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# Spiny Dogfish

by

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## Distribution, Biology, and Management

Spiny dogfish, *Squalus acanthias*, are distributed in the western North Atlantic from Labrador to Florida and are considered to be a unit stock in this region (Burgess 2002, Figure 26.1). During spring and autumn, spiny dogfish occur in coastal waters between North Carolina and Southern New England. In summer, dogfish migrate northward to the Gulf of Maine-Georges Bank region and into Canadian waters and return southward in autumn and winter (Jensen 1965). They tend to school by size and, when mature, by sex. Dogfish feed on many species of fish and crustaceans, but generally target the most abundant species (Link et al. 2002). In the Northwest Atlantic, maximum reported ages for males and females are 35 and 40 years, respectively (Nammack 1982). The species bears live young, with a gestation period of about 18 to 22 months, and produce between 2 to 15 pups with an average of 6. Size at maturity for females is around 80 cm, but can vary from 78 cm to 85 cm depending on the abundance of females. (Sosebee 2005).

The principal commercial fishing gears used to catch dogfish are otter trawls and sink gillnets. Dogfish are frequently caught as bycatch and discarded during groundfish operations, particularly in the Mid-Atlantic-Southern New England area. Recreational and foreign fishing are of minor importance. The fishery is managed under a Fishery Management Plan developed jointly by the Mid-Atlantic and New England Fishery Management Councils for federal waters and a plan developed concurrently by the Atlantic States Marine Fisheries Commission for state waters.

## The Fishery

Total landings peaked at 24,700 mt in 1974, declined sharply to a fairly stable average of about 6,300 mt per year during 1979-1988, increased to a record high of 28,200 mt in 1996, and subsequently declined to around 4,000 mt during 2003-2005 (Figure 26.2, Table 26.1). Between 1966 and 1977, distant-water fleets, mainly from the Soviet Union, accounted for virtually all of the reported landings, but have since ceased to be important. United States commercial landings during 1979-1988 averaged 4,300 mt per year, increased to 27,200 mt in 1996, and then declined

to a low of 1,000 mt in 2004 due to trip limits and quota management. Landings in the U.S. recreational fishery were estimated to be about 300-400 mt from 1987-1989, but subsequently were less than 100 mt in 2005. Canadian landings increased from an average of 500 mt from 1979-1988, peaked at 1,800 mt in 1994, declined to 400 mt in 1996 and 1997, but increased to 3,600 mt in 2002. Minor quantities have also been taken by European Union (EU) fleets fishing in Canadian waters in recent years.

The U.S. fishery for spiny dogfish targets large individuals (larger than 2.3 kg [5.1 lb] in weight, and 83 cm [33 in.] in length), which are primarily mature females, to meet processing and marketing requirements (NEFSC 1994; NEFSC 1998; Rago et al. 1998). Median length of landed female dogfish averaged about 94 cm during 1982 to 1988 but declined to about 84 cm between 1989 and 1999 as a consequence of the directed fishery (Figure 26.3). Average weights exhibited a similar pattern. Since 2000 the average lengths and weights have subsequently increased.

Spiny dogfish are caught as bycatch in a large number of fisheries in the Northeast. Estimated annual commercial discards during 1989-2005 range from 7,400 to 47,300 mt (NEFSC 2006). Dogfish are hardy and not all die when discarded. Dead discards peaked in the early 1990s at nearly 20,000 mt (in 1990 and 1992), but subsequently declined to below 4,000 mt in 1998. Since 2001, dead discards have varied between 4,000 and 5,000 mt (Figure 26.4). The recreational fishery also discards dogfish and estimates of dead dogfish have ranged between 100 and 300 mt during the last two decades. The current commercial fishery, which is regulated by trip limits and an overall quota, discards all sizes and both sexes of dogfish (NEFSC 2006).

**Research Vessel Survey Indices**

NEFSC spring survey relative biomass estimates (three-year average) of spiny dogfish increased from the mid-1970s to 1993 but have since gradually declined (Figure 26.5). However, mature biomass (individuals $\geq$80 cm, mostly females) declined much more rapidly; estimates peaked at about 250,000 mt in 1990, declined to less than 100,000 mt in 1999 before increasing to above 100,000 mt in 2006. Recruitment estimates of pups ($\leq$ 35 cm) were record-low from 1997 through 2003 and also in 2006 (Figure 26.6). Length frequency data from various surveys indicate that the average size of females $\geq$ 80 cm has declined from about 94 cm in the 1980s and early 1990s to 84 cm in the last few years (Figure 26.7). Average length of pups in the NEFSC spring survey has declined from 30 cm in 1980-1996 to about 27 cm since 1997 (Figure 26.8). These changes are consistent with the declining trend in body size of spawning females.

Marked changes in the size and sex composition have occurred as a result of the directed commercial fishery that occurred in the 1990's. The abundance of large females declined sharply whereas the size frequencies of the lightly harvested males were almost unaffected (Figure 26.9). As a result, the ratio of mature males ($\geq$ 60 cm) to mature females ($\geq$ 80 cm) increased from about 2:1 before 1993 to about 7:1 since 2000 (Figure 26.10). The long-term implications of this altered sex ratio are unknown. The decline in recruitment shown in Figure 26.6 is evident in Figure 26.9 for both males and females as is a progressive increase in the length of the smallest dogfish captured (from 20 to ca 60 cm since 1995).

**Assessment Results**

Assessments of spiny dogfish are based on NEFSC spring survey indices expanded to swept area biomass estimates. Uncertainty of the biomass estimates incorporates the sampling variability of the individual surveys, uncertainty in the area swept per tow, and inter-annual variation over a 3-year moving average. Stochastic biomass estimates for mature females decreased from about 250,000 mt in 1990-1991 to less than 60,000 mt from 1998-2004 (Figure 26.11). In 2006 the spawning stock biomass increased to 106,000 mt but this increase is driven entirely by the survey results in 2006.

Fishing mortality estimates on the exploitable female stock peaked in 1994 at almost 0.5, remained above 0.2 through 1999 and declined to 0.1 in recent years, except for a value of 0.5 in 2004 (Figure 26.12). Fishing mortality rate on the fully recruited dogfish followed a similar trend in the 1990s when total removals were high. During recent years this measure of fishing mortality has been higher owing to the shift toward larger size dogfish in the landings.

**Biological Reference Points**

Reference points for spiny dogfish are based on the female spawning stock biomass (i.e., $\geq$ 80 cm) and the rate of fishing mortality applied to the fully vulnerable stock. The biomass target is based on the relationship between indices of recruitment (<36 cm) and spawning stock biomass (females $\geq$ 80 cm). A Ricker stock-recruitment relationship was used to estimate the relative biomass at which recruitment is maximized. The relative biomass can be rescaled to swept area biomass using a conversion factor based on the nominal average area swept per tow.

Biological reference points for fishing mortality are based on joint effects of size at entry into the fishery and the rate of fishing mortality applied to the fully-recruited size class. A life history model is used to estimate the size specific fishing mortality rate corresponding to a lifetime female production of 1.0—the rate at which each female is expected to replace itself in the next generation. Size-specific estimates of fishing mortality are based upon the relationship between the composite length-frequency distribution of landings and discards and the length frequency of the NEFSC spring trawl survey. The size-specific pattern of selectivity varies annually resulting such that the fishing mortality applied to the fully recruited size classes will also vary annually.

