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Stock Assessment Framework for Strait of Georgia lingcod

Cadre d'évaluation du stock de morue-lingue du Détroit de Georgia

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ABSTRACT

This document outlines background information on lingcod biology, historical fishery and abundance trends of Strait of Georgia lingcod, sources of historical and current biological information on Strait of Georgia lingcod in order to develop monitoring and assessment programs for these populations. An extensive review of all research activities that have been conducted on Strait of Georgia lingcod is provided with discussion on their suitability for providing baseline biological and relative abundance data. Several types of surveys have been conducted on all life stages of lingcod, from purse seining for post-larval lingcod, to bottom trawling for young of year or juvenile lingcod, to handline, SCUBA or submersible surveys on age-2+ lingcod. Based on the results and conclusions of previous research surveys, along with sampling logistics, it is recommended that two types of surveys be implemented to provide information on the relative abundance of Strait of Georgia lingcod: 1)-bottom trawl surveys for young of year lingcod to estimate relative yearclass success; 2)-handline surveys for age-2+ lingcod to estimate the relative abundance of lingcod at index sites throughout the Strait of Georgia. Baseline information from similar surveys conducted in the past will provide points of reference to which future survey results can be compared. In addition to surveys, research projects investigating seasonal migration, recreational fishing recapture rates, population structure and Strait of Georgia ecosystem dynamics are recommended.

RÉSUMÉ

Ce document présente des renseignements de base sur la biologie de la morue-lingue du détroit de Georgia, les tendances historiques des prises et de l'abondance, ainsi que les sources de données biologiques historiques et actuelles utilisées pour élaborer des programmes de surveillance et d'évaluation de ces populations. Les résultats d'un examen exhaustif de toutes les activités de recherche visant la morue-lingue de ce bassin sont aussi inclus, ainsi qu'une discussion de leur pertinence comme source de données de base sur la biologie et l'abondance relative de l'espèce. Plusieurs types de relevés ont été effectués sur tous les stades du cycle vital de la morue-lingue : pêche à la senne coulissante visant les post-larves; chalutage sur le fond visant les jeunes de l'année et les juvéniles; pêche à la ligne à main et relevés en plongée autonome ou en submersible visant les individus de 2 ans et plus. D'après les résultats et les conclusions des relevés de recherche antérieurs et à la lumière de la logistique de l'échantillonnage, on recommande que deux types de relevés soient effectués afin d'obtenir de l'information sur l'abondance relative de la morue-lingue dans le détroit de Georgia, soit : 1) des relevés au chalut de fond visant les jeunes de l'année afin de pouvoir estimer le succès relatif de cette classe d'âge et 2) des relevés à la ligne à main des 2 ans et plus afin de pouvoir estimer l'abondance relative de l'espèce à des sites repères à l'échelle du détroit de Georgia. Les renseignements de base provenant de relevés semblables effectués par le passé serviront de points de référence auxquels on pourra comparer les résultats des relevés futurs. En plus des relevés, on recommande de mener des projets de recherche sur les migrations saisonnières, les taux de recapture de la pêche récréative, la structure de la population et la dynamique de l'écosystème du détroit de Georgia.

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1.0 OVERVIEW

Since 1990, retention of lingcod by the commercial fishery in the Strait of Georgia (Minor Statistical Areas 13-19, 28 and 29, Appendix A1) has been prohibited in response to conservation concerns (Richards and Hand 1989). In the recreational fishery, regulations prior to 2002 to protect lingcod included an eight month winter non-retention period to protect nest guarding males, size limits, and reduced daily and annual catch limits. In 2002, the recreational fishery was closed for the retention of lingcod as an additional measure to protect this stock; the non-retention regulation currently remains in effect.

Assessing the success of management strategies requires reliable measures of changes in the relative abundance of lingcod. This stock assessment framework was requested by the Groundfish Management Unit (see Appendix A2) to provide the necessary background information to develop monitoring and assessment programs for Strait of Georgia lingcod. The specific objectives requested for this stock assessment framework are:

- Outline historical fishery and abundance trends of Strait of Georgia lingcod.
- Outline current biological information on Strait of Georgia lingcod.
- Provide survey methodologies and considerations for survey design for monitoring and assessing the relative abundance and biological parameters of Strait of Georgia lingcod.
- Provide recommendations that prioritize survey and research requirements.

The objectives are addressed in Sections 3 through 6. In addition, we provide a brief review of lingcod biology, history of the fishery, and management history of Strait of Georgia lingcod.

2.0 INTRODUCTION TO LINGCOD AND THE STRAIT OF GEORGIA FISHERY

2.1 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 from 10 to 100 m. Lingcod are considered to be non-migratory. Tagging studies in the Strait of Georgia indicated that 95% of males remain within 11 km of their release site, and females within 34 km, during the first year of release after tagging (Smith et al. 1990). Similar studies 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). These concurrent tagging studies 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 canine 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).

2.2 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 1) and a 93% decline from handline catches in the mid-1940s (Appendix A3) . The commercial fishery was closed in 1990.

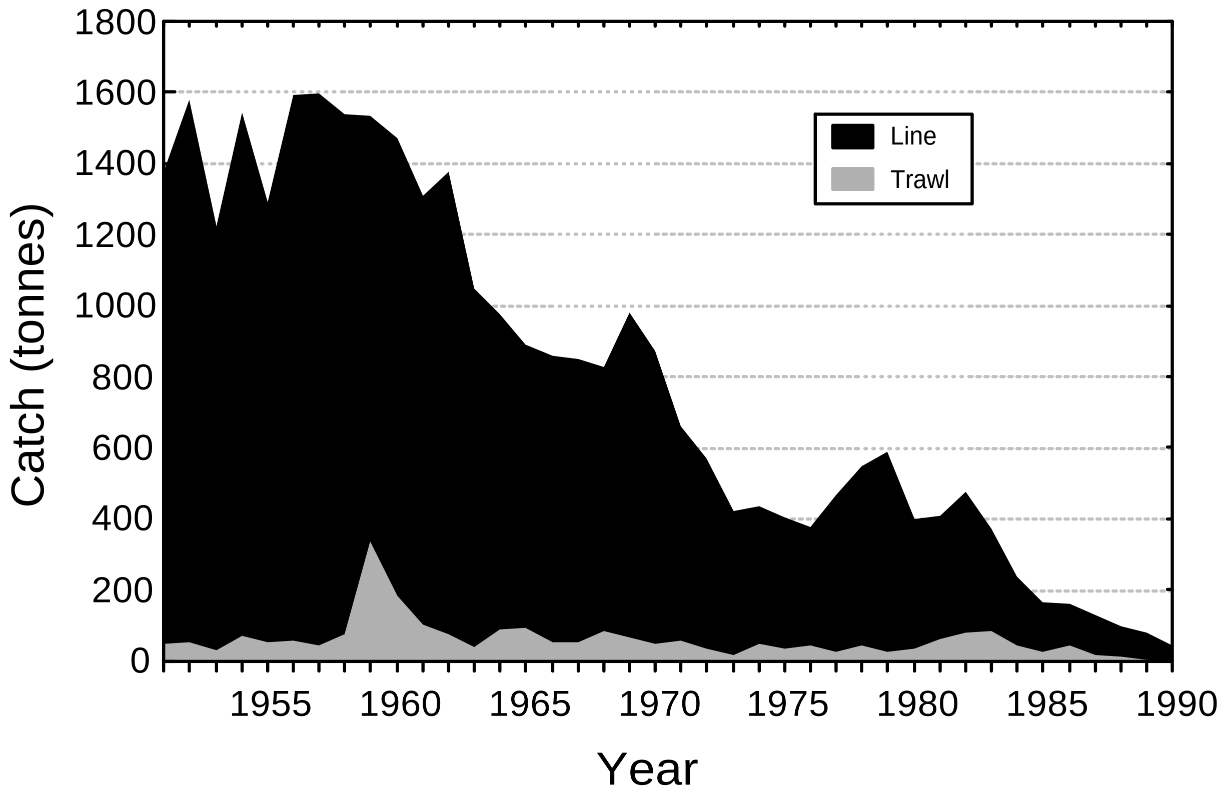

Figure 1. Commercial landings (tonnes) for combined hook and line (handline, troll, longline) and trawl gear in Major Statistical Area 4B from 1951 to 1990. Statistics and data sources are provided in Appendix A3.

Recreational catch statistics are estimated by the Strait of Georgia Creel Survey program. This survey has been conducted since 1981 and covers the whole of the Strait of Georgia (Minor Statistical Areas (MSA) 13-20, 28 and 29, Appendix A4). The survey provides expanded catch estimates for targeted species based on interview data and aerial surveys. Retained catch estimates (reported as pieces) for lingcod are available from 1981 through 2002 and have been used along with size information on retained lingcod to estimate retained catch in tonnes (Figure 2). Prior to the implementation of a size-limit, the recreational landings of lingcod was estimated to average 104 tonnes. This excludes 1981 which had limited sampling (July and August). Sampling in all other years covered the open season for lingcod. A dramatic increase in estimated lingcod landings occurred in 1984. In 1990 and 1991, the estimated landings declined, presumably as a response to bag limits and size limits. Since 1992, the estimated recreational landings have been relatively stable (mean estimated landings of 16 tonnes), with an increase in 2001 to 29 tonnes. In 2002, despite a recreational closure, an estimated 12 tonnes were landed.

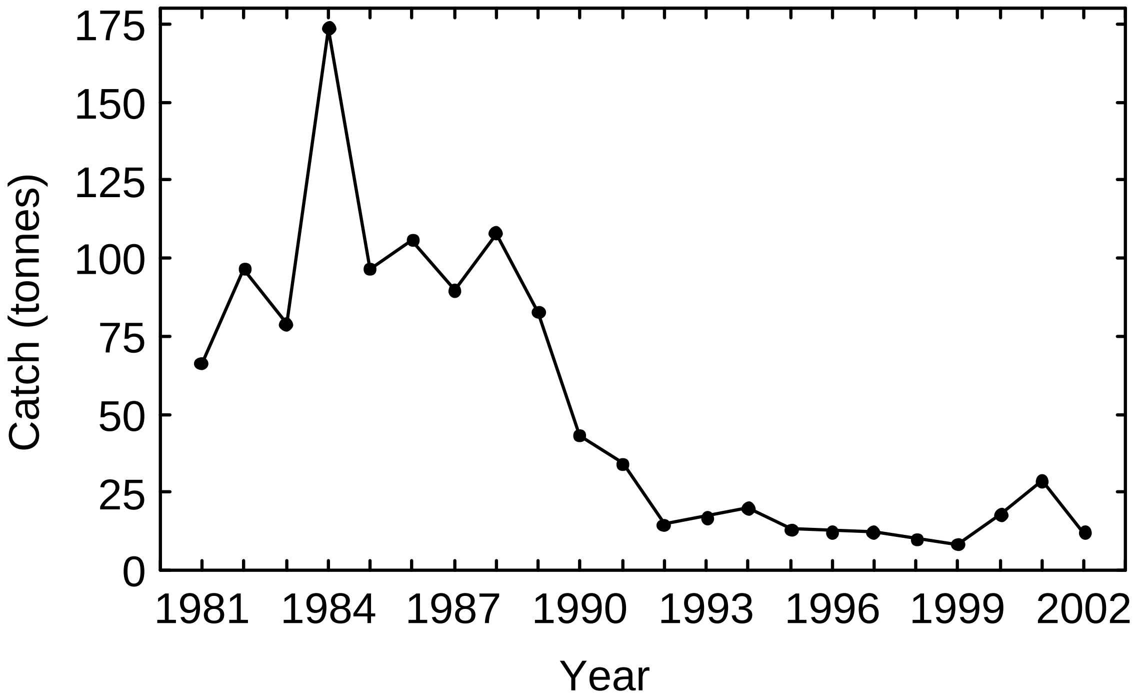

Figure 2. Recreational landings (tonnes) for Minor Statistical Areas 13-19, 28 and 29 as estimated from the Strait of Georgia creel survey program data. Statistics and data sources are provided in Appendix A4.

2.3 FISHERY MANAGEMENT OF LINGCOD IN THE STRAIT OF GEORGIA

Since the 1920s, the lingcod fishery was 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 and was implemented in both commercial and recreational fisheries. 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. A voluntary size limit of 58 cm was introduced to the recreational fishery in 1990 and a bag limit of 3 fish per day was implemented. In 1991, a mandatory size limit of 65 cm was implemented, along with a reduced bag limit (1 fish per day) and an extended winter closure (October 1 to May 31).

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). Within Major Area 4B, 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). The relative abundance of lingcod remained at historic lows throughout the 1990s, and the recreational fishery was closed in 2002 throughout MSA 13-19, 28 and 29.

3.0 SOURCES OF HISTORICAL DATA

3.1 BIOLOGICAL DATA

A number of surveys and tagging programs were conducted (in the late 1930 and early 1940s and since 1975) on Strait of Georgia lingcod from which biological data are available (Table 1). The majority of the surveys were conducted in Areas 13, 16, 17 and 18, with some minor coverage in Areas 14 and 19. No research surveys were conducted in Areas 28 or 29. The type of biological data collected with each survey varies, but generally length by sex is available. It is important to note that the tagging surveys would have relied on external sex determination, which is more difficult in juvenile lingcod (approximately < 40 cm). Length by sex data for juveniles and adults (age-2+) are available from numerous surveys in the late 1930s and early 1940s, 1985-88, 1993 and 1998 (Table 1) and are summarized by Area in Figure 3 to Figure 9. The surveys were conducted over similar depth ranges, but were not conducted during standard months. In order to address differences due to seasonal distributions of lingcod, the length data were grouped into two periods: spring and summer (April through September) or fall and winter (October through March).

Table 1. Summary of DFO lingcod research surveys conducted in the Strait of Georgia with available biological and catch data.

Date	Location	Type of survey	Biological Data	Catch Data	Reference
1938-1944 (Oct – April)	Mainly (65%) in Area 17; also in Areas 13, 14, 16 and 18.	Tagging program. Fish collected by handline.	n=2,368 (length, sex, weight)	Total catch. Effort difficult to determine.	Chatwin 1956
1975-1976 (Monthly)	Area 17 (Stuart Channel)	Bottom trawl for juvenile Pacific hake and walleye pollock, along with other groundfish.	n=368 (length 1976 only)	Catch by swept area.	Beamish et al. 1976; Beamish et al. 1978

Date	Location	Type of survey	Biological Data	Catch Data	Reference
1978 (Jan-June)	Area 17 (Dodd Narrows)	SCUBA observations on nesting behaviour	n=57 (estimated weight of nest guarding males)	Number of egg masses per area surveyed.	Low and Beamish 1978
1978 (July)	Mainly (99%) Areas 14 and 17; some in Area 12, 18 and 29.	Tagging program. Fish collected by bottom trawl.	n=751 (length, sex)	Total catch. Effort difficult to determine.	Cass et al. 1983
1982-1985 (Oct – Mar)	Areas 13, 14 and 16	Tagging program. Fish collected by handline.	n=10,529	Total catch. Effort difficult to determine.	Cass et al. 1984; Cass et al. 1986; Smith et al. 1990
1980-1981 (April-June)	Area 17	Purse seine survey for post-larval lingcod	n=5,321 (length; raw data lost; summarized data in report)	Post-larval density per area.	Cass and Scarsbrook 1984
1981-1982 (February)	Area 17	Bottom trawl for age-1 lingcod	n=248 (length; raw data lost; summarized data in report)	Catch by swept area.	Cass and Scarsbrook 1984
1984 (July-Oct)	Areas 15 and 16	SCUBA survey for nearshore reef fishes.	none	Count by area of transect.	Richards et al. 1985b
1984 (Oct-Nov)	Areas 15 and 16	Submersible survey for nearshore reef fishes.	none	Count by transect. Area difficult to determine.	Richards and Cass 1985a
1984-85 (June-Nov)	Areas 15 and 16	Handline survey for nearshore reef fishes	n=139 (length, sex)	Catch by sum of all fisher's fishing time. Effort in June-July 1984 is unknown.	Richards et al. 1985a; Richards and Cass 1985b
1986-88 (June-July)	Areas 13 and 16 (1986 only)	Handline survey for nearshore reef fishes	n=265 (length, sex, weight)	Catch sum of all fisher's fishing time.	Richards and Cass 1987; Richards and Hand 1987; Richards et al. 1988;
1985; 1987-88 (Oct-Feb)	Area 17 (Gulf Islands)	Handline survey for lingcod.	n=709 (length, sex, weight, maturity)	Catch by the sum of all fisher's fishing time.	Cass and Richards 1987; Hand and Richards 1987; Hand and Richards 1989

Date	Location	Type of survey	Biological Data	Catch Data	Reference
1989-1990 (May)	Area 17 (Nanaimo)	Purse-seine survey for post-larval lingcod.	n=1736 (length)	Post-larval density per area.	Hand and Richards 1991
1990-91 1994 (Dec-Mar)	Area 17 (Snake Island)	SCUBA surveys for egg mass density counts.	n=54 (length of nest guarding males 1990 only)	Number of egg masses per area surveyed.	Yamanaka and Richards 1995
1991 (July-August)	Areas 17 and 18 (Gulf Islands)	Bottom trawl for young of year lingcod index of abundance	n=696 (length)	Catch by swept area.	Workman et al. 1992
1993 (June-Oct)	Area 18 and 19	Handline survey for lingcod.	n=115 (length, sex, weight)	Catch by sum of all fisher's fishing time.	Yamanaka and Murie 1995
1998 (July)	Areas 18 and 19	Handline survey for rockfish.	n=235 (length, sex, maturity)	Catch by set time.	
2001 2002 (Jan-April)	Area 17 (Snake Island)	SCUBA surveys for egg mass density counts.	n=102 (length of nest guarding males)	Number of e gg masses per area surveyed.	King and Beaith 2001; King and Winchell 2002

Four purse seine surveys were conducted in Area 17 in 1980-81 and 1989-90 for post-larval lingcod (Table 1). Length data of post-larval lingcod caught in 1980-81 was not published (Cass and Scarsbrook 1984) and archived records can not be located. However, Hand and Richards (1991) provide a length frequency distribution for the 1980 survey and compare it to 1989-90 length data published in that report. The mean length of post-larval lingcod quickly increased during each sampling period. Lengths ranged from 30 mm (early May) to between 80-90 mm by late May. Modal distributions in annual post-larval lengths (at 55 and 65 mm) suggest two periods of lingcod hatching.

Four bottom trawl surveys were conducted for age 1+ juvenile lingcod in Area 17 in 1975-76 and in 1981-82. Actual length data for 1975-76 are published in Beamish et al. (1978), however data for 1981-82 are summarized as length frequency histograms in Cass and Scarsbrook (1994). In all years, the dominant mode in lengths was between 25-35 cm corresponding to age-1 lingcod. One bottom trawl survey for young-of-year lingcod was conducted in Areas 17 and 18 in 1991 (Table 1). Length frequency distribution is summarized in Figure 10.

The final source of biological data from research surveys are SCUBA surveys which observed nest guarding males in Area 17 in 1978, 1990 and 2001-2002. In 1978 the weight (kg) of the male was visually estimated, but in 1990 and 2001-2002 the lengths (cm) of the males were measured (Figure 11) . However, the sample size of these data are small (Table 1), and the surveys occurred in a limit area.

