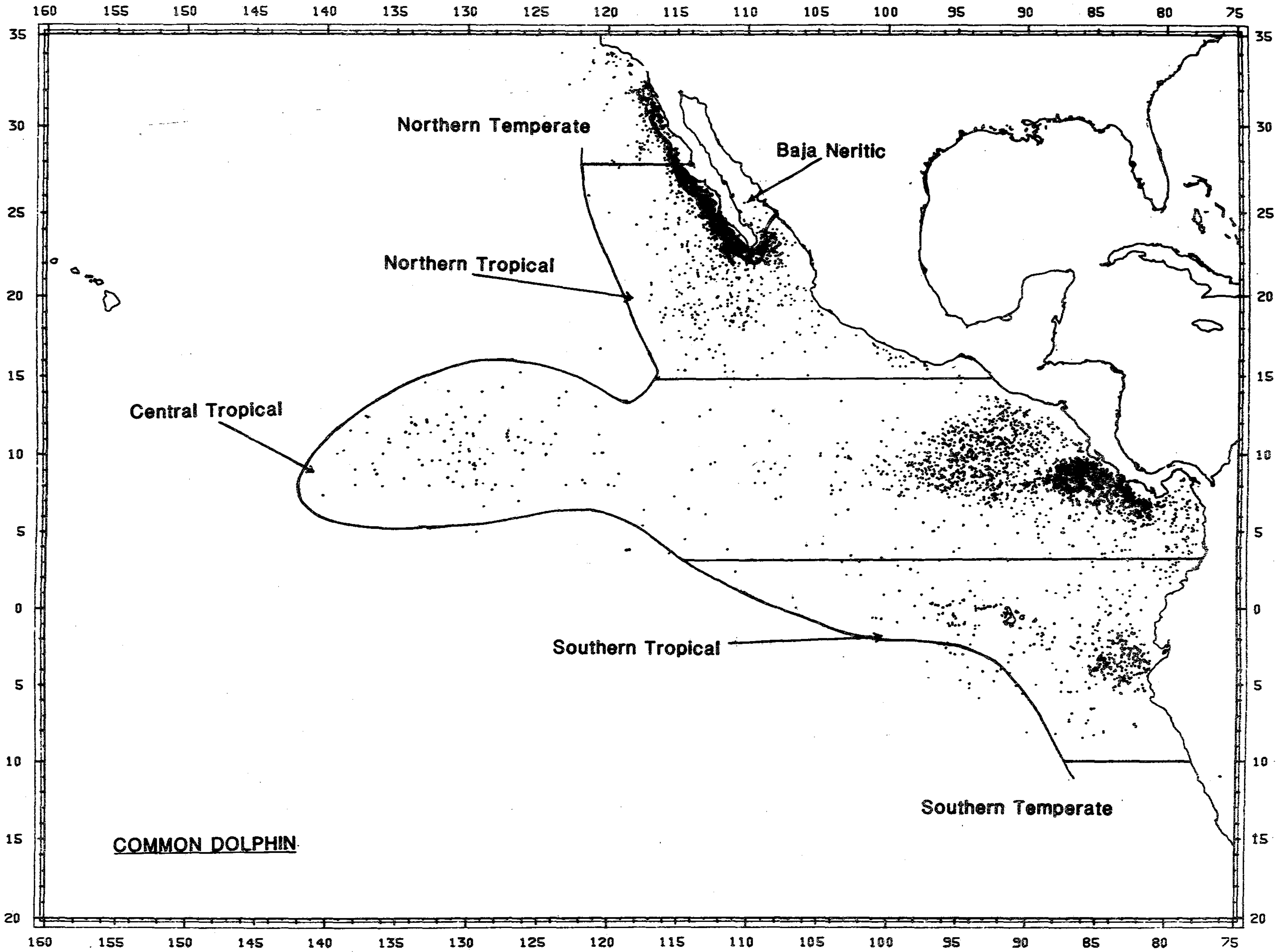

FIGURE 6. The distribution of sightings of common dolphins by technicians on purse seiners, 1977-1979.

