CHANGES IN BIOMASS OF FINFISHES AND SQUIDS FROM THE GULF OF MAINE TO CAPE HATTERAS, 1963-74, AS DETERMINED FROM RESEARCH VESSEL SURVEY DATA

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ABSTRACT

Trends in finfish and squid biomass for the 1963-74 period in the International Commission for the Northwest Atlantic Fisheries (ICNAF) Subarea 5 and Statistical Area 6, as evidenced by autumn bottom trawl survey data, were reviewed. Commercial statistics reported to ICNAF reveal that landings for groundfish species of major commercial importance peaked in 1965 and subsequently declined with shifts in directed effort to major pelagic species (for which landings peaked in 1971). Trends in landings for species of lesser commercial importance primarily reflect increasing effort throughout this period.

Relative abundance indices (stratified mean catch in kilograms per tow) from the autumn bottom trawl survey revealed drastic declines in abundance of haddock, *Melanogrammus aeglefinus;* silver hake, *Merluccius bilinearis;* red hake, *Urophycis chuss;* and herring, *Clupea harengus,* during this period although decreases were observed for nearly all finfish species of commercial importance. Possible evidence of changes in species composition were also observed, in that white hake, *Urophycis tenuis;* Atlantic mackerel, *Scomber scombrus;* and squids, *Loligo pealei* and *Illex illecebrosus,* have shown pronounced increases in relative abundance in recent years coincident with declines in other species occupying similar ecological niches. Analysis for four strata sets (Middle Atlantic, southern New England, Georges Bank, and Gulf of Maine areas) reveal unadjusted declines in biomass ranging from 37% on Georges Bank to 74% in the Middle Atlantic area; by combining data for all strata, a decline of 32% was obtained for the 1967-74 period (including the Middle Atlantic section, added in 1967), while for all remaining strata (1963-74) the corresponding figure is 43%. By adjusting biomass components according to catchability and computing stock size estimates for the entire biomass, a 65% decline was obtained for all strata (including the Middle Atlantic) using untransformed abundance indices, and a 66% decline was computed from retransformed abundance indices. For the remaining strata (Middle Atlantic strata excluded) declines of 47% and 46% were obtained, respectively. By combining these data sets, the corresponding figures were 51% and 47%. Stock size estimates for 1975 approximated 2.0×10^6 tons, one-fourth of the estimated virgin biomass level and one-half of the level corresponding to maximum sustainable yield.

The continental shelf waters of the northwest Atlantic adjacent to the U.S. coast support a valuable and productive fishery resource. Prior to 1960, this area was exploited almost exclusively by a coastal fleet of U.S. vessels of under 300 gross registered tons. Landings averaged less than 500×10^3 tons[2] annually (International Commission for the Northwest Atlantic Fisheries 1953-1961), a level substantially lower than the estimated maximum sustainable yield (MSY) of approximately 950×10^3 tons obtained for this area by various investigators (Au[3]; Brown et al.[4]; Brown et al. in press). In the early 1960's, however, distant-water fleets of the U.S.S.R., Poland, and other nations entered the fishery and as that decade progressed these fleets underwent continual modernization and expansion. As a result, fishing effort and landings have increased greatly in this area in recent years. Brown et al. (in press) estimated that during the 1961-72 period standardized effort increased sixfold, while landings more than tripled. Assessments now indicate that all major stocks in this area are fully exploited and some, notably haddock, *Melanogrammus aeglefinus,* and herring, *Clupea harengus,* on Georges Bank and yellowtail flounder, *Limanda ferruginea,* off southern New England have been

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[2]Landings and estimated stock levels in this paper are given in terms of metric tons.

[3]Au, D. W. K. 1973. Total sustainable finfish yield from Subareas 5 and 6 based on yield per recruit and primary production consideration. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1973, Res. Doc. No. 10, Serial No. 2912 (mimeo.), 7 p.

[4]Brown, B. E., J. A. Brennan, E. G. Heyerdahl, M. D. Grosslein, and R. C. Hennemuth. 1973. An evaluation of the effect of fishing on the total finfish biomass in ICNAF Subarea 5 and Statistical Area 6. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1973, Res. Doc. No. 8, Serial No. 2910 (mimeo.), 30 p.

Manuscript accepted September 1976.

demonstrably overfished (Hennemuth[5]; Brown and Hennemuth[6]; Schumaker and Anthony[7]). In addition, the June 1975 report of the ICNAF Standing Committee on Research and Statistics (STACRES) indicates that finfish landings for the 1971-74 period have substantially exceeded the MSY point (International Commission for the Northwest Atlantic Fisheries 1975c).

This expansion in fishing activity in recent years has stimulated considerable interest in its possible effects on biomass levels and productivity. Edwards (1968) developed biomass estimates for the area extending from Hudson Canyon to the Nova Scotia shelf (strata 1-40, Figure 1) by adjusting 1963-66 U.S. research vessel survey catches to compensate for availability and vulnerability to the survey gear by species and estimated that the annual harvest from this area (1.2×10^6 tons) approximated one-fourth of the fishable biomass during that period. He also reported a rapid decrease in fishable biomass during

[5]Hennemuth, R. C. 1969. Status of the Georges Bank haddock fishery. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1969, Res. Doc. No. 90, Serial No. 2256 (mimeo.), 21 p.

[6]Brown, B. E., and R. C. Hennemuth. 1971. Assessment of the yellowtail flounder fishery in Subarea 5. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1971, Res. Doc. No. 14, Serial No. 2599 (mimeo.), 57 p.

[7]Schumaker, A., and V. C. Anthony. 1972. Georges Bank (ICNAF Division 5Z and Subarea 6) herring assessment. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1972, Res. Doc. No. 24, Serial No. 2715 (mimeo.), 36 p.

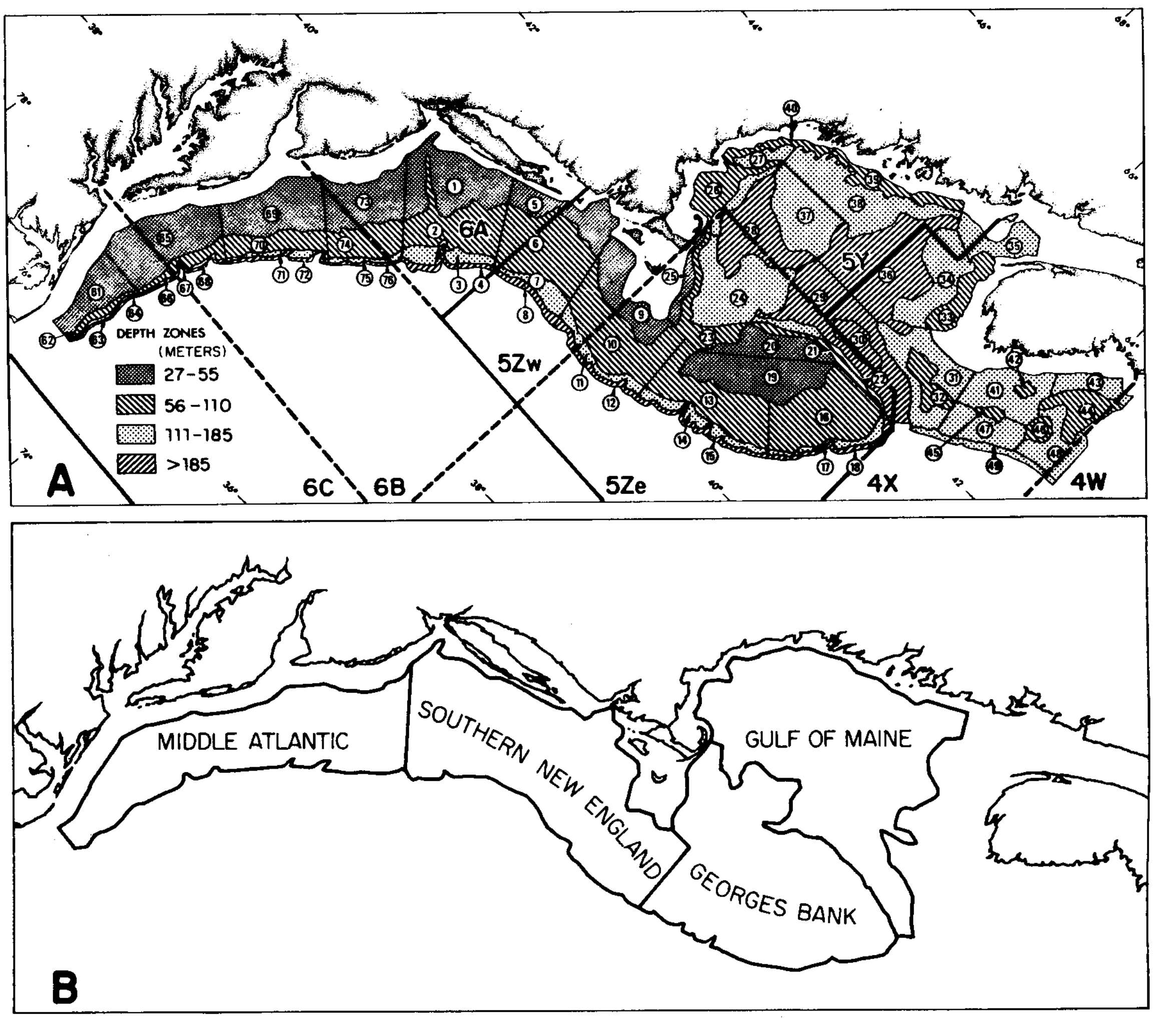

FIGURE 1.—Northwest Atlantic area from Nova Scotia to Cape Hatteras, (*a*) delineated into strata by depth, and (*b*) delineated into major units for analytical purposes, with ICNAF division boundaries superimposed.

the early and mid-1960's and noted that while the decrease had obviously been greater in the case of species for which there were directed fisheries, declines had nevertheless been general. Grosslein[8] examined autumn research vessel survey data (stratified mean catch per tow, pounds) for the 1963-71 period for southern New England and Georges Bank (strata 1-12, 13-23, and 25, Figure 1) and observed reductions in abundance of over 90% for haddock and ocean pout, *Macrozoarces americanus,* and more moderate reductions in other components of the groundfish community. Overall, Grosslein's data indicated declines in finfish biomass of 62% and 74% for southern New England and Georges Bank strata, respectively. Brown et al. (see footnote 4) presented additional analyses of Grosslein's data and documented pronounced declines for nearly all groundfish species or species groups, skates (*Raja* spp.), and sea herring; the decline for all species combined (with individual species weighted by cumulative landings for the 1962-71 period) was 64%. Brown et al. (in press) updated these analyses by including 1972 data and found an overall decline of 56%.

Since 1950, fishery management in the northwest Atlantic region has been conducted under the auspices of ICNAF, an international body currently consisting of 18 member nations pledged to cooperate in research and management of marine fishery resources in the northwest Atlantic area. This Commission, after considering the advice of various standing committees and subcommittees, formulates regulations, establishes quotas or "total allowable catches" (TAC's), and handles other matters necessary for the conservation of fish stocks in the seven regions composing the ICNAF Convention Area. The present study is concerned with the southernmost regions within this area adjoining the U.S. coast (ICNAF Subarea 5 and Statistical Area 6, Figure 1, hereafter referred to as SA 5 and 6).

In response to accumulating evidence indicating biomass declines in SA 5 and 6, STACRES in 1973 recommended an overall TAC for this area for 1974 (International Commission for the Northwest Atlantic Fisheries 1974d). Accordingly, a TAC of 923.9×10^3 tons was adopted by the Commission for 1974 to stabilize biomass levels (International Commission for the Northwest Atlantic Fisheries 1974a); for 1975, this figure was reduced to 850×10^3 tons (International Commission for the Northwest Atlantic Fisheries 1974b). In addition, STACRES further recommended that biomass levels, as measured by bottom trawl surveys, be used to monitor the effect of this regulation (International Commission for the Northwest Atlantic Fisheries 1974d).

