NOAA Technical Memorandum NMFS

SUMMARY REPORT OF THE BILLFISH STOCK ASSESSMENT WORKSHOP PACIFIC RESOURCES

Honolulu Laboratory, Southwest Fisheries Center
Honolulu, Hawaii
5 - 14 December 1977

Richard S. Shomura (Editor)

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July 1980

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Center

NOAA Technical Memorandum NMFS

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Philip M. Klutznick, Secretary
National Oceanic and Atmospheric Administration
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National Marine Fisheries Service
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INTRODUCTION

The recent extension of national fishery jurisdiction throughout the world has resulted in an increased interest in developing fishery management agreements, guidelines, and policies. Basic to this development is information on the status of exploited fish stocks. For many species, particularly the pelagic species, the dimensions of the resource base are unknown, since basic research on population dynamics and the collection of adequate fishery statistics have not been accomplished. This is certainly the case for the several species of billfishes even though they are important targets of commercial and recreational fisheries (Table 1). At the International Billfish Symposium convened in 1972 at Kailua-Kona, Hawaii, a glaring shortcoming of the virtual absence of information on stock assessment or fishery dynamics of billfishes was noted (Shomura and Williams 1974, 1975a, 1975b).

Table 1.--Total Pacific billfish catch (metric tons) by species, 1952-75.

Year	Blue marlin	Striped marlin	Swordfish	Sailfish and spearfish	Black marlin	Total
1952	15,525	4,992	11,339	2,000	1,806	35,662
1953	17,250	3,789	11,689	3,300	3,188	39,216
1954	10,519	7,256	13,392	2,400	5,370	38,937
1955	24,190	7,075	16,485	3,300	5,379	56,429
1956	18,770	7,724	12,584	3,200	6,466	48,744
1957	23,500	7,150	16,243	2,800	6,376	56,069
1958	22,106	8,999	21,341	3,400	4,548	60,394
1959	20,275	8,986	19,663	3,400	3,081	55,405
1960	18,155	7,362	23,409	5,000	2,721	56,647
1961	26,581	10,084	24,286	4,800	3,170	68,921
1962	30,743	13,685	14,604	6,800	4,066	69,898
1963	31,344	16,944	14,133	7,900	3,180	73,501
1964	23,233	23,480	10,112	6,100	2,805	65,730
1965	18,885	24,017	12,949	12,800	4,039	72,690
1966	18,588	20,967	14,601	11,100	3,729	68,985
1967	17,233	22,050	15,649	11,800	2,836	69,568
1968	15,283	27,143	15,230	12,500	2,362	72,518
1969	17,427	21,706	18,934	12,800	2,546	73,413
1970	20,115	24,221	15,727	9,000	2,207	71,270
1971	13,342	24,264	11,037	8,100	2,674	59,417
1972	15,300	14,541	11,029	8,600	3,424	52,894
1973	17,285	15,407	13,791	8,700	3,720	58,903
1974	15,594	14,669	11,664	7,100	3,048	52,075
1975	12,546	16,279	13,376	5,500	2,796	50,497

In early 1977 the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service developed plans jointly with the Western Pacific Regional Fishery Management Council (WPRFMC) to hold a Pacific Billfish Stock Assessment Workshop. The workshop was subsequently expanded to include the Atlantic stocks. Its objective was to produce a report containing a scientific assessment of the status of billfish stocks in the Pacific and Atlantic along with a summary of appropriate background information, supporting analyses, and recommendations. The workshop was held at the Honolulu Laboratory in December 1977 and consisted of two parts, a Pacific section (5-9 December), which reviewed the Pacific billfish stocks, and an Atlantic section (12-14 December), which treated the Atlantic billfish stocks. The Pacific workshop covered the six species of Pacific billfishes: blue marlin, *Makaira nigricans*; black marlin, *M. indica*; striped marlin, *Tetrapturus audax*; shortbill spearfish, *T. angustirostris*; sailfish, *Istiophorus platypterus*; swordfish, *Xiphias gladius*.

Since by far the greater part of the exploitation of the Pacific billfish resources is carried on by foreign fishermen, and consequently foreign governments possess most of the data relevant to their management, the success of the workshop required the joint participation of scientists from the major billfish fishing nations. Scientists from the Honolulu, La Jolla, and Miami Laboratories of the National Marine Fisheries Service, the California Department of Fish and Game, the Far Seas Fisheries Research Laboratory (Shimizu, Japan), National Taiwan University (Taipei, Taiwan), Fisheries Research & Development Agency (Pusan, Korea), and the International Commission for the Conservation of Atlantic Tunas were invited to participate in the workshop. The WPRFMC sponsored the participation of the foreign scientists. The Council has direct interest in the results of the workshop, since it is presently developing a management plan for the Pacific billfishes.

This report covers the Pacific section of the workshop including brief summaries of the Pacific billfish stock appraisals and recommendations for improvement of fishery statistics, research, and management. These are followed by the several rapporteurs' reports (Appendix A), which provide detailed discussions of the stock assessments. Appendix B lists the participants.

DATA LIMITATIONS

A complete understanding of the effects of fishing on fish stock productivity and catch requires a knowledge of growth rates, mortality rates, reproductive rates, and other vital determinants of population dynamics. Unfortunately, in the case of Pacific billfishes such detailed information has not been acquired. Except for a very limited amount of data on size composition and some estimates of growth rates, the only kinds of information available for stock assessment purposes are statistics on nominal fishing effort and catch. Under these data limitations the billfish stocks were assessed using catch per unit effort (CPUE) and effort trends, as well as the surplus production approach popularized by Schaefer (1954, 1957) in the 1950's and improved most recently by Fox (1975).

In using the production model we made two fundamental assumptions concerning the catch and effort data:

(1) the CPUE is proportional to average stock abundance, with the ratio of CPUE to abundance remaining constant over the period of analysis, and

(2) the total catch is known.

Violations of these assumptions were suspected for certain billfish stocks, and known to occur in others. In the latter cases no attempt was made to fit a production model or to estimate a maximum sustainable yield (MSY).

With respect to CPUE, the statistic used in all analyses was the catch per 1,000 hooks fished in the Japanese pelagic longline fishery, a fishery which generally concentrates on tunas and harvests billfishes only incidentally. Changes in the construction or deployment of the longline gear, shifts in fishing strategy or target species, and changes in availability of the fish to the gear are some of the factors which may alter the ratio of CPUE to average abundance. For example, in the North Pacific, a reduction in nighttime longlining activity targeted specifically on swordfish is almost certainly responsible for a sharp drop in the average swordfish CPUE in that area since the early 1960's. The assessment of the North Pacific swordfish stock is therefore complicated, because the effects of the change in fishing strategy on the ratio of CPUE to abundance are unknown. Similar problems may exist in the assessment of other species.

In the case of total catch, there are generally reliable figures in numbers of fish for the Japanese tuna longline fleet, which accounts for most of the overall harvest and dominates the catch statistics of most billfish species. An exception is the Japanese catch of sailfish and shortbill spearfish, which is reported as a combined total in the longline statistics. In addition, there are serious problems in estimating the total weight of billfishes taken in the inshore or coastal fisheries which use other kinds of gear, e.g., gill nets, and in determining the total catch of other major distant-water longline fleets, particularly the catch of Korean vessels. Where biased catch estimates are suspected, the magnitude of bias may vary from year to year, creating serious problems in interpretation of catch-effort relationships.

Aside from the major assumptions about the catch and effort data there are several other important conditions which must be met if the production model analysis is to be valid. The most important of these is that the data refer to a single stock of the species under consideration. Stock units for the Pacific billfish populations were selected on the basis of limited evidence concerning larval distribution, seasonality and locations of spawning, catch rate distribution, and tag return pattern. The validity of the stock boundaries assumed for this report remains to be established.

Other critical assumptions of the production model are discussed in detail by Fox (1975). When these are considered along with the ones discussed above, it is clear that the production model analysis and the resulting estimate of MSY can give at best only very rough approximations on the status of a fish stock and the effects of fishing effort on yield. The stock appraisals summarized below and discussed in greater detail in the rapporteurs' reports should be judged in this context.

SUMMARY OF STOCK APPRAISAL

Blue Marlin

A single Pacific-wide stock of blue marlin is assumed. Total harvest in 1975 was approximately 12,500 metric tons (mt), of which about 80% was taken by the longline fleet of Japan. Catch per unit effort has decreased steadily since the early 1950's, while total effective fishing effort has increased. The production model analysis gives an MSY estimate of about 22,000 mt, which is associated with an effective fishing effort equal to about 50% of the 1975 total effective effort. The Pacific blue marlin stock is judged to be overfished.

Black Marlin

The stock structure of black marlin is unknown, but the restricted coastal distribution of the species and the occurrence of isolated areas of high catch rates suggest the possibility of more than one stock in the Pacific. Furthermore, there is a strong likelihood that movement of black marlin between the western Pacific and the eastern Indian Ocean occurs. The total Pacific catch in recent years has been estimated at around 3,000 mt. Stock assessment is complicated by underestimation of total catches, particularly those made by the Taiwan fleet. For this reason no estimate of MSY is available; however, sharply declining catch rates during the 1950's and a more gradual reduction of apparent abundance since the early 1960's suggest that increased fishing effort, would, at best, produce only a small increase in average catch. Until better estimates of total catch are obtained, the status of black marlin harvests cannot be reliably ascertained.

Striped Marlin

Striped marlin total catches increased steadily from nearly 5,000 mt in 1952 to 24,000 mt in 1965. From 1965 to the early 1970's, the catches remained in the 20,000 to 27,000 mt range. In 1972 striped marlin catches dropped to 14,500 mt and remained between 14,500 and 16,300 mt through 1975.

The stock structure of the Pacific striped marlin is unclear; however, evidence based on distribution of catch rates and other factors suggests the population could consist of either (1) separate north and south stocks or (2) a single unit stock for the entire Pacific Ocean.

Estimated MSY is 24,000 mt in the case of a single Pacific-wide stock. Current assessments indicate that the stock(s) of Pacific striped marlin is (are) in good condition and not in need of restrictive management.

Swordfish

Most of the catch of swordfish from the Pacific Ocean is landed by the Japanese longline fleet and is made in the northwestern Pacific. The total Pacific catch increased from 11,300 mt in 1952 to a record high of 24,300 mt in 1961. The catch then declined abruptly to about 14,600 mt in 1962 and has leveled off at an average of 14,000 mt since 1962.

The stock structure of the Pacific swordfish population is not clearly understood. Current opinion is that the population consists either of a single Pacific-wide stock or of three separate stocks, the latter with centers of concentration in the northwestern, southwestern, and eastern Pacific. The MSY calculated from the production model analysis assuming a single Pacific-wide stock is 20,000 mt, compared to the current catch level of about 14,000 mt. Since present fishing effort is about 20% below the effort required to take the MSY, the fishery does not appear to be overexploiting the stock and the stock appears to be in good condition.

No individual estimates of MSY are available in the case of three separate stocks.

Shortbill Spearfish

The major longline fisheries report the catches of shortbill spearfish together with catches of sailfish. Very little of the combined catch, however, consists of shortbill spearfish. Since the shortbill spearfish commands the lowest price among the billfishes caught in longline fisheries, catches of this species are not consistently reported. The amount of shortbill spearfish reported is probably an underestimate of the actual catch.

The stock structure of shortbill spearfish is not known; however, the catch rates are relatively high around lat. 20°N and 20°S and low at the Equator, thus suggesting a possible North Pacific stock and a South Pacific stock.

Estimates of MSY for the stock(s) of shortbill spearfish are not available due to the unreliable catch statistics. Estimated catch rates of this species from longline data suggest that the stocks are currently at a relatively high level of abundance and the species is probably underutilized.

Sailfish

Although the catches of shortbill spearfish and sailfish are reported combined, the bulk of the catch consists of sailfish. The estimated sailfish-spearfish catch increased gradually from 2,000 mt in 1952 to 6,100 mt in 1964. It then increased markedly to a record high level of about 12,800 mt in the 1965-69 period. From 1970 through 1975 the catch declined to about 5,500 mt.

Based on distribution of catch rates, the sailfish in the Pacific is assumed to consist of two stocks--an eastern Pacific stock and a western Pacific stock. In the western Pacific the catch rate of sailfish has shown a decline since 1959. The 1975 catch rate of two fish per 10,000 hooks is the lowest average rate recorded for the western Pacific fishery. The CPUE for the eastern Pacific fishery increased sharply between 1960 and 1965 to about 200 fish per 10,000 hooks, fluctuating downward to about 110 fish per 10,000 hooks in 1975.

Estimation of MSY for sailfish was not attempted because there is yet no reliable method of separating the combined catch by species. The patterns in catch rates and associated nominal fishing effort, however, suggest that the sailfish stock(s) is (are) not in bad shape.

SUMMARY OF RECOMMENDATIONS

Statistics

The statistics needed to accurately assess the condition of a fish stock and to evaluate the effects of fishing include estimates of total catch, catch and effort, and data on the size, sex, and age composition of the catch. Except for catch and effort statistics from some segments of the longline fishery, required data are virtually nonexisting for billfishes. Even with the available catch and effort data several shortcomings were noted at the workshop. These were (1) incomplete catch and effort records for certain commercial fisheries, e.g., the Korean longline fishery; (2) the virtual absence of recreational billfish catch and effort data, e.g., the Australian and United States recreational fisheries; (3) the pooling of sailfish and shortbill spearfish catches in the basic logbooks maintained by the Japanese longline fleet; and (4) the reporting of catch in different units, e.g., round weight, dressed weight, or number.

The workshop recommended that all nations with billfish fisheries be urged to establish new sampling programs and procedures to insure the collection of adequate statistics including (1) total catch by species, gear, type of fishing operation, and ocean region; (2) total nominal effort by gear, type of fishing operation, and ocean region; (3) CPUE by effort, small area-time strata, gear, and type of fishing operations; and (4) size and sex composition of the catches by species and by small area-time strata.

Research

Appraisals of fish stock conditions rely on basic biological information and adequate statistics describing the fisheries over several years. For billfishes, such basic information and data are not adequate for comprehensive stock appraisals. The present assessment of billfish stocks is based on catch and effort data from the Japanese longline fishery and estimates of Pacific-wide catches. The lack of adequate data permitted only tentative assessments of the various billfish stocks. These assessments were based on assumed stock structures, and computed measures of effective fishing effort, a statistic which is assumed to be proportional to fishing mortality rates. These assumptions are difficult to test and verify because they require collections of extensive and detailed data, or long and expensive experimentation. It is possible, however, to use computer simulation models to examine the sensitivity of stock assessment conclusions and management advice to changes in assumptions, e.g., doubling the effective fishing effort. The cost of this kind of analysis is expected to be modest and should provide valuable guidance for research planning.

The workshop recommended that countries be urged to support modeling and computer simulation analyses as a high priority research task.

Another high priority research task identified at the workshop was the need to define the stock structure of the various species of billfishes. Proper assessment and management of the billfish resources will require some understanding of stock structure. While tagging programs provide some of the necessary information, the low catch rates of commercial and recreational fisheries suggest that other techniques are probably more suitable, e.g., immunogenetic methods.

The workshop also recognized the need for the application of other analyses to the billfish stocks, e.g., yield-per-recruit analysis. Since these approaches require age and growth information the workshop recommended that research be undertaken to determine the age of billfishes and to establish age-size relations.

The workshop noted that assessments of the billfish resources could be improved by conducting a further detailed study of the longline fishery and a more complete treatment of other fisheries for billfishes, including the Japanese gill net fishery. For the longline fishery it was noted that changes in fishing method and strategy, such as the recent increased effort by deep-fishing longline gear and the reduction in the longline fishery by swordfish, could have a marked influence in the computation of effective fishing effort. The workshop recommended that countries having access to extensive historical data undertake studies to define these changes and their relation to effective fishing effort.

Management

Sophisticated management advice for the Pacific billfish fisheries is difficult to formulate at this time because of (1) the lack of adequate data needed to fully understand the fish stocks and fisheries and (2) the absence of effective international arrangements for conservation of highly migratory species. Production model analyses of available data, however, provide a basis for tentative management advice.

The available data on the Pacific blue marlin stock suggest that this species is overfished. Whether the overfished condition is due to recruitment overfishing or yield-per-recruit overfishing is not known. If the condition is caused by recruitment overfishing, the situation is probably very serious and appropriate action should be taken to provide for additional escapement as a means of increasing the spawning stock. If, on the other hand, the condition is caused by yield-per-recruit overfishing, the situation is not as serious, but restrictions on effort and/or minimum size at capture would be required to improve the average yield.

The stocks of Pacific striped marlin and swordfish appear to be exploited at levels close to estimated MSY. Nevertheless, the stocks appear to be in good condition and from a biological viewpoint the fisheries are not in need of restrictive management. However, these species should be monitored closely for signs of overfishing.

The status of the stocks of black marlin, sailfish, and shortbill spearfish is less certain. It is conceivable that a detailed reassessment of historical data may provide the basis for separating the combined sailfish-shortbill spearfish catch data, thus permitting appropriate production model analyses to be undertaken. Similarly, improved estimates of total catch may lead to better assessment of the black marlin resources. In the meantime no restrictive management is deemed necessary from a biological viewpoint.

With respect to management institutions, the widespread distribution and migratory tendencies of the billfishes suggest that effective management can only be achieved by a broad-based management program, covering the entire range of the stocks. To date, a management mechanism of this nature does not exist in the Pacific.

The workshop recommended that countries harvesting billfishes in the Pacific support continuing efforts to assess the stocks and assist in formulating management options which will lead to optimal utilization of the billfish resources.

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APPENDIX A

RAPPORTEURS' REPORTS

BLUE MARLIN, MAKAIRA NIGRICANS

Heeny S. H. Yuen and Peter M. Miyake, Rapporteurs

REVIEW OF FISHERIES DATA

The blue marlin, *Makaira nigricans*, has been characterized as the predominant marlin of the central tropical Pacific. They are widely distributed in the Pacific Ocean: from the American to the Asiatic Continents between approximately lat. 45°N and 45°S (Appendix Figure 1). Blue marlin are taken primarily by longlines and small numbers are taken by gill nets and harpoons. Japan, Taiwan, and the Republic of Korea have large Pacific-wide longline fisheries that take blue marlin. Blue marlin are caught by recreational fishermen in Hawaii, from Mexico to Ecuador in the eastern Pacific, and from Australia to Japan in the western Pacific.

Catch Trends

The total annual Pacific catch of blue marlin from 1952 to 1975 rose irregularly and reached a peak of 31,300 mt in 1963 and declined irregularly thereafter (Appendix Table 1; Appendix Figure 2). The annual catches have been consistently greater in the North Pacific than in the South Pacific; the North Pacific catch in 1975 was 84% of the Pacific total.

Effort Trends

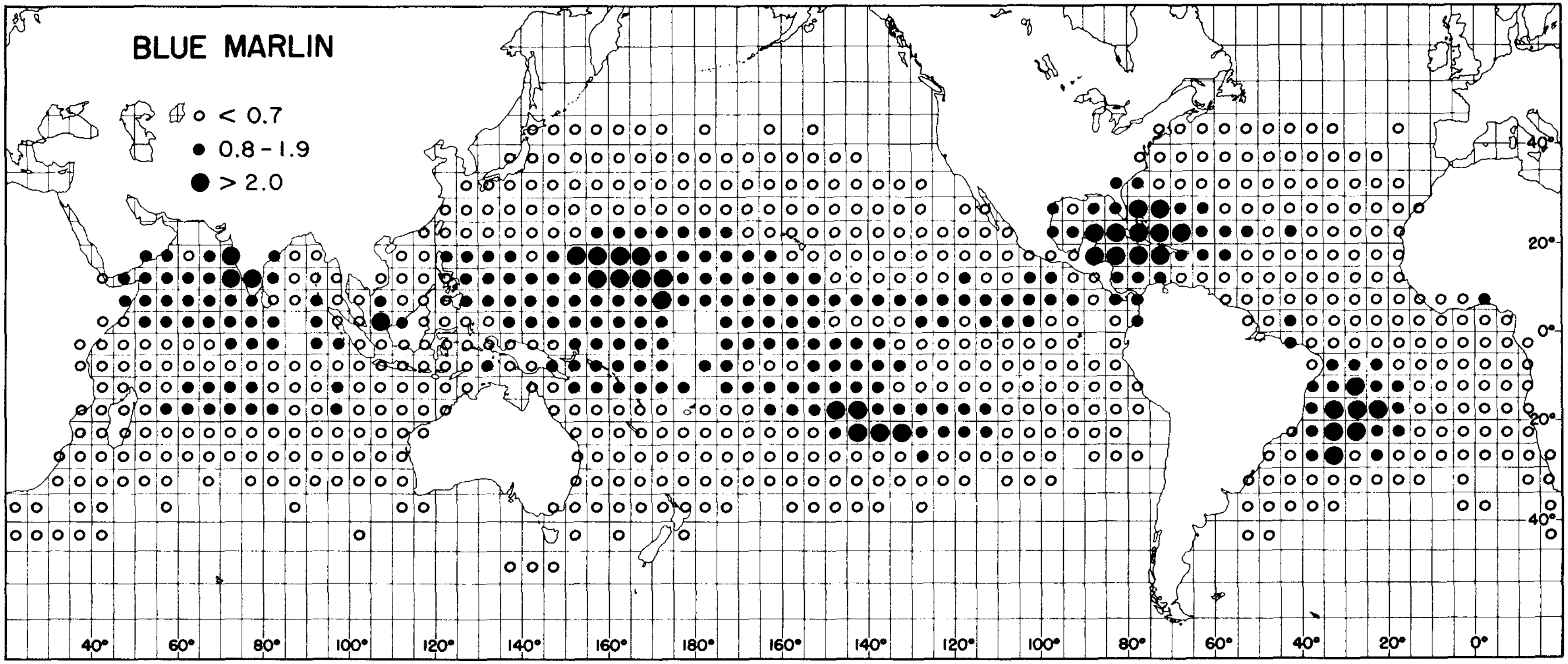
Effective fishing effort increased from about 50 million hooks in 1952 to about 260 million hooks in 1963 and fluctuated around 200 million hooks from 1964 to 1975 (Appendix Figure 3).

Catch Rate Trends

Catch per effort steadily declined from about 3.0 fish per 1,000 hooks in 1952 to about 0.5 fish per 1,000 hooks in 1975 (Appendix Figure 3). The 1975 CPUE was the lowest value recorded for blue marlin.

STOCK STRUCTURE

Blue marlin appear to comprise a single equatorially centered stock in the Pacific. Concentrations of blue marlin alternately appear at higher latitudes on both sides of the Equator during the respective summer periods. Evidence for a unit stock assumption is the apparently single, large spawning area in the western Pacific, including areas of high spawning densities in the west and declining densities eastward. As is true of the other billfishes, confirmation of the blue marlin stock structure hypothesis is needed.



Appendix Figure 1.--Distribution of blue marlin in the Pacific Ocean. The circles indicate mean catch rates (number of fish per 1,000 hooks).

Appendix Table 1.--Blue marlin catches (metric tons) by countries for the Pacific Ocean, 1952-75.

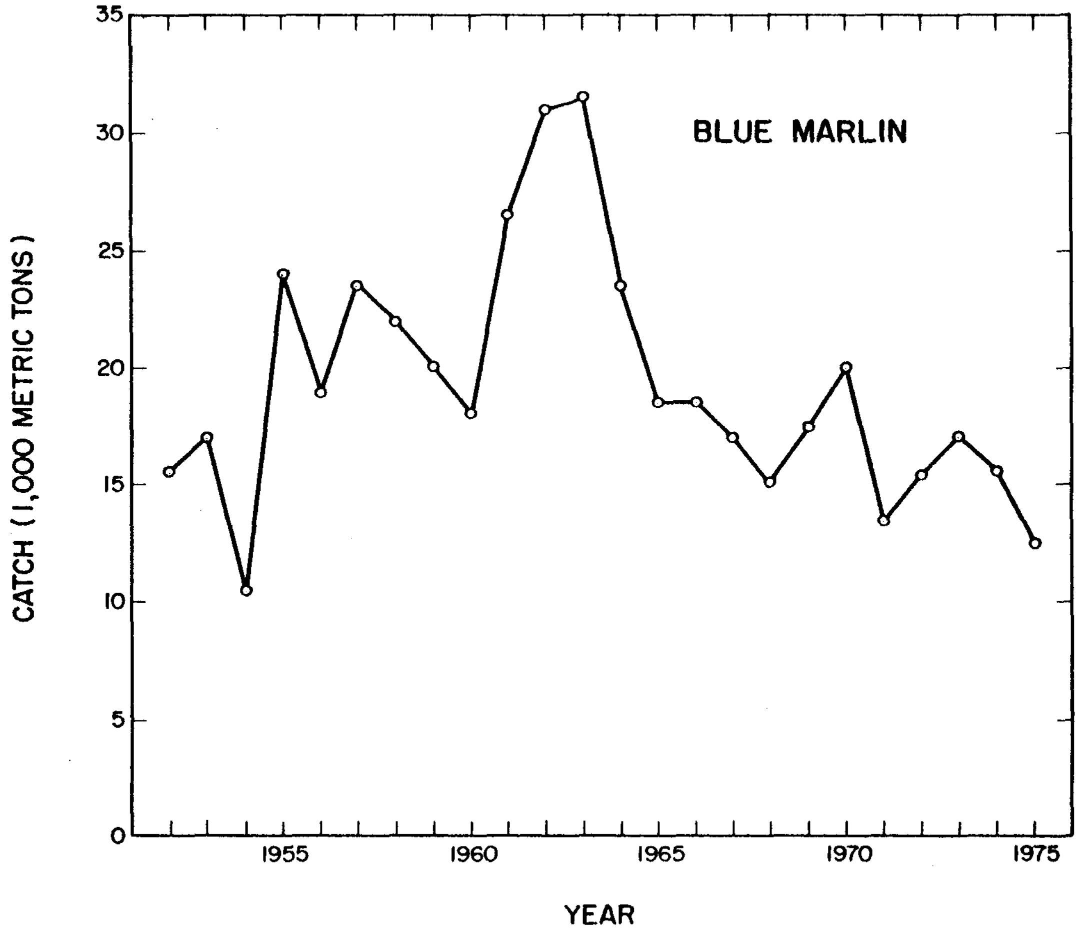
Year	Japan	Taiwan	Republic of Korea	Others	Total
1952	15,525				15,525
1953	17,250				17,250
1954	10,253	266			10,519
1955	23,590	600			24,190
1956	18,136	634			18,770
1957	23,030	470			23,500
1958	21,712	394			22,106
1959	19,908	367			20,275
1960	17,825	330			18,155
1961	26,267	314			26,581
1962	29,983	760			30,743
1963	29,434	1,910			31,344
1964	21,323	1,910			23,233
1965	16,675	1,910		300	18,885
1966	16,156	1,910	222	300	18,888
1967	13,944	2,428	461	400	17,233
1968	12,300	2,562	221	200	15,283
1969	14,415	2,371	441	200	17,427
1970	16,976	2,481	453	200	20,115
1971	9,932	2,757	453	200	13,342
1972	11,760	2,787	453	200	15,300
1973	13,252	3,280	453	300	17,285
1974	12,313	2,410	453	418	15,594
1975	9,735	2,229	453	129	12,546

POPULATION PARAMETERS

The available population parameters are shown in Appendix Table 5. Like the other billfishes, basic data on mortality rates, age and growth, fecundity, etc., are tentative and need to be improved. The inability to confirm age estimates of blue marlin has hampered stock assessment work. The existing growth equation should be verified so that age composition of the catch can be computed when length composition data become available.

STOCK ASSESSMENT

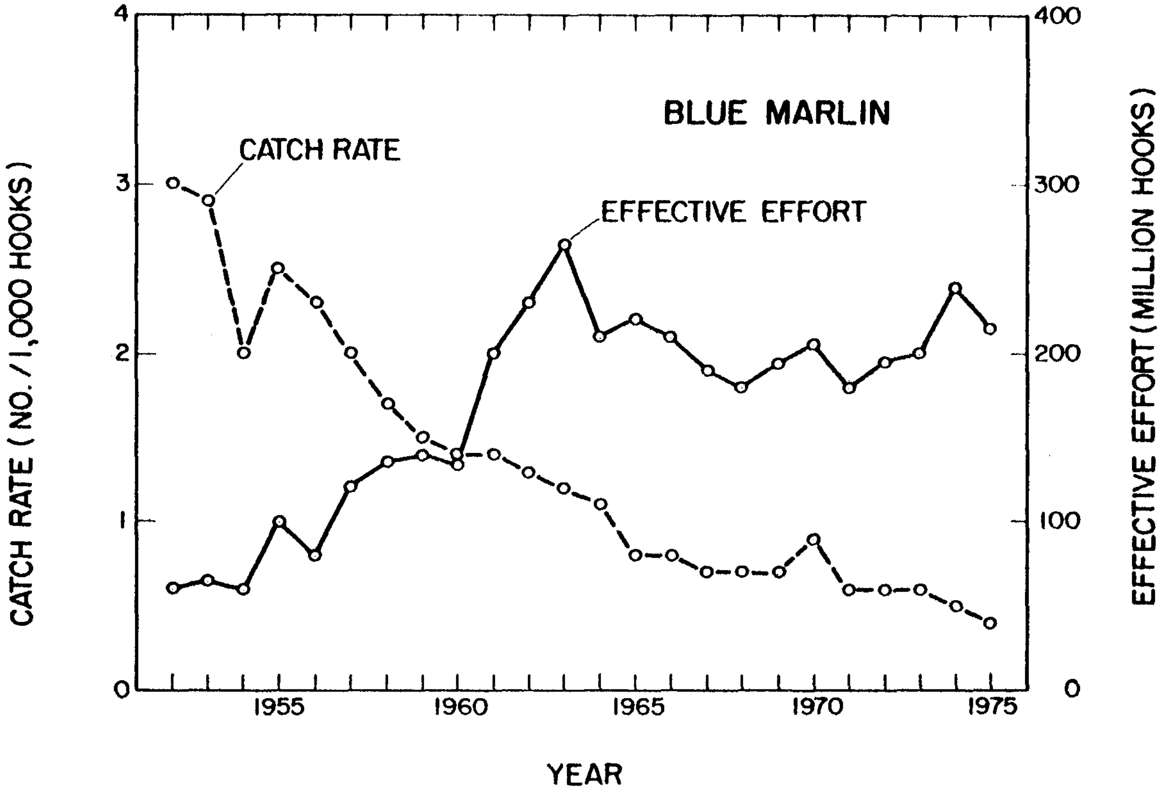
Pacific-wide catch and effort data (Appendix Table 1) were used to assess the current status of the assumed single blue marlin stock.



Appendix Figure 2.--Blue marlin catch in the Pacific, 1952-75.

The relation between CPUE and effective effort trends (Appendix Figure 3) provides indications of the condition of the stock. The CPUE from 1952 to 1975 steadily declined from 3 fish per 1,000 hooks in 1952 to 0.5 fish per 1,000 hooks in 1975, including only minor fluctuations. Over the period from 1952 to 1963, effort rose steadily, increasing by a factor of 4. Subsequently, a relatively constant, high level of effective effort was evident from 1964 to 1975. The steady decline in CPUE over the last 10 years in the presence of a fairly constant effort indicates a potential problem with the stock.

A production model was fitted to the 1952 to 1975 data for the entire Pacific (Appendix Figure 4). The results project an MSY of about 22,000 mt per year at an optimum effort level of 5.5×10^5 hooks per 5° square which is approximately equivalent to a total effective effort of 142 million hooks. The 1975 catch of 12,500 mt was taken by an effort of 10×10^5 hooks per 5° square or approximately 215 million effective hooks. The model appears to fit the data quite well.



Appendix Figure 3.--Catch rate and effective fishing effort for blue marlin in the Pacific, 1952-75.

Although it is not possible to perform additional analyses to estimate yield-per-recruit or recruitment indices, the combined evidence of CPUE and effort trends and production model analysis suggests that the blue marlin stock is being substantially overfished. This overfishing apparently began in the early 1960's and has continued through 1975.

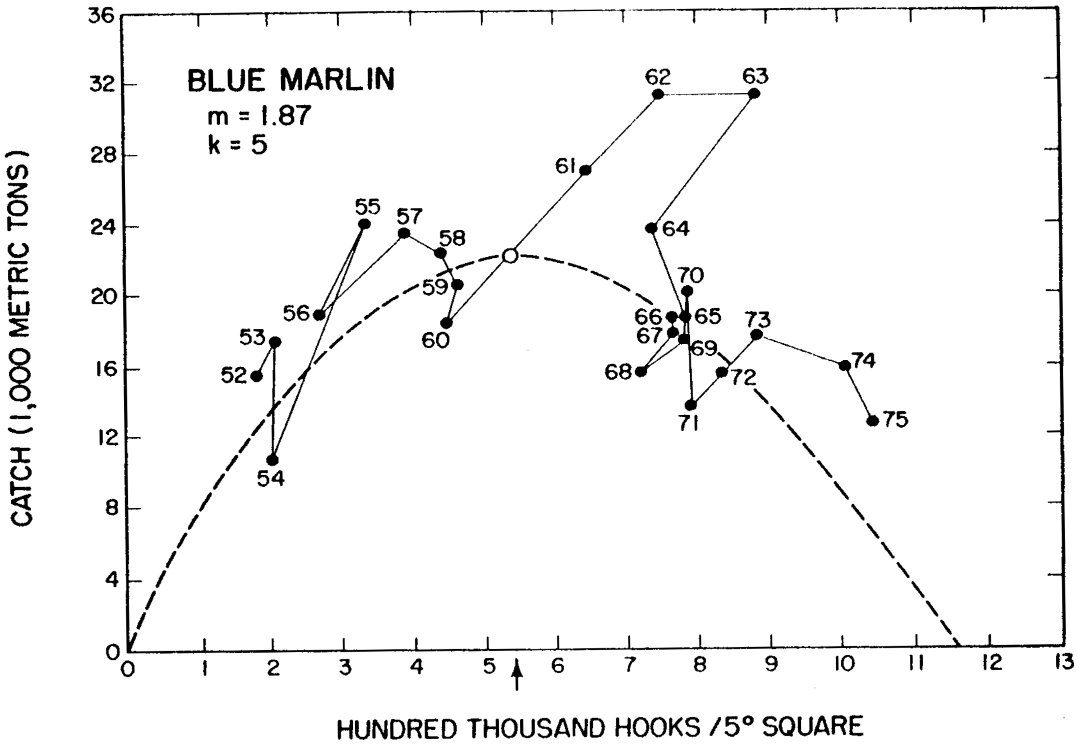
OVERALL STOCK APPRAISAL

The evidence of declining CPUE and the result of the production model analysis suggests that the blue marlin stock is being overfished. The present effort is almost twice that needed for MSY.

RECOMMENDATIONS

Statistics

To confirm the current appraisal of the blue marlin stock, additional basic data must be obtained. Length-composition samples by sex for current catches should be collected, and historical size-composition data should be analyzed. Additional catch and effort data should be collected from fleets with presently low coverage rates.



Appendix Figure 4.--Relation between catch of blue marlin and effective fishing effort. The equilibrium yield curve is based on the production model.

Research

The potentially serious condition of the blue marlin stock suggests that additional analyses to confirm the current appraisals are needed. The available age-growth results need to be confirmed. Yield-per-recruit and recruitment indices are needed. These analyses should, if possible, take into account differential catch rates and growth by sex.

Management

The production model analysis indicates that the Pacific blue marlin stock has been substantially overfished since the early 1960's. Effective fishing effort increased from 1952 to 1962, then essentially leveled off during 1963 to 1975; however, effective fishing effort in 1975 was at the highest level since the beginning of the fishery in 1952 and was almost twice the computed optimum effort. Relative to these effort trends, total yield has been declining since 1963 and CPUE has been declining since 1952.

The total yield obtained in 1975 from this level of effort was the second lowest recorded. Although information on stock-recruitment relations is not presently available for blue marlin, it seems clear that continued fishing at high levels will continue to reduce the abundance of the stock and a recruitment failure will become a distinct possibility.

These warning signs warrant the serious consideration of some form of management for blue marlin. In view of the apparent seriousness of the situation, it was recommended that the monitoring of the status of blue marlin in the Pacific be given the highest possible priority in billfish research.

STRIPED MARLIN, TETRAPTURUS AUDAX

Norman W. Bartoo and Shoji Ueyanagi, Rapporteurs

REVIEW OF FISHERIES DATA

Striped marlin, *Tetrapturus audax*, are widely distributed in the Pacific Ocean between lat. 50°N and 50°S. The tuna longline catch rates of striped marlin indicate bands of relatively high density across the North and South Pacific which merge in the eastern Pacific to form a horseshoe-shaped pattern of high density (Appendix Figure 5).

Striped marlin are caught in the Pacific tuna longline fisheries of Japan, Republic of Korea, and Taiwan, which harvested a combined total catch ranging between 14,000 and 16,000 mt annually in recent years (Appendix Table 2). The catch of these three countries accounts for most of the Pacific striped marlin harvest. In the central North Pacific striped marlin are caught by Hawaiian-based longliners and trollers (including sport fishing boats). The Hawaiian catch is small, once amounting to about 200 mt annually; in recent years it has amounted to only about 50 mt.

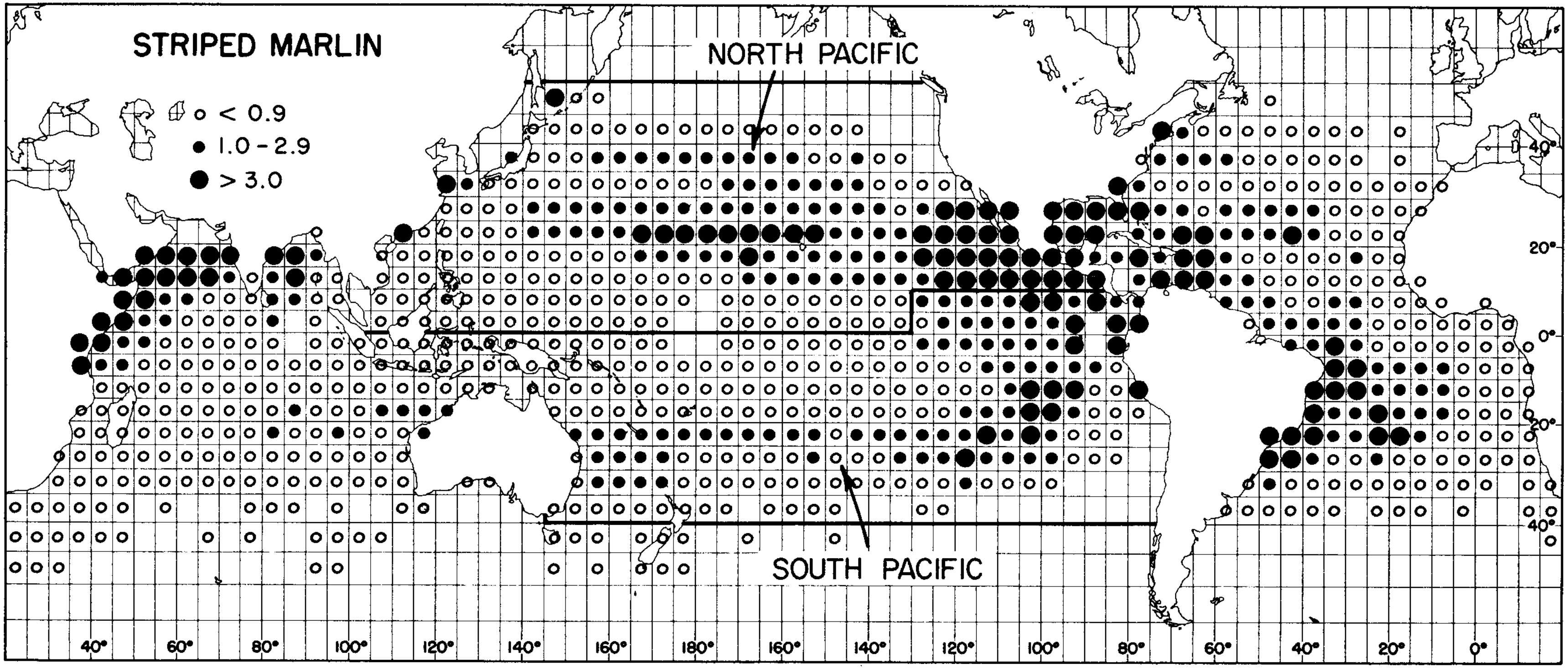
Gill nets are also used to catch striped marlin and since 1973 the drift-gill net catches off Japan have increased significantly. More than 3,000 mt or approximately one-third of the total catch from the North Pacific is landed annually by this fishery.

Small amounts of striped marlin are caught by recreational fishermen off California. Estimates indicate an annual catch averaging 40 mt. Off Mexico and Central America, striped marlin are also taken by recreational fishermen. The total catch is not known but may be as high as 200 mt per year.

Catch Trends

The Pacific-wide catch of striped marlin (Japan, Taiwan, Republic of Korea, and United States combined) rose steadily from approximately 5,000 mt in 1952 to 24,000 mt in 1965 (Appendix Table 2; Appendix Figure 6). From 1965 to 1971 the catch fluctuated between 21,000 and 27,100 mt. In 1972 the catch abruptly dropped to 14,500 mt and remained between 14,500 and 16,300 mt through 1975.

Catches of striped marlin from the North Pacific area contributed most to the Pacific-wide totals. The North Pacific catch increased slowly from 1952 through 1963, rose markedly to a peak of 21,000 mt in 1968, and since then fluctuated between 9,000 and 18,000 mt (Appendix Figure 6). Catches from 1973 through 1975 remained almost constant at near 12,000 mt per year.



Appendix Figure 5.--Distribution of striped marlin in the Pacific. The circles indicate mean catch rates (number of fish per 1,000 hooks). Also shown are the boundaries of the hypothesized stocks.

Appendix Table 2.--Striped marlin catches (metric tons) by countries in the Pacific Ocean, 1952-75.

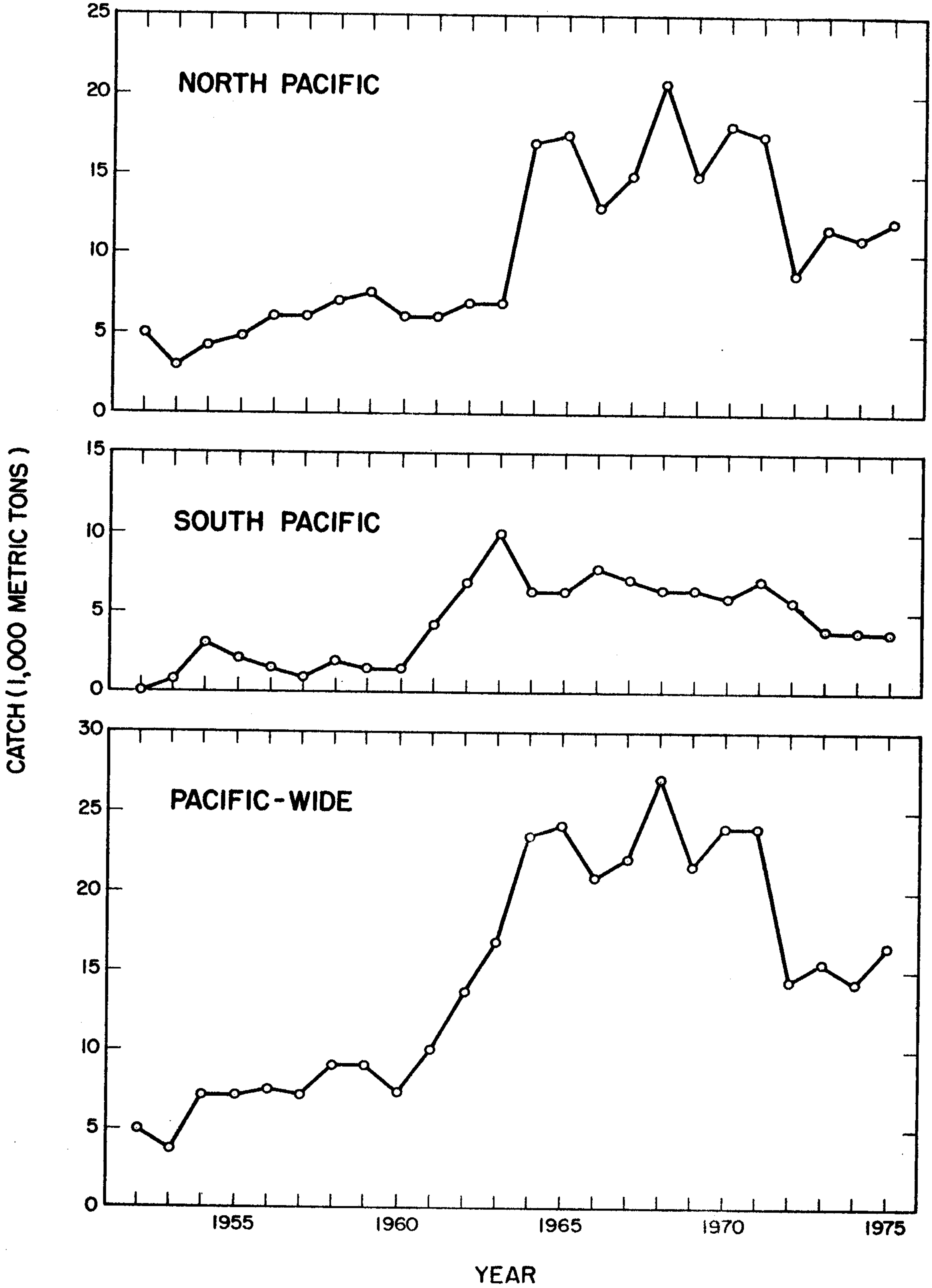
Year	Japan	Taiwan	Republic of Korea	United States	Total
1952	4,992				4,992
1953	3,789				3,789
1954	7,208	48			7,256
1955	6,927	148			7,075
1956	7,526	198			7,724
1957	6,944	206			7,150
1958	8,788	128		83	8,999
1959	8,803	108		75	8,986
1960	7,242	58		62	7,362
1961	9,922	104		58	10,084
1962	13,359	242		84	13,685
1963	16,347	500		97	16,944
1964	22,893	500		87	23,480
1965	19,830	4,100		87	24,017
1966	16,410	4,400	70	87	20,967
1967	18,109	3,711	143	87	22,050
1968	22,103	4,766	93	181	27,143
1969	16,813	4,589	159	145	21,706
1970	19,564	4,335	164	158	24,221
1971	19,099	4,923	164	78	24,264
1972	13,344	961	164	72	14,541
1973	14,122	1,079	164	42	15,407
1974	13,641	825	164	39	14,669
1975	15,254	812	164	49	16,279

Catches of striped marlin from the South Pacific area showed a similar trend but with less fluctuation than in the North Pacific. The catch rose from a few tons in 1952 to a peak of 10,000 mt in 1963, dropped to 6,500 mt in 1964 and began a slow decline to a low of 4,000 mt in 1975 (Appendix Figure 6). Annual catches from 1973 through 1975 remained nearly constant at 4,000 mt.

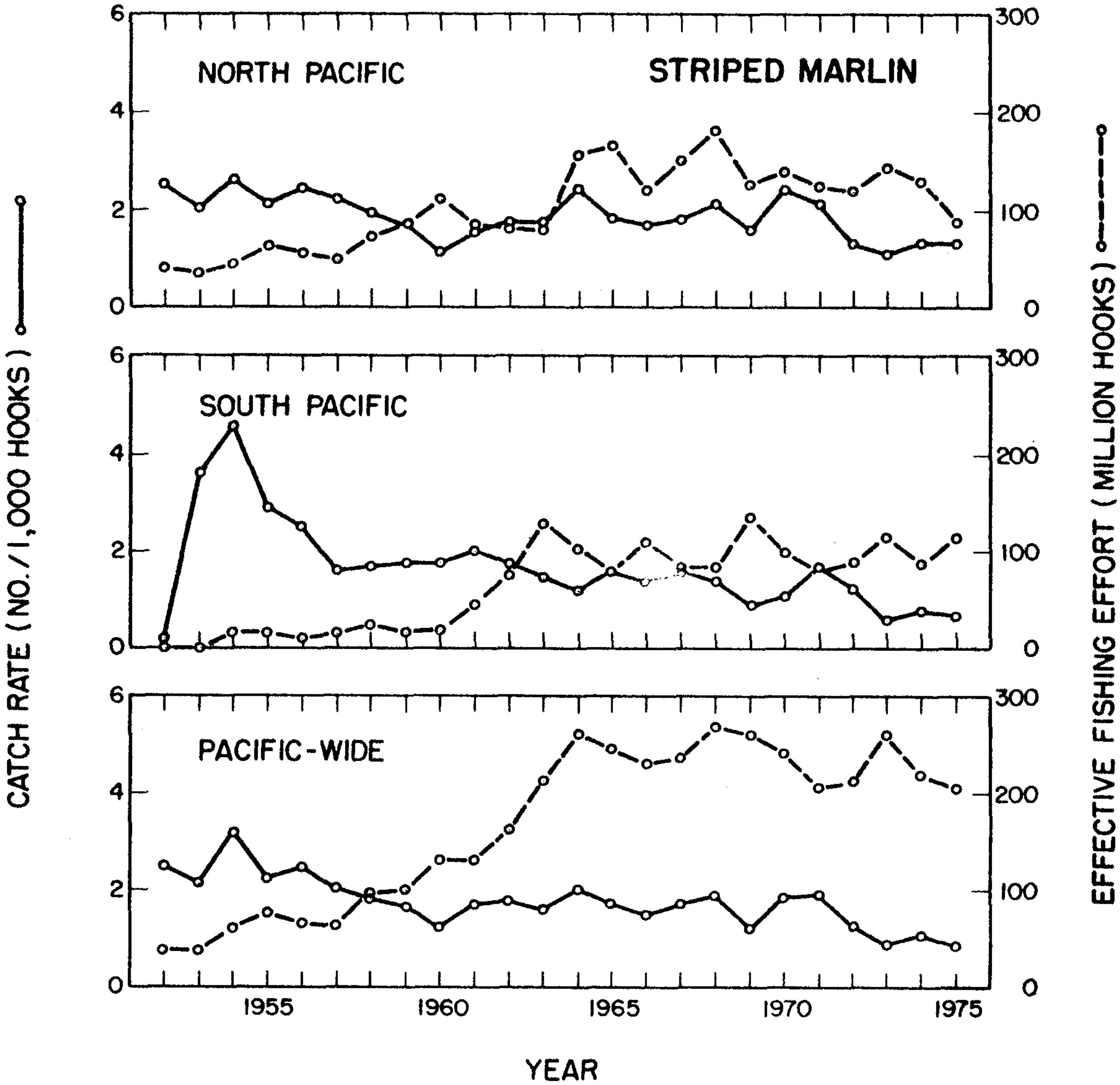
Effort Trends

Total effective fishing effort for the entire Pacific (Appendix Figure 7) showed an increasing trend from 1952 through 1964. Since then the trend has been relatively flat and fishing effort has been fluctuating between about 200 million and 300 million hooks.

Effective fishing effort in the North Pacific increased from 40 million hooks in 1952 to 180 million hooks in 1964, then declined irregularly to 90 million hooks in 1975 (Appendix Figure 7). Effective fishing



Appendix Figure 6.--Catches of striped marlin in the Pacific, 1952-75.



Appendix Figure 7.--Catch rates and effective fishing effort for striped marlin in the Pacific, 1952-75.

effort in the South Pacific showed a modest increase between 1952 and 1960, and a substantial increase by a factor of 6 from 1960 to 1963 (Appendix Figure 7). Since then it has fluctuated around 100 million hooks. Much of the fishing since 1970 in the South Pacific has been by Korean longliners, for which catch-effort data were not available; consequently the data on fishing effort is less reliable since 1970.

Catch Rate Trends

Catch rate of striped marlin for the entire Pacific fishery shows a slow long-term decline (Appendix Figure 7). From 1952 to 1975 the catch rate declined approximately 50%.

Catch rate in the North and South Pacific shows long-term declines since the mid-1950's (Appendix Figure 7). The decline has been much sharper in the South Pacific than in the North Pacific. The catch rate trend in the North Pacific closely followed that in the entire Pacific. The decline in the South Pacific catch rate was considerable from 1954 to 1957 following the 3 years of rising catch rates. After 1957, the South Pacific catch rate declined in a manner similar to that in both the entire Pacific and the North Pacific.

STOCK STRUCTURE

The stock structure of the Pacific striped marlin is not clear. While many hypotheses may be advanced, considering the distributional patterns and other biological data, the two most likely hypotheses are:

1. A single-unit stock in the Pacific.

The single stock hypothesis is supported by the continuous distribution of striped marlin in a horseshoe-pattern.

2. A two-stock structure, where the stocks are separated roughly at the Equator into North Pacific and South Pacific stocks with some intermixing in the eastern Pacific (Appendix Figure 5).

The two-stock hypothesis is supported by morphometric differences between adults from the north and south regions of the western Pacific (Kamimura and Honma 1958) and perhaps also in the eastern Pacific (Howard and Ueyanagi 1965). Honma and Kamimura (1958) noted that there is a zone of low longline catch rates along the Equator which suggests a separation of north and south stocks at the Equator. Larval distribution suggests two centers of spawning, one in the north and one in the south, although gonad index data (Kume and Joseph 1969a) suggest that spawning occurs throughout the eastern tropical Pacific, the supposed region of stock mixing.

POPULATION PARAMETERS

Few studies have concentrated on quantifying critical population parameters of striped marlin. Most published estimates are preliminary and need refinement.

Eldridge and Wares (1974) estimated that Pacific striped marlin reach sexual maturity between 140 and 165 cm and has a single mid-summer spawning period. Fecundity is in the order of 11.3×10^6 to 28.6×10^6 eggs for females 155 to 180 cm. Skillman and Yong (1974, 1976) reported length-weight relations and an age-length relation for the Pacific striped marlin. The length-weight relation, sexes combined is

$$W = (5.7126 \times 10^{-7})\ L^{3.3756}$$

where W = weight in kilograms and L = total length in centimeters. Estimates of other population parameters are given in Appendix Table 5.

It must be noted that with the exception of the growth curves, which still need to be verified, the other population parameters should be considered preliminary and serve only to indicate possible orders of magnitude.

STOCK ASSESSMENT

Very little data on the fisheries and population dynamics of striped marlin including reliable estimates of population parameters and size-composition data, are available. Total catch figures are available, although in some instances the catch estimates are based on marginal sample data. The Japanese longline fishery has provided the longest time series of catch and effort data. Because of this lack of reliable data, a simple approach was used in assessing the state of the Pacific striped marlin stocks which consisted of the determination of trends in longline catch rate and effort and the use of production model analysis.

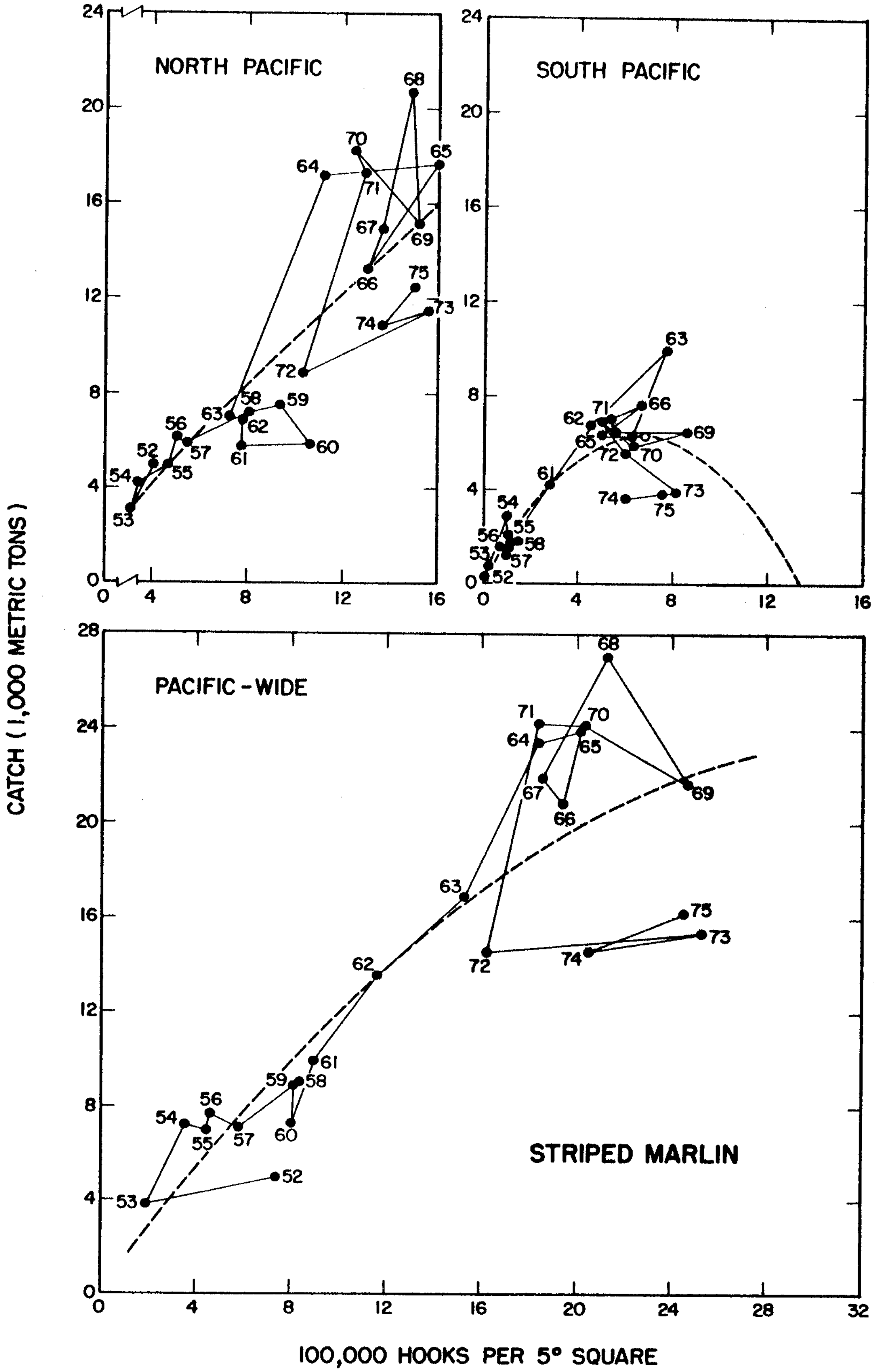
The results of the production model analysis should be interpreted cautiously, however, as it relies on the basic assumptions that (1) the model is applied to a unit stock, (2) equilibrium conditions apply to the stock, and (3) the age-groups being fished have remained and will continue to remain the same. These assumptions have not been adequately verified for striped marlin.

Northern Stock

The production model estimated an MSY of about 70,000 mt produced by an optimum effective effort of about 13.2 million hooks per 5° square for striped marlin in the North Pacific (Appendix Figure 8). This estimate of optimum effective effort is beyond the range experienced by the fishery (maximum of 1.5 million hooks per 5° square) so little confidence should be placed on the estimate of MSY. From the trend of the data, however, it appears that modest increase in effort could result in increased yields, although the margin of return would not be proportional to the increase in fishing effort.

Southern Stock

The production model estimated an MSY of 6,000 mt obtained by an optimum effective effort of 0.6 million hooks per 5° square (Appendix Figure 8). The equilibrium yield curve passes through the data points for 1952-72 reasonably well. Data points for 1973-75 cluster at the optimum effective fishing effort but fall considerably below the equilibrium yield curve. This suggests the possibility that (1) there is



Appendix Figure 8.--Production models for hypothesized striped marlin stocks in the Pacific.

considerable variability around the equilibrium yield curve because of large variation in recruitment, (2) the model is inappropriate, (3) there has been subtle changes in the fishing operation of the Japanese longline fleet that are not accounted for in the estimation procedure for effective fishing effort, or (4) a change has occurred in the age structure of the stock in the last few years (1973-75), thus violating an assumption of the model and making the inclusion of these data with the 1952-72 data series inappropriate. If case (1) is true, fishing effort is currently at about the optimum level and further increases in fishing effort would not result in substantial increases in long-term yield. If case (2) is true other population dynamics models must be used for stock appraisal. If case (3) is true, depending on the type of adjustments, the conclusion could range from an overfished to underfished condition. And if (4) is true the 1973-75 data should perhaps be treated separately, assuming they represent new equilibrium conditions. It therefore appears that further research is required to determine the reason for the deviation of the 1973-75 points to obtain an accurate appraisal of stock condition of striped marlin in the South Pacific.

Pacific-Wide Stock

The production model estimated an MSY of about 24,000 mt produced by an optimum effective effort of 3.4 million hooks per 5° square (Appendix Figure 8). Catches for 1964-75 ranged from about 14,500 to 27,100 mt, produced by an average effective effort ranging from about 1.5 to 2.25 million hooks per 5° square. From production model results it appears that the stock is not being overexploited and further increases in fishing effort could result in increased yield on the long term. However, the 1973 to 1975 data points are considerably lower than the equilibrium line and the cautions expressed above for the South Pacific stock apply here.

OVERALL STOCK APPRAISAL

From the Pacific-wide perspective, the striped marlin stock appears to be in good condition and may be capable of providing increased yields with modest increases in fishing effort. The outlook is better for increased yields from the North Pacific fishery than the South Pacific fishery, which may be operating at or beyond the MSY level.

RECOMMENDATIONS

Statistics

The statistics on catch, effort, and catch rate of striped marlin need improving. Catch and effort data, particularly for the Korean longline fleet after 1970, are needed. In addition, representative length-composition data by sex are needed for development of a more accurate assessment of the state of the stocks.

Research

Better information on the stock structure of the population is needed. Simulation studies should be undertaken to evaluate the sensitivity of stock assessments to various stock structure hypotheses before a major program for stock identification is undertaken. Such studies would not only provide information on whether a stock identification program is necessary but also provide information on the design of an effective program.

Better estimates of population parameters are needed for refined assessment techniques, such as yield-per-recruit and cohort analyses. First priority should be given to verification of age-growth equations. Better estimates of effective fishing effort from the longline fisheries are also needed, especially if there have been subtle changes in the operations which are not accounted for in the estimation technique.

Management

The striped marlin stocks appear to be in good condition and not in need of active management at this time. The fishery, however, should be monitored closely considering the uncertainty in the stock appraisals, especially in the South Pacific where only a modest increase in yield might be available.

SAILFISH, ISTIOPHORUS PLATYPTERUS, AND SHORTBILL SPEARFISH, TETRAPTURUS ANGUSTIROSTRIS

James L. Squire and Ziro Suzuki, Rapporteurs

REVIEW OF FISHERIES DATA

Sailfish, *Istiophorus platypterus*, are widely distributed in the Pacific but they are generally regarded as a species common to waters near continental or island areas. Their latitudinal limits in the Pacific appear to extend from 40°-45°N to about lat. 40°S (Appendix Figure 9).

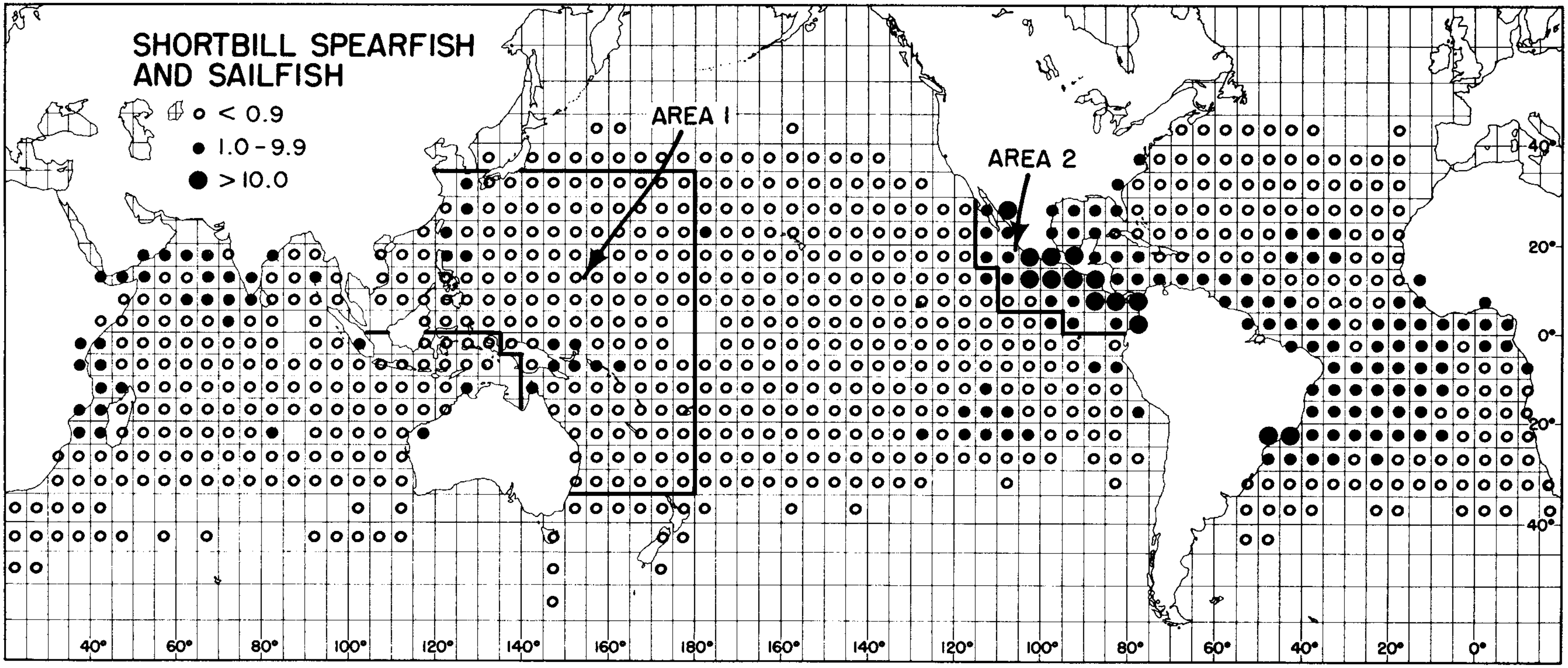
Shortbill spearfish, *Tetrapturus angustirostris*, are widely distributed in tropical and temperate offshore waters of the central Pacific and their distributional limits are similar to that of sailfish (Appendix Figure 9). However, relatively small numbers of this species are taken on tuna longlines. Because the two species are often combined in the longline catch statistics, the distributional chart, which is based on longline catches, should be considered tentative.

The major fishery for sailfish and shortbill spearfish is the commercial longline fishery conducted principally by Japan, Taiwan, and Republic of Korea, which accounts for about 90% of the Pacific catch of these species, Important areas of sailfish catches on longlines are in the eastern Pacific to approximately 600 miles offshore from North America and in the western Pacific from off northeast Australia and Papua New Guinea, and from the Philippine Islands to the southern islands of Japan. In the western Pacific, this species has been taken for several decades incidentally to tunas on longlines; in the eastern Pacific, substantial fishing effort was not applied until about 1965. Catches of sailfish are also made by harpoons and gill nets, and there is a recreational fishery in the eastern Pacific, off central Mexico to Ecuador. In the western Pacific, sailfish are taken primarily in the Coral Sea around Papua New Guinea and in the East China Sea.

One of the shortcomings of the sailfish and shortbill spearfish data is that catches of both species are combined in the catch statistics, and determining the exact catch of each species is difficult. Also, catch data by species are not available for the Republic of Korea and Taiwan fisheries. An additional problem is that some other incidentally caught species may be reported by fishing vessels in the sailfish/spearfish group.

Catch Trends

Before 1964 the annual Pacific landings of sailfish and shortbill spearfish amounted to less than 8,000 mt (Appendix Table 3; Appendix Figure 10). A marked increase in catch to 12,800 mt was recorded in 1965. During the remainder of the 1960's, the catches continued at around the 12,000 mt level and thereafter declined to about 5,500 mt in 1975. The actual catches of sailfish and shortbill spearfish are probably



Appendix Figure 9.--Distribution of sailfish and shortbill spearfish in the Pacific. The circles indicate mean catch rates (number of fish per 1,000 hooks) for shortbill spearfish and sailfish. Also shown are boundaries of hypothesized stocks of sailfish.

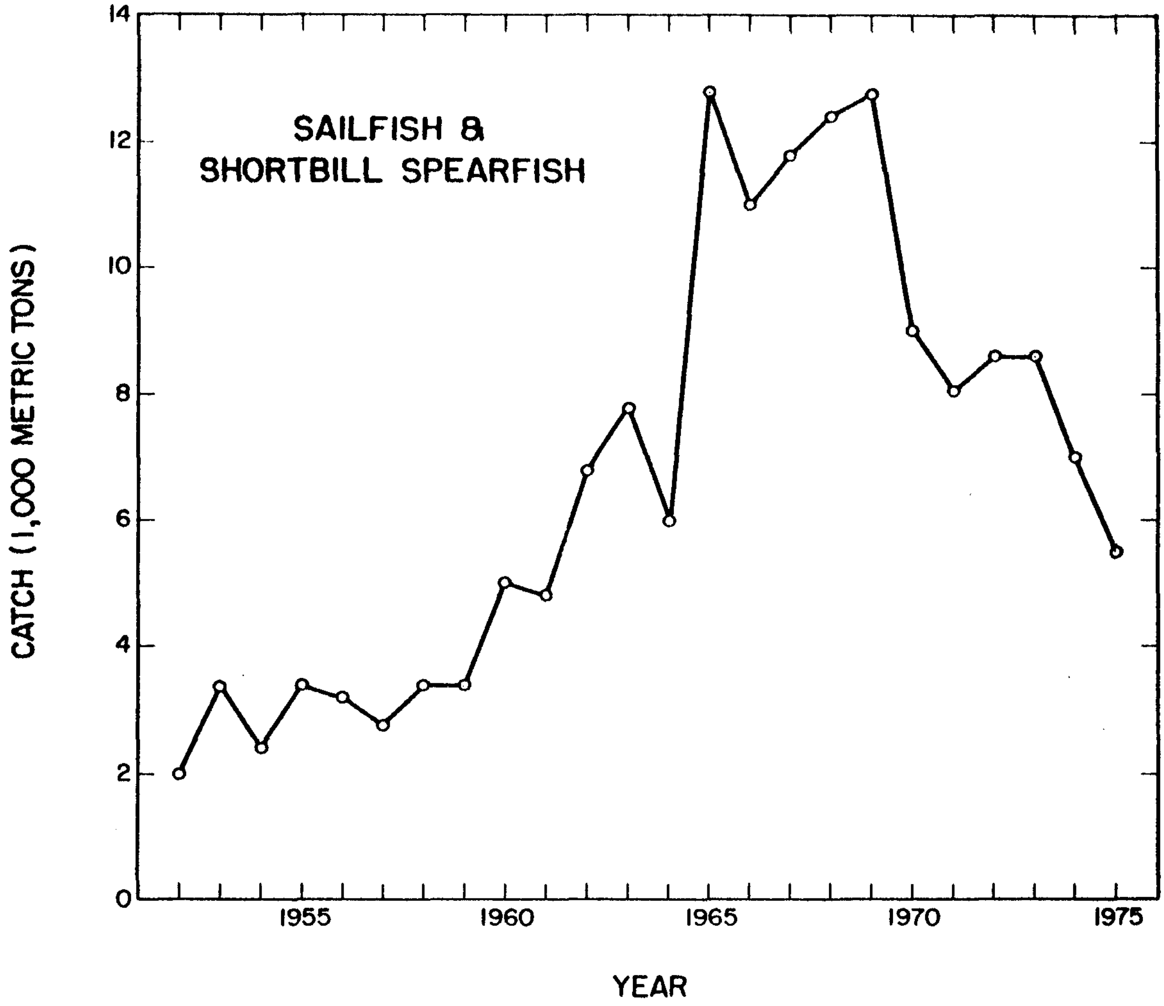
lower than reported because totals include catches of species other than sailfish or shortbill spearfish.

Effort Trends

Sailfish.--Effective fishing effort in the Japanese longline fishery for sailfish was summarized for two areas: the western (Area 1) and eastern Pacific (Area 2) (Appendix Figure 11). Effective effort for sailfish in the western Pacific showed large fluctuations and no obvious trends. Effective effort was higher during the 1961-67 period than it was before and after that period. In the eastern Pacific, the effective effort did not increase substantially until 1965, then it peaked in 1968, and declined gradually through 1975.

Appendix Table 3.--Annual combined landings of Pacific sailfish and shortbill spearfish, 1952-75 by number of fish and metric tons.

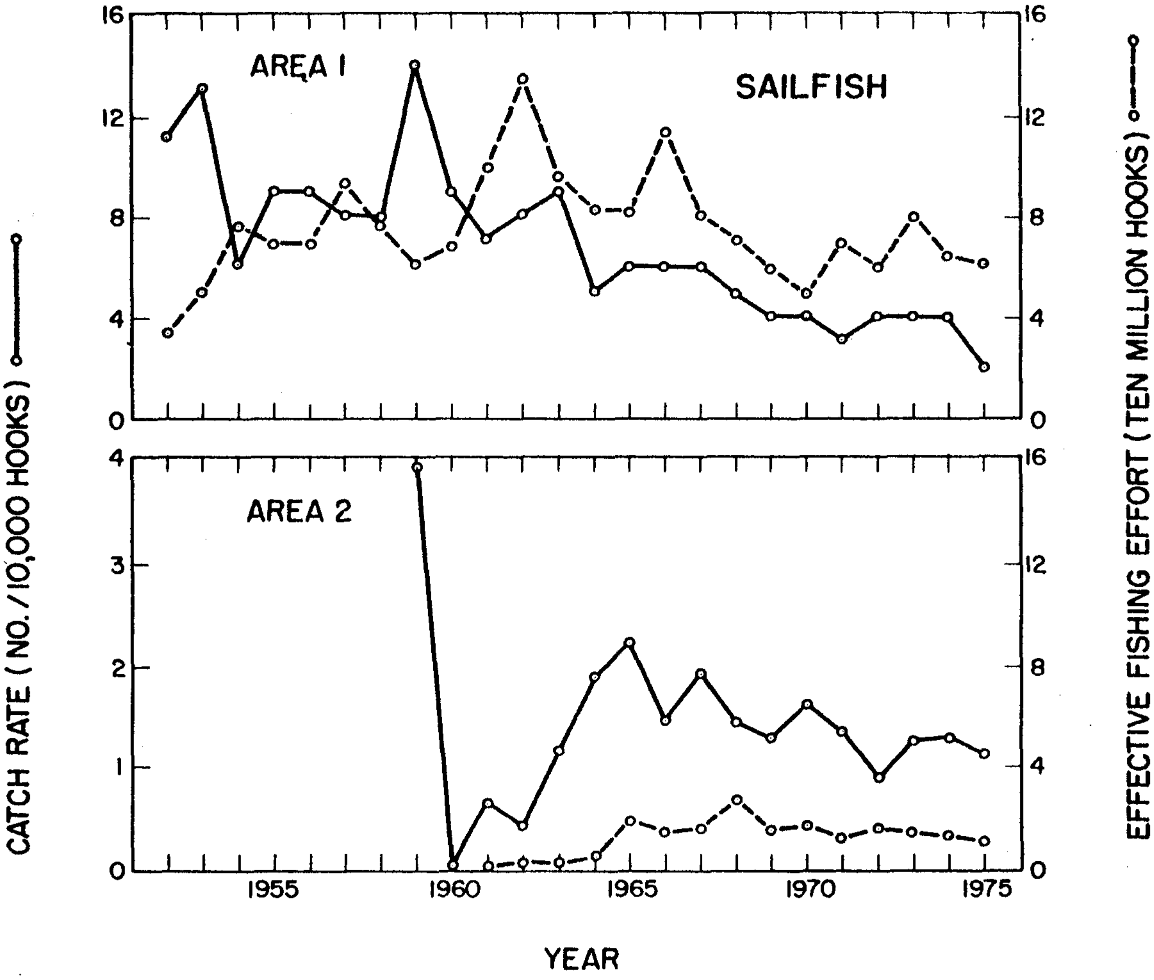
Year	Number of fish (10^3)	Metric tons (10^3)
1952	72.6	2.0
1953	119.2	3.3
1954	88.2	2.4
1955	120.6	3.3
1956	115.5	3.2
1957	171.6	2.8
1958	122.0	3.4
1959	142.0	3.4
1960	129.2	5.0
1961	152.2	4.8
1962	216.3	6.8
1963	289.3	7.9
1964	250.4	6.1
1965	598.1	12.8
1966	435.3	11.1
1967	487.3	11.8
1968	676.5	12.5
1969	333.2	12.8
1970	466.4	9.0
1971	260.3	8.1
1972	230.0	8.6
1973	304.3	8.7
1974	253.5	7.1
1975	191.3	5.5



Appendix Figure 10.--Catches of sailfish and shortbill spearfish in the Pacific, 1952-75.

Longline fishing in the Pacific is also conducted by vessels of the Republic of Korea and Taiwan. This effort is principally in the south central and southwestern Pacific. The Taiwan nominal effort, which is centered in the southwestern and north central Pacific, appears to have peaked in 1973 to 54.7 million hooks and declined to 39.3 million hooks in 1976. The amount of effort expended by the harpoon, gill net, and recreational fisheries is unknown.

Shortbill spearfish. Longline effort data for shortbill spearfish north and south of the Equator (Appendix Figure 12) were available in terms of nominal effort (Appendix Figure 13). In the northern area nominal fishing effort increased from 1952 through 1961 and fluctuated between about 180 million and 230 million hooks from 1962 to 1975. In the southern area, effort increased from 1952 through 1963, declined from 1964 through 1968, and has been stable since 1969.

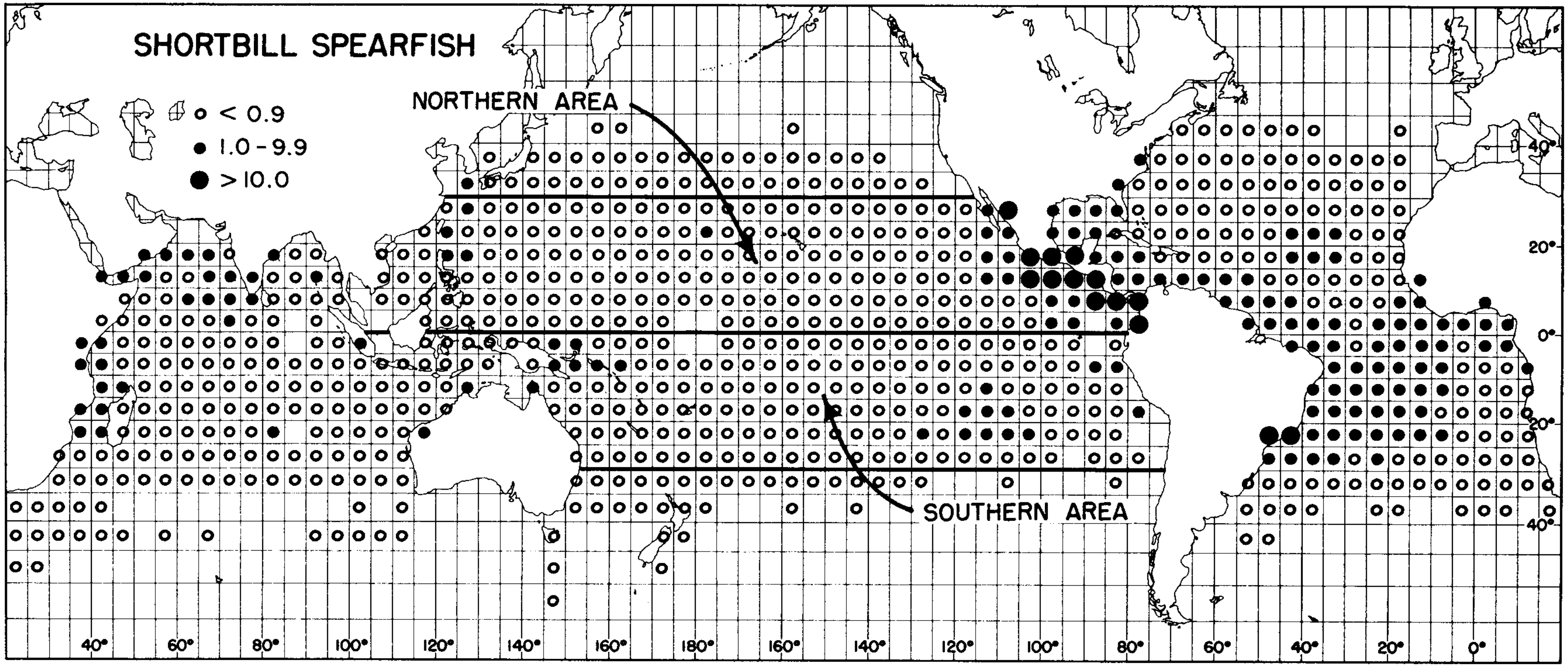


Appendix Figure 11.--Catch rates and effective fishing effort for sailfish in the Pacific, 1952-75.

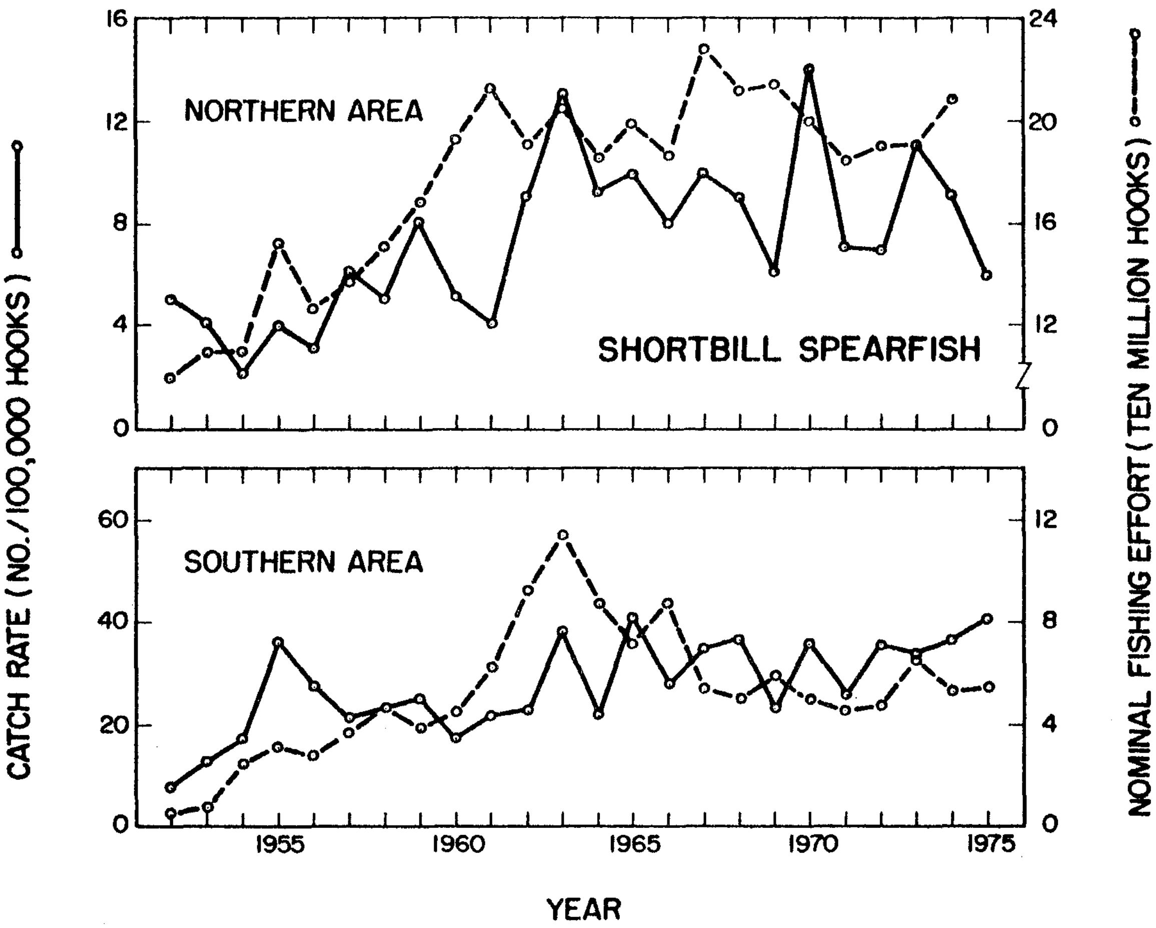
Catch Rate Trends

Sailfish.--The sailfish catch rate in the western Pacific (Area 1) fluctuated between about 6 and 14 fish per 10,000 hooks from 1952 to 1959 and has been declining since 1959 (Appendix Figure 11). The average catch rate from 1960 to 1975 was about one-half of that during 1952-59. The sharp decline in 1975 may be partially the result of deep fishing for bigeye tuna, Thunnus obesus, a method which is less effective for sailfish, which tend to inhabit the upper layers of the ocean.

In the eastern Pacific (Area 2) there were large fluctuations in a generally rising trend of catch rates from 1959 to 1965; subsequently the catch rate has fluctuated less on a downward trend (Appendix Figure 11). The 1975 catch rate is approximately two-thirds of that observed during the high catch rate period of 1964 to 1968.



Appendix Figure 12.--Boundaries of suggested shortbill spearfish stocks. The circles indicate mean catch rates (number of fish per 1,000 hooks) for shortbill spearfish and sailfish.



Appendix Figure 13.--Catch rates and nominal fishing effort for shortbill spearfish in the Pacific, 1952-75.

Shortbill spearfish.--Because shortbill spearfish and sailfish catches are pooled in the catch statistics, shortbill spearfish catches were estimated by using historical sailfish to shortbill spearfish catch ratio data; the catch rate is based on nominal effort (Appendix Figure 11). The catch rate for shortbill spearfish in the northern area increased from a level of four fish per 100,000 hooks during the period 1952 through 1961, to an average of about eight fish per 100,000 hooks in recent years. The southern area annual catch rate shows a smaller increase, from about 20 fish per 100,000 hooks during the period 1952 through 1962, to about 30 fish per 100,000 hooks since 1962, a much better (by a factor of 4) catch rate than in the northern area.

STOCK STRUCTURE

Sailfish.--Based on the distribution of larvae and longline catch rates, a possible two unit, western and eastern Pacific, stock structure for sailfish was suggested (Appendix Figure 9).

Shortbill spearfish.--On similar types of evidence, a two unit, northern and southern, stock structure for shortbill spearfish was proposed (Appendix Figure 12).

POPULATION PARAMETERS

Sailfish.--Kume and Joseph (1969b) determined the following length-weight relation for eastern Pacific sailfish.

$$\log_{10} Y = -3.9357 + 2.4156 \log_{10} X,$$

and Wares and Sakagawa (1974) the following:

$$\log_{10} Y = -4.360 + 2.628 \log_{10} X,$$

where Y is weight in kilograms and X is eye-fork length in centimeters.

Skillman and Yong (1974) determined the length-weight relation for central Pacific sailfish as follows:

$$W = 2.0739 \times 10^{-5} L^{2.6054},$$

where W is weight in kilograms and L is snout-fork length in centimeters.

Other population parameters for sailfish are found in Appendix Table 5.

Shortbill spearfish.--Kume and Joseph (1969b) determined the following length-weight relation for eastern Pacific shortbill spearfish:

$$\log_{10} Y = -6.8146 + 3.7242 \log_{10} X,$$

where Y is weight in kilograms and X is eye-fork length in centimeters.

Skillman and Yong (1974) determined the following length-weight relation for central Pacific sailfish:

$$W = 5.0083 \times 10^{-8} L^{3.8338},$$

where W is weight in kilograms and L is snout-fork length in centimeters.

No other population parameters for shortbill spearfish are available.

STOCK ASSESSMENT

Because of problems with the basic longline data relative to species separation of sailfish and shortbill spearfish catches and unknown amounts of other species included in the sailfish/spearfish catch data, production model analysis was not performed. Appraisal of stock condition was therefore based on estimates of apparent abundance as deduced from Japanese longline data.

Sailfish.--The substantial decline in catch rate that occurred between 1953 and 1975 in Area 1 suggests that any increase in effort probably will not result in a substantial increase in catch and if further increases in deep longlining occurs, the catch would decrease even if effort remains constant.

Since 1965 there has been a decrease in catch rate in Area 2, although the decline was not as sharp as that in Area 1. Thus, it is possible that an increase in effort may result in a slight increase in catch. However, if effort is switched to deep longlining, the catch could decline without a change in nominal effort.

Shortbill spearfish.—The catch rate in both the northern and southern areas has generally increased from 1952 to the present. Therefore, fishing has not resulted in a decline in stock abundance and any increase in effort should result in an increase in catch.

OVERALL STOCK APPRAISAL

Catch rates of sailfish in both the western and eastern Pacific declined substantially, and any increase in effort will probably produce little increase in catch.

The catch for shortbill spearfish has shown a general increase, and any increased effort should result in higher catches.

RECOMMENDATIONS

Statistics

The workshop recommended that the maintenance of accurate statistics on the catch of sailfish and shortbill spearfish be encouraged and that better estimates be made of the catch of the gill net and recreational fisheries.

Research

The workshop recommended that investigations be conducted on the length/weight/sex by quarters of the two species to provide coverage of the suggested stocks and that studies on age and growth be conducted throughout the range of the species.

The need to determine estimates of interchange rates among the suggested and assumed stocks and the need to define spawning areas and seasons for both species, with particular emphasis on the south and eastern Pacific, were indicated.

It was also recommended that currently available data be analyzed with production model analysis, using different combinations of catch statistics to evaluate biases in catch estimates and the different stock structure hypotheses. These outputs should then be evaluated to determine what additional studies might be needed.

Management

A general management recommendation cannot be made at this time. From current analyses of the data, there appears to be no critical management problems with the stocks at this time. However, it is recognized that there has been a substantial decline in catch rate for sailfish. It is recommended that the fisheries be monitored at an increased level and that the evaluation of data be intensified.

SWORDFISH, *XIPHIAS GLADIUS*

Gary T. Sakagawa and Robert R. Bell, Rapporteurs

REVIEW OF FISHERIES DATA

Swordfish, *Xiphias gladius*, occur in waters off California to Chile in the eastern Pacific, throughout the central Pacific, and in waters from Japan to Australia in the western Pacific (Appendix Figure 14). They are caught by surface gears (harpoons, gill nets, and handlines) and by longlines. Nations participating in the fishery include: United States (harpoon fishery off California); Chile, Mexico, and Peru (coastal handline fisheries); Japan (Pacific-wide longline fishery and a coastal, mainly drift-gill net fishery off Honshu and Hokkaido); Taiwan (Pacific-wide longline fishery and a coastal, primarily longline and harpoon fishery); and Republic of Korea (Pacific-wide longline fishery). Swordfish are not caught in significant quantities by recreational fishermen anywhere in the Pacific.

The surface fisheries are directed to catching swordfish whereas the longline fisheries are generally directed to catching tunas. In certain regions of the northwestern Pacific, however, longlines are set at night specifically for swordfish. This practice has been on a decline since the mid-1960's and most of the sets are now daylight operations directed at tuna with incidental catches of swordfish.

Catch Trends

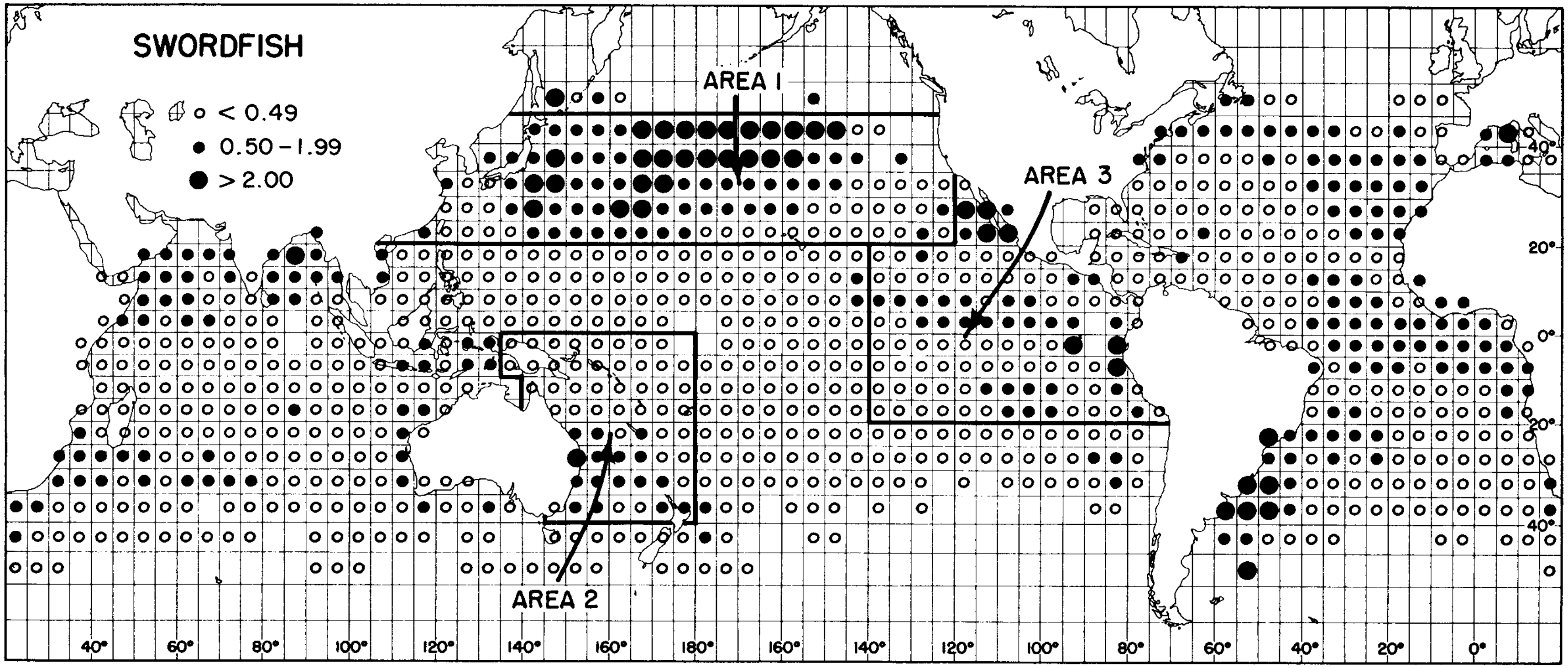
The total annual Pacific catch of swordfish increased from 11,300 mt in 1952 to a record high of 24,300 mt in 1961. Since then the catch has fluctuated within a narrow range of 10,100 to 18,900 mt, averaging 13,800 mt annually (Appendix Table 4; Appendix Figure 15). Most of the catch is landed by the Japanese longline fleet (about 58% in 1975) in the northwestern Pacific (about 75% in 1975).

Effort Trends

Effective fishing effort for Pacific swordfish has fluctuated between 270 million and 550 million hooks (Appendix Figure 16). The level in 1975 was about 300 million hooks.

Catch Rate Trends

The longest available time series of catch rates is for the Japanese longline fleet. Total Pacific catch rates for this fleet reached a peak of about 10 fish per 10,000 hooks in 1958, declined to a low of 4 fish per 10,000 hooks in 1967, and since then stabilized at about 5 fish per 10,000 hooks (Appendix Figure 16).



Appendix Figure 14.--Distribution of swordfish in the Pacific. The circles indicate mean catch rates (number of fish per 1,000 hooks). Also shown are centers of concentration of hypothesized swordfish stocks in the Pacific.

Appendix Table 4.--Swordfish catches (metric tons) by countries for the Pacific Ocean, 1952-75.

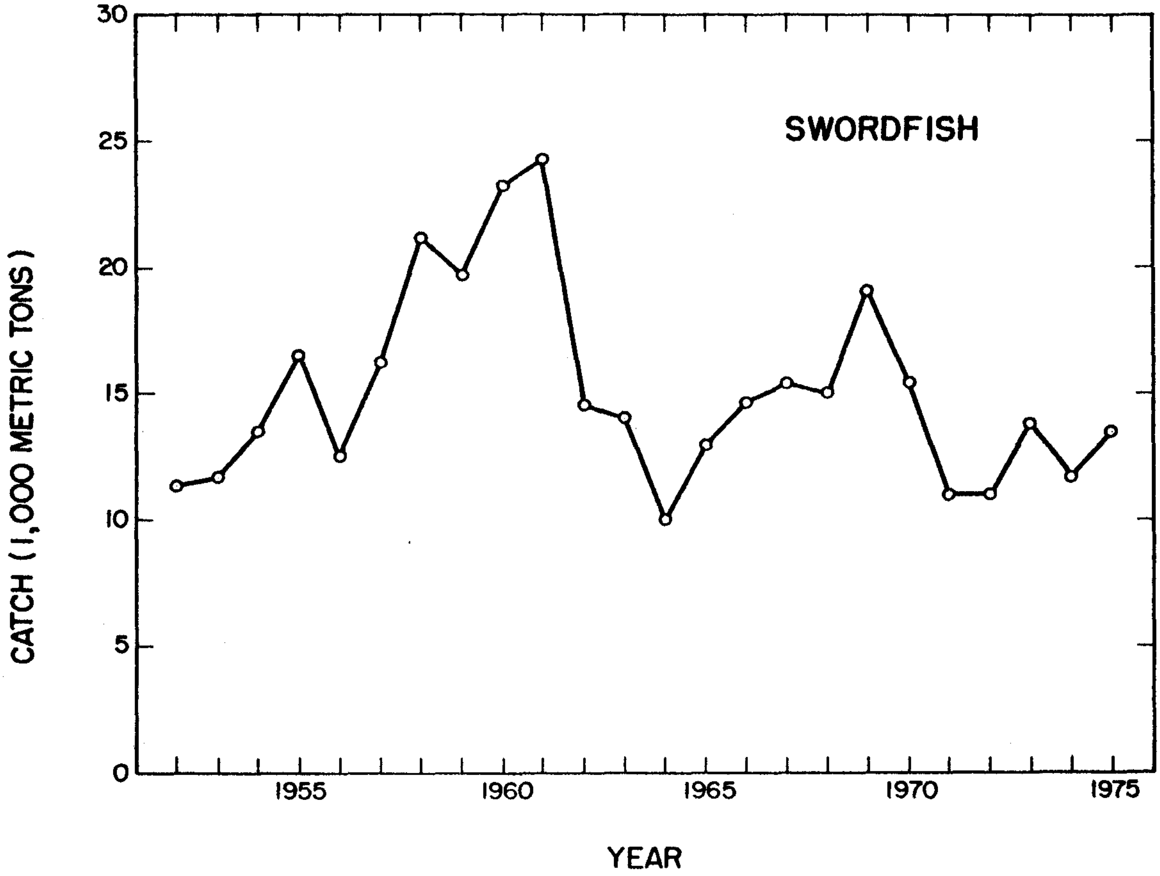
Year	Japan	Taiwan	Republic of Korea	United States	Chile	Peru	Others	Total
1952	11,182			157				11,339
1953	11,604			85				11,689
1954	13,301	77		14				13,392
1955	16,220	185		80				16,485
1956	12,167	254		163				12,584
1957	15,771	250		222				16,243
1958	20,815	247		279				21,341
1959	19,136	262		265				19,663
1960	22,944	273		192				23,409
1961	23,636	432		218				24,286
1962	14,037	544		23				14,604
1963	13,775	300		58				14,133
1964	9,703	300		109				10,112
1965	11,955	300		194	200	300		12,949
1966	13,283	600	41	277	200	200		14,601
1967	13,083	838	47	181	200	1,300		15,649
1968	12,983	974	55	118	200	800	100	15,230
1969	15,612	1,023	89	610	300	1,200	100	18,934
1970	11,301	1,053	115	558	200	2,400	100	15,727
1971	9,182	1,149	115	91	200	200	100	11,037
1972	8,846	1,111	115	157	100	600	100	11,029
1973	9,644	1,269	115	363	400	1,900	100	13,791
1974	9,517	1,157	115	384	218	270	3	11,664
1975	11,274	1,099	115	512	218	158		13,376

STOCK STRUCTURE

The stock structure of the swordfish population of the Pacific Ocean is not clearly known. Available data on distribution of larvae and on longline catch rates suggest that the population consists of either (1) a single, Pacific-wide stock, or (2) three separate stocks with centers of concentration in the northwestern (Area 1), southwestern (Area 2), and eastern (Area 3) regions of the Pacific Ocean (Appendix Figure 14).

POPULATION PARAMETERS

Estimates of basic, critical, population parameters for swordfish are lacking. Available estimates are shown in Appendix Table 5. They include estimates of growth and mortality rates that are judged to be crude. The difficulty in obtaining reliable estimates appear to be limited by the ability to age swordfish. A reliable aging technique has not yet been developed and most population parameters rely on age-dependent data.



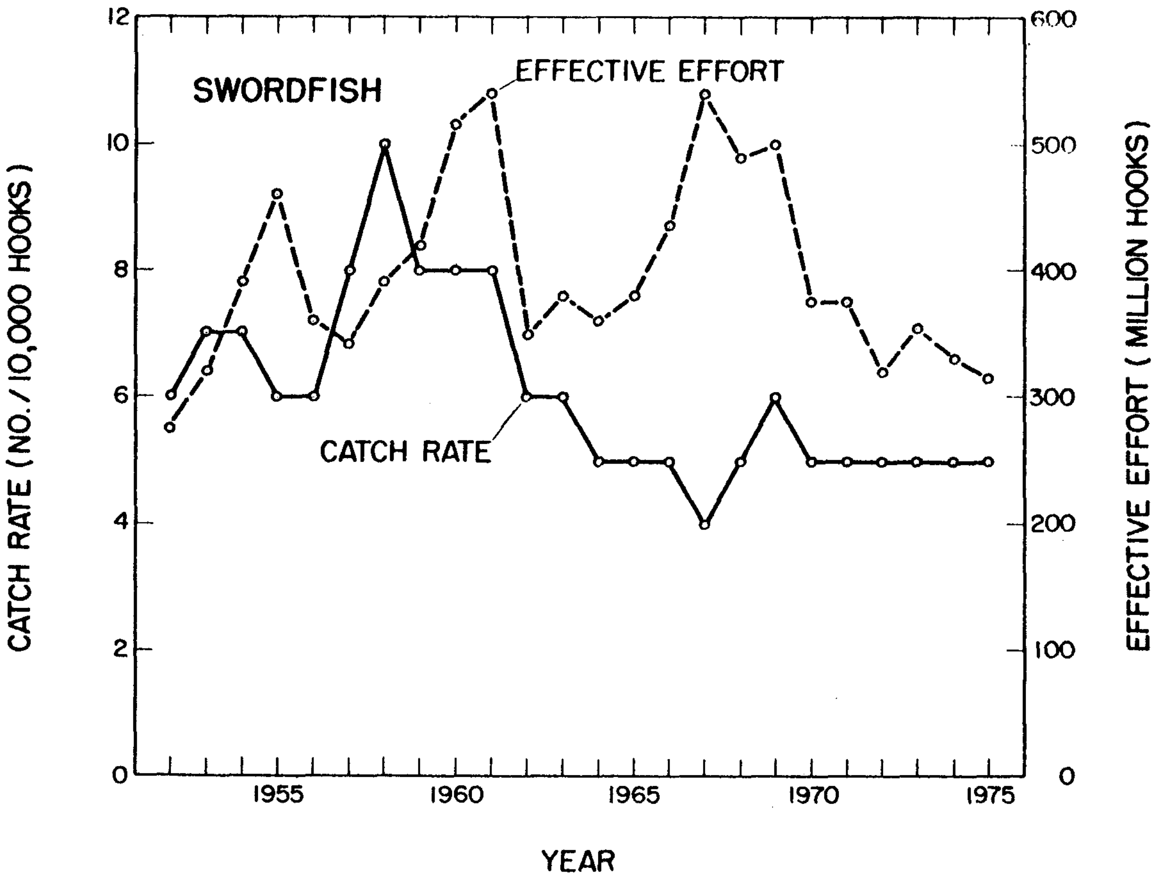
Appendix Figure 15.--Total catch of swordfish in the Pacific, 1952-75.

STOCK ASSESSMENT

The condition of the swordfish stocks of the Pacific was evaluated based on different hypotheses about the stock structure of the population: hypothesis 1, a single Pacific-wide stock, and hypothesis 2, three separate stocks. Because of limited data on the stocks the evaluation was restricted primarily to the use of production model analysis.

Single Pacific-Wide Stock

The relation of catch and effective fishing effort, assuming a single Pacific-wide stock is shown in Appendix Figure 17. The data points fall into two clusters separated by a break between 1963 and 1964, which corresponds approximately to the period when the operational methods in the longline fishery changed in the productive northwestern fishing area. As indicated earlier, longline night fishing which is directed at swordfish, was the predominant manner of fishing in the northwestern region prior to the mid-1960's. Since then, fishing in that region has become more a day operation for tunas rather than a night operation for swordfish.



Appendix Figure 16.--Pacific-wide catch rate and effective fishing effort for swordfish, 1952-75.

Production model analysis of the separate clusters of points gave no solution for the 1964-75 data series, and an MSY estimate of 20,000 mt per year with 2.2 million hooks per 5° square for the 1952-63 data series. Presumably during the 1952-63 period the fishery was more efficient in catching swordfish than during the 1964-75 period. The current (average for 1966-75) catches of about 14,100 mt produced by 1.8 million hooks per 5° square indicate that the fishery does not appear to be overexploiting the stock and that the stock is in good condition.

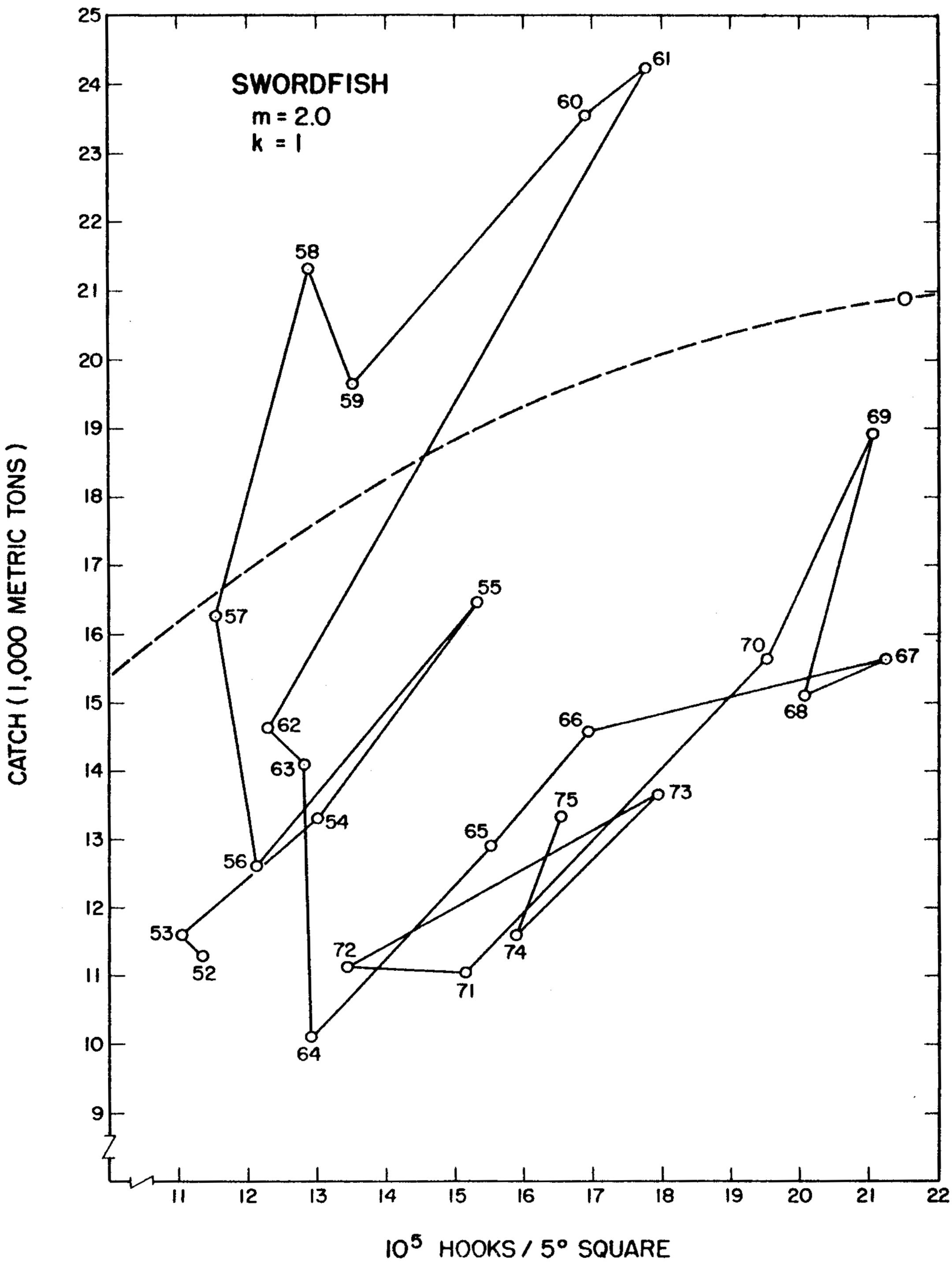
Three Separate Stocks

Complete data for production model analysis, assuming three stocks in the Pacific were not available for examination. An appraisal of the condition of the stocks was therefore based on estimates of apparent abundance from Japanese longline data for 1952-75.

Appendix Table 5.--Summary of estimates of some population parameters for billfishes. Growth parameters are for the von Bertalanffy growth equation and mortality rates are for the coefficient of instantaneous total mortality (Z) and coefficient of instantaneous natural mortality (M).

Species and locality	Growth parameter			Size range (cm)	Mortality rate		Source
	K	t_0(yr)	L_∞		Z	M	
Sailfish, Atlantic	0.901		95.55 in. (243 cm)			1.73	Based on data from de Sylva (1957)
Sailfish, Pacific	0.472		232 cm	[1]130-210		0.90	Based on data from Koto and Kodama (1962a)
Sailfish, Atlantic	0.289		248 cm			0.54	Based on data from Jolley (1977)
Swordfish, Atlantic	0.230		365 cm	60-279	0.12-0.65	0.21-0.43	Caddy (1977)
Swordfish, Pacific	0.124		309 cm	[1]61-245			Estimates of K based on data from Yabe et al. (1959); L_∞ estimated by Yabe et al. (1959)
White marlin, Atlantic					0.35±0.10		Mather et al. (1974)
Blue marlin, Pacific							
Male	0.285-0.815	0.106	282-371 cm	100-280		0.53-1.56	K, t_0, and L_∞ estimated by Skillman and Yong (1976); estimates of M based on data from Skillman and Yong (1976)
Female	0.123-0.175	-0.202	540-626 cm	50-400		0.15-0.21	
Striped marlin, Pacific	0.264		[1]275	[1]120-235			Based on data from Koto (1963)
Male	0.315-0.417	-0.521	277.4-314.4 cm		1.94	0.59-1.55	Estimates of K, t_0, and L_∞ by Skillman and Yong (1976). Estimates of M based on data from Skillman and Yong (1976). Estimates of Z based on data from Skillman and Yong (1976) and Yoshida (1974)
Female	0.696-0.709	0.136	251.0-251.8 cm		1.38	1.33-1.36	
Black marlin, Pacific	0.474		[1]282	[1]150-250			Based on data from Koto and Kodama (1962b)

[1]Eye-fork length.



Appendix Figure 17.--Relationship of catch of swordfish and effective fishing effort. The equilibrium yield curve (Schaefer production model) is shown for data for 1952-63 only.

In the northern region (Area 1), the longline catches ranged from about 6,800 to 22,900 mt (Appendix Figure 18); the catch rates showed a gradual decline from about 20 fish per 10,000 hooks in 1958 to 8 fish per 10,000 hooks in 1971 (Appendix Figure 19). Since 1971 the catch rate gradually recovered to the current level of 12 fish per 10,000 hooks in 1975.

In the southwestern region (Area 2) the longline catches showed a gradually increasing trend (Appendix Figure 18); the catch rates fluctuated between two fish per 10,000 hooks and three fish per 10,000 hooks during the period 1952-67 (Appendix Figure 19). The rate then increased to the current high level of four fish per 10,000 hooks.

Longline catches in the eastern Pacific (Area 3) showed an increasing trend after 1960, following a period of small catches from 1952 to 1960 (Appendix Figure 18); the catch rates gradually increased from about two fish per 10,000 hooks in 1954 to six fish per 10,000 hooks in 1968 (Appendix Figure 19). In 1969 and 1970 the catch rates increased sharply to a record high of about 11 fish per 10,000 hooks before declining to a level of about 5 fish per 10,000 hooks in 1971-75.

OVERALL STOCK APPRAISAL

The swordfish stocks of the Pacific Ocean appear to be healthy and capable of sustaining increased yields with increased effort. However, should the longline fishery resort to night fishing, which was the standard method of fishing in some areas prior to the mid-1960's, then the greater efficiency of the gear could result in the catch exceeding the MSY with about a 25% increase in the current levels of fishing effort.

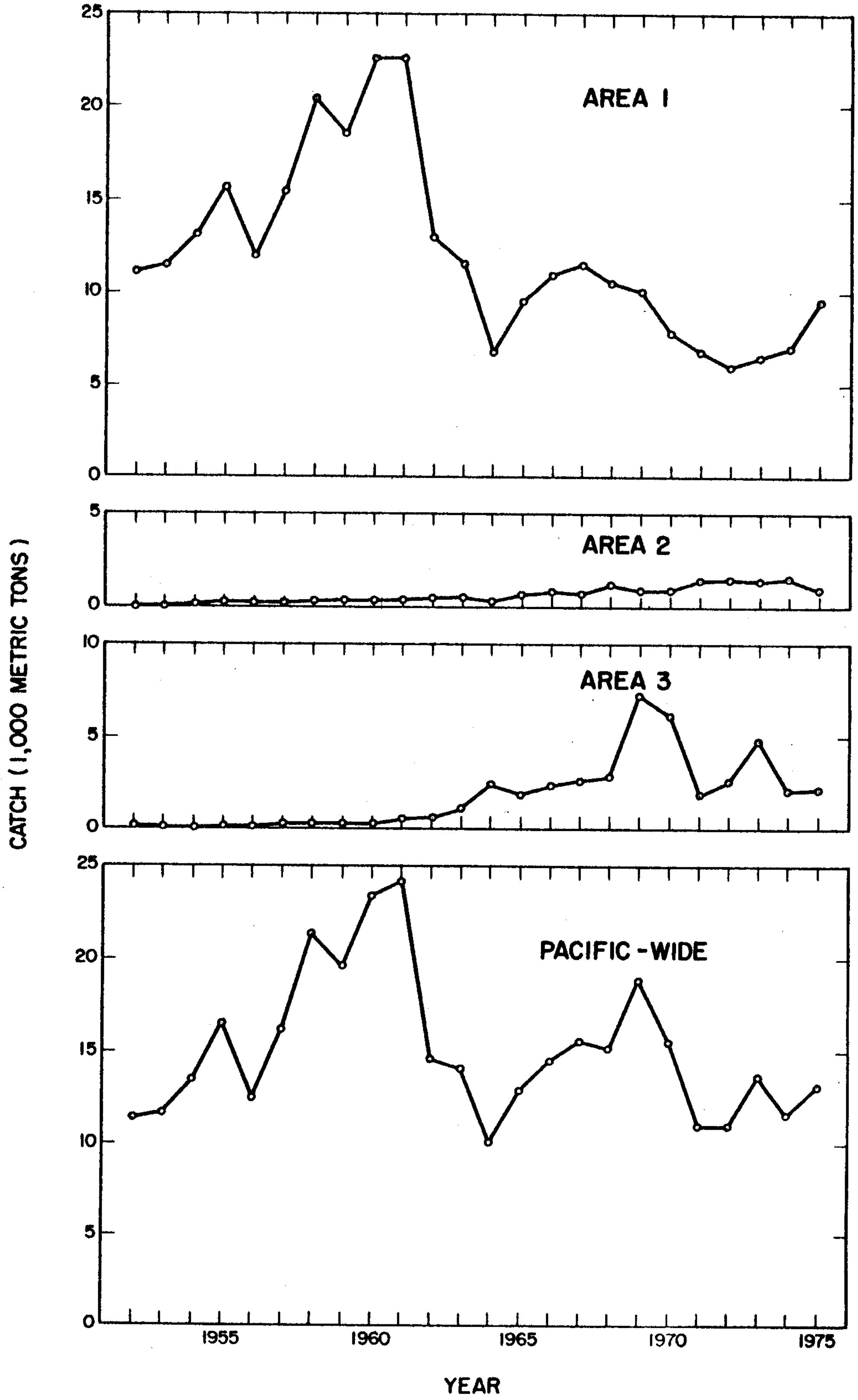
RECOMMENDATIONS

Statistics

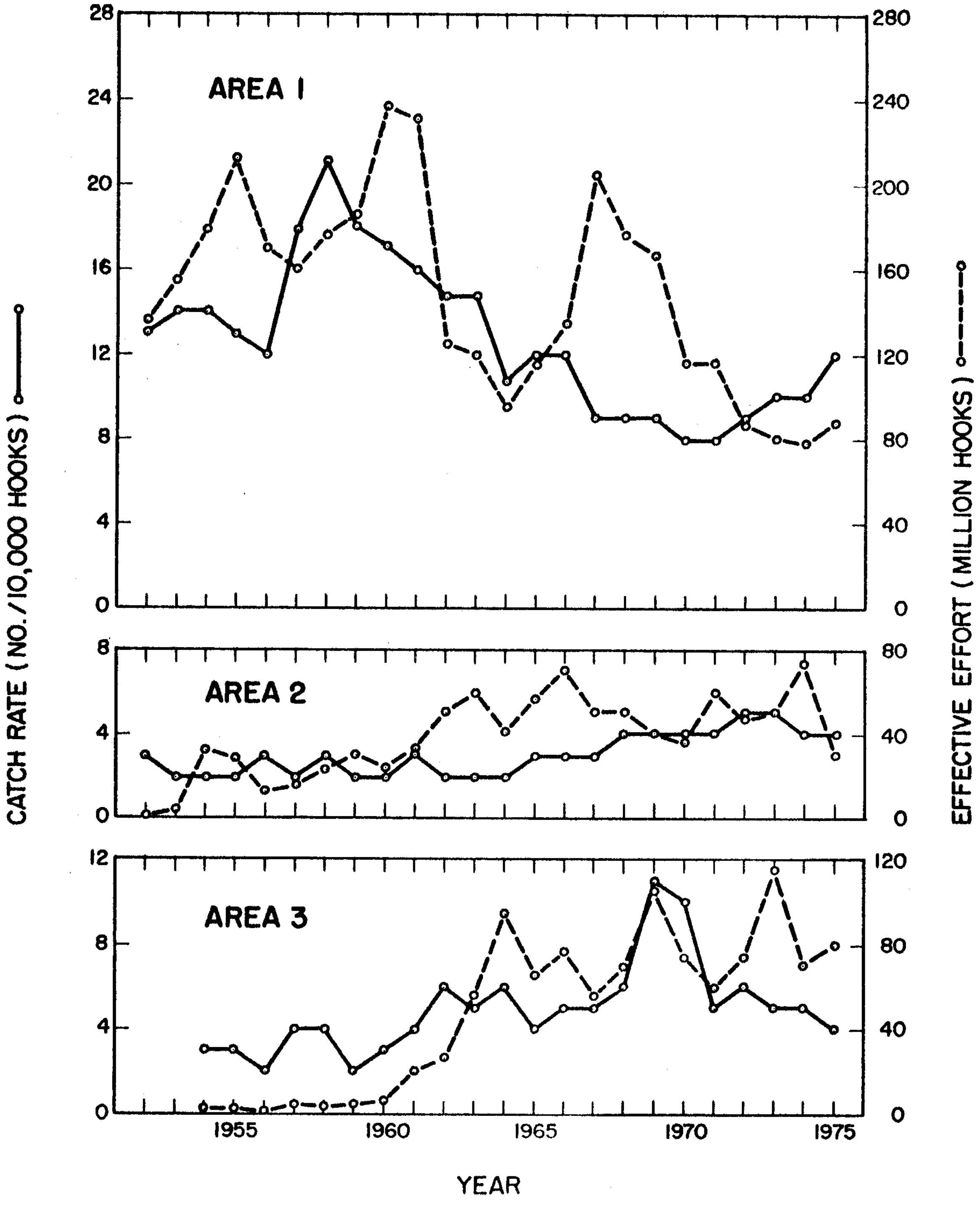
Longlining for swordfish is most effective during the night, whereas, longlining for tunas is most effective during the day. Prior to the mid-1960's, longlining in the more productive swordfish areas, especially in the northwestern Pacific, was conducted during the night. Since then this practice has decreased as the fishery has been targeting the higher priced tunas.

This change in fishing practice has complicated the longline statistics which are used to measure apparent abundance of swordfish. Published statistics currently do not identify type of fishing, i.e., night and day operations, and more precise stock assessments based on the longline data will require separation of the data. The participants, therefore, recommended that the longline catch-effort statistics be separated into type (day and night) of operations.

The participants also recommended that size and sex data be collected from all fisheries, and catch-and-effort data be collected from the surface fisheries. These data are essential for using more sophisticated assessment techniques and for obtaining more precise management advice.



Appendix Figure 18.--Swordfish catch in the Pacific Ocean, 1952-75.



Appendix Figure 19.--Catch rates and effective fishing effort for swordfish in the Pacific, 1952-75.

Research

Information on stock structure of a fish population is important for proper management of the resource. For Pacific swordfish, the stock structure is not clearly known although available data suggest that the population might consist of a single Pacific-wide stock or possibly, three separate stocks. Available techniques for stock identification are expensive to apply and not entirely reliable in producing clear results. The participants therefore recommended that different stock structure hypotheses be tested using existing fisheries data to determine their impact on assessments before any major program for stock identification of swordfish is considered.

The key to more precise stock assessments for swordfish is more reliable information on stock densities and better estimates of population dynamics parameters. The participants recommended that methods of aging swordfish receive more research attention since this is important for estimating population dynamics parameters.

Management

With current levels of fishing effort (about 1.8 million hooks per 5° square) and the current mode of longline operations (fishing predominantly during the day), the swordfish stocks are not being exploited beyond the estimated MSY of about 20,000 mt for the Pacific-wide stock. However, the fishery should be monitored closely for changes in the mode of operation, especially changes to night fishing, which could result in the stocks being exploited beyond MSY.

BLACK MARLIN, MAKAIRA INDICA

Jerry A. Wetherall and Rong-Tszong Yang, Rapporteurs

REVIEW OF FISHERIES DATA

Black marlin, Makaira indica, occur across the entire Pacific Ocean between about lat. 45°N and 50°S. Their latitudinal distribution is somewhat more restricted in the eastern than in the western Pacific (Appendix Figure 20). Catch rates in the tuna longline fisheries show that the density of black marlin is generally very low except in certain coastal waters. In the western Pacific, seasonal concentrations of this species are seen in such areas as the East China Sea and the Coral Sea. The Coral Sea is assumed to include spawning areas for black marlin as evidenced by gonad condition and larval occurrence. In the eastern Pacific, high densities are observed in the coastal waters of Panana and Ecuador. In the mid-Pacific region, occurrence of black marlin is highest in the vicinity of islands.

Catch Trends

The total catch of black marlin in the Pacific rose to a peak of about 6,500 mt in 1956, then dipped to about 3,100 mt in 1959 and fluctuated between about 2,000 and 4,000 mt from 1960 to 1975 (Appendix Table 6; Appendix Figure 21). There are uncertainties in the estimates of black marlin catches in the Pacific; it is believed that some catches are unreported.

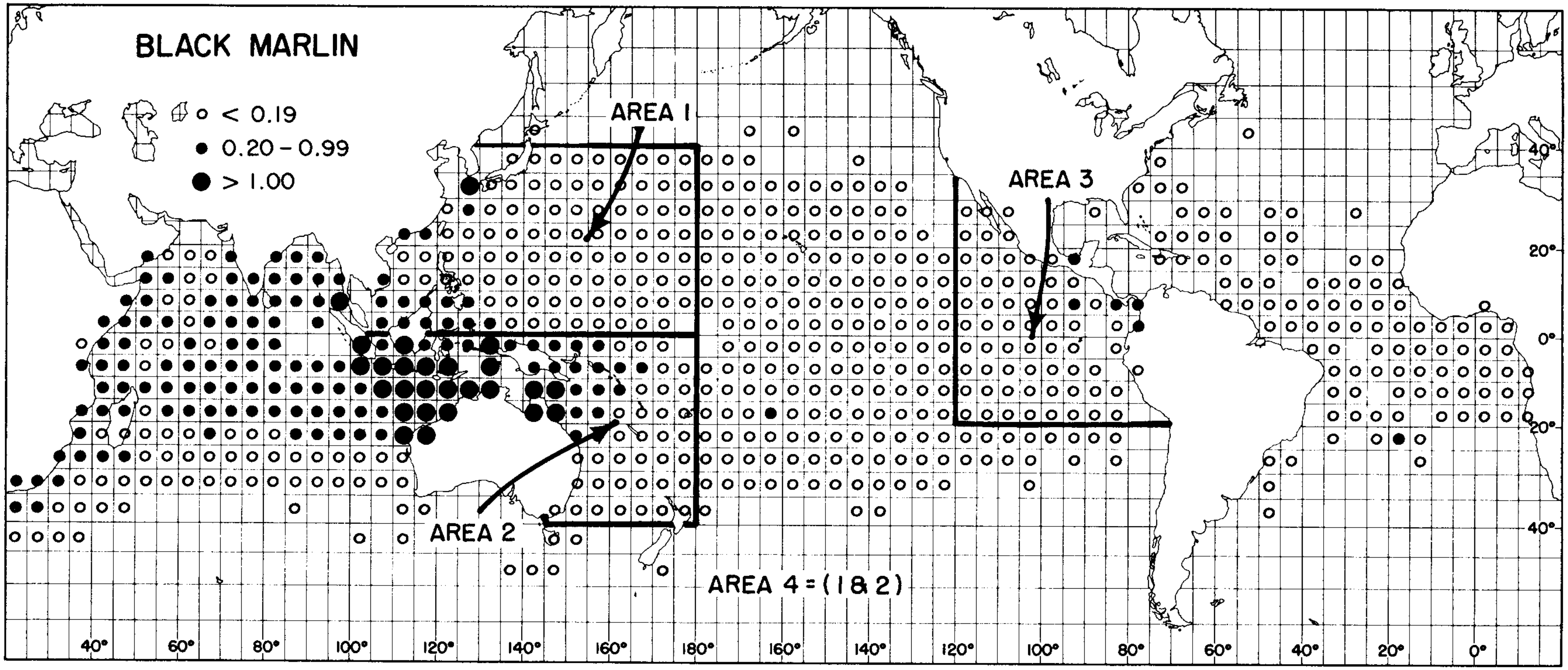
Most of the black marlin catches in the northwestern Pacific are made by Taiwan commercial fishermen using mostly tuna longlines on short-range vessels under 50 GT, or using harpoons. Catches made by Japanese tuna longliners in the area are relatively minor.

