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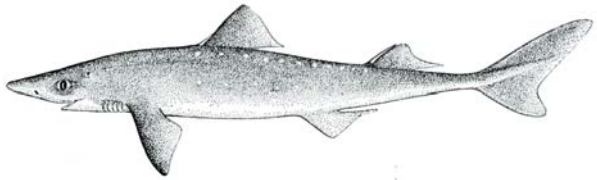
Pacific Region
Canadian Science Advisory Secretariat
Science Advisory Report 2010/057

ASSESSMENT OF SPINY DOGFISH (*SQUALUS ACANTHIAS)* IN BRITISH COLUMBIA IN 2010



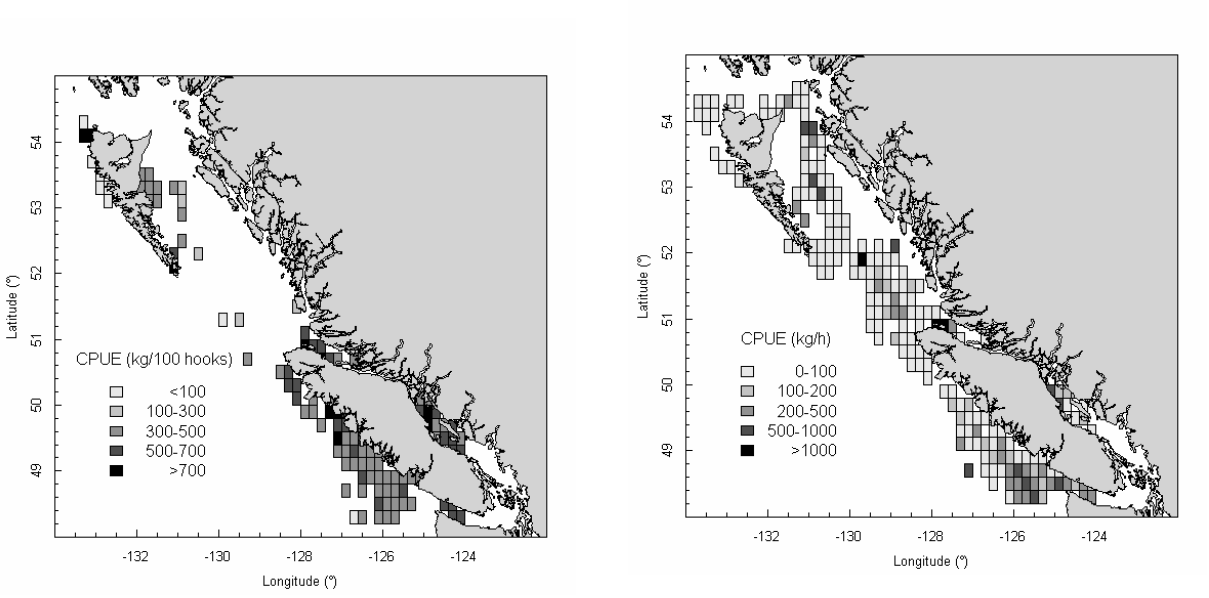


Figure 1: Mean catch per unit effort (CPUE) within 0.2º by 0.2º grid of) landed spiny dogfish for longline gear (left panel) from 1994-2006 and trawl gear (right panel) from 1996-2007.

Context :

The fishery for spiny dogfish in BC occurs primarily in the Strait of Georgia and off the southwest coast of Vancouver Island. In B.C., this species has a long history of commercial exploitation dating back to the 1870's, with maximum exploitation (5,000-32,000 tonnes) occurring from 1937-1950, to supply shark livers for Vitamin A production. Since 1986, the fishery has been smaller by comparison (100-5,000 tonnes).

The last comprehensive stock assessment of Pacific spiny dogfish was conducted in 1988. Advice was requested by Fisheries and Aquaculture Management (FAM) on the current stock status and potential yields for the Strait of Georgia (inside) and southwest coast of Vancouver Island (outside management areas. This assessment was completed in collaboration with the BC Dogfish Hook and Line Industry Association to support eco-certification of this fishery