Reference points established in the MAFMC/NEFMC Spiny Dogfish Fishery Management Plan (1999) include: $B_{target}$ = 180,000 mt; $B_{threshold}$ = 100,000 mt, (both expressed in terms of adult ($\geq$ 80 cm) female biomass), and $F_{MSY}$ = 0.11 and $F_{target}$ =0.08. These threshold and target fishing mortality rates represent fully recruited Fs, and were calculated assuming a knife edge fishery selectivity pattern with a minimum size of 70 cm (Figure 26.13). $F_{MSY}$ corresponds to a lifetime female pup production of 1.0; $F_{target}$ corresponds to lifetime female pup production of 1.5. The $B_{target}$ reference point in the FMP was subsequently disapproved by NMFS because it did not correspond to the biomass associated with maximum recruitment (~200,000 mt) in a Ricker stock-recruitment function.
The biomass target in the ASMFC FMP ($SSB_{max}$ = 167,000 mt) was derived by applying a Ricker model to the swept area estimates of SSB and recruits in the NEFSC spring trawl surveys. The ASMFC reference point differs from that used by the MAFMC and NEFMC because it is

based on a slightly larger estimate of the average area swept by the NEFSC trawl survey. All of the biomass targets, however, are based on the same relative biomass index equal to an average of 31 kg/tow in the Ricker model analysis; the relative biomass threshold is 50 % of the value or 16.5 kg/tow.

The overfishing threshold was updated in NEFSC (2006) using the current (2005) size selectivity of the fishery. Detailed analyses of the size composition of discards and landings in NEFSC (2006) revealed that discards occurred over all size classes. The revised estimate of $F_{MSY}$ of 0.39 reflects a shift in size selectivity to larger individuals in the landings and discards. The estimate of $F_{MSY}$ is highly sensitive to changes in size at entry into the fishery when the size exceeds about 82 cm (Figure 26.13). Estimates of $F_{MSY}$ vary from 0.3 to 0.6 as size-at-entry increases from 82 to 87 cm. Estimates of $F_{MSY}$ in Figure 26.13 are based on a simplifying assumption of so-called knife-edge selection to the fishery. The complexity of reference point estimation increases when actual selection patterns are estimated from the catch and survey size frequencies. In particular, the selectivity pattern can distribute fishing mortality over a broad range of size classes. The general convention of expressing $F_{MSY}$ as the rate applied to fully recruited size classes can lead to seemingly high estimates. Marked changes in the discarding patterns of the mix of fisheries that encounter spiny dogfish are expected to affect the population's rate of stock rebuilding in the coming years. Nonetheless, the basic principle remains—spiny dogfish are a slow growing, low productivity species with limited capacity to withstand fishing mortality concentrated on mature females.

**Summary**

Based on the existing biomass threshold (NEFSC 2003), the spiny dogfish stock is not currently overfished. The current estimated stock size of mature females (>80 cm) is 106,000 mt (72,000-140,000; 80% confidence interval) (Figure 26.11), and this value exceeds $B_{threshold}$ (100,000 mt mature females, P=0.724). The biomass target in the spiny dogfish FMP (180,000 mt) was subsequently disapproved by NMFS; currently there is no approved biomass target in place. The estimate for 2005 of F on fully recruited females is 0.128 (0.09-0.17; 80% confidence interval) (Figure 26.12). This fishing mortality rate exceeds the existing overfishing threshold ($F_{threshold}$=0.11) and the existing rebuilding target ($F_{rebuild}$=0.03). The overfishing threshold was updated in the current assessment ($F_{threshold}$=0.39). Based on the updated estimate, overfishing is not occurring. Despite the much lower level of landings since 2001, fishing mortality rates on fully recruited females have remained above the rebuilding F (0.03).

Spawning stock biomass of spiny dogfish declined rapidly in response to a directed fishery during the 1990s. Management measures, initially implemented in 2001, have been effective in reducing landings and reducing fishing mortality. Overfishing is not occurring. The directed fishery targeted mature females but had little effect on the males. Current sex ratio of mature males to mature females rose from about 2:1 in 1990 to over 7:1 in 2006. Recruitment has been very low since 1997. The NEFSC spring survey biomass index increased markedly in 2006 and the stock is not considered overfished. Rebuilding however, is expected to take more than a decade even if fishing mortality remains low. Recent poor recruitment poses a substantial risk to the long-term spawning stock of spiny dogfish. Reductions in fishing mortality are expected to increase stock biomass for several more years until the reduced recruitment acts to lower SSB.

Conclusions regarding the overfished and overfishing status of spiny dogfish are strongly dependent on the NEFSC spring survey estimates in 2006. Concerns have been raised about the influence of these data (NEFSC 2006); future surveys will be closely monitored to determine if the 2006 results signal a true increase in abundance.

**Table 26.1**. Recreational and commercial landings of spiny dogfish (thousand metric tons).

| Category | 1986-95 Average | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **U. S. Recreational** | 0.2 | <0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.2 | <0.1 | 0.1 | <0.1 |
| **Commercial** | | | | | | | | | | | |
| **United States** | 12.0 | 27.2 | 18.4 | 20.6 | 14.9 | 9.3 | 2.3 | 2.2 | 1.2 | 1.0 | 1.2 |
| **Canada** | 0.7 | 0.4 | 0.4 | 1.1 | 2.5 | 2.8 | 2.8 | 3.6 | 1.3 | 2.3 | 1.5 |
| **Other** | 0.2 | 0.2 | 0.2 | 0.6 | 0.6 | 0.4 | 0.7 | 0.5 | 0.6 | 0.3 | 0.3 |
| **Total Nominal Catch** | 13.1 | 27.8 | 19.1 | 22.3 | 18.0 | 12.5 | 5.8 | 6.5 | 3.1 | 3.7 | 3.0 |

**Table 26.2** Summary of MSY-based reference points for spiny dogfish.

**MSY-based Reference Points**

MSY = undetermined

$B_{MSY}$ = undertermined

Biomass Threshold = 100,000 mt

$F_{MSY}$ = 0.39[1]

