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COMMENTS ON THE USE OF WATER TEMPERATURE TO DELIMIT TROPICAL TUNA DISTRIBUTIONS

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SUMMARY

A large body of research has been directed toward placing spatial constraints on tropical tuna distributions based on water temperature. Recent physiological experiments, both in the laboratory and with acoustically tagged fish, indicate that tropical tunas routinely frequent water colder than once considered lethal. Results of these experiments indicate that water temperature may not be a constraining factor and that its use to partition multi-species fishing effort should be reviewed.

RESUME

Un gros volume de recherche a porté sur la façon de délimiter les zones de distribution des thonidés tropicaux à partir de la température de l'eau. Des expériences physiologiques récentes, aussi bien en laboratoire qu'en observant des poissons porteurs de marques acoustiques, montrent que les thonidés tropicaux fréquentent habituellement des eaux plus froides que celles qu'on leur considérait néfastes. Ces expériences ont servi à démontrer que la température de l'eau n'est peut-être pas forcément un facteur de délimitation, et qu'il faut évaluer de nouveau son utilité pour répartir l'effort dans la pêche pluri-pécifique.

RESUMEN

Se ha orientado gran parte de la investigación hacia la delimitación espacial de la distribución de los atunes tropicales, basadas en la temperatura del agua.

Experimentos fisiológicos recientemente llevados a cabo en laboratorio, y con peces portando marcas acústicas, indican que los atunes tropicales frecuentan aguas más frías que las, en un principio, consideradas letales. Los resultados de estos experimentos indican que la temperatura del agua puede no ser un factor restrictivo, y que su utilización, en cuanto a la distribución del esfuerzo de pesca multiespecífico, debe ser revisado.

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by

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INTRODUCTION

Fishermen, researchers and resource managers have sought to define the geographic limits of yellowfin tuna (Thunnus albacares) and skipjack tuna (Katsuwonus pelamis) stocks. An accurate distribution boundary for these species would reduce the search time and exploitation costs incurred by fishermen. It would assist biologists in the assessment of migration patterns, spawning patterns and substock structure. Finally, it would assist population dynamicists in estimating population sizes and maximum substainable yields for these two species.

Traditional approaches to defining stock distribution have included mapping the limits of yellowfin and skipjack tuna sightings and catches (Matsumoto, 1974) and using sea surface temperature at the time of catch to infer distribution limits (Le Guen, Poinsard and Troadec, 1965). In this paper the correlation of water temperature, particularly sea surface temperature, with the distribution of tunas is reviewed, as is the use of these correlations in apportioning effort on yellowfin and skipjack tuna in the eastern Atlantic.

Results of sea surface temperature/catch occurrence observations for a number of studies are summarized in Figure 1. These results indicate that although distribution limits vary by species, by area and by study, overlap does exist for the distributions presented. The total range of temperature for both combined yellowfin and skipjack tuna is 15^{0} to 31^{0}C with yellowfin having a range of 15^{0} to 31^{0}C and skipjack 15^{0} to 30^{0}C. Mean values within the overall species ranges appear to be about 25^{0}C for yellowfin and from 23^{0} to 25^{0}C for skipjack.

For the fishery temperature or species optimum temperature ranges in Figure 1, a similar overlap of the ranges exist for yellowfin in each case while for skipjack the ranges do not overlap. Examination of the fishery optimum temperature range (Figure 1) for both yellowfin and skipjack suggests marked differences for each species by area. This is probably due to the fact that Evans and Miller (In prep.) used no longline data in their analysis which would tend to bias their results toward warmer temperatures.

From the above it would appear that the distribution ranges and means, as inferred from sea surface temperature at catch are very nearly the same, especially within areas.