SUMMARY

- The fishery for spiny dogfish in BC occurs primarily in the Strait of Georgia and off the southwest coast of Vancouver Island. In British Columbia, this species has a long history of commercial exploitation dating back to the 1870's, with maximum exploitation (5,000-32,000 tonnes) occurring from 1937-1950, to supply shark livers for Vitamin A production. A smaller food fish fishery (100-5,000 tonnes) has been conducted since 1974.
- In British Columbia, there are two discrete stocks of spiny dogfish; an outside stock that extends from Baja California to Alaska and an inside stock, in the Strait of Georgia. Spiny dogfish, like most shark species grow slowly, mature late (35-36 years for females) and produce between 2 and 17 offspring (pups) per year resulting in very low intrinsic rates of population increase. These life history features make them highly susceptible to overexploitation and stock depletion.
- The current assessment concluded that there is no immediate conservation concern for either the inside or outside stocks of Pacific spiny dogfish and that, given the perceptions of the current stock status, it is unlikely that deleterious or irreversible declines in stock abundance are likely to occur over the five year time frame established for the next assessment at the current (2000-2009) level of removals.
- For the Strait of Georgia, the use of the average long-term yield between 1978 and 2009 (the period of the modern food fish fishery) was recommended as the basis for establishing yield recommendations. This approach results in a yield recommendation of 1,579 mt. While, the current TAC is 3000 mt, total landings (long line and trawl) have averaged approximately 1,000 mt, since 2000, exceeding this 1,579 mt marginally in one year.
- For the outside fishery, there was no consensus reached on a scientifically valid approach on which to base yield recommendations.
- Given the uncertainties in the current assessment, it is recommended that an updated stock assessment be conducted at the earliest date possible and that the harvest advice provided herein should stand for a period of no more than five years. It is acknowledged that it may take five years to accrue sufficient new data to update the assessment.
- Overall, given the perceptions of the current stock status and nature of the fishery, it is unlikely that deleterious or irreversible declines in stock abundance are likely to occur over the five year time frame established for the next assessment.

INTRODUCTION

Stock Structure

The spiny dogfish is a small, gregarious shark belonging to the order Squaliformes and inhabiting temperate waters off the east and west coasts of North America. Recent re-examination of differences in natural history and demography between Pacific and Atlantic populations has resulted in a recommendation that these two populations should be re-separated into two different species, *S. suckleyi* in the Pacific and *S. acanthias* in the Atlantic.

Tagging data suggests that, in the northeast Pacific, there are discrete stocks primarily an offshore stock that extends from Baja California to Alaska and two coastal stocks, one in the Strait of Georgia and one in Puget Sound. Spiny dogfish in British Columbia waters are managed as two discrete stocks: an inside stock (Groundfish Management Area 4B) and an outside stock (Groundfish Management Areas 3C, 3D, 5AB, and 5CDE).

Biology

Reproduction in the spiny dogfish is carried out through internal fertilization. Breeding occurs during the late fall and early spring. Large eggs, approximately 35 mm in diameter and numbering 2 to 17, are released from the ovaries of the females, where they then pass through the shell gland for simultaneous fertilization and encapsulation in thick, rubbery "shells" before proceeding into the oviducts. Development is ovoviviparous (internal). Encapsulated eggs remain in the oviducts for nearly 2 years (18-22 months), a gestation period almost unmatched by any other species. During gestation, the shells dissolve and the free embryos are nourished by yolk material which they gradually deplete until they reach a full-term size averaging between 26 and 27 cm. In British Columbia waters, average fecundity in the spiny dogfish is between six and seven (range from 2 to 16 pups).

As a result of their low metabolic rate, spiny dogfish in the Northeast Pacific exhibit exceptionally slow growth. Age-at-maturity in females is approximately 35-36 years (Strait of Georgia) corresponding to approximately 94 cm total length. The maximum recorded age in females is 80 years old, and the recorded maximum size is approximately 130 cm total length, which corresponds to an estimated age of 90 years, based on growth.

Role in the Ecosystem

Young spiny dogfish, born as miniature replicas of their parents, are released in midwater layers overlying depths of 165 – 350 m, where they almost immediately begin feeding on a variety of small invertebrates. As growth progresses and juveniles begin to assume a more bottom-dwelling existence, their diet gradually shifts to fish. As opportunistic feeders, adult spiny dogfish prey on a number of species of fish including herring, capelin and eulachon, rising only occasionally in the water column to feed on surface swarms of euphasiids. Digestion is a slow process in spiny dogfish, with an observed time between feeding events of 16 days in British Columbia waters. The relationship between spiny dogfish and higher trophic level predators such as lingcod, sablefish, other shark species, and northern sea lions is not well understood.

