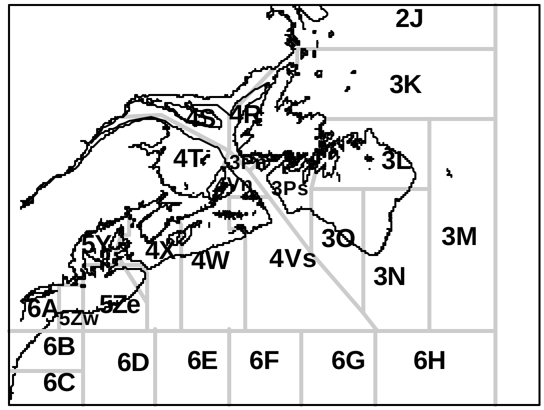
Fisheries and Oceans / Pêches et Océans
Maritimes Region

DFO Science
Stock Status Report B3-09(1999)



Porbeagle Shark in NAFO Subareas 3 - 6

Background

The porbeagle shark (Lamna nasus) is a cold-temperate species that occurs in the north Atlantic, south Atlantic and south Pacific oceans. The species range extends from Newfoundland to New Jersey and possibly to South Carolina in the west Atlantic and from Iceland and the western Barents Sea to Morocco and the Mediterranean in the east Atlantic. In the northwest Atlantic, this pelagic shark inhabits inshore and offshore waters colder than 14°C, and is commonly seen in the 6 - 12°C range. Porbeagle sharks move onto the Scotian Shelf in early spring and into the Gulf of St. Lawrence and onto the Grand Banks during the summer and early fall. Segregation occurs by sex and size. Mating probably occurs in the early fall off southern Newfoundland. Porbeagle move south and into deeper water in late fall and are taken off the continental shelf in winter. They are also taken in deep water areas such as Emerald Basin and in the Gulf of Maine during the winter.

The stock structure of the porbeagle shark is relatively unstudied, but independent tagging studies all indicate that there is little or no exchange between the east and west Atlantic. The same studies suggest that only one stock resides in the northwest Atlantic, migrating between the Gulf of Maine and southern Newfoundland on an annual basis. Therefore, the stock is defined by NAFO SA 3 - 6.

Unlike most of the teleosts (bony fishes), the fertilization of eggs occurs internally in elasmobranchs (sharks, skates and rays). In porbeagle sharks, fertilized eggs continue to develop in the uterus of the female and young are born as fully formed juveniles or "pups" after a gestation period of 8-9 months. The young are born at a relatively large size of 65-70 cm, thus reducing the number of potential predators. Pregnant females continue to release eggs and the embryos obtain nourishment by consuming unfertilized eggs in the uterus. The number of young produced annually averages 4 pups per litter. Males mature at about 175 cm fork length while females mature at about 210 cm fork length. The age of first maturity in males occurs at age 7, but is closer to age 14 in females. Porbeagle sharks may live to an age of more than 30 years. Maximum reported size is 320cm fork length and 250kg; however specimens over 250cm are rare.

The diet of the porbeagle shark consists primarily of midwater and pelagic fishes, but includes squid and a variety of other fishes. The only likely natural predators are other large sharks.

Summary

- An intensive research program on porbeagle was initiated in 1998 with the support and funding of the shark fishing industry, and in collaboration with the Apex Predator Program of the National Marine Fisheries Service.
- A standardized catch rate analysis indicated that the relative abundance of porbeagle in 1998 was about 50% of its 1991 level. The standardized catch rate of mature porbeagle has declined to 30% of its 1992 level.
- Yield per recruit analysis produced an $F_{0.1}$ reference fishing mortality of 0.08. However, spawning stock biomass is sensitive to even lower levels of F, and will continue to decline at $F_{0.1}$. Natural mortality is about 0.1.
- Independent measures of fishing mortality all suggest that F has been around 0.11 since 1996, about 33% higher than $F_{0.1}$.
- Porbeagle have a low pup production rate and mature considerably after the age they first appear in the fishery. In light of the very low numbers of mature females now found in the population, it is important to protect them, possibly by restricting access to areas and/or seasons where large females are present.

