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28. Status of Spiny Dogfish in Atlantic and Pacific Canada

Scott S. Wallace*

David Suzuki Foundation, 2211 West 4th Avenue, Vancouver, British Columbia, V6K 4S2, Canada

Gordon A. McFarlane

Department of Fisheries and Oceans, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, British Columbia, V9T 6N7, Canada

Steven E. Campana

Population Ecology Division, Bedford Institute of Oceanography, Post Office Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, Canada

Jackie R. King

Department of Fisheries and Oceans, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, British Columbia, V9T 6N7, Canada

Abstract.—In this paper we summarize recent trend and management information relevant to the status of Canada's Atlantic and Pacific populations of spiny dogfish *Squalus acanthias*. Information includes current distribution, migration and movements, biological and abundance trends, status in adjacent jurisdictions, and current commercial catch and management. Based on annual research surveys, the dogfish population on the Atlantic coast appears to be at a low level of abundance on Georges Bank but stable or possibly increasing along the Scotian Shelf region and in the Gulf of St. Lawrence. Off Canada's Pacific coast, indicators suggest that the population is stable; but there may have been a decrease in larger individuals in recent years. It is proposed that the recent increases in large individuals in Alaska may be linked to a shift in the core distribution of dogfish from Canada's Pacific waters.

Introduction

Spiny dogfish *Squalus acanthias* have a long and varied history of exploitation in Canada. Their body oils have been used for industrial lubrications, lighting, and vitamin A; their flesh for fertilizer, meat, and fish meal; their fins enter the international shark fin trade; and finally they have been the subject of directed eradication programs due to their "nuisance" factor in commercial fisheries (Ketchen 1986). Their reputation as a "pest" in fisheries directed for other species is partly responsible for the lack of proper management. For most of their long period of exploitation in North American waters, there has been very little attempt to actively manage their populations. Dogfish have a low intrinsic rate of increase resulting in several overfished populations worldwide (Smith et al. 1998; Federal Republic of Germany 2003). The International Union for Conservation of Nature has listed dogfish as *near threatened* on a global basis with populations in the northwest and northeast Atlantic assessed as *vulnerable* and *endangered*, respectively (Fordham 2000, 2003a, 2003b). The status of dogfish populations in Canada is presently under review by the Committee on the Status of Endangered Wildlife in Canada. In this paper we review information relevant to understanding the status of dogfish populations in Canada's Atlantic and Pacific waters.

* swallace@davidsuzuki.org

Atlantic Population

Distribution, migration, and dispersal

For management purposes, spiny dogfish are considered as one population throughout the northwest Atlantic (Atlantic States Marine Fisheries Commission [ASMFC] 2002). Campana et al. (2007 and 2009, this volume) suggest there are possibly several loosely structured stock components in Atlantic Canada with little interchange between northern dogfish around Newfoundland and those in southern populations along the Scotian shelf.

Groundfish surveys undertaken by the Canadian Department of Fisheries and Oceans (DFO) and the U.S. National Marine Fisheries Service (NMFS) indicate that the population of spiny dogfish in the northwest Atlantic is most abundant between the Scotian Shelf off Nova Scotia and Cape Hatteras (North Carolina) with some of the population in the Gulf of St. Lawrence. There are few records of dogfish catches north of the Grand Banks (Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, unpublished) (Figure 1).

Based on tagging studies, it has been shown that at least some portion of the southern stock on the Scotian Shelf (~Halifax southwards) also migrates to waters off the United States (Campana et al. 2007, 2009; Northeast Fisheries Science Center [NEFSC] 2003). The northern stock component, with concentrations around Newfoundland (southern edge of the Grand Banks), exhibits some movement into the Gulf of St. Lawrence, south to the USA and even to Europe, but largely remains around Newfoundland (Templeman 1984). There does not appear to be any pattern of size and location, with both mature and immature spiny dogfish being found throughout the range.

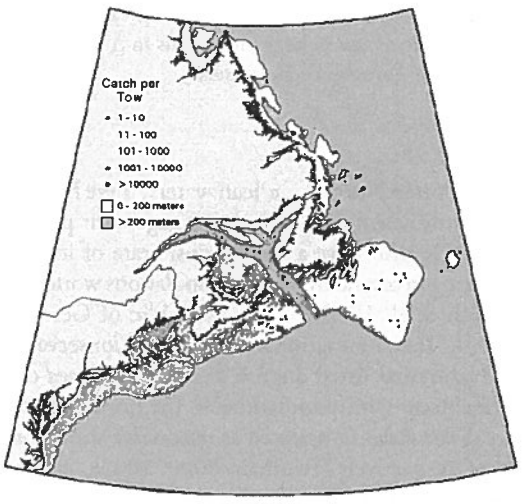

Figure 1. Distribution of spiny dogfish *Squalus acanthias* in the northwest Atlantic based on Canadian and American research surveys from 1975 to 1994. Source: East Coast of North America Strategic Assessment Project, unpublished.

Based on catch distributions, it appears that a portion (unknown amount) of the spiny dogfish population consists of summer migrants to Atlantic Canadian waters from U.S. waters, with the remainder of the population remaining resident throughout the year (Campana et al. 2007, 2009). By June, dogfish are regularly landed off Nova Scotia, in the Bay of Fundy, and off southwestern Newfoundland. By July, some of the population moves into the Gulf of St. Lawrence and north into waters off southern Labrador and around Newfoundland. By late fall some of the dogfish migrate out of Canadian waters and move south to waters off of North Carolina or New England. It is unknown what percentage of the overall population resides in Canadian waters all year (Campana et al. 2007, 2009).

There is no evidence from commercial records or research sampling of expansion or contraction of the spiny dogfish range. The area of occupancy in Atlantic Canadian waters is estimated to be 425,000 km^2, which is the combined area of the Gulf of St. Lawrence, southern Newfoundland, the Scotian Shelf, and the Gulf of Maine.

In summary, understanding of spiny dogfish dispersal is still limited. However, there is certainly mixing of populations throughout the northwest Atlantic with individuals occasionally moving between the northeast and northwest Atlantic (Templeman 1984). The presence of large overwintering aggregations off the Scotian Shelf and Newfoundland at a time when the annual migration has returned other dogfish to U.S. waters is consistent with the view that a significant number of dogfish do not migrate between Canadian and U.S. waters. Catch data also indicate that there is a significant component of the population that does not migrate (Campana et al. 2007, 2009).

Comercial fishery and management

Canada

Over most of the past 40 years, Canadian spiny dogfish landings have been minimal; however,

since 1997 there has been a steady increase in landings (Figure 2) taken primarily from the Scotian Shelf region (NAFO statistical area 4X) (Figure 3). Throughout the entire time series the Canadian catch in the northwest Atlantic has only comprised 5.4% of the northwest Atlantic recorded landings. In the last five years Canadian landings have increased while at the same time the U.S. landings have decreased (due to harvest restrictions) to the point where Canadian landings now exceed American landings.

While accurate catch data (i.e., including discards) are not always available, it is widely recognized that there has been substantial discarding of spiny dogfish caught in both mobile and fixed gear. Estimates based on observer records indicate that the numbers of dogfish that are discarded may be equal to or larger than those that are landed (Campana et al. 2007). Depending on the magnitude of discard mortality, discarding may be a major source of mortality for the population. The commercial fishery generally targets large individuals, resulting in the mean length of dogfish in the commercial catch being much larger than that found in research surveys (Figure 4).

Current quota for fixed gear licenses is 2,500 metric tons (mt). Vessels with mobile gear (i.e., trawl) are restricted to 25 mt per year per vessel less than 19.5 m and 10 mt per year per vessel greater than 19.5 m. There are presently no commercial catch indices suitable for assessing trends or abundance.

United States

In the early 1990s the combination of high abundance of spiny dogfish (Fogarty and Murawski 1998) and good markets in Europe resulted in strong fishing pressure. Between 1988 and 2002 U.S. fisheries removed ~230,000 mt which equates to ~75,000,000 mature females from U.S. waters (Figure 2). During this period, 93% of the landings were female and in 6 of these years the ratio was over 99% female (NEFSC 2003). Accordingly, the mean size of females landed by the U.S. commercial fishery also decreased by 15 cm during this period, a trend consistent with data from research surveys (NEFSC 2003). There is little question that the high U.S. landings, coupled with the life history of dogfish, negatively impacted the population (Fordham 2009, this volume).

In 1998 NMFS declared U.S. spiny dogfish *overfished*. Since that time a number of management measures and rebuilding targets have been introduced. To meet a fisheries mortality goal of FSSB = 0.03, landings in 2003–2004 were reduced to 1,300 mt. The 2004 estimated spawning stock biomass (SSB) was 53,625 mt and the rebuilding SSB target was 167,000 mt. Once the SSB reaches 83,500 mt the stock will no longer be considered *overfished* and F will be increased to 0.08 (Gamble et al. 2004; Rago and Sosebee 2009, this volume).

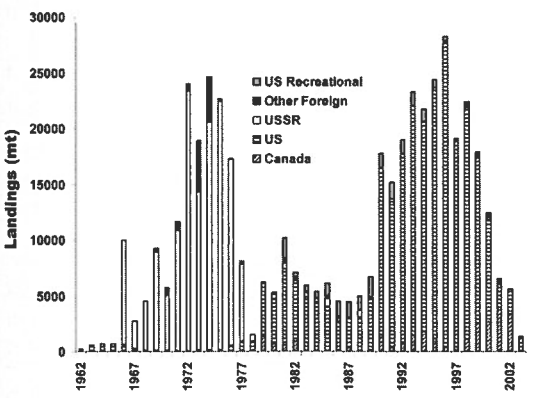

Figure 2. Total spiny dogfish landings (metric tons, mt) in the northwest Atlantic, 1962–2000. Source: Atlantic States Marine Fisheries Commission (ASMFC) (2003).

Population trends

The population size and trends in the northwest Atlantic are estimated from (1) research survey trends on the Scotian Shelf, Georges Bank, and the Gulf of St. Lawrence (Campana et al. 2007); (2) biological data from DFO research surveys and commercial fisheries; and (3) U.S. NMFS research survey data. Note that research surveys conducted on the Grand Banks are not included as this area is not part of the core distribution for spiny dogfish (see Figure 1).