Rationale for Assessment

Advice was requested by Fisheries and Aquaculture Management on the stock status of spiny dogfish to inform the management of the fishery. This assessment is based, in part, on work commissioned by BC Dogfish Hook and Line Industry Association, to support an eco-certification process. Note that in November 2010 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) will review the Status Report for spiny dogfish, and may consider current assessment advice in their deliberations. Spiny dogfish was considered for listing under Appendix II of the Convention on International Trade of Endangered Species of Wildlife and Fauna (CITES) in March 2010. The application for CITES listing was declined.

The Fishery

Commercial fisheries for spiny dogfish in British Columbia began in the late-1800s (Figure 2). There have been several major fishery eras that have mirrored changes in the market demands of spiny dogfish, ranging from a source of oil for industrial lubrication, lighting, and fertilizer to a source of liver oil for Vitamin A, or most recently, since 1978, as a source of food. It is important to note that declines in spiny dogfish landings at the end of each major fishery era have not been attributed solely to declines in abundance, but rather also to the discovery of alternate sources for the products that each fishery provided. For example petroleum replaced

dogfish oil for illumination purposes and the synthetic production of Vitamin A replaced the use of spiny dogfish products as a source of Vitamin A.

Commercial annual landings of spiny dogfish in the Strait of Georgia have fluctuated from minimum catches of 100-300 tonnes (during the 1960s), to catches of over 15,000 tonnes, during the large liver fishery that took place from 1937 to 1950 (Figure 2). Since the late-1970s, spiny dogfish has been fished as a source of food using longline and trawl gear, with total annual landings averaging approximately 1,500 tonnes for the inside stock, and 1,600 tonnes for the outside stock.

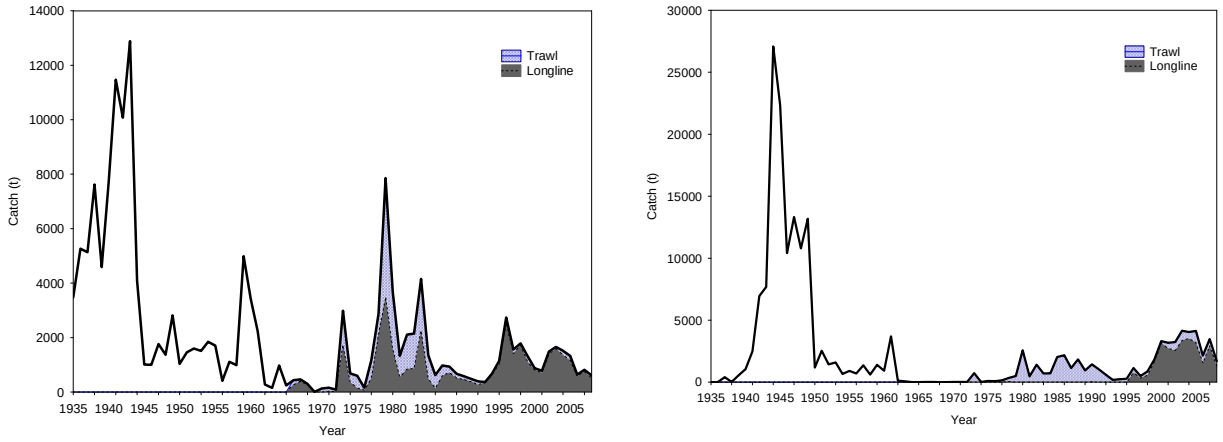


Figure 2. Total mortality (landings and discard mortality; tonnes) of spiny dogfish in the inside stock (left panel) and the outside stock (right panel) from 1935-2008. From 1966 onwards, total mortality is estimated separately for trawl (hatched area) and longline (solid area) gear. Solid black line is total mortality for all gear types combined.

Spiny dogfish in British Columbia are managed with an annual quota that was recommended in 1980, based on a population model that assumed compensatory density-dependent mortality. Annual fishery updates were conducted until 1995. The TAC for the outside stock was initially set at the low risk option of the original assessment (15,000 tonnes), and was decreased to 12,000 tonnes in 1994 (Table 1). The TAC for the inside stock was initially set at the high risk option of the original assessment (3,000 tonnes), decreased to 2,500 tonnes in 1994, and subsequently increased to its current level of 3,000 tonnes (Table 1).