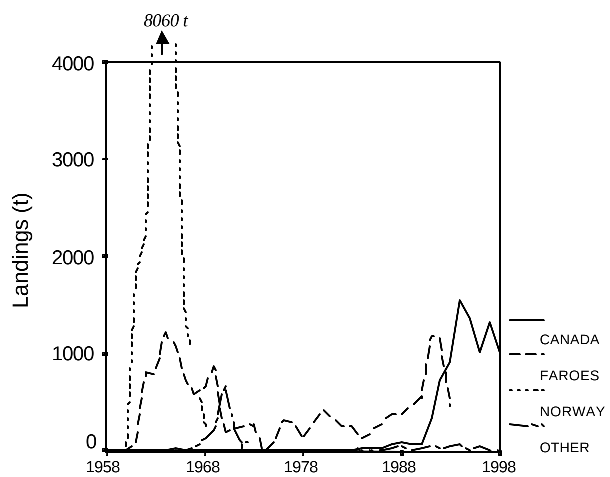
Background

The previous assessment of this resource was limited to a review of landings and catch rates. There was insufficient information available at the time upon which to base any calculations of growth, mortality, abundance or yield.

The Fishery

Landings (t)

Year	1993	1994	1995	1996	1997	1998	1999
TAC	-	-	-	-	1000	1000	1000
Foreign	512	66	4	48	2	0	
Canada	919	1549	1379	1024	1304	1008	
TOTAL	1431	1615	1383	1072	1306	1008	

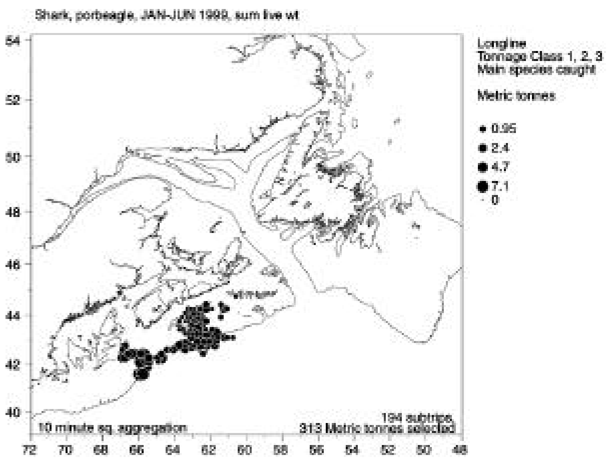


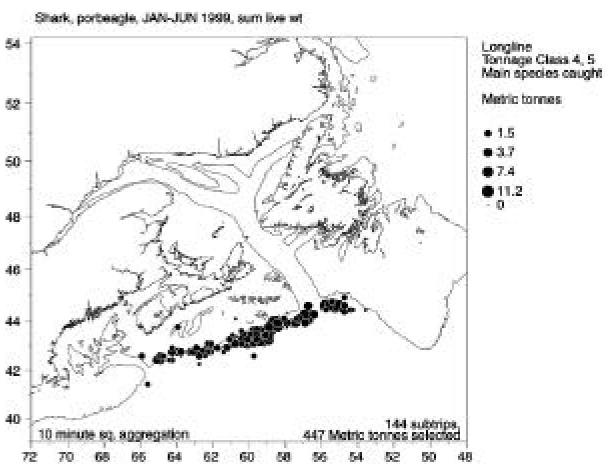
The **fishery** for porbeagle sharks in the Northwest Atlantic (NAFO subareas 3 - 6) started in 1961 when Norwegian vessels began exploratory fishing on a virgin population. These vessels had previously fished for porbeagle in the Northeast Atlantic. They were joined by vessels from the Faroe Islands during the next few years. **Reported landings** in the Northwest Atlantic rose from 1,924t in 1961 to 9,281t in 1964 and then fell to less than 1,000t in 1970 as a result of a collapse of the fishery. Although the fishery was unrestricted, reported landings were less than 500t until 1989. Reported landings rose to 1,917t in 1992, due to increased effort by Faroese vessels and also due to the entry of Canadian interests into this fishery. Faroese participation was phased out of the directed fishery by 1994, at which time total landings by three Canadian offshore pelagic longline vessels and a number of inshore vessels was 1615t. Since that time, the fishery has been almost exclusively Canadian, with landings declining gradually to 1008t in 1998. Catches by foreign vessels fishing outside of Canadian waters are unknown, but are believed to be small. Landings in the first half of 1999 have reached nearly 800t. Since 1996, approximately 2/3 of the directed catch has been made by the 2 remaining offshore vessels; the other 1/3 was made by a fleet of inshore vessels based in Nova Scotia.

