International Commission for the Northwest Atlantic Fisheries

Serial No. 3541
(D.c. 3)

ICNAF Res.Doc. 75/59

ANNUAL MEETING - JUNE 1975

A preliminary assessment of the redfish fishery in ICNAF Subarea 5

by

Ralph K. Mayo
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543

Abstract

Commercial catch and effort statistics are presented and utilized to calculate maximum sustainable yield for Subarea 5 redfish. Recent trends in catch and catch per unit effort by vessel size and depth fished are also examined. In addition, commercial length frequency data and research cruise length frequency and catch per tow indices are analyzed to document trends in abundance and recruitment.

The US catch rose from 519 metric tons in 1934 to 59,783 tons in 1941, and subsequently declined, reaching 30,077 tons in 1951, 11,375 tons in 1961, and 8,690 tons in 1974. Recent catches from nations other than the US increased the total to 20,034 tons in 1971, dropping slightly to 17,360 tons in 1973. The US catch per unit effort index declined from 6.9 metric tons per day fished in 1942 to 3.3 tons per day in 1949, remained relatively stable until 1964, and increased to 14.7 tons per day in 1968. The index has subsequently declined to 5.0 tons per day in 1974.

There appears to have been no shift in the depths fished by US vessels between 1964 and 1973, but an increase in vessel size was evident during these years. Recruitment to the fishery appeared to be relatively good from 1965 to 1969, poorer between 1970 and 1972, with a slight improvement evident in 1973 and 1974.

Estimates of maximum sustainable yield and the corresponding effort and catch per unit effort were obtained using the logistic (Schaeffer) and Gompertz models with 6 and 8 year average effort. The Gompertz curve with an 8 year averaging period most closely approximated the data and the estimated MSY was 19,683 metric tons with a corresponding effort of 3930 days fished and a catch per unit effort of 5.01 tons per day.

Introduction

The Subarea 5 redfish fishery first became important in the mid-1930's with the development of midwestern American markets for frozen fillets. Catch and effort data date back to 1942, and the exploitation history is an interesting example of the interaction of a slow-growing species and its fishery. Unlike many of the important stocks in this area, the redfish continue to be exploited mainly by US fishermen. US catch rose from 519 metric tons in 1934 to 59,783 tons in 1941, and subsequently declined, reaching 30,077 tons in 1951, 11,375 tons in 1960, and 8,690 tons in 1974. Recent catches from nations other than the US increased the total to 20,034 tons in 1971, dropping slightly to 17,360 tons in 1973.

In this paper the biology of the species and the history of the fishery are reviewed, and finally the present status of the stock is examined.

Biology

Distribution

The redfish (Sebastes marinus) is found in the Western North Atlantic from West Greenland to south of Georges Bank (Templeman, 1959). Two types of Sebastes marinus have been observed on both sides of the Atlantic. Both forms, according to Templeman, are abundant only in areas where temperatures between 3° and 8° C exist at depths between 200 and 500 meters. Redfish are reported by Bigelow and Schroeder (1953) from depths as shallow as 20 meters along the coast of the Gulf of Maine and as deep as 500 meters along the southern slope of Georges Bank. In areas from the Grand Banks northward, however, redfish are found only in deeper waters and are abundant only at depths below 200 to 300 meters where the suitable temperatures are to be found.

In general, Sebastes marinus mentella Travin inhabits the deeper water while Sebastes marinus marinus (L.) is found in shallower waters. In the Northwest Atlantic the mentella type is found in the deeper, warmer waters while the marinus type is found in the overlying layer of colder water. In the Eastern North Atlantic the mentella type inhabits the deeper colder water while the marinus type is found in the shallower layer of warm water (Templeman, 1959). It is most likely that the mentella type is the more abundant form in the Subarea 5 commercial fishery.

Growth

Age and growth studies of redfish from the Northwest Atlantic have been reported by several authors (Kelly and Wolf, 1959; Perlmutter and Clarke, 1949; Sandeman, 1961). The redfish is an extremely slow growing, long lived fish compared to other species. The reported growth rates vary considerably, but generally older fish were found in the more northern areas. Data from Sandeman (1961) indicate a slight increase in length up to about 50 years in fish taken off Southern Newfoundland. The maximum observed size in this study was 39 cm for males and 42 cm for females. More recently, Parsons and Parsons (1974) reported maximum ages of 26 and 34 years and maximum lengths of 44 and 53 cm for males and females respectively in the 1972 Polish commercial fishery in divisions 2J and 3K.

In the Gulf of Maine, Kelly and Wolf (1959) noted ages up to 20 plus years and maximum observed lengths of 35 cm for males and 40 cm for females. Some of the 20 plus fish in their sample may have been considerably older than 20 years, as the observed lengths of these fish were not much smaller than those observed by Sandeman. The authors also state that definitive growth was still evident after 20 years. The maximum observed lengths of redfish in the US commercial catch in the present study were 40 and 44 cm for males and females respectively.

Both Kelly and Wolf, and Sandeman found similarities in the relative growth of males and females. Growth rates were similar for both sexes up to 10 years. After this point females continued to grow at a rapid rate while the male growth curves were more asymptotic. In both studies, the female growth curves approached a higher asymptotic value than the male growth curves.

According to Perlmutter and Clarke (1949), redfish in the Gulf of Maine reach maturity in about nine years at an average length of 22 to 23 cm. Their studies also indicate that growth during this period is almost linear with slight decreases in the year to year increments between ages seven and nine years. The age at maturity is almost identical to the age at which differential growth between sexes becomes apparent.

Using the data of Kelly and Wolf, Beverton (1965) calculated estimates of L_∞ and K for Subarea 5 redfish. The L_∞ values range from 38 to 42 cm and the K values from 0.09 to 0.14. Beverton also calculated a mean selection length (L_c) of 21 cm. This value is also similar to the average length at maturity reported by Perlmutter and Clarke in their study of immature redfish. Present US commercial length samples indicate a mean selection length of between 22 and 24 cm.

As a result of the redfish's longevity and extremely slow growth rate, many year-classes are found in the population, and a virgin stock will tend to accumulate many large, older individuals.

Reproduction

Redfish are viviparous, retaining eggs in the ovary after fertilization until yolk sac absorption. In the Gulf of Maine, larvae are extruded from May to August with maximum larval concentrations appearing in the surface waters in July and August. Water temperature at the time of larval extrusion varies between 3° C and 9° C (Bigelow and Schroeder, 1953) Redfish fecundity, according to Leim and Scott (1966), is between 25,000 and 40,000 young per female per year. Templeman (1959) states that the ripening of the male testis occurs months before the ripening of the ovaries in the females. He postulates that females and males accumulate near the bottom in the late summer and early autumn before and during the period of copulation. Sorokin (1961) describes in detail the gametogenesis and the shift in maturity index of Barents Sea redfish. Sorokin proposes that mating takes place in August and September, followed by fertilization in February and March and spawning or extrusion of larvae in April and May.

Larval redfish remain in the upper layers throughout July and August. In September, according to Kelly and Barker (1961), a significant change in depth distribution occurs, the larvae moving to the colder waters below the thermocline. The length of the majority of the larvae during this period of movement from the surface layer was between 15 and 40 mm.

Food habits

Redfish are known to feed primarily on crustaceans, especially mysids, and euphausids, and some molluscs. Steele (1957) noted that the diurnal variation in the vertical distribution of redfish in the Gulf of St. Lawrence was correlated with distribution of *Meganyctiphanes norvegica*. This euphausid constituted the principal food item of redfish from this area. Information from *Albatross IV* research cruises in the Gulf of Maine indicate that over 98% of the food organisms in non-empty redfish stomachs were euphausids.[1]

Behavior

Redfish inhabit rocky or mud bottoms. They rise to feed on their pelagic prey primarily at night, but ambient light levels and food species pursued are important in determining the time and extent of this movement (Steele, 1957). The seasonal cycle of sexual development also influences movement. Prior to and during fertilization in the fall both sexes became more available on the bottom (Steele, 1957). Templeman (1959) concluded that females were more pelagic during the winter-spring period as the embryos developed, and that they moved into deep water during the spring-summer spawning period.

Redfish appear to be very localized in distribution. A population at Eastport, Maine, studied by Kelly and Barker (1961) appeared to have remained in the same area since 1956. Up to 64% of the fish marked in July, 1956 were recaptured. Steele (1957) found large differences in growth rates among different populations of redfish from the Gulf of St. Lawrence. The related Pacific ocean perch (*Sebastes alutus*) is also reported to form localized aggregations with specific biological characteristics (Gunderson, 1972; Westrheim, 1974). Similarly, *Sebastes flavidus* in Southeastern Alaskan waters appears to form localized populations and even to display a remarkable homing ability (Carlson and Haight, 1972).

Commercial fishery

Historical aspects

The redfish fishery in ICNAF Subarea 5 was conducted almost exclusively by US vessels until 1971. From 1971 through 1973, 19 to 31% of the total was taken by other countries. The fishery

[1]Arvidson, L. Unpublished manuscript, NMFS, Woods Hole, MA, USA 02543.

commenced in 1916 with US vessels landing 53 metric tons. Catches averaged less than 100 metric tons until 1934 when a dramatic increase occurred, culminating in a maximum yield of 59,783 metric tons in 1941 (Table 1, Figure 1). This increase was due to new freezing techniques that led to the development of "ocean perch" markets in the US midwest.

During this period of expansion in Subarea 5, effort was also directed towards a fishery in Subarea 4. Substantial increases in the Subarea 4 catches occurred after catches from Subarea 5 had begun to decline. Subarea 5 catches had peaked in 1941 with the fishery shifting to the central Gulf of Maine. With effort diverted to the Subarea 4 fishery, catches there rapidly rose to a maximum of 83,315 metric tons in 1951. Meanwhile, the Subarea 5 catches had dropped to 30,077 tons. In the same year, US vessels landed 13,562 metric tons of redfish from Subarea 3 indicating further expansion of the US fishery to more productive grounds. The US Grand Bank redfish fishery in Subarea 3 quickly rose to 33,114 metric tons in 1953, but has since been a minor contributor to overall US redfish landings.

In Subarea 5 US redfish catches have declined from the 1941 maximum to only 8690 metric tons in 1974. Between 1968 and 1971, there was a brief reversal of this trend, but since 1971 the decline has continued. The Subarea 4 catch has also declined to a level approximately equal to the Subarea 5 catch.

Participation in the Subarea 5 redfish fishery by countries other than the US began in 1958 with 4 metric tons caught by Canadian vessels. Since then, USSR and Canada have been the main non-US participants in this fishery. Recently the total redfish catch by all countries other than the US had increased to 5938 metric tons in 1972 and 5406 metric tons in 1973 (Table 1).

Within Subarea 5, the major portion of US redfish landings have come from Division 5Y; other catches, however, are taken primarily from Division 5Z (Table 2). Recent increases in the latter catches, particularly from the USSR, have increased the total Subarea 5 redfish catch to approximately 20,000 metric tons in 1971 and 1972. The total catch declined to 17,360 metric tons in 1973.

In the beginning of the Subarea 5 fishery, the major redfish ports were Boston and Gloucester. Recently, however, there has been a shift in landings to Portland and Rockland.

US catch per unit effort data are available for the period 1942 to 1973. The index was calculated for all trips landing 50% or more redfish at the ports of Portland, Rockland, and Gloucester. Prior to 1964, catch and effort information was not available in any finer vessel tonnage classification than less than 500 gross tons. The catch per unit effort index calculations did not take into account differences in the fishing power of the various vessel sizes. This information is available from 1964 to the present and is included in a later section. However, for comparative purposes, annual catch per unit effort indices for this later period were calculated in the same manner as the indices for the years prior to 1964. Since redfish are generally fished only during daylight hours, the effort values for these trips are doubled to approximate a 24-hour fishing day before being divided into the catch. The catch per effort index is thus expressed in terms of a 24-hour fishing day.

The total US effort and total effort for Subarea 5 (Table 3, Figure 1) is calculated by dividing the total catch values by the corresponding US catch per effort index for each year.

The catch per effort index declined from 6.9 metric tons per day in 1942 to 3.3 tons per day in 1949. Effort had remained nearly constant (largely between 8000-9000 days fished), and this drop in catch per effort reflected the fishing up of an accumulated stock of many old fish. A contraction of the Subarea 5 fishery began that continued almost uninterrupted until 1968. The catch per effort index increased very slowly between 1950 and 1964, averaging about 4 tons per day and varying between 3.2 tons per day in 1950 to 5.3 tons per day in 1962. Effort was being rapidly reduced in Subarea 5 during this period, particularly between 1952 and 1956 when expansion into Subareas 3 and 4 was occurring. The redfish stocks seemed to be recovering from the high effort levels of the 1940-1950 period. The nearly linear decrease in catch with effort is a further demonstration of the slow recovery time. The general trend in the 1950-1960 retraction period was a proportional drop in catch and effort so that the catch per effort index remained nearly stable (Table 3, Figure 1).

In 1965 a sharp rise in the catch per effort index accompanied by a drop in total effort occurred, culminating in a peak value of 14.7 tons per day in 1968. The index has since declined to 5.0 metric tons per day in 1974, a level comparable to the long-term average.