The validity of such an approach is well documented. Grosslein (1971) has presented evidence that abundance indices derived from bottom trawl surveys are of sufficient accuracy to monitor major changes in stock size; for selected groundfish species, current levels of sampling appear adequate to detect changes on the order of 50%. Similarly, Schumaker and Anthony (see footnote 7) and Anderson[9] have found that trends in bottom trawl survey data accurately reflect major changes in stock abundance for pelagic species (herring and Atlantic mackerel, *Scomber scombrus,* respectively).

The objective of the present study was to further investigate changes in biomass of finfishes and squids in SA 5 and 6 as evidenced by trends in U.S. research vessel survey data. In this study, we have expanded on previous analyses of untransformed data (Grosslein see footnote 8; Brown et al. see footnote 4; Brown et al. in press) so as to include all available data from SA 5 and 6 for the 1963-74 period. In addition, we have attempted to compensate for anomalies in survey catch data and bias resulting from catchability differences by transforming and weighting data by species and summarizing resulting values to provide combined biomass estimates by year. We believe that the resulting trends obtained are more realistic than those derived from unadjusted survey data.

In this paper, we define biomass as consisting of weight of all species of finfishes and squids reported to ICNAF, excluding other invertebrates and large pelagic species such as swordfish, *Xiphias gladius;* sharks other than dogfish (*Squalus acanthias* and *Mustelus canis*); and tunas, *Thunnus* spp. We have also chosen to exclude inshore species such as American eel,

[8]Grosslein, M. D. 1972. A preliminary investigation 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 the relative biomass of groundfish in Division 5Z as indicated by research vessel surveys, and probable maximum yield of the total groundfish resource. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1972, Res. Doc. No. 119, Serial No. 2835 (mimeo.), 20 p.

[9]Anderson, E. D. 1973. Assessment of Atlantic mackerel in ICNAF Subarea 5 and Statistical Area 6. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1973, Res. Doc. No. 14, Serial No. 2916 (mimeo.), 37 p.

Anguilla rostrata; white perch, *Morone americana;* and Atlantic menhaden, *Brevoortia tyrannus*. The latter species is an important component of the biomass, but is taken primarily inshore in the southern portion of SA 6 and is, therefore, not of direct interest in the present study.

The term species, for convenience, refers to both species and species groups. Terms such as other pelagics, other fish, and groundfish refer to species so designated in ICNAF statistical bulletins (International Commission for the Northwest Atlantic Fisheries 1965-1973, 1974c, 1975a).

BOTTOM TRAWL SURVEY PROCEDURES

Autumn bottom trawl survey data have been collected by the U.S. National Marine Fisheries Service RV *ALBATROSS IV* since 1963; the RV *DELAWARE II* has also participated infrequently. In all of these surveys, both vessels have used the standard "36 Yankee" trawl with a 1.25-cm stretched mesh cod end liner. This trawl measures 10-12 m along the footrope and 2 m in height at the center of the headrope, and is equipped with rollers to make it suitable for use on rough bottom (Edwards 1968).

The area sampled extends from Nova Scotia to Cape Hatteras. A stratified random sampling design has been used in this survey (Cochran 1953); thus, the survey area has been stratified into geographical zones (Figure 1) primarily on the basis of depth (Grosslein 1969). During 1963-66, only strata from the New Jersey coast northward (1-42, Figure 1) were sampled; additional strata (61-76, Figure 1) were added in autumn 1967 to cover the mid-Atlantic region (Grosslein[10]). An additional section covering part of the Scotian Shelf was also added in 1968 but is not considered in this study.

In each cruise, sampling stations were allocated to strata roughly in proportion to the area of each stratum and were assigned to specific locations within strata at random. A 30-min tow was taken at each station at an average speed of 3.5 knots. After each tow, weight and numbers captured, fork length, and other pertinent data were recorded for each species. Data were summarized, audited, and transferred to magnetic tape following the completion of each survey. The reader is referred to Grosslein (1969, footnote 11) for further details concerning survey procedures.

Following procedures given by Cochran (1953:66) we calculated stratified mean catch per tow values in terms of weight by

$$\bar{y}_{st} = 1/N \sum_{h=1}^{k} \left[N_h \bar{y}_h\right] \qquad (1)$$

where $\bar{y}_{st}$ = stratified mean catch per tow,
N_h = area of the hth stratum,
N = total area of all strata in the set,
$\bar{y}_h$ = mean catch per tow in the hth stratum, and
k = number of strata in the strata set.

We calculated the estimated population variance as

$$S^2 = 1/N \left[\sum_{h=1}^{k} \left[N_h \bar{y}_h{}^2\right] - N\bar{y}_{st}{}^2 + \sum_{h=1}^{k} s_h{}^2 \left[(N_h - 1) + \frac{(N_h - N)}{N}\frac{(N_h - n_h)}{n_h}\right]\right] \qquad (2)$$

where S^2 = estimated population variance,
n_h = number of tows in the hth stratum,
$s_h{}^2$ = variance within the hth stratum, and
$\bar{y}_{st}$, N, N_h, $\bar{y}_h$, and k are defined as before.

We used stratified mean weight per tow (kilograms) in preference to numbers as an index of biomass change due to its convenience when working with different species groups and the high degree of variability in numbers associated with fluctuations in recruitment. Obviously, numbers would also tend to overemphasize the importance of small organisms in the community under study, as pointed out by Odum and Smalley (1959).

RECENT TRENDS IN LANDINGS

Commercial landings as reported to ICNAF (International Commission for the Northwest Atlantic Fisheries 1965-1973, 1974c, 1975a,

[10]Grosslein, M. D. 1968. Results of the joint USA-USSR groundfish studies. Part II. Groundfish survey from Cape Hatteras to Cape Cod. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1968, Res. Doc. No. 87, Serial No. 2075 (mimeo.), 28 p.

[11]Grosslein, M. D. 1969. Groundfish survey methods. NMFS, Woods Hole, Mass., Lab. Ref. No. 69-2, 34 p.

footnote 12) for the major species groups considered in this paper (principal groundfish, principal pelagics, flounders, other groundfish, other pelagics and other fish, and squid, Table 1) are given in Figures 2 and 3. Effort was concentrated on principal groundfish during the mid-1960's; landings peaked at approximately 643 × 10^3 tons in 1965, declined to approximately 575 × 10^3 tons in 1966, and dropped off sharply thereafter (Figure 2). Statistical data for individual species (International Commission for the Northwest Atlantic Fisheries 1965-73, 1974c, 1975a, see footnote 12) reveal that this pattern resulted primarily from great increases in landings of cod, haddock, and silver and red hake in the mid-1960's, followed by subsequent declines. Landings of redfish and pollock have increased somewhat in more recent years, but not enough to offset declines in the remaining species.

Landings for principal pelagics during this period (herring and mackerel) declined initially followed by a subsequent upswing. This can be attributed primarily to a diversion of USSR effort from herring to haddock and hake in 1965 and 1966 (Schumaker and Anthony see footnote 7). In 1967, however, the USSR redirected much of its effort back to the Georges Bank herring stock and also initiated an intensive mackerel fishery (Anderson see footnote 9) and other distant water fleets also began to exploit these species at about this time. This increase in effort produced increased landings of herring and mackerel to a total

[12]International Commission for the Northwest Atlantic Fisheries. 1975. Provisional nominal catches in the Northwest Atlantic, 1974 (Subareas 1 to 5 and Statistical Areas 0 and 6). Int. Comm. Northwest Atl. Fish. Annu. Meet. 1975, Summ. Doc. No. 32, Serial No. 3590 (mimeo.), 61 p.

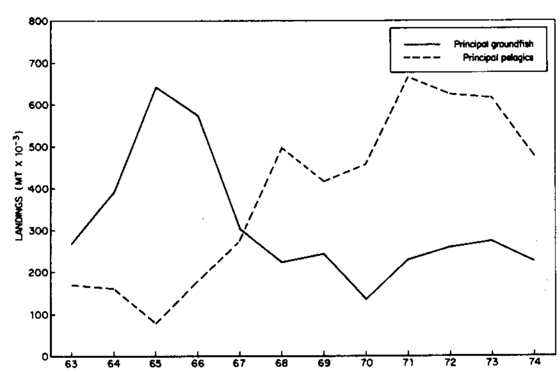

FIGURE 2.—Landings of principal groundfish and principal pelagics in ICNAF Subarea 5 and Statistical Area 6, 1963-74.

TABLE 1.—Scientific and common names of species considered[1] in this study, grouped as in ICNAF statistical bulletins.

Common name	Scientific name
Principal groundfish (except flounders):	
Cod	*Gadus morhua*
Haddock	*Melanogrammus aeglefinus*
Redfish	*Sebastes marinus*
Silver hake	*Merluccius bilinearis*
Red hake	*Urophycis chuss*
Pollock (saithe)	*Pollachius virens*
Flounders:	
American plaice	*Hippoglossoides platessoides*
Witch	*Glyptocephalus cynoglossus*
Yellowtail	*Limanda ferruginea*
Winter flounder	*Pseudopleuronectes americanus*
Summer flounder	*Paralichthys dentatus*
Other groundfish:	
Angler	*Lophius americanus*
Cusk	*Brosme brosme*
Ocean pout	*Macrozoarces americanus*
Sculpins	*Myoxocephalus* spp.
Scup	*Stenotomus chrysops*
Searobins	*Prionotus* spp.
White hake	*Urophycis tenuis*
Principal pelagics:	
Herring	*Clupea harengus*
Mackerel	*Scomber scombrus*
Other pelagics and other fish:	
Butterfish	*Poronotus triacanthus*
Spiny dogfish	*Squalus acanthias*
Skates and rays	*Raja* spp.
Squid:	
Short-finned squid	*Illex illecebrosus*
Long-finned squid	*Loligo pealei*

[1]Note that for all groupings except principal groundfish, principal pelagics, and squid, other species were considered but are not mentioned specifically.

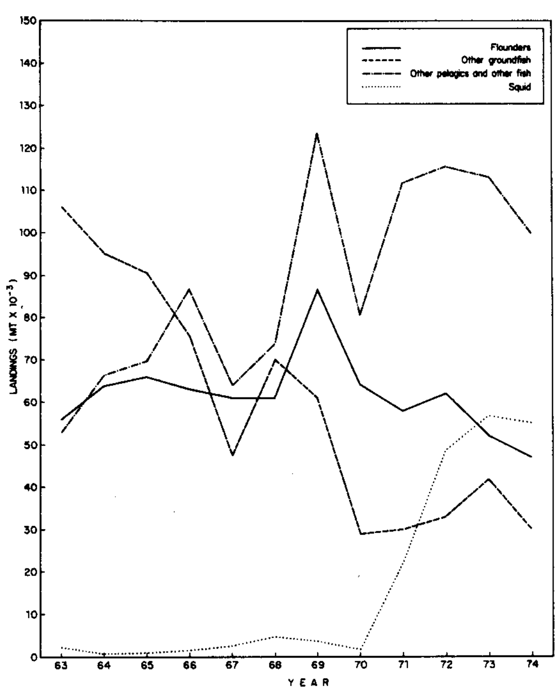

FIGURE 3.—Landings of flounders, other groundfish, other pelagics and other fish, and squid in ICNAF Subarea 5 and Statistical Area 6, 1963-74.

of approximately 667 × 10^3 tons in 1971 (Figure 2). Landings of herring and mackerel peaked in 1968 and 1972, respectively (International Commission for the Northwest Atlantic Fisheries 1965-1973, 1974c, 1975a, see footnote 12).

Landings for the remaining species groups (Figure 3) generally reflect decreasing abundance in response to increasing effort. Landings of flounders were relatively constant but did increase until 1969 followed by a gradual decline. The somewhat anomalous 1969 value resulted primarily from sharply increased catch of yellowtail by distant water fleets (Brown and Hennemuth see foonote 6). Steadily declining landings of other groundfish throughout the period of study can be attributed in part to declining abundance, while other pelagics and other fish show a general increase which would appear to be associated with increased effort as shown later. Squid landings also increased sharply since 1970.