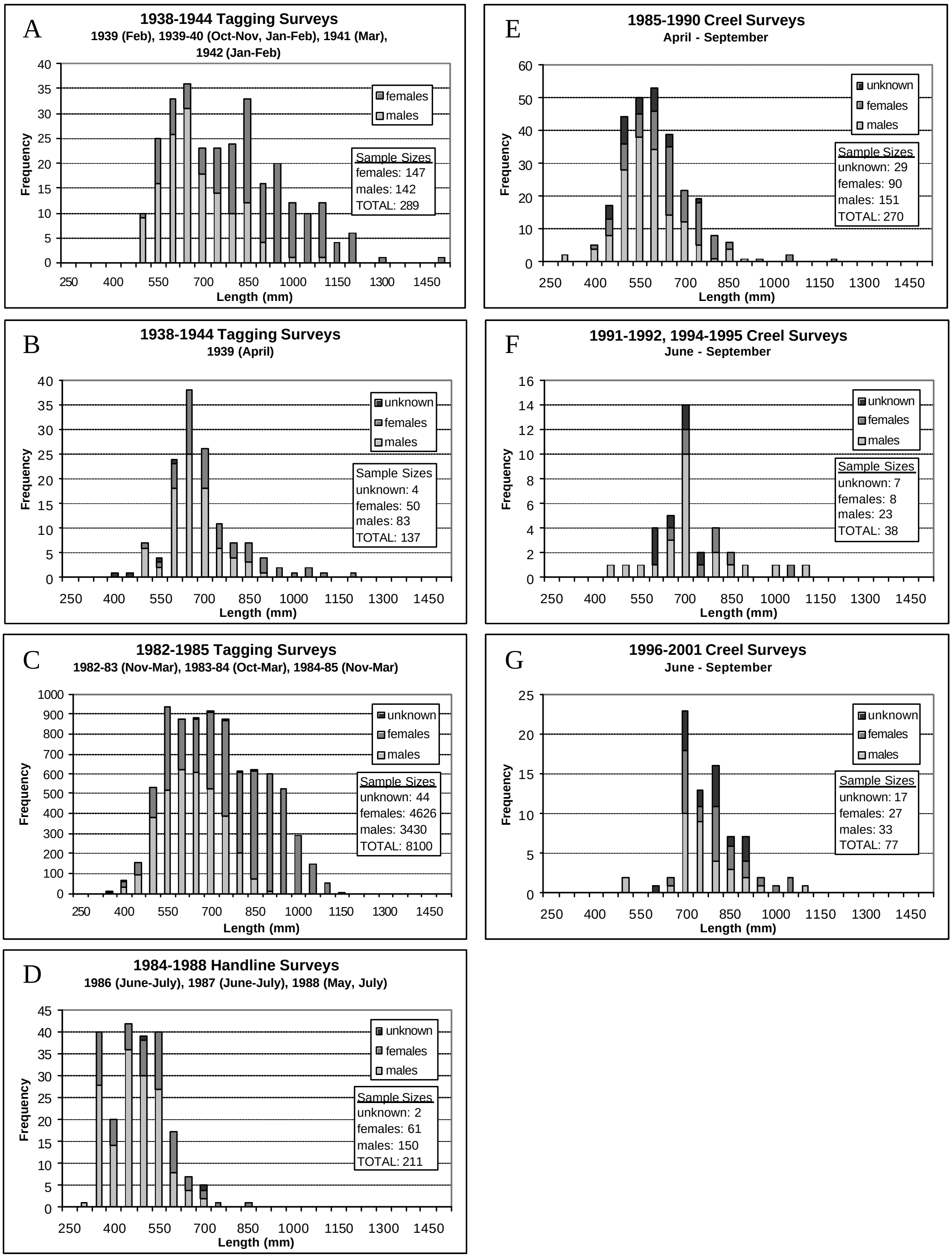

Figure 3. Length frequencies (by sex) of lingcod sampled in research and creel surveys conducted in Area 13. Data have been grouped by sampling periods, spring and summer (April through September) or fall and winter (October through November).

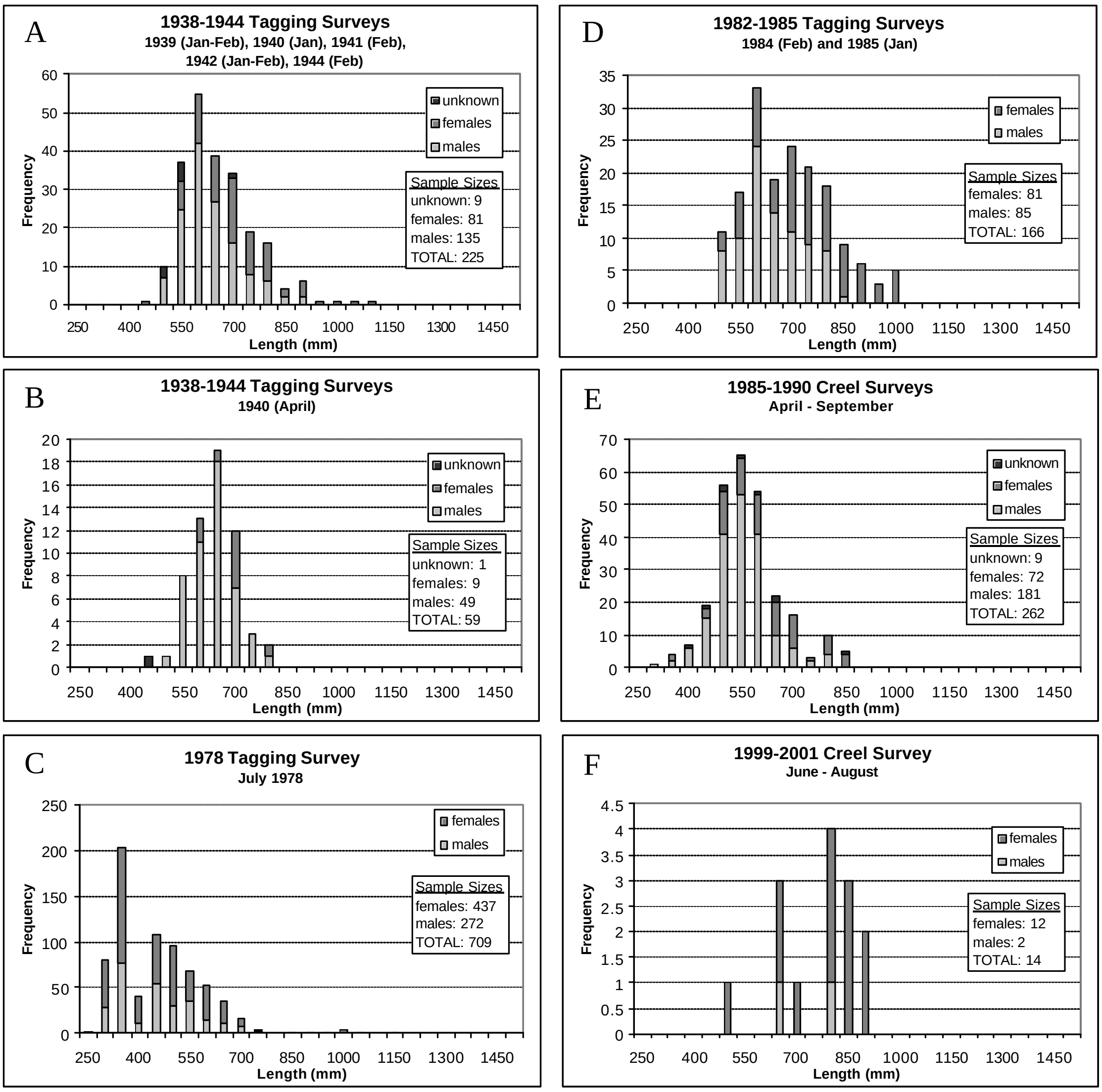

Figure 4. Length frequencies (by sex) of lingcod sampled in research and creel surveys conducted in Area 14. Data have been grouped by sampling periods, spring and summer (April through September) or fall and winter (October through November).

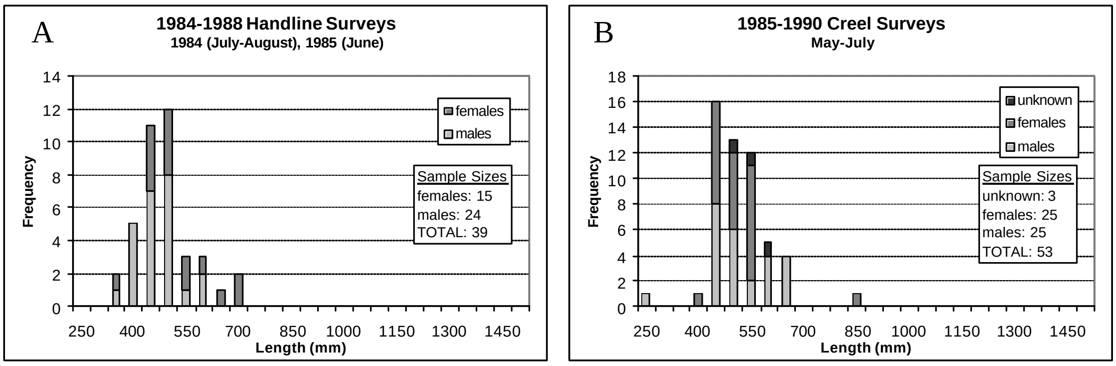

Figure 5. Length frequencies (by sex) of lingcod sampled in research and creel surveys conducted in Area 15. Data have been grouped by sampling periods, spring and summer (April through September) or fall and winter (October through November).

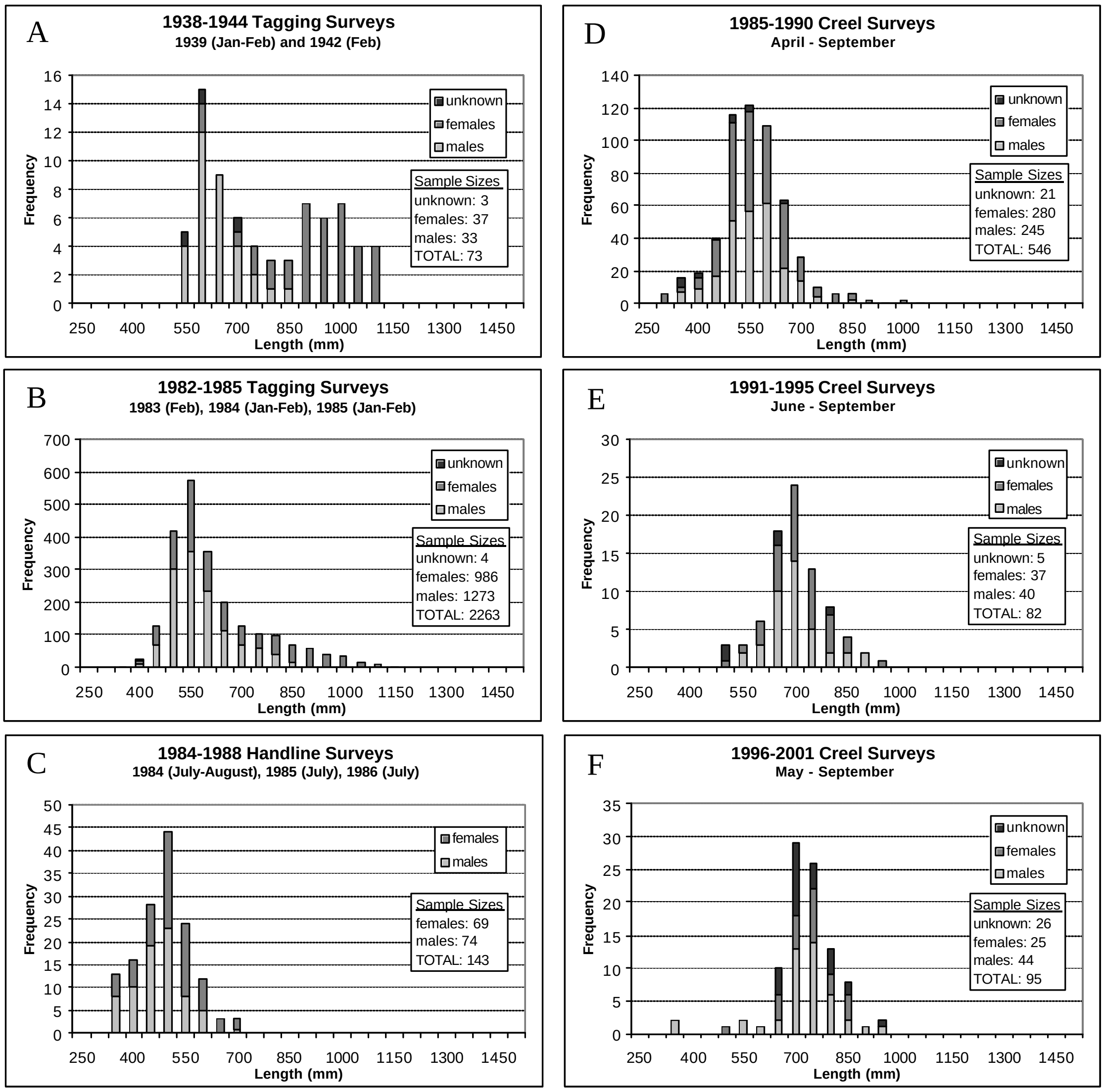

Figure 6. Length frequencies (by sex) of lingcod sampled in research and creel surveys conducted in Area 16. Data have been grouped by sampling periods, spring and summer (April through September) or fall and winter (October through November).

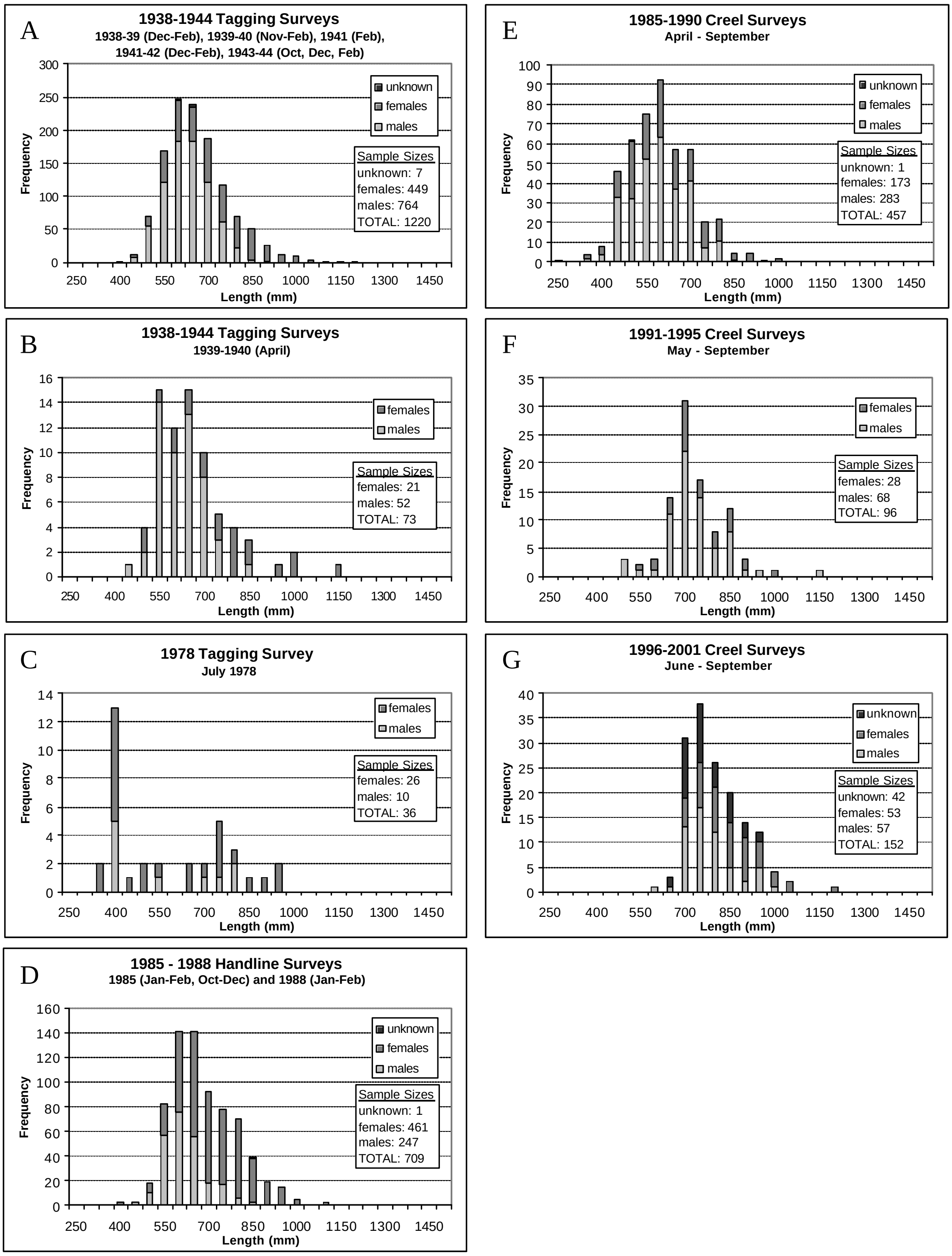

Figure 7. Length frequencies (by sex) of lingcod sampled in research and creel surveys conducted in Area 17. Data have been grouped by sampling periods, spring and summer (April through September) or fall and winter (October through November).

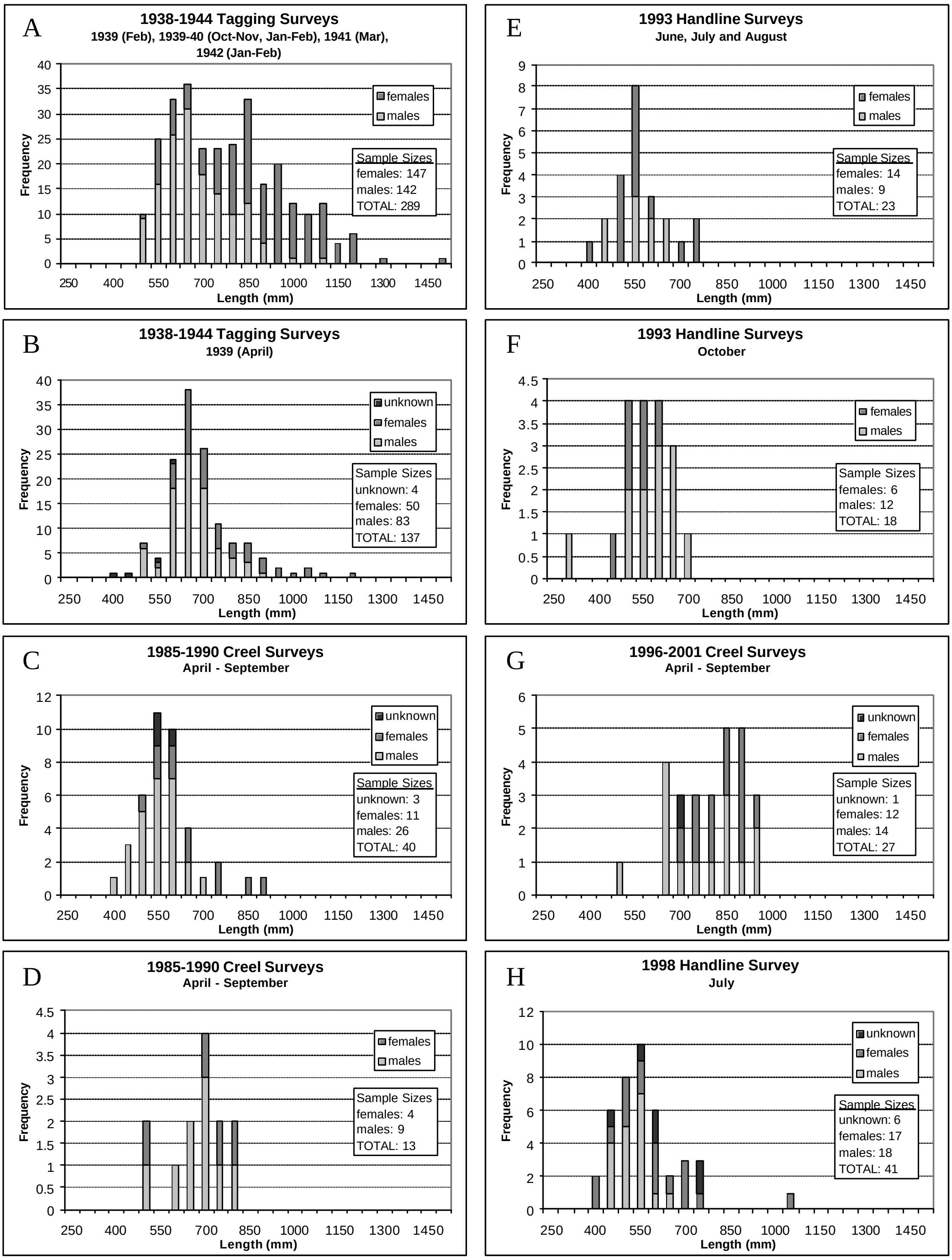

Figure 8. Length frequencies (by sex) of lingcod sampled in research and creel surveys conducted in Area 18. Data have been grouped by sampling periods, spring and summer (April through September) or fall and winter (October through November).