[1]Using 2005 size-at-entry into the fishery

## For further information


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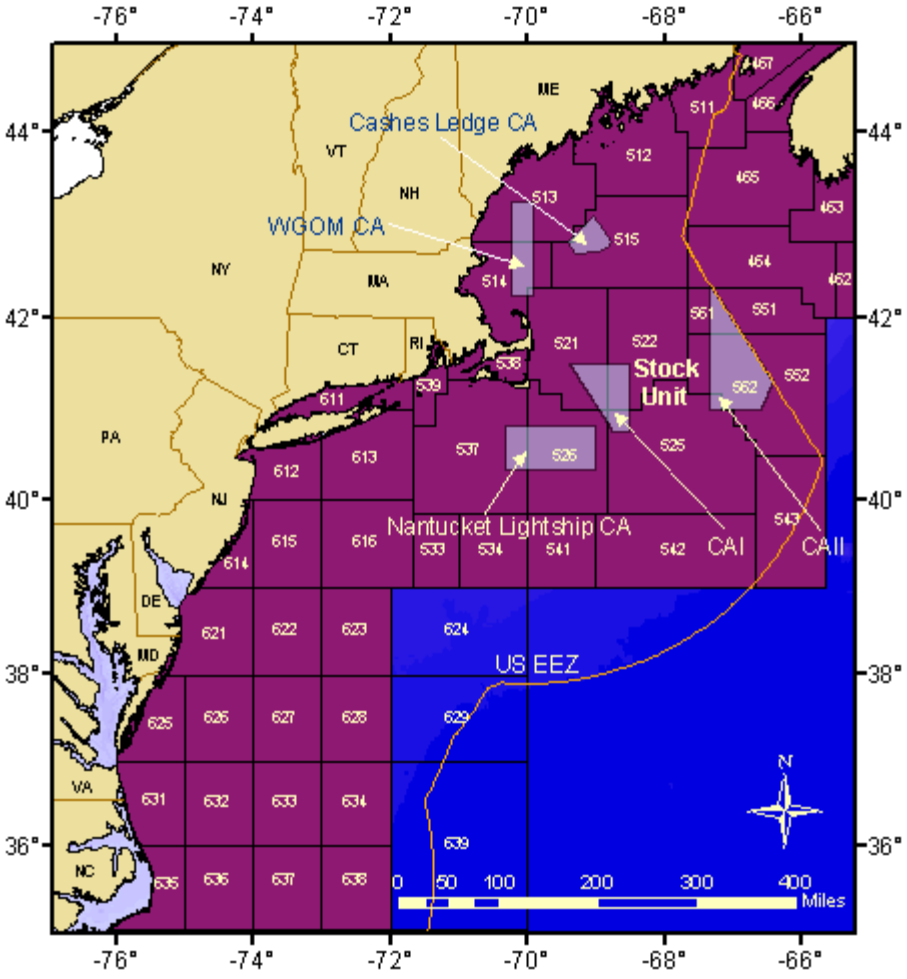


Figure 26.1. Statistical areas used to define the spiny dogfish stock.

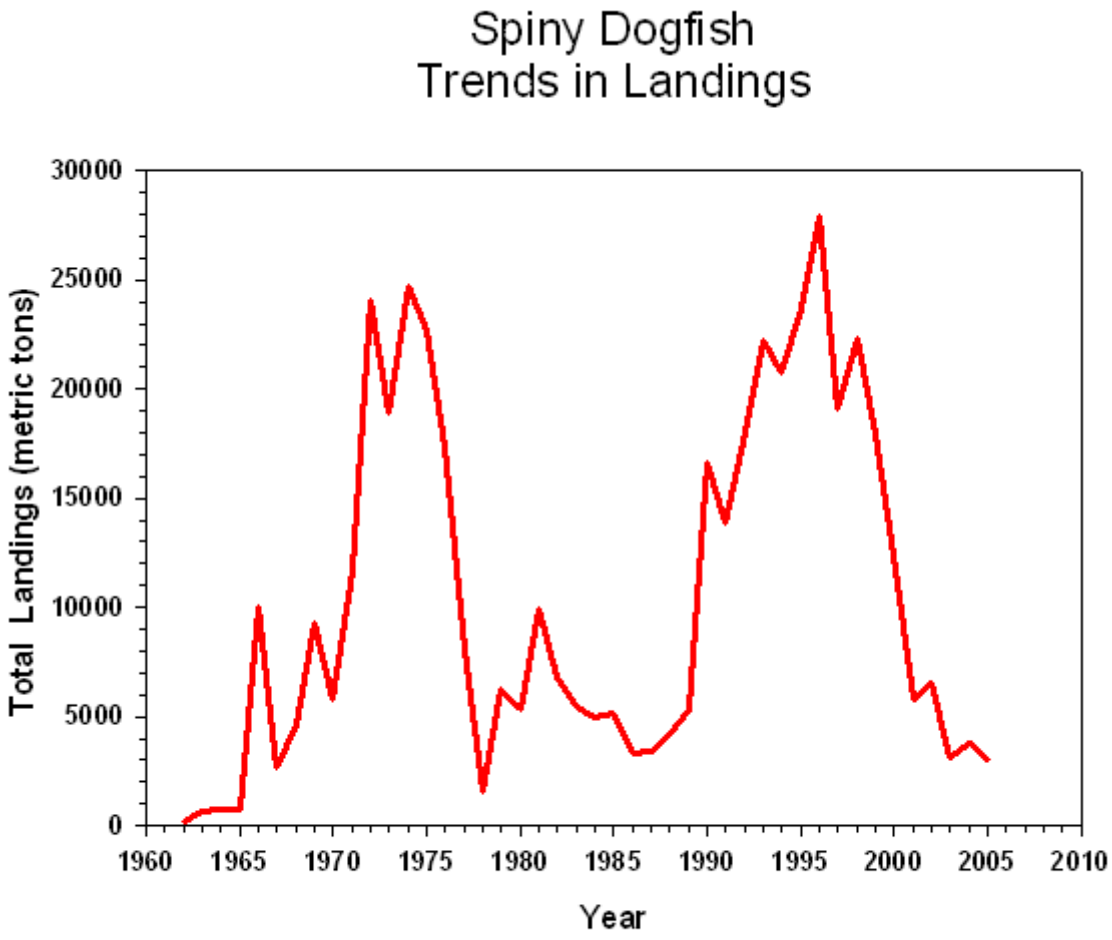


Figure 26.2. Total landings (metric tons, live) of spiny dogfish from NAFO Subareas 2-6.

