AN ESTIMATION OF PAPUA NEW GUINEA'S TUNA FISHERIES POTENTIAL

R. E. Kearney
South Pacific Commission
Noumea, New Caledonia

Abstract

The catches of tuna, predominantly skipjack Katsuwonus pelamis (Linnaeus), by Papua New Guinea have increased in recent years to 41,780 tonnes in 1974. The available catch and effort data, tagging results and other biological and aerial survey information indicate that the future yields of skipjack from the waters adjacent to Papua New Guinea can be anticipated to increase, perhaps, the author suggests, to approach twice the present levels. There is evidence that the baitfish resources of Papua New Guinea, if used rationally, are adequate to support these increased catches.

The resources of yellowfin tuna Thunnus albacares (Bonnaterre), bigeye tuna Thunnus obesus (Lowe), long-tailed tuna Thunnus tonggol (Bleeker) and mackerel tuna Euthynnus affinis (Cantor) have been briefly discussed in the light of the very limited available data.

INTRODUCTION

In 1969 Papua New Guinea's total tuna landings were probably less than 100 tonnes. In just a few years the country has developed into a major tuna fishing nation with the 1974 skipjack (Katsuwonus pelamis) landings of 40,350 tonnes ranking third behind only Japan and the United States of America (FAO 1975). This rapid expansion has greatly stimulated interest in skipjack and tuna fisheries in the region and has resulted in considerable speculation about the size and yield potential of the resources. The newness of the Papua New Guinean fishery and the extreme fluctuations in total annual landings to the end of 1974 make it difficult to accurately assess the potential of the resources. However, as a result of an intensive research programme commenced within the Department of Agriculture, Stock and Fisheries in Papua New Guinea, in March 1971, the data base is now comparable to many more mature fisheries, and some resource evaluation is possible.

Because skipjack dominate the tuna landings in Papua New Guinea, other tuna species have been the subject of much less research and thus less is known about their potential. Nevertheless, there is a great deal of scientific and commercial interest in these other tuna species, particularly yellowfin tuna (Thunnus albacares), bigeye tuna (Thunnus obesus), long tailed tuna (Thunnus tonggol), and mackerel tuna (Euthynnus affinis) each of which has been the subject of investment negotiations. Resource estimates, even though preliminary, are therefore required.

SKIPJACK

Four basic techniques were employed in the study of the skipjack fishery in Papua New Guinea:

(i) A detailed analysis of catch and effort data.

(ii) Tagging and biological studies.

(iii) Aerial surveys of surface schools.

(iv) Detailed studies of the main bait species and the interaction between bait and skipjack catch.

The methods employed in these studies have been previously described (Kearney, 1974b) and many of the results on each aspect have been presented elsewhere. In the present study, these results are combined with some additional data to present a more comprehensive appraisal of the skipjack resource.

Catch and Effort Data from the Papua New Guinean Fishery

As commercial skipjack fishing only commenced in Papua New Guinea in 1970, the number of data available on fluctuations with time, of total catch and catch per unit of effort, CPUE, are limited. On the other hand, the data which are available are accurate and extremely detailed because of the nature of the joint-venture fishing agreements which enabled the Government to ensure that each fishing company supplied all relevant catch information.

All catch and effort data from the live bait and pole fishery have been compiled from daily catch returns submitted by each catcher vessel. These are computed to produce catch and effort statistics for each vessel, company or 1-degree square by each moon phase, month or year (Kearney, 1974b). Only data collated by month and year are considered in this report and annual summaries are presented in Table 1.

Table 1

Estimation of unit effort

As with other tuna fisheries a precise definition of unit effort has proven difficult. Almost all of the skipjack catches registered in Papua New Guinea were taken by live bait and pole vessels, and with the exception of a very small quantity taken by a single Californian vessel, all of these catches were made by vessels of standard Japanese design. As these vessels varied in length from 18.4 to 38.5 metres, and crews ranged in number from 15 to 33, detailed analyses of the relative fishing power of vessels of different sizes were undertaken. Surprisingly, these analyses revealed that while there was considerable variation in the fishing power of the vessels of the fleet, this variation was not correlated with either the size of the vessel or the number of the crew (Kearney, manuscript in preparation). It is probable that the observed variations in fishing power were largely attributable to the skill of the crews involved. Possibly the necessity to return to harbour each night to catch bait, brought about by the fragility of the common bait species (Smith, 1974), negated much of the advantage normally attributed to larger vessels.

A day's fishing by each vessel has been adopted as the unit of effort and because of the comparative uniformity in the fishing power of vessels of varying size, no data manipulation to standardize effort was effected. A fishing day was considered to be any day on which a catcher boat had sufficient bait to warrant fishing and did in fact proceed to the skipjack fishing grounds. No differentiation has been made between days and parts of days, all being considered as one unit of effort.

Geographical distribution of effort and catch

The most commonly used baitfish in the Papua New Guinean skipjack fishery have been several species of Stolephorus anchovies. While these species have been found to be excellent for attracting skipjack, their fragility and subsequent high mortalities when transferred to bait tanks has hampered expansion of the fishery by forcing fishing vessels to catch bait every night. This coupled with the lack of refrigeration on most catcher vessels has restricted skipjack fishing generally to within 100 km of the bait fishing grounds.

Arguing that overexploitation of the known bait resources was possible, each of the four joint venture companies applied for, and was granted a coastal area (20 mile radius) for

Table 2

its exclusive use as a baitfishing zone (Table 2). This has not only segregated the baitfishing efforts of the four companies, but has effectively given each company a discrete skipjack fishing area with little competition between vessels of any two companies (Kearney, 1975a). Therefore, the area of operation of the Papua New Guinean skipjack fleet can effectively be divided into four units adjacent to the respective baitfishing areas of the four companies. For ease of discussion these companies and their respective areas are referred to as A, B, C, or D, and the locations

Fig. 1 of their baitfishing areas are given in Fig. 1.

Because of their geographical isolation and the obvious differences in the total catch and catch per unit of effort between the various areas, statistics from each company have, in the main, been treated separately. Summaries of the variation in total catch, total effort and CPUE with time, and with each other, for all four companies are given in

Table 3 Table 3.

Several interesting trends are apparent from the catch and effort relationships:

1. There have been great fluctuations in the average skipjack CPUE for each company (Table 3).

2. All companies experienced comparatively bad fishing in 1972 and early 1973 when the average catch per day fell (Fig. 2) to less than 3 tonnes (Figure 2). The remaining periods produced overall average catches approximating four tonnes per day (Table 1). This one period of unusually poor fishing has resulted in extreme variation in average daily catch on a year-to-year basis.

3. Companies A and B have consistently enjoyed better fishing than the other two companies (Table 3).

4. In general, total catch has tended to increase (Fig. 3 and 4) proportionally with total effort (Figures 3 and 4). There has been no decrease in the CPUE as total effort increased.

5. Total catch per year is still increasing and to the end of 1974 had shown no indication of reaching an asymptotic level.

The steady increase in total catch with increased effort in each of the fishing grounds, and the high degree of correlation of the available data with this linear relationship (Figures 3 and 4) show that the available catch and effort data are of little, if any, value in predicting upper limits in yield from the Papua New Guinean skipjack fishery using methods such as those of Schaefer (1957).

Catch and Effort Data from Adjacent Fisheries

Table 4

A joint-venture skipjack fishery similar to that in Papua New Guinea has been operating in the Solomon Islands since 1971. Table 4 summarizes the catches from this fishery. While tag recapture data shows there is some intermingling of fish between Papua New Guinean and Solomon Islands fisheries, insufficient data has been accumulated to enable description of the stocks from each area or to determine if the abundance of fish in either area is detectably influenced by the fishing pressure in the other.

The fluctuations in the catch per unit effort from year to year in the Solomon's fishery parallel those from Papua New Guinea and similarly show no long-term tendency to decrease with increase in effort.