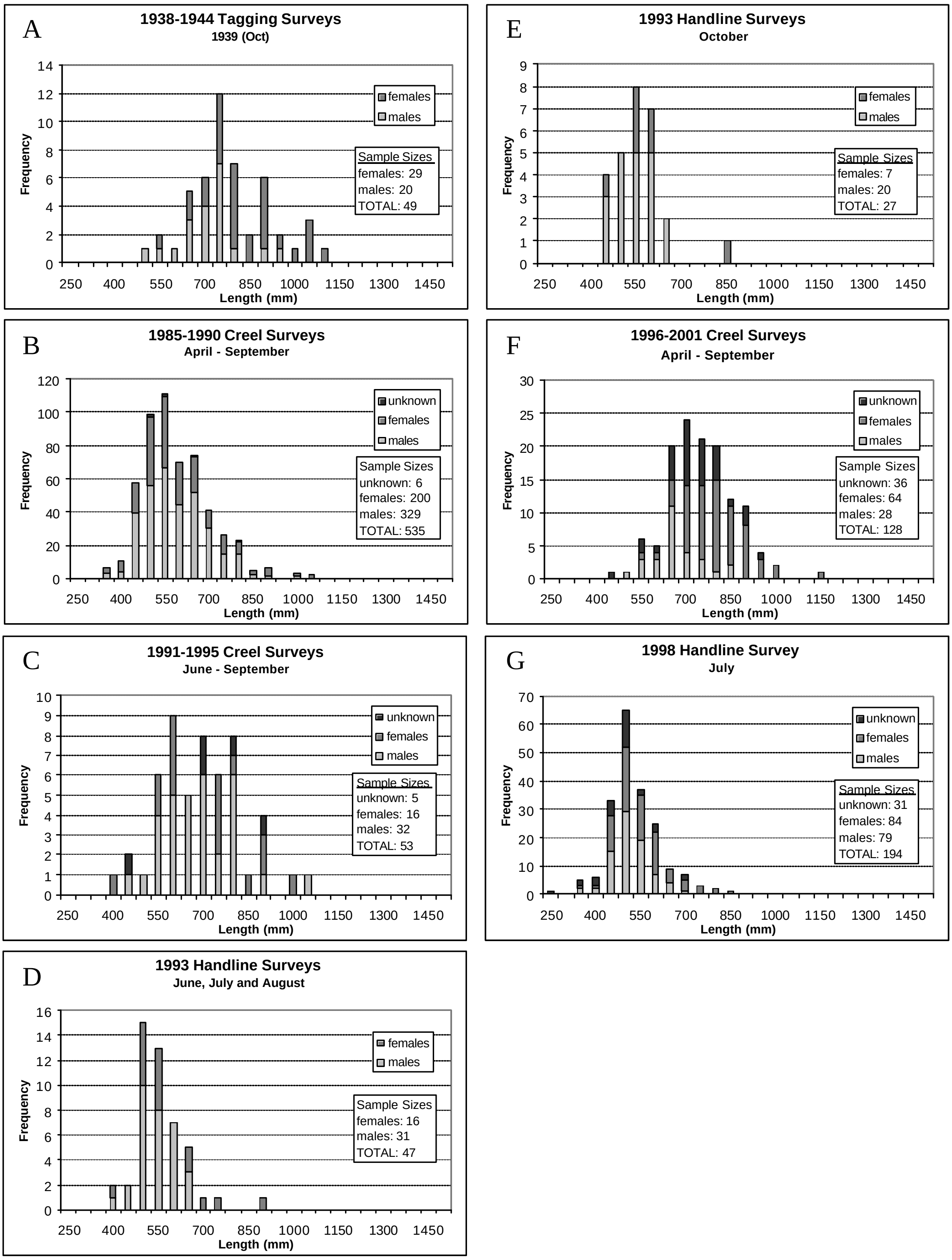

Figure 9. Length frequencies (by sex) of lingcod sampled in research and creel surveys conducted in Area 19. Data have been grouped by sampling periods, spring and summer (April through September) or fall and winter (October through November).

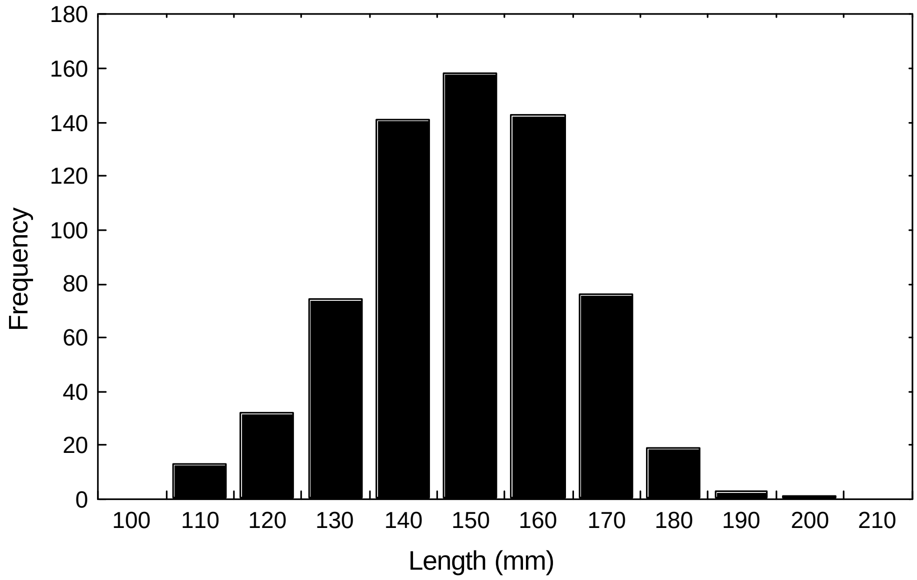

Figure 10. Length (mm) frequency of young-of-year lingcod captured by bottom trawl in Areas 17 and 18 in late-July, 1991.

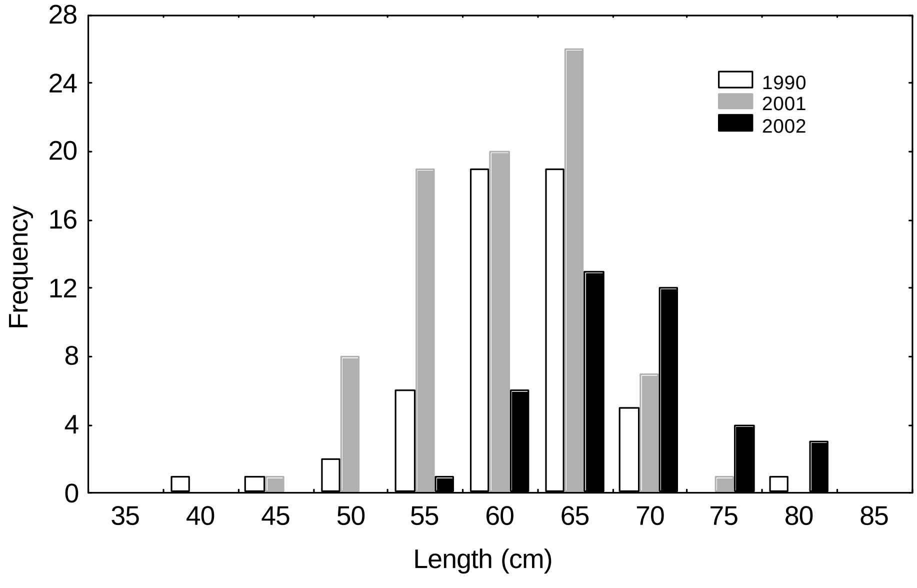

Figure 11. Length (cm) of male lingcod guarding egg masses as observed in SCUBA surveys conducted in 1990, 2001 and 2002 at Snake Island in Area 17.

In addition to research surveys, biological data are available from the Strait of Georgia creel survey. The survey collects biological data from lingcod kept by recreational fishers. It is important to note that a mandatory size limit of 65 cm for retained lingcod was implemented in 1991. The size limit was increased in 1991 to 65 cm. Interviews and biological sampling are conducted on a volunteer basis by recreational fishers. Total lengths (to the nearest cm) and sex are recorded. These data are available from 1985 to 2001 for Areas 13-19, 28 and 29. The number of samples available per year varies for each Area, and periodically data for some Areas were not collected (Table 2). Length data from the creel survey program are summarized along with the data from the handline research surveys by Area in Figure 3 to Figure 9. For Areas 28 and 29, creel survey data are the only source of biological information (Figure 12). All data were collected during the April to September period.

Table 2. The number of lingcod length samples available by Area and year from the Strait of Georgia creel survey.

Year	Unknown Area	Minor Statistical Area									All Areas
		13	14	15	16	17	18	19	28	29	
1985	53	3	18	0	4	44	5	74	1	0	202
1986	9	54	113	11	85	75	15	55	35	3	455
1987	0	70	37	9	101	90	13	129	6	6	461
1988	0	27	16	0	101	50	4	46	25	18	287
1989	0	34	18	13	97	52	1	91	3	2	311
1990	0	82	60	20	158	146	2	140	8	0	616
1991	0	3	0	0	12	20	1	5	11	4	56
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	19	18	4	87
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	15	3	6	57
1999	2	1	2	0	5	15	0	36	6	3	70
2000	19	23	10	0	33	71	1	26	3	0	186
2001	0	48	12	3	44	24	17	35	6	1	190
Total	385	291	59	723	705	80	716	204	65	85	3313

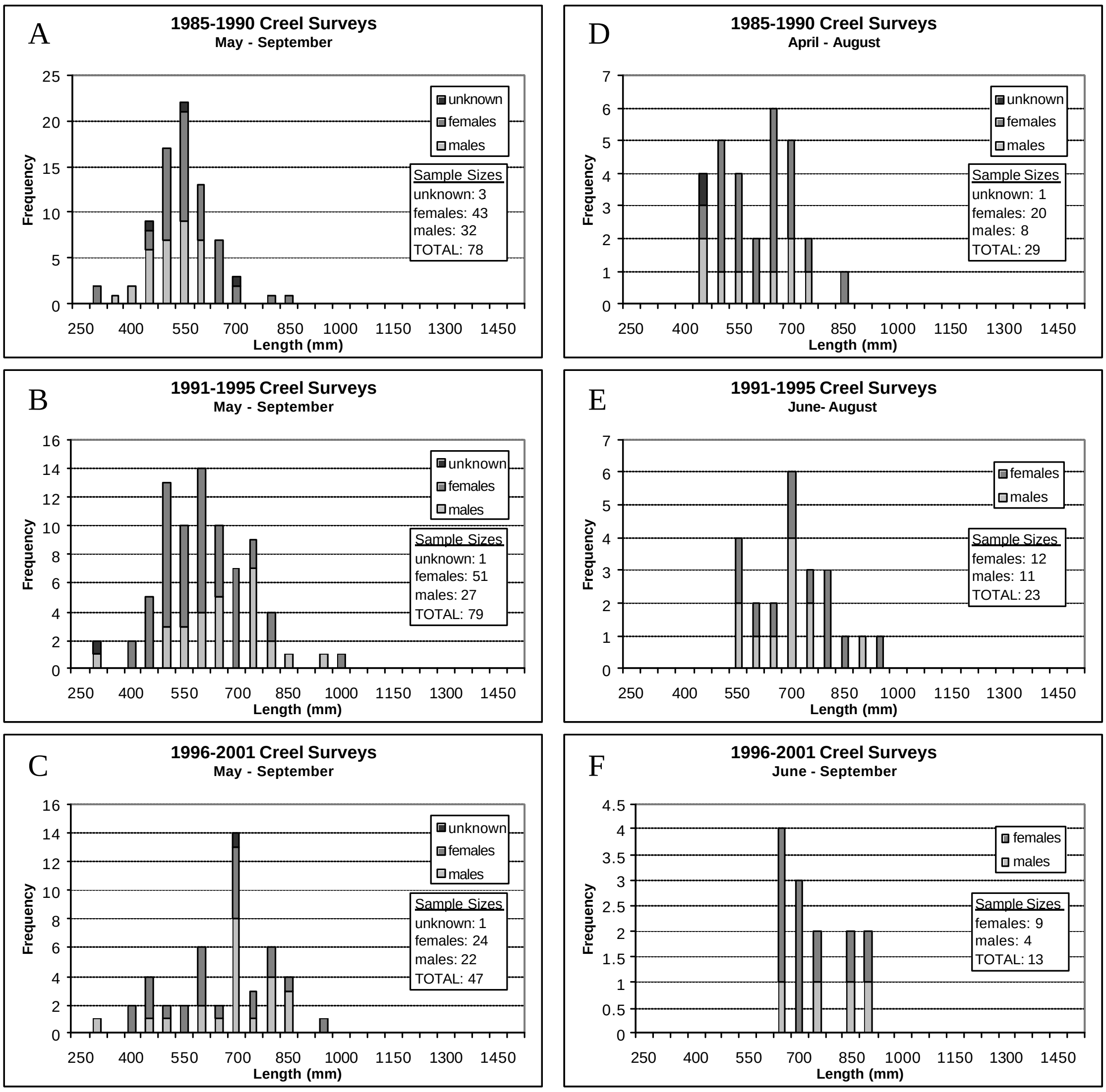

Figure 12. Length frequencies (by sex) of lingcod sampled in the creel survey conducted in Area 28 (A-C) and 29 (D-F).

A final source of biological information are samples from the commercial fishery (Table 3). Most samples were taken in Areas 13 and 17, and mainly for 1981-1984 with additional samples in 1979 and 1988. Fin rays were collected in 1979, 1981-1983 and subsamples of these were used for age estimation and for estimating growth curves for lingcod in Areas 13, 14 and 17 (Figure 13).

Table 3. Biological data available from the Strait of Georgia commercial fishery. Months of sampling are indicated for each year; number of samples are provided by Area.

Year	Biological data
1979 (May-June)	n=353 (Area 14) n=220 (Area 17) length, sex, age
1981 (July, November)	n=276 (Area 13) n=634 (Area 17) length, sex, age
1982 (April, June)	n=228 (Area 13) n=680 (Area 17) length, sex, age
1983 (April, Oct-Nov)	n=667 (Area 13) n=1207 (Area 17) length, sex, age
1984 (April, July)	n=285 (Area 13) length, sex
1988 (June)	n=164 (Area 13) length, sex

All of the historical data outlined above provides a baseline for measuring changes in population age structure and length composition, and changes in growth. In most MSA the number of historical samples available is large and the temporal coverage, while not continuous, is extensive. Future monitoring programs can collect comparable biological data.

3.2 RELATIVE ABUNDANCE DATA

Previous stock assessments on Strait of Georgia lingcod have used commercial handline and longline catch per unit effort (CPUE) data determined from sales slip records as an index of abundance (Richards and Hand 1988). Sales slip data with catch and effort information are available for 1967 until 1990 (the last year of the commercial fishery). Since commercial trawl landings of lingcod in the Strait of Georgia were typically small (Richards and Hand 1988), commercial CPUE was calculated using commercial handline and longline catch and effort data only. Historically, these fisheries targeted lingcod until the late 1970s when increased effort was directed on rockfish (Richards and Hand 1988). To avoid including directed rockfish effort in the lingcod CPUE calculation, Richards and Hand (1988) suggested using only sales slip records with reported lingcod catch of at least 100 kg. Since the close of the commercial fishery in 1990, this source of abundance information is no longer available, but the existing time series is useful in providing historical relative abundance information (Appendix A5). Mean qualified CPUE exhibited a 60% decline from 1967 through 1990 (Figure 14).

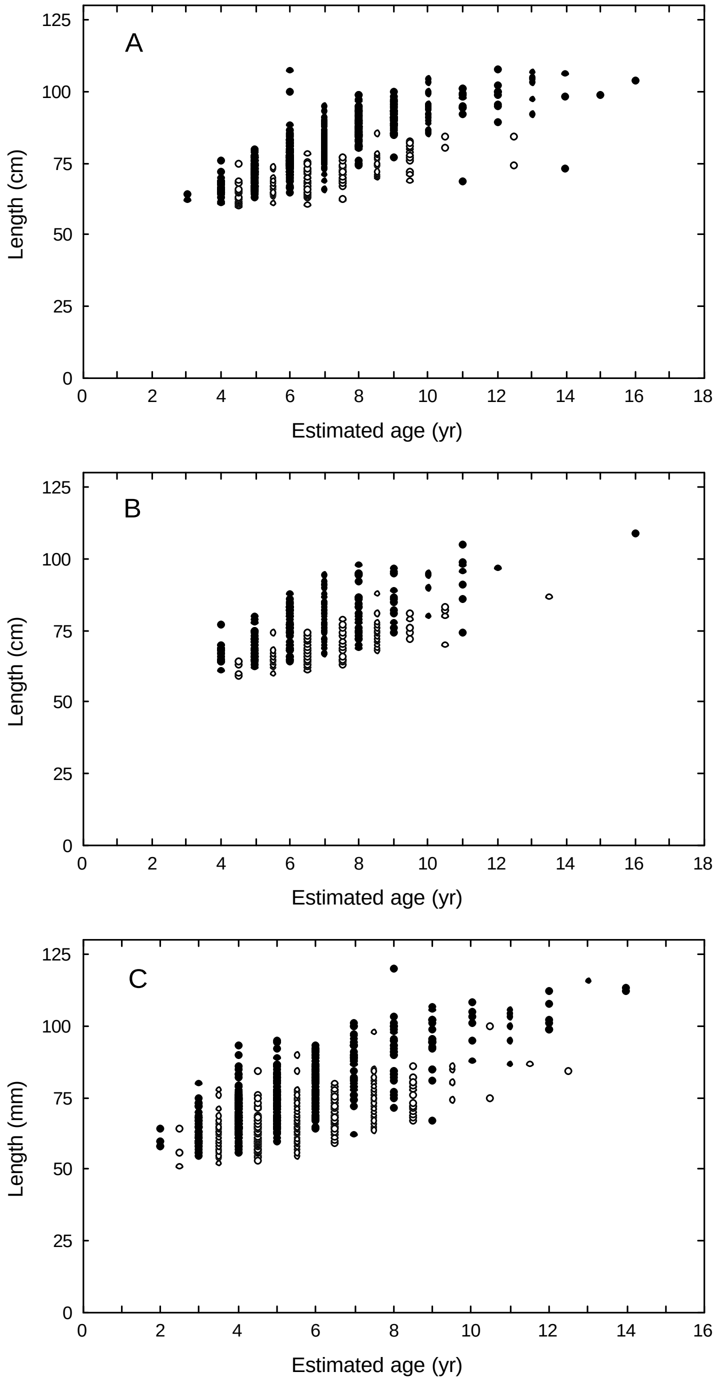

Figure 13. Size (cm) at estimated age (yr) of male (o) and female (•) lingcod captured in commercial fisheries (Table 3) for A) Area 13; B) Area 14 and C) Area 17. Male ages are offset by 0.5 from age value.

