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Status Report on Canary rockfish *Sebastes pinniger*

Rapport sur l'état du sébaste canari, *Sebastes pinniger*

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ABSTRACT

Canary rockfish (*Sebastes pinniger*) is one of 102 species of the genus *Sebastes*, 96 of which are found in the North Pacific. This report treats canary rockfish as a single unit in B.C. waters but examines abundance trends by region. Canary rockfish have been managed in B.C. waters as two stocks: SW coast of Vancouver Island and central Queen Charlotte Sound stocks. Fishers report that they are abundant in more northern areas off the west coast of the Queen Charlotte Islands; but trawl effort in these areas have been limited. Populations are most abundant between B.C. and northern California. The B.C. population probably overlaps to some extent with U.S. populations. They are broadly distributed in coastal and enclosed waters of B.C. Larvae and pelagic juvenile canary rockfish occupy the top 100 m for up to 3-4 months after live-berth and then settle to a benthic habitat. Adults typically inhabit rocky bottom in 70-270 m depth on the continental shelf.

Maximum observed length, weight, and age for canary rockfish from B.C. waters is 68 cm, 5.7 kg, and 84 y, respectively. Average harvested weight is 2.03 kg. They first appear at age five in the fishery and are fully recruited by 13-14 y. The instantaneous rate of natural mortality (M) for males and young females is about 0.06. M for females appears to increase with age for an age-averaged M of about 0.09. Age of 50% maturity is 13 and 7-8 for females and males respectively. Generation time is 20-30 y. Pelagic juveniles feed on planktonic items. Adults and subadults primarily eat krill and small fishes. Trawl catches indicate a seasonal depth migration from 160-210 m in late winter to 100-170 m in late summer.

Surveys and harvest rates indicate a current adult abundance of many millions. A long term relative index for the WC of Vancouver Island indicates that, while the population may have recently returned to levels observed at the beginning of the index in the mid 1970's, the average value of the index in recent years is 39-61% of the long term mean, or 23-45% of the earliest period. Commercial trawl catch rates in the same region appear stable since 1996. There is no long-term index available for the central coast area, but trawl catch rates appear stable since 1996.

Commercial fisheries are well monitored. Recreational and First Nations' catches are less well monitored but will probably remain negligible over the short term. A number of surveys have been implemented in B.C. since 2000 to improve tracking of relative abundance. U.S. fisheries may have an impact on abundance in Canadian waters, however since the declaration in 1999 of an "overfished" status for canary rockfish for Washington-California waters, fishing effort and catches have been drastically reduced. Canary rockfish are a significant economic component of the commercial fisheries (>800 t/y), but play a minor role in the recreational fishery, where they are a non-directed species. Catches are small in First Nations' fisheries, but their cultural importance may be larger than is reflected by the catches. Landings are currently constrained in these fisheries through a variety of harvest controls.

RÉSUMÉ

Le sébaste canari (*Sebastes pinniger*) est l'une des 102 espèces du genre *Sebastes*, dont 96 vivent dans le Pacifique Nord. Dans le présent rapport, le sébaste canari est traité comme une entité distincte des eaux de la C.-B., mais les tendances d'abondance sont examinées par région. Cette espèce a été gérée dans les eaux de la C.-B. comme deux stocks distincts : l'un sur la côte sud-ouest de l'île de Vancouver et l'autre, au centre, dans le détroit de la Reine-Charlotte. Selon les pêcheurs, elle est abondante dans des régions plus au nord de la cote ouest des îles de la Reine-Charlotte; mais les efforts de pêche au chalut dans ces zones ont été limités. Les populations sont surtout abondantes entre la C.-B. et le nord de la Californie. L'aire de la population de la C.-B. recoupe probablement dans une certaine mesure celle des populations américaines. L'espèce est largement répartie dans les eaux côtières et confinées de la C.-B. Les larves et les jeunes sébastes canaris pélagiques évoluent dans la portion supérieure de 100 m jusqu'à environ 3 ou 4 mois après la naissance vivante et se déplacent ensuite vers un habitat benthique. Les adultes vivent généralement sur un fond rocheux, entre 70 et 270 m de profondeur, sur la plate-forme continentale.

La longueur, le poids et l'âge maximums du sébaste canari observés dans les eaux de la C.-B. sont de 68 cm, 5,7 kg et 84 ans, respectivement. Le poids moyen des poissons capturés est de 2,03 kg. Les poissons font leur première apparition au sein de la population exploitable à l'âge 5 et sont entièrement recrutés vers l'âge 13-14. Le coefficient instantané de moralité naturelle (*M*) des mâles et des jeunes femelles est d'environ 0,06. Pour les femelles, *M* semble augmenter avec l'âge, la moyenne selon l'âge étant d'environ 0,09. L'âge à 50 % de la maturité est de 13 ans et 7-8 ans pour les femelles et les mâles respectivement. La durée d'une génération est de 20 à 30 ans. Les jeunes poissons pélagiques se nourrissent de plancton. Quant aux adultes et aux jeunes adultes, ils consomment principalement du krill et des petits poissons. Les prises au chalut révèlent une migration en profondeur saisonnière de 160-210 m à la fin de l'hiver, jusqu'à 100-170 m à la fin de l'été.

L'indice de relevé et les taux de prise indiquent une abondance actuelle de plusieurs millions d'adultes. L'indice relatif à long terme sur la côte ouest de l'île de Vancouver montre que, si la population a récemment retrouvé les niveaux observés au début du calcul de l'indice, au milieu des années 1970, sa valeur moyenne pour les dernières années est de 39 à 61 % de la moyenne à long terme, ou 23 à 45 % de la période initiale. Les taux de prises commerciales au chalut dans la même région semblent stables depuis 1996. Il n'y a pas d'indice à long terme pour la région de la côte centrale, mais les taux de prises au chalut semblent également stables depuis 1996.

Les pêches commerciales sont bien contrôlées. Les prises des pêcheurs sportifs et des Premières nations sont moins bien surveillées, mais demeurent probablement négligeables à court terme. Un certain nombre de relevés ont été entrepris en C.-B. depuis 2000, afin d'améliorer le suivi de l'abondance relative. Les pêches pratiquées par les Américains pourraient avoir un effet sur l'abondance dans les eaux canadiennes; toutefois, depuis que le sébaste canari se trouvant entre l'État de Washington et la Californie a été déclaré « surexploité », en 1999, l'effort de pêche et les prises ont diminué radicalement. Le sébaste canari constitue une composante économique importante des pêches commerciales (>800 t/an), mais joue un rôle moindre dans la pêche sportive, car il ne fait pas l'objet d'une pêche dirigée. Les pêches pratiquées par les Premières nations sont limitées, mais leur importance culturelle pourrait être plus grande que ne semblent l'indiquer les captures. Les débarquements sont actuellement restreints dans le cadre de ces pêches par diverses mesures de contrôle des prises.

INTRODUCTION

Purpose

This paper summarizes the material presented on canary rockfish (*Sebastes pinniger*) at the November 1-2, 2005, National Advisory Process meeting to review marine species subject to upcoming assessment by COSEWIC (DFO, 2005). Terms of Reference for the document are shown in Appendix 1.

