Restricted

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Serial No. 2835
(D.c. 9)

ICNAF Res.Doc. 72/119

ANNUAL MEETING - JUNE 1972

A Preliminary Evaluation of the Effects of Fishing on the Total Fish Biomass, and First Approximations of Maximum Sustainable Yield for Finfishes, in ICNAF Division 5Z and Subarea 6

Part I. Changes in relative biomass of groundfish in Division 5Z as indicated by research vessel surveys, and probable maximum yield of the total groundfish resource.

by M. D. Grosslein

Introduction

There has long been an interest in possible effects of heavy fishing on stability as well as productive capacity of the marine fish community as a whole. In fact, effects of fishing may extend to other biotic components of the marine ecosystem. However, since our understanding of the ecosystem is still rudimentary, we can only speculate on the probable nature and magnitude of such interactions. Study of the problem for fish populations alone has been hampered by the lack of accurate data on the composition and size of the total fish biomass. It is true that landings statistics have steadily become more complete and detailed as to species composition, but information on the ratio of removals to stock size has accumulated slowly and only for a few important commercial species.

Changes in catch per unit effort alone in relation to removals can provide some measure of the impact of fishing but commercial statistics do not provide reliable indices of relative abundance for more than a few species. A consistent measure of relative abundance for all species available to any given type of gear can only be obtained with a research vessel employing strictly standard fishing techniques, recording catches of all species, and sampling throughout the entire area of interest as well as locations where priority species are aggregated.

Groundfish surveys of this type have been conducted in New England waters by the U. S. A. research vessel Albatross IV since 1963, and the time series represented by these surveys provides some first approximations to the relative changes in standing crops of all components of the groundfish community. Survey data from Division 5Z are briefly reviewed in this paper in an attempt to assess the impact of recent fishing on the total groundfish resource, to determine whether there has been any significant shift in species composition of the groundfish biomass, and to estimate the total sustainable yield of the groundfish community as a whole.

METHODS

Specifications of the standard survey trawl and rationale for the stratified random sampling design used in the Albatross IV surveys have already been reported (Grosslein, 1968). Also, evidence has been presented for selected groundfish species that abundance indices derived from these surveys are of sufficient accuracy to monitor major changes in stock size (Grosslein, 1971; Halliday, et. al., 1971). Even in the case of certain pelagic species such as sea herring which are relatively unavailable to the standard Yankeee 36 survey trawl, there has been a correlation between trends in spring survey catches and decline in the Georges Bank stock (Anthony, 1972). Thus it appears that survey data can be relied on to indicate major changes in relative changes in fish biomass even when availability coefficients are small.

Only autumn (Oct. -Nov.) surveys are presented in this paper because they represent the longest unbroken time series available. Relative abundance indices are presented for two areas, Georges Bank (sampling strata 13-23, 25) and southern New England (sampling strata 1-12), (see Figure 1). These two areas taken together represent a major part of Division 5Z and part of 6A, but taken separately they do not correspond closely with subdivisions 5Z east and west. Stratum boundaries do not correspond exactly with statistical boundaries since they were chosen on the basis of biological communities rather than statistical areas. Stratum sets could be constructed to correspond more closely to statistical subdiviions but the given sets were available from another analysis, and taken together provide a reasonable measure of changes in 5Z.

Stratified mean catch in pounds per haul for each species was calculated for each stratum set for each cruise in the manner described by Grosslein (1971). The data are given in terms of catch per standard 30-minute haul, and no transformations were used in the computations (Tables 1 and 2). Emphasis is given to species in the ICNAF statistical category "groundfish and flounders" since these make up the bulk of fishes available to the Yankee 36 trawl. However, figures for skates, spiny dogfish, and all other finfish (mostly "pelagic" species) are also listed in Tables 1 & 2 to give a complete picture of all finfish combined. For comparisons of abundance indices with removals, total landings of comparable species or species groups from 5Z are given in Table 3 and are shown in Figure 2.

CHANGES IN RELATIVE BIOMASS OF GROUNDFISH IN RELATION TO REMOVALS

Principal Commercial Species

Estimates of fishing mortality rate, stock size and/or sustainable yields have been obtained for several of the major groundfish species in 5Z, notably cod, haddock, yellowtail flounder, silver and red hake, and these data have been summarized in reports of the Assessment Subcommittee. The survey data reported here adds no new information for these species, but the changes in survey indices are reviewed briefly to demonstrate that they are consistent with changes in stock size inferred from the most accurate commercial abundance indices available.

The precipitous decline in the Georges Bank haddock stock following heavy fishing in the mid-1960's and poor recruitment since 1963, is illustrated in figure 3. Haddock landings tripled from around 50,000 tons in the early 1960's to 150,000 tons in 1965, and the haddock survey index dropped from a peak of nearly 200 lb/haul in 1964 to less than 10 lb/haul in 1971, suggesting a reduction

116

in total haddock biomass on the order of 15-20 fold (Table 1). The apparent magnitude of this decline is considerably greater than indicated by comparisons of current estimates of available stock with estimates of stock size prior to onset of fishing by countries other than U. S. A. These latter estimates show a decline of roughly 7-fold from 145 to 21 million age 2+ haddock (Res. Doc. 72/1). However, it must be remembered that the exceptionally strong 1963 year class probably was fully available to the Albatross IV survey gear in 1964 when the peak survey abundance was recorded. Thus a 15-fold decrease in standing crop from 1964 to the present may be a fairly reasonable estimate of the actual decline in biomass over the last 7 years. The relative decline in haddock survey indices for southern New England was even more drastic, with the species all but disappearing from catches in that area (Table 2, Figure 4).

In the case of red hake there also seems to be a rather clear relation between increase in landings and decline in abundance. Landings increased from a few thousand tons in the early 1960's to over 80 thousand tons in 1966, and the catch per haul on Georges Bank surveys dropped from a high in 1963 of 17 lb/haul to about 1-1/2 lb/haul in 1967 (Tables 1 and 3, Figures 2 and 3). The survey indices are rather variable and the changes are not closely correlated with removals for individual years. Nevertheless the downward trend is significant suggesting a drop in biomass of at least 5-fold. Estimates of decline in red hake biomass in Division 5Z east based on U. S. S. R. data suggest a decline by a factor of about 10 (Res. Doc. 72/1). The U. S. S. R. data also showed about the same level of removals from Division 5Z west and Subarea 6 from 1965 to 1967. However, this level of harvest did not appear to reduce stock size nearly as much in the southern New England area, and this result was observed in the survey indices as well, with the minimum index in 1967 being little more than 1/3 the peak index observed in 1963 (Table 2, Figure 4). Removals in 5Z dropped to less than 20,000 tons in 1968, increased again to nearly 50,000 tons in 1969 and then dropped to only 10,000 tons in 1970 partly as a result of the closed area (Table 3). From 1968-1971, survey abundance indices on both Georges Bank and southern New England were higher than in 1967 suggesting a partial recovery in biomass, but the indices in both areas showed declines from 1969 to 1970 following the fairly heavy removals in 1969 (Tables 1 and 2).