PHYSIOLOGICAL EXPERIMENTS WITH CAPTIVE TUNAS

The effects of water temperature on the behavioral response of skipjack tuna has been monitored using captive fish from the Pacific. These results summarized in Figure 2, show that for skipjack lethal water temperature limits are somewhat broader (15^{0} to 33^{0}C) than limits inferred from temperature at catch in Figure 1. Computations by Barkley, Neill and Gooding (1978), (Figure 2) indicate that larger skipjack tuna are confined to colder water with age (increased size). These results are confirmed by temperature size comparison data for Atlantic caught skipjack presented in Aloncle and Delaporte (1977). The swimming energetics modeling of Sharp and Vlymen (1978) also confirm this premise for several tuna species including yellowfin tuna.

It is unfortunate that no data similar to that for skipjack in Figure 2 are available for yellowfin tuna. There is no reason, however, to assume that results for yellowfin would be different from those presented for skipjack. In fact, Dizon, Neill and Magnuson (1977) surmise that because yellowfin swim slower they may respond more rapidly to changes in water temperature than skipjack tuna.

ACOUSTIC TRACKING EXPERIMENTS WITH TUNAS

Acoustic tracking studies, with telemetered depth data, have been made with skipjack tuna in the Pacific. The depth data from the tracked fish when integrated with the known vertical thermal structure over time defines the thermal habitat of the animal. The temperature selected by the age 3+ skipjack used in the study documented by Dizon, Brill and Yuen (1978) (Figure 2) ranged from 12° to 26°C.

It is interesting that this range exceeds the lower lethal limit previously indicated by 3°C and the upper distribution limit for 3-year-old skipjack (Figure 2) by about the same amount. This is presumably due to the fact that skipjack briefly transit environs which would be lethal over the long term.

A similar finding has been reported for north Pacific albacore Thunnus alalunga (Figure 3). In this case an acoustically tracked albacore spent the majority of its time in waters 2° to 5°C below the low end of what had been believed to be the range of optimal temperature preference (15-20°C Uda, 1957). The albacore descended several times into water as cold as 9.5°C. It can be speculated that the behavior of yellowfin in the wild would be similar to that observed for skipjack and albacore.

WATER TEMPERATURE AS A DELIMITOR OF SPECIES CATCH DISTRIBUTION

Results from laboratory and field studies on tunas (Figures 1-3) suggest that yellowfin and skipjack tuna may be capable of functioning in a wide range of water temperatures (15°-31°C). A range for both which is much larger than the annual mean sea surface temperature range within the distribution of the fishery in the eastern Atlantic (Evans, McLain and Bauer, 1979). Further, information in Figure 1 indicates that the temperature distribution criteria for the two species should be identical. This conclusion is substantiated by data adapted from Bages and Fonteneau (1979) for the year 1977. The data they present summarizes sea surface temperature at catch by quarter and year for six sectors areas of the eastern Atlantic where commercial catches of yellowfin and skipjack tuna routinely occurred. These data are presented in Figures 4 and 5.

In Figure 4 there were 30 cases where the sea surface temperature at the modes of yellowfin and skipjack catches could be compared. In 87% (26) of the cases the temperature value at the catch mode for the two species was identical. In 13% (4) of the cases the water temperature at the catch mode was warmer for skipjack.

Figure 5 gives a similar result for the minimum temperature of catches of yellowfin and skipjack tuna for the same sectors and times. In this figure the minimum temperature of the catch is identical for both species in 67% (16) cases. In 21% (5) cases the minimum catch temperature is warmer for skipjack than for yellowfin and in 12% (3) cases the minimum catch temperature for skipjack was colder than for yellowfin. It should be noted that all three cases where the temperature for skipjack was warmer were from a single sector, the equatorial sector. These data suggest that in the eastern Atlantic skipjack and yellowfin occupy identical areas in both space and time.

DISCUSSION

The data presented herein indicate that: 1) yellowfin and skipjack tuna in the eastern Atlantic inhabit the same areas in both space and time as defined by sea surface temperature (Figures 4 and 5), 2) that movement within the area of the combined fishery does not seem to be constrained at the sea surface in any way by water temperature (Figures 2) and 3) that there is no difference in the temperature preference ranges of skipjack and yellowfin (Figures 2, 4 and 5).