Name and Classification

The canary rockfish, or sébaste canari (*Sebastes pinniger*), is one of 102 species of rockfish belonging to the genus *Sebastes* of which 96 species are found in the North Pacific (Love et al. 2002). The scientific names are from the Greek *sebastos* (magnificent) and the Latin *pina* (fin) and *gero* (to bear) (Hart 1973), which translates to "I bear a large fin" (Love et al. 2002). At least 36 species of rockfish have been found in Canada's Pacific waters (Graham Gillespie, pers. comm.) with the number growing coincident with advances in DNA research (Gharrett et al. 2005). At the present time, there are no identified subspecies of canary rockfish. Canary rockfish have been referred to by many other names including orange rockfish, snapper, red snapper, and fantail rockfish. They are often confused with other red or yellow rockfish such as yelloweye rockfish (*S. ruberrimus*).

Morphological Description

Mature canary rockfish are primarily mottled orange in colour with a pale grey or white background (Love et al. 2002). They have three distinctive bright orange stripes that lie diagonally across the head. The lateral line is well demarcated and is either white or grey extending anteriorly from the caudal fin. Their fins are bright orange. The anal fin is pointed with the outside edge strongly slanted towards the anterior (Mecklenburg et al. 2002). The caudal fin is strongly indented (Love et al. 2002).

Genetic Description

No genetics studies have been conducted on Canadian specimens. Genetics work by Wishard et al. (1980) indicated restricted gene flow between populations in northern California and northern Washington, but the results were inconclusive. Preliminary work on nine polymorphic microsatellite loci has been described by Gomez-Uchida et al. (2003). They noted that the polymorphism at the nine loci revealed 6-28 alleles with expected heterozygosities ranging from 0.42-0.88. This led them to conclude that high-resolution population structure could be investigated for this species.

Designatable Units

There is presently no basis to assign more than one designatable unit for canary rockfish, but we do discuss abundance trends by region. Canary rockfish have been managed in Canada's Pacific waters as two assumed stocks: a southern or west coast of Vancouver Island stock (Pacific Marine Fisheries Commission Areas 3C+3D) and a central or Queen

Charlotte Sound stock (PMFC Area 5A+5B) (Stanley 1999, see also the Pacific Groundfish Management Plan[1]) (Fig. 1).

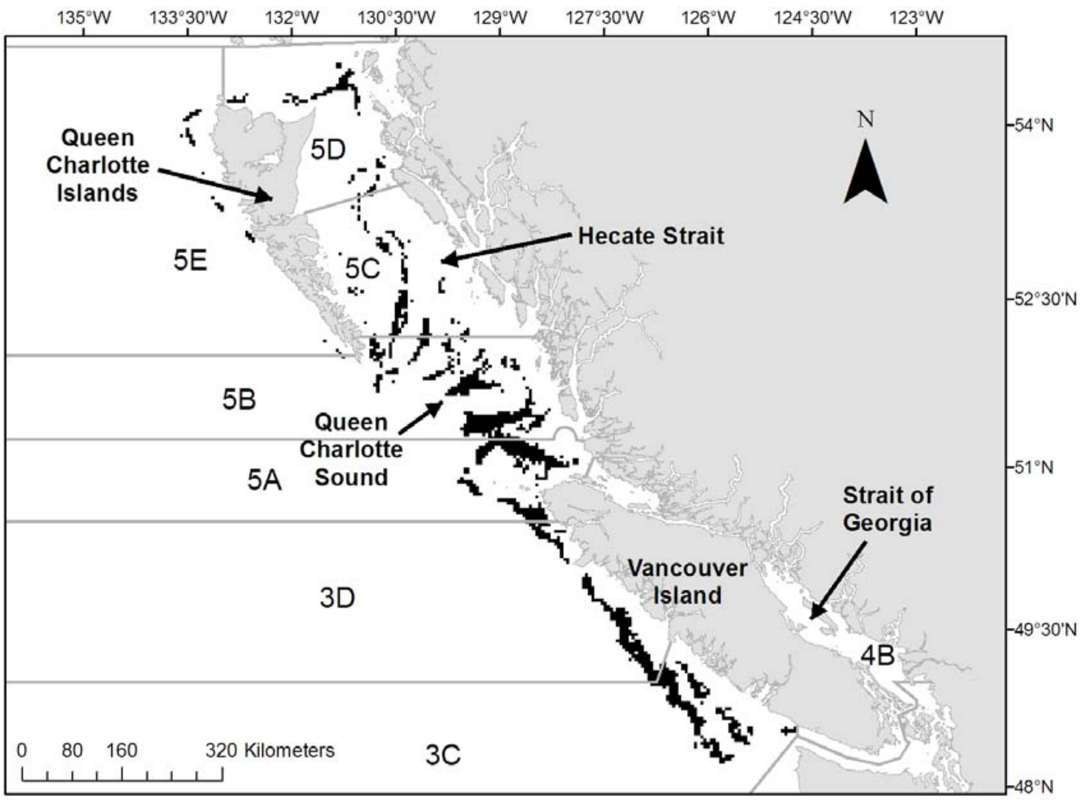

Figure 1. Spatial distribution of catches of canary rockfish in B.C. as recorded in commercial trawl observer logbooks (1996-2004). Also shown are the Pacific Marine Fisheries Commission (PMFC) Area designations.

Canary rockfish are also present in PMFC Areas 5C, 5D and 5E, particularly the southern portion of 5C and all of 5E, but trawl landings from these areas have been limited owing to the lack of trawlable ground, particularly in 5E. Thus, no assessments have been conducted on these populations. The stock boundaries were not based on biological evidence, rather a precautionary measure to distribute the fishing mortality given the possibility of stock structure. The B.C. population probably overlaps to some extent with U.S. populations. The California to Washington population is assessed as a single stock (Methot and Stewart 2005).

[1] Pacific Region Integrated Fisheries Management Plan Groundfish Trawl April 1, 2005 to March 31, 2006. http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/MPlans.htm

DISTRIBUTION

Global Distribution

Canary rockfish are found from northern Baja California to the western Gulf of Alaska (Shelikof Strait) (Love et al. 2002). Populations are most abundant between northern California and B.C. (Figure 2).

Figure 2. Global distribution of canary rockfish (modified and reprinted with permission from Love *et al.* (2002).

Canadian Range

Canary rockfish are widely distributed throughout B.C. coastal waters. The prevalence of this species in recreational fishing in the Strait of Georgia (SoG) indicates that they are probably well distributed in enclosed waters and inlets (Table 1: data source: South Coast Creel Database). They have also been observed at Bowie Seamount, 150 km west of the Queen Charlotte Islands (QCI) (data source: GFBio).

Trawl observations indicate that canary rockfish generally occupy coastal shelf waters (Fig. 1) over bottom depths of 73 to 268 meters (Fig. 3). This translates to an area of occupancy of >60,000 km^2 (Fig. 4). This may be overestimated as canary rockfish prefer hard bottom within this area. However, it appears that they can be encountered within most 25 km^2 blocks over or near the continental shelf which would translate to a minimum extent of occurrence of >32,000 km^2.