Table 1. Spiny dogfish total allowable catch (TAC) limits (in tonnes) by stock from 1979-2008 for gears combined. In 1996, an error in the management plan for the inside stock set the TAC to 5,000 tonnes instead of 2,500 tonnes. This error was corrected in 2005.

	TAC		
Year	**Inside**	**Outside**	**Coastwide**
2005-2008	3,000	12,000	15,000
1996-2004	5,000	11,940	16,940
1994-1995	2,500	12,000	14,500
1979-1993	3,000	15,000	18,000

ASSESSMENT

Total Mortality

Annual landings are available for all gear types combined starting in 1935, and by gear type starting in 1966. Annual discard data (tonnes) were available from 2001 onwards for longline fisheries and from 1966 onwards for trawl fisheries. Discard mortality (tonnes) was calculated using mortality discard rates (%) from the Integrated Fisheries Management Plan (IFMP) for Pacific Canadian groundfish fisheries. Estimated discard mortality was added to the landings to estimate total fishing mortality (tonnes) by year for each stock. Catch, estimated discards and total mortality from 1935 to 2008 are show in Figure 2.

Stock Indices

Catch with effort data were available from 1980 onwards. Commercial indices were developed based on trips where landings of spiny dogfish comprised at least 60% of total landing. Longline effort data were sparse and only 11 years between 1979 and 2008 had data adequate to produce CPUE estimates for the inside stock (Figure 3, left panel) and outside stock (Figure 4, left panel). Trawl effort data prior to 1996 are not available on a tow by tow basis and were not used in this assessment. From 1996 onwards trips in which trawl landings of spiny dogfish comprised at least 60% of total landing were selected for calculating mean catch per unit effort (kg per hour). Trawl index values were produced for years with at least 30 trips were included. From 1996-2008, only four years met these criteria for the inside stock (Figure 3, right panel), and nine years for the outside stock (Figure 4, right panel).

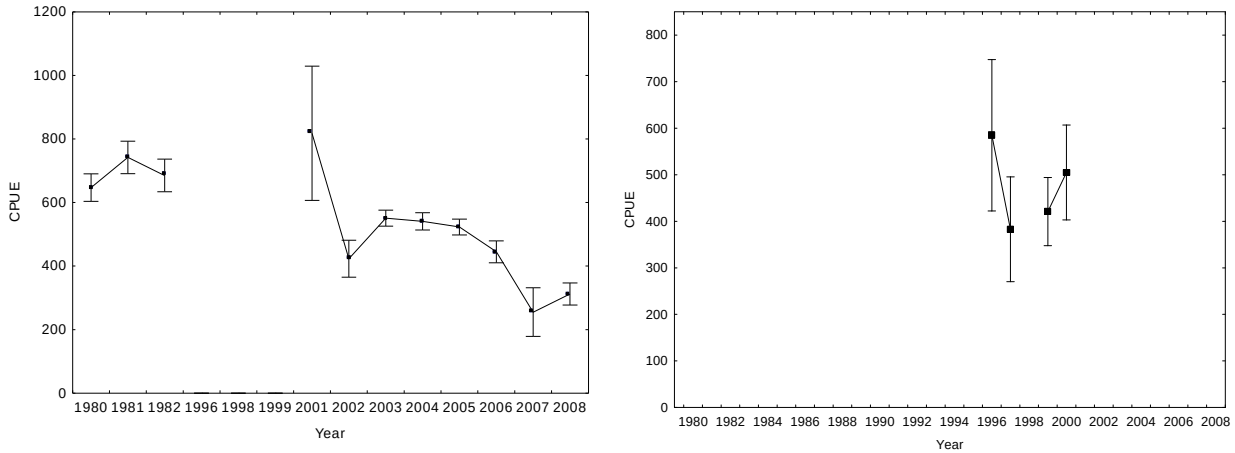


Figure 3. Mean commercial longline fishery catch per unit effort (CPUE; kg per 1000 hooks; left panel) and mean trawl fishery catch per unit effort (CPUE; kg per hour; right panel) and standard deviation for fisheries conducted in the inside stock. Only trips with 60% or more of the total landings comprised of spiny dogfish were considered, and years with at least 30 trips that met this criterion were retained.

The commercial longline CPUE for the inside stock (Figure 3, left panel) exhibits a decline of approximately 50% from 1980 to 2008. However, the commercial trawl CPUE for the inside stock does not exhibit any significant trend from 1996-97 to 1999-2000; it remains fairly stable with overlapping annual variability (Figure 3, right panel).

