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Spiny Dogfish (*Squalus acanthias*) Assessment and Catch Recommendations for 2010

Évaluation de l'aiguillat commun (*Squalus acanthias*) et recommandations quant aux prises pour 2010

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ABSTRACT

Spiny dogfish (*Squalus acanthias*) is a small shark that inhabits temperate waters off the east and west coasts of North America. They are ovoviviparous and gestation is 2 years. Females produce 2-16 pups, averaging between 26-27 cm in length at birth. Spiny dogfish are a long-lived species with maximum ages in the Pacific population of between 80-90 years and a maximum size of 130 cm. Age-at-maturity of females is approximately 35-36 years corresponding to approximately 94 cm. Length-at-maturity for males is 70 cm.

Spiny dogfish have a long history of commercial exploitation in British Columbia dating back to 1870. From 1870-1916, spiny dogfish were harvested for their liver and body oils for use in industrial lubrication and lighting. Spiny dogfish livers were used as a source of Vitamin A, and a large liver fishery took place from 1937-1950 with recorded annual landings between 5,139-31,187 tonnes. Stock declines, market shifts and production of synthetic Vitamin A led to a collapse of the liver fishery. By 1977, market demand for spiny dogfish as food fish revived the fishery and since 1980 annual landings have ranged between 139 tonnes (in 1986) to 4,952 tonnes (in 2003). The longterm mean annual total fishing mortalities for the food fishery era (1978-2008) are 1,599 tonnes for the inside fishery and 1,690 tonnes for the outside fishery.

The spiny dogfish population in British Columbia is assessed as two distinct stocks: an inside stock inhabiting the Strait of Georgia (Statistical Area 4B); and an outside stock inhabiting all remaining coastal areas (Statistical Areas 3C through 5E). This stock assessment employs generalized Schaefer and Pella-Tomlinson surplus production models to estimate the current biomass of each stock. Model parameter estimates for the intrinsic rate of population increase (r) were available from the literature, and a range of estimates between 0.017-0.07 were used. The carrying capacity (K) estimates were based on estimates of biomass at the start of the liver fishery in the 1940s which were 166,667 and 333,333 tonnes for the inside and outside stock respectively. Catch per unit effort data available from the longline and trawl fisheries and from several research surveys were used as indices of relative abundance.

Model runs that use intermediate r values and that allow the model to estimate K are recommended for consideration in assessing the status of the inside and outside stocks and selecting yield limits. For the inside stock both the Schaefer and the Pella-Tomlinson model runs estimate that the population is in the Cautious zone, i.e. between 40-80% of B_{MSY}. The yield limit derived from the Schaefer model is 525 tonnes, and the limit derived from the Pella-Tomlinson model is 168 tonnes. For the outside stock both model runs estimate that the population is in the Healthy zone, i.e. greater than 80% of B_{MSY}. The yield limit derived from the Schaefer model is 5,964 tonnes, and the limit derived from the Pella-Tomlinson model is 10,087 tonnes.

There is some indication from length data collected from research surveys that there are slightly fewer very large spiny dogfish (>100 cm) in the inside stock and fewer large females (>85 cm) in one area (Hecate Strait) in the outside stock. Caution should be taken when interpreting these

results. The research survey data for the inside stock requires calibration for a change in gear type and the data for the outside stock is only for one area and is derived from bottom trawl data that targets flatfish habitat.

RÉSUMÉ

L'aiguillat commun (*Squalus acanthias*) est un requin de petite taille qui vit dans les eaux tempérées au large des côtes est et ouest de l'Amérique du Nord. Ce sont des ovovivipares et leur gestation dure 2 ans. Les femelles produisent entre 2 et 16 petits qui mesurent en moyenne entre 26 et 27 cm de longueur à la naissance. Les aiguillats communs sont des poissons à grande longévité, la population du Pacifique présentant des spécimens âgés de 80 à 90 ans qui atteignent 130 cm de longueur. L'âge à la maturité des femelles est d'environ 35 ou 36 ans; elles mesurent alors environ 94 cm. La longueur à maturité des mâles est de 70 cm.

En Colombie-Britannique, cette espèce fait depuis longtemps l'objet d'une pêche commerciale historique qui a commencé dans les années 1870. De 1870 à 1916, on pêchait ce poisson pour en extraire l'huile du foie et de l'organisme et l'utiliser comme lubrifiants industriels et aux fins d'éclairage. Entre 1937 et 1950, une vaste pêche annuelle visant à répondre à la demande de foies de ce type de requins pour la production de vitamine A et se chiffrant entre 5 139 et 31 187 tonnes a été enregistrée. Le déclin des stocks, les changements dans les marchés et la production de vitamine A synthétique sont les facteurs qui ont mené à un effondrement de ce type de pêche. En 1977, la demande du marché de l'alimentation pour l'aiguillat commun en a ravivé la pêche, et depuis 1980, les débarquements annuels se sont situées entre 139 tonnes (en 1986) et 4 952 tonnes (en 2003). Le total annuel moyen à long terme des mortalités durant la période de pêche destinée à l'alimentation (1978-2008) était de 1 599 tonnes pour les pêches menées dans les eaux intérieures et de 1 690 tonnes pour celles menées dans les eaux extérieures.

On recense deux stocks distincts d'aiguillats communs en Colombie-Britannique, l'un étant situé dans les eaux intérieures du détroit de Georgia (secteur statistique 4B) et l'autre, dans les eaux extérieures de tous les autres secteurs de la côte (secteurs statistiques 3C à 5E). Cette évaluation des stocks se fonde sur les modèles généralisés de production excédentaire de Schaefer et de Pella-Tomlinson afin d'estimer la biomasse actuelle de chacun des stocks. Des estimations des paramètres de modèles du taux intrinsèque d'accroissement (*r*) de la population ont été trouvées dans la documentation, et une plage d'estimations de 0,017 à 0,07 a été utilisée. Les estimations de la capacité de charge (*K*) étaient fondées sur des estimations de la biomasse du début de la période de pêche visant à répondre à la demande de foies dans les années 1940 qui se chiffraient à 166 667 et à 333 333 tonnes pour les stocks des eaux intérieures et extérieures respectivement. Les données sur les prises par unité d'effort fournies par les palangriers et les chaluts de fond et par divers relevés scientifiques ont été utilisées comme indices de l'abondance relative.

Pour l'évaluation de l'état des stocks dans les eaux intérieures et extérieures et l'établissement des limites de rendement, il est recommandé de prendre en considération les passages de modèle qui utilisent des valeurs *r* intermédiaires et qui permettent au modèle de calculer la capacité de charge (*K)*. En ce qui a trait au stock des eaux intérieures, les passages de modèle de Schaefer et de Pella-Tomlinson estiment tous deux que la population se trouve dans la zone de prudence, c'est-à-dire entre 40 % et 80 % de la B_{RMS}. Selon le modèle de Schaefer, la limite du rendement est de 525 tonnes; selon le modèle de Pella-Tomlinson, elle est de 168 tonnes. En ce qui concerne le stock des eaux extérieures, les deux passages de modèles estiment que la population se trouve dans la zone saine, c'est-à-dire supérieure à 80 % de la B_{RMS}. La limite du rendement obtenue au moyen du modèle de Schaefer est de 5 964 tonnes, et celle obtenue grâce au modèle de Pella-Tomlinson est de 10 087 tonnes.

Les données sur la taille signalée dans des relevés scientifiques indiquent qu'il y a légèrement moins d'aiguillats communs de très grande taille (> 100 cm) dans le stock des eaux intérieures et moins de femelles de grande taille (> 85 cm) dans une zone (détroit d'Hécate) des eaux extérieures. Ces résultats doivent être interprétés avec précaution. Les données des relevés scientifiques concernant le stock des eaux intérieures doivent être reconsidérées pour tenir compte d'un changement du type d'engin fixe; par ailleurs, les données sur le stock des eaux extérieures ne concernent qu'une seule zone et proviennent de données de chaluts de fond qui ciblent l'habitat des poissons plats.

INTRODUCTION

REQUEST FOR ADVICE

Spiny dogfish (*Squalus acanthias*) will be considered by the Convention on International Trade of Endangered Species of Wildlife and Fauna (CITES) in March 2010 to be listed under Appendix II. Species listed under Appendix II are those that are not necessarily currently threatened with extinction but may become threatened unless trade is closely controlled. The CITES proposal does explicitly identify the Pacific population of spiny dogfish as a possible exception to some of the criterion required for this listing. As a response to this CITES proposal, the Canadian Pacific Spiny dogfish Fishermen's Association has initiated a Marine Stewardship Certification process, that includes this current stock assessment of the status of spiny dogfish in Canadian Pacific waters. In April 2010, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) will review the Status Report for spiny dogfish. In addition, a Request for a Working Paper (Appendix A) was submitted by the Groundfish Management Unit of Fisheries and Oceans Canada in January 2009, requesting advice by December 2009 on the status of the spiny dogfish populations in British Columbia with appropriate catch level recommendations for DFO Statistical Areas (Figure 1).

STOCK STRUCTURE

Globally

Spiny dogfish are found in the north Pacific and the north Atlantic. Conditions of stock in other parts of the world is currently best summarized in Gallucci et al. (2009). There has been a recent re-examination of differences in natural history and demography between Pacific and Atlantic populations that suggest that these two populations should be re-separated into two different species, *S. suckleyi* in the Pacific and *S. acanthias* in the Atlantic (Hauser et al. 2009). These two populations were considered to be these two separate species until circa 1950.

British Columbia

The targeted spiny dogfish fishery is primarily executed in the Strait of Georgia (DFO Statistical Area 4B, Figures 2 and 3) and off the southwest coast of Vancouver Island (DFO Statistical Area 3C, Figures 2 and 3). Tagging data suggests that in the northeast Pacific, there are discrete stocks primarily an offshore stock that extends from Baja California to Alaska (Ketchen, 1986) and two coastal stocks, one in the Strait of Georgia and one in Puget Sound (McFarlane and King, 2003; 2009). It should be noted that there is continuity between the populations in Alaska and Washington State, including Puget Sound (see Gallucci et al., 2009). This continuity is important to consider because management of spiny dogfish in both Alaska and Washington could impact size distributions, abundance and the likelihood of migration into British Columbia waters (Gallucci et al., 2009). Spiny dogfish in British Columbia waters are managed as two discrete stocks: an inside stock and an outside stock.

<u>Inside stock</u>

Detailed analyses of tag and recapture data for spiny dogfish throughout British Columbia indicated that, although there was some intermixing between the Strait of Georgia and the other coastal stocks (Puget Sound, west coast of Washington State and Vancouver Island, northern British Columbia), the rate of exchange of tagged spiny dogfish was low and the Strait of Georgia stock could be considered discrete for the purposes of management (McFarlane and King, 2003; 2009). For stock assessment advice and management, the inside stock is defined as inhabiting the Strait of Georgia, DFO Statistical Area 4B (Figure 1).

Outside stock

Spiny dogfish tagged in open continental shelf waters demonstrated extensive latitudinal and longitudinal movements but relatively low exchange with the inside stock (McFarlane and King, 2003). For stock assessment advice and management, the outside stock is defined as inhabiting the waters of the west coast of Vancouver Island, Queen Charlotte Sound, Hecate Strait, and Queen Charlotte Islands which are DFO Statistical Areas 3C, 3D, 5A, 5B, 5C, 5D and 5E (Figure 1).

GENERAL BIOLOGY

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. The spiny dogfish has two dorsal fins with a sharp spine at the leading edge of each (hence the name 'spiny'), five gill slits, and no anal fin (for a more complete morphological description, see Compagno 1973).

Reproduction and Fecundity

Like all sharks and rays, reproduction in the spiny dogfish is carried out through internal fertilization. In the Northeast Pacific, breeding occurs during the late fall and early winter when males insert their reproductive appendages or "claspers" into the females, transmitting seminal fluid directly into the oviducts. Large eggs approximately 35 mm in diameter and numbering 2 to 17 are released from the ovaries of the females (Bonham et al. 1949), 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. Encapsulated eggs remain in the oviducts for nearly 2 years (18-22 months), a gestation period almost unmatched by any other species in the animal kingdom (Ketchen 1986). 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 (Ketchen 1986).

In British Columbia waters, fecundity in the spiny dogfish varies from 2 to 16 pups, and is highly dependent on the size of the mother with larger females bearing more young (Bonham et al. 1949). The average number of pups born is between six and seven (Ketchen 1986, King and McFarlane 2009).

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 (Jones and Geen 1977). As opportunistic feeders, adult spiny dogfish prey on a number of species of fish including herring, capelin and eulachon (Chatwin and Forrester 1953, Ketchen 1986), rising only occasionally in the water column to feed on surface swarms of euphasiids (Ketchen 1986). Although commonly viewed by fishermen a scourge upon other commercial species, digestion is a slow process in spiny dogfish, with an observed time between feeding events of 16 days in British Columbia waters (Jones and Geen 1977). However, the true impact of this species as a predator on valuable species within British Columbia waters and elsewhere remains a topic of much dispute

(Jones and Geen 1977), as does their importance to higher trophic level predators such as lingcod, sablefish, other shark species, and northern sea lions (Ketchen 1986).

Age and Growth

As a result of their low metabolic rate, spiny dogfish in the Northeast Pacific exhibit exceptionally slow growth. Recent von Bertalanffy growth curve estimates for females in the Strait of Georgia were derived from observed and calculated annulus counts on the surface of 2nd dorsal spines (McFarlane and King 2008). Length infinity (L_∞) estimates ranged from 85 cm to 99 cm and growth curve coefficient (k) estimates ranged from 0.08 to 0.04, with varied values reflecting the range of precision in no-wear point diameter measurements between readers (see Ketchen 1975 and McFarlane and King 2008 for a full description of ageing methodologies for spiny dogfish).

Age-at-maturity in females is approximately 35-36 years (Strait of Georgia; Saunders and McFarlane 1993) corresponding to approximately 94 cm total length (TL) (Ketchen 1975, Saunders and McFarlane 1993). Maximum recorded age in females is 80 years old (corresponding to a total size of 70 cm TL) (Saunders and McFarlane 1993), and the recorded maximum size is approximately 130 cm TL (Ketchen 1975) which corresponds to an estimated age of 90 years based on growth.

Life History Strategy and Productivity

The “slow” life history characteristics of spiny dogfish are typical of almost all species of shark, making them highly susceptible to overexploitation and stock depletion (DFO 2007a). Compared to bony fish, sharks grow slowly, mature later, and produce fewer offspring per year resulting in very low intrinsic rates of population increase (Smith et al. 1998). Spiny dogfish are listed as near threatened on a global basis by the International Union for the Conservation of Nature (IUCN) (Wallace et al. 2009), populations of spiny dogfish have exhibited marked declines and slow recoveries typical of equilibrium strategists (Winemiller and Rose 1992, Smith et al. 1998, King and McFarlane 2003).

The equilibrium strategist life history strategy is consistent with the more commonly referred to, terrestrially-based K-strategy suite of life history characteristics, namely relatively large size, low fecundity and a high degree of parental investment. Fish species belonging to this group typically exhibit steady state population dynamics, with environmental forcing (i.e. climate regime shifts) having little effect on recruitment (King and McFarlane 2003). Instead, recruitment is governed primarily by the age-structure of the stock, and reproductive capacity is limited by the number of breeding females-at-age. Given the low rates of natural mortality estimated under equilibrium conditions, there is little margin for high or variable environmental mortality (including fishing mortality). According to calculations by Wood et al. (1979), under conditions of natural equilibrium, the natural mortality rate of spiny dogfish appears to be less than 9% per year (M = 0.094), meaning the stock can withstand only a very limited fishing mortality if it is to remain at equilibrium (replacement mortality) (Holden 1977).

In 2007, DFO produced a National Plan of Action for the Conservation and Management of Sharks (DFO 2007a). In this plan, it was stated that harvest rates of spiny dogfish – along with those of all other elasmobranches in the Northeast Pacific - should be low to moderate, and considered within a precautionary management framework given the “slow” life history strategy of these species and the resulting naturally low variability in their population dynamics. Quotas should continue to account for bycatch of the inherently unproductive spiny dogfish in mixed species fisheries targeting more productive fishes (Benson et al. 2001, King and McFarlane 2003, DFO 2007a).

HISTORY OF THE FISHERY

Advent of the Fishery 1870-1916: Lubrication and Lighting Oil

Since its advent in 1870, the commercial fishery for spiny dogfish along the Northwest coast of Canada has had a long and varied history marked both by spectacularly high landings and rapid declines (Figure 4; see Ketchen 1986 and Bonfil 1999). Various forms of utilization of this species have arisen over time, with fluctuating catches reflecting both changes in market demand for spiny dogfish and the status of the stock (Ketchen 1986).

Traditionally, spiny dogfish were fished primarily for use of their liver and body oils as industrial lubricants and for lighting purposes. In 1917, however, the introduction of calcium carbide lighting and the displacement of spiny dogfish-oil lamps in mines by safety and electric lamps brought about a decline in demand for spiny dogfish. Rapid increases in landings only resumed after 1922, when interest turned to spiny dogfish liver oil and flesh for the manufacture of agricultural meal and in the production of fertilizers. The economic crash of 1929 again brought about a sharp decline in production, and by the late 1930s in the Strait of Georgia only two plants remained
involved in the reduction of spiny dogfish (Ketchen 1986).

Liver Fishery 1937-1950: Source of Vitamin A

However, a discovery of the vitamin A potency of spiny dogfish liver oil and rising war-time demand brought a resurgence in demand for spiny dogfish. Coincident with the increase in demand, fishing vessels and gear evolved to better supply processing needs. During the early 1940s, set-line (longline), sunken gillnet (set-net), and otter-trawl vessels were targeting spiny dogfish and stocks began exhibiting the classical effects of overfishing, especially in the set-line fishery where the supply of large spiny dogfish was dwindling (Ketchen 1986). This decline was in part due to the novel practice of “buying on test”. Companies started buying spiny dogfish livers on the basis of assayed oil content and vitamin A potency instead of size alone, increasing the demand for large (old) fish with significantly more valuable livers (Hart 1973).

In Canadian Pacific waters, a total of 170,000 tonnes of spiny dogfish were landed in the 1940s (Figure 4). Catch peaked in 1944 at a record 31,000 tonnes (Figure 4), with British Columbia accounting for 58 percent of the total catch of spiny dogfish (53,000 t) in the wide area extending from southeast Alaska to Oregon. A species historically maligned by fishermen as a “pest” had become the 4th most valuable species landed in Canada and the number one species taken in British Columbia waters (Ketchen 1986, Wallace et al. 2009).

This bonanza, however, was short-lived, with production in 1945 marking the start of a steep downturn. Stock declines; a growing scarcity of large spiny dogfish; and market shifts towards Japanese imports and synthetic vitamin A greatly affected the fishery which by 1950, had virtually collapsed (Figure 4). Government subsidy (control) programs set in place in the years that followed (1951-1974), increased captures (Hart 1973), but did little to encourage resumption of viable commercial fishing for spiny dogfish, and were generally ineffective at reducing the number of “nuisance” spiny dogfish that were gradually returning to British Columbia waters (Ketchen 1986). For example, by 1958 there was already a noticeable resurgence in the “marketable stock”, but nothing of substance developed from experimental spiny dogfish marketing programs, and by 1971-72 the total landings in British Columbia and Washington had fallen to less than 273 t, levels lower than anything reported since 1915 (Ketchen 1986).

Food Fish Fishery 1975-present

Declines in European and Japanese spiny dogfish stocks and subsequent new import markets in Europe and Asia (Ketchen 1986, DFO 2007a) eventually brought about the revival of the North American spiny dogfish fisheries. By 1977, a firm foodfish fishery was established in British Columbia, with effort concentrated mainly in the Strait of Georgia (Figures 5 and 6). Production peaked in the Strait of Georgia in 1979 at 4334 t, but by 1980, there were indications of a renewed decline in the supply of fish to both set-liners and trawlers operating in the Strait of Georgia. Trawl fishing shifted to grounds off the west coast of Vancouver Island, despite the fact that sites in this region were not particularly noted for the production of large fish.

In 1981, the Strait of Georgia share increased to 60% of the British Columbia total; however, total production for the Strait of Georgia stood at 1212 t, or only 28% of that in the peak year of 1979 (Figure 5). An unequivocal explanation for the decline is not apparent, with statistics of overall catch and effort (CPUE) from the region failing to confirm the other indications of decline in supply. Likely a combination of overfishing, reduced market demand due to increasing competition with processors on the east coast of the United States and Canada, and other general economic difficulties brought about a decline in landings from inshore waters (see Ketchen 1986).

Today the spiny dogfish continues to be the shark species of greatest commercial importance on the Pacific coast (DFO 2007a). It is fished throughout British Columbia, with the largest concentrations occurring off the west coast of Vancouver Island and in the Strait of Georgia (Figures 3 and 4). The distribution of marketable spiny dogfish from commercial catches indicates that concentrations are found mainly on the continental shelf, and that a seasonal shift to shallower shelf waters occurs in the summer (Ketchen 1986).

From 1996-2004, the annual catch (landings and discards) in Canadian Pacific waters typically ranged from between 5,000 and 7,000 tonnes, with the majority of fish taken by longline (approx 75%) and the rest by trawl (approx 25%) (Figures 5 and 6; DFO 2001, Wallace et al. 2009). Between 2005-2008, the annual catches were slightly lower, with a 4-yr average of just under 5,000 t (DFO 2008b). In 2008 the total catch from both the inside and outside longline and trawl fisheries was just over 3300 t, with the longline fishery accounting for 58% of the catch (DFO 2008b). In the longline fishery, landings outnumbered discards in both inside and outside waters, with the bulk of the catch coming from outside waters, specifically Major Area 3CD (approx 65%). Likewise, in the trawl fishery the bulk of the catch came from outside waters, namely Major Area 3CD (approx 72%); however, trawl discards outnumbered landings in both inside and outside waters (DFO 2008b).

Overall, total catch (landings and discards) by the trawl fleet has been relatively stable over the last 13 years (1996-2008) (DFO 2008b); however, retention and hence fishing mortality, has increased (Wallace et al. 2009). In the directed longline fishery, combined landings and discards increased steadily from 1996 until 2004 (Wallace et al. 2009), after which they decreased, reaching a value of 1919 tonnes in 2008 (see Commercial Fishery Data in Methods Section).