Recent trends

US commercial fishery statistics from 1964 to 1973 were analyzed to determine probable causes for the recent sharp rise and subsequent decline in the Subarea 5 catch per effort index (Figure 1). This departure from the long-term average may be related to changes in fishing patterns of the fishery or to changes in abundance of redfish stocks in the Gulf of Maine as a response to reduced fishing.

Using the depth zone fished recorded for each trip, the contribution to the total catch from each depth zone was summarized for each year. The data presented in Table 4 indicate that most redfish are taken from depths between 111 and 274 meters. Little significant change occurred between 1964 and 1973 except for the increased contribution from the unknown depth category which was a result of reduced interviewing of vessel captains. Taking this into consideration, the following conclusions can be drawn. The catch from the shallow inshore areas has remained fairly constant (about two percent) in relation to the total catch. Of the remaining catches, about 20 percent were taken in depth zone 4 and 80 percent from depth zone 3 consistently throughout these years. Very small amounts were taken in deeper waters.

Within the Gulf of Maine, the major redfish catches are taken from the deeper areas in the central basin and the southern portion off Cape Cod. Between 1964 and 1973 these two areas (represented by statistical areas 515 and 521 respectively) have accounted for 65 to 85 percent of the total US Subarea 5 catch.

The fishery in the central Gulf of Maine is conducted by vessels whose average catch is greater than 80% redfish. Consequently, the redfish catch per unit of effort from this area is considerably higher than other areas in the Gulf. Vessels fishing in the southern and coastal areas typically land catches consisting of between 10 and 40 percent redfish. Recently there has been a slight increase in the percentage composition of redfish per trip from the southern portion of the Gulf.

Although there have been shifts in the relative proportion of redfish caught in the central and southern areas between 1964 and 1973, no major trends are evident. In 1968, when the catch per effort index rose to its maximum value, the overall fishing pattern in Subarea 5 was similar to that existing in 1973. However, the distribution of directed redfish trips (catching 50% or more redfish per trip) in 1968 was considerably different. In this year, and in the years immediately preceding and following, most of the directed effort and catch was associated with statistical area 515 in the central Gulf.

The high catch per effort values in those years may be partially attributable to the disproportionate influence of the trips from this area. However, since the catch per effort of the trips within statistical area 515 also rose and declined between 1964 and 1973 in a pattern similar to the overall index, a true change in redfish abundance is indicated by these data.

The number of redfish directed trips as well as the total number of trips in which any redfish were caught underwent a sharp decline and subsequent increase between 1964 and 1973. Minimum values for both data sets occurred in 1968. The total US catch and the catch from directed trips showed a gradual rise during these years with peak values in 1971 (Figure 2a). The data for Subarea 5 show a sharp decline in directed redfish effort coupled with fluctuating catches between 1964 and 1968. The resulting catch per effort index consequently rose sharply until 1968 when effort began to increase with the increased catches. Data for the US fishery in Subarea 4 show an almost identical pattern with minimum effort values in 1969.

The seasonal distribution of catch and effort in the Gulf of Maine for the years 1964 to 1973 is presented in Figure 2b. Catches were highest from February to July with the maximum present in April. The frequency of directed redfish trips follows a pattern similar to that of the catch, while the frequency of the total trips in which redfish are caught remains fairly constant throughout the year.

The monthly catch per unit of effort indices show similar seasonal trends with highest values generally occurring in April, May, and June. In addition, the ratio of redfish catch to the total catch is highest during this period. These data suggest that the major portion of the redfish catch in Subarea 5 is taken from late winter to early summer.

The US catch and effort data for Subarea 5 summarized by vessel tonnage class are presented in Table 5 for the years since 1964. These data include the major portion of the fleet fishing for redfish in the Subarea. The catch per effort statistics are only for directed redfish trips which fished in depth zone 1 to 7, while the catch was taken to include all trips landing redfish from all depth zones. The percentage figures represent the proportion of the total Subarea 5 catch landed by each vessel class.

From these data, it is evident that, within a year, the catch per effort of the larger vessels is generally greater than that of the smaller vessels. It is also evident that, except for the smaller vessels, the catch per effort values of all vessel classes rise to a maximum in 1968 and decline thereafter. Catch statistics also show that a greater proportion of the catch was taken by the larger vessels in the later years. In 1968, when the catch per effort indices of the larger vessels were highest, over 80% of the total catch was landed by larger vessels between 151 and 310 gross tons.

During the period 1966 to 1973, when the overall catch per unit effort index was above the long-term average, the percentage of the total catch taken by the larger vessels was relatively high. Thus, when the catch and effort data of these vessels was combined with those of the entire fleet, the catch per unit effort index was weighted in favor of these larger, more efficient vessels. However, since the catch per unit effort of these larger vessels rose and fell in a pattern similar to the overall index, the change in the overall index cannot be attributed solely to changes in size composition of the redfish fleet. A true shift in redfish abundance is indicated by these data.

Between 1964 and 1973 the US Subarea 5 redfish fishery underwent a contraction and subsequent expansion. Effort in terms of days fished and number of trips declined sharply from 1964 to 1968. Most of the catch was landed by a small number of larger vessels fishing intensively in a few areas, predominantly in the central Gulf of Maine. The catch per unit effort index rose sharply during the period of contraction partially as a result of increased stock abundance and as less efficient vessels discontinued fishing for redfish.

In 1969 the fishery began to expand again, and as landings and effort both increased, the catch per unit effort index began to decline.

Length frequencies

US Subarea 5 commercial length frequency samples were examined to determine sex ratios, average lengths and weights, and length frequency distribution of the catch from 1965 to 1974. The average length of males and females in the samples were used to compute the corresponding average weight using the equation: $W = 0.0000180 \; L^{3.132}$. The average weights and the number of fish of each sex sampled gave estimates of the weight by sex and the sex ratios in the samples. The sex ratios were then used to estimate the total annual landings for each sex which, divided by the corresponding average individual weight by sex estimated the annual number of males and females landed (Table 6). Average lengths from 1942 to 1964 and length frequency distributions from 1958 to 1964 have been presented by Brown and Hennemuth.[1]

The average length of males declined from 26.7 cm in 1942 to 24.0 cm in 1961, but has since risen to 28.6 cm in 1974. Female average lengths have undergone a similar decline and rise (Table 6, Figure 3). The recent period from 1964 to the present is characterized by a steady increase in the average size of fish landed.

The sex ratio of numbers landed from 1965 to 1974 shows a shift from a predominance of males to a predominance of females. Chi-square tests on the sample sex ratios indicate highly significant ($P = 0.01$) differences in all years except 1966, 1967, and 1968. In 1967 the sex ratio difference was significant only at the 95% probability level, while in 1966 and 1968 there was no significant difference at this level. Recent landings have been dominated by a relatively high proportion of large females. The weight ratio of females to males between 1971 and 1974 was approximately 2 to 1.

US commercial length frequency data for the years 1965 to 1974 (Figure 4) reflect some recruitment trends. Most of the fish were between 22 and 38 cm; however, some fish as small as 13 cm and as large as 45 cm were present in the samples. Most of the males were between 22 and 32 cm, while the slightly longer females were generally between 25 and 38 cm.

---

[1]Brown, B. E. and R. C. Hennemuth, 1965. Report on Redfish Abundance. Lab. Ref. No. 65-2, NMFS, Woods Hole, MA, 02543, USA. 14 pp. Mimeo.

Between 1965 and 1969 the modal lengths of males increased from 24 to 28 cm. The distribution in 1970 was multi-modal with peaks at 24, 26, and 28 cm. From 1971 to 1974 the distribution remained fairly uniform with a single dominant mode at 28 cm; the distribution in 1974 also showed evidence of incoming recruits between 13 and 20 cm.

The female length frequencies are more varied with several modes appearing in most years. However, the general trend is similar to that of males. Modal lengths tended to increase from 27-30 cm in 1965 to 31-34 cm in 1969. In 1970 the appearance of smaller fish shifted the overall distribution downward. Beginning in 1971, the distribution became increasingly uni-modal until 1974 when the majority of the females were between 32 and 36 cm.

The approximate ages represented in the catch were determined from age and growth data presented by Kelly and Wolf (1959). Males were present in the catches between ages 5 and 20+ years, with the majority between 8 and 17 years. Females were evident from age 6 to 20+ years but were abundant only between ages 8 and 20+ years. The modal lengths of males and females in 1974 correspond to ages 13 and 15 years respectively.

The length data for the recent period of 1971 to 1974 contrast markedly with those presented by Brown and Hennemuth for the period 1958 to 1964 by the predominance of larger males and females. The length frequencies and the average length data lend strong evidence that the fishery is currently being sustained by the presence of yearclasses which were recruited between 1966 and 1969. Thus it appears that recruitment has been relatively poor since.

Research vessel surveys

Data from USA research vessel survey cruises were also used to determine annual changes in abundance and length composition of the Subarea 5 redfish stocks. Fall cruise data from 1963 to 1974 were utilized to compute the stratified mean number per tow and length frequencies. A preliminary analysis of average size of redfish from the various sampling strata in the Gulf of Maine for the past ten years indicated the presence of at least two different size groups. Consequently, the abundance indices and the length frequency summaries were calculated separately for two different strata sets. Only those strata in Subarea 5 in which redfish were consistently sampled between 1963 and 1974 were used in the analysis.

One strata set consisting of strata 26, 27, 39, and 40 represents the shallow coastal areas with a maximum depth of 110 meters. The second set was composed of strata 24, 28-30, and 36-38 in the central basin and the channel between Georges Bank and Nantucket Shoals. Depths in these strata exceeded 111 meters. Together, these two strata sets represent every redfish fishing area in Subarea 5.

The length frequency data confirm the presence of two distinct size compositions although fish of all sizes were present to some extent in both sets (Figure 5). In the coastal strata, the distribution was uni-modal with the mode in the various years falling between 14 and 19 cm. After 20 cm, the number per tow dropped rapidly indicating relatively low abundance of the larger fish. The deeper strata showed a multi-modal length distribution of redfish with modal values varying between 19 and 36 cm throughout the years. Movement of redfish from the shallow coastal areas to the deeper offshore strata is indicated by a scarcity of fish larger than 20 cm inshore and by a similar lack of fish below this length in the offshore area. The second observation is not as consistent as the first since, in a few years, good numbers of redfish between 16 and 20 cm were evident in the survey catches from the offshore strata.

The size differences in terms of catch per tow from the inshore and offshore strata appear to be useful in indicating relative magnitude of future recruitment to the commercial fishery and further analysis may allow the development of pre-recruit indices. The progression of the modal lengths from 16 cm to 19 cm between 1963 and 1965 inshore and the subsequent appearance of 19 cm and 20 cm fish offshore in 1967 and 1968 indicates offshore movement of larger redfish. A similar pattern is indicated in 1969 and 1970. Between 1971 and 1974, the progression of modal lengths from 6 cm to 17 cm shows the presence of small fish in the inshore strata in above average numbers. These fish also became evident in the offshore survey catches in 1973 and 1974 and in the commercial catches in 1974 (Figure 4). Fish from this group will probably form a major component of the harvest of the fishery in the next few years since no new group of fish below 14 cm can be seen in either 1973 or 1974.

Because of differences in the average size of redfish in the two strata sets, I used the mean number per tow instead of the weight per tow as an overall abundance index. These data illustrate a similar pattern of increases in offshore areas following increases in inshore areas (Table 7, Figure 6b). In 1965 and 1966 high catch per tow indices are evident in the inshore strata. During the following two years the inshore index declined sharply while the offshore index showed a comparable rise in abundance. An identical pattern occurred in 1969 and 1970. Both fluctuations agree with the results obtained in the length frequency analysis previously discussed. The years 1965, 1966, and 1969 showed above average catches inshore and below average catches offshore. In 1968 and 1973 the inshore catches were below average.

The overall index for both strata sets combined follows the same general pattern exhibited by the commercial catch per effort index for Subarea 5 (Figure 6a). Both indices show a rise in redfish abundance from 1964 to a peak in 1968, with a subsequent decline thereafter. Survey data further illustrate that the increase in abundance can be attributed to four successive years from 1963 to 1966 of above average survival.

Present status

The total catch and effort data for the years 1942 to 1973 are illustrated in Figures 7 through 10. The individual data points indicate a number of distinct groupings during this period. The first in 1945-49 occurred during a period of declining catch per effort and stable total effort, while the second (1954-60) exhibited stable catch per effort and declining effort. In both cases increases in catch and effort follow increases in the catch per unit effort that accompanied decreasing effort. The periods terminate with declining catch per unit effort and effort. The present fishery is at the end of a third, longer period which began in 1964, and like the first consists of declining catch rates while effort remains steady.

The relationship between catch and effort was examined using the generalized stock production model (Pella and Tomlinson, 1969) in which any particular curve is determined by the value of the parameter, M. Two special cases of this model were used in this analysis. The Schaeffer curve (Schaeffer, 1954, 1957) has the M value fixed at 2.0, while the Gompertz curve (Fox, 1970) has M equal to 1.0. The PRODFIT fitting procedure (Fox, 1975) is used here, and equilibrium catches are approximated by relating the annual catch per unit effort to the average fishing effort for a number of previous years equal to the average duration of a yearclass in the fishery (Gulland, 1969).

