Fisheries and Oceans Science
Pêches et Océans Sciences

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Canadian Science Advisory Secretariat

Secrétariat canadien de consultation scientifique

Research Document 2001/132

Document de recherche 2001/132

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Assessment of Lingcod in the Strait of Georgia

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ISSN 1480-4883
Ottawa, 2001

Canada

ABSTRACT

This working paper examines recreational fishing information, nest density survey results and biological data for lingcod within the Strait of Georgia. Annual catch estimates (pieces) from the Strait of Georgia creel survey program are updated from 1999. Biological data on the length (cm) of lingcod retained by recreational fishers is updated from 1994. Mean lengths and a weight-length relationship is used to convert estimated catch in pieces to estimated catch in tonnes. Recreational catch per unit (CPUE) indices are presented as a relative measure of lingcod abundance trends. In 2001, a nest density SCUBA survey was conducted on Snake Island in Minor Statistical Area 17 and the results are compared to 1990, 1991 and 1994 results. Biological data on nest guarding males and egg mass volume were collected during the 1990 and 2001. The Vancouver Aquarium Marine Science Center conducts an annual egg mass count survey in Howe Sound (Minor Statistical Area 28) and their analyses and results are provided for 1994-2001.

The recreational CPUE index has remained fairly constant from 1982-2000. There have been slight decreases and increases (e.g. decrease 1985-1995) however these are non-significant. Since 1990, there is evidence of two above average year classes (1995 and 1999 or 2000) and following these, increases in the abundance of juvenile lingcod, however there is a lack of evidence for an increase in the abundance of large, adult lingcod. These year classes are above average only compared to very poor year classes in the 1990s. It is important to note, that in some areas the size of landed lingcod in the recreational fishery is below the 65 cm size limit. There is some slight indication that the spawning population has increased, but the evidence is not overwhelming. The size of nest guarding males was not significantly larger in 2001 than in 1990.

Since the closure of the commercial fishery in 1990, lingcod abundance appears to have remained at very low and stable levels. Presently, there is no indication that overall lingcod population abundance has continued to decline nor rebuilt to levels similar to pre-collapse of the commercial fishery. In order to foster an increase in lingcod abundance, commercial fishing should remain closed and recreational closures should be implemented.

RÉSUMÉ

De l’information sur la pêche récréative, les résultats de relevés de la densité des nids et des données biologiques sur la morue-lingue dans le détroit de Georgia sont examinés dans le présent document de travail. Les estimations des prises annuelles (en nombre) tirées du programme d’enquêtes auprès des pêcheurs qui remontaient à 1999 ont été mises à jour. Les données biologiques sur la longueur (cm) des morues-lingues conservées par les pêcheurs récréatifs qui remontaient à 1994 ont été mises à jour. Les longueurs moyennes et la relation entre le poids et la longueur servent à convertir le nombre de prises estimées en tonnes. Les indices de prises récréatives par unité d’effort (PUE) sont présentés comme étant une mesure relative des tendances dans l’abondance de morue-lingue. Les résultats d’un relevé en plongée autonome de la densité des nids effectué en 2001 sur l’île Snake dans le secteur statistique mineur 17 sont comparés à ceux obtenus en 1990, 1991 et 1994. Des données biologiques sur les mâles protégeant les nids et sur le volume des amas d’œufs ont été recueillies en 1990 et en 2001. Le centre des sciences marines de l’Aquarium de Vancouver effectue un décompte annuel des amas d’œufs dans le détroit Sound (secteur statistique mineur 28), et ses analyses et résultats sont présentés pour 1994-2001.

L’indice de prises récréatives par unité d’effort (PUE) est resté assez constant de 1982 à 2000. Il y a eu de légères fluctuations (p. ex. une diminution de 1985 à 1995) qui n’étaient toutefois pas significatives. Depuis 1990, deux classes d’âge se démarquent comme étant plus importantes que la moyenne (1995 et 1999 ou 2000), et les juvéniles des classes d’âge suivantes sont plus abondants; cependant, rien ne démontre que les grosses morues-lingues adultes soient plus abondantes. Les classes d’âges plus abondantes que la moyenne ne le sont qu’en comparaison avec des classes d’âge très pauvres pendant les années 1990. Il est important de mentionner qu’à certains endroits, la taille des morues-lingues dans les débarquements de la pêche récréative est inférieure à la limite de 65 cm. Les quelques indices d’une hausse de la population de reproducteurs ne sont pas concluants. La taille des mâles défendant leur nid n’était pas significativement plus importante en 2001 qu’en 1990.

Depuis la fermeture de la pêche commerciale en 1990, l’abondance de la morue-lingue semble être demeurée très faible et stable. Pour l’heure, rien n’indique que la population de morue-lingue dans son ensemble a continué de fléchir ni commencé à se reconstituer jusqu’aux niveaux qui ont précédé l’effondrement de la pêche commerciale. Afin de favoriser une plus grande abondance de la morue-lingue, il faudrait garder la pêche commerciale fermée et fermer la pêche récréative dans certains secteurs.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

OVERVIEW

This working paper examines recreational fishing information, nest density survey results and biological data for lingcod within the Strait of Georgia. For this working paper, the Strait of Georgia is defined by Fisheries and Oceans Canada Minor Statistical Areas 13-19, 28 and 29 of Major Area 4B (Figure 1) which roughly overlaps the physical oceanographic boundaries of the Strait of Georgia (Thomson 1994). As a general background to lingcod, sections on the biology and life history of lingcod are presented. In addition, the historical commercial fishery, management and stock assessments are reviewed. The Strait of Georgia creel survey program is conducted throughout Minor Statistical Areas 13-19, 28 and 29 and the annual catch estimates (pieces) are updated from 1999. Biological data on the length (cm) of lingcod retained by recreational fishers is updated from 1994. Mean lengths and a weight-length relationship is used to convert estimated catch in pieces to estimated catch in tonnes. Recreational catch per unit (CPUE) indices are presented as a relative measure of lingcod abundance trends. In 2001, a nest density SCUBA survey was conducted on Snake Island in Minor Statistical Area 17 (King and Beaith 2001) and the results are compared to 1990, 1991 and 1994 results. Biological data on nest guarding males and egg mass volume were collected during 1990 and 2001. The Vancouver Aquarium Marine Science Center conducts an annual egg mass count survey in Howe Sound (Minor Statistical Area 28) and their analyses and results are provided for 1994-2001 (J. Marliave, unpublished data, Vancouver Aquarium Marine Science Center, PO Box 3232, Vancouver, BC, V6B 3X8).

INTRODUCTION TO LINGCOD AND THE FISHERY IN THE STRAIT OF GEORGIA

1.1 General Biology of Lingcod

Lingcod (*Ophiodon elongatus*) are unique to the west coast of North America and occur from Baja, California to the Shumagin Islands, Alaska. They inhabit nearshore waters and are commonly found along the bottom at depths ranging from 3 to 400 m, with most found in rocky areas 10 to 100 m. Lingcod are considered to be a non-migratory species. Tagging studies in the 1980s off the west coast of Vancouver Island indicated that 95% of the lingcod recovered in the first and second year after tagging tended to be within 10 km of their release site (Cass et al. 1990). Concurrent tagging studies in the Strait of Georgia indicated very little mixing between offshore and inshore stocks (Cass et al. 1990).

Female lingcod mature between ages 3 to 5 years at a mean size of 61-75 cm, while males mature at age 2 at a mean size of 50 cm (Cass et al. 1990). Males can be distinguished externally from females by the presence of a short, broadly conical papilla anterior to the anal opening (Wilby 1937). In Canadian waters, spawning begins in December and continues into March with the peak spawning activity in late January to early February (Wilby 1937; Low and Beamish 1978). Seasonal migration to nearshore spawning sites begins in October, with the males migrating before the females (Cass et al. 1990). Nesting sites are typically in rock crevices or ledges where there are strong currents (Low and Beamish 1978). Lingcod are one of the few marine fishes that exhibit parental care for incubating eggs. The males remain within 1 meter of an egg mass and exhibit aggressive behaviour to larger predators such as kelp greenling (*Hexagrammos* *decagrammus*) and striped seaperch (*Embiotica lateralis*) which typically feed on lingcod eggs and larvae (Low and Beamish 1978). Egg mortality due to predation can be very significant, and nests that are left unguarded, or that have males removed from them, do not survive to hatching (Low and Beamish 1978).

Lingcod begin to hatch in early March through late April, at a length of about 6-10 mm (Phillips and Barraclough 1977). For the first few weeks, the larvae are planktonic and are found in the upper 3 m of the water column during the day (Phillips and Barraclough 1977), but migrate to deeper waters at night (Cass et al. 1990). By about mid-May the post-larval lingcod are approximately 50-70 mm and have become demersal, inhabiting areas near kelp or eelgrass beds (Phillips and Barraclough 1977). By September, the young-of-year are found in a wider range of flat bottom areas, and by age 2 begin to inhabit similar substrates as older lingcod (Cass et al. 1990). Typically, larger lingcod inhabit deep banks and reefs, while smaller lingcod inhabit shallow waters and banks (Forrester 1973).

Growth during the first years of life is rapid and up to age 2 it is similar for males and females with both reaching an average length of 45 cm (Cass et al. 1990). After age 2, females grow faster than males, with the growth of males tapering off at about age 8 and females continuing to grow rapidly until about age 12-14. For waters off the west coast of Canada, the maximum age recorded for lingcod was 14 years for males and 20 years for females. Females reach lengths in excess of 100 cm, while males rarely exceed lengths of 90 cm.

As evident from their huge gaping mouths and long, pointed teeth, lingcod are voracious predators. As larvae, lingcod feed on calanoid copepods, decapod larvae, amphipods, euphausiids and larval herring (*Clupea harengus*) (Phillips and Barraclough 1977). As the young-of-year move inshore and begin a demersal life, their diet switches from zooplankton to juvenile herring (Phillips and Barraclough 1977). Juveniles consume herring, Pacific sand lance (*Ammodytes hexapterus*), flatfish (Pleuronectidae), shiner perch (*Cymatogaster aggregata*) and walleye pollock (*Theragra chalcogramma*) (Phillips and Barraclough 1977; Cass et al. 1990). Some invertebrates such as shrimp (*Neomysis macrops*) and prawn (*Pandalus danae*) are consumed (Cass et al. 1990). Adults feed mostly on herring and Pacific hake (*Merluccius productus*), but are predators of many fish and invertebrates including Pacific sand lance, flatfish, rockfish (*Sebastes*), spiny dogfish (*Squalus acanthias*), Pacific cod (*Gadus macrocephalus*), sablefish (*Anoplopoma fimbria*), Pacific tomcod (*Microgadus proximus*), salmon (*Oncorhynchus*), crabs, shrimps, squid and octopus (Cass et al. 1990). Aside from the early larval stage, lingcod themselves have few predators. The predators of adult lingcod are mainly marine mammals including sea lions (*Zalophus californianus*) and harbour seals (*Phoca vitulina*) (Cass et al. 1990).

1.2 History of the Strait of Georgia Fishery

Commercial fishing for lingcod in British Columbia began around 1860 (Cass et al. 1990). Between 1900 and the 1940s, lingcod was ranked fourth in commercial importance after salmon, herring and sardines, and was the main source of fresh fish throughout the year (Cass et al. 1990). Prior to 1927, lingcod landings were grouped with other groundfish species into a ‘cod’ category, though there is some suggestion that lingcod comprised almost all of the catch (Ketchen et al. 1983). The hook and line fishery accounted for over 90% of the lingcod commercial catch in

Major Area 4B. Catches in the Strait of Georgia reached a historic high level in the 1930s and 1940s. The handline catch in the Strait of Georgia was approximately 4500 tonnes in the mid-1930s (Ketchen et al. 1983) and 4000 tonnes in the mid-1940s (Cass et. al. 1990). By the 1950s, the handline catch had declined to an average of 1400 tonnes (Cass et al. 1990). The handline catch of lingcod in Major Area 4B declined through to the 1980s, when it reached an average of 277 tonnes, an approximate 80% decline from the catches in 1950s (Figure 2, Table 1). Due to conservation concerns, the commercial fishery was closed in 1990. In 1990 the retention of lingcod by all commercial fishermen was prohibited throughout most of Major Area 4B (Minor Statistical Areas (MSA) 12 to 20, 28 and 29).