Recent efforts have been made to address historic shortfalls in management and catch monitoring. Trawl vessels targeting groundfish (including spiny dogfish) in the Northeast Pacific have been 100% observed since 1996; while the longline fishery was only partially covered through logbook records and at-sea observers (DFO 2007a). In 2006, as part of an extensive pilot plan for the integration of commercial groundfish fisheries, 100% at-sea electronic- and video-monitoring systems were put in place for all commercial trap and longline vessels. Also included in the new Integrated Fisheries Management Plan (IFMP) was the implementation of individual transferable quotas (ITQs) in all groundfish fisheries not currently under a quota regime. This system allows fishers to account for their bycatch by considering discard mortality of individual species – including spiny dogfish - in commercial quota recommendations for all groundfish (DFO 2006b, DFO 2007a, DFO 2008a). Although the extent of high-grading in the directed spiny dogfish fishery remains unknown (Wallace et al. 2009), it is thought to be minimal given the extensive observer coverage.

HISTORY OF ASSESSMENT

Until recently, management of the spiny dogfish in Canadian Pacific waters has been minimal, with set Total Allowable Catches (TACs) implemented and monitored but with no defined fisheries objectives or updated stock assessments. The intrinsic tendency for population decline in this species, coupled with growing local, national, and international concern for sharks in general, increases the need for thorough and timely management plans considering all aspects of spiny dogfish life history (Wallace et al. 2009).

Initial Assessment: 1979

In 1979, Wood et al. carried out the first formal stock assessment for spiny dogfish in the Pacific region. They combined estimates of age-at-recruitment and age-at-maturity with changes in fecundity with age, and natural mortality rate in a mathematical, age-structured model to test hypotheses about the principal factor controlling spiny dogfish population growth in the northeastern Pacific, and to determine how it responds to the effects of fishing. They concluded that density-dependent compensatory change in natural mortality rate is the main mechanism limiting growth in the stock-recruitment relationship of spiny dogfish (Wood et al. 1979). Simulations that took into account this compensatory mechanism indicated that a reduction in the marketable biomass of spiny dogfish to 57% of its unharvested level would result in a maximum sustainable yield (MSY) of 9,000-11,000 t/yr for inside and outside stocks combined (i.e. all British Columbia waters), and that minimum size at entry into the fishery had little effect on MSY.

Overall, Wood et al. (1979) recommended the cautious development of a sustained effort fishery, a strategy shown through simulations to promote maximum stability. Periodic or “pulse” fishing was deemed higher risk due to the combined destabilizing effects of large removals and a long-lag time between reproduction and recruitment on population abundance cycles (Wood et al. 1979). Ketchen (1986) in turn suggested that a sustained catch (i.e. quota) fishery would be more practical from a management standpoint given that markets develop rapidly and sustained effort can be more difficult to control than sustained catch.

Assessment Updates: 1980s

The most recent stock assessment for spiny dogfish was carried out in 1988, in which recommended yield options for the spiny dogfish fishery off the west coast of Canada for 1989 were presented (Saunders 1989). In this assessment, Saunders modified the original version of the model, updating it with catches to 1987, and came up with a Canadian coast-wide (not including Strait of Georgia) biomass estimate of approximately 150,000 – 200,000 t (assuming that one-half to two-thirds of the total stock biomass of 280,000 t resided off the coast of Canada). In the Strait of Georgia-Puget Sound, the biomass estimate was in the order of 60,000 t. Saunders (1989) predicted that at annual harvest levels of less than 2,500 t for the outside stock, and of approximately 1,000 t in the Strait of Georgia, the marketable biomass of spiny dogfish would continue to increase over the next two decades (Saunders 1989).

Along with updating the model of Wood et al. (1979) with current catch data, Saunders (1989) examined the implications of a sex-bias in the coast-wide (not including Strait of Georgia) fishery. At the time, both trawl and longline fleets concentrated their operations during the first and second quarters when the large, primarily female spiny dogfish (> 80cm) that processors demanded were accessible to the fisheries (Saunders 1989). Port samples of spiny dogfish from 1977-1987 reflected this difference in availability, with catch greatly weighted toward females. For fish with such a low fecundity, a heavily sex-biased catch could severely hamper the reproductive capacity of the population and in turn result in lower sustainable yields over the long term. Potential seasonal changes in the sex ratio in the fishery were therefore modeled in the updated assessment.

Historic Recommended Yield and Implemented Total Allowable Catches (TAC)

For the outside stock (including US waters) under a sustained yield strategy, and assuming an equal sex ratio in the catch, Saunders (1989) considered annual yields of less than 15,000 t to be low risk whereas yields of 25,000 t were considered high risk (Table 1). In the event of a true sex-bias in the 1st and 2nd quarter fishery, yields of up to 9,000 t were deemed low risk while yields of 14,000 t were deemed high risk if the fishery was to be maintained (Saunders 1989). The Canadian TAC for the outside stock was set at 15,000 tonnes for all gear types combined. In 1994 the TAC was reduced to 12,000 tonnes (Table 1).

For the inside stock (Strait of Georgia), bias in the sex ratio was less pronounced and therefore not considered in the 1989 analyses (Saunders 1989). Annual removals of 2000 tonnes were considered low risk while removals of 3000 t were considered high risk (Table 1). In 1989, the TAC for Area 4B was set at 3,000 tonnes, and reduced to 2,500 tonnes in 1994. In 1996, the TAC for Area 4B was inadvertently reported in the Management Plan as 5,000 tonnes (instead of 2,500 tonnes). This was corrected in 2005 when the TAC was reset at 3,000 tonnes (Table 1). However, from 1996-2005 the annual landings never exceeded 1,900 tonnes (Tables 3 and 4).

Since the implementation of the IFMP in 2006, the Canadian Pacific spiny dogfish total allowable catch (TAC) for all sectors and areas has remained unchanged at 15,000 t. The combined longline and trap fisheries have been allotted 68% of the TAC (10,200 t), with 2,040 t designated for inside fisheries (Area 4B) and 8,160 t designated for fisheries operating on the rest of the coast. Trawl fisheries operating in Area 4B have been allotted 960 t annually, leaving the remaining 3,840 t to the trawl fleet in outside waters (DFO 2006b, DFO 2007b, DFO 2008a). Prior to the IFMP, the 2005 Pacific quota was 14,940 t (DFO 2005).

Currently neither the longline/ trap or trawl fisheries targeting spiny dogfish fulfill their combined annual quota of 15,000 t. In fact, combined landings and discards have been well below the TAC ever since quota regulations were first put in place. As such, even with an assumed 100% mortality rate in the catch, it is highly unlikely that the present low fishing effort is having a dramatic effect on the Canadian Pacific spiny dogfish population biomass (Wallace et al. 2009).

Nevertheless, the exploitation history of the spiny dogfish here on the Pacific coast (Ketchen 1986)– along with experiences from other parts of the world (Fordham 2006) - clearly indicate that spiny dogfish populations can easily become over-fished, in some cases to the point of meriting endangered species' classification (Wallace et al. 2009).

PREVIOUS STOCK STATUS

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. 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.

METHODS

DATA SOURCES

Commercial Fishery Data

Landings

Ketchen (1986) provides annual spiny dogfish landings (tonnes) by large areas equivalent to DFO Statistical Areas 4B (inside stock) 3CD, 5AB and 5CD (outside stock) for 1935-1953 (Appendix 6 in Ketchen, 1986) and 1954-1965 (Appendix 9 in Ketchen, 1986). These landings were not available by gear type, and are longline and trawl landings combined. For 1935-1953, landings were reported in round weight. However, an increasing proportion of spiny dogfish landings could not be assigned to Statistical Areas. In this assessment, the unassigned landings were assigned to Statistical Areas based on an Area's proportion of assigned landings (Table 2). For 1954-1965, only weight of landed livers were reported, and these weights (tonnes) were converted to round weight with a conversion factor of 8.85 (Table 2; see Ketchen (1986) Table 27 and Appendix 3). Landings for the years 1962 and 1963 were not divided by area in Ketchen (1986). The average proportion of the catch from the years immediately before and after (1961 and 1964) was applied to the totals in Ketchen (1986) to estimate area-specific values for 1962 and 1963 (Table 2).

Using the same area designations as Ketchen (1986), annual longline landings by Area were compiled from the last spiny dogfish assessment update (Thomson 1995) for 1979-1992 and from the British Columbia Commercial Catch Statistics annual reports (DFO, Pacific Region, Catch Statistics Unit, Vancouver, BC; available online at (http://www.pac.dfo-mpo.gc.ca/stats/comm/ann/index-eng.htm) for 1993-1995 (Table 3). The annual trawl landings by Area were compiled from the GFCatch database (DFO, Pacific Region, Groundfish, Data Unit, Nanaimo, BC) for 1966-1995 (Table 4). Longline annual landings for 1996-March 31, 2006 were compiled from the PacHarv3 and PacHarvHL databases (DFO, Pacific Region, Groundfish, Data Unit, Nanaimo, BC). From April 1, 2006 onwards, longline landings were compiled from the GFFOS database (DFO, Pacific Region, Catch Statistics Unit, Vancouver, BC). Trawl annual landings were compiled from the PacHarvTrawl database (DFO, Pacific Region, Groundfish, Data Unit, Nanaimo, BC) for 1996-March 31, 2007 and from GFFOS for data since April 1, 2007. In both the longline and trawl fisheries, there were some years (1996-2008) in which landings could not be assigned to a Statistical Area. Typically these totalled less than 300 tonnes for both fisheries combined, except for 1996-1998, which averaged approximately 1200 tonnes (Tables 3 and 4). Because the number of years with large unassigned landings were relatively few, these data were assumed to not be highly influential on the model results and divided equally between the inside and outside stocks.

<u>Discards</u>

Discards result from spiny dogfish bycatch in other groundfish targeted fisheries. These data are included in the stock assessment since the discards the biomass was removed from the stock and no longer available for production, as if they were captured in the targeted fishery. There were no discard data available for a number of fisheries that are known to capture spiny dogfish: salmon troll; salmon gillnet; sports catch and halibut longline. Estimates of discards for these fisheries are not included here, so it is important to note that the total mortality due to discards are underestimated.

Discard data were not available from 1935-1965. Annual discard data (tonnes) were available from 2001 onwards for longline fisheries (Table 5) and from 1966 onwards for trawl fisheries and (Table 6). Data were compiled from the DFO databases listed in the landings section. The average annual ratio of discards to landings in the longline fisheries (2001-2006) was 22.7% for the inside stock and 3.2% for the outside stock (Table 3 and Table 5). These averages were applied to the longline landings from 1966-2000 to estimate that discards (tonnes) for the inside (Table 7) and the outside stocks (Table 8). Data on longline discards (tonnes) were incomplete in 2007 and 2008 and were also estimated with the average ratio, with the exception of 2008 for the outside stock were the incomplete discard estimate of 84 tonnes was larger than the extrapolated discard estimate of 42 tonnes. Caution should be applied when interpreting discard data in the trawl fishery prior to 1996 (start of on board observer program) and in the longline fishery prior to 2006 (electronic monitoring program), since it is not likely that all discards were recorded in fisher logbooks.

Discard mortality (tonnes) was calculated using mortality discard rates (%) from the Integrated Fisheries Management Plan (IFMP) for Pacific Canadian groundfish fisheries (DFO, 2009) which are currently used to manage bycatch mortality within species' quota allocations. The spiny dogfish discard mortality rate is 6% for longline gear, and this rate was applied to all longline discards (tonnes) to estimate discard mortality (tonnes, Tables 7 and 8). For the trawl fishery, the IFMP uses 5% for the first two hours of a trawl fishing event with 5% for each additional hour (DFO, 2009). The application of tow duration-dependent discard mortality rate required trawl effort data. Prior to 1996, trawl data were rolled up by multiple fishing events, and tow duration for individual fishing events were not available. The average tow duration was calculated from the total number of hours and the number of fishing events within a roll-up for 1980-1995. Data from 1996 onwards were available on a tow by tow basis. A weighted average of the trips within each year (with the discards per trip as the weights) was used to estimate to annual trawl discard mortality rate (Tables 6 and 7):

$$M_y = \sum_t b_t M_t \Big/ \sum_t b_t \qquad (1)$$

where,

b_t is the kg of discarded spiny dogfish in trip t.

M_t is the mortality rate for trip *t* where:

M_t = 5% (first 2 hours) + 5% (each additional hour)

M_y is the annual mortality rate for year *y*.

Missing years were interpolated from the prior year and the subsequent year. Trawl discard and effort data were not available for 1966-1979 to estimate annual discard mortality rates with equation 1. To obtain discard mortality rates for these years the average discard mortality for the subsequent ten years (1980-1989) was extrapolated back.

The annual discard mortality (tonnes) was calculated for the inside stock (Table 7) and for the outside stock (Table 8) using the gear specific discards (tonnes) and the gear specific , and in the case of trawl data the year specific, discard mortality rates (Table 5). These discard mortality data (tonnes) were added to the landings (tonnes) to estimate total fishing mortality (tonnes) by year for each stock (Tables 7 and 8).

Catch per unit effort

Catch with effort data were available from 1980 onwards, and were obtained from the databases outlined in the Landings section above. An attempt was made to select trips that targeted spiny dogfish, so only trips in which landings of spiny dogfish comprised at least 60% of total landings were selected for calculating catch per unit effort. Longline effort data were sparse in general and only years with at least 30 trips or more that had effort data were used. In the mid-1990s, a change from standard J-hook gear to circle hook gear occurred in the fishery. King and McFarlane (2009) found differences in catch per unit effort between the two gear types: the catch by circle hook was greater and increased with depth. Catch per unit effort data by depth was corrected as per King and McFarlane (2009) to account for changes in gear type. Based on all criteria, only 11 years between 1979-2008 had suitable CPUE estimates for the inside stock and 11 for the outside stock as well (Table 9). In 2007 and 2008, the inside longline commercial fleet reduced its targeted effort for spiny dogfish in the Strait of Georgia due to increased financial costs of obtaining quota for bycatch species (as required under the new Integrated Fisheries Management Plan). In the Strait of Georgia, rockfish quota restrictions are limiting. Fishermen reduced their inside spiny dogfish season to October through late-December (as opposed to historically fishing from October to late-March), and moved offshore to avoid rockfish bycatch restrictions. In addition, the market preference shifted from medium size fish to large size fish. To supply the market with larger spiny dogfish, fishermen targeted known 'clean hotspots'. As such, the inside longline commercial catch per unit effort for 2007 and 2008 were not included in these analyses.

Trawl effort data prior to 1996 were not available on a tow by tow basis, but were available as rolled-up data that were aggregated over individual depth ranges and fishing grounds for a fishing trip. These rolled up data were not used in this assessment. Since 1996, the data are available on a tow by tow basis. As with the longline data, only trips in which landings of spiny dogfish comprised at least 60% of total landings were selected for calculating catch per unit effort (kg per hour). Only years with at least 30 trips were retained. From 1996-2008, only four years met these criteria for the inside stock, and nine years for the outside stock (Table 10)

Joint Venture Pacific hake fishery data

This is a mid-water fishery that operates off the west coast of Vancouver Island. Data on discards were available for 1981-1987 as paper records (K. Rutherford, pers. comm., Pacific Biological Station, Nanaimo, BC, V9T 6N7) and for 1988-2008 from the GFBio database (DFO, Pacific Region, Groundfish, Data Unit, Nanaimo, BC). Juvenile spiny dogfish are typically found in the midwater (Beamish et al. 1982). These discards were not included in the total mortality used as input to the model, since the model estimates the demersal exploitable (and presumed adult) biomass. Based on lengths available from onboard observers in the JV hake fishery, no less than 80% of the spiny dogfish caught are immature with an average proportion of 93%.

Research Survey Data

Spiny dogfish catch per unit effort data from a number of research surveys were examined for utility as abundance indices in the assessment model. As identified below, surveys that did not have many years of data, or did not span a large number or years were not included. In addition, surveys that produced CPUE with high variability (CV) were also excluded.

Strait of Georgia spiny dogfish longline survey
Four longline abundance surveys have been conducted for spiny dogfish in the Strait of Georgia: October 10-25, 1986 and October 15-30, 1989 on the *F.V. Velma C* (McFarlane et al., 2005b); October 19-31, 2005 on the *F.R.V. Neocaligus* (McFarlane et al., 2005c); October 10-22, 2008 on the *F.R.V. Neocaligus* (King and McFarlane, 2009). In all four surveys, three depth strata were sampled at each of ten sites throughout the Strait: 56-110m, 111-165 m and 166-220 m. In 1986 and 1989, J-hook gear were used, and in 2005 and 2008 circle hook gear were used. In 2004, a calibration survey was conducted to compare catch rates by depth strata between these two gear types (McFarlane et al., 2005a). As with the commercial longline fishery catch per unit effort data noted above, the 2005 and 2008 catch rates were standardized using correction factors determined in King and McFarlane (2009). Catch and effort data were available in McFarlane et al. (2005b; 2005c) and King and McFarlane (2009). These data were included in the model for the inside stock (Table 11).

DFO groundfish trawl surveys
From 1983-1993, bottom trawl surveys were conducted in July on La Perouse bank off the southwest of Vancouver Island. This survey was part of an ecosystem study, and spiny dogfish CPUE data were obtained from the GFBio database (DFO, Pacific Region, Groundfish, Data Unit, Nanaimo, BC). CPUE of spiny dogfish was highly variable (ranged from 12 kg/hour to 1700 kg/hour) with CVs ranging from 35-85%. Data from this survey were not included in the model.

From 1984-2003, DFO conducted a biannual, random non-stratified trawl survey in Hecate Strait used to assess the abundance of flatfish species. The survey was generally conducted from mid-May to mid-June of each year. An overview of survey and sampling is provided in Sinclair et al. (2007) and data were taken from that report (Table 12). CVs for CPUE data were relatively low (5.2-6.4%) and these data were included in the model for the outside stock.

In 2005, 2006 and 2008 a new synoptic trawl survey was conducted in Hecate Strait with a stratified, random design (Workman et al. 2008). In addition, similar synoptic surveys were conducted in Queen Charlotte Sound (Stanley et al. 2007) in 2003-2005; 2007 and off the west coast of Vancouver Island in 2004, 2006 and 2008. Catch and effort data for these synoptic surveys were obtained from GFBio database (DFO, Pacific Region, Groundfish, Data Unit, Nanaimo, BC). The timespans of these surveys are still very short (less than 5 years), and the number of years (4 years for Queen Charlotte Sound and 3 years for Hecate Strait and WCVI) available are still few, so these surveys were not included in the model.

West Coast Vancouver Island DFO shrimp trawl survey
Since 1975, a systematic shrimp trawl survey has been conducted off the west coast of Vancouver Island. Fixed stations are located along east-west transect lines with approximately five stations evenly spaced along a transect. Outside boundaries were determined when shrimp catch was negligible or bottom area was too rough to trawl, but bottom depth of tows are typically within 50 – 200 m. Catch and effort data were available from the GFBio (DFO, Pacific

Region, Groundfish, Data Unit, Nanaimo, BC) and SHRIMPTRBio (DFO, Pacific Region, Shellfish, Data Unit, Nanaimo, BC) databases. These data had high inter-annual variability in spiny dogfish CPUE ranging from 23 to 850 dogfish kg/hr, and CVs within each year as high as 86%, suggesting that dogfish are not well sampled by the shrimp trawl survey. This is not surprising given that the survey samples depths that are too shallow to adequately represent spiny dogfish habitat. These survey data were not included in the model.

International Pacific Halibut Commission standardized stock assessment survey
Longline surveys for the abundance estimation of Pacific halibut have been conducted in Canadian waters since 1963, with enumeration of non-halibut species since 1998. The survey is conducted along a standardized grid that is 10 nmi (18.5 km) by 10 nmi within 25-275 fathoms (approximately 45-500 m) during the summer months. In Canadian waters, the grid extends along the west coasts of Vancouver Island and Queen Charlotte Islands, throughout Queen Charlotte Sound and Hecate Strait. The gear usually consists of 5 skates of about 100 fixed hooks (16/0 circle hooks), with 18 ft (5.5 m) spacing so that each skate is 1,800 ft (548 m) long. Soak time is a minimum of 5 hours, and is not permitted to exceed 24 hours. From 1993-1996, all hook were enumerated for non-halibut species, however between 1997-2002 only 20 hooks per skate, at or near the beginning of each skate, were enumerated for species composition. Since 2003, all hooks are enumerated for species composition. Kronlund (2001) reviewed the survey and sampling design, and examined the catch rates of non-halibut species. Spiny dogfish was a recommended species for indexing the relative abundance from this survey, since they were captured in comparable quantities to Pacific halibut (Kronlund, 2001). Data were obtained from the International Pacific Halibut Commission (C. Dykstra, IPHC, Seattle, WA, pers. comm.) and were included in the model for the outside stock (Table 13).

NMFS triennial trawl survey
The US National Marine Fisheries Service (NMFS) conducted triennial trawls surveys off the west coast of North America, including the southwest coast of Vancouver Island from 1980-2001 (see Weinberg et al. 2002 for a survey description). Abundance estimate data (kg/area) based on swept area biomass extrapolations by depth strata (55-183 m; 184-366 m; 367-500 m) were obtained from the NMFS (M. Wilkins, NMFS, Alaska Fisheries Science Center, Seattle, WA, pers. comm.). The CVs ranged from 19-46% and these data were included in the model for the outside stock (Table 23).

MODEL SELECTION

There are a limited number of models possible for the stock assessment of the spiny dogfish fishery. Some are more data intensive than others since more parameters need to be estimated. The paucity of catch-age data 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. The model chosen for this stock assessment is a surplus production model because of its minimal data requirements and because it is a standard model used for fisheries assessments. There are two versions presented here: the generalized Schaefer surplus production model which assumes a symmetric shape to the resultant yield versus biomass curve, with the maximum denoted as maximum sustainable yield (MSY); the Pella-Tomlinson surplus production model which produces an asymmetric yield versus biomass curve. A recent stock assessment for spiny dogfish in the northwest Atlantic compared the results of a age structured model and a surplus production model, and acknowledged the utility of using the surplus production model for providing management advice given the difficulty in reliable age estimates for spiny dogfish (V. Gallucci, pers. comm.).