In a preliminary assessment of Subarea 5 redfish, Gulland (1961) used a 3-year and a 6-year averaging period. He found no relationship between catch per unit effort and effort using the 3-year period and a slight relationship using the 6-year average. His data only covered the period 1935-1955 when catch per effort was relatively constant.

The commercial sample data presented above suggests the presence of between 10 and 12 yearclasses in the major portion of the length frequency distributions. Since yearclasses will recruit to the fishery at various ages due to differences in growth rate, the average duration of the exploited phase of a single yearclass may be somewhat less than the number of yearclasses found in the fishery. Consequently, the Schaeffer and the Gompertz models were run with 6-year and 8-year average total effort fitted to the annual catch per unit effort between 1942 and 1973 (Table 3). The total effort was calculated by dividing the total catch by the US catch per unit effort index. Linear correlation coefficients of the regression of catch per effort versus effort using the Schaeffer model (0.62 for the 6-year average, 0.66 for the 8-year average) indicate a slightly better fit with the 8-year averaging period (Figure 7). The calculated residual sum of squares was highest using the Schaeffer model with a 6-year average and lowest with the Gompertz model and an 8-year averaging period (Table 8). A stock composed of many yearclasses and many small pockets of fish that require searching does not seem likely to be reduced with excessive effort as fast as the Schaeffer model would predict. Based on these considerations, the results obtained by using the Gompertz model should be closer to the true relationship.

Equilibrium yield versus effort curves (Figures 9 and 10) were derived by multiplying the predicted catch per effort values by the corresponding total effort. Estimates of the maximum sustainable yield (MSY) and the corresponding effort (F_{opt}), and catch per unit effort (U_{opt}) as determined from each curve are listed in Table 8. The MSY values derived from the Schaeffer curve were 35% higher than those estimated from the Gompertz for the 6-year and the 8-year averaging periods. Both sets of yield curves show that the fishery was above equilibrium from 1938 to 1952. The peak catch in 1941 was three times higher than the MSY estimated using the Gompertz and two times higher than the MSY estimated using the Schaeffer model. High ratios of peak catch to estimated MSY are characteristic of slow-growing, long-lived species. As Ricker (1973) points out, for species such as cod (Gadus morhua), and halibut (Hippoglossus) it is well recognized that sustainable yield is likely to be half or less than half of the early maximum catch.

The Gompertz model with an 8-year averaging period (the curve with the smallest residual sum of squares) estimated a maximum sustained yield of 19,683 metric tons with a corresponding fishing effort of 3930 days fished. The estimated U_{opt} value at this point on the equilibrium curve is 5.01 metric tons per day fished, a value equal to the 1974 landings per day index (Table 2).

Since the yield curves derived from both the Gompertz and the Schaeffer models indicated a 12-year period was needed for the yield to fall from the maximum to the equilibrium curve under the stable effort levels existing from 1941 to 1952, a 12-year averaging period was also applied to the effort data from 1942 to 1973. In addition, the data from 1952 to 1973 (after the period of initial expansion) were examined using the Gompertz and Schaeffer models with 8 and 12-year averaging periods. The results obtained from these analyses (Table 8) indicate slightly lower MSY and F_{opt} values and higher U_{opt} values than the previous analyses.

Using the 12-year average and the full set of catch and effort statistics results in very little change in the MSY and F_{opt} values. However, employing the data from 1952 to 1973 only results in greatly reduced estimates of these parameters and higher estimates of U_{opt} since the initial period of high yield was excluded from the analysis. Linear correlation coefficients for the regression of catch per unit effort versus average effort using the 1952 to 1973 data only (0.520 for the 8-year average, 0.554 for the 12-year average) indicate a poorer fit than those resulting from using the full data set from 1942 to 1973.

Discussion

In the early phase of the redfish fishery, high catches were supported by an accumulated virgin stock composed of perhaps 20 yearclasses. Given the long lifespan and low natural mortality reported for this species (Davis and Taylor, 1957), it is likely that older redfish comprised a relatively large proportion of the biomass at this time. Peak catches in 1941 and 1942 were two to three times above the estimated MSY, and rapidly declined in subsequent years. This pattern is characteristic of long-lived, slow-growing species when exploitation builds up as rapidly as it did between 1934 and 1941. Redfish distribution is commonly believed to be of a clumped nature, with large aggregations of fish inhabiting localized areas. The catch per unit effort during the expansion and initial contraction phase of the fishery, therefore, remained high as fishermen moved from one relatively unexploited aggregation to another. By the late 1940's the accumulated biomass in each of these pockets had been exploited and catch per unit effort dropped sharply. The fishery continued to expand, however, as effort was directed into Subarea 4.

During the long period of declining catches, the redfish stocks were apparently recovering from the initial phase of high exploitation. This relatively long period of recovery is an indication of the slow response of redfish to changes in level of exploitation, and of the many yearclasses in the stocks.

In 1966, as a result of the gradual rebuilding of the stocks, the yield rose slightly above the equilibrium curve, but at a much reduced level of effort. The yield then rose to a new maximum in 1971 and fell below equilibrium once again in 1972 and 1973. Recent catches have been approximately equal to or slightly below the estimated MSY. Although the recent catch per unit effort indices are equivalent to the values during the early period of high exploitation, the stock structure is considerably changed. During the expansion phase, the average age of the stocks declined as the accumulation of older individuals was being fished. The average age during the recent period (1964-1973), however, is increasing as a result of the slow rebuilding.

Although the recent catch per unit effort indices are comparable to the early period of the fishery, the total redfish stock size in Subarea 5 has been reduced since the rebuilding may have resulted in an increased abundance of redfish in only some of the localized pockets. The number of these localized aggregations may be less than what existed in the virgin population. Hence, the contracted fishery fishing these pockets of high abundance will still show relatively high catch rates.

Recent research cruise length frequency evidence indicates improved future recruitment to the fishery in 1975 and 1976 compared with the 1970-1974 period, but little evidence of recruitment beyond these years can be seen.

Gulland's (1961) assessment of the Subarea 5 redfish stocks indicated an MSY of approximately 40,000 metric tons. However, because Gulland was only able to utilize data from 1935 to 1955, the resulting equilibrium curve was based almost entirely on catch and effort data from the initial period of high exploitation. The present estimate of approximately 20,000 metric tons is more appropriate, in light of the recent trends in catch and effort.

Recent effort and catches appear to be close to equilibrium under the Gompertz model of population growth. However, a word of caution should be noted. When the model is restricted to that fit to the data for the recent period of 1952 to 1973, effort in the period 1971 to 1973 is estimated to be between 30 and 46 percent above the MSY level although the current catches are not excessive.

Literature cited

Beverton, R. J. H. 1965. Catch/effort assessment in some ICNAF fisheries. Int. Comm. Northw. Atl. Fisheries Res. Bull. No. 2: 59-72.

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. US F&WS Fish. Bull., 53: 430-437.

Carlson, H. R. and R. E. Haight. 1972. Evidence of a home site and homing of adult yellowtail rockfish, Sebastes flavidus. J. Fish. Res. Bd. Can. 29: 1011-1014.

Davis, W. S. and C. C. Taylor. 1957. Optimum exploitation of Gulf of Maine redfish as indicated by a simple population model. ICNAF, ICES, FAO Joint Sci. Meet., Lisbon, Contr. 31 pp. Mimeo.

Fox, W. W. 1970. An exponential surplus yield model for optimizing exploited fish populations. Trans. Am. Fish. Soc. 99(1): 80-88.

________. 1975. Fitting the generalized stock production model by least squares and equilibrium approximation. Fish. Bull., US 73(1): 23-37.

Gulland, J. A. 1961. A note on the population dynamics of the redfish with special reference to the problem of age determination. Int. Comm. Northw. Atl. Fisheries. Spec. Publ. No. 3: 254-257.

________. 1969. Manual of methods for fish stock assessment. Part 1. Fish population analysis. Food and Agr. Org., UN. pp. 120-126.

Gunderson, D. R. 1972. Evidence that Pacific Ocean perch, Sebastes alutus, in Queen Charlotte Sound form aggregations that have different biological characteristics. J. Fish. Res. Bd. Can. 29: 1061-1070.

Kelly, G. F. and R. S. Wolf. 1959. Age and growth of the redfish, Sebastes marinus, in the Gulf of Maine. Fish. Bull., US, 60: 1-31.

Kelly, G. F. and A. M. Barker. 1961. Vertical distribution of young redfish in the Gulf of Maine. Int. Comm. Northw. Atl. Fisheries. Spec. Publ. No. 3: 220-233.

Kelly, G. F. and A. M. Barker. 1961. Observations on the behavior, growth, and migration of redfish at Eastport, Maine. Rapp. et. Proc. Verb., Vol. 150. Cons. Internat. Explor. de la Mer. : 263-275.

Leim, A. H. and W. B. Scott. 1966. Fishes of the Atlantic Coast of Canada. Fish. Res. Bd. Can., Bull. No. 155: 338-340.

Parsons, L. S. and D. G. Parsons. 1974. Some observations on Subarea 2 + Divisions 3K, Divisions 3L-N, and Division 30 redfish. Inter. Comm. Northw. Atl. Fisheries. Res. Doc. 74/79.

Pella, J. J. and P. K. Tomlinson. 1969. A generalized stock production model. Inter. Amer. Trop. Tuna Comm., Bull. 13(3): 421-496.

Perlmutter, A. and G. M. Clarke. 1949. Age and growth of immature rosefish, Sebastes marinus, in the Gulf of Maine and off Western Nova Scotia. Fish. Bull., US, 51: 207-228.

Ricker, W. E. 1973. Two mechanisms that make it impossible to maintain peak-period yields from stocks of Pacific salmon and other fishes. J. Fish. Res. Bd. Can. 30: 1275-1286.

Sandeman, E. J. 1961. A contribution to the problem of the age determination and growth rate in Sebastes. Int. Comm. Northw. Atl. Fisheries Spec. Publ. No. 3: 276-284.

Schaeffer, M. B. 1954. Some aspects of the dynamics of population important to the management of the commercial marine fisheries. Inter-Amer. Trop. Tuna Comm. Bull., 1(2): 25-56.

________. 1957. A study of the dynamics of the fishery for yellowfin tuna in the Eastern Tropical Pacific Ocean. Inter-Amer. Trop. Tuna Comm. Bull., 2(6): 245-285.

Sorokin, V. P. 1961. The redfish; gametogenesis and migration of the Sebastes marinus (L.) and Sebastes mentella Travin. Int. Comm. Northw. Atl. Fisheries. Spec. Publ. No. 3: 245-250.

Steele, D. H. 1957. The redfish, Sebastes marinus (L.), in the western Gulf of St. Lawrence. J. Fish. Res. Bd. Can. 14(6): 899-924.

Templeman, W. 1959. Redfish distribution in the North Atlantic. Fish. Res. Bd. Can., Bull. No. 120, pp. 1-173.

Westrheim, S. J. 1974. Length-weight relations of Pacific Ocean perch, Sebastes alutus, in the North Pacific Ocean. J. Fish. Res. Bd. Can. 31: 363-366.

Table 1. Total landings of redfish by country from ICNAF Subarea 5 (metric tons, live).

Year	Canada	USSR	Poland	Other Non-US	Total Non-US	USA	Subarea 5 Total
1934						519	519
1935						7549	7549
1936						23162	23162
1937						14823	14823
1938						20638	20638
1939						25401	25401
1940						26762	26762
1941						59783	59783
1942						55892	55892
1943						48348	48348
1944						50439	50439
1945						37912	37912
1946						42423	42423
1947						40613	40613
1948						43631	43631
1949						30743	30743
1950						34307	34307
1951						30077	30077
1952						21377	21377
1953						16791	16791
1954						12988	12988
1955						13914	13914
1956						14388	14388
1957						18490	18490
1958	4				4	16043	16047
1959						15521	15521
1960	2				2	11373	11375
1961	25	11			36	14040	14076
1962	3	1590			1593	12541	14134
1963	89	1086			1175	8871	10046
1964	56	445			501	7812	8313
1965	68	968	25	10	1071	6986	8057
1966	420	939	6		1365	7204	8569
1967	194		215	13	422	10442	10864
1968	197			2	199	6578	6777
1969	260	15	56	82	413	12041	12454
1970	338		30	839	1207	15534	16741
1971	269	3394	84	20	3767	16267	20034
1972	124	5639	1	174	5938	13157	19095
1973	68	5240	28	70	5406	11954	17360
1974	58	5000	2	23	5083[1]	8690	13773

[1] 1974 total non-US catch preliminary.

Table 2. Total catch of redfish from ICNAF divisions 5Y and 5Z (metric tons, live).