Canada introduced a shark management plan in 1995 which defined a non-restrictive catch guideline of 1,500t. In 1997, a TAC of 1000t was imposed under the **1997-99 Shark Management Plan**. Landings reached or exceeded the TAC in both 1997 and 1998.

Porbeagle sharks are taken almost exclusively by a Canadian directed longline fishery. **By-catch** in the Canadian swordfish longline fishery, the Japanese tuna longline fishery, and various inshore fisheries is minimal, seldom exceeding 40t in recent years. There is almost no recreational fishery for porbeagle sharks.

The **geographic location and timing of the fishery** is different for the inshore and offshore fleets. Both fleets fish the Scotian Shelf in the spring, but the offshore fleet concentrates on the Shelf edge while the inshore fishery extends well onto the Shelf. There is little directed effort for porbeagle by the inshore fleet in the fall; most of the fall catch is made by the offshore fleet fishing off southern Newfoundland and in the Gulf of St. Lawrence. There was no directed fishery during the summer of 1999 when the industry voluntarily agreed to reserve quota for the fall.





The **size composition** of the 1999 spring catch was smaller than that of 1998, with mean fork lengths of 140 and 155 cm, respectively. While both fleets caught some larger (>200 cm) sharks at various locations on the Scotian Shelf and on Georges Bank, most were taken by the inshore fleet at shallower depths or at locations closer to shore than those fished by the offshore fleet.

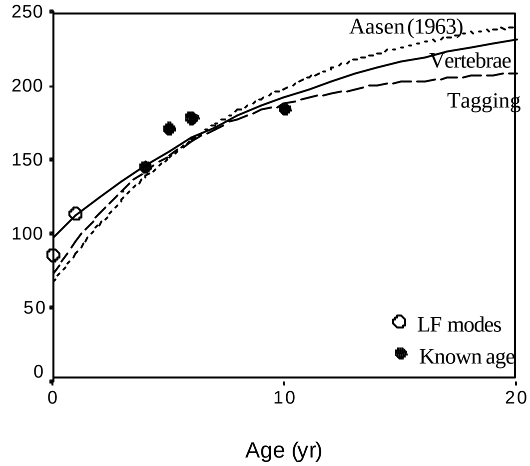
Resource Status

An intensive **research program** on porbeagle shark was initiated in 1998 with the support and funding of the shark fishing industry. On-board collection of detailed measurements and tissues were made by scientific staff, while members of the fishing industry measured more than 75% of all sharks landed in 1998 and 1999. This information provided a view of the resource that is seldom possible in other fisheries, and greatly assisted in the preparation of this stock assessment. In addition, collaboration with the Apex Predator Program of NMFS in the USA provided access to both expertise and unpublished data. As a result, our understanding of porbeagle biology and population dynamics has increased considerably in the past 2 years.

The **stock structure and migration** pattern of porbeagle was studied through analyses of unpublished Norwegian, Canadian and US tagging studies carried out since the 1960s. All three studies demonstrated extensive annual migrations of porbeagle between the Gulf of Maine and the Gulf of St. Lawrence/southern Newfoundland, with no evidence of more than one stock. There was also no evidence of stock mixing between the western and eastern Atlantic.

The **age and growth rate** of porbeagle was determined through examination of growth bands on the vertebrae of 315 sharks. The accuracy of the growth bands as age indicators was confirmed through analysis of length frequency modes (for ages 0-1), recaptures of porbeagle tagged as 0-group which were at liberty for 4-6 years, recaptures of porbeagle injected with tetracycline at the time of tagging, and analysis of growth rates in 48 tagged porbeagle at liberty for 1-6 years. There were no obvious differences in growth rate between males and females, although the age at maturity in females was considerably older (age 14; 212 cm FL) than in males (age 7; 170 cm FL). The longevity of porbeagle sharks appears to be between 30-40 years.

