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Fisheries Organization

Serial No. N902

NAFO SCR Doc. 84/IX/105

SCIENTIFIC COUNCIL MEETING - SEPTEMBER 1984

<u>Changes in Population Structure and Abundance of Spiny Dogfish</u> off the Northeast Coast of the United States

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Abstract

Analysis of bottom trawl surveys by the Northeast Fisheries Center for the period 1968-1983 shows a change in size composition of the spiny dogfish population. Large female dogfish (>100 cm total length) were rare in the late 1960's and early 1970's, but are now frequently observed in the surveys. Also juvenile dogfish (<35 cm; age 0-1) have increased in recent years. These changes indicate an increase in mean age and probably average fecundity, and they are consistent with the apparent increase in population abundance as shown by the mean catch per haul indices from recent surveys. Minimum biomass estimates by size group were calculated as a basis for estimating minimum consumption of finfish and squid by dogfish.

INTRODUCTION

Spiny dogifsh (<u>Squalus acanthias</u>) are distributed in the western North Atlantic from Florida to Newfoundland (Bigelow and Schroeder 1953). They are highly migratory (Figure 1) and travel in schools which are generally segregated by size and, for large mature individuals, by sex. During winter, they migrate south and are concentrated in the Mid-Atlantic region where pupping and mating presumably occur (Templeman 1944, Hisaw and Albert 1947, unpublished National Marine Fisheries Service, Northeast Fisheries Center (NMFS/NEFC) research vessel data). Dogfish are chiefly summer visitors to the Gulf of Maine (including Georges Bank) and more northern waters (Bigelow and Schroeder 1953, Jensen 1965).

Results of tagging studies conducted off Newfoundland (Templeman 1954)

and off the northeastern coast of the United States (USA) (Jensen 1965, 1967; Shafer 1970) indicate that dogfish in the Northwest Atlantic probably comprise one population which makes extensive seasonal migrations. Templeman (1965), however, reported the occurrence of overwintering immature females and immature and mature males off Newfoundland.

Age and growth of the Northwest Atlantic dogfish stock has been the subject of three recent studies. Soldat (1982) obtained maximum ages of 20 and 26, respectively, for males and females, Nammack (1982) obtained ages up to 35 and 40 years, respectively, for males and females; and the oldest ages obtained by Slauson (1982) for males and females were 36 and 37 years, respectively. The oldest ages for each sex from these studies were approximately 1.5 times those determined for the North Sea stock by Holden and Meadows (1962).

Commercial fishing for dogfish off the northeast coast of the USA has been conducted since the late 19th century (Jensen 1965). Annual landings during the first half of the 20th century remained below 400 metric tons (mt) and were taken exclusively by USA vessels. Beginning in 1966, distantwater fleets (DWF), particularly USSR vessels, began taking dogfish in their trawl fisheries. From 1966 to 1976, total annual landings were between 3,000 and 22,000 mt. Following implementation of the Magnuson Fishery Conservation and Management Act of 1976 (MFCMA, Public Law 94-265) in March 1977, DWF landings have been substantially reduced. Since 1977, USA landings have averaged 5,000 mt annually resulting from recent improvements in processing methods and the development of a European export market.

This paper examines long-term changes in size composition and abundance of dogfish taken in NEFC bottom trawl surveys and provides minimum estimates of dogfish consumption.

METHODS

Dogfish length frequencies (mean number per tow) and minimum biomass estimates (Grosslein 1969) were derived from NMFS/NEFC bottom trawl surveys conducted since 1968 in the spring and autumn offshore (27. m) waters between Nova Scotia and Cape Hatteras, North Carolina (Figure 2). Analysis of spring data was based on catches from the entire area (sampling strata 1-42, 49, and -61-76), whereas analysis of autumn data was based on catches from all areas except the Mid-Atlantic sampling strata (61-76) since the distribution of dogfish

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is shifted to more northern waters at that time of year. Since an unknown portion of the stock, predominantly individuals ≥ 50 cm (Templeman 1982), is north of the area surveyed in the autumn, length frequencies from autumn surveys are not presented. The 1973-1981 spring survey data were adjusted to account for fishing power differences between the Yankee #36 trawl used in the spring 1968-1972 and 1982-1983 trawl surveys and the #41 trawl used in the 1973-1981 spring trawl surveys (Sissenwine and Bowman 1978). Correction factors (41/36 of <u>1.40</u> for numbers and <u>1.45</u> for weight were used. The #36 trawl was employed for the entire (1968-1982) autumn time series.

Length frequencies (mean number per tow) for female dogfish (78-89 cm) taken in 1968-1980 spring surveys were estimated by applying the average sex ratio, over 3 cm intervals, from the 1981-1983 data. This is the only time period for which dogfish length measurements by sex were available. All dogfish (\geq 90 cm) were assumed to be females.