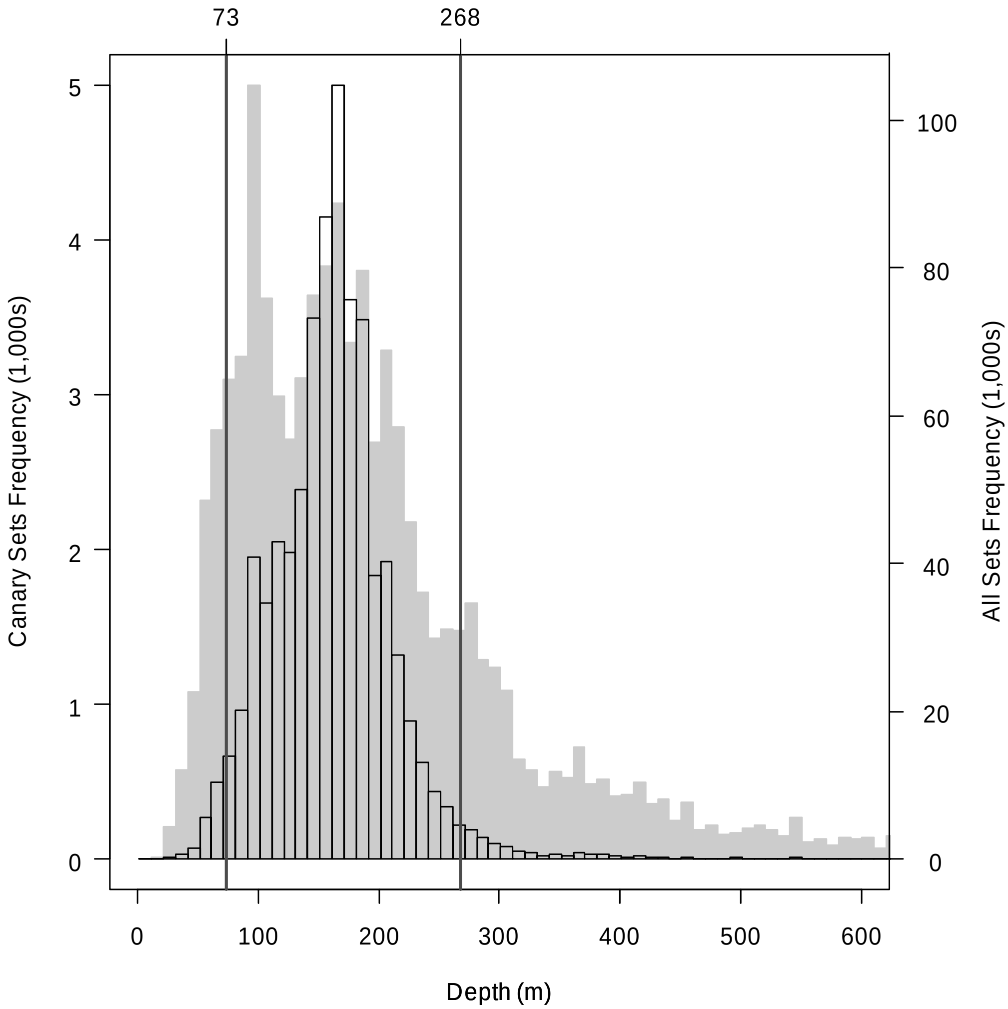

Figure 3. Histogram of the frequency of occurrence of canary rockfish in commercial tows by depth-of-capture as recorded in observer logbooks from the British Columbia commercial trawl fleet (bottom trawls only). The vertical lines denote the 2.5% and 97.5% quantiles of the observations and are located at 73 m and 268 m. The background histogram is the depth-of-capture from all sets recorded in observer logbooks.

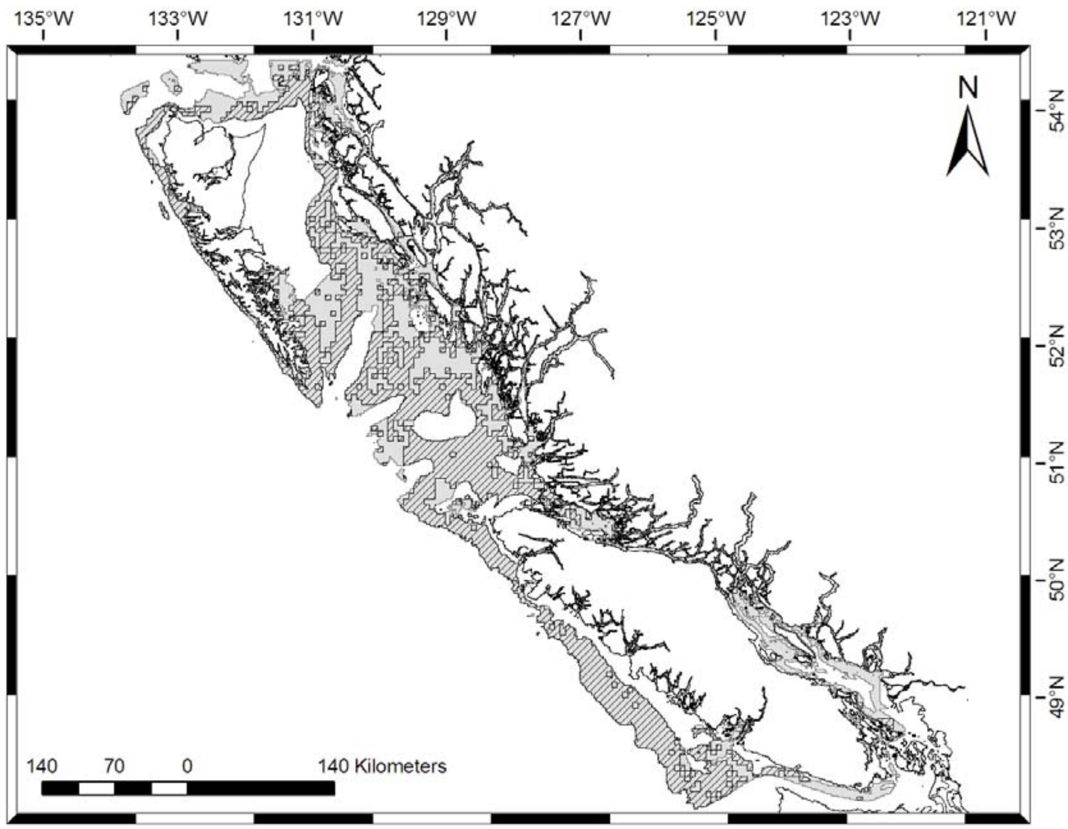

Figure 4. Canary rockfish habitat in British Columbia. The grey shaded region defines the potential maximum area (=60,043 km^2) of canary rockfish habitat based on depth-of-capture in the commercial trawl fleet. The hatched zone indicates within this region, the area where canary rockfish were actually captured (presence/absence on a 25 km^2 grid =32,788 km^2 or 54.6% of the potential habitat), based on logs from the commercial trawl, and hook and line fleets.

