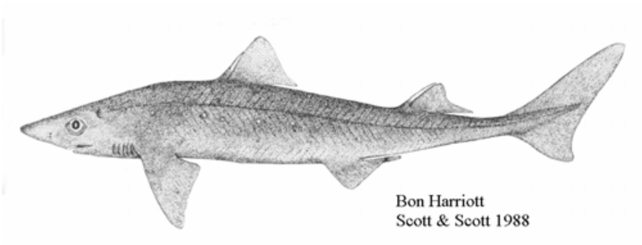
ASSESSMENT OF SPINY DOGFISH IN ATLANTIC CANADA



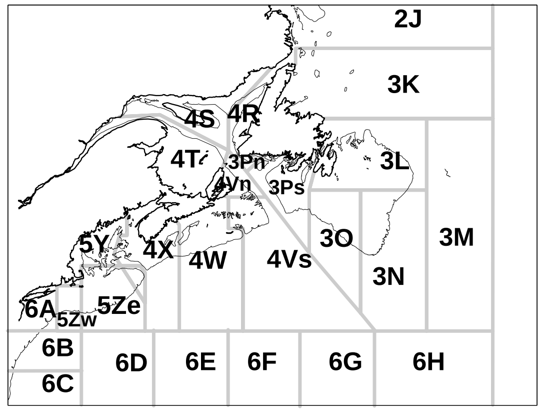


Figure 1. Map of NAFO areas relevant to this assessment.

Context :

Most Atlantic Canadian landings of spiny dogfish are taken in directed handline, longline, and gillnet fisheries. Catches were unrestricted prior to 2002. Since 2002, precautionary directed catch quotas based on past catches have been in place. The quota since 2004 has been set at 2500 mt. Quotas to this point have not been based on scientific advice, and there are no restrictions on discarding and bycatch in other fisheries.

In recognition that spiny dogfish stock components are found on both sides of the Canada/U.S. border, an information exchange forum was held at the Bedford Institute of Oceanography in 2003 so that science, fisheries management and industry from both the U.S. and Canada could exchange information and views about spiny dogfish biology, management and fisheries. The meeting was recognized as the first step in a process to work towards more integrated management of spiny dogfish.

In 2003, an intensive 5-year research program on Canadian dogfish was initiated by the Department of Fisheries & Oceans (DFO), conducted in cooperation with the dogfish fishing industry through a Joint Project Agreement (JPA). The JPA provided for the collection of large numbers of at-sea and landed samples of dogfish catches that were used in analyses of commercial catches and dogfish biology.

This report is an overview of all work done to date to better understand the stock structure, migration patterns, abundance trends and current state of the Canadian portion of the Atlantic spiny dogfish population. The information and advice provided is expected to be used in the management of the fishery and to guide future discussions with the U.S.

There are no available methods for determining the absolute population abundance or biomass of spiny dogfish in the northwest Atlantic. Research vessel (RV) surveys towing otter trawls provide a relative measure of abundance and biomass. When the area sampled by the otter trawl during a standard 30-minute tow is scaled up to the total survey area, the resulting estimate of minimum trawlable biomass is a measure of total biomass in the survey area. However, since the net does not capture all fish in its path, it is recognized that minimum trawlable biomass is almost certainly an underestimate of total biomass.

SUMMARY

- The Atlantic population of spiny dogfish is more productive than is the northwest Pacific population. However, the long gestation period (approximately 2 years), late age of sexual maturation and slow growth rate for spiny dogfish means that the species is relatively unproductive compared to other fish species.
- For the most part, dogfish tagged in Canadian waters have remained in Canadian waters, and those tagged in U.S. waters have remained in U.S. waters. However, there is some movement (10-20%) between Canadian and U.S. waters, with the Gulf of Maine region being the primary mixing ground.
- In terms of numbers, 66% of the commercial catch consists of females, and 26% consists of mature females. These numbers are much lower than those present in the U.S. commercial catch, where females made up 91% of the catch numbers between 2002-2005.
- Estimated dogfish discard mortality has averaged about 850 mt annually since 1986. Discard mortality often exceeded reported catch prior to 1999, but recent landings have greatly exceeded discard mortality.
- Spring minimum trawlable biomass estimates for spiny dogfish in Canadian and U.S. waters show similar trends, increasing from the early 1980s to the early 1990s, then declining somewhat to the present. Mean values for both indices were around 500,000 mt in the early 1990s, declining to about 300,000 mt in 2007 for the Canadian index. The spring index is considered to be a better indicator of total adult biomass than is the summer index.
- The trends in summer/fall minimum trawlable biomass estimates for spiny dogfish in Canadian and U.S. waters show considerably more variability than do those from the spring. Both indices show a consistent upward or stable trend from about 1985 to the present. The most recent Canadian biomass value is about 350,000 mt (corresponding to about 200 million dogfish). The summer index is considered to be a better indicator of sub-adult biomass than adult biomass.
- In the absence of a viable population model, it is not possible to estimate the exploitation rate for spiny dogfish in Atlantic Canada. However, it does not appear that the apparent decline in total Canadian spring biomass can be attributed solely to commercial exploitation. Total catch (including dead discards) between 1990 and 2006 accounted for about 3,000 mt per year, while the apparent decline in total biomass was closer to 18,000 mt per year.
- It is not currently possible to estimate trends in mature female biomass for spiny dogfish in Atlantic Canada. However, mature female biomass in the U.S. spring RV survey has declined to much lower values in recent years, albeit with an upturn in the last two years. Without knowing the extent that Canadian spawners contribute to the health of northwest Atlantic dogfish metapopulation, it may not be wise to increase the exploitation rate on mature females.
- Spiny dogfish have many characteristics of a metapopulation, and as such present some interesting implications for fisheries management. First of all, it would suggest that Canadian dogfish cannot be viewed in isolation. Secondly, the existence of a metapopulation would imply that managing northwest Atlantic dogfish as a single stock would be inappropriate. Finally, without knowing the extent that Canadian spawners contribute to the health of the northwest Atlantic dogfish metapopulation, it is possible that a fishery on mature females in either Canadian or U.S. waters could impact the abundance in all areas.

BACKGROUND

Species Biology

Spiny dogfish (*Squalus acanthias*) are small squaloid sharks common both on the bottom and in the water column of coastal temperate oceans around the world. Dogfish populations are known to be present in the waters off of Europe, Argentina, New Zealand and Japan, as well as in the northeast Pacific and northwest Atlantic. In the northwest Atlantic, dogfish are common from North Carolina to southern Newfoundland, and can be found further to the south and north.

Dogfish in Atlantic Canada are usually associated with bottom water temperatures between 0 and 12 °C throughout the year, although 6-11 °C appear to be the preferred temperatures. The species has been collected at depths from 0-350 m, although it is most commonly observed at depths of 50-200 m.

Fishery

The fishery for spiny dogfish in the Northwest Atlantic began long before commercial catch statistics came to be reported. Reported landings prior to extension of jurisdiction in 1977 were dominated by USSR (Russia) and other European countries, and peaked at about 25,000 mt annually (Fig. 2).

After 1977, U.S. commercial landings accounted for most of the reported catch, peaking at more than 27,000 mt annually. Canadian landings have been a relatively small proportion of the total catch until 2000, at which point the introduction of quotas in the U.S. made Canadian landings a significant portion of the total.

Canadian landings have averaged about 2500 mt annually since 2000, with the majority being directed catch by handline and longline, followed by gillnets. Almost all of the dogfish were caught in the Bay of Fundy, southwest Nova Scotia or off Halifax during the summer (Fig. 3). Catches were unrestricted prior to 2002. From 2002 onwards, precautionary directed catch quotas based on past catches were put in place. The 2002 quota of 3200 mt was exceeded by 384 mt, but directed catches in subsequent years have not exceeded the quota. The quota since 2004 has been set at 2500 mt. Quotas to this point have not been based on scientific advice. There are no restrictions on discarding and bycatch in other fisheries.

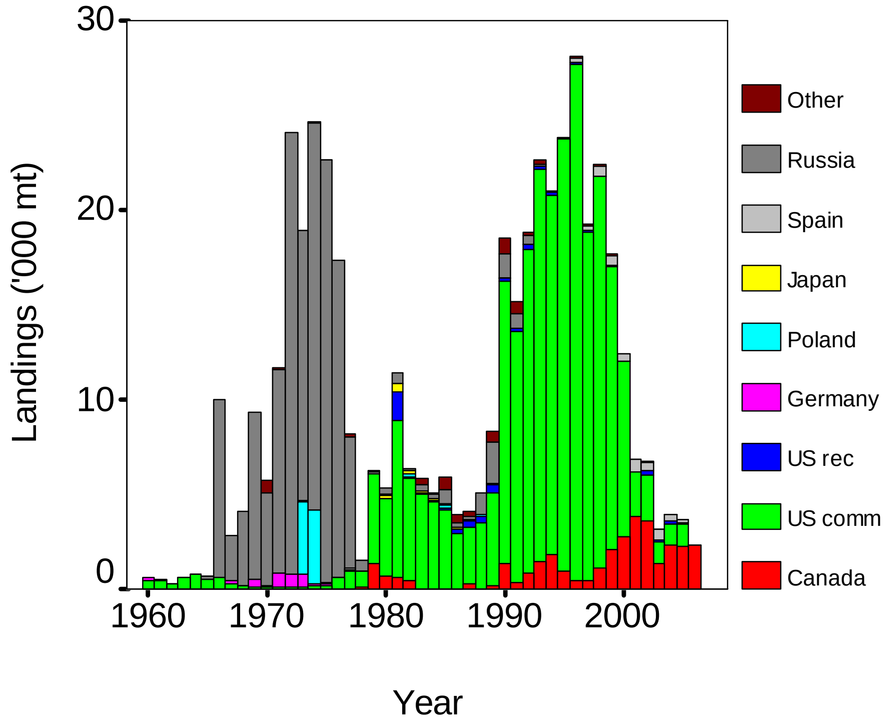


Figure 2. Reported landings of spiny dogfish by country by year in NAFO Areas 2-6.