Canadian research surveys (Atlantic)

Estimates of trends in spiny dogfish abundance in Atlantic Canadian waters are derived from three independent research vessel trawl surveys. The surveys consist of sampling by randomly distributed trawl sets. Dogfish tend to form patchily distributed aggregations that cause significant variance among sets, ranging from zero to several thousand animals per set. Because of this limitation, intra- and inter-annual variability can be very large. In addition to the behavioral aspects, environmental factors can influence a species distribution under varying temporal scales. Some of the annual total values presented in this report represent the annual mean of all sets multiplied by the number of *trawlable units* to give an expanded swept area biomass estimate. Trawl surveys assume

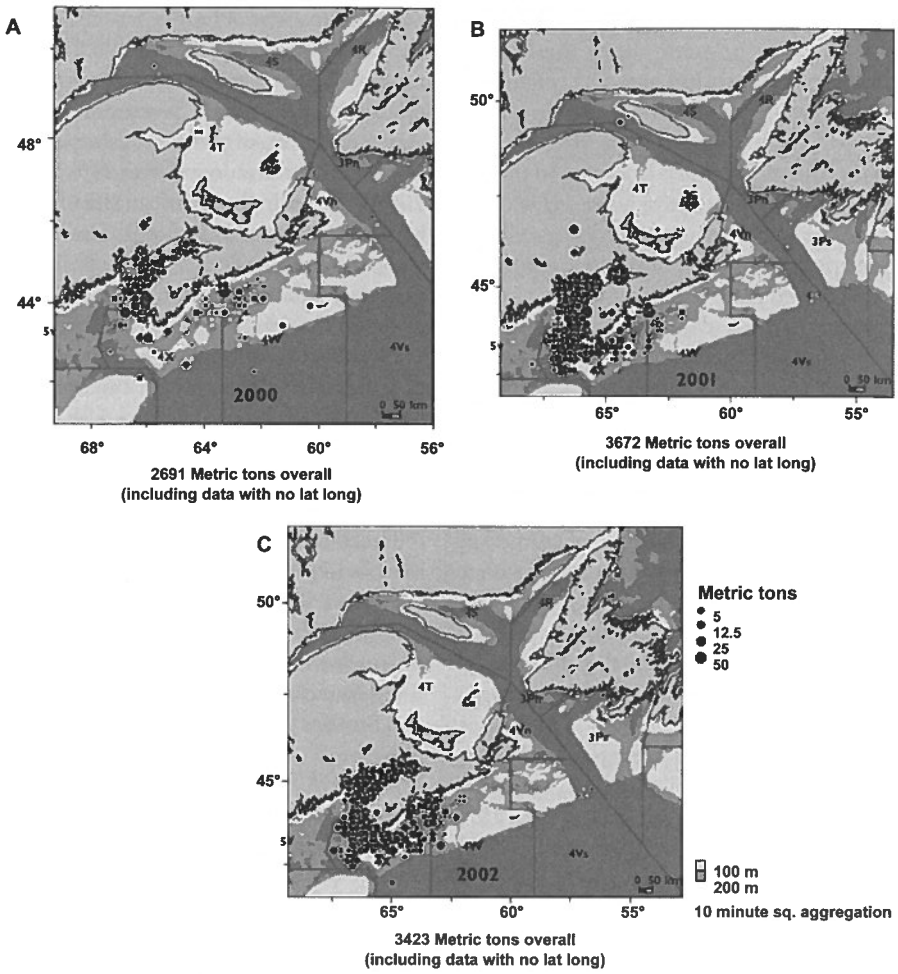

Figure 3. Distribution of spiny dogfish commercial landings in the Atlantic region from 2002 to 2007. Data source: Zonal Interchange Format database, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, unpublished.

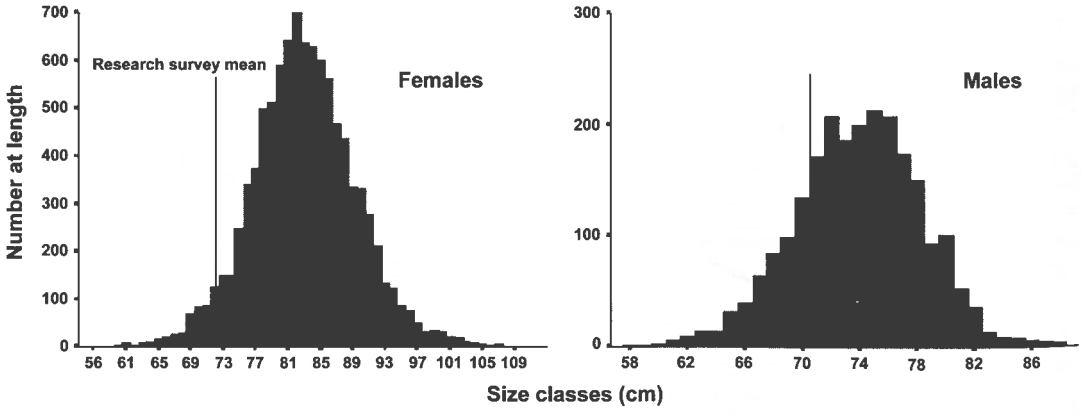

Figure 4. Length-frequency distribution of commercially caught spiny dogfish in 2002 compared to research survey mean length. Data source: Nova Scotia Port sampling program.

that all dogfish within the path of the research trawl are captured and that there are no dogfish outside the expanded area. Both of these assumptions result in a minimum biomass estimate.

Scotian shelf summer survey 1970–2007

The Scotian Shelf survey is undertaken annually and typically consists of 220 stratified random sets covering the shelf area from northern Nova Scotia around the eastern shelf to the southern tip of Nova Scotia and into the Bay of Fundy (Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, unpublished) (Figure 5A). Spiny dogfish are seemingly most abundant in nearshore areas with the highest densities found in the southern part of the survey, particularly the Bay of Fundy.

Since 1985, the abundance of spiny dogfish (all size classes) has been on average considerably higher than that found between 1970 and 1984 (Figure 5B). On average, the estimated biomass since 1985 has been greater than the long-term average of 131,000 mt. The number of individuals in this area, calculated from 2007 data, is estimated at 206 million. Over the 39-year period from 1978 to 2002, the abundance estimate ranged from a low of 0.8 million animals to a high of 295 million with considerable interannual variability. During this period, mature females (≥80 cm) on average constituted only 2.7% of the total estimated population whereas mature males (≥60 cm) constituted 66.1% (Figure 6A–6B). The number of mature females can be crudely estimated by multiplying the mature female ratio (i.e., 2.7%) by the estimated total population (i.e., 129 million), resulting in an estimate of ~3.5 million mature females.

Mean length can also be used as an indicator of fishing pressure. Through the 1970s mean length was relatively high; beginning in the 1980s the mean length dropped and maintained a variable but overall lower level throughout the time series (Figure 7A). Recent years show a mean length slightly above the long-term mean.

In summary, the overall long-term trend indicated by this survey is an increase in total abundance, an increase in reproductively mature males, and a recent increase in mean length.

Georges Bank (February) survey 1986–2003

This survey takes place each February and typically comprises between 45 and 132 stratified random sets restricted to Georges Bank (both U.S. and Canadian waters) (Campana et al. 2007) (Figure 8). The highest abundance of spiny dogfish is found on the edge of the bank with much of the top of the bank consistently devoid of dogfish (Figure 8A).

This survey has indicated a rapid and continued decline in abundance to a historical low in 2004 (Figure 8B). From 1986 to 1995 the estimated number of spiny dogfish was on average about 240 million individuals. From 1996 to 2004 the abundance declined to an average of about 12 million individuals; a 95% reduction. In 2004 the number of dogfish on Georges Bank was estimated to be 1.3 million individuals. The percentage of mature females in the sampled population averaged 3.8% from 1986 to 2003 (latest data available) (Figure 9). For 2003, mature female abundance was estimated at 0.6 million individuals (6.1% of the total number, data not shown) (Figure 6C–6D). The 2004 mature

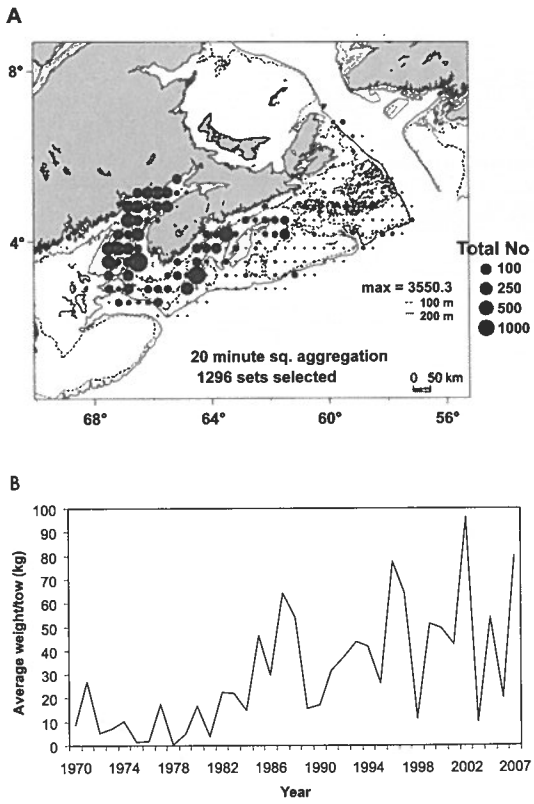

Figure 5. Scotian Shelf (summer) stratified random groundfish survey 1970–2007. (A) Set locations and abundance of spiny dogfish (mean numbers per tow) for 2000–2007. (B) Trend in groundfish survey catch per unit of effort (kg/tow). Source: Campana et al. 2007.