Potentially more influential on the catch rates in the Papua New Guinean fishery is the Japanese long-range, southern water skipjack fleet. Since 1970 this fleet has continually increased its fishing effort, and subsequent skipjack catches in the waters south of 20°N, and intensively fishes the waters surrounding Papua New Guinea on a seasonal basis

Table 5

(Tohoku Regional Fisheries Research Laboratory, undated; Tanaka, undated). Table 5 gives the recent catches of this fleet within FAO statistical area 71, which is effectively that south of 20°N.

It is difficult to estimate what fraction of the catch in Table 5 is taken from waters adjacent to Papua New Guinea, but from the published atlases of southern fishing grounds (Tohoku Regional Fisheries Research Laboratory, undated; Tanaka, undated), Kearney (1976) has estimated that between 20,000 and 30,000 tonnes were captured within 200 miles of Papua New Guinea in 1974. While some competition for fish between the Papua New Guinean and Japanese fleets can be assumed to occur, it is impossible at this time to determine if either fleet is operating to the detriment of the other. What is demonstrated is the importance of considering Papua New Guinea's fishery statistics in the context of other fisheries operating on the same stocks. A resource of a magnitude much greater than current catches in Papua New Guinea is clearly indicated.

Tagging and Biological Studies

At the commencement of the Papua New Guinean skipjack research programme in 1971, tagging was adopted as a major research strategy (Kearney et al., 1972). It was hoped that the release of 10,000 tagged skipjack and the subsequent recapture information would provide a description of the major movements of skipjack in the area and enable growth parameters and mortality rates of skipjack in the region to be estimated. The methods employed in these tagging experiments have previously been described in detail (Kearney et al., 1972; Lewis et al., 1974).

To the end of 1974, 8,748 tagged skipjack had been released in the Bismark Sea by the Department of Agriculture, Stock and Fisheries, and 593 of these had been recorded as recaptured. Recaptures were recorded from as far away as the Marshall Islands, Irian Jaya, Palau and the Solomon Islands. In addition, 254 tagged skipjack were released in the northern Solomon Sea, south of New Britain, and 615 in the Coral Sea, off the southern Papuan coast. Five recaptures have been recorded from Solomon Sea releases, but only two from those released in the Coral Sea.

Lewis (unpublished manuscript) analyzed in detail the returns from fish released in 1972 and detected two distinct migratory patterns: (i) "a northward emigration out of the Papua New Guinea area relatively soon after recruitment." Additional unpublished recapture data on tagged skipjack released in the vicinity of Papua New Guinea (Department of Primary Industry, Papua New Guinea, unpublished data) together with data from fish released between 10^{o}N and 20^{o}N and recaptured in Papua New Guinean waters (Tohoku Regional Fisheries Laboratory, unpublished data) clearly indicates that the major peaks in abundance of skipjack in Papua New Guinea are a result of the immigration of fish from further north. The lack of tagging in other areas has made it impossible to evaluate, or even detect, immigration of skipjack from the south or east, and (ii) "a clockwise movement around the eastern half of the Bismark Sea, with fish retracing this same route to pass out of the Bismark Sea up to two years later." Lewis further indicated the presence of two distinguishable groups of skipjack (designated alpha and beta) which could not definitely be aligned with the A and B groups postulated by Fujino (1972).

Additional unpublished data from later tag releases within Papua New Guinea strengthens the hypothesis of at least two distinguishable groups (Department of Primary Industry, Papua New Guinea, unpublished data) and supports the migratory routes outlined by Lewis.

Preliminary estimates of the growth rates and L_∞ of skipjack in the vicinity of Papua New Guinea were presented as unpublished data at the 1974 Lake Arrowhead (U.S.A.) Tuna Conference (Kearney, 1975b). These estimates of growth of 7 cm per year and L_∞ of 65 cm are both much lower than those previously reported for other skipjack fisheries (Joseph & Calkins, 1969) and their possible significance has been previously described (Kearney, 1975b). No additional information is available at this time.

Reliable estimates of total, natural or fishing mortalities are not possible from the limited data available. Lewis (personal communication, 1975) suggests that a selection of tagging locality, coupled with the present knowledge of the migratory patterns of the skipjack being tagged, enables prediction of the probable percentage recovery of selected batches of tagged fish. However, insufficient fish have been tagged over the whole range of distribution of the species to give any comprehensive assessment of the dynamics of the skipjack resource as a whole, particularly appreciating that several sub-populations are thought to exist. The tag return data indicates that fishing mortalities are not substantially higher than in other skipjack fisheries.

Published data on the biology of skipjack from Papua New Guinean waters are very limited. The only detailed study is that by Lewis et al. (1974) and even in this case, the data is restricted to 1,779 individual fish collected over a limited time period (approximately one year). However, this data, together with available as yet unpublished results (Department of Primary Industry, Papua New Guinea), clealry shows that the skipjack catch from Papua New Guinea is comprised of fish weighing between 2 kg and 6 kg, with individuals above this range being extremely rare. The absence of very large fish indicates that all skipjack taken are from Fujino's (1972) postulated western Pacific population (Kearney, 1975b).

The indications given by Lewis et al. (1974) that (i) at least some skipjack spawning occurs throughout most of the year, and (ii) the size at first maturity is slightly in excess of 45 cm, or smaller than the average size of the fish taken, have been confirmed by more recent unpublished data (Department of Primary Indsutry, Papua New Guinea). If intermittent spawning, or multiple spawning activity each year, does occur, then the resultant involved relationship between the abundance of adults and subsequent recruitment will make estimation of future yields by existing methods even more difficult.

An analysis of the average size of skipjack taken at various localities within the Papua New Guinean fishery

Fig. 5 (Figure 5) emphasizes the comparative stability at each locality. This regularity in average size in consistent with the hypothesis of frequent spawning with regular recruitment into the various fishing grounds. It also supports the hypothesis that one part of the stock being fished undergoes a clockwise migration after entering the fishery at its north-eastern extreme.

There now appears little doubt that the skipjack stocks in the western and central Pacific Ocean are comprised of two or more populations (Fujino, 1972; Kearney, 1975b). Lewis (unpublished manuscript) indicates the presence of two groups in the vicinity of Papua New Guinea as does Fujino (1972), while Sharp (G.D. Sharp, personal communication, 1976), using biochemical genetics suggests that perhaps as many as four sub-populations are taken in the Papua New Guinea fishery alone. It would appear that the sub-populations or groups postulated by Fujino, Lewis and Sharp for the western skipjack population of Fujino (1972) have sufficient in common (e.g. slow growth, low L_∞, small size at first spawning) to readily distinguish them from the eastern population(s), but are sufficiently discrete to necessitate individual study for stock description purposes. The available data are obviously inadequate to enable this detailed stock description in Papua New Guinean waters. Furthermore, although the tagging information has greatly increased the knowledge of migratory paths of skipjack from this fishery, very little is known of the origin of fish being recruited into the fishery, and the influence of the abundance of fish of one age-class or group on the recruitment of the next or subsequent age-classes of the same or different groups. Any attempt at comprehensive skipjack stock assessment for Papua New Guinean waters based on conventional yield per recruitment models would therefore be of little, if any, value. The tagging information has shown that skipjack from Papua New Guinea do migrate over long distances and any future predictions of yield, or management proposals, will need to be considered acknowledging the regional distribution and abundance of the species.

During cruises of the research vessel Tagula which were geared primarily for tagging and other biological studies, several areas of good concentrations of skipjack, other than those being fished by Papua New Guinean registered vessels, were detected (Kearney *et al.*, 1972; Lewis *et al.*, 1974). Subsequent aerial surveys confirmed that good concentrations of skipjack did occur at least on a seasonal basis, in parts of the Solomon and Coral Seas which had not been fished to that time (Department of Primary Industry, Papua New Guinea, manuscript in preparation).