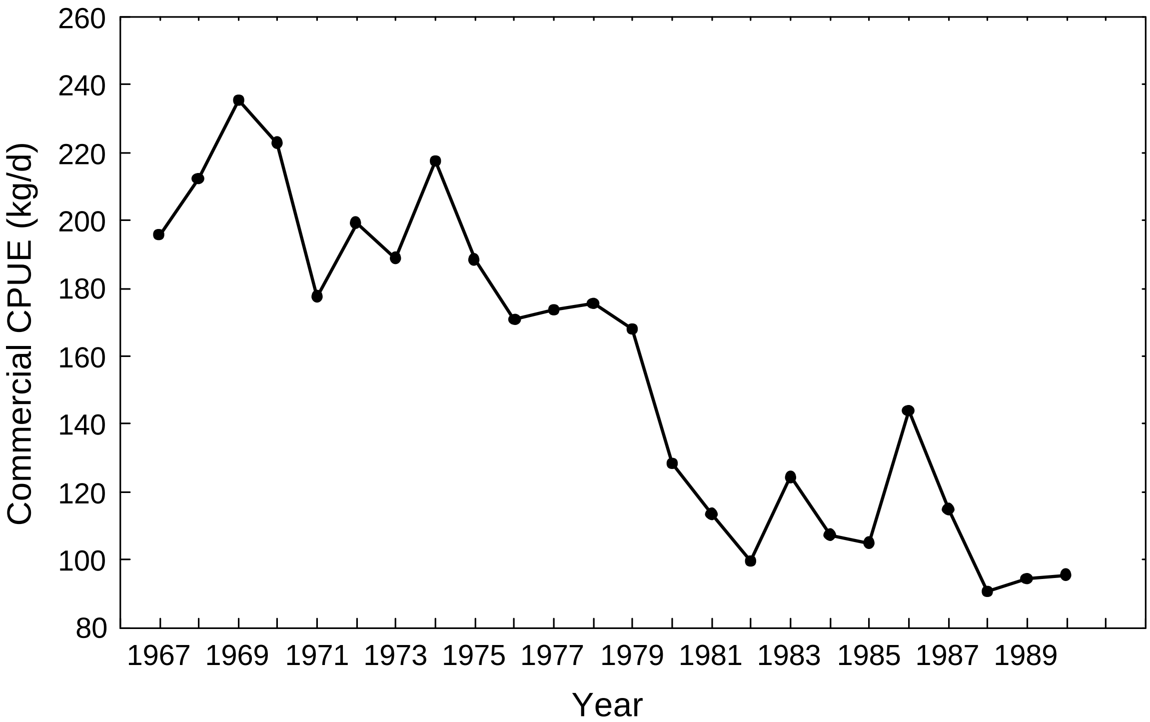

Figure 14. Mean commercial CPUE for lingcod landed in the handline and longline fisheries conducted in Areas 13-19, 28 and 29. See Appendix A5 for statistics and sources of data.

More recent stock assessments for Strait of Georgia lingcod (Beamish et al. 1995; Haist 1995; King and Surry 2000; King 2001) have used catch per unit effort indices derived from the Strait of Georgia creel survey program as indices of the relative abundance of lingcod. There are several types of data obtained from angler interviews that can be used to calculate CPUE including fishing effort expressed as either number of boat trips or fishing hours, and fish caught either as retained lingcod or released lingcod. King (2001) used lingcod encountered (retained and released) per 100 hours of fishing as an index of relative abundance (Appendix A6). The mean recreational CPUE remained low throughout the early and mid-1990s, and has increased in recent years (Figure 15). Reports from anglers suggest that the increase reflects increased abundance in juvenile lingcod. In 1999 - 2001, over 90% of lingcod encounters were released lingcod. Length information obtained from anglers in 1999 and 2000 indicate that over 95% of released lingcod were considered sub-legal, i.e. less than 65 cm (King 2001).

Catch per unit effort data can be derived from many of the research surveys listed in Table 1. The tagging surveys did not have the objective of providing relative abundance information and there is insufficient effort information to provide reliable catch per unit effort (CPUE) indices of abundance from these surveys. However, there are many handline surveys for nearshore reef-fish or lingcod for which there are comparable CPUE. Unfortunately these data are not continuous time series, but they could be useful as points of reference for comparison to future surveys.

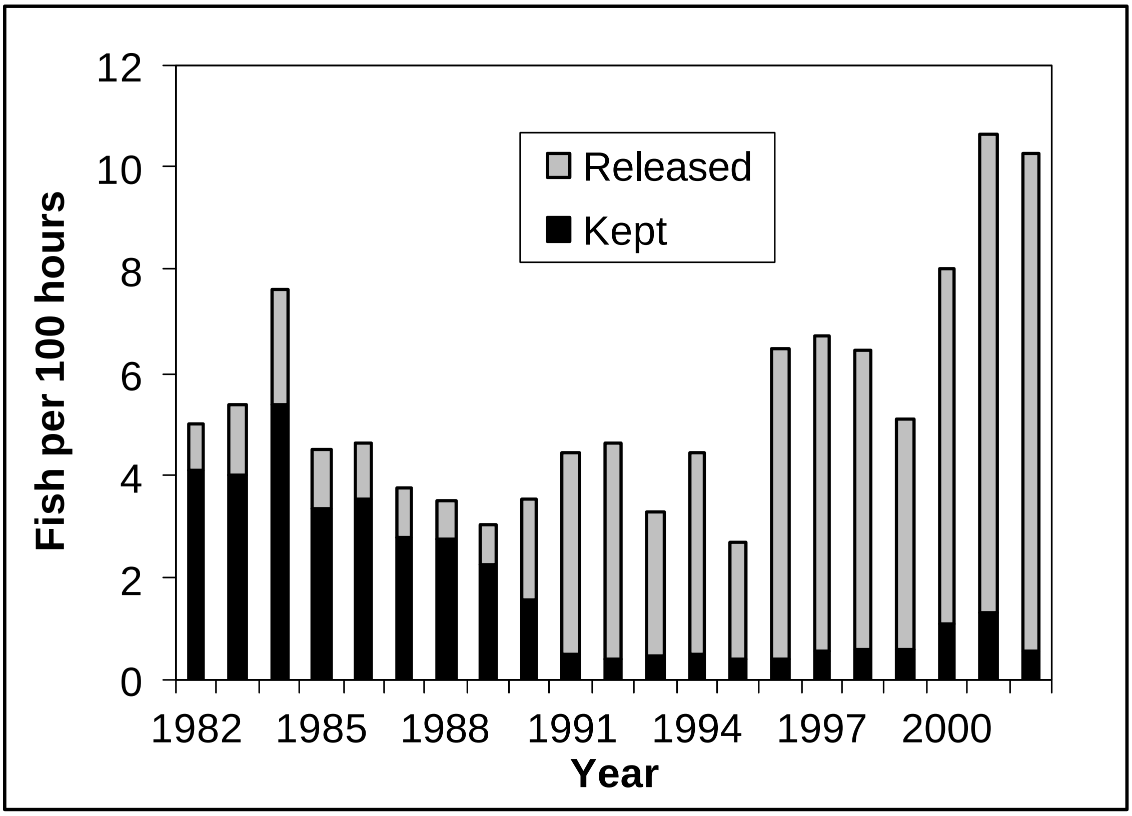

Figure 15. Mean recreational CPUE for lingcod encountered (kept and released) in the recreational fishery conducted in Areas 13-19, 28 and 29. See Appendix A6 for statistics and sources of data (Tables A6.4 and A6.6.).

4.0 LINGCOD RELATIVE ABUNDANCE SURVEYS

There are a number of survey methodologies that have been employed in the Strait of Georgia to provide indices of relative abundance during various life stages of lingcod. Below we present the main findings of each survey program, along with considerations for future surveys or reported sources of bias that limit the survey's suitability for indexing lingcod abundance.

4.1 POST-LARVAL PELAGIC STAGE

By about late May to early June, post-larval lingcod form dense schools in nearshore areas. They have settled out of the plankton and adopted a demersal habitat in shallow waters near the edges of eelgrass and kelp beds. In the spring of 1980 and 1981 and again in 1989 and 1990 purse-seine surveys were conducted in Area 17 to provide estimates of post-larval lingcod during their pelagic phase when they are concentrated in shallow areas (Cass and Scarsbrook 1984; Hand and Richards 1991). Survey locations were similar in both periods of sampling. Sites were sampled once in each week for a similar sampling period in May. Slightly different gear was used in each sampling year. In 1980-81 a 275 m x 18 m purse seine, with a 5 mm stretched mesh bunt end was used. In 1989 a 210 m x 22 m purse seine was used with a 6 mm stretched mesh bunt end. In 1990, a 375 m x 25 m purse seine with a 5 mm stretched mesh bunt end was used. Abundance of post-larval lingcod was measured as density per area sampled, where the length of the purse seine was assumed to represent the circumference of the circle formed by the net during sampling. The post-larval surveys indicated only slight differences in lingcod abundance for the period 1980 to 1990, despite a substantial decrease as measured by commercial catch statistics and adult lingcod surveys (Hand and Richards 1991). In addition, Hand and Richards (1991) found large among-site variances within a sampling year and inconsistent variability between site densities across the four sampling years. While year to year differences in gear made their interpretations difficult, they were able to detect interannual differences in timing and duration of larval hatching. Given these timing differences, the limited period for which post-larval lingcod remain in the water column, Hand and Richards (1991) concluded that purse-seine surveys were a poor method for monitoring changes in lingcod abundance.

4.2 YOUNG-OF-THE-YEAR STAGE

During mid-July to late-August, young of year (age-0) lingcod move to deeper, flat bottom habitats. A bottom trawl survey to index young-of-the-year lingcod abundance was conducted in late-July 1991 in Areas 17 and 18 between Comox and Sidney (Workman et al. 1992). Trawl sites were selected based on three criteria: a shallow slope; mud/sand/shell substrate and depth between 15 to 35 m. Catch densities (catch per area swept) were used to calculate mean and median densities as indices of age-0 lingcod abundance. The highest mean densities were obtained over a mixed sand and rock substrate, though these trawls had a high coefficient of variation (Workman et al. 1992). Trawls over flat sandy bottom yield the most consistent density estimates i.e. lowest coefficients of variation. Mud bottom trawls displayed the lowest mean densities, and the highest coefficient of variation. Overall, the bottom trawl survey was suggested to be the best method for indexing young-of-the-year lingcod abundance. However, it was cautioned that, given the high coefficients of variation in lingcod density, that small year to year differences in abundance might not likely be detectable. A sustained increase in abundance would be required across several years in order for the survey to measure differences. Workman et al. (1992) offered considerations for improvement to survey design in order to reduce coefficients of variation in lingcod density: 1)-increase the number of hauls, or increase effort across fewer study sites and 2)-restricting the survey to standardized depths and bottom types.

4.3 JUVENILE (AGE-1 AND AGE-2) STAGE

By age-1 or age-2, lingcod begin to inhabit rocky habitats similar to adults, but at shallower depths. In 1975 and 1976, monthly bottom trawl surveys for juvenile Pacific hake and walleye pollock was conducted in Stuart Channel and Porlier Pass, located in Area 17 (Beamish et al. 1976; Beamish et al. 1978). During February 1976, large catches of age-1 lingcod (1975 yearclass) in Porlier Pass were encountered. This above average 1975 yearclass was also reported in subsequent stock assessment documents. Overall, the catch of age-1 and age-2 lingcod in these bottom trawl surveys were small.

In 1981-1982, similar trawl surveys were conducted in the same areas (Cass and Scarsbrook 1984), though the focus of these surveys were to provide indices of relative abundance for juvenile lingcod. As with previous years, the concentrations of age-1 lingcod were highly localized near Porlier Pass and accounted for over 90% of the total catches for each year. Cass and Scarsbrook (1984) concluded that because of the limited and localized distributions of age-1 lingcod over trawl-able bottom, bottom trawls targeting this life stage may not be well suited for providing indices of relative abundance.

4.4 JUVENILE (AGE-2+) AND ADULT STAGES

<u>Handline Surveys</u> – *Nearshore reef-fish surveys.* In conjunction with SCUBA and submersible surveys (outlined below), handline surveys were conducted in Areas 15 and 16 from July to November in 1984 and 1985 (Richards et al. 1985a; Richards and Cass 1985b). The objective of the survey in 1984 was to develop standardized fishing techniques for nearshore reef-fishes, including lingcod, which were later applied to subsequent handline surveys. The standardized method selected involved angling with trolling rods and reels, using 12 cm frozen herring as bait. The fishing line was 9-kg test mono-filament with a 7-kg test leader. Two single Mustad #92553 size 3/0 hooks with a 6-cm spacing were used on each line. Effort was measured as fishing duration for each angler and summed for a fishing event. A stratified-random sampling design was used to select survey locations. Each MSA was divided into 1 minute latitude by 1 minute longitude blocks. The blocks that included fishable areas (i.e. included a section of shoreline or a reef) were numbered. Blocks with only sand or mud substrates were excluded. Blocks were stratified by habitat type (steep wall, rocky slope or reef) and by fishing effort (high and low) as identified by recreational and commercial activity. The overall sampling design was stratified by fishing effort and by habitat type within each statistical area. Block numbers were randomly drawn and assigned to strata. For MSA 16, four blocks were drawn for each effort and habitat combination, and for MSA 15, three blocks were drawn for each. Sampling was further stratified by depth within each site: 5-40 m, 41-70 m and 71-100 m. Overall, the catch compositions were dominated by dogfish (*Squalus acanthias*), copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*) and lingcod. For lingcod, catch per unit effort decreased with increasing depth.

In 1986, the nearshore reef-fish handline survey was repeated in Area 16 and initiated in Area 13 (Discovery Channel). In 1987-88 only Area 13 was surveyed (Richards and Cass 1987; Richards and Hand 1987; Richards et al. 1988). The survey sites in Area 13 were selected from areas of commercial fishing activity. Sampling was stratified by depth within each site: 5-40 m, 41-70 m and 71-100 m.

Lingcod surveys. In 1985-1987 handline surveys that focused specifically on lingcod were developed and conducted in the Gulf Islands Region of Area 17 (Cass and Richards 1987; Hand and Richards 1987; Hand and Richards 1989). Each year compared the fishing technique used in the nearshore reef-fish surveys (1985-88) to the most common commercial fishing method used to catch lingcod in the Strait of Georgia. The commercial method used fishing lines of a single 23-kg test monofilament and a steel leader with a 0.5 kg weight. A single Mustad #9550 size 8/0 hook was suspended from each line. Live 10-20 cm herring were used as bait. The survey design used in the nearshore reef-fish survey was applied to this lingcod survey. The survey area was divided into 1 min latitude by 1 min longitude blocks, and those blocks encompassing known lingcod fishing areas were identified. Ten blocks were randomly selected and used as the fishing sites for the survey. Fishing at each site was stratified by depth: 10-25 m; 26-45 m; and 46-55 m. Effort was measured as fishing time for each angler.

The species composition of the catch in the lingcod survey was similar to those in the nearshore reef-fish surveys, namely lingcod, quillback rockfish, copper rockfish, spiny dogfish and yelloweye rockfish (*S. ruberrimus*). Fishing method had a significant effect on species composition. A higher proportion of lingcod (and larger lingcod) were caught by the commercial fishing method (Hand and Richards 1989). Quillback and copper rockfish catch per unit effort was higher using research gear. As with the nearshore reef-fish surveys, lingcod catch per unit effort decreased as depth increased (Cass and Richards 1987). No other factor (such as cloud cover, time of day, current, sea condition, tide) had a significant effect on lingcod catch per unit effort. Hand and Richards (1989) were able to detect among year differences in lingcod CPUE that reflected stock abundance trends measured by commercial sales slip data, suggesting that handline survey catch per unit effort was a useable index of lingcod abundance. They also accounted for changes in lingcod CPUE due to differences in the timing of the surveys among years. Lingcod appeared to be more available during pre-spawning periods (October to December) than during spawning periods (January to February).

In 1993, a final handline survey for lingcod was conducted in Areas 18 and 19 during three sampling periods, June, August and October (Yamanaka and Murie 1995). Research fishing gear used in other lingcod and nearshore reef-fish surveys was used, along with 12 cm frozen herring as bait. Effort was measured as the sum of fishing time for each angler. Ten fishing sites were identified by fishermen as “nuisance” sites for lingcod and another ten sites were randomly selected from 1 minute latitude by 1 minute longitude blocks that encompassed rocky habitat. Fishing events were stratified by depth: 0-25 m and 25-50 m. Catch rates for lingcod were highest in October, though the difference in CPUE was not significant. Lingcod CPUE during the October survey was significantly greater ($p<0.05$; Kruskal-Wallis test) for the shallow depth stratum than for the deeper depth stratum (Yamanaka and Murie 1995). Overall, lingcod CPUE decreased with increasing depth.

<u>SCUBA Surveys</u> - In 1984 a pilot survey was conducted in Areas 15 and 16 to obtain visual estimates of densities of nearshore reef-fishes, including lingcod (Richards et al. 1985b). Transect counts were completed between depths of 9 to 20 m. The transect depth remained constant throughout each dive. During the survey months, July to October, age-2 lingcod may be present at these depths, but older lingcod would likely be found in deeper habitats. This is confirmed by the forklengths estimated by divers during the survey. Hexagrammidae (including lingcod, kelp greenling, painted greenling and white-spotted greenling) accounted for less than 5% of the fish counted. Over 90% of the fish counted were Embiotocidae (kelp perch, shiner perch, striped perch and pile perch) and Scorpaenidae (mainly copper, yellowtail, quillback, tiger and yelloweye rockfish). It was noted, that unlike rockfish, lingcod were wary of divers and quickly swam away as divers approached.

<u>Submersible Survey</u> – A submersible survey was conducted during October to November 1984 (Richards and Cass 1985a). This survey covered many of the same sites covered by the SCUBA and handline surveys in MSA 15 and 16 in 1984. Each transect began at the maximum depth (typically 150 m) and ended at 20 m. The submersible remained 2 m above the bottom

throughout each transect dive. All transects were repeated at least once, and in some cases a third dive was possible. It was not possible to determine with accuracy the width of the transect, and therefore the area counted. As with the SCUBA observations, it was noted that rockfish did not alter their behaviour when approached by a submersible, but lingcod typically did avoid the submersible. Some of the problems encountered during this survey included: 1) restricted vision in view ports 2) inability to examine crevices 3) limited bottom time 4) difficulty in determining area covered. Richards and Cass (1985a) suggested that despite these limitations submersible surveys could be a valuable tool for estimating relative abundance and for collecting information on fish habitat and behaviour.

4.5 EGG MASS GUARDING MALES

SCUBA surveys have been conducted from December to April to measure lingcod egg mass densities in Dodd Narrows (1978) and at Snake Island (1990-1991, 1994, 2001-2002) in Area 17 (Low and Beamish 1978; Yamanaka and Richards 1995; King and Beaith 2001; King and Winchell 2002). The males remain near the egg mass, guarding it from predators. Egg masses are large (approximately 5 L in volume, King and Winchell 2002) and easy to visually locate. Different methodologies were used in different years, but all dives were conducted at depths up to 20 m. In 1978, all egg masses were counted in a small survey area. At Snake Island reef, transect counts (50 or 60 m length, 14 m width) were initially employed in 1991 at randomly selected sites, but in all other years circular quadrat counts (10 m radius) were used. Recent genetic studies have discovered that more than one male will contribute genetic material to an egg mass, however each egg mass is comprised of eggs from one female only (Withler et al. 2003). Egg mass counts can therefore be used to infer number of spawning females only.

