Micronesica 23(2): 131–138, 1990

Ocean Temperature Structure and the Seasonality of Pelagic Fish Species Near Guam, Mariana Islands

STEVEN S. AMESBURY and MICHELLE BABIN

University of Guam Marine Laboratory, UOG Station, Mangilao, Guam 96923, USA

Abstract—Temperature and depth data from bathythermograph casts made in the 1° square around Guam (13° to 14° N latitude, 144° to 145° E longitude) were analyzed to determine average monthly temperature patterns in the upper 500 m of the waters around the island. Characteristic features include (1) a year-round permanent thermocline extending from 120 m to more than 400 m in which water temperature drops from 27° to 8° C, (2) a deep mixed layer extending from the surface to 120 m during winter months, (3) development of a seasonal thermocline and reduction in the depth of the mixed layer during spring and summer, and (4) redevelopment of a deep mixed layer during the autumn months.

Patterns of seasonal abundance of five important pelagic fishery species around Guam were examined with respect to seasonal water temperature patterns. Blue marlin (*Makaira mazara*), skipjack tuna (*Katsuwonus pelamis*), and yellowfin tuna (*Thunnus albacares*) are most abundant during summer months when surface waters are warm and the seasonal thermocline has developed. Wahoo (*Acanthocybium solandri*) catch rates peak in November and December as surface waters cool and the mixed layer deepens. Mahimahi (*Coryphaena hippurus*) is most abundant in the winter and early spring when the mixed layer is at its deepest and surface waters are at their coolest.

Introduction

The most important recreational and commercial fishery species of Guam are migratory pelagic species, including skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), mahimahi (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), and blue marlin (*Makaira mazara*). These species generally occur around Guam during predictable "seasons" (e.g. mahimahi season is from January to April; blue marlin season is from June to October; wahoo season is from November to December; Amesbury *et al.* 1986), but their abundance in any particular year is unpredictable (mahimahi, for instance, may comprise anywhere from 10% to 40% of the total Guam trolling catch in a given year; Guam Division of Aquatic and Wildlife Resources 1978–1988).

A better understanding of the factors influencing the abundance of pelagic species in the waters around Guam, and an ability to predict variations in the abundance of these species, would help to improve the effectiveness of recreational fisheries as well as reduce waste of these resources in the commercial fishery at times when an unusually high abundance of fish swamps the ability of local markets to absorb them. An understanding of patterns of variation is also essential for management of the species.

Fluctuations in the abundance of migratory pelagic species around an island area may be caused by changes in the numerical abundance of the fishes in the stock, or by changes in their migratory patterns which may bring the fish closer to or farther from the island or deeper or shallower in the water column, thereby affecting their availability to local trolling fishermen. These fluctuations may be correlated with variations in the oceanographic characteristics of the waters within which the fish live and migrate. Barkley *et al.* (1978) and Mendelssohn & Roy (1986) have related distribution and abundance of skipjack and yellowfin tuna to oceanographic variables, and the National Marine Fisheries Service Honolulu Laboratory has had success in predicting the harvest of skipjack tuna in the waters around Hawaii by relating their abundance to thermal characteristics of adjacent waters (Boggs 1988, 1989).

A project was initiated by the University of Guam Marine Laboratory and the Guam Division of Aquatic and Wildlife Resources to gather historical data on oceanographic characteristics of the waters around Guam to see whether fluctuations in fish abundance around the island can be related to oceanographic fluctuations. Should such relationships be determined, they might provide a basis for forecasting the abundance of important recreational and commercial target species in the future.

The first phase of this project, and the one reported on here, is an analysis of the temperature structure of the upper 500 m of the ocean in the 1° square around Guam (13° to 14° N latitude and 144° to 145° E longitude).

Materials and Methods

Temperature and depth data for the waters around Guam were acquired from the National Oceanographic Data Center. These data were collected with mechanical and expendable bathythermograph (BT) casts carried out from July 1944 to June 1988. The total number of BT records for the 1° square around Guam was 472. For each month, the number of records was as follows: Jan - 17, Feb - 32, Mar - 60, Apr - 51, May - 49, Jun - 46, July - 52, Aug - 39, Sep - 35, Oct - 40, Nov - 35, Dec - 16.