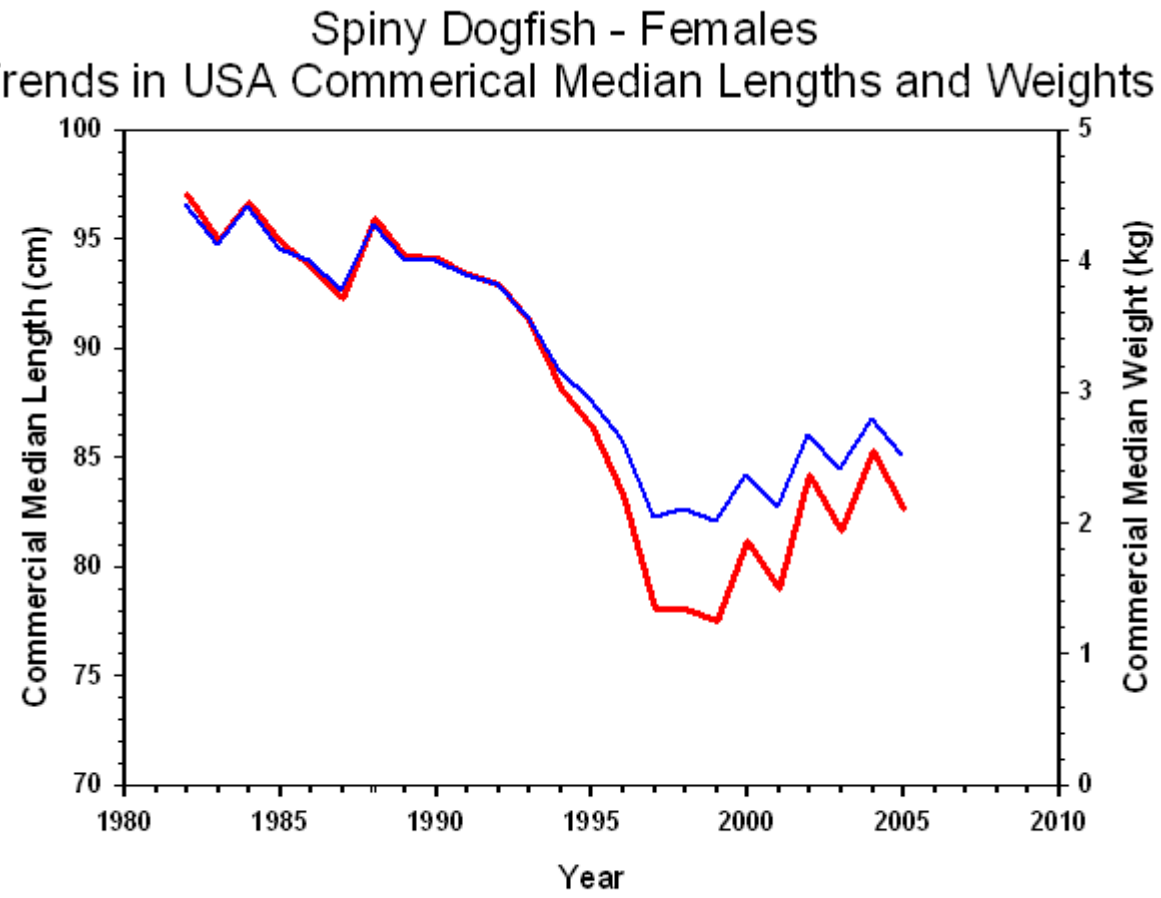


Figure 26.3. Trends in USA commercial median lengths (red, thick line) and weight (blue, thin line) of female spiny dogfish.

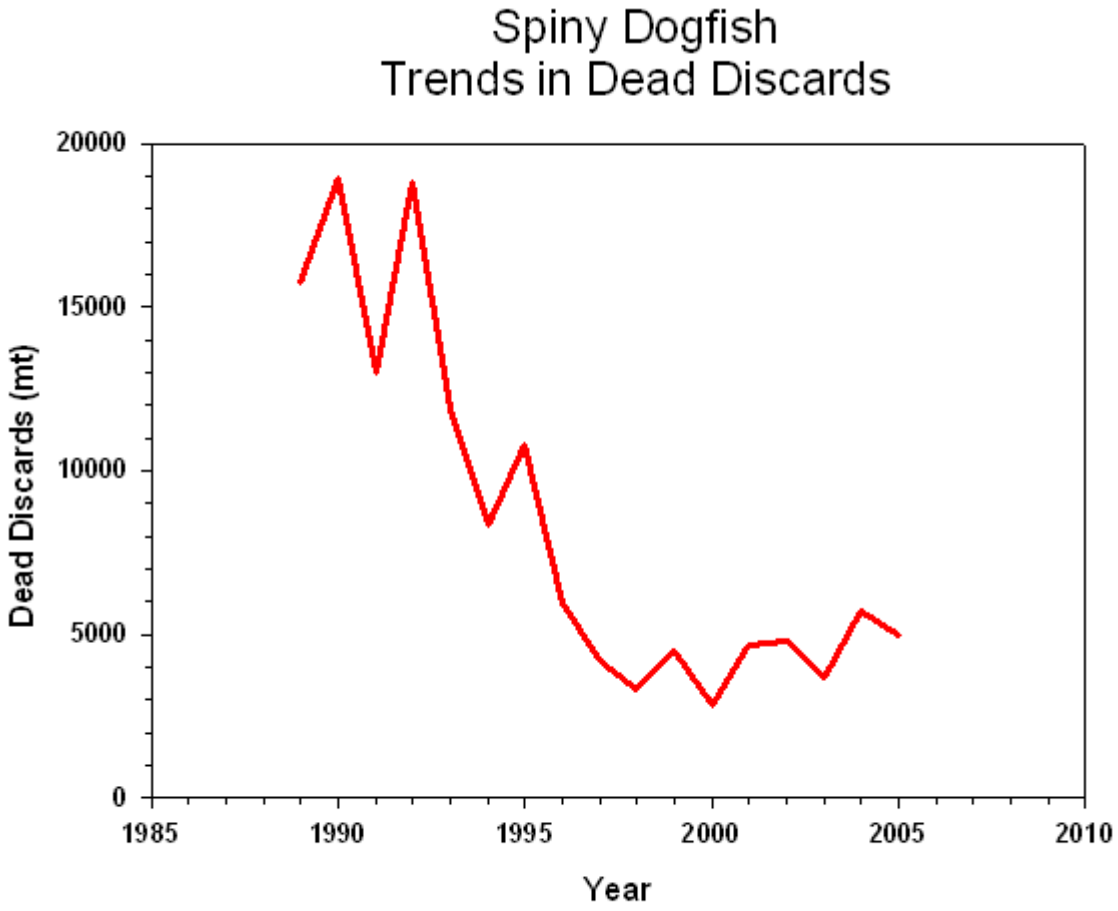


Figure 26.4. Estimates of total dead discards (metric tons) of spiny dogfish, 1989-2005.

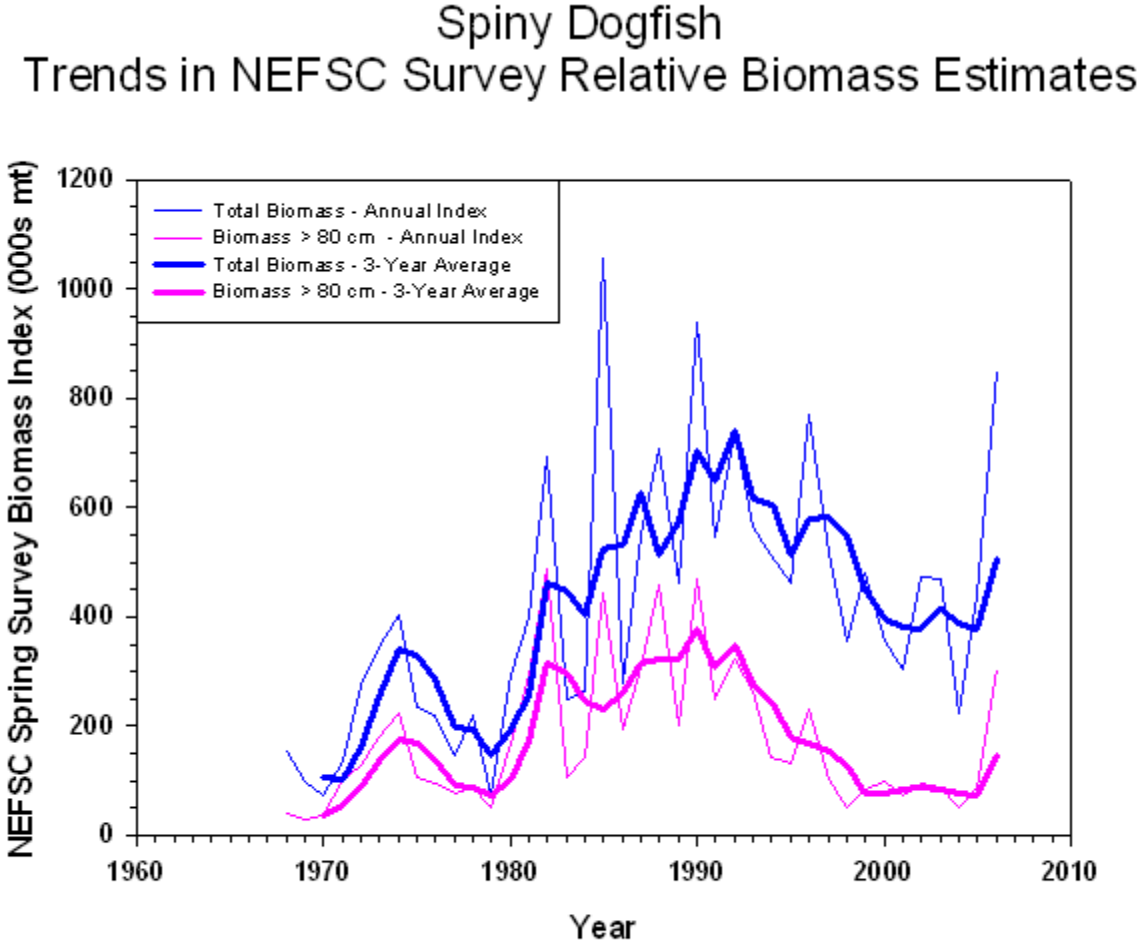


Figure 26.5. Trends in NEFSC spring survey total biomass (000s mt) and biomass of fish >= 80 cm (000s mt).