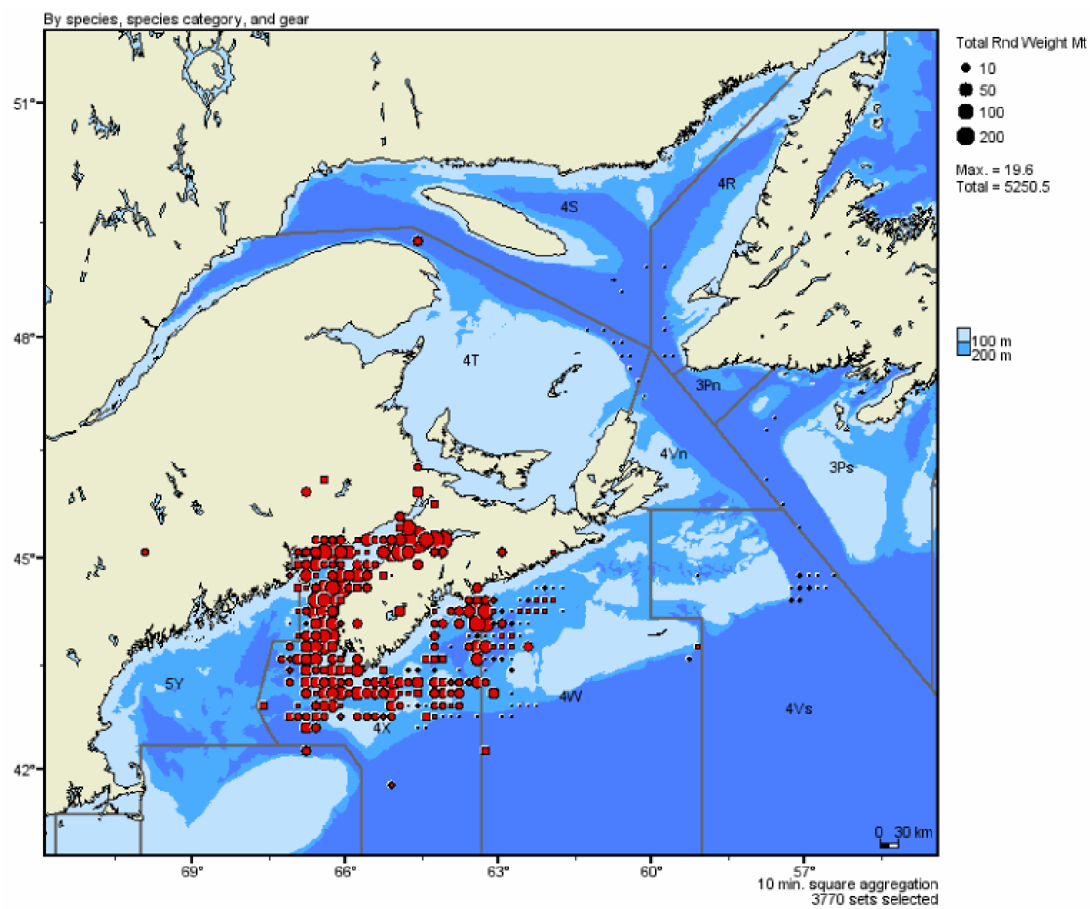


Figure 3. Landings of spiny dogfish in Scotia-Fundy for 2002-2006 as recorded in log books.

ASSESSMENT

Growth and Reproduction

As part of an intensive study of dogfish conducted in cooperation with the commercial dogfish fishery (dogfish JPA), the sexual maturation and growth of dogfish in Atlantic Canada were studied. **Sexually mature and pregnant females** were distributed throughout the waters of southwest Nova Scotia during the summer and fall, but moved offshore to deeper waters in the winter (Fig. 4). Females of mature size have also been observed in the southern Gulf of St. Lawrence and off southern Newfoundland.

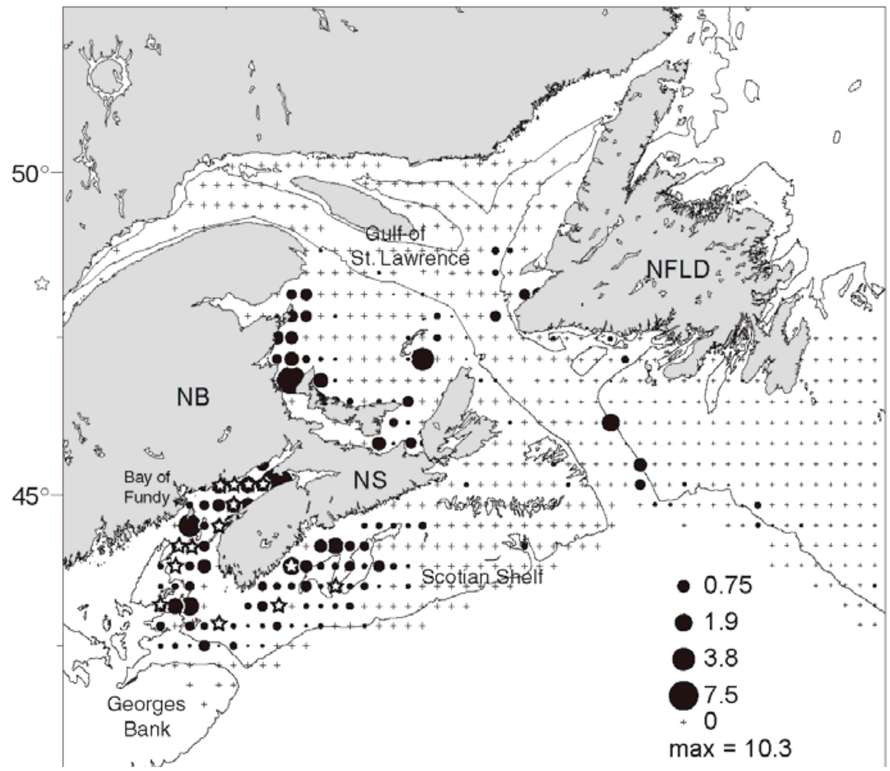


Figure 4. Distribution of female spiny dogfish of mature size (FL > 73 cm) in summer research surveys of the Scotian Shelf and Gulf of St. Lawrence. Survey coverage of the northern Gulf of St. Lawrence and around Newfoundland was 1993 – 2005 (August) and 1971 – 2004 (all months), respectively. Crosses represent survey sets where mature females were absent. Starred symbols show capture locations of pregnant females in 2003 – 2005 surveys of the Scotian Shelf; maturity examinations were not made in the Gulf or around Newfoundland.

The fork length (FL) at **50% maturity** for males was 55.5 cm (= 63.6 cm total length (TL)) at age 10, while that for females was 72.5 cm (= 82 cm TL) at age 16.

Free embryos were observed in 62% of all pregnant females (n=1491). The number of free embryos in any given female ranged between 1 and 14 with a mode of 5. Larger females tended to have significantly more free embryos, such that a 90-cm FL female had on average four times as many free embryos as a female 60 cm FL. Free embryos first became apparent in June at a fork length of 16 cm, and would be expected to reach their birth size of 22-25 cm during the winter. Dogfish gestation takes around 2 years, thus making the species relatively unproductive.

Pupping grounds have not been observed in either Canadian or U.S. waters. However, large aggregations of mature females occur in deep warm waters off the edge of the continental shelf and in the deep basins of the central shelf throughout their range in the winter. Based on the presumed birth months in late winter, pupping occurs in these deep offshore areas. Small juveniles are seldom collected in either Canadian or U.S. research surveys, but those that are collected are found in the same areas as the mature females in winter. It appears likely that the small juveniles pursue a largely pelagic existence for the first few years of their lives before moving onto the continental shelf. Based on the presence of mature females and young juveniles in offshore waters each winter, pupping probably occurs in Canadian waters.

The accuracy of dogfish age interpretations using spine growth bands has been confirmed using bomb radiocarbon dating (Campana et al. 2006). Males and females grow at similar rates until the size and age of male maturity, after which male **growth rate** slows considerably (Fig. 5). **Maximum observed age** is 31 years. Northwest Atlantic dogfish appear to grow more quickly, mature at a younger age, and die at a younger age than northeast Pacific dogfish. Thus, the Atlantic population is more productive than the northwest Pacific population.