Recent catches by the Japanese distant-water skipjack fleets in these areas (Tohoku Regional Research Laboratory, undated) have ascertained the value of these additional fishing grounds and accentuated the possible future benefits to Papua New Guinea from fishing such areas.

The relationship between the stocks fished in these new areas and those currently harvested by Papua New Guinean vessels has not yet been determined and the implications of expanding the existing fishing area can only be surmised.

Aerial Survey

In November 1972 an extensive aerial survey for surface schooling tunas in the waters of Papua New Guinea was commenced. The aims, methods and preliminary findings of this survey have been described elsewhere (Kearney, et al., 1973) or are in manuscript (Department of Primary Industry, Papua New Guinea) and only the conclusions relevant to estimates of apparent abundance or stock potential will be discussed here.

The usefulness of aerial survey techniques to obtain estimates of abundance of skipjack and other tunas is restricted to the fraction of the total stock present which occur as surface schools in the area/time strata surveyed. In addition, variability in the "observed abundance" or "visibility" of fish will be influenced directly by weather and sea conditions and indirectly by changes in fish behaviour as influenced by such additional variables as season, time of day, sea surface temperature and abundance of feed. Nonetheless, if sufficient hours are flown and the survey area repeatedly scanned, a meaningful index of abundance of surface schools can be obtained. This index can then be used in conjunction with other measures of abundance (for example from catch and effort data) to add some refinement to an overall stock description. As almost 500 hours flying time were spent searching for tuna in Papua New Guinea between November 1972 and June 1973, the results are considered to be of considerable value in assessing the resources in the areas surveyed.

Table 6

Brief summaries of these results are given in Table 6. The findings of the survey relevant to estimating the skipjack resources in Papua New Guinea were:

(i) Clearly skipjack were neither randomly nor uniformly distributed throughout the survey area.

(ii) Areas of greatest observed skipjack concentration were closer to the baiting grounds, and hence to the fishing grounds, of Companies B, A and D than to Company C (later discussed).

(iii) Periods when greatest surface concentrations were observed did not correspond to the times of greatest recorded catches by the fishing vessels. This difference appeared to be due to both (a) vessels not being in the area of greatest school concentration, even though such concentrations were within their range, and (b) "catchability" of skipjack being not always closely related to observed occurrence. The latter was confirmed by an additional survey in mid 1974 when very few skipjack were observed, but the catch rates by the live bait and pole vessels were extremely high, even though the aeroplane and catcher vessels were operating in the same area (Department of Primary Industry, Papua New Guinea, manuscript in preparation).

(iv) More skipjack (fewer but larger schools) were observed outside the Papua New Guinea declared fishing zone (12 miles) than inside, however, most schools were observed with 30 miles of land.

Considering these findings, the most significant conclusion from the aerial survey was that the poor catches by the fishing vessels in 1972-1973 appeared to be influenced not only by the low absolute abundance of skipjack, but also by low "catchability" of those present. In this regard the low index of abundance obtained from the catch per unit of effort for this period can be explained, at least partially, and any total stock descriptions based on these figures should be reconsidered in the light of the additional information.

Kearney et al. (1973) concluded that the fishing power of the live bait and pole vessels could be increased by the use of survey aircraft for school detection, at least on a part-time basis. If this is so, then the average catch per day can be expected to increase without a corresponding increase in the absolute abundance of skipjack. This increased fishing power would need to be weighted in any estimates of total skipjack abundance based on catch and effort data.

The Influence of Baitfish Abundance on Skipjack Catches

Because of the reliance of the Papua New Guinean skipjack fishery on the availability of adequate supplies of suitable bait much of the pelagic fisheries research effort has been focused on the baitfish fishery. Over 300 species have been captured by experimental baitfishing, but less than 20 of these have contributed signifcantly to the total quantity of bait taken (Lewis, 1974). The distribution and abundance of the prized species have previously been studied (Kearney *et al*., 1972; Lewis, 1974; Lewis *et al*., 1974) and ways of improving the skipjack yield from the bait used have been covered in theory (Kearney, 1974a; Smith, 1974).

The geographical isolation of the various baitfishing areas (Figure 1) necessitates that each be considered as a separate entity when estimating the baitfish stocks. The baiting grounds are therefore considered on the basis of the four fishing companies, and the results presented in Tables 7 and 8.

Tables 7 and 8

A. From Table 7, it is apparent that for Company A the average bait catch per day has not changed significantly since 1971, even though the total effort has doubled. There may of course have been an increase in the efficiency of the effort since 1971 helping to maintain the high average daily catch. There is no evidence to suggest that a further increase in total baitfishing effort will cause a marked reduction in the catch per unit of effort. However, in view of the decrease in the productivity from baitfishing area 1 of Company C (later discussed), fluctuations in catch and effort should be carefully monitored and caution should be exercised when increasing total effort.

B. The results from Company B are of limited value because this company did not submit accurate returns of bait catch in 1971, restricting the period of available data to three years. During these three years there has been no significant change in the average daily bait catch (Table 7) suggesting that productivity can be anticipated to be at least maintained at present levels.

C. Company C experienced severe bait shortages from 1972 onwards and by the end of 1974 many of its catcher vessels had moved to the second of its exclusive baitfishing

Table 9

areas. In Table 9, the bait catches in area 1 are presented separately and the collapse of this bait fishery since 1972 is readily apparent. Even with proper management the yield from this baitfishing area would probably be only of the order of 30,000 buckets per year, a quantity not considered sufficient to support skipjack catches of sufficient size to enable a fleet of the type currently operating in Papua New Guinea to continue economically, even though skipjack may be abundant. It is therefore anticipated that because of limited bait, Company C will be forced to move its skipjack fishing base to an alternative area. Area 1 may continue to be used by one or two medium range, refrigerated vessels, or several small vessels, if shore facilities are installed, but the annual skipjack yield from this area could not be expected to exceed 2,000 tonnes in a normal year, unless supported by bait from other areas.

D. Company D did not consistently fish until the later part of 1972, hence only two full years data are available. Even in these years the baitfishing effort was inconsistently divided between the company's two exclusive fishing areas, rendering the data of little predictive value. It is perhaps significant that the average daily bait catch has increased each year (Table 7).

In his study of the species composition of the baitfish used in the Papua New Guinean commercial fishery, Lewis (1974) pointed out that the Stolephorid anchovies S. devisi and S. heterolobus dominated the bait catches in all fishing areas currently being used. He also presented research findings which indicated that these two species were widely distributed in the coastal waters of Papua New Guinea, and numerous areas currently not being fished, could be anticipated to yield useful quantities of suitable bait to supplement supplies from the present grounds. Smith (1974) discussed the "attractiveness" and utility of the Papua New Guinean baitfish, particularly the two anchovy species, and considered that poor handling of these comparatively delicate fish was reducing their effectiveness as bait. He concluded that substantial expansion in the skipjack fishery would be contingent upon increasing the skipjack yield from the known baitfish resources by more efficient utilization, and he considered improved bait handling techniques would result in substantial increases in the skipjack catching potential of the known bait resources. In a later report Smith and Wilson (1975) outlined improved baithandling techniques which greatly decreased bait mortality during a survey on one of the commercial vessels operating in Papua New Guinea. These workers proved that contrary to accepted practice, Stolephorid anchovies, if correctly handled, were suitable for extended range fishing operations.

If the currently accepted baitfish mortalities of up to 50 percent (Smith, 1974) can be reduced to around 5 percent (Smith and Wilson, 1975) and a more equitable distribution of the bait catch achieved, then the known baitfish resources currently being fished by Companies A, B and D should collectively be adequate to sustain skipjack catches approaching twice their current levels. The increased efficiency in utilization of the resources currently being fished could well be assisted by the establishment of bait catching units independent of the skipjack fishing vessels. Such independent bait facilities could then supply the skipjack vessels with bait at a price to be negotiated. Advantages of such a system would be:

(i) Each catcher boat would be more assured of bait each day as the catch from all baiting units could be made available to the total fleet (Kearney, 1974a).