HABITAT

Habitat Requirements

California studies indicate that larvae and pelagic juvenile canary rockfish are found in the top 100 m of the water column for up to 3-4 months after parturition, and then settle to benthic habitats (Love et al. 2002). They have been reported in depths of 15-20 m at the interfaces between sand and rock outcrops (Love et al. 2002). Research on the west coast of Vancouver Island (WCVI) indicated that juveniles tended to move from depths of 10 m to deeper waters as they grew and aged, although adults were found at shallow depths (Gillespie et al. 1993; data source: GFBio). While the observed depth range for adults indicated by the bottom trawl fishery is about 70-270 m (95% percentile), most trawl catches came from bottom trawl tows in bottom depths of 135-190 m (Fig. 3) (source database: PacHarvTrawl).

Habitat Trends

We are not aware of any trends with respect to canary rockfish habitat quality or availability.

Habitat Protection/Ownership

Canary rockfish are a marine and generally sub-tidal species; thus all habitat is within Canada's Federal marine waters. Most of these waters are exploited by commercial, recreational and First Nations' fishers. A small percentage of canary rockfish habitat has been closed to commercial and sport fishing. These include relatively small "sponge reef" closures[2] in Queen Charlotte Sound (QCSd) and Hecate Strait (HS), and a series of small Rockfish Conservations Areas in the SoG and the outer coast.

BIOLOGY

Lifespan, life cycle, and reproduction

Ageing of canary rockfish is currently conducted with the break-and-burn method (MacLellan 1997). While the method is imprecise (Stanley 1999), recent analyses of B.C. canary rockfish specimens using lead-radium dating and a bomb radiocarbon chronometer indicated that the method is unbiased (Allen Andrews, pers. comm.). Maximum observed age for canary rockfish from B.C. waters is 77 and 84 for females and males, respectively (Fig. 5). Females grow faster, but older females are relatively rare in the samples (Figs. 5 to 8). The maximum length observed in B.C. samples is 68 cm for both sexes. U.S. data indicate a trend of increasing size-at-age with increasing latitude (Methot and Stewart 2005) (further analyses of length and age data are provided on pages 35-42).

[2] See Fisheries and Oceans Canada websites for descriptions of these areas: http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/MPlans.htmGroundfish Management Plan and http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/fisheriesmgmt/rockfish/default_e.htm.

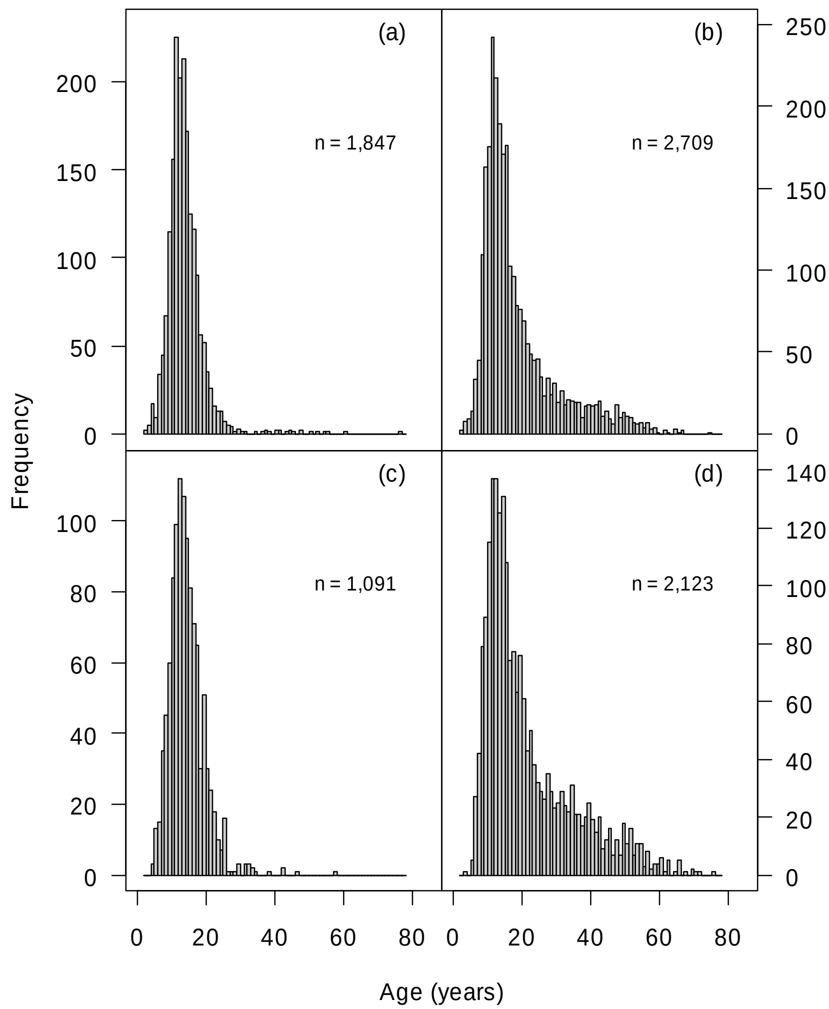

Figure 5. Histogram of canary rockfish ages (cutoff at 80y): (a) Females from Area 3C+3D; (b) Males from Area 3C+3D; (c) Females from Area 5A+5B; (d) Males from Area 5A+5B (Data from 5E are omitted owing to the large gap in years between samples, see Fig. 8).

The reason for the more truncated age composition of the females is unknown. It has also been observed in yellowtail rockfish (*S. flavidus*). Early assessments of both of these species entertained the possibilities that it was caused by an increasing rate of natural mortality with age in females or, decreasing selectivity/availability/vulnerability for older females in the fishery, or both. Most recent assessments attribute the effect to increasing *M* with age. Models appear to obtain their best fit if *M* is allowed to increase rapidly coincident with the age of maturation (see Methot and Stewart 2005). There is no evidence that the absence of older females is caused by higher *F* at earlier ages since the sexes appear to enter the fishery in equal proportions. There are also no reports of spatial refugia or a gear selectivity bias that could cause this effect.

The maximum observed weight for this species was a male of 5.70 kg. The average weight in commercial samples is 2.03 kg. Fish appear in small numbers at age five in the fishery but the age of full recruitment is probably about 13 or 14 y (Figs. 5 to 8).