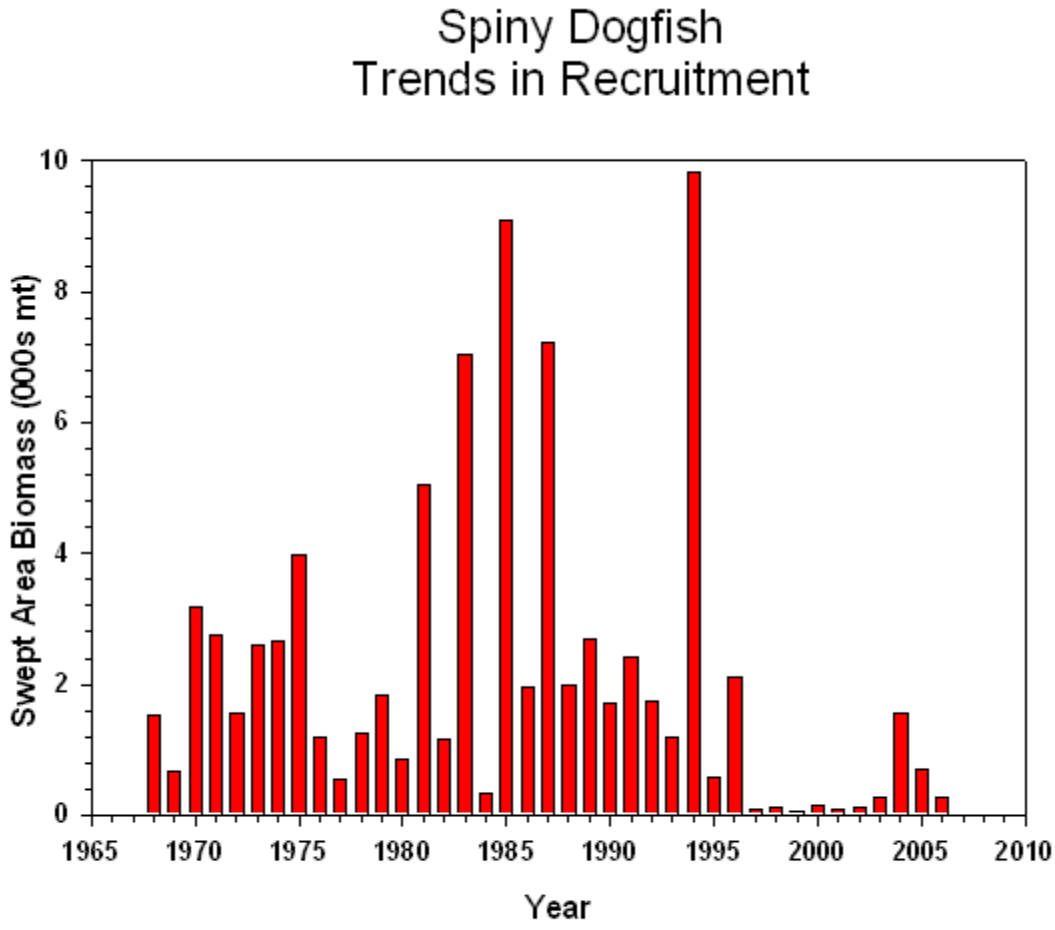


Figure 26.6. NEFSC spring survey relative biomass estimates of spiny dogfish recruits (individuals less than 36 cm, total length), 1968-2006.

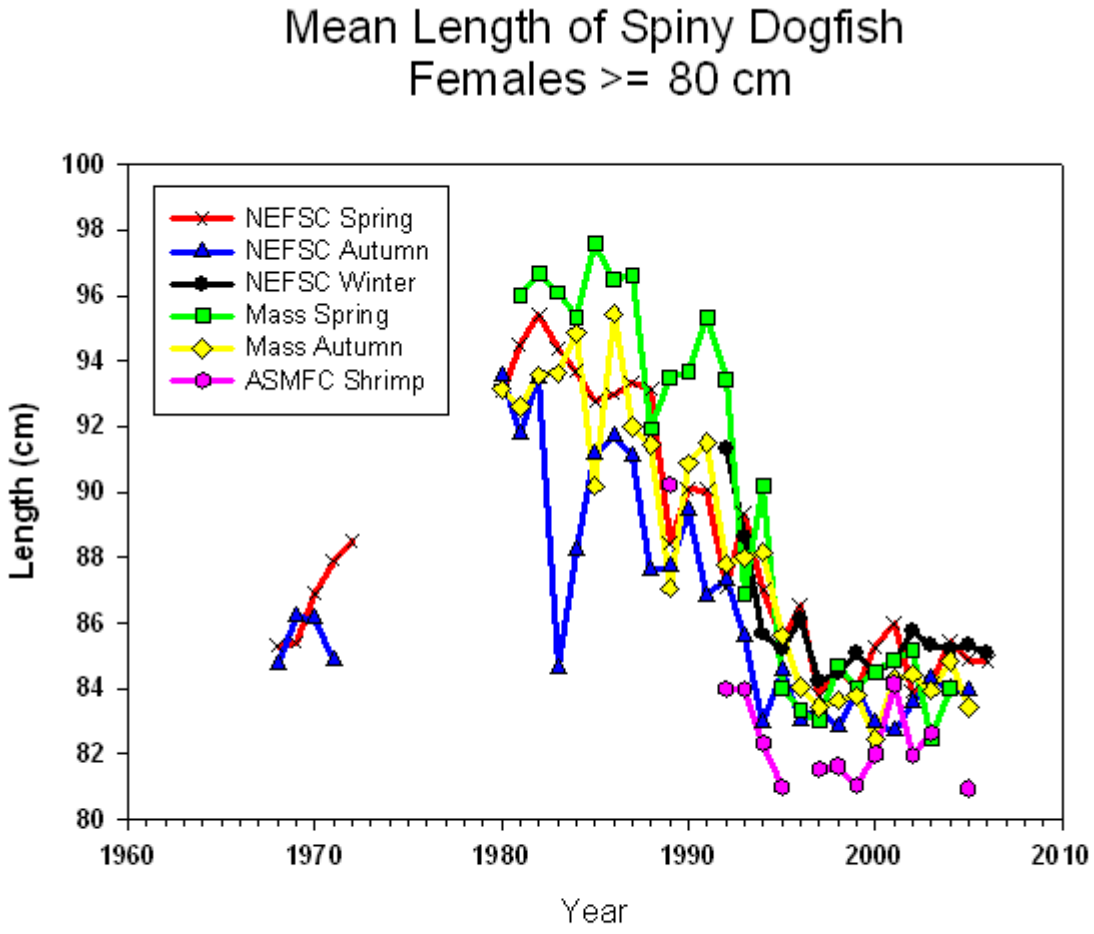


Figure 26.7 Mean length (cm) of mature (>80 cm) spiny dogfish females from NEFSC, Massachusetts and ASMFC shrimp surveys.