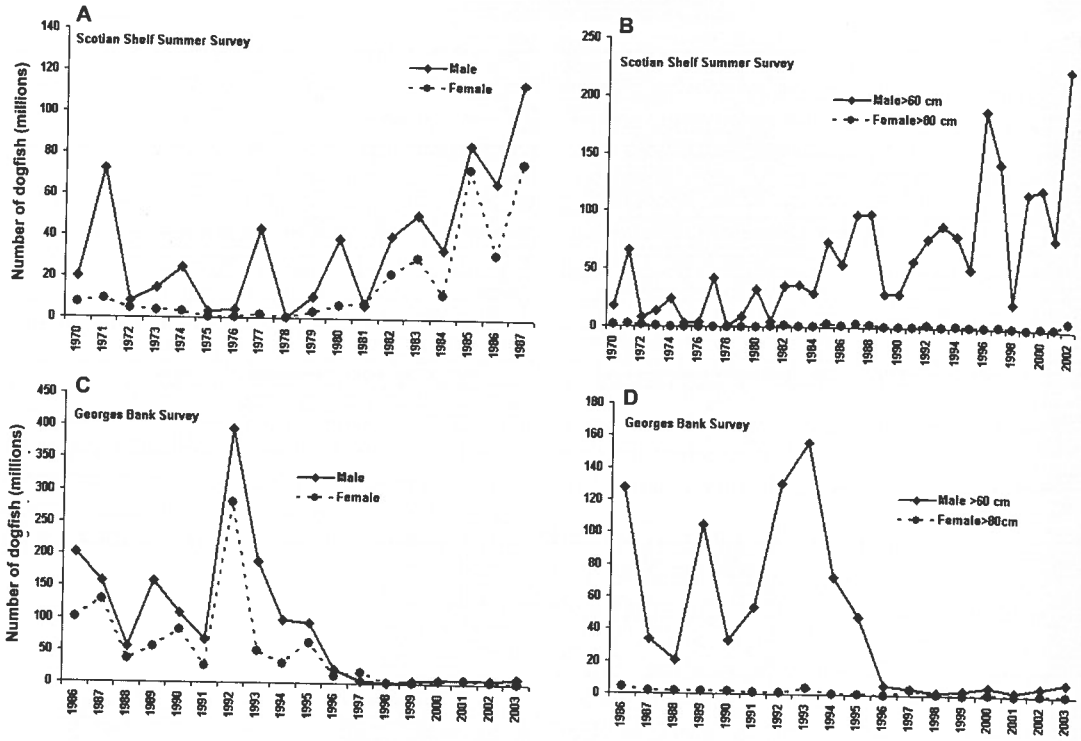

Figure 6. Estimated total number of spiny dogfish by sex and maturity from the Scotian Shelf (A and B); and Georges Bank research surveys (C and D). Data source: Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, unpublished.

female abundance can be estimated by applying the 2003 mature female ratio (i.e., 6.1%) to the 2004 abundance estimate (i.e., 1.3 million). From this calculation the most recent estimate of mature females in this component of the population is 78,000 individuals. The trends in this survey are consistent with those found by U.S. surveys (NEFSC 2003).

With the exception of a decline in 2001, the trend in mean length since 1986 has been a gradual increase, with 2003 reporting the greatest mean length in the time series (Figure 7B).

Gulf of St. Lawrence (September) survey 1984–2002

This survey typically consists of 208 stratified sets covering the southeast Gulf of St. Lawrence: waters between the Gaspé Peninsula and Cape Breton Island and south to Prince Edward Island, as well as partial coverage in the Northumberland Strait (Campana et al. 2007) (Figure 10A–C). Spiny dogfish in this survey area are concentrated inshore around the periphery of the survey area (Figure 10, A–C). Since 1990 there has been an apparent reduction in the distribution of dogfish in the survey area (Figure 10A–C).

Over the 23 years covered by this survey, estimates of abundance have been highly variable with no recorded dogfish prior to 1984, and a variable but continued decline since 1985. The most recent data show a biomass of ~5,000 mt (1.8 million individuals), which is below the long-term mean of 10,500 mt (Figure 10D).

U.S. research surveys (Atlantic)

The NEFSC has conducted both spring and autumn annual trawl surveys of the U.S. continental shelf since 1968; coverage extends from the Gulf of Maine to Cape Hatteras (North Carolina) and includes both the U.S. and Canadian portions of the Georges Bank. The spring survey is considered to provide the best representative sample of the total abundance in U.S. waters (NEFSC 2003). Following an increase through much of the time series (1968–early 1990s), there has been a gradual decline

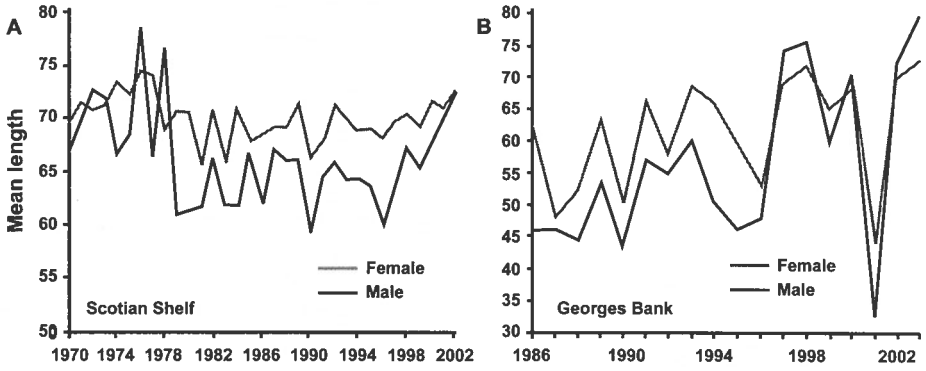

Figure 7. Mean length of male and female spiny dogfish in research vessel surveys from (A) the Scotian Shelf between 1970 and 2002, and (B) Georges Bank from 1986 to 2003. Data source: Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, unpublished.

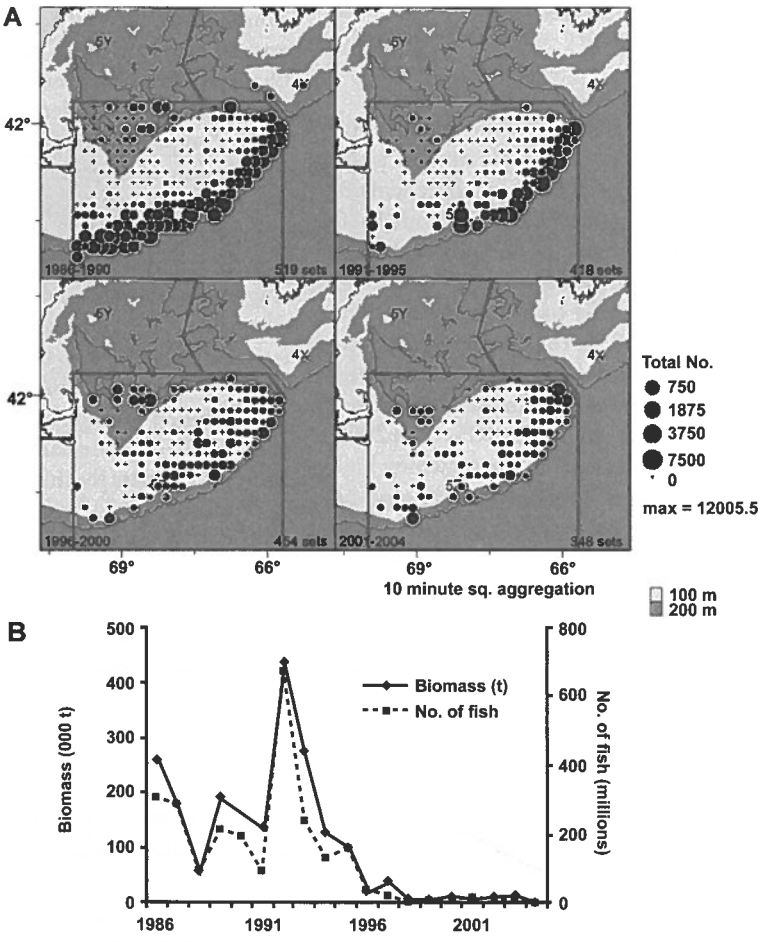

Figure 8. Georges Bank (February) stratified random groundfish survey 1986–2003: (A) set locations and relative abundance of spiny dogfish (numbers) by aggregated years; and (B) trend in biomass and numbers of fish based on extrapolations of swept area biomass. Data source: Grand Banks Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, unpublished.

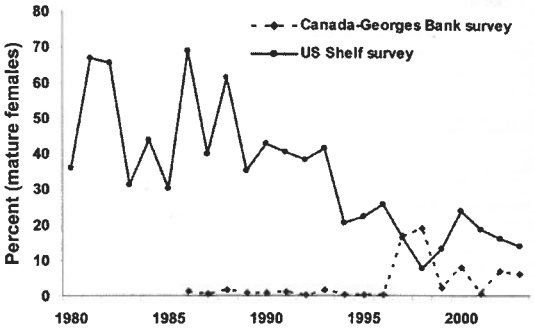

Figure 9. Comparison of the percentage of mature female spiny dogfish (≥80 cm) in the Canadian Georges Bank survey with the U.S. trawl survey from 1980 to 2003. Data source: ASMFC 2003; Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, unpublished.

in biomass in the spring R/V trawl survey since the early 1990s (Figure 11A). Of notable concern is the decline of larger spiny dogfish, particularly females greater than 80 cm (Figure 11B, 11C). From 1980 to 1989, the stock biomass was composed of 47% mature females. This ratio dropped to 34% between 1990 and 1996, and finally to 15% between 1997 and 2003 (NEFSC 2003). The decline in the proportions of mature females has also been matched with a well-documented decline in the mean size of mature females from 95 cm in 1970–85 cm in 2002 (NEFSC 2003). The decrease in the spawning biomass (i.e., mature females) may be responsible for the apparent recruitment failure shown in Figure 12A; furthermore, the mean size of recruits has declined during this same time period (Figure 12B). Both fecundity and pup length have shown to be positively correlated with female length, which is the basis for the accepted mechanism behind the observed recruitment failure. Over-harvesting of mature females has resulted in a decline in the average size and numbers of pups, which in turn results in low survivorship and eventual recruitment failure (NEFSC 2003).

