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A PRELIMINARY EXAMINATION OF CATCH RATES IN HAWAII'S TROLL AND HANDLINE FISHERIES OVER A PERIOD OF DOMESTIC LONGLINE FISHERY EXPANSION

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EXECUTIVE SUMMARY

This study examines data from Hawaii's troll and handline fisheries for evidence of interaction with the domestic longline fishery. The Western Pacific Regional Fishery Management Council (WPRFMC) requested the study because of concern that catches by Hawaii's domestic longline fishery may have become great enough to impact the local abundance of fish. Within the limited range of Hawaii's pelagic fisheries, catch per unit effort (CPUE) is characterized by wide fluctuations which are due to many factors. Some of these fluctuations may obscure or mimic fishery interaction. A more thorough study--addressing major problems with the available fisheries data and considering biological, environmental, and economic factors--was recommended by the WPRFMC Plan Monitoring Team for the Pelagic Fishery Management Plan. Contrary to this recommendation the present study was done quickly, without quantifying important factors that may affect the results.

Annual (1983-89) and monthly (January 1987 to June 1990) summaries of catch and number of trips in Hawaii's commercial troll and handline fisheries, provided by the Hawaii Division of Aquatic Resources (HDAR), were used to examine catch per trip over time in these fisheries. The data were also deseasonalized so that 1990 data could be compared with earlier years. Catch per trip may not be a good measure of CPUE since there undoubtedly have been changes in fishing methods and in reporting over the years. However, this is the only catch rate index that can be calculated from HDAR data. Troll and handline catch per trip was also examined in relation to Hawaii's longline catches as given by the National Marine Fisheries Service market sample data for January 1987 to June 1990 to see whether there was any evidence of fishery interaction. This analysis was broken down by season to remove a potential source of bias.

The most interesting results were the yellowfin tuna, *Thunnus albacares*, catch rates, which gave the appearance of declining in relation to the increase in longline catch. However, this decline could well be due to other factors. Whatever the causes, the decline in yellowfin tuna catch per trip over the last few years seems very real, being reflected in data from many gear types. However, that decline did not result in catch rates lower than in 1983. Also important was the absence of any clear relationships between longline catch and catch rates for blue marlin, *Makaira mazara*; striped marlin, *Tetrapturus audax*; mahimahi, *Coryphaena hippurus*; ono (wahoo), *Acanthocybium solandri*; bigeye tuna, *T. obesus*; and swordfish, *Xiphias gladius*. Because the most recent data available for the present study were from June 1990 and Hawaii's domestic longline fishery has doubled in size since then, future data would be more likely to show evidence of fishery interaction.

A review of the status of the small-vessel pelagic fisheries at a greater-than-annual resolution indicates that some overall declines may have occurred that are not apparent from the annual time series. The average of annual catch per trip values for

1988-89 compared with the average for 1983-85 indicates that troll catch rates for both marlin species were higher in 1988-89, but troll catch rates for yellowfin tuna, mahimahi, and ono were lower, and catch rates for all species except bigeye tuna were lower in the handline fishery. However, these changes were small compared to changes seen over a longer time period (1962-89).

Further study using data collected over the next 3 years will be necessary to reliably assess possible impacts of the longline fleet expansion.

CONTENTS

INTRODUCTION

This study was undertaken to provide timely information to the Western Pacific Regional Fishery Management Council (WPRFMC) for its use in considering the implementation of a moratorium on domestic longline fishing in Hawaii. Hawaii's fisheries exploit only a small fraction of the pelagic fish populations in the Pacific, but the fishery community is concerned that local catches may have grown so large that local fish abundance is being affected, especially in areas where fishing is most intense. When the catch of one fishery affects the catch of another, it is called fishery interaction. Recently, the local increase in catch has been by Hawaii's domestic longline fishery.

The hypothesized mechanism for fishery interaction in Hawaii is that local fisheries impact one another (and themselves) if they remove fish from the area more rapidly than fish are replaced by immigration and recruitment. Although such depletion would not affect the overall population dynamics of wide-ranging pelagic species, it could negatively affect local fisheries. Several studies suggest that localized fishing effort can reduce catch rates for wide-ranging pelagic stocks in a local area (Lovejoy 1977, 1981; Wetherall and Yong 1983; Skillman and Kamer In prep.; Squire and Au 1990).

Within the limited range of Hawaii's fisheries, tuna and marlin are characterized by wide fluctuations in catch rates (Wetherall and Yong 1983). Some of this variation may be due to environmental changes that affect fish recruitment, movement, and vulnerability to different types of fishing gear. Variation may also be caused by a reduction in fishing effort when catch rates are low or by increased effort when prices are high. These and other factors may obscure or mimic fishery interaction. A more thorough study--addressing major problems with the available fisheries data and considering biological, environmental, and economic factors--was recommended by the WPRFMC Plan Monitoring Team (PMT) for the Pelagic Fishery Management Plan (FMP) (Appendix A). The PMT's recommendations emphasize using new, high-quality data to be collected using longline logbooks over the next 3 years. The most recent data available are for June 1990. Hawaii's domestic longline fishery has doubled in size since that time, so future data would be more likely to show evidence of fishery interaction. Nevertheless, this study was undertaken to see whether the most recent data on Hawaii's troll and handline fisheries show any interesting trends or relationships with the domestic longline fishery. A simple approach was purposefully taken to avoid giving undue credence to the raw data, which contain many potential errors and biases.

DATA AND METHODS

Two approaches were followed in this preliminary study. Both approaches used catch per trip (catch rate) by Hawaii's troll and handline fishermen as an index of the local abundance of fish. In the first approach, troll and handline catch rates were examined over time to see whether trends existed that might correspond with the expansion of Hawaii's domestic longline fishery. The second approach was to examine troll and handline catch rates in relation to the longline catch, to see whether there was evidence of fishery interaction. Each analysis was applied to yellowfin tuna, *Thunnus albacares*; bigeye tuna, *T. obesus*; blue marlin, *Makaira mazara*; and striped marlin, *Tetrapturus audax*; mahimahi, *Coryphaena hippurus*; and ono (wahoo), *Acanthocybium solandri*. Troll and handline catch per trip time series data on swordfish, *Xiphias gladius*, were examined, but the relationship with longline catch could not be examined because National Marine Fisheries Service longline data on swordfish were not available.

The data used to calculate troll and handline catch per trip were provided by the Hawaii Division of Aquatic Resources (HDAR) as summaries of commercial catch (pounds of fish) and total number of fishing trips, by year (1983-89) and month (January 1987 to June 1990). Annual and monthly catch rates were calculated as the ratio of total catch (in pounds) to the number of trips. The only geographic categorization of the data was between the main and the Northwestern Hawaiian Islands, and only the main Hawaiian Islands data were used. The HDAR catch data do not actually contain reports of trips; rather, each date for each vessel in the records is counted as a trip if any pelagic management unit species (PMUS) or tuna was reported. (Note: By this method, the catch per trip for a given species can be zero--even for a month or year--if no catch is reported for that species). The assumption of 1-day trips is fairly realistic for the small-vessel troll and handline fisheries.

The data on the longline catch are from the NMFS market sampling data for January 1987 to June 1990. These data were summarized monthly to give an index of the longline fishing pressure on each species over the broad, undefined range of the longline fishery. The range of the troll and handline fisheries is much smaller and roughly centered within the area fished by the longline fishery. The reason for using NMFS longline catch data is that they cover a large majority of the longline catch in Hawaii, whereas the HDAR data cover only a small fraction of it. Conversely, the NMFS market sampling data cover only a fraction of the troll and handline catches and do not distinguish between these gear types which have markedly different catch rates. Longline catch per trip was not examined in this study (but see Appendix A for an analysis of longline catch versus effort). Although fishing effort is the more traditional and appropriate measure of fishing pressure, catch was used in this study because factors related to longline effort (target species, fishing depth, time of day) have been quite variable over the last 3 years.

Catch per trip may not be a good measure of catch per unit effort (CPUE) since there undoubtedly have been important operational changes and improvements in methods over the years. The catch per trip index does not standardize trips as a unit of effort, estimate or correct for underreporting, nor estimate or correct for changes in reporting over time. Any of these factors could bias trends or relationships in the data or give the appearance of a trend or relationship where none exists.

Despite the problems with catch per trip as an index, it can provide some indication of changes in the local abundance or availability of fish to troll and handline fishermen in Hawaii. For example, although trips with no catch are seldom reported, it is logical that when unreported trips with no catch are frequent, reported catch per trip also will be low, and vice versa. Also, when the data for several different types of gear show a similar pattern, it suggests that a true pattern may be emerging through the noise, unless some bias affects several gear types similarly. Catch per trip indexes based on HDAR data sometimes mirror trends and patterns seen in more sophisticated indexes from nearby fisheries, such as catch per hook or catch per set (Wetherall and Yong 1983; Skillman and Kamer In prep.). In any case, catch per trip is the only available measure of CPUE for Hawaii's troll and handline fisheries. More definitive examinations of trends in CPUE will require logbook data that more accurately specify fishing effort.

Several different handline gear types categorized in the HDAR data have changed with time:

1962-78	1983-84	1985-90
deep-sea handline	deep-sea handline	deep-sea handline (trivial amount)
	ika shibi (night handline)	ika shibi
	palu ahi (drop-stone, day handline)	palu ahi
		drifting handline

The catch rates for some species differ among these gear types, so they have been examined separately where possible. The oldest data readily available for the non-tuna species are estimates of catch per trip for 1962-78 (Skillman and Kamer In prep.). Over this period (1962-78), deep-sea handline was the only handline gear category. To compare these older catch rate data with more recent data, handline catch and trip summaries for 1983-89 were lumped into a single category (Table 1). Otherwise, the individual handline gear type data were examined separately. Beginning in 1985, many of the reports that were once categorized as deep-sea handline were classified as a new gear called drifting handline, to more clearly distinguish trips catching mostly pelagic fish from deep-sea handline trips catching bottomfish. Although deep-sea handline remained a category that included some pelagic fish, the amount has been trivial after 1985 and was not shown on the graphs.

The time series examination of catch rates (the first approach above) was conducted at an annual resolution, because longer time series were readily available at that resolution. Catch rates were also examined monthly so that data for 6 months of 1990 could be included. To compare 1990 data with earlier years required removing the seasonal component of the monthly data. Thus three types of catch rate data were examined as time series (annual, monthly, and deseasonalized monthly) for each species.

Seasonal decomposition of the data was accomplished using a STATGRAPHICS (1989) procedure which removes the long-term trend using a 13-month running average and then estimates a (multiplicative) seasonal index of the residuals. The STATGRAPHICS procedure then divides the original data by this index, producing a time series that reflects long-term trends and nonseasonal residuals. The seasonal decomposition would be more accurate if a longer time series were examined. All of the time series would be more useful if they were longer. These analyses made use of all readily available data summaries, but data for many past years are on file and should be summarized. A comprehensive study would make use of all these data (Appendix A).

Deseasonalization of the catch rate data was the only adjustment made for environmental factors in this study. One source of variation was thus eliminated, but interannual environmental variation and other factors remain as important potential biases. A good way to account for environmental or biological influences is to examine local catch rates against a background of stockwide abundance (Wetherall and Yong 1983; Skillman and Kamer In prep.). However, no indexes of stockwide abundance are currently available. Large-scale environmental perturbations may influence fish stocks oceanwide. Local environmental changes may also cause changes in localized fish distributions and the availability of fish to specific fishing gear. Thus a more comprehensive study of local and stockwide catch rate dynamics is much needed (Appendix A).

In the analysis of troll and handline catch rates in relation to longline catch (the second approach, above), the hypothesis is that the fish removed by the longliners might otherwise have been available to the troll or handline fisheries. To do the analysis, a time frame had to be hypothesized within which removal of fish by longliners might affect the local abundance of fish. Two scenarios are shown for each species and gear type: In the first, fish move in and out of the local area so rapidly that fish removal could influence fish abundance primarily within the same month; in the second, fish move more slowly and their abundance could be affected over a 3-month period. Thus the graphs show troll and handline catch rates versus the monthly longline catch and the last 3 months of longline catch (i.e., the current and preceding 2 months averaged). The latter scenario has the advantage of smoothing some of the variation in the monthly longline catch. Also examined were other scenarios (not shown) in which longline catches were considered over longer periods (up to 7 months).

Fishery interaction might be strongest during the season of low fish abundance, because the replacement rate of fish might be slower. Contrarily, the ability to discern fishery interaction might be greatest during the season of high fish abundance, since catch rates are more accurate when there are lots of trips (increased sample size). If the seasonal pattern in the longline catch of a species is opposite to the seasonal pattern in catch per trip of the potentially impacted troll or handline fishery, this would give the appearance of a negative interaction. If the seasonal patterns of the two fisheries are similar, it could mask a negative interaction. It was not appropriate to use deseasonalized data in this approach, so to circumvent these problems, troll and handline catch rates in seasons of high abundance (in-season months) were examined separately from catch rates at times of low abundance (non-season months). In-season and non-season months were identified for each species by gear type, based on the high and low index months from the seasonal decomposition of the January 1987 to March 1990 time series (where possible). In each figure showing troll and handline catch rates versus longline catch, separate plots are shown for in-season catch rates and non-season catch rates, unless no seasonality in the data was apparent. A high catch rate index from the seasonal decomposition was ignored if it was isolated from a generally recognized season. For example, the troll catch per trip for yellowfin tuna indexed high in December as well as in May-October; however, December was coded neutral and was not shown in the plots of troll-handline catch rate by season versus longline catch. Only a few months for a few species and gear had anomalous seasonal indexes, and elimination of these months did not substantially alter the results.

RESULTS

Yellowfin Tuna

For yellowfin tuna, annual troll and handline catch rates (Fig. 1) increased from 1983 to 1986 or 1987 (or 1988 for palu ahi), then declined to the 1983 level. Monthly longline catches (fishing pressure) fluctuated greatly within each year (Fig. 2) but generally increased over the period of declining troll handline catch rates (1988-89). One could attribute the decline in troll and handline catch rates to the expansion of the longline fishery, but this provides no explanation for why catch rates were so low in 1983-84. At that time, foreign longline fishing in Hawaii's 200-mile fishery conservation zone had ceased 3-4 years earlier, and the domestic longline fishery was relatively small. Perhaps the increase in catch per trip from

1983 to 1986 or 1987 represents an improvement in fishing methods, a change in fishing operations, or the result of some environmental change. The consistency in the pattern among gear types suggests that the change was not due to fishing practices or trends in reporting, unless these changed similarly among several different gear types. A simultaneous change in fishing operations among several sectors of the fishery is the type of effect that might be expected from an economic factor such as operating costs (insurance, fuel, labor) or fish prices. The greatest longline catches of yellowfin tuna in the 42-month time series were in July and August 1989 (Fig. 2B). These are in-season months for the troll and handline fisheries, which (except for palu ahi) had relatively poor seasons in 1989 (Fig. 3A, B, C, D). The monthly catch per trip time series shows some increase in catch rates by the troll, ika shibi, and drifting handline fisheries during the first half of 1990 (Fig. 3A, B, D).

The deseasonalized monthly yellowfin tuna catch rates for most of the gear types (except palu ahi) showed a downward trend after the spring of 1987 (Fig. 4A, B, D) and were low most frequently in 1989. However, some of the lowest catch rate months were in early 1987, when longline catches were relatively low (Fig. 2B). Deseasonalized catch rates for part of a year (i.e., 1990) provide estimates that can be compared with earlier years. In 1990, deseasonalized ika shibi yellowfin tuna catch rates were as high as in 1987 (Fig. 4B); deseasonalized troll and drifting handline catch per trip also increased in 1990 (Fig. 4A, D). However, this does not address the question of what may have happened later in 1990 when the longline fleet doubled in size.

One striking aspect of all of the yellowfin tuna time series (annual, monthly, deseasonalized monthly) is the great variation in catch rates. At the annual resolution, the high catch rates are more than twice as high as the low annual average catch rates (Fig. 1). At the monthly resolution, the high catch rates are three to five times higher than the low catch rates (Fig. 3), and a surprising amount of variation remains in the deseasonalized data (Fig. 4; the deseasonalized time series are plotted on the same scale as the regular monthly time series so that the reduction in variation can be visualized). The results for the other species are similar in this regard, as are older time series data on Hawaii's pelagics fisheries (Wetherall and Yong 1983; Skillman and Kamer In prep.). The implication is that fishermen targeting these species must be prepared to experience drastic changes in availability as a normal occurrence.

Some correspondence between high troll and handline catch rates for yellowfin tuna and low longline catches can be seen in some of the plots of catch per trip versus longline catch (Figs. 5 and 6). The highest troll and handline catch rates occurred when the longline catch of yellowfin tuna was less than 180,000 lb (Fig. 5) and when the current and preceding 2 months (i.e., the last 3 months) had a longline yellowfin tuna catch averaging less than 100,000 lb (Fig. 6).

Several of the plots suggest a weak negative interaction between the longline catch and the troll and handline catch per trip (Figs. 5A, C, G and 6A, B, C, G, H); however, there is a lot of scatter in the data, and low troll and handline catch rates occurred across most of the range in longline catch in most cases. So, although the absence of high catch rates for yellowfin tuna in months of high longline catches could be attributed to the removal of fish by the longliners, this could not explain the low catch rates at times when longline catches were low. The vertical scatter on these plots (Figs. 4 and 5) suggests that other factors besides longline catch are affecting catch rates. One source of variation (discussed below) is the misclassification of bigeye tuna as yellowfin tuna. Misidentified bigeye tuna are mostly a source of error in the ika shibi data.

Perhaps the in-season data on yellowfin tuna (Figs. 5A, C, E, G and 6A, C, E, G) showed more indication of interaction than the non-season data (Figs. 5B, D, F, H and 6B, D, F, H), but it is not clear and should await a more comprehensive analysis. The in-season and non-season data are plotted on the same scale so that one can more easily visualize the differences and similarities between them.

The suggestion of interaction seemed clearer when catch rates were plotted against the last 3 months of longline catch (Fig. 6) than when plotted against the same month's longline catch (Fig. 5). Using the average of even longer periods of longline catch (i.e., the last 5 or 7 months) produced patterns (not shown) very similar to Figure 6. For all of the species examined below, generally if there was a relationship between catch per trip and longline catch in the same-month time frame, that relationship was also found using a sustained (3-, 5-, or 7-month average) time frame. Most typically, no relationship was apparent with any time frame. Compared with other species, the results for yellowfin tuna were more indicative of a negative interaction.

If a trend in troll or handline catch rate data happens to be opposite a trend in longline data, this will create an apparent relationship even if the relationship does not reflect cause and effect. If a relationship is apparent when there is no clear trend, this would constitute stronger evidence of fishery interaction, because it would suggest that short-term variations in catch rate mirror fluctuations in longline catch. To take the analysis a step further, the catch rate data could be de-trended and reexamined in relation to longline catch.

The results for yellowfin tuna have been discussed in detail, both as an example of how to interpret each type of graph, and because the results are more suggestive of fishery interaction than are the results for other species. The graphical analysis of the remaining species is presented with less comment.

Bigeye Tuna

The HDAR data on bigeye tuna is problematic, especially in regard to handline gear, because many fishermen fail to identify the fish except as "ahi," which in Hawaii may refer to either yellowfin or bigeye tuna. Given no other information, HDAR codes categorize ahi as yellowfin tuna. Although ika shibi handline fishermen are known to land substantial amounts of bigeye tuna, the HDAR data indicate very low catch rates for this species. The true ika shibi catch rates for bigeye tuna are much greater. Faulty reporting is evidenced by bigeye tuna comprising <2% of the troll and handline catches in the 1989 HDAR data and around 15% of the total non-longline catch in the NMFS market data. The NMFS market sampling accurately identifies the two species. Misidentified bigeye tuna also create some errors in the yellowfin tuna data, especially in the ika shibi category. In the other handline fisheries and in the troll fishery, the catch ratio of bigeye tuna to yellowfin tuna is known to be very small; therefore, for most types of fishing, the yellowfin tuna data are not badly biased by misidentified bigeye tuna.

Some troll and handline fishermen do report bigeye tuna catch, and some similarities are apparent in the trends indicated by the data for different gear types; therefore, the troll and handline data for bigeye tuna may not be completely meaningless as an index of local abundance. Catch per trip data for three handline gear types declined from 1985 to 1986 (Fig. 7) and stayed low through 1987, increasing in 1988. Troll catch rates are very low but show a gradual increase from 1984 to 1989.

Interestingly, the minimum annual catch rate for bigeye tuna in 1986-87 corresponded with the peak in annual catch rate for yellowfin tuna (Fig. 1). Previous studies (Otsu 1954; Shomura 1959) have noted an inverse relationship between catches of yellowfin and bigeye tunas in Hawaii's longline fishery and hypothesized it was due to a shift in fishing areas. Perhaps there is also a reduced local abundance of bigeye tuna (which is most abundant in winter) in years of increased local abundance of yellowfin tuna (which is most abundant in summer). If there is an environmental influence, it might be expected to affect summer and winter species in the opposite way. Spring sea-surface temperatures around Hawaii were typical in 1986 and 1987 but much higher than average in 1988 and 1989 (NMFS unpublished data). However, the mechanism for such an environmental relationship is obscure, since one might expect the warmwater, summer-associated species (yellowfin tuna) to be more abundant in anomalously warm years.