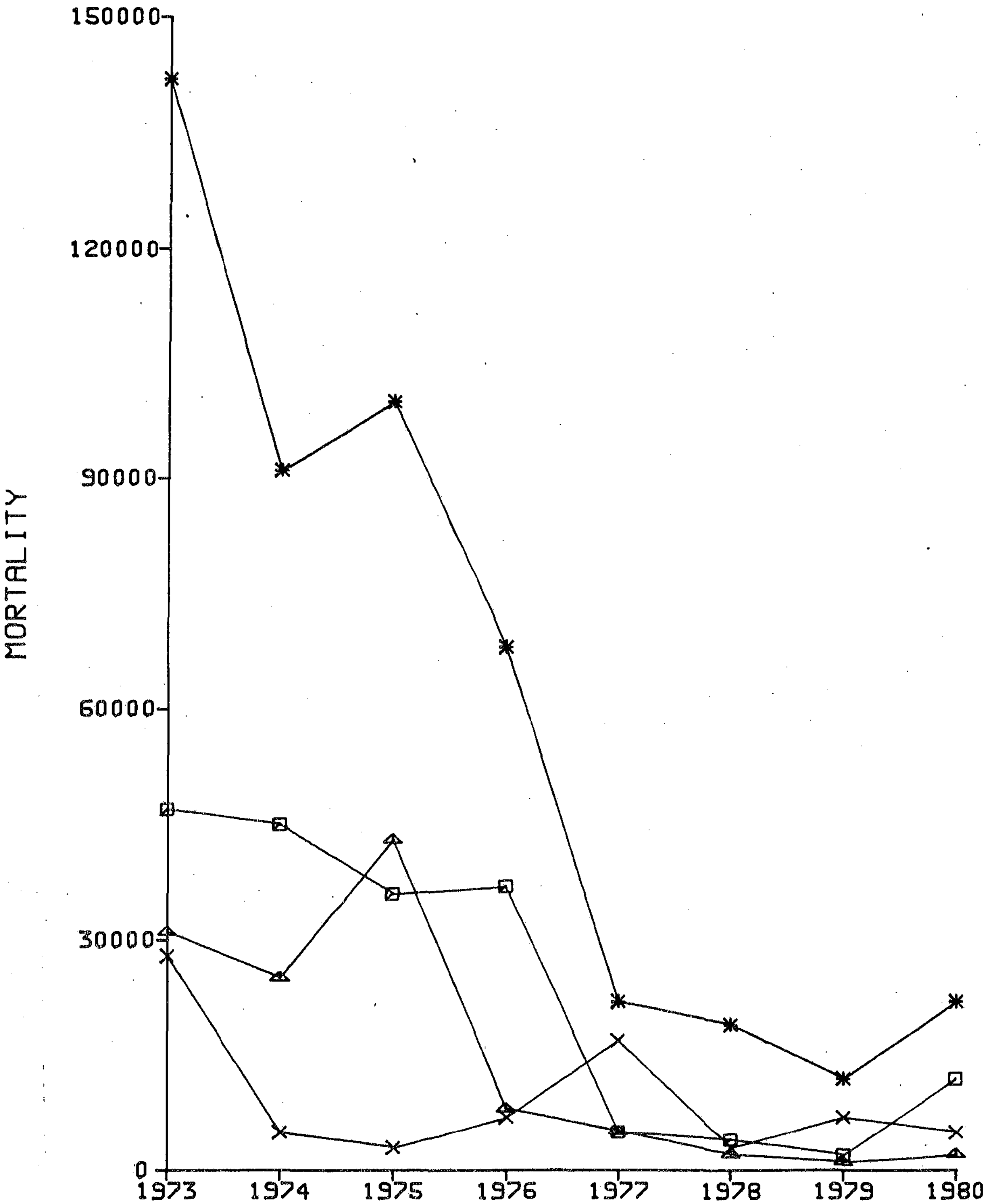

FIGURE 7. Estimates of dolphin mortality incidental to purse seining, 1973-1980. ✱ offshore spotted, ⊡ whitebelly spinner, △ eastern spinner, × common dolphin.