5.0 RECOMMENDED LINGCOD SURVEYS

The primary objective of surveys will be to provide indices of relative abundance of lingcod, along with biological data to measure changes in size composition and growth. Given the reported increase in the relative abundance of recent year classes, it would be useful to survey pre-recruitment life stages of lingcod (e.g. young of year) to see if year class success has increased from previous years. In addition, an index of relative abundance of adult lingcod is required to assess the status of the exploitable portion of the population. Conducting surveys similar to previous ones would provide information in a short timeframe that could be compared to historical data. Based on the results and recommendations of previous surveys the most suitable methods include bottom trawl surveys for young-of-the-year and handline surveys for age-2+ lingcod. Submersible surveys for rockfish are planned for Strait of Georgia and provide an additional opportunity for indexing the relative abundance of lingcod.

5.1 BOTTOM TRAWL SURVEY FOR YOUNG-OF-THE-YEAR

<u>Gear type</u> – Similar to other bottom trawl surveys for juvenile lingcod, this survey would use a Gulf Stream 12 m Marinovich flat trawl net with a 1 cm codend lining.

Survey period – Late-July or early-August to coincide with young-of-year available to trawl gear and overlap the sampling period (July 15-Aug 2) of the 1991 survey.

Survey design – The bottom trawl survey conducted in 1991 made 63 useable trawls. The trawls were classified by bottom type and depth strata. There were four bottom type classifications: mud; sand; rock or a combination of sand and rock. There were two depth strata: 15 to 24 m; 25 to 35 m. The overall mean lingcod density (1337 fish/km^2) had a high coefficient of variation (125). Workman et al. (1992) concluded that this type of survey would not likely detect small among-year differences in abundance, and that any gradual, sustained increase in abundance may not be measurable for several years. However, they did recommend that coefficients of variation could be reduced by increasing the number of trawls, or restricting the survey to standardized bottom types and depths. Using the 1991 trawl data, we examined the coefficients of variation associated with mean densities for different bottom type and depth combinations (Table 4). The coefficients of variation were lowest when only trawls on sand or rock, or both bottom types were considered, suggesting that these would be appropriate bottom types to sample. Selecting the deeper trawls (25-35 m) further reduced the coefficients of variation.

Table 4. The number of trawls (N), range of lingcod density values (fish/km^2), mean density, and coefficient of variation of density (C.V.) for each bottom type (mud, sand, rock or combined sand & rock) and by depth ranges. These data are also presented with mud bottom type excluded and for rock or sand bottom types together.

			Density		
Bottom type	Depth (m) range	N	Range	Mean	C.V.
Mud	15-35	13	0-4467	767	163
	15-24	5	0-1870	503	162
	25-35	8	0-4467	1516	163
Sand	15-35	22	110-4120	1252	91
	15-24	8	187-4120	1469	100
	25-35	14	110-3907	952	84
Rock	15-35	11	0-2148	896	94
	15-24	5	0-1454	600	138
	25-35	6	0-2148	866	68
Sand & Rock	15-35	17	0-11111	2169	135
	15-24	9	0-5109	1541	132
	25-35	8	0-11111	2878	126
No mud	15-35	50	0-11111	1486	129
	15-24	22	0-5109	1264	127
	25-35	28	0-11111	1661	129
Sand or Rock	15-35	33	0-4120	1134	93
	15-24	13	0-4120	1072	120
	25-35	20	0-3907	1174	77

In order to provide an estimate of the number of trawls that would be required to detect various levels of changes in abundance, we used the observed sample variance and mean density of the 1991 trawl survey in a power analysis:

$$n \geq 2 \cdot \left(\frac{s^{2}}{d^{2}} \right) \cdot \left[t_{a(2),v} + t_{b(1),v} \right]^{2} \qquad \text{Eqn. 1}$$

where

- n = required sample size
- σ^2 = true variance, estimated by the observed sample variance (s^2)
- δ = target difference between means that is desired to be detected
- α = 0.05
- v = degrees of freedom; estimated as $2 \cdot (n - 1)$
- β = 0.2 (assuming a Power value of 0.8 suggested by Peterman and Bradford, 1987).

Sample sizes were estimated for target differences of 10-50%, 75% and 100% changes in abundance from the 1991 observed mean density (Table 5). If sand or rock bottom type locations are targeted, then a typical two week survey (approximately 60 trawls) could be used to detect at least a 50% change in relative abundance. Though management strategies have not been developed for lingcod, the anticipated level of change in relative abundance that would reflect recovery of the stock would likely be much higher than a 50% increase.

Table 5. Estimated number of trawls on sand, rock, or combined sand & rock bottom types required to be able to detect indicated level (as percentage increase or decrease) of change in abundance from the 1991 observed mean density assuming observed sample variance estimates true variance.

	Bottom Types	
Level (%) of change in abundance	Sand or Rock	Sand, Rock or Combined Sand & Rock
10	1357	2605
20	340	652
30	152	290
40	85	165
50	55	104
75	25	47
100	15	27

Biological sampling – All lingcod will be measured for length.

Survey area - Only Areas 17 and 18 were surveyed in 1991 and the initial survey should focus in these previously surveyed areas. Trawl locations (n=32) could be selected from the 1991 survey which were sand or rock bottom type (Figure 16). Additional locations could be selected using the criteria outlined in Workman et al. (1992): identify areas of shallow slope, between 15 and 35 m deep, and randomly select trawl locations along areas of low relief.

Bycatch of rockfish – Since this bottom trawl survey targets shallow, flat and mainly sandy bottom types, bycatch of rockfish should be at a minimum. In 1991, less than 1% of the total catch in the bottom trawl survey was comprised of copper and quillback rockfishes combined. The species that comprised the five largest proportions of the total catch were Pacific cod (15.5%), english sole (13.1%), Pacific sanddab (10.3%), rock sole (9.5%) and Pacific herring (8.7%).

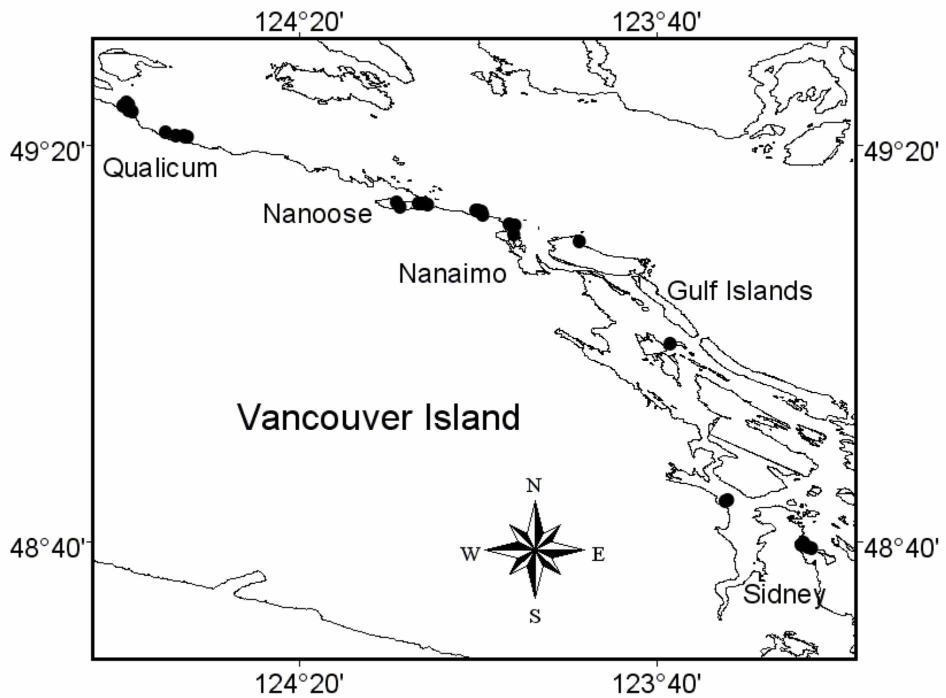

Figure 16. General trawl locations (n=32) from 1991 bottom trawl survey which were over sand or rocky bottom types.

5.2 HANDLINE SURVEY FOR AGE-2+

Gear type – In the past, two gear types have been used: 1-research gear (rod and reel with 9 kg test monofilament and 7 kg test leader with 170 g mooching weights, double Mustad #92553 size 3/0 hooks with 6 cm spacing, frozen 12 cm herring) and 2-commercial gear (23 kg test monofilament handline with a steel leader and 0.5 kg lead weight, double Mustad #93664 size 6 hooks with 10 cm spacing, live 15 to 20 cm herring). The commercial gear was used in a special aspect of the Area 17 survey to investigate commercial gear CPUE under experimental conditions and validate the use of commercial CPUE from sales slip data as an index of relative abundance. Research gear was used in all survey years, so it would be appropriate to continue to use research gear in order to remain compatible to all surveys.

Survey period – The handline surveys conducted for nearshore rockfish in Areas 13, 15 and 16 were typically conducted during June-July. Handline surveys that targeted lingcod in Area 17 were conducted October-February, while those in Areas 18 and 19 were conducted June, August and October (Table 6). This makes a north-south split in the Strait of Georgia for historical sampling periods, with summer surveys targeting all nearshore reef-fishes in the north, and fall-winter surveys targeting lingcod in the south.

Table 6. Dates of nearshore rockfish (Areas 13, 15 and 16) and lingcod (Areas 17, 18 and 19) handline surveys.

Area	Year	Date	Reference
13	1986	July 28-31	Richards and Cass 1987
	1987	June 2-5 July 21-23	Richards and Hand 1987
	1988	May 9-12 July 18-25	Richards et al. 1988
15	1984	July 4-10 July 24 – Aug 2 August 14-25 Oct 2-8	Richards et al. 1985a
	1985	June 11-20	Richards and Cass 1985b
16	1984	July 4-10 July 24 – Aug 2 August 14-25 Oct 2-8	Richards et al. 1985a
	1985	July 7-18	Richards and Cass 1985b
	1986	July 9-17	Richards and Cass 1987
17	1985	Oct 28-Dec 11	Cass and Richards 1987
	1987	Jan 15-Feb 12 Dec 11-15	Hand and Richards 1987 Hand and Richards 1989
	1988	Jan 8-Feb 18	Hand and Richards 1989
18	1993	June 24- July 5 Aug 3-12 Oct 18-29	Yamanaka and Murie 1995
19	1993	June 24- July 5 Aug 3-12 Oct 18-29	Yamanaka and Murie 1995

Selecting an appropriate time for survey work is difficult given the behavioural differences with the onset of spawning and seasonal changes in depth distribution. Hand and Richards (1989) analysed the differences in survey CPUE between the Oct-Nov 1985 survey and the Jan-Feb 1987 and 1988 surveys in Area 17. There was a decline in survey CPUE from 1985 through to 1988. This decline was mirrored in sales slip CPUE for the commercial fishery, indicating that the decline in CPUE was likely a reflection of a decline in abundance. However, the decline in the survey CPUE was more dramatic than the decline in commercial CPUE, likely reflecting the difference in the timing of the surveys among years. This, coupled with the changes in the composition of the catch (from 70% lingcod in 1985, to 45% in 1987 and 38% in 1988), led Hand and Richards (1989) to conclude that behaviour of lingcod during spawning (Jan-Feb) affected their catchability. This was likely true for both male and female lingcod since CPUE series for males and females both declined, though there were proportionately fewer males in the catches of lingcod in the Jan-Feb surveys. Based on these survey results, it would be more appropriate to conduct a survey in non-spawning months.

In 1993, the survey in Areas 18 and 19 targeted depths <50 m (Yamanaka and Murie 1995) and was conducted in June, August and October (Table 6). Comparing length frequencies between months indicates that a shift in the size composition from smaller lingcod (modal length 50-55 cm) to larger lingcod (modal length 55-60 cm) occurs from June through October (Figure 17). Within Area 18, the CPUE in June and August were similar, but October CPUE was much higher indicating a greater availability of lingcod in the fall ($p=0.04$, Kruskal-Wallis test). There was no significant difference ($p>0.05$, Kruskal-Wallis test) in monthly CPUE in Area 19, though August CPUE was lower than either June or October.

In the northern areas the only survey year with fishing conducted in summer and fall-winter months was 1984 in Areas 15 and 16 (Richards et al. 1985a). Unfortunately that year was used as a pilot study and similar fishing gear was not used until late-August. Weather conditions in November did not permit sampling in Area 15, and only a few sites were actually fished in Area 16. There were no detectable differences ($p>>0.05$, Kruskal-Wallis test) between August lingcod CPUE and October lingcod CPUE for either Area, in any of the depth strata or even when all depths were included (Table 7). This might be due to the small number of samples. As with other surveys, the lingcod CPUE decreased with increasing depth. In October, no lingcod were caught in depths > 40 m.

Table 7. Number of samples (n), mean CPUE and its coefficient of variance (C.V.) by depth strata in August and October, from the 1984 handline survey conducted in Areas 15 and 16.

Depth strata	August			October		
	n	Mean CPUE	C.V.	n	Mean CPUE	C.V.
Area 15						
<40	14	0.68	164	14	0.57	209
41-70	17	0.10	225	4	0	--
71-100	4	0.39	125	4	0	--
All depths	35	0.37	211	22	0.36	270
Area 16						
<40	18	0.99	127	5	1.05	224
41-70	11	0.39	174	4	0	--
71-100	5	0	--	3	0	--
All depths	34	0.65	162	12	0.44	346

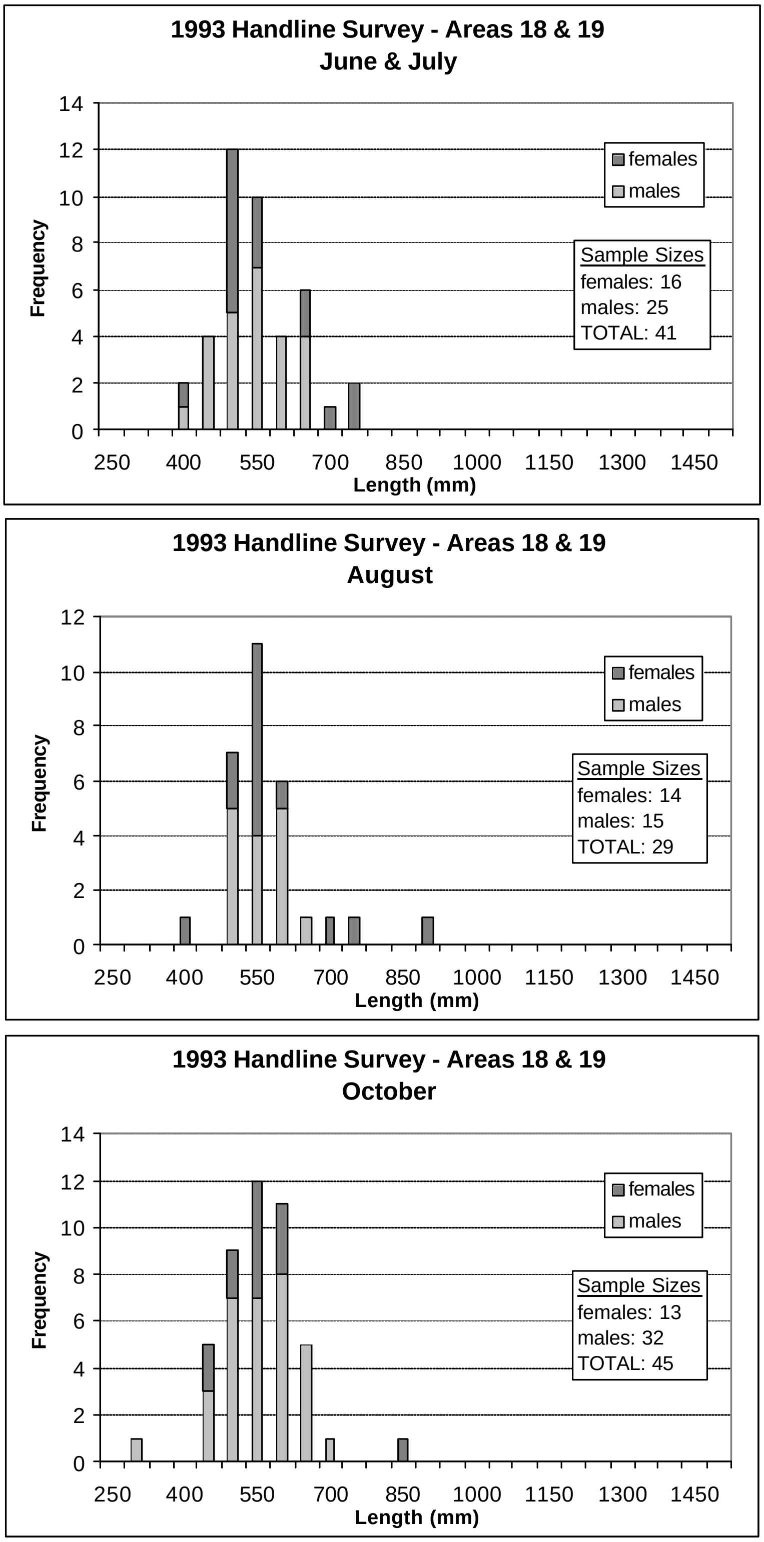

Figure 17. Length frequency distributions for lingcod captured in 1993 handline survey conducted in Areas 18 and 19 between 0-50 m.

Based on these findings we suggest surveys in Areas 17, 18 and 19 be conducted in October-November in order to sample the population when they are most available to the fishing gear. This time period would also allow comparison of present CPUE values to those observed in 1985 (Area 17) and in 1993 (Area 18 and 19). In Areas 13, 15 and 16, handline surveys should be conducted in July-August in order to provide CPUE estimates during comparable periods to surveys conducted in 1986-88 for Area 13, 1984 for Area 15 and 1985-87 for Area 16. In order to accommodate a bottom-trawl survey for young-of-year in July and to initiate research programs outlined below, the first July-August northern survey could be conducted in 2004. The first October-November southern survey could be conducted in 2003.

<u>Biological sampling</u> – Length, weight and sex can be measured for all caught lingcod to provide size composition data. Lingcod could be released live. Subsamples for ageing structures could be collected; however, recent samples are available from the creel survey program which could be used to detect any recent changes in growth and provide a length-age relationship.

<u>Survey design</u> – For each Minor Statistical Area, the observed mean CPUE for all depths and associated variance was used for the selected survey month to estimate the number of sets required to detect a range of increases (or decreases) in the CPUE estimates (Table 8). Previous surveys were able to complete approximately 45 fishing sets within a 7-day period, and this level of coverage would allow for a detection of a 100-150% increase in CPUE estimates. It would be likely that the level of change in relative abundance that would reflect recovery of the stock would likely be much higher than a 100-150% increase.

Table 8. Estimated number of sets required in an Area's handline survey in order to be able to detect indicated level (as percentage increase or decrease) of change in mean CPUE from historical surveys, assuming observed sample variance estimates true variance. For Areas 13, 15 and 16, only depth strata less than 70 m are included.