Temperature-depth plots were made for each BT record, and these plots were used to determine the temperature at specific depths (0, 50, 100, 200, 300, and 400 m). These data were then used to calculate the average temperature at each of these depths for each month, and each of the individual plots for each month was compared with the monthly average to determine the degree to which the individual record varied from the monthly average.

For each month, the particular BT record which most closely approximated the average temperature conditions for that month was selected to represent the average monthly temperature pattern. For one month (April), a composite of two BT records was used because no single record was sufficiently similar to the monthly average throughout the whole depth range to adequately represent average conditions.

Seasonal abundance patterns of major trolling species were determined by calculating average monthly harvest rates (kg/boat-h) for the period from October 1977 to September 1988 from survey data collected by the Guam Division of Aquatic and Wildlife Resources (1978–1988).

Results

The plots of average monthly temperature-depth patterns for January to December are shown in Figure 1. Several features of these patterns are apparent:

1) During all months there is a permanent thermocline from approximately 120 m to more than 400 m in which water temperature declines from approximately 27° to 8° C.

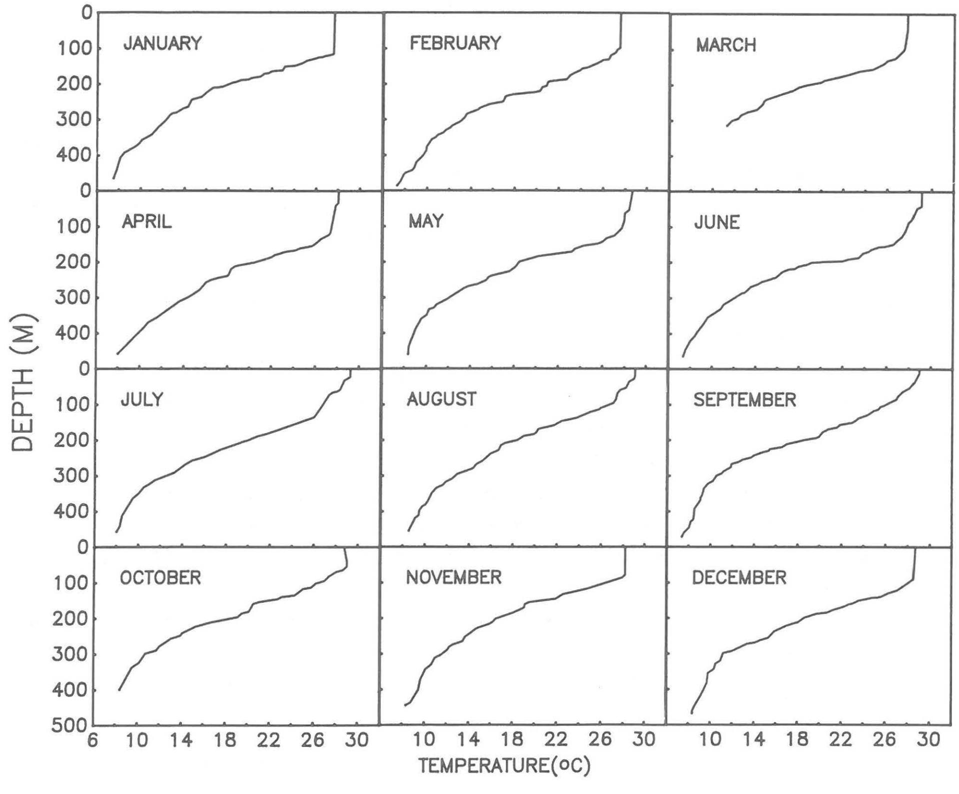

Figure 1. Monthly temperature-depth relationships for the ocean waters near Guam. Individual plots are from years with temperature conditions most nearly approximating longterm average conditions for that month: Jan–1972, Feb–1974, Mar–1976, Apr (0–250 m)–1982, Apr (250–475 m) –1981, May–1975, Jun–1970, Jul–1979, Aug–1974, Sep–1974, Oct–1976, Nov–1979, Dec–1971.

2) During winter months, the surface mixed layer is deep, extending from the surface to the top of the permanent thermocline at approximately 120 m.
3) As spring and summer progress, a seasonal thermocline develops at shallow depths; the mixed layer becomes shallower and almost disappears in September.
4) The mixed layer increases in depth during the autumn months as the seasonal thermocline breaks down.