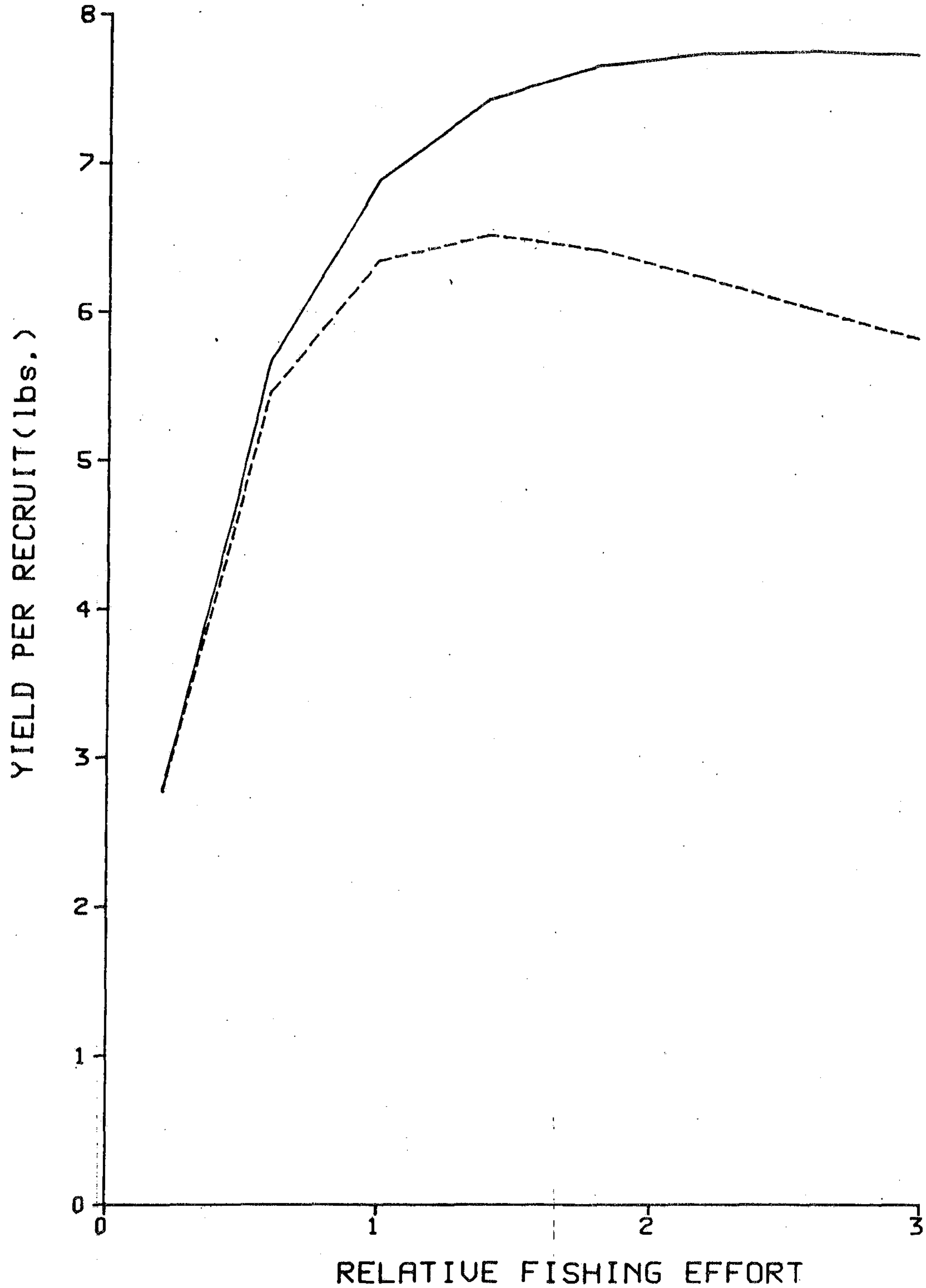

FIGURE 8. Yield per recruit of yellowfin for two age specific catchability vectors, (———) typical of fishing in association with dolphins, and (– – –) typical of fishing schools not associated with dolphins.