	Minor Statistical Area					
	13	15	16	17	18	19
Month of survey	July	August	July	November	October	October
Level (%) of change in CPUE estimate						
10	2104	7788	3646	5846	4433	3746
20	527	1948	912	1463	1109	938
30	235	867	406	651	493	417
40	133	488	229	367	278	235
50	85	140	147	235	178	151
75	38	85	66	105	80	68
100	22	79	38	60	45	39
150	10	36	18	27	21	18

The nearshore reef-fish survey used depth strata <40 m; 41-70 m and 71-100 m. Since lingcod CPUE declined with increasing depth, and rockfish CPUE increased with increasing depth, the 71-100 m strata could be removed from the survey design in Areas 13, 15 and 16. This would limit the bycatch of rockfish. Removing the deeper depth strata would also allow for either more fishing sets per survey, or for selection of additional survey sites. Survey areas could be divided into blocks of 1 minute latitude by 1 minute longitude and a random selection of fishing sites could be taken from blocks identified as important lingcod habitat with input from recreational fishermen. The depth strata employed in the surveys for lingcod in Areas 17, 18 and 19 were similar and will be used in future surveys.

Survey areas – The same index sites that were surveyed in previous years will be surveyed in upcoming handline surveys. A number of sites fall within proposed Rockfish Conservation Areas. Handline in these areas could provide baseline information on rockfish abundance that could be useful in the management of these populations. If these sites are not selected, then additional survey sites could be selected using the criteria outlined above. Figure 18 through Figure 22 provide mean CPUEs by fishing sites in each of the Minor Statistical Areas and identify the proposed Rockfish Conservation Areas. Additional sites could be selected using recreational fishing effort by location available from the creel survey program to identify areas with high lingcod catch.

Three Minor Statistical Areas have not been previously surveyed by handline: Areas 14, 28 and 29. Historically, Area 14 has been an active fishing area for lingcod by recreational anglers (see Appendix A4). A handline survey in Area 14 could be initiated in fall 2003. The survey would employ the same design for selection of sites outlined above, use research gear and would target depth strata <25 m and 25-50 m. Based on the variance in mean CPUE observed in other areas, approximately 40 sets per survey would be appropriate. However, it should be noted that there are no historical survey data with which to compare CPUE, and since only large changes in CPUE would be detectable, the survey would not provide information on any changes in relative abundance of lingcod for several years.

Bycatch of rockfish – In previous surveys, copper and quillback rockfish comprised a large component of the catch in handline surveys. Yelloweye rockfish and dogfish were periodically caught in large numbers, but did not typically dominate the catches (Richards and Cass 1987; Hand and Richards 1989). Within depths up to 40 m, copper rockfish comprise approximately 35% of the total catch, quillback rockfish comprise about 30% and yelloweye rockfish less than 20% (Richards and Cass 1987). Copper rockfish are not a large component of catches at depths greater than 40 m. Typically, quillback rockfish are the dominant species (approximately 55%) in the handline catches between 41-100 m (Richards and Cass 1987). Bycatch of quillback could be reduced by eliminating the deeper depth stratum (71-100 m) or restricting fishing to depths < 50 m.

5.3 SUBMERSIBLE SURVEYS FOR ROCKFISH

The Inshore Rockfish Program has two visual estimation surveys planned for the Strait of Georgia in 2003 which may provide information on depth distribution, habitat use and relative abundance of lingcod (L. Yamanaka, Pers. Comm.).

Submersible Survey – From August 9-23, 2003 transect counts will be made from a submersible vessel within two areas in Areas 17 and 18: Gabriola Passage and along the eastern sides of Valdez and Galiano Islands. Transect sites within Gabriola Passage will encompass a number of different habitats and the objective of the survey is to quantify habitat and depth distribution of rockfish. Counts of lingcod will also be collected. Transect areas along Valdez and Galiano Islands will be selected within and adjacent to Rockfish Conservation Areas (RCA). The objective of the survey will be to provide relative abundance indices for inside and outside these

RCA. The submersible will be used at deeper depths, and a towed video camera will be used in shallower waters that are not reachable by the submersible. Counts of lingcod will also be collected.

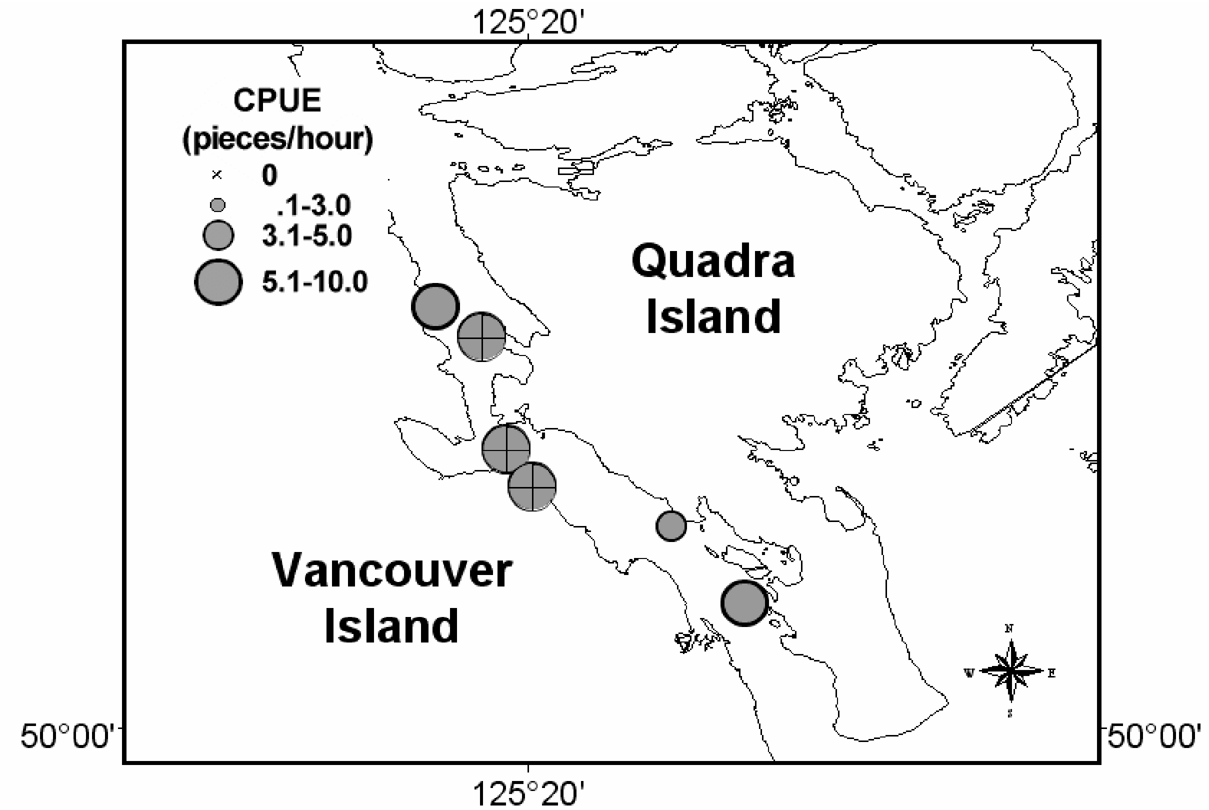

Figure 18. Mean July lingcod catch per unit effort (CPUE) at handline survey sites in Area 13 for surveys in 1986-1988 for depth strata less than 70 m. Size of circle represents CPUE classification in legend. Circles with crosses denote proposed Rockfish Conservation Areas.

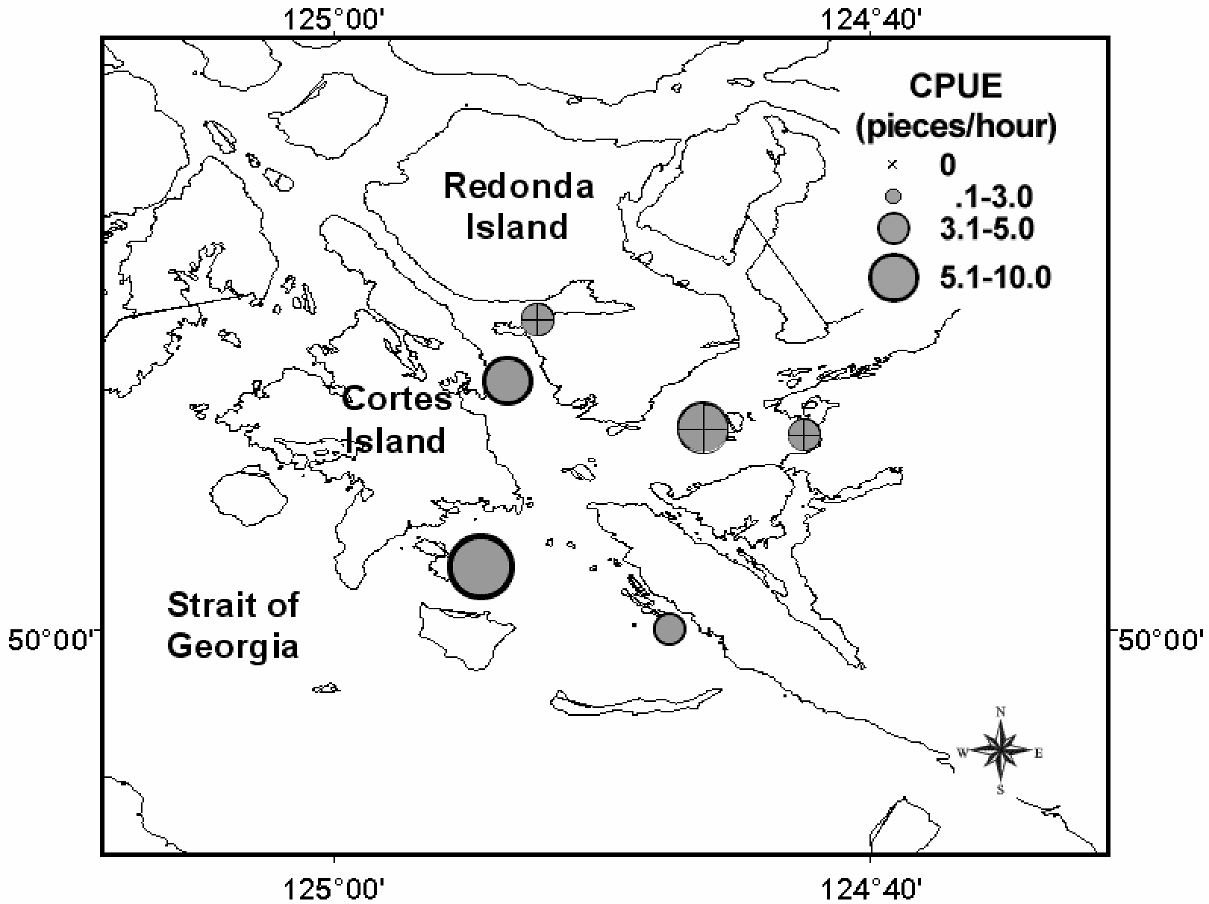

Figure 19. Mean August lingcod catch per unit effort (CPUE) at handline survey sites in Area 15 in 1984 for depth strata less than 70 m. Size of circle represents CPUE classification in legend. Circles with crosses denote proposed Rockfish Conservation Areas.

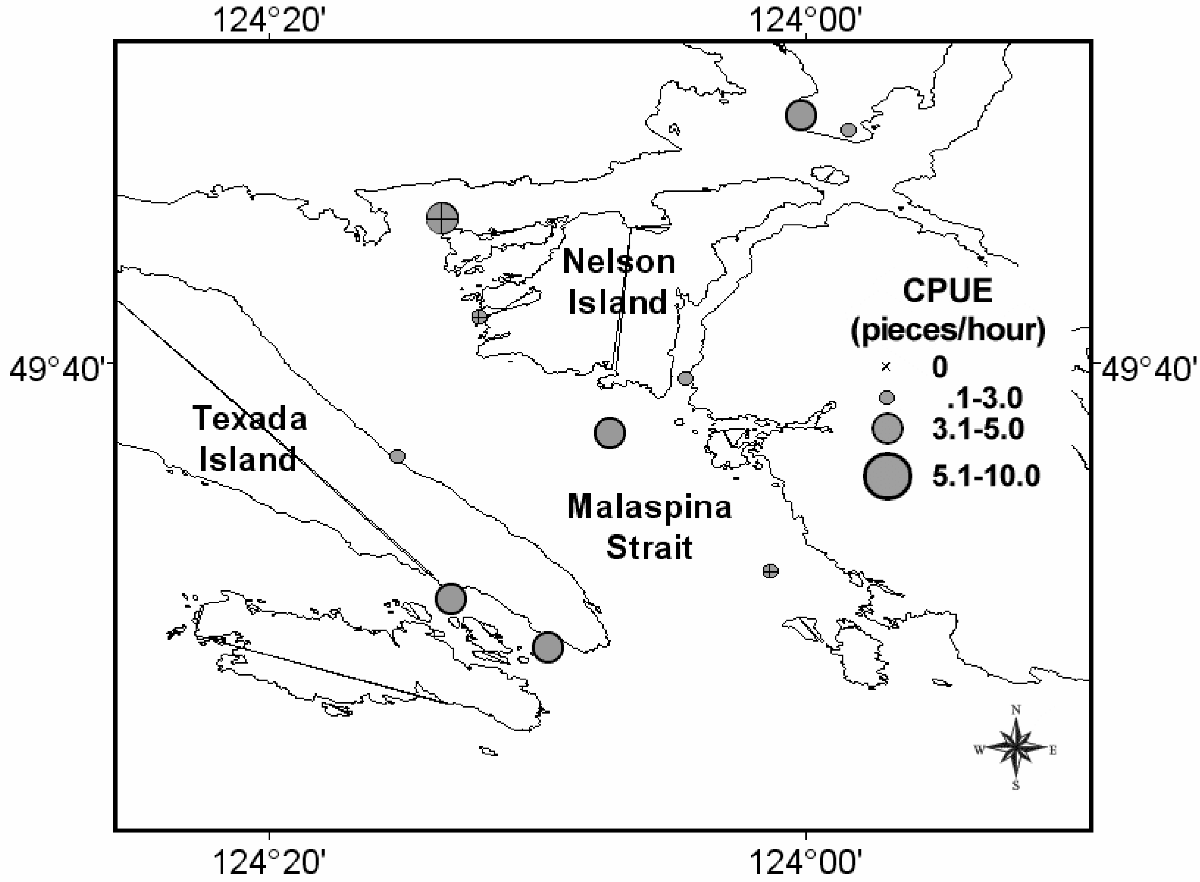

Figure 20. Mean July lingcod catch per unit effort (CPUE) at handline survey sites in Area 16 for surveys in 1985 and 1986 for depth strata less than 70 m. Size of circle represents CPUE classification in legend. Circles with crosses denote proposed Rockfish Conservation Areas.

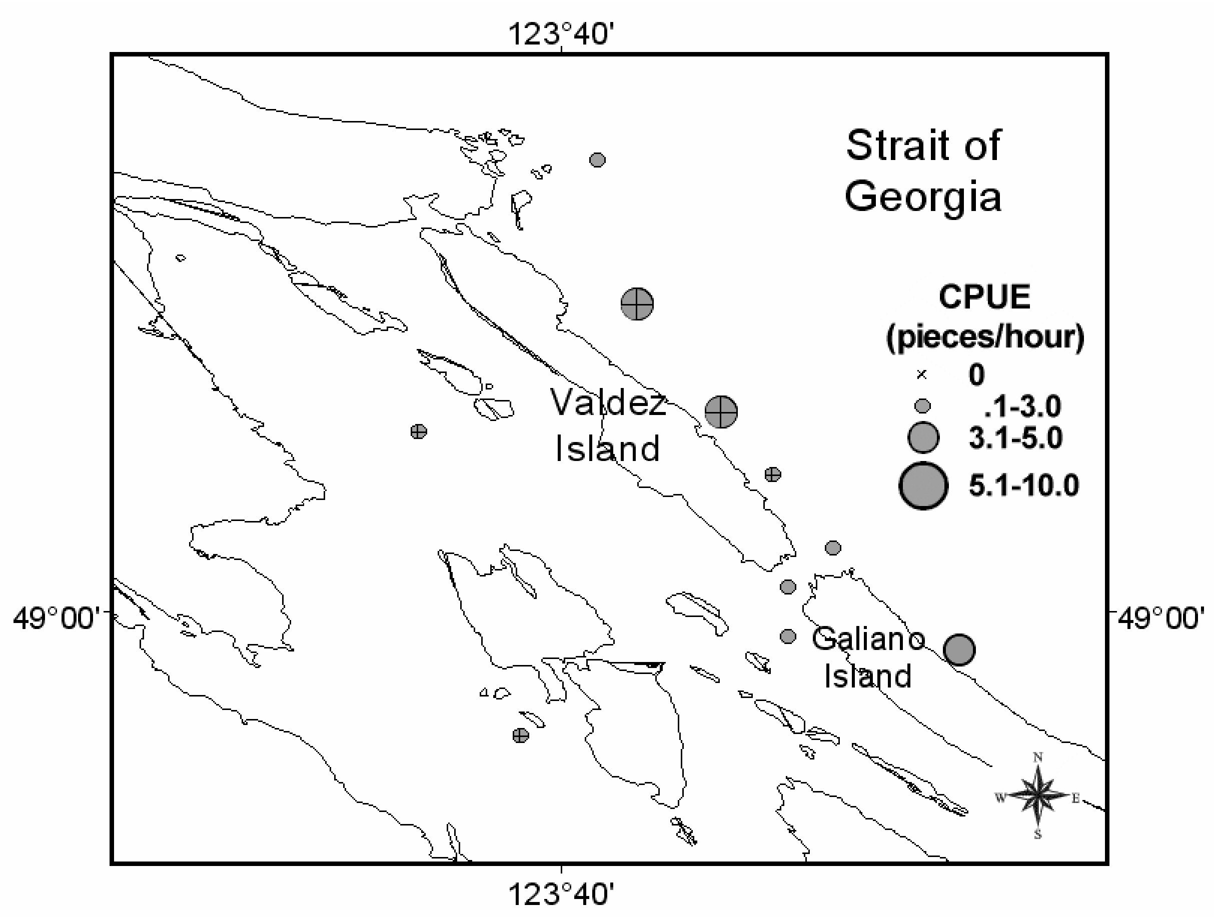

Figure 21. Mean October-November lingcod catch per unit effort (CPUE) at handline survey sites in Area 17 for surveys in 1985 and 1987. Size of circle represents CPUE classification in legend. Circles with crosses denote proposed Rockfish Conservation Areas.