MODEL STRUCTURE

A generalized Schaefer or Pella Tomlinson (PT) stock production model (Quinn and Deriso 1999) is used. The primary objective is to estimate parameters such as maximum sustainable yield (MSY), and others.

$$B_{t+1} = B_t + rB\left(1 - \left(B/K\right)^m\right) - C_t \tag{2}$$

where,

B_t is the biomass in year t (in tonnes),

r is the intrinsic rate of growth of the population, representing the maximum increase in population size as a fraction of the population size in a given year,

K is the carrying capacity or equilibrium population size,

m is a shape parameter which controls the position of the maximum of the surplus production curve relative to the equilibrium population size where a value of 1 denotes a symmetric shape (Schaefer model) and a value of 3 denotes an asymmetric shape (PT model), and

C_t is the total removals in year t or also known as the yield,

It is further noted that the catch or yield function C_{it} for a survey or fishery of type i in year t can be written as

$$C_{it} = q_i f_{it} B_t \,, \tag{3}$$

where,

q_i is a constant of proportionality for survey or fishery of type i, and

f_{it} is the fishing effort for survey or fishery of type i in year t.

The catch per unit effort (*CPUE*) follows as

$$CPUE_{it} = \frac{C_{it}}{f_{it}} = q_i B_t \,, \tag{4}$$

where *CPUE* is a convenient index for quantifying the relationship between the observed ratio of catch to effort and the corresponding ratio of catch to effort predicted by the PT model.

The surplus production or yield (Y) as a function of B_t is given by

$$Y(B) = rB\left(1 - \left(B/K\right)^m\right), \tag{5}$$

which comes from setting $B_t = B_{t+1}$ in (2) so that the stock is in equilibrium, and solving for $C_t = Y$, the yield. Thus, all solutions of (5) in terms of B are B^* = a steady state value and all Y-values are steady state-values.

The maximum surplus production or yield of the steady state equation (5) follows from the derivative with respect to biomass,

$$\frac{dY(B)}{dB} = 0 , \tag{6}$$

and solving for $B = B_{MSY} = B^*$ or,

$$B^* = B_{MSY} = \frac{K}{(m+1)^{(1/m)}} . \tag{7}$$

The fraction of the carrying capacity (K) at which MSY occurs is

$$\frac{B_{MSY}}{K} = \frac{1}{(m+1)^{(1/m)}} . \tag{8}$$

While K is a meaningful and measurable biological parameter, m is not, so a relationship for the maximum yield MSY = Y^* in terms of biological parameters r and K (and m) follows from substitution of B^* into (4) to obtain,

$$MSY = \frac{rK}{(m+1)^{(1/m)}} \cdot \frac{m}{m+1} . \tag{9}$$

The instantaneous rate of fishing mortality which maximizes yield, F_{MSY} , can be calculated by equating the exponential of this rate to the fraction of the population which survives removal by the fishery,

$$e^{-F_{MSY}} = 1 - \frac{MSY}{B_{MSY}} \tag{10}$$

Solving for F_{MSY} therefore gives,

$$F_{MSY} = -\ln\left(1 - \frac{MSY}{B_{MSY}}\right) \tag{11}$$

At m = 1, the PT model is equal to the simpler Schaefer Model (Quinn and Deriso, 1999), where B_{MSY}/K= 0.5 and MSY = $rK/4$. For m > 1, B_{MSY}/K is shifted to a higher value and vice versa for m < 1.

The population in each area (inside and outside stocks) was assumed to be at the carrying capacity, K, in 1935 when the first high removal fishery began.

PARAMETER ESTIMATION

Parameters occurring in the model (specifically *r, K* and *m*) can be estimated with an optimization procedure, or they can be estimated independently of the model from other sources. Estimates published in the literature were used for estimates of the rate of intrinsic increase, *r* (Smith et al. (1998), Taylor and Gallucci (2009), Rice (2007), Pawson (2009)) and carrying capacity, *K* (Wood et al. (1979), Beamish and Sweeting (2009)), and are discussed below in the Literature and Empirical Estimates of Parameters section.

The two major alternative approaches for estimation of the model parameters are (1) the use of maximum likelihood optimization which essentially finds the parameter values that minimize the differences between model predictions for the different sources of CPUE and the observed data from these sources; and (2) the use of Bayesian estimation methods where the parameter estimates are influenced by assumed prior distributions. These probability density functions are typically specified in terms of a mean and a variance of the chosen distribution function. In this case the posterior distribution for the parameters will depend on the choice of the prior distribution and its expected first and second moments, in addition to the influence of the expected values of the observed data.

In approach (1), the search for a set of parameters that managed the difference between model predicted output and the observed data can lead to extreme parameter values which are unrealistic in the multi-dimensional parameter space for the real problem. For these situations, constraints on the optimization process are imposed that limit the parameter space to a range believed realistic in the context of the problem.

In approach 2, it is necessary to choose prior distributions for each parameter, often with a mean and a variance. This more complex set of assumptions could be simplified to a uniform distribution over a range that matched the same constraints chosen for approach (1), in which case the Bayesian approach and the frequentist constrained maximum likelihood are essentially quite similar.

In the case at hand, a considerable intuition can be applied based on knowledge of the biology of spiny dogfish, history of fishing in this region and others, and stock assessment methods applied some decades ago. The maximum likelihood methods of approach (1) offer a simple way to use this intuition to directly limit the range of allowed parameter estimates, whereas a chosen prior distribution specified with a mean and variance would also influence the parameter estimates, but in a less direct way that makes the degree of the influence less clear.

Maximum Likelihood Optimization

This approach minimizes the difference between the predicted value of an index *I* and the value of that index calculated from catch data. The index selected is CPUE, I_{it} ,

$$I_{it} = q_i B_t e^{\varepsilon_{it}} , \qquad (12)$$

where ε_{it} is a N(0,σ_{it}) random variable, with σ_{it} the standard deviation of the log of the observed index value I_{it} for fishery or survey i in year *t*. Thus, a log normal error structure is assumed for the relationship between biomass and *CPUE* (Haddon 2001).

For each combination of year (t), gear type (i, trawl or longline), and stock (outside or inside) that has an observed index value I_{it}, a corresponding prediction $\hat{I}_{it}$ is calculated from the model as follows:

from (12), the predicted index value is

$$\hat{I}_{it} = \hat{q}_i \hat{B}_t \,, \qquad (13)$$

where.

$\hat{q}_i$ is the estimated value of the parameter q_i, and

$\hat{B}_t$ is the predicted value of the biomass in year t for the outside or inside stock. This biomass is calculated from the model, (1) since it is a function of the parameters K, r, and m, the time-series of removals, C_t , for that stock.

The fit of the predicted index values to the observed index values is the basis for the likelihood that is used in estimating these parameters.

The predicted index values calculated from (13) are compared to the observed index values under the assumption that the indices of abundance are lognormally distributed. For index i, the likelihood contribution is given by,

$$L_i = \prod_t \frac{1}{\sigma_{it}\sqrt{2\pi}} e^{-\frac{\left(\ln(I_{it})-\ln(\hat{I}_{it})\right)^2}{2\sigma_{it}^2}} \,, \qquad (14)$$

where the values of t include all years for which there is an observation for fishery or survey *CPUE* type i, and σ_{it} is the estimated standard deviations of the log of the index for type i in year t.

The negative of the natural logarithm of this function is proportional to

$$-\ln(L_i) \approx \sum_t \frac{\left(\ln(I_i)-\ln(\hat{I}_i)\right)^2}{2\sigma_{it}^2} \,. \qquad (15)$$

The sum of these negative log likelihoods across index or *CPUE* types,

$$-\ln(L_{total}) = \sum_{i=1}^{N} -\ln(L_i) \,. \qquad (16)$$

is a function of the parameters in the model. The parameter values which minimize this total negative log likelihood are estimated using the ADMB software algorithms.

Since the intrinsic rate of increase r, the carrying capacity K, and the shape parameter or exponent parameter m can either be fixed parameters or be estimated from the model as above, it is important to explore their interrelationships.

Exploring r as a function of assumed values of K, m, and *MSY* assumes that

$$\text{MSY} = Y_m^* = \frac{rK}{(m+1)^{(1/m)}} \cdot \frac{m}{m+1} \,, \qquad (17)$$

and redefining the part containing *m* as,

$$\alpha = \frac{1}{(m+1)^{(1/m)}} \cdot \frac{m}{m+1}, \tag{18}$$

gives

$$Y_m^* = rK\alpha \,. \tag{19}$$

For *m*-values from 0.5 to 4, *α* ranged from 0.15 to 0.53. A value of *m* = 1 corresponds to the Schaefer model with *α* = 0.25 and *m* = 3 is a Pella-Tomlinson model with *α* = 0.47.

Assuming a current catch level for the inside stock of about 1300 tonnes is Y_m = *MSY*, and that *K* = 65,000 tonnes on model independent data, then equation (19) can be used to calculate *r* for different values of *m*.

$$r = \frac{Y_m^*}{K\alpha} \,. \tag{20}$$

At *m* = 1, the assumptions above give *r* = 0.08, while at *m* = 3, *r* = 0.042.

If it's assumed that the current harvest is lower than *MSY*, say the recent average catch of 1300 tonnes = *MSY/2*, so that Y_m^* = 2600 tonnes., then similar calculations to those above give *r* = 0.16 at *m* = 1, and *r* = 0.084 at *m* = 3.

LITERATURE AND EMPIRICAL ESTIMATES OF PARAMETERS

A Range of Estimates of *r* (intrinsic rate of population growth)

Estimation of the parameter *r* is inevitably difficult since it cannot be directly observed, and it is especially difficult when the Pella Tomlinson model is used over the Schaefer model. In the former case, it is the fundamental inverse relationship between *r* and the exponent *m*, that governs the location of the *MSY* (Y^*_m) along the different steady state values of biomass, *B**. In addition to estimating *r* as outlined above, literature estimates of *r* were considered.

Northeast Atlantic population

The Pawson et al. (2009) stock assessment for a spiny dogfish population in the vicinity of Ireland using age and length-based (Sullivan et al., 1990) methods. They used demographic parameters and both a maximum likelihood approach and the Bayesian approaches outlined in McAllister et al. (2001) and Hammond and Ellis (2005) to estimate *r*. The maximum likelihood approach estimated *r* = 0.42, while the Bayesian approach excluded the possibility that *r* could be as high as 0.42, and estimated median *r* values between 0.04 – 0.07. Pawson et al. (2009) recommended the Bayes estimates. No variance estimates were provided, so it is unknown if the confidence interval for the maximum likelihood approach would include the Bayes estimates.

Northwest Atlantic population

Smith et al. (1998) investigated the rebound potential of sharks, including spiny dogfish in the northwest Atlantic. The northwest Atlantic population had an estimated *r* = 0.034 if natural mortality was density dependent and r = 0.047 if fecundity and natural mortality were density dependent.

Northeast Pacific populations

The initial stock assessment on spiny dogfish in British Columbia (Wood et al., 1979) estimated *r* = 0.094. No variance estimate was provided. A subsequent stock assessment (Saunders and McFarlane, 1993) used revised age estimates, which increased the age of maturity estimates and decreased growth rate estimates. These revisions suggest the Wood et al. (1979) estimate of *r* was too high. In addition to estimating *r* for a northeast Atlantic population, Smith et al. (1998) provided estimates for spiny dogfish in British Columbia. They estimated *r* = 0.017 if natural mortality was density dependent and r = 0.023 if fecundity and natural mortality were density dependent. Taylor and Gallucci (2009) estimated an upper bound for *r* of 0.092 based on the population growth that would occur if there was zero natural mortality in conjunction with demographic parameters for spiny dogfish in the northeast Pacific derived from age estimates using current ageing methods. This estimate was calculated from a Leslie matrix model, in which survival is set to 100% for all ages. That is, if all spiny dogfish live forever the population would still only grow at about 9% per year given the best estimates of fecundity and age at maturity. This value of *r* is not a plausible estimate, since spiny dogfish do not live forever, but it represents an absolute outer limit of population growth rate and suggests that suitable *r* selected must be below 0.092.

Gulf of Alaska

A Pella-Tomlinson model for a Gulf of Alaska population (Rice and Gallucci, 2009) using commercial catch data, estimated *r* values with associated *K* and *MSY*. The catch per unit effort data were more variable than in this current assessment, since the data were bycatch data where skippers did not target spiny dogfish and no 60% filter was applied. Maximum likelihood estimates of *r* ranged between 0.02 and 0.53 (with CVs ranging from 0.02 – 0.53). Bayes estimates varied 0.03< *r* < 0.04 and 0. 52<CV<0.53. Based on the wide range produced by the maximum likelihood estimates, and their large range of CVs, the Bayes estimates are probably more reasonable. In addition the *K* values (1.2-1.8 million tonnes) and the *MSY* values (20,000 – 30,000 tonnes) produced by the Bayesian approach were also more reasonable, suggesting the Bayes estimates of *r* are also reasonable.

Based on the range of estimates of *r* listed above, we chose the following values to insert in the model to evaluate the consequences of *r* values over a reasonable range, when combined with ranges of the other parameters: a low value of 0.017 (Smith et al., 1998), a high value of 0.07 (Pawson, 2009), and an intermediate value of 0.043 (the mean of these two values).

A Range of Estimates of *K* (carrying capacity)

Ketchen (1969) estimated a biomass of 300,000 – 500,000 tonnes of marketable fish at the start of the great liver fishery of the 1940s. This range of estimates were for all of the northeast Pacific, including Puget Sound, Washington coast and Oregon. Wood et al. (1979) assumed half of these biomass estimates applied to spiny dogfish in British Columbia waters i.e. 150,000 – 250,000 tonnes, with one third of British Columbia estimates assigned to the inside stock and two thirds to the outside stock.

Based on the above, we selected a two maximum *K* values (high and low) each for the inside and outside stocks and used these in the maximum likelihood estimation as upper bounds. The high upper bounds for the optimization were based only on the highest estimate from Ketchen (1969) i.e. 500,000 tonnes with one third (166,667 tonnes) for the inside stock and two thirds (333,333 tonnes) for the outside stock. The low upper bounds for the optimization were based on the lowest estimate from Wood et al. (1979) partitioning i.e. 150,000 tonnes, again with one third (50,000 tonnes) for the inside stock and two thirds (100,000 tonnes) for the outside stock.

However, initial model runs with these low upper bounds resulted in spiny dogfish population trajectories that crashed under historical catch history so these values (50,000 tonnes for the inside stock and 100,000 tonnes for the outside stock) were not investigated further. The model runs used in this assessment either estimated *K*, or used 166,667 tonnes (inside stock) and 333,333 tonnes (outside stock) as an upper restraint for *K*.

A Range of Estimates of *m* (shape parameter)

There is a series of papers (Prager, 2002; Maunder, 2003) that address the choice of *m* for the generalized Pella-Tomlinson model. Prager argues that unless there is a compelling reason not to use the Schaefer model (m = 1), it is the preferred model. Maunder argues the opposite, i.e. that alternative value of *m* should be used when it results in better model fit. This issue is further addressed in Rice (2007) from which it was concluded that the value of 3 was an appropriate choice. Therefore, for completeness and because the choice of *m* makes a huge difference in the MSY estimated by the model, this report uses both m = 1 and m = 3.

RESULTS

For the inside and outside stocks, 16 model runs each were completed (Tables 15 and 16) with runs 1-8 setting the *K* value to the high upper bound described above (K=166,667 tonnes for the inside stock; K=333,333 tonnes) and runs 9-16 allowing the model to estimate *K*. Within each suite of model runs (*K* set to upper bound; *K* estimated), *r* was set to 0.017, 0.043 or 0.07 and was also estimated by both types of surplus production models (m=1 for Schaefer; m=3 for Pella Tomlinson). The inside stock model estimates for *K* (runs 9-16, Table 15) ranged from 76, 267 tonnes to 166,667 tonnes. The outside stock model estimates for *K* (runs 9-16, Table 16) were all constrained by the upper bound i.e. all estimates were 333,333 tonnes. The inside and the outside stock model runs that estimated *r* values did produce values that were equal to the upper constraints 0.017 (runs 8) and 0.07 (runs 15 and 16). When the constraint was set to 0.043, the Schaefer model (m=1) estimated r = 0.024 for both the inside stock (run 7, Table 15) and the outside stock (run 7, Table 16). The magnitude of the negative log likelihood values are larger for the outside stock models (Table 16) than for the inside stock model (Table 15) because there are more data for the outside stock for the model to fit. All the estimated model fits for the outside stock have a similar negative log likelihood value, illustrating that regardless of r parameter estimates, the stock is basically constant at the carrying capacity. The model fits for the inside stock have varying negative log likelihood values illustrating that the models for this stock depend more heavily on the parameter estimates.

The current biomass (B_{2009}) estimated for the inside stock ranges from 18,193 tonnes (runs 14 and 16) to 161,279 tonnes (run 6) which corresponds to 24% and 97% respectively of the runs' initial biomass (*K*) (Table 15). Estimates of maximum sustainable yield (MSY) ranged from 708 tonnes (runs 3 and 11) with associated F_{MSY} of 0.009 to 5,512 tonnes (run 6) with associated F_{MSY} of 0.054 (Table 15). The proportion of current biomass (B_{2009}) to biomass at maximum sustainable yield (B_{MSY}) ranged from 38% (run 16) to 172% (run 5).

The current biomass (B_{2009}) estimated for the outside stock ranges from 210,063 tonnes (runs 3 and 11) to 318,841 tonnes (runs 6, 14 and 16) which corresponds to 63% and 96% respectively of the runs' initial biomass (*K*) (Table 16). Estimates of maximum sustainable yield (MSY) ranged from 1,417 tonnes (runs 3 and 11) with associated F_{MSY} of 0.009 to 11,024 tonnes (runs 6, 14 and 16) with associated F_{MSY} of 0.054 (Table 16). The proportion of current biomass

(B_{2009}) to biomass at maximum sustainable yield (B_{MSY}) ranged from 126% (runs 3 and 11) to 178% (runs 5, 13 and 15).

SELECTION OF MODEL RUNS

A range of model runs have been provided for both stocks, with varying parameter values for *r*, *K* and *m*. We propose that appropriate model runs are those informed by the input data to produce estimates of *K* (runs 9-16). Since a relatively large range of *r* values were reported in the literature with no clear indication of which end of the range to select, we suggest that the intermediate *r* value be considered (runs 9 and 10). Taylor and Gallucci, 2009) noted that demographic parameters such as growth and fecundity of spiny dogfish changed significantly over a 60 year period, most likely as a response to density dependence. While the surplus production model here does not specifically employ these demographic parameters, it will have an impact on population growth (*r*). In lieu of estimating how *r* may vary overtime, given changes in density, it is reasonable to select an intermediate *r* value from available estimates. For both the inside and outside stocks, we only consider further these two runs (9 and 10; Tables 15 and 16).

Figures 7 and 8 show the model fits for runs 9 and 10 to the indices of abundance (CPUE) that were used for the inside and outside stocks, and residuals are plotted in Figures 9 and 10. In each plot the estimated annual biomass is multiplied by the catchability coefficient (*q*) associated with each index. The spiny dogfish longline survey and the longline CPUE indices for the inside stock had reasonable fits, with the majority of years with fits within the 95% CI of the annual index value. The indices of abundance used to fit the inside stock model contain opposite signals: the DFO spiny dogfish survey does show an increase, on average, from the 1980s to the 2000s; and both the trawl and longline commercial fisheries (after correction for circle hooks), show a slight decline, on average. The larger number of data points in these fishery-dependent data sources give them more weight than the 4 data points of DFO fishery-independent survey so the model fits a slight decline. Model reliance on fishery-dependent indices of abundance does not account for any changes in fishing patterns that might impact catch rate or the gear change standardization.

<u>Biomass Trajectories of Selected Model Runs</u>

Biomass trajectories (tonnes) for model runs 9 and 10 for the inside stock are at the lower range of biomass estimates produced across all model runs (Figure 11). Model run 16 (r=0.07, m=3, K=76,267) produced the lowest current biomass estimate (B_{2009}=18,193; Table 15) and the biomass trajectories produced by model runs 9 and 10 are similar. It is interesting to note, that the only difference between model run 16 which produces the lowest current biomass estimate and model run 6 (r=0.07, m=3, K=166,667) which produces the highest current biomass estimate is the carrying capacity, or starting biomass value. All population trajectories declined sharply from 1935-1945 (Figure 11), reflecting the high exploitation of the liver fishery, with particularly high landings from 1941-1943 (Table 2). Model runs 9, 10 and 16 estimate population trajectories that remain relatively stable since 1945, while model run 16 estimates a rebound in the population to levels similar to 1935 (Figure 11).

It is important to note that the model runs that we recommend do not suggest that the recent fishery has caused any significant declines in the inside stock. Rather the very large liver fishery of the 1940s decreased the population down to approximately 35% of it's initial abundance. It is the slow rate of growth of the spiny dogfish, coupled with low to moderate exploitation that has since then kept the population from reaching historic estimates of abundance. There are processes that could not be included in the model that would result in underestimating abundance since the liver fishery, including any migration into the Strait of Georgia and recruitment of juvenile spiny dogfish to the mature portion of population after being unsusceptible to the liver fishery.

The biomass trajectory for the outside stock based on model run 9 (Figure 11) lies midway between the trajectory for model run 11 (r=0.017, m=1, K=333,333) which produced the lowest current biomass estimate (B_{2009}=210,063; Table 16) and the trajectory for model run 6 (r=0.07, m=3, K=333,333) which produced the highest current biomass estimate (B_{2009}=318,841; Table 16). The biomass trajectory for model run 10 was at the upper range, similar to model run 6 (Figure 11). Since model runs that estimated K all produced estimates that limited by the constraint of 333,333 tonnes, the biomass trajectories for all model runs have the initial starting biomass and remain similar to about 1945, when biomass estimates start to diverge, but all dramatically decline (Figure 11). These signals in the biomass trajectories are the response to the pulse of extremely high exploitation of the outside stock from 1940-1949 when landings were estimated to range between 10,730 to 33,131 tonnes (Table 2). When this pressure was reduced in 1950, the biomass trajectory of model run 11 remained stable and low over the remaining 58 years, while the model runs with higher r values (i.e. model runs 6, 9 and 10) eventually estimated higher biomasses that were similar to the starting K value (Figure 11).