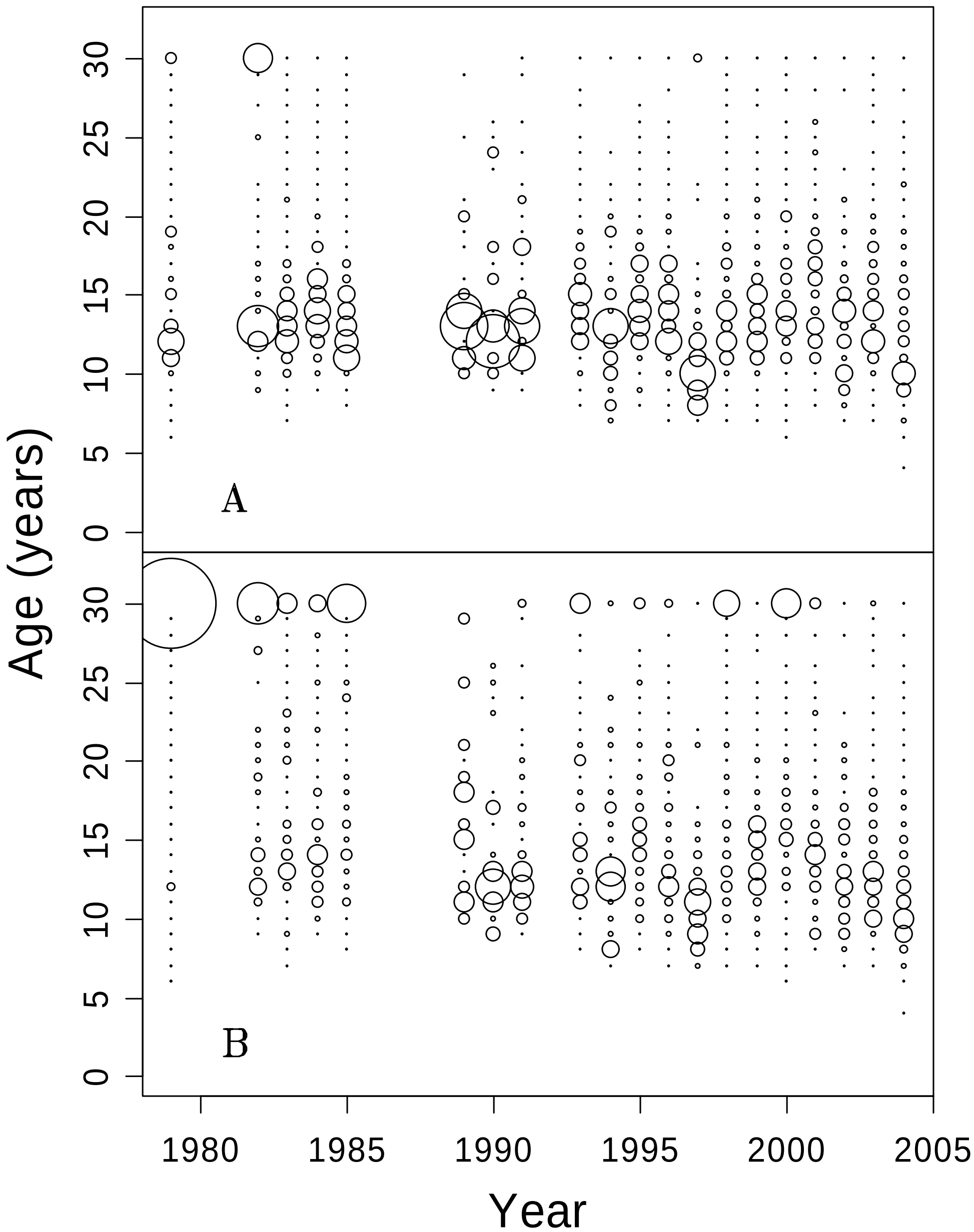

Figure 6. Proportions-at-age by year for (A) female and (B) male canary rockfish from Area 3C+3D. The radius of each circle is scaled relative to the proportion-at-age within each sex, age 30 = 30+ group. Commercial and survey samples combined (see Table 7).

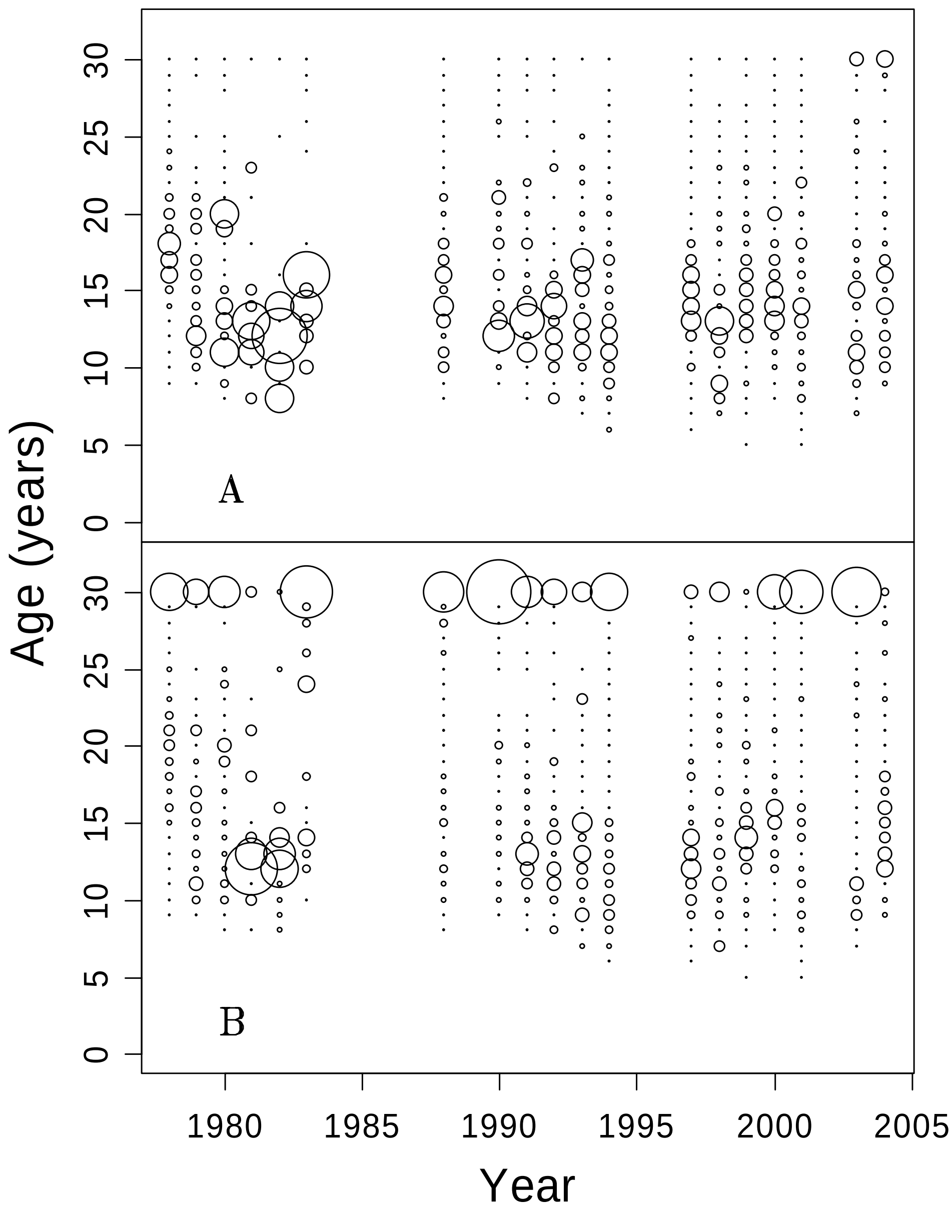

Figure 7. Proportions-at-age by year for (A) female and (B) male canary rockfish from Area 5A+5B. The radius of each circle is scaled relative to the proportion-at-age within each sex , age 30 = 30+ group. Commercial and survey samples combined (see Table 7).