As TAC's have been imposed for certain stocks since 1970, their possible influence should be considered. It is not believed, however, that quota management affected these trends appreciably. Species subject to quota management in 1970 and 1971 (i.e., haddock and yellowtail) had already been seriously depleted, while in 1972 and 1973 TAC's did not appear to be limiting with the exception of those imposed for haddock, yellowtail, and herring, and for the latter two species TAC's were in fact exceeded (International Commission for the Northwest Atlantic Fisheries 1975c). It appears likely that TAC's imposed for 1974 had a greater effect, particularly in the case of herring and mackerel; also, the overall TAC of 923.9 × 10^3 tons (referred to above) undoubtedly limited total catches by nation to some degree although it was exceeded by approximately 75 × 10^3 tons (International Commission for the Northwest Atlantic Fisheries 1975c). In summary, however, it would appear that the influence of quota management on the overall trends depicted in Figures 2 and 3 was relatively minor for the level of effort being exerted which, as noted previously, increased by a factor of six during the period 1962-72. It is not possible to speculate whether or not significant additional effort would have been added in 1973 and 1974 (say from new entrants to the area), had there not been regulations.

The possible influence of bias upon reported landings remains to be mentioned. In ICNAF statistical bulletins, some landings have been recorded as "not specified," e.g., "groundfish (not specified)," "other pelagics (not specified)," etc. Insofar as possible, we have combined these landings with landings data reported by species within each species group. In recent years, however, an improvement has occurred in reporting accuracy which appears to have affected the relative amounts of "not specified" landings (and thus annual totals as depicted in Figures 2 and 3). For instance, examination of data in ICNAF statistical bulletins (International Commission for the Northwest Atlantic Fisheries 1965-1973, 1974c, 1975a) reveals a decrease in the relative percentage of "not specified" groundfish of from 15 to 20% of the other groundfish category in the mid-1960's to approximately 10% in 1970-73, while for "other fish" a complete reversal of this trend occurred. The "not specified" proportion of the total "other fish" category increased from approximately 10% in the mid-1960's to 25-30% during 1970-73. This implies that landings for principal groundfish and other species may have been erroneously included under other groundfish to a greater extent in former years, thus biasing the observed trend for other groundfish downward, while the trend for other pelagics and other fish may have been biased upward due to inclusion of previously omitted landings data in more recent years. The actual extent to which trends depicted in Figures 2 and 3 were distorted by this factor is problematical, but it should be noted that for principal groundfish, principal pelagics, flounders, and squid, more important (and/or more readily identified) species were involved which probably were not affected by reporting inaccuracies to the same degree. Consequently, it is our judgement that trends for the remaining species groups were probably not appreciably biased.

CHANGES IN BIOMASS

Unweighted Analyses

Summaries of survey data by species and area permit preliminary evaluation of the magnitude and direction of change in selected biomass components in recent years and of the degree of year-to-year variability that may be encountered. Accordingly, we examined trends for different species and strata sets and for data summed over all strata before attempting transformation or weighting procedures.

Individual strata can be grouped for analysis on the basis of stock structure, ecological factors, exploitation patterns, and availability of survey data. In the present paper, we have selected four major strata sets in SA 5 and 6 based on the above factors (Figure 1) which we considered separately prior to examination of data for the area as a whole. These are as follows:

1. Middle Atlantic area (strata 61-76, corresponding approximately to ICNAF Divisions 6B and C);
2. Southern New England area (strata 1-12, corresponding approximately to ICNAF Divisions 6A and Subdivision 5Zw);
3. Georges Bank (strata 13-25, corresponding approximately to ICNAF Subdivision 5Ze), and
4. Gulf of Maine (strata 26-30 and 36-40, corresponding approximately to ICNAF Division 5Y).

The rationale for this arrangement is based on differences in faunal assemblages although exploitation patterns and data availability were also considered. A number of stock identification studies support such an arrangement (Wise 1962; Grosslein 1962; Anthony and Boyar 1968; Ridgway et al.[13]; Anderson[14]; and others). In addition, Grosslein's[15] study indicated a relatively high diversity of species in the southern New England-Middle Atlantic areas in contrast to the Gulf of Maine, with Georges Bank being a rather transitional area. Exploitation patterns and reporting of commercial fishery statistics also dictate some form of division between Subdivision 5Ze and the Subdivision 5Zw-Statistical Area 6 region and other areas to the north or south (Figure 1). Finally, the fact that survey data are nonexistent for Middle Atlantic strata prior to 1967 required a division between this area and the remainder of SA 5 and 6 for analytical purposes.

Trends in relative abundance from 1963 to 1974 (stratified mean catch per tow [kilograms], U.S. autumn bottom trawl survey data) are given by area for selected species in Tables 2-5 and for major ICNAF categories in Figures 4-9. Pronounced declines of principal groundfish are evident both on Georges Bank and in the Gulf of Maine, with lesser declines in the remaining areas (Figure 4). The trends observed resulted primarily from declining relative abundance of haddock and silver and red hake (Tables 2-5). Haddock, in particular, appears to have greatly decreased on

[13]Ridgway, G. J., R. D. Lewis, and S. Sherburne. 1969. Serological and biochemical studies of herring populations in the Gulf of Maine. Cons. Perm. Int. Explor. Mer, Memo No. 24, 6 p.

[14]Anderson, E. D. 1974. Comments on the delineation of red and silver hake stocks in ICNAF Subarea 5 and Statistical Area 6. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1974, Res. Doc. No. 100, Serial No. 3336 (mimeo.), 8 p.

[15]Grosslein, M. D. 1973. Mixture of species in Subareas 5 and 6. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1973, Res. Doc. No. 9, Serial No. 2911 (mimeo.), 20 p.

TABLE 2.—Stratified mean catch per tow (kilograms) for selected species of finfish and squid, *Albatross IV* autumn bottom trawl survey data, 1967-74, Middle Atlantic area (strata 61-76).

Species	1967	1968	1969	1970	1971	1972	1973	1974
Principal groundfish:								
Silver hake	0.9	0.9	0.1	0.2	0.3	0.5	0.4	[1]0.0
Red hake	0.1	0.8	0.5	0.2	0.4	0.2	0.1	0.0
Flounders:								
Yellowtail	3.4	5.5	3.6	[1]0.0	0.3	0.1	[1]0.0	0.0
Winter flounder	1.7	1.3	0.6	[1]0.0	0.2	0.1	0.1	0.0
Summer flounder	2.0	1.5	0.8	[1]0.0	0.4	0.1	0.3	0.8
Other	0.7	2.0	0.6	0.4	0.8	1.0	1.6	0.5
Other groundfish:								
Angler	0.7	0.6	0.3	[1]0.0	0.1	1.4	0.9	[1]0.0
Scup	2.6	0.8	8.4	0.1	0.3	3.2	0.2	0.7
Searobins	130.1	13.8	5.4	6.9	3.1	1.7	1.9	1.9
Other	0.5	0.3	0.3	[1]0.0	[1]0.0	[1]0.0	[1]0.0	0.0
Principal pelagics:								
Herring	0.0	0.0	0.0	0.0	0.0	0.0	[1]0.0	0.0
Mackerel	[1]0.0	0.1	0.0	0.0	[1]0.0	0.0	0.0	0.0
Other pelagics and other fish:								
Butterfish	3.6	18.1	3.9	5.4	5.0	4.2	11.0	3.7
Spiny dogfish	47.8	3.1	4.9	0.0	0.0	0.0	[1]0.0	0.0
Skates and rays	4.0	8.4	29.5	7.0	12.8	6.6	10.4	5.4
Other[2]	9.8	7.0	4.5	5.9	9.6	3.1	9.4	3.3
Squid:								
Short-finned squid	0.3	0.2	0.1	0.4	0.2	0.3	[1]0.0	0.1
Long-finned squid	10.6	9.3	9.2	4.8	2.5	12.6	11.2	11.1
Total finfish and squid	218.8	73.7	72.7	31.3	36.0	35.1	47.5	27.5

[1]Less than 0.05.
[2]Does not include data for tunas, sharks, swordfish, American eel, or white perch.

TABLE 3.—Stratified mean catch per tow (kilograms) for selected species of finfish and squid, *Albatross IV* autumn bottom trawl survey data, 1963-74, southern New England area (strata 1-12).

Species	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Principal groundfish:												
Cod	3.0	0.5	1.8	0.7	2.9	0.8	1.5	0.6	0.1	2.1	[1]0.0	0.4
Haddock	2.7	7.1	1.2	0.1	0.5	[1]0.0	0.1	0.5	0.1	0.0	[1]0.0	0.0
Silver hake	5.2	5.7	7.6	3.6	4.4	4.8	2.3	2.6	4.6	4.0	3.2	1.3
Red hake	8.1	4.4	5.6	2.9	2.7	4.4	4.8	3.9	3.4	6.6	3.0	0.5
Flounders:												
Yellowtail	12.0	11.8	8.7	7.9	11.9	11.1	12.3	13.7	7.6	26.8	2.6	1.2
Winter flounder	2.4	3.1	3.1	2.1	1.5	1.0	1.3	2.4	1.0	3.0	0.5	0.4
Other	4.8	3.8	2.7	4.5	1.9	2.9	1.7	1.9	1.3	2.9	2.4	2.9
Other groundfish:												
Angler	4.4	7.0	4.9	6.7	1.9	1.2	2.5	2.8	1.5	9.8	2.9	1.0
Ocean pout	0.7	0.4	0.3	1.1	0.6	0.5	0.3	0.3	0.1	0.1	0.2	0.0
Sculpins	0.3	1.0	1.7	2.5	1.6	1.0	1.4	1.1	0.3	2.2	0.1	0.1
Scup	1.3	2.5	0.7	0.5	0.6	0.4	1.6	0.4	0.2	1.9	1.6	1.4
Searobins	1.0	0.8	0.5	0.7	0.8	0.3	0.5	0.2	0.3	4.7	0.3	0.1
White hake	1.2	0.4	0.6	1.2	1.3	1.4	0.6	0.5	0.4	0.4	0.1	0.1
Other	0.1	0.1	0.1	[1]0.0	0.3	[1]0.0	0.1	0.1	0.3	[1]0.0	[1]0.0	0.0
Principal pelagics:												
Herring	0.2	[1]0.0	0.5	1.8	0.5	0.1	[1]0.0	[1]0.0	[1]0.0	[1]0.0	0.0	0.0
Mackerel	[1]0.0	[1]0.0	[1]0.0	[1]0.0	1.0	0.2	3.9	[1]0.0	0.1	[1]0.0	[1]0.0	[1]0.0
Other pelagics and other fish:												
Butterfish	2.6	6.0	4.5	1.5	2.2	4.0	6.5	1.1	5.8	2.4	6.3	6.1
Spiny dogfish	71.2	194.4	93.0	92.4	96.9	58.5	216.5	67.6	13.2	32.7	46.1	18.6
Skates and rays	15.8	10.4	11.3	13.6	3.7	1.2	2.3	2.9	6.6	9.1	3.0	3.2
Other[2]	0.1	1.9	2.0	0.7	1.7	1.3	4.1	5.1	4.1	3.1	5.3	5.2
Squid:												
Short-finned squid	([3])	[4]0.1	[4]0.1	[4]0.1	0.5	0.7	0.1	0.3	0.3	0.6	0.1	0.2
Long-finned squid	([3])	[4]1.2	[4]1.6	[4]2.2	2.0	12.2	18.1	3.6	5.4	6.7	16.7	12.1
Total finfish and squid	137.1	262.6	152.5	146.8	141.4	108.0	282.5	111.6	56.7	119.1	94.4	54.8

[1]Less than 0.05.
[2]Does not include data for tunas, sharks, swordfish, American eel, or white perch.
[3]Data not recorded.
[4]Squid catches for 1964-66 prorated by species according to relative percentages caught in later years.

TABLE 4.—Stratified mean catch per tow (kilograms) for selected species of finfish and squid, *Albatross IV* autumn bottom trawl survey data, 1963-74, Georges Bank area (strata 13-25).

Species	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Principal groundfish:												
Cod	11.0	7.1	7.2	5.0	8.4	5.3	4.9	7.8	6.1	14.2	19.1	5.1
Haddock	51.2	75.2	56.1	21.4	20.5	9.3	5.8	10.6	3.6	5.1	7.2	2.8
Redfish	0.9	4.0	1.1	2.0	2.6	3.5	6.5	4.6	1.9	3.9	2.6	1.9
Silver hake	5.4	1.7	1.6	2.1	1.0	2.2	1.6	2.3	1.2	2.4	2.4	1.5
Red hake	7.4	2.2	1.8	1.2	0.8	1.1	1.5	0.9	1.9	1.2	2.8	1.4
Pollock	2.3	2.1	1.7	2.9	1.1	1.0	1.4	0.4	2.2	1.0	1.6	0.4
Flounders:												
American plaice	5.5	2.0	1.2	3.3	1.7	1.3	1.1	1.5	0.9	0.9	0.9	0.4
Witch	1.0	0.5	0.5	1.5	0.6	0.9	0.5	1.5	0.5	1.0	1.5	0.4
Yellowtail	8.2	8.4	5.6	2.5	4.5	6.7	5.4	3.0	3.7	4.0	3.8	2.2
Winter flounder	1.8	2.1	2.0	3.6	1.3	1.5	1.7	4.7	1.0	1.5	1.6	1.5
Other	1.0	0.7	0.6	1.1	1.1	1.2	1.3	0.4	0.6	1.3	3.5	1.8
Other groundfish:												
Angler	3.5	2.6	5.0	5.8	0.5	1.9	1.1	0.7	0.6	1.6	2.2	1.1
Ocean pout	1.7	1.0	0.9	0.9	0.2	0.1	[1]0.0	0.1	[1]0.0	0.4	0.2	[1]0.0
Sculpins	3.4	1.8	3.3	3.3	2.0	3.8	3.1	4.9	3.1	2.8	3.6	2.0
White hake	1.4	0.5	0.8	[1]0.0	1.6	1.0	1.8	2.4	2.2	2.2	3.5	2.0
Other	0.5	0.5	0.6	1.0	0.7	1.0	0.2	0.5	0.1	0.4	0.7	0.3
Principal pelagics:												
Herring	1.0	0.2	0.9	1.5	0.6	0.2	0.2	[1]0.0	0.3	0.1	[1]0.0	[1]0.0
Mackerel	[1]0.0	0.0	0.1	0.1	0.2	0.2	0.4	0.1	[1]0.0	0.4	[1]0.0	0.3
Other pelagics and other fish:												
Butterfish	0.7	1.3	0.3	0.1	0.6	1.0	0.3	0.2	1.1	1.2	0.4	1.0
Spiny dogfish	2.9	3.0	3.5	1.8	2.5	5.6	2.4	3.5	3.3	9.7	36.2	2.2
Skates and rays	31.3	15.0	21.7	17.7	15.2	12.3	8.7	15.7	8.9	15.4	28.9	15.4
Other[2]	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.2	0.6	0.9	1.0	2.8
Squid:												
Short-finned squid	([3])	[4]0.2	[4]0.5	[4]0.3	0.1	0.3	[1]0.0	0.2	0.4	0.2	5.0	0.1
Long-finned squid	([3])	[4]0.2	[4]0.5	[4]0.4	0.4	0.4	1.5	1.1	1.0	1.1	0.1	2.2
Total finfish and squid	142.6	132.7	118.0	80.0	68.7	62.2	51.8	67.3	45.2	72.9	128.8	48.8

[1]Less than 0.05.
[2]Does not include data for tunas, sharks, swordfish, American eel, or white perch.
[3]Data not recorded.
[4]Squid catches for 1964-66 prorated by species according to relative percentages caught in later years.

TABLE 5.—Stratified mean catch per tow (kilograms) for selected species of finfish and squid, *Albatross IV* autumn bottom trawl survey data, 1963-74, Gulf of Maine area (strata 26-30 and 36-40).

Species	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Principal groundfish:												
Cod	10.9	14.1	7.4	8.0	5.7	12.0	9.5	10.2	10.2	8.0	5.4	5.5
Haddock	39.1	14.2	12.8	10.1	9.8	11.9	7.8	4.3	5.1	3.2	5.3	2.2
Redfish	26.9	59.1	14.0	31.8	25.7	43.2	21.3	33.8	25.4	25.0	17.3	26.4
Silver hake	28.3	4.8	8.7	4.2	2.6	2.0	2.6	2.4	3.0	6.3	4.0	3.9
Red hake	4.9	0.7	1.0	0.8	0.3	0.1	0.3	0.1	1.0	2.0	0.5	0.5
Pollock	8.6	7.8	3.6	2.4	2.9	5.4	13.1	3.6	5.5	8.4	5.9	6.2
Flounders:												
American plaice	6.2	3.6	6.0	6.3	3.5	4.3	3.5	2.5	2.9	2.2	2.9	2.3
Witch	3.6	2.3	2.5	4.5	2.0	3.7	5.1	3.4	3.2	2.3	1.3	1.6
Other	1.1	0.4	1.0	0.1	[1]0.0	0.1	1.2	0.3	0.1	0.7	0.2	0.6
Other groundfish:												
Angler	3.7	1.6	1.9	3.6	1.7	2.0	4.5	3.1	4.0	1.5	3.6	2.3
Cusk	2.2	1.2	1.3	3.8	1.1	1.8	1.7	2.0	1.8	3.0	1.3	0.5
White hake	7.8	5.2	7.9	9.5	4.2	5.8	17.7	16.3	15.3	16.9	15.9	14.0
Other	0.3	0.4	0.6	1.0	0.2	0.5	0.1	0.6	0.3	0.8	0.4	0.3
Principal pelagics:												
Herring	1.6	0.1	0.2	0.3	0.1	[1]0.0	[1]0.0	0.1	0.6	[1]0.0	[1]0.0	[1]0.0
Mackerel	[1]0.0	0.0	0.0	[1]0.0	0.0	[1]0.0	[1]0.0	[1]0.0	[1]0.0	[1]0.0	[1]0.0	[1]0.0
Other pelagics and other fish:												
Spiny dogfish	58.2	10.6	11.8	4.0	7.8	22.8	9.8	18.3	11.9	17.3	7.2	8.7
Skates and rays	15.1	9.4	11.1	17.4	4.9	10.0	14.4	16.2	12.1	7.9	7.6	4.4
Other[2]	2.5	0.1	0.2	0.3	0.4	0.2	0.1	0.3	0.2	0.3	0.2	0.2
Squid:												
Short-finned squid	([3])	[1,4]0.0	[4]0.2	[4]0.4	0.1	0.1	0.1	0.3	0.5	0.2	0.6	1.2
Long-finned squid	([3])	[4]0.0	[1,4]0.0	[4]0.1	[1]0.0	[1]0.0	[1]0.0	[1]0.0	[1]0.0	[1]0.0	[1]0.0	[1]0.0
Total finfish and squid	221.0	135.6	92.2	108.6	73.0	125.9	112.8	117.8	103.2	106.0	79.6	80.8

[1]Less than 0.05.
[2]Does not include data for tunas, sharks, swordfish, American eel, or white perch.
[3]Data not recorded.
[4]Squid catches for 1964-66 prorated by species according to relative percentages caught in later years.

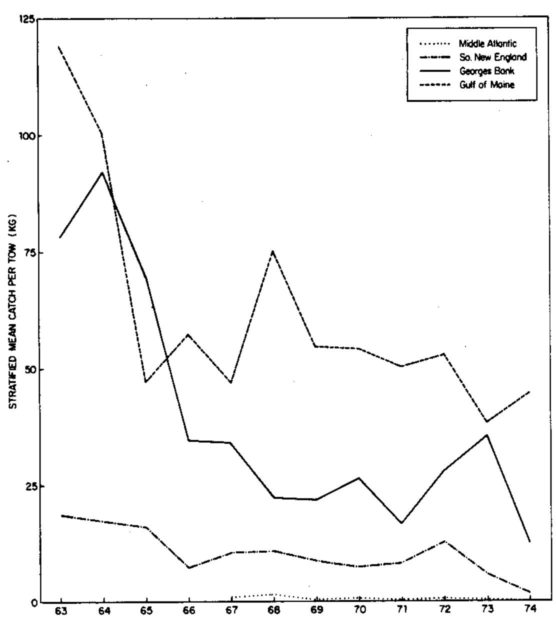

FIGURE 4.—Catch of principal groundfish in U.S. autumn bottom trawl surveys for the Middle Atlantic (strata 61-76), 1967-74, and for southern New England (strata 1-12), Georges Bank (strata 13-25), and the Gulf of Maine (strata 26-30 and 36-40), 1963-74.

Georges Bank and in the Gulf of Maine and to be almost nonexistent in southern New England waters. Relative abundance indices for redfish and pollock, however, appear to have remained relatively stable (Tables 4, 5). Cod declined somewhat in the Gulf of Maine but remained relatively stable in other areas (Tables 3-5).

Catches of flounders indicate substantial declines in relative abundance for all areas (Figure 5) and nearly all species (Tables 2-5) with yellowtail declining very sharply in recent years. Unusually high catches of yellowtail were taken in southern New England waters in 1972 (Figure 5, Table 3); factors involved are unclear but appear to reflect changes in availability, as actual increases in abundance do not appear to have occurred (Parrack[16]).

Data for other groundfish (Figure 6) suggest a decline in biomass for Middle Atlantic strata, an increase for Gulf of Maine strata, and relatively stable levels elsewhere. The observed trend for Middle Atlantic strata is strongly influenced by large catches of searobins in 1967 (Table 2) which

[16]Parrack, M. L. 1973. Current status of the yellowtail flounder fishery in ICNAF Subarea 5. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1973, Res. Doc. No. 104, Serial No. 3067 (mimeo.), 5 p.

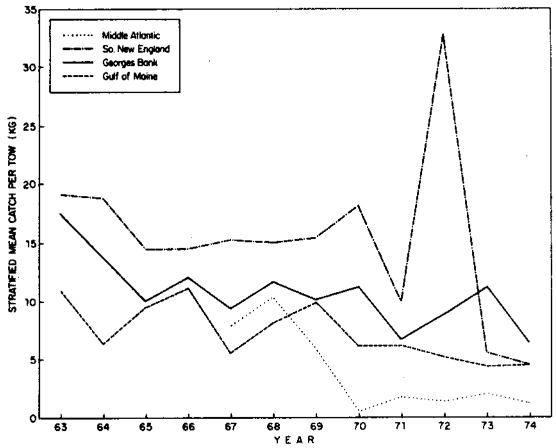

FIGURE 5.—Catch of flounders in U.S. autumn bottom trawl surveys for the Middle Atlantic (strata 61-76), 1967-74, and for southern New England (strata 1-12), Georges Bank (strata 13-25), and the Gulf of Maine (strata 26-30 and 36-40), 1963-74.

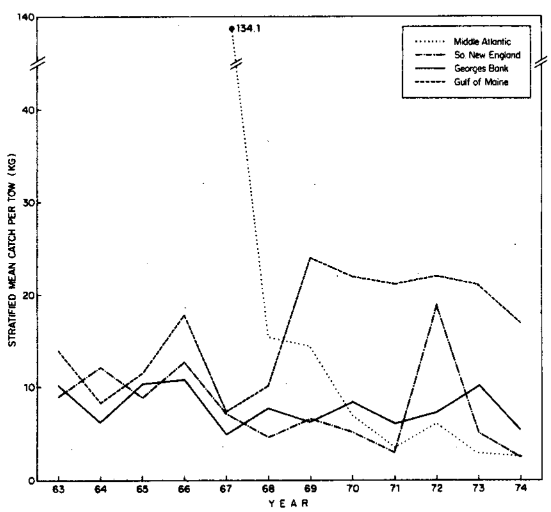

FIGURE 6.—Catch of other groundfish in U.S. autumn bottom trawl surveys for the Middle Atlantic (strata 61-76), 1967-74, and for southern New England (strata 1-12), Georges Bank (strata 13-25), and the Gulf of Maine (strata 26-30 and 36-40), 1963-74.

continued to decline in succeeding years. Ocean pout also appear to have declined sharply during the period of study in southern New England and Georges Bank strata (Tables 3, 4). Abundance of white hake, however, appears to have increased in the Gulf of Maine in recent years (Table 5), leading to an increase in other groundfish biomass for these strata.

Principal pelagics appear to have declined in relative abundance although considerable fluctuation is evident (Figure 7). Most of this variation is, however, associated with the presence of outstanding year-classes of herring in the early and mid-1960's (Schumaker and Anthony see footnote 7) and the appearance of an outstanding year-class of mackerel in 1967 (Anderson see footnote 9). Considerable fluctuation is also evident in catches of other pelagics and other fish (Figure 8, Tables 2-5) although the trend is generally downward (anomalous peaks relate primarily to high catches of spiny dogfish in certain years). Data for squid (Figure 9) indicate increased abundance although catches of long-finned squid appear to be lower in 1970 and 1971 in Middle Atlantic strata and from 1970 to 1972 in southern New England strata than in the years immediately preceding and following (Tables 2, 3). The actual degree of change throughout the period of study is uncertain, however, in that complete records of catches for squid were not kept prior to 1967.

A summary of trends in relative abundance by area is given in Tables 6 and 7 and Figure 10. We computed percentage changes from mean catch values (averaged over 1967-68 and 1973-74 for Middle Atlantic strata and 1963-65 and 1972-74 for all other strata sets). We obtained declines of

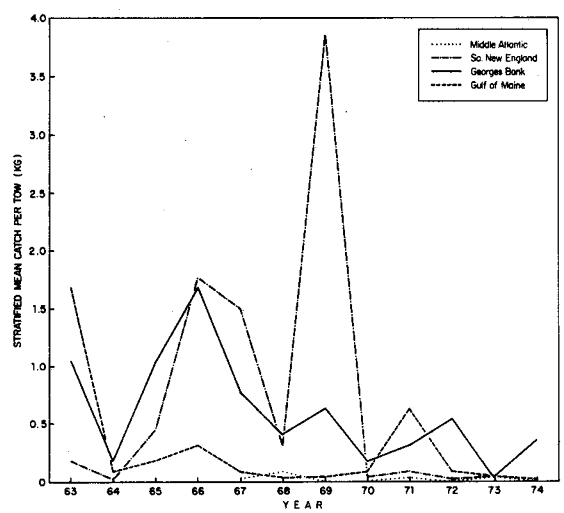

FIGURE 7.—Catch of principal pelagic species in U.S. autumn bottom trawl surveys for the Middle Atlantic (strata 61-76), 1967-74, and for southern New England (strata 1-12), Georges Bank (strata 13-25), and the Gulf of Maine (strata 26-30 and 36-40), 1963-74.

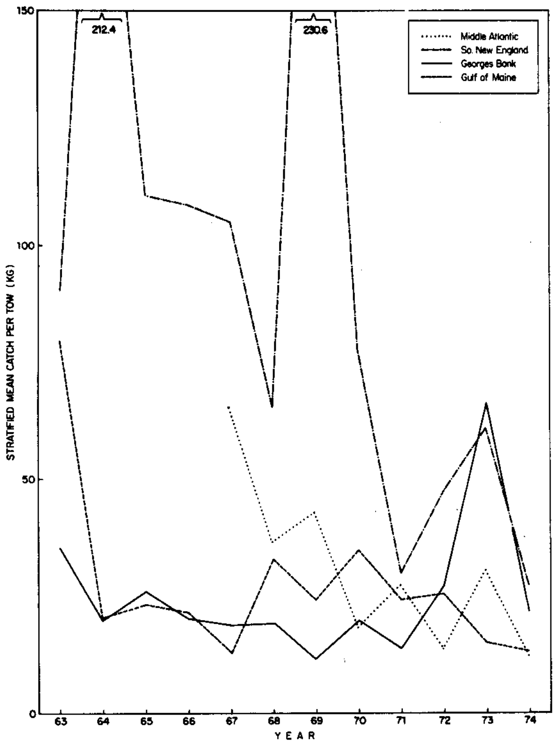

FIGURE 8.—Catch of other pelagics and other fish in U.S. autumn bottom trawl surveys for the Middle Atlantic (strata 61-76), 1967-74, and for southern New England (strata 1-12), Georges Bank (strata 13-25), and the Gulf of Maine (strata 26-30 and 36-40), 1963-74.

over 90% for certain species, while for all data combined we obtained declines of 74%, 52%, 37%, and 41% for the Middle Atlantic, southern New England, Georges Bank, and Gulf of Maine areas, respectively. Omission of catches of searobins for the Middle Atlantic area, however, reduces that value to 52%. Further omitting data for squid for all strata sets (as squid catches were inadequately recorded during the early years of the survey) provides corresponding declines of 62%, 58%, 38%, and 41%. Consequently, even greater declines may be more realistic than those initially computed.

After examining data for the above strata sets, we evaluated trends for the entire region by combining data over all strata (Tables 8, 9) and compared between means of initial and final periods (1967-68/1973-74 data for all strata; 1963-65/1972-74 data, Middle Atlantic strata excluded). For 1967-74, all strata (Table 8), we observed a decline of 32%, while for 1963-74,

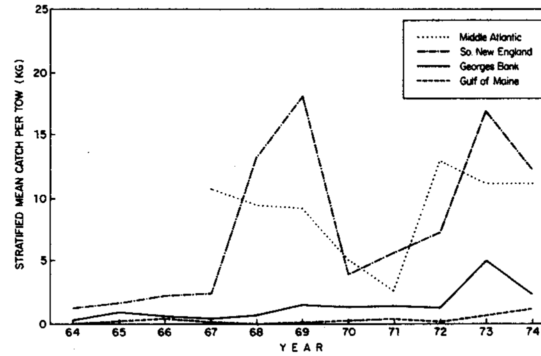

FIGURE 9.—Catch of squid in U.S. autumn bottom trawl surveys for the Middle Atlantic (strata 61-76), 1967-74, and for southern New England (strata 1-12), Georges Bank (strata 13-25), and the Gulf of Maine (strata 26-30 and 36-40), 1963-74.

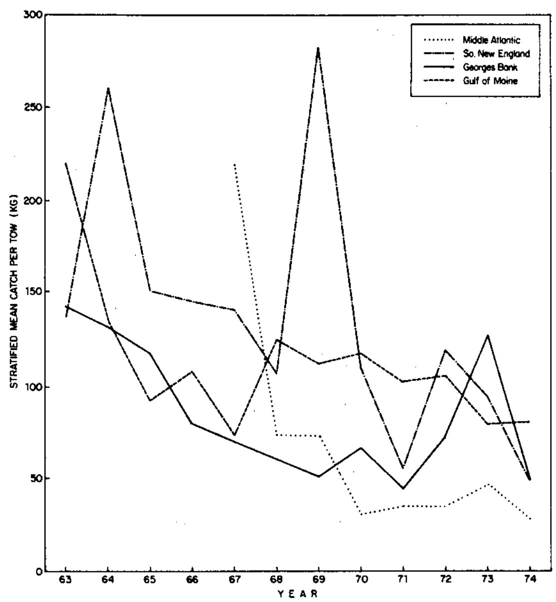

FIGURE 10.—Catch of total finfish and squid in U.S. autumn bottom trawl surveys for the Middle Atlantic (strata 61-76), 1967-74, and for southern New England (strata 1-12), Georges Bank (strata 13-25), and the Gulf of Maine (strata 26-30 and 36-40), 1963-74.

Middle Atlantic strata excluded (Table 9), the decline is 43%. The corresponding figures are 37% and 46%, respectively, with squid omitted.

The above data demonstrate that significant changes in biomass levels occurred in SA 5 and 6 after the early 1960's. It will be noted, however, that the summaries presented above are biased by "catchability" differences among species and do

TABLE 6.—Stratified mean catch per tow (kilograms) for selected species, *Albatross IV* fall survey data, Middle Atlantic (1967-68 and 1973-74) and southern New England (1963-65 and 1972-74) areas.[1] Mean catch per tow values represent simple averages of values given in Tables 2 and 3 for these areas and years.

	Middle Atlantic			Southern New England		
Species	1967-68 mean	1973-74 mean	% change	1963-65 mean	1972-74 mean	% change
Principal groundfish:						
Cod	0.0	0.0	0	1.7	0.8	−53
Haddock	0.0	0.0	0	3.7	[2]0.0	−99
Silver hake	0.9	0.2	−78	6.2	2.8	−55
Red hake	0.5	0.1	−80	6.0	3.4	−43
Flounders:						
Yellowtail	4.5	[2]0.0	−99	10.8	10.2	− 6
Summer flounder	1.8	0.5	−72	0.5	0.9	+80
Winter flounder	1.5	0.1	−93	2.9	1.3	−55
Other	1.2	1.1	−8	3.3	1.8	−45
Other groundfish:						
Angler	0.7	0.5	−29	5.4	4.5	−17
Ocean pout	[2]0.0	[2]0.0	− 0	0.5	0.1	−80
Sculpins	0.1	0.0	−100	1.0	0.8	−20
Scup	1.7	0.5	−71	1.5	1.6	+7
Searobins	71.9	1.9	−97	0.7	1.7	+143
White hake	0.1	0.0	−100	0.8	0.2	−75
Other	0.3	[2]0.0	−99	0.1	[2]0.0	−99
Principal pelagics:						
Herring	0.0	[2]0.0	+0	0.2	[2]0.0	−99
Mackerel	0.1	0.0	−100	[2]0.0	[2]0.0	+0
Other pelagics and other fish:						
Butterfish	10.9	7.4	−32	4.4	4.9	+11
Spiny dogfish	25.5	[2]0.0	−100	119.4	32.5	−73
Skates and rays	6.2	7.9	+27	12.5	5.1	−59
Other	8.4	6.4	−24	1.3	4.5	+246
Squid:						
Short-finned squid	0.3	0.1	−67	0.1	0.3	+200
Long-finned squid	9.9	11.1	+12	1.4	11.8	+743
Total finfish and squid	146.5	37.8	−74	184.4	89.2	−52

[1]Middle Atlantic and southern New England areas represented by strata sets 61-76 and 1-12, respectively.
[2]Less than 0.05.

TABLE 7.—Stratified mean catch per tow (kilograms) for selected species, *Albatross IV* fall survey data, Georges Bank and Gulf of Maine areas,[1] 1963-65 and 1972-74. Mean catch per tow values represent simple averages of values given in Tables 4 and 5 for these areas and years.

	Georges Bank			Gulf of Maine		
Species	1963-65 mean	1972-74 mean	% change	1963-65 mean	1972-74 mean	% change
Principal groundfish:						
Cod	8.4	12.8	+52	10.8	6.3	−42
Haddock	60.8	5.0	−92	22.0	3.5	−84
Redfish	2.0	2.8	+40	33.3	22.9	−31
Silver hake	2.9	2.1	−28	13.9	4.7	−66
Red hake	3.8	1.8	−53	2.2	1.0	−55
Pollock	2.0	1.0	−50	6.7	6.8	+1
Flounders:						
American plaice	2.9	0.7	−76	5.3	2.4	−55
Yellowtail	7.4	3.4	−54	0.4	0.2	−50
Winter flounder	2.0	1.5	−25	0.4	0.3	−25
Witch	0.7	1.0	+43	2.8	1.7	−39
Other	0.8	2.2	+175	0.1	[2]0.0	−99
Other groundfish:						
Angler	3.7	1.6	−57	2.4	2.5	+4
Cusk	0.3	0.2	−33	1.6	1.6	0
Ocean pout	1.2	0.2	−83	[2]0.0	0.1	+474
Sculpins	2.8	2.7	−4	0.2	0.2	0
White hake	0.9	2.6	+189	6.9	15.6	+126
Other	0.2	0.3	+50	0.3	0.1	−66
Principal pelagics:						
Herring	0.7	[2]0.0	−99	0.6	[2]0.0	−99
Mackerel	[2]0.0	0.2	+300	[2]0.0	[2]0.0	0
Other pelagics and other fish:						
Spiny dogfish	3.1	16.0	+416	26.9	11.1	−59
Skates and rays	22.7	19.9	−12	11.9	6.6	−45
Other	1.2	2.4	+100	0.8	0.2	−75
Squid:						
Short-finned squid	0.4	1.8	+350	0.1	0.7	+600
Long-finned squid	0.4	1.1	+175	[2]0.0	[2]0.0	0
Total finfish and squid	131.3	83.3	−37	149.6	88.5	−41

[1]Georges Bank and Gulf of Maine areas represented by strata sets 13-25 and 26-30 and 36-40, respectively.
[2]Less than 0.05.

TABLE 8.—Stratified mean catch per tow (kilograms) for selected species of finfish and squid, *Albatross IV* autumn bottom trawl survey data, 1967-74, Middle Atlantic, southern New England, Georges Bank, and Gulf of Maine (strata 61-76, 1-30, and 36-40).

Species	1967	1968	1969	1970	1971	1972	1973	1974
Cod	4.5	5.0	4.4	5.1	4.6	6.4	6.4	2.9
Haddock	8.1	5.8	3.8	4.0	2.4	2.2	3.3	1.3
Redfish	8.2	13.6	7.9	11.1	7.9	8.3	5.7	7.7
Silver hake	2.3	2.5	1.8	2.0	2.4	3.6	2.6	1.9
Red hake	1.0	1.6	1.8	1.3	1.7	2.6	1.6	0.7
Pollock	1.2	1.9	4.2	1.2	2.2	2.7	2.1	1.8
Yellowtail	4.8	5.6	5.2	4.2	2.9	7.9	1.6	1.0
Other flounder	4.6	5.4	5.1	5.1	3.5	4.3	4.2	3.5
Herring	0.3	0.1	0.1	[1]0.0	0.3	0.1	[1]0.0	[1]0.0
Mackerel	0.3	0.2	1.1	[1]0.0	[1]0.0	0.1	[1]0.0	[1]0.0
Other finfish[2]	80.9	47.1	89.2	49.3	33.6	43.3	54.5	27.4
Short-finned squid	0.2	0.3	0.1	0.3	0.4	0.3	0.3	0.4
Long-finned squid	2.8	5.1	6.8	2.2	2.1	4.6	7.6	5.8
Total finfish and squid	119.2	94.2	131.5	85.8	64.0	86.4	89.9	54.4

[1]Less than 0.05.
[2]Does not include data for tunas, sharks, swordfish, American eel, or white perch.

TABLE 9.—Stratified mean catch per tow (kilograms) for selected species of finfish and squid, *Albatross IV* autumn bottom trawl survey data, 1963-74, southern New England, Georges Bank, and Gulf of Maine areas (strata 1-30 and 36-40).

Species	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Cod	8.5	7.6	5.6	4.8	5.7	6.4	5.6	6.4	5.7	8.1	8.0	3.6
Haddock	31.6	31.2	22.9	10.5	10.2	7.4	4.7	5.1	3.1	2.8	4.2	1.6
Redfish	10.3	23.1	5.8	12.4	10.4	17.1	10.0	14.0	10.0	10.5	7.2	10.0
Silver hake	13.8	4.1	6.1	3.3	2.7	2.9	2.2	2.4	2.9	4.4	3.2	2.4
Red hake	6.7	2.3	2.7	1.6	1.2	1.8	2.1	1.6	2.0	3.2	2.0	0.8
Pollock	4.1	3.6	1.9	1.8	1.5	2.3	5.3	1.5	2.7	3.4	2.7	2.2
Yellowtail	6.6	6.5	4.5	3.2	5.2	5.6	5.6	5.3	3.6	9.8	2.1	1.2
Other flounder	8.8	6.1	6.7	9.2	4.6	5.6	5.8	6.3	4.0	5.1	4.8	4.0
Herring	1.0	0.1	0.5	1.2	0.4	0.1	0.1	0.1	0.3	0.1	[1]0.0	0.1
Mackerel	[1]0.0	[1]0.0	0.1	0.1	0.4	0.2	1.4	0.1	0.1	0.2	0.1	0.1
Other finfish[2]	75.6	89.4	61.8	62.9	49.8	45.8	97.5	55.5	33.7	49.4	59.9	30.6
Short-finned squid	([3])	[1,4]0.0	[4]0.1	[4]0.1	0.2	0.4	0.1	0.3	0.4	0.3	0.4	0.5
Long-finned squid	([3])	[4]0.5	[4]0.8	[4]1.0	0.8	4.0	6.2	1.5	2.0	2.5	6.7	4.5
Total finfish and squid	167.0	174.5	119.5	112.1	93.1	99.6	146.6	100.1	70.5	99.8	101.3	61.6

[1]Less than 0.05.
[2]Does not include data for tunas, sharks, swordfish, American eel, or white perch.
[3]Data not recorded.
[4]Squid catches for 1964-66 prorated by species according to relative percentages caught in later years.

not reflect the relative magnitude of various species within the biomass as a whole. For instance, herring and mackerel together appear to have constituted over 50% of the biomass present during this study (Edwards 1968; International Commission for the Northwest Atlantic Fisheries 1974e, footnote 17) yet account for less than 1% of the weight taken in autumn bottom trawl surveys. Furthermore, the aggregated distribution of finfishes and squid in nature, and the behavior of the gear employed, insure that catch data for individual species will seldom be normally distributed but rather will tend to conform to the negative binomial or some other contagious form (Taylor 1953). In the following sections, we utilize selected transformation and weighting procedures in attempts to correct for these factors.

[17]International Commission for the Northwest Atlantic Fisheries. 1975. Report of the herring working group, April 1975. ICNAF Annu. Meet. 1975, Summ Doc. No. 19, Serial No. 3499 (mimeo.), 31 p.

Weighted Analyses

Catchability differences among species imply that trends in biomass as defined in this study will be primarily determined by trends for species most vulnerable to the survey gear unless adjustments in terms of catchability are made. Accordingly, we developed catchability coefficients by year for the species and species groups in Tables 8 and 9 for use in computing weighting factors by relating stratified mean catch per tow by stock to available estimates of stock size, all computations being in terms of weight. Annual estimates of stock size (weight at the beginning of year i) were required for this purpose for each individual stock for which TAC's have been established (International Commission for the Northwest Atlantic Fisheries 1975c); thus, separate estimates were required for cod in 5Y[18] and 5Z, haddock in 5Ze, silver hake in

[18]Alphanumeric designations refer to divisions and subdivisions of SA 5 and 6 given in Figure 1.

5Y, 5Ze, and 5Zw-SA 6, red hake in 5Ze and 5Zw-SA 6, yellowtail in 5Ze, 5Zw, and SA 6, and herring in 5Y and 5Z-SA 6. (We considered the remaining species and species groups indicated as stocks for the purpose of this analysis.) Silver hake, herring, and mackerel stock sizes were available from virtual population analyses in previous assessments (International Commission for the Northwest Atlantic Fisheries 1974e, see footnote 17; Anderson[19,20]), while annual estimates for haddock and red hake had also been computed earlier (Hennemuth see footnote 5; Anderson[21]; Clark[22]) using average weight or mean weight at age data and the relationship:

$$C_i = N_i F_i / Z_i (1 - \exp[-Z_i]) \quad (3)$$

where C_i = landings (number) in year i,
N_i = stock size (number) at the beginning of year i,
F_i = instantaneous fishing mortality rate in year i, and
Z_i = instantaneous total mortality rate in year i ($=F_i + M$, the instantaneous natural mortality rate).

Approximations of stock size for both long-finned and short-finned squids are also available for recent years (International Commission for the Northwest Atlantic Fisheries 1975c). We used these approximations for all years in view of uncertainty regarding stock size and historical trends in abundance for these species (International Commission for the Northwest Atlantic Fisheries 1975c).

Stock size estimates for the remaining species and species groups are currently unavailable, and we computed estimates by a variety of procedures. For yellowtail, we assumed an F value of 1.0 for the southern New England (5Zw) stock in 1967-68 (M = 0.2 in all cases) based on earlier assessment work (Brown and Hennemuth see footnote 6), and calculated stock size for each year using Equation (3); 1964-66 stock sizes were then assumed to be similar to the 1967-68 average as commercial abundance indices were stable through this period. We then obtained values for succeeding years by adjusting the 1967-68 average by stock abundance indices based on pre-recruit survey catches (Brown and Hennemuth see footnote 6; Parrack[23]), i.e.,

$$\text{Stock size in year } i = \text{Mean stock size for 1967-68}$$

$$\times \frac{\text{Abundance index for year } i}{\text{Mean abundance index for 1967-68}} \quad (4)$$

For an estimate of SA 6 stock size, we obtained values for the 1963-66 period by multiplying the computed average stock size value for southern New England by the ratio between mean survey abundance indices between the SA 6 and southern New England stock areas and the ratio between the actual bottom areas considered; we obtained the remaining values using stock abundance indices (Parrack see footnote 23) as above. For the Georges Bank (5Ze) stock, we assumed an F value of 0.8 in 1964 and 1965 (Brown and Hennemuth see footnote 6), calculated stock sizes by Equation (3), and averaged these values to obtain an initial estimate; we then adjusted this value by means of commercial abundance indices (Brown and Hennemuth see footnote 6; Parrack see footnote 23) according to Equation (4) to obtain estimates for later years. The Cape Cod yellowtail stock was considered to have been relatively stable in recent years; we computed an estimate for 1969 by Equation (3) assuming an F value of 0.8 and added the resulting value to each Georges Bank stock size estimate to obtain combined estimates for the Georges Bank area.

We obtained stock size estimates for the remaining stocks from Equation (3) using available estimates of F and M and historical catch data (International Commission for the Northwest Atlantic Fisheries 1965-1973, 1974c, 1975a, see footnote 12). We computed an average stock size for the entire 1965-75 period for 5Y cod using mortality rates reported by Penttila and Gifford[24],

[19]Anderson, E. D. 1975. Assessment of the ICNAF Division 5Y silver hake stock. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1975, Res. Doc. No. 62, Serial No. 3544 (mimeo.), 13 p.

[20]Anderson, E. D. 1975. Assessment of the ICNAF Subdivision 5Ze and Subdivision 5Zw-Statistical Area 6 silver hake stocks. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1975, Res. Doc. No. 94, Serial No. 3574 (mimeo.), 17 p.

[21]Anderson, E. D. 1974. Assessment of red hake in ICNAF Subarea 5 and Statistical Area 6. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1974, Res. Doc. No. 19, Serial No. 3165 (mimeo.), 27 p.

[22]Clark, S. 1975. Current status of the Georges Bank (5Ze) haddock stock. Int. Comm. Northwest Atl Fish. Annu. Meet. 1975, Res. Doc. No. 48, Serial No. 3527 (mimeo.), 9 p.

[23]Parrack, M. L. 1974. Status review of ICNAF Subarea 5 and Statistical Area 6 yellowtail flounder stocks. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1974, Res. Doc. No. 99, Serial No. 3335 (mimeo.), 17 p.

[24]Penttila, J. A., and V. M. Gifford. 1975. Growth and mortality rates for cod from the Georges Bank and Gulf of Maine areas. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1975, Res. Doc. No. 46, Serial No. 3525 (mimeo.), 13 p.

while for 5Z cod we computed an average figure for the 1970-75 period using mortality rates from the above paper and obtained values for the remaining years by adjusting this average by commercial abundance indices reported by Brown and Heyerdahl.[25] We followed an analogous procedure in the case of "other finfish" by computing a value for 1967 (chosen to be in the middle of the period) assuming an F value of 0.4 and $M = 0.2$; we then calculated commercial abundance indices from historical catch data and total effort estimates for SA 5 and 6 (Brown et al. in press) and obtained stock size estimates for the remaining years by adjusting the 1967 value by means of these abundance indices according to Equation (4), as above. For redfish, other flounders, and pollock, we computed average values from Equation (3) using available sustainable yield estimates and assumed values of F, as follows ($M = 0.2$ in all cases):

Species	*Period*	*Sustainable yield estimate (tons × 10⁻³)*	F
Redfish	1964-75	16 (Mayo[26])	0.4
Other flounders	1964-69	25	0.7
Other flounders	1970-75	20	0.9
Pollock	1964-75	[27]16	0.4

Turning to survey abundance indices, an inherent problem in any analysis of trawl data lies in the fact that the computed means and variances are seldom, if ever, independent. The present data are no exception; Grosslein (1971) has found that in the present survey individual stratum variances are approximately proportional to the squares of the stratum means, indicating that a logarithmic transformation is appropriate (Steel and Torrie 1960). Under these conditions, use of a logarithmic scale transformation tends to normalize the data and render means and variances independent, thereby permitting use of parametric statistical methods (obviously, anomalous fluctuations in observed trends are also reduced considerably). Accordingly, we computed stratified mean catch per tow values for all stocks using ln (kilograms + 1) values for each tow; strata sets used are given by species and stock in Table 10. We then computed estimates of stratified mean catch per tow in original units by retransforming as suggested by Bliss (1967:128) according to the relation:

$$E(\bar{y}_{st}) = \exp(\bar{y}_{st} + S^2/2) \quad (5)$$

where $E(\bar{y}_{st})$ represents the estimated (retransformed) stratified mean catch per tow and $\bar{y}_{st}$ and S^2 represent the stratified mean and the estimated population variance, respectively, in logarithmic units, computed as in Equations (1) and (2) above. We also calculated untransformed ($\bar{y}_{st}$) values for the stocks and strata sets in Table 10 for comparative purposes.