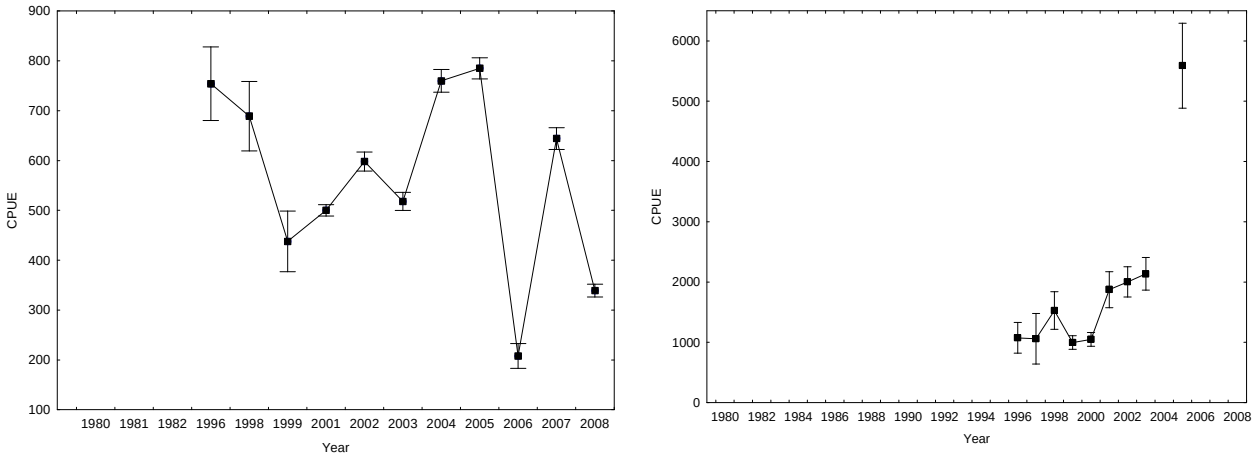


Figure 4. Mean commercial longline fishery catch per unit effort (CPUE; kg per 1000 hooks; left panel) and mean trawl fishery catch per unit effort (CPUE; kg per hour; right panel) and standard deviation for fisheries conducted in the outside stock. Only trips with 60% or more of the total landings comprised of spiny dogfish were considered, and years with at least 30 trips that met this criterion were retained.

Spiny dogfish catch per unit effort data from a number of research surveys were examined for utility as abundance indices in the assessment model. Surveys with several years of data, or that span a large number of years and that produced CPUE with low variability (CV) were included. These surveys included: DFO Strait of Georgia longline spiny dogfish survey (1986, 1989, 2005, 2008; Figure 5); DFO Hecate Strait random non-stratified bottom trawl flatfish survey (biannually 1984-2003; Figure 6); International Pacific Halibut Commission longline halibut survey conducted throughout the outside waters (1993-2008; Figure 7); the US National Marine Fisheries Service triennial bottom trawls surveys off the southwest coast of Vancouver Island (1980-2001; Figure 8).

The CPUE for the spiny dogfish research survey conducted on the inside stock (Figure 5) exhibits an increase in recent years (2005 and 2008) relative to previous years (1986 and 1989). The CPUE from research surveys conducted in the outside waters exhibit either a decrease over time (Figure 6) or no discernible trend (Figures 7 and 8).

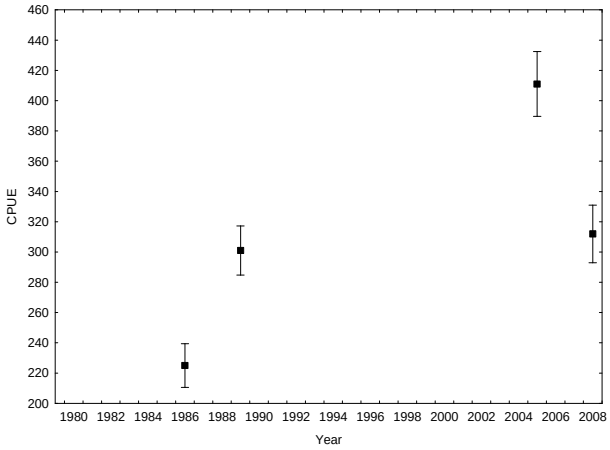


Figure 5. Spiny dogfish mean catch per unit effort (CPUE; kg per 1000 hooks) and standard deviation for the targeted spiny dogfish longline survey conducted for the inside stock.