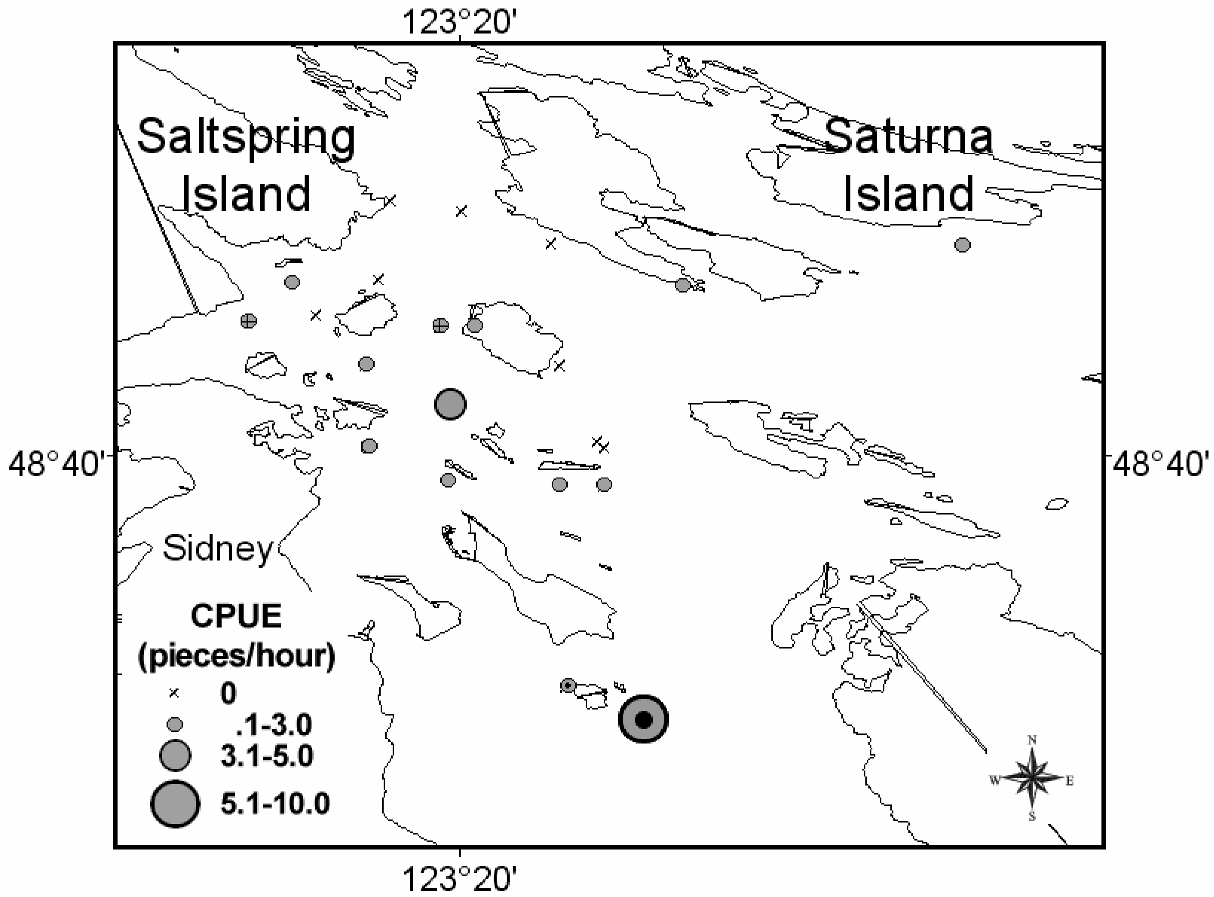

Figure 22. Mean October lingcod catch per unit effort (CPUE) at handline survey sites in Areas 18 and 19 for 1993. Size of circle represents CPUE classification in legend. Circles with crosses denote proposed Rockfish Conservation Areas. Circles with dots denote interim Rockfish Protection Areas.

Video Drop Survey – A pilot study in the late-summer of 2003 will be conducted that investigates the use of video drop technique in estimating rockfish abundance (L. Yamanaka, Pers. Comm., Fisheries and Oceans Canada, Nanaimo, BC, V9T 6N7). A camera attached to a rigid frame is dropped to the bottom and the area directly under the video is surveyed. A depth stratified random design will be incorporated into site selection and the survey will be conducted off Valdez and Galiano Islands.

6.0 RECOMMENDED RESEARCH

Assessment and management programs for lingcod could be augmented with research that addresses specific management concerns. The research recommended here is dependent on resource availability.

6.1 SEASONAL MIGRATION

It is generally accepted that lingcod undergo seasonal migrations with respect to depth, with lingcod inhabiting deeper waters in summer and shallower waters in winter. Females probably occupy deeper waters than males, and there has been some speculation that spawning females enter shallower waters only to spawn and remain in deep waters all season. There are likely differences between males and females in the timing of seasonal migrations, with males remaining in shallow waters for a larger part of the year than females. Changes in size composition by depth in commercial data tend to support these concepts, as do underwater visual observations on spawning lingcod. Knowledge of the recreational anglers on depth distribution of lingcod also suggests that lingcod undergo these seasonal migrations. However, the collection of individual lingcod movements over full seasons has not been undertaken. Research into seasonal migration of lingcod would be able to provide precise information on the timing of migration, and depth distribution of lingcod and differences in both for males and females, and also juvenile and adult lingcod. This information would aid in the refinement of surveys, particularly with depth strata selection and the timing of the surveys. It would also provide information on the availability of lingcod to the survey.

Archival tags can provide information on the depth that an individual lingcod is occupying and the temperature of its surrounding water. The tags are attached to the dorsal side of a fish. Data can be recorded at pre-selected intervals (e.g. once or twice a day, or even every minute) for up to 2 years. These data are stored until the tag is retrieved. Data could be collected on day and night distributions for two cycles of seasons for juvenile and adult, male or female lingcod. The lingcod could be tagged in conjunction with the handline survey or with the involvement of the recreational community. Anglers would be asked to release tagged lingcod for the first year, after which the return of tagged lingcod could be requested. Returned tags can be redeployed after data are downloaded.

6.2 RECAPTURE RATES

The capture and release mortality for lingcod has been estimated to be less than 5% (Albin and Karpov 1998). Lingcod are relatively sedentary, remaining associated with a specific locale. The high rate of survival after release along with their residency nature, could mean that lingcod captured and released by anglers are often recaptured. There are some concerns that increases in recreational CPUE of released lingcod reflect increased targeting on lingcod habitat and high recapture rates, and do not reflect increased abundance.

The recapture rate of lingcod by recreational fishermen could be estimated by deploying Floy spaghetti tags in limited sites and fishing for tagged lingcod. Lingcod would be captured by recreational gear, tagged and released. After an appropriate recovery time for the tagged lingcod, recreational fishing at the specific sites would be repeated and recaptured lingcod could be used to estimate the recapture rate. This project would require the involvement of the recreational fishing community.

6.3 POPULATION STRUCTURE

Future management strategies for Strait of Georgia lingcod could be implemented by sub-areas within the Strait of Georgia. While the Strait of Georgia population is likely a metapopulation, the stock structure of the Strait of Georgia lingcod population is unknown. Genetic microsatellite variation could be used to investigate the population structure of Strait of Georgia lingcod. This would provide input into the selection of suitable management areas based on stock structure. Genetic markers for lingcod have already been developed (Withler et al. 2003). Samples would need to be obtained from spawning populations and previous work has been able to use developing embryos from egg masses for genetic mapping (Withler et al. 2003). These samples could be collected with the involvement of the recreational diving community.

6.4 ECOSYSTEM DYNAMICS

One of the ongoing concerns regarding the low level of lingcod abundance throughout the 1990s and their lack of recovery, has been the predation pressure by marine mammals such as harbour seals and sea lions (King 2001). In King (2001) it was noted that 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. 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. It is important to note that even if the harbour seal population has returned to historic levels, 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. What is currently unknown is the effect that marine mammal predation has on the population dynamics of lingcod in the current state of the Strait of Georgia ecosystem. Ecosystem models, such as tropho-dynamic or mass balance models, could be used to investigate the impacts of various sources of natural mortality, such as the impact of predation, prey availability and ocean-climate influences on recruitment for lingcod. In addition, it would be useful to use population simulations to investigate the effects on other species of increasing or decreasing lingcod abundance in an attempt to look for interactions with prey species such as herring and hake.

7.0 SUMMARY

There are several sources of biological and relative abundance data for lingcod in the Strait of Georgia that can provide historical references for future work. Many surveys have been conducted in the Strait of Georgia for various life stages of lingcod. Building on the findings of previous researchers, and the need for a measure of the relative abundance of adult lingcod, we suggest that handline surveys be conducted with designs similar to previous surveys. In addition, we proposed that a bottom trawl survey for young-of-year lingcod be conducted to measure any recent changes in year class success. There are a number of research projects that could be conducted to help develop management strategies for lingcod. A number of these research projects could include the involvement of stakeholders, particularly the recreational fishing and diving communities.

Given adequate resources, we propose the following timeframe for lingcod monitoring and research work for the 2003-2005 fiscal years (Table 9).

Table 9. Proposed timeframe for lingcod monitoring and research for 2003-2005.

Date	Survey or Project	Minor Statistical Areas
July 2003	Bottom trawl survey for young of year.	Areas 17 and 18.
August-September 2003	Tagging projects (archival and recapture rate estimation). Involvement of recreational fishing community.	Selected in consultation with stakeholders.
October-November 2003	Handline surveys	Areas 14, 17, 18 and 19
March 2004	Collection of samples for genetic population analyses. Involvement of recreational diving community.	Selected in consultation with stakeholders.
July-August 2004	Handline surveys	Areas 13, 15 and 16.
August-September 2004	Continue tagging projects.	

With monitoring of the relative abundance of lingcod in place, the next focus should be on developing a conservation-based management strategy for Strait of Georgia lingcod. The development of such a strategy should be conducted with consultation of stakeholders, and with consideration to relevant legislation (e.g. Oceans Act, Species at Risk Act) and regional policies. We propose that the development of a conservation-based management strategy be initiated immediately. Such a strategy should involve managers identifying though a 'decision framework', anticipated responses to specific changes in relative biomass trajectories. These benchmarks may require a large magnitude of change in the indices of relative abundance. For example, Martell and Wallace (1998) estimated the exploitable biomass in the early 1990s to be 2.5% of the biomass estimated for the early 1950s. If managers selected a target exploitable biomass of 25% of the early 1950s estimated biomass, then an increase of 500-1000% would need to be detected in the relative abundance indices.

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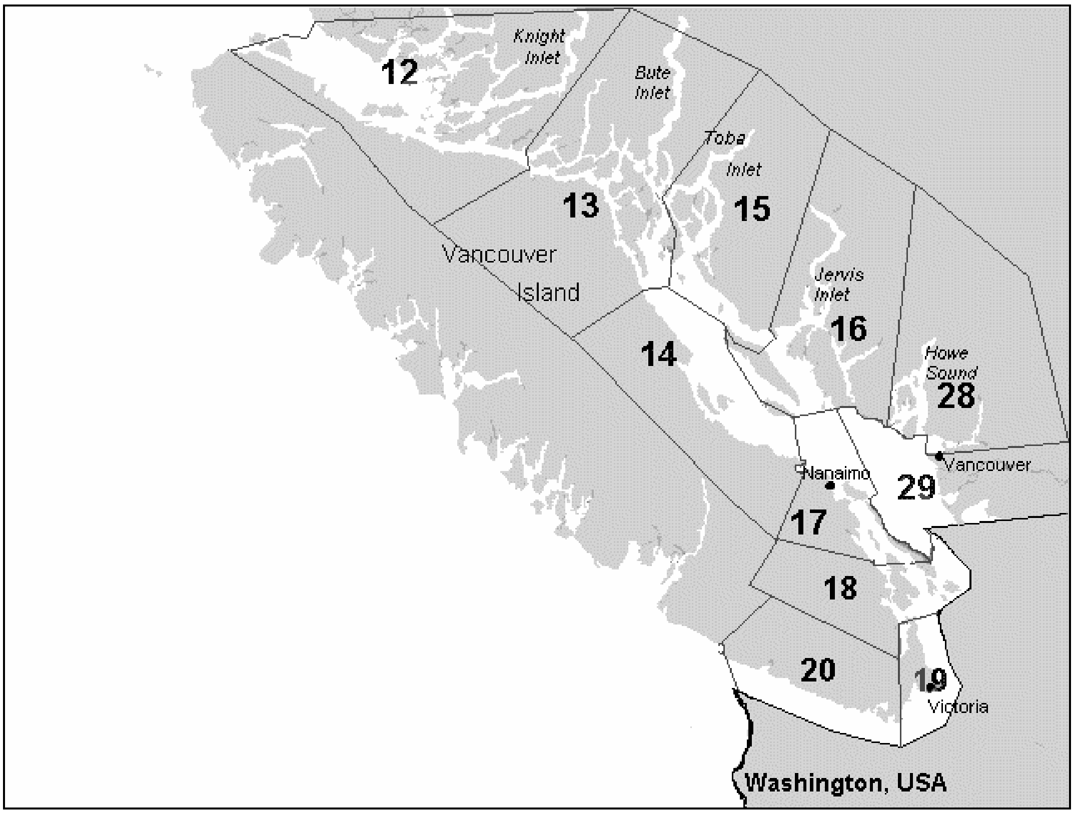
APPENDIX A1: Minor Statistical Areas (MSA) within the Major Area 4B.
This paper focuses only on MSA 13-19, 28 and 29.



APPENDIX A2: Request for Scientific Advice

Date Submitted: December 16, 2002

Proposed PSARC Presentation Date: May 2003

Group Requesting Advice: Groundfish Management Unit

Subject of Paper: Stock Assessment Framework for Strait of Georgia Lingcod

Stock Assessment Lead Author: Jacquelynne King

Fisheries Management Lead Author: Allan Macdonald

Rational for request

Since 1990, retention of lingcod by the commercial fishery in the Strait of Georgia has been prohibited in response to conservation concerns. In the recreational fishery, regulations prior to 2002 to protect lingcod included an eight month winter non-retention period to protect nest guarding males, size limits, and reduced daily and annual catch limits. In 2002, the recreational fishery was closed for the retention of lingcod as an additional measure to protect this stock; the non-retention regulation currently remains in effect.

Information on the Strait of Georgia lingcod population is required to address the following objectives: monitor changes in relative abundance, and provide the support for development of fisheries conservation-based management strategies.

Preparation of a stock assessment framework is requested to provide a detailed outline of scientific monitoring and assessment plans for the lingcod population necessary to achieve the above mentioned objectives. Detailed survey designs will be based on this stock assessment framework and will be produced prior to initiating any monitoring and assessment work.

Questions to be addressed in the Working Paper:
What is known about the biology and abundance of lingcod in the Strait of Georgia?
What methods of monitoring are required to measure changes in relative abundance over time of Strait of Georgia lingcod?
What research activities are required to support assessment and monitoring of Strait of Georgia lingcod?

Objectives of the Working Paper
Outline historical fishery and abundance trends of Strait of Georgia lingcod.
Outline current biological information on Strait of Georgia lingcod.
Provide survey methodologies and considerations for survey design for monitoring and assessing the relative abundance and biological parameters of Strait of Georgia lingcod.
Provide recommendations that prioritize survey and research requirements.

APPENDIX A3: Lingcod hook and line and trawl landings (tonnes) and total commercial landings (tonnes) for the whole of Major Area 4B 1951-2000.

Year	Hook and Line[a]	Trawl[b]	Total[c]	Year	Hook and Line[a]	Trawl[b]	Total[c]
1927	--	--	2845	1965	788.8	93.8	882.6
1928	--	--	2850	1966	804.3	53.7	858.0
1929	--	--	2823	1967	795.6	51.2	51.2
1930	--	--	2836	1968	769.2	83.9	853.1
1931	--	--	3108	1969	778.4	65.6	844.0
1932	--	--	2426	1970	823.4	48.1	871.5
1933	--	--	2446	1971	599.4	55.5	654.9
1934	--	--	2887	1972	532.7	34.5	567.2
1935	--	--	3706	1973	404.4	14.8	419.2
1936	--	--	4105	1974	372.3	49.4	421.7
1937	--	--	2656	1975	368.8	33.2	402.0
1938	--	--	2688	1976	331	43.4	374.4
1939	--	--	2827	1977	433	27.2	460.2
1940	--	--	2430	1978	495.3	42.5	537.8
1941	--	--	2295	1979[d]	562.6	25.2	587.8
1942	--	--	2328	1980	353.3	33.5	386.8
1943	--	--	2569	1981	351.5	63.1	414.6
1944	--	--	4591	1982	370.9	79.1	450.0
1945	3943	90	4032	1983	287.9	85.3	373.2
1946	3357	48	3406	1984	196.6	42.7	239.3
1947	--	57	--	1985	138.7	27.1	165.8
1948	--	25	--	1986	117.2	44.5	161.7
1949	--	13	--	1987	112.7	17.0	129.7
1950	--	34	--	1988[e]	82.9	13.0	95.9
1951	1318.1	48.1	1366.2	1989	77.5	2.9	80.4
1952	1512.7	54.0	1566.7	1990[f]	44.4	0.2	44.6
1953	1187.8	28.3	1216.1	1991[g]	25.3	1.5	26.8
1954	1462.5	69.2	1531.7	1992	13.4	2.0	15.4
1955	1231.9	50.6	1282.5	1993	15.9	1.0	16.9
1956	1512.3	55.7	1568.0	1994	14.5	4.0	18.5
1957	1546.4	42.0	1588.4	1995	13.3	0.9	14.2
1958	1450.9	74.6	1525.5	1996	16.6	0.6	17.2
1959	1192.4	336.4	1528.8	1997	19.5	1.5	21.0
1960	1279.6	184.1	1463.7	1998	30.4	1.6	32.0
1961	1199.9	102.1	1302.0	1999	39.9	1.0	40.9
1962	1293	75.4	1368.4	2000	21.3	1.5	22.8
1963	1002.3	39.6	1041.9	2001	21.4	0.4	21.8
1964	878	90.3	968.3				

[a] 1927-1944: Catch not reported by gear type.
1945-1946: Calculated as the difference between total catch and reported trawl catch.
1947-1950: No area totals reported.
1951-1981: Obtained from Fisheries and Oceans Canada, British Columbia Catch Statistics Annual Reports which summarize catch from sales slip records. Catches were reported as dressed weight, DW (head and viscera removed; Wilby 1937), and converted to round weight, RW, using the formula RW = 1.39 * DW (K. Rutherford, Pers. Comm.).
1982-1995: Obtained from the sales slip database, PacHarv3 (Fisheries and Oceans Canada, Pacific Region, Catch Statistics Unit, Vancouver BC).
1996-present: Obtained from the sales slip database, PacHarv3 (Fisheries and Oceans Canada, Pacific Region, Catch Statistics Unit, Vancouver BC) and the groundfish hook and line database, PacHarvHL (Fisheries and Oceans Canada, Pacific Region, Groundfish Data Unit).
[b] 1927-1944: Catch not reported by gear type.
1945-1953: Thomson and Yates (1960, 1961a, 1961b). Data obtained by Port Observers and supplemented with sales slip records.

1954-1995: 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).

1996-present: Obtained from the groundfish trawl observer database, PacHarvTrawl (Fisheries and Oceans Canada, Pacific Region, Groundfish Data Unit).

[c] 1927-1946: Dominion Bureau of Statistics, Fisheries Division (in Waddell and Ware 1995). Catches were reported as dressed weight, DW (head and viscera removed; Wilby 1937), and converted to round weight, RW, using the formula RW = 1.39 * DW (K. Rutherford, pers. comm., Pacific Biological Station, Nanaimo, British Columbia). Catch was not reported by gear type, but is known to be primarily from the line fishery, especially in nearshore waters (Forrester et al. 1978).

1947-1950: No area totals reported.

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

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

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

[g] 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. Landings 1991-2000 are for these open Areas.

APPENDIX A4: Estimated recreational lingcod landings (pieces) for Minor Statistical Areas 13-19, 28 and 29 from the Strait of Georgia creel survey program (months that the survey was conducted are indicated). Total landings (pieces and tonnes) are provided, along with landings (pieces) reported by English et al. (2002).