Minimum biomass (mt) estimates were derived by areal expansion of spring and autumn bottom trawl survey biomass indices (kg) using the following equation:

$$\hat{B} = \frac{(A)(\overline{w})}{\alpha}$$

where \hat{B} is the biomass estimate, \overline{w} is the stratified mean wt/tow, A is the area sampled by the bottom trawl survey (sq. miles), and α is the area swept by each tow (0.011 sq. miles). These data were portioned into sex length categories (20=30 cm, 36-55 cm, 56-100 cm, and \geq 101 cm) corresponding to the six separate feeding size classes reported by Nammack (1982).

Dogfish food habits, percent (weight) by site categories, were obtained from Nammack (1982) and Bowman and Eppi (1984). Mean annual dogfish intake requirements per unit stock weight from Jones and Geen (1977) were 5.0 kg for young, 3.2 kg for immature, 2.7 kg for subadult males, 2.5 kg for adult males, and 2.6 kg for adult females. In this paper, an intake requirement of 5.0 kg for young was assumed to apply to the size groups measuring 21-39 cm and 31-35 cm, and a requirement of 3.2 kg for immatures was used for the 36-55 Cm group. The average of the three values for subadult males and adult males and females (2.6 kg) was used for the three length classes \geq 56 cm. This was justified since the latter three size/sex groups used by Jones and Geen (1977) do not correspond to the larger three categories used in this paper. The intake values were used in conjunction with reported food habits data and biomass

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estimates to obtain minimum consumption estimates. The method used in calculating consumption estimates was obtained from Bowman and Eppi (1984).

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RESULTS

Length frequency distributions of the mean catch per tow of dogfish from the 1968-1970 and 1980-1981 spring surveys are shown in Figure 3 to illustrate the population size structure at times of low and high abundance. Four modes of varying strength are generally observed in all years between 25 and 35 cm, 45 and 60 cm, 65 and 80 cm, and 82 and 95 cm. Plots of the 1981 data by sex (Figure 4), the first year in which dogfish were measured by sex, exemplify these modal distributions. The first mode represents predominantly age 0 fish (pups) with some contribution of ages 1-2. The second mode represents young males and females, mostly ages 3-5. The third mode consists mainly of mature males (age 6+) with some contribution from large immature females (ages 6-11) The last mode represents principally mature females (ages 12+) with some contribution from large mature males (ages 25-35). The modes reflect the schooling behavior of this species. The estimated age groupings of these modes are based on Nammack's (1982) data.

Female length frequencies from alternate spring surveys are plotted in Figure 5 to illustrate that the population size composition, particularly individuals >100 cm, has increased over the 16-year time series. Concurrently, the modal distribution of mature females shifted from 80-85 cm in earlier years to 95-100 cm in recent years.

Minimum biomass (mt) estimates of dogfish from 1968-1983 spring and 1968-1982 autumn surveys have fluctuated greatly in recent years (Figure 6). The spring estimates ranged from 96,000 to 898,800 mt and averaged 285,700 mt, while the autumn estimates ranged from 85,400 mt to 347,500 mt and averaged 148,000 mt. Since dogfish school, there tends to be rather high variability among the survey catches which result in year-to-year fluctuations in biomass estimates which do not reflect absolute changes. For example, the 1980 spring biomass estimate (336,000 mt) increased 244% above the 1979 value (97,700 mt), and the spring 1983 value (229,400 mt) was 74% below the 1982 value (898,800 mt).

The spring and autumn biomass estimates were partitioned into six length groups (Table 1). These results indicate that the variability observed in the annual biomass estimates (Figure 6) was strongly influenced by the availability of the larger size classes of dogfish to the sampling gear, which was particularly evident in the 1979 spring and the 1974 and 1982 autumn data. Also, in 1981 the biomass estimates increased dramatically for all size groups in both the spring and autumn data (Table 1). This increase continued into the spring of 1982 for the larger size groups (i.e., 256 cm). The 1982 autumn biomass estimates declined as sharply as they increased in the preceding year. Likewise, the 1983 spring biomass estimates for the larger size group declined sharply from the 1982 estimates.

From Nammack (1982) and Bowman and Eppi (1984) it was estimated that teleosts comprised 70% (wt) of the diet of dogfish (>60 cm). Based on an average biomass of 213,000 mt, an intake requirement of 2.6 kg and following the method reported by Bowman and Eppi (1984), it was estimated that the larger dogfish consume 387,000 mt of fish annually. Likewise, it was estimated that squids (<u>Illex</u> and <u>Loligo</u>) comprised 19% (wt) of the diet of dogfish (\leq 60 cm). Based on an average biomass of 21,900 mt and an average intake requirement of 4.3, this size category of dogfish consume 179,000 mt of squid annually.

DISCUSSION

Modes in the bottom trawl survey length frequency data characterize the size composition of dogfish schools off the northeast USA Coast. The large year-to-year variability in the magnitude of the modes is probably more related to availability than changes in abundance, given the long life span of the species.