Landings of yellowtail in 5Z were 15,000 tons in 1961, and then increased to about twice this level by 1963 and remained approximately at that level except for 1969 when they increased to 50,000 tons (Table 3). Survey indices indicated a decline in standing crop from 1963 to 1966 on southern New England grounds, followed by a recovery to about the same stock level as before (Table 2). However, a sharp drop in abundance in southern New England was noted in 1971 following continued high removals (50,000 and 35,000 tons in 1969 and 1970). On Georges Bank yellowtail abundance also declined from 1963 to 1966 and then recovered but only partially; abundance appears to be significantly lower now than in the early '60's (Table 1). Since yellowtail landings have been fairly stable, the apparent changes in relative stock size probably reflect changes in recruitment. For example, the recovery in abundance in southern New England after 1966 probably was due to the better than average recruitment of the 1965 year class as indicated by a high pre-recruit (I+) index in 1966 (Res. Doc. 72/1). In general, biomass of yellowtail in both areas has exhibited much less drastic change than either haddock or red hake, which indicates that the average level of removals in the last decade was more in line with the productive capacity of this flounder species than was the case for the two gadid species. However, the current assessment of the southern New England yellowtail population indicates that removals must be reduced because of low recruitment and excessive fishing (Res. Doc. 72/1).

Cod abundance indices on Georges Bank have shown no definite trend since 1963 even though 5Z cod landings doubled from 1963 to 1966, and thereafter remained at a level about 1-1/2 times that of 1963 (Tables 1, 3). The current assessment for Subarea 5 cod indicates that the 1970 level of removals is about the maximum sustainable yield for this stock (Res. Doc. 72/1). Thus for cod as for yellowtail, biomass appears to have been maintained in spite of increased fishing, but in the case of both species removals have been near levels of maximum yield per recruit. It might be noted however that in southern New England cod abundance dropped to its lowest recorded level in the 1971 survey suggesting that there is little basis for optimism (Table 2).

Of all the major groundfish species, silver hake show the least relationship between survey indices and removals. For example, Georges Bank indices were remarkably similar from 1964 to 1967 and yet landings in 1965 were more than double what they were in 1963. Survey abundance indices did recover somewhat in 1968 and 1969 on Georges Bank, after 5Z landings dropped off rapidly following the peak removals in 1965, but then catch per haul declined again in 1970 and 1971 (Table 1, Figures 2, 3). Variable recruitment and/or availability may be involved as well as above average sampling errors, and these factors have yet to be analyzed in detail.

In southern New England survey indices for silver hake showed a substantial drop in 1966 after the peak removals of 1965, then increased slightly in 1967 and 1968, and then dropped to their lowest levels in 1969 and 1970 - to about half the level of the period 1963-1965 (Table 2, Figure 4). Abundance appeared to increase slightly in 1971. However the average abundance in the last 3 years has been roughly half that observed in the period 1963-1965, suggesting that relative biomass of silver hake in southern New England has dropped 50 percent. That abundance must have declined is intuitively obvious in view of the substantial drop in landings at a time when total fishing effort remained at a high level.

<u>Other Groundfish Species</u>

I turn now to groundfish or flounder species which are intentionally fished by only a small portion of the total fishing fleet in 5Z, and are taken incidentally by the remainder of the vessels. Among this group are included white hake, winter flounder and other flounders (exclusive of yellowtail and winter flounder).

Recorded annual landings of white hake were small (less than 1,000 tons) throughout the decade and survey abundance indices on both Georges Bank and in southern New England were fairly stable although there is some indication of a decline in the latter area since 1968 (Tables 1-3). Winter flounder landings increased significantly after 1963, and in the latter part of the period were about twice as large as at the beginning. The relative abundance of winter flounder showed no consistent trend on Georges Bank but again the average catch per haul in southern New England was noticeably lower (about 50 percent lower) in later years. In the case of "other flounders," landings increased in about the same pattern as for winter flounder, and abundance indices declined in the later years to about 50 percent and 60 percent of the earlier levels in southern New England and Georges Bank respectively.

Other groundfish species for which there is relatively little intentional fishing are sculpins (chiefly longhorn sculpin), ocean pout and angler, which were lumped into the miscellaneous category of landings statistics until the mid-1960's (Table 3). These three species undoubtedly made up a significant proportion of the category "other groundfish" in the period 1961-65 but the actual quantity is unknown, and presumably even now there is someunknown quantity of discard. In any case there has been a major increase in the removals during the last decade, particularly for ocean pout and sculpins.

Recorded landings of ocean pout first became substantial in 1966, and they reached a peak of 25,000 tons in 1969 (Table 3). On Georges Bank there was a very prominent decline in survey abundance of ocean pout from an initial index of about 4-1/2 lb/haul in 1963 to 1/10 lb/haul by 1969, an apparent reduction on the order of 40-50 fold, and catch per haul remained at this very low level in 1970 and

1971 (Table 1). In southern New England decline in ocean pout survey indices was much less drastic but it was at least 50 percent (Table 2).

Sculpin landings were first recorded separately in 1966 and reached a peak of 10,000 tons in 1969 (Table 3). Catch per haul of longhorn sculpin on Georges Bank surveys fluctuated from year to year but there is indication of a modest upward trend, with average catch per haul in the last three years (1968-1971) nearly twice that observed in the first three years (1963-1965, Table 1). In southern New England, sculpin abundance indices increased from 1963 to 1966 and then leveled off (Table 2). In the case of Angler, recorded landings were negligible but survey indices on Georges Bank indicate about a four-fold decline in biomass from 1963 to 1971, and a 50 percent decline in southern New England (Tables 1-3).

The remainder of groundfish species are lumped into the category "other groundfish" and the landings statistics imply a very large proportional increase in 5Z removals of "other groundfish" since 1961 assuming that in the earlier years, sculpins, pout and angler were caught in about the same relative proportion to other groundfish as in later years (Table 3). Whether or not this is true it is difficult to relate landings of such a conglomerate of species to relative abundance changes. In any case Georges Bank survey abundance indices for the category "other groundfish" were about 50 percent lower in the latter half as compared with the first half of the period 1963-1971 (Table 1). In southern New England the decline was about 25 percent (Table 2).

Other Species

Among the species not included in the category "groundfish and flounders," skates and spiny dogfish are most available to the Yankee 36 trawl. Recorded landings of skates suggest a low rate of removal relative to what undoubtedly is a sizeable biomass, but discards may amount to considerably greater tonnage than the recorded landings. Survey abundance indices for all skate species combined show considerable year to year fluctuations on Georges Bank (attributable mainly to chance variation in catches of large individuals of barndoor skates) but there is a definite downward trend and average catch per haul in the last 4 years of the time series was 50 percent lower than in the first 4 years (Table 1). The apparent decline was even greater in southern New England where abundance indices in the latter part of the period were only 1/4 as high as in the early years (Table 2, Figure 4). Although the actual total removals of skates is unknown the decline in relative biomass of skates is not at all surprising in view of the tremendous increase in bottom trawling activity and the relatively low reproductive potential of these species.

Dogfish are essentially unexploited in ICNAF waters so far, and survey indices provide no evidence of any significant change in 5Z. On Georges Bank where dogfish are relatively scarce in autumn, the catch per haul figures were quite stable throughout the entire time series (Table 1, Figure 3). In southern New England where dogfish are concentrated in autumn, catch per haul values are highly variable because dogfish form such dense schools. No definite trend either up or down has yet been established even though three of the lowest values occurred since 1968 (Table 2, Figure 4).

The final group "all other finfish" shown in tables 1 and 2 represents mostly so-called pelagic species such as sea herring, round herring, alewives, mackerel, butterfish, etc., for which the survey trawl has very low efficiency. Since these are schooling species, trawl catches are extremely variable and hence the survey abundance indices vary widely from year to year. Not surprisingly there are no trends revealed either on Georges Bank or in southern New England for the "all other finfish" category, but it may be noted that relative abundance of the category is significantly higher in southern New England than on Georges B ank (Tables 1 and 2). It should be noted that the category "miscellaneous" shown in figures 3 and 4 includes all other finfish not listed in the figures. Landings of the major pelagic species are reviewed in Part II.