	5Y			5Z			
Year	U.S.	Other	Total	U.S.	Other	Total	Subarea 5 Total
1954	11561	-	11561	1427	-	1427	12988
1955	11132	-	11132	2782	-	2782	13914
1956	10678	-	10678	3710	-	3710	14388
1957	14471	-	14471	4019	-	4019	18490
1958	13900	4	13904	2143	-	2143	16047
1959	12438	-	12438	3083	-	3083	15521
1960	9321	2	9323	2052	-	2052	11375
1961	12457	-	12457	1583	36	1619	14076
1962	10196	-	10196	2345	1593	3938	14134
1963	6785	44	6829	2086	1131	3217	10046
1964	6137	2	6139	1675	499	2174	8313
1965	5045	51	5096	1941	1020	2961	8057
1966	4719	292	5011	2485	1073	3558	8569
1967	6746	75	6821	3696	340	4036	10857
1968	4062	22	4084	2516	177	2693	6777
1969	9640	25	9665	2401	314	2715	12380
1970	13551	159	13710	1983	1048	3031	16741
1971	12541	121	12662	3726	3466	7192	20034 (1)
1972	7150	94	7244	6007	5844	11851	19905
1973	7001	11	7012	4953	5395	10348	17360
1974	5464			3226			

(1) includes unallocated subarea 5NK catches

Table 3. Catch and Catch/Effort statistics (Metric Tons, live) and Effort (days fished) for Subarea 5 redfish.

Year	U. S. Catch	Calculated U. S. Effort	U. S. C/E	Non-US Catch	Total Catch	Calculated Total Effort
1942	55892	8100	6.9		55892	8100
1943	48348	7216	6.7		48348	7216
1944	50439	9341	5.4		50439	9341
1945	37912	8425	4.5		37912	8425
1946	42423	9026	4.7		42423	9026
1947	40613	8288	4.9		40613	8288
1948	43631	8080	5.4		43631	8080
1949	30743	9316	3.3		30743	9316
1950	34307	8368	4.1		34307	8368
1951	30077	7336	4.1		30077	7336
1952	21377	6108	3.5		21377	6108
1953	16791	4419	3.8		16791	4419
1954	12988	3820	3.4		12988	3820
1955	13914	3092	4.5		13914	3092
1956	14388	3270	4.4		14388	3270
1957	18490	4300	4.3		18490	4300
1958	16043	3646	4.4	4	16047	3647
1959	15521	3610	4.3		15521	3610
1960	11373	2984	3.8	2	11375	2993
1961	14040	3057	4.6	36	14076	3060
1962	12541	2322	5.4	1593	14134	2617
1963	8871	2164	4.1	1175	10046	2450
1964	7812	1817	4.3	501	8313	1933
1965	6986	998	7.0	1071	8057	1151
1966	7204	616	11.7	1365	8569	732
1967	10442	842	12.4	422	10864	876
1968	6578	447	14.7	199	6777	461
1969	12041	1056	11.4	413	12454	1086
1970	15534	1726	9.0	1207	16741	1773
1971	16267	2324	7.0	3767	20034	2862
1972	13157	2308	5.7	5938	19095	3350
1973	11954	2256	5.3	5406	17360	3275
1974	8690	1738	5.0	5083[1]	13773	2755

[1] 1974 non-US catch preliminary.

Table 4. US redfish catch (Metric tons, live) and percentages( ) by depth from ICNAF Subarea 5.

Depth zone	1	2	3	4	5	6	8	9	
Depth range (m)	0-55	56-110	111-183	184-274	275-366	367-549	Mixed	Unknown	Total
Year									
1964	24	180	5051	1625			50	882	7812
	(0.3)	(2.3)	(64.6)	(20.8)			(0.6)	(11.3)	(100.0)
1965	21	130	4253	868			78	1636	6986
	(0.3)	(1.9)	(60.9)	(12.4)			(1.1)	(23.4)	(100.0)
1966	17	71	4484	810	2		58	1758	7204
	(0.2)	(1.0)	(62.3)	(11.2)	(0.03)		(0.8)	(24.4)	(100.0)
1967	17	55	5434	1257	1		79	3599	10442
	(0.2)	(0.5)	(52.0)	(12.0)	(0.01)		(0.8)	(34.5)	(100.0)
1968	16	44	2410	736	6		184	3180	6578
	(0.2)	(0.7)	(36.6)	(11.2)	(0.09)		(2.8)	(48.4)	(100.0)
1969	9	46	3965	933	t	t	145	6942	12041
	(0.07)	(0.4)	(32.9)	(7.7)	(-)	(-)	(1.2)	(57.7)	(100.0)
1970	5	78	3416	539	t		236	11259	15534
	(0.03)	(0.5)	(22.0)	(3.5)	(-)		(1.5)	(72.5)	(100.0)
1971	15	218	8535	697	t	t	213	6587	16267
	(0.09)	(1.3)	(52.5)	(4.3)	(-)	(-)	(1.3)	(40.5)	(100.0)
1972	65	150	8421	1104	4	11	134	3268	13157
	(0.5)	(1.1)	(64.0)	(8.4)	(0.03)	(0.08)	(1.0)	(24.8)	(100.0
1973	32	187	8999	1201	8	4	124	1399	11954
	(0.3)	(1.6)	(75.3)	(10.0)	(0.07)	(0.03)	(1.0)	(11.7)	(100.0)

t = less than 1 metric ton.

Table 5. US redfish catch per effort and catch (Metric tons, live) and percentage of catch by vessel tonnage class from ICNAF Subarea 5.

Tonnage class	24	25	31	32	33	41	42	43	44
Tonnage (Gross tons)	23-33	34-50	51-72	73-104	105-150	151-215	216-310	311-440	441-500
1964									
C/E	3.46	3.56	4.21	4.33	4.70	5.16	7.29	---	---
Catch	285	902	1283	2341	1657	1308	67	---	---
%	3.6	11.5	16.3	29.8	21.0	16.7	0.9	---	---
1965									
C/E	3.96	5.76	6.68	6.70	6.89	9.06	8.63	---	---
Catch	26	804	1578	1763	1189	1309	310	---	---
%	0.4	11.5	22.6	25.2	17.0	18.7	4.4	---	---
1966									
C/E	---	10.52	10.68	9.27	2.70	13.60	17.32	---	---
Catch	25	568	1563	1915	349	2170	592	---	---
%	0.3	7.9	21.7	26.6	4.8	30.1	8.2	---	---
1967									
C/E	---	4.10	8.02	8.56	---	13.61	17.12	21.37	---
Catch	38	95	611	1496	283	4891	2165	766	---
%	0.4	0.9	5.9	14.4	2.7	47.2	20.9	7.4	---
1968									
C/E	---	---	1.62	2.48	1.48	15.27	29.65	18.37	---
Catch	22	34	132	155	323	3592	1813	503	---
%	0.3	0.5	2.0	2.4	4.9	54.6	27.6	7.6	---
1969									
C/E	---	---	7.90	6.52	7.64	12.97	14.36	18.22	12.93
Catch	47	61	182	1431	1045	5189	2322	922	795
%	0.4	0.5	1.5	11.9	8.7	43.2	19.4	7.7	6.6
1970									
C/E	---	4.70	4.19	4.67	6.82	8.47	10.18	12.12	16.48
Catch	178	574	388	1610	1609	5552	2802	2178	623
%	1.1	3.7	2.5	10.4	10.4	35.7	18.0	14.0	4.0
1971									
C/E	3.02	5.48	3.73	4.70	5.67	8.01	7.32	1.16	14.49
Catch	132	799	573	2533	1916	5234	2577	2163	308
%	0.8	4.9	3.5	15.6	11.8	32.2	15.9	13.3	1.9
1972									
C/E	---	4.72	3.25	5.09	3.58	6.33	8.08	9.24	12.05
Catch	89	664	318	2891	2198	4644	1289	1012	41
%	0.7	5.1	2.4	22.0	16.7	35.3	9.8	7.7	0.3
1973									
C/E	---	3.28	---	4.70	4.02	5.80	6.84	7.60	8.08
Catch	93	391	163	2234	3349	4031	1226	327	126
%	0.8	3.3	1.4	18.7	28.0	33.7	10.3	2.7	1.1

Table 6. Subarea 5 redfish landings by weight (Metric tons, live) and estimated numbers landed (1000's of fish) by sex.

	MALES				FEMALES				
	Est. Landings				Est. Landings				
Year	Metric tons	Number landed (1000's)	Mean Length (cm)	Mean Weight (lbs)	Metric tons	Number landed (1000's)	Mean Length (cm)	Mean Weight (lbs)	Sex Ratio 1/ Male/Female
1965	3124	17,409	24.3	0.40	3852	13,199	28.4	0.64	1.319
1966	2941	13,339	26.0	0.49	4134	13,126	29.1	0.69	1.016
1967	4074	17,685	26.4	0.51	6273	18,877	29.6	0.73	0.937
1968	2681	11,197	26.7	0.53	3892	11,374	30.0	0.75	0.984
1969	4456	17,827	27.1	0.55	7533	20,156	30.8	0.82	0.884
1970	5745	25,053	26.3	0.51	9786	29,584	29.6	0.73	0.847
1971	5470	18,019	28.8	0.67	10768	24,511	32.4	0.97	0.735
1972	4580	14,950	28.9	0.68	8550	18,223	33.1	1.03	0.820
1973	4193	15,543	27.7	0.59	7711	16,806	32.8	1.01	0.925
1974	2999	10,113	28.6	0.65	5673	11,295	33.8	1.11	0.895

1/ Calculated from Est. Number Landed.

Table 7. Stratified mean number per tow indices for Subarea 5 redfish from fall survey cruises of *Albatross IV*.

Year	Inshore[1] Strata	Offshore[2] Strata	Total[3] Gulf of Maine
1963	86.3	87.5	89.9
1964	81.4	122.4	116.3
1965	189.5	33.9	57.0
1966	172.8	77.8	91.9
1967	63.0	107.1	100.5
1968	41.1	161.3	143.4
1969	105.9	65.2	71.2
1970	18.2	107.2	94.0
1971	20.7	52.8	48.0
1972	36.4	58.9	55.6
1973	26.2	41.4	39.2
1974	44.2	49.0	48.3

1/ Strata 26, 27, 39, 40
2/ Strata 24, 28-30, 36-38
3/ Strata 24, 26-30, 36-40

Table 8. Estimates of Y_{max} (metric tons, live), F_{opt} (days fished), and U_{opt} (metric tons per day) for Subarea 5 redfish.

	Schaeffer Model (M = 2.0)			Gompertz Model (M = 1.0)		
Averaging period (years)	12	8	6	12	8	6
	Catch and Effort Statistics from 1942 to 1973					
Correlation coefficient	.66	.66	0.62			
Residual sum of squares	124.6	139.6	152.5	108.3	101.3	110.5
Maximum sustainable yield (Y_{max})	23,919	25,799	27,586	20,818	19,683	20,335
Optimum effort (F_{opt})	4,447	5,459	6,141	3,983	3,930	4,361
Optimum catch per effort (U_{opt})	5.38	4.73	4.49	5.23	5.01	4.66
	Catch and Effort Statistics from 1952 to 1973					
Correlation coefficient	.55	.52				
Residual sum of squares	91.5	62.5	---	94.5	56.8	---
Maximum sustainable yield (Y_{max})	17,888	17,008	---	17,346	15,590	---
Optimum effort (F_{opt})	2,317	2,339	---	2,407	2,135	---
Optimum catch per effort (U_{opt})	7.72	7.27	---	7.21	7.30	---

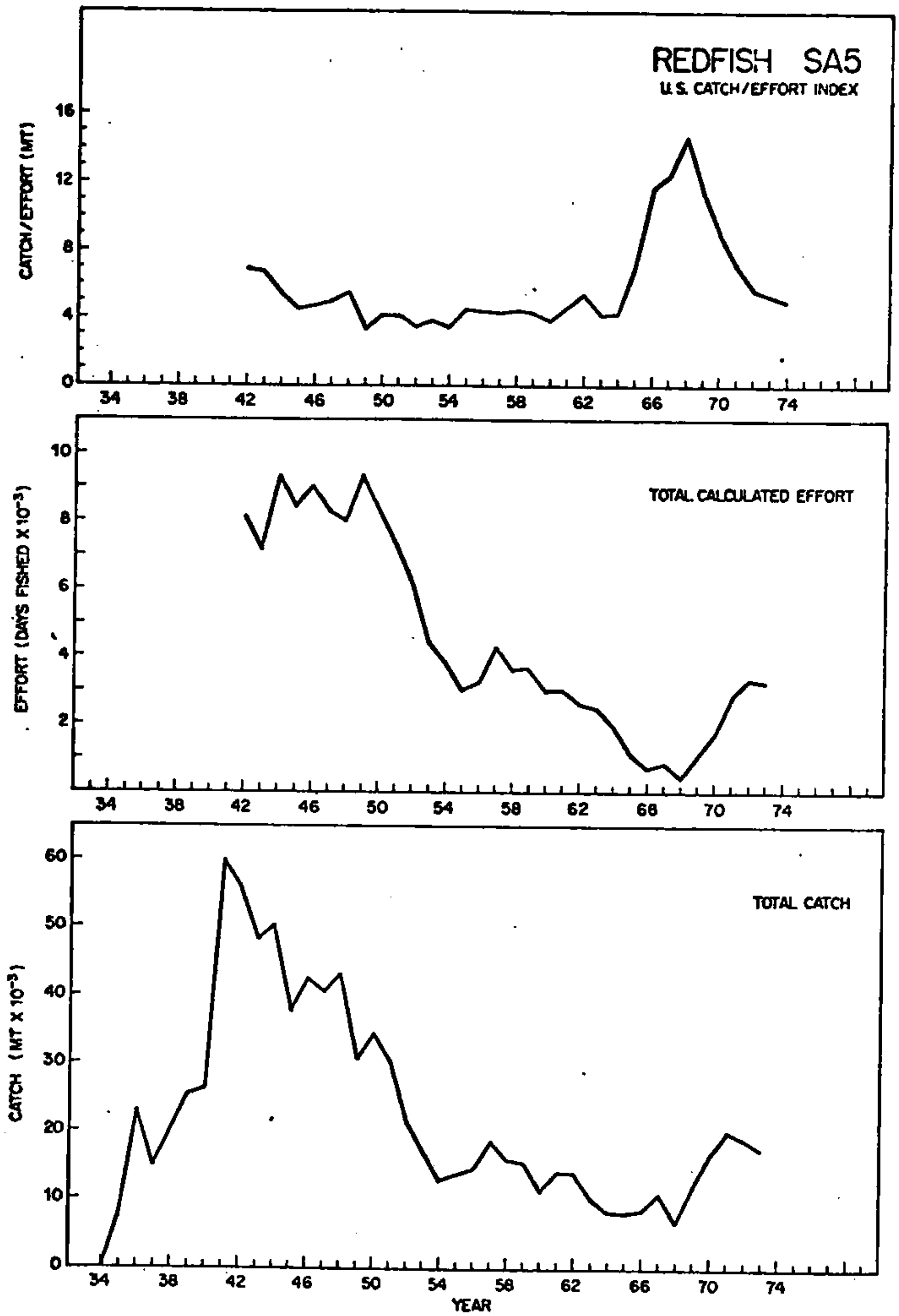


Figure 1. Total catch and effort and U.S. catch per unit effort for Subarea 5 redfish.

