Relationship of Sea Surface Temperature Isotherm Patterns off Northwestern Mexico to the Catch of Striped Marlin, *Tetrapturus audax*, off Southern California

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Introduction

The relationship of sea surface temperatures to the availability of striped marlin, *Tetrapturus audax*, off southern California has interested both fishery researchers and recreational billfish fishermen. The establishment of a reasonable correspondence would provide an indicator of variations in catch resulting from anomalous environmental conditions.

Uda (1957) outlined the basic biological principles of the association between the environment, as represented by one parameter, sea surface temperature (SST), to the catch of tunas, Scombridae; and billfishes, Istiophoridae. In his paper, he discussed some of the principles of fish distribution for such larger pelagics as tunas and billfishes, including the one which states that "marine organisms are distributed according to the variable environment (hydrobiological) conditions which they require for successful development." This paper describes one such association between the distribution of striped marlin and sea surface temperature.

Many researchers have reviewed the migration of pelagic species off the North American west coast (yellowtail, *Seriola lalandei*; Pacific bonito, *Sarda chiliensis*; Pacific barracuda, *Sphyraena argentea*; white seabass, *Atractoscion nobilis*; and skipjack tuna, *Euthynnus pelamis*) into more northern latitudes during years of anomalous warm sea surface temperatures (Hubbs and Schultz, 1929; Walford, 1931; Radovich, 1961). The number of studies comparing the catches of coastal northeast Pacific pelagic species to SST changes is limited and the more recent ones are by Radovich (1961, 1975) and Squire (1982).

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Several studies relate striped marlin catch to SST. Squire (1974) made a comparison of striped marlin catch rates in southern California from 1963 through 1970 for periods with either continuous or discontinuous 68°F (20.0°C) and 70°F (21.1°C) isotherm extensions into the southern California area from the south or southwest. Bimonthly temperature charts produced by the NMFS Southwest Fisheries Center, La Jolla, Calif., were used in the 1963-70 analysis. The current analysis extends the hypothesis which was first described in the 1974 study. In that study, Squire speculated that the continuity of isotherm patterns crossing the Pacific Ocean from the west and recurving northward into southern California waters may have a greater influence on the catch of striped marlin than sea surface temperature observed in fishing areas off southern California.

SST Climatology vs. Striped Marlin Catch

Uda (1957) provided a range of sea surface temperatures for a number of oceanic pelagic species of tunas and billfishes, including those for striped marlin. Optimum SST's for striped marlin, determined from commercial longline catch data, ranged from 18.5°C (64.4°F) to 24°C (75.1°F), with a minimum and maximum range of temperature from 16°C (60.8°F) to 29°C (84.2°F).

Studies of SST associated with catch of striped marlin off southern California (catch temperature) in the early 1970's were made by Squire (1974) and Talbot and Wares (1975). These studies used SST measurements from airborne infrared equipment or nearshore and shipboard measurements, and the striped marlin catch off southern California as recorded by the major billfish clubs. Striped marlin catch data for both studies were obtained from the records of one or more of the following organizations: The Tuna Club, Avalon, Catalina Island, Calif.; Balboa Angling Club, Balboa, Calif.; and The Marlin Club, San Diego, Calif.

Mean catch-temperature for striped marlin landed at San Diego was calculated by Squire (1974) based on temperature data derived from monthly airborne infrared SST surveys of southern California waters in 1963-68 (Squire, 1971) and catch location data for the same period obtained from records of The Marlin Club, San Diego, Calif. Catch-temperature for a sample size of 3,595 fish ranged from 61°F (16.1°C) to 73.0°F (22.8°C) with a mean catch temperature of 67.8°F (19.9°C) and a standard deviation of 0.5°F (0.9°C). This temperature is slightly below the midpoint (69.7°F or 20.8°C) of the optimum temperature range for striped marlin as defined by Uda (1957).

In their study on striped marlin catch-temperature, Talbot and Wares (1975) used SST data recorded at Scripps Pier, located at the Scripps Institution of Oceanography, La Jolla, Calif. They made three statistical tests from the data.

Landings of striped marlin during the month of August from 1960 through 1970 at Avalon, Balboa, and San Diego were compared with sea surface temperatures at Scripps Pier. Correlation coefficients (r^2) (Snedecor, 1956) between SST and landings were 0.39 for Avalon, 0.26 for San Diego, and 0.35 for Balboa landings. Only the correlation for Avalon landings was significant (1 percent level).

In the second approach, Talbot and Wares (1975) used mean monthly SST's determined from Scripps Pier data for June through September (1960-70) and landings at Avalon, Balboa, and San Diego. Correlation coefficients were 0.47 for Avalon, 0.39 for Balboa, and 0.50 for San Diego. Correlation with the Avalon data was significant at the 1 percent level, and with San Diego data at the 5 percent level. Balboa catch data were not significantly correlated with Scripps SST data.

In the third test, Talbot and Wares (1975) used SST data developed bimonthly from 1947 through 1966 by the National Marine Fisheries Service, La Jolla, Calif., for three areas of 2° longitude by 2° latitude off southern California. The three areas included the major striped marlin catch areas off southern California. Correlation coefficients between SST and catches for the three areas were 0.42 for Avalon, 0.42 for Balboa, and 0.32 for San Diego. None of the coefficients was significant at the 5 percent level. Based on the available data, Talbot and Wares (1975) found that only 15-25 percent of the variation in striped marlin catch was related to SST changes off southern California. In the discussion, they stated that since a small amount of variation could be attributed to SST changes, other factors were more important than local water temperatures in determining catch of striped marlin in southern California waters.

Important Fishery Characteristics

The southern California sport fishing season for striped marlin extends from late July to early November, the months of latitudinal warming. Normally, no catches are recorded for the period from December through early June. Angler catch rates in this area are 4-5 times lower than those observed about the southern tip of Baja California Sur, Mexico, where striped marlin are caught during all months of the year by both sportfishermen and commercial longliners.

High catch rates for striped marlin have been recorded by Japanese longline operations off the southern portion of the Baja California Sur, Mexico, peninsula during all months of the year. Japanese longline data from commercial and exploratory operations show low hooking rates for striped marlin west and southwest of southern California within the California Current region during all months of the year (Anonymous, 1964-80).

The results of tagging striped marlin in the recreational fishery about the southern tip of Baja California Sur, Mexico, indicate some movement from this area toward the northwest or southern California in early summer. Some of the striped marlin tagged off the east coast of the southern tip of the Baja California peninsula have been recovered off Magdalena Bay, Mexico, northwest of the southern tip of Baja California Sur, and off southern California. The precise migration route of these tagged fish is unknown; however, the relatively short period of time between tagging off Baja California Sur, Mexico, and recovery off Magdalena Bay and southern California indicate movement to the northwest during the late spring and early summer season.

Important Oceanographic Characteristics

The ocean off southern California, sometimes called the Southern California Bight, supports a major sportfishing area for striped marlin. The general boundaries of the Bight extend from Point Conception to near the northwestern border of Baja California, Mexico. The marine environment of the Bight is different from the areas along the west coast immediate to the northwest and the southeast. From studies of current patterns off southern California using drift bottles and cards by Tibby (1939), Schwartzlose (1963), Reid et al. (1958), and Squire (1977), it was determined that in the Bight a counterclockwise current pattern was sometimes evident. The southern California Bight has numerous eddies due to the effects of the chain of offshore islands.

Studies of sea surface temperature using an airborne infrared radiometer off southern California from Point Arguello to Pta. Salsipuedes, Mexico (near lat. 32°N), were conducted from 1963 to 1979 by the NMFS in cooperation with the U.S. Coast Guard (Squire, 1971). These temperature surveys covered the major fishing areas for striped marlin off southern California. During the late summer and early fall months, the period when striped marlin catches are made, temperature survey data indicate the warmest temperature to be in the Gulf of Santa Catalina. Based on catch records from 1960 to 1981, September is the month of greatest striped marlin catch in numbers. Airborne SST survey results showing a typical distribution of SST isotherms off southern California for September 1966 (from an airborne survey on 9-14-66) are shown in Figure 1. The 5-year average temperature isotherms observed in 10″ longitude by 10″ latitude areas for September airborne surveys (1963-67) are shown in Figure 2. Included in Figure 2 is an outline of the major striped marlin fishing areas off southern California.

Sea surface temperatures within the Southern California Bight are usually warmer during the summer, when compared with sea surface temperatures to the area north of Point Conception or south of the area near the U.S.-Mexico border. On many of the airborne infrared monthly charts (Squire, 1971) and the 5-year average chart, colder temperatures have been recorded (Fig. 1 and 2) denoting significant upwelling to the north and south of San Diego.

SST Isotherm Patterns and Their Relation to Catch

Talbot and Wares' (1975) study dealt with the correlation between the catch in the high catch rate areas and the sea surface temperatures at Scripps Pier as an indicator of the trend of temperature in the major fishing areas. Temperatures observed at Scripps Pier, La Jolla, Calif., were in most cases not the same

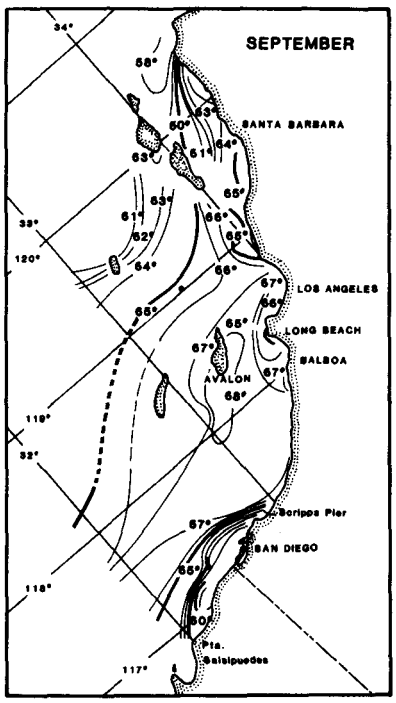

Figure 1.—Infrared sea surface temperature isotherms off southern California typical of those observed by airborne infrared sea surface surrvey during the late summer. Survey is for 14 September 1966.

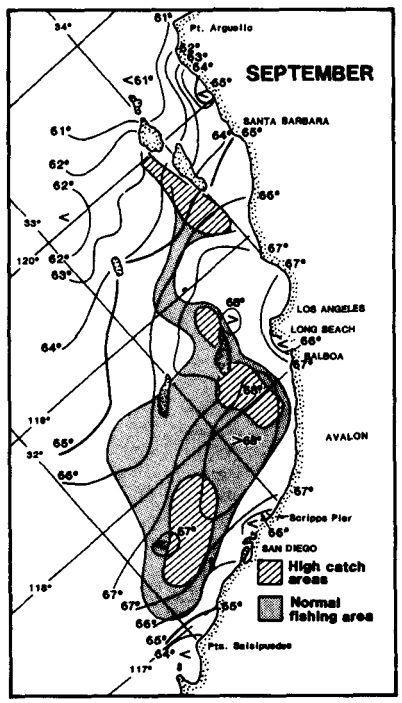

Figure 2.—Five-year mean sea temperature distribution (°F) for September airborne surveys conducted 1963-67 with outline of normal and high catch areas for striped marlin.

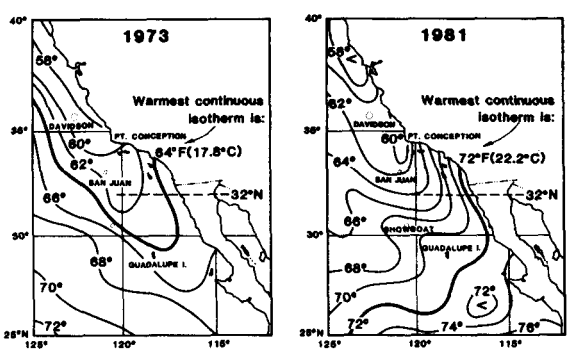

Figure 3.—Biweekly sea surface isotherm charts issued by the NMFS Southwest Fisheries Center showing examples of interception of isotherms at lat. 32°N for 16-30 September 1973 and 16-30 September 1981.

as those observed in the major fishing areas for striped marlin as shown in Figure 2. Since comparisons of SST data and catch for the southern California area have provided a rather inconclusive correlation, it was evident that striped marlin catch off southern California should be examined in relation to other environmental features. Thus, I decided to study the relationship between variation in catch and the changes in climatology of the ocean area off northwestern Baja California.

Sea surface temperature isotherm charts in 2°F (1.1°C) increments representing boundaries of areas having a mean temperature range for biweekly periods from July through November 1960-81 were used to determine the climatology of the area. These charts, which were published by the NMFS Southwest Fisheries Center, La Jolla, Calif., were examined to determine the warmest isotherm that extends continuously into southern California waters from the area south and west of a line extending off the coast at lat. 32°N (near Pta. Salsipuedes, Mexico). Examples of the warmest continuous isotherm are found on the charts for 16-30 September during 1973 and 1982 (Figure 3). That period in 1973 (Fig. 3) was characterized by low temperatures during the fishing season. For the same time period in 1981 (Fig. 3), very warm sea surface temperatures were observed. For the 1973 chart (Fig. 3) an example of the warmest continuous isotherm extending into southern California from the south or southwest at lat. 32°N is 64°F (18°C), and for the 1981 chart (Fig. 3), the warmest continuous isotherm observed was 72°F (22.2°C).

Catch data by biweekly periods from June through November 1960-81 were collected from The Marlin Club, San Diego, Calif. A total of 10,807 striped marlin were recorded during the 22-year period. Striped marlin landed during periods when isotherms of 62° - 72°F (16.7° - 22.2°C) were observed to be continuous into southern California at lat. 32°N were recorded. The frequency of striped marlin landings during different isotherm regimes for each 2-week period 16-31 July through 16-31 October 1960-81 is given in Table 1.

A linear regression was fitted in which the predictor variable was isotherm temperature (Table 1, column 1) and the criterion variable was mean number of striped marlin per 2-week period (Table 1, column 4). The results

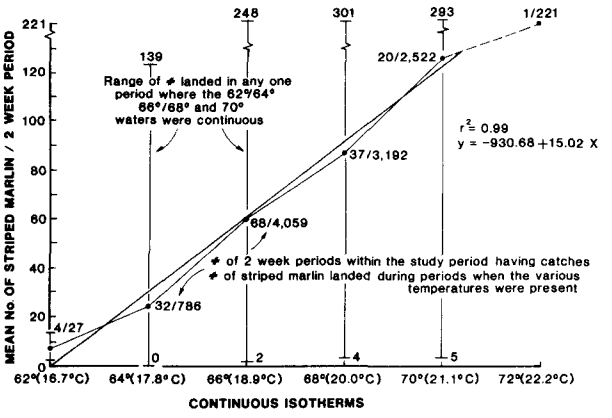

Figure 4.—Average number of striped marlin caught during 2-week periods (16-31 July through 16-31 October) and during periods when isotherms 62° - 70°F (16.7° - 21.2°C) were continuous at lat. 32°N. Data for 72°F (22.2°C) represent only one occurrence (16-30 September 1981) during the 1960-81 period. Range of catch observed within 2-week period for each isotherm is given.

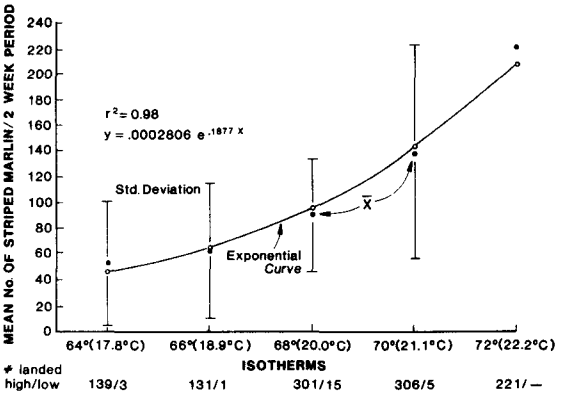

Figure 5.—Average number of striped marlin caught during 2-week periods, (1-15 August through 16-31 September) minimum and maximum number of striped marlin landed during each temperature, calculation of exponential curve and standard deviation of the mean catch observed for each temperature.

Table 1.—Number of striped marlin caught off southern California and number of periods from 16-31 July through 16-31 October when the 62°F-72°F (16.7° - 22.2°C) isotherms were the warmest isotherms continuous into southern California waters from the south, southwest, or west at lat. 32°N, 1960-81.

Isotherm °F(°C)	No. of 2-week periods when isotherms were present	Total no. of striped marlin landed	Mean no. of striped marlin per 2-week period
62°(16.7°)	4	27	6.8
64°(17.8°)	32	786	24.6
66°(18.9°)	68	4,059	59.7
68°(20.0°)	37	3,192	86.3
70°(21.1°)	20	2,522	126.1
72°(22.2°)	1	221	221.0

are presented in Figure 4. The relationship between mean catch data and the occurrence of progressively warmer isotherms is linear (r^2 = 0.99). However, the variation in catch (criterion) was substantial during periods when the 62° - 72°F (16.7° - 22.2°C) isotherms were continuous.

Examination of catch and temperature data of some of the larger pelagic fishes (yellowtail and Pacific bonito) off southern California by Squire (1982) indicates that the migration of fish northward from off Mexico during late spring and early summer is more related to increasing sea surface temperatures than is movement south out of southern California during the fall period of decreasing sea surface temperature. Therefore, the relationship between the catch of fish latitudinally or north-south along the coast may be more related to warming during the first part of the fishing season. To examine this possibility for striped marlin, isotherm data were plotted for the biweekly periods 1-15 August through 16-31 September (Figure 5). The curve of catch vs. temperature (Fig. 5) increases at an exponential rate, indicating that for isotherms 64°F (17.8°C) through 72°F (22.2°C) average catches increased from 46 to 208 striped marlin per period, respectively. However, the variation about the isotherm mean temperature (Fig. 5) is considerable. Therefore, results from the use of the isotherm position as a predictor of catch during any 2-week period (1-15 August - 16-31 September) could be highly variable.

Summary and Conclusions

The sport fishery catch of striped marlin off southern California during the period July through October appears to be related to sea surface temperatures observed off the Pacific coast of northwestern Mexico. Isotherms that are continuous into southern California waters from the west or southwest at 68°F (20.0°C) and above tend to be accompanied by an increase in catch; the peak continuous temperature isotherm observed in 1981 (72°F or 22.2°C) was accompanied by an increase in catch. Data also show a high variability in catch relative to any continuous isotherm during the 2-week periods. Therefore, any short-term prediction of catch based on continuous isotherm data may yield highly variable results.

Striped marlin are common to subtropical and tropical waters of lower latitudes than southern California. Sea surface temperatures in these high catch rate areas (commercial and recreational fisheries) are higher than temperatures observed to the south of the Southern California Bight. From available catch and temperature data (1960-81) and observations of the temperature range of striped marlin, it is reasonable to assume that the ocean temperatures, as defined by continuous isotherms extending into southern California from the south or southwest, never attain values

that would result in a maximum catch off southern California because catches appear to be increasing at the peak continuous isotherm recorded (72°C or 22.2°C).

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