SUMMARY OF CHANGES IN RELATIVE COMPOSITION OF GROUNDFISH COMMUNITY

Of the major groundfish and flounder species which were the object of directed fisheries by one or more ICNAF countries in Division 5Z in the last decade, it appears that only two species, cod and yellowtail, have maintained a fairly stable biomass. The biomass of haddock appears to have declined to only 5-10 percent of its size 8 years ago, following heavy fishing and subsequent poor recruitment. Red hake and silver hake biomass declined at least by 80 percent and 50 percent respectively immediately after heavy removals in the middle 1960's, but then recovered partially with subsequent recruitment. No trend was observed for the standing crop of winter flounder on Georges Bank but biomass of this species appeared to drop about 50 percent in southern New England. Abundance of other flounders as a group (exclusive of winter flounder and yellowtail) apparently declined by 50 percent in both areas.

Among species taken incidentally by most vessels of ICNAF countries, ocean pout showed the most dramatic decline on Georges Bank to less than 5 percent of its abundance at the beginning of the survey series; a reduction of only 1/2 was indicated for southern New England. Skate biomass dropped by 50 to 75 percent on Georges Bank and in southern New England respectively, and angler abundance declined about the same degree but in the reverse order relative to area. Abundance of the miscellaneous category "other groundfish" also appeared to drop 50 and 25 percent on Georges and in southern New England. White hake biomass appeared to remain stable but recorded removals were minimal. Sculpin abundance appeared to increase throughout the decade and this was the only species for which biomass appeared to increase. Dogfish abundance showed no trends and there was no fishery for this species.

In a general sense then, the most obvious changes in the composition of the groundfish community have been the drastic reductions in haddock, ocean pout, and skates, moderate reductions in most of the other components, but relatively little change in cod, yellowtail, dogfish and sculpins.

There is no evidence of any species or group filling ecological niches opened up by reduction in biomass of major species. This is perhaps not surprising. Even if inter-specific competitive or prey-predator interactions did serve to help limit populations of certain species, these effects very likely would take more than a few years to manifest themselves because most major species are relatively long-lived. Furthermore, such effects could very well be masked by the over-riding effects of heavy fishing. In any case, the general picture is that the standing crop of most species in the groundfish community has been reduced by at least 50 percent over the last 10 years, chiefly as a result of fishing.

MAXIMUM SUSTAINABLE YIELD OF TOTAL GROUNDFISH RESOURCE

It is obvious that the groundfish resource as a whole cannot sustain harvests at the peak levels recorded in the mid-1960's. Ten years after the onset of major increases in fishing effort and landings in 5Z, the total landings of groundfish and flounders had dropped back approximately to the same level as in 1961 when the U. S. was virtually the only country fishing for groundfish in 5Z (Figure 2). Since total effort has remained at a high level or even increased in the latter half of the 1960's, the reduction in landings occurred as a result of significant reduction in the biomass of most groundfish species and there is little doubt that the reduction in biomass can be attributed largely to heavy fishing. Furthermore, there are no alternative groundfish stocks which could provide sustainable yields comparable to those obtained in the mid-1960's. The many species making up the miscellaneous groundfish category are not very abundant even taken collectively, as indicated by the fact that relatively low levels of incidental catches generated significant declines in abundance. Other species which represent a sizeable biomass such as skates and dogfish (excluded from the statistical category groundfish) appear not to offer any major alternative from the standpoint of tonnage, because of low reproductive capacity. For all these reasons it seems quite clear that maximum sustainable yield (MSY) of groundfish must be substantially less than the peak landings recorded in 1965 and 1966.

A first approximation to the MSY for the total groundfish stock in 5Z has been made by combining estimates of maximum yield for major species based on available assessments, with first approximations of sustainable yield for most remaining groundfish species. The latter estimates are based on an assumed relationship between maximum yield and the ratio of the stock size at the MSY level to the original stock size prior to exploitation. I have generally assumed that the MSY is equivalent to that level of harvest which reduced the relative biomass by 50 percent from the levels of stock size present at the beginning of the last decade, which for purposes of a first approximation may be considered as nearly virgin stock levels.

Following through with this reasoning the estimated long term MSY's for the major groundfish species are as follows:

Species	Division 5Z MSY in tons x 10^{-3}
Cod	35
Haddock	50
Yellowtail	30
Red Hake	50
Silver Hake	100
Winter Flounder	10
Other Flounder	10
Sculpin	10
Other groundfish	20
All groundfish and flounders	315

Thus the long term maximum sustainable yield of groundfish might be on the order of 300,000 tons, and if skates and dogfish were exploited fully and included with the groundfish, this might raise the total to 350,000 tons. Note, however, that this level of yield depends upon maintenance of average recruitment. The possibility that stocks may be fished down to levels where recruitment is impaired, as may now be the case with Georges Bank haddock, of course may prevent realization of the MSY for that species. There appears to be real danger that other stocks besides haddock may soon reach this stage in ICNAF areas, and that the productive capacity of the groundfish resource as a whole may be depressed. Therefore, it will become more and more important to assess the fisheries as a total resource. Use of research vessel data such as that reviewed here will be essential to help monitor changes in the total fish biomass. It is hoped that the preliminary analysis presented here will stimulate work in other areas.

LITERATURE CITED

Anthony, V. C. 1972. Georges Bank (ICNAF Division 5Z and Subarea 6) herring assessment. ICNAF Annual meeting, May 1972. Res. Doc. 72/24.

Grosslein, M. D. 1968. Results of the joint USA-USSR groundfish studies. Part II. Groundfish Survey from Cape Hatteras to Cape Cod. Ann. Meet. int. Comm. Northw. Atlant. Fish., Res. Doc. 68/87, Ser. No. 2075.

____________. 1971. Some observations on accuracy of abundance indices derived from research vessel surveys. Int. Comm. Northw. Atlant. Fish., Redbook 1971, Part III, pp. 249-266.

Halliday, R. G., A. C. Kohler and M. D. Grosslein. 1971. Comparisons of abundance indices from research vessel surveys and commercial statistics for cod and haddock in ICNAF Subarea 4. Int. Comm. Northw. Atlant. Fish., Redbook 1971, Part III, pp. 229-238.

Table 1 -- Mean catch per haul (lb) of groundfish and flounders, and other species, on Georges Bank (sampling strata 13-23, 25) on __Albatross IV__ autumn surveys.

Species	1963	1964	1965	1966	1967	1968	1969	1970	1971
Haddock	118.6	193.6	131.0	50.8	43.7	19.2	5.6	22.0	6.3
Cod	25.1	15.6	7.5	8.8	20.0	10.8	7.5	13.3	8.0
Silver hake	7.9	2.8	3.3	3.3	2.3	5.5	3.7	2.8	2.7
Red hake	17.3	5.8	4.6	3.1	1.4	2.9	4.0	2.2	4.5
White hake	2.0	1.2	1.4	5.6	3.2	2.0	2.2	3.8	1.0
Yellowtail flounder	21.6	22.3	14.7	6.5	11.7	17.7	14.4	8.0	9.7
Winter flounder	4.8	5.5	5.0	9.5	3.4	3.7	4.4	12.3	2.6
Other flounders	7.6	4.8	2.6	8.0	4.8	2.8	5.1	3.4	2.8
Longhorn Sculpin	5.4	2.9	5.9	7.2	3.8	8.7	7.0	10.5	7.6
Ocean Pout	4.4	2.7	2.3	2.4	0.5	0.3	0.1	0.2	0.1
Angler	8.2	5.7	11.3	14.5	1.0	5.0	2.8	1.5	1.6
Other Groundfish	7.6	8.6	6.4	10.9	5.9	3.6	4.0	4.2	4.7
Total (all groundfish and flounders)	230.5	271.5	196.0	130.6	101.7	82.2	60.8	84.2	51.6
Skates	76.9	33.8	52.9	37.8	27.4	25.7	19.6	33.0	17.9
Spiny dogfish	7.4	7.4	9.1	4.5	4.2	11.6	5.2	8.1	7.7
All other finfish (pelagics)	5.5	4.9	3.4	5.6	4.7	4.7	3.4	1.5	5.1
Total all finfish 1/	320.0	317.5	261.0	178.0	137.5	123.6	87.8	126.4	82.3

1/ Exclusive of invertebrates.

Table 2 -- Mean catch per haul (lb) of groundfish and flounders, and other species, in southern New England (sampling strata 1-12) on Albatross IV autumn surveys.

Species	1963	1964	1965	1966	1967	1968	1969	1970	1971
Haddock	8.2	15.6	2.6	0.3	1.1	0.1	0.3	1.0	0.2
Cod	8.0	1.1	3.9	1.6	6.3	1.6	3.4	1.3	0.3
Silver hake	11.5	12.5	16.8	7.9	9.7	10.9	5.1	5.7	10.1
Red hake	16.8	9.6	12.4	6.4	5.9	9.7	10.6	8.6	7.4
White hake	2.6	0.9	1.4	2.6	2.8	3.0	1.3	1.0	0.9
Yellowtail flounder	28.2	26.1	19.1	17.2	26.2	24.4	27.2	30.3	16.8
Winter flounder	6.2	6.9	6.9	4.6	3.3	2.2	2.9	5.2	2.2
Other flounders	10.1	8.3	5.9	9.9	4.1	6.2	3.7	3.5	2.9
Longhorn Sculpin	0.5	2.2	3.6	5.3	3.4	2.1	2.9	2.3	0.5
Ocean Pout	1.4	0.9	0.7	2.4	1.4	1.2	0.6	0.6	0.1
Angler	9.2	15.5	10.9	14.7	4.1	2.7	5.4	6.1	3.2
Other groundfish	7.3	12.0	5.8	4.4	8.3	3.0	10.2	2.4	5.8
Total (all groundfish and flounders)	110.0	111.6	90.0	77.3	76.6	67.1	73.6	68.0	50.4
Skates	33.8	21.2	23.1	30.0	7.5	2.7	3.2	6.2	14.6
Spiny dogfish	148.9	439.4	205.0	203.6	213.7	128.9	477.2	149.0	29.0
All other finfish (pelagics)	6.6	16.1	15.5	8.7	12.0	13.7	30.5	13.9	20.1
Total all finfish (exclusive of invertebrates)	299.3	588.3	333.6	319.6	309.8	212.4	584.5	237.1	114.1

Table 3 -- Total landings (metric tons) of groundfish and flounders, and also skate landings, from Subarea 5Z by all ICNAF countries.

Species	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Haddock	46,483	53,973	54,822	64,086	150,362	121,274	51,458	40,928	22,174	11,294
Cod	14,276	23,081	26,953	25,165	38,333	52,863	36,332	42,758	37,355	25,144
Silver hake	16,846	60,822	119,969	188,869	300,566	140,649	86,364	55,071	72,961	37,194
Red hake	1,428	1,395	5,789	28,018	71,873	86,546	44,619	19,031	49,834	10,547
White hake	651	411	496	990	605	249	32	-	702	934
Yellowtail flounder	15,375	24,086	33,749	35,295	36,353	29,956	24,641	31,716	51,237	34,055
Winter flounder	6,757	7,022	7,002	12,802	10,678	13,951	10,900	8,289	16,614	11,060
Other flounder	3,387	3,373	3,519	5,468	6,745	6,327	9,326	9,367	5,661	5,873
Sculpin	-	-	-	-	-	3,964	8,187	6,872	10,681	4,838
Ocean Pout	-	-	-	1,161	547	13,377	7,351	12,697	25,563	6,746
Angler	-	-	-	-	-	782	-	2,362	2,194	633
All other groundfish	28,330	9,870	12,450	16,570	31,120	26,587	16,844	28,345	12,693	8,863
All groundfish and flounders	133,533	184,033	264,749	378,424	647,182	496,525	296,054	257,436	307,669	157,181
Skates	-	-	-	4,047	2,322	2,807	4,630	6,435	8,677	3,920

F 3

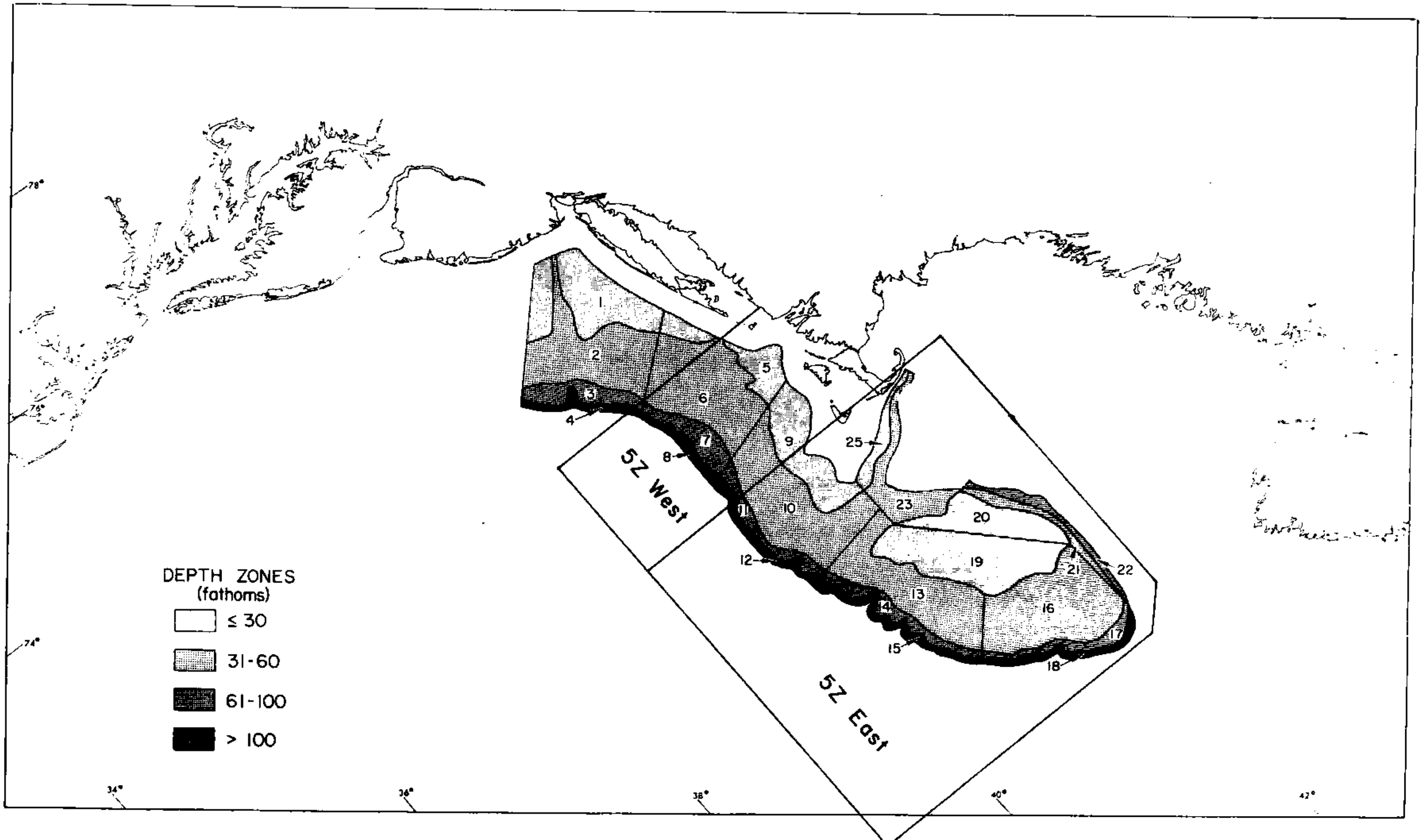

Figure 1. -- Sampling strata included in summary of USA surveys for this document. Georges Bank (strata 13-23, 25); southern New England (strata 1-12).

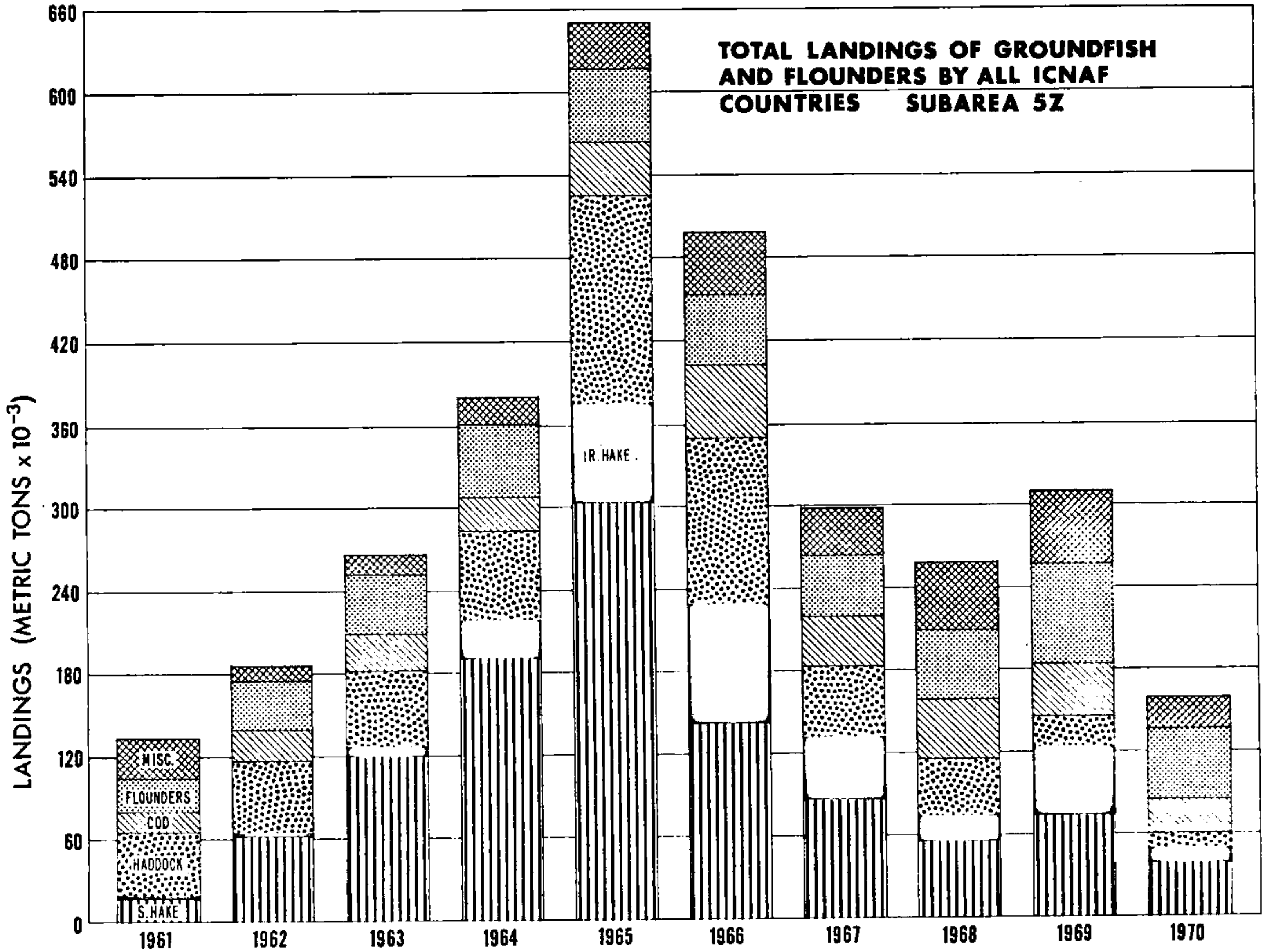

Figure 2. -- ICNAF landings of groundfish and flounders in Division 5Z.

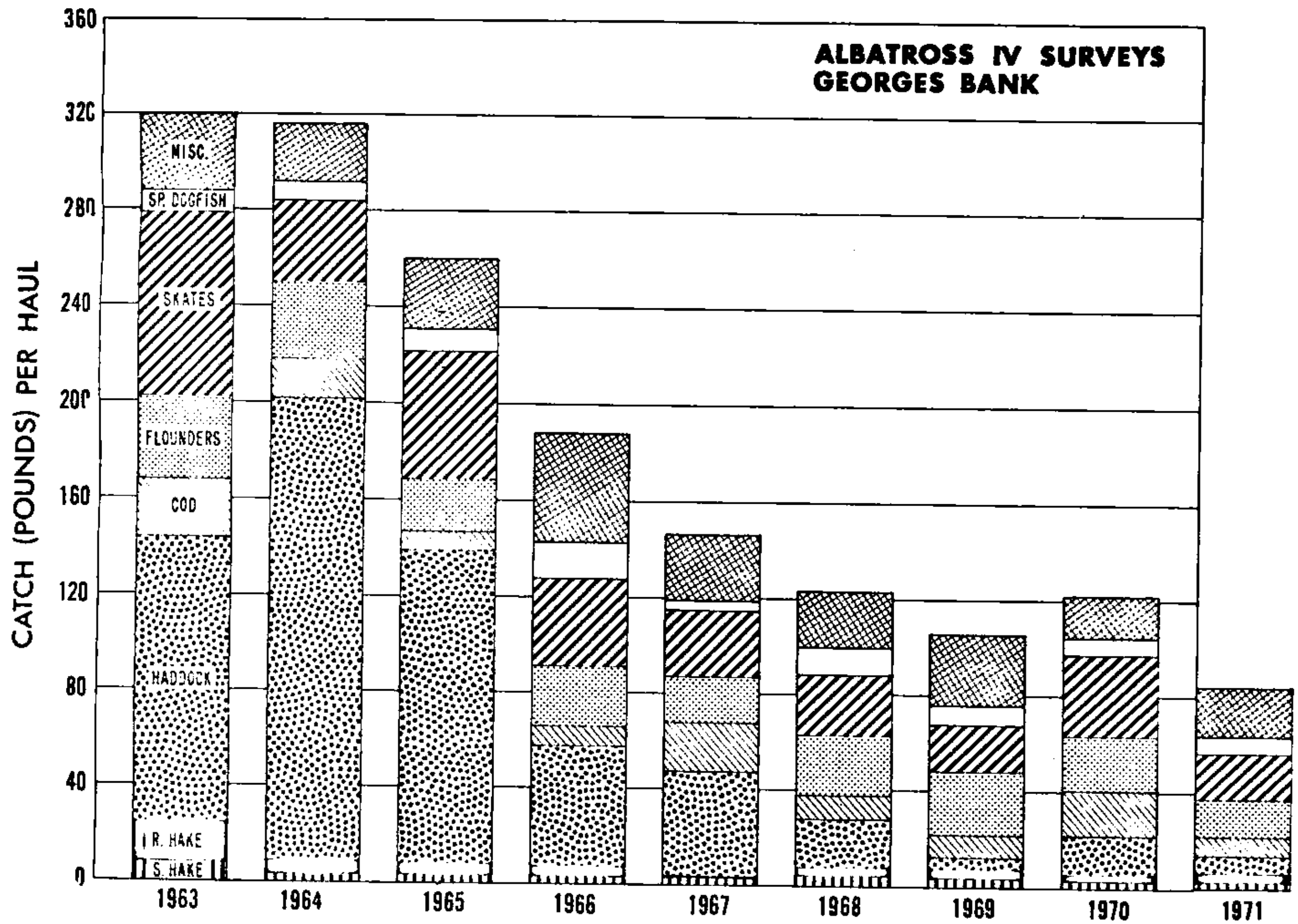

Figure 3. -- Stratified mean catch per haul of finfish on fall Albatross IV surveys on Georges Bank (strata 13-23, 25).

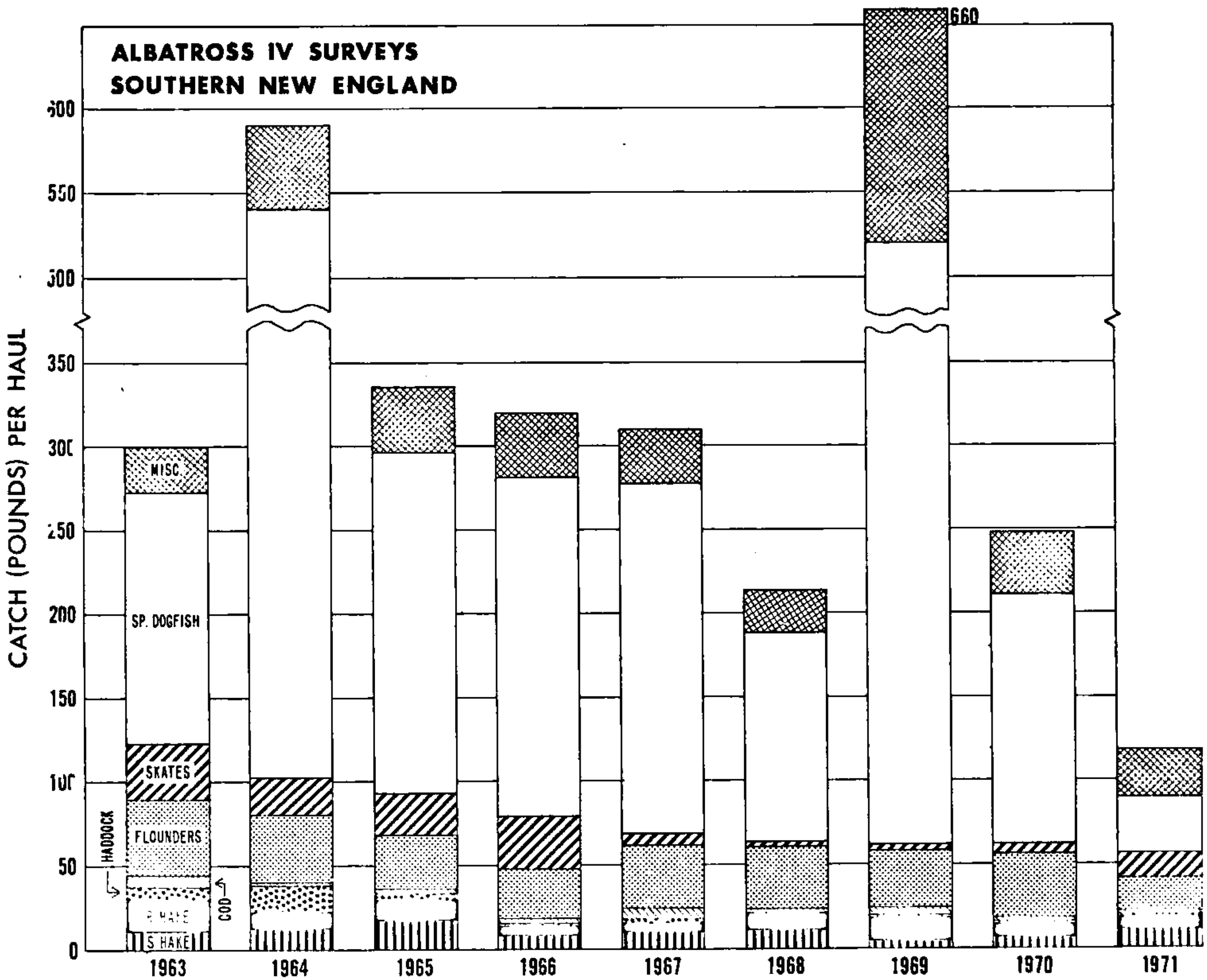

Figure 4. -- Stratified mean catch per haul of finfish on fall Albatross IV surveys in southern New England (strata 1-12).

A Preliminary Evaluation of the Effect of Total Fishing Effort on the Total Fish Biomass and First Approximation of Maximum Sustainable Yield for Finfishes in ICNAF Division 5Z and Subarea 6

Part II. Estimates of total fishing effort and its relation to sustainable yield of finfish

B. E. Brown and J. A. Brennan

INTRODUCTION

In the decade 1960 to 1970 fishing effort greatly increased in ICNAF Division 5Z and Subarea 6 with the entry of several countries into the fisheries. In order to make a preliminary evaluation of the effects of the fishing on the total biomass, it is necessary to establish a measure of total effort that enables the effort to be related to fishing mortality, so that $F = qf$ where F is the instantaneous rate of fishing mortality, q is the catchability coefficient and f is the amount of fishing effort. In this paper fishing power coefficients are estimated for various categories of fishing units based on total catch per day of all species. Using these coefficient, effort through the decade has been expressed in standardized units. Fishing effort is then examined relative to trends in catch and estimates of total sustainable yield for finfish.

METHODS

Robson (1966) proposed determining fishing power coefficients using an analysis of variance technique for a logarithmic linear model. In the present study the following model was utilized:

$$Y_{ijk} = m\, a_i\, b_j\, e_{ijk}$$

where Y_{ijk} is the catch per day of all species, for the ith country, for the jth gear-tonnage class category and for the kth year, m is the overall mean,

a_i is the country factor,

b_j is the gear-tonnage class category factor, and

e_{ijk} is the error of the kth observation at the i-j level assumed to follow a N (), σ^2) distribution.

A natural logarithmic transformation of the observations is used to achieve linearity of the model. The coefficients were then estimated using the analysis of variance procedure outlined by Snedecor and Cochran (1967) for a row x column design with unequal cell frequencies and missing obersvations.

Fishing power estimates are determined for each cell by the ratio of $a_i\, b_j$ for ith, jth cell to the $a_i\, b_j$ value for a selected standard cell.

The catch and effort data used in this analysis were obtained from Tables 4 and 5 of ICNAF Statistical Bulletins 10 through 20 (for years 1960-1969). The data were not complete and estimates were used for some entries.

In 1962 USSR effort was not reported in terms of days fishes, although hours fished and days on grounds were given. The numbers of days fished for the USSR otter trawl fleet was estimated from a linear relationship of hours fished to days fished, and hours fished to days on ground which were determined for each category over all other years of USSR data. For USSR drift-gill netters, 1961 was the only year with complete effort data, therefore, entries from that year were used to estimate effort for all other years. Missing effort for other entries in Table 4 were estimated by dividing the total catch for that entry by the catch per day for all other years for that country, gear-tonnage class category. Danish seines were eliminated because of their minor contribution to effort and catch totals.

F 9

The category U.S. side otter trawlers in the 0-50 MT class was selected as the standard cell as this was a very consistent entry.

Division 5Z and Subarea 6 were combined for this study. Prior to 1966 when ICNAF statistics for 6 were not reported, catches were determined from fishery statistics of the U.S. for 1960-1965, and from previous correspondence with USSR scientists. U.S. menhaden landings, which are captured close to shore, and miscellaneous shellfish were excluded from the analysis.

RESULTS OF THE ANALYSIS OF VARIANCE

The results of this analysis of variance are presented in Table 1. Both vessel class differences and country differences were significant at the $\alpha = .01$ level. The former showed the greatest differences. With missing cells, the presence of an interaction sum of squares invalidates the analysis. Since large F values for interaction were obtained, the cell values were examined to determine its source (Table 2). The interaction sum of squares could be attributed mainly to the following gear-tonnage class levels: stern otter trawler, tonnage classes 0-50 MT and 51-150 MT, each for Canada and U.S.; dredge, tonnage class 0-50 MT for U.S. and Canada; and purse seines, tonnage class 151-500 MT for country combinations involving USSR.

Considering the relatively minor contribution of these categories to the total catch and effort it was decided to ignor the interaction and proceed with the analysis. Fishing power coefficients are presented in Table 3 for all country, gear tonnage categories which were present on the fishery.

ESTIMATION OF TOTAL EFFORT

Total effort in standard days fished directed at finfish was estimated for each year from 1960 to 1970 by multiplying the unadjusted days fished by the fishing power coefficient relative to the standard (U.S. otter trawlers) and summing over all categories. Catch per day of finfish was estimated for each year from the above effort and the sum of the catch for that effort. The total estimated annual finfish catch for Division 5Z and Subarea 6 (minus menhaden) was divided by these values to obtain the total effort. The results are presented in Table 4.

These values clearly illustrate the importance of a standardization procedure in assessing the effort exerted on the fisheries in a particular area. According to the unadjusted effort figures, the effort approximately doubled during the period 1960-1970 for both regions, while according to the standardized effort figures, that effort tripled during the same period.

The catch per day peaked in 1966 for the unadjusted efforts and in 1965 for the standardized effort. The standardized values also have lesser fluctuations from year to year than the unadjusted ones. The initial increase may be at least partially the result of a learning factor which might be expected for those countries initiating new fisheries during this period. Such a factor would cause a more rapid rise in standard days fished than estimated here.

RELATIONSHIP TO MAXIMUM SUSTAINABLE YIELD VALUES

Grosslein (Part I) has estimated that the 5Z area has a maximum sustainable yield of all groundfish,(except hakes), flounders, dogfish and skates of 200,000 MT.

Anderson (1972) and Anderson and Au, 1972) indicate a maximum sustained yield of about 200,000 MT for hakes in 5Z-6. Anthony (1972) has estimated MSY for the 5Z-6 stocks of herring to be between 225,000 and 325,000 MT. For the purposes of this document, a MSY value of 250,000 MT is used. In view of the historic catches in the area, a value of 100,000 MT for the numerous miscellaneous species with small individual catches does not seem unreasonable and perhaps even on the high side. Since 1967 considerable effort has been directed toward the mackerel fishery. The mackerel catch in 5Z-6 increased from 20,000 MT in 1967 to almost 200,000 MT in 1970. How long this and higher levels can be sustained is questionable given the past history of fluctuations in that fishery. However, an estimate of MSY of 100,000 MT does not appear unreasonable.

The total estimated yield for all three species is thus 850,000 MT in the total region.

Landings of 850,000 MT (Table 4) were slightly exceeded in 1965 with an effort of 97,000 days fished. However, mackerel were not being harvested at that time. If mackerel are not considered landings of other species almost reached maximum sustainable yields in 1964 at 87,000 days fished. (At the 1964 catch per day of 8.0, an additional 100,000 MT of mackerel could have been taken with 12,500 days fished giving a total 99,500 days fished.) The peak effort level of 1970 was 136 percent of the above level. In 1971 effort was still 117 percent of the estimated maximum value. However, the catch per day in 1971 is only 74 percent of the peak 1965 value indicating an overall decrease in the exploited biomass. If effort in 1971 had been reduced by the same proportions as catch per day, then there would have been only 87,000 days fished rather than 118,000. It is likely that effort would have to be reduced even further than this figure to allow for recovery of the overall biomass of finfish in this region.

All of the estimates in this paper are first approximations; however, it is hoped that they will stimulate further discussion and research so that the question of total effort-total biomass removals can be more adequately addressed.

REFERENCES

Anderson, E. D. 1972. Assessment of the silver hake stock in ICNAF Subareas 5 and 6. ICNAF Res. Doc. 72/ .

Anderson, E. D., and E. W. K. Au. 1972. Assessment of the red hake stocks in ICNAF Subareas 5 and 6. ICNAF Res. Doc. 72/ .

Anthony, V. C. 1972. Georges Bank (ICNAF Division 5Z and Subarea 6) herring assessment. ICNAF Res. Doc. 72/ .

Robson, D. C. 1966. Estimation of the relative fishing power of individual ships. Res. Bull. Int. Comm. Northw. Atlant. Fish., No. 3, p. 5-14.

Snedecor, George W., and William G. Cochran. 1967. Statistical Methods, the Iowa State University Press, Ames Iowa, 7 ed., p. 484-493.

Table 1. -- Analysis of variance results on $\log_e$(catch/effort) entries of data from ICNAF Subareas 5Z plus 6.

Source of Variation	s.s	d.f.	m.s.	F value
Subareas 5Z and 6				
Total	634.98	323		
country (unadj.)	150.10	11		
gear-tn. class (adj.)	394.40	32	12.32	38.158**
country (adj.)	10.07	11	.916	2.836**
gear-tn. class (unadj.)	534.43	32		
interaction	31.31	31	1.010	
error	59.15	249	.237	
interaction plus error	90.47	280	.323	

**Significant at 0.01 level.

Table 2. -- Estimates and/observed values of catch per day fished for given country, gear-tonnage class combination in ICNAF Subareas 5Z plus 6.