Discussion

Guam is located in the North Pacific Central Water mass near the western end of the North Pacific Equatorial Current (Sverdrup *et al.* 1942, Tchernia 1980, Pickard & Emery 1982). Underlying the North Pacific Central Water is North Pacific Intermediate Water. Data presented by deWitt (1972) indicate that the core of the Intermediate Water mass may lie at 500 m or shallower in the waters around Guam, at the deep end of the depths reached by the BT records used in this study. Thus the seasonal temperature patterns noted above are those that characterize the North Pacific Central Water mass and the transition to the North Pacific Intermediate Water mass. This water is carried toward Guam by the North Pacific Equatorial Current, and the observed seasonal variations in temperature structure are the result of factors affecting these surface waters as they are transported westward across the Pacific.

The seasonal variations in temperature structure shown in Figure 1 closely resemble typical patterns at midlatitude sites in the Northern Hemisphere (e.g. Knauss 1978), differing only in the range of seawater temperatures involved. This pattern is generally attributable to two factors, seasonal variations in incoming heat from the sun, which warms surface waters, and seasonal variations in wind strength, which mixes surface waters.

During the winter, when solar heating is least and winds strongest (Figure 2), surface waters are at their coolest and the mixed layer reaches its greatest depth. As insolation increases and winds slacken during the spring and summer months, surface waters warm and stratify, and the mixed layer becomes shallower. As autumn progresses into winter, solar heating decreases while winds strengthen, breaking down the seasonal thermocline and reestablishing conditions of cool surface waters and a deep mixed layer.

The seasonal abundance patterns of Guam's five most important trolling species are shown in Figure 3. Wahoo, mahimahi, and blue marlin exhibit much more distinct seasonal patterns than do skipjack and yellowfin tuna, but all show seasonal variations that are presumably related to their schedules of pelagic migration relative to Guam.

Blue marlin, skipjack tuna, and yellowfin tuna are more abundant during the summer months when surface waters are warm and the seasonal thermocline has developed. Wahoo catch rates peak in November and December as surface waters cool and the mixed

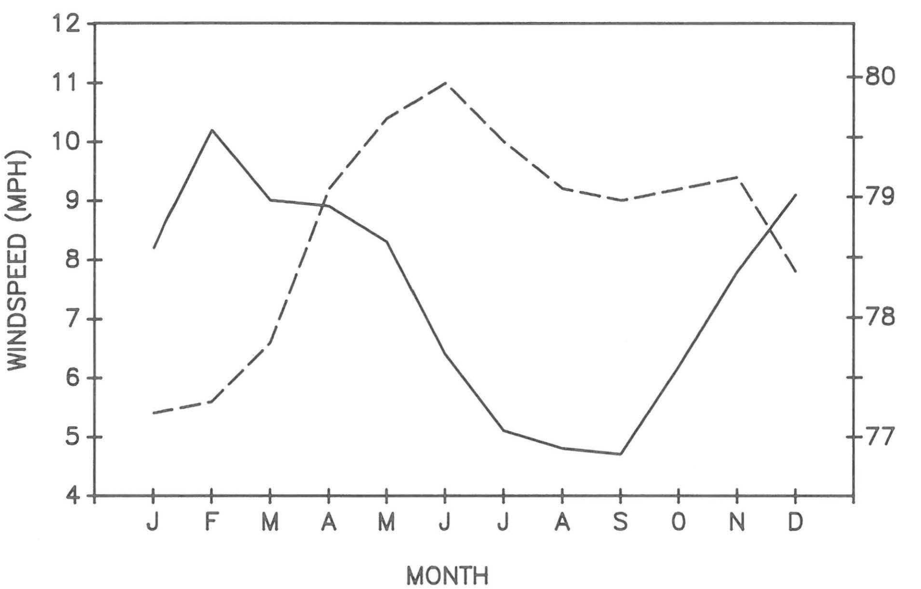

Figure 2. Monthly average windspeed and air temperature measured on Guam. Based on records for the 1951–1980 period. Solid line: windspeed; dashed line: temperature. Source: Local Climatological Data, Annual Summary with Comparative Data, 1983, Guam, Pacific, National Climatic Data Center, NOAA.