(ii) In times of great abundance of baitfish less baitcatching units could be used, tending to conserve the bait stocks.

(iii) Uncommonly large bait catches would not be wasted (as is now the case) because of limited bait-holding capacity of the catcher boat which caught it.

(iv) Because bait catching vessels or platforms could be moored in one position for extended periods, it would be possible to keep bait for more than one day, allowing it to harden as described by Lewis et al., 1974. This should greatly reduce the high mortality currently associated with the transfer of bait onto the catcher boats.

(v) It would be possible to keep bait over periods of full moon, when as shown by Kearney, (1974a) skipjack catches are high but bait is difficult to catch.

(vi) Hardened bait may well be used to increase the range of the large, refrigerated pole boats and permit them to remain at sea for extended periods.

The baitfish resources not being used (Lewis, 1974) will probably be of benefit in relocating Company C or, to medium- or long-range vessels of any company, should such vessels gain greater acceptance in Papua New Guinea. Additional resources of species currently not being used as baitfish in Papua New Guinea may also be used in future years. Also reintroduction of the "drive-in" fishery for species other than Stolephorid anchovies could increase the reserves of baitfish available. It should be remembered that in 1970 Company A maintained average daily skipjack catches of 4.76 tonnes using exclusively bait captured by the "drive-in" method (Kearney, 1973).

The efficiency of operation of the Papua New Guinean skipjack fleet as a whole can probably be also improved by regular review of the exclusive baitfishing areas of the fishing companies, with a view to maintaining optimum fishing effort on both the skipjack and baitfish resources. Present information indicates that the baitfish resources may require management, in the form of regulated distribution of the fishing effort, but increases in the total baitfish catch are still anticipated.

Discussion and Conclusions

The Papua New Guinean skipjack fishery has been in operation for only five years, and hence the catch and effort data available are very limited. However, the data which are available on this fishery are sufficiently precise to enable detailed analyses of the changes in catch and effort which have occurred in this time.

These analyses are of particular benefit in considering the relative performances of the various fishing companies and the present and possible future value of the baitfish resources, particularly with reference to the restructuring of bait and skipjack fishing licensing systems within the country. The present licensing system in which each company is considered independently, allows the Papua New Guinean Government great control and versatility in the regulation of fishing pressure on both the skipjack and baitfish resources within the immediate vicinity of Papua New Guinea. The catch and effort data and other biological information forms the basis of all management decisions by the Tuna Resources Management Advisory Committee (Tuna Resources Management Ordinance, 1973) on which both the Government and the industry are represented.

On the other hand the data are of very limited value for predicting potential total yields from the skipjack fishery. It is not as yet possible to determine the relationship between the skipjack resources exploited by the Papua New Guinean fleet and the stock(s) of the western or central Pacific as a whole. It has been indicated that the fish taken are from the western population of Fujino (1972) but it has not been possible to detect any impact of any of the several fleets fishing this population on the fishery in Papua New Guinea. As yet no relationship between changes in total fishing effort and the catch per unit effort has been established for any of the time/area strata considered. Certainly within the areas fished by each of the four companies, neither the effort nor the fish are randomly or uniformly distributed in time or space. As described by Kearney (1974b) Papua New Guinea's skipjack catch and effort data have been compiled by much smaller time/area units (1° squares/day for each boat) but analysis of this data even further accentuates the fluctuations which occur in skipjack abundance and makes detection of fishery-induced changes even more difficult. It appears that a time/area unit in which the great natural fluctuations in skipjack abundance can be absorbed to give a comparatively uniform data base, can only be obtained by combining over several years, data from a greater fishing area. On the basis of the present data a four-year time unit appears reasonable.

The fishing by Companies A, B and D appears to be largely dependent upon the abundance of essentially similar sized skipjack which can probably be considered to be from the same unit of stock. Therefore, the three areas fished by these companies could be combined and considered as a unit of area. The skipjack commonly taken in the area fished by Company C are much larger and their abundance should be considered independently by acceptance of a separate unit of area.

It was hoped that the apparent abundance of large skipjack in the fishing area of Company C could be compared with the abundance of the corresponding cohort in the areas of Companies A, B and D. This comparison, together with the growth and migratory data obtained from fish tagged in area B and recaptured in C, was hopefully to give an indication of fishery-induced changes in successive cohorts of fish. Unfortunately the decline in the availability of baitfish in area C (Table 9) and the irregular relationship between bait and skipjack catch (Kearney, 1974a) made standardization of the fishing effort in this area extremely difficult, introducing the possibility of errors which would render the results meaningless. Until a far more accurate stock description is available and some relationship between fishing effort and apparent abundance can be ascertained conventional catch and effort models will be of little predictive value. Simarly the paucity of growth and mortality data and the almost complete lack of knowledge of spawning and subsequent recruitment, renders estimates of potential yield by yield-per-recruitment studies of little value. Although the linear relationship found between total catch and total effort cannot be expected to be valid for a finite resource at all levels of increased effort, it suggests that the skipjack catch from the waters of Papua New Guinea can be anticipated to continue to increase with further increases in total effort, at least in the immediate future. It may well be that the maximum total catch achieved by the Papua New Guinean fleet will be limited by factors other than the absolute abundance of skipjack. Although the availability of baitfish may well prove limiting, improvements in the bait catching and handling techniques are anticipated to increase the skipjack catching potential of the known baitfish resources to, of the order of, twice present catches.

YELLOWFIN TUNA

Live bait and pole vessels fishing primarily for skipjack have taken all the recorded commercial catches of yellowfin tuna within Papua New Guinea's declared fishing zone. No estimates of the catches by village fishermen are available. No commercial longline vessels have operated on a regular basis from Papua New Guinean ports even though the waters surrounding the country, beyond the 12 mile limit, have been fished for yellowfin tuna by longline fleets of several countries.

Catch and effort statistics have been obtained from both the skipjack and longline fleets (either directly or through published material) and also a limited amount of data was obtained independently through Papua New Guinea's own research programmes. However, it must be noted from the outset that fishery constraints and limited research and monitoring resources have meant that the collection of

TABLE 1

Annual catch (tonnes) and declared species composition of landings by live bait and pole vessels of all companies in Papua New Guinea to the end of 1974. (Modified from Kearney, 1975a).

	1970		1971		1972		1973		1974	
	Total Catch	Av/Boat Day	Total Catch	Av/Boat Day	Total Catch	Av/Boat Day	Total Catch	Av/Boat Day	Total Catch	Av/Boat Day
January	--	--	918	3.54	681	1.75	411	1.13	1,529	5.11
February	--	--	992	3.49	744	2.09	294	1.02	1,808	7.69
March	307	3.74	1,461	4.40	1,359	2.69	678	1.66	1,625	3.47
April	348	4.70	1,512	4.27	966	2.51	839	1.48	3,259	4.59
May	370	4.51	1,884	5.51	1,633	2.78	2,906	3.58	5,722	5.55
June	441	5.44	2,039	6.43	793	1.69	3,011	3.67	5,485	5.80
July	480	6.40	1,952	5.52	846	2.17	4,038	4.50	5,214	4.81
August	113	4.03	2,027	4.23	748	2.24	4,373	4.70	4,351	4.29
September	--	--	1,490	3.55	345	1.36	4,719	5.26	3,367	3.84
October	--	--	1,065	3.78	1,336	3.42	1,782	2.85	3,833	3.88
November	145	4.54	962	2.86	2,243	5.11	2,571	4.53	3,236	3.43
December	226	3.97	700	2.33	1,430	3.44	2,647	5.14	2,216	2.99
TOTAL	2,430	4.76	17,002	4.19	13,124	2.67	28,269	3.68	41,780	4.44
% Skipjack	96.8		99.0		86.5		94.4		96.6	
% Yellowfin	3.1		0.8		12.5		4.6		2.9	
% Other Species	0.1		0.2		1.0		1.0		0.5	

TABLE 2

Positions of the exclusive baitfishing areas of each company (From Kearney, 1975)

COMPANY	EXCLUSIVE BAITFISHING AREA(S)
A	20 mile radius from S 02° 17' 48" E 150° 28' 36"
B	20 mile radius from S 04° 15' 13" E 151° 46' 03"
C	10 mile radius from S 05° 10' 0" E 145° 50' 0" and
	10 mile radius from S 05° 33' 30" E 149° 14' 30"
D	10 mile radius from S 05° 25' 0" E 150° 06' 0" and
	10 mile radius from S 05° 21' 30" E 150° 40' 0"

TABLE 3

Skipjack catches by the Papua New Guinea live bait and pole vessels, 1970-1974.