Relationship between Canadian and U.S. stocks

There is strong evidence from U.S. fishery and research data that the component of the population in U.S. waters is severely overfished. Movement of individuals throughout the Atlantic continental shelf region (i.e., between Canada and the USA) has been documented (Templeman 1984). The question of immediate concern is whether the severe trends observed from U.S. surveys are relevant or applicable to the Canadian components of the population. It is likely that the downward trend in biomass indicated by the Canadian Georges Bank survey reflects the same downward trend observed by U.S. surveys. Furthermore, the rapid decline in abundance coincides directly with the time period of the large U.S. fishery.

The percentage of mature females in the Canadian Georges Bank survey has always been very low relative to the U.S. trawl survey (Figure 9). In recent years the percentage of mature females has increased slightly in the Canadian survey whereas in the U.S. survey there has been a steady decline since the late 1980s.

Contrary to the U.S. finding, the Canadian Georges Bank survey (Figure 7B) indicates an increase in mean length of *all* females whereas in the U.S. survey there is a pronounced decline in mature female (≥80 cm) mean length. The two indices may not be comparable because it is possible for the mean length of *all* females to be increasing over time, while the mean length of mature females equal to or greater than 80 cm is actually decreasing. For example, length frequencies from the Scotian Shelf survey indicate a general truncation of the larger and smaller length classes with an overall increasing mean size (Figure 13). In this example, the larger size classes have virtually disappeared, while the mode has still shifted towards larger size classes. A similar phenomenon may be occurring on Georges Bank but size-frequency data for this region were not available to the authors.

Overall, it is highly likely that the spiny dogfish on the Canadian portion of Georges Bank have a high rate of exchange with those in adjacent U.S. waters, and as such have experienced a similar rate of decline and fishing pressure.

Abundance trends from the Scotian Shelf surveys suggest that this component of the population is stable or increasing and has generally been above the long-term average over the last decade (Figure 5B). However, it is unknown how abundance on the Canadian Scotian Shelf is influenced by mature females from U.S. waters.

Overall trend in Atlantic Canadian waters

Under the assumption that all spiny dogfish in Canada constitute a distinct Canadian population, the combined survey results (i.e., Scotia Shelf, Georges Bank, and Gulf of St. Lawrence combined) suggest

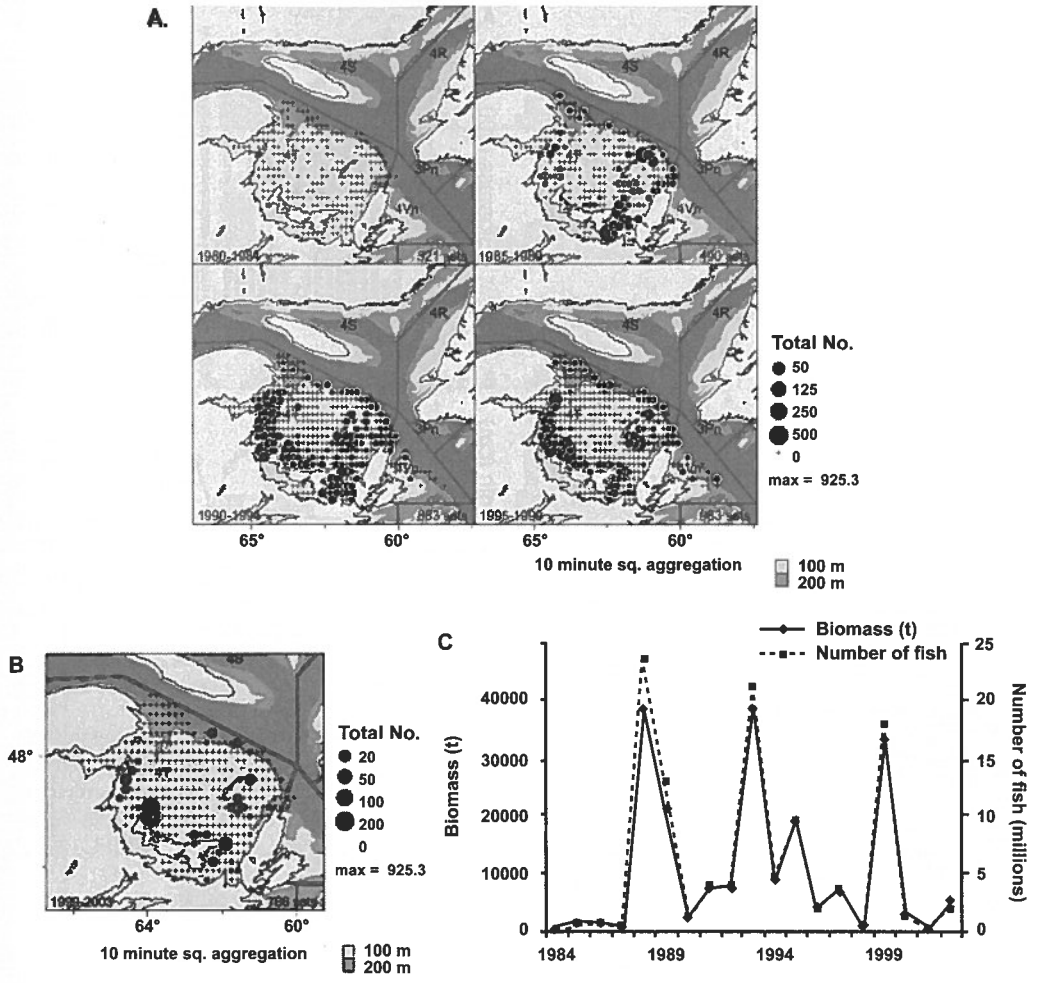

Figure 10. Gulf of St. Lawrence (Summer) stratified random groundfish survey 1984–2005: (A) set locations and abundance of spiny dogfish (numbers) by aggregated years 1984–1989; (B) 1990–1999; (C) 2000–2004; and (D) trend in biomass based on extrapolations of swept area biomass. Source: Campana et al. (2007).

that the population as a whole has not declined, and is generally above long-term average abundance. However, when account is taken of the extensive mixing of Canadian and American dogfish, the decline in the American component may have significant implications for the Canadian component. Until the relative proportions of the population in the two countries can be determined, the overall trend in population numbers cannot be determined. In addition, it is possible that the abundance of immature dogfish (as is seen most often in Canadian surveys) is relatively stable, while the abundance of mature females (which are seldom seen in Canadian research surveys) has declined. A crude estimate of mature females is ~3,500,000 mature females on the Scotian Shelf and 78,000 on Georges Bank, resulting in ~3.6 million mature females. A more recent overview of Canadian abundance trends is shown in Campana et al. (2007).

Pacific Population

Distribution, stocks, migration and dispersal

The Pacific population of spiny dogfish is thought to consist primarily of an offshore coastal stock extending from Alaska to Baja California and two

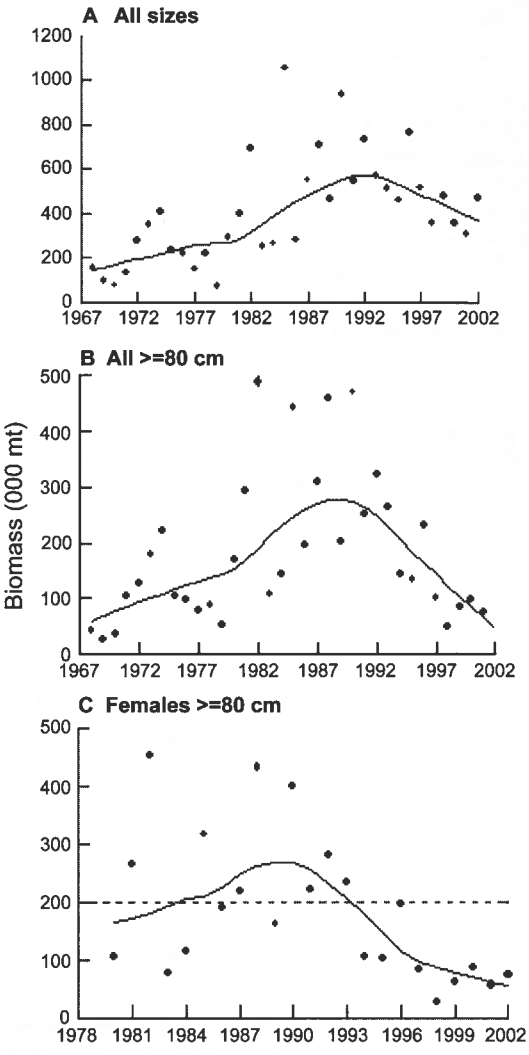

Figure 11. Swept area estimate of spiny dogfish biomass (000 mt) in the U.S. spring R/V trawl survey, 1968–2003 from Cape Hatteras to Gulf of Maine for (A) all spiny dogfish, all lengths; (B) all (length ≥80 cm); and (C) all females (length ≥ 80 cm). Line represents Lowess smooth with tension factor = 0.5. Source: ASMFC 2003.