Gear	Tonnage class(MT)	USA	CAN	USSR	SPAIN	POLAND	UK	FRANCE	GERM(FR)	NORWAY	ICELAND	NONMEMBER	ROMANIA
Otter Trawler (side)	0-50	8.04/8.41	8.25/5.00	-	-	-	-	-	-	-	-	-	-
	51-150	5.32/5.58	5.46/5.26	-	-	-	-	6.35/5.00	-	-	-	-	-
	151-500	6.99/4.76	7.18/8.21	5.58/7.46	-	-	-	8.35/10.59	6.87/7.39	-	-	-	-
	501-900	-	13.82/12.18	10.73/10.18	-	8.34/10.70	-	16.07/9.48	-	-	-	7.69/4.01	-
	901-1800	-	-	10.44/8.41	-	8.11/11.47	4.53/5.58	-	-	-	-	7.48/9.97	-
	over 1800	-	-	30.14/33.45	-	23.41/18.73	13.09/10.70	-	-	-	-	21.60/20.70	-
Pair Trawler	all	-	-	8.88/8.85	15.13/15.18	-	-	-	-	-	-	-	-
Purse Seine	unknown	71.86/71.52	-	-	-	-	-	-	-	-	-	-	-
	0-50	6.33/6.36	-	-	-	-	-	-	-	-	-	-	-
	51-150	61.97/47.46	63.57/184.93	-	-	-	-	-	-	-	-	-	-
	151-500	44.47/73.70	45.63/130.32	35.45/10.38	-	-	-	-	-	-	162.1/162.4	-	-
	501-900	-	-	13.81/13.74	-	-	-	-	-	-	-	-	-
Draft Gill Net	0-50	.147/.148	-	-	-	-	-	-	-	-	-	-	-
	501-900	-	-	4.98/5.00	-	-	-	-	-	-	-	-	-
Set Gill Net	0-50	.161/.161	-	-	-	-	-	-	-	-	-	-	-
	501-900		-	8.19/8.17	-	-	-	-	-	-	-	-	-

Table 2. -- ICNAF Subareas 5Z plus 6 (cont'd)

Gear	Tonnage class(MT)	USA	CAN	USSR	SPAIN	POLAND	UK	FRANCE	GERM(FR)	NORWAY	ICELAND	NONMEMBER	ROMANIA
Pound Net	all	1.58/1.58	-	-	-	-	-	-	-	-	-	-	-
Long Line	all	1.21/1.29	1.24/1.18	.963/.871	-	-	-	-	-	3.68/3.67	-	-	-
Hand Line	all but 51-150	.841/.841	-	-	-	-	-	-	-	-	-	-	-
	51-150	4.40/4.39	-	-	-	-	-	-	-	-	-	-	-
Other Line	0-50	2.38/2.38	-	-	-	-	-	-	-	-	-	-	-
Dredge	unknown	10.16/10.16	-	-	-	-	-	-	-	-	-	-	-
	0-50	3.94/3.35	4.04/14.59	-	-	-	-	-	-	-	-	-	-
	all others	6.06/5.36	6.22/6.82	-	-	-	-	-	-	-	-	-	-
Harpoon	all	.713/.942	.73/.543	-	-	-	-	-	-	-	-	-	-
Dip Net	over 1800			28.22/28.22	-	-	-	-	-	-	-	-	-
Otter Trawler (stern)	0-50	18.84/27.83	19.33/5.99	-	-	-	-	-	-	-	-	-	-
	51-150	3.27/8.83	3.36/1.25	-	-	-	-	-	-	-	-	-	-
	151-500	7.10/7.16	7.29/7.24	-	-	-	-	-	-	-	-	-	-
	500-900	-	11.52/10.48	8.95/6.96	-	-	-	-	-	-	-	6.40/14.44	-
	901-1800	-		25.29/46.06	-	19.64/16.78	-	-	-	-	-	18.10/5.37	-
	over 1800	-	49.40/42.52	38.38/41.68	-	29.81/26.05	-	-	-	-	-	27.50/35.87	23.13/23.10
	unknown	-	6.31/6.30	-	-		-	-	-	-	-	-	-

Table 3. -- Estimates of fishing power factors for given country and gear-tonnage class combination for ICNAF Subareas 5Z and 6 data.

Gear	Country tonnage class (MT)	US	CAN	USSR	SPAIN	POLAND	UK	FRANCE	GERM(FR)	NORWAY	ICELAND	NONMEMBER	ROMANIA
Otter Trawler (side)	0-50	1.00	1.03	-	-	-	-	-	-	-	-	-	-
	51-150	.66	.68	-	-	-	-	.79	-	-	-	-	-
	151-500	.87	.89	.69	-	-	-	1.04	.85	-	-	-	-
	501-900	-	1.71	1.33	-	1.04	-	-	1.65	-	-	.95	-
	901-1800	-	-	1.30	-	1.01	.56	-	-	-	-	.93	-
	1800	-	-	3.75	-	2.91	1.63	-	-	-	-	2.68	-
Pair Trawler	all	-	-	1.10	1.88	-	-	-	-	-	-	-	-
Purse Seine	unknown	8.93	-	-	-	-	-	-	-	-	-	-	-
	0-50	.79	-	-	-	-	-	-	-	-	-	-	-
	51-150	7.70	7.90	-	-	-	-	-	-	-	-	-	-
	151-500	5.53	5.67	4.41	-	-	-	-	-	-	20.16	-	-
	501-900	-	-	1.72	-	-	-	-	-	-	-	-	-
Drift Gill Net	0-50	.02	-	-	-	-	-	-	-	-	-	-	-
	501-900	-	-	.62	-	-	-	-	-	-	-	-	-
Set Gill Net	0-50	.02	-	-	-	-	-	-	-	-	-	-	-
	501-900	-	-	1.02	-	-	-	-	-	-	-	-	-
Pound Net	all	.20	-	-	-	-	-	-	-	-	-	-	-
Long Line	all	.15	.15	.12	-	-	-	-	-	.45	-	-	-
Hand Line	all but 51-150	.11	-	-	-	-	-	-	-	-	-	-	-
	51-150	.55	-	-	-	-	-	-	-	-	-	-	-
Other Line	0-50	.30	-	-	-	-	-	-	-	-	-	-	-
Dredge	unknown	1.26	-	-	-	-	-	-	-	-	-	-	-
	0-50	.49	.50	-	-	-	-	-	-	-	-	-	-
	all others	.75	.77	-	-	-	-	-	-	-	-	-	-
Harpoon	all	.09	.09	-	-	-	-	-	-	-	-	-	-
Dip Net	1800	-	-	3.50	-	-	-	-	4.32	-	-	-	-
Otter Trawler (stern)	0-50	2.34	2.40	-	-	-	-	-	-	-	-	-	-
	51-150	.41	.42	-	-	-	-	-	-	-	-	-	-
	151-500	.88	.91	-	-	-	-	-	-	-	-	-	-
	501-900	-	1.43	1.11	-	-	-	-	-	-	-	.79	-
	901-1800	-		3.14	-	2.44	-	-	3.87	-	-	2.25	-
	1800	-	6.14	4.77	-	3.71	-	-	5.88	-	-	3.41	2.87
Unknown	-	.76	.78	.61	-		-	-	.75	-	-	.44	-

Table 4. -- Estimate of unadjusted effort, standardized effort, total catch, catch/unadjusted effort, catch/standardized effort for years 1960-1970, ICNAF Subareas 5Z plus 6.

Subareas 5Z plus 6

Year	Unadjusted Raw Effort	Standardized Effort	Catch	Catch/Unadjusted Effort	Catch/Standardized Effort
1960	41,420	38,257	223,165	5.4	5.8
1961	40,471	36,236	273,050	6.7	7.5
1962	58,304	64,543	470,876	8.1	7.3
1963	64,177	70,696	529,776	8.3	7.5
1964	76,378	86,871	699,139	9.2	8.0
1965	89,591	97,064	887,530	9.9	9.1
1966	69,853	109,565	891,563	12.8	8.1
1967	69,129	77,759	677,848	9.8	8.7
1968	81,870	99,382	833,359	10.2	8.4
1969	117,558	136,487	1,021,941	8.7	7.5
1970	96,589	117,629	787,851	8.2	6.7