Yield Curves of Selected Model Runs

Model run 9 (m=1) produces the symmetrical Schaefer yield vs. biomass curve, while model run 10 (m=3) produces the right-skewed Pella-Tomlinson curve (Figure 12). For both the inside stock and the outside stock, model run 10 estimates a higher maximum sustainable yield than model run 9 (Figure 12). For the inside stock, the *MSY* for model run 10 is 1.5 times higher than for model run 9 but the biomass estimates associated with these yields (B_{MSY}) are virtually equal. For the outside stock, the *MSY* for model run 10 is almost twice that of model run 9, and the B_{MSY} is 1.25 times higher (Figure 12).

For both stocks model run 6 (r=0.07; m=3, K=166,667 or 333,333) produced the highest *MSY* estimate and model run 11 (r=0.017; m=1; K=166,667 or 333,333) produced the lowest. Figure 12 illustrates that across the range of model runs, the range *MSY* and B_{MSY} estimates for the inside stock were not large, albeit the difference between the lowest *MSY* (708 tonnes) and the highest *MSY* (5,512 tonnes) is almost 8 fold. The range of *MSY* and B_{MSY} estimates produced for the outside stock did vary greatly across model runs, with a difference of over 9,500 tonnes between the lowest *MSY* and the highest *MSY* estimate (Figure 12). The range of B_{MSY} associated with these estimates only differed by approximately 50,000 tonnes (Figure 12).

The yield curves for the outside stock illustrate the impact of the selection of r on estimates of *MSY*. Model runs 9 and 11 have the same shape parameter (m=1) but model run 9 has a higher r estimate (0.043 vs. 0.017 for model run 11), and hence its estimate of *MSY* is almost double that of model run 11 at similar estimates of B_{MSY} (Figure 12). The same can be said for model runs 10 and 6 (m=3). Model run 6 has a higher r estimate (0.07 vs. 0.043 for model run 10), and at similar estimates of B_{MSY}, model run 6 has a *MSY* estimate that is 1.6 times higher (Figure 12).

STOCK STATUS, HARVEST LEVELS AND ASSOCIATED YIELD

The DFO national policy within the Sustainable Fisheries Framework outlines a Fishery Decision-making Framework Incorporating the Precautionary Approach (http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/precaution-eng.htm). This framework requires the definition of stock status zones (Healthy, Cautious and Critical) based on reference points, where the boundary between Healthy and Cautious is defined by an Upper Stock Reference, and the boundary between Cautious and Critical is defined by a Limit Reference Point (DFO, 2006a). Within the Healthy zone, the Removal Reference, or the maximum acceptable harvest rate, can be applied. In the Cautious zone (i.e. the stock level is below the Upper Stock Reference), the harvest rate is reduced and should progressively decrease as the stock level approaches the Limit Reference Point (i.e. enters the Critical zone). Within the Cautious zone, fisheries management actions should promote rebuilding to the Healthy zone. If the stock level is below the Limit Reference Point, productivity is considered to be sufficiently impaired to cause serious harm due to over-fishing, other human induced mortality, or changes in population dynamics not related to fishing. In the Critical zone harvest levels must be kept in the lowest possible level and fishery management actions must promote stock growth.

Annex 1B of the Fishery Decision-making Framework Incorporating the Precautionary Approach outlines reference points and that may be considered as the best available guidance for management and for assessing the stock when there is insufficient stock-specific information available to develop them. Biomass estimates from the surplus production models can be linked to the suggested reference points for assessing the current status spiny dogfish stocks:

- Upper Stock Reference Point: Biomass=80% of B_{MSY}
- Limit Reference Point: Biomass=40% of B_{MSY}

These reference points mean that stocks are assessed as in the Healthy zone if current biomass estimates are greater than $0.8 \cdot B_{MSY}$, in the Cautious zone if current biomass estimates are between $0.8 \cdot B_{MSY}$ and $0.4 \cdot B_{MSY}$, and in the Critical zone if current biomass estimates are below $0.4 \cdot B_{MSY}$. Furthermore, when there is no pre-agreed harvest rule developed in the context of the precautionary approach, Annex 1b also provides guidance on a provisional Removal Reference (i.e. harvest rate or fishing mortality, F_{LIMIT}) to apply within each stock status zone:

- When the stock is in the Healthy zone: $F_{LIMIT} < F_{MSY}$
- When the stock is in the Cautious zone:
  $F_{LIMIT} < F_{MSY}$ x [(Biomass – 40% B_{MSY}) / (80% B_{MSY} − 40% B_{MSY})]
- When the stock is in the Critical zone: F_{LIMIT}=0.

The surplus production models employed in this current stock assessment calculate F_{MSY} in Equation 11. The F_{LIMIT} values defined above were used to calculate associated Yield limits (Y_{LIMIT}) with the relationship between biomass, yield and fishing mortality defined in Equation 10, such that:

$$Y_{LIMIT} = B_{2009} \cdot \left(1 - e^{-F_{LIMIT}}\right) \qquad (21)$$

Alternatively for stocks that appear to be stable (based on relative abundance indices), if biomass or MSY estimates based on model results are not used, historical fishing mortality could be used as yields limits. Since recent food fishery for spiny dogfish began in 1978, these yield limits should be based on average total fishing mortality (landings and discard mortality) for

1978-2008. This timeframe is close to one generation time. For the inside stock, that average total mortality from 1978-2008 is 1,599 tonnes (Table 7). For the outside stock, that average total mortality from 1978-2008 is 1,690 tonnes (Table 8).

INSIDE STOCK

Model run 9 estimates the current biomass as 37,752 tonnes, which is 65% of the B_{MSY} estimate of 58,370 tonnes (Table 17). The inside stock appears to be in the Cautious zone and the recommended *F* should be lower than F_{MSY} x [($Biomass_{2009}$ – 40% B_{MSY}) / (80% B_{MSY} − 40% B_{MSY})], or 0.014 (Table 17). The yield associated with this limit (Y_{LIMIT}) is 525 tonnes (Table 17). Model run 10 estimates the current biomass as 28,057 tonnes, which is 47% of the B_{MSY} estimate of 59,077 tonnes (Table 17). The inside stock appears to be in the Cautious zone and the recommended *F* should be lower than F_{MSY} x [($Biomass_{2009}$ – 40% B_{MSY}) / (80% B_{MSY} − 40% B_{MSY})], or 0.006 (Table 17). The yield associated with this limit (Y_{LIMIT}) is 168 tonnes (Table 17).

Alternate annual yields for the inside stock based on proportions of F_{MSY} as the harvest rates for the current biomass estimated by runs 9 and 10 are:

Run 9				Run 10		
Proportion of F_{MSY}	Harvest rate	Yield (tonnes)		Proportion of F_{MSY}	Harvest rate	Yield (tonnes)
1	0.022	821		1	0.033	911
0.9	0.02	748		0.9	0.03	829
0.8	0.018	673		0.8	0.026	720
0.7	0.015	562		0.7	0.023	638
0.69	0.015	562		0.6	0.02	556
0.68	0.015	562		0.5	0.017	473
0.67	0.015	562		0.4	0.013	362
0.66	0.015	562		0.3	0.01	279
0.65	0.014	525		0.2	0.007	196
0.64	0.014	525		**0.19**	**0.006**	**168**
0.63	0.014	525		0.18	0.006	168
0.62	0.014	525		0.17	0.006	168
0.61	**0.013**	**488**		0.16	0.005	140
0.6	0.013	488		0.15	0.005	140
0.5	0.011	413		0.14	0.005	140
0.4	0.009	338		0.13	0.004	112
0.3	0.007	263		0.12	0.004	112
0.2	0.004	151		0.11	0.004	112
0.1	0.002	75		0.1	0.003	84

The numbers in bold denote values at which the harvest rate drops below the F_{LIMIT} suggested for each model run.

Additional Considerations

Longline survey catch per unit effort

A spiny dogfish longline survey was conducted in the Strait of Georgia to assess the trends in relative abundance of the inside stock in 1986, 1989, 2005 and 2008 (McFarlane et al., 2005b; McFarlane et al., 2005c; King and McFarlane, 2009a). In all four surveys, three depth strata were sampled at each of ten sites throughout the Strait: 56-110m, 111-165 m and 166-220 m. These data were included as an index of relative abundance in the inside stock model runs. King and McFarlane (2009b) examined the trends in abundance from 1986, 1989 and 2005 surveys and determined that there was a significant difference in annual median CPUE (Kruskal-Wallis ANOVA: $F_{0.05(1),2,87} = 18.03$; $P < 0.001$; $n = 90$). Bonferroni corrected comparison of mean ranks determined that the median CPUE was higher in 2005 than the other two years (King and McFarlane 2009b). An updated similar analyses with 2008 data included produced similar results with a significant difference in annual median CPUE (Kruskal-Wallis ANOVA: $F_{0.05(1),3,116}= 12.20$; $P < 0.001$; $n = 120$). Bonferroni corrected comparison of mean ranks determined that the median CPUE was higher in 2005 than the other three years (Figure 13). These data support King and McFarlane's (2009b) conclusion there is no evidence that the relative abundance of spiny dogfish has declined in the Strait of Georgia over the last 20 years. From 1986-2006 the mean annual spiny dogfish landings (longline and trawl fisheries) for the inside stock was 947 tonnes (Tables 3 and 4). Recall that in 2007 and 2008, the inside longline commercial fleet reduced its targeted effort for spiny dogfish in the Strait of Georgia due to increased financial costs of obtaining quota for bycatch species (primarily rockfish), so these years were not included in the 20 year mean. This longterm mean annual removal, coupled with no evidence of a decline in the relative abundance as measured by the longline survey, suggests that annual removals of 947 tonnes have not negatively impacted the inside stock. If these surveys continue in the future, they may be expected to provide better information on changes in abundance. Continuance of these surveys should be a high priority.

Commercial and research length data

Biological data were not included in the surplus production model, but commercial and research length data have been collected and were reported in King and McFarlane (2009b). 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. For 1975-1979, 41 fishing trips were sampled; for 1980-1984 only 10 fishing trips were sampled; 1985-1999 no fishing trips were sampled; 2000-2004 24 fishing trips were sampled (King and McFarlane, 2009b). 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 that 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 (McFarlane et al. 2005b, 2005c), 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 (King and McFarlane 2009b; Figure 14). 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 14). A modal length for females was not as pronounced (Figure 14). The frequency distribution of female spiny dogfish exhibited two characteristics overtime: 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 14). 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 2009b). There is need to monitor the potential decrease in large females (>100 cm), and a planned survey in 2011 will provide additional information.

These additional considerations suggest that over the past 25 years, the inside stock population has been stable, with a potential increase in recruitment of juvenile fish to the bottom habitat.

OUTSIDE STOCK

Model run 9 estimates the current biomass as 274,106 tonnes, which is 164% of the B_{MSY} estimate of 166,667 tonnes (Table 18). The outside stock appears to be in the Healthy zone and the recommended F should be lower than F_{MSY} or 0.022 (Table 18). The yield associated with this limit (Y_{LIMIT}) is 5,964 tonnes (Table 18). Model run 10 estimates the current biomass as 310,730 tonnes, which is 148% of the B_{MSY} estimate of 209,987 tonnes (Table 18). The outside stock appears to be in the Healthy zone and the recommended F should be lower than F_{MSY} or 0.033 (Table 18). The yield associated with this limit (Y_{LIMIT}) is 10,087 tonnes (Table 18).

Alternate annual yields for the outside stock based on proportions of F_{MSY} as the harvest rates are:

Run 9				Run 10		
Proportion of F_{MSY}	Harvest rate	Yield (tonnes)		Proportion of F_{MSY}	Harvest rate	Yield (tonnes)
1	0.022	5964		1	0.033	10087
0.99	0.022	5964		0.99	0.033	10087
0.98	0.022	5964		**0.98**	**0.032**	**9786**
0.97	**0.021**	**5696**		0.97	0.032	9786
0.96	0.021	5696		0.96	0.032	9786
0.95	0.021	5696		0.95	0.031	9485
0.94	0.021	5696		0.94	0.031	9485
0.93	0.02	5428		0.93	0.031	9485
0.92	0.02	5428		0.92	0.03	9183
0.91	0.02	5428		0.91	0.03	9183
0.9	0.02	5428		0.9	0.03	9183
0.8	0.018	4890		0.8	0.026	7975
0.7	0.015	4081		0.7	0.023	7065
0.6	0.013	3540		0.6	0.02	6153
0.5	0.011	2999		0.5	0.017	5238
0.4	0.009	2456		0.4	0.013	4013
0.3	0.007	1912		0.3	0.01	3092
0.2	0.004	1094		0.2	0.007	2168
0.1	0.002	548		0.1	0.003	931

The numbers in bold denote values at which the harvest rate drops below the F_{LIMIT} suggested for each model run.

Additional Considerations

There are limited amounts of length data available from landed spiny dogfish (data from GFBio). Data were only available for the 7 trips in 1980s (1980, 1984, 1985, 1987), a single trip in the 1990s (in 1991) and only two trips in recent years (one in 2002 and one in 2003). More trips were sampled in the trawl fishery for landed spiny dogfish with 8 trips sampled in the 1970s (from 1973; 1977-1979), 11 trips sampled in the 1980s (from 1981; 1984-1985; 1987), 20 trips sampled in the 1990s (from 1996-1999) and 11 trips sampled from 2000-2002 (data from GFBio). A shift in the size distribution of females in the trawl fishery is most evident from the 1970s and 1980s to the 1990s when the model length for females shift from the 95-105 cm range to the 60-65 cm range (Figure 15). However, as previously noted a market demand for smaller sized fish began in the 1990s and is likely an large influence on the size of landed spiny dogfish. Caution should be taken in interpreting these size frequency distributions.

There is no directed survey for spiny dogfish on the outside stock. However, one of the time series used in this assessment as an index of relative abundance is the DFO Hecate Strait bottom trawl survey (Table 12). Length data were available for the 1980s (from 1984; 1987; 1989), the 1990s (from 1991; 1993; 1998) and from the last decade (from 2000; 2002; 2003). The mean size of males has decreased from 71.64 cm in the 1980s to 64.4 cm in the last decade; the mean size of females has decreased from 78.1 cm to 67.38 cm during the same time period. There has been a dramatic loss of females greater than 85 cm in the frequency distribution (Figure 16).

CONCLUSIONS

INSIDE STOCK

The inside stock appears to be stable, although the status of the stock varies greatly between model runs and is therefore linked to selection of model parameters. If the yield advice is selected from the surplus production models recommended above, the yield limits are 168 tonnes (Pella-Tomlinson) and 525 tonnes (Schaefer). Both models classify the status of the stock as Cautious. If the yield advice is not selected from the estimates provided from the surplus production models, the longterm mean annual estimated total fishing mortality from 1978-2008 could be used as a yield limit and is 1,599 tonnes. Continuation of the longline spiny dogfish survey on the inside stock should be a high science priority to monitor the ongoing stability of this population and to monitor the size distribution.

OUTSIDE STOCK

All model runs for the outside stock suggest that this stock is in the Healthy zone. If the yield advice is selected from the surplus production models recommended above, the yield limits are 5,964 tonnes (Schaefer) and 10,087 tonnes (Pella-Tomlinson). If yield advice is not selected from the surplus production models, then longterm mean annual estimated total fishing mortality from 1978-2008 (1,690 tonnes) could be used as a yield limit. This level of exploitation has not negatively impacted the population status of the outside stock. Based on the change in size distribution in the Hecate Strait bottom trawl research survey, a high priority be placed on the collection of spiny dogfish size data in groundfish bottom trawl surveys in all areas throughout British Columbia.

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Table 1. Spiny dogfish total allowable catch (TAC) limits (in tonnes) by area from 1979-2008 for trawl, longline/trap, and all sectors combined, with assessment advice on which the annual TACs were based. It is important to note that the assessment advice for the inside stock (Area 4B) included Puget Sound and advice for the outside stock (Areas 3CD, 5AB, and 5CDE) included Gulf of Alaska, Washington, Oregon and California waters.

Year	Area	TAC			Assessment Advice	Assessment
		All gear	Longline	Trawl		
2005-2008	Inside stock	3,000	2,040	960	Low Risk: 2,000 tonnes; High Risk: 3,000 tonnes	Saunders (1989)
	Outside stock	12,000	8,160	3,840	Low Risk: 15,000 tonnes; High Risk: 25,000 tonnes	
	Coastwide total	15,000	10,200	**4800**†		
1997-2004	Inside stock	5,000	3,400	1,600	Low Risk: 2,000 tonnes; High Risk: 3,000 tonnes	Saunders (1989)
	Outside stock	11,940	8,100	3,840	Low Risk: 15,000 tonnes; High Risk: 25,000 tonnes	
	Coastwide total	16,940	11,500	5,440		
1996	Inside stock	**5000**‡	-	-	Low Risk: 2,000 tonnes; High Risk: 3,000 tonnes	Saunders (1989)
	Outside stock	12,000	-	-	Low Risk: 15,000 tonnes; High Risk: 25,000 tonnes	
	Coastwide total	17,000	-	-		
1994-1995	Inside stock	2,500	-	-	Low Risk: 2,000 tonnes; High Risk: 3,000 tonnes	Saunders (1989)
	Outside stock	12,000	-	-	Low Risk: 15,000 tonnes; High Risk: 25,000 tonnes	
	Coastwide total	14,500	-	-		
1979-1993	Inside stock	3,000	-	-	Low Risk: 2,000 tonnes; High Risk: 3,000 tonnes	Ketchen (1980)
	Outside stock	15,000	-	-	Low Risk: 15,000 tonnes; High Risk: 25,000 tonnes	Wood et al. (1979)
	Coastwide total	18,000	-	-		Saunders et al. (1989)

†in the 2005 Groundfish IMFP, the coastwide total is erroneously written as 5,440 tonnes instead of 4,800 tonnes
‡ a typo, in which the TAC for Area 4B was inadvertently reported as 5,000 tonnes instead of 2,500 tonnes

Table 2. Annual landings (tonnes) of spiny dogfish estimated from Ketchen (1986) Appendices 6 and 9. Landings are for all gear types. Total landings, are all landings reported, including those that were not assigned to an Area by Ketchen (1986) and the proportion of these that were not assigned by Ketchen (1986) to an Area is included. From 1954-1965, the landings are estimated from landed liver weights (tonnes) as per Ketchen (1986). The inside stock is comprised of Area 4B. The outside stock is comprised of Areas 3CD, 5AB, 5CDE.

	Inside stock	Outside stock					
Year	4B	3CD	5AB	5CDE	Total	Total landings	Proportion (%) not assigned
1935	3484	0	0	0	0	3484	0
1936	5268	0	0	0	0	5268	0
1937	5135	0	0	410	410	5545	0
1938	7617	0	0	23	23	7640	4.9
1939	4590	0	0	549	549	5139	2
1940	7744	0	0	1046	1046	8790	23.4
1941	11473	0	0	2492	2492	13965	46.5
1942	10075	0	0	6952	6952	17027	54.8
1943	12884	0	0	7683	7683	20567	72.2
1944	4097	2067	0	25023	27090	31187	73.1
1945	1014	2374	0	19985	22359	23373	48.4
1946	1000	2784	846	6787	10417	11417	34.2
1947	1763	1650	3108	8568	13326	15089	57.6
1948	1375	2137	3399	5267	10803	12178	71
1949	2819	3400	3765	6026	13191	16010	81.9
1950	1037	588	400	188	1176	2213	69.7
1951	1460	863	1451	226	2540	4000	66.9
1952	1602	758	648	45	1451	3053	60.2
1953	1517	1003	514	81	1598	3115	56.6
1954	1847	363	9	301	673	2522	0
1955	1708	310	80	522	912	2620	0
1956	416	62	27	620	709	1125	0
1957	1115	558	80	726	1364	2479	0
1958	991	186	62	372	620	1611	0
1959	4991	637	89	681	1407	6398	0
1960	3434	71	80	779	930	4364	0
1961	2230	3071	62	558	3691	5921	0
1962	280	106	2	19	127	407	0
1963	152	57	1	10	68	221	0
1964	982	0	0	0	0	982	0
1965	248	0	9	0	0	257	0

Table 3. Annual landings (tonnes) of spiny dogfish from longline fisheries 1966-2008 by Statistical Area.

	Inside stock	Outside stock					
Year	4B	3CD	5AB	5CDE	Total	Unknown area	Total landings
1966	270		6		6		276
1967	398						398
1968	263						263
1969							
1970							
1971	29						29
1972	15	1			1		16
1973	1715						1715
1974	362						362
1975	145						145
1976	71						71
1977	500	9			9		509
1978	2111	50			50		2161
1979	3452				37		3452
1980	1541				134		1541
1981	550				32		550
1982	839				86		839
1983	861				173		861
1984	2232				76		2232
1985	483				476		483
1986	139				184		139
1987	598				1659		598
1988	702				2666		723
1989	511				1227		511
1990	468				1426		495
1991	383				1716		383
1992	275				1541		275
1993	343	213	27	73	313		343
1994	627	694	125	58	877		627
1995	1017	929	80	95	1104		1023
1996	1748	2	1	2	5	1534	3287
1997	1069			2	2	646	1717
1998	1169	21		11	32	1093	2294
1999	1074	1220	32	344	1596	43	2713
2000	808	2459	97	582	3138		3946
2001	701	2654	22	70	2746	1	3448
2002	1388	2284	37	227	2548		3936
2003	1544	2692	149	503	3344	64	4952
2004	1351	3157	155	205	3517		4868
2005	1145	2914	122	175	3211		4356
2006	554	1321	124	57	1502	30	2086
2007	737	2786	74	61	2921	30	3688
2008	514	1194	72	43	1309	6	1829

Table 4. Annual landings (tonnes) of spiny dogfish in trawl fisheries 1966-2008 by Statistical Area.