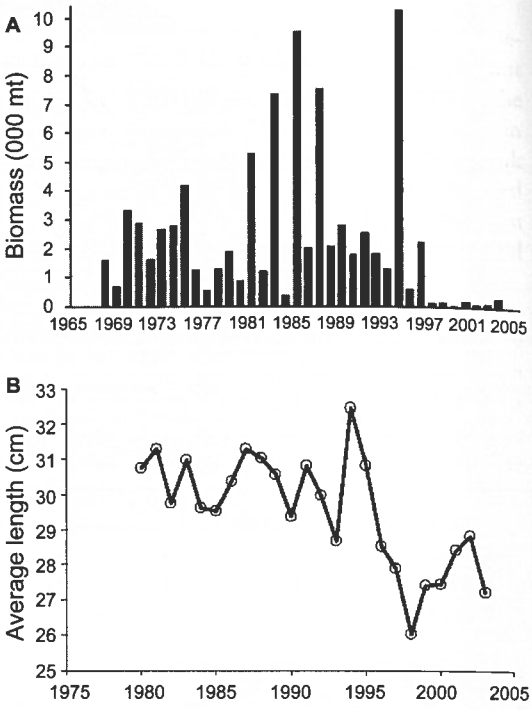

Figure 12. (A) Swept area estimate of spiny dogfish biomass (000 mt) recruits (pups) in the U.S. spring R/V trawl survey, 1968–2003; and (B) trend in average size of spiny dogfish recruits, 1980–2003. Recruits defined as individuals less than 36 cm. Source: ASMFC (2003).

inshore stocks, one in the Strait of Georgia and the other in Puget Sound. Although extensive migrations (up to 7,000 km to Japan and Mexico) and interchange at regional scales have been documented, in several cases tag recaptures were close to release sites, indicating the possibility of stock structure at smaller scales. Based on tagging studies, dogfish from the Strait of Georgia infrequently leave this semi-enclosed water body; over a 25-year period only 10–14% of recaptures were found outside of the region (Ketchen 1986; McFarlane and King 2003) (Figure 14). Furthermore, dogfish tagged in the Strait of Georgia were rarely recaptured in Puget Sound (<1%), data which suggest the existence of two discrete inshore stocks (McFarlane and King 2009, this volume). Dogfish tagged on the offshore continental shelf waters demonstrated extensive latitudinal and longitudinal migrations with a large portion of tag recaptures occurring outside the release area (49–80%), as well as movements into the Strait of Georgia. Similar conclusions based on growth parameters are found in Vega et al. (2009, this volume).

Waters off British Columbia constitute a large portion of the core range of spiny dogfish in the northeast Pacific. Concentrations have been found in the Strait of Georgia, on the continental shelf of west coast Vancouver Island, and in Hecate Strait

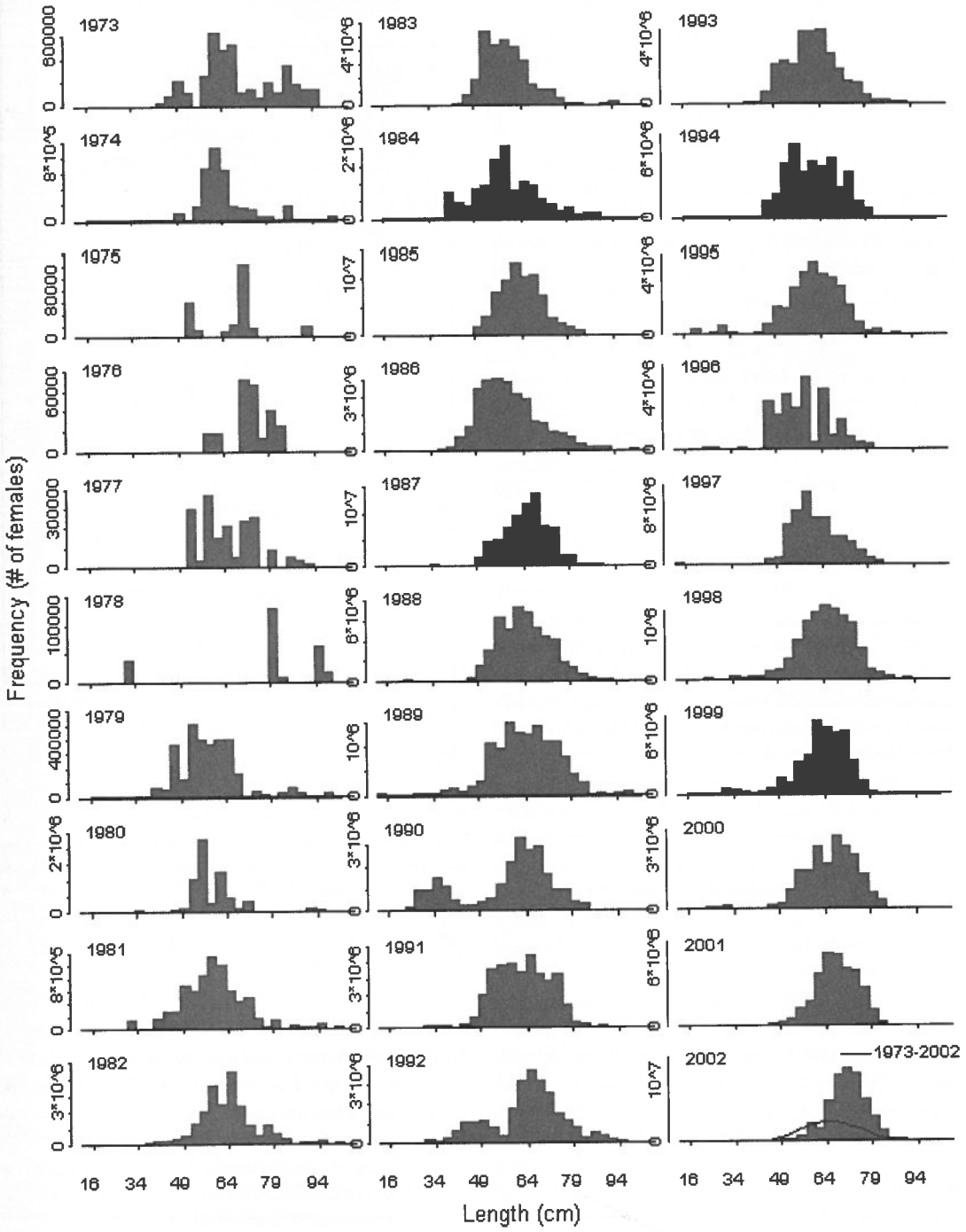

Figure 13. Length-frequency distributions of female spiny dogfish in the Scotian Shelf summer survey between 1973 and 2002. Data source: Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, unpublished.

(Ketchen 1986). The current distribution in Canadian waters is best shown from the distribution of commercial catches (Figure 15). Seasonally there appears to be a shift from deep water in the winter to shallower shelf waters in the summer (Fargo et al. 1990).

There is also some indication that some individuals may make a latitudinal migration between Oregon waters in winter and northern British Columbia waters in summer (Ketchen 1986). There is no information to suggest a contraction or expansion of the range of this species in Canada. The area of occupancy is estimated at ~94,000 km^2 based on captures by the commercial fishing fleet and research surveys (Figure 15). There is recent evidence that dogfish abundance has increased in the Gulf of Alaska since 1990, based on data from research surveys and increases in commercial bycatch (Goldman 2001; Courtney et al. 2004). This increase is possibly explained by either a northward shift in the core distribution or an increase in abundance throughout the entire northeast Pacific.

Relationship between Canadian and U.S. stocks

On the Pacific coast of North America, the center of abundance is found primarily in Canadian waters (Figure 16). The rate of exchange between Canadian and U.S. waters is partly known (McFarlane and King 2003; Taylor et al. 2009; Vega et al. 2009, both this volume). The available evidence suggests that there is considerable interchange between spiny dogfish stocks found off Canada's southwest coast with those found in adjacent U.S. waters to the south; little exchange between stocks in the Strait of Georgia and Puget Sound; and little exchange between stocks in northern British Columbia and those found in U.S waters to the south (Figure 14). Movement of dogfish into and out of Alaskan waters has not been well studied.

Spiny dogfish found off the west coast of Vancouver Island and those found off Washington State appear to be the same stock. Therefore, the status of the Canadian population would reflect that in U.S. waters and vice versa. Dogfish in the Strait of Georgia likely have some interchange with those found off Washington State but not much interchange with those in the adjacent Puget Sound. Palsson (2009, this volume) reports that the Puget Sound stock is at a low level of abundance and, based on tagging evidence, it is not expected that this stock will receive much of a rescue effect from Canadian stocks (McFarlane and King 2003).

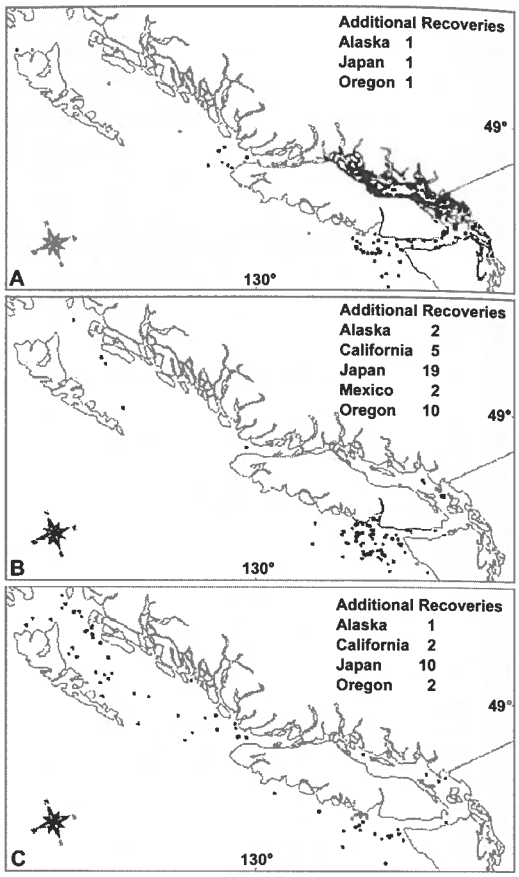

Figure 14. Recapture locations of tagged spiny dogfish released from 1978 to 1988 in (A) the Strait of Georgia, (B) west coast of Vancouver Island, and (C) northern British Columbia. The number of additional recoveries (by recapture area) that are not plotted on each figure are listed and represent tagged spiny dogfish. Source: McFarlane and King (2003).