No clear trends were evident in the monthly time series of bigeye tuna catch rates from 1987-1990 (Fig. 8) even though longline bigeye tuna catches increased steadily over the period (Fig. 2A). Catch rates reached a record peak in March or April of 1990 among all four gear types (Fig. 8A-D). Seasonal decomposition produced no clear pattern, but rather a scatter of isolated high and low index months. Therefore the bigeye tuna data were not deseasonalized, nor was catch rate versus longline catch examined on a seasonal basis. (Whenever no consistent seasonal indexes were found for a given species and gear type, no deseasonalized data have been shown.)

In the plots of troll and handline catch rates versus longline catch, the highest bigeye tuna catch rates by all gear types occurred in the middle of the range of longline bigeye tuna catches (Figs. 9 and 10). If the highest catch rate is ignored as an outlier, there might be a very slight indication of a negative relationship between the troll catch rate and the longline catch of bigeye tuna (Figs. 9A and 10A). However, in the only non-longline fishery where bigeye tuna are important (ika shibi), catch rates appeared to be completely random in relation to longline catches (Figs. 9B and 10B).

Blue Marlin

Aside from yellowfin tuna, the interaction between troll or handline catch rates and longline catches might be greatest for blue marlin, a principal target species of troll fishermen which also experienced increases in longline catches in the last 2 years (Fig. 2D). Nevertheless, annual troll catch rates for blue marlin remained relatively constant during 1983-87 and then increased (Fig. 11). The monthly (Fig. 12A) and deseasonalized monthly (Fig. 13) troll catch per trip time series also suggested an increase in blue marlin troll catch per trip in 1987-90. Changes in reporting, targeting, stockwide abundance, or the environment are possible causes for this apparent increase. For the handline gear, the catch of blue marlin was so incidental as to preclude deseasonalization, and few similarities existed among gear types in the pattern of handline catch rates at the annual or monthly resolution (Figs. 11 and 12B-D).

There were no clear relationships between catch rates by troll and handline gear and longline catches of blue marlin (Figs. 14A, C-E and 15A, C-E) except for non-season troll catch per trip, which appeared to increase in relation to longline catch (Figs. 14B and 15B).

Striped Marlin

In 1984, striped marlin troll catch per trip had a small peak, and two of the handline gear had strong peaks (Fig. 16). Annual troll and drifting handline catch rates of striped marlin showed a decline after 1988 (Fig. 16). The partial match in pattern among gear types makes the data more believable. In the monthly catch rate time series, there was a strong peak in December 1988 for both troll and drifting handline gear (Fig. 17A, B).

The longline catch of striped marlin increased in 1988 and 1989 and stayed about the same in 1990 (Fig. 2C). In comparison, monthly troll catch per trip declined during peak troll catch rate periods in November-February 1987-88, 1988-89, and 1989-90 (Fig. 17A). The deseasonalized time series (Fig. 18) also showed this decline, but the lowest deseasonalized troll catch rates were in the first quarter of 1987, when longline catches of striped marlin were low (Fig. 2C). The deseasonalized time series of monthly striped marlin troll catch per trip indicates a major increase in the first half of 1990 (Fig. 18).

No relationship was evident between troll or drifting handline catch rates for striped marlin and longline catches (Figs. 19 and 20), except perhaps in the troll fishery where a weak positive relationship may exist (Figs. 19A and 20A). Catches by the ika shibi and palu ahi handline gear were too incidental to be considered, and the drifting handline catch was too incidental to allow deseasonalization.

Swordfish

The catch of swordfish by the ika shibi handline fishery in the summer was incidental and of low magnitude, but this gear type had the highest annual catch rate over the 1983-87 period (Fig. 21), and catch rates showed a slightly declining trend in 1984-89. The monthly ika shibi catch per trip data also suggest a declining series of seasonal peaks (Fig. 22). Although data on the expanding catches of swordfish by the longline fleet are not yet available, targeting of swordfish did not begin until mid-1988. The handline catch rates are presented here because of the great concern expressed regarding possible overexploitation of swordfish. Note that the apparent decline predates the longline expansion and that the deseasonalized monthly time series (Fig. 23) suggests less of a decline than the raw data (Fig. 22).

Mahimahi

Annual catch rates for mahimahi by troll and drifting handline gear increased up until 1987. Catch rates of these gear and palu ahi then fell to a minimum in 1988, and catch rates by all gear types rose back to an average value in 1989 (Fig. 24). Longline catches of mahimahi did not increase substantially until spring 1989 (Fig. 2E), which coincided with peak catch rates by troll, ika shibi, and drifting handline gear (Fig. 25). The deseasonalized catch rate time series indicates average or increasing catch rates as longline catch increased after February 1989 (Fig. 26). For troll, palu ahi, and drifting handline gear, the deseasonalized monthly catch rate time series indicated an abrupt decline in early 1987 (Fig. 26). Several gear types showed slight increases throughout the rest of the time series.

Some low catch rates occurred at all levels of longline catch, and some of the higher catch rates occurred at moderately high levels of longline catch (Figs. 27 and 28). These results suggest that no negative fishery interaction occurred between longline catches of mahimahi and troll or handline catch rates.

Ono (Wahoo)

Common patterns among gear types were found in the annual time series of ono troll and handline catch per trip, which generally increased from 1984 to 1986, declined in 1987, and then increased slightly after 1987 (Fig. 29). Longline catches of ono did not increase much until May-August 1989 (Fig. 2F) and thereafter declined to previous levels. Monthly catch per trip data for troll and handline gear seemed to follow typical patterns right through the period of maximum longline catch (Fig. 30). The deseasonalized monthly data did not indicate any clear trends (Fig. 31), nor were catch rates appreciably lower during or after summer 1989.

Neither troll or drifting handline catch rates appeared to be related to longline catches (Figs. 32A-D and 33A-D). The two highest ika shibi and palu ahi monthly catch rates coincided with low longline catches, but fairly high ika shibi and palu ahi catch rates occurred throughout the range of longline catches (Figs. 32E, F and 33E, F).

CONCLUSIONS

Any conclusions are preliminary, for as described in Appendix A, the task of analyzing the potential impact of expanded local longline fishing on the local abundance of pelagic fish will require more time, improved data, and consideration of other factors. It is especially important to note that the impact of *current* longline fishing pressure is not addressed by the data herein, which do not extend beyond early 1990.

Only yellowfin tuna catch rates gave the appearance of declining in relation to the increase in longline catch, but this decline could well be due to other factors. Convincing (though not conclusive) evidence of fishery interaction would consist of a clearly declining relationship between troll and handline catch rates and longline catches, whereas the yellowfin tuna data presented here show much variation unrelated to longline catches and low catch rates throughout most of the range in longline catch. Whatever the causes, the decline in yellowfin tuna catch per trip over the last few years seems very real, being reflected in data from many gear types. This species dominates the catch of the troll and handline fisheries and is singularly important to the handline fisheries which are Hawaii's most traditional pelagic fisheries. Longer time series of local data, comparison with Pacific-wide variations in catch rate, and analysis of environmental influences must be considered to rigorously describe the nature of this trend.

The lack of clear relationships between longline catch and catch rates for blue and striped marlins, mahimahi, ono, bigeye tuna, and swordfish suggests that longline fishing through early 1990 did not have much impact on the catch rates of these species by other gear. However, except for bigeye tuna and striped marlin, these are species for which the larger troll and handline catches would be expected to exert an equal or greater impact than longline catches (prior to 1990 anyway), and such an impact was not considered here.

To assess the relative status of the small-vessel pelagic fisheries during the period of longline expansion, it is useful to examine the annual summary data at a lower resolution. Comparing the averages of the catch per trip estimates from each year for 1988-89 (N = 2) with those for 1983-87 (N = 5, Table 1) shows that, although troll catch rates for both marlin species were higher in 1988-89, troll catch rates for yellowfin tuna, mahimahi, and ono were lower, as were handline catch rates for all species except bigeye tuna. These changes are not large compared with the range in annual catch per trip (data for non-tuna species only) over a longer time period (1962-89, Table 1), but they confirm the testimony of Hawaii's troll and handline fishermen who say that catch rates have declined during the period of longline expansion. Although available data provide no clear-cut evidence that longline catches have had a significant impact on troll and handline catch rates, new data collected over the next 3 years may do so. Until more data are available, we will not be able to reliably assess impacts of the longline fleet expansion.

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The NMFS data summaries for this study were provided by Sam Pooley and Stacey Yoshimoto, and the HDAR data summaries were provided by Reggie Kokubun. An earlier draft of this document was reviewed by George Boehlert, Sam Pooley, Jerry Wetherall, and Stacey Yoshimoto.

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Table 1.--Annual catch (pounds) per annual number of trips averaged over four periods: historical (1962-72), maximum foreign longline (1973-78), pre-domestic longline expansion (1983-87), and domestic longline expansion (1988-89). Trips were counted as the annual number of the Hawaii Division of Aquatic Resources' records for tuna or pelagic management unit species, excluding multiple records with the same vessel-date combination. Data on deep-sea handline, ika shibi, palu ahi, and drifting handline gear were combined under handline gear. Data for 1962-78 are from Skillman and Kamer (In prep.). Tuna data were not available for 1962-78.

	Average of annual catch/trips				Range in annual catch/trip			
Species	(62-72)	(73-78)	(83-87)	(88-89)	Maximum	Year	Minimum	Year
Troll Gear								
Yellowfin tuna	---	---	51	34	78	1987	29	1989
Bigeye tuna	---	---	0.4	0.5	0.6	1989	0.3	1984
Blue marlin	32	20	23	34	66	1964	10	1975
Striped marlin	4.8	9.7	2.7	4.4	15	1974	1	1963
Mahimahi	10	8.8	19	17	25	1987	7	1967
Ono	6.9	11	17	15	18	1986	4	1962
Handline Gear								
Yellowfin tuna	---	---	272	233	351	1986	201	1983
Bigeye tuna	---	---	3.9	4.1	10	1983	0.4	1986
Blue marlin	1.0	2.1	3.1	2.4	4.2	1978	0	1972
Striped marlin	1.2	2.3	0.5	0.3	4.2	1974	0.1	1989
Swordfish	0.1	0.8	2.6	2.2	5.0	1983	0	many
Mahimahi	10	4.8	7.5	5.0	16	1963	3.4	1977
Ono	10	6.1	4.2	3.5	14	1964	1.9	1984

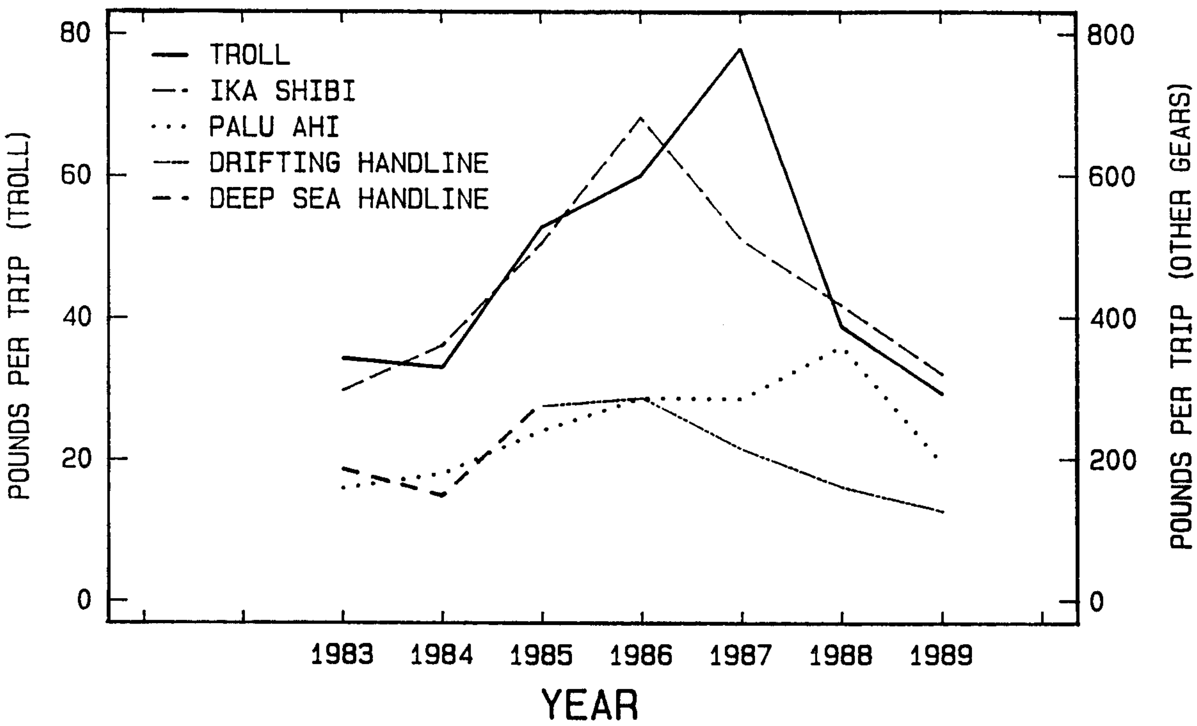

Figure 1.--Annual catch of yellowfin tuna per trip, by gear type, in Hawaii during 1983-89. Data are from the Hawaii Division of Aquatic Resources.

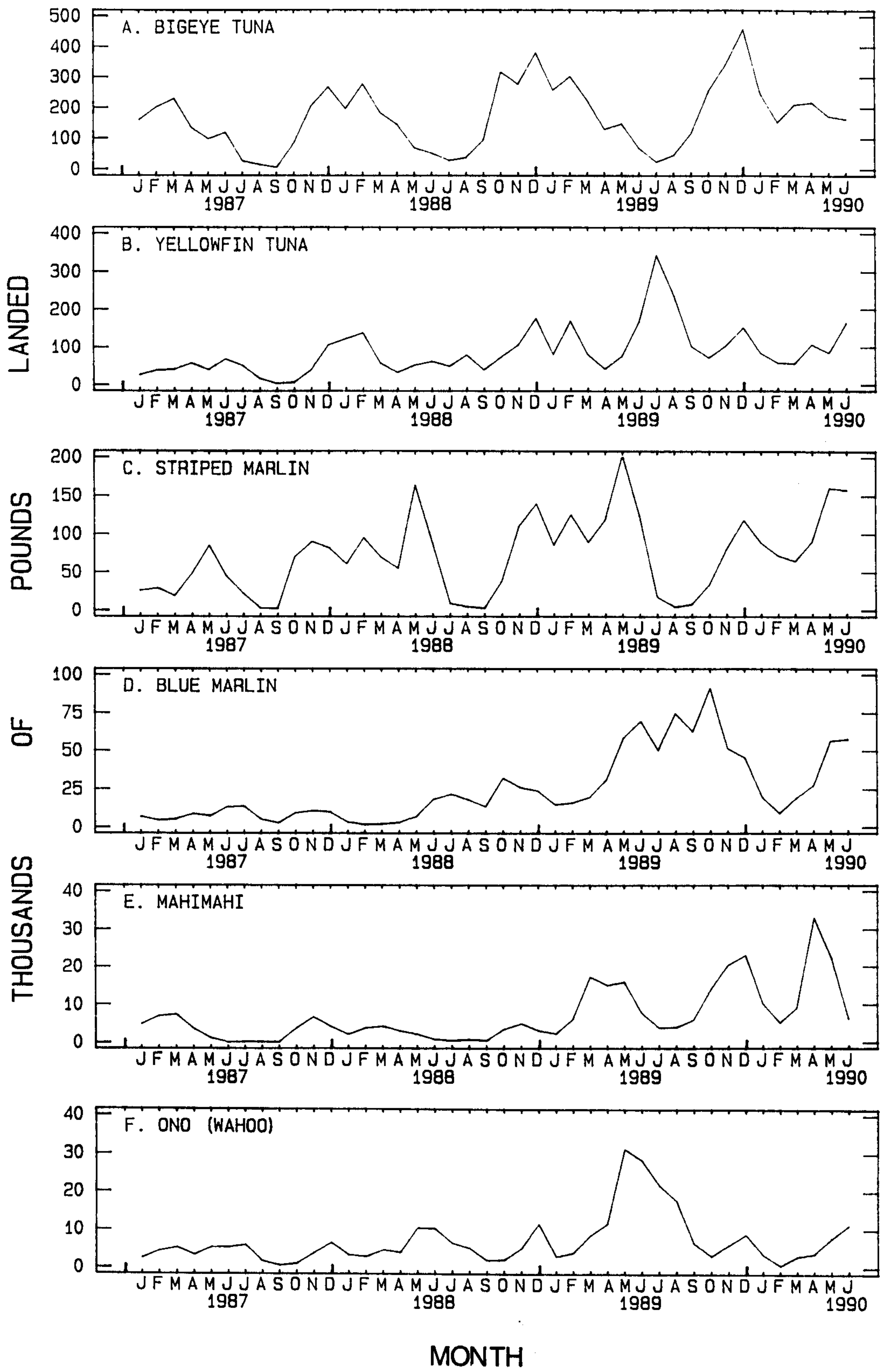

Figure 2.--Monthly catch of six important species by longline gear in Hawaii during January 1987 to June 1990. Data are from the market monitoring program of the Honolulu Laboratory.

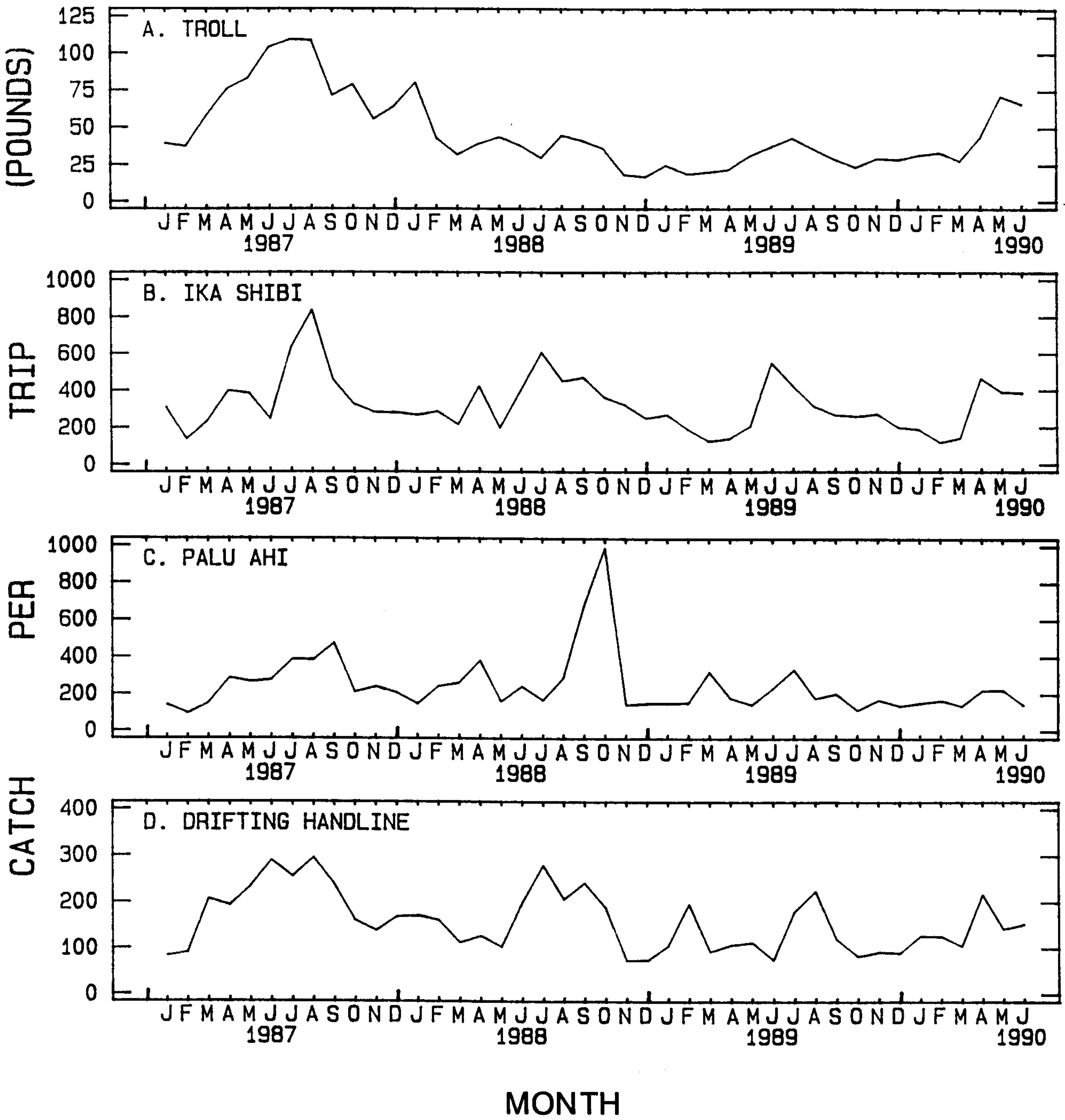

Figure 3.--Monthly catch of yellowfin tuna per trip, by gear type, in Hawaii during January 1987 to June 1990. Data are from the Hawaii Division of Aquatic Resources.