Fork length (cm) and age



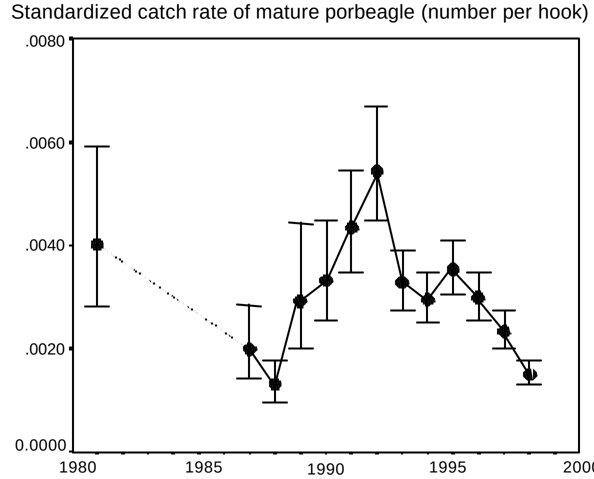
Annual trends in length composition were examined for evidence of overexploitation. Fall catches on the Grand Banks, a presumed mating ground, have generally been dominated by large sexually mature porbeagle, but the median fork length has declined since the early 1980s, suggesting a reduced abundance of large sharks. While there were no consistent changes in the length composition of spring catches on the Scotian Shelf, the latter has usually been composed of smaller, mainly immature sharks.

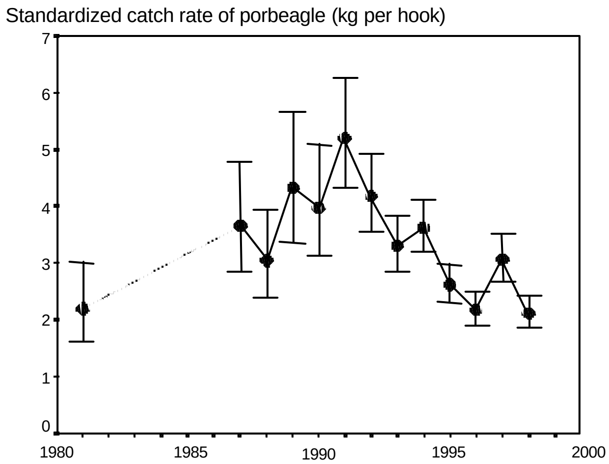
Median fork length (cm) in 3L, 3NO - Sept to Oct

Trends in commercial catch rate were used as indicators of abundance, both in terms of overall biomass (kg/hook) and in terms of the numbers of sexually mature (>200 cm FL) individuals per hook. The catch rates of sexually mature animals in both offshore vessels declined substantially in most areas after 1994, although the 1998 fall catch rates may have been affected by the early closure of the fishery. The history for the inshore fleet is much shorter, but significant declines in the catch rates of mature sharks were observed in most areas since 1997 or 1998. In contrast, the overall catch rates (kg/hook) of both fleets have not shown consistent trends in recent years.

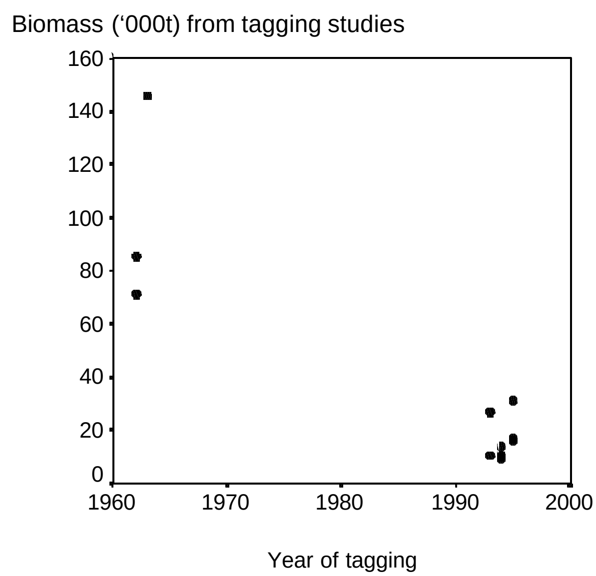
A **standardized catch rate analysis** showed a marked increase in the catch rate of large sharks between 1988 and 1992, followed by an equally marked decline to a very low level in 1998 (to about 30% of its peak level). This trend is consistent with the gradual entry of the Canadian fleet into the fishery in the early 1990s, followed by reduced abundance of the mature fish due to heavy fishing. The standardized catch rate for all size classes (kg/hook) showed a similar, but less marked, decline since 1991 (to 50% of its peak level), although catch rates have been relatively stable since 1996.