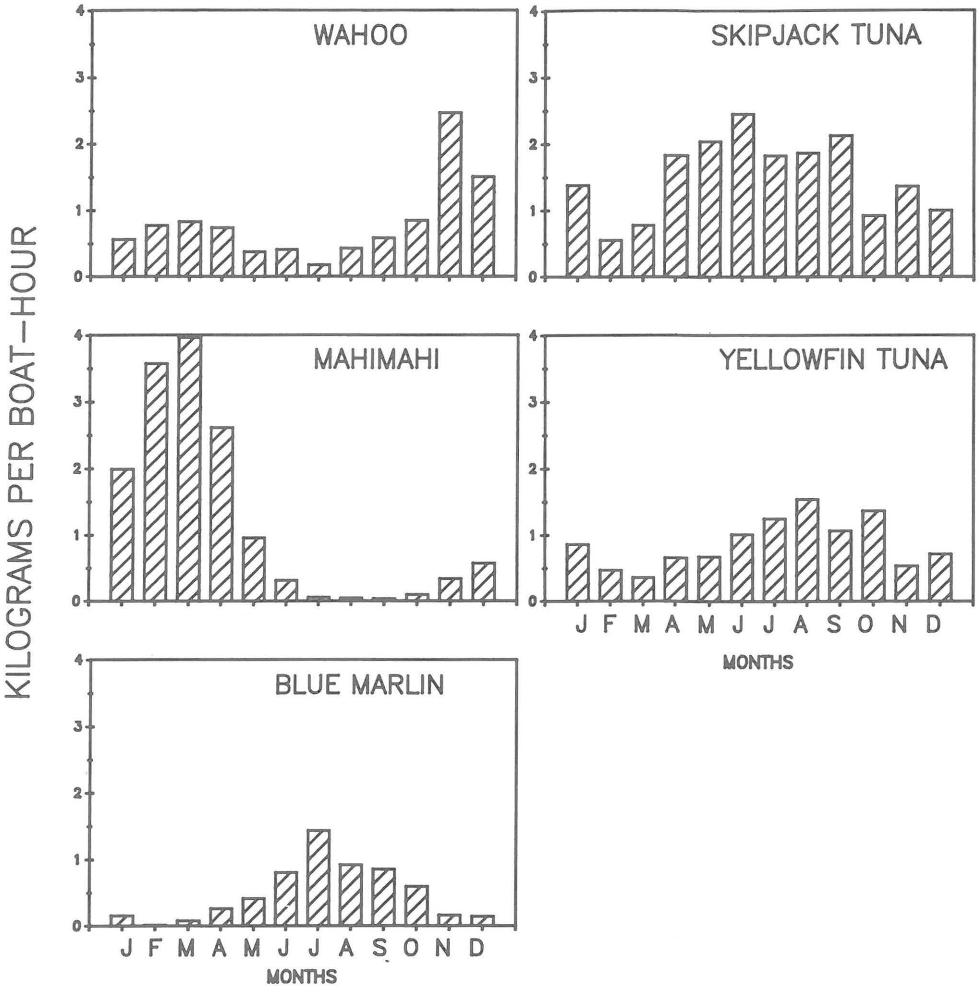

Figure 3. Mean monthly catch rates (kg/boat-hour) of major pelagic species in the Guam trolling fishery. Plots based on data compiled by Guam Division of Aquatic and Wildlife Resources (1978–1988).

layer deepens. Mahimahi is most abundant in the months of winter and early spring when the mixed layer is at its deepest and surface waters are at their coolest.

Little is yet known about the migratory patterns of these pelagic species in the Pacific. The best studied species is skipjack tuna, which has been the subject of considerable work by Japanese fishery scientists as well as an extensive tagging program by the South Pacific Commission (SPC) (Kearney 1983).

Fujino (1970) presents data which suggest that a major stock of skipjack tuna moves eastward into the area of the Mariana Islands from June to October, after which it spreads out to the west and south of the archipelago. Tagging data from the SPC Skipjack Survey and Assessment Programme (Tuna Programme 1984) is sparse for the Guam-Marianas area. Of the nine tag recoveries which originated in the Marianas region (as of October 1983), two were recovered in Japanese waters, two in the Marshall Islands, three in the Federated States of Micronesia (FSM), and two in international waters. Of eight recoveries of tagged skipjack in the waters around the Mariana Islands, one originated in Palau, four in the FSM, one in Japan, one in Papua New Guinea, and one in New Caledonia.

Thus far, the tagging data are insufficient to indicate migratory routes for the skipjack tuna in the Guam area. The migratory patterns of the other major species around Guam are even less well known.

The data presented here indicate the temperature conditions of the water at the time when these species are in the vicinity of Guam, but this does not necessarily imply that the species would be more abundant if these conditions persisted longer or were more pronounced during certain years. Our further studies will involve examination of deviations from average monthly conditions to determine whether there are consistent relationships between yearly fluctuations in fish abundance and variations in sea surface temperature, mixed layer depth, depths of isotherms, or other thermal patterns which would permit forecasts of fish abundance around Guam to be made.

Acknowledgments

This project has been supported by the Dingle-Johnson/Wallop-Breaux Federal Aid in Sportfish Restoration program (Project No. FW-2R-25, administered by the Guam Division of Aquatic and Wildlife Resources) and the University of Guam College Work-Study program. We received much help from Dr. Luan Nguyen and Mr. Rudy Villaverde of the University of Guam Computer Center, from Mr. Herling Sanger and Mr. Dave Hopper of the University of Guam Marine Laboratory, and from Mr. Gerry Davis and Mr. Tim Sherwood of the Guam Division of Aquatic and Wildlife Resources. This paper is contribution No. 295 from the University of Guam Marine Laboratory.

References

Amesbury, S. S., F. A. Cushing & R. K. Sakamoto. 1986. Guide to the Coastal Resources of Guam: Vol. 3. Fishing on Guam. University of Guam Press, Mangilao. 110p.

Barkley, R. A., W. H. Neill & R. M. Gooding. 1978. Skipjack tuna, *Katsuwonus pelamis,* habitat based on temperature and oxygen requirements. Fish. Bull. 76: 653–662.

Boggs, C. 1988. Forecasting skipjack tuna availability in Hawaii. Tuna Newsletter 91, pp. 5–7.

Boggs, C. 1989. Hawaii aku forecast for 1989 issued. Tuna Newsletter 94, p. 4.

deWitt, P. W. 1972. Physical oceanography in the Marianas Islands area, spring and fall 1971. M.S. thesis in Oceanography, University of Hawaii. 48p.

Fujino, K. 1970. Skipjack tuna subpopulation identified by genetic characteristics in the western Pacific. *In* J. C. Marr (ed.), The Kuroshio: A symposium on the Japan Current. East-West Center Press, Honolulu. pp. 385–393.

Guam Division of Aquatic and Wildlife Resources. 1978–1988. Annual reports, fiscal years 1978 to 1988. Department of Agriculture, Government of Guam.

Kearney, R. E. 1983. Assessment of the skipjack and baitfish resources in the central and western tropical Pacific Ocean: A summary of the skipjack survey and assessment programme. South Pacific Commission, Noumea, New Caledonia. 37p.

Knauss, J. A. 1978. Introduction to Physical Oceanography. Prentice-Hall, Inc. Englewood Cliffs, N.J. 338p.

Mendelssohn, R., & C. Roy. 1986. Environmental influences on the French, Ivory Coast, Senegalese and Moroccan tuna catches in the Gulf of Guinea. Proceedings of the ICCAT Conference on the International Skipjack Year Programme, ICCAT, 1986: 170–188.

Pickard, G. L. & W. J. Emery. 1982. Descriptive Physical Oceanography: an Introduction, 4th ed. Pergamon Press, Oxford. 249p.

Sverdrup, H. U., M. W. Johnson & R. H. Fleming. 1942. The Oceans: Their Physics, Chemistry, and General Biology. Prentice-Hall, Inc. Englewood Cliffs, N.J. 1087p.

Tchernia, P. 1980. Descriptive Regional Oceanography. Pergamon Press, Oxford. 253p.

Tuna Programme. 1984. An assessment of the skipjack and baitfish resources of Northern Mariana Islands, Guam, Palau, Federated States of Micronesia, and Marshall Islands. Skipjack survey and assessment programme final country report No. 18. South Pacific Commission, Noumea, New Caledonia. 111p.