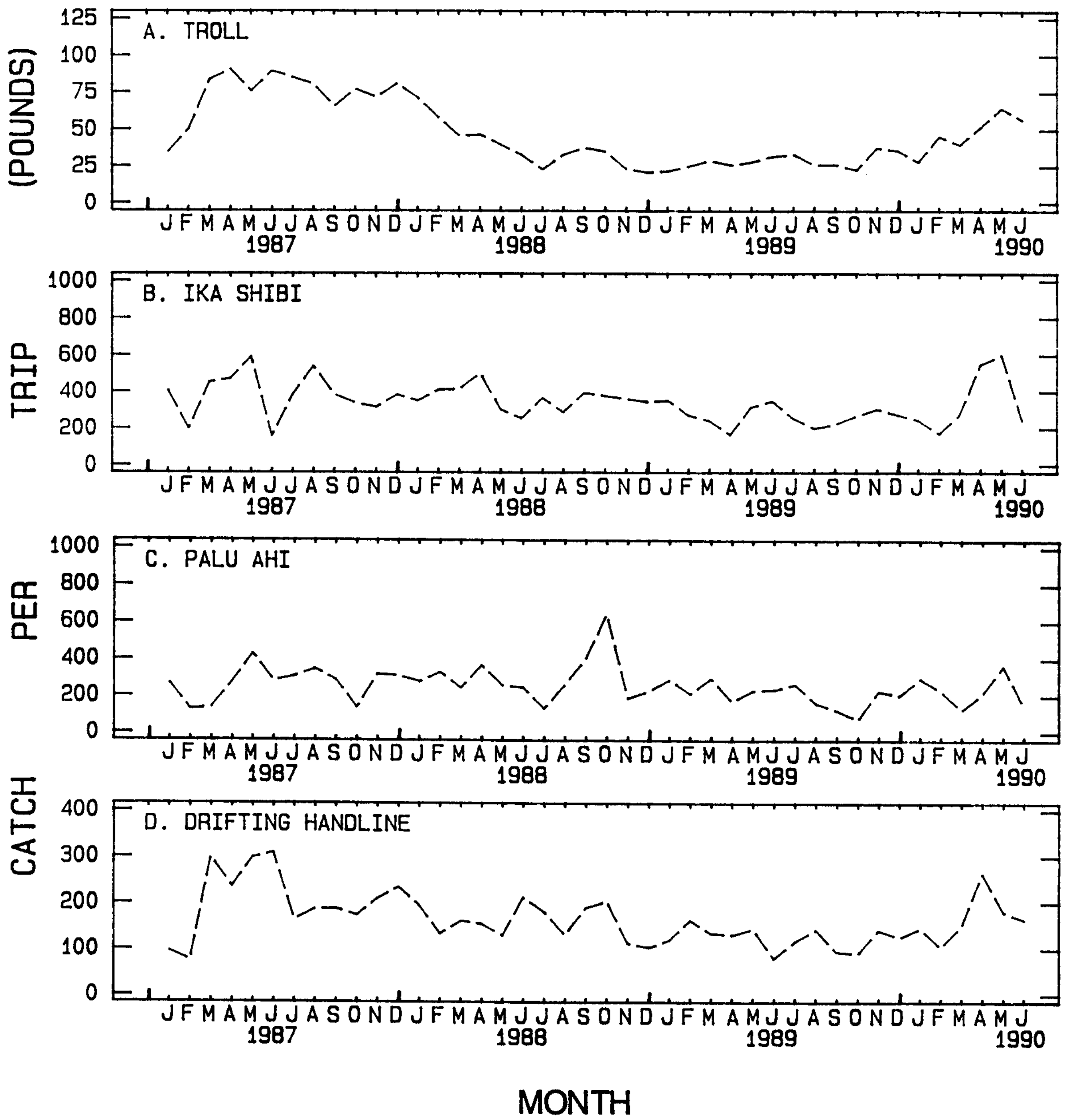

Figure 4.--Deseasonalized data on the catch of yellowfin tuna per trip, by gear type, in Hawaii during January 1987 to June 1990. Data are from the Hawaii Division of Aquatic Resources.

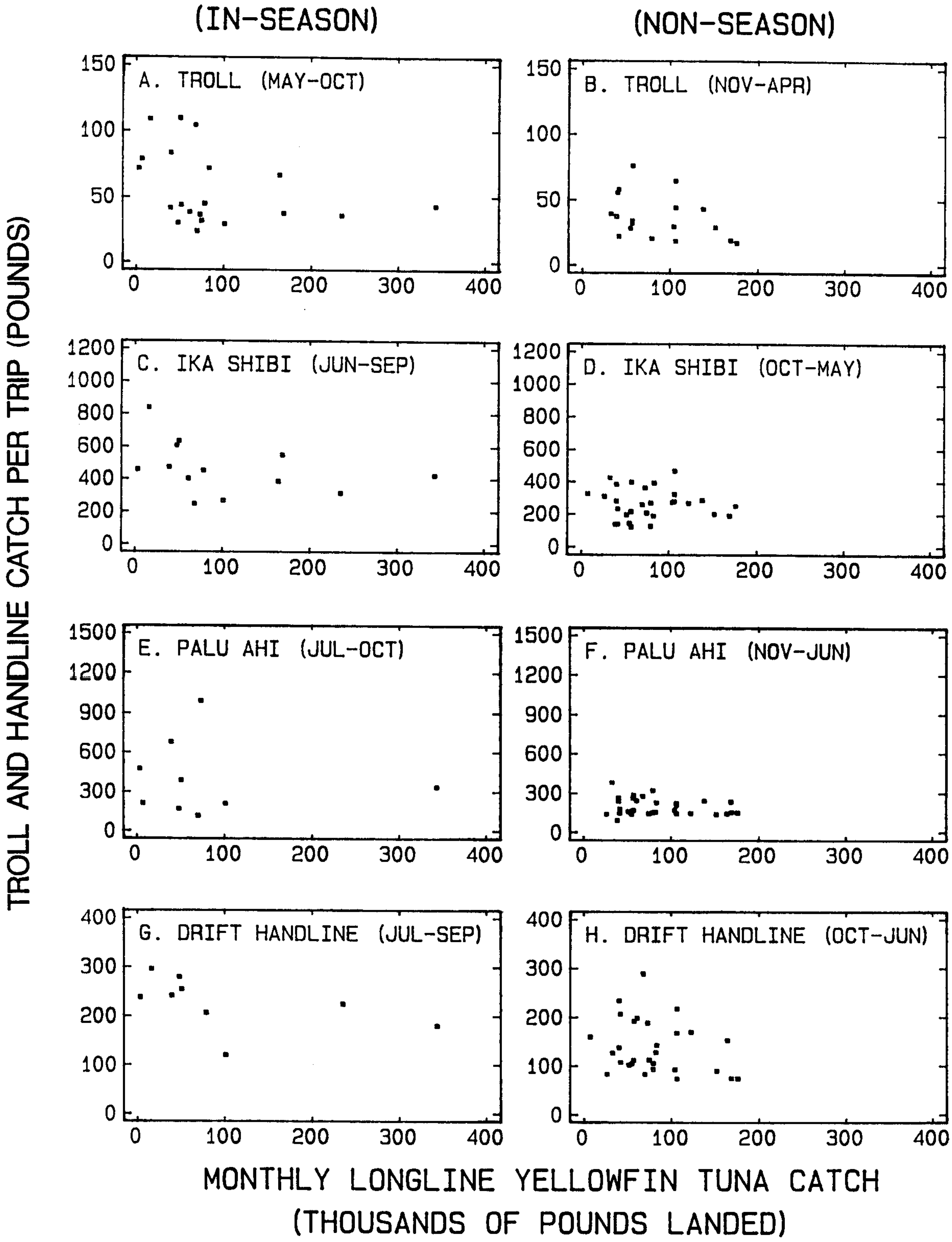

Figure 5.--Catch of yellowfin tuna on a monthly per-trip basis by troll and handline gear versus the monthly catch by longline gear in Hawaii during January 1987 to June 1990. The data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

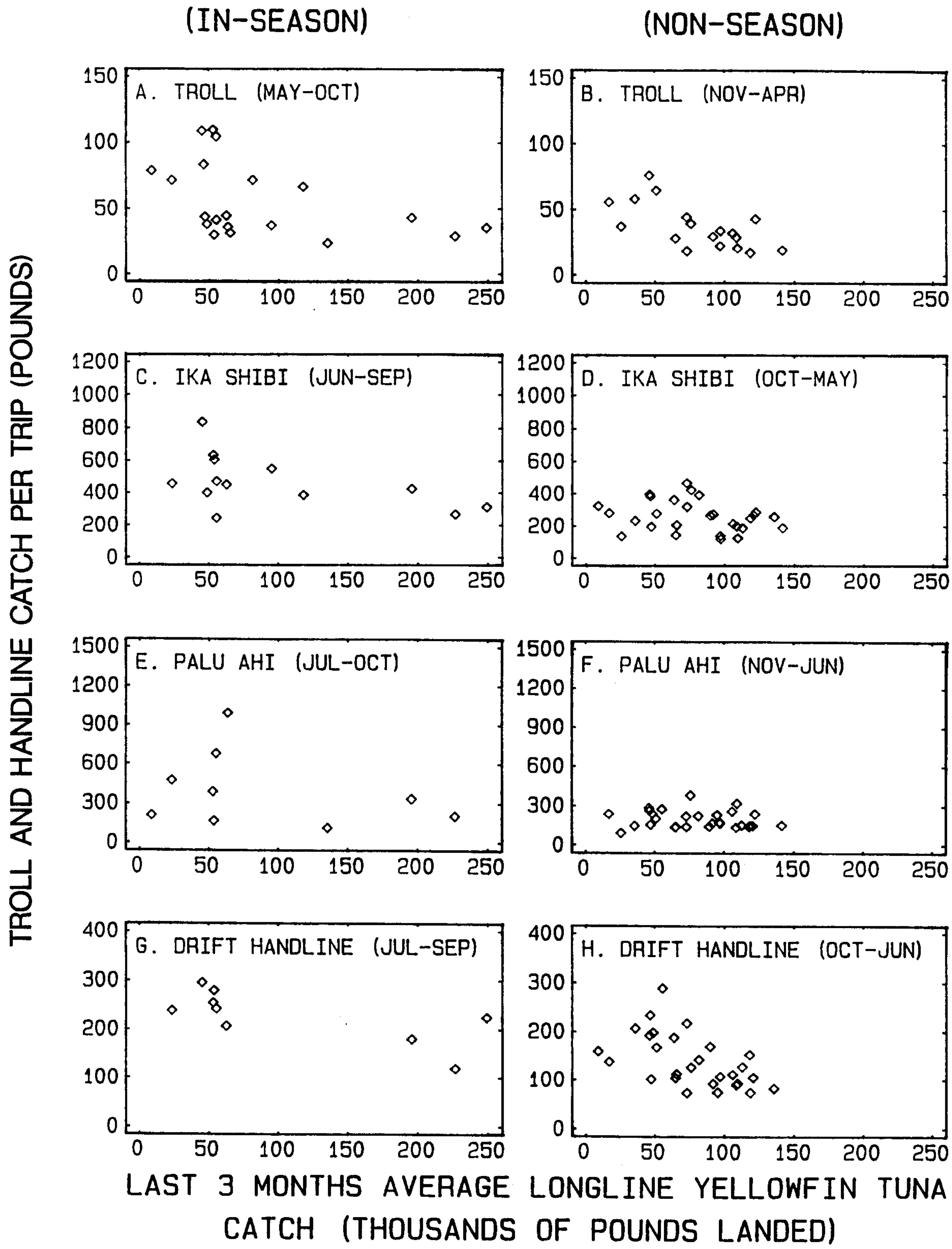

Figure 6.--Catch of yellowfin tuna on a monthly per-trip basis by troll and handline gear versus the most recent 3-month average catch by longline gear in Hawaii during January 1987 to June 1990. The data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

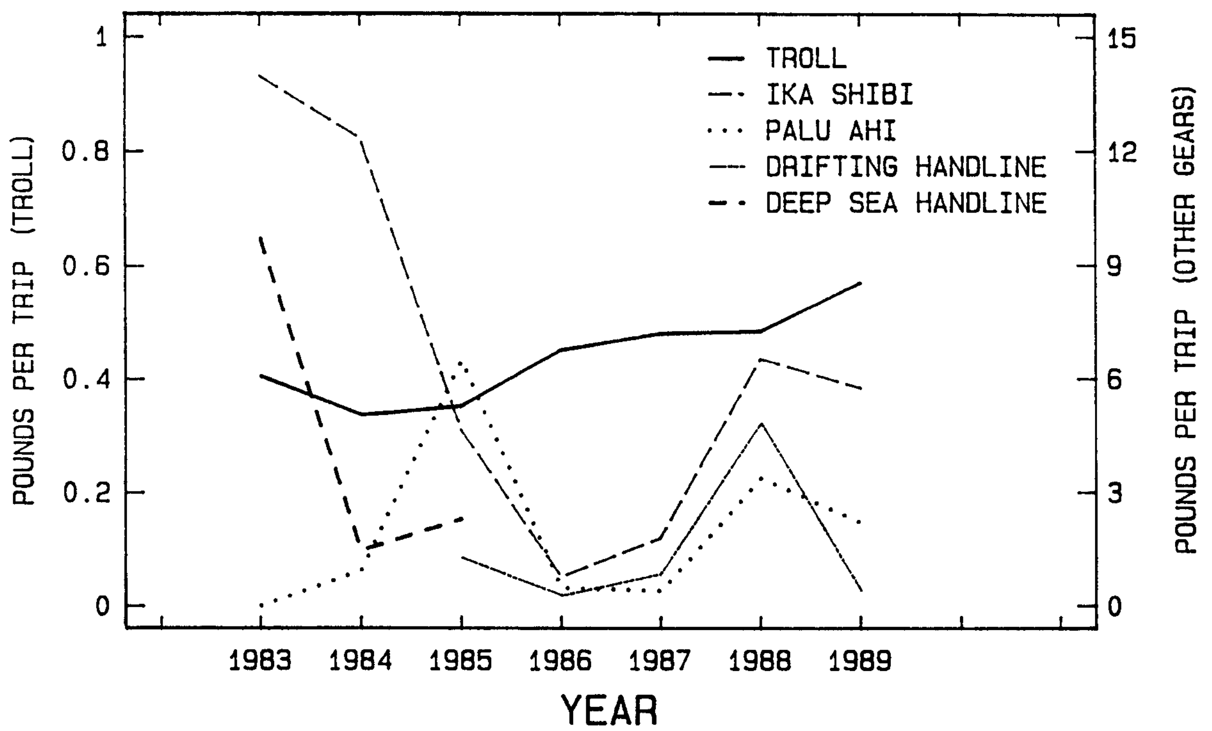

Figure 7.--Annual catch of bigeye tuna per trip, by gear type, in Hawaii during 1983-89. Data are from the Hawaii Division of Aquatic Resources.

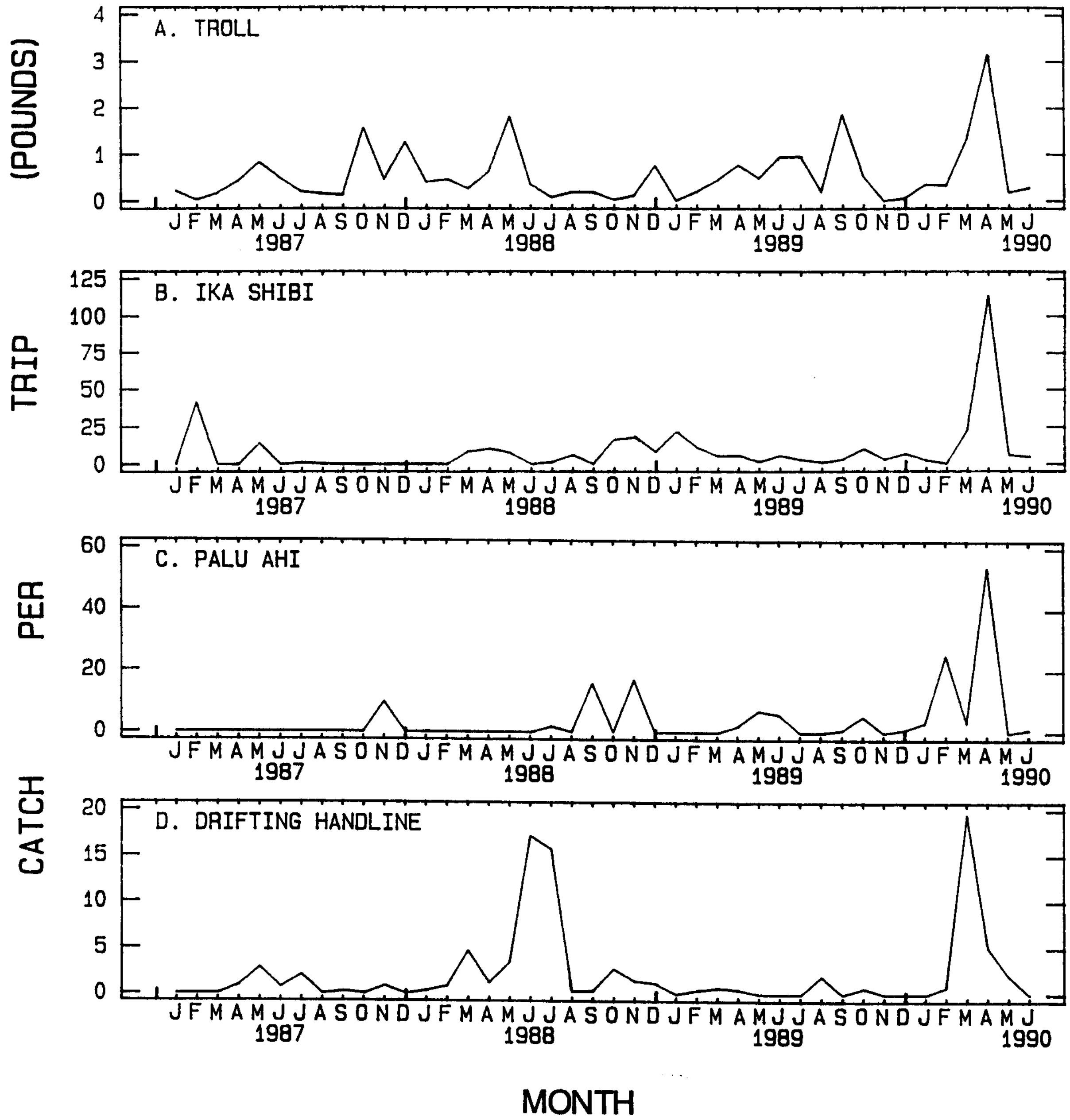

Figure 8.--Monthly catch of bigeye tuna per trip, by gear type, in Hawaii during January 1987 to June 1990. Data are from the Hawaii Division of Aquatic Resources.

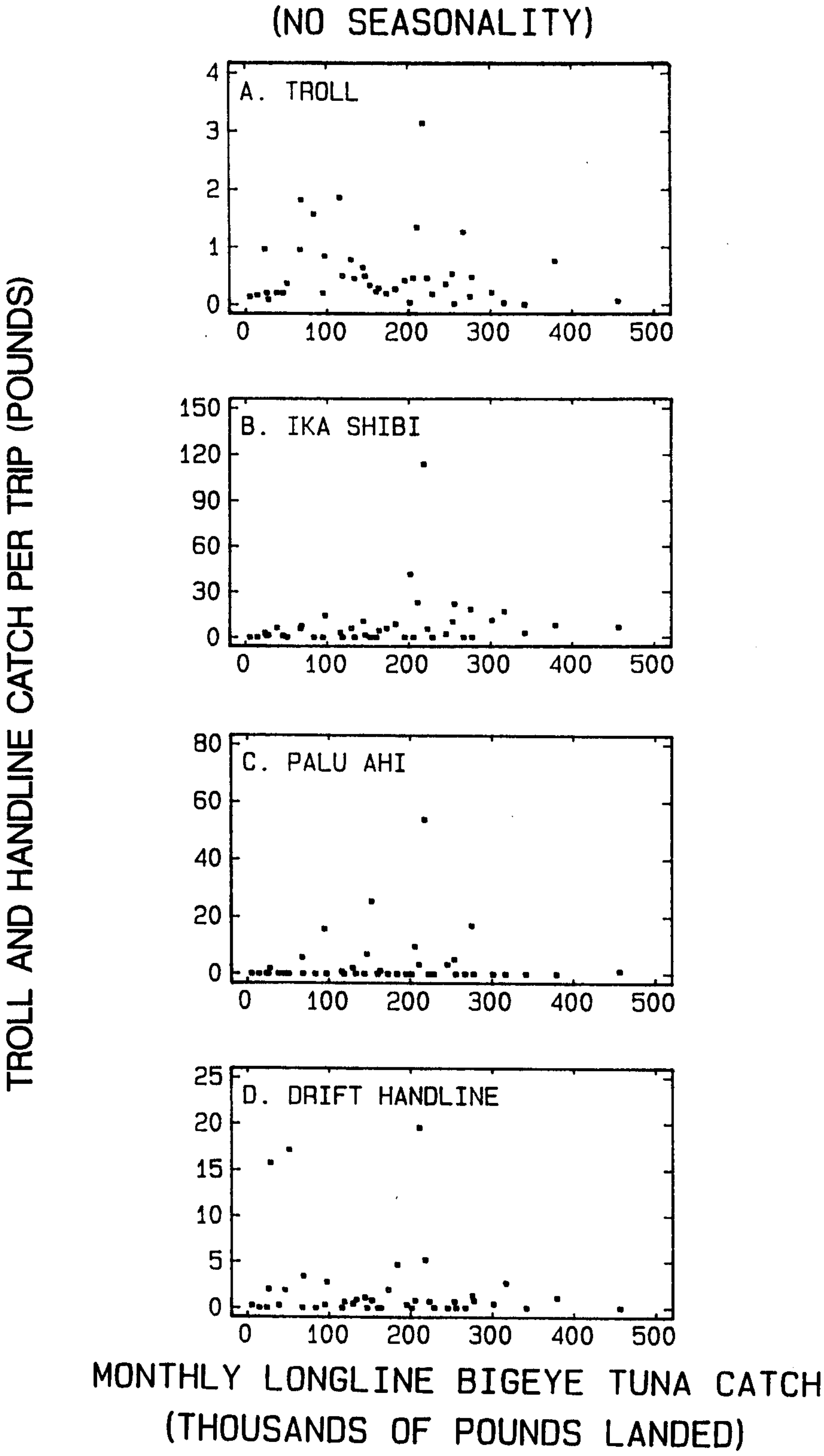

Figure 9.--Catch of bigeye tuna on a monthly per-trip basis by troll and handline gear versus the monthly catch by longline gear in Hawaii during January 1987 to June 1990. The data were not segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