After obtaining stock size estimates and abundance indices as described above, we computed catchability coefficients for all years by dividing both untransformed and retransformed stratified mean catch per tow for year i by the appropriate stock size value at the beginning of year $i + 1$ (or by the computed average stock size). Deviations from the arithmetic mean were then plotted by year; where trends were apparent,

TABLE 10.—Strata sets used in computing stratified mean catch per tow values by stock.

Species and stock	Strata sets: Middle Atlantic north[1]	Strata sets: Southern New England north[2]
Cod		
5Y[3]	26-30, 36-40	26-30, 36-40
5Z	5-30, 36-40	5-30, 36-40
Haddock		
5Ze	13-25	13-25
Redfish	18, 22, 26-30, 36-40	1-30, 36-40
Silver hake		
5Y	26-30, 36-40	26-30, 36-40
5Ze	13-25	13-25
5Zw-6	61-76, 1-12	1-12
Red hake		
5Ze	13-25	13-25
5Zw-6	61-76, 1-12	1-12
Pollock	61-76, 1-30, 36-40	1-30, 36-40
Yellowtail		
5Ze	13-25	13-25
5Zw	5-12	5-12
6	69-76, 1-4	1-4
Other flounders	61-76, 1-30, 36-40	1-30, 36-40
Herring		
5Y	26-30, 36-40	26-30, 36-40
5Z-6	63-76, 1-25	1-25
Mackerel	61-76, 1-30, 36-40	1-30, 36-40
Other finfish	61-76, 1-30, 36-40	1-30, 36-40
Short-finned squid	61-76, 1-30, 36-40	1-30, 36-40
Long-finned squid	61-76, 1-30, 36-40	1-30, 36-40

[1]Strata for the Middle Atlantic area (61-76) added in 1967.
[2]Since 1963 (strata 1-40).
[3]Alphanumeric designations refer to divisions and subdivisions of SA 5 and 6 shown in Figure 1.

[25]Brown, B. E., and E. G. Heyerdahl. 1972. An assessment of the Georges Bank cod stock (Div. 5Z). Int. Comm. Northwest Atl. Fish. Annu. Meet. 1972, Res. Doc. No. 117, Serial No. 2831 (mimeo.), 24 p.

[26]Mayo, R. K. 1975. A preliminary assessment of the redfish fishery in ICNAF Subarea 5. Int. Comm. Northwest Atl. Fish. Annu. Meet. 1975, Res. Doc. No. 59, Serial No. 3541 (mimeo.), 31 p.

[27]Pollock in ICNAF Divisions 4VWX, Subarea 5, and Statistical Area 6 are currently considered as a unit stock. Accordingly, this figure represents the SA 5 and 6 proportion of the estimated sustainable yield for this stock as determined from historical catch data.

linear regressions were fitted to the data to evaluate the degree of relationship. A significant ($P<0.01$) negative trend was obtained for haddock for both untransformed and retransformed data (Figure 11). This could have resulted from overestimates of stock size in later years or actual differences in catchability associated with changing availability as stock size decreased. A plot of numbers captured per tow by year during the period of study suggested that actual differences in catchability may have occurred (Figure 11); accordingly, we divided the period of study into two units (1963-68 and 1969-74) for the purpose of calculating weighting coefficients for the species. The dividing line was taken as the point in which the percentage of tows containing five haddock or less reached 90%.

In the case of species for which more than one stock had been defined, some question existed as to whether coefficients should be computed for the entire species or on a stock basis. As no consistent trends had been found for these species over time, one-way analysis of variance was used to test for differences between stocks, using years as replicate observations. These tests revealed significant differences ($P<0.05$) between individual stocks for all species except yellowtail (i.e., cod, silver and red hake, and herring). We therefore retained individual stocks as discrete units in computing biomass declines (i.e., no attempt was made to combine stocks on a species basis).

After obtaining the desired sets of catchability coefficients for all stocks, we obtained weighting coefficients by calculating arithmetic means of untransformed and retransformed sets (Tables 11, 12), using the entire set except in the case of haddock as explained above. We then computed biomass estimates by year, viz.

TABLE 11.—Weighting coefficients calculated by stock from untransformed and retransformed survey data, 1967-74, Middle Atlantic, southern New England, Georges Bank, and Gulf of Maine area (strata 61-76, 1-30, and 36-40).

Species and stock[2]	Calculated from: Untransformed data		Retransformed data[1]	
	Weighting coefficient[3]	Coefficient of variation[4]	Weighting coefficient[3]	Coefficient of variation[4]
Cod:				
5Y	39.954	0.31	44.545	0.44
5Z	5.160	0.52	3.433	0.50
Haddock[5]:				
5Ze	14.146, 10.193	0.25, 0.46	15.591, 7.461	0.71, 0.56
Redfish	40.063	0.29	49.188	0.32
Silver hake:				
5Y	8.714	0.80	8.348	0.94
5Ze	0.727	0.30	0.650	0.31
5Zw-6	1.325	0.33	1.101	0.40
Red hake:				
5Ze	6.565	0.65	5.384	0.74
5Zw-6	2.341	0.74	1.422	0.71
Pollock	4.069	0.45	1.442	0.37
Yellowtail:				
5Ze	17.391	0.24	15.106	0.31
5Zw	45.722	0.79	42.229	0.70
6	67.795	0.95	39.969	0.76
Other flounders	10.897	0.18	11.134	0.17
Herring:				
5Y	0.125	>1.0	0.039	0.97
5Z-6	0.010	>1.0	0.002	0.75
Mackerel	0.015	>1.0	0.005	0.57
Other finfish	12.809	0.31	14.553	0.14
Short-finned squid	0.302	0.37	0.206	0.34
Long-finned squid	5.240	0.46	4.302	0.65

[1]Estimated stratified mean catch per tow values computed from transformed data according to the relation, $E(\bar{y}_{st}) = \exp(\bar{y}_{st} + S^2/2)$, where $\bar{y}_{st}$ and S^2 represent the mean and estimated population variance, respectively, on the transformed scale.

[2]Weighting coefficients calculated by individual stock for cod, haddock, silver hake, red hake, yellowtail, and herring; stock areas are given in Figure 1. Stock areas for the remaining species are equivalent to all strata in SA 5 and 6 covered during 1967-74.

[3]Weighting coefficients calculated as $\frac{\sum_{i=1}^{n}\left[C_i/S_{i+1}\right]}{n}$ where C_i = stratified mean catch per tow (tons) in year i and S_{i+1} = stock size at the beginning of the following year. All values $\times 10^8$.

[4]Coefficient of variation calculated over all years.

[5]Weighting coefficients computed separately for 1967-68 and 1969-74 data due to apparent changes in catchability.

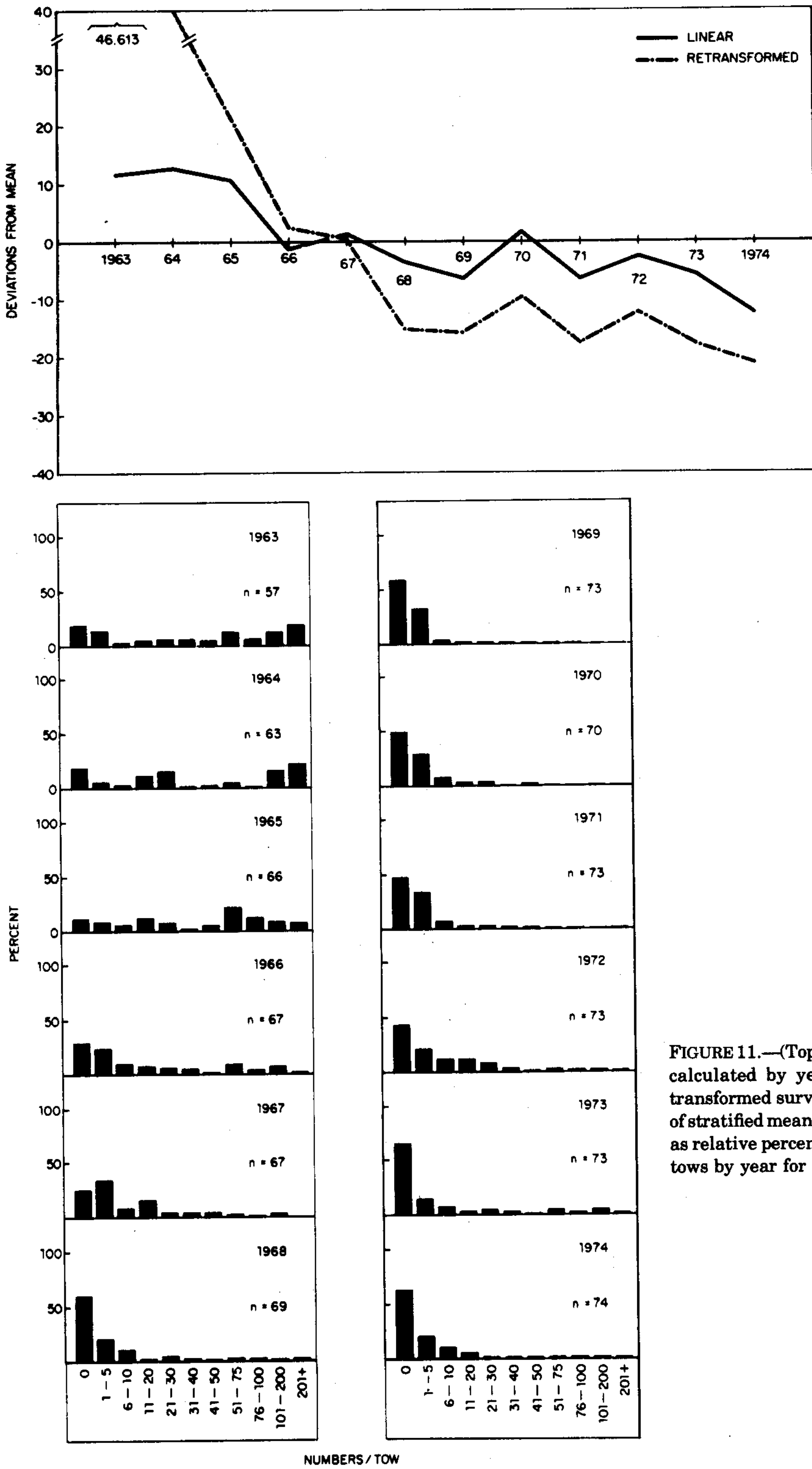

FIGURE 11.—(Top) Trends in catchability coefficients calculated by year using untransformed and retransformed survey data, and (bottom) distributions of stratified mean catch per tow in numbers expressed as relative percentages of the total number of survey tows by year for Georges Bank haddock.

TABLE 12.—Weighting coefficients calculated by stock from untransformed and retransformed survey data, 1963-74, southern New England, Georges Bank, and Gulf of Maine area (strata 1-30 and 36-40).

Species and stock[2]	Calculated from: Untransformed data: Weighting coefficient[3]	Untransformed data: Coefficient of variation[4]	Retransformed data[1]: Weighting coefficient	Retransformed data[1]: Coefficient of variation[4]
Cod:				
5Y	42.877	0.31	41.000	0.41
5Z	4.918	0.46	3.462	0.47
Haddock[5]:				
5Ze	20.696, 10.193	0.36, 0.46	38.857, 7.461	0.63, 0.56
Redfish	42.776	0.41	46.898	0.34
Silver hake:				
5Y	7.948	0.79	8.205	0.94
5Ze	0.814	0.49	0.724	0.46
5Zw-6	2.122	0.32	2.116	0.37
Red hake:				
5Ze	6.503	0.69	5.380	0.77
5Zw-6	3.644	0.68	3.070	0.62
Pollock	5.174	0.41	2.279	0.46
Yellowtail:				
5Ze	17.143	0.28	15.221	0.38
5Zw	39.399	0.77	40.716	0.62
6	104.145	>1.00	121.231	>1.00
Other flounders	13.016	0.22	14.293	0.25
Herring:				
5Y	0.178	>1.00	0.095	>1.00
5Z-6	0.027	>1.00	0.005	0.94
Mackerel	0.015	>1.00	0.006	0.56
Other finfish	12.569	0.31	13.648	0.18
Short-finned squid	0.254	0.70	0.177	0.63
Long-finned squid	3.124	0.80	2.099	>1.00

[1]Estimated mean catch per tow values computed from transformed data according to the relation, $E(\bar{y}_{st}) = \exp(\bar{y}_{st} + S^2/2)$, where $\bar{y}_{st}$ and S^2 represent the mean and estimated population variance, respectively, on the transformed scale.
[2]Weighting coefficients calculated by individual stock for cod, haddock, silver hake, red hake, yellowtail, and herring; stock areas are given in Figure 1. Stock areas for the remaining species are equivalent to all strata in SA 5 and 6 covered during 1967-74.

[3]Weighting coefficients calculated as $\frac{\sum_{i=1}^{n} \left[C_i/S_{i+1}\right]}{n}$ where C_i = stratified mean catch per tow (tons) in year i and S_{i+1} = stock size at the beginning of the following year. All values $\times 10^8$.
[4]Coefficient of variation calculated over all years.
[5]Weighting coefficients computed separately for 1967-68 and 1969-74 data due to apparent changes in catchability.

$$\sum_{j=1}^{k} \left[C_{ij}/W_j\right] \quad \text{for all } i \qquad (6)$$

where C_{ij} refers to stratified mean catch per tow for the jth stock in the ith year and W_j refers to the weighting coefficient for the jth stock (Tables 13, 14), summation being over k stocks. For the purposes of this paper, we consider each computed estimate as representing stock size at the beginning of the year following collection of the survey data ($i + 1$), as catchability coefficients were calculated by relating catch per tow values in autumn of year i to stock size at the beginning of year $i + 1$ (above). Note that with the exception of 1970 figures for "all data" (Tables 13, 14), values computed from retransformed data agree reasonably well with those computed from untransformed values; consequently the general appropriateness of assuming a lognormal distribution for these data is confirmed.

The average stock size estimate for 1964-66 obtained for all species of 5.0×10^6 tons (Table 14) is almost identical to that obtained by Edwards (1968) for the same area and period (5.1×10^6

TABLE 13.—Stock size estimates (tons $\times 10^{-3}$) for ICNAF Subarea 5 and Statistical Area 6, 1967-74, Middle Atlantic, southern New England, Georges Bank, and Gulf of Maine, inclusive (strata 61-76, 1-30, and 36-40).

Year	Calculated with: Untransformed data: All data	Untransformed data: Data for principal pelagics excluded	Retransformed data: All data	Retransformed data: Data for principal pelagics excluded
1968	7,481	1,783	8,012	1,806
1969	3,826	1,795	5,209	1,880
1970	9,555	1,859	5,158	1,750
1971	2,097	1,567	2,964	1,736
1972	3,156	1,331	3,062	1,418
1973	3,136	1,870	3,661	1,825
1974	2,098	1,841	2,541	1,760
1975	1,828	1,107	1,934	1,119

TABLE 14.—Stock size estimates (tons × 10^{-3}) for ICNAF Subarea 5 and Statistical Area 6, 1963-74, southern New England, Georges Bank and Gulf of Maine, inclusive (strata 1-30 and 36-40).

	Calculated with			
	Untransformed data		Retransformed data	
Year	All data	Data for principal pelagics excluded	All data	Data for principal pelagics excluded
1964	6,616	3,317	7,357	3,640
1965	2,780	2,373	2,677	2,151
1966	5,079	2,088	5,382	2,184
1967	8,331	1,610	7,770	1,605
1968	6,056	1,478	6,431	1,493
1969	3,400	1,787	4,238	1,763
1970	11,490	2,012	5,158	1,867
1971	2,174	1,642	2,828	1,759
1972	2,644	1,411	2,751	1,501
1973	3,231	1,964	3,622	1,937
1974	2,371	2,009	2,717	1,931
1975	2,036	1,217	1,981	1,165

tons). Edwards obtained biomass estimates by adjusting minimum biomass figures for each species by a factor accounting for differences in availability and vulnerability, and although estimates obtained for individual species by these methods differed in certain cases it can be seen that, on the average, results are quite comparable.

The data of Tables 13 and 14 again reveal pronounced declines. In Table 13 (1968-75, all strata) comparisons of averages for "all data" between 1968-69 and 1974-75 reveal a 65% decline for untransformed data and a 66% decline in the case of retransformed values; with principal pelagics excluded, the corresponding figures are 18 and 22%, respectively. In Table 14 (1964-75, Middle Atlantic strata excluded) comparisons between averages for "all data" for 1964-66 and 1973-75 reveal declines of 47% and 46% for untransformed and retransformed values, respectively, while with principal pelagics excluded the corresponding figures were 33% and 37%. The greater decrease for the 1968-75 period for "all data" might appear somewhat anomalous but actually results primarily from appearance of the outstanding 1967 mackerel year class.

As the estimates in Tables 13 and 14 purport to measure declines in biomass in SA 5 and 6, it might logically be argued that they could be combined in some way (use of the 1968-75 data would be preferable in that survey coverage extended further to the south). Paired t-tests indicated no differences between corresponding stock size estimates in Tables 13 and 14 for the 1968-75 period. Therefore, we combined the 1968-75 estimates in Table 13 with the 1964-67 estimates in Table 14 (Figures 12, 13) and computed percentage changes between the means of the 1964-66 and 1973-75 periods, as before. For "all data," we obtained declines of 51% and 47% with untransformed and retransformed values; with herring and mackerel excluded, the corresponding figures were 38% and 41%.

Analysis of both untransformed and retransformed data yield essentially similar results. The data of Figures 12 and 13 illustrate the effectiveness of the transformation in reducing anomalies caused by variability in the data. For untransformed estimates (Figure 12) it will be

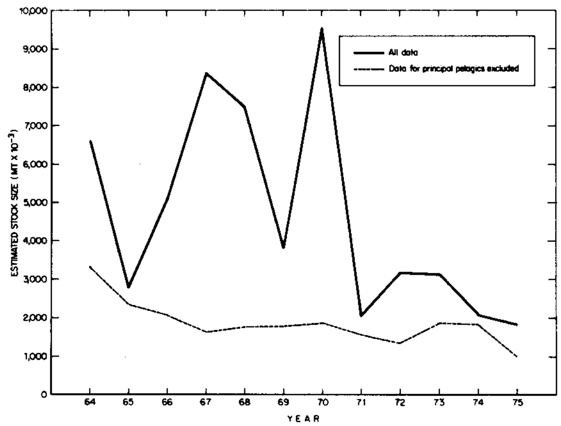

FIGURE 12.—Estimates of fishable biomass by year for ICNAF Subarea 5 and Statistical Area 6, 1964-75, calculated with untransformed survey data. Curves were plotted by combining 1968-75 estimates from Table 13 with 1964-67 estimates from Table 14.

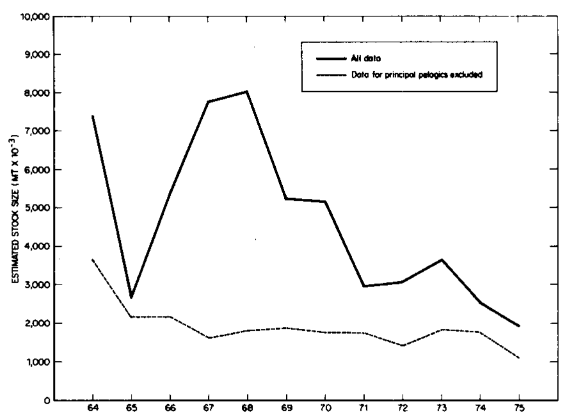

FIGURE 13.—Estimates of fishable biomass by year for ICNAF Subarea 5 and Statistical Area 6, 1964-75, calculated with retransformed survey data. Curves were plotted by combining 1968-75 estimates from Table 13 with 1964-67 estimates from Table 14.

noted that an anomalous peak occurs in 1970, which examination of biomass estimates on a per-species basis revealed to have been caused by anomalously high mackerel catches in certain tows during the 1969 survey. The influence of this factor appears to have been compensated for by use of the logarithmic transformation (Figure 13). On the other hand, the anomalously low data point for 1965 (Figures 12, 13) appears to have been caused by anomalously low catches of herring in that year, a circumstance in which the transformation was ineffective. It does appear, however, that by and large the transformation was of definite value in following trends through time, although estimates for most of the years considered proved to be similar.

The above analyses clearly indicate that biomass levels have decreased significantly in SA 5 and 6 in recent years; the trend observed correlates well with increases in fishing effort observed by Brown et al. (in press). In addition, we have also found evidence indicating that major changes in species composition have occurred as well. The apparent increase in white hake abundance in the Gulf of Maine in recent years (Table 5) could have resulted from population increases in response to reductions in other groundfish species. Similarly, increased mackerel abundance coincident with declining abundance of herring (Tables 3, 4) may indicate some form of species interaction coincident with exploitation, while apparent increases in abundance of squid (Tables 2-7, Figure 9) may have occurred in response to declining abundance of finfish species. The relationships involved are unclear at present and further study is obviously necessary.

Comparisons of annual landings data since 1971 (over 1.0×10^6 tons) with biomass estimates in Tables 13 and 14 indicate that the fraction of the biomass harvested annually has increased significantly in recent years (i.e., from less than one-fifth of the total in the early and mid-1960's to between one-third and one-half of the total at present). Furthermore, landings since 1971 have exceeded the composite MSY figure of 950×10^3 tons calculated by Brown et al. (in press) based on the Schaeffer yield model. This information, together with declines in stock size approximating 50% as indicated in this paper, imply that a significant degree of overfishing has occurred and that stock size has been reduced below the level corresponding to MSY. Back-calculations for all species in Tables 13 and 14 provide an average stock size estimate of approximately 7.0×10^6 tons prior to 1964, from which (allowing for the U.S. coastal fishery in previous years) it may be inferred that the actual virgin biomass for this fishery probably approximated $8.0\text{-}9.0 \times 10^6$ tons. Since the Schaeffer yield model postulates that MSY will be taken at a stock level corresponding to one-half the maximum (Schaeffer 1954), we may in turn assume that a stock level of approximately $4.0\text{-}4.5 \times 10^6$ tons should be maintained for SA 5 and 6 if MSY from this resource is to be achieved. In contrast, estimates for fishable biomass in the present paper approximate 2.0×10^6 tons at the start of 1975, implying that a lengthy period of reduced exploitation is necessary if stocks are to be rebuilt to the MSY level.

In April 1975, the Assessments Subcommittee (STACRES) reviewed evidence relating to declines in biomass in SA 5 and 6 in recent years and concluded that substantial reductions in catch would be necessary if stocks are to recover (International Commission for the Northwest Atlantic Fisheries 1975c). Accordingly, a TAC of 650×10^3 tons was recommended to ICNAF and approved at the Seventh Special Commission Meeting (International Commission for the Northwest Atlantic Fisheries 1975b) in September. Even with a reduction of this magnitude, STACRES estimated that a minimum of 7 yr would be required for this resource to recover to the MSY point.

ACKNOWLEDGMENTS

We thank Judith Brennan for her helpful comments and suggestions on data analysis, Kathryn Paine for her assistance with computer programming, and Elizabeth Bevacqua and Maureen Romaszko for numerous tabulations of the data. Richard C. Hennemuth reviewed the manuscript and made suggestions for improvement. The work of the numerous biologists and technicians who have participated in *Albatross IV* autumn bottom trawl surveys and the processing of the sample data since the beginning of the program is also sincerely appreciated.

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