YEAR		COMPANY				TOTAL
		A	B	C	D	
1970	Total Catch (Tonnes)[1]	2,349	--	--	--	2,349
	No. of Days Fished[2]	510	--	--	--	510
	Av. Catch/Day (Tonnes)	4.61	--	--	--	4.61
1971	Total Catch (Tonnes)	4,424	8,691	3,748	--	16,862
	No. of Days Fished	1,253	1,718	1,089	--	4,060
	Av. Catch/Day (Tonnes)	3.53	5.06	3.44	--	4.15
1972	Total Catch (Tonnes)	4,138	5,805	1,078	697	11,718
	No. of Days Fished	1,823	1,788	907	397	4,915
	Av. Catch/Day (Tonnes)	2.27	3.25	1.19	1.76	2.38
1973	Total Catch (Tonnes)	8,888	12,631	2,092	3,624	27,234
	No. of Days Fished	1,790	3,397	1,126	1,378	7,691
	Av. Catch/Day (Tonnes)	4.97	3.72	1.86	2.63	3.54
1974	Total Catch (Tonnes)	15,242	14,120	6,425	4,428	40,214
	No. of Days Fished	2,504	3,221	2,125	1,558	9,408
	Av. Catch/Day (Tonnes)	6.09	4.38	3.02	2.84	4.27
TOTAL	Total Catch (Tonnes)	35,041	41,247	13,343	8,749	98,380
	No. of Days Fished	7,880	10,124	5,247	3,333	26,584
	Av. Catch/Day (Tonnes)	4.45	4.07	2.54	2.62	3.70

1. All figures in tonnes
2. All figures in days

TABLE 4

Skipjack catches by the Solomon Islands fleet 1971-1974 (From James, 1975).

YEAR	TOTAL SKIPJACK CATCH (Tonnes)	AV. CATCH/BOAT/DAY (Tonnes)
1971	4,666	5.70
1972	7,641	2.28
1973	6,301	3.24
1974	10,274	4.65

TABLE 5

Skipjack catches by Japan in FAO Statistical Area 71, 1970-1974 (From FAO, 1975)

YEAR	SKIPJACK CATCH (Tonnes)
1970	53,400
1971	79,300
1972	79,700
1973	106,900
1974	144,975

TABLE 6

Surface schools of tuna species observed during aerial survey in Papua New Guinea, November 1972 - June 1973.

SPECIES CATEGORY	NO. OF SCHOOLS	% OF TOTAL SCHOOLS	EST. TONNAGE	% OF TOTAL TONNAGE
Skipjack	1,340	45.1	16,300	44.7
Yellowfin	249	8.4	1,160	3.2
Skipjack Yellowfin)mixed	867	29.2	17,551	48.1
Mackerel Tuna	357	12.0	795	2.2
Skipjack Others)mixed	93	3.2	437	1.2
Others	63	2.1	226	0.6
TOTAL	2,969	100.0	36,469	100.0

TABLE 7

Bait catches by the Papua New Guinean live bait and pole vessels, 1971-1974.

YEAR		COMPANY				TOTAL
		A	B	C**	D	
1971	Total Bait Catch[1]	94,215	*	98,633	--	192,848
	Total Days Fished	1,253	*	1,089	--	2,342
	Bait Catch/Day[1]	75.2	*	90.6	--	82.34
1972	Total Bait Catch	138,240	103,619	70,447	1,810	330,407
	Total Days Fished	1,823	1,788	907	397	4,915
	Bait Catch/Day	75.8	58.0	77.7	45.6	67.23
1973	Total Bait Catch	126,966	220,329	37,204	69,692	454,191
	Total Days Fished	1,790	3,397	1,126	1,378	7,691
	Bait Catch/Day	70.9	64.9	33.0	50.6	59.05
1974	Total Bait Catch	178,551	195,157	44,583	99,777	518,068
	Total Days Fished	2,504	3,221	2,125	1,558	9,408
	Bait Catch/Day	71.3	60.6	21.0	64.0	55.07
TOTAL	Total Bait Catch	537,972	519,105	250,867	187,570	1,495,514
	Total Days Fished					
	Bait Catch/Day					

* Company B did not declare bait catches accurately in 1971.

** Figures for Companies C and D are from both baitfishing areas of each company.

1. All figures in buckets, the contents of which is thought be be between 2 and 4 kg.

TABLE 8

Relationships between tuna (all species combined) and baitfish catches by the Papua New Guinea live bait and pole vessels, 1971-1974.

YEAR		COMPANY				TOTAL
		A	B	C	D	
1971	Total Tuna Catch[1]	4,480	8,708	3,814	--	17,002
	Total Bait Catch[2]	94,215	*	98,633	--	*
	Tuna Catch/Bait Bucket[3]	47.55		38.67	--	*
1972	Total Tuna Catch	5,252	5,831	1,254	787	13,124
	Total Bait Catch	138,240	103,619	70,447	18,101	330,407
	Tuna Catch/Bait Bucket	38.00	56.28	17.79	43.46	39.72
1973	Total Tuna Catch	9,339	12,799	2,169	3,963	28,270
	Total Bait Catch	126,966	220,329	37,204	69,692	454,191
	Tuna Catch/Bait Bucket	73.55	58.09	58.29	56.86	62.24
1974	Total Tuna Catch	16,261	14,291	6,590	4,638	41,780
	Total Bait Catch	178,551	195,157	44,583	99,777	518,068
	Tuna Catch/Bait Bucket	91.07	73.23	147.81	46.48	80.65
TOTAL	Total Tuna Catch	35,332	41,629	13,827	9,388	100,176
	Total Bait Catch	537,972	*	250,867	187,570	*
	Tuna Catch/Bait Bucket	65.68	*	55.12	50.05	*

All company baitfish catches are declared in buckets, the average contents of which is variable and has not been estimated.

* Company B did not accurately declare baitfish catches in 1971.

1. All figures in tonnes.
2. All figures in buckets.
3. All figures in kg.

TABLE 9

Fluctuations with time of total bait, and average bait catch per day for baitfishing area 1 of Company C.