Commercial fishery and management

The commercial fishery for spiny dogfish in Canada's Pacific waters has a long history dating back to 1870 (see reviews in Ketchen 1986; Bonfil 1999), including a period of exceptionally high landings during the 1940s when 170,000 mt were landed with a peak catch of 31,000 mt in 1944 (Figure 17A). Since that time, landings have been considerably lower, typically less than 5,000 mt/year (Figure 17A). In recent years, the annual catch, including landings and discards, for all of Canada's Pacific waters, has typically ranged between 5,000 and 7,000 mt (Figure 17B), with most taken by the directed longline

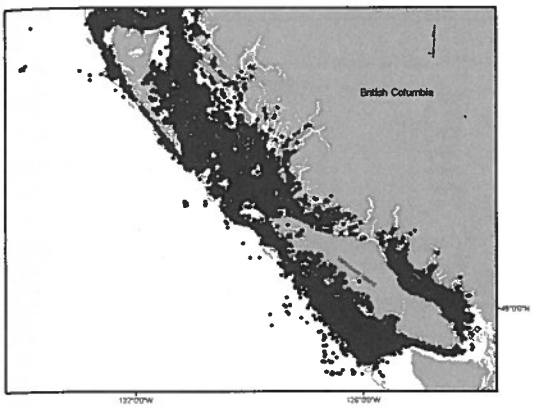

Figure 15. Distribution of spiny dogfish off the west coast of British Columbia based on commercial catch data (1954–2006) and research survey cruises. Each dot represents a set in which dogfish were captured. Data source: PacHarvHL, PacHarvTrawl, GFCatch, GFBio, PacharvTrawl databases, Department of Fisheries and Oceans, Pacific Biological Station, Nanimo, British Columbia, Canada, unpublished.

fishery for dogfish (75%) and the rest by the trawl fishery (25%).

The 2005 Pacific quota of 14,940 mt is based on the last stock assessment undertaken in 1987 (Saunders 1988) that in turn was based on a model by Wood et al. (1979). Saunders (1989) estimated the coast-wide biomass, including U.S. waters, to be 280,000 mt, of which one-half to two-thirds likely resided in Canada (i.e., 150,000–200,000 mt). Yields of 15,000 mt are considered *low risk sustainable*. Even under the assumption of 100% mortality in the current catch, it is unlikely that the present low fishing effort is drastically altering the population. Neither the trawl nor hook-and-line fisheries fulfill their combined annual quota of 14,940 mt, of which only 3,000 mt is permitted from area 4B (Strait of Georgia). Discards have been recorded by a 100%-coverage observer program in the Option A trawl fleet since 1996 and from a logbook program in the hook-and-line fleet since 2001 (Figure 17B). Past levels of discarding in the hook-and-line fleet are not precisely known but estimates made since 2001 are thought to be reasonably accurate due to a partial observer program (DFO 2001). Overall catch (including discards) by the trawl fleet has been relatively stable during the last 9 years; however, retention, and hence fishing mortality, has increased. Landings and discards in the directed hook-and-line fleet have been steadily increasing over the last 8 years. The extent of high grading of catches is unknown.

Population trends

Population trends and abundance on the Pacific coast are estimated from (1) groundfish assemblage trawl surveys in Hecate Strait and the west coast of Vancouver Island, (2) biological data collected on research surveys, and (3) International Pacific Halibut Commission (IPHC) standardized stock assessment survey database.

Research surveys in Canadian waters

Hecate Strait trawl survey (1984–2003)

The Hecate Strait trawl survey is a random non-stratified survey typically carried out on an annual or biannual basis. All sets used in this analysis were carried out between May 25 and June 26, but the onset of the survey changed each year (Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, British Columbia, Canada, unpublished). The relative distribution of spiny dogfish and the location of the survey are shown in Figure 18. The mean catch rate of spiny dogfish in 2003, measured as CPUE (kg/h) and CPUE (kg/set), is the lowest in the time series at 8.9 kg/h and 3.8 kg/set, respectively (Figure 19A, 19B); additionally, in 2003 the percentage of sets with dogfish was also at a historical low (Figure 19C). Apart from the low estimate in 2003, which may have been anomalous, the long-term trend appears to be stable. The timing of the Hecate Strait survey straddles the period in which dogfish move from deeper to shallower waters. Therefore, it is possible that in 2003 dogfish moved up onto the banks later than usual, after the survey was complete (J. Fargo, Pacific Biological Station, personal communication). Unfortunately 2003 was the last year of this survey and, as a result, it is unknown whether the 2003 data indicate a decline in stocks or an anomaly in data collection.

Length-frequency distributions of female spiny dogfish from 1984 to 2002 indicate a striking decrease in the proportion of larger size classes (Figure 20). The percentage of mature females (>900 mm) declined from 30.5% in 1984 to 0.9% in 2002 (Figure 21). Although the catch by the directed fishery is relatively low relative to the estimated population, size selection by the directed fishery in certain areas, in combination with movement of large dogfish out of the sampling area in recent years, could be contributing to this demographic change. However,

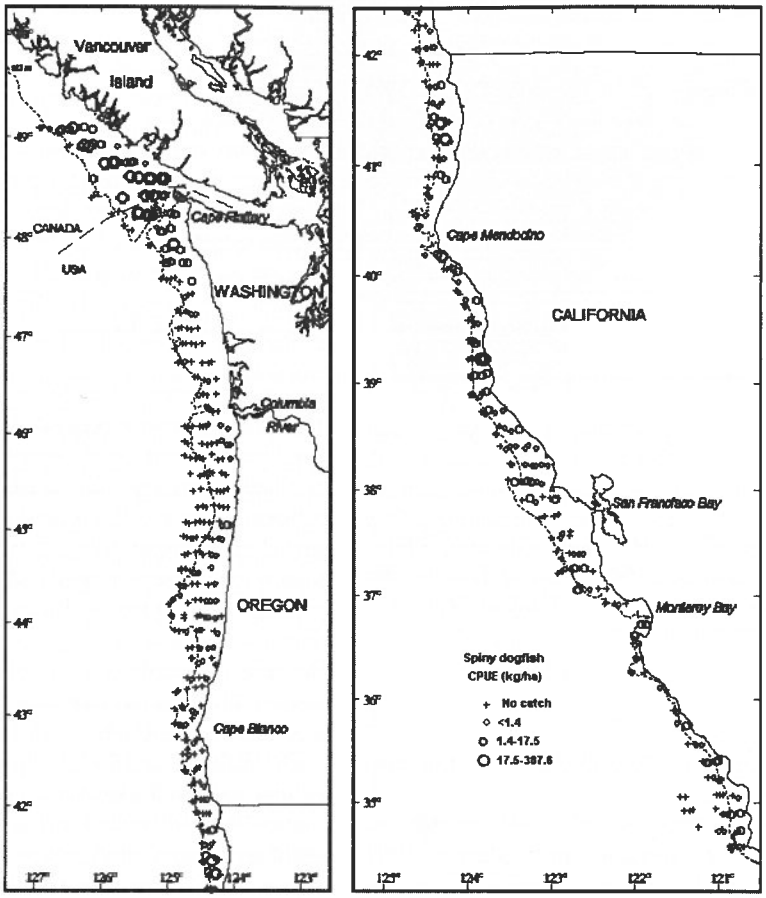

Figure 16. Spiny dogfish distribution and relative abundance measured bycatch rates (kg/ha) from the West Coast Triennial Bottom Trawl Survey. Source: Weinberg et al. (2002).

the combination of the known dispersal pattern of dogfish in this area (i.e., highly migratory) and the low catch (relative to the estimated population) suggests that fishing is not likely the proximate cause of the decline in this population, though it may be a minor contributing factor.

IPHC standardized stock assessment survey (1993–2004)

Catch rates from the IPHC SSA survey in Area 2B (British Columbia) can be used to index the abundance of the offshore stock of spiny dogfish; in fact catch rates of dogfish in all years are greater than Pacific halibut *Hippoglossus stenolepis* (Kronlund 2001). This is the only survey that is presently conducted coast-wide and on an annual basis (International Pacific Halibut Commission, Seattle, Washington, unpublished). The SSA survey methodology and its applicability to non-halibut species is reviewed in Kronlund (2001). A maximum of 172 stations are surveyed between May and September, with most of the survey effort taking place in June, July, and August.

The distribution of spiny dogfish as estimated from relative survey catch rates by station during 1998 to 2004 is consistent with distribution estimates based on commercial catch and data from other surveys. Catch rates are greatest along the southwest coast of Vancouver Island and Hecate Strait and can often exceed 40 dogfish per 100 hooks (Figure 22A).

Figure 22B presents the mean catch rates by station for each survey year (1993–2004). Throughout the Area 2B, mean catch rates of spiny dogfish peaked

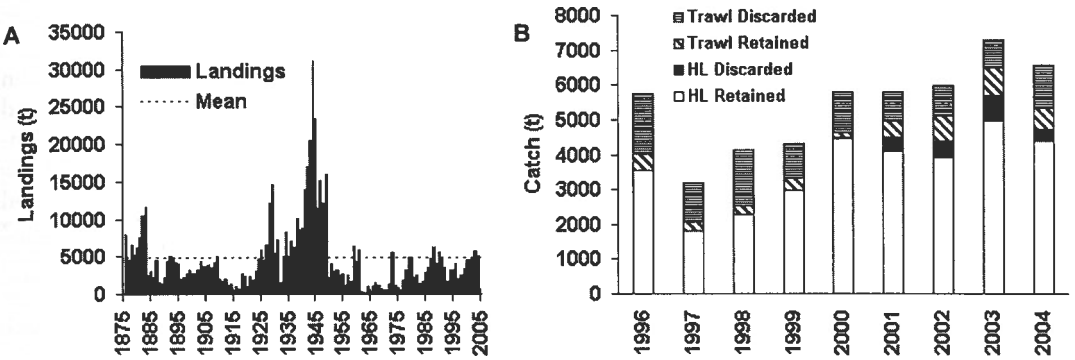

Figure 17. A) Commercial landings of spiny dogfish in Canada's Pacific waters from 1875 to 2004; and B) commercial catch (landings and discards) by gear type and utilization. Hook and line (HL) data prior to 2001 are only landings. Data from DFO 2001; PacHarvTrawl database, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, British Columbia, Canada, unpublished; 1996–2000 Dockside Monitoring Program (HL only), Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, British Columbia, Canada, unpublished; 2001–2004 PacHarvHL database, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, British Columbia, Canada, unpublished.

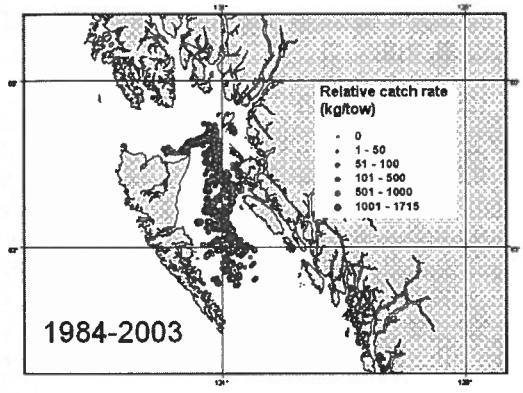

Figure 18. Distribution and relative catch rate of spiny dogfish in the Hecate Strait assemblage survey from 1984 to 2003. Data source: Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, British Columbia, Canada, unpublished.

in 1997 and then declined to rates similar to those at the beginning of the time series (1993).

West Coast triennial survey (1980–2001)

NMFS conducts surveys on a triennial basis along the west coast of North America (survey explained in Weinberg et al. 2002). Most of the survey takes place in U.S. waters with only a small northerly extension into the Canadian waters off the southwest coast of Vancouver Island (Figure 16). NMFS provided the authors with abundance estimates based on swept-area biomass extrapolations from the survey data of spiny dogfish by the International North Pacific Fisheries Commission (INPFC) Vancouver (see Weinberg et al. 2002).

The trend in estimated abundance shown in Figure 23 was largely influenced by a single year (1989) when survey vessels took the two largest spiny dogfish sets in the survey's history (in both U.S. and Canadian portions of the survey). Aside from the 1989 data, this survey has not indicated any overall appreciable change in abundance (Figure 23A, 23B).

NMFS has collected length-frequency data for spiny dogfish since 1980; however, the sex of captured individuals has only been recorded since 1999. In general very few large individuals are represented in the length-frequency distributions (Figure 24A). Mature females (>900 mm) represent less than 0.5% of the individuals recorded since 1999 (Figure 24B). Dogfish are known to travel in schools segregated by size and sex, and therefore the virtual absence of large individuals from the all years of survey data suggests that some form of segregation occurs in the Vancouver region (Ketchen 1986).

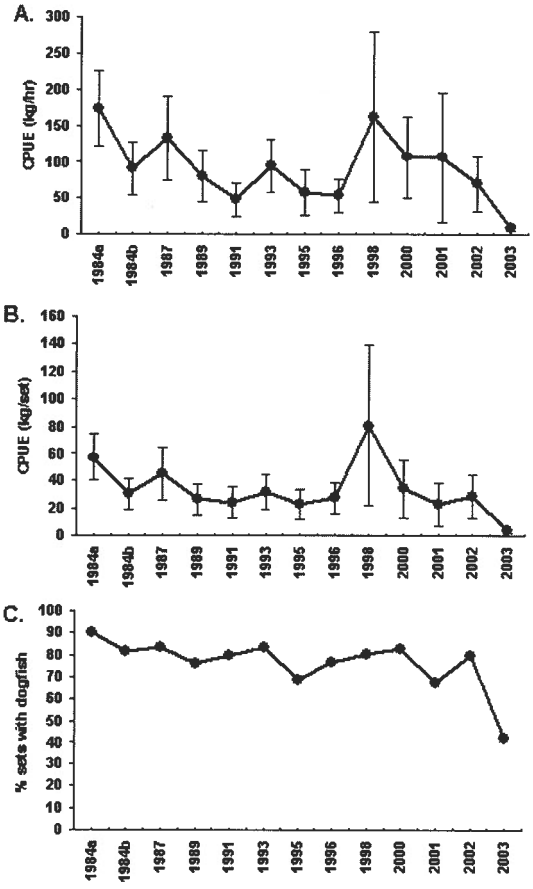

Figure 19. Trends in the abundance of spiny dogfish from Hecate Strait trawl surveys between 1984 and 2003 using (A) mean CPUE (kg/h); and (B) mean CPUE (kg/set); and (C) percentage of sets with spiny dogfish. Error bars represent 95% confidence intervals around the mean. Data source: unpublished, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, British Columbia, Canada.

U.S. research surveys (Pacific)

West Coast triennial survey (1980–2001)

The NMFS covers U.S. waters off Washington, Oregon and California (Figure 16) (Weinberg et al. 2002). If 1989 data are not considered, there is no discernible abundance trend from offshore Washington State (see explanation in previous section) (Figure 23).

Washington Department of Fish and Wildlife (WDFW) Puget Sound survey

WDFW has conducted six synoptic trawl surveys in the Puget Sound Region since 1987 (survey described in Palsson et al. 2003). In 2001, the estimated abundance of Puget Sound spiny dogfish was at a very low level compared to estimates from the late 1980s and early 1990s, but was slightly higher than the 1997 estimate (Palsson et al. 2003).

NMFS (1984–2003) and IPHC Gulf of Alaska (1997–2003) surveys

There are two relevant surveys conducted in adjacent U.S. waters: one by the NMFS Alaska Fisheries Science Center (AFSC) and the other by the IPHC (Courtney et al. 2004; IPHC, Seattle, Washington, unpublished; see also Conrath and Foy 2009, this volume). The NMFS survey indicates a relatively stable trend since 1984 with a particularly high abundance in 2003 (Figure 25A). Similarly, the IPHC survey shows a stable trend in catch rates since 1997 with an increase in 2003 (Figure 25B). Overall, both surveys indicate that spiny dogfish abundance is stable or possibly increasing in Gulf of Alaska waters.

Overall trend in Pacific Canadian waters

In Canadian waters, three separate indices of spiny dogfish abundance have been examined: (1) Hecate Strait survey, (2) IPHC survey, and (3) NMFS survey. In recent decades these surveys have not found any obvious long-term upward or downward trends. Therefore the offshore stocks as a whole are considered to be stable. Nonetheless, there has been a decrease in the relative abundance of larger individuals sampled from Hecate Strait. This decline does not appear to be explained by fishing effort, because the offshore stocks are lightly fished, and so might reflect a change in the seasonal availability of larger individuals. However, this size trend should be closely monitored. The last stock assessment for Canadian Pacific waters was published in 1988 and a similar trend in declining size in U.S. Atlantic waters resulted from overfishing (Saunders 1988). In adjacent U.S. Pacific waters, abundance appears to be stable or increasing in the Gulf of Alaska, stable on the outside waters of Washington State, and at a low level in Puget Sound.

It is noteworthy to point out that abundance indices from the Canadian Hecate Strait (2003) and IPHC (2004) surveys are among the lowest in both of

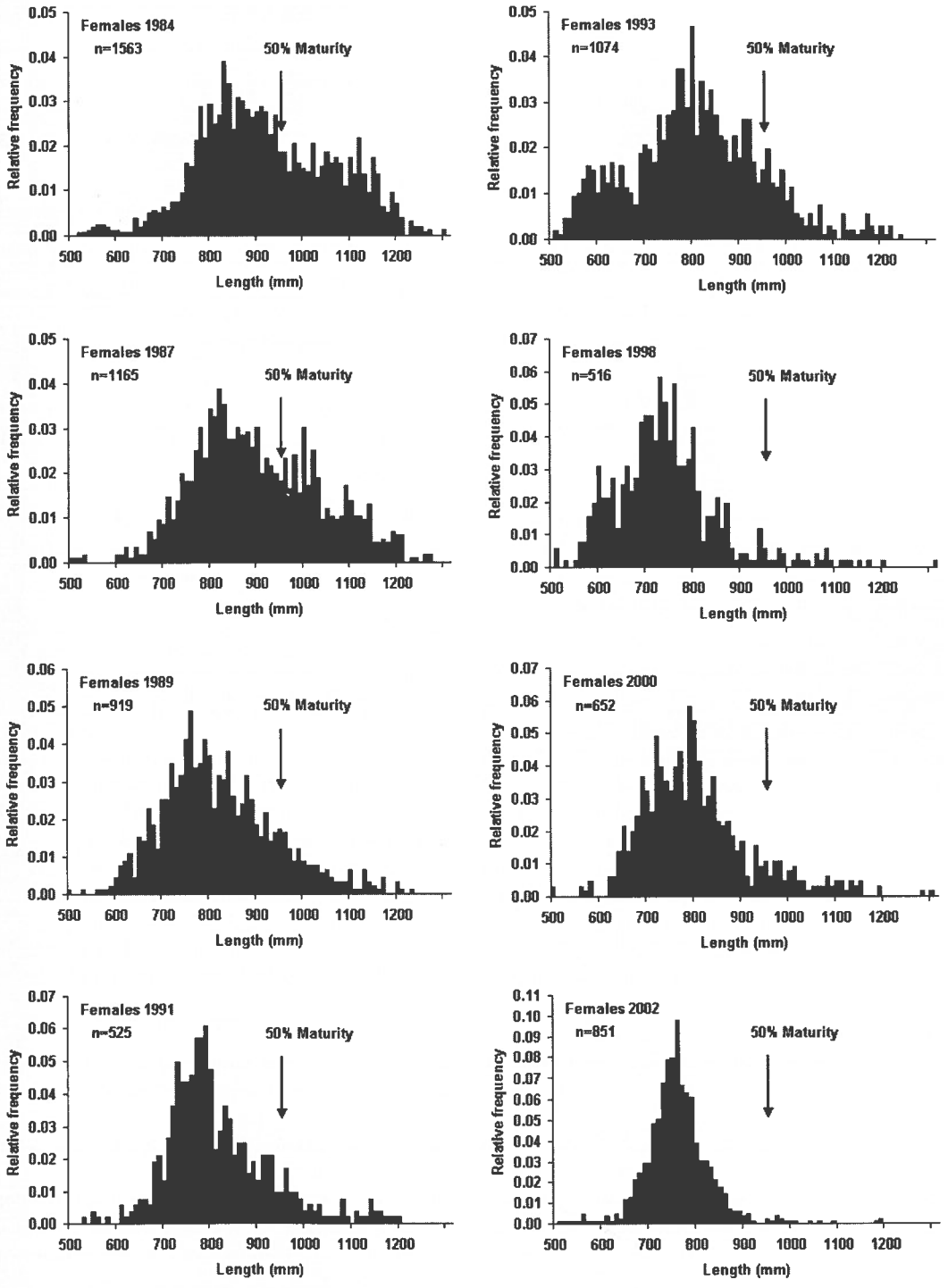

Figure 20. Relative length-frequencies of female spiny dogfish sampled in the Hecate Strait trawl survey between 1984 and 2002. Data source: Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, British Columbia, Canada, unpublished.