These results have important consequences for tuna resource assessment. For example, they fail to substantiate the approach taken by Bages and Fonteneau (1979) that fishing effort can be partitioned between skipjack and yellowfin tuna in the eastern Atlantic using the distribution of sea surface temperature as the primary criteria. However, given that such an approach is valid and that a discrete value of sea surface temperature is selected (22°C, Fonteneau, 1980), the senario developed herein raises further questions about the approach as follows:

1. Bages and Fonteneau (1979) used sea surface temperature and catch data from 1977, a year in which the environment and the fishery may have been abnormal for a number of reasons including:

   a. anomalous distribution of sea surface temperature in space and time,

   b. anomalous distribution of species (yellowfin and skipjack tuna) in the catch,

   c. anomalous distribution of fishing effort on yellowfin and skipjack tuna.

Changes in any of these variables would substantially alter the resulting partition of effort.

2. Inter-annual variations in sea surface temperature fields, fishing effort applied and species composition of the catch may be so large as to render the approach of using an average value for sea surface temperature to partition multispecies effort untenable. In this regard Sette (1961) and others have stressed that assessment of population size and behavior of tunas cannot be tied to an equilibrium ocean.

3. The appearance of dominant year classes in either of the target stocks of yellowfin or skipjack tuna could substantially impact the sea surface temperature value selected as the effort partitioning criteria. It is obvious from Figure 2 (values computed by Barkley, Neill and Gooding, 1978) that the best case for separating yellowfin and skipjack fishing effort using water temperature would be when the catch is composed of mainly older skipjack and younger yellowfin. (i.e. when the greatest separation in the means of preferred water temperature range occurs). When the catch is predominately younger skipjack and older yellowfin (much more likely) the opposite occurs and it becomes more difficult to separate the means of the preferred water temperature ranges.

CONCLUSIONS

1) Movements of yellowfin and skipjack tuna are not constrained by surface water temperatures within the geographic confines of their distribution.

2) Correlation of temperature and distribution of tunas suggests that water temperature by itself is a poor criterion for delimiting space and time boundaries of skipjack and yellowfin tuna distributions in the eastern Atlantic.

3) Partitioning of fishing effort on yellowfin and skipjack tuna in the eastern Atlantic using sea surface temperature as the criteria is suspect.

4) Further research is needed to address fluctuations in the marine environment, fishing effort, stock structure, year-class dominance and, of course, the physiological constraints placed eastern Atlantic yellowfin and skipjack tunas, before environmental variables can be considered in any fishing effort partitioning scheme.

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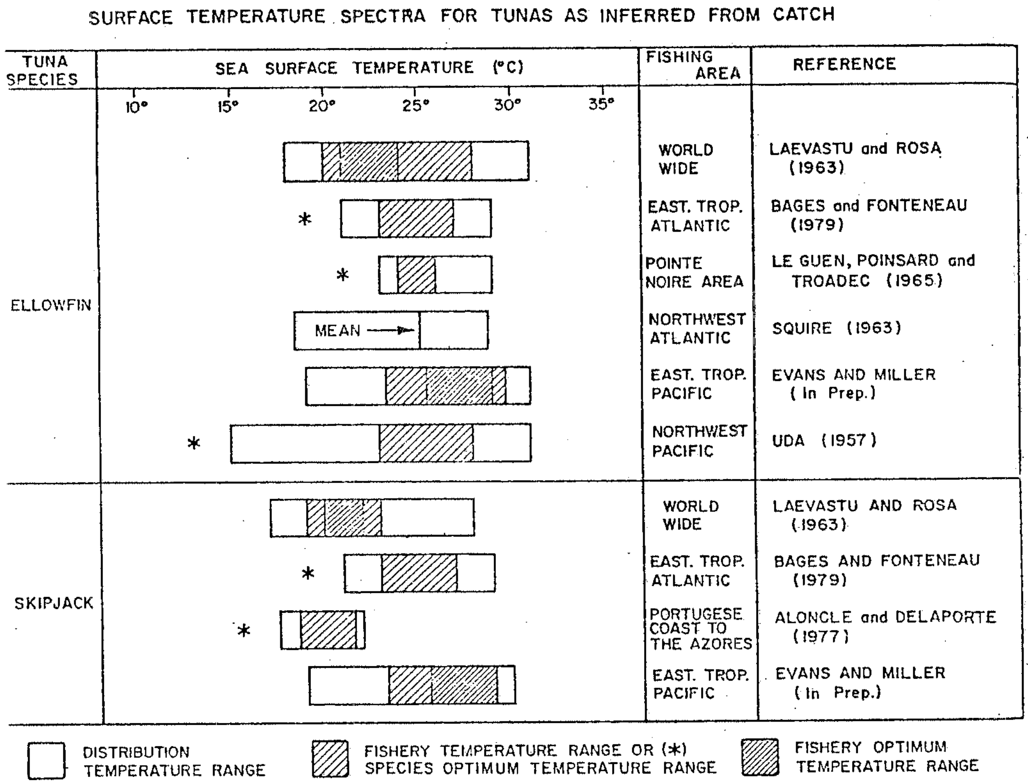

Figure 1. Temperature spectra for tunas as inferred from sea surface temperature values collected at the time of catch.

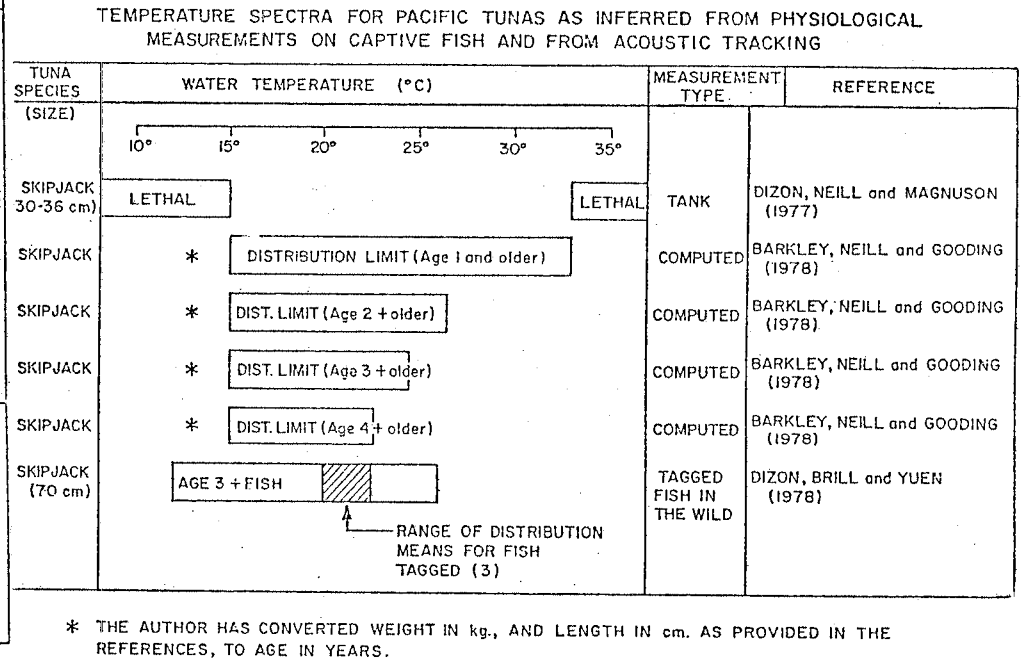

Figure 2. Temperature spectra for Pacific tunas as inferred from physiological measurements on captive fish and from acoustic tagging. Skipjack ages are computed as per Coan (1976).