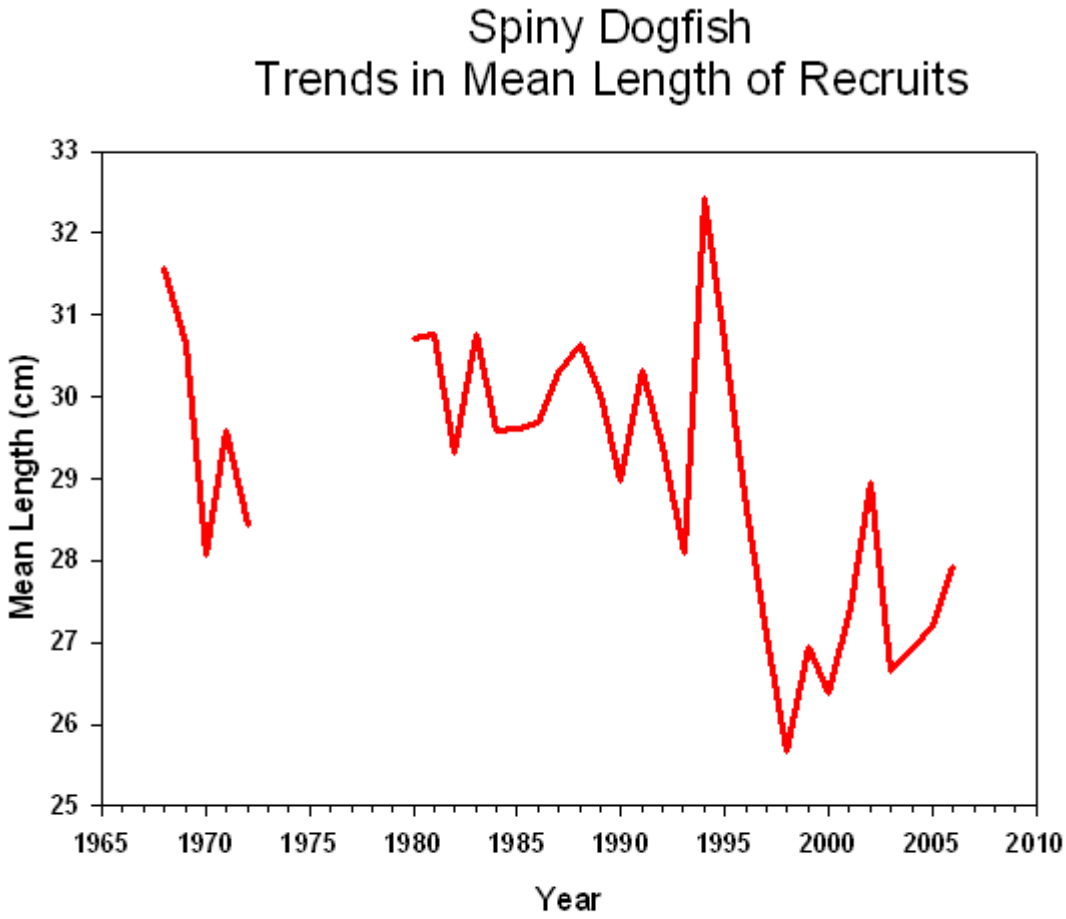


Figure 26.8. Trends in mean length of female juvenile dogfish (<36 cm) in NEFSC spring surveys, 1968-1972, 1980-2006. Sex-specific data unavailable for 1973-1979.

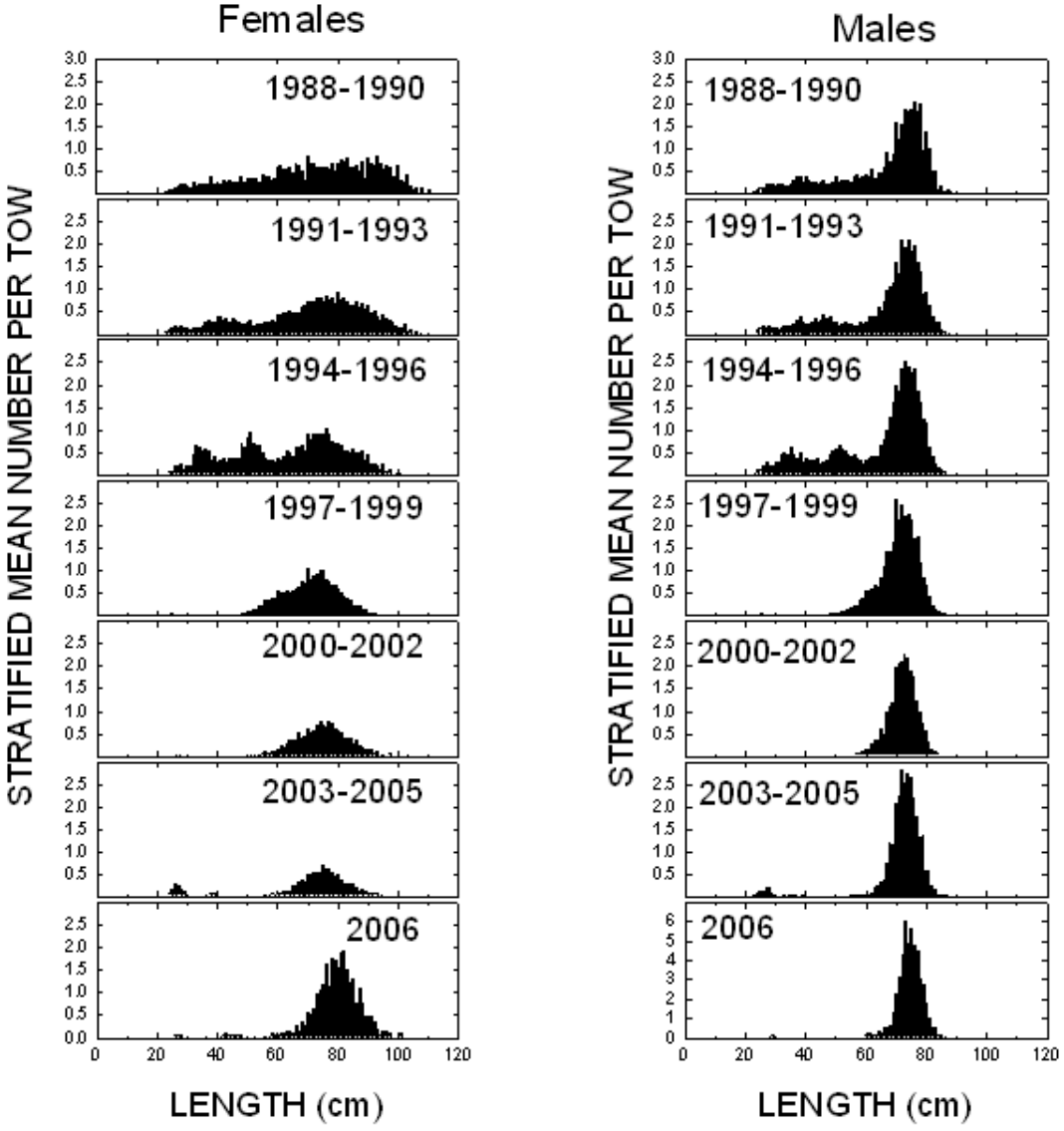


Fig. 26.9. Number of spiny dogfish per tow by 1 cm length class for females (left) and males (right) in NEFSC spring survey by 3-yr period 1988-2005 and for 2006 separately. Note the scale change for males in 2006.