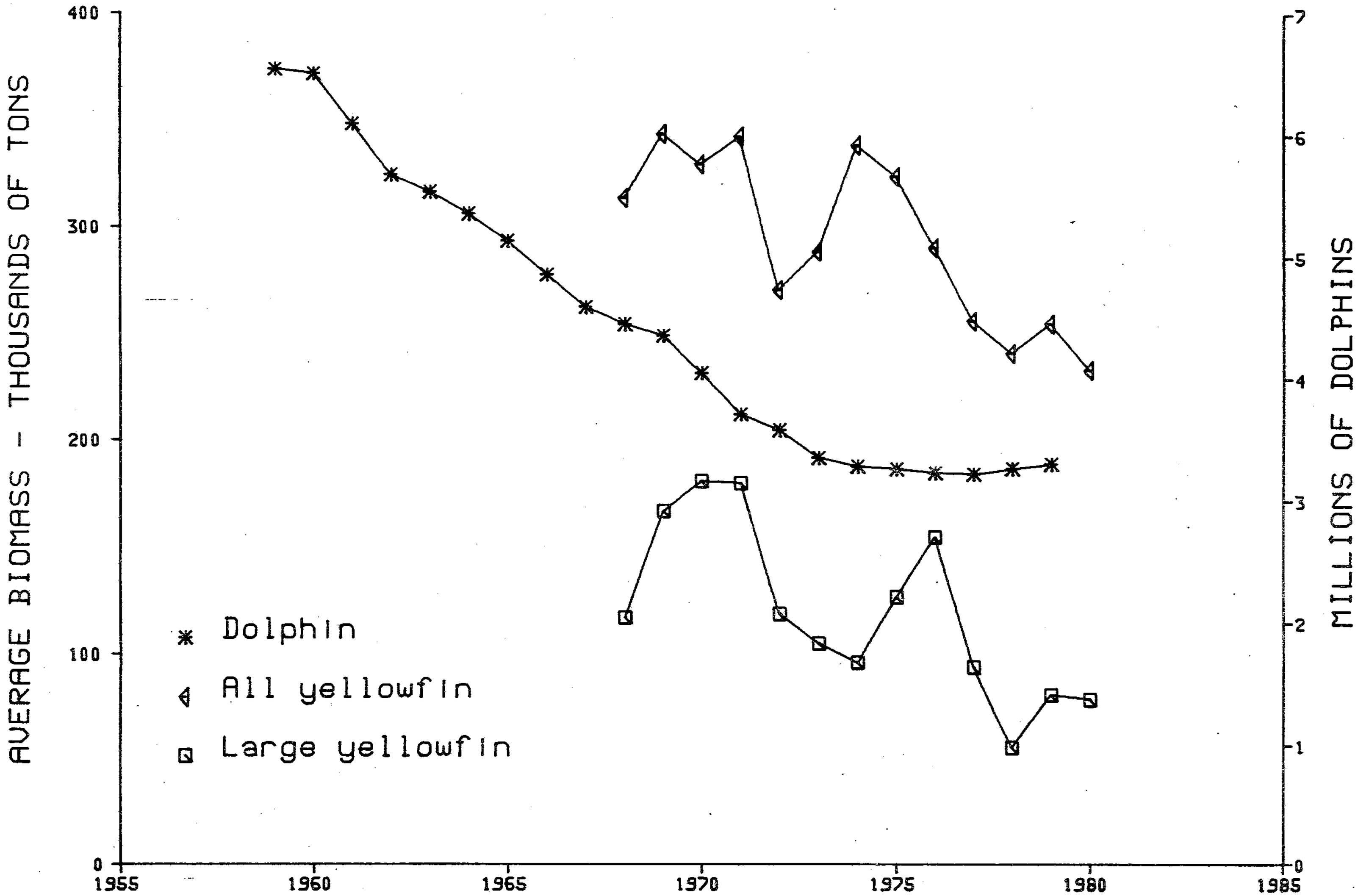

FIGURE 9. Estimated changes in population size of spotted dolphins and yellowfin tuna over the period 1959-1980.