1.3 Fishery Management of Lingcod in the Strait of Georgia

Since the 1920s, the lingcod fishery was been subject to winter closures in order to protect spawning fish and nest-guarding males. Commercial closures were initially in place from December to February in the Gulf Island region of the Strait of Georgia. In 1979, after further studies into spawning and nest guarding behaviour, this winter closure was extended to November 15 to April 15, and applied to the entire Major Area 4B. Since 1942, a size limit of 58 cm (head-on) on retained lingcod was applied to the commercial fishery. In Major Area 4B, this was extended to 65 cm in 1989.

In 1990, the retention of lingcod by all commercial fisheries was prohibited throughout the Strait of Georgia (MSA 13-19, 28 and 29). Within Major Area 4B, the Queen Charlotte Strait (Sub-areas 12-7, 12-9 to 12-10, 12-13 to 12-14) and Juan de Fuca Strait west of Sheringham Point (Sub-areas 20-1, 20-2, 20-3, 20-4) remain open to both the trawl and hook and line fisheries because populations within these regions are considered to be part of either the Queen Charlotte Sound (Major Area 5A) population or the south west coast of Vancouver Island (Major Area 3C) population (Richards and Yamanaka 1992). Since the commercial closure in 1990, catch is still reported for Major Area 4B (Table 1). It is important to note that this reflects catches in the open areas in MSA 12 and 20. Unfortunately, with the lack of logbooks from the hook and line fishery, lingcod caught in MSA 12 and 20 were not always specifically identified to location. As a result, allocation algorithms used to enter catch into the database automatically assigned lingcod catch to MSAs for which it is prohibited to retain lingcod and in which lingcod were not actually caught.

The recreational fishery has also been subject to winter closures and size restrictions (W. Grider, pers. comm. Regulations Unit, Fisheries Management Branch, Fisheries and Oceans Canada, 555 West Hastings Street, Vancouver, BC, V6B 5G3). In 1979, a winter closure (November 15 to April 15) was initiated for the recreational fishery in the Strait of Georgia (Major Area 4B), and was extended to October 1 to May 31 in 1991. The winter closure is intended to protect nest guarding males (See section 2.1). In 1991, a size limit of 65 cm was applied to lingcod retained in the Major Area 4B recreational fishery. The 65 cm size limit attempts to ensure that most male and female lingcod have spawned at least once (See section 2.1). Presently for Major Area 4B, there are daily catch limits of 1 with an annual limit of 10.

1.4 Assessment Methods for Lingcod in the Strait of Georgia

From the initial stock assessment of Strait of Georgia lingcod in 1979 until the commercial closure in 1990, the primary index of abundance used to assess the status of the stock was a commercial catch per unit effort series based on handline and troll catch and effort (Ketchen 1980). Handline and troll landings accounted for over 88% of the annual landings for lingcod in the Strait of Georgia (Ketchen 1980). By 1985 the effort directed to lingcod had declined, and a qualified landed catch per unit effort index was used based on the landings and effort for handline and troll vessels that had directed effort on lingcod (Cass 1985). After the commercial closure, a recreational catch per unit effort index was used as an index of abundance (Haist 1995; King and Surry 2000).

FISHERY STATISTICS

1.5 Recreational Catch Statistics

Since the closure of the commercial fishery, the only ongoing source of data for abundance indicators is the Strait of Georgia Creel Survey for the recreational fishery. This survey has been conducted annually since 1980. The Strait of Georgia Creel Survey covers the whole of the Strait of Georgia (MSA 13-20, 28 and 29) and provides expanded catch estimates for targeted species based on interview data and aerial surveys. Catch (retained) estimates for lingcod are available from 1981 through 2000 (L. Nagy, pers. comm., Stock Assessment Division, Science Branch, Fisheries and Oceans Canada, 555 West Hastings Street, Vancouver, British Columbia, V6B 5G3). Typically, the estimated catch (pieces) was highest in MSA 13-14, 16-17 and 19 (Table 3). In 1984, a dramatic increase in catch occurred, with more than double the number of lingcod retained (Table 3). In 1991, a 65 cm size limit for lingcod retained in the recreational fishery was initiated and the estimated catch declined abruptly (Table 3). The total number of lingcod retained in the 2000 recreational fishery is estimated to be 6712 pieces.

The estimated lingcod catch from the recreational fishery is not provided in weight. Mean forklengths (cm) are available for lingcod sampled in the recreational fishery. Analyses of lengths is deferred until Section 5.1, but lengths are used here to estimate the mean weight of lingcod landed in the recreational fishery. For each year, and each MSA, mean lengths (cm) were converted to mean weights using research survey length and weight data in Cass et al. (1990, Appendix Table 8), and a length-weight relationship for lingcod:

$\ln W_{kg}=3.3287*\ln(L_{cm})-12.94$.

The estimated catch of lingcod retained by the recreational fishery is presented in Table 4. For the last five years, the estimated catch has averaged 23 tonnes. The 1999 estimated catch (21 tonnes) is less than that previously reported (30 tonnes, King and Surry 2000). The catch reported in King and Surry (2000) was for Major Area 4B and included Johnstone Strait. The estimate reported here is for the Strait of Georgia only and does not include Johnstone Strait. Additionally, King and Surry (2000) used a larger mean length, based on samples taken outside of the Strait of Georgia, to estimate mean weight.

The estimated catch (whether pieces or tonnes) should be considered a minimum estimate. The Strait of Georgia Creel Survey covers the entire open season for lingcod fishing. However, there is no quantification of the retention of lingcod outside of the legal lingcod fishing season (October through May).

1.6 Recreational Catch per Unit Effort

The Strait of Georgia creel survey conducts thousands of interviews each year (Table 5). In 1998 and 1999, the number of interviews conducted dropped dramatically, but is not a reflection of reduced sampling effort, rather a reduction in the number of recreational fishers (R. Nagtegaal, pers. comm., Stock Assessment Division, Science Branch, Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, V9R 5K6). In 2000, the number of interviews increased to pre-1998 levels. Since 1984, information on directed effort to lingcod has been collected (Table 5). Typically, less than 2% of the interviewed anglers report directed effort towards lingcod. Initially, the proportion of interviews was approximately 1.5%, but subsequent to the size limit and daily catch restrictions introduced in 1991, that proportion dropped to less than 0.5% (Table 5). Since 1998, there has been a threefold increase in the proportion of interviews with directed lingcod effort, which is likely a reflection of the recent restrictions for recreational salmon fishing.

Prior to size limit and daily catch restrictions introduced in 1991, over 70% of the lingcod caught by interviewed anglers were kept (Table 5). Since 1991, that proportion has been less than 10%, inclusive for recent years when there has been an increase in directed effort for lingcod. In 1999 and 2000, information was collected from interviewed anglers regarding the size of their released catch. More than 95% of the released lingcod were reported to be below the 65 cm size limit (Table 5). It is likely that in previous years the proportion of released lingcod which were below the 65 cm size limit was also high. It is important to note that since 1991, the relative number of released lingcod has increased, particularly since 1996. However, the relative number of kept lingcod (i.e. > 65 cm) has remained fairly constant. This might reflect a persistent overall low abundance of large lingcod.

3.2.1 CPUE based on number of interviews as effort

Haist (1995) reviewed a number of abundance indices derived from interview data available from the creel survey program. Haist (1995) concluded that significant correlation between recreational fishery based indices and historical commercial catch rates (CPUE) supported the use of recreational fishery data to assess trends in stock abundance. A previous stock assessment used a recreational CPUE based on the number of lingcod caught by interviewed anglers and the number of interviews without directed lingcod effort since it was the most readily available information (King and Surry 2000). For reasons outlined in the following section (Section 3.2.2), indices based on the number of interviews as effort are not the most suitable for interpretation and are presented in this section only because a similar index was used in King and Surry (2000).
Information on directed effort to lingcod has been collected since 1984. Haist (1995) proposed that anglers who direct their effort to lingcod are likely able to maintain high catch rates independent of the general stock status, therefore interviews with non-directed effort were most appropriate. This CPUE index (I1) was significantly correlated with a commercial CPUE index (Richards and Yamanaka 1992) used to assess the stock status prior to the commercial closure

(r=0.81, p=0.028, Figure 3). However, since this recreational CPUE index is based on the sum of all reported lingcod, the inclusion of standard errors for the index is difficult. As a means of providing some measurement of standard error associated with recreational CPUE index values, the mean annual CPUE based on MSA values (I2) was calculated along with the associated standard error (Figure 4). The two recreational CPUE indices (I1 an I2) were highly correlated with each other (Figure 4), but the five years of overlap for the second index (I2) with the commercial CPUE index did not produce a significant correlation (r=0.82, p=0.09).

The two recreational CPUE indices (I1 and I2) declined from 1985 to 1990 (Figure 4). Throughout the first half of the 1990s, the indices remained roughly constant, until 1996 when they both increased. The standard error associated with I2 also began to increase, suggesting that these indices are not reliable. The 2000 values are higher than 1985 level, however the standard error associated with I2 is extremely large.

3.2.2 CPUE based on fishing hours as effort

The recreational CPUE index (I2) is based on number of interviews as a measurement of effort. However this does not account for varying number of hours of fishing per interview. For example, an interview in which there were four hours of fishing is allotted the same effort as an interview with two hours of fishing. In order to account for changes in fishing effort across years, a third recreational CPUE index (I3) was calculated. Changes in geographic effort will effect CPUE rates, so the index was calculated for each MSA. Using the interview database, the mean number of lingcod caught (kept and released) per 100 hours of fishing (Table 6) was calculated for each MSA (K. Hein, pers. comm., Stock Assessment Division, Science Branch, Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, V9R 5K6). Fishing hours were available from 1982 onwards. Overall, the highest CPUE was observed in MSA 13 while the lowest CPUE values were observed in MSA 14, 28 and 29 (ANOVA: $F_{8, 162}$=18.95, p<0.001, Least Squares Difference test p<0.001). The remaining MSA 15-19, had similar mean CPUE values. An overall mean CPUE index based on all MSA values, along with its associated standard error, is presented in Figure 5. This recreational CPUE index (I3) was significantly correlated with the commercial CPUE index (r=0.66, p=0.05, n=9) and when an extreme high value for 1984 in the recreational CPUE is excluded, the correlation is even tighter (r=0.94, p<0.001, n=8).

Since this recreational CPUE index (I3) is based on fishing hours as effort, it is likely a more appropriate index than I1 and I2 in Section 3.2.1 to use for interpretation. An ANCOVA was used to test for differences between years while accounting for covariance attributable to area (MSA). Overall there were significant differences in annual values ($F_{18, 151}$=5.47, p<0.001). The higher values observed in 1984 and 1997 and 1998 were significantly different than all other years, except that 1997 and 1998 were not significantly different than 1996 and 1999 (Least square difference test: p<0.05). The increase in 1984 reflects an increase in kept and released lingcod. The significant increase in 1997 and 1998, is a result of a dramatic increase in released lingcod, not kept lingcod (Table 5). It might therefore be a signal of an above average 1995 or 1996 yearclass. It is likely a signal for the 1995 year class, since the CPUE index significantly (p<0.05) increased in 1996 compared to 1995. The 1999 and 2000 values were not significantly different than previous years (except 1984, 1997 and 1998; and 1999 was significantly higher than 1995), indicating no overall significant trend (Least square difference test: p>0.05).

However, it is important to note that the year class signal is above average only compared to other year classes in the time series. During the time series year class strength was exceptionally low, so any signal will appear large. It should not be used to infer a historically strong year class for lingcod, nor infer a rebuilding of lingcod stocks. Several concurrent and strong year classes are required before any inference regarding a possible sustained increase in the abundance of lingcod should be considered. Additionally, there is no evidence that the 1995 year class has recruited to the recreational fishery.

There are limitations to using creel survey data as an index of abundance for lingcod. The Strait of Georgia creel survey program is designed to survey anglers that target salmonids, and as such the interview locations and times might not capture anglers that specifically target groundfish species, including lingcod. Since there is a winter closure for lingcod fishing in the Strait of Georgia, the period of the creel survey program does cover the period when anglers are permitted to retain lingcod.