	Inside stock	Outside stock					
Year	4B	3CD	5AB	5CDE	Total	Unknown area	Total landings
1966	163						163
1967	56						56
1968	29						29
1969	1						1
1970	130	4			4		134
1971	118						118
1972	76	8			8		84
1973	1251		2	711	714		1965
1974	307	12			13		320
1975	447	17		1	19		466
1976	82			3	3		85
1977	658	67	13		80		738
1978	722	163	28	30	221		943
1979	4335	300	16	104	419		4755
1980	2105	1873	162	405	2440		4545
1981	764	311	25	51	387		1151
1982	1259	973	69	277	1320		2578
1983	1271	597	24	19	641		1911
1984	1894	458	107	88	653		2547
1985	862	1499	451	7	1958		2820
1986	480	1935	178	22	2135		2615
1987	368	1001	67	3	1072		1440
1988	221	1660	86	2	1748		1969
1989	152	842	30	3	875		1027
1990	109	1249	24	9	1282		1391
1991	103	889	28		917		1020
1992	110	439	4	25	468		577
1993	19	68			68		88
1994	49	123	8	8	138		188
1995	111	197	17	5	219		330
1996	152	225	1	11	237	80	468
1997	69	18	10		29	174	273
1998	5	144	1	23	169	86	261
1999	103	37	3	1	41	216	360
2000	49	93	1	1	96	16	161
2001	22	341	2	4	346	93	460
2002	16	522	39	1	562	140	718
2003	33	624	76	1	701	51	785
2004	71	373		2	375	165	611
2005	22	710	8	4	723	274	1018
2006	10	531	9	3	543	106	659
2007	13	438	5	3	446	56	515
2008	9	248	1	2	252	128	389

Table 5. Annual discards (tonnes) of spiny dogfish in longline fisheries 2001-2006 by Statistical Area.

	Inside stock	Outside stock					
Year	4B	3CD	5AB	5CDE	Total	Unknown area	Total discards
2001	255	1	5		6	88	349
2002	218	19	3		22	52	291
2003	385	87	5	8	100	72	558
2004	199	13	5		19	75	293
2005	323	25	7		32	122	477
2006	94					3	98

Table 6. *Annual discards (tonnes) of spiny dogfish in trawl fisheries 1966-2008 by Statistical Area.*

	Inside stock	Outside stock				
Year	4B	3CD	5AB	5CDE	Total	Total discards
1966	3	87	2	163	251	255
1967	114	137		200	337	452
1968	56	42	14	42	97	153
1969	147	23		55	78	225
1970	80	17	18	161	197	277
1971	240	50	2	236	288	528
1972	1	13	18	14	45	47
1973		254	80	33	368	368
1974	160	22	3	68	94	254
1975	149	567		832	1399	1548
1976						
1977	116	299	9	929	1236	1353
1978	174	352	159	815	1325	1500
1979	322	543	171	601	1316	1638
1980	285	772	296	1122	2190	2475
1981	172	472	331	669	1472	1644
1982	69	706	286	841	1834	1902
1983	8	419	241	377	1037	1045
1984	6	418	73	580	1072	1078
1985	10	429	283	554	1266	1275
1986	34	153	215	319	687	721
1987	126	201	174	863	1239	1364
1988	71	305	260	745	1310	1381
1989	79	449	100	728	1277	1356
1990	39	432	362	883	1677	1717
1991	27	840	174	855	1869	1896
1992	98	805	328	765	1898	1995
1993	42	517	287	793	1597	1639
1994	56	529	272	662	1463	1518
1995	29	335	238	357	931	960
1996	64	609	407	648	1663	1727
1997	1	264	365	472	1101	1102
1998	24	359	516	687	1562	1586
1999	3	251	182	515	948	951
2000	7	313	392	426	1131	1138
2001	12	193	239	397	828	840
2002	13	249	330	291	869	883
2003	22	146	142	499	787	809
2004	70	185	256	737	1178	1248
2005	114	100	183	956	1239	1354
2006	165	102	197	507	807	971
2007	190	78	149	729	956	1146
2008	97	69	81	745	894	991

Table 7. Total estimated fishing mortality (tonnes) for the inside stock (Area 4B). Landings (tonnes) based on data from Tables 1-3 and estimates for missing years or unknown area allocation provided in text. Discard mortality (tonnes) is calculated for longline fisheries using a 6% discard mortality rate applied to discards (tonnes). Discard mortality (tonnes) is calculated for trawl fisheries by applying the calculated annual weighted average discard mortality rate to discards (tonnes). See text for estimates of missing years.

		Trawl			Longline		
Year	Total landings	Discards	Discard mortality rate	Discard mortality	Discards	Discard mortality	Total mortality
1935	3484						3484
1936	5268						5268
1937	5135						5135
1938	7617						7617
1939	4590						4590
1940	7744						7744
1941	11473						11473
1942	10075						10075
1943	12884						12884
1944	4097						4097
1945	1014						1014
1946	1000						1000
1947	1763						1763
1948	1375						1375
1949	2819						2819
1950	1037						1037
1951	1460						1460
1952	1602						1602
1953	1517						1517
1955	1708						1708
1956	416						416
1957	1115						1115
1958	991						991
1959	4991						4991
1960	3434						3434
1961	2230						2230
1962	280						280
1963	152						152
1964	982						982
1965	248						248
1966	433	3	6.2%	0.2	61	3.7	437
1967	454	114	6.2%	7.1	90	5.4	466
1968	292	56	6.2%	3.5	60	3.6	299
1969	1	147	6.2%	9.1	0	0.0	10
1970	130	80	6.2%	5.0	0	0.0	135
Table continued on next page							

Table 7 continued.

		Trawl			Longline		
Year	Total landings	Discards	Discard mortality rate	Discard mortality	Discards	Discard mortality	Total mortality
1971	147	240	6.2%	14.9	7	0.4	162
1972	91	1	6.2%	0.1	3	0.2	91
1973	2966	0	6.2%	0.0	389	23.4	2989
1974	669	160	6.2%	9.9	82	4.9	684
1975	592	149	6.2%	9.2	33	2.0	603
1976	153	133	6.2%	8.2	16	1.0	162
1977	1158	116	6.2%	7.2	114	6.8	1172
1978	2833	174	6.2%	10.8	479	28.8	2873
1979	7787	322	6.2%	20.0	784	47.0	7854
1980	3646	285	5.3%	15.1	350	21.0	3682
1981	1314	172	5.7%	9.8	125	7.5	1331
1982	2098	69	7.4%	5.1	190	11.4	2115
1983	2132	8	5.8%	0.5	195	11.7	2144
1984	4126	6	6.7%	0.4	507	30.4	4157
1985	1345	10	9.0%	0.9	110	6.6	1352
1986	619	34	5.0%	1.7	32	1.9	623
1987	966	126	5.8%	7.3	136	8.1	981
1988	923	71	5.7%	4.0	159	9.6	937
1989	663	79	5.5%	4.3	116	7.0	674
1990	577	39	5.5%	2.1	106	6.4	586
1991	486	27	5.3%	1.4	87	5.2	493
1992	385	98	9.5%	9.3	62	3.7	398
1993	362	42	10.1%	4.2	78	4.7	371
1994	676	56	7.0%	3.9	142	8.5	688
1995	1128	29	17.1%	5.0	231	13.9	1147
1996	2707	64	4.7%	3.0	571	34.3	2744
1997	1548	1	5.6%	0.1	316	19.0	1567
1998	1764	24	6.5%	1.6	389	23.4	1788
1999	1307	3	5.1%	0.2	249	14.9	1322
2000	865	7	7.6%	0.5	183	11.0	877
2001	770	12	5.0%	0.6	275	16.5	787
2002	1474	13	5.2%	0.7	230	13.8	1488
2003	1635	22	4.8%	1.1	401	24.1	1660
2004	1505	70	4.8%	3.4	216	13.0	1521
2005	1304	114	5.0%	5.7	351	21.0	1331
2006	632	165	4.9%	8.1	95	5.7	646
2007	793	190	7.8%	14.8	171	10.2	818
2008	590	97	17.2%	16.7	117	7.0	614

Table 8. Total estimated fishing mortality (tonnes) for the outside stock (Areas 3CD, 5AB, 5CDE). Landings (tonnes) based on data from Tables 1-3 and estimates for missing years or unknown area allocation provided in text. Discard mortality (tonnes) is calculated for longline fisheries using a 6% discard mortality rate applied to discards (tonnes). Discard mortality (tonnes) is calculated for trawl fisheries by applying the calculated annual weighted average discard mortality rate to discards (tonnes).

		Trawl			Longline		
Year	Total landings	Discards	Discard mortality rate	Discard mortality	Discards	Discard mortality	Total mortality
1935	0						0
1936	0						0
1937	410						410
1938	23						23
1939	549						549
1940	1046						1046
1941	2492						2492
1942	6952						6952
1943	7683						7683
1944	27090						27090
1945	22359						22359
1946	10417						10417
1947	13326						13326
1948	10803						10803
1949	13191						13191
1950	1176						1176
1951	2540						2540
1952	1451						1451
1953	1598						1598
1955	666						666
1956	916						916
1957	708						708
1958	1359						1359
1959	619						619
1960	1411						1411
1961	938						938
1962	3695						3695
1963	217						217
1964	119						119
1965	0						0
1966	6	251	5.80%	14.6	0	0.0	21
1967	0	337	5.80%	19.5	0	0.0	20
1968	0	97	5.80%	5.6	0	0.0	6
1969	0	78	5.80%	4.5	0	0.0	5
1970	4	197	5.80%	11.4	0	0.0	15
1971	0	288	5.80%	16.7	0	0.0	17

Table continued on next page.

Table 8 continued.

		Trawl			Longline		
Year	Total landings	Discards	Discard mortality rate	Discard mortality	Discards	Discard mortality	Total mortality
1972	9	45	5.80%	2.6	0	0.0	12
1973	714	368	5.80%	21.3	0	0.0	735
1974	13	94	5.80%	5.5	0	0.0	18
1975	19	1399	5.80%	81.1	0	0.0	100
1976	3	1318	5.80%	76.0	0	0.0	79
1977	89	1236	5.80%	71.7	0	0.0	161
1978	271	1325	5.80%	76.9	2	0.1	348
1979	419	1316	5.80%	76.3	0	0.0	495
1980	2440	2190	6.00%	131.4	0	0.0	2571
1981	387	1472	5.40%	79.5	0	0.0	466
1982	1320	1834	5.40%	99.0	0	0.0	1419
1983	641	1037	5.70%	59.1	0	0.0	700
1984	653	1072	5.30%	56.8	0	0.0	710
1985	1958	1266	6.40%	81.0	0	0.0	2039
1986	2135	687	6.20%	42.6	0	0.0	2178
1987	1072	1239	5.80%	71.9	0	0.0	1144
1988	1769	1310	5.90%	77.3	1	0.0	1846
1989	875	1277	5.80%	74.1	0	0.0	949
1990	1309	1677	7.40%	124.1	1	0.1	1433
1991	917	1869	6.60%	123.4	0	0.0	1040
1992	468	1898	7.00%	132.9	0	0.0	601
1993	68	1597	7.20%	115.0	0	0.0	183
1994	138	1463	7.10%	103.9	0	0.0	242
1995	225	931	6.40%	59.6	0	0.0	285
1996	1049	1663	5.90%	98.1	25	1.5	1149
1997	441	1101	5.50%	60.6	10	0.6	502
1998	791	1562	5.50%	85.9	19	1.1	878
1999	1767	948	5.50%	52.1	52	3.1	1822
2000	3242	1131	5.50%	62.2	100	6.0	3310
2001	3139	828	5.00%	41.4	9	0.5	3181
2002	3180	869	5.40%	46.9	24	1.4	3228
2003	4103	787	5.80%	45.6	102	6.1	4154
2004	3975	1178	5.90%	69.5	21	1.3	4045
2005	4071	1239	5.00%	62.0	36	2.2	4135
2006	2113	807	5.20%	42.0	0	0.0	2155
2007	3410	956	6.80%	65.0	94	5.6	3481
2008	1628	894	7.00%	62.6	84	5.0	1696

Table 9. Commercial longline fishery catch per unit effort (CPUE; kg per 1000 hooks) and coefficient of variance (CV) for commercial longline fisheries conducted in the inside and 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.

	Inside			Outside		
Year	CPUE	CV	Number of trips	CPUE	CV	Number of trips
1980	647	6.7%	123	--	--	--
1981	742	6.9%	73	--	--	--
1982	685	7.5%	118	--	--	--
1996	--	--	--	754	9.8%	133
1998	--	--	--	689	10.1%	73
1999	--	--	--	438	13.9%	74
2001	818	25.8%	111	500	2.3%	1721
2002	423	13.8%	127	598	3.2%	1858
2003	551	4.6%	147	518	3.5%	1540
2004	541	5.0%	98	760	3.0%	1242
2005	523	4.7%	110	785	2.7%	1055
2006	445	7.7%	65	208	12.0%	1263
2007	255	30.0%	40	644	3.4%	998
2008	312	11.1%	61	339	3.8%	678

Table 10. Commercial trawl fishery catch per unit effort (CPUE; kg per hour) and coefficient of variance (CV) for commercial longline fisheries conducted in the inside and 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.

	Inside			Outside		
Year	CPUE	CV	Number of trips	CPUE	CV	Number of trips
1996	585	27.8%	63	--	--	--
1997	383	29.4%	36	--	--	--
1998	--	--	--	1074	23.8%	31
1999	421	17.4%	105	1059	39.5%	36
2000	505	20.2%	56	1527	20.5%	47
2001	--	--	--	996	11.4%	90
2002	--	--	--	1048	10.9%	83
2003	--	--	--	1873	15.9%	77
2004	--	--	--	2003	12.5%	90
2005	--	--	--	2136	12.7%	81
2006	--	--	--	--	--	--
2007	--	--	--	5590	12.6%	45

Table 11. Spiny dogfish catch per unit effort (CPUE; kg per 1000 hooks) and coefficient of variance (CV) from the targeted spiny dogfish longline survey conducted for the inside stock.

Year	CPUE	CV	Number of sets
1986	225	0.064	36
1989	301	0.054	36
2005	411	0.052	36
2008	312	0.061	39

Table 12. Spiny dogfish catch per unit effort (CPUE; kg per hour) and coefficient of variance (CV) from the groundfish Hecate Strait (outside stock) trawl research surveys.

Year	CPUE	CV	Number of tows
1984	148.07	0.18	146
1987	190.37	0.28	85
1989	102.18	0.28	90
1991	45.49	0.32	98
1993	87.05	0.20	93
1995	46.07	0.28	102
1996	46.47	0.20	101
1998	229.45	0.39	86
2000	88.32	0.25	105
2002	64.64	0.27	93
2003	8.08	0.18	94

Table 13. Spiny dogfish catch per unit effort (CPUE; number of fish per 1000 hooks) and coefficient of variance (CV) from the International Pacific Halibut Commission longline surveys conducted in Statistical Areas 3C through 5E (outside stock).

Year	CPUE	CV	Number of sets
1998	128	0.097	128
1999	134	0.097	170
2000	105	0.102	129
2001	129	0.074	170
2002	103	0.077	170
2003	105	0.105	170
2004	88	0.124	170
2005	125	0.076	170
2006	139	0.063	170
2007	154	0.061	170
2008	106	0.091	170

Table 14. Spiny dogfish biomass estimates (kg per km^2) and coefficient of variation from the National Marine Fisheries Service groundfish bottom trawl survey that extends in Area 3CD (outside stock).

Year	Biomass	CV	Number of tows
1980	26759	0.37	12
1983	44640	0.37	20
1989	99040	0.46	77
1992	38650	0.22	21
1995	14220	0.26	9
1998	40219	0.19	31
2001	29321	0.24	23

Table 15. Model runs' results for the inside stock. Bold values indicate estimated values, which in some runs are equal to the upper constraint. In runs 1-8, the K-values are restrained at the upper bound of 166,667 tonnes and in cases 9-16 K is estimated. Values for r were 0.017, 0.043 and 0.07 (discussion in text); m =1 denotes symmetric yield vs. biomass curve (i.e. Schaefer surplus production model) and m=3 denotes an asymmetric curve (i.e. Pella Tomlinson surplus production model).

run	*r*	*K*	*m*	B_{2009}	B_{2009}/K	B_{msy}	B_{2009}/B_{msy}	*MSY*	F_{MSY}	-log likelihood
1	0.043	166667	1	117247	70%	83334	141%	1792	0.021738	111.8
2	0.043	166667	3	155982	94%	104994	149%	3386	0.032781	114.5
3	0.017	166667	1	52629	32%	83334	63%	708	0.008532	111.1
4	0.017	166667	3	98398	59%	104994	94%	1339	0.012835	102.0
5	0.07	166667	1	143676	86%	83334	172%	2917	0.035631	115.8
6	0.07	166667	3	161279	97%	104994	154%	5512	0.053926	115.4
7	**0.024**	166667	1	74885	45%	83334	90%	1017	0.012279	95.5
8	**0.017**	166667	3	98398	59%	104994	94%	1339	0.012835	102.0
9	0.043	**116739**	1	37752	32%	58370	65%	1255	0.032777	85.7
10	0.043	**93779**	3	28057	30%	59077	47%	1905	0.008532	78.8
11	0.017	**166667**	1	52629	32%	83334	63%	708	0.012832	111.1
12	0.017	**147532**	3	62673	42%	92939	67%	1185	0.035619	94.0
13	0.07	**91565**	1	22803	25%	45782	50%	1602	0.05392	73.4
14	0.07	**76267**	3	18193	24%	48045	38%	2522	0.035619	67.6
15	**0.07**	**91565**	1	22803	25%	45782	50%	1602	0.05392	73.4
16	**0.07**	**76267**	3	18193	24%	48045	38%	2522	0.032777	67.6

Table 16. Model results for the outside stock. Bold values indicate estimated values, which in some runs are equal to the upper constraint. In runs 1-8, the K-values are restrained to the upper bound of 333,333 tonnes and in runs 9-16 K is estimated. Values for r were 0.017, 0.043 and 0.07 (discussion in text); m =1 denotes symmetric yield vs. biomass curve (i.e. Schaefer surplus production model) and m=3 denotes an asymmetric curve (i.e. Pella Tomlinson surplus production model).

run	r	K	m	B_{2009}	B_{2009}/K	B_{msy}	B_{2009}/B_{msy}	MSY	F_{MSY}	-log likelihood
1	0.043	333333	1	274106	82%	166667	164%	3583	0.021732	958.5
2	0.043	333333	3	310730	93%	209987	148%	6772	0.032781	957.6
3	0.017	333333	1	210063	63%	166667	126%	1417	0.008538	961.1
4	0.017	333333	3	272563	82%	209987	130%	2677	0.01283	958.6
5	0.07	333333	1	296959	89%	166667	178%	5833	0.035625	957.8
6	0.07	333333	3	318841	96%	209987	152%	11024	0.053927	958.2
7	**0.024**	333333	1	235008	71%	166667	141%	2034	0.012279	959.5
8	**0.017**	333333	3	272563	82%	209987	130%	2677	0.01283	958.6
9	0.043	**333333**	1	274106	82%	166667	164%	3583	0.032781	958.5
10	0.043	**333333**	3	310730	93%	209987	148%	6772	0.008538	957.6
11	0.017	**333333**	1	210063	63%	166667	126%	1417	0.01283	961.1
12	0.017	**333333**	3	272563	82%	209987	130%	2677	0.035625	958.6
13	0.07	**333333**	1	296959	89%	166667	178%	5833	0.053927	957.8
14	0.07	**333333**	3	318841	96%	209987	152%	11024	0.035625	958.2
15	**0.07**	**333333**	1	296959	89%	166667	178%	5833	0.053927	957.8
16	**0.07**	**333333**	3	318841	96%	209987	152%	11024	0.032781	958.2

Table 17. Model runs for the inside stock, with estimated current biomass (B_{2009}), and its proportion (%) of biomass at maximum sustainable yield (B_{MSY}) for classification of the current stock status in a Healthy, Cautious or Critical zone. The fishing mortality limit (F_{LIMIT}) is based on classification of current stock status and yield limit (Y_{LIMIT}) is the level at which harvest to is be below. Classification of stock status, F_{LIMIT} and Y_{LIMIT} are based on the DFO Fishery Decision-making Framework Incorporating the Precautionary Approach outlined in the national policy 'Sustainable Fisheries Framework'.

Run	B_{2009}	B_{MSY}	B_{2009}/B_{MSY} (%)	Zone	F_{MSY}	F_{LIMIT}	Y_{LIMIT}
1	117247	83334	141%	Healthy	0.022	0.022	2551
2	155982	104994	149%	Healthy	0.033	0.033	5063
3	52629	83334	63%	Cautious	0.009	0.005	262
4	98398	104994	94%	Cautious	0.013	0.013	1271
5	143676	83334	172%	Healthy	0.036	0.036	5080
6	161279	104994	154%	Healthy	0.054	0.054	8478
7	74885	83334	90%	Healthy	0.012	0.012	893
8	98398	104994	94%	Healthy	0.013	0.013	1271
9	37752	58370	65%	Cautious	0.022	0.014	525
10	28057	59077	47%	Cautious	0.033	0.006	168
11	52629	83334	63%	Cautious	0.009	0.005	262
12	62673	92939	67%	Cautious	0.013	0.009	562
13	22803	45782	50%	Cautious	0.036	0.009	204
14	18193	48045	38%	Critical	0.054	0	0
15	22803	45782	50%	Cautious	0.036	0.009	204
16	18193	48045	38%	Critical	0.054	0	0

Table 18. Model runs for the outside stock, with estimated current biomass (B_{2009}), and its proportion (%) of biomass at maximum sustainable yield (B_{MSY}) for classification of the current stock status in a Healthy, Cautious or Critical zone. The fishing mortality limit (F_{LIMIT}) is based on classification of current stock status and yield limit (Y_{LIMIT}) is the level at which harvest to is be below. Classification of stock status, F_{LIMIT} and Y_{LIMIT} are based on the DFO Fishery Decision-making Framework Incorporating the Precautionary Approach outlined in the national policy 'Sustainable Fisheries Framework'.