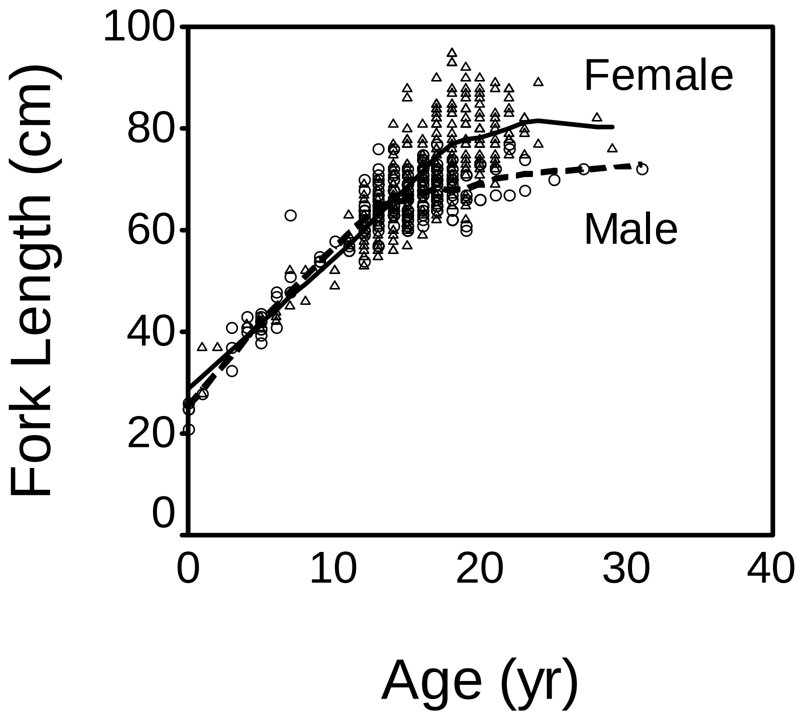


Figure 5. Length at age of male (circle) and female (triangle) spiny dogfish off southwest Nova Scotia (n=525). Loess regressions have been fit to the data for each sex.

Stock Structure

A preliminary **genetic analysis** of population structuring in Canadian dogfish was conducted by the Aquatic Biotechnology Lab at the Bedford Institute of Oceanography based on microsatellite DNA from dried muscle on dogfish spines (n=307) collected around Nova Scotia and Newfoundland. Samples were collected from six locations in three different years, with the majority of the samples having been collected in 2006. Additional samples were requested from U.S. waters, but these have not yet arrived. Seven microsatellite loci developed for dogfish (McCauley et al. 2004) were used for the microsatellite analysis. This study did not find evidence of dogfish population structuring in Canadian waters based on the loci used. However, it is possible that a larger sample size and a larger number of polymorphic loci, or sampling of mating aggregations, would have detected population structuring. U.S. samples will be analyzed for differences from the Canadian samples when they become available.

Several published and unpublished **tagging** studies have been conducted on spiny dogfish in the northwest Atlantic, but these studies have never been synthesized. In all, over 46,000 dogfish have been tagged, with 667 recaptures. For the most part, dogfish tagged in Canadian waters remained in Canadian waters, and those tagged in U.S. waters remained in U.S. waters (Fig. 6). However, there was clearly some movement between Canadian and U.S. waters, with the Gulf of Maine region being the primary mixing ground. Overall, 346 of 384 (=90%) of recaptures from U.S. tagging sites were recaptured in U.S waters, and 267 of 283 (=94%) recaptures from Canadian tagging sites were recaptured in Canadian waters. Restricting the analysis to the Gulf of Maine, 75/86 (=87%) of U.S. tagged fish and 41/51 (=80%) of Canadian tagged fish remained within their host country. There was no evidence that migration was most associated with a particular sex or size of dogfish, although the fact that most tagging was focused on mature females limits the ability to test for differences.

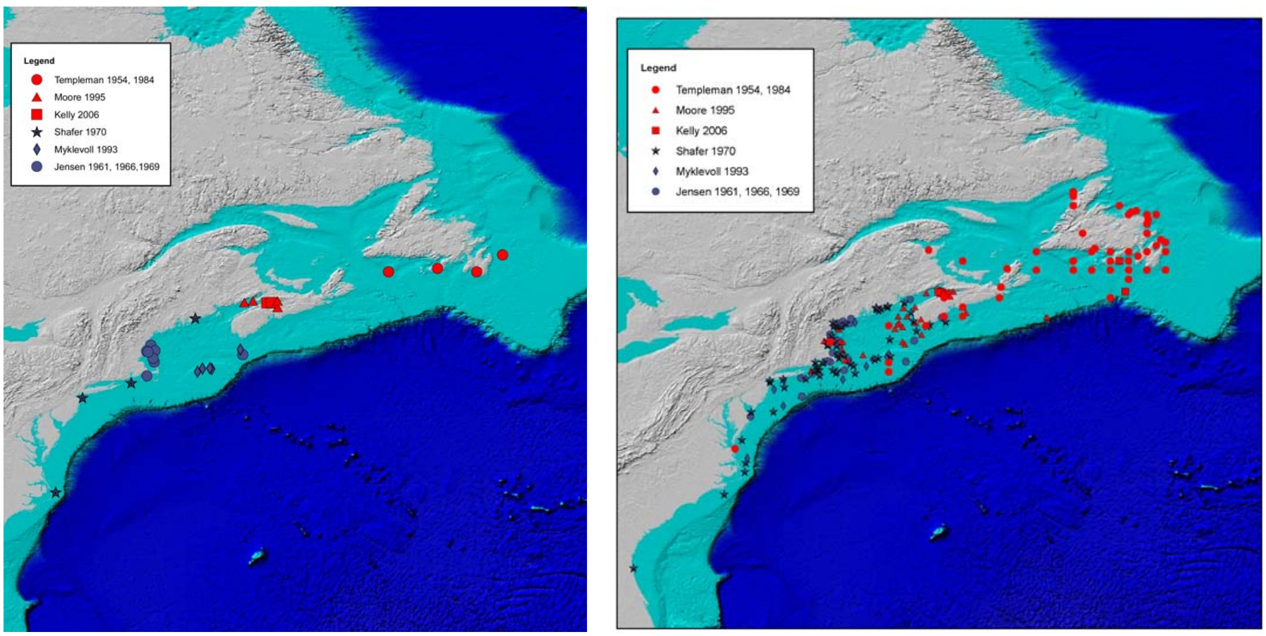


Figure 6. Distribution of spiny dogfish tag recaptures (right panel) from all studies except those of Rulifson (unpublished). Tags applied in Canadian waters are shown in red, while those applied in U.S. waters are shown in blue (left panel).

An analysis of each of the individual tagging studies indicated a strong **seasonal pattern** in the direction of movement, particularly for dogfish south of the Gulf of Maine. In most studies, dogfish tended to be recaptured in more northerly waters in the summer, peaking in August (Fig. 7). To some extent, this pattern is forced by spatial patterns in fishing effort, since there is little or no fishing for dogfish in winter months in northerly waters, and thus no recaptures are possible there during the winter. Nevertheless, the fish tagged in North Carolina waters clearly migrated north to the southern Gulf of Maine during the spring and returned in late fall, given that there were few recaptures in southerly waters during the summer (Fig. 7).