YEAR	NO. DAYS FISHED	TOTAL BAIT CATCH (Buckets)	AV. BAIT/DAY (Buckets)
1971	895	71,972	80.42
1972	586	37,775	64.46
1973	482	11,371	23.59
1974	1,083	16,182	14.94

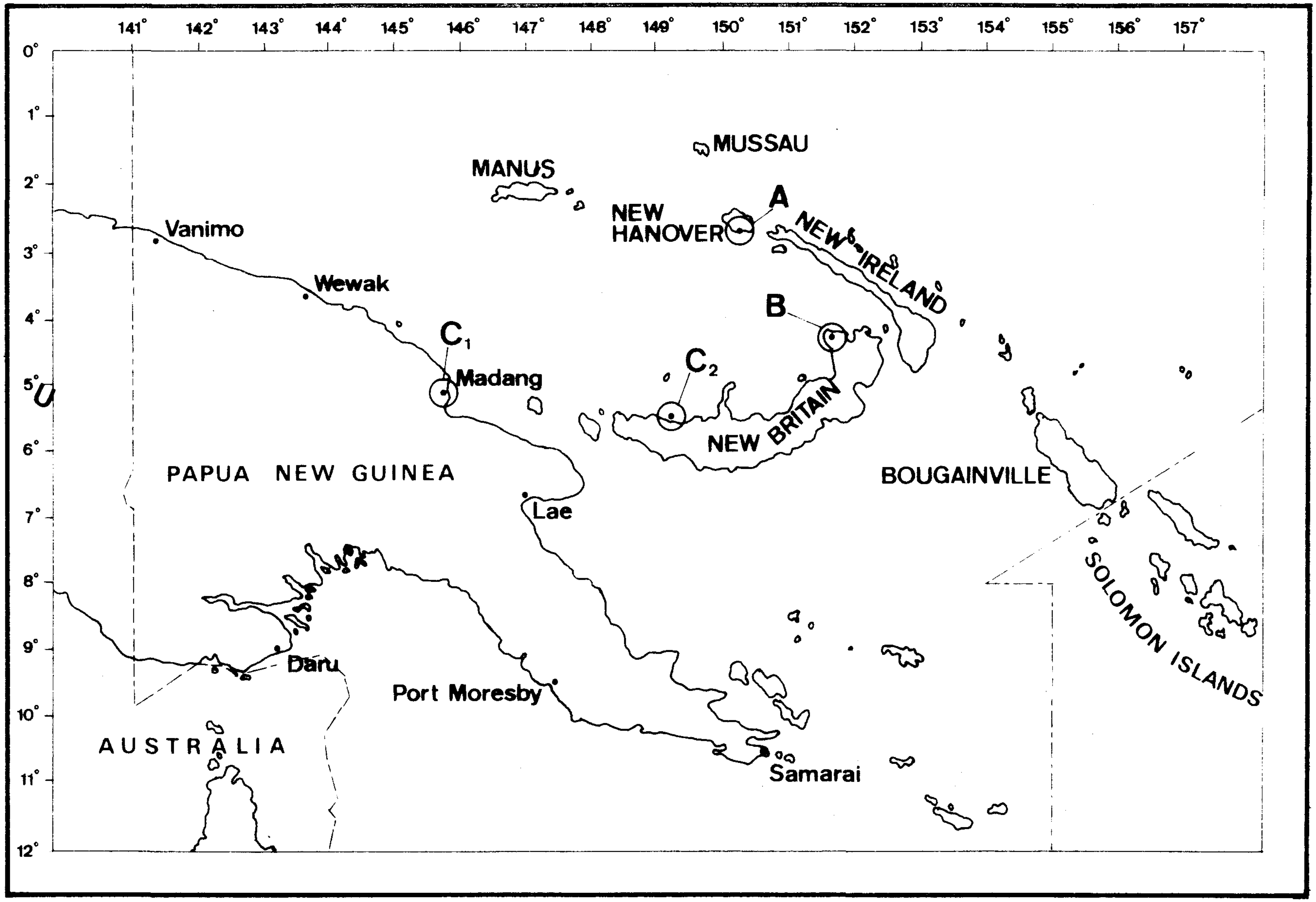
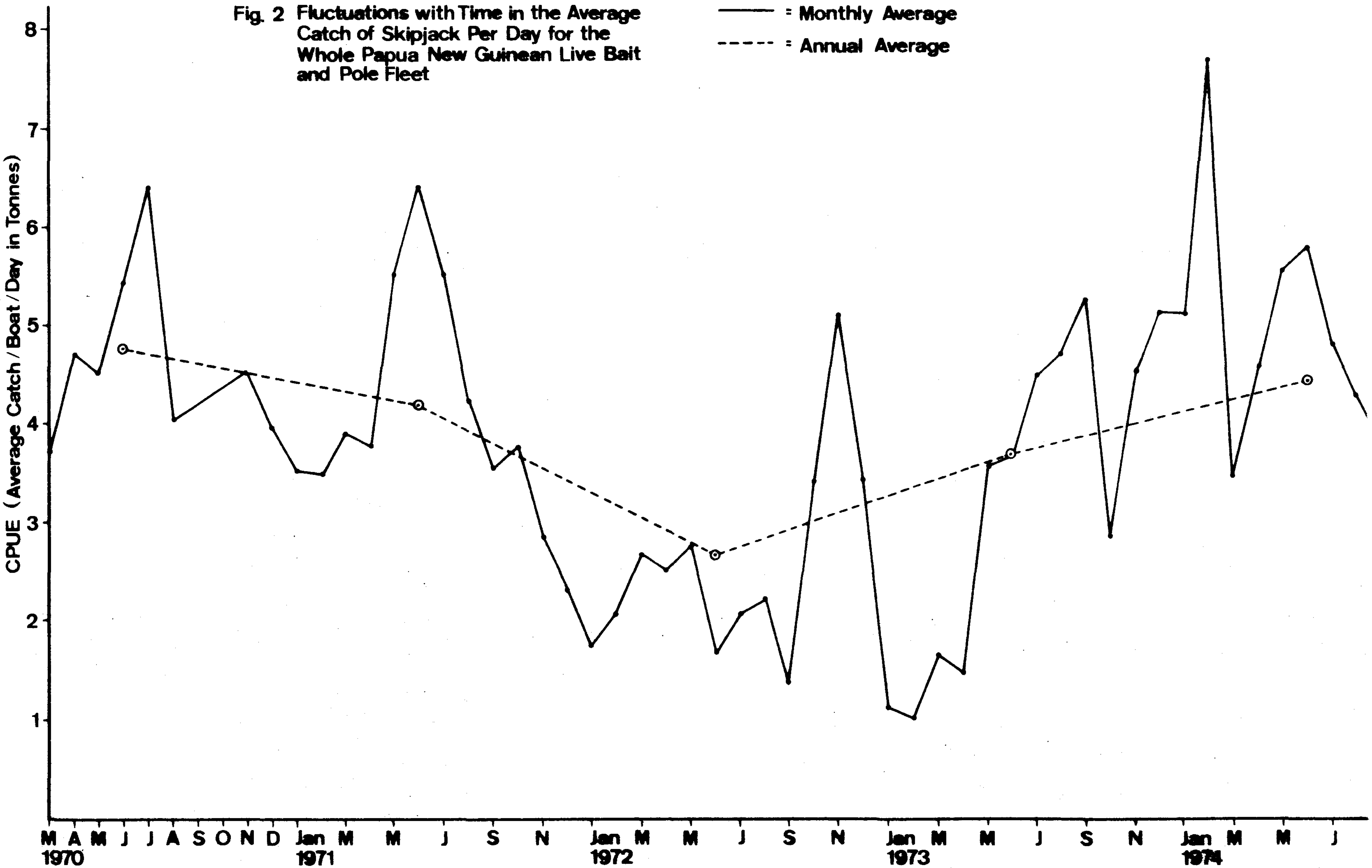


Fig. 1 Positions of the Exclusive Baitfishing Areas of Each Company

Fig. 2 Fluctuations with Time in the Average Catch of Skipjack Per Day for the Whole Papua New Guinean Live Bait and Pole Fleet