Run	B_{2009}	B_{MSY}	B_{2009}/B_{MSY} (%)	Zone	F_{MSY}	F_{LIMIT}	Y_{LIMIT}
1	274106	166667	164%	Healthy	0.022	0.022	5,964
2	310730	209987	148%	Healthy	0.033	0.033	10,087
3	210063	166667	126%	Healthy	0.009	0.009	1,882
4	272563	209987	130%	Healthy	0.013	0.013	3,520
5	296959	166667	178%	Healthy	0.036	0.036	10,500
6	318841	209987	152%	Healthy	0.054	0.054	16,761
7	235008	166667	141%	Healthy	0.012	0.012	2,803
8	272563	209987	130%	Healthy	0.013	0.013	3,520
9	274106	166667	164%	Healthy	0.022	0.022	5,964
10	310730	209987	148%	Healthy	0.033	0.033	10,087
11	210063	166667	126%	Healthy	0.009	0.009	1,882
12	272563	209987	130%	Healthy	0.013	0.013	3,520
13	296959	166667	178%	Healthy	0.036	0.036	10,500
14	318841	209987	152%	Healthy	0.054	0.054	16,761
15	296959	166667	178%	Healthy	0.036	0.036	10,500
16	318841	209987	152%	Healthy	0.054	0.054	16,761

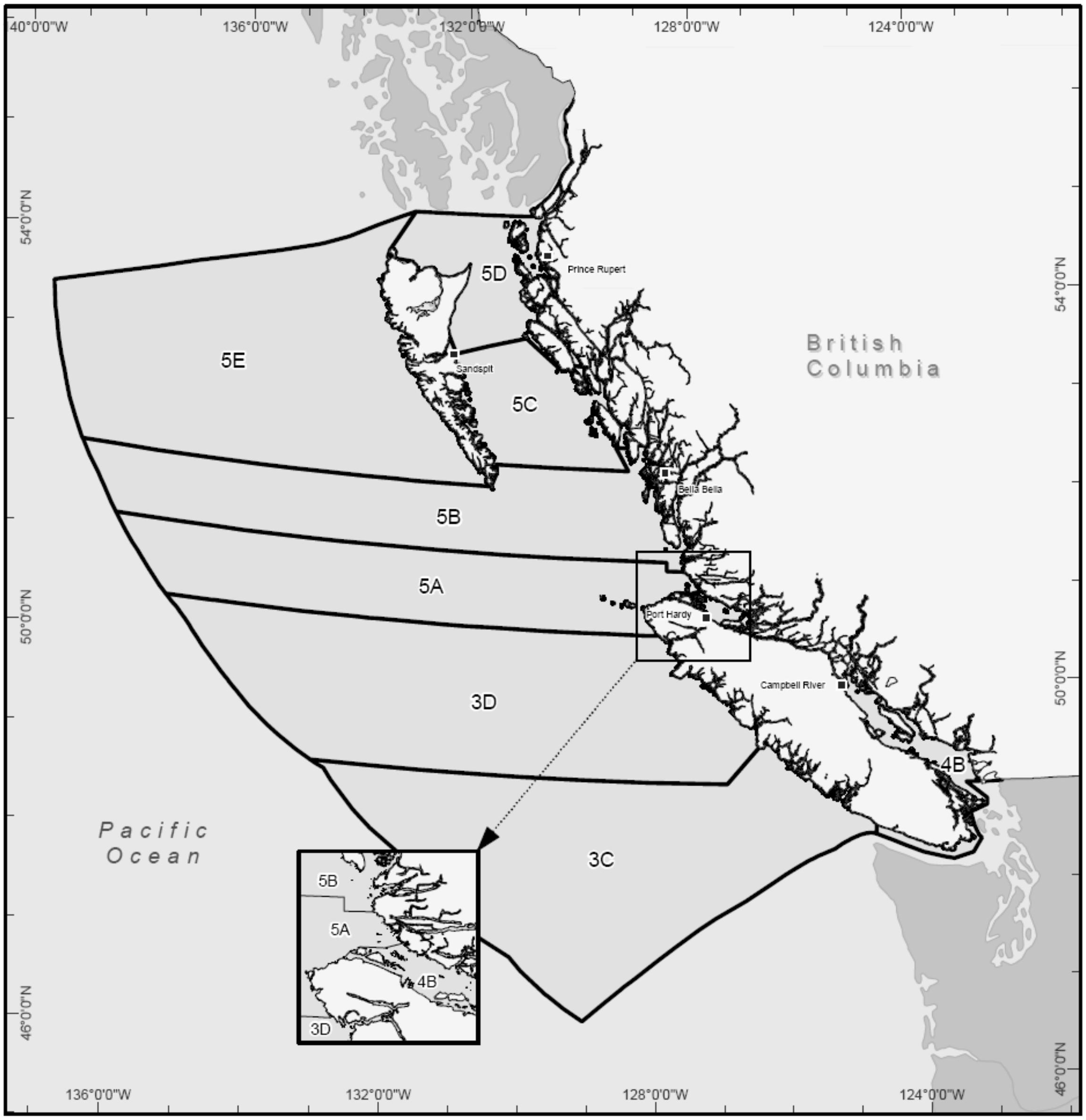

Figure 1: DFO Groundfish Statistical Areas. Spiny dogfish in British Columbia waters are managed as two discrete stocks: an inside stock (Strait of Georgia, Area 4B) and an outside stock (Areas 3C through 5E).

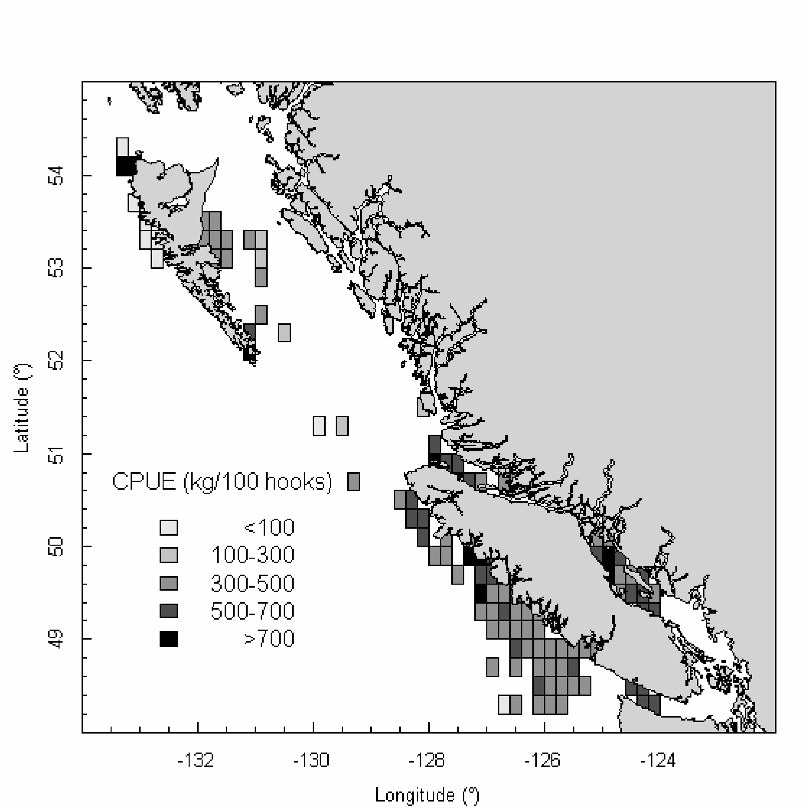

Figure 2: Mean catch per unit effort (CPUE) within 0.2º by 0.2º grid for longline landed spiny dogfish from 1994-2006. (data source PacHarvHL).

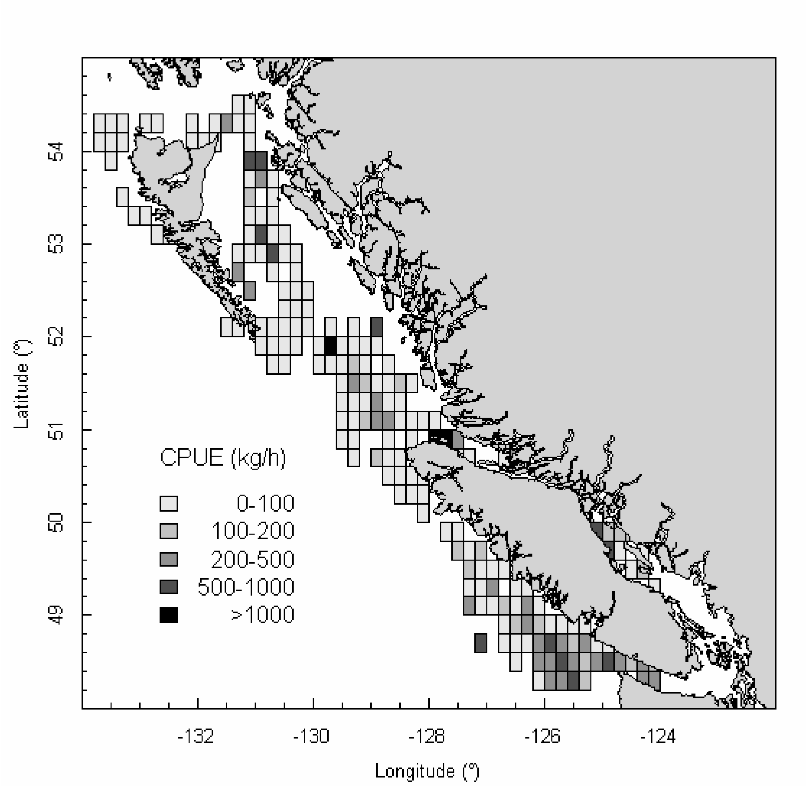

Figure 3: Mean catch per unit effort (CPUE) within 0.2º by 0.2º grid for trawl landed spiny dogfish from 1996-2007. (data source PacHarvTrawl).

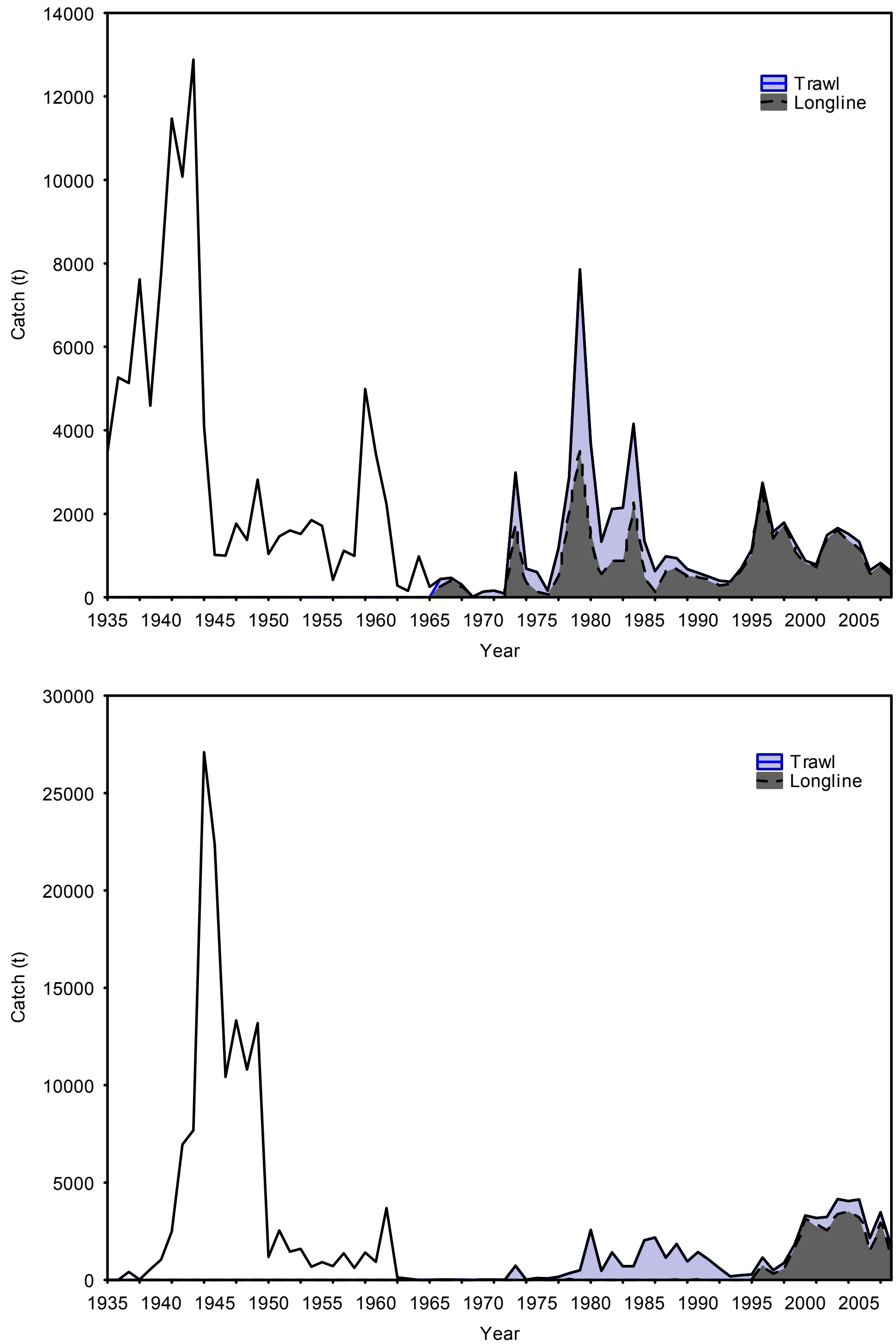

Figure 4: Total mortality (landings and discard mortality; tonnes) of spiny dogfish in the inside stock (upper panel) and outside stock (lower panel) from 1935-2008 (Tables 2-8). From 1966 onwards, total mortality is estimated separately for trawl (hatched area) and longline (solid area) gear. Solid black line is total mortality for all gear types combined.

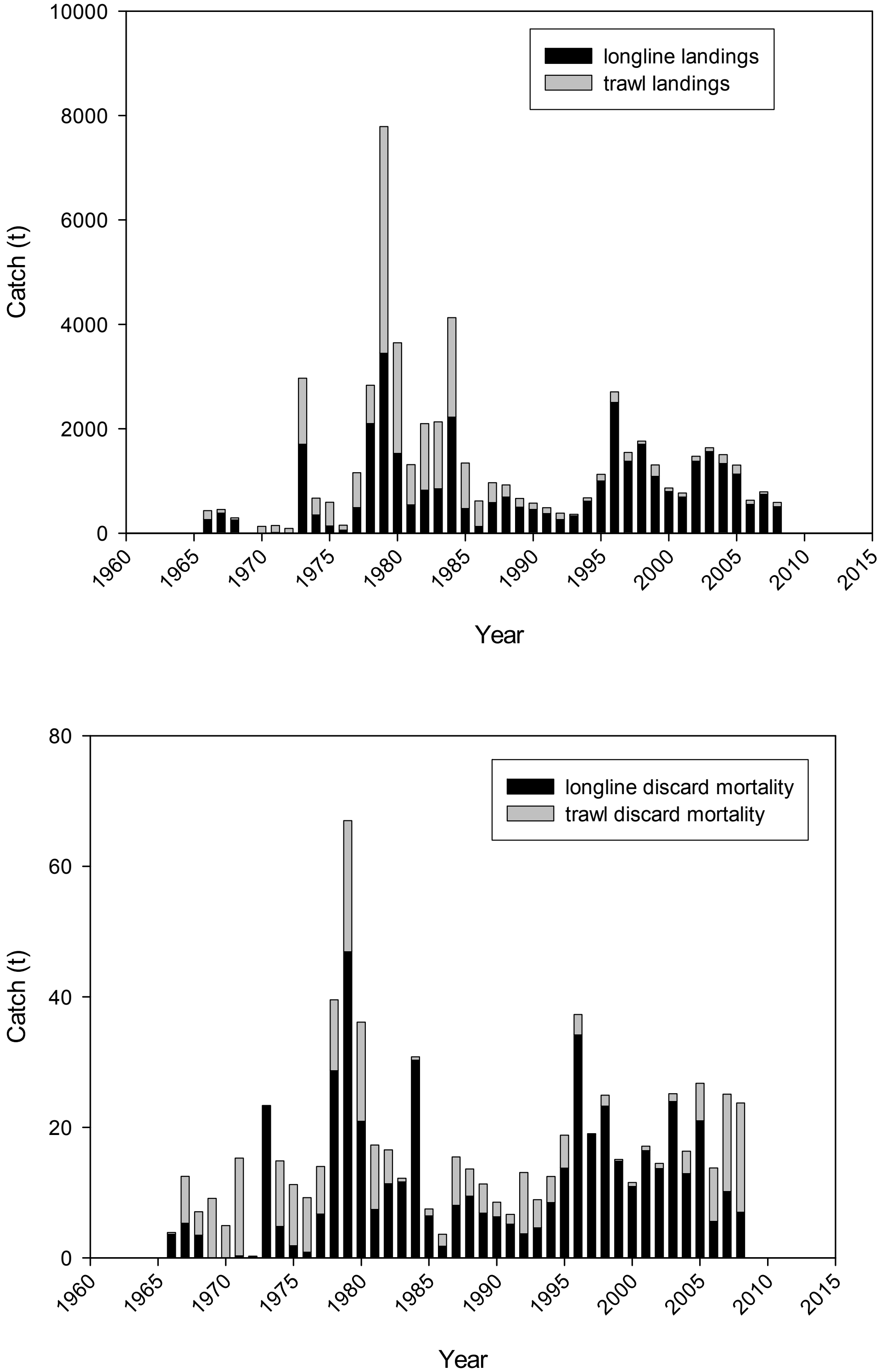

Figure 5: Total landings (upper panel; tonnes) and discard mortality (lower panel; tonnes) based on estimated discard mortality rates of spiny dogfish for the inside stock 1966-2008 for longline (black bars) and trawl (gray bars) gear.

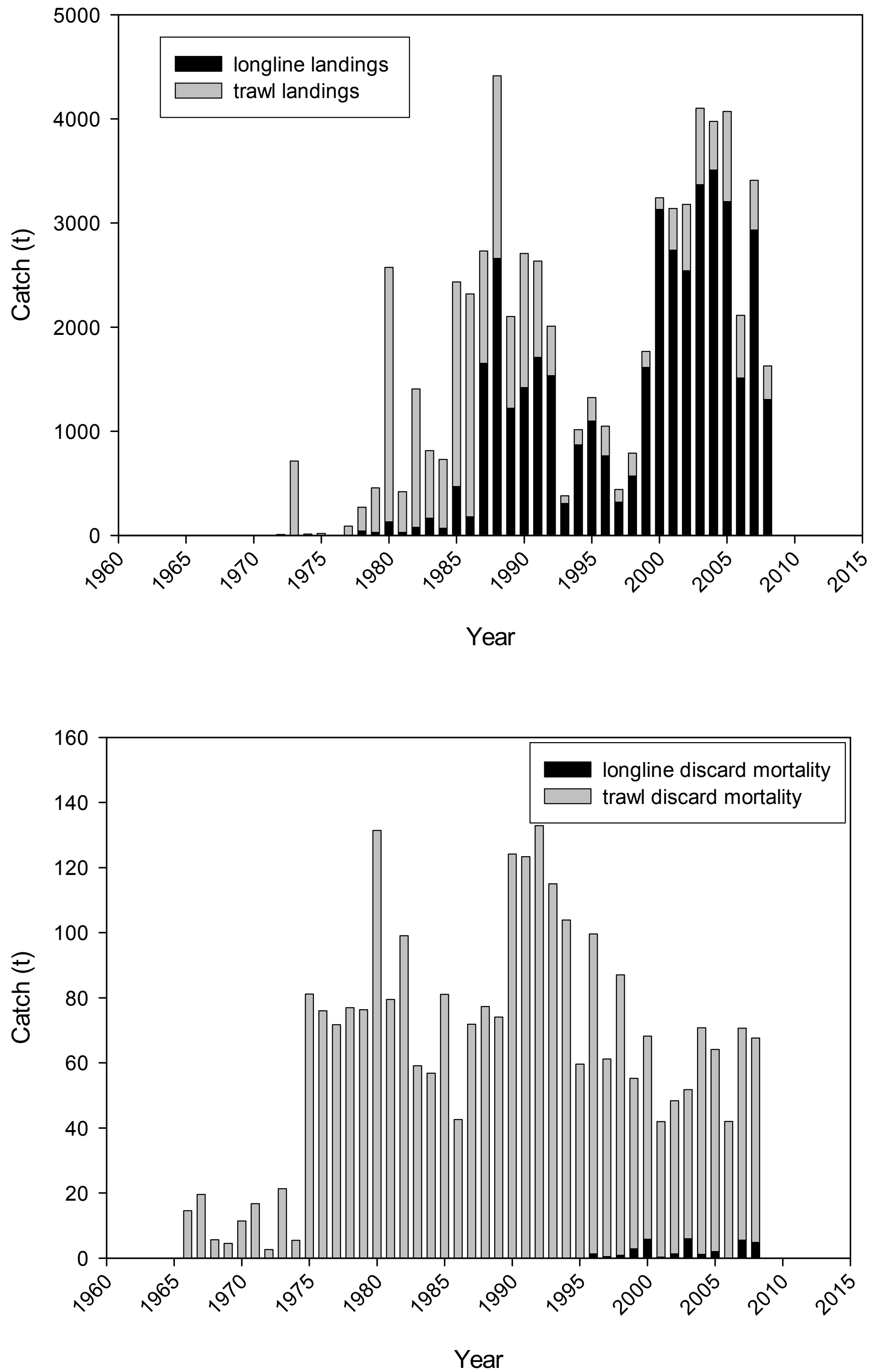

Figure 6: Total landings (upper panel; tonnes) and discard mortality (lower panel; tonnes) based on estimated discard mortality rates of spiny dogfish for the outside stock 1966-2008 for longline (black bars) and trawl (gray bars) gear.