1.7 Preliminary 2001 estimates

Preliminary interview data were available for 2001 (K. Hein, pers. comm., Stock Assessment Division, Science Branch, Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, V9R 5K6). The recreational CPUE index (I3) for 2001 is approximately 10.6 (lingcod per 100 fishing hours). This is more than double the average value for 1985-2000 (Figure 5). It appears as if this increase in CPUE index is driven mainly by released lingcod but information on the relative proportion of the released lingcod that are sub-legal size (i.e. <65 cm) is not yet available. However, the 2001 increase in CPUE is not due to more kept lingcod (>65 cm) and is therefore not likely a reflection of 1995 year class entering the recreational fishery. It is likely a signal for a 1999 or 2000 above average year class, and if correct is likely a larger year class than that observed for the 1995 yearclass. These results should be treated as preliminary only. It is important to note, that anecdotal information from the general public have reported an increase in juvenile lingcod throughout the Strait of Georgia observed in 2000 and 2001. Again, several concurrent and strong year classes are required before any inference regarding the possible rebuilding of lingcod should be considered.

NEST DENSITY SURVEYS

1.8 Snake Island Nest Density SCUBA Survey

In January-March 2001, a nest density SCUBA survey was conducted at Snake Island reef outside of Departure Bay, Nanaimo in MSA 17 (King and Beaith, 2001). Previous surveys were conducted in 1990, 1991 and 1994 (Yamanaka and Richards 1995). Methodology for the 2001 survey is outlined in King and Beaith (2001). Briefly, the Snake Island reef was divided into 8 sections and for each dive a section was randomly selected. A surface deployed anchor buoy was released according to both a GPS position and a diveable depth (<60 ft.) on the reef. Two divers descended from the marker buoy to the cannonball and then attached a 10 m quadrat line to the fixed base of the marker buoy. The team of two divers would then swim a circumference, with a radius of 10 m, around the fixed point searching for lingcod nests. Upon discovery of a nest, the presence of a nest guarding male was noted, its length recorded to the nearest centimeter and the volume of the egg mass estimated to the nearest 0.5 L.

Seventy-four quadrat counts were conducted over 18 days during the period of January 23-April 6, 2001. One hundred and seven nests were located within a total area of approximately 23,236 m^2 with an overall median nest density of 0.0032 $nests \cdot m^{-2}$ and a range of 0.0000-0.0287 $nests \cdot m^{-2}$. Differences in median nest density estimates between survey years (Figure 6) were tested by Kruskal-Wallis one-way ANOVA. At least one of the survey years tended to yield higher nest density estimates then at least one of the other survey years (Kruskal-Wallis test statistic=18.40; $p<0.001$). Comparison of mean ranks (Table 7) using critical z-values determined that 1994 and 2001 were significantly higher than 1990 and 1991. This likely reflects the higher maximum nest densities observed in 1994 and 2001 (Figure 6).

There have been differences in survey methodology over the years that might contribute to differences observed in nest density estimates. Surveys conducted in 1990, 1991 and 1994 did not record locations of quadrat dives so it is not known what coverage of the reef was attained. There appear to be preferred spawning locations on the Snake Island reef (King and Beaith 2001). If quadrats focused on preferred areas of the reef, nest density estimates might be inflated, and the opposite would be true for a focus on non-preferred areas. It is also important to note that this survey is conducted on single reef on which recreational fishing takes place. The inference of abundance trends might be applicable to other locations within MSA 17, but might not be applicable to the whole Strait of Georgia.

1.9 Howe Sound Lingcod Egg Mass Survey

The Vancouver Aquarium Marine Science Center has sponsored a lingcod egg mass count SCUBA survey using Vancouver Aquarium personnel and volunteers from the dive community. The egg mass count has been conducted in February in Howe Sound since 1994. The data and analyses reported in this section are unpublished and are provided by the Vancouver Aquarium Marine Science Center (J. Marliave, unpublished data, Vancouver Aquarium Marine Science Center, PO Box 3232, Vancouver, BC, V6B 3X8). Divers are asked to swim rocky habitats that are suitable for lingcod nesting sites and record the number of nests observed along with estimated distance (m) covered underwater (in a straight line) and time (min) spent searching. The index of abundance used by the Vancouver Aquarium Marine Science Center is a count per unit effort index calculated as the number of nests observed in 1 hour of bottom time (Figure 7). Differences in count per unit effort between survey years were tested by Kruskal-Wallis one-way ANOVA. At least one of the survey years tended to yield higher counts per unit effort estimates then at least one of the other survey years (Kruskal-Wallis test statistic=25.84; $p<0.001$). The mean ranks for 2000 and 2001 are higher than in previous years, however they are only significantly higher than 1994 ($z=3.12$, $p<0.05$). All other years were not significantly different.

It is important to note that elements of this survey's design might result in an inflated count per unit effort. Since the survey relies on volunteer divers, the behaviour and experience of divers over the years can affect the count per unit effort. The sites within Howe Sound that are surveyed have varied over the years and relative effort data are not available to make comparisons in this working paper between years. Long-time participants might not return to sites that did not have any egg masses which would inflate the count per unit effort. However, attempts are made to keep the same sample sites and to provide even coverage of Howe Sound. Additionally, as divers become more efficient at searching for egg masses, the encounter rate (i.e. the count per unit effort) will increase.

BIOLOGICAL DATA

1.10 Length of Lingcod Landed in the Recreational Fishery

The Strait of Georgia Creel Survey collects biological data from lingcod kept by recreational fishers. Interviews and biological sampling are conducted on a volunteer basis by recreational fishers. Forklengths (to the nearest cm) and sex are recorded. Preliminary analyses of the data indicated that sex determination was suspect, for example a 107 cm lingcod was recorded as a male which is highly unlikely since the maximum length for males is approximately 80-85 cm. Therefore lengths are not reported here by sex. Additionally, length-at-age relationships cannot be applied to these data since growth curves for males and females are different.

The number of annual samples varies across MSA with reduced sampling in 13-15, 18, and 29 after 1990, likely since fewer lingcod (>65 cm) were landed (Table 9). In 1991, a size limit of 65 cm was initiated for lingcod retained in the recreational fishery. One-way ANOVAs for lengths observed in 1985-1990 and 1991-2001 (Table 10) indicate that there are significant differences ($F=10.25$, $df=8$, $p<0.0001$; $F=17.84$, $df=8$, $p<0.0001$) in mean lengths between MSA, therefore lengths are not pooled across areas. Comparisons of mean lengths prior to 1991 and after 1991 were conducted for MSA 13, 16-17, 19 and 28 since they appeared to have more consistent sampling across years, especially after 1991 (Table 9). Length frequency distributions were not normally distributed and could not be transformed to approximate normality. Kolmogorov-Smirnov two-sample tests indicated that in each MSA the mean length of lingcod landed increased ($p<0.001$) after the implementation of the 65 cm size limit (Table 11). However, the length data for recent years (1999 and 2000) indicates that lingcod less than 65 cm are still being landed throughout the Strait of Georgia, but the relative proportion varies each year (Figure 8). In 1999, the lingcod less than 65 cm were landed in MSA 13, 14, 16, 18 and 28 and accounted for 30% of the lingcod sampled (Figure 8). In 2000, the lingcod less than 65 cm were landed in MSA 15, 16, 17, 19 and 29 but only accounted for 6% of the lingcod sampled (Figure 8). It is important to note, that in MSA 28 the mean length of landed lingcod since 1991 is 60 cm, which is below the 65 cm size limit (Table 10).

1.11 Length of Nest Guarding Male Lingcod on Snake Island Reef

In the 1990 and 2001 Snake Island nest density SCUBA surveys, the total length (cm) of the nest guarding males were estimated (King and Beaith 2001). There is no significant difference between years in the mean length of male lingcod guarding nests when lengths are transformed to approximate normality ($t=0.88$; $df=126$; $p=0.39$, Figure 4). In 1990, the mean estimated length of nest guarding male lingcod was 63 cm (n=54, standard deviation=7) and in 2001 it was 62 cm (n=74, standard deviation=7) (Figure 9). This suggests that has been no discernible increase in the proportion of larger, older males.

1.12 Egg Mass Volume

In the 1990 and 2001 Snake Island nest density SCUBA surveys, the total length (cm) of the nest guarding males along with the volume of the egg mass (nearest 0.5 L) were estimated (King and Beaith 2001). There is no significant relationship (r^2=0.01, p=0.95) between size of the male and volume of the egg mass. Since spawning likely occurs at night and females do not remain associated with an egg mass, there are no data available to relate the size of females to the egg masses observed. Preliminary genetic testing on eggs retrieved from egg masses in 2001 suggest that more than one female contributes to an egg mass (R. Withler, pers. comm. Aquaculture Division, Science Branch, Fisheries and Oceans, Pacific Biological Station, Nanaimo, BC, V9R 5K6). This suggests that use of egg mass volume observed in the field to infer the size of females is complicated. However, laboratory observations on female size and egg mass volume have been used to infer an above average year class in 1995 based on field observations made in 2000 in Howe Sound (J. Marliave, pers. comm., Vancouver Aquarium Marine Science Center, PO Box 3232, Vancouver, BC, V6B 3X8). Wilcoxon Rank Sum test indicated that the egg mass volumes observed at Snake Island reef in 1990 tended to be higher than that in 2001 (z-value=2.08, p=0.04) even though in both years the median egg mass volumes were equal (2.0 L). In 1990, the mean volume was 2.7 L (range 0.5 L to 6.0 L) and in 2000 it was 2.0 L (range 0.5 L to 4.0 L).

CONDITION OF THE STOCK

Since the closure of the commercial fishery in 1990, lingcod abundance appears to have remained at very low and stable levels. A reconstructed historical biomass of lingcod based on commercial fishery data and an age synthesis model estimated that the 1991 biomass had been reduced by over 95% from 1951 levels (Martell and Wallace 1998). Concern regarding declining lingcod populations were expressed in the first assessment (in Ketchen 1980) and by 1984, stock assessments identified overfishing as a likely suspect for the cause of the decline in abundance (Cass 1985). In conjunction with the recommendation to close the commercial fishery, it was recommended that the recreational fishery also be closed in 1990 and remain closed (Richards and Hand 1991). In 1995, it was recommended that the recreational fishery remain open not because there was an indication of increasing lingcod abundance, rather because it was the only source of abundance information (Beamish et al. 1995). It was also noted that it was too early to detect if regulations had stopped the decline in lingcod abundance. Presently, there is no indication that overall lingcod population abundance has continued to decline nor rebuilt to levels similar to pre-collapse of the commercial fishery.

The recreational CPUE index (I3) has remained fairly constant from 1982-2000. There have been slight decreases and increases (e.g. decrease 1985-1995) however these are non-significant. Since 1990, the exception is the significant increase in 1997 and 1998. This increase was driven by an increase in the relative number of released, and presumably small (<65 cm), lingcod. This is likely a signal of an above average year class in 1995 (i.e. 2 and 3 year olds). However, there is no evidence that the year class has entered and dominated the recreational fishery. Male lingcod reach 65 cm by age 5 and female lingcod by age 3. Therefore, this year class should have been evident as an increase in the relative proportion of kept (>65 cm) lingcod by 1998 through 2000. Preliminary results for 2001 do not suggest an increase in the relative proportion of kept lingcod. Information on released lingcod in 1999 and 2000 indicated that only 5% of those lingcod were >65 cm. Preliminary data from the 2001 creel survey suggests that there is another above average year class in 1999 or 2000. As explicitly stated in Section 3.2.2., these year class signals are above average only compared to other year classes in the time series. During the time series year class strength was exceptionally low, so any signal will appear large. Several concurrent and strong year classes are required before any inference regarding the possible rebuilding of lingcod should be considered.

Contrasting to these results is the increase in observed lingcod nest densities from SCUBA surveys conducted at Snake Island reef (MSA 17) and in Howe Sound (MSA 28). Compared to 1990 and 1991, the nest densities observed in 1994 and 2001 at Snake Island were significantly higher. Though no significant difference was detected between 1994 and 2001, the maximum number of nest densities estimated in 2001 was higher than 1994. The Howe Sound survey observed higher nest density estimates in 2000 and 2001, though these were only significantly higher than those observed at the start of the survey in 1994. Overall, there is some slight indication that the spawning population has increased, but it is not overwhelming.