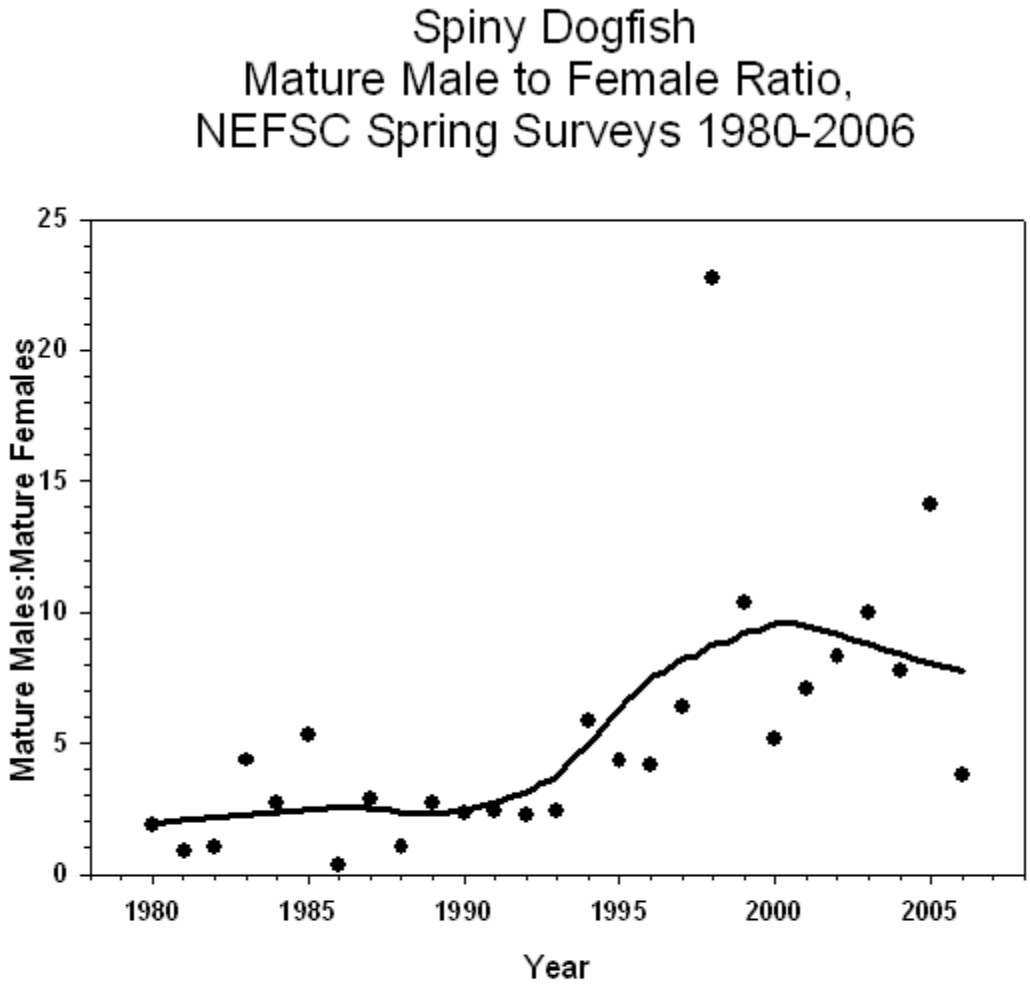


Fig. 26.10. Ratio of numbers per tow of mature male (>60cm) to mature female (>80 cm) spiny dogfish in NEFSC spring trawl surveys, 1980-2006. Line represents Lowess smooth with tension =0.5.

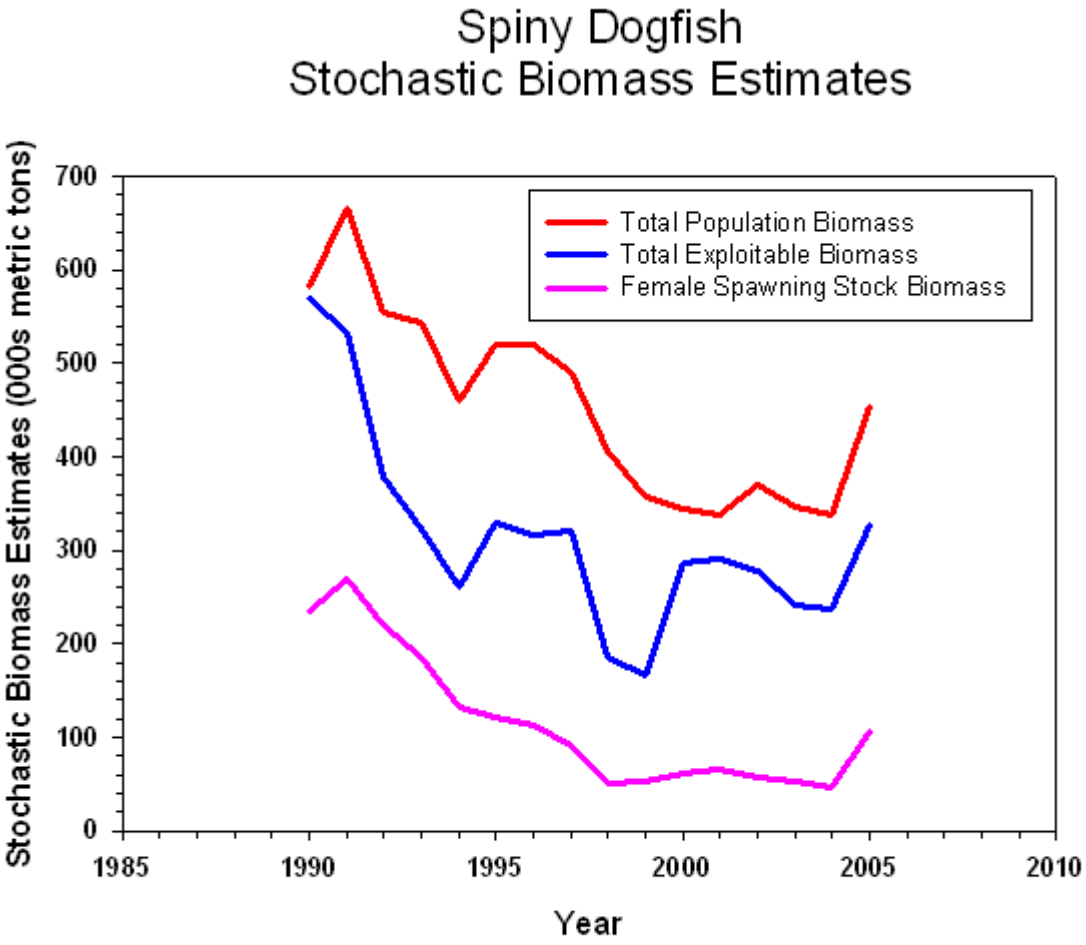


Figure 26.11. Stochastic estimates of biomass for spiny dogfish.