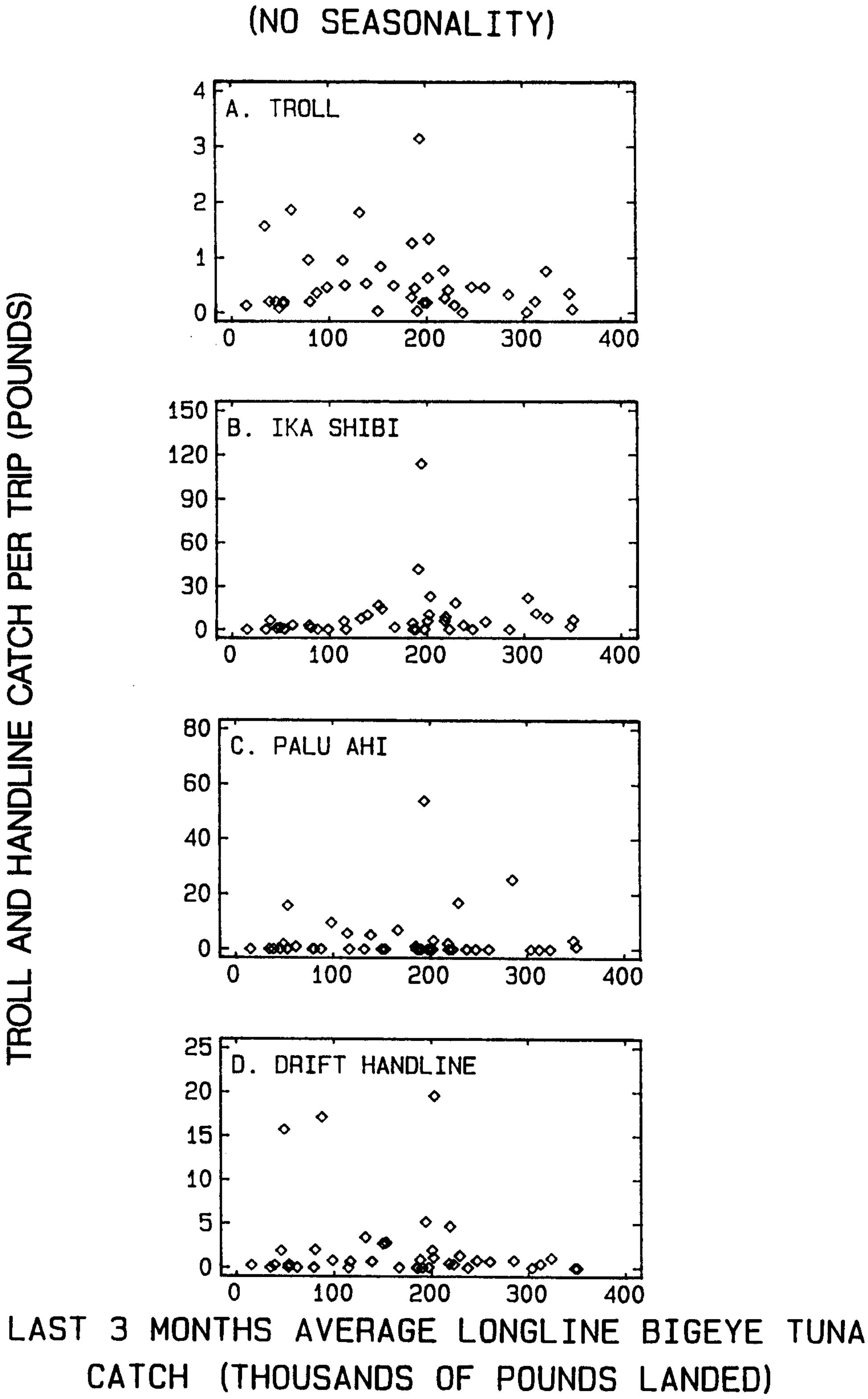

Figure 10.--Catch of bigeye tuna on a monthly per-trip basis by troll and handline gear versus the most recent 3-month average catch by longline gear in Hawaii during January 1987 to June 1990. The data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

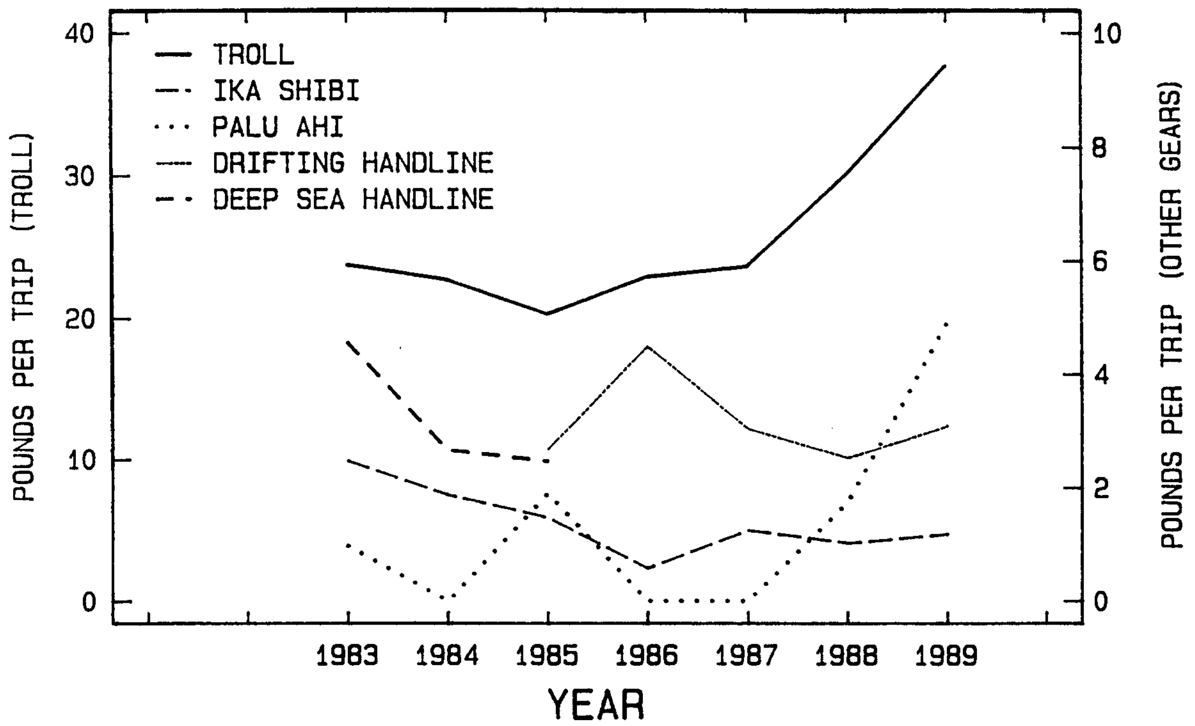

Figure 11.--Annual catch of blue marlin per trip, by gear type, in Hawaii during 1983-89. Data are from the Hawaii Division of Aquatic Resources.

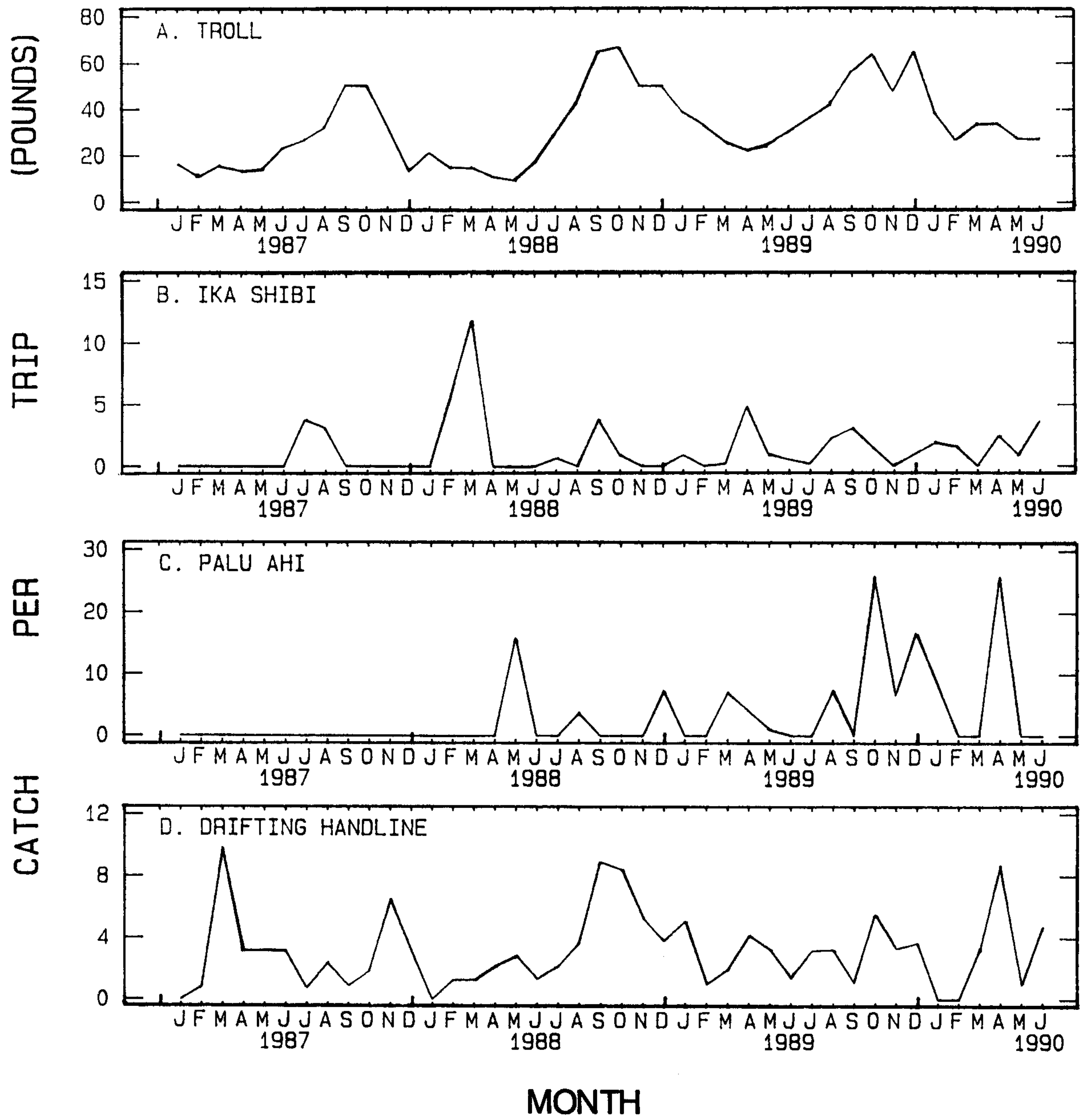

Figure 12.--Monthly catch of blue marlin per trip, by gear type, in Hawaii during 1983-89. Data are from the Hawaii Division of Aquatic Resources.

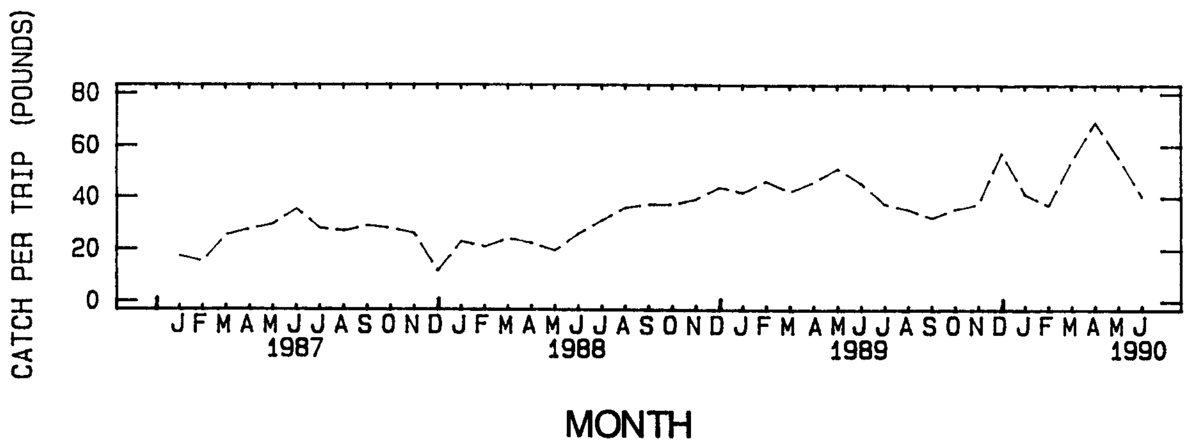

Figure 13.--Deseasonalized data on the catch of blue marlin per trip, by troll gear, in Hawaii during January 1987 to June 1990. Data are from the Hawaii Division of Aquatic Resources.

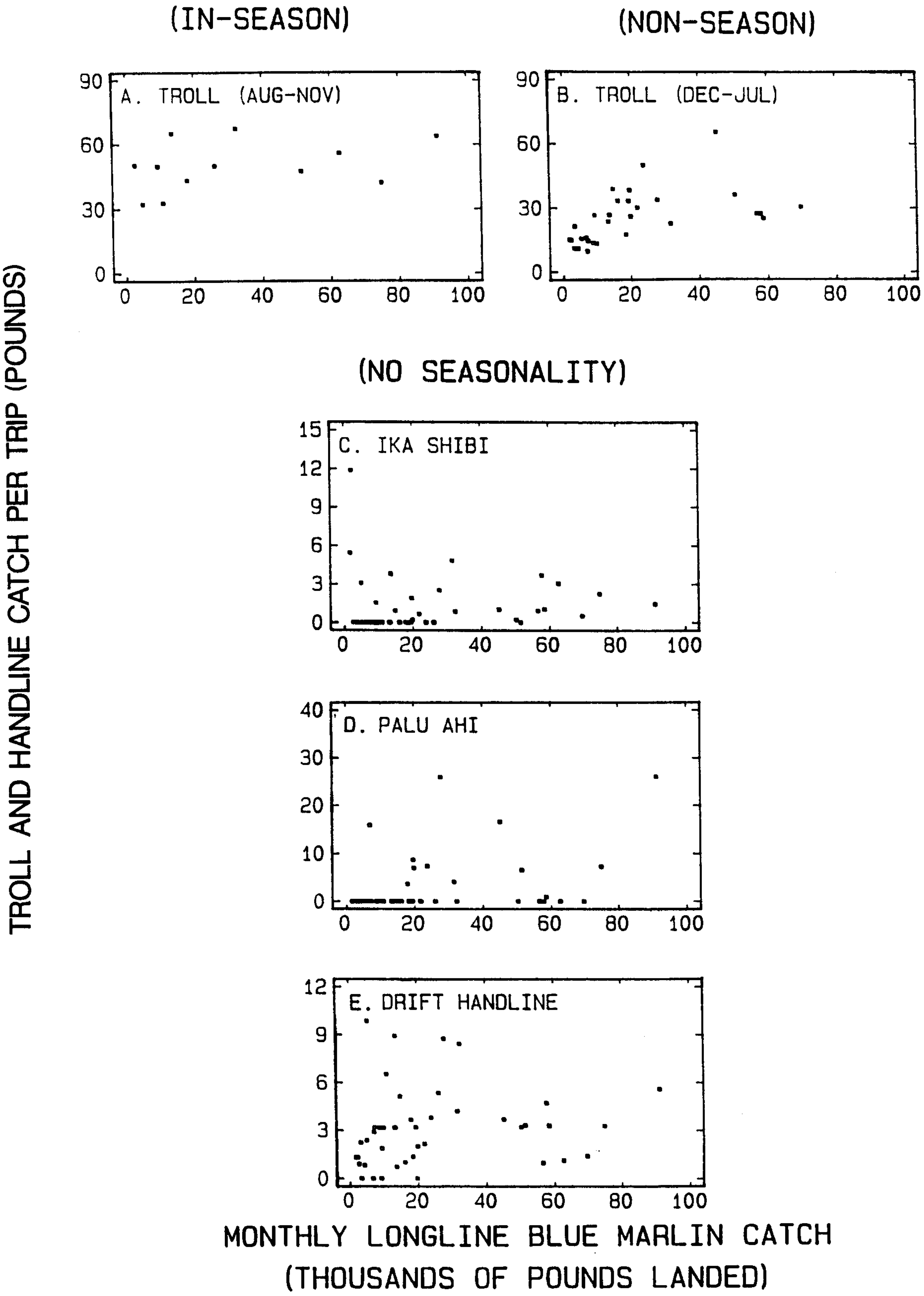

Figure 14.--Catch of blue marlin on a monthly per-trip basis by troll and handline gear versus the monthly catch by longline gear in Hawaii during January 1987 to June 1990. Some of the data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

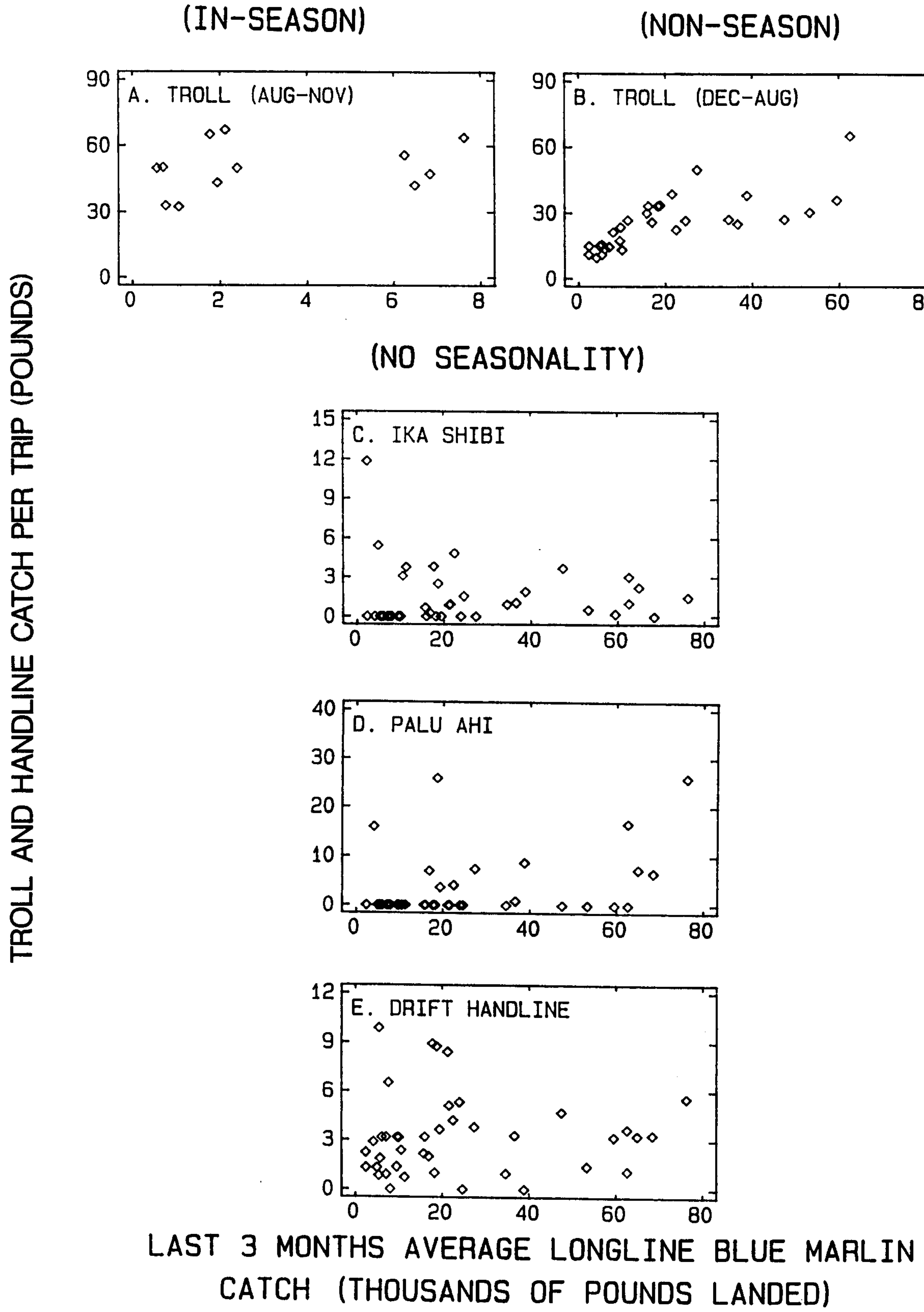

Figure 15.--Catch of blue marlin on a per-trip basis by troll and handline gear versus the most recent 3-month average catch by longline gear in Hawaii during January 1987 to June 1990. Some of the data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

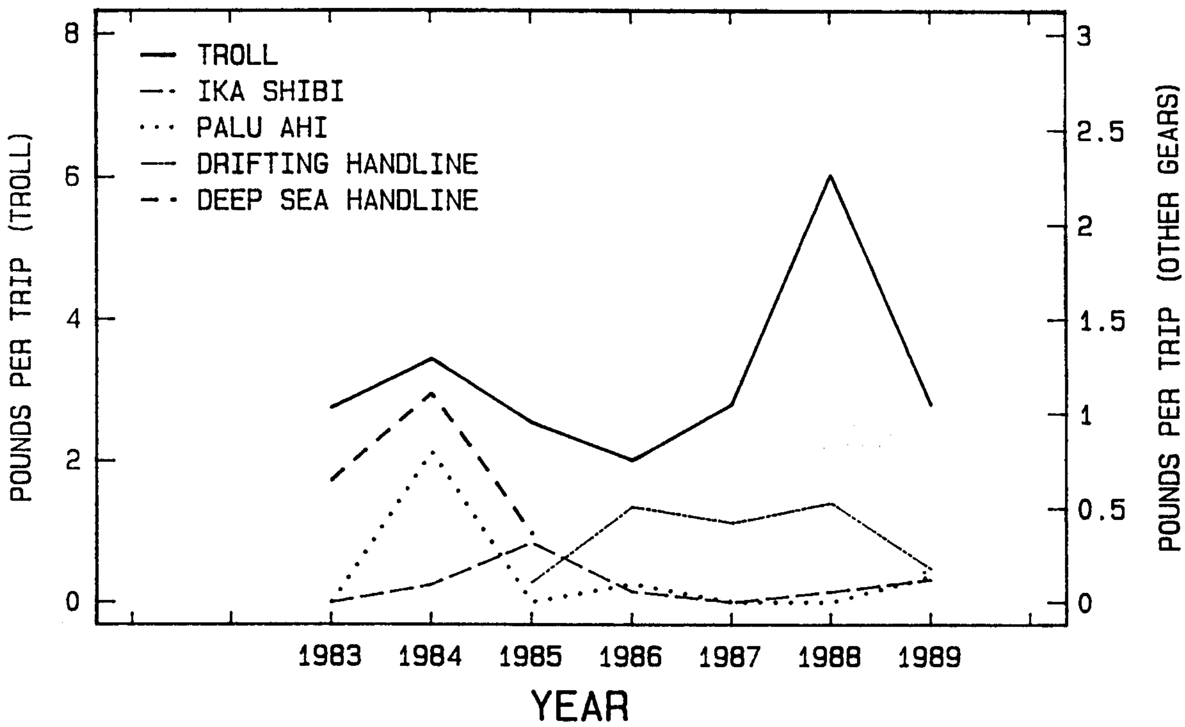

Figure 16.--Annual catch of striped marlin per trip, by gear type, in Hawaii during 1983-89. Data are from the Hawaii Division of Aquatic Resources.

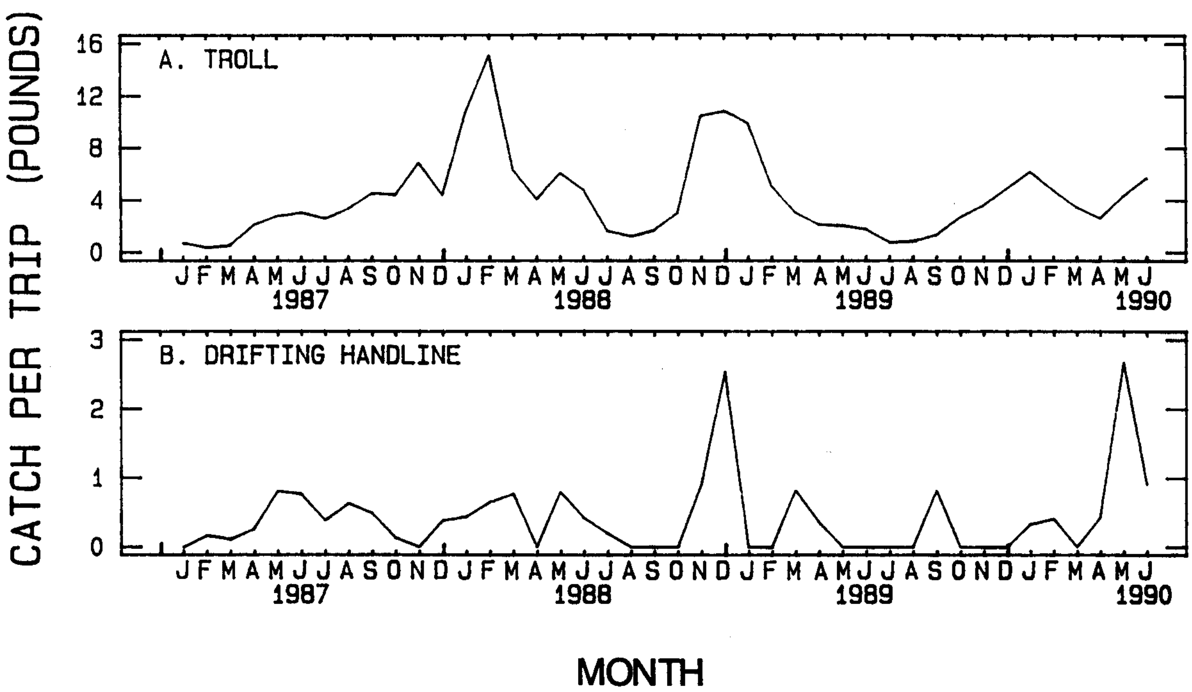

Figure 17.--Monthly catch of striped marlin per trip, by troll and handline gear, in Hawaii during January 1987 to 1990. Data are from the Hawaii Division of Aquatic Resources.

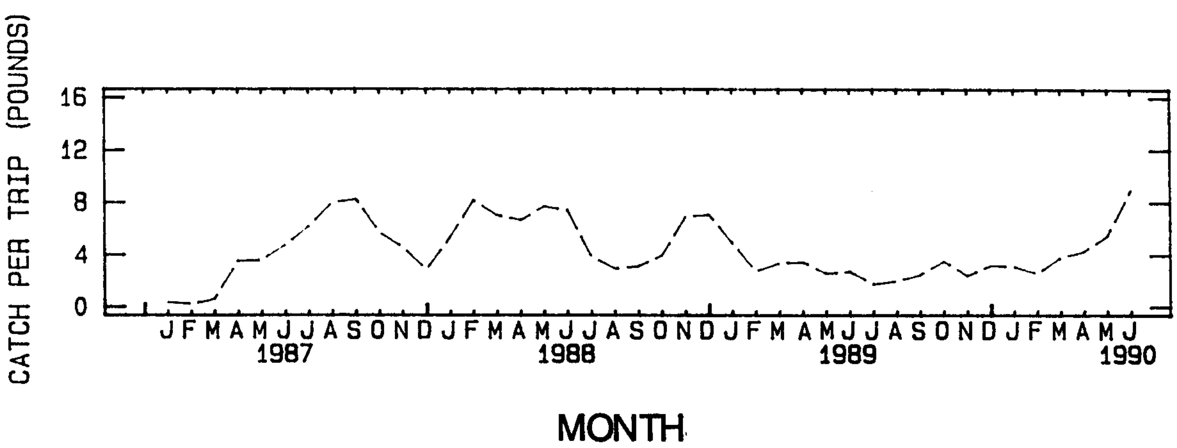

Figure 18.--Deseasonalized data on the catch of striped marlin per trip, by troll gear, in Hawaii during January 1987 to June 1990. Data are from the Hawaii Division of Aquatic Resources.

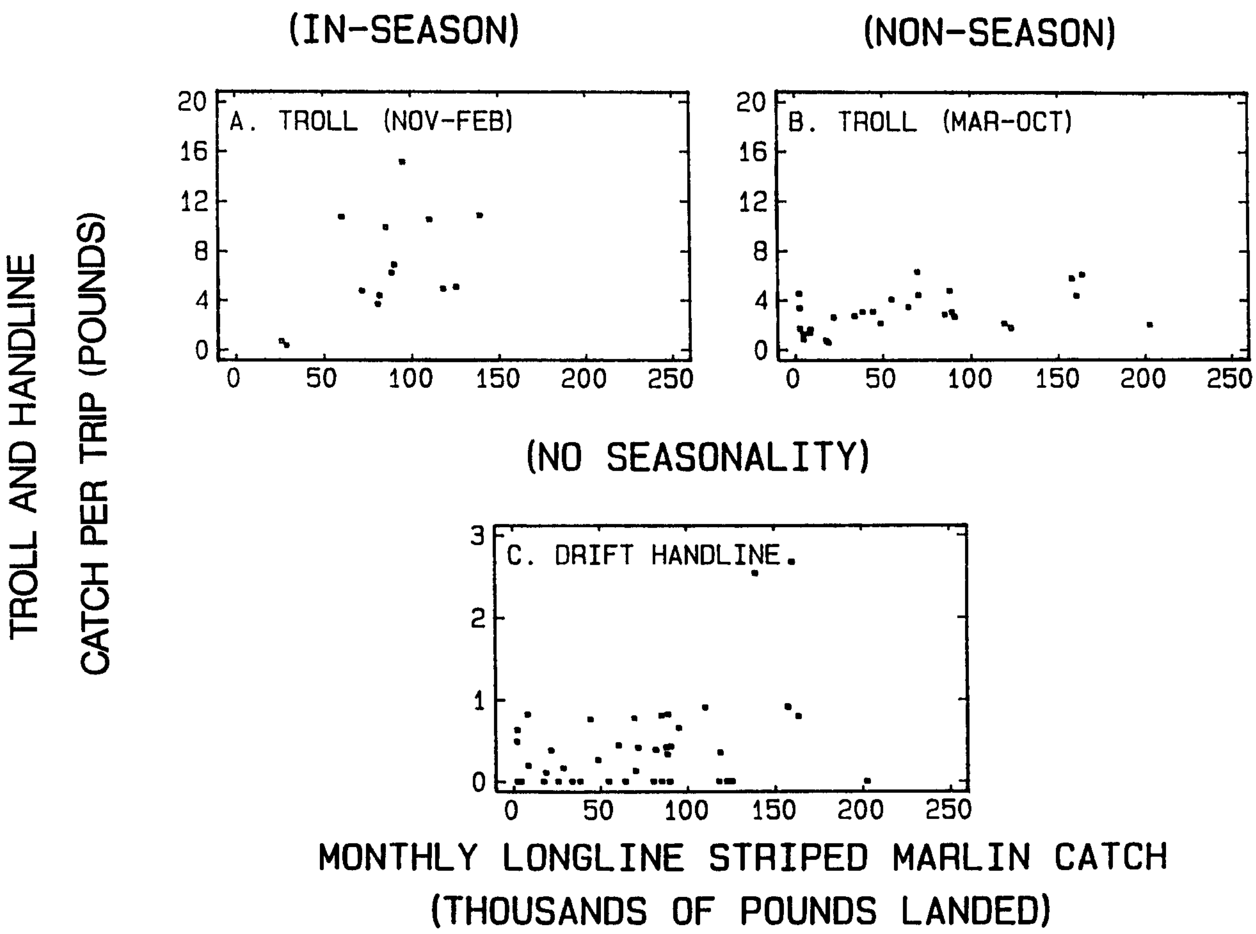

Figure 19.--Catch of striped marlin on a monthly per-trip basis by troll and handline gear versus the monthly catch by longline gear in Hawaii during January 1987 to June 1990. Some of the data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

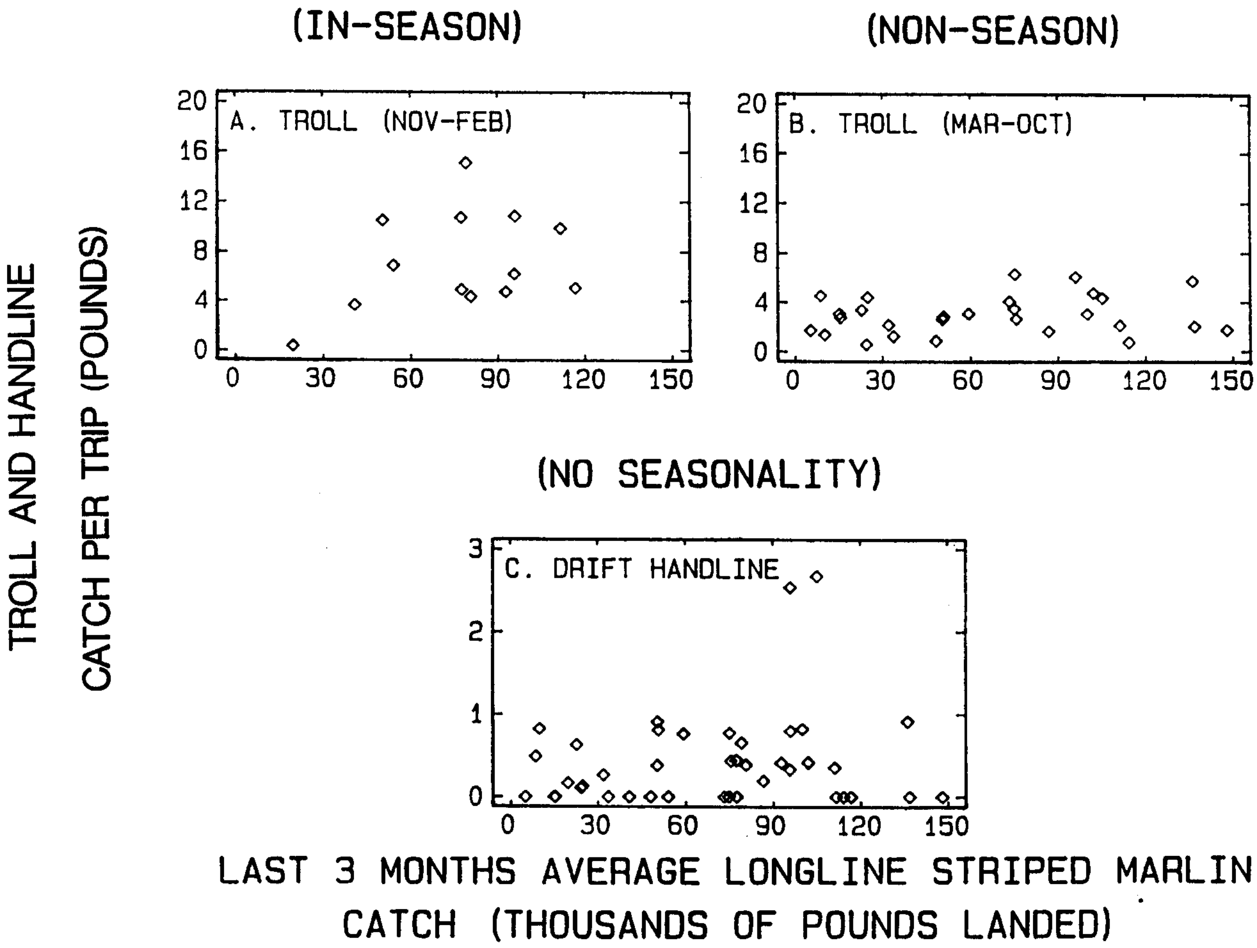

Figure 20.--Catch of striped marlin on a monthly per-trip basis by troll and handline gear versus the most recent 3-month average catch by longline gear in Hawaii during January 1987 to June 1990. Some of the data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

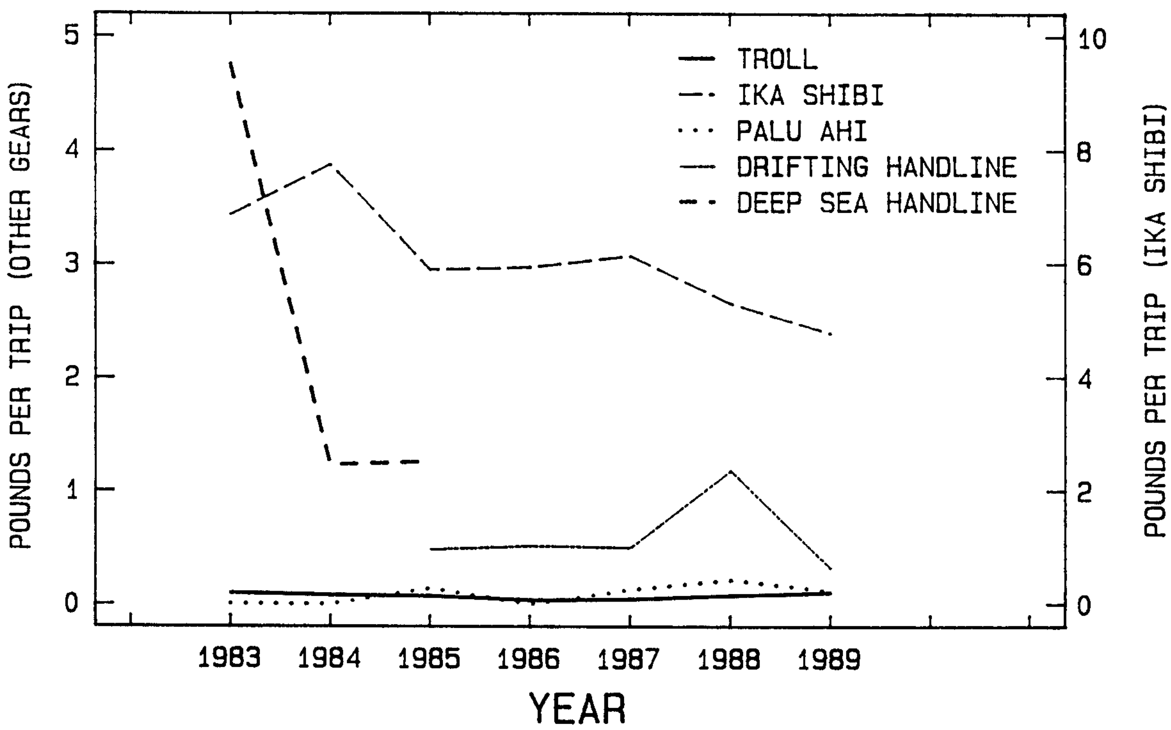

Figure 21.--Annual catch of swordfish per trip, by gear type, in Hawaii during 1983-89. Data are from the Hawaii Division of Aquatic Resources.

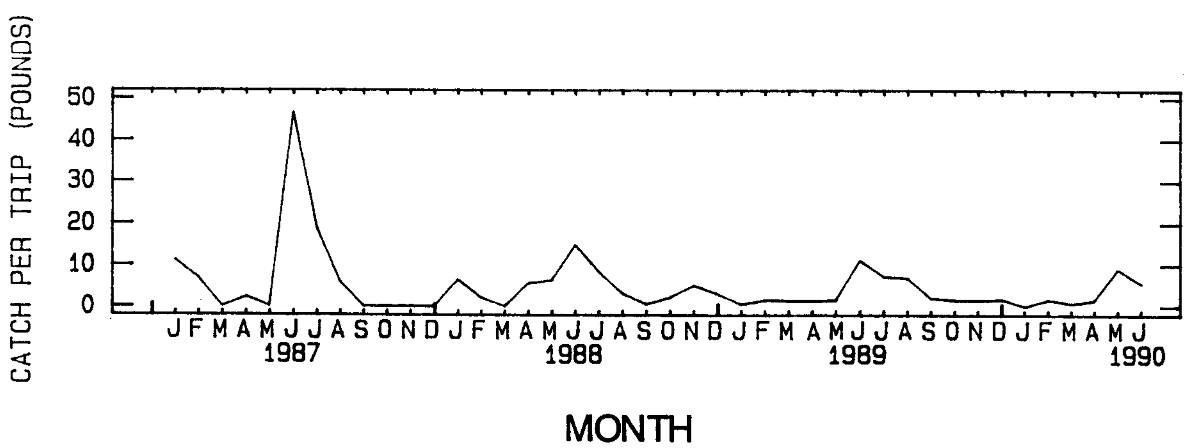

Figure 22.--Monthly catch of swordfish per trip by the ika shibi fishery in Hawaii during January 1987 to 1990. Data are from the Hawaii Division of Aquatic Resources.

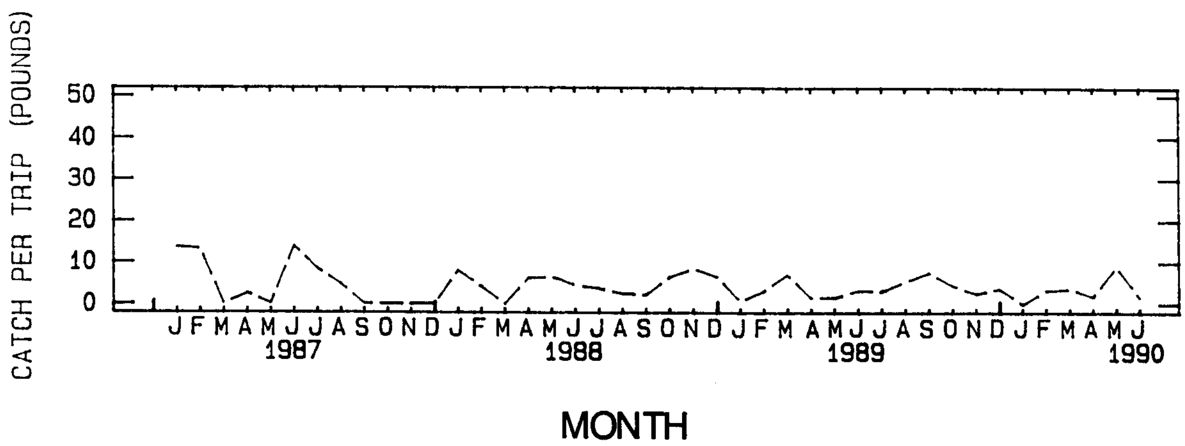

Figure 23.--Deseasonalized data on the catch of swordfish per trip by the ika shibi fishery in Hawaii during January 1987 to June 1990. Data are from the Hawaii Division of Aquatic Resources.