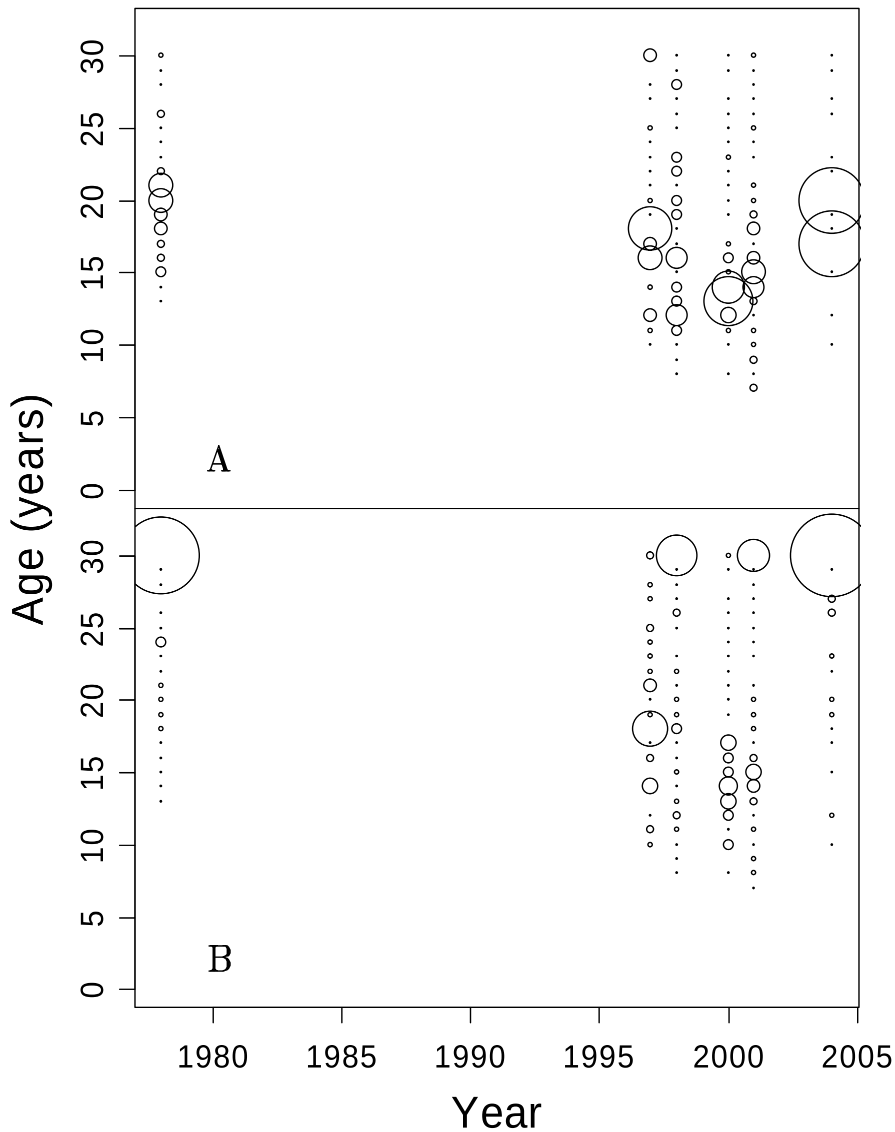

Figure 8. Proportions-at-age by year for (A) female and (B) male canary rockfish from Area 5E. The radius of each circle is scaled relative to the proportion-at-age within each sex, age 30 = 30+ group. Commercial and survey samples combined (see Table 7).

Stanley (1999) reviewed the existing information on estimates of *M* and suggested plausible ranges of 0.02-0.04 for males and 0.06-0.08 for females. However, most catch-at-age analyses (Stanley and Haist 1997, Methot and Piner 2001, Methot and Stewart 2005) obtain the best model fits when female *M* is allowed to increase coincident with reproductive maturation. The current U.S. assessment fixes *M* for males and young females at 0.06, and then allows the model to fit a linear increase in *M* to age 14. To calculate the generation time for females, the U.S. assessment uses an age-averaged value of 0.09.

Some female canary rockfish in B.C. waters are mature at 8 y but 50% and 100% maturity occurs at about 13 y and 20 y, respectively (Fig. 9). If we assume that an estimate of an age-averaged *M* falls between 0.06 and 0.15, the generation time for canary rockfish lies between 20 and 30 y (A50% + 1/M). The current U.S. assessment assumes that M=0.09 and A50% = 8 y to derive a generation time of 22.8 y (Methot and Stewart 2005).

The live-bearing females undergo parturition from January-March in B.C. waters (Westrheim 1975). Fecundity in California specimens ranged from 260,000-1,900,000 (Love et al. 2002). Males in B.C. waters appear to be 50% mature at 7-8 y and 100% mature at about 15 y (Fig. 9).

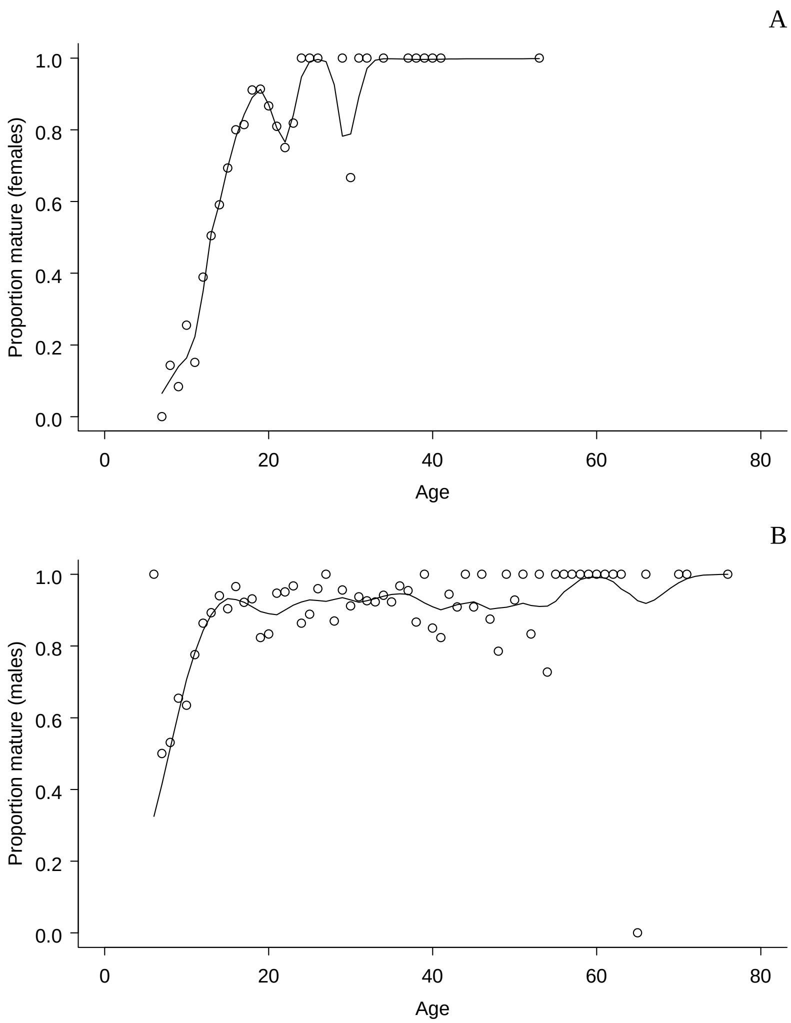

Figure 9. Age-at-maturity for (A) female and (B) male canary rockfish.