The appearance and apparent increase in abundance of dogfish >100 cm, beginning in the early 1970's, may be explained by the response of dogfish to the large increase in total fishing mortality generated by the distantwater fleets during the early 1960's to mid-1970's (Brown and Halliday 1983). Although fishing mortality on dogfish increased during this period, catches were well below the MSY (40,000 mt) calculated by Grosslein (1974). More importantly, the DWF fisheries were principally responsible for the large reductions in groundfish stocks (i.e., cod, silver hake and pollock) (Clark and Brown 1977) which are competitors of dogfish (Maurer and Bowman 1975). Additionally, reductions in the stocks of pelagic species (i.e., herring and mackerel) (Anthony and Waring 1980, Anderson 1983), major dogfish prey items (Maurer and Bowman 1975) were probably compensated for by increases in the populations of <u>Illex</u> and <u>Loligo</u> squid (Lange 1983a,b) and sand lance (Morse 1982). Thus, the combination of low dogfish removals, reduced competition for food, and increases in abailable prey would provide a mechanism for increased growth and population biomass.

Since all dogfish >100 cm are sexually mature females, the increased abundance of this size group has important implications on total fecundity or pup production. Recent studies by Soldat (1978), Nammack (1982) and Slauson (1982) indicated that the average number of pups per female in USA waters increased 1.6-3.0 times above the 3.72 average reported by Templeman (1944) for dogfish off Newfoundland. The increase was observed for all comparable length categories. However, Templeman (1944) observed only one individual >100 cm in length. Additionally, whereas Templeman (1944) counted a miximum of 7 pups per female, Nammack (1976) and Slauson (1982) obtained values of 15 and 18, respectively.

Holden (1973) compared fecundity estimates of the Scottish-Norwegian stock with those obtained by Templeman (1944) and noted a higher fecundity for the European stock which he attributed to a density-dependent response by dogfish to exploitation. He also theorized that density-dependent changes in fecundity would provide a greater degree of response to exploitation than density-dependent changes in growth rates. However, Wood et al. (1977) questioned the conclusions arrived at by Holden (1973) for two reasons. First, they believed he failed to consider how fishing mortality affected the contribution of older age groups to total production. And secondly, they cite Ketchen's (1972) finding, that growth rates and production vary greatly among geographically distinct populations as an explanation for the fecundity differences Holden (1973) reported.

Wood et al. (1977) used age structure models to examine the response to exploitation by the Northeast Pacific dogfish population under three different density-dependent mechanisms. These mechanisms were compensatory mortality, compensatory fecundity, and compensatory growth. Of these, compensatory changes in natural mortality was the principal mechanism of density-dependence which allow the stock to respond to exploitation.

From calculations of average dogfish biomass, food habits data and

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intake requirements, by size group, dogfish consumption of finfish and squid off the Northeast USA Coast is equivalent to 180% of their biomass.

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Nammack (1982) reported that sand lance followed by mackerel were the major components of identifiable fish in the diet of dogfish, whereas Bowman and Eppi (1984) reported just the opposite from samples collected in 1983. However, the food habits data analyzed by Nammack (1982) was collected almost exclusively in the NEFC's Southern New England sampling strata (1-12) while Bowman and Eppi (1984) sampled the entire survey region (Figure 2). Additionally, in 1983 the stock size (millions of fish) of age 1+ mackerel increased sharply due to strong recruitment of the 1982 year class (Anderson 1983).

Available data indicate that the size composition and fecundity of dogfish in the Northwest Atlantic has increased in recent years. These increases are believed to result from a combination of limited exploitation, reduced competition, and increased abundance of suitable prey. Although the gradual increase in the abundance of dogfish (≥101 cm) may be related to a series of years of good recruitment in the early 1950's, no data exist to examine this mechanism.

The rather high variability among the biomass estimates, particularly in recent years, may be related to availability, seasonal shifts in dogfish distribution in response to water temperatures, or timing in the bottom trawl surveys.

Preliminary estimates of consumption indicate that a significant component of the dogfish diet is teleosts, particularly sand lance and Atlantic mackerel. Being an opportunistic feeder (Templeman 1944, Jones and Geen 1977, Soldat 1978 and Nammack 1982), dogfish can be expected to readily shift their diet to the most abundant prey item. Bowman and Eppi (1984) documented such shifts for the dogfish stock in the Northwest Atlantic.

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Figure 1. Seasonal migratory patterns of spiny dogfish in the Northwest Atlantic.







Figure 4. Length frequency distributions for spiny dogfish taken in the NEFC 1981 spring offshore (>27 m) bottom trawl survey, by sex and combined over both sexes.



Figure 5. Length frequency distributions for female spiny dogfish taken in NEFC 1968-1975 (bottom) and 1976-1982 (top), by two year intervals, bottom trawl surveys from Nova Scotia to Cape Hatteras.

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Figure 6. Minimum biomass estimates from 1968-1983 spring and 1968-1982 autumn NEFC bottom trawl surveys for spiny dogfish from Nova Scotia to Cape Hatteras.

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