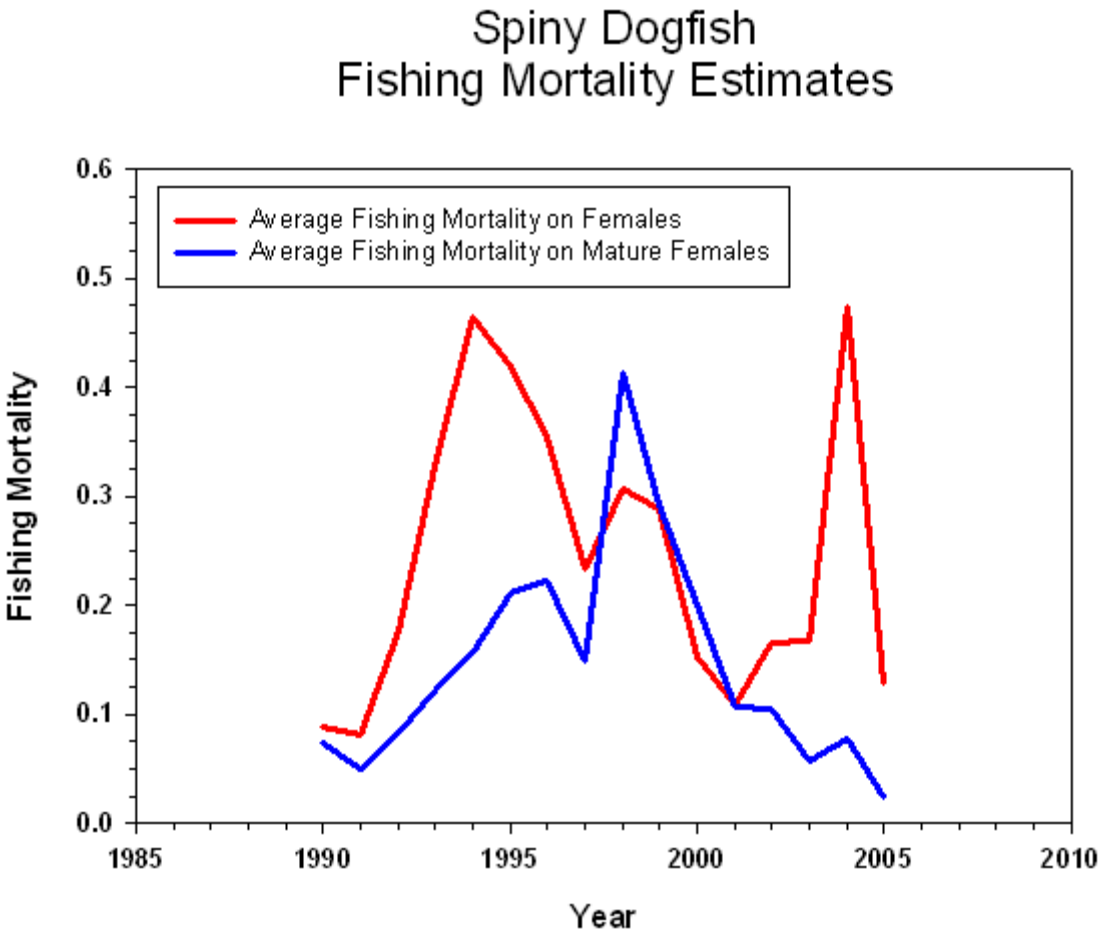


Figure 26.12. Estimates of fishing mortality for female spiny dogfish.

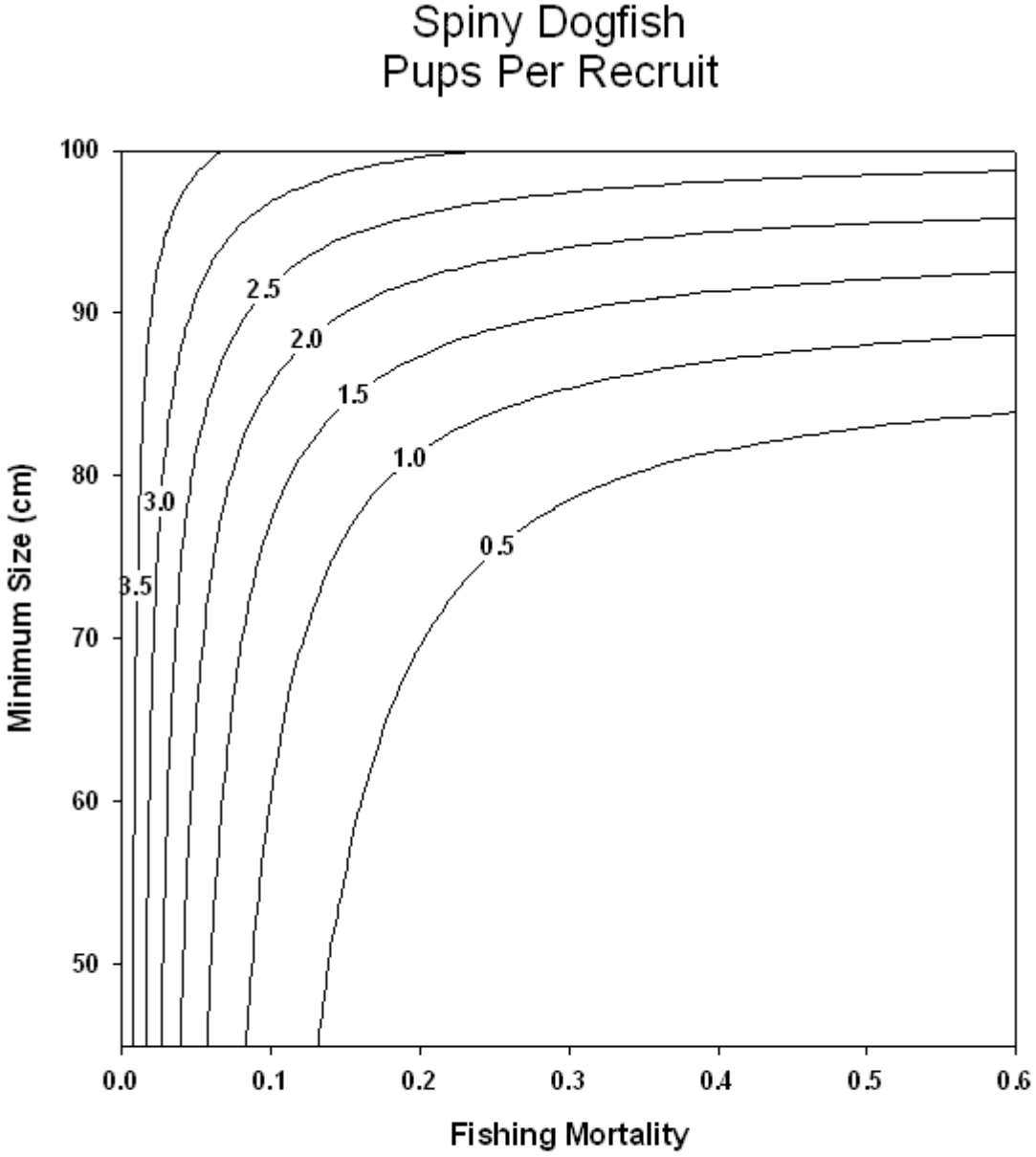


Figure 26.13. Contours of lifetime number of female pups per female recruit for varying levels of fishing mortality and minimum size at entry in the fishery. Size at entry into the fishery is assumed to be knife-edged.