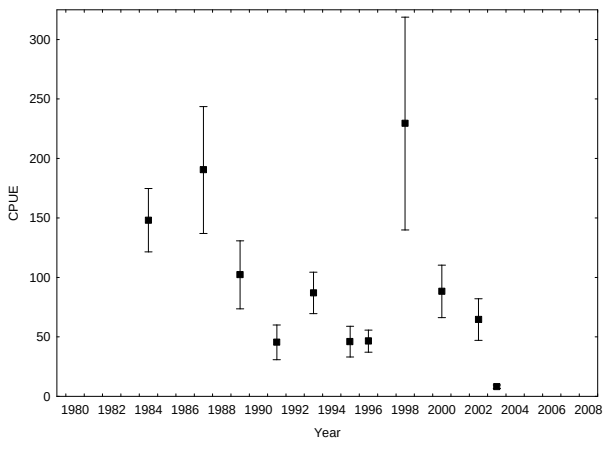


Figure 6. Spiny dogfish mean catch per unit effort (CPUE; kg per hour) and standard deviation for the groundfish Hecate Strait (outside stock) trawl research surveys.

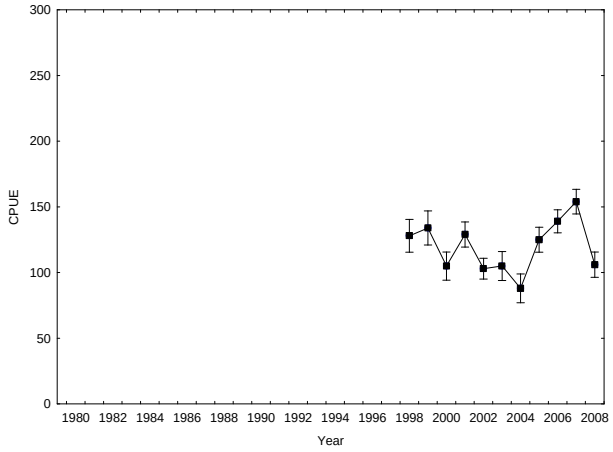


Figure 7. Spiny dogfish mean catch per unit effort (CPUE; number of fish per 1000 hooks) and standard for the International Pacific Halibut Commission longline surveys conducted in Statistical Areas 3C through 5E (outside stock).

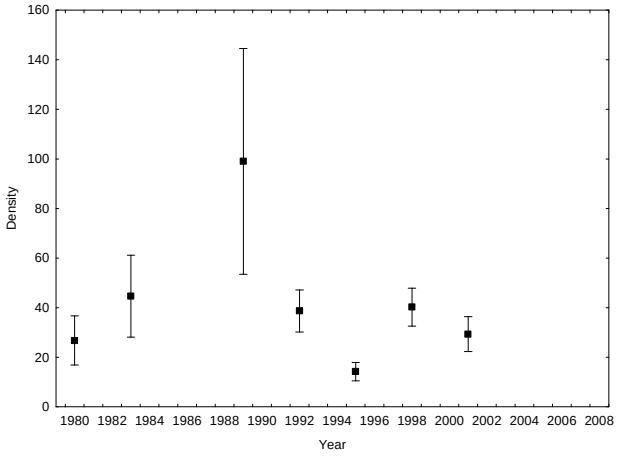


Figure 8. Spiny dogfish mean biomass density estimates (thousand kg per km^2) and standard deviation for the National Marine Fisheries Service groundfish bottom trawl survey that extends in Area 3CD (outside stock).

Commercial and research length data – Inside stock

For the period 1974-2004, there was a dramatic decline in the mean size of females in the longline fishery data from 124 cm (1975-1979) to 80 cm (2000-2004). It should be noted that the sampling frequency across years was inconsistent. Part of the decline in size can be attributed to market conditions for smaller dogfish that developed in the mid-1990s that probably led to the retention of smaller fish. In addition, the switch to circle-hook gear in the commercial fishery occurred during the same period. Circle-hook gear is more efficient than traditional J-hook gear at both catching and retaining hooked spiny dogfish at deeper depths. This gear efficiency, coupled with the distribution of smaller dogfish at deeper depths, probably also contributed to the shift in the size composition of commercial landings.