It is important to consider ecosystem dynamics when assessing the condition of any stock. In particular, the decadal-scale dynamics associated with climate-ocean regimes have been documented to have had major impacts on British Columbia ecosystems (Beamish et al. 2000). McFarlane et al. (2000) noted that key Canadian groundfish species experienced average to above average year class success during the 1977 to 1988 regime. Conversely, year class success tended to be average to below average during the 1989 to 1998 regime. A recent regime shift has been documented as occuring in the winter of 1998 (McFarlane et al. 2000) and there is general agreement that the manifestation of this change was detectable in British Columbia ecosystems in 1999. The 1989 regime shift has been associated with changes in the Strait of Georgia ecosystem, most notably changes in Fraser River discharge (Beamish and McFarlane 1999). Corresponding shifts in dominant fish species have also been noted, and include increases in the numbers of Pacific hake and herring, along with substantial declines in coho marine survival. Some species such as Pacific cod, English sole and inshore rockfishes are at low abundance levels (Beamish and McFarlane 1999). Given observations regarding poor recruitment for many marine species throughout British Columbia waters during the 1989-1998 regime (McFarlane et al. 2000), increases in lingcod abundance in the Strait of Georgia during the 1990s might be expected to be slow. The regime shift in 1999 may result in the occurrence of above average or strong lingcod year classes, however the complex nature of ecosystem assemblages makes prediction difficult. Irrespective of the possible impact of the most recent regime shift, the level of lingcod abundance in the Strait of Georgia has remained at such dramatically low levels, that several concurrent strong year classes, coupled with increased recruitment, are required before this stock should be considered to be outside of conservation concerns.

Since 1990, there is evidence of two above average year classes compared to other year classes in the 1990s. These signals are evident as increases in the abundance of juvenile lingcod, however there is a lack of evidence for an increase in the abundance of large, adult lingcod. There are a number of hypotheses for this lack of an increase. First, the continued harvesting of adult lingcod by recreational fishers. There is no quantification of fishing outside legal seasonal limits. In addition, there is no requirement for the reporting of retained lingcod by recreational fishers. Since reporting is done on a voluntary basis, it is likely that the estimated catch (pieces) is an underestimate. A second hypothesis is that prey species for adult lingcod have declined in abundance. As noted in Section 2.1, adults feed mainly on herring and Pacific hake. In the 1990s, the biomass of these two species has remained relatively stable and at either historic high levels (herring) or at average levels (Pacific hake) (McFarlane et al. 2000). If adult lingcod are limited by prey availability, it is not due to prey abundance (i.e. there may be increased competition for prey resources). A third hypothesis is that predator species on adult lingcod have increased in abundance. Lingcod are preyed upon by marine mammals, such as harbour seals and sea lions (Section 2.1). Olesiuk (1999) has estimated that the abundance of harbour seals in the Strait of Georgia has attained historic levels observed during the early 1900s. However, during the 1990s the abundance of harbour seals has plateaued suggesting that they have reached a stabilized carrying capacity. The 1996-1998 estimate of harbour seals in the Strait of Georgia was 37, 257 individuals (Olesiuk 1999). The proportion of lingcod in the diet of harbour seal is approximately 1.1% and the period of greatest predation is November through March when lingcod nesting occurs (Olesiuk 1995). Using a mean daily food intake of 1.9 $kg \cdot d^{-1}$ (Olesiuk 1995), the consumption of lingcod during the nesting season would be approximately 117 tonnes and for the year, 284 tonnes. These estimates are provided to indicate a possible range of predation and should not be considered absolute values. Even if the harbour seal population has returned to historic levels, it is important to remember that during those historic periods, the lingcod commercial catch was greater than 2000 tonnes (Cass et al. 1990). So historically, lingcod have been abundant when harbour seals were also abundant. It is not suggested that predation is the cause of the decline of lingcod in the Strait of Georgia, rather that it may be a contributing factor to the continuing low levels. There are no current population and diet estimates for sea lions in the Strait of Georgia on which to calculate their possible consumption of lingcod.

RECOMMENDATIONS

1. In order to foster an increase in lingcod abundance, commercial fishing should remain closed and recreational closures should be implemented. Providing a source of abundance information should not be a justification for continuance of a recreational fishery. Information on released lingcod and approximate size would still be available through a creel survey program and would be comparable to information available now. Management objectives regarding target abundance levels and management options should be developed in consultation with stakeholders.

2. Fishery independent measures of lingcod abundance in the Strait of Georgia (e.g. nest density surveys, video assessment techniques) should be developed and used to assess the status of lingcod stocks.

3. If recreational fishing remains open, an educational campaign similar to that implemented for inshore rockfish should be undertaken by the Department aimed at advertising the biological rationale behind size and seasonal limits for lingcod. The objectives of the campaign would be to encourage voluntary release of lingcod and help curtail any illegal lingcod fishing.

4. Research should be conducted by a group of experts with varied expertise in the Strait of Georgia ecosystem in order to integrate efforts to understand trophic scale dynamics. Lingcod is one component of an ecosystem, and attempts to understand factors such as predation on lingcod abundance are limited without consideration of all components.

5. Data issues regarding the allocation of commercial catch in open portions of 4B should be resolved (See Section 2.3 for data allocation issues).

YIELD OPTIONS

Increased management efforts should be implemented to foster an increase in lingcod abundance. Efforts should focus on the recreational fishery. It is recommended that the Strait of Georgia be closed to all gear types (commercial and recreational), with no incidental catch permitted.

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Table 1. Lingcod hook and line catch (tonnes) and trawl catch (tonnes) and total commercial catch (tonnes) for Major Area 4B 1951-2000.

Year	Hook and Line[a]	Trawl[b]	Total	Year	Hook and Line[a]	Trawl[b]	Total
1951	1318.1	48.1	1366.2	1982	369.6	79.1	448.7
1952	1512.7	54.0	1566.7	1983	286.9	85.3	372.2
1953	1187.8	28.3	1216.1	1984	192.8	42.7	235.5
1954	1462.5	69.2	1531.7	1985	137.7	27.1	164.8
1955	1231.9	50.6	1282.5	1986	106.2	44.5	150.7
1956	1512.3	55.7	1568.0	1987	80.4	17.0	97.4
1957	1546.4	42.0	1588.4	1988[d]	83.5	13.0	96.5
1958	1450.9	74.6	1525.5	1989	77.3	2.9	80.2
1959	1192.4	336.4	1528.8	1990[e]	44.4	0.2	44.6
1960	1279.6	184.1	1463.7	1991[f]	25.3	1.5	26.8
1961	1199.9	102.1	1302.0	1992	13.4	2.0	15.4
1962	1293	75.4	1368.4	1993	14.7	1.0	15.7
1963	1002.3	39.6	1041.9	1994	18.4	4.0	53.2
1964	c878	90.3	968.3	1995	19.8	0.9	47.9
1965	788.8	93.8	882.6	1996	31	0.4	0.4
1966	804.3	53.7	858.0	1997	29.2	1.7	30.9
1967	795.6	51.2	51.2	1998	45.6	1.2	46.8
1968	769.2	83.9	853.1	1999	47.7	0.0	47.7
1969	778.4	65.6	844.0	2000	25.3	0.0	25.3
1970	823.4	48.1	871.5				
1971	599.4	55.5	654.9				
1972	532.7	34.5	567.2				
1973	404.4	14.8	419.2				
1974	372.3	49.4	421.7				
1975	368.8	33.2	402.0				
1976	331	43.4	374.4				
1977	433	27.2	460.2				
1978	495.3	42.5	537.8				
1979[c]	562.6	25.2	587.8				
1980	353.3	33.5	386.8				
1981	351.5	63.1	414.6				

[a] 1951-1966: British Columbia Catch Statistics, Annual Reports.
1967-1994: Sales slip data files (Fisheries and Oceans Canada, Pacific Region, Catch Statistics Unit, Vancouver BC).
1995-present: Sales slip data files (Fisheries and Oceans Canada, Pacific Region, Catch Statistics Unit, Vancouver BC) and PacHarvestHL Database (Fisheries and Oceans Canada, Pacific Region, Groundfish Data Unit).

[b] 1951-1953: Data obtained by Port Observers and supplemented with sales slip records.
1954-1996: Obtained from the groundfish catch database, GFCatch (Fisheries and Oceans Canada, Pacific Region, Groundfish Data Unit). Catch data based on logbook records (source 1, catch and effort data) and/or sales slip records (source 2, no effort data).
1997-present: Obtained from the groundfish trawl observer database, PacHarvest (Fisheries and Oceans Canada, Pacific Region, Groundfish Data Unit).

[c] Winter closure extended (November 15 – April 15).

[d] Winter closure extended (November 15 – April 30).

[e] Minor Statistical Areas 13- to 19, 28 and 29 closed.

[f] Minor Statistical Subareas 12-1 to 12-6, 12-11, 12-15 to 12-48, and 20-5 to 20-7 closed. Remaining subareas of Minor Statistical Area 12 opened from April 1 – October 31. Subareas 20-1 to 20-4 open between May 15 – November 15.

Table 2. Lingcod hook and line catch (tonnes) for Area 4B by Minor Statistical Area, 1951-2000.

	Minor Statistical Area											Unkown	
Year	12	13	14	15	16	17	18	19	20	28	29	Area	Total
1951	23.3	397.9	88.5	46.3	99.3	357.9	253.2	32.2	17.3	1.8	0.4		1318.1
1952	11.8	440.3	83.6	73.2	169.3	438	235.7	28.6	25.2	7	0		1512.7
1953	5.7	345.8	84.4	46.1	166.2	289	179	38.9	28.2	4.4	0.1		1187.8
1954	16	437.3	157.6	21.5	244.9	362.5	169.1	33.7	13.2	4.8	1.9		1462.5
1955	6.5	330	84.4	64.7	243	338.9	112.3	44.1	8	0	0		1231.9
1956	17.2	564.7	96.3	60.6	235	396.8	106.9	44.1	2.1	1.2	0.8		1525.7
1957	7	542.4	82.4	107.2	288.4	364.7	96.9	54	2.3	0.3	0.8		1546.4
1958	16.5	497.2	105.6	79.3	229.7	350.2	93.5	73.8	4.5	0.6	0		1450.9
1959	16.1	338.3	86.7	31.4	167.8	345.3	85.3	104.7	0.8	0.6	15.4		1192.4
1960	24.3	337.9	110.7	47.1	173.9	378	97	82.8	23.1	1.3	3.5		1279.6
1961	32.1	393.1	92.1	45.6	183.7	285.7	64.3	63.6	29.6	7.7	2.4		1199.9
1962	160.2	412	114.1	60.4	139	241.2	57.2	76.4	19.4	8.9	4.1		1292.9
1963	68	301.4	63.1	30.5	159.6	250.6	44.7	63.5	20.7	0.1	0.1		1002.3
1964	36.3	289.8	43.3	18.8	170	191.5	53.8	52.6	21.4	0.1	0.4		878
1965	30.3	303.2	52.4	6.6	135.8	155.3	50.1	39.3	11.2	0	4.6		788.8
1966	44.4	299.5	61.7	28.7	125.7	131.4	61.2	33	17.6	1.1	0		804.3
1967	49.3	332.8	55.7	19.8	133.3	109.6	69.9	17.8	7	0	0.4		795.6
1968	50.7	273.6	54.2	22	104.7	157.7	53.3	14.8	10.5	0	0.7		742.2
1969	61.9	227.7	81.9	56	109.5	143.5	52.3	31.7	13.8	0	0.1		778.4
1970	46.4	225.5	40.8	84.7	85.7	272.1	37.4	23.7	6.5	0	0.6		823.4
1971	50.1	119.2	30	66.5	89.7	199.9	22.7	18.9	2.2	0.1	0.1		599.4
1972	39.5	152.3	25.1	43.6	81.3	129.9	19.6	38.5	2.4	0	0.5		532.7
1973	22.2	85.9	8.4	62	38.2	123.7	34.4	27.7	1.1	0.6	0.2		404.4
1974	11.2	129.6	13.3	25.2	23.3	127.6	22.2	16.7	2.9	0	0.3		372.3
1975	8.6	93.9	15.1	76	26.5	123	10.9	8.9	5	0	0.9		368.8
1976	10.4	96	12.9	74.9	17.2	82.5	13.4	9.8	7.8	5.7	0.4		331
1977	25.7	128	31.4	63.4	19	104.1	40.6	15.7	2.6	2.2	0.3		433
1978	13.8	158	25.3	48.3	18.4	145.3	36.1	42.2	5.7	0.2	2		495.3
1979	29.2	215.5	36.8	28.7	15.6	157.4	26.9	30.2	13.7	7.1	1.5		562.6
1980	14.7	131.6	14.2	25.8	6.6	103.3	23.9	23	5.3	4.5	0.7		353.6
1981	17.5	137.4	28.9	34.6	12.9	83.6	16.4	16.3	3.3	0.1	0.5		351.5
1982	20.1	177.8	14.9	48	7.7	59.6	20.3	17.5	2.1	0.5	1.1		369.6
1983	16.8	112.3	17.9	32.9	13.2	56.5	18	14.1	4.6	0.3	0.3		286.9
1984	18.7	65.6	7	4	5.2	46.5	30.1	13	2.5	0	0.2		192.8
1985	20.1	46	8.2	4	0.3	29.8	15.9	10.5	2.6	0	0.3		137.7
1986	21	20.2	16	0.5	2.4	17.2	12.9	13.7	1.8	0	0.5		106.2
1987	15.6	22.6	2.2	0.9	0.1	10	8	8.4	5.9	6.7	0		80.4
1988	43.6	12.1	2.5	0.1	0.2	7.1	4.4	8.4	2.4	1.6	1.1		83.5
1989	33.6	12.9	5	0.3	0.9	4.7	5.1	12.2	2.6	0	0		77.3
1990	40.3	0	2.3	0	0	0.1	0	0.1	1.3	0.3	0		44.4
1991	15.6	9.6	0	0	0	0	0	0	0.1	0	0		25.3
1992	12.1	0.5	0.3	0.1	0	0	0.3	0	0.2	0	0		13.5
1993	12.3	0.1	0	0	0	0.6	0	0	0.6	1.1	0		14.7
1994	13.3	0	0.4	0	0	0	0	0	4.7	0	0		18.4
1995	17.9	0.1	0	0	0	0.1	0	0	1.6	0	0.1		19.8
1996	16.8	0.7	0.1	0	0	0	0	0	0	0	0	13.4	31.0
1997	14.7	0.1	0	0	0	0	0	0	0	0	0	14.4	29.2
1998	24.5	0	0	0	0	0.8	0.4	0	0	0	0	19.9	45.6
1999	25.6	0	0	0	0	0	0	0	0	0	0	22.1	47.7
2000	16.3	0.2	0.2	0	0	0	0	0	0	0	0.2	8.4	25.3

Table 3. Catch (pieces) of lingcod retained in the recreational fishery estimated by the Strait of Georgia creel survey program, with standard error (SE) of estimates.

	Minor Statistical Area									
	13		14		15		16		17	
Year	Catch	SE	Catch	SE	Catch	SE	Catch	SE	Catch	SE
1981	31400	2733	17042	2007	6176	705	9266	992	8932	855
1982	30008	1631	11448	1069	2570	300	35236	4534	17772	1402
1983	30256	1925	4458	556	2171	243	37311	4666	12196	900
1984	79438	5320	22870	2421	3336	585	57412	4297	32810	3103
1985	46354	4165	12388	1194	1716	225	27970	2078	17726	1842
1986	51576	3125	19428	2213	2544	268	18732	1915	12664	1189
1987	46988	3513	20576	3725	2864	359	16200	1329	13832	1719
1988	45160	2867	23080	2904	2570	291	19604	1880	11592	1453
1989	20905	2879	8629	868	799	120	7454	632	4763	622
1990	26594	3041	9526	1439	916	178	10009	1287	4617	569
1991	5029	572	2306	517	102	33	1952	453	3138	799
1992	3282	431	936	278	48	21	2052	431	2242	626
1993	1946	371	978	195	106	30	4650	746	1928	352
1994	2854	1056	1516	574	170	59	4182	806	1878	271
1995	1686	303	1324	1635	28	16	2248	552	1954	435
1996	2464	521	152	52	122	34	548	213	1238	261
1997	2070	368	648	178	214	89	768	238	578	145
1998	1028	202	454	178	48	23	1100	467	1204	359
1999	2740	318	140	67	50	19	391	174	1072	222
2000	984	194	925	192	22	9	1130	375	1002	182

Table 3 continued.

	Minor Statistical Area									
	18		19		28		29		Total	
Year	Catch	SE	Catch	SE	Catch	SE	Catch	SE	Catch	SE
1981	7356	1439	8076	881	6720	565	7662	711	102630	4169
1982	12038	912	25466	1891	12252	1240	7312	760	154102	5739
1983	11952	944	17656	908	12694	719	7881	761	136575	5429
1984	14296	1332	30898	1851	17708	1295	16202	2372	274970	8666
1985	10566	1169	26032	2071	6136	501	5338	679	154226	5737
1986	8500	803	21302	1517	3770	377	3124	314	141640	4796
1987	6058	859	21920	1642	1588	226	1594	204	131620	5881
1988	6958	979	18046	1557	1454	168	3394	345	131858	5090
1989	2990	938	5714	701	319	90	756	110	52329	3352
1990	2004	377	8013	759	292	59	672	127	62643	3750
1991	556	120	2440	364	355	496	559	160	16437	1363
1992	407	103	1865	254	606	116	468	98	11906	969
1993	412	133	2438	459	382	96	764	188	13604	1063
1994	924	274	1080	241	498	99	666	165	13768	1530
1995	628	186	1390	269	94	23	306	105	9658	1838
1996	774	204	1658	292	290	69	126	36	7372	722
1997	1108	236	1708	281	604	120	474	110	8172	643
1998	500	101	1784	318	364	102	100	42	6582	738
1999	205	55	2353	883	310	164	93	31	7354	998
2000	205	46	1958	1221	368	97	118	29	6712	1324

Table 4. The expanded catch (tonnes) of lingcod using the estimated recreational catch (pieces) and the estimated mean weight (kg) of lingcod landed in the recreational fishery.

	Minor Statistical Area									
Year	13	14	15	16	17	18	19	28	29	Total
1981	55.9	25.4	6.3	13.0	15.0	12.3	13.6	7.8	13.6	162.8
1982	53.4	17.1	2.6	49.4	29.8	20.2	42.8	14.2	13.0	242.5
1983	53.8	6.6	2.2	52.3	20.5	20.1	29.6	14.7	14.0	213.9
1984	141.3	34.1	3.4	80.5	55.1	24.0	51.9	20.5	28.8	439.6
1985	82.5	18.5	1.7	39.2	29.8	17.7	43.7	7.1	9.5	249.7
1986	91.7	29.0	2.6	26.3	21.3	14.3	35.8	4.4	5.6	230.8
1987	83.6	30.7	2.9	22.7	23.2	10.2	36.8	1.8	2.8	214.8
1988	80.3	34.4	2.6	27.5	19.5	11.7	30.3	1.7	6.0	214.0
1989	37.2	12.9	0.8	10.5	8.0	5.0	9.6	0.4	1.3	85.6
1990	47.3	14.2	0.9	14.0	7.8	3.4	13.5	0.3	1.2	102.6
1991	19.2	8.4	0.2	5.9	13.1	1.9	4.9	1.2	1.9	56.7
1992	12.6	3.4	0.1	6.2	9.4	1.4	3.7	2.0	1.6	40.3
1993	7.4	3.6	0.2	14.0	8.1	1.4	4.9	1.3	2.5	43.4
1994	10.9	5.5	0.3	12.6	7.9	3.2	2.2	1.7	2.2	46.5
1995	6.4	4.8	0.0	6.8	8.2	2.2	2.8	0.3	1.0	32.6
1996	9.4	0.6	0.2	1.7	5.2	2.7	3.3	1.0	0.4	24.4
1997	7.9	2.4	0.4	2.3	2.4	3.9	3.4	2.0	1.6	26.3
1998	3.9	1.7	0.1	3.3	5.0	1.7	3.6	1.2	0.3	20.9
1999	10.5	0.5	0.1	1.2	4.5	0.7	4.7	1.0	0.3	23.5
2000	3.8	3.4	0.0	3.4	4.2	0.7	3.9	1.2	0.4	21.0

Table 5. Summary of Strait of Georgia Creel Survey interview data for 1984-2000.

			Number of Lingcod		
Year	Total number of interviews	Percentage of interviews with lingcod effort	Kept	Released (Sub-legal size)	Total
1980	29141		4602	1626	6228
1981	11693		1192	2071	3263
1982	16599		2013	536	2549
1983	20537		2107	1074	3181
1984	26118	2.5	4558	2404	6992
1985	33165	1.57	3601	1435	5036
1986	29129	1.36	3392	1350	4742
1987	30393	1.86	3132	1405	4537
1988	27436	1.76	2693	755	3448
1989	24763	1.06	1860	847	2707
1990	25088	0.83	1150	1709	2859
1991	21882	0.23	326	2934	3260
1992	29389	0.18	303	4612	4915
1993	24590	0.24	238	2685	2923
1994	19859	0.35	203	2144	2347
1995	15579	0.51	182	1337	1519
1996	15154	0.42	175	2760	2935
1997	13307	0.76	204	2402	2606
1998	7391	1.96	152	1710	1862
1999	9819	1.31	344	2795 (2795)	3139
2000	13427	1.81	413	3558 (3375)	3971

Table 6. The recreational CPUE index (I3) calculated as the number of lingcod caught (kept and released) per 100 fishing hours based on interview data collected by the Strait of Georgia creel survey.

	Minor Statistical Area								
Year	13	14	15	16	17	18	19	28	29
1982	6.44	2.00	4.94	10.79	8.39	5.57	3.88	5.82	3.50
1983	8.54	0.95	4.63	7.00	4.54	8.01	4.74	4.87	4.29
1984	12.84	4.85	3.98	11.04	7.42	9.27	8.74	12.46	4.77
1985	7.15	2.06	3.04	5.62	3.63	7.55	5.53	5.19	2.08
1986	9.01	4.44	3.25	6.13	3.68	7.64	4.60	3.23	1.64
1987	7.91	2.81	4.19	6.67	2.77	3.93	3.83	1.94	1.23
1988	8.83	1.86	4.27	5.82	3.40	4.58	3.60	2.11	1.81
1989	7.29	2.23	5.29	4.81	3.32	3.42	2.54	1.75	1.21
1990	9.98	2.18	3.08	4.67	3.06	4.00	2.90	1.20	0.47
1991	13.62	3.56	4.80	5.07	4.85	6.88	1.88	2.05	0.82
1992	10.28	2.20	3.80	3.75	3.39	7.62	4.18	2.77	0.61
1993	9.06	1.78	2.52	4.81	2.64	6.84	2.68	1.49	0.49
1994	7.95	3.26	2.85	6.28	4.09	7.14	2.38	1.39	0.54
1995	8.15	3.55	4.99	3.10	3.33	2.16	1.00	0.96	0.39
1996	12.43	3.28	6.77	4.76	5.11	6.49	8.07	1.96	1.81
1997	11.51	3.19	8.00	14.26	5.92	8.89	4.87	3.20	6.15
1998	12.6	4.64	10.51	10.83	8.58	6.80	10.47	1.85	1.49
1999	8.76	1.85	5.68	5.53	3.46	5.17	9.00	5.62	2.37
2000	4.32	1.84	0.17	6.07	5.75	5.70	9.61	0.43	1.21

Table 7. Mean ranks and sample size for comparison by Kruskal-Wallis one-way ANOVA of Snake Island reef nest density estimates for survey years 1990, 1991, 1994 and 2001.

Year	Mean Rank	Sample Size
1990	77.72	37
1991	49.86	22
1994	105.10	29
2001	83.55	74

Table 8. Mean ranks and sample size for comparison by Kruskal-Wallis one-way ANOVA of Howe Sound egg mass counts per hour bottom time.

Year	Mean Rank	Sample Size
1994	106.20	26
1995	142.58	30
1996	132.78	49
1997	133.72	61
1998	127..53	34
1999	104.06	8
2000	185.75	34
2001	174.44	44

Table 9. The number of lingcod forklength samples available from the Strait of Georgia creel survey.

		Minor Statistical Area									
Year	Unknown	13	14	15	16	17	18	19	28	29	Total
1985	59	4	19	0	13	44	8	83	1	0	231
1986	10	66	115	11	93	101	23	89	43	4	555
1987	0	70	38	9	102	99	17	172	6	6	519
1988	0	27	16	0	101	56	7	69	25	19	320
1989	0	34	20	13	97	74	9	107	3	2	359
1990	0	84	60	20	162	146	2	140	8	0	622
Total	*69*	*285*	*268*	*53*	*568*	*520*	*66*	*660*	*86*	*31*	
1991	0	4	0	0	12	20	1	5	11	5	58
1992	0	30	5	2	12	26	2	13	26	4	120
1993	0	0	0	1	17	12	3	14	12	7	66
1994	1	1	0	0	27	13	4	20	19	4	89
1995	0	4	0	0	14	25	3	2	12	4	64
1996	1	2	0	0	4	6	0	6	10	0	29
1997	0	2	0	0	5	9	8	10	19	3	56
1998	0	1	0	0	4	27	1	16	3	6	58
1999	2	1	2	0	5	15	0	36	6	3	70
2000	0	23	12	1	42	74	3	37	2	1	195
Total	*4*	*68*	*19*	*4*	*142*	*227*	*25*	*159*	*120*	*37*	
Overall	*73*	*353*	*287*	*57*	*710*	*747*	*91*	*819*	*206*	*68*	*3411*

Table 10. Mean (standard deviations) forklength (cm) of lingcod landed by interviewed recreational fishers by Minor Statistical Area.

	Minor Statistical Area									
Year	13	14	15	16	17	18	19	28	29	Total
1985	53 (8)	50 (6)		56 (11)	55 (10)	55 (9)	55 (12)	49 (0)		53
1986	57 (10)	55 (9)	50 (14)	52 (11)	58 (11)	55 (8)	56 (12)	55 (10)	62 (17)	56
1987	55 (10)	54 (13)	47 (8)	55 (12)	57 (11)	58 (10)	56 (13)	57 (13)	54 (5)	55
1988	60 (13)	54 (10)		55 (10)	56 (12)	65 (16)	62 (14)	52 (8)	59 (9)	58
1989	64 (15)	58 (14)	48 (7)	56 (8)	55 (11)	61 (7)	56 (10)	45 (4)	58 (18)	56
1990	61 (10)	57 (11)	52 (6)	53 (12)	61 (11)	51 (0)	60 (12)	48 (14)		55
1985-90	*58 (12)*	*55 (11)*	*49 (9)*	*54 (11)*	*57 (11)*	*57 (10)*	*57 (12)*	*51 (10)*	*58 (10)*	*55 (11)*
1991	66 (8)			71 (10)	69 (13)	49 (0)	76 (14)	55 (8)	61 (7)	64
1992	70 (15)	70 (20)	56 (14)	65 (10)	72 (9)	75 (6)	64 (18)	53 (11)	73 (12)	66
1993			57 (0)	63 (10)	69 (8)	69 (2)	68 (11)	66 (7)	70 (16)	66
1994	69 (0)			70 (7)	70 (6)	69 (7)	68 (12)	58 (13)	67 (12)	68
1995	71 (7)			71 (6)	75 (11)	56 (6)	61 (14)	72 (14)	69 (5)	68
1996	89 (29)			59 (8)	80 (10)		71 (6)	68 (14)		73
1997	91 (2)			56 (21)	76 (7)	79 (16)	73 (9)	59 (14)	67 (5)	71
1998	65 (0)			69 (4)	78 (10)	74 (0)	77 (8)	58 (10)	78 (8)	71
1999	49 (0)	64 (0)		69 (5)	84 (15)		70 (12)	64 (19)	71 (10)	67
2000	76 (8)	75 (10)	61 (0)	71 (7)	77 (8)	70 (3)	73 (14)	71 (3)	63 (0)	71
1991-00	*73 (13)*	*72 (13)*	*58 (9)*	*68 (9)*	*75 (10)*	*71 (13)*	*70 (13)*	*60 (13)*	*70 (11)*	
Overall	66	61	53	62	68	63	65	58	65	64

Table 11. Kolmogorov-Smirnov two-sample test statistics (T) and *p*-values for comparison of mean lengths (cm) of lingcod landed by interviewed recreational fishers 1985-1990 and 1991-2000. A size limit of 65 cm was implemented in 1991.

			1984-1990		1991-2000	
Minor Statistical Area	T statistic	p-value	mean	standard deviation	mean	standard deviation
16	0.66	<0.001	54	11	68	9
17	0.67	<0.001	58	11	75	10
19	0.48	<0.001	57	12	71	13
28	0.37	<0.001	53	10	60	13

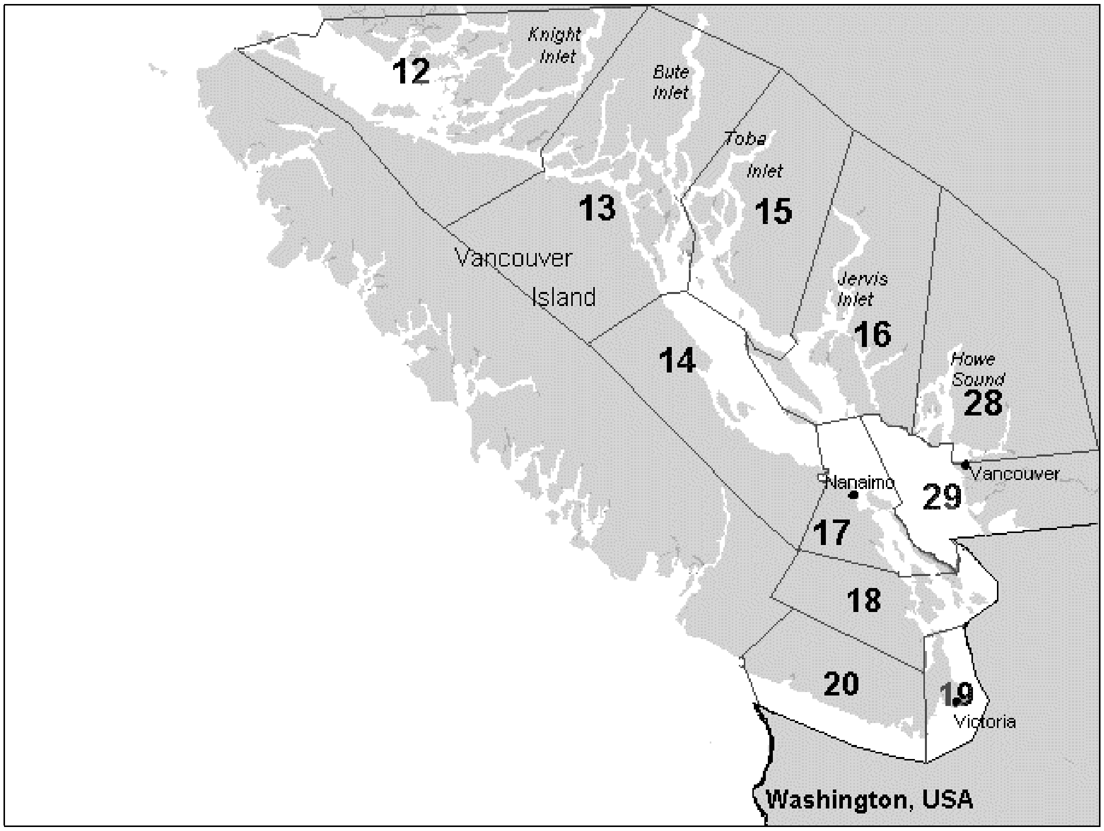

Figure 1. Minor Statistical Areas (MSA) within the Major Area 4B. For this working paper, the Strait of Georgia is defined as MSA 13-19, 28 and 29.

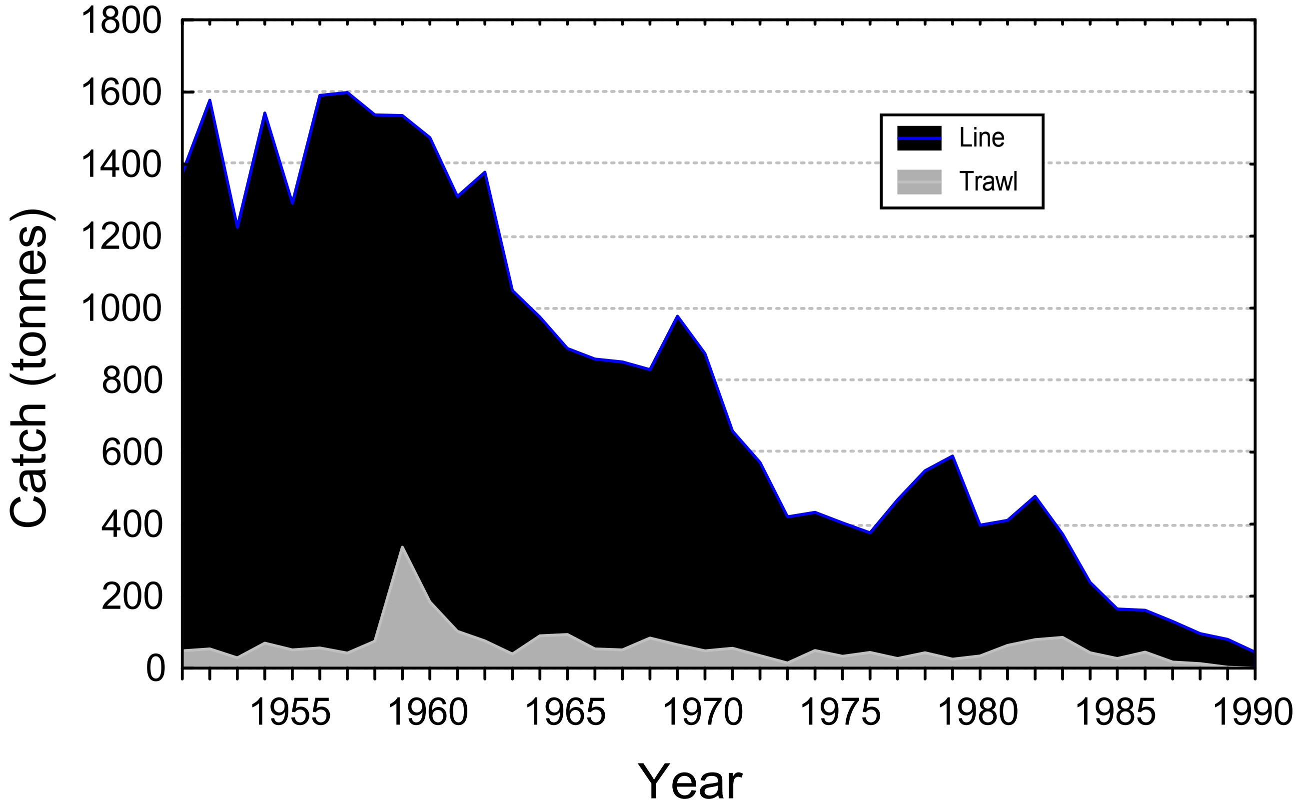

Figure 2. Catch (tonnes) for combined hook and line (handline, troll, longline) and trawl gear in Major Statistical Area 4B from 1951 to 1990.