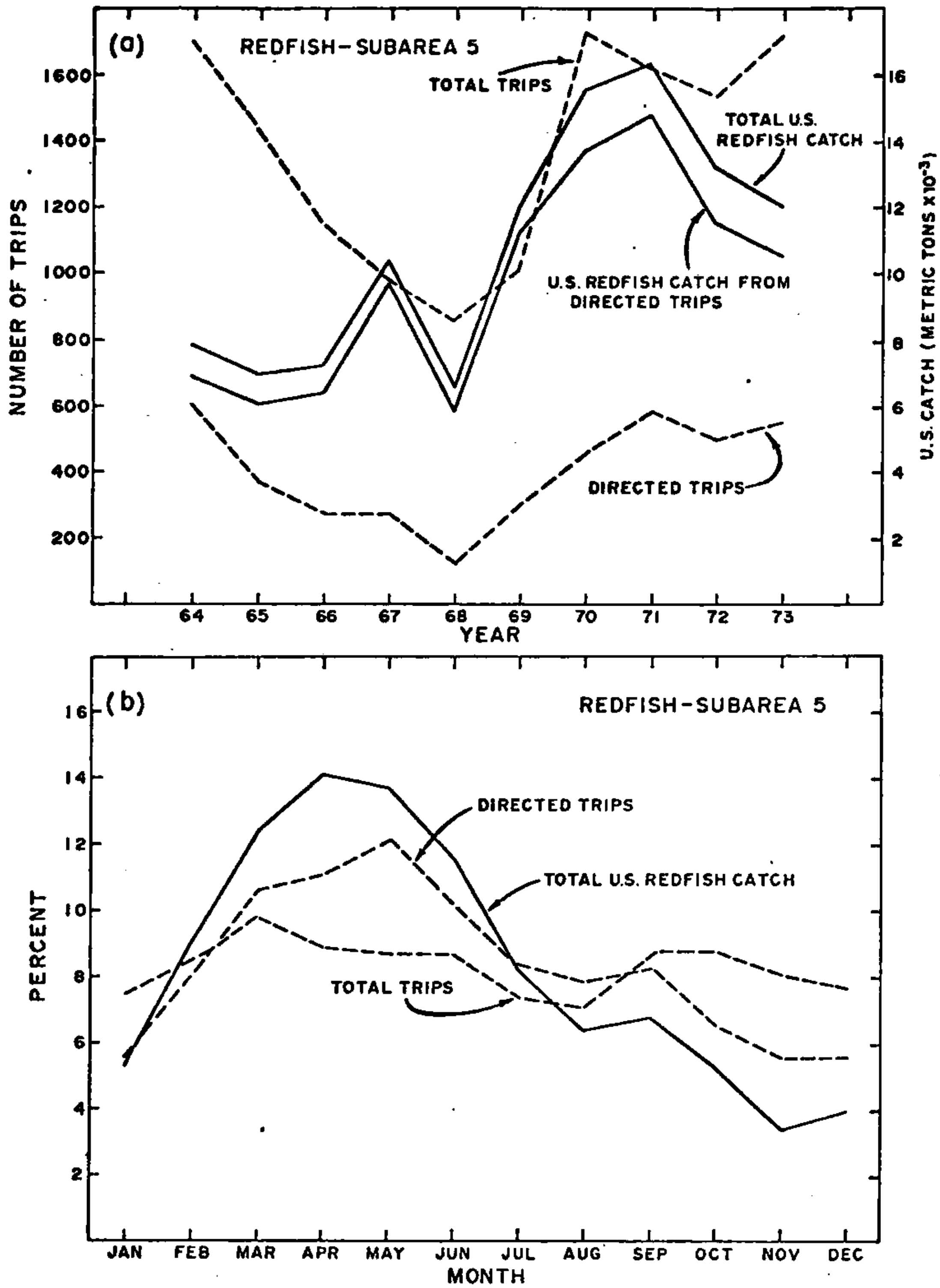


Figure 2. (a) Total number of U.S. trips in which redfish were caught, number of directed redfish trips (catching 50% or more redfish), and total and directed U.S. redfish catch from 1964 to 1973.

(b) Seasonal distribution of U.S. redfish catch and number of trips from 1964 to 1973 in Subarea 5.

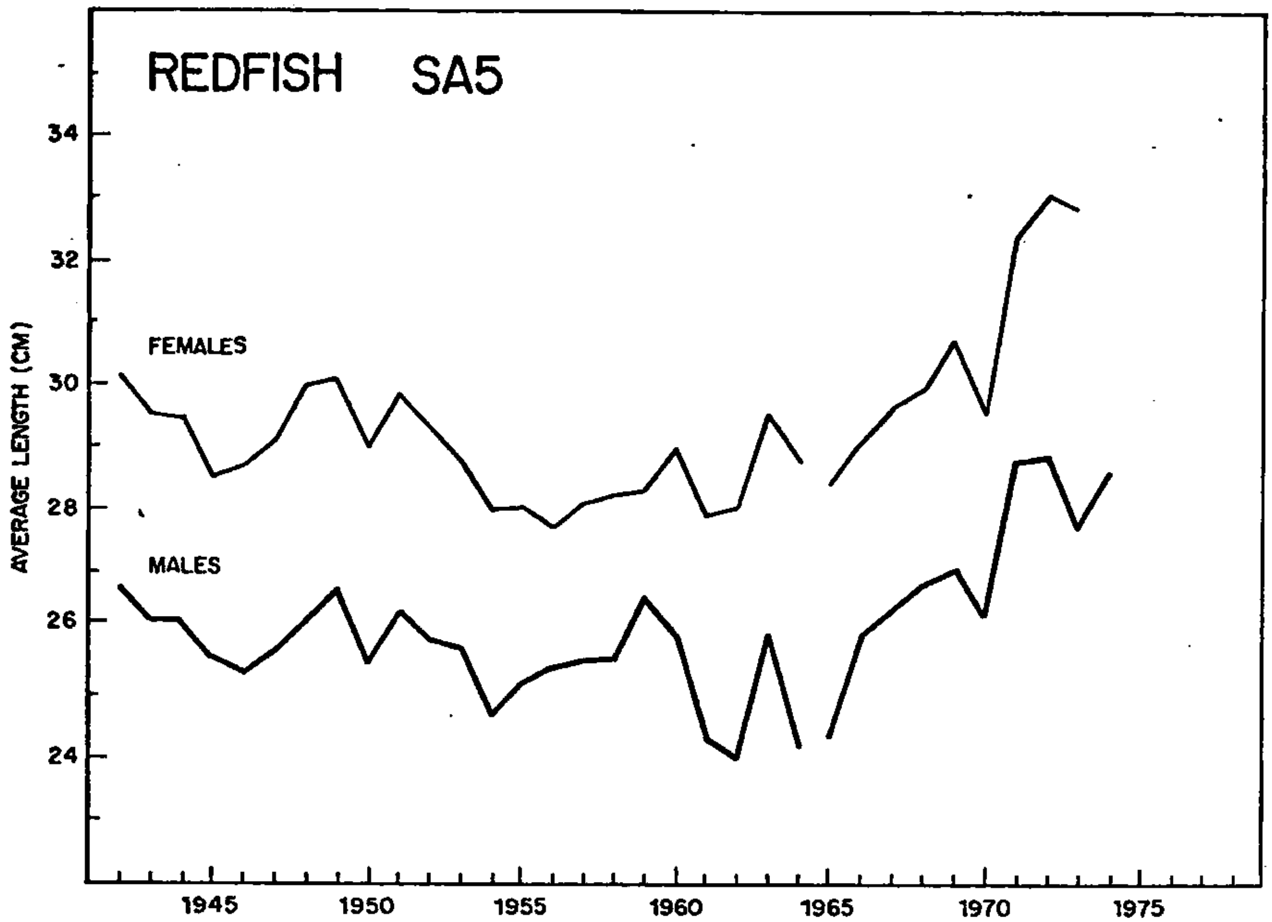


Figure 3. Average length of male and female redfish landed in the U.S. commercial fishery in Subarea 5. Data from 1942 to 1964 was taken from Brown and Hennemuth (cited in text).

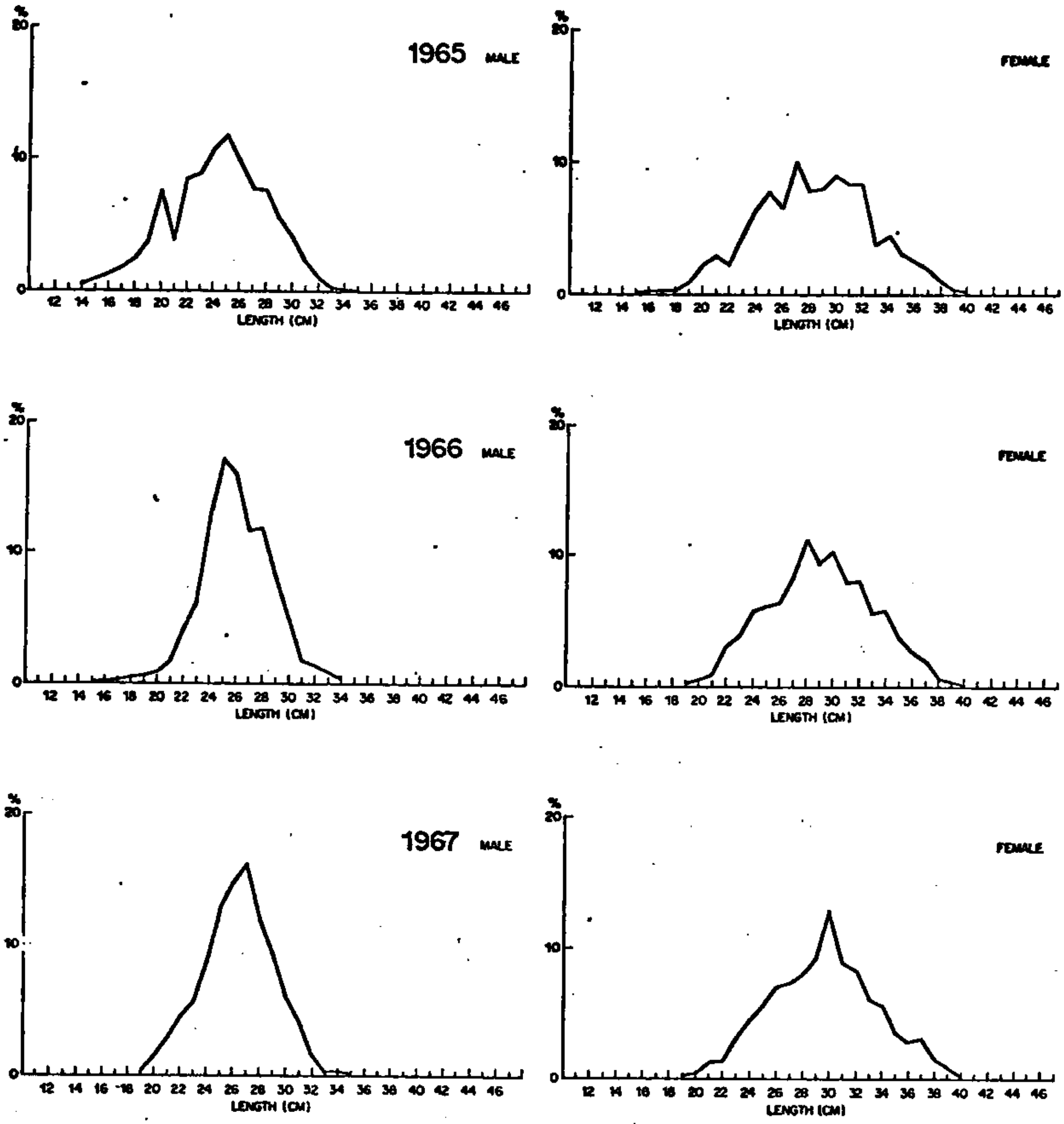


Figure 4. Length frequency distribution of male and female redfish landed in the U.S. commercial fishery in Subarea 5, 1965 - 1974.