Standardized catch rate of mature porbeagle (number per hook)



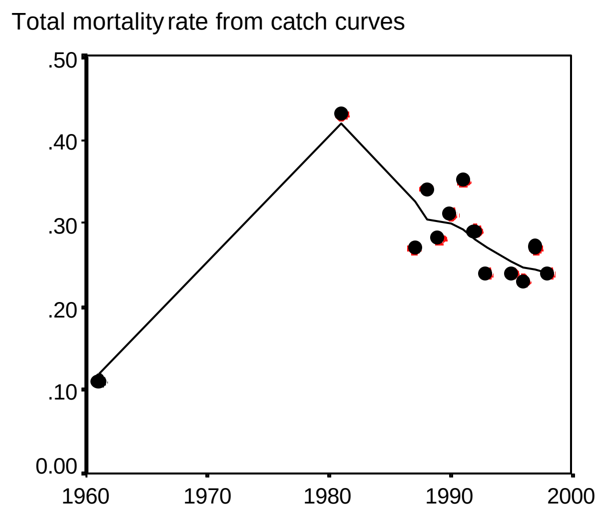


The **stock abundance** of both the virgin population of the 1960s and that of the fished population in the 1990s was estimated through Peterson analysis of tag recaptures. The independent tagging studies of the US and Canada provided similar estimates of population biomass between 1994 and 1997. These population estimates were about 15-20% of the size of the virgin population tagged by the Norwegians.

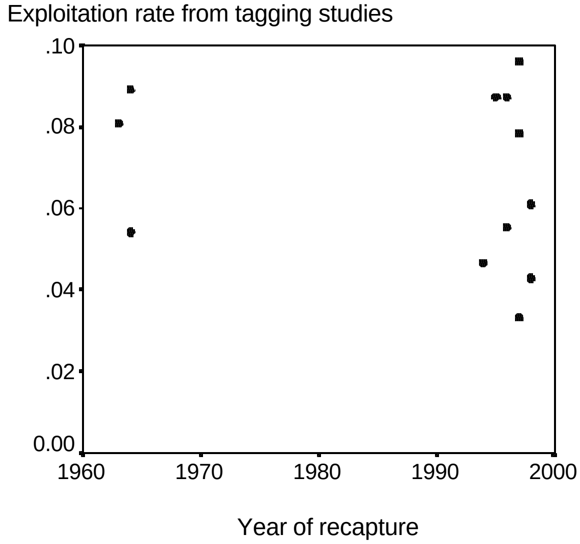


The **age composition** of past and present landings was reconstructed using the growth model described earlier as applied to annual reconstructions of population length frequency. Prior to 1991, the age of full recruitment off southern Newfoundland in the fall generally varied between 10-14 years, suggesting that this area serves as a mating ground. However, the age of full recruitment to the fishery has dropped to an age of less then 5 years since 1991.

Total mortality rates were estimated from annual and seasonal catch curves. Catch curves for the virgin 1961 population indicated a natural mortality rate (M) of about 0.1. Total mortality rates for all years subsequent have been considerably higher, but generally lie between 0.17 and 0.35. Total mortality appears to have declined slightly since the 1980s, with the rate for the past 5 years being on the order of 0.17-0.25. By subtracting the rate of natural mortality, this would provide an estimate of 0.07-0.15 for recent fishing mortality.