		Minor Statistical Area[a]									Total	Total	English et al. (2002)	
Year	Month	13	14	15	16	17	18	19	28	29	Landings[a] (pieces)	Landings[b] (tonnes)	Landings[c] (pieces)	Landings[b] (tonnes)
1981[d]	July-Aug	15700	8521	3088	4633	4466	3678	2926	3360	3831	50203	66.15		
1982	May-Dec	15004	5724	1285	17618	8886	6019	8986	6126	3656	73304	96.59		
1983	Jan-Dec	14119	2137	1036	17263	5123	5621	4910	5965	3636	59810	78.81	62770	82.71
1984	Jan-Dec	39719	11435	1668	28706	16405	7148	9761	8854	8101	131797	173.67	137485	181.17
1985	Jan-Dec	23177	6194	858	13985	8863	5283	9008	3068	2669	73105	96.33	77113	101.61
1986	Jan-Dec	25788	9714	1272	9366	6332	4250	6611	1885	1562	66780	105.7	70820	112.09
1987	Jan-Dec	23494	10288	1432	8100	6916	3029	5426	794	797	60276	89.85	65810	98.1
1988	Jan-Dec	22580	11540	1285	9802	5796	3479	3734	727	1697	60640	107.87	65929	117.28
1989	Jan-Dec	20905	8630	799	7455	4764	2991	5714	319	755	52332	82.83	52329	82.83
1990	Feb-Oct	13297	4763	458	4993	2298	1002	1727	146	327	29011	43.25	31376	46.77
1991[e]	Jan-Nov	2509	1153	51	976	1569	278	6881	177	266	13860	34.22	8251	20.37
1992	Feb-Dec	1635	468	24	1026	1121	204	397	303	234	5412	14.8	5968	16.32
1993	Jan-Sept	973	489	53	2325	964	206	734	191	382	6317	17.28	7175	19.62
1994	April-Oct	1427	758	85	2091	939	462	259	249	333	6603	19.95	6996	21.13
1995	March-Oct	843	662	14	1124	977	314	260	47	153	4394	13.27	4899	14.8
1996	April-Sept	1232	76	61	274	619	387	468	145	63	3325	12.72	3901	14.92
1997	April-Oct	1035	324	107	384	289	554	273	302	237	3505	12.22	4152	14.48
1998	April-Oct	514	227	24	550	602	250	519	182	50	2918	10.18	3345	11.67
1999	April-Sept	1369	71	25	197	536	103	409	155	47	2912	8.37	3688	10.6
2000	Jan-Dec	988	925	22	1251	1097	226	229	332	128	5198	18.13		
2001	Jan-Nov	1,460	1,150	124	1,884	2,134	563	544	251	109	8219	28.66		
2002[f]	April-Oct	73	9	0	2505	291	38	95	237	223	3471	12.11		

[a] Area data from Catch Statistics Unit (http://www-sci.pac.dfo-mpo.gc.ca/sa/Recreational/Georgia%20Strait%20Summaries_e.htm downloaded April 1, 2003). Pieces have been corrected from previous reported totals which overlapped counts within Areas for 1981-1999. Additionally, since February 2002, the Catch Statistics Unit has reallocated estimated catch in a subarea of Area 19 to Area 20, applicable to the whole time series.

[b] Landings in tonnes estimated by applying Strait of Georgia mean length of landed lingcod reported in King (2001) to length-weight relationship ($\ln W_{kg}=3.3287*\ln(L_{cm})-12.94$. Mean length from 1985 applied to 1981-1984. Mean length from 2001 was applied to 2002. As with estimated pieces, catch (tonnes) is corrected from previous reported totals which overlapped counts within Areas for 1981-1999. Additionally, since February 2002, the Catch Statistics Unit has reallocated estimated catch in a subarea of Area 19 to Area 20, applicable to the whole time series.

[c] Landings (pieces) from English et al. (2002) available as total for all areas only.

[d] Recreational fishery open April 16-November 14 from 1981-1990 with a size limit of 58 cm.

[e] Recreational fishery open June 1-September 30 from 1991-2001 with a size limit of 65 cm.

[f] Recreational fishery closed year round.

APPENDIX A5: Lingcod qualified catch per unit effort (kg/d) by Minor Statistical Area from commercial handline and troll sales slip data. Catch per unit effort is determined for landings with at least 100 kg of lingcod.

	Minor Statistical Area								
Year	13	14	15	16	17	18	19	28/29	Mean
1967[a]	301	236	314	213	127	124	164	87	195.8
1968	318	179	375	194	127	110	168	227	212.3
1969	272	168	438	213	136	129	292	--	235.4
1970	254	168	351	196	175	154	228	257	222.9
1971	266	171	267	196	166	113	217	25	177.6
1972	301	201	283	178	143	150	191	147	199.3
1973	287	132	264	185	167	150	207	119	188.9
1974	312	253	269	135	139	135	170	327	217.5
1975	312	160	242	194	171	189	193	46	188.4
1976	275	150	250	123	174	126	128	140	170.8
1977	200	192	256	222	148	125	131	115	173.6
1978	192	126	206	278	155	105	132	210	175.5
1979[b]	149	147	271	188	163	166	113	147	168
1980	159	80	226	75	161	122	85	118	128.3
1981	158	84	137	126	143	101	105	54	113.5
1982	163	68	96	81	114	112	102	59	99.4
1983	153	140	194	78	138	98	139	55	124.4
1984	88	106	104	106	115	157	147	35	107.3
1985	98	113	85	156	106	74	111	96	104.9
1986	51	176	424	165	99	112	76	48	143.9
1987	27	72	150	--	92	101	67	295	114.9
1988	28	117	--	--	102	71	68	157	90.5
1989	65	102	9	279	52	59	--	--	94.3
1990	--	167	--	--	--	--	--	24	95.5

[a] Data for 1967 – 1978 from Richards and Hand (1991)

[b] Data for 1979 – 1990 from Richards and Yamanaka (1992).

APPENDIX A6. Catch per unit effort of lingcod kept and released per boat trip or 100 hours of fishing by recreational anglers for each Minor Statistical Area estimated[a] from Strait of Georgia creel survey interviews.

A6.1: Encounters (kept and released) per boat trip.

	Minor Statistical Area									
Year	13	14	15	16	17	18	19	28	29	Mean
1982	0.22	0.06	0.16	0.34	0.24	0.17	0.16	0.21	0.12	0.19
1983	0.26	0.03	0.16	0.23	0.13	0.26	0.28	0.22	0.26	0.2
1984	0.45	0.14	0.15	0.37	0.26	0.28	0.39	0.43	0.15	0.29
1985	0.23	0.06	0.09	0.22	0.14	0.28	0.25	0.16	0.09	0.17
1986	0.27	0.14	0.11	0.21	0.14	0.34	0.2	0.1	0.06	0.17
1987	0.26	0.09	0.13	0.24	0.09	0.11	0.21	0.08	0.04	0.14
1988	0.26	0.06	0.11	0.19	0.09	0.13	0.14	0.05	0.06	0.12
1989	0.27	0.07	0.09	0.19	0.08	0.08	0.11	0.05	0.03	0.11
1990	0.31	0.08	0.09	0.17	0.09	0.13	0.17	0.04	0.01	0.12
1991	0.49	0.11	0.11	0.18	0.14	0.11	0.13	0.06	0.03	0.15
1992	0.36	0.07	0.11	0.15	0.13	0.14	0.35	0.08	0.03	0.16
1993	0.25	0.06	0.06	0.19	0.09	0.08	0.2	0.05	0.01	0.11
1994	0.25	0.11	0.07	0.24	0.11	0.34	0.21	0.05	0.02	0.16
1995	0.25	0.12	0.08	0.09	0.1	0.08	0.06	0.03	0.02	0.09
1996	0.4	0.09	0.14	0.12	0.14	0.19	0.75	0.08	0.04	0.22
1997	0.35	0.12	0.18	0.53	0.19	0.21	0.31	0.12	0.07	0.23
1998	0.38	0.1	0.2	0.3	0.26	0.11	0.43	0.06	0.02	0.21
1999	0.34	0.04	0.21	0.16	0.11	0.14	0.4	0.15	0.07	0.18
2000	0.24	0.12	0.26	0.52	0.37	0.17	0.59	0.16	0.07	0.28
2001	0.29	0.17	0.25	0.61	0.42	0.23	1.05	0.19	0.02	0.36
2002	0.24	0.11	0.51	0.59	0.49	0.22	0.65	0.19	0.08	0.34

A6.2: Encounters (kept and released) per 100 hours fishing.

	Minor Statistical Area									
Year	13	14	15	16	17	18	19	28	29	Mean
1982	5.83	1.72	4.45	9.42	7.11	4.76	4.1	4.5	2.71	4.96
1983	7.44	0.78	4.91	6.24	3.77	7.42	7.48	4.68	5.61	5.37
1984	11.98	4.44	4.33	9.22	7.43	7.09	10.89	10.17	3.22	7.64
1985	6.21	1.96	2.89	6.06	4.21	6.8	6.51	3.92	1.8	4.48
1986	7.22	4.07	3.46	5.14	4.05	8.38	5.61	2.45	1.17	4.62
1987	6.73	2.76	3.76	6.25	2.81	3	5.66	1.92	0.76	3.74
1988	7.12	1.85	3.53	5.31	2.74	3.9	4.1	1.24	1.43	3.47
1989	7.00	1.97	2.91	5.64	2.5	2.49	3.05	1.16	0.7	3.05
1990	8.3	2.35	2.96	5.07	2.6	3.94	5.22	1.13	0.31	3.54
1991	13.34	3.45	3.72	5.61	3.93	3.54	3.91	1.63	0.58	4.41
1992	9.15	2.28	3.41	4.34	4.39	4.35	11.46	1.84	0.63	4.65
1993	6.71	1.78	1.61	5.66	3.02	2.69	6.51	1.33	0.2	3.28
1994	6.57	3.32	1.73	6.97	3.62	10.13	6.25	1.08	0.33	4.44
1995	6.79	3.98	2.15	2.52	3.3	2.5	1.93	0.66	0.33	2.68
1996	10.7	2.96	4.29	3.34	4.45	5.96	23.69	1.92	0.88	6.47
1997	9.22	3.88	5.47	14.65	5.94	7.18	9.58	2.81	1.56	6.7
1998	10.62	3.46	7.42	9.19	8.19	3.91	13.18	1.29	0.61	6.43
1999	8.91	1.31	5.68	4.55	3.49	4.31	12.67	3.31	1.63	5.1
2000	6.83	3.61	7.29	15.34	10.98	5.5	17.33	3.93	1.52	8.04
2001	8.16	5.17	6.68	16.84	14.39	7.4	32.17	4.43	0.55	10.64
2002	7.13	3.16	13.34	17.19	15.44	7.62	21.62	4.98	1.84	10.26

A6.3: Kept lingcod per boat trip.

	Minor Statistical Area									
Year	13	14	15	16	17	18	19	28	29	Mean
1982	0.16	0.05	0.14	0.3	0.2	0.14	0.11	0.17	0.1	0.15
1983	0.18	0.02	0.13	0.19	0.1	0.18	0.13	0.2	0.24	0.15
1984	0.3	0.11	0.13	0.3	0.18	0.18	0.23	0.33	0.1	0.21
1985	0.15	0.05	0.08	0.19	0.1	0.17	0.17	0.14	0.07	0.12
1986	0.2	0.11	0.06	0.15	0.11	0.3	0.15	0.08	0.04	0.13
1987	0.19	0.06	0.11	0.19	0.08	0.09	0.14	0.06	0.03	0.11
1988	0.2	0.05	0.09	0.17	0.07	0.09	0.11	0.04	0.05	0.1
1989	0.18	0.05	0.07	0.16	0.05	0.06	0.07	0.04	0.02	0.08
1990	0.11	0.03	0.04	0.08	0.04	0.07	0.07	0.03	0.01	0.05
1991	0.03	0.01	0	0.03	0.02	0.02	0.02	0.02	0	0.02
1992	0.02	0	0	0.01	0.01	0.03	0.02	0.03	0	0.01
1993	0.01	0	0.01	0.02	0.02	0.02	0.02	0.03	0	0.01
1994	0.01	0	0	0.04	0.02	0.04	0.02	0.02	0	0.02
1995	0.02	0	0	0.02	0.02	0.03	0.01	0.02	0.01	0.01
1996	0.02	0	0	0.01	0.01	0.02	0.04	0.02	0.01	0.01
1997	0.03	0.01	0.01	0.03	0.01	0.03	0.02	0.03	0.02	0.02
1998	0.02	0.01	0.01	0.03	0.04	0.01	0.04	0.01	0	0.02
1999	0.05	0	0.02	0.01	0.03	0.01	0.03	0.02	0	0.02
2000	0.03	0.01	0	0.08	0.08	0.04	0.04	0.06	0.01	0.04
2001	0.04	0.01	0.01	0.1	0.08	0.05	0.05	0.03	0.01	0.04
2002	0	0	0	0.07	0.01	0.01	0.01	0.05	0	0.02

A6.4: Kept lingcod per 100 hours fishing.

	Minor Statistical Area									
Year	13	14	15	16	17	18	19	28	29	Mean
1982	4.29	1.44	3.88	8.31	6	4	2.84	3.69	2.28	4.08
1983	5.13	0.68	3.9	5.31	2.92	5.03	3.46	4.26	5.13	3.98
1984	8.04	3.48	3.67	7.45	5.14	4.57	6.39	7.78	1.98	5.39
1985	4.17	1.6	2.33	5.38	3.08	4.23	4.42	3.47	1.39	3.34
1986	5.43	3.31	1.89	3.75	3.15	7.38	4.14	1.85	0.8	3.52
1987	4.93	1.89	3.04	4.89	2.4	2.38	3.82	1.38	0.55	2.81
1988	5.39	1.53	2.8	4.78	2.29	2.6	3.17	1.1	1.14	2.76
1989	4.76	1.54	2.16	4.63	1.56	1.8	2.12	0.91	0.52	2.22
1990	2.99	0.91	1.2	2.33	1.2	2	2.24	0.79	0.13	1.53
1991	0.86	0.34	0.11	0.77	0.59	0.54	0.7	0.65	0.09	0.52
1992	0.44	0.14	0.11	0.34	0.44	0.81	0.62	0.61	0.09	0.4
1993	0.28	0.04	0.15	0.69	0.55	0.78	0.57	0.75	0.05	0.43
1994	0.27	0.08	0.04	1.16	0.66	1.06	0.58	0.49	0.1	0.49
1995	0.5	0.05	0	0.59	0.77	0.81	0.37	0.34	0.12	0.39
1996	0.6	0.06	0.09	0.24	0.38	0.6	1.16	0.37	0.21	0.41
1997	0.72	0.25	0.26	0.7	0.44	0.88	0.48	0.7	0.34	0.53
1998	0.66	0.19	0.37	0.97	1.19	0.43	1.31	0.22	0	0.59
1999	1.36	0.1	0.61	0.4	0.78	0.46	1.04	0.37	0.09	0.58
2000	0.77	0.32	0.08	2.44	2.22	1.17	1.29	1.4	0.18	1.1
2001	1.2	0.44	0.32	2.8	2.63	1.5	1.57	0.75	0.24	1.27
2002	0.07	0	0	2.12	0.33	0.44	0.46	1.42	0	0.54

A6.5: Released lingcod per boat trip.

	Minor Statistical Area									
Year	13	14	15	16	17	18	19	28	29	Mean
1982	0.06	0.01	0.02	0.04	0.04	0.03	0.05	0.04	0.02	0.03
1983	0.08	0	0.03	0.03	0.03	0.08	0.15	0.02	0.02	0.05
1984	0.15	0.03	0.02	0.07	0.08	0.1	0.16	0.1	0.06	0.09
1985	0.08	0.01	0.02	0.02	0.04	0.1	0.08	0.02	0.02	0.04
1986	0.07	0.03	0.05	0.06	0.03	0.04	0.05	0.03	0.02	0.04
1987	0.07	0.03	0.03	0.05	0.01	0.02	0.07	0.02	0.01	0.03
1988	0.06	0.01	0.02	0.02	0.01	0.04	0.03	0.01	0.01	0.02
1989	0.09	0.01	0.02	0.03	0.03	0.02	0.03	0.01	0.01	0.03
1990	0.02	0.05	0.05	0.09	0.05	0.07	0.1	0.01	0.01	0.05
1991	0.46	0.1	0.11	0.16	0.12	0.09	0.11	0.04	0.02	0.13
1992	0.34	0.07	0.1	0.14	0.12	0.11	0.33	0.05	0.03	0.14
1993	0.24	0.06	0.05	0.17	0.07	0.06	0.18	0.02	0.01	0.1
1994	0.24	0.1	0.06	0.2	0.09	0.3	0.19	0.02	0.01	0.13
1995	0.23	0.12	0.08	0.07	0.08	0.06	0.05	0.01	0.01	0.08
1996	0.37	0.09	0.13	0.11	0.13	0.17	0.71	0.06	0.03	0.2
1997	0.32	0.11	0.17	0.5	0.18	0.19	0.3	0.09	0.06	0.21
1998	0.36	0.09	0.19	0.27	0.22	0.1	0.39	0.05	0.02	0.19
1999	0.29	0.04	0.19	0.15	0.09	0.12	0.37	0.13	0.07	0.16
2000	0.22	0.11	0.26	0.44	0.3	0.14	0.54	0.1	0.06	0.24
2001	0.24	0.16	0.24	0.51	0.34	0.18	1	0.15	0.01	0.31
2002	0.24	0.11	0.51	0.52	0.48	0.21	0.64	0.13	0.08	0.32

A6.6: Released lingcod per 100 hours of fishing.

	Minor Statistical Area									
Year	13	14	15	16	17	18	19	28	29	Mean
1982	1.54	0.28	0.58	1.11	1.11	0.76	1.27	0.81	0.43	0.88
1983	2.31	0.1	1.01	0.94	0.85	2.38	4.02	0.42	0.48	1.39
1984	3.94	0.97	0.66	1.76	2.29	2.52	4.5	2.39	1.24	2.25
1985	2.04	0.36	0.55	0.68	1.13	2.58	2.09	0.46	0.41	1.14
1986	1.8	0.76	1.57	1.39	0.9	1.01	1.46	0.6	0.37	1.1
1987	1.8	0.87	0.72	1.35	0.41	0.62	1.84	0.55	0.22	0.93
1988	1.73	0.32	0.73	0.54	0.45	1.3	0.93	0.14	0.29	0.71
1989	2.24	0.43	0.75	1.01	0.93	0.68	0.94	0.25	0.18	0.82
1990	5.31	1.43	1.76	2.74	1.4	1.93	2.98	0.34	0.18	2.01
1991	12.48	3.11	3.62	4.84	3.34	2.99	3.21	0.98	0.48	3.89
1992	8.71	2.14	3.31	4	3.95	3.54	10.85	1.23	0.54	4.25
1993	6.43	1.74	1.45	4.97	2.47	1.9	5.95	0.59	0.15	2.85
1994	6.3	3.24	1.68	5.81	2.96	9.07	5.68	0.59	0.23	3.95
1995	6.29	3.93	2.15	1.93	2.53	1.69	1.56	0.32	0.21	2.29
1996	10.1	2.9	4.2	3.1	4.06	5.36	22.53	1.56	0.67	6.05
1997	8.5	3.63	5.21	13.96	5.5	6.3	9.1	2.1	1.22	6.17
1998	9.95	3.27	7.05	8.23	6.99	3.48	11.87	1.07	0.61	5.84
1999	7.56	1.21	5.07	4.15	2.71	3.84	11.63	2.93	1.54	4.52
2000[b]	6.06	3.29	7.2	12.91	8.76	4.33	16.04	2.53	1.34	6.94
2001	6.96	4.73	6.36	14.04	11.77	5.9	30.6	3.68	0.31	9.37
2002	7.06	3.16	13.34	15.06	15.11	7.17	21.16	3.56	1.76	9.71

[a] Estimates provided by Karl English, LGL Limited, 9768 Second Street, Sidney, BC, V8L 3Y8 from interview data provided by South Coast Chinook Stock Assessment, South Coast Area, Fisheries and Oceans Canada, 3225 Stevenson Point Road, Nanaimo, BC.

[b] 2000 data are corrected from King (2001) to include released sub-legal sized fish.