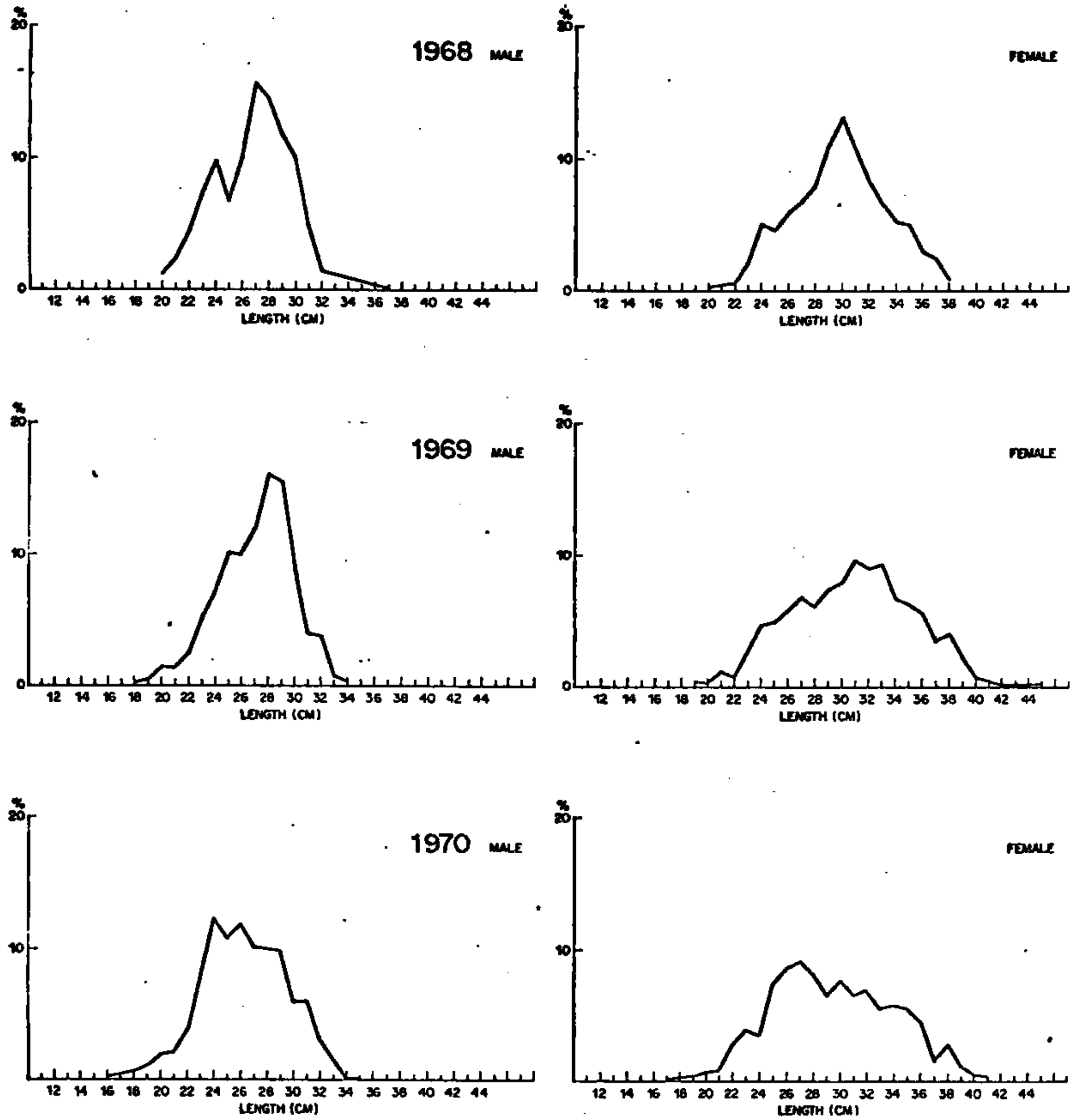


Figure 4. (Continued)

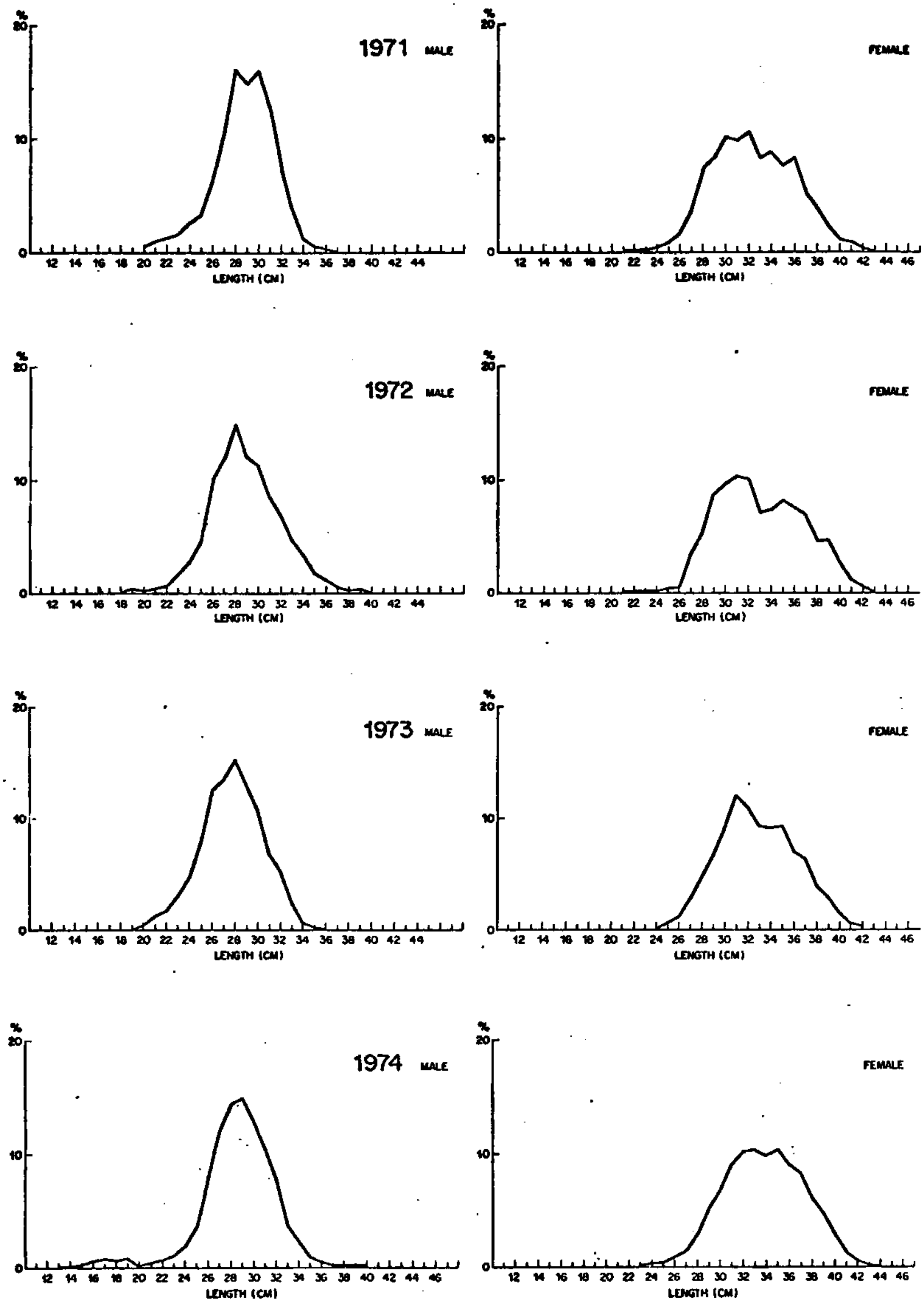


Figure 4. (Continued)

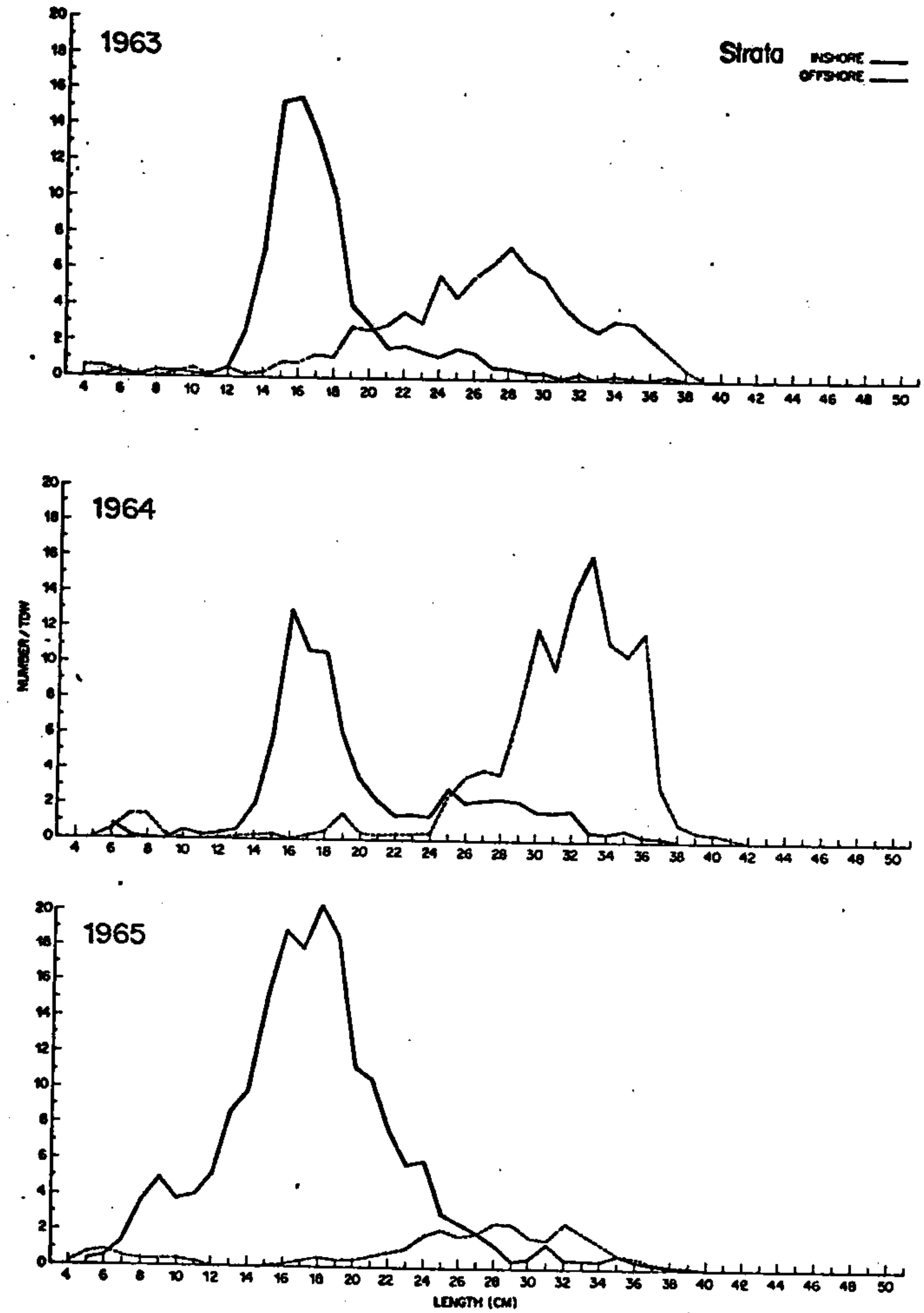
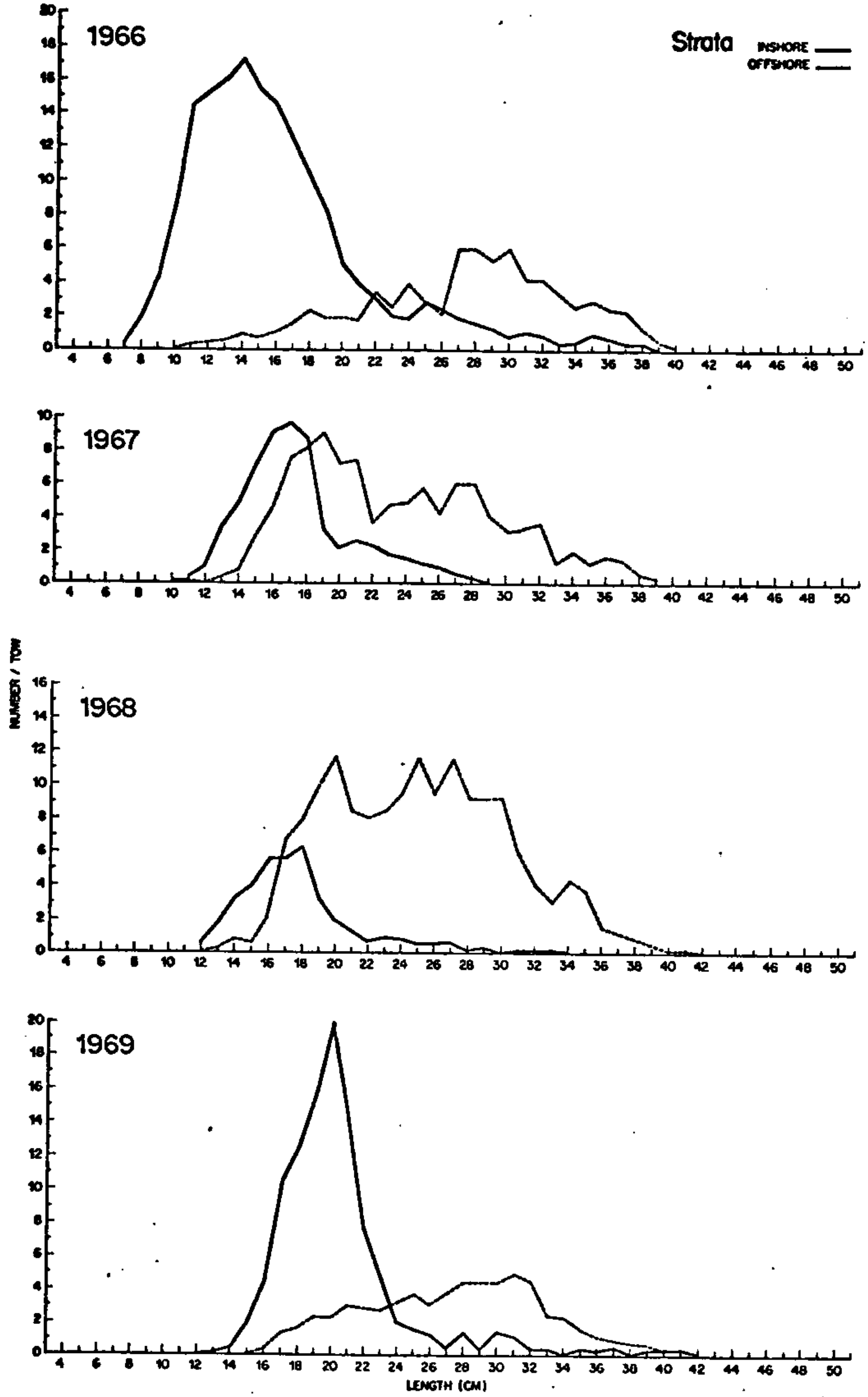