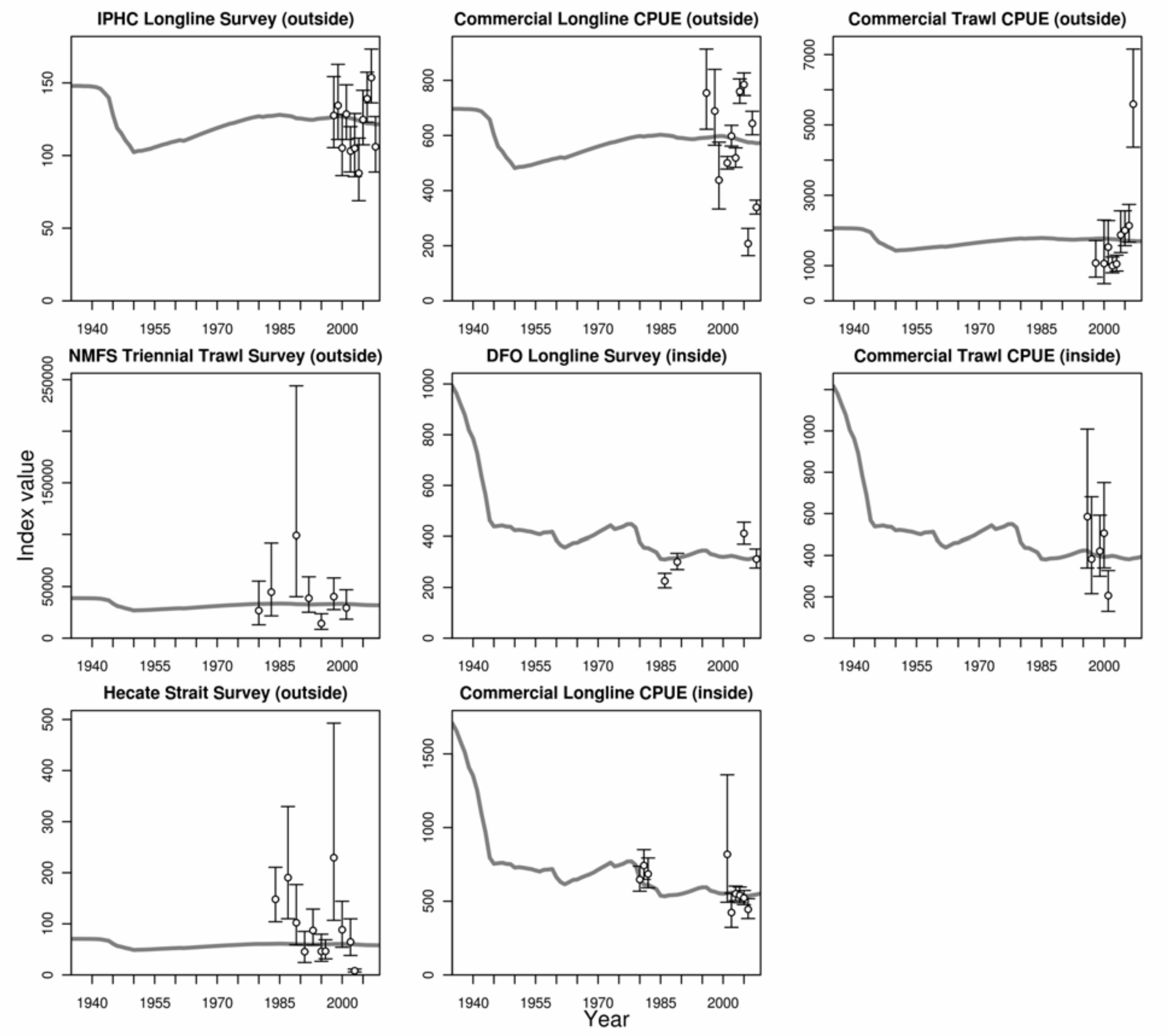

Figure 7:Model fits to the eight indices of abundance (CPUE) that were included in the model run 9 (where r=0.043, m=1, K is estimated) for the inside stock (K=116,739) and the outside stock (K=333,333) . Solid line is estimate biomass multiplied by the catchability coefficient q associated with each index. Circles are point estimates of the CPUE values, and bars designate 95% intervals based on a lognormal distribution. Indices are described in Tables 9-14.

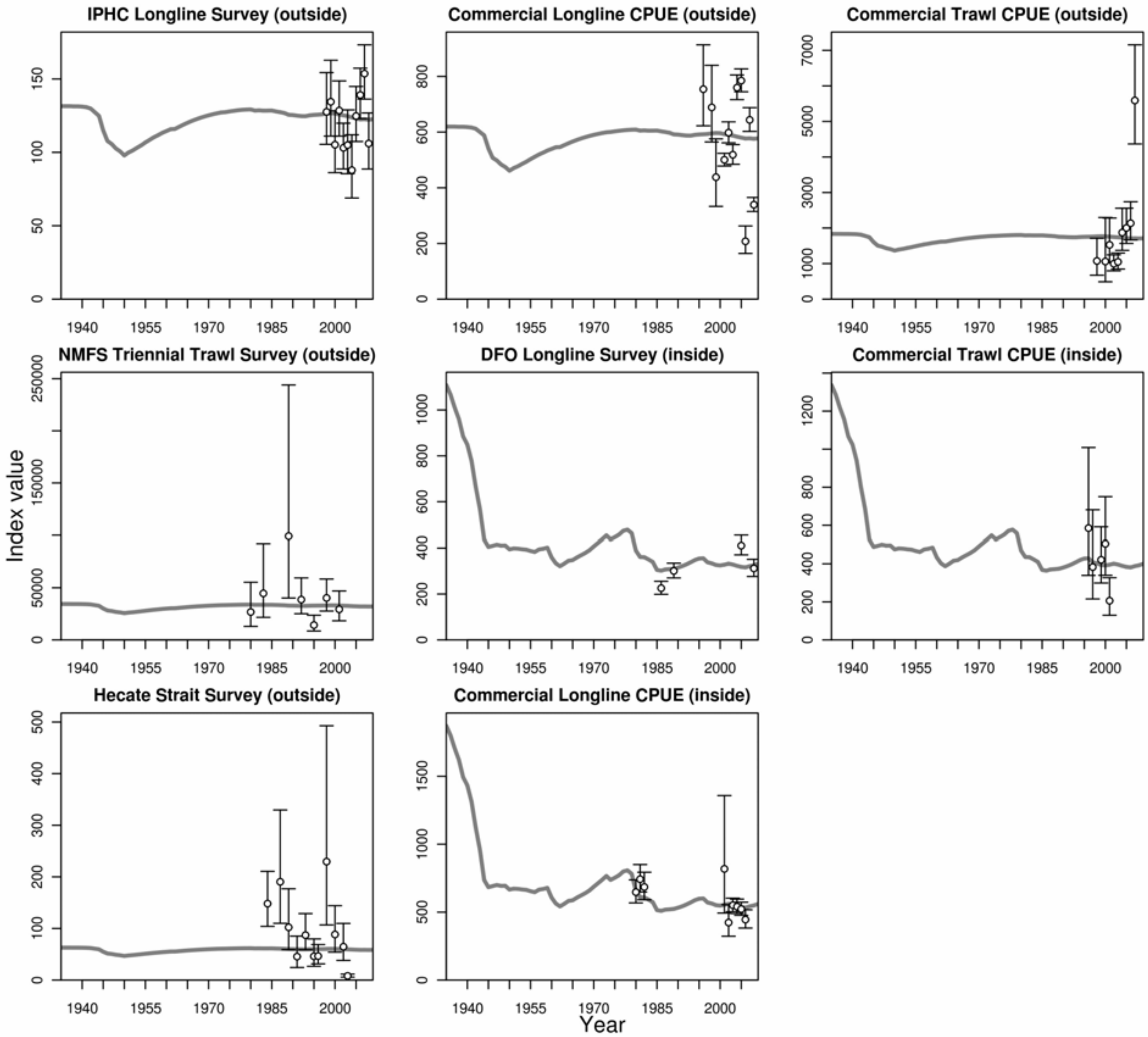

Figure 8: Model fits to the eight indices of abundance (CPUE) that were included in the model run 10 (where r=0.043, m=3, K is estimated) for the inside stock (K=93,779) and the outside stock (K=333,333) . Solid line is estimate biomass multiplied by the catchability coefficient q associated with each index. Circles are point estimates of the CPUE values, and bars designate 95% intervals based on a lognormal distribution. Indices are described in Tables 9-14.

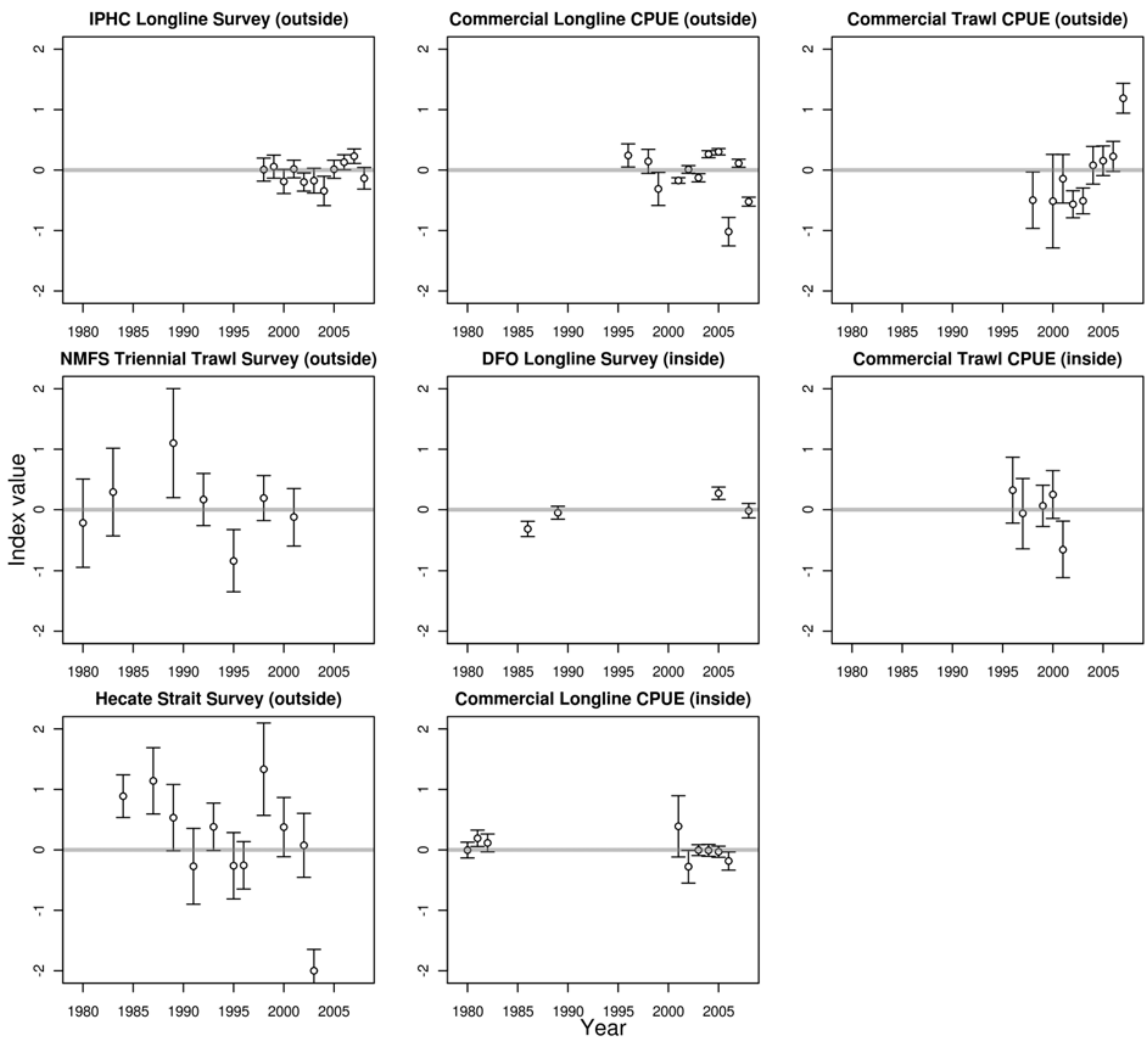

Figure 9: Residuals for the model fits to CPUE indices shown in Figure 7. Values are calculated as log(observed) - log(expected) based on the assumed lognormal error structure. Bars represent 95% intervals.

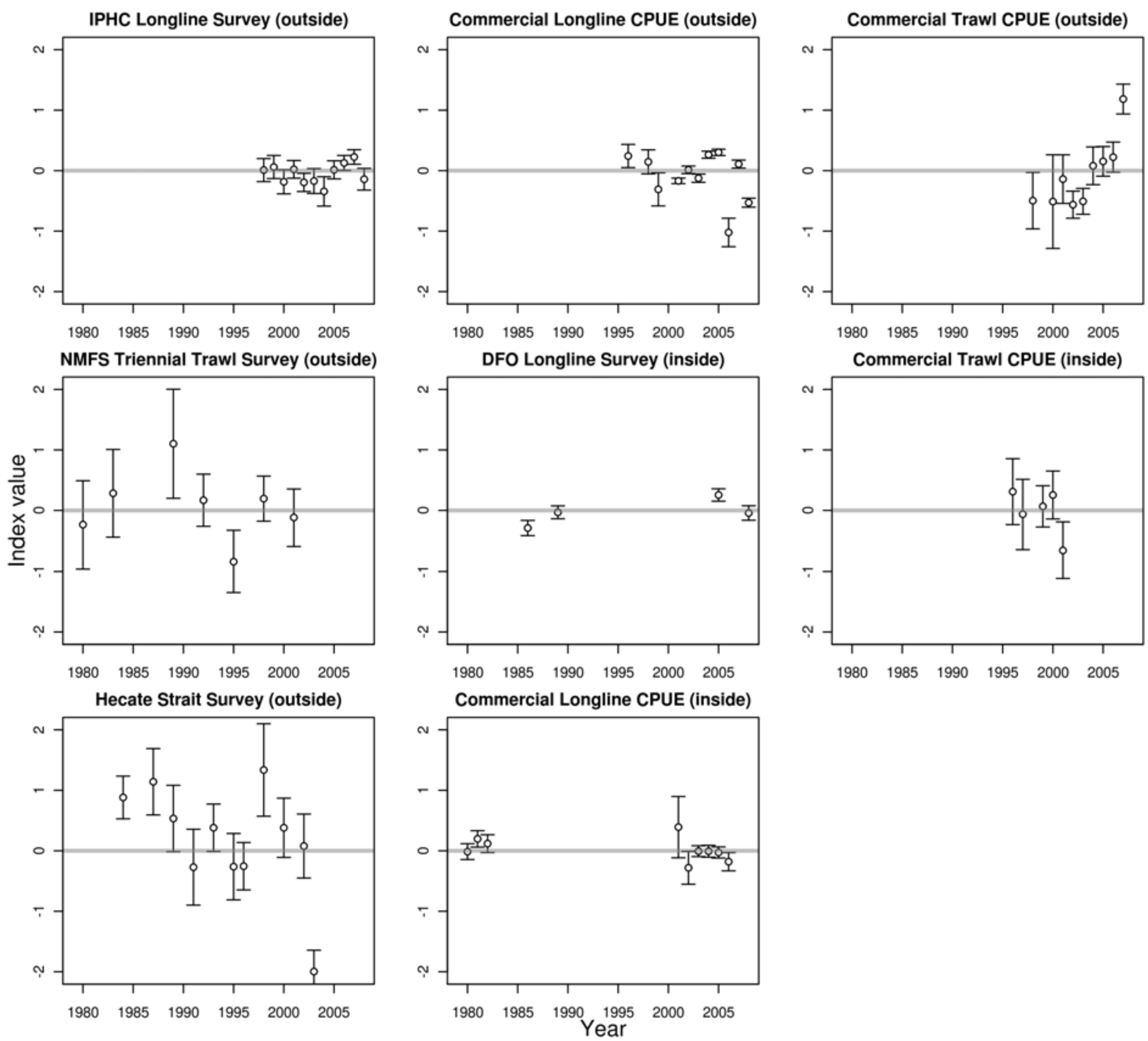

Figure 10: Residuals for the model fits to CPUE indices shown in Figure 8. Values are calculated as log(observed) - log(expected) based on the assumed lognormal error structure. Bars represent 95% intervals.

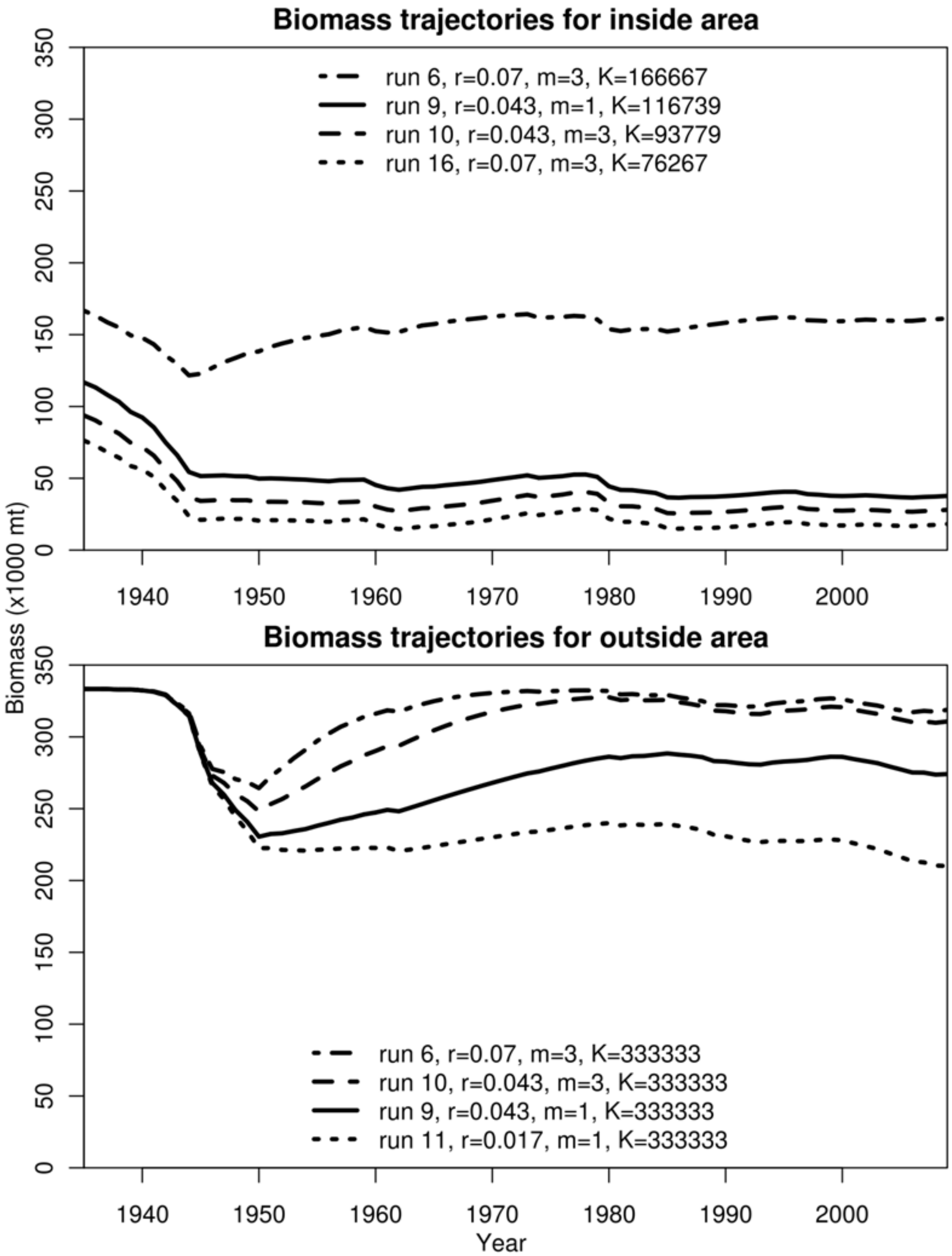

Figure 11: Population trajectories for the inside stock (upper panel) and the outside stock (lower panel) based on model runs 9 and 10 (r=0.043; m=1 or 3, K estimated) and the model runs that produce the lowest current biomass estimate (model run 6 for both stocks) and the highest current biomass estimate (model run 16 for the inside stock; model run 11 for the outside stock).

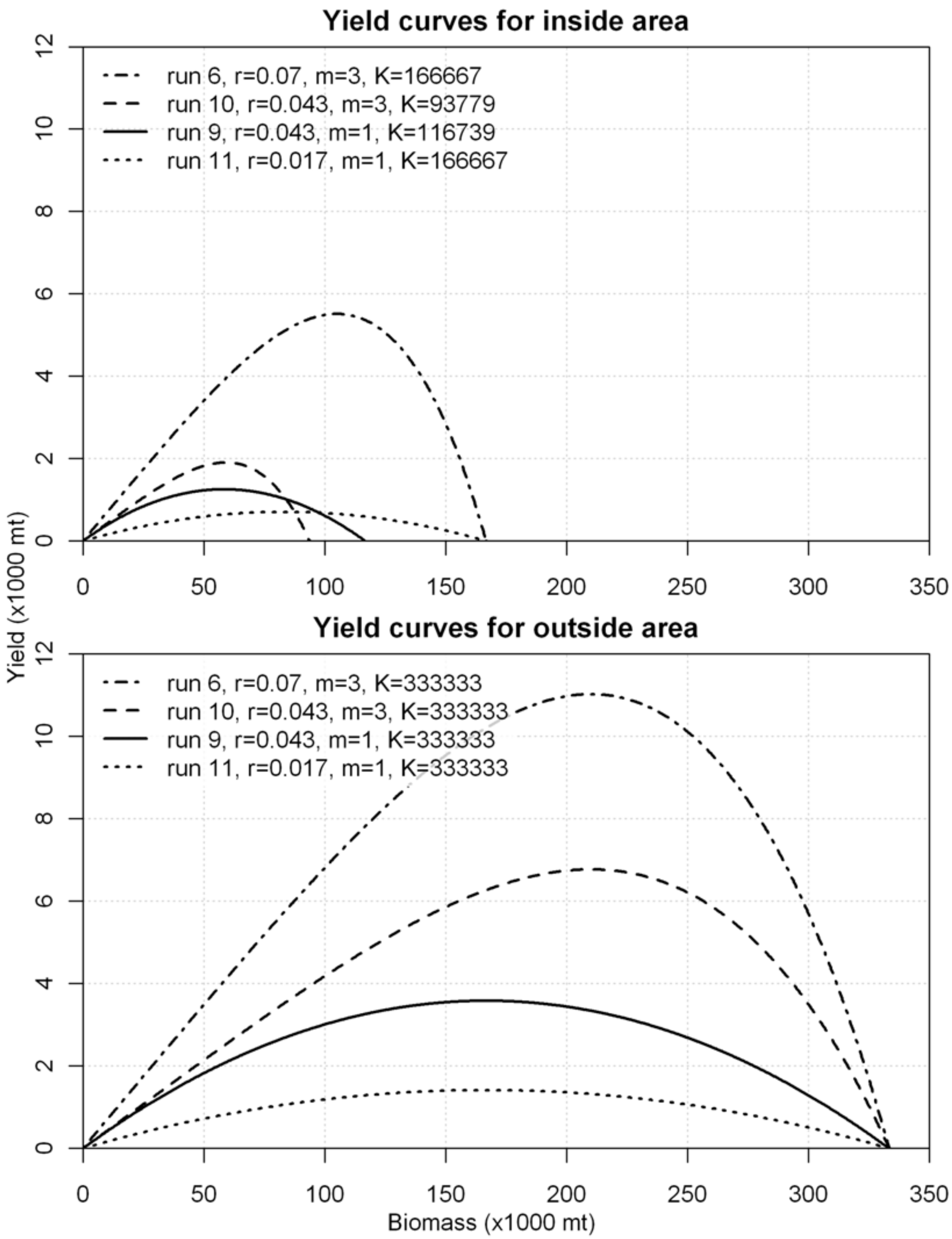

Figure 12: Yield curves as a function of population size for the inside stock (upper panel) and the outside stock (lower panel) based on model runs 9 and 10 (r=0.043; m=1 or 3, K estimated) and the model runs that produce the lowest maximum sustainable yield estimate (model run 11) and the highest maximum sustainable yield estimate (model run 6).