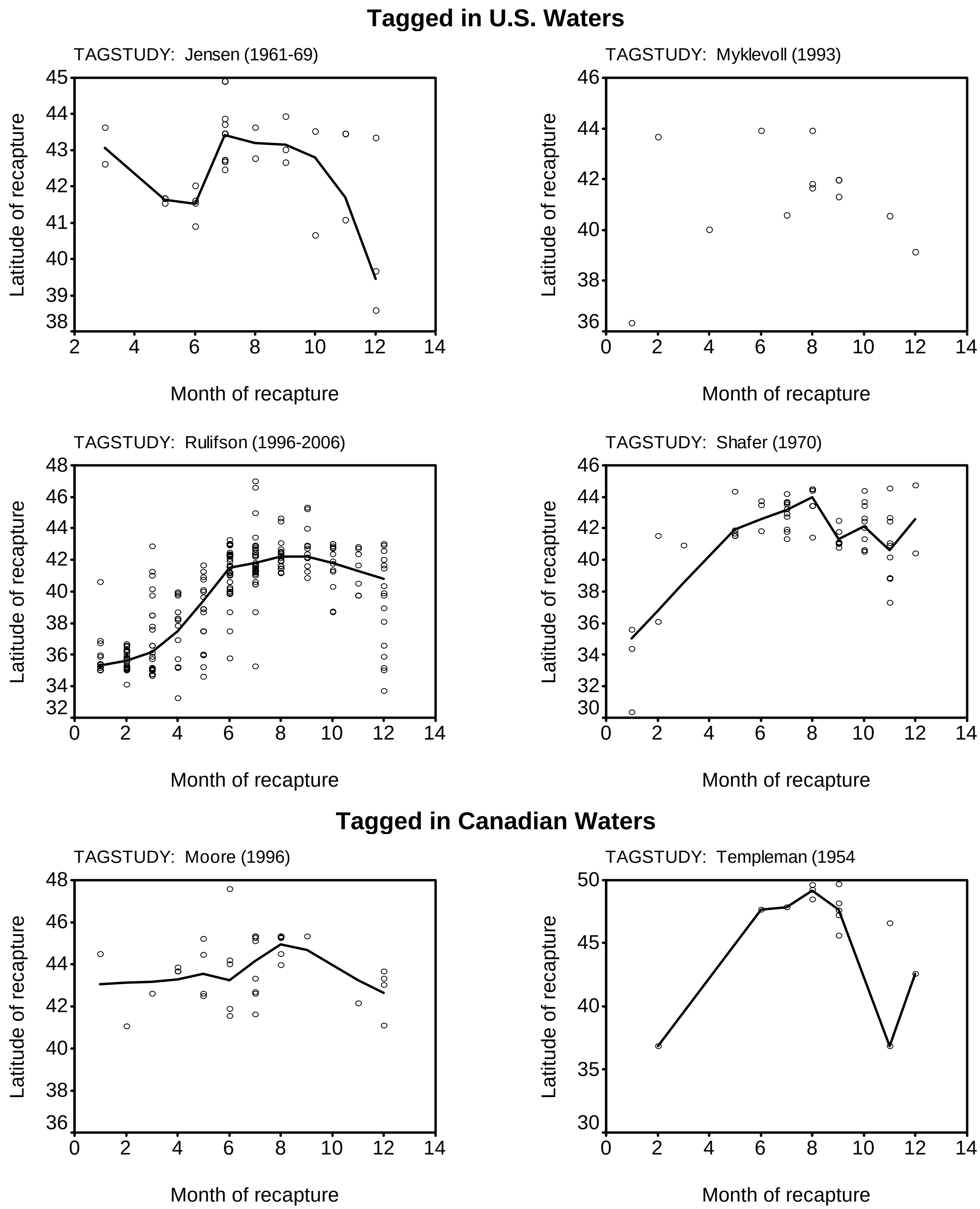


Figure 7. Seasonal migration of spiny dogfish in individual tagging studies as inferred from latitude of recapture. A loess curve has been fit to the data.

Analysis of all available dogfish tagging data supports the view that there are several non-independent dogfish **stock components** in the northwest Atlantic. Dogfish movements between Canadian and American waters are not the predominant pattern, accounting for only 10-20% of tag recaptures. Large-scale annual migrations occur along the east coast of the U.S., but are limited primarily to the area between North Carolina and the Gulf of Maine. Therefore, there appears to be both migratory and resident components.

A **comparison of summer and early spring research vessel (RV) survey distributions** of dogfish on the Scotian Shelf, southern Gulf of St Lawrence and off southern Newfoundland indicates that dogfish move offshore into deeper, warmer waters in winter (Fig. 8). Summer distributions tend to be throughout coastal waters, including on shallow banks. In contrast, spring distributions are almost entirely in deep basins and off the edge of the continental shelf. In all areas, spring distributions are further offshore (or deeper) than summer distributions.

In all surveyed areas in both Canada and the U.S., total stratified spring abundance and biomass exceeded summer/fall abundance and biomass by an average of 2-5. The **apparent increase in spring biomass** was most consistent with a change in catchability and distribution, with spring aggregations of dogfish in deeper, offshore waters being easier to catch in the RV gear. The observation that catchability increased by a comparable factor in both Canadian and U.S. surveys suggests that there is little in the way of net southern migration out of Canada for the winter. Seasonal migrations appear to be exclusively (or at least mostly) inshore-offshore.

A comparison of the length composition between the seasonal RV surveys indicates that there are large and significant differences between the sex-specific length compositions between spring and summer, such that large males and in particular large mature females are much more represented in the offshore spring aggregations. Thus it seems likely that these deep-water spring **aggregations** are mating or pupping aggregations (Fig. 9).

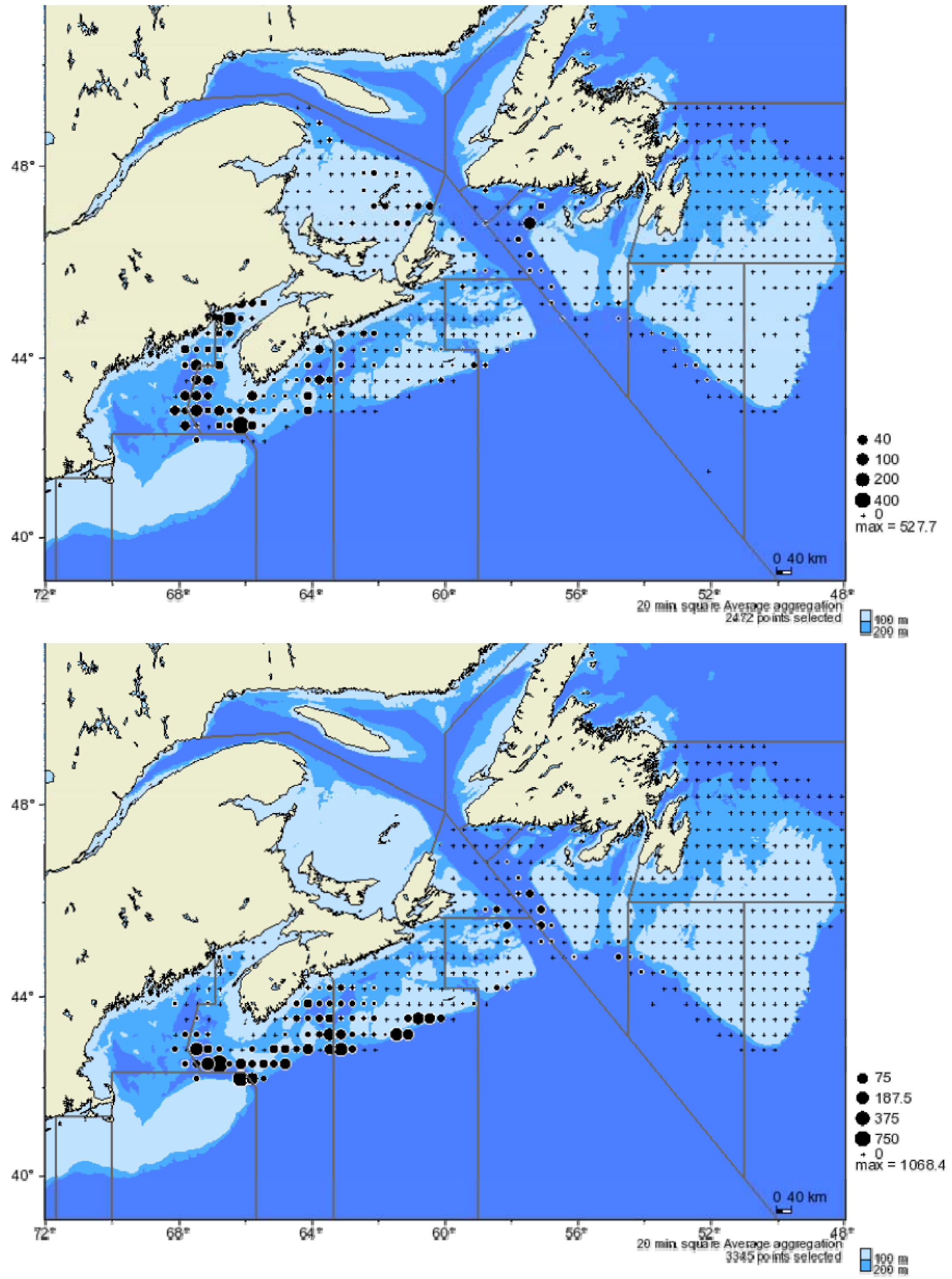


Figure 8. Summer (top) and spring (bottom) distributions of spiny dogfish in RV surveys of the Scotian Shelf (1979-84), Newfoundland (1979-84) and southern Gulf of St. Lawrence (1985). Dogfish move to deeper, offshore waters in the winter and spring, but do not appear to leave Canadian waters.

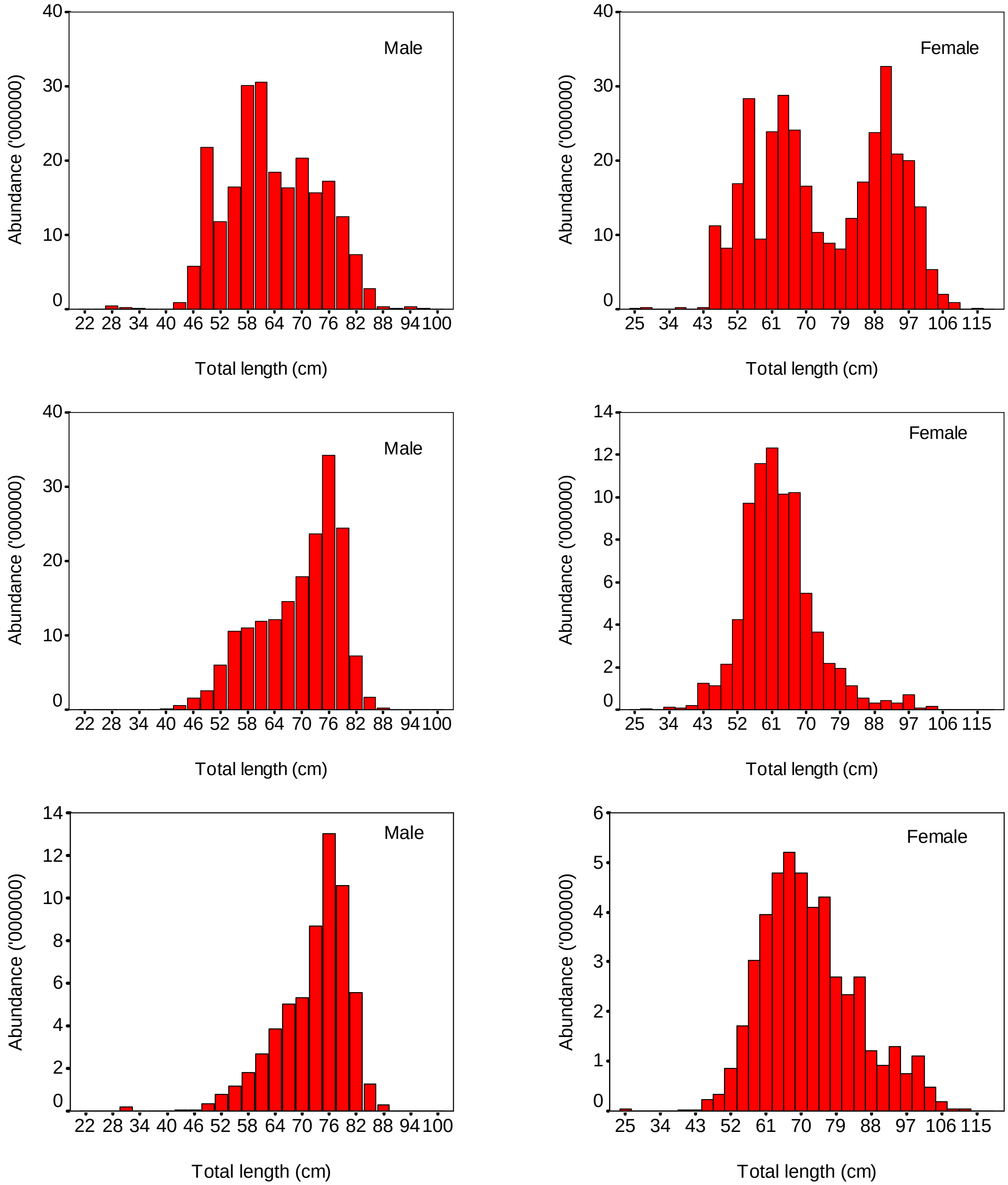


Figure 9. Spring (top), summer (middle), and fall (bottom) length frequency distributions of spiny dogfish in RV surveys of the Scotian Shelf between 1979-84, summed across years.

The apparently greater numbers of **mature females** in the spring surveys compared to the summer surveys are not consistent with known or assumed migration patterns into or out of the area. Rather, summer RV surveys appear to strongly under-represent the abundance of mature females in the survey area. A comparison of the summer RV size composition in 4X for the years 2002-2006 with that of commercial longline and gillnet catches over the same time period in the same area indicates that the summer RV catches relatively few (< 5%) females of mature size (Fig. 10). In contrast, the catch of mature females in commercial gear exceeds 45% of the catch numbers. Therefore, the mature females are definitely present in the summer, but not easily caught with the RV otter trawl gear. Consistent with this hypothesis are observations by fishermen that large females are most common inshore in shallow regions not surveyed by research vessels. Thus spring RV surveys are a better representation of sub-adult and adult abundance than are summer RV surveys. Large females remain on the Scotian Shelf throughout the year, moving inshore during the summer and offshore during the fall and winter.

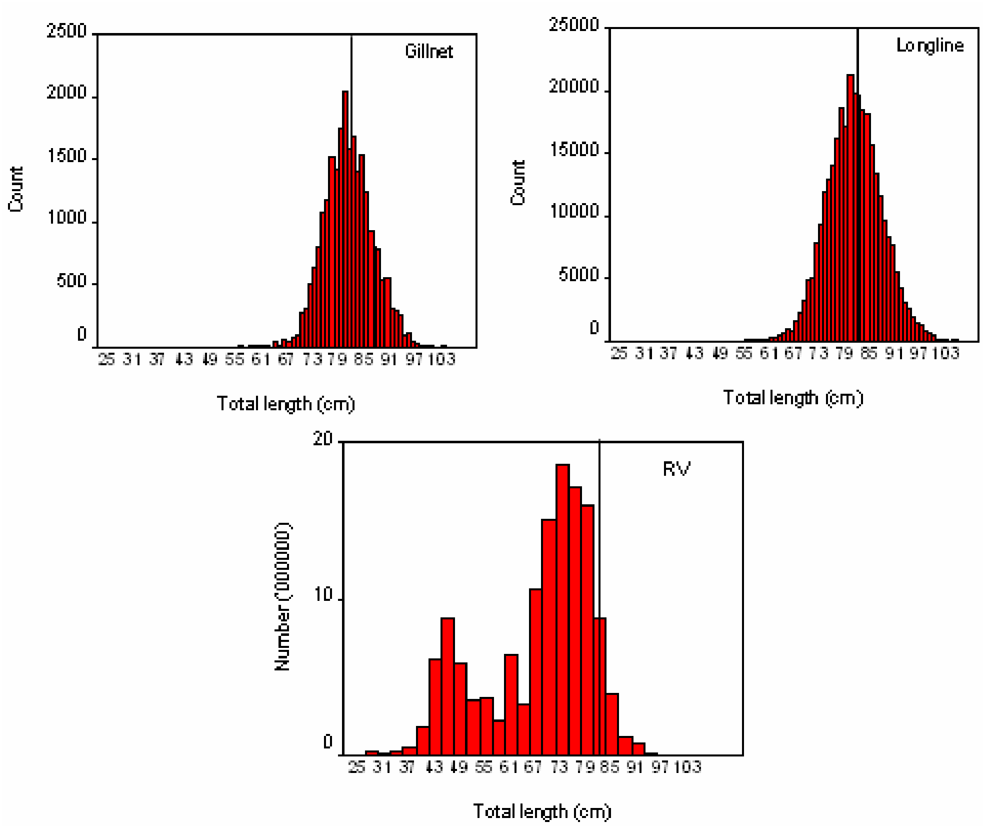


Figure 10. Summer length frequency distributions of female spiny dogfish in 4X in RV surveys compared to longline and gillnet catch between 2002 and 2006, summed across years. The vertical line indicates the length at female maturity (L50). Commercial catches do not reflect the presence of small juvenile fish, while the RV catch under-represents the abundance of large females.

A **metapopulation** can be defined as a group of spatially separated groups or populations of the same species that interact at some level. Range expansions can bring one group into contact with another, or re-populate areas vacated by another group. As a result, periodic mixing can prevent the development of genetic differences. Although it is not clear that spiny dogfish fit the exact definition of a metapopulation, there do appear to be some characteristics in common:

- There are several more or less well-defined 'groups' of dogfish, such as those occupying the southern Gulf of St. Lawrence, around Newfoundland, the eastern and central Scotian Shelf, Bay of Fundy and Southwest Nova Scotia, Massachusetts and North Carolina.
- The groups remain largely separate, and engage in seasonal onshore-offshore migrations. Some groups undertake seasonal north-south migrations, particularly those in the south. The migrations may be an evolutionary adaptation to remain in a "preferred" temperature range of 5-12 degrees °C throughout the year.
- There is occasional mixing between groups, particularly those in the Gulf of Maine.
- Although genetic studies are incomplete, there are unlikely to be genetic differences among groups.

- At least one of the groups – that in the southern Gulf of St. Lawrence – is almost certainly a "sink" population. That is, it was colonized abruptly in 1985, and the same group has resided there ever since, growing larger in size but smaller in numbers, with no evidence of outside immigration.
- The Eastern Shelf dogfish component appears to have remained resident for many years in NAFO 4VW, then abruptly disappeared in 1992. At around the same time, the Georges Bank component disappeared. These dogfish, whose minimum trawlable biomass was about 300,000 mt, apparently moved to another area, since the abrupt decline cannot be explained by fishing.

Dogfish Bycatch and Discarding

Unintended and unwanted **bycatch of dogfish** by Canadian fisheries is substantial. To quantify the bycatch, observer records of dogfish catch relative to target catch were calculated by fishery, NAFO area, season and year since 1986. The proportion of dogfish in each observer cell was then multiplied by the total reported landings of the target catch in each cell to obtain the estimated dogfish catch in each cell. The largest bycatches were associated with the otter trawl (OTB), longline (LL) and gillnet groundfish fleets and OTB redfish fleets in 4X5Y, although all areas and most fleets reported large dogfish bycatches at some times. Total discards have averaged 2,000-3,000 mt annually in recent years, although discards of up to 10,000 mt were estimated for some years in the 1990s.

Spiny dogfish are relatively hardy fish, so it is only reasonable to assume that discard mortality is not 100%. There are a few available estimates for dogfish **discarding mortality**. Published studies report discard mortalities of 0-29% for dogfish caught with OTB (depending on catch size), and 55% mortality for gillnet-caught fish. Therefore, dogfish discard mortality in Canadian waters was calculated as per the following: 25% for OTB catches > 200 kg, 0% for OTB catches < 200 kg, 55% for gillnet catches, 10% for longline catches, and 25% for purse seine catches. The exact values are debatable, although all appear to be consistent with the experimental values reported above and observer observations of the manner in which fishers and their gear treat dogfish catch. Estimated dogfish discard mortality has averaged about 850 mt annually since 1986. Discard mortality often exceeded reported catch prior to 1999, but recent landings have greatly exceeded discard mortality (Fig. 11).

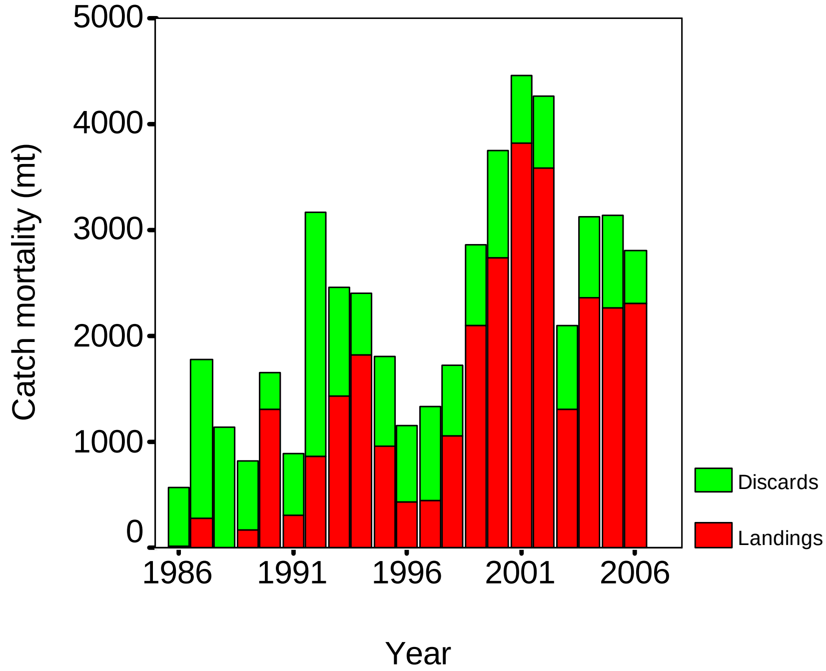


Figure 11. Total catch and discard mortality of spiny dogfish caught in Canadian waters since 1986.

Commercial Catch Composition

The **length composition** of the commercial catch included both sub-adult and adult dogfish. Median size of females in the catch was 81 cm TL, while that of males was 74 cm. In terms of numbers, 66% of the catch consisted of females, and 26% consisted of mature females. These numbers are much lower than those present in the U.S. commercial catch, where median body size of females in the catch was 86 cm TL and females made up 91% of the catch numbers between 2002-2005 (NFSC 2006).

Landed dogfish were not significantly larger than at-sea (pre-discarding) dogfish, indicating that any “highgrading” (size-culling) of the catch would have to be small scale.

Dogfish in the commercial catch tended to be fairly old, with a **mean age** of 16 years for males (n=450) and 18 years for females (n=1085).

Abundance Indices

There are a number of RV surveys and industry surveys in Atlantic Canada that catch significant numbers of dogfish. Although these surveys together do not cover the entire range of spiny dogfish, they can be used to provide an index of relative abundance across years. Where possible, relative abundance has been calculated in terms of minimum trawlable biomass so as to allow comparison of relative biomasses among regions. However, differences in gear catchability between surveys may scale the total biomasses differently.

The **summer RV survey** of the Scotian Shelf has remained high but variable since the mid 1980s (Fig. 12).

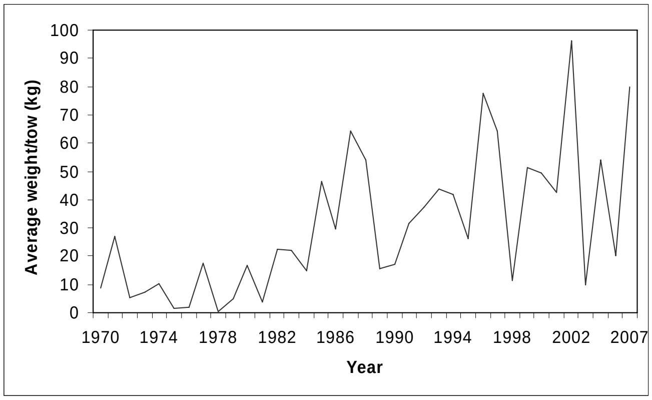


Figure 12. Relative biomass of spiny dogfish in summer RV surveys of the Scotian Shelf, 1970-2007.

In contrast, the **spring 4VW RV survey** and **February Georges Bank RV survey** declined abruptly after 1992 (Figs. 13 and 14).

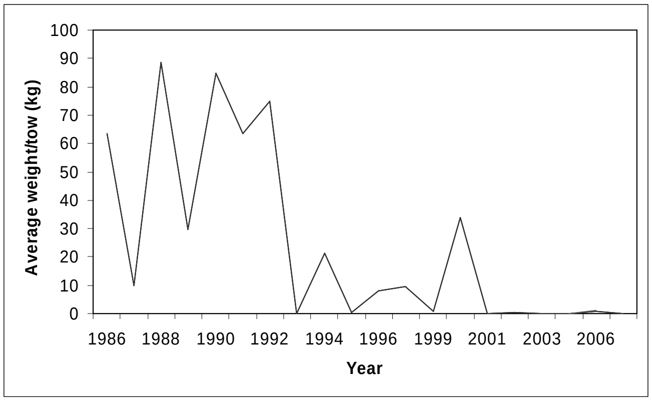


Figure 13. Relative biomass of spiny dogfish in spring RV surveys of the eastern Scotian Shelf (NAFO 4VW), 1986-2006.

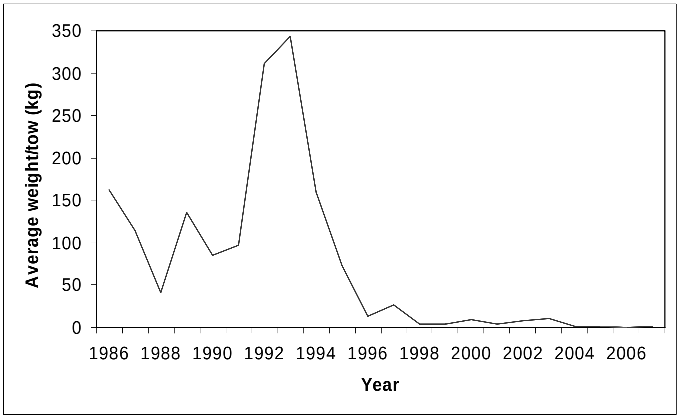


Figure 14. Relative biomass of spiny dogfish in Feb RV surveys of Georges Bank, 1986-2007.

The sudden appearance (in 1985), progressive increase in size composition, and gradual decline in abundance of dogfish in the **southern Gulf of St. Lawrence RV survey** are all consistent with that of a ‘sink population’ – a pulse of dogfish that arrives from somewhere else, then never leaves. The subsequent presence of dogfish in the deep warmer waters of the Laurentian Channel in **January RV surveys** confirms that at least some of the dogfish remained resident all year round.

A **comparison of minimum trawlable biomasses from all Canadian RV surveys** gives a relative indication of the stock proportion present in each area (Fig. 15). The fall and summer trawlable biomasses are roughly comparable and show similar trends. However, the trawlable biomass in the southern Gulf of St Lawrence is roughly 10% of that on the Scotian Shelf, and thus is small by comparison.

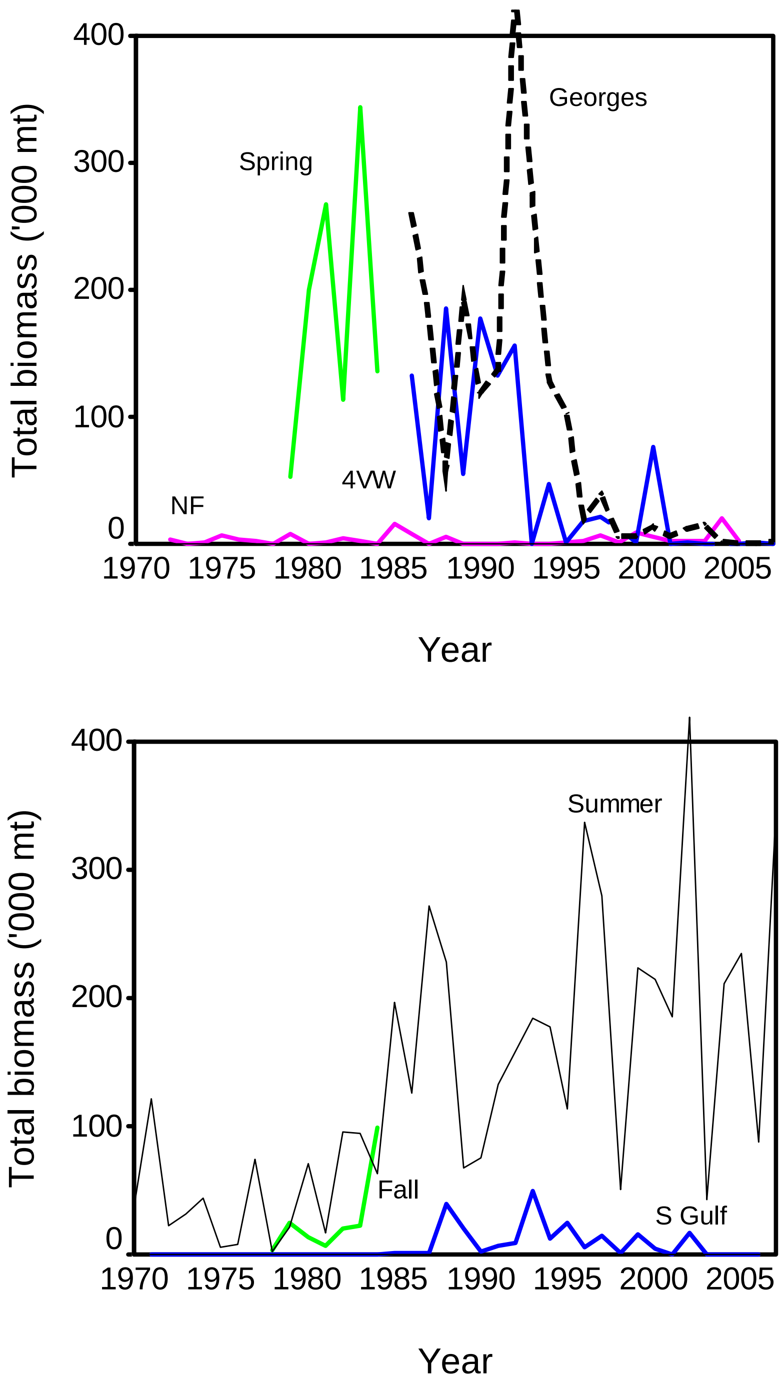


Figure 15. Canadian time series of minimum trawlable biomass of spiny dogfish in spring (top) and summer/fall (bottom) RV surveys of Atlantic Canada, 1970-2007. Spring=Mar RV of Scotian Shelf; 4VW=Mar RV of 4VW; NF=spring RV of southern Newfoundland; Georges=Feb RV of Georges Bank; Summer=July RV of Scotian Shelf; Fall=Nov RV of Scotian Shelf; S Gulf=Sept RV of southern Gulf of St. Lawrence.

A **comparison of the spring RV surveys** shows that the spring 4VWX, spring 4VW and the Feb Georges Bank trawlable biomasses are all comparable, although the spring 4VWX survey does not overlap in time with any other spring survey (Fig. 15). The trawlable biomass in Newfoundland waters was negligible compared to the other regions prior to 1997, but the biomass in the other regions subsequently declined so that the Newfoundland biomass is now comparable.

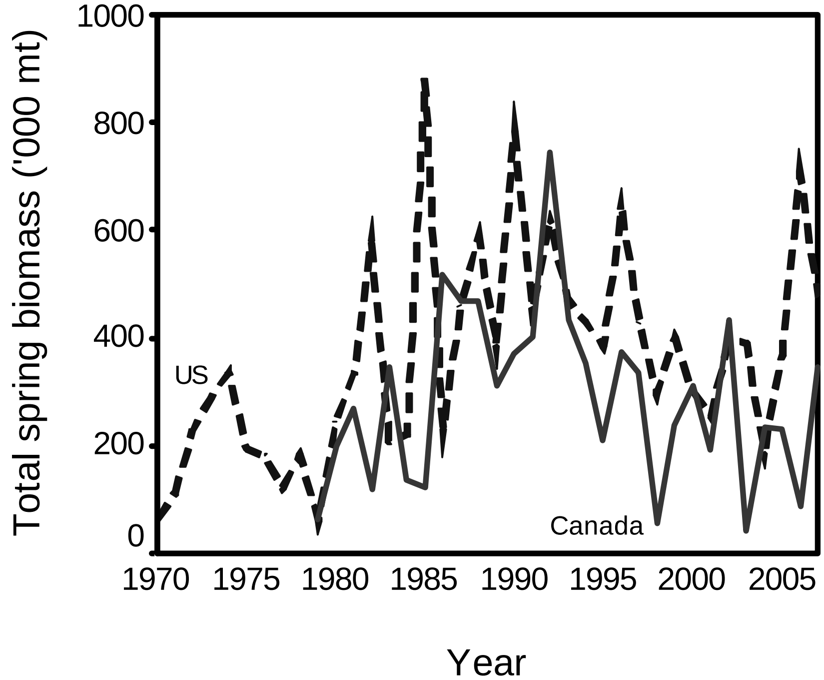
A comparison of the relative abundance indices among the various **industry surveys** (including both longline and mobile gear surveys) provides no strong insights and therefore was not used.

In light of the differing seasons for RV surveys across regions in Atlantic Canada, it is difficult to prepare a single within-season index that covers all regions and time periods. Nevertheless, an approximation was prepared. A **spring estimate of minimum trawlable biomass** was calculated by summing the biomasses from the Feb Georges Bank RV survey (1986 onwards), spring 4VWX RV survey (1979-1984 only), spring 4VW RV survey (1986 onwards) and spring Newfoundland surveys. Aside from gaps prior to 1979 and in 1985, the glaring problem with this estimate is the absence of any spring survey value from 4X after 1984. Given that 4X accounts for most of the dogfish in Atlantic Canada, any viable Canadian spring index must contain a value for 4X in spring. As a proxy value for spring 4X, we used the dogfish biomass in 4X (only) from the summer RV survey for 1985 onwards. By doing so, we have necessarily assumed that summer 4X biomass is comparable to spring 4X biomass. We were able to test this assumption by comparing spring and fall 4X biomasses between 1979-1984, when seasonal surveys were available. On average, spring 4X biomass exceeded summer 4X biomass by a factor of 3.8. Therefore, it seems reasonable to conclude that use of summer 4X biomass as a proxy for spring 4X biomass would, if anything, result in a conservative estimate of total biomass. Accordingly, our estimate of total Atlantic dogfish spring trawlable biomass is the sum of the biomasses from the Feb Georges Bank RV survey (1986 onwards), spring 4VWX RV survey (1979-1984 only), spring 4VW RV survey (1986 onwards), spring Newfoundland, and summer 4X (1985 onwards) surveys. This index does not include estimates from 4T, and is probably a gross underestimate for years prior to 1979. However, it probably provides a reasonable approximation of the minimum trawlable adult biomass summed across areas.

The estimate of **summer minimum trawlable biomass** in Canadian waters was calculated as the sum of the summer RV survey and southern Gulf of St. Lawrence RV surveys. Therefore, the index does not include an estimate for Newfoundland waters, for which no RV survey is available for the 3Ps area most populated by dogfish. Since the summer RV surveys do not adequately represent the abundance of mature females, the summer index is probably a better representation of sub-adult biomass than adult biomass.

A **comparison of the spring minimum trawlable biomass between Canadian and U.S. waters** is shown in Fig. 16. Neither of these indices is completely accurate, since the U.S. surveys cover parts of NAFO 4X and the Canadian side of Georges Bank, while the Canadian index includes the U.S. side of Georges Bank. To a rough approximation, these two biases may cancel each other out. Both time series show comparable trends, increasing from the early 1980s to the early 1990s, then declining somewhat to the present. Mean values for both indices were around 500,000 mt in the early 1990s, declining to about 300,000 mt in 2007 for the Canadian index. Across the time series as a whole, the U.S. minimum trawlable biomass estimate (NFSC 2006) has been slightly greater than the Canadian minimum trawlable biomass estimate.

The summer/fall minimum trawlable **biomass estimates trends for both countries** are considerably more variable than are those from the spring (Fig. 16). Both indices show a consistent upward or stable trend from about 1985 to the present. Once again, the U.S. minimum trawlable biomass estimate slightly exceeds the Canadian estimate. The most recent Canadian biomass value is about 350,000 mt, corresponding to about 200 million fish.



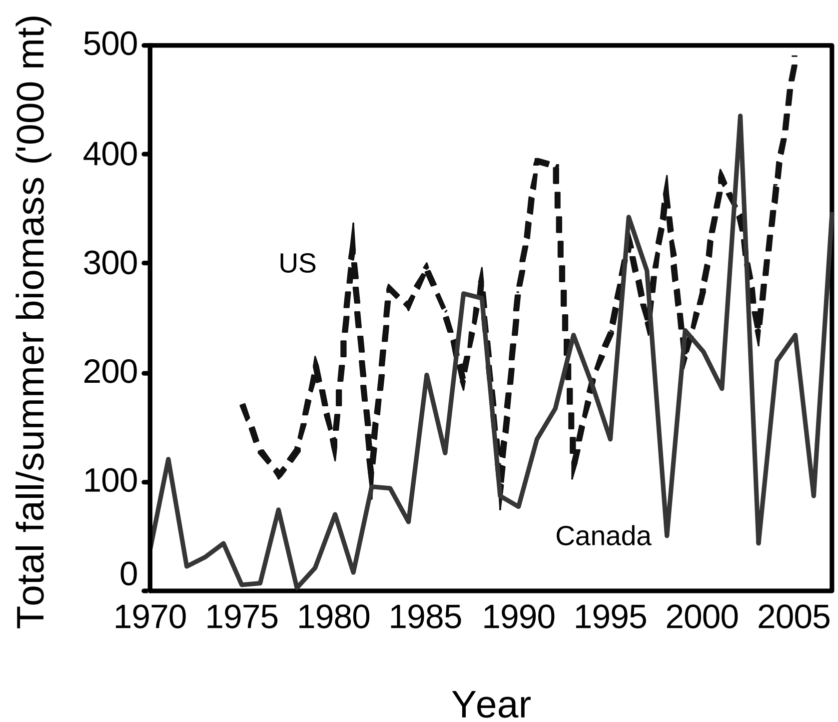


Figure 16. Time series of minimum trawlable biomass of spiny dogfish (summed across areas) in spring (top) and summer/fall (bottom) surveys in Atlantic Canada (solid line) compared to the matching U.S. surveys (dashed line), 1970-2007.

In the absence of a reliable **index of female mature biomass** in 4X (since mature females were largely unavailable to the summer RV survey), it was not possible to calculate overall mature female biomass for Canadian waters. However, mature female biomass in the U.S. spring RV survey has declined to much lower values in recent years, albeit with an upturn in the last two years (NFSC 2006) (Fig. 17). Without knowing the extent that Canadian spawners contribute to the health of northwest Atlantic dogfish metapopulation, it may not be wise to increase the exploitation rate on mature females.

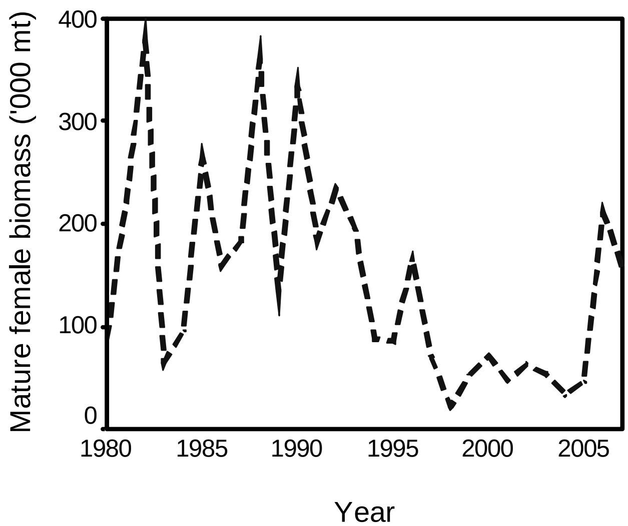


Figure 17. Time series of minimum trawlable biomass of mature female spiny dogfish in the U.S. (NFSC 2006).

Exploitation Rate

It was not possible to estimate exploitation rate in the absence of a viable population model. However, it did not appear that the apparent decline in total Canadian spring biomass from Fig. 16 can be attributed solely to commercial exploitation. Total catch (including dead discards) between 1990 and 2006 accounted for about 3,000 mt per year, while the apparent decline in total biomass was closer to 18,000 mt per year. It is unknown if this is an actual loss to the population and, if a loss, if it was temporary or permanent. Emigration to unsurveyed areas and/or unexplained natural mortality could account for this loss, among other factors.

Population Model

A **preliminary population model** has been developed for dogfish. This model is an age- and sex-structured, forward projecting population model, which estimates a starting population size and age structure (in 1960), and projects the population forward by adding recruits (age-1 fish) to the population and subtracting catches and natural mortality. Both foreign and domestic landings are included in the model. The model is fit to the abundance indices obtained from research surveys as well as the proportions-at-length in the surveys and commercial catch. Some of the data series used in the model are short and highly variable, and although the summer RV survey potentially indicates a stable or slightly increasing population, some of the other surveys indicate a declining trend. As a result, the model in its present form does not provide robust estimates of abundance. Three variants of the model were used to estimate abundance, each with a different assumed reproductive scenario. The variants were fit to the summer RV survey data alone, and in another iteration to six research surveys. These variants illustrated several problems with the model in its present form, including several aspects of the fishery, dogfish biology and/or data collection process that are not adequately captured. Recommendations for the next iteration of the model included a recompilation of the commercial catch and survey data on the same spatial scale so that spatial structuring within the population and movement can be examined, further separation of the two sexes in the model, examination of sample sizes to ensure that data is weighted appropriately, and further development of a relationship between variability of length-at-age and age. If possible, immigration and emigration should be incorporated. Robustness of the model estimates with respect to the length of the time series incorporated into the model should also be examined.

Sources of Uncertainty

There is uncertainty surrounding the conclusions of the **genetic analysis** of spiny dogfish conducted to date at the Bedford Institute of Oceanography. Small sample size, the number of polymorphic loci, and lack of samples from mating aggregations contribute to uncertainty. Lack of U.S. samples is an additional source of uncertainty.

Surveys do not cover the entire range of spiny dogfish in Atlantic Canada. In particular, lack of a spring RV survey in 4X hampers calculations of mature female biomass.

The accuracy of some historic **foreign landings** has been questioned. The size composition of foreign landings was not reported.

Tagging of males and juveniles has been limited. Limited Canadian fishing effort in winter months complicates the interpretation of winter recaptures.

Bycatch and discarding estimates were based on observer coverage that was limited or absent in some fisheries and years, for which mean values from adjacent years were used. This undoubtedly introduced some error into the discarding estimates.

Some observations from the fishing industry indicate that there might be **large females** that remain in the Bay of Fundy throughout the winter. This needs to be explored.

CONCLUSIONS AND ADVICE

For the most part, **dogfish tagged in Canadian waters** have remained in Canadian waters, and those tagged in U.S. waters have remained in U.S. waters. However, there is some movement (10-20%) between Canadian and U.S. waters, with the Gulf of Maine region being the primary mixing ground. To date, there has been no evidence that migration is associated with a particular sex or size of dogfish.

Spiny dogfish have many characteristics of a metapopulation, and thus presents some interesting **implications for fisheries management**. First of all, it would suggest that Canadian dogfish cannot be viewed in isolation. At a minimum, if some of the dogfish that currently reside in Canadian waters actually originated in U.S. waters, it means that at least some of the recruitment is dependent on the U.S. stock. Secondly, the existence of a metapopulation would imply that managing northwest Atlantic dogfish as a single stock would be inappropriate. If, as seems likely, some dogfish aggregations colonize or depart Canadian waters *en masse* at periodic multi-year intervals, and then remain resident in those waters for many years at a time, alternate management measures may be more appropriate. Finally, without knowing the extent that Canadian spawners contribute to the health of the northwest Atlantic dogfish metapopulation, it is possible that a fishery on mature females in either Canadian or U.S. waters could impact the abundance in all areas.

Based on analysis to date, median size of females in the **catch** was found to be 81 cm TL, while that of males was 74 cm TL. In terms of numbers, 66% of the catch consisted of females and 26% consisted of mature females. These numbers are much lower than those present in the U.S. commercial catch, where median body size of females in the catch was 86 cm TL and females made up 91% of the catch numbers between 2002-2005. Dogfish in the Canadian commercial catch tended to be fairly old, with a mean age of 16 years for males and 18 years for females. There was no evidence of “highgrading” at sea.

Estimated dogfish **discard mortality** has averaged about 850 mt annually since 1986. Discard mortality often exceeded reported catch prior to 1999, but recent landings have greatly exceeded discard mortality.

In the absence of a viable population model, it is not possible to estimate the **exploitation rate** for spiny dogfish in Atlantic Canada. However, it does not appear that the apparent decline in total Canadian spring biomass can be attributed solely to commercial exploitation. Total catch (including dead discards) between 1990 and 2006 accounted for about 3,000 mt per year, while the apparent decline in total biomass was closer to 18,000 mt per year. It is unknown if this an actual loss to the population and, if a loss, if it was temporary or permanent. Emigration to unsurveyed areas and/or unexplained natural mortality could account for this apparent decline, among other factors.

The Atlantic population of spiny dogfish is more **productive** than is the northwest Pacific population. However, the long gestation period (~ 2 years), late age of sexual maturation and slow growth rate for spiny dogfish means that the species is relatively unproductive compared to other fish species.

Spring minimum trawlable **biomass estimates** for spiny dogfish in Canadian and U.S. waters show similar trends, increasing from the early 1980s to the early 1990s, then declining somewhat to the present. Mean values for both indices were around 500,000 mt in the early 1990s, declining to about 300,000 mt in 2007 for the Canadian index. The Canadian spring index is considered to be a better indicator of total adult biomass than is the summer index.

The trends in **summer/fall minimum trawlable biomass** estimates for spiny dogfish in Canadian and U.S. waters show considerably more variability than are those from the spring. Both indices show a consistent upward or stable trend from about 1985 to the present. The most recent Canadian biomass value is about 350,000 mt (corresponding to about 200 million fish). The summer index is considered to be a better indicator of sub-adult biomass than adult biomass.

It is not currently possible to estimate trends in mature female biomass for spiny dogfish in Atlantic Canada. However, mature female biomass in the U.S. spring RV survey has declined to much lower values in recent years, albeit with an upturn in the last two years. Without knowing the extent that Canadian spawners contribute to the health of northwest Atlantic dogfish metapopulation, it may not be wise to increase the exploitation rate on mature females.

OTHER CONSIDERATIONS

A spring RV survey of 4X would greatly improve the ability to monitor mature female biomass in Canada.

Research to identify the habitat for pupping and the juvenile pelagic stage, and to quantify pup abundance, would aid in predicting stock abundance and determining stock composition.

Further research on stock structure and cross-border movements is required, perhaps through acoustic tagging of both adult and juvenile stages.

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