Figure 5. Autumn length frequency distributions of redfish caught by Albatross IV in Subarea 5 in inshore strata (26,27,39,40) and offshore strata (24,28-30,36-38) from 1963 to 1974.



Figuro 5. (Continuod)

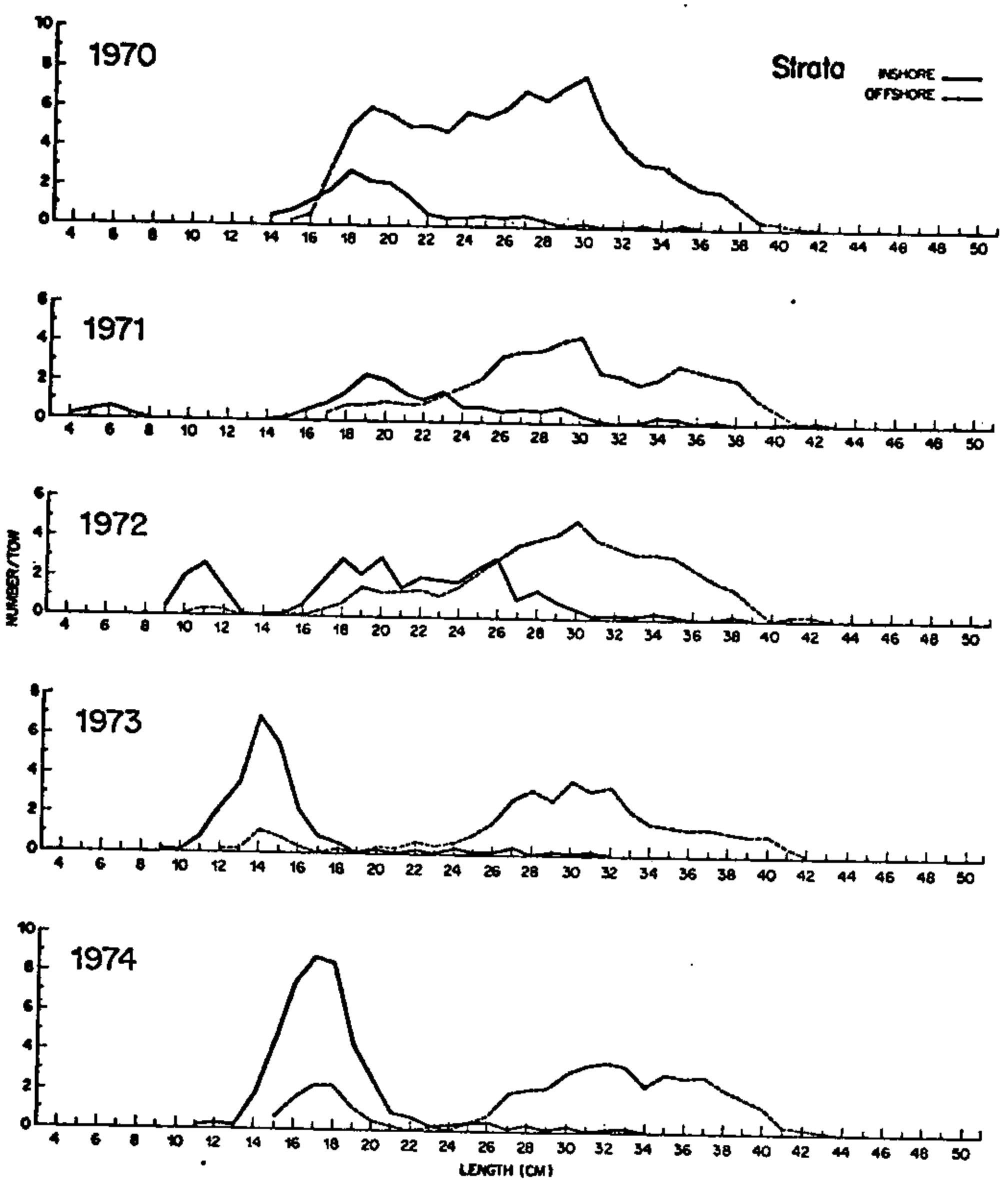


Figure 5. (Continued)

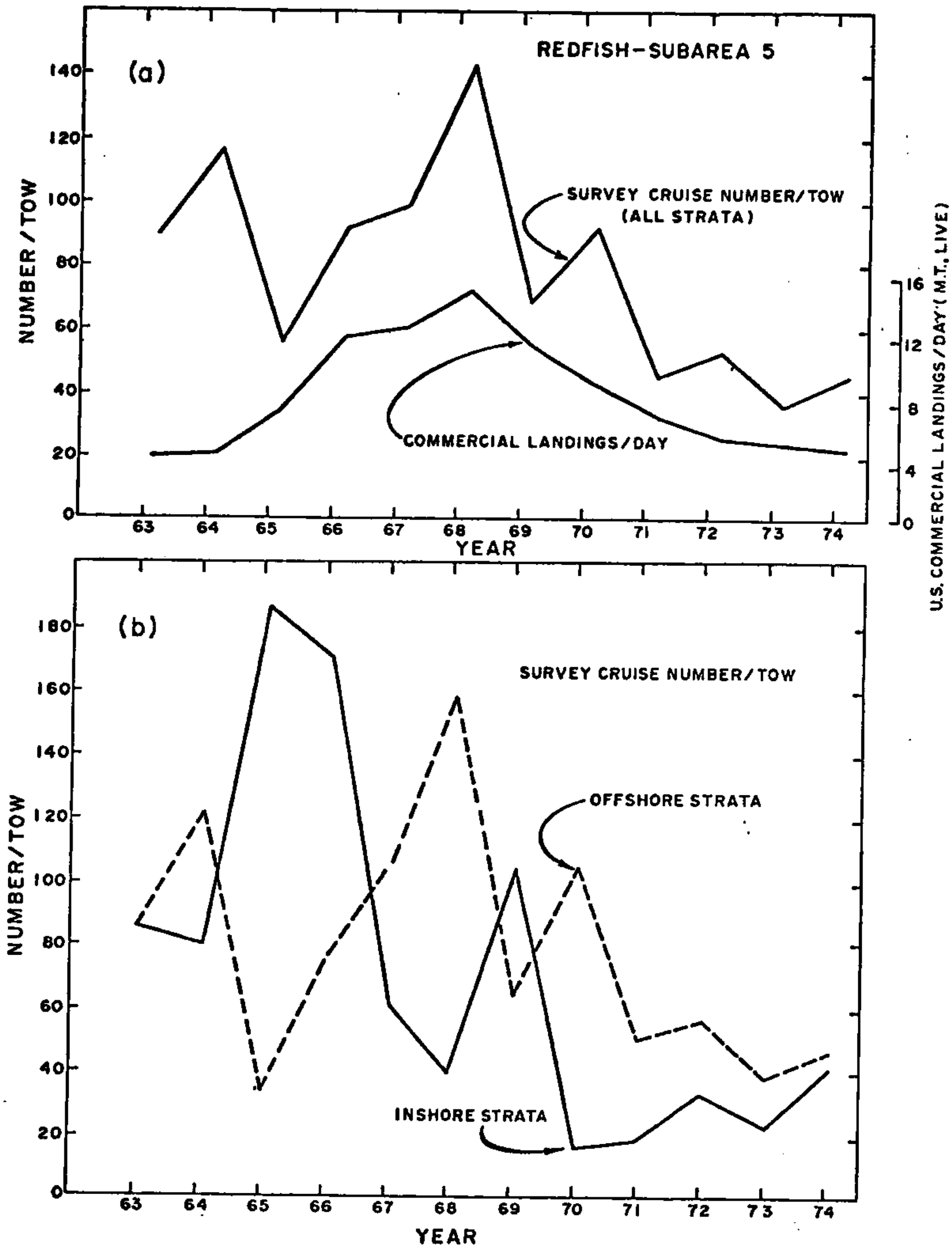


Figure 6. (a) Comparison between annual U.S. Subarea 5 commercial landings per day indices and autumn catch per tow indices by Albatross IV for all Gulf of Maine strata (24,26-30,36-40) from 1963 to 1974.

(b) Autumn redfish catch per tow indices from Albatross IV cruises in Subarea 5 from 1963 to 1974 for inshore strata (26,27,39,40) and offshore strata (24,28-30,36-38).

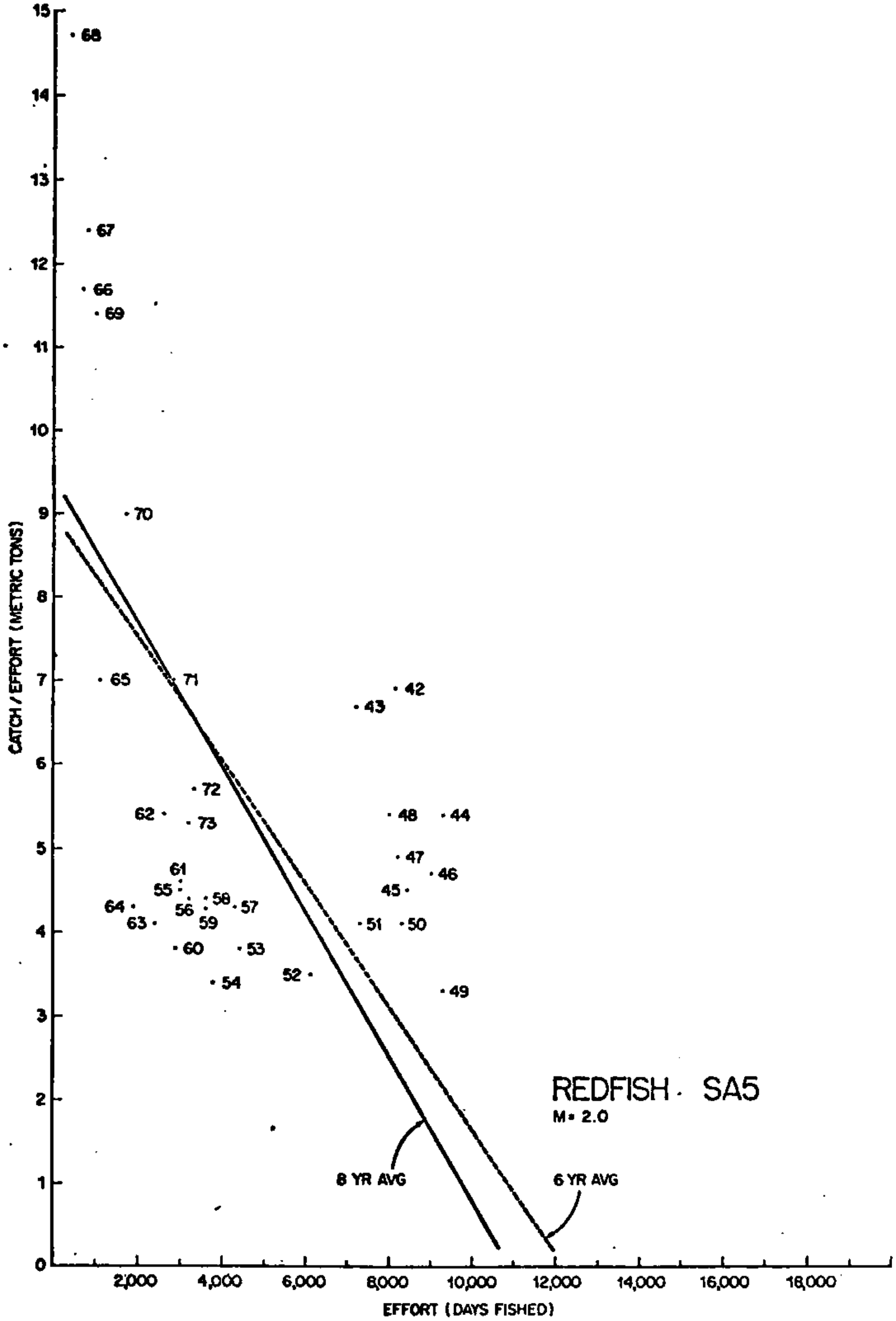


Figure 7. Regression of U.S. catch per unit effort versus calculated total effort using the Schaeffer model for Subarea 5 redfish.