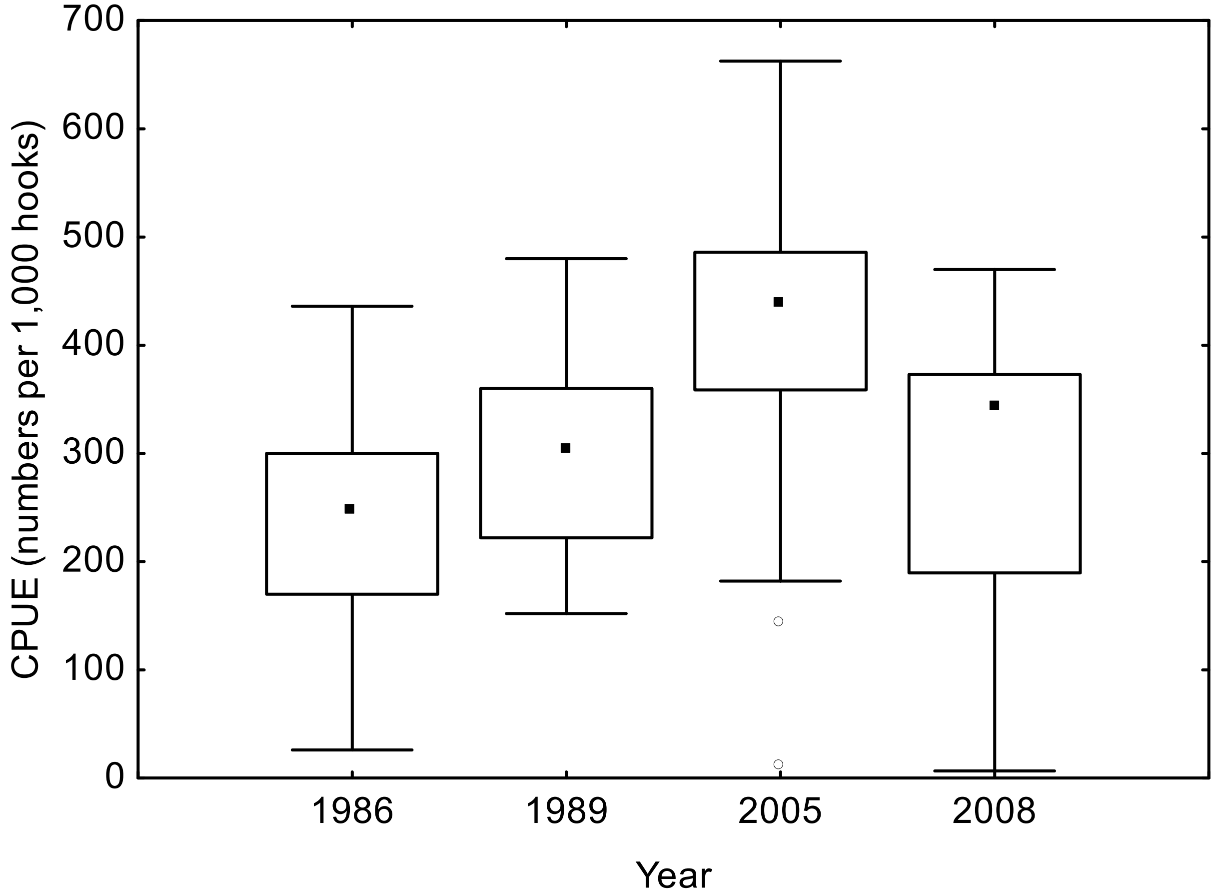

Figure 13. Boxplots of catch per unit effort (CPUE) in numbers of fish per thousand hooks captured by the DFO spiny dogfish longline survey conducted for the inside stock. Squares denote median CPUE values; boxes denote the 25th and 75th percentiles; whiskers denote the non-outlier range. Updated from King and McFarlane (2009b) with 2008 data reported in King and McFarlane (2009a).

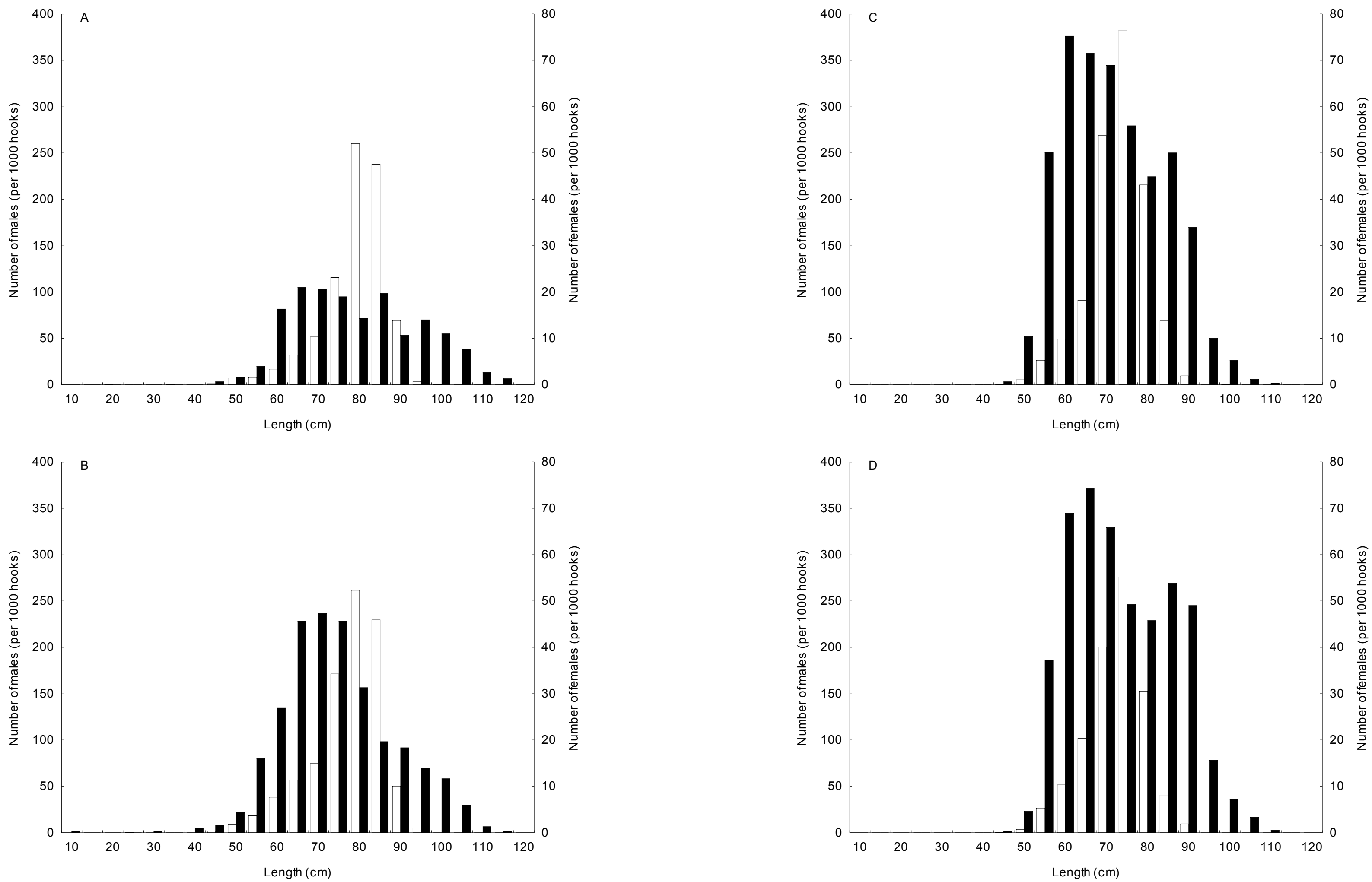

*Figure 14. Frequency (number of fish) distributions of male (open bars; left axes) and females (closed bars; right axes) spiny dogfish captured in the inside stock longline survey in A) 1986; B) 1989; C) 2005 and D) 2008 per **thousand** hooks. The frequencies for the 2005 and 2008 surveys were corrected for differences in gear catchability by depth as per King and McFarlane (2009b).*

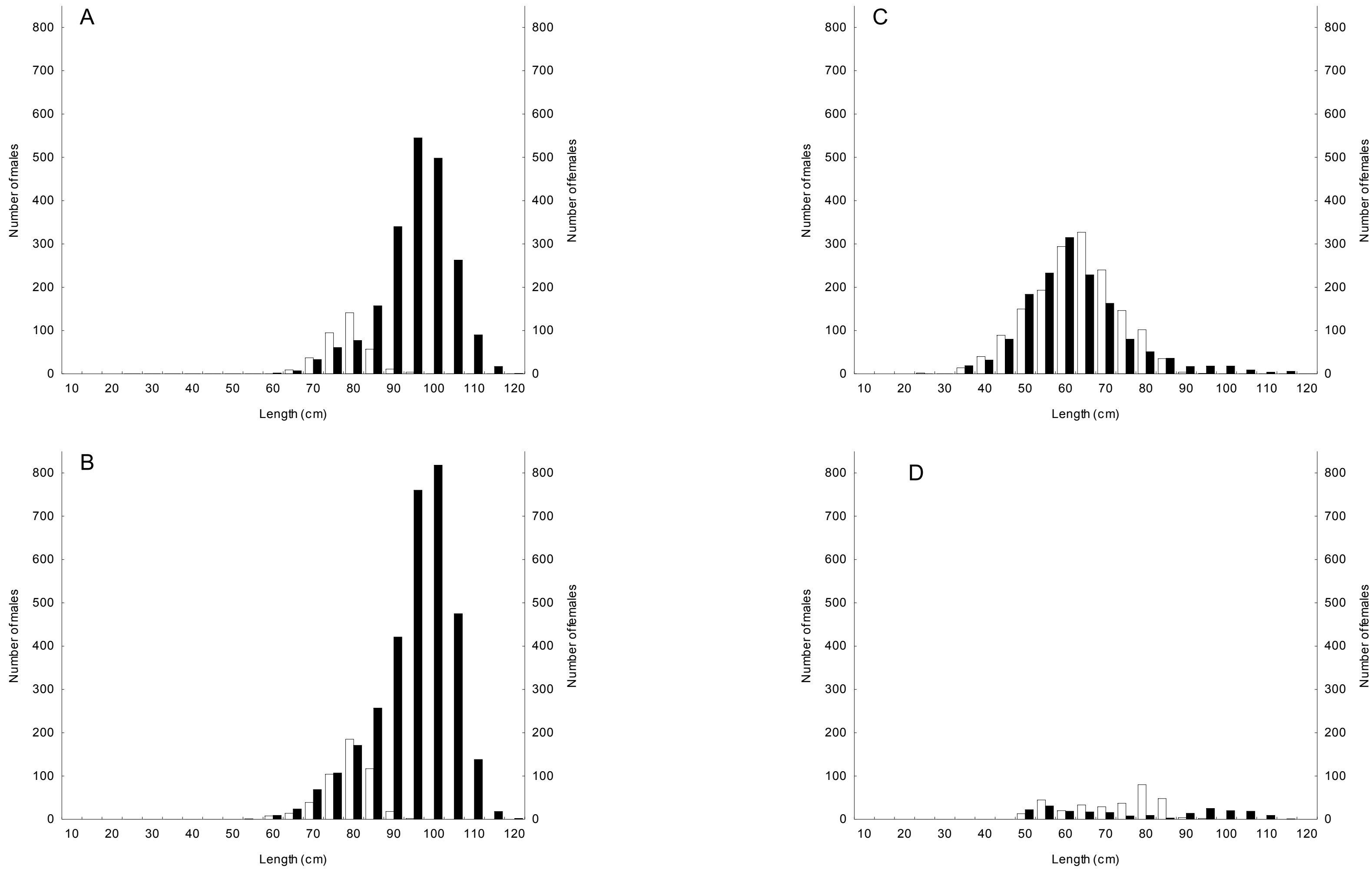

Figure 15. Frequency (number of fish) distributions of male (open bars; left axes) and females (closed bars; right axes) spiny dogfish captured in the outside stock trawl fishery in A) 1973; 1977-1979 (n=354 males; n=2091 females); B) 1981; 1984-1985; 1987 (n=488 males; n=3,269 females) C) 1996-1999 (n=1,637 males; n=1,494 females) and D) 2000-2002 (n=311 males; n=213 females. (data from GFBio).

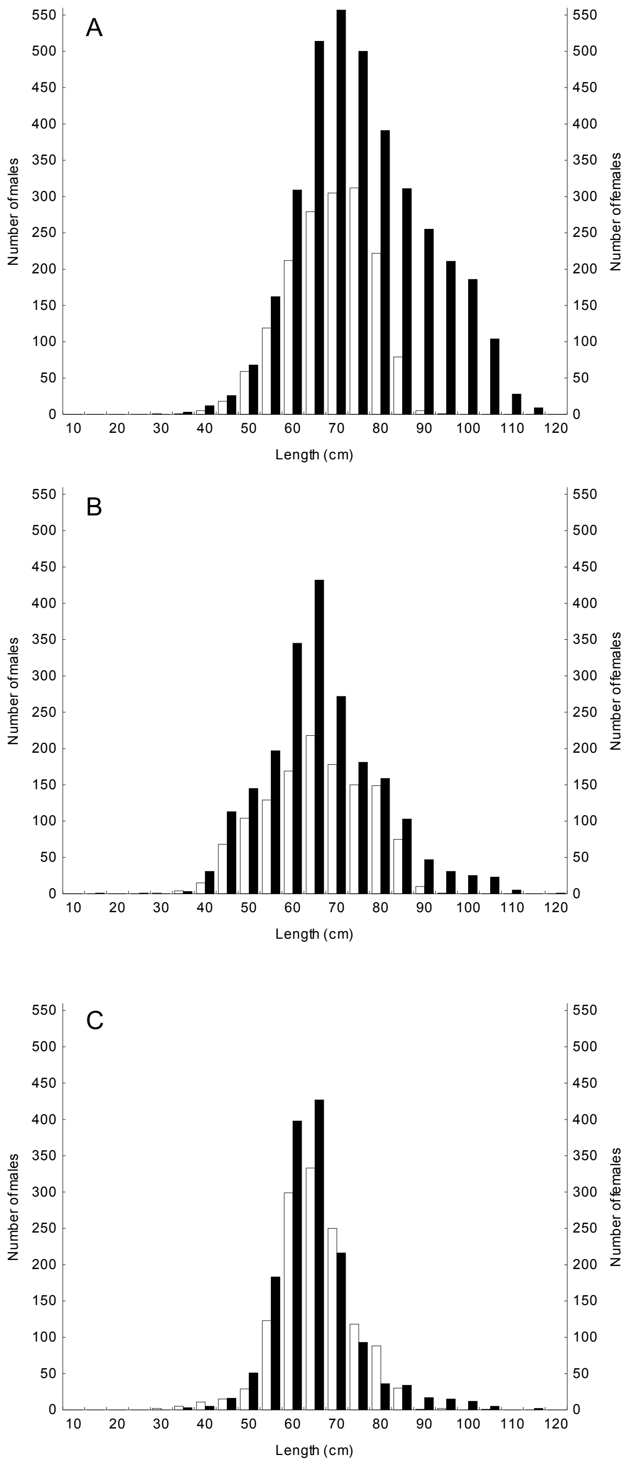

Figure 16. Frequency (number of fish) distributions of male (open bars; left axes) and females (closed bars; right axes) spiny dogfish captured in Hecate Strait (outside stock) DFO bottom trawl research survey in A) 1984; 1987; 1989 (n=1,618 males; n=3,647 females); B) 1991; 1993; 1998 (n=1,271 males; n=2,115 females) C) 2000; 2002-2003 (n=1,307 males; n=1,513 females). (data from GFBio).

APPENDIX A: REQUEST FOR SCIENCE INFORMATION AND/OR ADVICE

PART 1: DESCRIPTION OF THE REQUEST – TO BE FILLED BY THE CLIENT REQUESTING THE INFORMATION/ADVICE

Date *(when initial client's submission is sent to Science)***:**

Directorate, Branch or group initiating the request and category of request

Directorate/Branch/Group	Category of Request
X Fisheries and Aquaculture Management	X Stock Assessment
☐ Oceans & Habitat Management and SARA	☐ Species at Risk
☐ Policy	☐ Human impacts on Fish Habitat/ Ecosystem components
☐ Science	☐ Aquaculture
☐ Other (please specify):	☐ Ocean issues
	☐ Invasive Species
	☐ Other (please specify):

Initiating Branch Contact:

Name: Gary Logan	Telephone Number: 604-666-9033
Email:Gary.Logan@dfo-mpo.gc.ca	Fax Number:

Issue Requiring Science Advice (i.e., "the question"):
Issue posed as a question for Science response.

Dogfish, all groundfish management areas including 4B, coastwide abundance and advice for catch.

Rationale for Advice Request:
What is the issue, what will it address, importance, scope and breadth of interest, etc.?

There is currently a commercial fishery for dogfish along the entire coast of British Columbia. The TAC is split between the hook and line and trawl sectors. The last partial dogfish assessment was conducted in 1994/95. Given the fact that the directed dogfish fleet is applying for certification, and the fact that the majority of product is sold overseas, current catch advice is imperative. Furthermore, Dogfish is being considered for listing under SARA therefore an updated assessment would be beneficial.

Possibility of integrating this request with other requests in your sector or other sector's needs?

Groundfish management is submitting several species for review. Hopefully these can all be addressed within the multi-species survey.

Intended Uses of the Advice, Potential Impacts of Advice within DFO, and on the Public:
Who will be the end user of the advice (e.g. DFO, another government agency or Industry?). What impact could the advice have on other sectors? Who from the Public will be impacted by the advice and to what extent?

Catch advice for commercial harvesters and DFO managers.

Date Advice Required: Opening of the 2010 groundfish fishery.

Latest possible date to receive Science advice: December 2009. Rationale justifying this date: Advice for 2010 commercial fishery with a common season (opening/closing date) of late February 2010.

Funding: Specific funds may already have been identified to cover a given issue (e.g. SARCEP, Ocean Action Plan, etc.)
Source of funding: Nil Expected amount: Nil

Initiating Branch's Approval:
Approved by Initiating Director: X   Date: January 2, 2009 Name of initiating Director: Sue Farlinger **Send form via email attachment following instructions below**: *Regional request: Depending on the region, the coordinator of the Regional Centre for Science Advice or the Regional Director of Science will be the first contact person. Please contact the coordinator in your region to confirm the approach.* *National request: At HQ, the Director of the Canadian Science Advisory Secretariat (Ghislain.Chouinard@dfo-mpo.gc.ca) AND the Director General of the Ecosystem Science Directorate (Sylvain.Paradis@dfo-mpo.gc.ca) will be the first contact persons.*

PART 2: RESPONSE FROM SCIENCE

In the regions: to be filled by the Regional Centre for Science Advice.
At HQ: to be filled by the Canadian Science Advisory Secretariat in collaboration with the Directors of the Science program(s) of concern.

Criteria characterising the request:	*Constraints regarding the planning of a standard peer review/Workshop:*	*Other criteria that could affect the choice of the process, the timelines, or the scale of the meeting:*
☐ ***Science advice is requested (rather than just information)*** ☐ ***A sound basis of peer-reviewed information and advisory precedent already exists.*** ☐ ***Inclusiveness is an issue*** ☐ ***Advice on this specific issue has been provided in the past.*** ☐ ***Urgent request.*** ☐ ***DFO is not the final advisory body.*** ☐ ***CEAA process*** ☐ ***COSEWIC process*** ☐ ***Other:***	☐ ***External expertise required*** ☐ ***This is a scientifically controversial issue, i.e., consensus does*** not ***currently exist within DFO science.*** ☐ ***Extensive preparatory work is required.*** ☐ ***Determination of information availability is required (prior to provision of advice).*** ☐ ***Resources supporting this process are not available.*** ☐ ***Expected time needed for the preparatory work:*** ☐ ***Other (please specify):***	☐ ***The response provided could be considered as a precedent that will affect other regions.*** ☐ ***The response corresponds to a new framework or will affect the framework currently in place.*** ☐ ***Expertise from other DFO regions is necessary.*** ☐ ***Other (please specify):***

Recommendation regarding the advisory process and the timelines:

☐ ***Science Special Response Process (SSRP)*** ☐ ***Workshop*** ☐ ***Peer Review Meeting***

Rationale justifying the choice of process:

Types of publications expected and if already known, number of report for each series:

☐ ***Science Advisory Report ( )*** ☐ ***Research Document ( )***
☐ ***Proceeding ( )*** ☐ ***Science Response Report ( )***
☐ ***Other:***

Date Advice to be Provided:

☐ Date specified can be met.
☐ Date specified can NOT be met.

Alternate date, as agreed to by client Branch lead and Science lead:

OR

☐ ***No Formal Response to be Provided by Science***

Rationale:

☐ ***DFO Science Region does not have the expertise required.***
☐ ***DFO Science Region does not have resources available at this time.***
☐ ***The deadline can not be met.***
☐ ***Not a natural science issue (e.g. socio-economic)***
☐ ***Response to a similar question has been provided elsewhere:***
Reference:

Additional explanation:

Science Branch Lead:

Name: Telephone Number:
Email:

* Please contact Science Branch lead for additional details on this request.

Science Branch Approval:

Approved by Regional Director, Science (or their delegate authority):
☐ Date:

Name of the person who approved the request:

Once part 2 completed, the form is sent via email attachment to the initiating Branch contact person.

PART 3: **PLANNING OF THE ADVISORY PROCESS**

Science Branch Approval:

Coordinator of the event:

Potential chair(s):

Suggested date / period for the meeting:

Need a preparatory meeting:

Leader of the Steering Committee: