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ENVIRONMENTAL INFLUENCES ON SKIPJACK AVAILABILITY

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NOT FOR PUBLICATION

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PREFACE

This report represents a written presentation for the workshop on **Forces of Change in Hawaii's Aku (Skipjack Tuna) Industry** held in Honolulu on April 30 and May 1, 1986. The workshop was coordinated by the National Marine Fisheries Service, Southwest Fisheries Center Honolulu Laboratory. Workshop results will be summarized in a forthcoming Southwest Fisheries Center Administrative Report.

The workshop presentations were prepared by independent scientists and are reported here verbatim. Therefore the results, conclusions, and recommendations are those of the author and do not necessarily represent the views of the National Marine Fisheries Service.

INTRODUCTION

There are many causes to the decline in the tuna fishery in Hawaii, not the least among them being the seeming decline in the number of fish available to the fishery. Even if we could know for certain the biological or oceanographic causes of the decline, it is not clear that the industry could survive given the present economic conditions of the tuna industry throughout the U.S. - the closing of most of the canneries and the moving of the fleets to foreign flags or to more distant waters. However, it is worthwhile to try to ascertain the causes of the decline, as different answers could lead to different future actions.

The main question for the group today therefore is whether the decline is due to overfishing of the skipjack stock, whether environmental factors have increased mortality and decreased reproduction to lessen the stock, or whether the fish are still out there but are migrating to areas farther from Hawaii due to changes in the environment. Unfortunately, since we have relatively little data on the skipjack fishery, do not know where the fish come from, and therefore what other fishing takes place on this stock, no definitive answer can be given to this question. However, it is possible to look at evidence both from Hawaii and from other tuna fisheries to see what factors have influenced the variations in tuna abundance.

Not surprisingly, the debate over whether variations in the skipjack fishery in Hawaii are due mainly to year-class fluctuation or due to environmental factors is an old one. Rothschild (1965) presents an analysis that suggests it is mainly due to year-class fluctuations. Seckel (1970), however, shows that the data are not inconsistent with a model of buoys dispersing with the currents. E.C. Jones developed an index, based on the location of the 20C isotherm in the eastern Pacific, that had a reasonable correlation with the yearly catch level. Jones hypothesized that the tuna migrated in a unimodal distribution, and when the isotherm was more northerly, the mode of the distribution reached Hawaii, while when it was more southerly only the tails of the distribution reached the islands.

Today, I will first look at the catch record from the skipjack fishery, and decompose it (much like economic data are decomposed) using an algorithm due to Gersch (from U.H.) and Kitigawa, to determine the trend in the data and empirically see when the presumed decline began, if at all. Then, I will present some new evidence, from Hawaii and elsewhere, that tuna are affected by the dominant oceanographic patterns in an area, and that this in part may explain some of the observed decline in the fishery.

DECOMPOSITION OF THE SIZE-SPECIFIC CATCHES

Figures 1-3 show the original data and the trend line for the catch of extra small, small and medium size tuna for the years 1964-1982. While

the catch of these three size classes has fluctuated up and down over the period of question, there is neither a long-term decline nor evidence of a short-term decline in these size classes. The most noticeable feature of this data is that the big catch in 1965 was due to an unusually large catch of medium sized fish that year.

Figures 4-5 show the original data and the trend line for the catch of large skipjack and the total catch of skipjack for 1964-1984. While previous analyses of the data have suggested a slow linear decline in the overall catch, the trends estimated here suggest that the catch collapsed after 1973 and has never recovered, with what appears to be a one-time drop in level. Moreover, the decline in the total catch is almost totally due to the disappearance of the large fish from the fishery after 1972.

While it may just be a coincidence, the 1972-1973 period was marked by a very strong El Nino that caused the virtual collapse of the anchoveta fishery off of Peru. Norton in a recent study has shown that the 1972-1973 event, while not as long in duration as other El Ninos, (and therefore producing a smaller integrated effect) heated the ocean deeper and more quickly than the other major El Ninos of the last 25-30 years, including the major El Nino of 1982-1983. If the 1972-1973 El Nino is indeed the culprit the mechanism that caused the disappearance of the large tuna can only be guessed at; moreover why the large skipjack have not come back in the intervening years is also a puzzle. Still, the timing of the decline in the catch is my first and intriguing piece of evidence that the environment is a major factor in the decline of the skipjack fishery.

STATISTICAL MODELS RELATING TUNA AND THE ENVIRONMENT

Having seen what the empirical trends tell us about the skipjack fishery, we can examine some more direct evidence that suggests that skipjack as well as other tuna are affected by oceanographic conditions. Several years ago I reexamined E.C. Jones hypothesis using more sophisticated statistical techniques. This analysis showed several things. When examined by size-classes, the key component, not just in terms of total variability but also in terms of the underlying structure of the dynamics, is the catch of large tuna. This agrees with the results of the decomposition presented earlier.

I developed an empirical index based on the position of the 20C isotherm for the months of January, February, and April of the winter preceding the catch. The formula for the index, as well as a plot of the index versus the total catch and catch of large tuna is shown in figure 6. The index can be viewed as a weighted difference between the January position of the isotherm and an average of the February and April positions. It thus is a measure of how fast the 20C isotherm moves northward - that is an indirect measure of the warming of the ocean. This area in the ocean reflects both the California Current extension as well as the North Equatorial Current and the index may be indirectly

measuring frontal structures or other properties of the waters dominating the area that year. When lagged values were considered, the index was found to be a good predictor of the catch of large tuna off of the Hawaiian Islands.

Recently, Claude Roy of ORSTOM and I completed a study of the dynamics of tuna in the Gulf of Guinea area off the coast of west Africa. This area differs greatly from Hawaii - the coastal regions are major upwelling regions and the area under study is not an island group surrounded by huge areas of open ocean as is Hawaii. Also, the tuna fishery in the Gulf of Guinea is a purse seine fishery rather than a pole and line fishery, so the conditions leading to favorable catches may be quite different. However, the results of the study tell us several interesting things about the behavior of tuna.

The Gulf of Guinea was divided into 11 areas for our study. A local model was developed for each area. Figure 7 summarizes the results of the local models. Each area shows, on the average whether wind or sea surface temperature (SST) was the most important predictor in the area. The C (for colder) and W (for warmer) gives the difference in SST two weeks and one month earlier that produced the greatest CPUE. These parameters were always about equal in absolute value. What is noticeable is that wind is more dominant in the major upwelling areas, and that a sharp change in SST is desirable, rather than any one value. This suggests that the tuna are affected by upwelling, probably taking advantage of the concentrated food sources produced by upwelling.

The local models have the ability to complete missing data, that is to estimate in this instance CPUE during periods when there was no fishing. As a test of the local models, we artificially deleted almost a year of yellowfin CPUE data from area 5, and reestimated the models to see what values were given by the model. The resulting estimates are very close to the observed values of CPUE (fig. 8); as the only data available to the model during this stretch was environment data (sea surface temperature and wind) this is strong evidence that knowledge of the environmental conditions is sufficient to obtain reasonable predictions of CPUE.

The local winds in the Gulf of Guinea do not appear to be strong enough to produce the level of upwelling observed in that region. One theory is that the zonal winds off the coast of Brazil produce an underwater wave called a Kelvin wave that forces the upwelling. The wave propagates along the equator and then poleward in both directions when it intersects the coast. Figure 9 shows at a frequency of one year and six months the dominant progression of both SST and catch for yellowfin tuna in the area. SST progresses much as is predicted by the theory. Moreover, we have extended the analysis to a broader area in the Gulf, and this more clearly shows a progression in SST that is consistent with this remote forcing theory.

What is more noticeable, is that the dominant progression in the CPUE for tuna follows roughly the same pattern, slightly lagging the SST

progression. We estimate that some 50 to 60 percent of the variance in the data at all 11 areas at these frequencies are contained in this dominant progression. Since the SST progression does not really reach all 11 areas, in some areas the predictability is even higher.

Why should tuna follow a progression of SST that is associated with upwelling? Again, upwelled waters in Eastern Boundary Current areas are known to be associated with plankton blooms and aggregations. Other recent studies have shown that other fish species that feed on plankton also either come to the surface or aggregate following upwelled waters. The most likely explanation therefore is that the tuna are following food sources, and that their migratory patterns are influenced by the oceanographic conditions that produce food. (As an aside, a recent tagging study has proposed a migratory pattern for the tuna similar to the one Claude and I found using statistical models.)

CONCLUSION

The Gulf of Guinea results are similar in spirit to Seckel's and Jones' hypothesis rather than to Rothschild's. Tuna are pretty similar throughout the world, and it would be very surprising if the skipjack tuna around Hawaii are influenced by very different factors. We should further note that 1982 was the start of a major El Nino, and that since 1976, there has been an overall warming in the ocean, as if a change in regime were taking place. These events may help explain why the large skipjack have not returned since the collapse following 1973. There is good reason to believe that the environment has influenced the catch.

What is not clear, finally, is whether the tuna have just been moved elsewhere, or whether these changes have affected the reproduction and mortality of stocks.

As I said at the start, I have presented some evidence that tuna follow favorable environments, favorable in the sense of food sources, and that the environment may well be a major cause in the observed decline in skipjack catch off Hawaii. However, as I also stated earlier, it is not clear that even if this is true that the level of knowledge we have now about the problem is adequate to overcome the other problems facing the skipjack fishery around the islands.

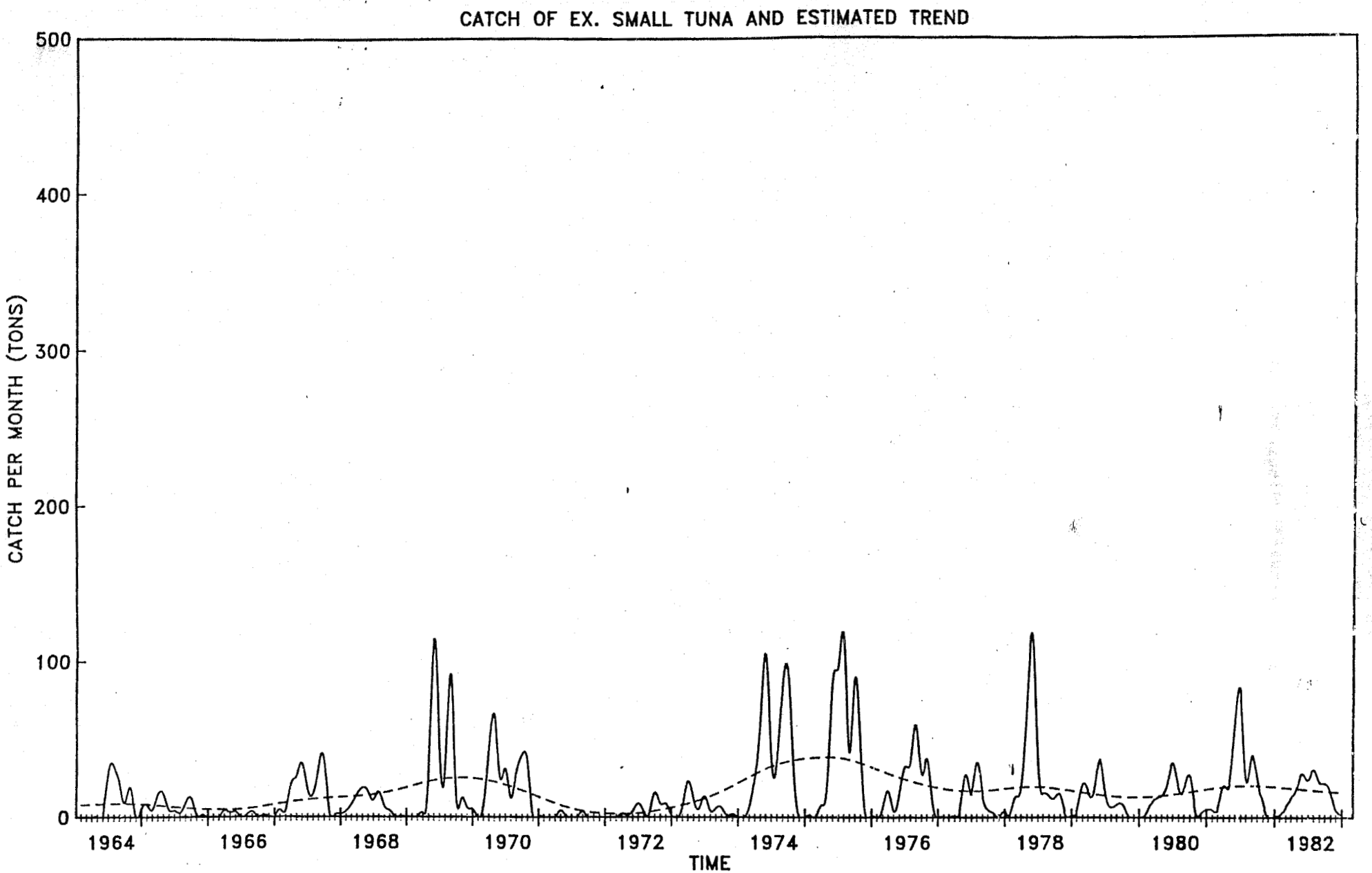

CATCH OF EX. SMALL TUNA AND ESTIMATED TREND
CATCH PER MONTH (TONS)
500
400
300
200
100
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
TIME

Fig. 1

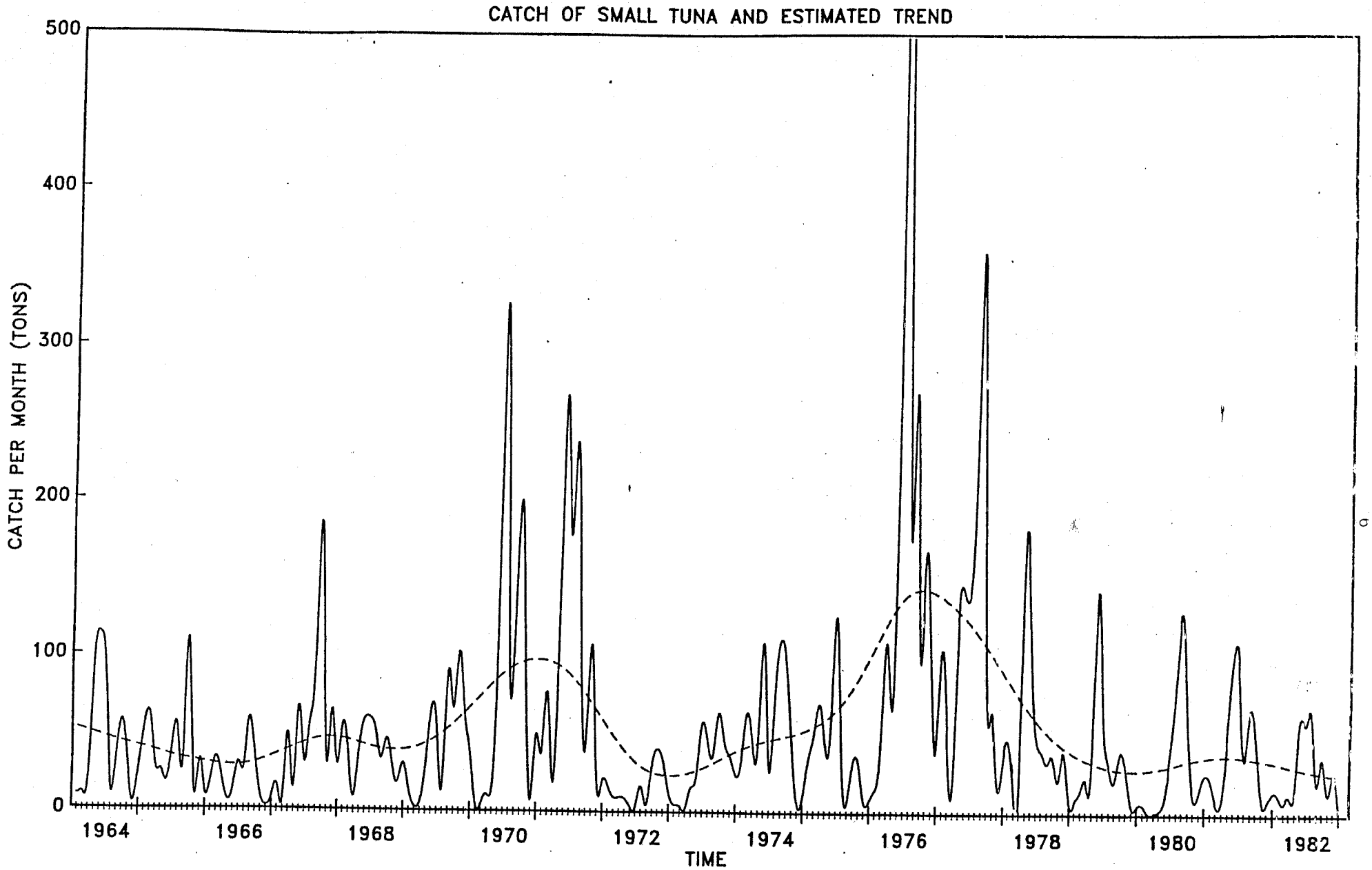

CATCH OF SMALL TUNA AND ESTIMATED TREND
CATCH PER MONTH (TONS)
500
400
300
200
100
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
TIME

Figure 2

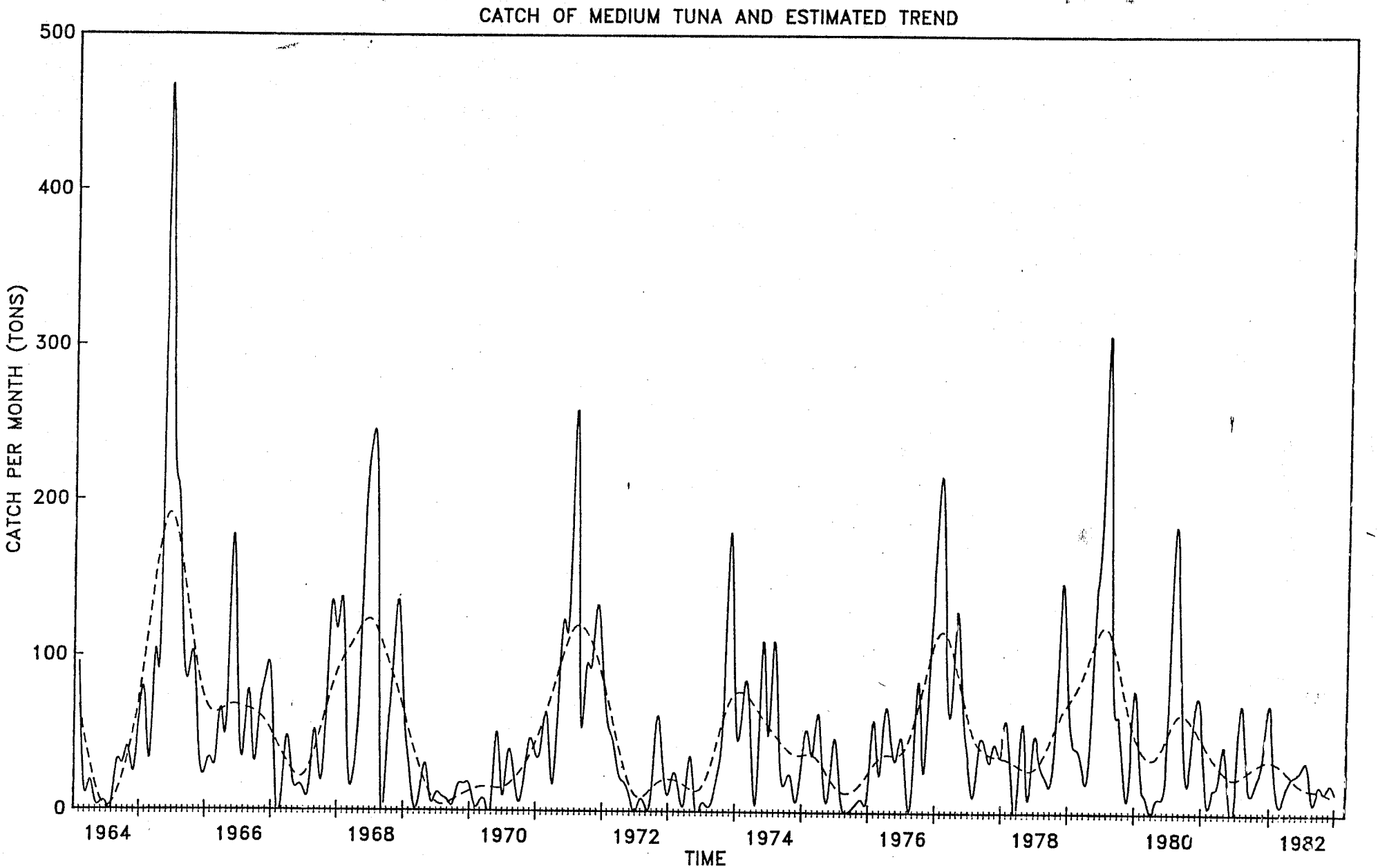

CATCH OF MEDIUM TUNA AND ESTIMATED TREND
CATCH PER MONTH (TONS)
500
400
300
200
100
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
TIME

Fig. 3

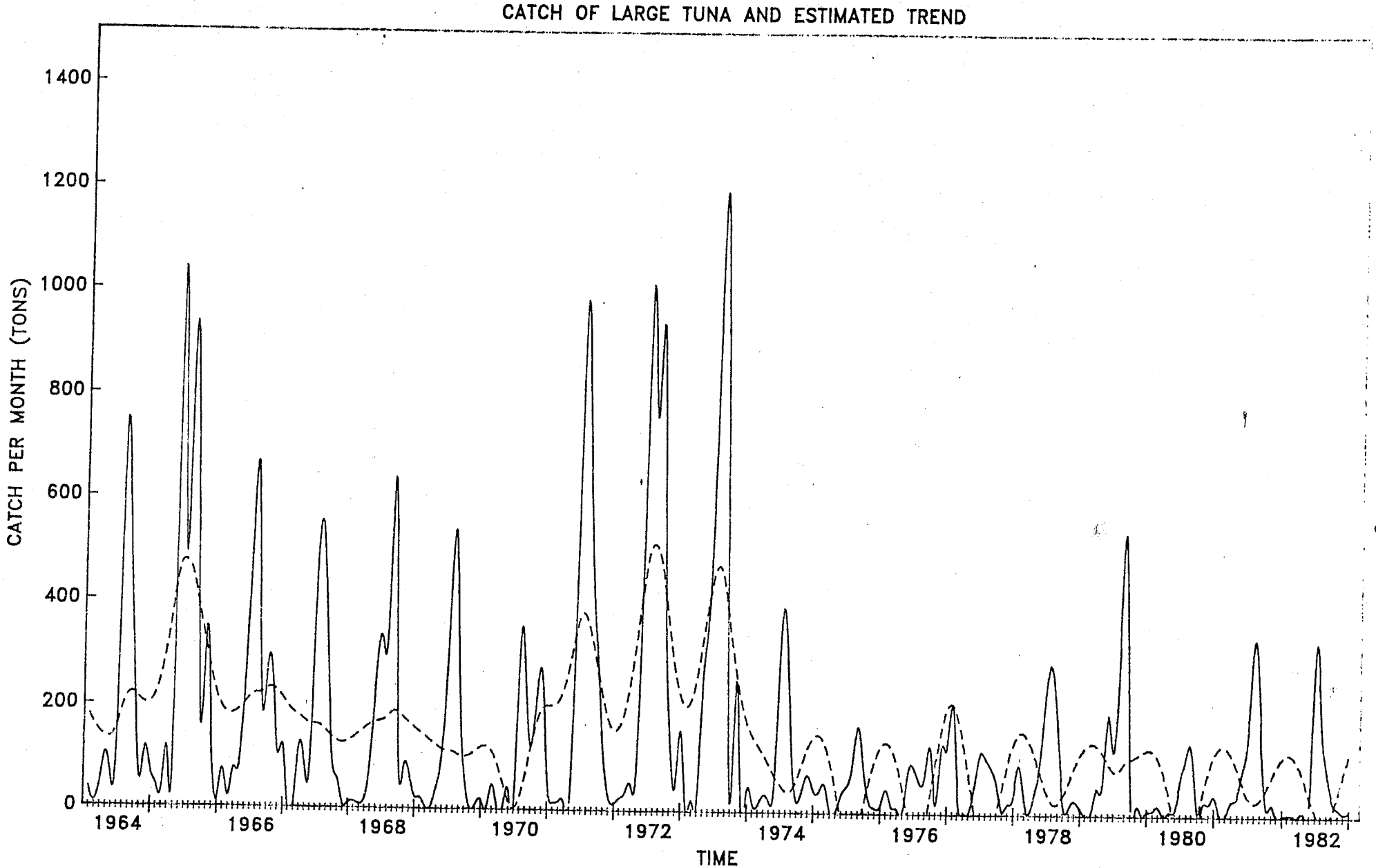

CATCH OF LARGE TUNA AND ESTIMATED TREND
CATCH PER MONTH (TONS)
1400
1200
1000
800
600
400
200
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
TIME

Figure 4

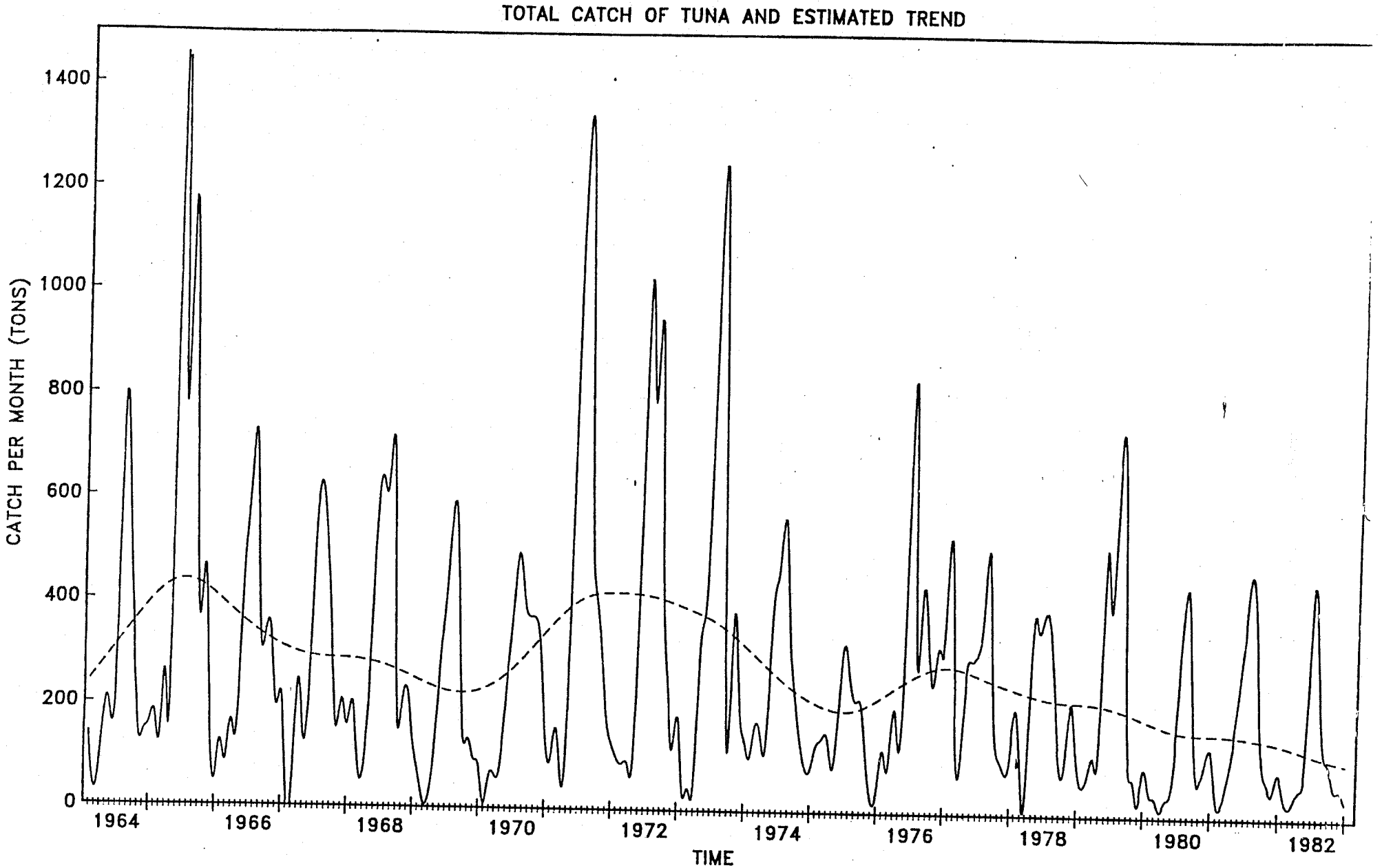
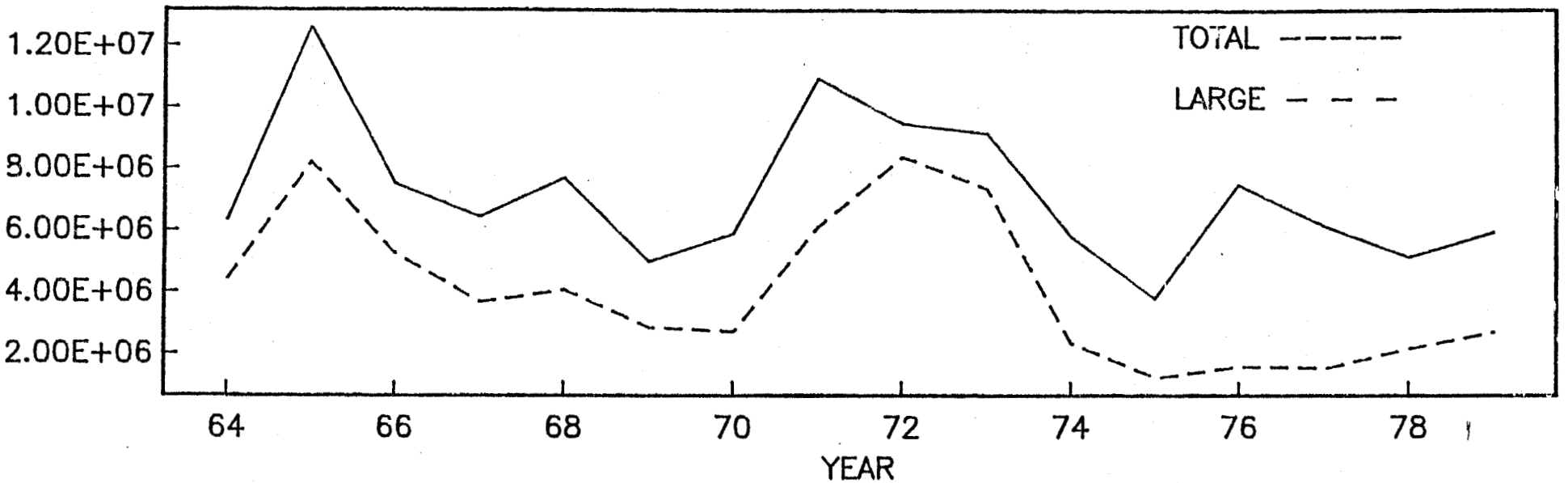
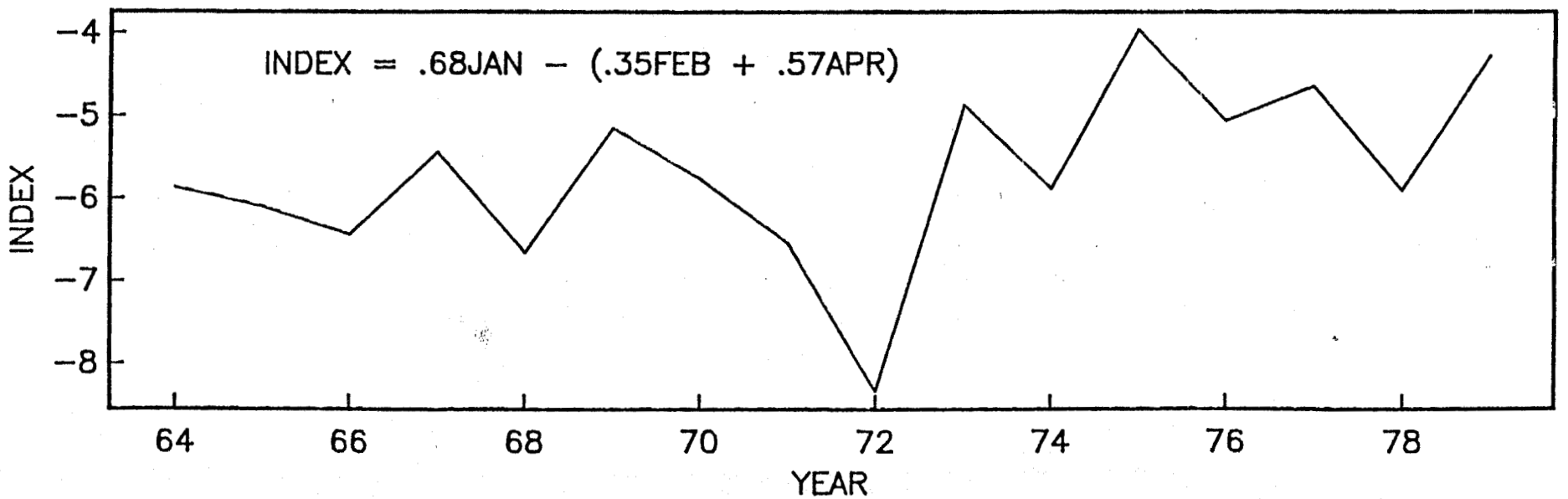

TOTAL CATCH OF TUNA AND ESTIMATED TREND
CATCH PER MONTH (TONS)
1400
1200
1000
800
600
400
200
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
TIME

Fig. 5

TOTAL CATCH AND CATCH OF LARGE SKIPJACK OFF HAWAII



INDEX OF POSITION OF 20C ISOTHERM THE PREVIOUS WINTER



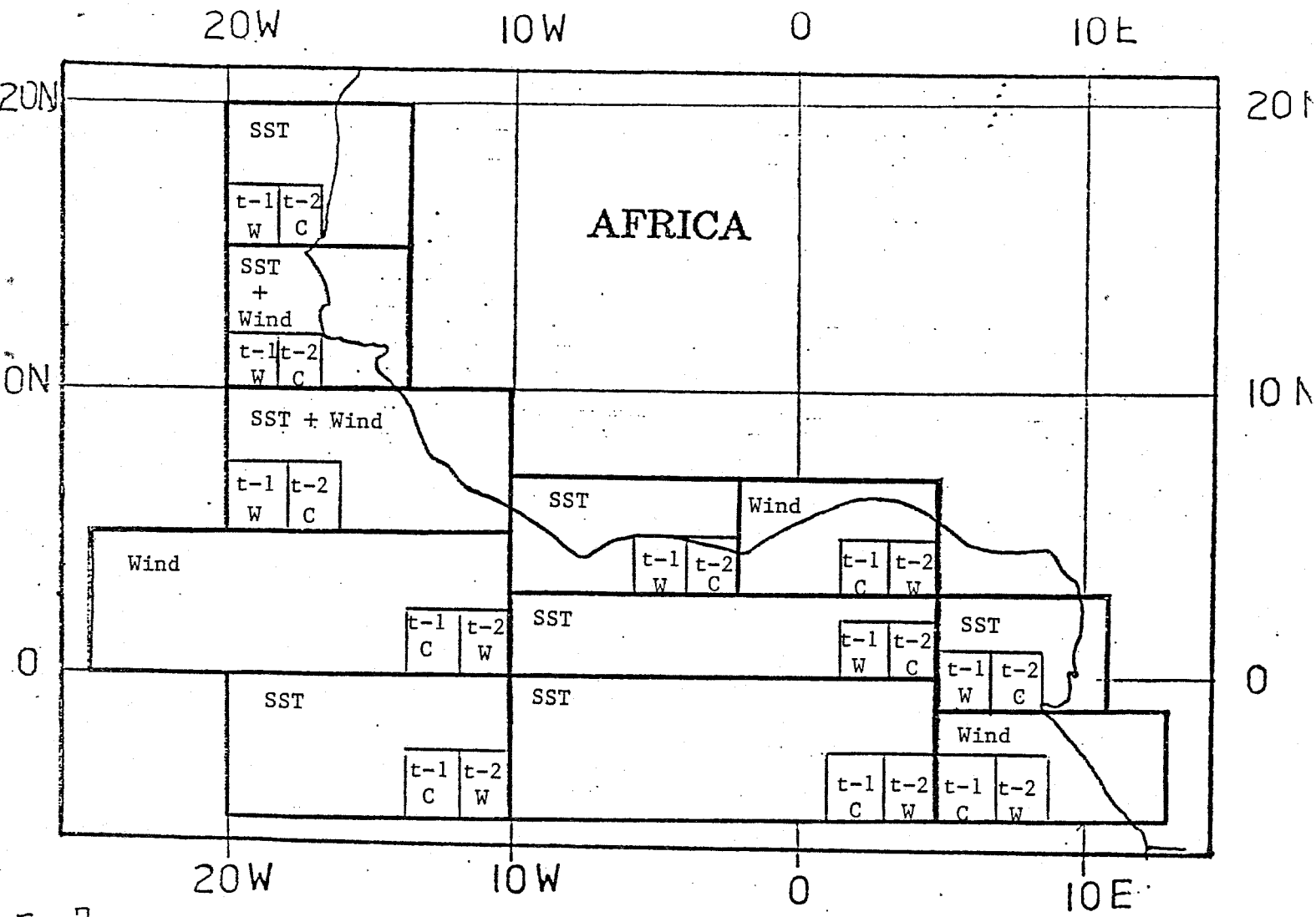


Fig. 7a

7a : Summary of the local models for yellowfin. In the upper corner of each area is the environmental parameter which contributes the most to the predictive power of the local model.

The C and W in the lower corner indicate the time periods t-1 and t-2 that yield optimum CPUE.

- W means relatively warmer water
- C means relatively colder water

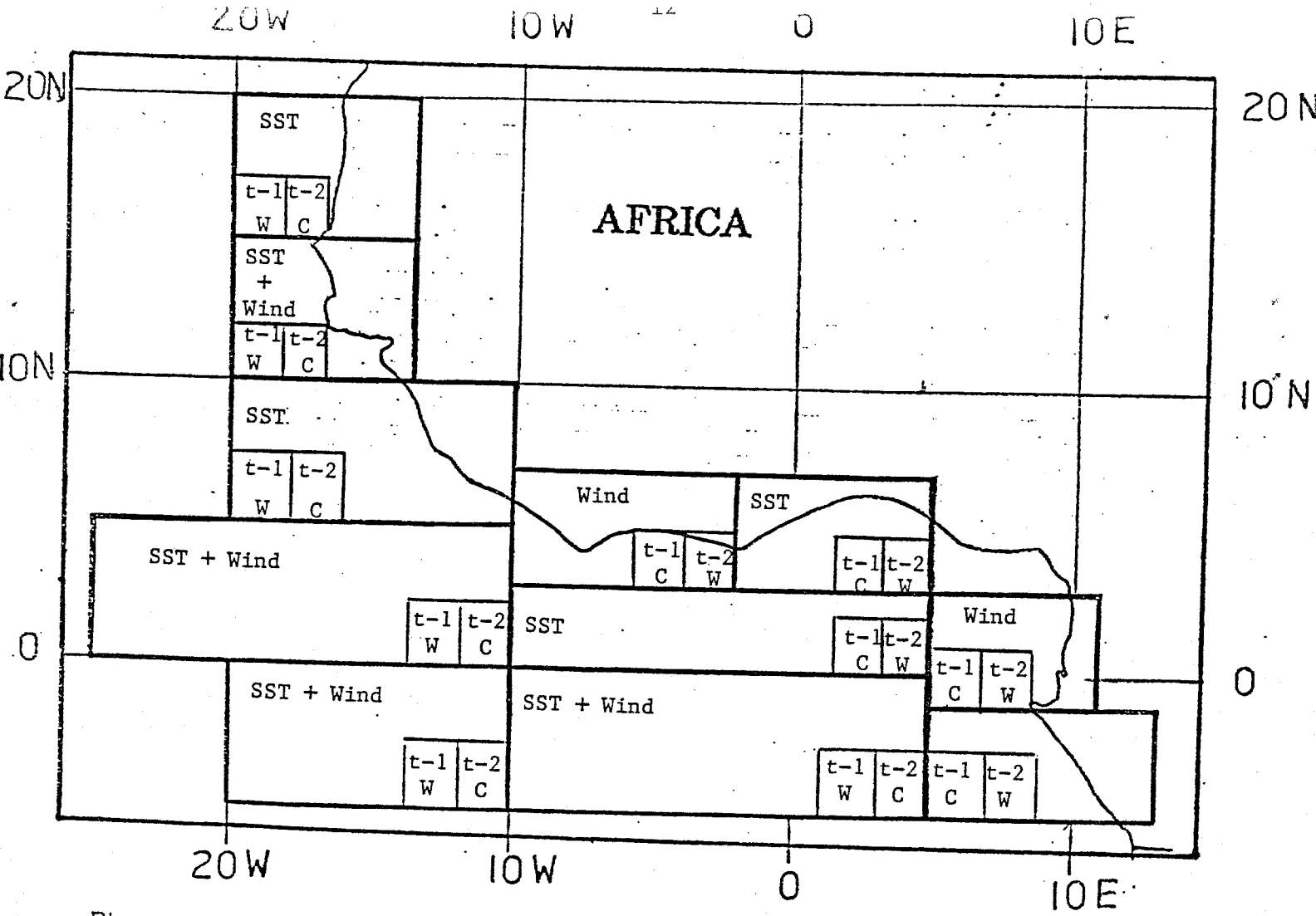


Fig. 7b.

7b: Summary of the local models for skipjack. In the upper corner of each area is the environmental parameter which contributes the most to the predictive power of the local model.

The C and W in the lower corner indicate the time periods t-1 and t-2 that yield optimum CPUE.

- W means relatively warmer water
- C means relatively colder water

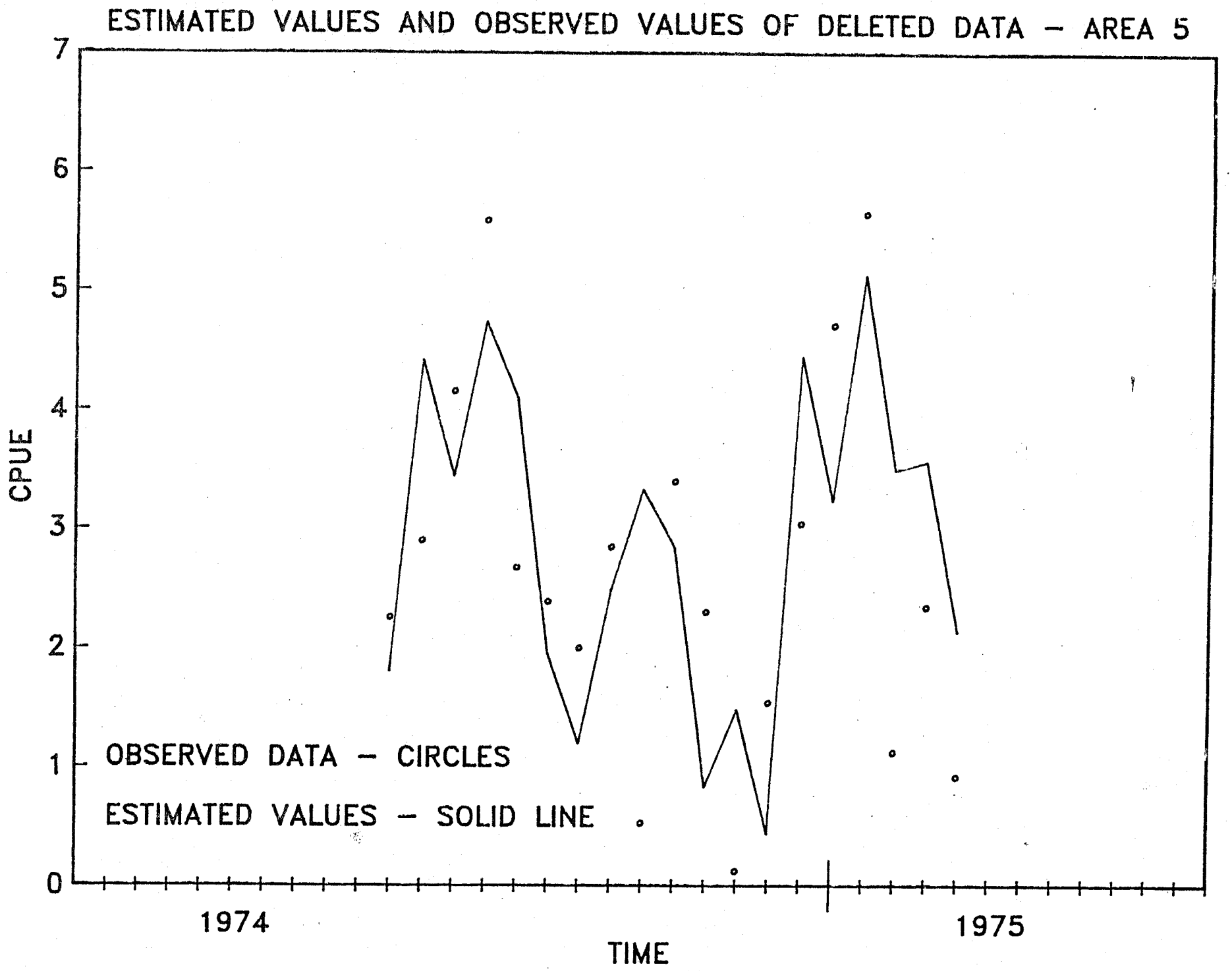

ESTIMATED VALUES AND OBSERVED VALUES OF DELETED DATA – AREA 5
CPUE
0
1
2
3
4
5
6
7
OBSERVED DATA – CIRCLES
ESTIMATED VALUES – SOLID LINE
1974
1975
TIME

Fig. 8

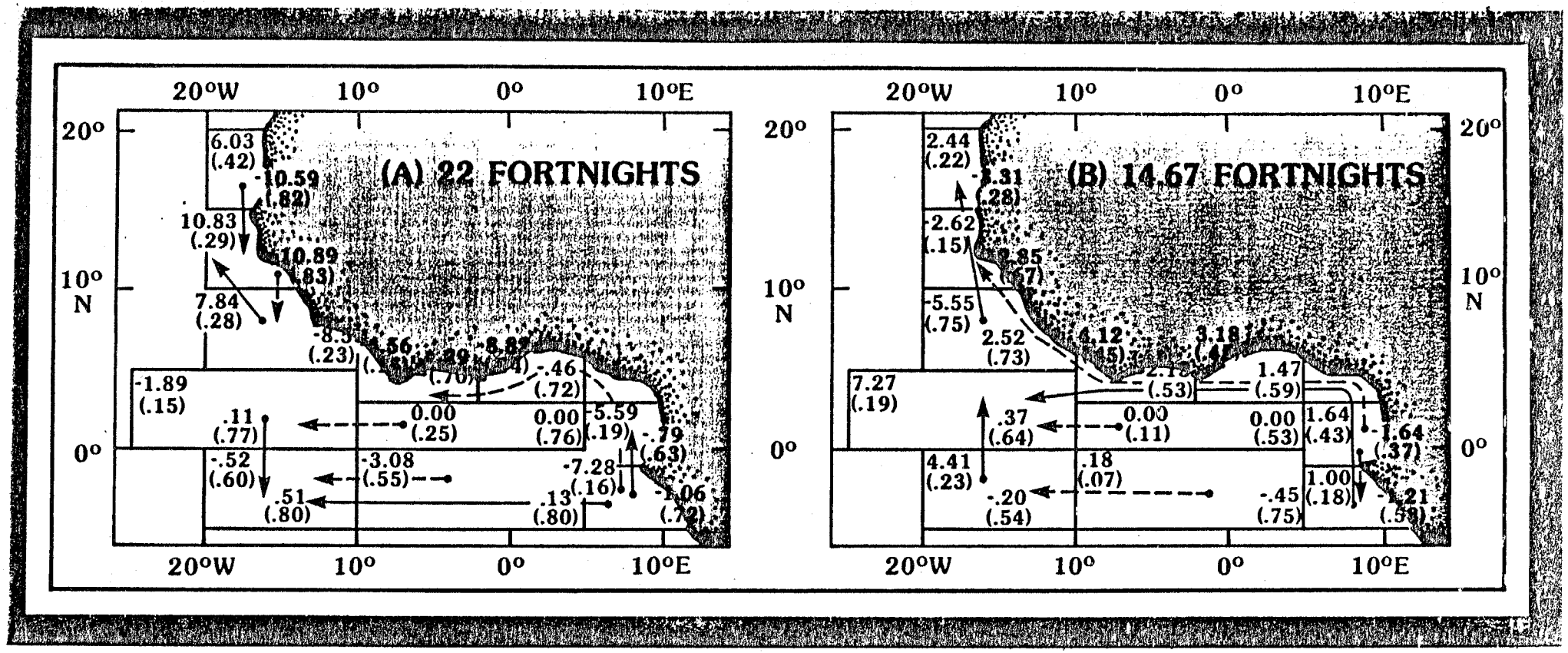

(A) 22 FORTNIGHTS
(B) 14.67 FORTNIGHTS
20°W
10°
0°
10°E
20°
10° N
0°
6.03 (.42)
-10.59 (.82)
10.83 (.29)
10.89 (.83)
7.84 (.28)
-8.3 (.23)
-.46 (.72)
-1.89 (.15)
.11 (.77)
0.00 (.25)
0.00 (.76)
-5.59 (.19)
-.79 (.63)
-.52 (.60)
-3.08 (.55)
-7.28 (.16)
.51 (.80)
.13 (.80)
-1.06 (.72)
2.44 (.22)
-3.31 (.28)
-2.62 (.15)
-5.55 (.75)
2.52 (.73)
4.12
3.18
1.47 (.59)
7.27 (.19)
.37 (.64)
0.00 (.11)
0.00 (.53)
1.64 (.43)
-1.64 (.37)
4.41 (.23)
.18 (.07)
-.20 (.54)
-.45 (.75)
1.00 (.18)

Figure 9