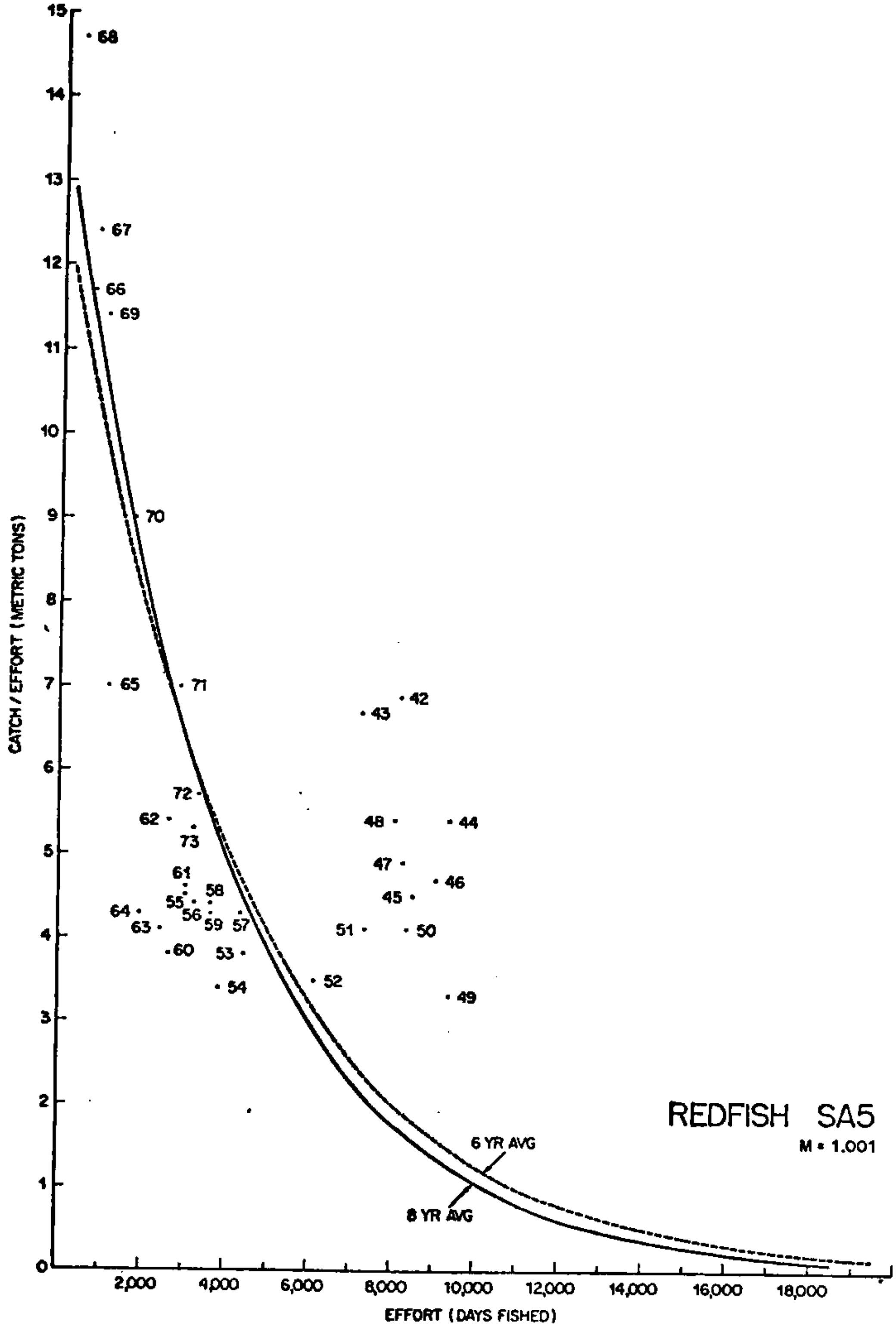


Figure 8. Regression of U.S. catch per unit effort versus calculated total effort using the Gompertz model for Subarea 5 redfish.

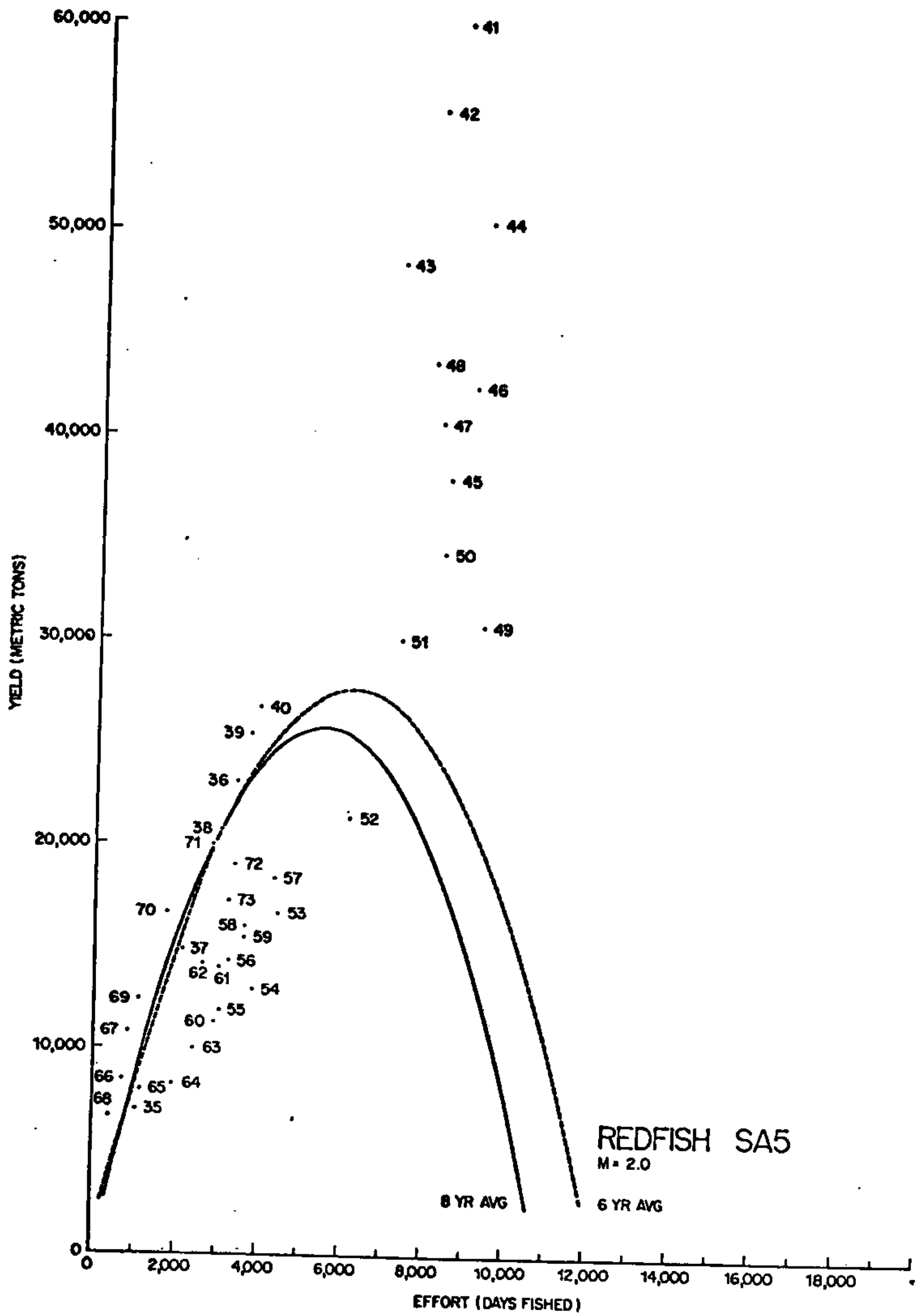


Figure 9. Yield curve derived from the relationship between U.S. catch per unit effort and calculated total effort using the Schaeffer model for Subarea 5 redfish.

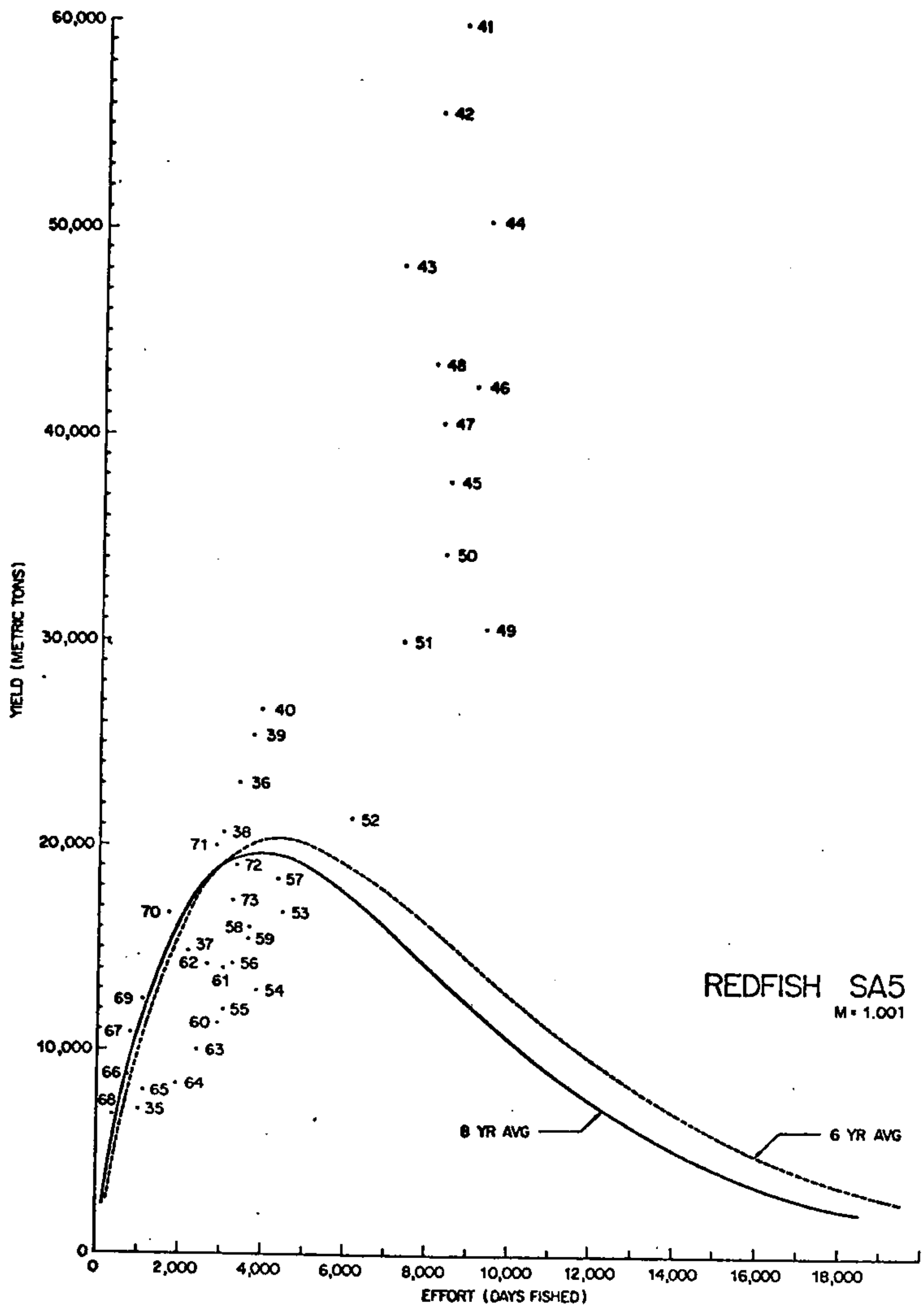


Figure 10. Yield curve derived from the relationship between U.S. catch per unit effort and calculated total effort using the Gompertz model for Subarea 5 redfish.