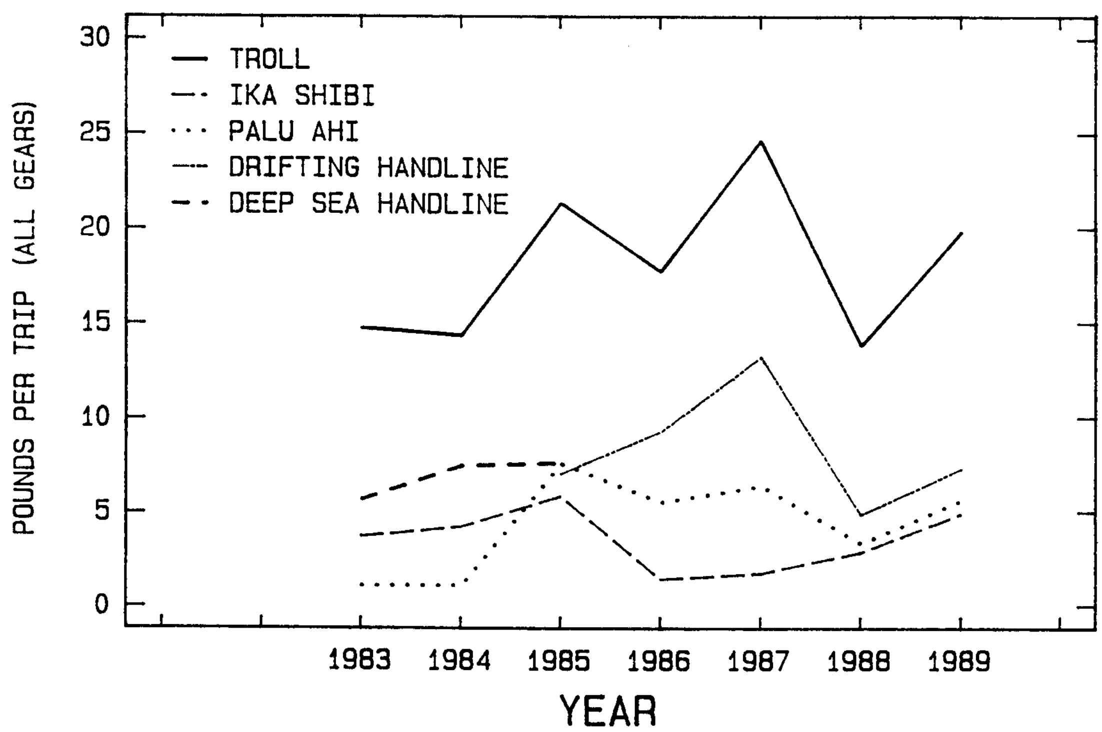

Figure 24.--Annual catch of mahimahi per trip, by gear type, in Hawaii during 1983-89. Data are from the Hawaii Division of Aquatic Resources.

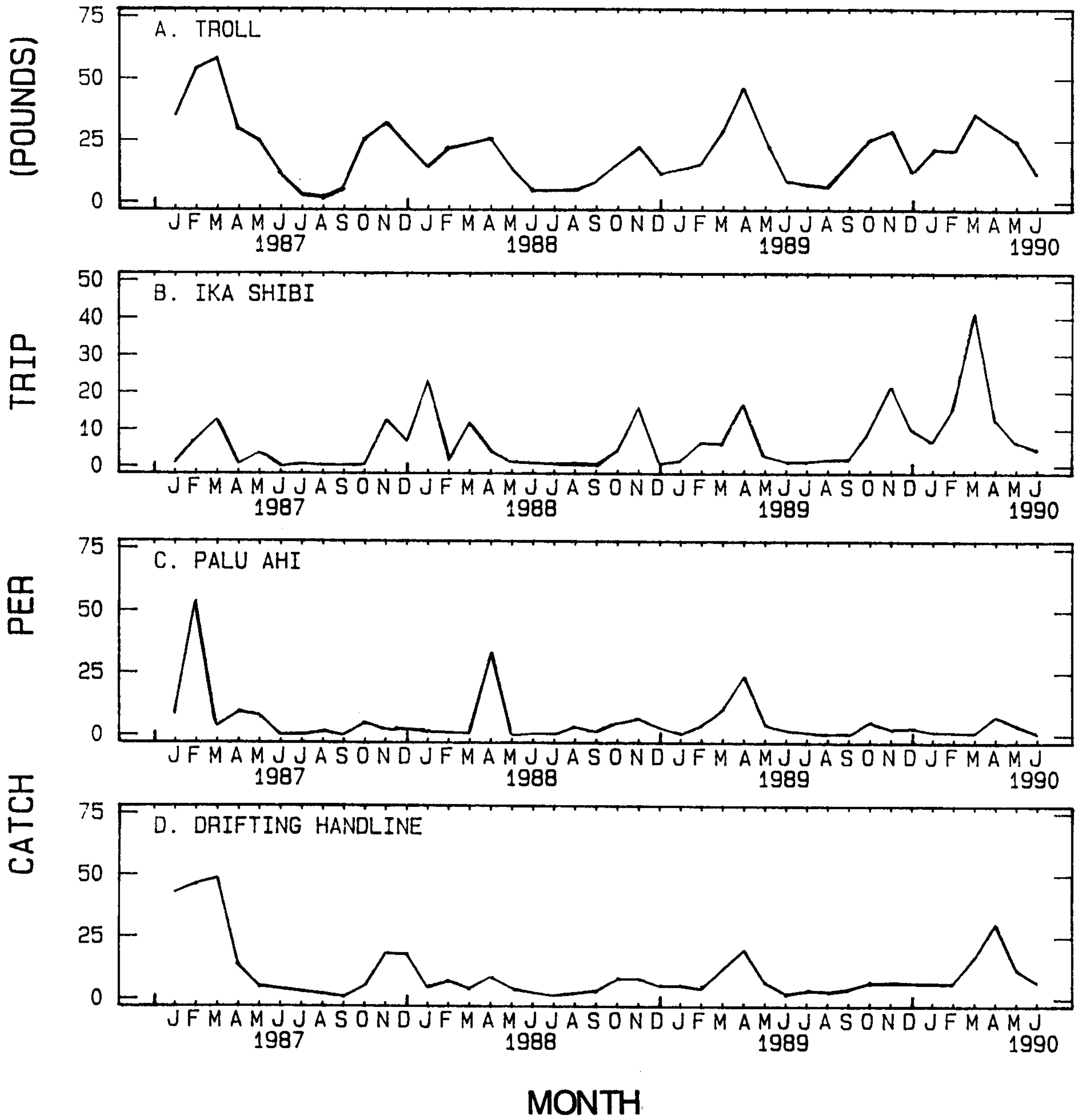

Figure 25.--Monthly catch of mahimahi per trip, by gear type, in Hawaii during January 1987 to 1990. Data are from the Hawaii Division of Aquatic Resources.

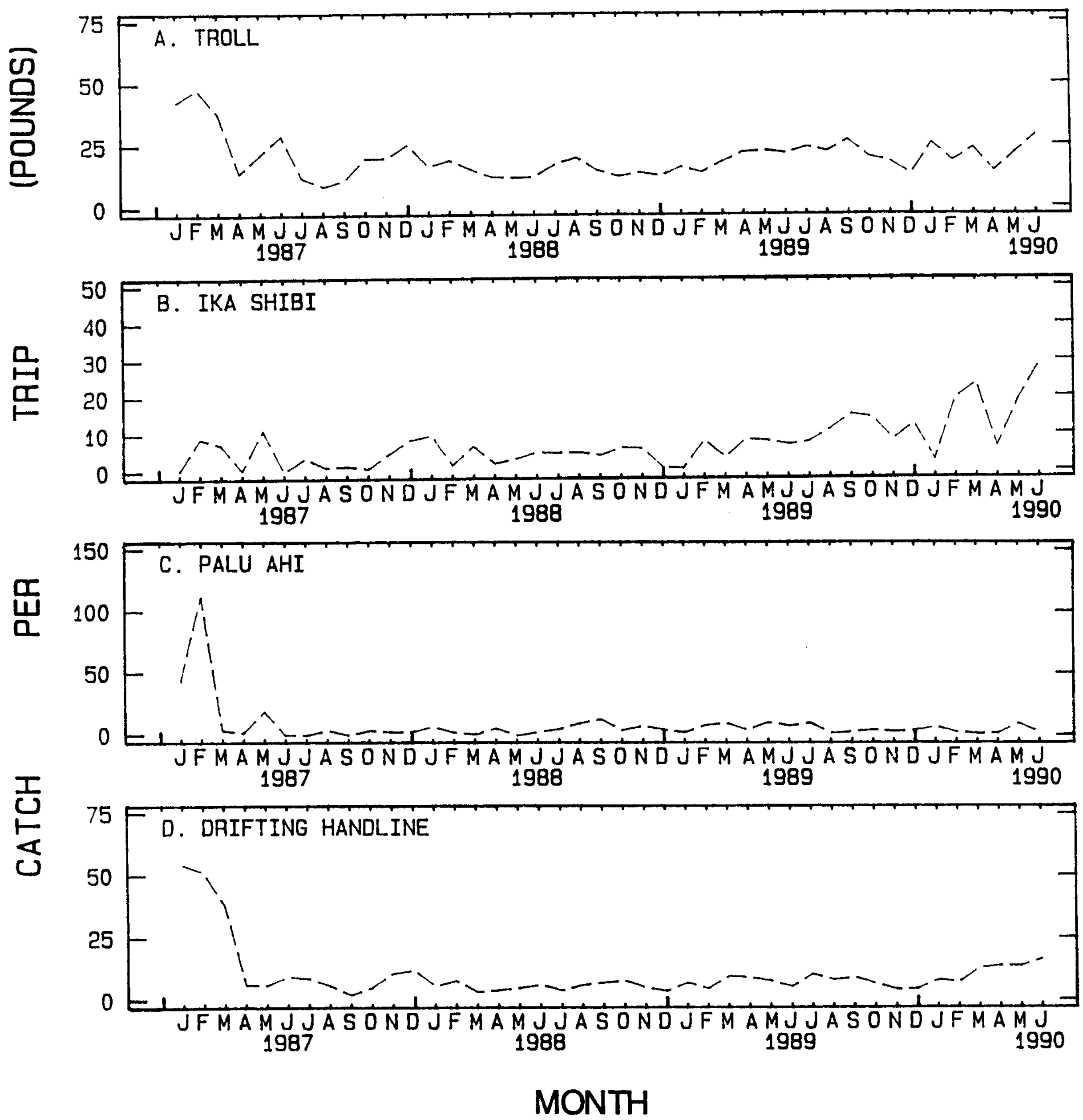

Figure 26.--Deseasonalized data on the catch of mahimahi per trip, by troll and handline gear, in Hawaii during January 1987 to June 1990. Data are from the Hawaii Division of Aquatic Resources.

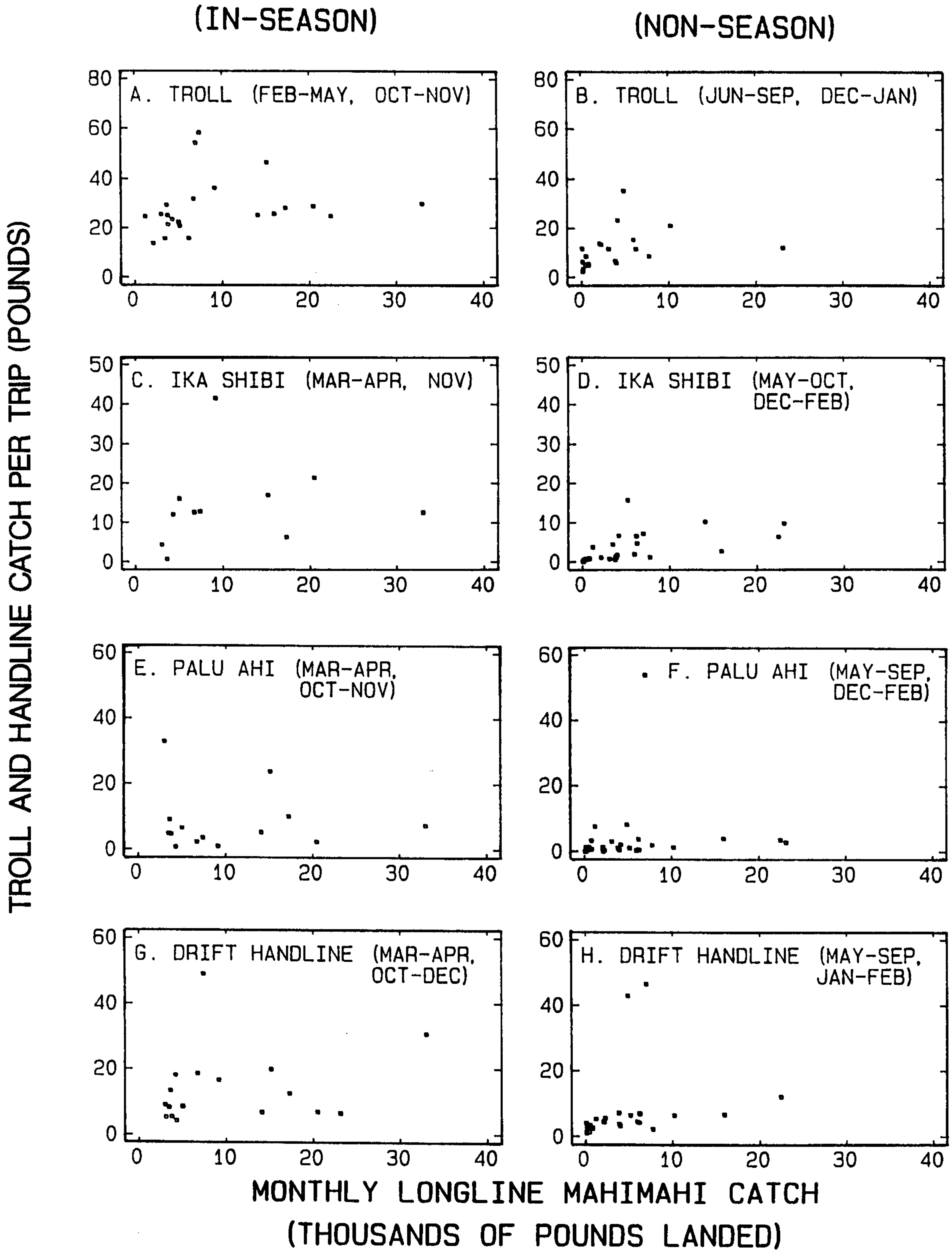

Figure 27.--Catch of mahimahi on a monthly per-trip basis by troll and handline gear versus on the monthly catch by longline gear in Hawaii during January 1987 to June 1990. The data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

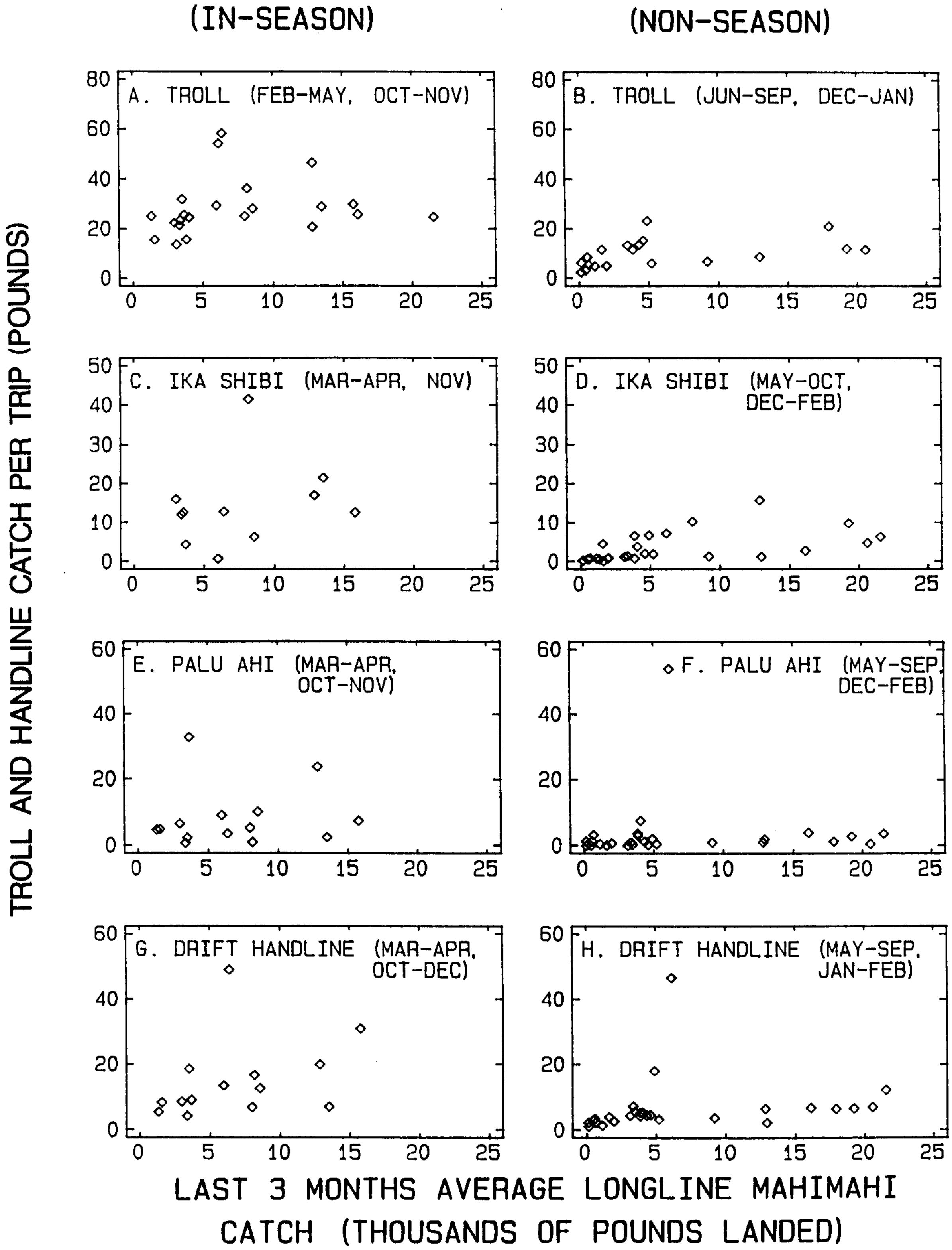

Figure 28.--Catch of mahimahi on a monthly per-trip basis by troll and handline gear versus the most recent 3-month average catch by longline gear in Hawaii during January 1987 to June 1990. The data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

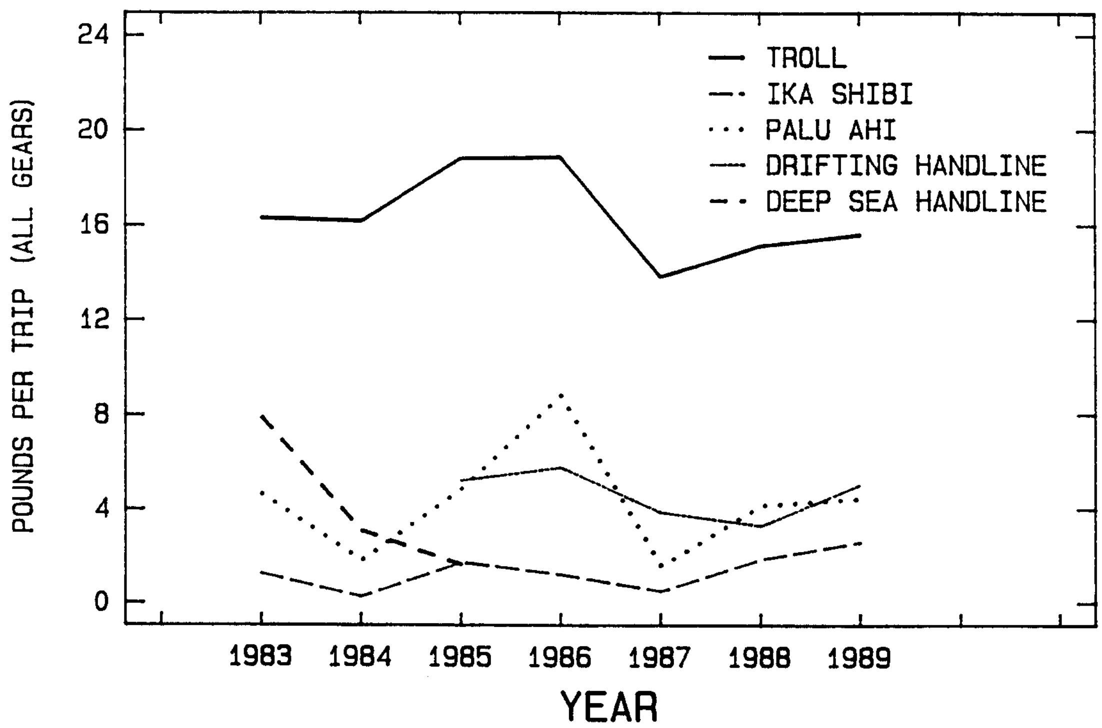

Figure 29.--Annual catch of ono (wahoo) per trip, by gear type, in Hawaii during 1983-89. Data are from the Hawaii Division of Aquatic Resources.