Herbivory/predation

Love et al. (2002) reports that pelagic juveniles are diurnal feeders on a diverse array of prey items. Adults and sub-adults primarily eat krill and small fishes. Herring and sandlance are probably important in B.C. waters, but no diet studies have been conducted. Predators are unknown; however, port sampling observations indicate that lingcod prey heavily on rockfish species.

Physiology

There has been no directed work on the physiology of canary rockfish. Like other rockfish, they have physoclistic swim bladders (no direct opening) and typically die from barotrauma if released after typical fishing procedures.

Dispersal/Migration

No tagging studies have been conducted in B.C. waters. DeMott (1983) recovered 23 individuals from 348 tagged off Oregon in 1983. No information is available on the sizes which were tagged, but nine individuals moved more than 100 km south, with one moving 236 km to the south and offshore. Three moved more than 100 km to the north; one of the three moved 142 km. The tagging took place between June 1978 and September 1980; the recovery period was from June 1978 to January 1982. Trawl catches indicate a seasonal depth migration from 160-210 m in late winter to 100-170 m in late summer (data source: PacHarvTrawl).

Interspecific Interactions

The role and importance of canary rockfish in the ecosystem has not been directly examined. It is one of many rockfish species in B.C. waters. There is no basis for assuming canary rockfish are a “keystone” species, but large variations in canary rockfish abundance may have an unknown level of impact on specific elements of the ecosystem.

Adaptability

There is no information available on the adaptability of canary rockfish.

COMMERCIAL FISHERIES

Description of Fisheries

The U.S. trawl fishery moved northward to Area 3C+3D in the 1950’s and reached central coast areas (5A+5B+5C) in the early 1960’s about the same time as Canadian trawlers moved south from Area 5D in northern B.C. The remaining region, to the west of the QCI (5E), began to be fished by the late 1970’s, although this region is largely untrawlable at canary rockfish depths.

Table 1. Canary rockfish landings[1,2] (t) in B.C. waters (1980-2004) summarized from Appendix 1:Table1.

	4B			3C+3D		5A+5B		5C+5D		5E		Unknown		Totals			Grand Total
Year	Trawl	HL	Creel	Trawl	HL	Trawl	HL	Trawl	HL	Trawl	HL	Trawl	HL	Trawl	HL	Creel	
1980	0.0			602.2		365.4		205.2		0.5		0.0		1173.3			1173.3
1981	0.3			311.8		184.7		127.2		2.4		0.0		626.4			626.4
1982	0.5			388.8		359.4		59.6		18.3		0.0		826.6			826.6
1983	0.0			845.9		360.3		118.9		10.4		0.0		1335.5			1335.5
1984	0.6			1189.6		513.3		73.6		12.7		0.0		1789.8			1789.8
1985	0.0			904.2		394.9		190.4		9.4		0.0		1498.9			1498.9
1986	0.1		1.0	720.7		280.0		44.5		110.5		0.0		1155.8		1.0	1156.8
1987	0.0		5.7	727.4		563.3		102.9		12.6		0.0		1406.2		5.7	1411.9
1988	0.0		4.0	1061.9		585.7		83.6		79.1		0.0		1810.3		4.0	1814.3
1989	0.0		2.0	1170.9		502.3		122.0		19.5		0.0		1814.7		2.0	1816.7
1990	0.0		4.6	767.1		601.1		153.7		64.4		0.0		1586.3		4.6	1590.9
1991	0.0		0.7	650.9		517.7		154.3		29.0		0.0		1351.9		0.7	1352.6
1992	0.9		0.3	768.6		480.2		125.5		26.3		0.0		1401.5		0.3	1401.8
1993	0.0		0.0	827.4		191.0		73.8		21.7		0.0		1113.9		0.0	1113.9
1994	0.0		5.1	780.2		293.9		112.0		7.7		0.0		1193.8		5.1	1198.9
1995	0.0	0.3	2.6	625.2	9.1	171.5	14.5	60.3	5.5	3.5	5.5	0.0	26.2	860.5	61.1	2.6	924.2
1996	0.0	0.2	2.2	473.5	20.4	149.8	9.9	68.8	4.2	10.6	10.7	0.0	11.3	702.7	56.7	2.2	761.6
1997	0.0	0.7	1.5	438.7	9.9	189.9	8.4	41.6	4.4	20.1	8.7	0.2	22.6	690.5	54.7	1.5	746.7
1998	0.0	0.2	0.4	421.3	21.4	288.4	13.5	43.7	5.5	2.5	17.9	0.0	17.9	755.9	76.4	0.4	832.7
1999	0.0	0.5	4.6	542.9	31.0	314.6	9.5	42.0	4.7	7.2	11.9	0.0	6.9	906.7	64.5	4.6	975.8
2000	0.0	1.0	1.4	459.7	19.1	216.2	10.5	78.7	1.5	15.5	11.4	0.0	6.2	770.1	49.7	1.4	821.2
2001	0.0	1.2	5.4	492.2	13.3	223.0	15.6	73.0	4.0	2.0	17.7	2.2	2.4	792.4	54.2	5.4	852.0
2002	0.0	0.1	0.5	566.5	10.0	236.2	5.8	64.3	2.9	3.2	5.7	0.0	1.2	870.2	25.7	0.5	896.4
2003	0.0	0.8	0.9	503.1	10.8	239.9	10.1	71.4	1.2	18.6	5.6	0.0	2.3	833.0	30.8	0.9	864.7
2004	0.0	0.2	0.5	516.1	8.5	191.7	14.2	65.8	1.7	3.9	5.8	0.0	0.8	777.5	31.2	0.5	809.2

[1]Trawl data includes discards for 1996-2004.
[2]Creel data include estimates of kept and released from the recreational fishery. When necessary, weight was extrapolated from pieces x average weight of 2.028 kg (Source: South Coast Creel Database).

The U.S. landings were not recorded to species until 1967, but Westrheim (1977) indicates significant landings from Area 3C+3D back to at least 1960. Following Extended Jurisdiction in 1977, Canadian trawlers gradually replaced the U.S. fishery, with the U.S. fishery ceasing in Canadian waters by 1982. Since 1982, there have been no foreign fisheries for canary rockfish other than a negligible bycatch while midwater trawling for hake (*Merluccius productus*).

Large-scale foreign trawl fisheries were conducted by Soviet vessels in the 1960’s and Japanese Vessels in the 1970’s, but limited observer data were obtained from these fisheries. These fisheries targeted deeper aggregations of Pacific ocean perch (*S. alutus*) (Ketchen 1980), but there may have been catches of canary rockfish.