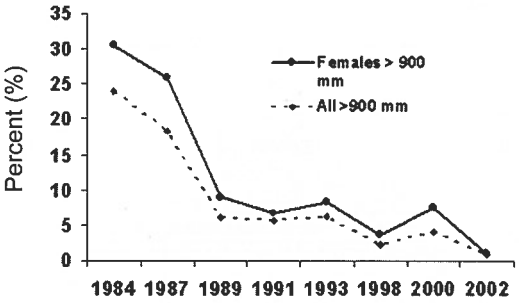

Figure 21. Percentage of spiny dogfish (>900 mm) found in Hecate Strait trawl survey from 1984 to 2002. Note female size at 50% maturity is ~940 mm. Data source: Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, British Columbia, Canada, unpublished.

these time series, whereas 2003 data from the NMFS and the IPHC surveys in the Gulf of Alaska show the highest abundance of the time series.

Discussion

To gain insight into the current status of spiny dogfish stocks in Atlantic and Pacific Canada, in this paper we reviewed the species' current distribution, migration and movement, biological and abundance trends, status in adjacent jurisdictions, and commercial fishery. Globally, overfishing is considered the only proximate threat to dogfish at a population level (Federal Republic of Germany 2003). In the northeastern Atlantic, populations are below 5% of their former abundance (Heessen 2003). The depletion of northeast Atlantic populations opened up European markets to North American fishing fleets, a development that is in part responsible for the rapid development of the U.S. northwest Atlantic fishery (Federal Republic of Germany 2003; Fordham 2008).

On the Atlantic coast, in both the Georges Bank (Canada) and adjacent U.S. waters, over-fishing of spiny dogfish has noticeably diminished the abundance and altered the size structure of the population. However, it is not clear that there has been a reduction in other Atlantic Canadian waters. On the Pacific coast there have been no obvious upward or downward abundance trends since the 1980s and overall the stock is therefore considered to be stable. However, in Hecate Strait there has been a decreasing trend in the abundance of larger individuals that must be closely monitored because it resembles population changes in U.S. Atlantic waters that resulted from overfishing.

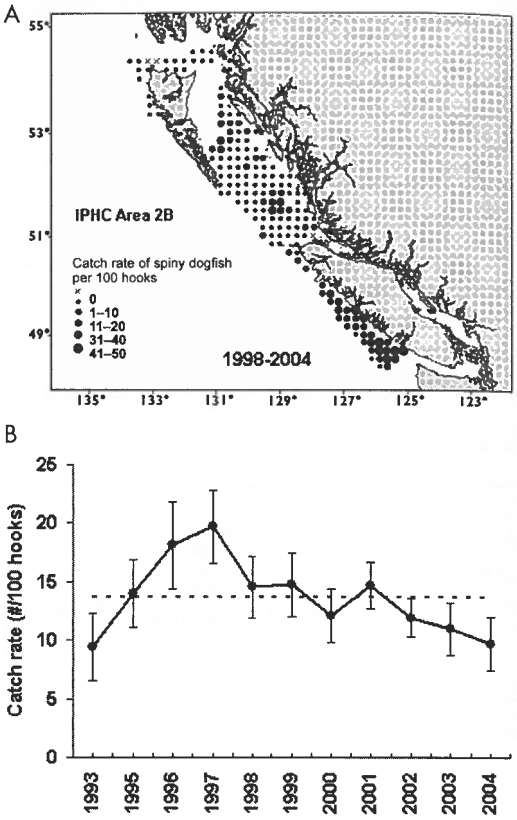

Figure 22. A) Distribution of spiny dogfish in IPHC Area 2B shown by relative catch rates from 1998 to 2004 at IPHC survey stations; and B) mean catch rate by year (error bars represent 95% confidence intervals around the mean). Dashed lined represents the series average. Data from IPHC standardized stock assessment survey 1993–2004. Note: no survey in 1994. Data source: International Pacific Halibut Commission, Seattle, Washington, unpublished.

While current evidence suggests that this species may not be depleted in Canada, experience from elsewhere clearly shows that spiny dogfish populations can become overfished to such a degree that they fit international criteria for an endangered species. Until recently, dogfish in Canada have been loosely managed with no defined fisheries objectives or management plan. Given the growing international

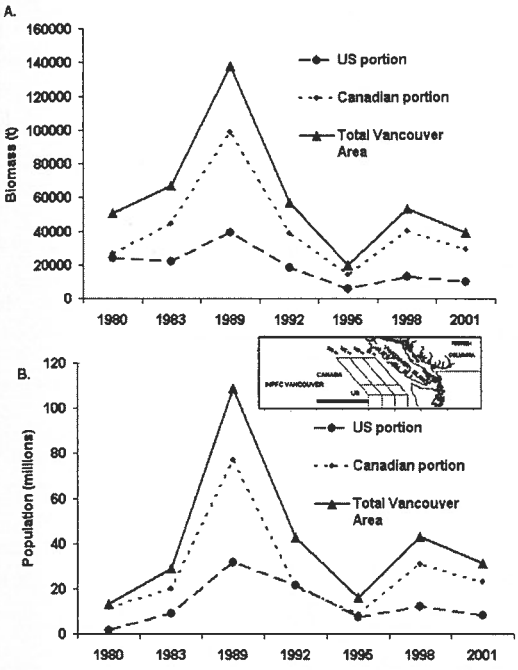

Figure 23. Swept area abundance estimates expressed as A) biomass; and B) population in both the Canadian and U.S. portions of the INPFC Vancouver region. Survey CV ranged from 0.18 to 0.73. Data source: AFSC.)

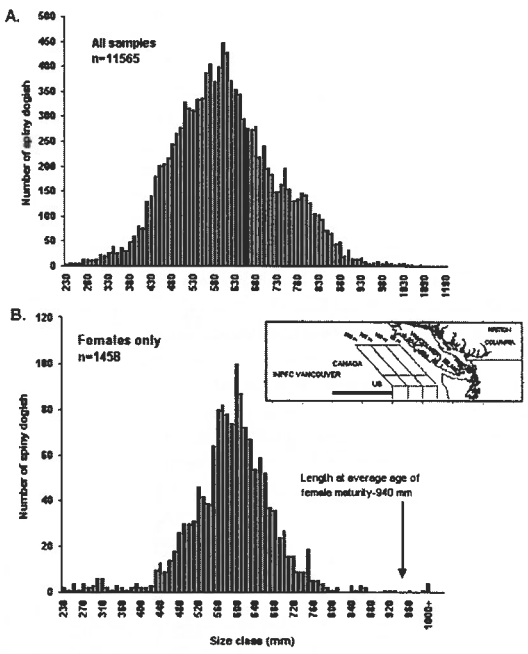

Figure 24. Length-frequency distributions of spiny dogfish in the INPFC Vancouver region from the NMFS trawl survey database for A) all spiny dogfish in database from 1986 to 2004 and; B) females from 1999 to 2004. Note: Prior to 1999 the sex of animals was not identified with the exception of a small sample in 1986. Data source: AFSC.

conservation concern surrounding spiny dogfish, the Canadian government will need to develop comprehensive and timely dogfish management plans that fully consider all aspects of spiny dogfish life history.

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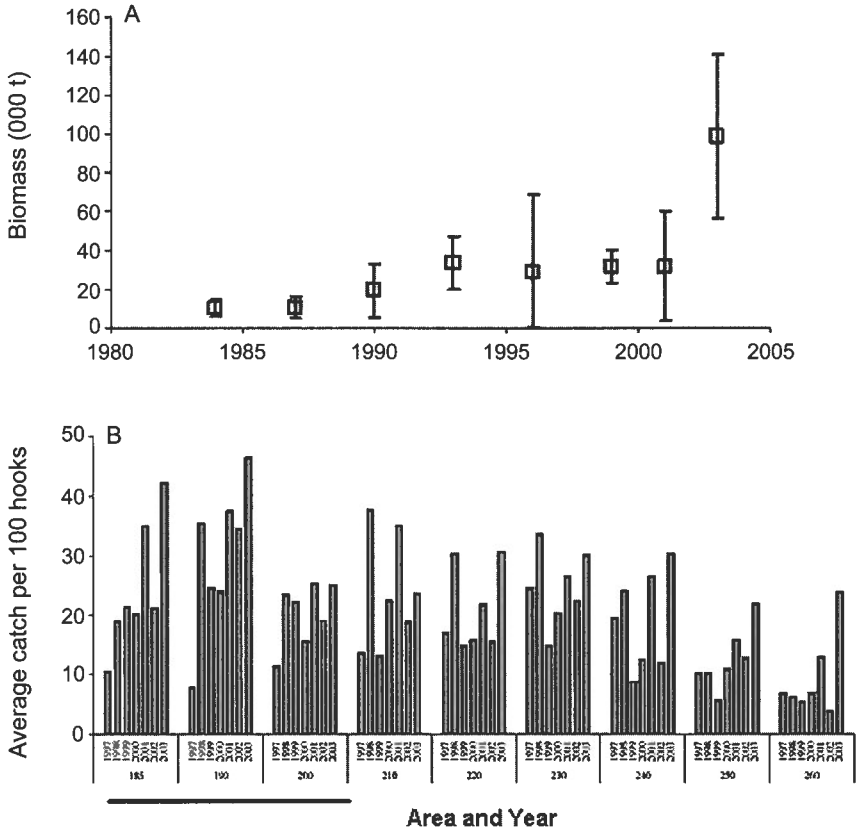

Figure 25. Trends in the abundance of spiny dogfish in Gulf of Alaska from (A) biomass estimates (mt) derived from the AFSC bottom trawl survey (error bars represent 95% confidence intervals), and (B) catch rates in the IPHC set survey. Waters adjacent to Canada off southeast Alaska are represented by IPHC areas 185, 190, and 200. Figure modified from Courtney et al. 2004.

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