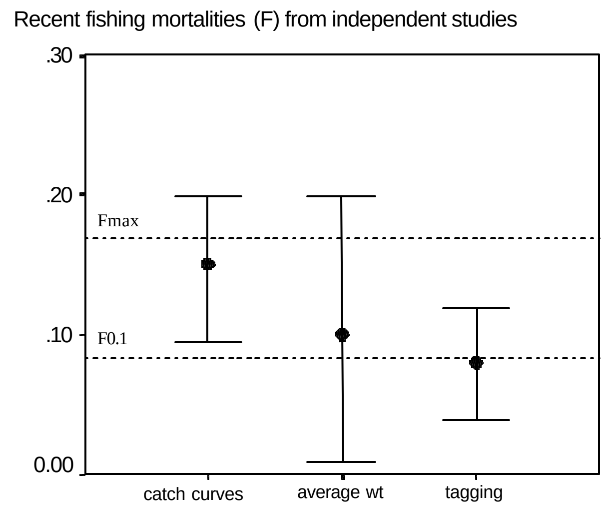


Exploitation rate of both the virgin population of the 1960s and that of the fished population in the 1990s was estimated through Peterson analysis of tag recaptures. The independent tagging studies of the US and Canada provided similar estimates of exploitation rate since 1994, varying between 3-9% with a mean of about 7%. This estimate is only slightly lower than that observed during the intensive fishing of the mid 1960s, just prior to the collapse of the fishery.



Yield per recruit analysis was based on the calculated growth model, an empirically-determined length-weight relationship, the estimate of M=0.1 determined from the catch curve analysis, and an assumed selectivity curve. The estimated $F_{0.1}$ value was 0.083 while F_{max} was estimated to be 0.17. Because the age of capture occurs well before the age of sexual maturity, spawning stock numbers would be expected to be susceptible to even modest fishing mortalities (<0.05), reminiscent of the decline which was observed in the catch rate of sexually mature porbeagle. The reference point at which the spawning population is maintained at 30% of its original level is F_{30} = 0.067. It is considered that 30% of the virgin biomass should be viewed as a minimum level, and that higher levels of biomass (lower F) are likely to be required to sustain a spawning population. An independent calculation of **minimum replacement mortality rate** estimated from life table analysis indicates that a fishing mortality of less than about 0.07 is required if the spawning numbers are to be maintained.

This assessment contains several independent measures of **recent fishing mortality**. Fishing mortalities estimated from catch curves, Peterson exploitation rates and the mean weight in the catch (compared to that expected of $F_{0.1}$ catches) all suggested that fishing mortalities between 1996-1998 were between that of $F_{0.1}$ and F_{max}, with a mean F of about 0.11. Since both fishing effort and quotas were stable between 1996-1998, these results suggest that the recent level of F has been about 33% higher than $F_{0.1}$ = 0.08.



Sources of Uncertainty

There are several sources of uncertainty in this assessment. There are large gaps in our understanding of porbeagle reproduction, including uncertainty in the size and age of female sexual maturity, and the location of the pupping grounds. Mature sharks are seldom seen in the winter and spring, and their overwintering grounds remain unknown. This uncertainty affects the estimation of spawning stock size, and could also influence yield projections through effects on availability.

Other sources of uncertainty include some of the assumptions of the Peterson tag analysis, specifically those dealing with tag-induced mortality and tag loss rates. The age determination of old sharks (>10 yr) remains unvalidated, and could affect the accuracy of the catch curve calculations. In any event, further age determinations are required to more accurately reconstruct age composition from length composition.

Outlook

Porbeagle sharks produce few offspring and mature at a late age compared to the age of first capture. This combination of life history characteristics makes porbeagle highly susceptible to over-exploitation. Average catches of about 4500t per year in the early 1960s resulted in a fishery which collapsed after only 6 years, and which did not fully recover for another 20 years. However, the fishery appeared sustainable during the 1970s and 1980s when landings averaged 350t annually. Catches of 1000-2000t throughout the 1990s appear to have impacted the population, producing lower catch rates and markedly lower numbers of mature females.

The provisional TAC of 1000t introduced in 1996 was based on very limited scientific information, and did not include any estimates of yield, mortality or stock abundance. Nevertheless, it has apparently been effective in reducing overall mortality closer to a sustainable level. Recent catches averaging 1130t per year (1996-1998) have resulted in fishing mortality rates which exceed $F_{0.1}$ by 33%. However, the life history characteristics of porbeagle suggest that a sustainable spawning stock will require an overall fishing mortality which is somewhat less than $F_{0.1}$. Alternatively, a fishing mortality equal to $F_{0.1}$ on the immature population may be sustainable if the mature population is protected.

The life history characteristics of porbeagle indicate that the diminishing population of mature females needs to be protected. In light of the size segregation by season and location, reduced mortality of mature females may be achieved by restricting access to areas and/or seasons where large females are present.

Industry funding and support for the scientific study of this stock improved the accuracy and precision of the stock assessment, and should help ensure the sustainability of the fishery.

For More Information

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