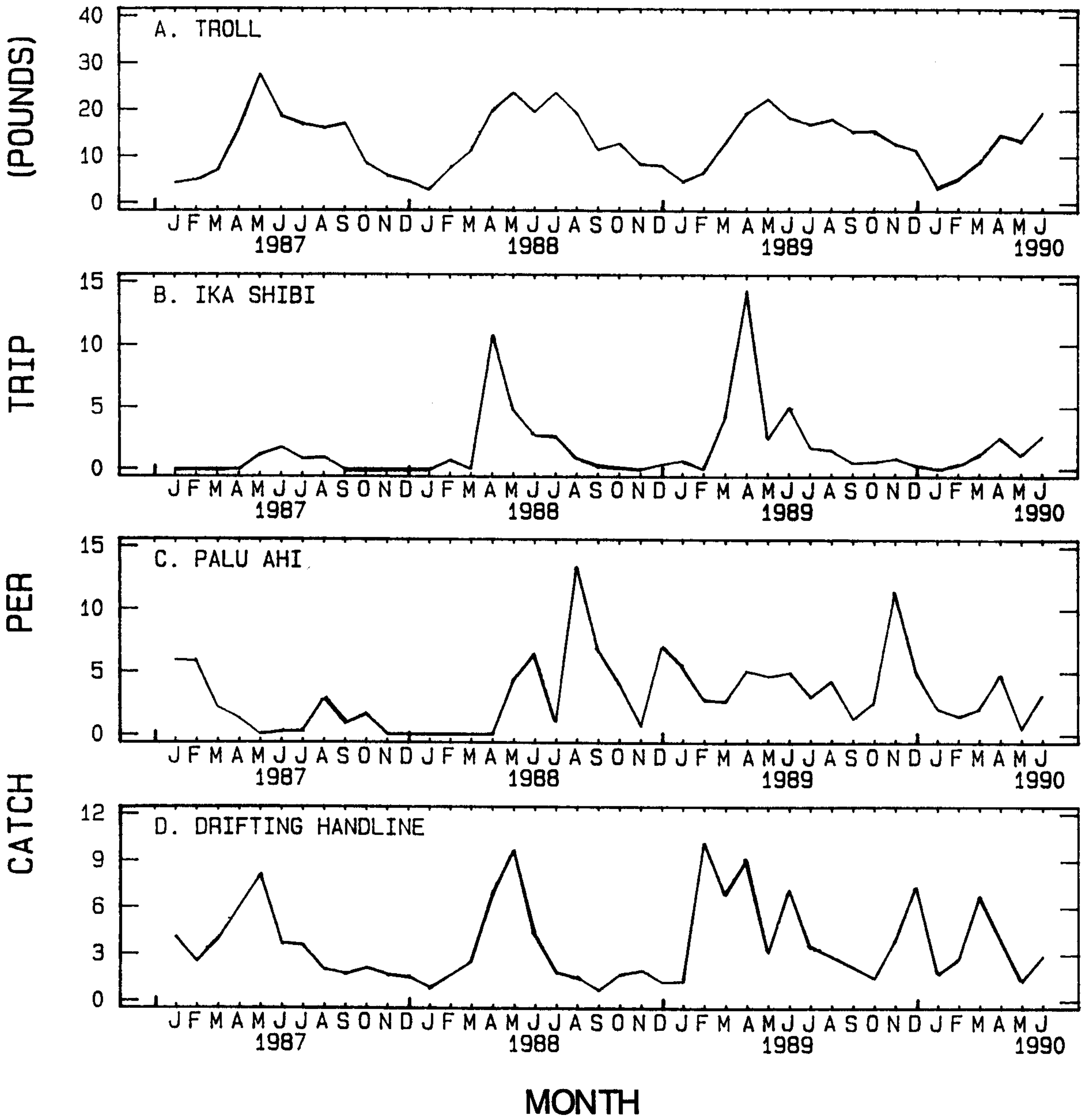

Figure 30.--Monthly catch of ono (wahoo) per trip, by gear type, in Hawaii during January 1987 to 1990. Data are from the Hawaii Division of Aquatic Resources.

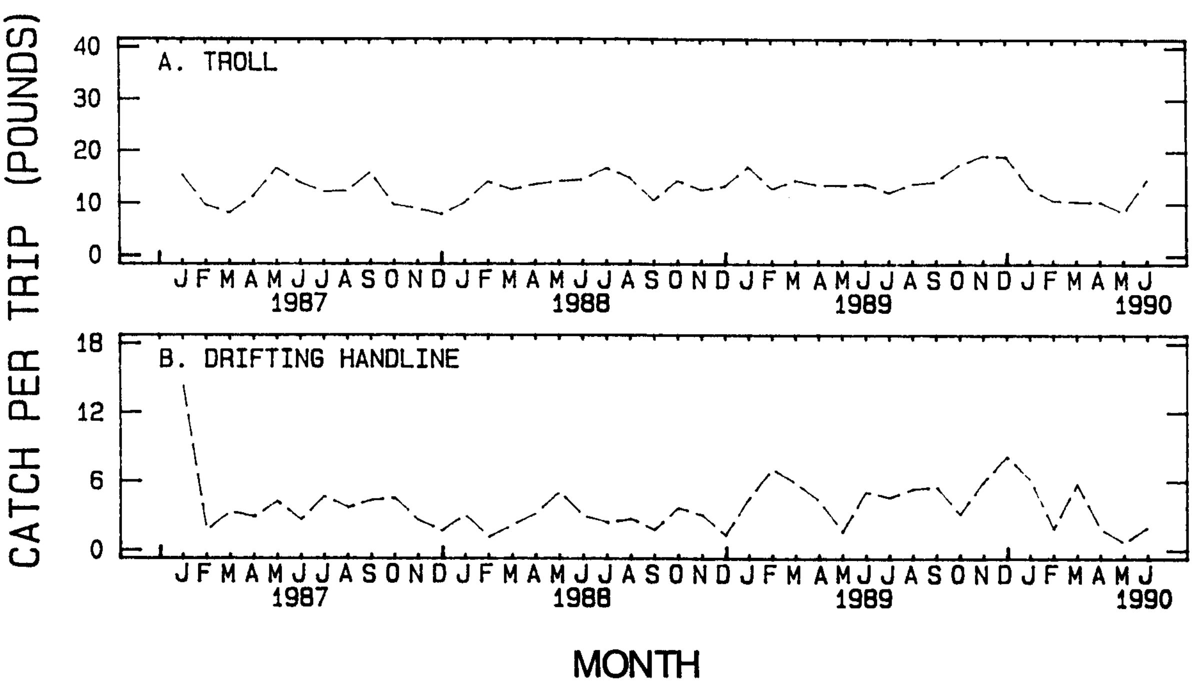

Figure 31.--Deseasonalized data on the catch of ono (wahoo) per trip, by troll and handline gear, in Hawaii during January 1987 to June 1990. Data are from the Hawaii Division of Aquatic Resources.

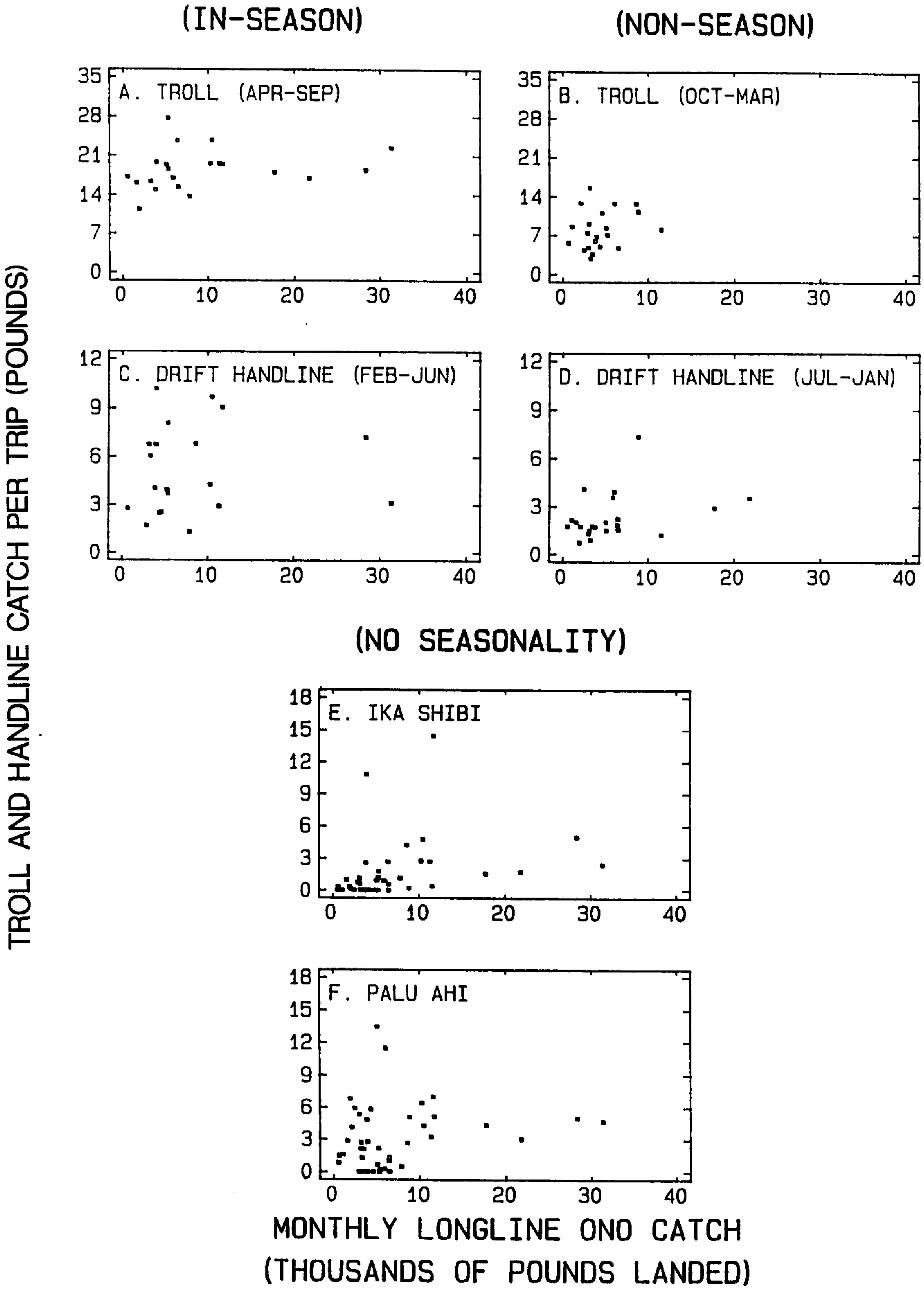

Figure 32.--Catch of ono (wahoo) on a monthly per-trip basis by troll and handline gear versus the monthly catch by longline gear in Hawaii during January 1987 to June 1990. Some of the data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

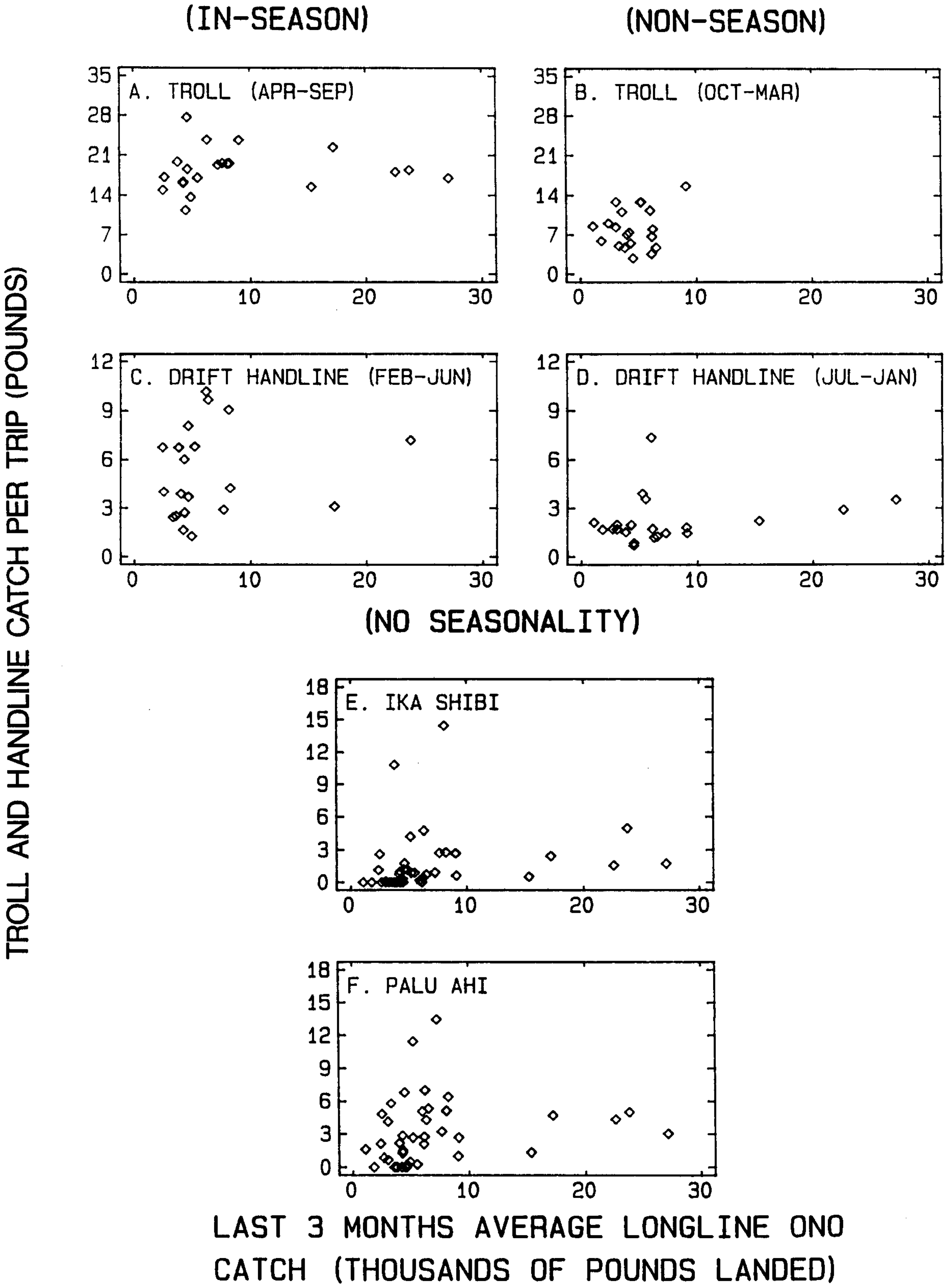

Figure 33.--Catch of ono (wahoo) on a monthly per-trip basis by troll and handline gear versus the most recent 3-month average by longline gear in Hawaii during January 1987 to June 1990. The data were segregated on a seasonal basis. Troll and handline data are from the Hawaii Division of Aquatic Resources, and longline data are from the market monitoring program of the Honolulu Laboratory.

APPENDIX

APPENDIX A.--A 3-year plan for quantifying the effect of longline effort on Hawaii's pelagic fisheries by the Western Pacific Regional Fishery Management Council's (WPRFMC's) Plan Monitoring Team (PMT) for the Pelagic Fisheries Management Plan (FMP).

A temporary freeze on the number of vessels participating in Hawaii's pelagic longline fishery will provide the opportunity to analyze catch per unit effort (CPUE) in this fishery at a new, high, but relatively stable level of fishing effort. In comparison with historical data at lower levels of effort, a 2- or 3-year average of CPUE at a relatively stable level of fishing effort will provide a useful indicator of the dynamics of local fish availability. Data to be obtained through the Pelagic FMP's new logbook program will provide the first high-quality catch and effort data for the area around Hawaii since foreign fishing ceased in 1980. The most important objective of the work outlined in this plan will be to seek evidence of an effort threshold beyond which pelagic catches do not increase. It will be essential to describe thresholds by area, since local concentration of effort may impact competing sectors of the local fishery. This information may suggest target levels of fishing effort for regulation to prevent local overfishing.

Although it may be true that locally caught pelagic fishes constitute a small fraction of stocks that extend beyond the range of Hawaii's fisheries, the rate of replacement of fish within the local area is finite. A useful definition of local overfishing would be when the local rate of exploitation approaches the rate of fish replacement. Beyond this threshold, an increase in effort does not result in an increase in catch. This becomes overfishing in the economic sense if the increase in effort comes from increased capitalization, because there is a decline in catch per dollar invested. (It is not growth overfishing or recruitment overfishing unless a significant proportion of the entire stock, or spawning stock, resides in the local area. There remains too little information on the pelagic species to make this case, as discussed in the recently submitted overfishing amendment to the Pelagic FMP).

Before local fishing effort increases to the point of no additional returns (Fig. 1), there should be an interval of diminishing returns, as in a production model (Fig. 2). Some local fisheries (e.g., the trolling charter fishery for marlins) may require catch rates higher than the threshold defined above. The WPRFMC may decide to limit effort in total, or by gear or area, to achieve particular benefits for certain pelagic fishery sectors. There may be no level of fishing effort that optimizes utilization by all sectors. The 3-year research plan is designed only to quantify the effect of local effort on yield, and the distribution of those effects. It will not determine how the resources should be allocated. The latter should be the subject of WPRFMC discussion and action in the interim, so that selection of a target number of longline fishing vessels (a limited entry plan) is possible.

A number of different analytical approaches and data will be required to properly determine the effect of local longline fishing effort on the catch of pelagic fish by Hawaii's fisheries. Many of the data and research needs have been outlined in the annual reports of the PMT and in other WPRFMC documents. The development of a limited entry program within 3 years accelerates the schedule by which these are required, but does not change the general nature of the work to be done. The following plan to provide information for the development of a limited entry program will also provide information needed to meet other high-priority objectives of the Pelagic FMP.

Work Plan Outline

I. Develop local threshold models from catch and effort data

  A. Use historical data to make projections of catch

    1. Obtain area summaries of 1956-80 foreign longline data

    2. Summarize domestic catch and effort by gear type and area

    3. Standardize effort statistics from diverse gear/sources

    4. Incorporate seasonal effects on local CPUE dynamics

    5. Index catch against stockwide CPUE or other factors

    6. Project indexed catch vs. standardized effort by area

      a. For each gear type in the domestic fishery

      b. For all gear types combined (if possible)

  B. Examine 1991-93 data for evidence of thresholds

    1. Check if catches differ significantly from projections

    2. Check if CPUE by gear declines vs. total effort (all gear)

  C. Estimate thresholds for use in limiting entry

    1. Based on longline gear alone

    2. Based on other gear types (dependent on A6b and B2)

II. Test alternative hypotheses for changes in CPUE

A. Check for stockwide declines in abundance

1. Obtain 1991-1993 catch and effort data for a wider area, or

2. Obtain a substitute measure of stockwide CPUE

B. Check for environmental influences on local availability

1. Look for significant, fishery-independent factors

C. Examine 1987-1993 data for economic factors

1. Check if trip activity is endogenous to CPUE and price

2. Estimate production substitution rates between gear,

3. Employ a search model to examine the economics of vessel movement and vessel interaction

D. Correct or reject threshold estimates

III. Develop simulation models of local overfishing

A. Synthesize information on fish growth, movement, and mortality

B. Model fish turnover and exploitation by each gear type

C. Estimate thresholds from simulated catch and effort data

Catch Projections

Some examples of the use of historical longline data to make projections of expected catch are provided (Figs. 3-7). If at higher levels of fishing effort catches fall below the 95% confidence limits of the projections, this could be evidence that longline fishing effort in local waters has a negative impact on catches in local waters. A threshold model (Fig. 1) could be fit to the data if it shows a decline, and the threshold would provide an estimate of the amount of effort that has an impact on local fish availability.

The examples of catch projections were made using data from Yong and Wetherall (1980), and Wetherall and Yong (1983). In some cases, outliers were deleted to provide better projections. Comparison of CPUE in catch per trip by the domestic longliners with CPUE in catch per hook by the foreign longliners (1959-78) indicated that a domestic trip was equivalent to 1,140 hooks. This was similar to other estimates based on the number of hooks per basket, number of baskets per set, and number of sets per trip reported by domestic longliners early in the same period. A more thorough job of standardizing effort will be necessary for the development of threshold models. It will be extremely important to account for changes in type of gear and fishing depth, which greatly influences the efficiency of hooks in catching different species.

Effort will be hard to standardize within the troll and handline fisheries, where State of Hawaii catch reports will be the only source of data. It will be more difficult to standardize effort across gear types but this will be needed to demonstrate that total effort has an effect on catch in the local area. For many species the troll and handline catches are larger than the longline catches. It may be possible to use total catch as a proxy for total effort. Instead of projecting catch versus effort, CPUE would be projected as a constant value versus increasing catch levels (although there are statistical problems with this approach).

In the examples, no attempt was made to better represent the dynamics of local abundance by using seasonal peaks in the catches of certain species and in the effort during those seasons. This was shown to be a useful approach by Wetherall and Yong (1983) and should be used to reduce some of the variation in the data. Where catches are less seasonal, months may be a useable time frame for analysis (e.g., Fig. 1), increasing the number and range of the data available.

Projected catch of bigeye tuna as a function of millions of hooks deployed in the two 5° squares adjacent to the main Hawaiian Islands (Fig. 3) is based on foreign and domestic catch and effort in 1959-78, with one outlier (1974) rejected. The inner and outer pair of dashed lines shows 95% confidence and prediction limits, respectively. The testable hypothesis is that catch will go up in proportion to effort, i.e., CPUE will be constant in relation to effort, with a certain amount of independent variation, and no threshold will be reached.

The projection of catch may depend on the area fished. For example, bigeye tuna catch as a function of effort during 1959-78 seems to have been greater in the vicinity of the main Hawaiian Islands (Fig. 3) than in the entire fishing conservation zone (FCZ) around Hawaii during 1965-77 (Fig. 4). This illustrates the importance of having logbook data to test the hypothesis of catch being proportional to effort. The data in years with a new, high level of effort must be segregated by area to test for a deviation from the catch projected for a given area.

Raw data on catch may contain a lot of variation independent of effort. In such cases, the 95% prediction limits will be so broad as to hinder a meaningful test, because even very low catches might not differ significantly from projections. The importance of identifying and accounting for other sources of variation in catch is illustrated with a projections for data on blue marlin by Japanese longliners fishing adjacent to the main Hawaiian Islands in 1958-80 (Figs. 5 and 6). The domestic data contain so much unexplained variation that they were not used in these examples. Raw catch data (Fig. 5) are much more variable than catch divided by an index (Suzuki 1989) of Pacific blue marlin population size (Fig. 6). Local catches vary as the stockwide abundance of blue marlin changes, and this variation is independent of local effort. The indexed catch projection provides for a better test of whether local catches are lower than expected. The index was normalized to equal 1.0 in 1985, so the projected catch should be multiplied by whatever degree the stockwide abundance of blue marlin has changed in proportion to its 1985 abundance. Similar indexes are recommended to account for variation due to environmental factors, if they can be described.

Figure 7 gives an example of the projected catch of yellowfin tuna.

Evidence of Thresholds

The NMFS estimates of the 1989 catch and effort provide the most recent data available for comparison with the catch projections. The catch estimates are made by expanding the landings observed by NMFS shore-side monitoring program. The effort estimates are guesses based on the number of trips observed per vessel, the number of vessels registered as longliners, the type of gear carried, and scattered observations of the number of hooks per set and the number of sets per trip.

So although the estimate of pelagic longline fishing effort in 1989 is crude, it suggests a total of around 8.3 million hooks. There is no breakdown on the geographic distribution of this fishing effort. An estimated 30% of the effort in 1989 was made up of gear set very close to the surface, which may have had a comparatively low effectiveness in catching bigeye tuna. Thus in considering bigeye tuna catch projections, 6 million hooks might be a crude estimate of standardized effort. Contrarily, the new, shallow longline gear may be even more effective at catching blue marlin or yellowfin tuna. Therefore, the standardized effort might be estimated to be greater than 8 million hooks, but at this time, there is no estimate of how much greater. The comparison of 1989 estimates with the catch projections is summarized in the following table:

Species	Estimated longline effort (in millions of hooks)	95% prediction limits for (t) projected catch	Estimated catch (t)
Bigeye tuna	6	2,000-3,500	1,400
Bigeye tuna	6	1,100-2,900	1,400
Yellowfin tuna	8	750-1,350	980
Blue marlin	8	170-340	346

The second bigeye tuna projection ((ig. 4) assumes effort distributed throughout the FCZ, and the blue marlin projection assumes no change in stockwide abundance since 1985 (Fig. 6). These examples suggest no clear evidence that a catch threshold had been reached by 1989, unless the great majority of the 6 million hooks directed at bigeye tuna represent fishing adjacent to the main Hawaiian Islands.

In 1989, effort may have increased by about 50% over 1989 levels. The main goal of the work plan will be to compare 1991-93 federal longline logbook data against improved projections. More thorough standardization of effort and consideration of other influences will be needed. If the data show evidence that catches are lower than projected at high levels of effort, threshold models (e.g., Fig. 1) will be fit to the data. Together with economic data, these will permit a quantitative assessment of options for limiting fishing effort by limiting entry. Choice among these options will depend on the objectives of the WPRFMC (i.e., different effort levels maximize profits, or catches by different fishery sectors).

Supplemental Analyses

Alternative explanations for changes in local fish availability must be explored. In the example of blue marlin (Figs. 3 and 4), it is clear that stockwide variations in abundance have a major influence. Thus it will be necessary to cooperate with other agencies and governments to obtain statistics on the fisheries outside the WPRFMC's jurisdiction. Also, environmental factors may affect catch, and fishery-dependent factors may bias fishing effort. Low prices or low catch rates may cause a curtailment of effort that tends to obscure reduced catch rates at high levels of effort. Attempts should be made to account for these effects and to correct the threshold models accordingly.

Despite the best efforts to extract usable information from the State of Hawaii Division of Aquatic Resources' (HDAR's) catch reports on the troll and handline fisheries, these data may not be sufficient to demonstrate the relationship effort and catch in these sectors of the local fishery. An alternative approach would be to make a series of rational assumptions about the movement of fish in the local area, rates of recruitment, growth, and natural mortality and to use these to simulate the various fisheries in Hawaii under a wide range of fishing efforts. This would provide the PMT with another way of estimating thresholds and choosing reasonable target levels for fishing effort. However, there is no substitute for accurate fishery data. If the current level of reporting reflected in HDAR data proves to be a major handicap in this analysis, then alternative data collection mechanisms may be required.

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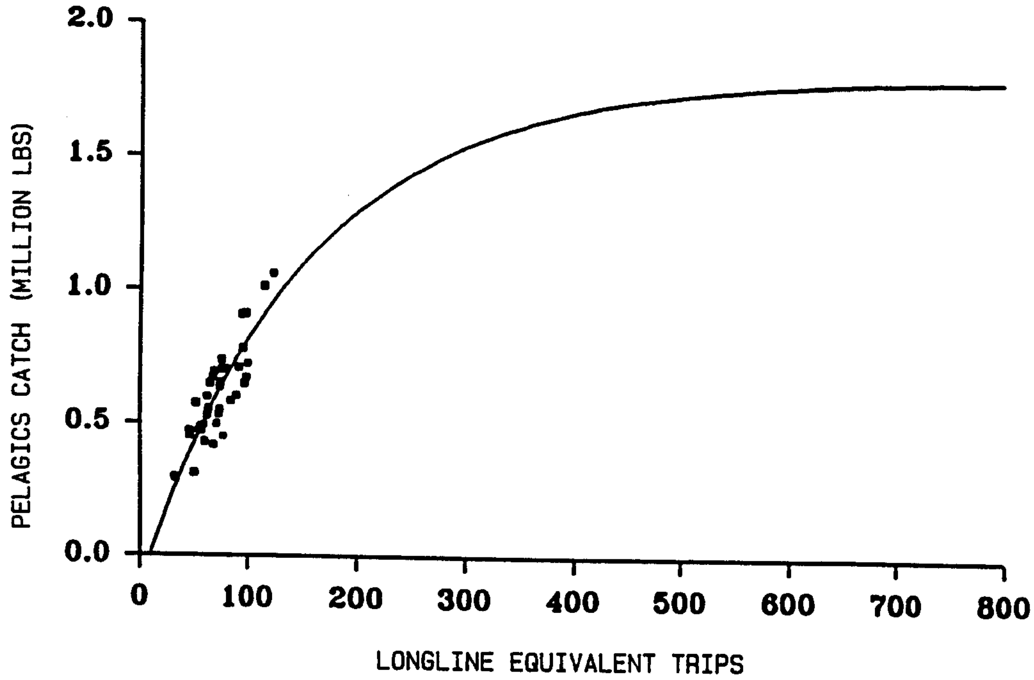

Figure 1: One hypothetical threshold model of Hawaii's pelagic fishery. This model views total fishery catch each month (the vertical axis) as the result of certain levels of total fishing effort (the horizontal axis) by all gears standardized as longline equivalent trips (in each month, 1987-89).

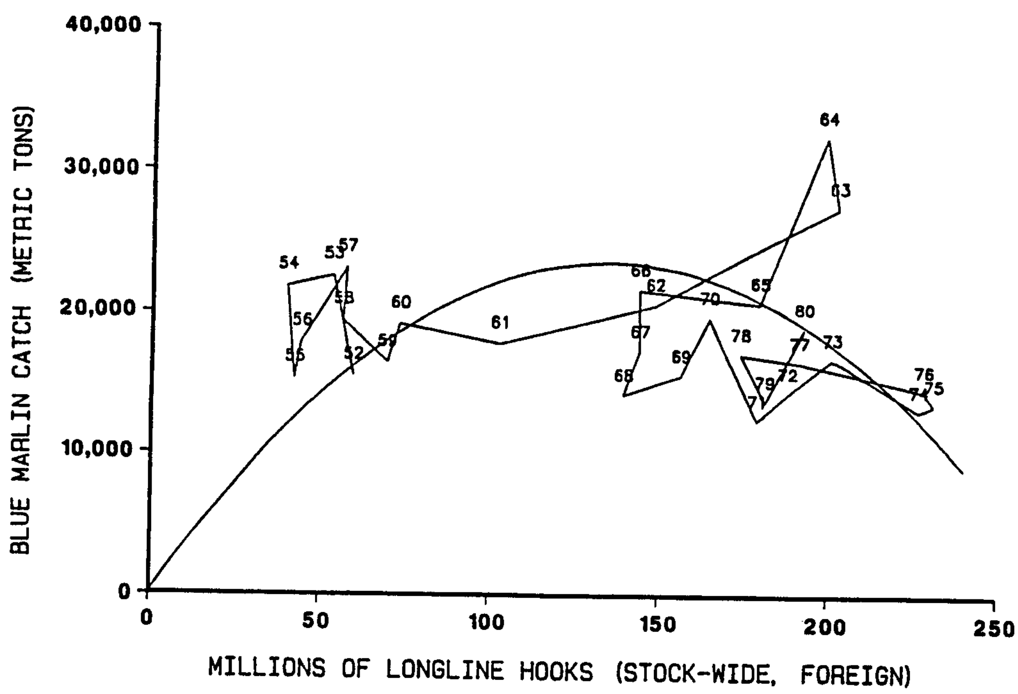

Figure 2: A production model for the entire stock of Pacific blue marlin. This differs from a local threshold model because catches actually decline as increasing effort impacts the ability of the stock to replenish itself.

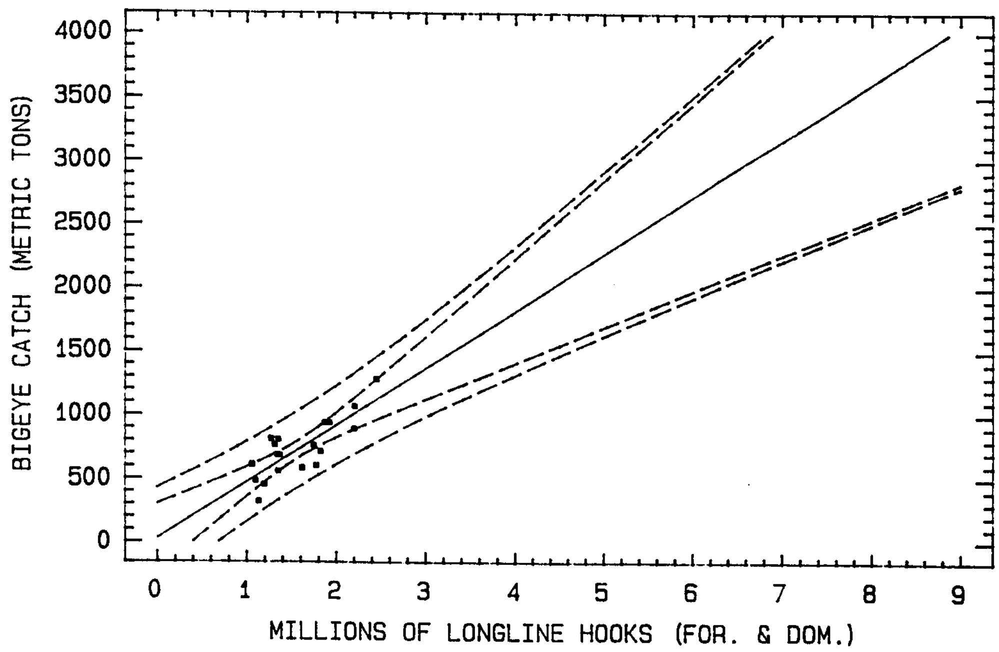

Figure 3: Projected catch of bigeye tuna in the two 5-degree squares adjacent to the main Hawaiian Islands, assuming that catch remains proportional to effort.

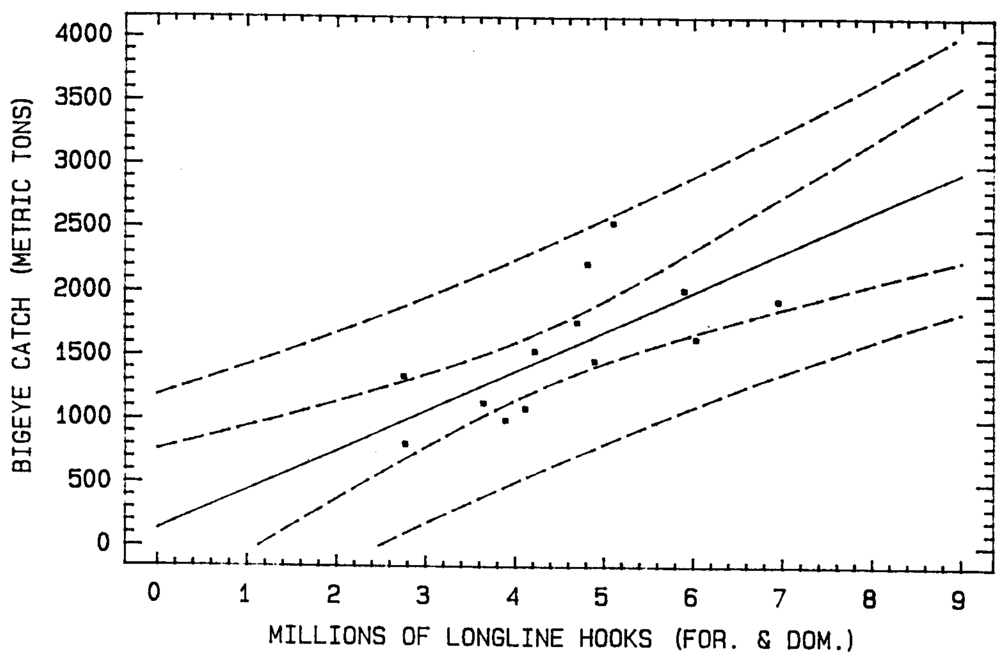

Figure 4: Projected catch of bigeye tuna in the entire FCZ of the Hawaiian Islands, again assuming that catch remains proportional to effort.

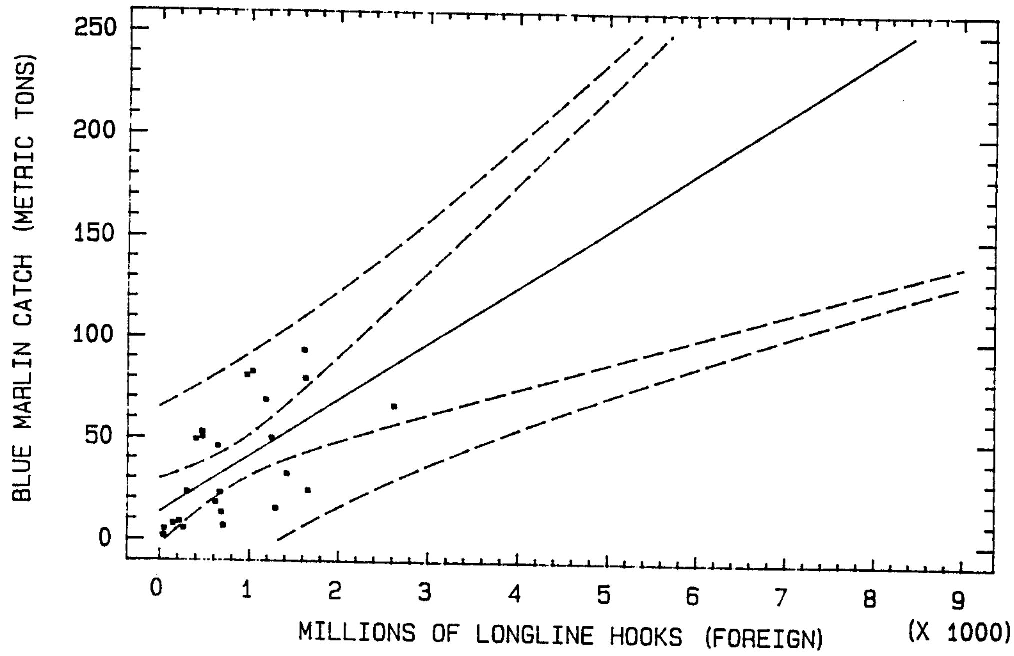

Figure 5: Projected catch of Pacific blue marlin in the main Hawaiian Islands area, assuming catch proportional to effort.

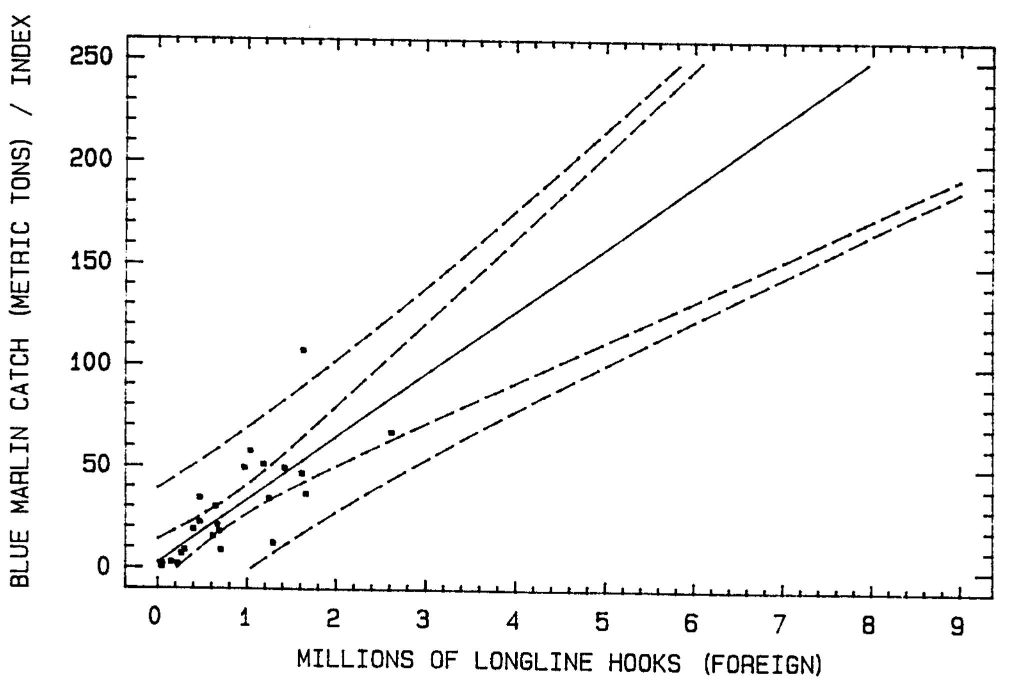

Figure 6: Projected blue marlin catch in the main Hawaiian Islands area indexed to the stock wide abundance in 1985. Assumes catch proportional to effort.

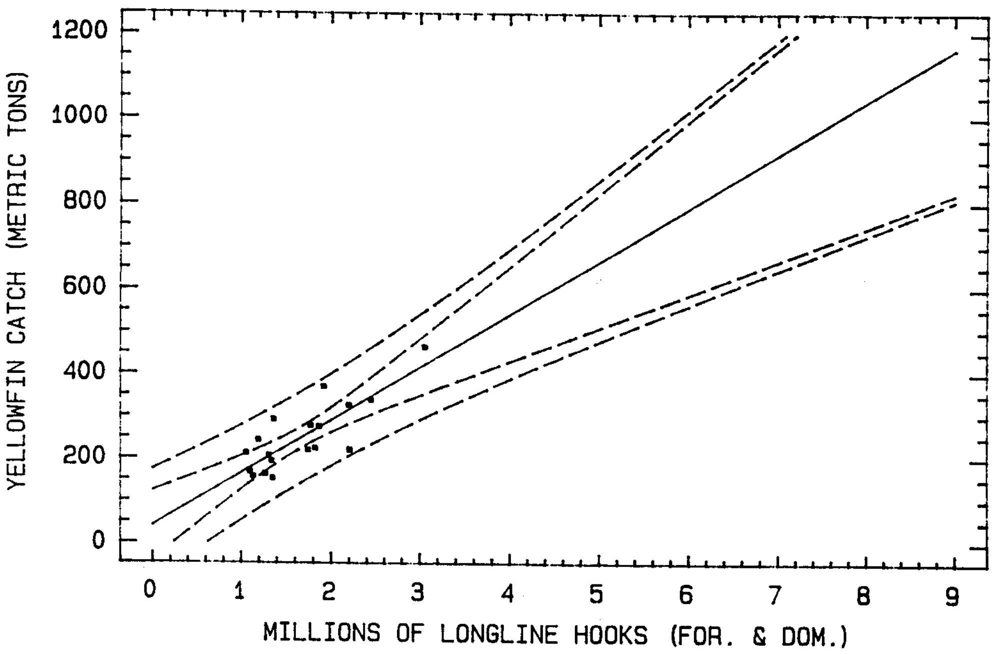

Figure 7: Projected catch of yellowfin tuna in the two 5-degree squares adjacent to the main Hawaiian Islands, assuming that catch remains proportional to effort.