However, a shift in size composition was mirrored in the research data when frequency distributions were corrected for depth effect of gear catchability and differences in fishing effort. The modal length interval for males shifted from the 80-85 cm interval observed in 1986 and 1989 to the 75-80 cm interval observed in 2005 and 2006 (Figure 9). A modal length for females was not as pronounced (Figure 9). The frequency distribution of female spiny dogfish exhibited two characteristics over time: 1-the decrease in the number of large sized fish (>100 cm); 2-the increase in the number of small sized fish (55-85 cm) (Figure 9). Large, mature fish are still present in the size composition, suggesting that the decline in mean size, both in the research and commercial size composition, is not attributable to high commercial removals of large, mature fish. Given that the relative abundance index indicates an increase in relative numbers of spiny dogfish, this shift in the size distribution might instead reflect increased numbers of juvenile fish to bottom habitat (King and McFarlane 2009). There is need to monitor the potential decrease in large females (>100 cm), and a planned survey in 2011 will provide additional information.

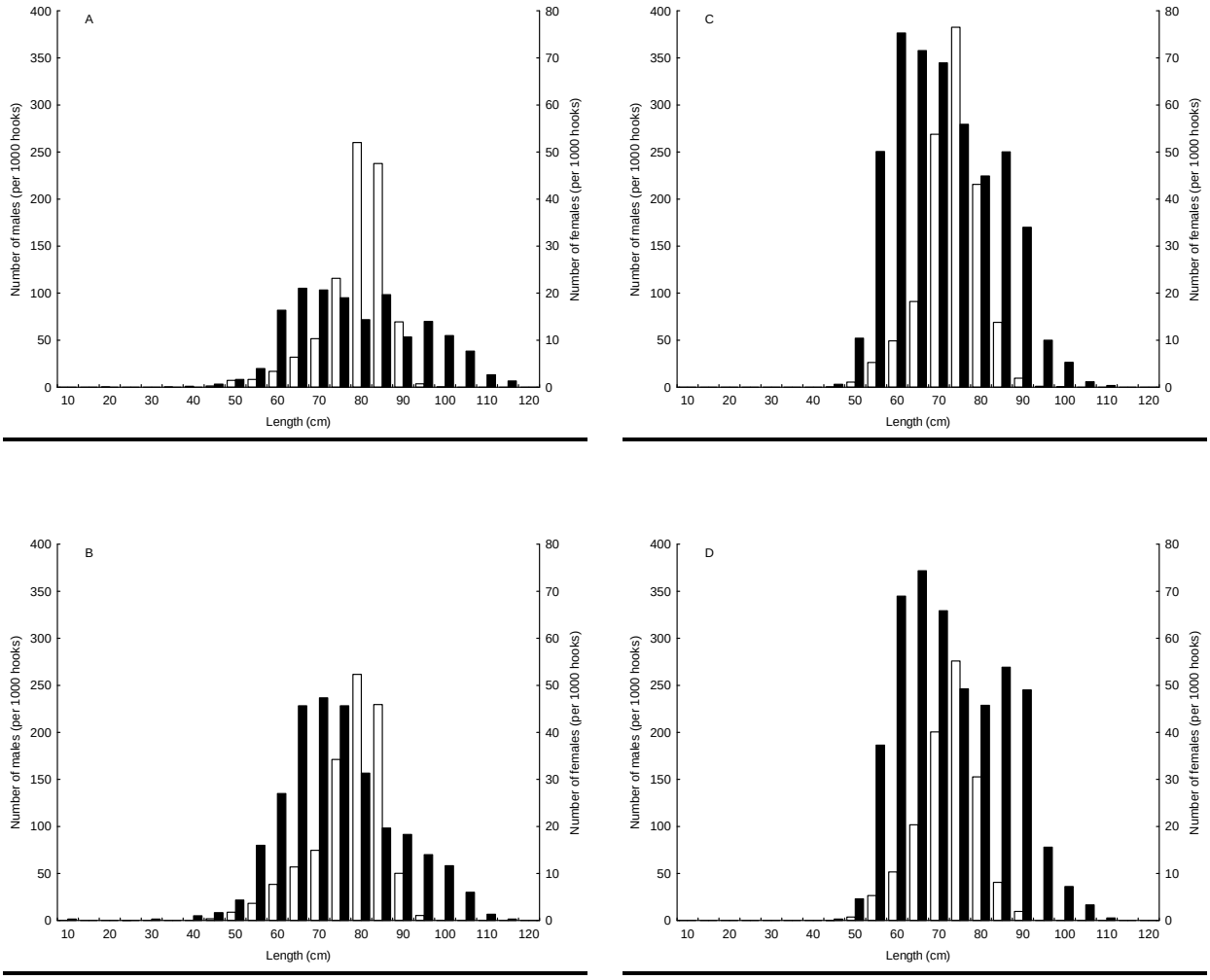


Figure 9. Frequency (number of fish) distributions of male (open bars; left axes) and females (closed bars; right axes) spiny dogfish captured in the inside stock longline survey in A) 1986; B) 1989; C) 2005 and D) 2008 per thousand hooks. The frequencies for the 2005 and 2008 surveys were corrected for differences in gear catchability by depth as per King and McFarlane (2009b).

Population Modeling

The paucity of catch-age data for spiny dog-fish precludes the development of an age-structured model, and given the longevity of spiny dogfish, the inclusion or dependence on a length-age key would be questionable. Data were available to support a generalized surplus-production model configured as either (*i*) the generalized Schaefer surplus production model, or (ii) the Pella-Tomlinson surplus production model.

The maximum likelihood optimization procedure for parameter estimates of *r* and *K* resulted in many model runs for which the estimates were at the upper constraints; this suggests that either the data contains little information for biomass estimates, or that the likelihood structure is poor. For this reason, the results of the modeling have not been considered in the provision of advice.

Sources of Uncertainty

- The discard rates applied to longline and commercial fishery discards (tonnes) to estimate total fishing mortality are not verified by research studies. It is likely that the discard rates are underestimates and, as such, the total fishing mortality is underestimated.
- Historic and current levels of discards in other fisheries (such as troll fisheries, gillnet fisheries, seine fisheries or recreational fisheries) are unknown.

CONCLUSIONS AND ADVICE