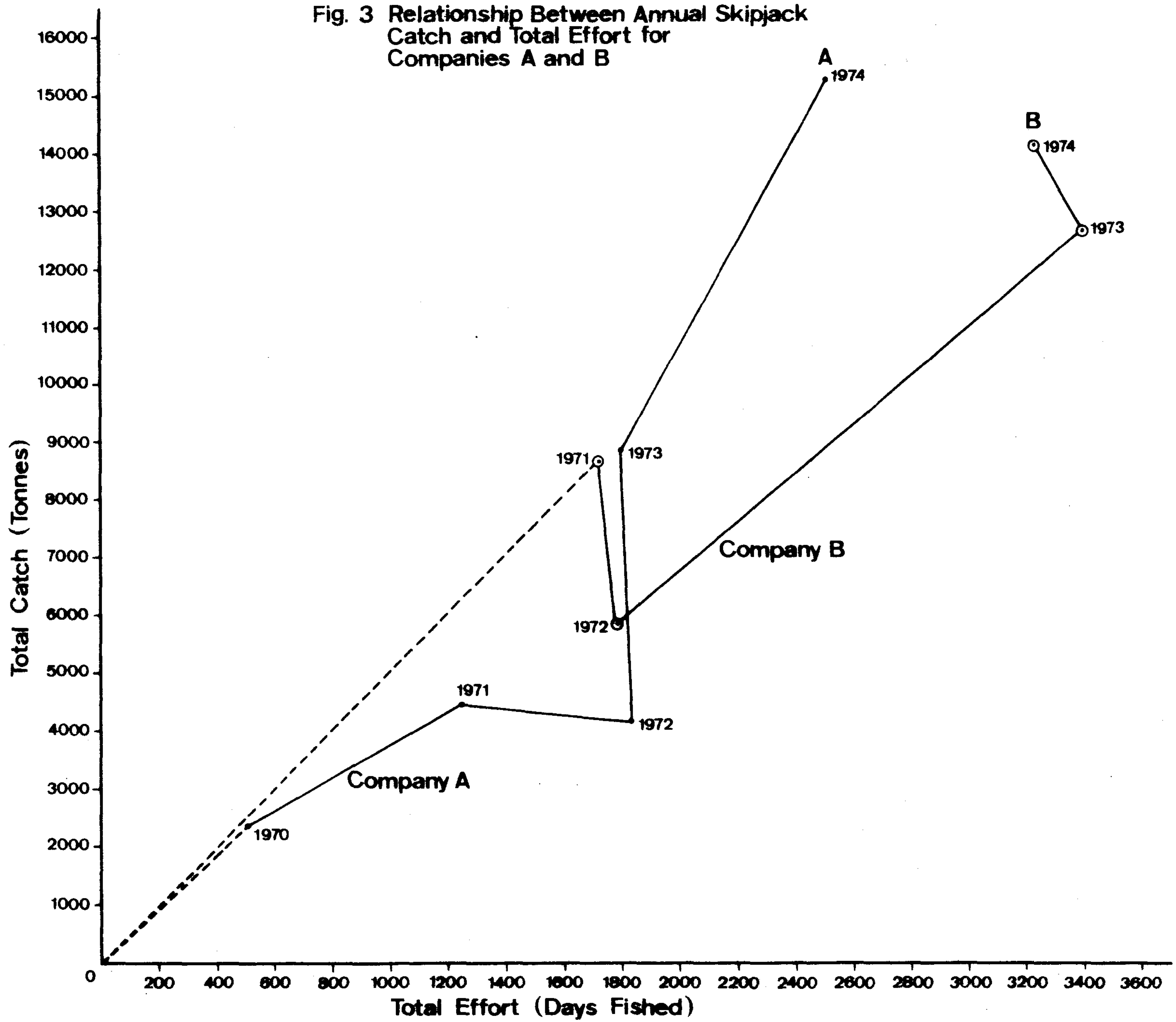


Fig. 3 Relationship Between Annual Skipjack Catch and Total Effort for Companies A and B
A
1974
B
1974
1973
1971
1973
Company B
1972
1971
1972
Company A
1970
Total Catch (Tonnes)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
Total Effort (Days Fished)

Fig. 4 Relationship Between Annual Skipjack Catch and Total Effort for Companies C and D

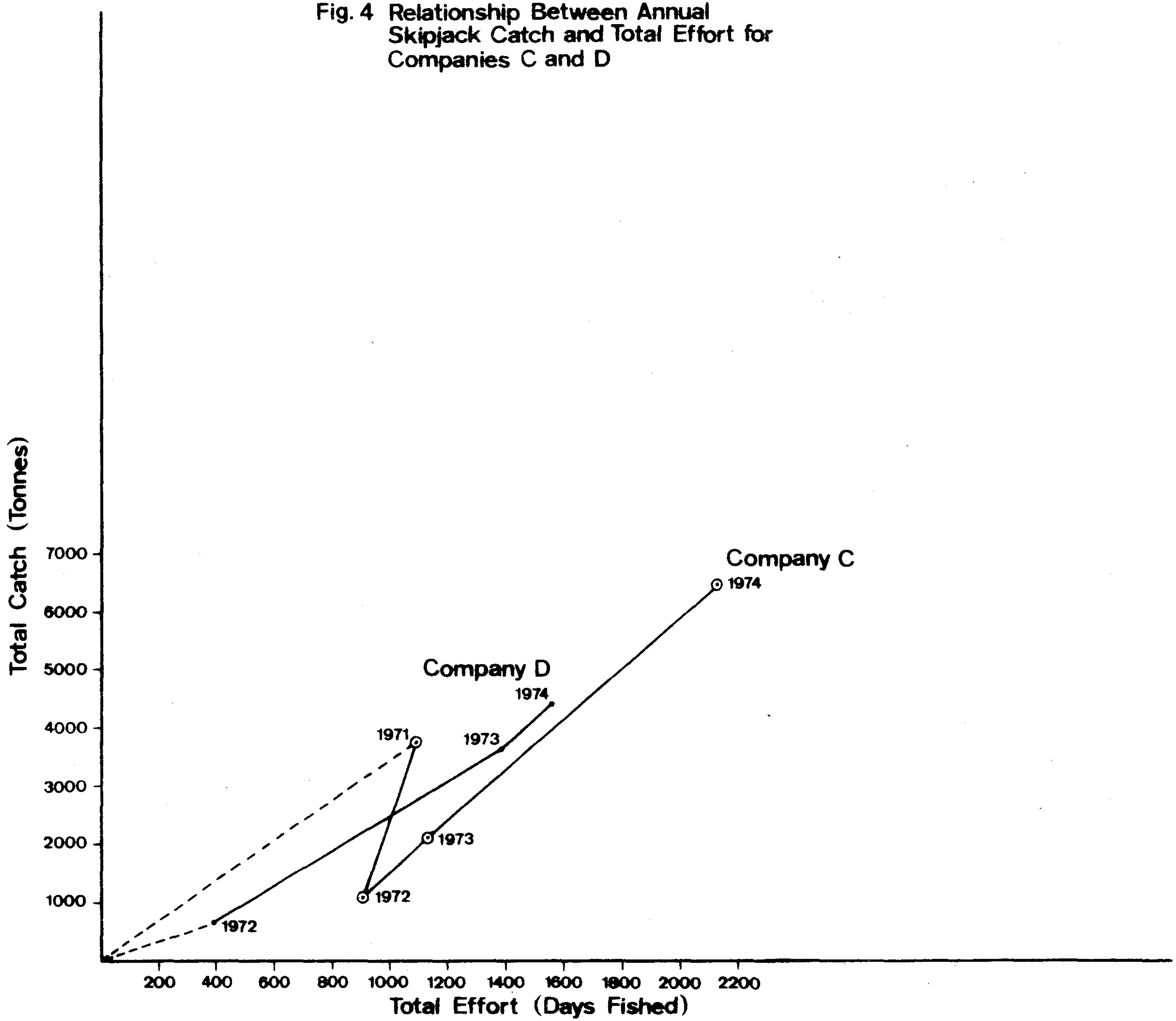
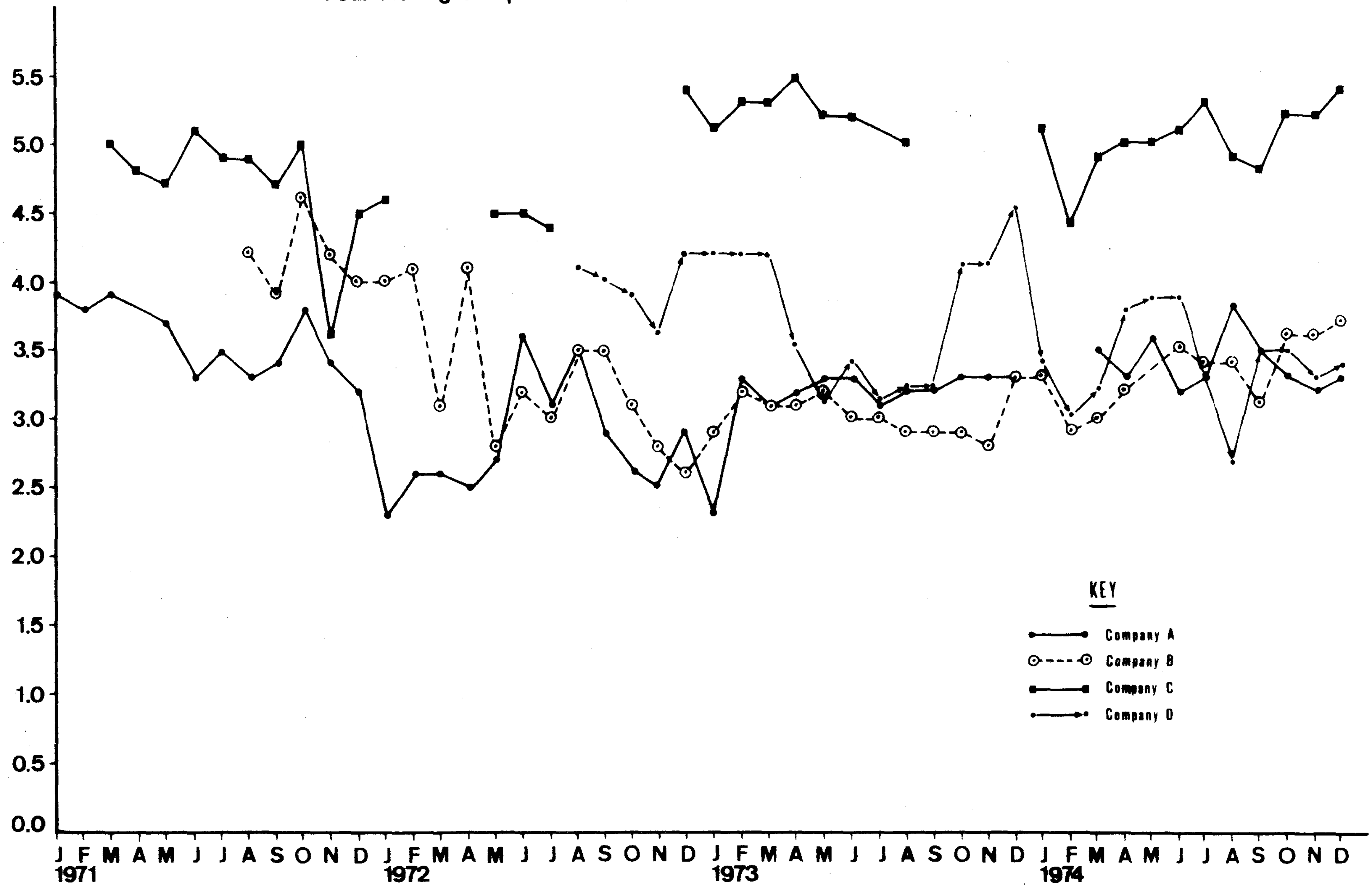