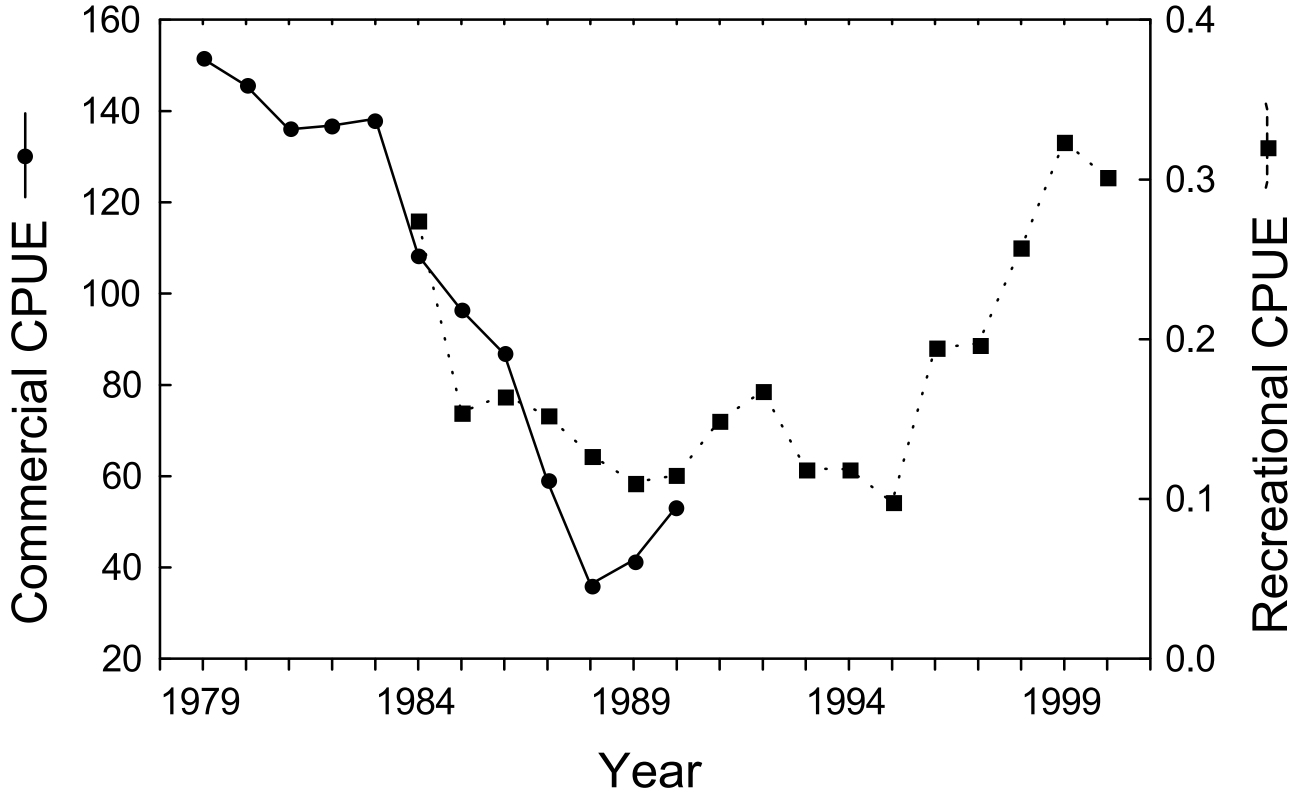

Figure 3. The commercial CPUE (kg/d) from Richards and Yamanaka (1992) along with the recreational CPUE (I1) as derived from Haist (1995) and presented in King and Surry (2000) which is calculated as number of lingcod caught (kept and released) per interview without directed lingcod effort.

The CPUE (I1) index is based on number of interviews as a unit of effort and is not recommended as an appropriate index to interpret, since fishing hours vary across interviews.

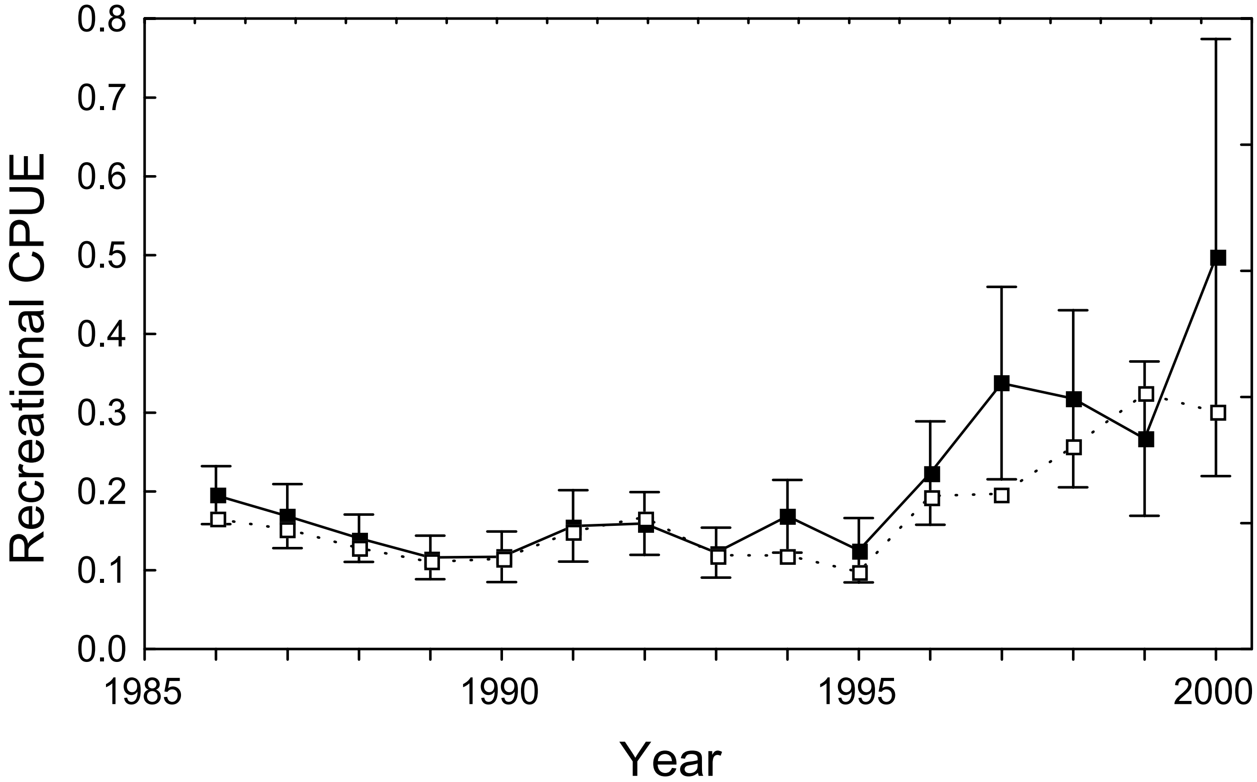

Figure 4. Recreational CPUE indices based on number of interviews as unit effort. Open squares and dotted line denote CPUE (I1) calculated as total lingcod caught (kept and released) per interview without directed lingcod effort.

Closed squares and solid line denote CPUE (I2) calculated as mean number of lingcod caught (kept and released) per interview without directed lingcod effort averaged across Minor Statistical Areas. Standard error bars are associated with the mean values (I2). These indices are based on number of interviews as a unit of effort and are not recommended as appropriate for interpretation, since fishing hours vary across interviews.

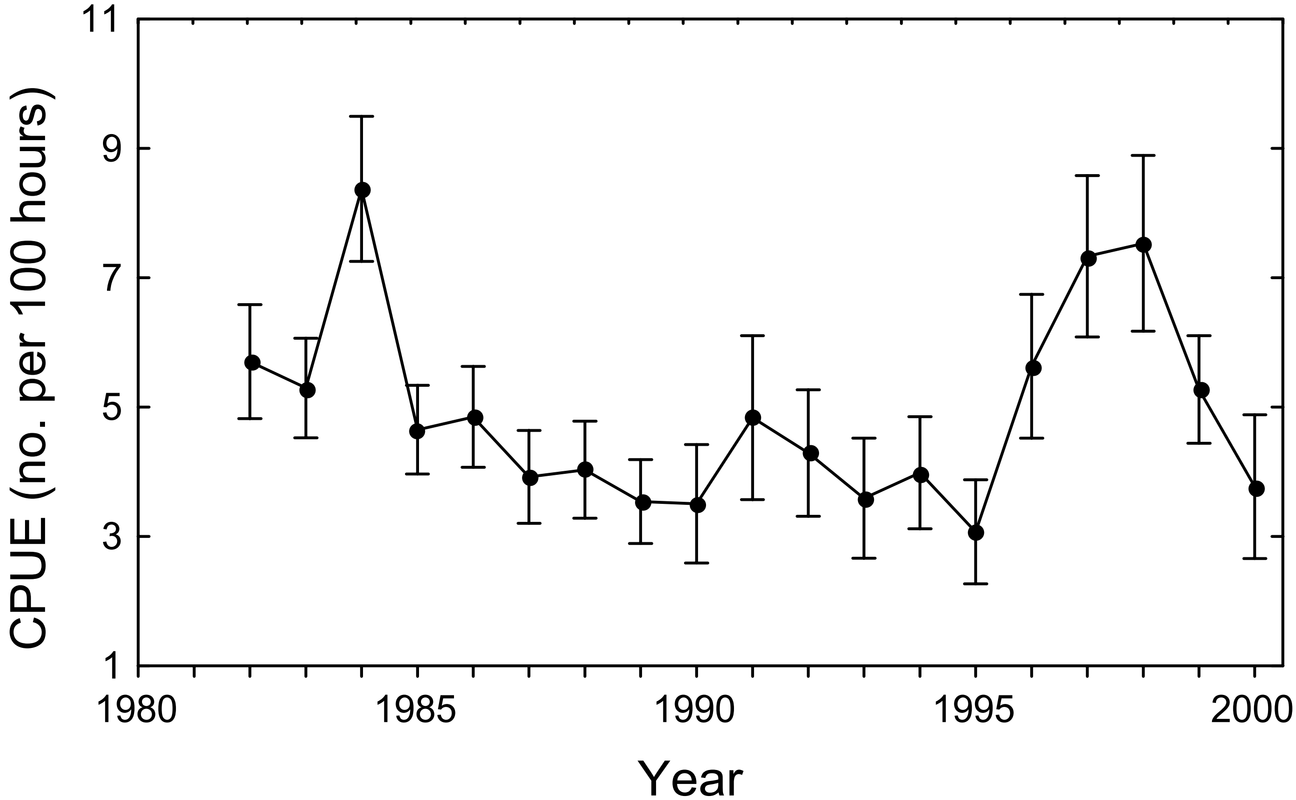

Figure 5. Recreational CPUE (I3) calculated as the mean number of lingcod caught (kept and released) per 100 fishing hours averaged across Minor Statistical Areas.

Whiskers denote standard errors. This index uses fishing hours as a unit of effort, and is the most appropriate index for interpretation. Prior to the size limit change in 1991, the number of kept lingcod was higher than released lingcod. Since 1991, the number of released lingcod has been an order of magnitude higher than the number of kept lingcod. Information on released lingcod available for 1999 and 2000 suggests that 95% of released lingcod are less than 65 cm in length.

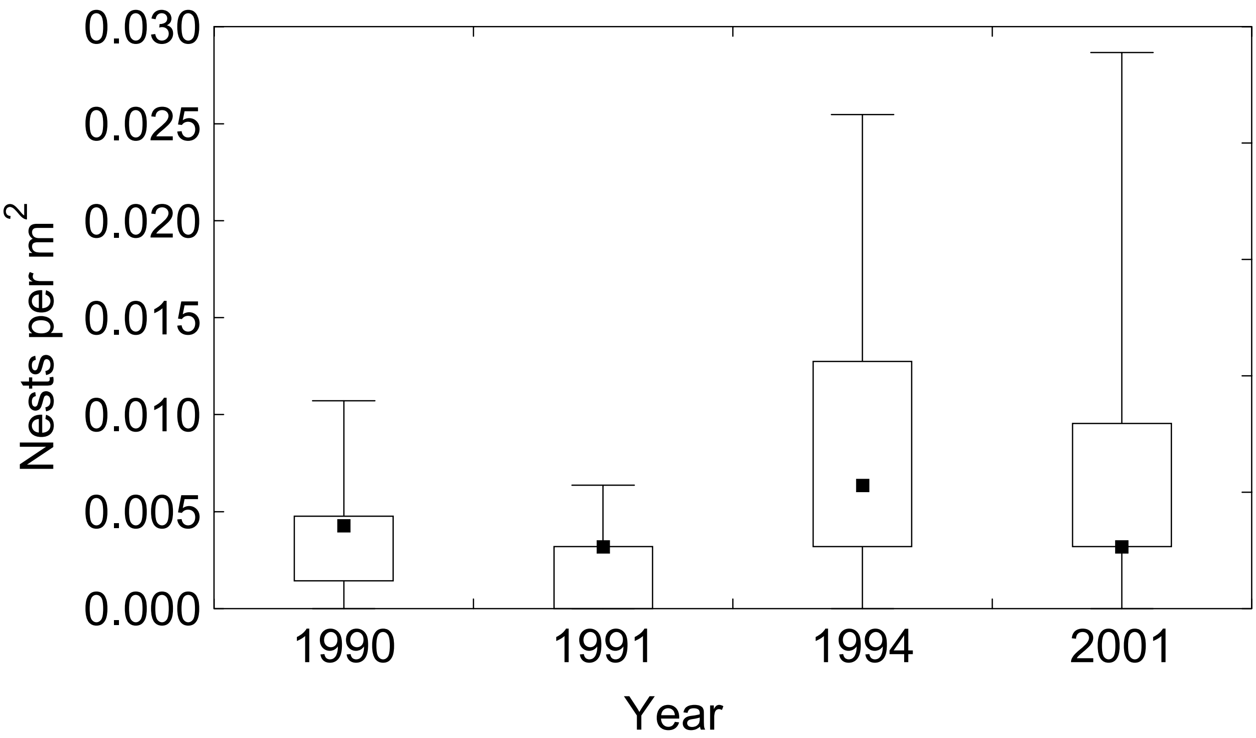

Figure 6. Median nest density estimates from SCUBA surveys at Snake Island reef (Minor Statistical Area 17).

Whiskers denote maximum and minimum nest densities observed, boxes denote 25 and 75 percentiles.

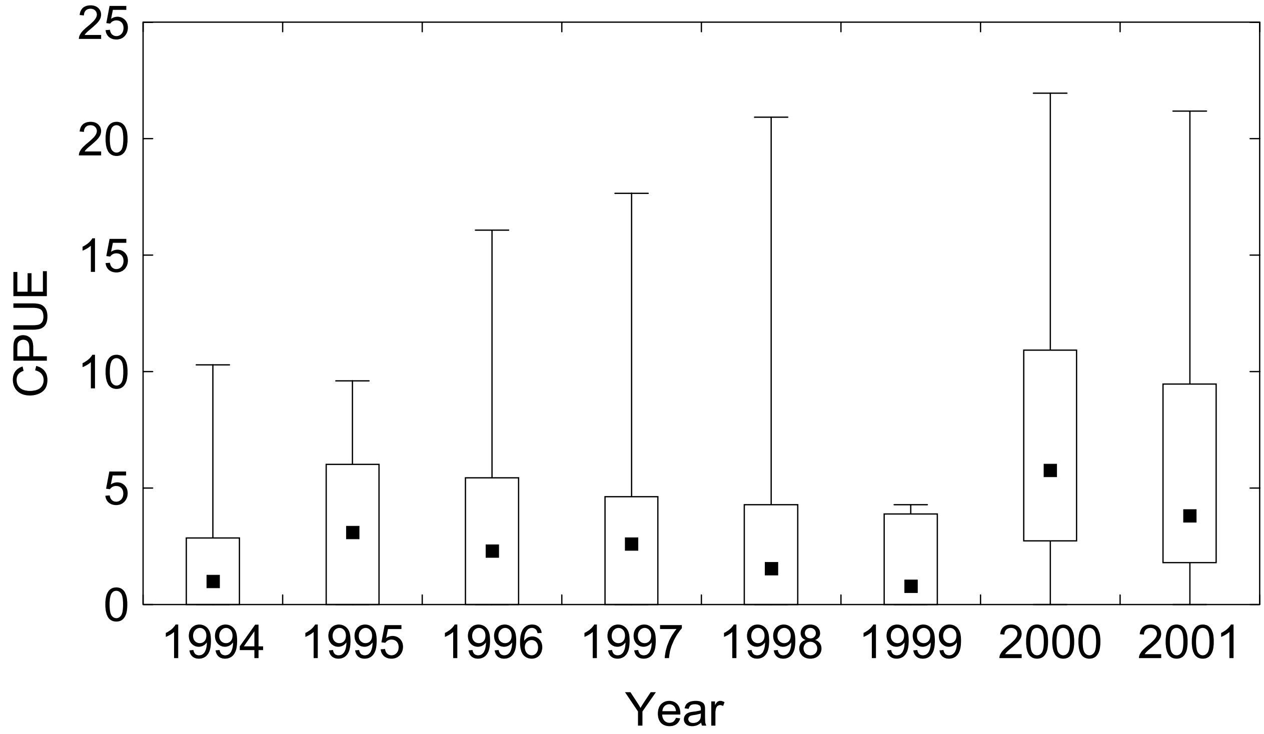

Figure 7. Median number of nests counted per 1 hour of bottom time (CPUE) from the Vancouver Aquarium Marine Science Center egg mass SCUBA survey conducted in Howe Sound.
Whiskers denote maximum and minimum nest densities observed, boxes denote 25 and 75 percentiles.

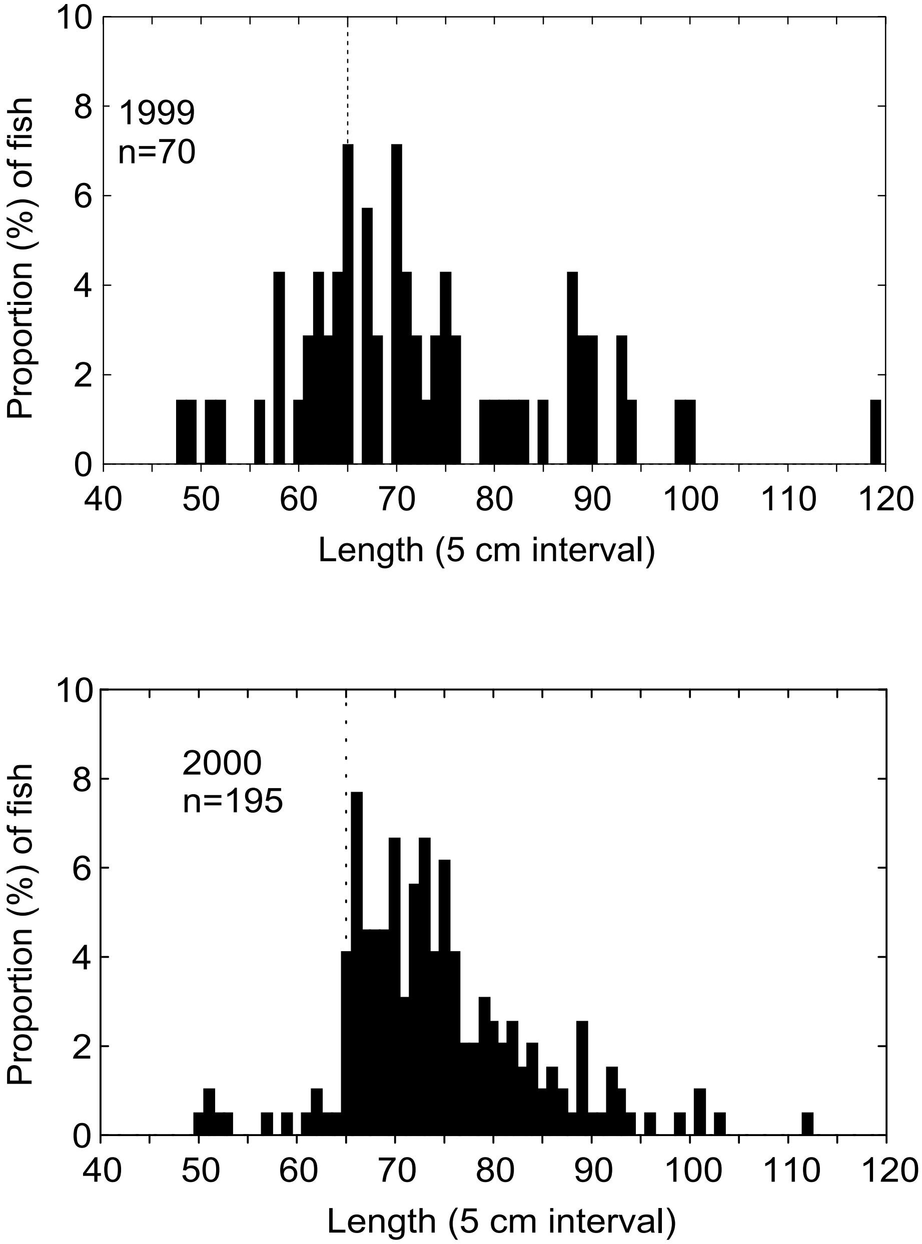

Figure 8. Proportion of lingcod sampled in the Strait of Georgia creel survey program with forklengths that fall within 5 cm intervals.

Dotted lines denote the 65 cm size limit initiated in 1991.

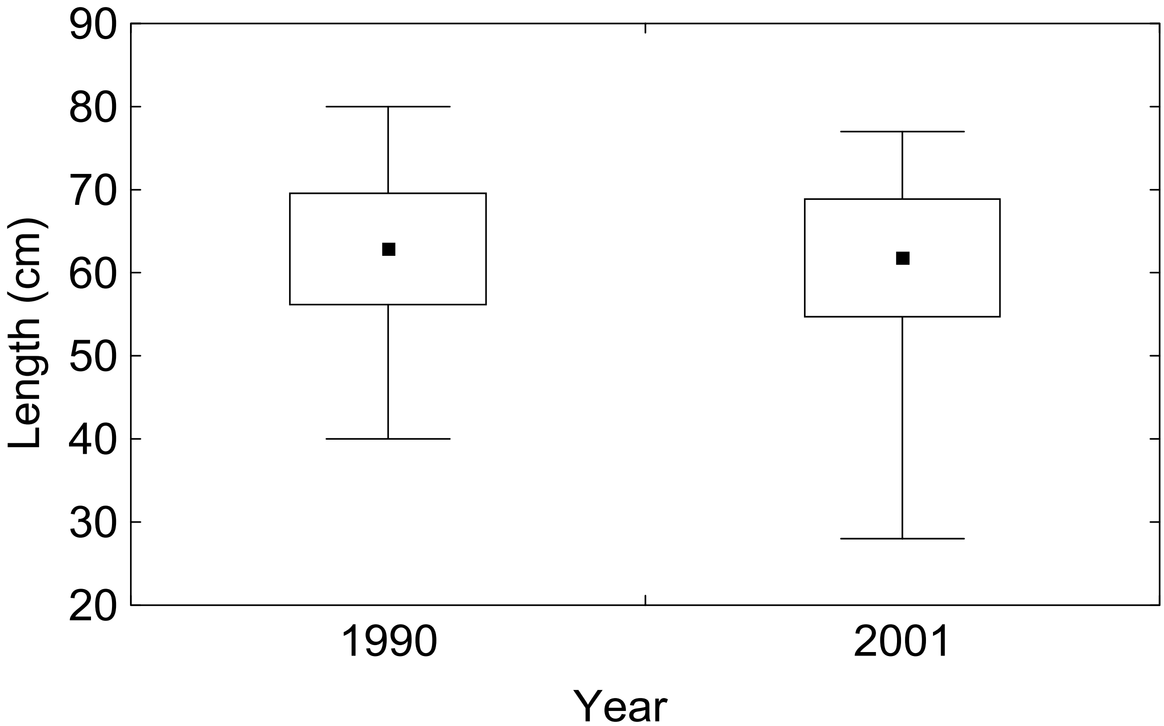

Figure 9. Mean total length (cm) of nest guarding males at Snake Island reef (Minor Statistical Area 17).
Boxes denote standard deviations, whiskers denote maximum and minimum lengths.

Appendix I: Request for Advice

Date Submitted: June 26, 2001

Individual or group requesting advice: Groundfish Management Unit

Proposed PSARC Presentation Date: November 2001

Subject of Paper (title if developed):

Assessment of Lingcod in the Strait of Georgia and Yield Recommendations for 2002 and beyond.

Stock Assessment Lead Author: Jackie King

Fisheries Management Author/Reviewer: D. Trager

Rational for request:

In 1990, the commercial fishery for lingcod in the Strait of Georgia was close due to conservation concerns. Size limits were implemented in the recreational fishery in an effort to conserve lingcod.

In 2000, a coastwide assessment of lingcod was conducted. This assessment included the Strait of Georgia stock area. Additional assessment information is available through the nest count survey program.

Given the additional data, and feedback from stakeholders regarding a change in lingcod abundance in the Strait of Georgia, a more detailed assess of lingcod in the Straight of Georgia is requested.

Question(s) to be addressed in the Working Paper:

1. What is the stock status of lingcod and how does this relate to historical stock conditions?
2. What are the appropriate harvest levels for all sectors (recreational, commercial First Nations combined).
3. What have been the impacts of the commercial closure?
4. What ecosystem considerations are relevant to the recovery of the stock?

Objective of Working Paper: *(StAD staff to develop further jointly with management)*

1. To review surveys, biological sampling, catch records, logbooks, observer reports and fishing practices for Strait of Georgia Lingcod to provide a basis for management for the fishery in 2002/2003 and beyond.
2. To provide an assessment of Strait of Georgia Lingcod stock status.
3. To recommend appropriate yield options.
4. To recommend other management measures necessary for the conservation of lingcod.