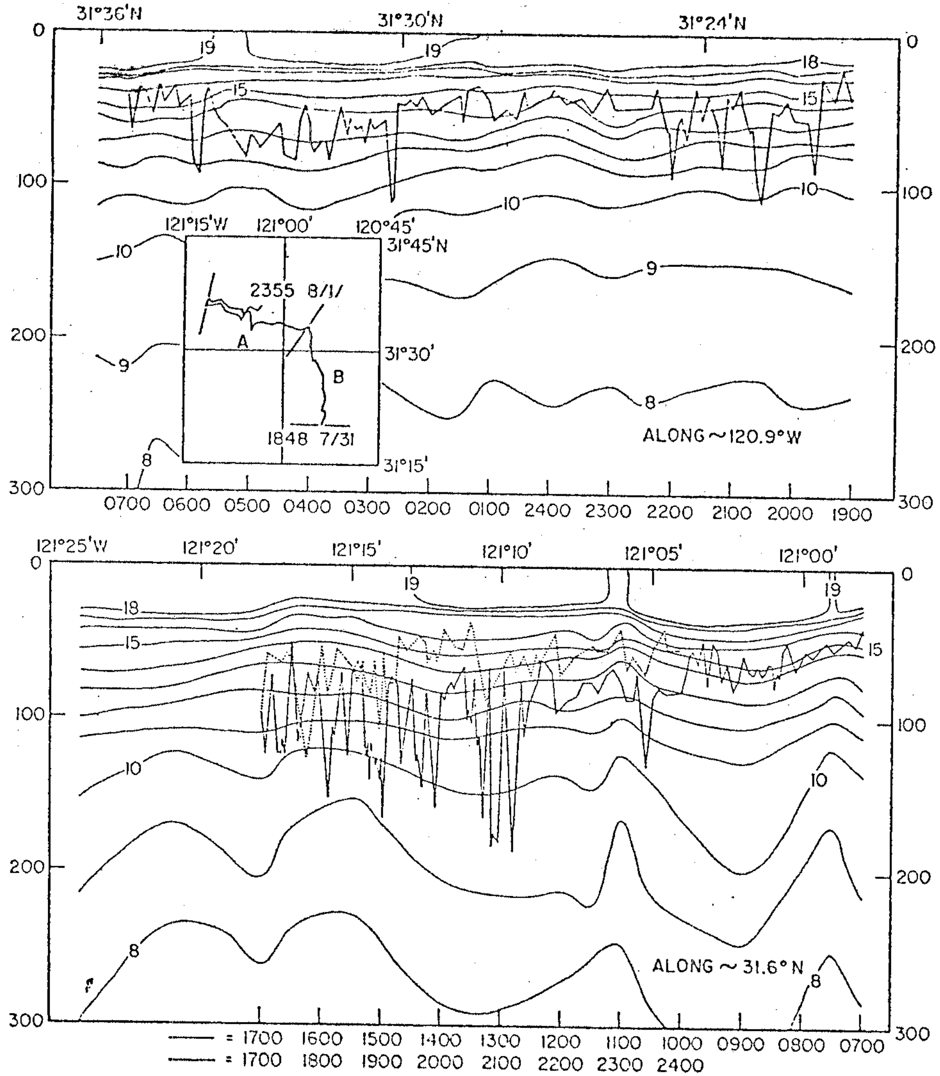

Figure 3. Vertical movements (in meters) of an acoustically tracked Pacific albacore tuna plotted against time with vertical thermal structure overlayed. From Laurs et al (1980).

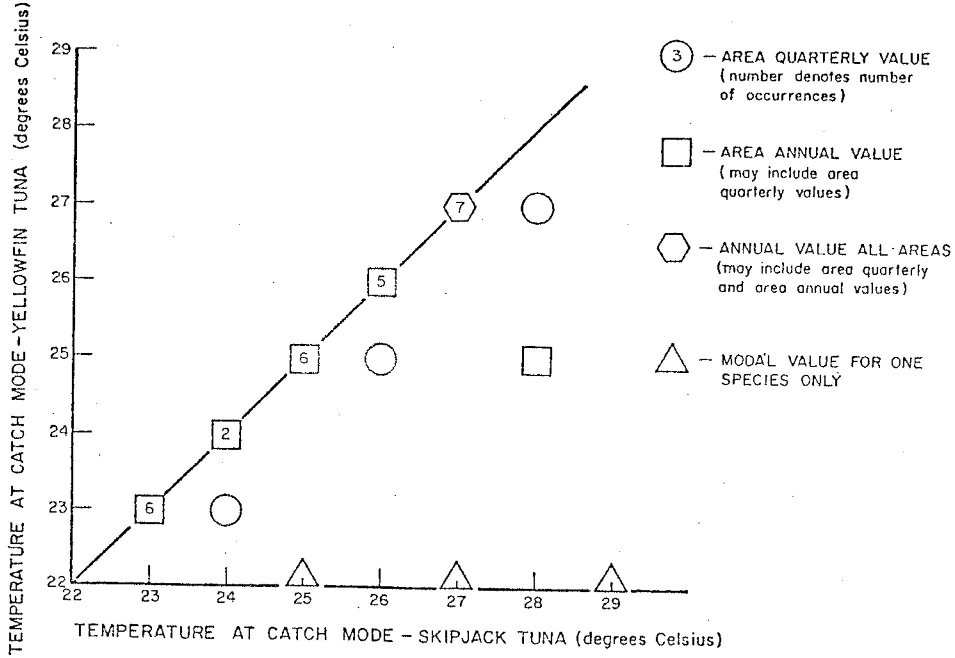

Figure 4. Comparison of sea surface temperature at catch by quarter and by year for six sectors of the eastern Atlantic where yellowfin and skipjack tuna are routinely caught. The sectors are as follows: Equatorial, Point Noire, Cape Lopez, Cape Three Points, Liberia and Guinea. Plotted values are comparison of the sea surface temperature at the mode(s) of the catch for skipjack and yellowfin. (Data adapted Bages and Fonteneau, 1979).

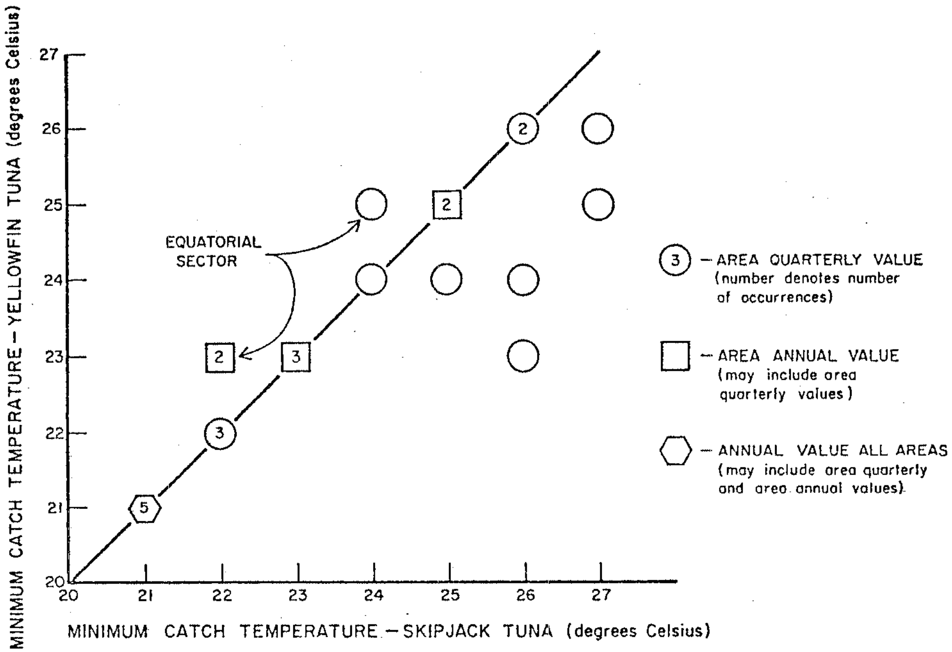

Figure 5. Comparison of sea surface temperature at catch, by quarter and by year for six sectors of the eastern Atlantic where yellowfin and skipjack tuna are routinely caught. The sectors are as follows: Equatorial, Point Noire, Cape Lopez, Cape Three Points, Liberia and Guinea. Plotted values are comparison of the minimum values of sea surface temperature where catches of yellowfin and skipjack occurred (Data adapted from Bages and Fonteneau, 1979).