In the southwestern Pacific, most of the black marlin catches are made by Japanese tuna longliners and lesser amounts are taken by Taiwan and Republic of Korea vessels. There is also an active recreational fishery for black marlin primarily off Cairns, Australia.

A recreational fishery accounts for some of the catch of black marlin in the eastern Pacific but almost all the catch in this area is made by Japanese longliners.

Effort Trends

Effort data have been summarized for four areas in the Pacific, northwestern (Area 1), southwestern (Area 2), eastern (Area 3), and western (Area 4) (Appendix Figure 22), where black marlin are relatively densely distributed. Black marlin occupying these areas may represent separate stocks. Because total catch figures are used to estimate effective fishing effort, these estimates are biased to the same extent as the corresponding catch estimates.



Appendix Figure 20.--Distribution of black marlin in the Pacific Ocean. The circles indicate mean catch rates (number of fish per 1,000 hooks). Also shown are the boundaries of suggested black marlin stocks.

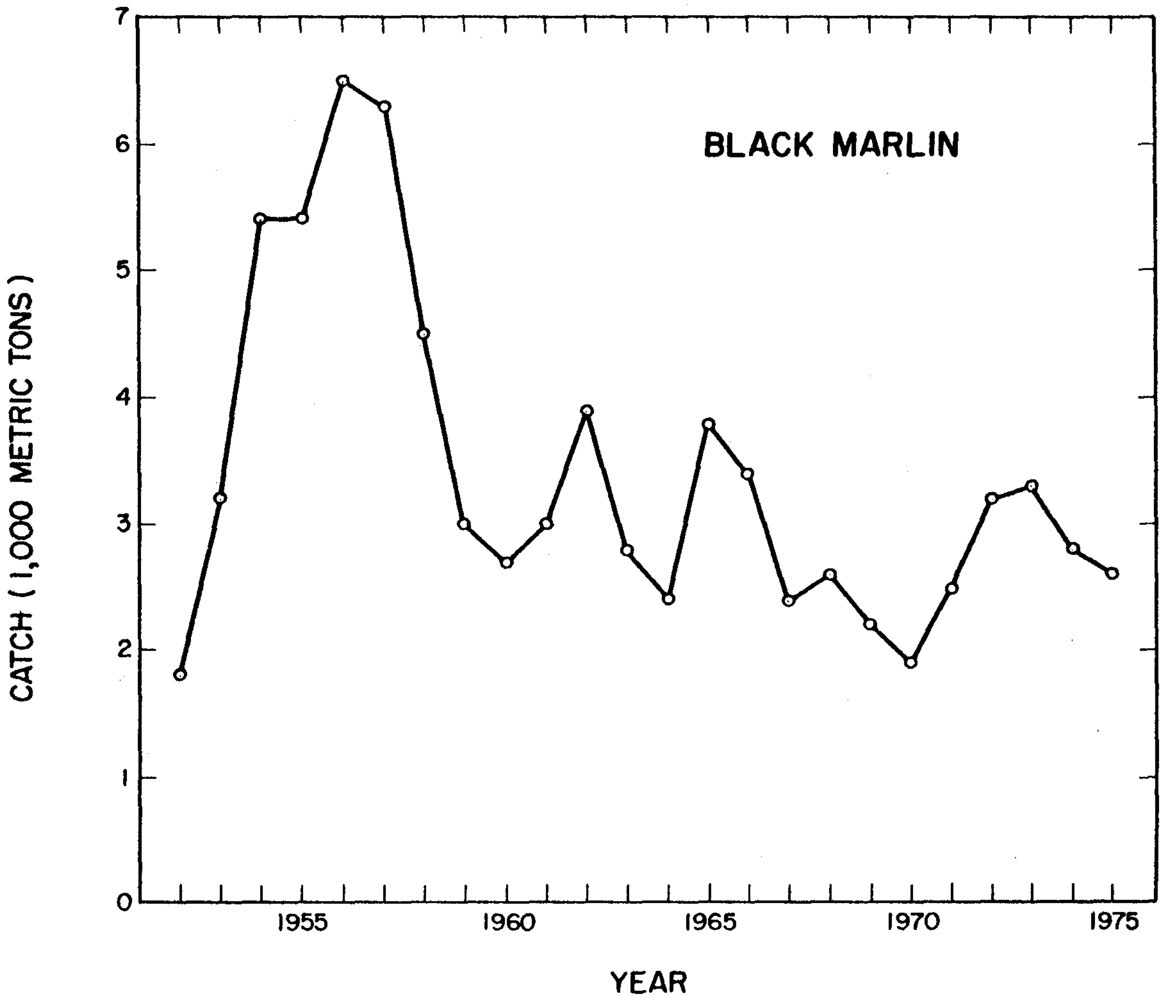
Appendix Table 6.--Black marlin catches (metric tons) by countries in the Pacific Ocean, 1952-75.

Year	Japan	Taiwan	Republic of Korea	Total
1952	1,806			1,806
1953	3,188			3,188
1954	4,713	657		5,370
1955	3,690	1,689		5,379
1956	4,443	2,023		6,466
1957	5,107	1,269		6,376
1958	2,581	1,967		4,548
1959	1,905	1,176		3,081
1960	1,938	783		2,721
1961	2,312	858		3,170
1962	2,852	1,214		4,066
1963	2,580	600		3,180
1964	2,205	600		2,805
1965	3,439	600		4,039
1966	3,225	400	104	3,729
1967	2,034	648	154	2,836
1968	1,588	661	113	2,362
1969	2,053	343	150	2,546
1970	1,644	453	110	2,207
1971	1,773	791	110	2,674
1972	1,424	1,890	110	3,424
1973	1,614	1,996	110	3,720
1974	1,175	1,763	110	3,048
1975	962	1,724	110	2,796

Effective fishing effort from 1952 to 1975 has been erratic and does not show any discernible trends in Areas 1, 2, and 4. In the eastern Pacific (Area 3), where the Japanese tuna fishery commenced in 1956, the effective fishing effort has been on a generally increasing trend.

Catch Rate Trends

In the northwestern Pacific (Area 1), the catch rate reached a peak in 1953 and declined to its lowest level in 1975. In the southwestern Pacific (Area 2), the catch rate reached a peak early in the development of the fishery in 1955, declined to less than four fish per 10,000 hooks in 1957 and fluctuated between about one and three fish per 10,000 hooks from 1958 through 1975. The catch rate in the eastern Pacific (Area 3) reached a peak in 1957 and declined thereafter. The western Pacific (Area 4) catch rate reflects the same trends as that in the constituent areas (Areas 1 and 2).



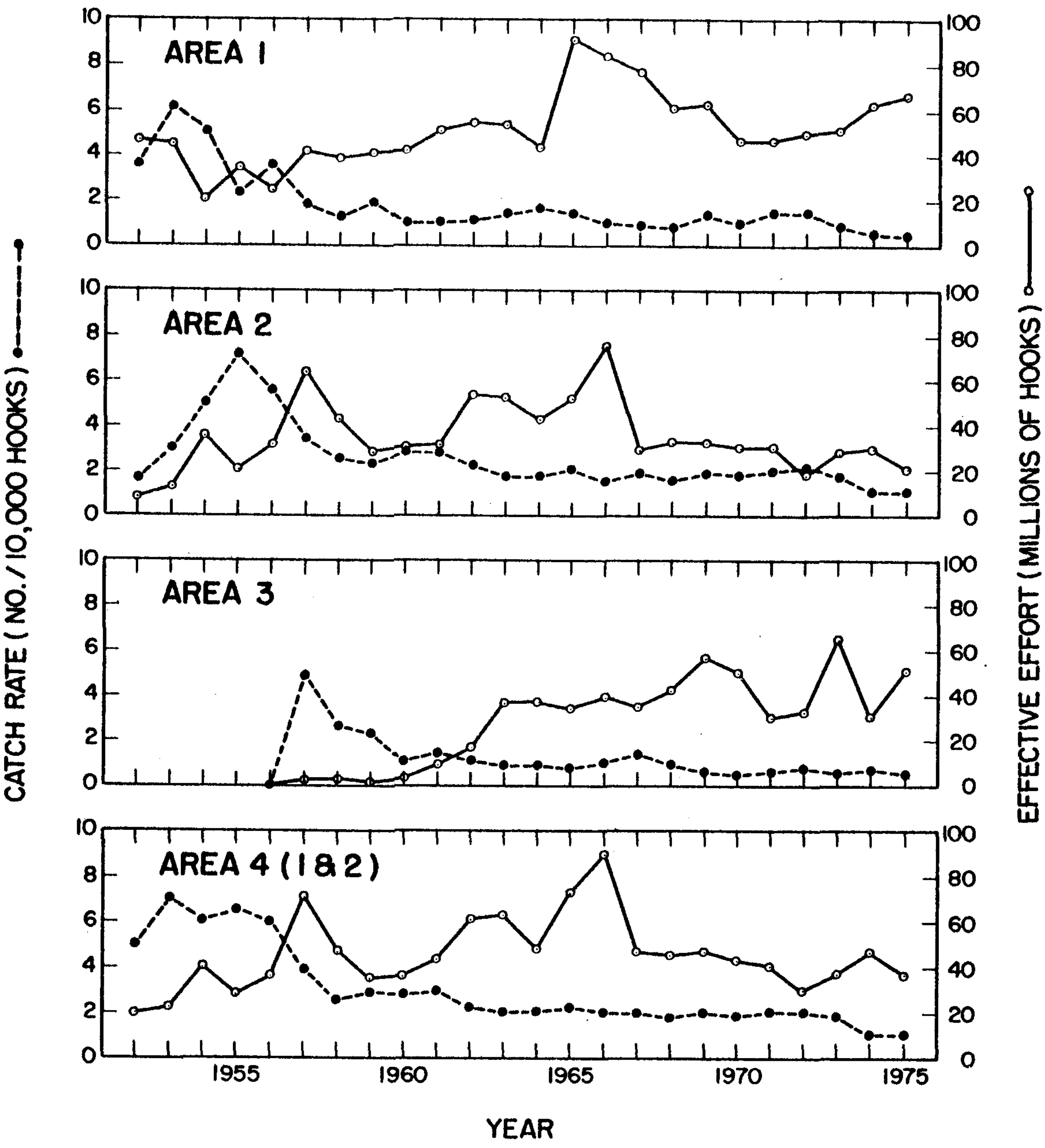
Appendix Figure 21.--Total catch of black marlin in the Pacific, 1952-75.

STOCK STRUCTURE

The stock structure of black marlin in the Pacific is not clear; however, their restricted coastal distribution and the presence of isolated high catch-rate areas suggest the possible existence of more than one stock in the Pacific. It has been suggested that there may be two or three stocks; one in the eastern Pacific and one or two in the western Pacific (Appendix Figure 20). The situation is complicated by the strong possibility of mixing between black marlin in the Indian Ocean and the western Pacific.

POPULATION PARAMETERS

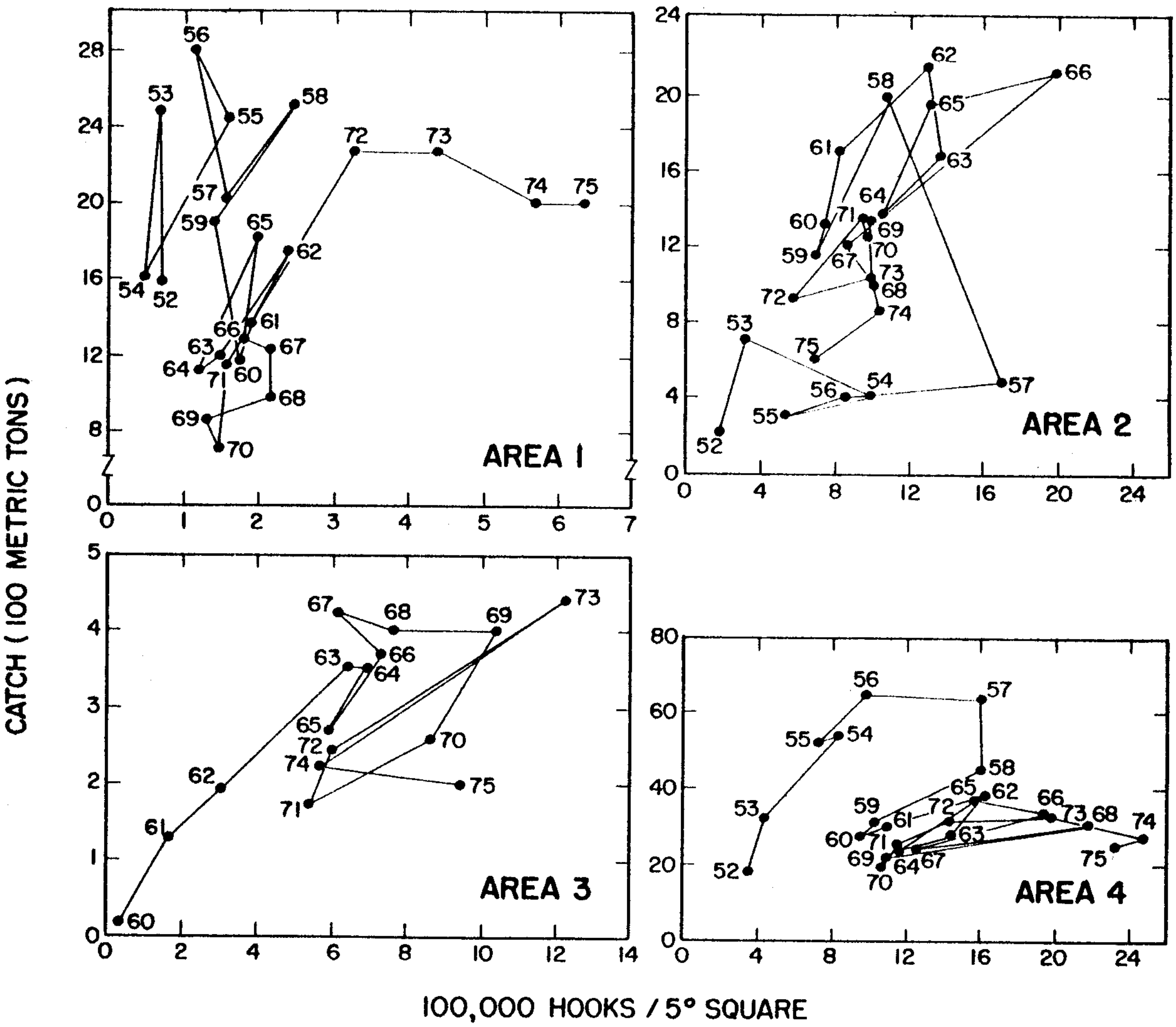
Owing to a lack of black marlin age data, no estimates of mortality have been made. Estimates of K and L_∞ (von Bertalanffy growth parameters) for black marlin are found in Appendix Table 5.



Appendix Figure 22.--Catch rates and effective fishing effort for black marlin in the Pacific, 1952-75.

STOCK ASSESSMENT

Because of the uncertainty in total catch figures and stock structure, no attempt was made to fit production models or to estimate MSY for black marlin in any area in the Pacific. However, the relationships between estimated catch and effort were examined (Appendix Figure 23). The consensus of the participants was that a reliable production model analysis will require a better accounting of catches.



Appendix Figure 23.--Relation between catch and effective effort for black marlin in four areas in the Pacific.

OVERALL STOCK APPRAISAL

While no definitive assessments of black marlin stocks are yet available, the substantial decline in catch rates from the early 1950's to 1975 suggests that a very large increase in total catch over recent levels is probably not sustainable.

RECOMMENDATIONS

Statistics

For improved stock assessments of black marlin, it is essential that complete catch and nominal effort statistics be made available from all harvesting nations, especially the Republic of Korea, Japan, and Taiwan.

In addition, statistics on total catch and effort should be gathered systematically from recreational fisheries, particularly off northwest Australia.

Thorough stock assessments will require extensive data on the size composition of black marlin catches in commercial and recreational fisheries. These statistics should be acquired over all time-area strata.

Research

Continued research is required to evaluate the status of black marlin stocks. Attention must be paid to improve understanding of stock structure, to better estimate total catches, and to validate the stock density measures.

In view of the importance of population structure to proper stock assessment, the tagging programs currently underway should be maintained.

Finally, concerted efforts are needed to determine the age of black marlin and to establish age-size relationships.

Management

Because no MSY estimates are available, it is presently not useful to make any management recommendations with respect to catch or effort limitations. However, future analyses may show that catches of black marlin presently exceed MSY in some stocks, and that restraints should be considered. In any case, effective management will depend on a much improved understanding of stock structure and stock dynamics.

APPENDIX B

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