In the absence of accepted model derived yield recommendations, qualified harvest recommendations are provided for the inside stock, based on average catch history, trends in survey results and expert opinion. This approach is consistent with the DFO policy "*Fishery decision-making framework incorporating the Precautionary Approach".* Specifically, this policy directs that in the absence of model based estimates of Maximum Sustainable Yield (MSY), F_{MSY} and Biomass at MSY (B_{MSY}), average long-term yield or average fishing mortality (or an index of fishing mortality), which did not lead to stock decline over a productive period, can be used an acceptable proxy for F_{MSY}. An acceptable time series of fishing mortality was not available to provide harvest recommendations for the outside stock. However, expert opinion and an evaluation presented in Wallace et al. (2009) form the basis for the stock status statement hat follows.

Specific conclusions and recommendations:

- There is no immediate conservation concern for either the Strait of Georgia or Outside stocks of Pacific Spiny Dogfish, at current levels of removals (2000 to 2009).
- For the Strait of Georgia, the use of the average long-term yield between 1978 and 2009 (the period of the modern food fish fishery) was recommended as the basis for establishing yield recommendations. This approach results in a yield recommendation of 1,579 mt. While, the current TAC is 3000 mt, total landings (long line and trawl) have averaged approximately 1,000 mt, since 2000, exceeding this 1,579 mt marginally in one year.
- For the outside fishery, there was no consensus reached on a scientifically valid approach on which to base yield recommendations.
- Given the uncertainties in the current assessment, it is recommended that an updated stock assessment be conducted at the earliest date possible and that the harvest advice provided herein should stand for a period of no more than five years. It is acknowledged that it may take five years to accrue sufficient new data to update the assessment.
- Overall, given the perceptions of the current stock status and nature of the fishery, it is unlikely that deleterious or irreversible declines in stock abundance are likely to occur over the five year time frame established for the next assessment.

OTHER CONSIDERATIONS

There are two recent reviews of spiny dogfish abundance trends based on catch per unit effort data for the inside stock (King and McFarlane, 2009) and the outside stock (Wallace et al. 2009). King and McFarlane (2009) examined the catch per unit effort (CPUE) data from spiny dogfish longline surveys conducted in the Strait of Georgia and concluded that the relative abundance of spiny dogfish has remained stable over the last 20 years based on cpue trend analysis. Wallace et al. (2009) examined CPUE indices from groundfish trawl research surveys

conducted off the southwest of Vancouver Island and in Hecate Strait and from the International Pacific Halibut Commission longline survey conducted throughout the outside stock waters (Vancouver Island up through Hecate Strait) and concluded the outside stock is stable and fishing pressure is considered to be low relative to the estimated size of the population.

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