Fig. 5 Fluctuations With Time of the Average Size of Skipjack Taken By Each of the Four Fishing Companies



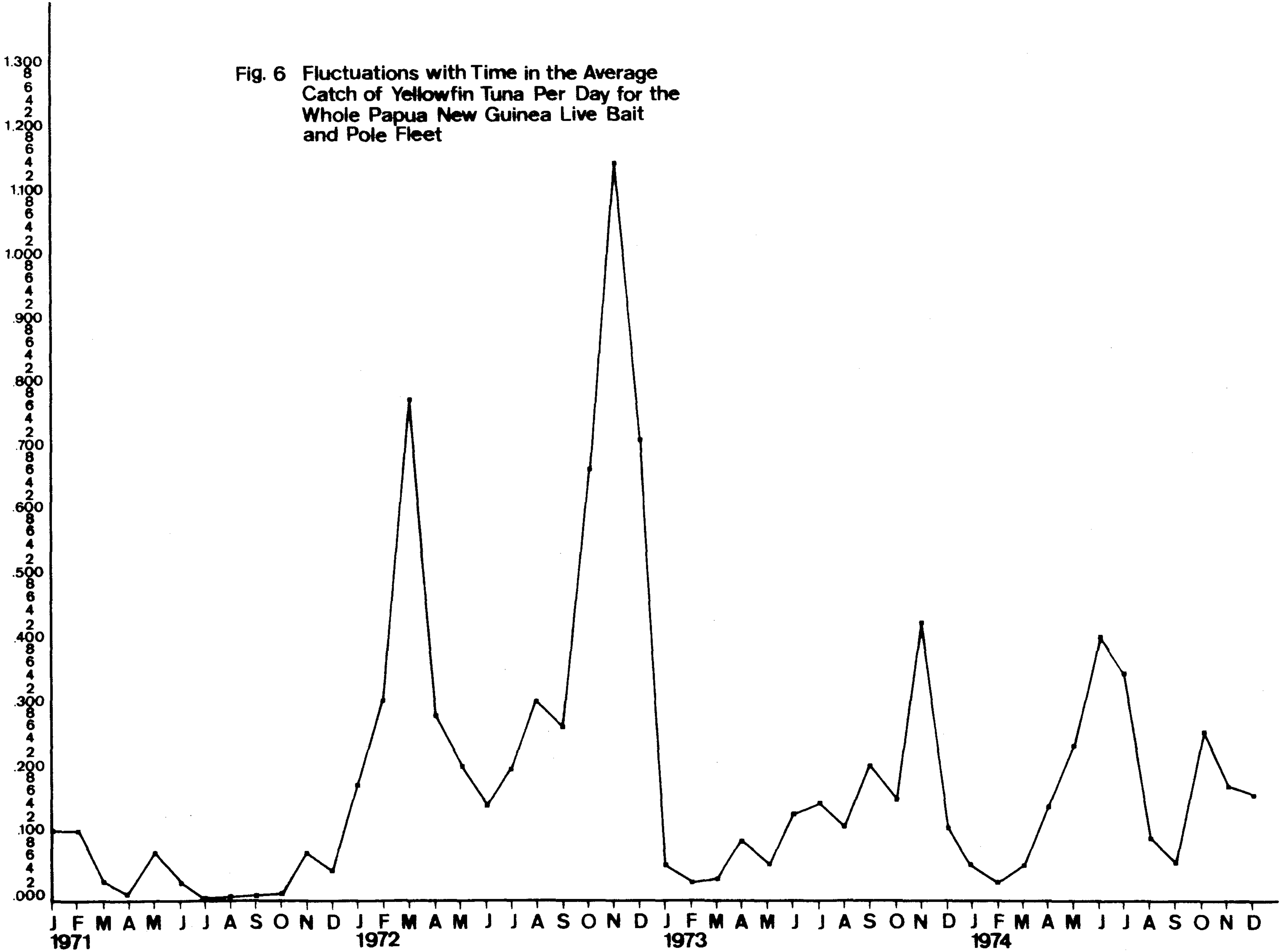


Fig. 6 Fluctuations with Time in the Average Catch of Yellowfin Tuna Per Day for the Whole Papua New Guinea Live Bait and Pole Fleet