Canadian fishers reported that dumping at sea was prevalent from the mid 1980’s to mid 1990’s in order to avoid trip-limit overages, but the magnitude of this error is unknown. Many fishers argue that the discards were large relative to the total amount landed. However, during this period there were many cases of landed overages that were misreported as other species. The catch figures are not trustworthy in 1985-1995 period. They could be significant under- or over-estimates for any given year, with the bias changing almost yearly as management of the fishery experimented with different kinds of catch constraints. In fact, the lack of confidence in the landings figures and the resulting difficulty in applying quota management for rockfish was the driving force which led DFO to mandate 100% dockside monitoring in 1994 and 100% observer coverage for the trawl fleet in 1996. The annual costs of this program are about $3,000,000, with over two-thirds of this cost covered by industry.

We suggest that estimated landings only be used to characterize the approximate magnitude of the harvest over the 1967-1996 period (Table 1 or Appendix 1: Table 1). We have confidence in the actual values only since the introduction of 100% observer coverage in the trawl fishery in 1996. Even for the more recent period, 1996-2006, we lack discard estimates for the hook-and-line fleets, although these fleets have now moved to 100% monitoring (2006/2007). Therefore, we discourage readers from inferring population trends from trends in total landings (and CPUE) over the entire duration of the canary rockfish fishery. Not only have the management regulations in the form of trip limits and annual quotas varied widely, but so has the manner in which catch has been reported (or deliberately misreported).

Since 1996, about 840 t/y of canary rockfish are reported captured by various license sectors and gear types. About 95 % of the reported catches are produced by the commercial trawl fleet, principally by bottom trawl (Fig. 10, Table 1, Appendix 1). The commercial groundfish hook-and-line fleets produce about 5% of the reported landings, although canary rockfish is typically a non-directed species in these fisheries (Table 1, Appendix 1: Table 2). Unlike trawl landings, reported hook-and-line landings do not include discards. Haigh et al. (2002) summarized catch ratios in various hook-and-line fisheries based on partial observer coverage from 1999-2001 observations and showed that the resulting expanded estimates of total catches (landings plus discards) from observers were less than the reported landings (see Table 17 in Haigh et al. 2002), indicating non-representative sampling in the observer program.

Catches of canary rockfish in the south coast salmon troll fisheries were projected from observer data for 1998-2001 (Wrohan et al. 2002) (Appendix 1: Table 4). Observed salmon troll catches of canary rockfish ranged from 0-11,250 pieces for an average of 2,866 pieces/y (5.8 t/y, assuming an average weight of 2.03 kg) for the WCVI and SoG in those years. Catches were probably higher when effort was much larger prior to the late 1990's, but no data are available for that period. Logbooks and a phone-survey covering the troll fishery off the west coast of the QCI indicate about 1,000 pieces/y, or about 1 t/y. Catches from this fishery are probably not significant relative to other fisheries; especially given the reduction in salmon troll effort in this region. Canary rockfish catches appear negligible in the salmon commercial seine and gillnet fisheries (Wrohan et al. 2002). Catches are negligible in the invertebrate fisheries, especially since the introduction of bycatch reduction devices for shrimp trawls in 2000 (Olsen et al. 2000, Dennis Rutherford, pers. comm.).

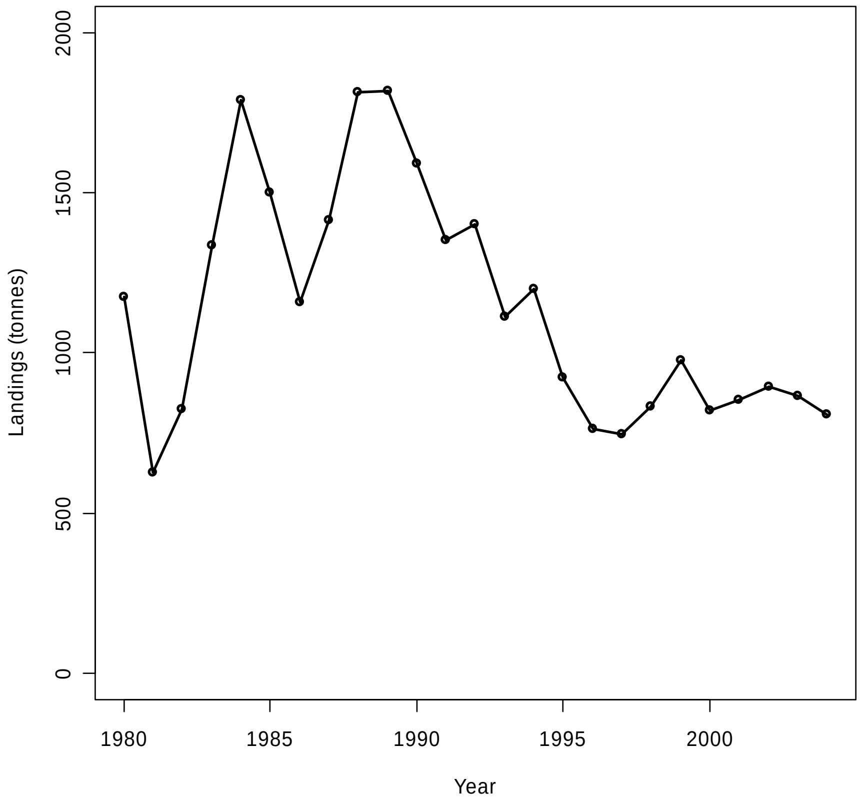

Figure 10. Total landings by year of canary rockfish in British Columbia waters.

FIRST NATIONS' FISHERIES

Description of Fisheries

The authors followed the COSEWIC guidelines for the collection of aboriginal knowledge. The only required Wildlife Management Board contact was the Nisga'a Joint Fisheries Management Committee who reported that they had "no additions or comments to their status" (Harry Nyce, pers. comm. 2005).

There is no information readily available to estimate the magnitude of either historical or current catch of canary rockfish by the First Nation bands in B.C. Therefore, this element of the report is incomplete. It is likely canary rockfish have always been taken occasionally by coastal First Nations while pursuing other fish resources, including other rockfish species, halibut (*Hippoglossus stenolepis*) and lingcod. Early ethnographers all recognized the importance of the "various specimens of cod" to a variety of coastal First Nations (Boas 1895), but according to Stewart (1975), explicit reference to rockfish as a subgroup is absent in the early ethnographies. Archaeological records of *Sebastes* spp. based on the presence of otoliths, skulls, and pelvic girdle elements are typically only classified to the genus (i.e., *Sebastes*) and therefore species information is absent (Stewart 1975).

The majority of the canary rockfish population lives in offshore areas in depths typically greater than 80 m. It seems reasonable to assume that shallower rockfish species, such as yelloweye rockfish, copper rockfish (*S. caurinus*) and quillback rockfish (*S. maliger*) might have been the preferred species in aboriginal fisheries. Aboriginal traditional knowledge referring to the population status of this species likely does not exist.

We could find no quantitative estimates of the catches of canary rockfish by First Nations. Available data only indicate the “rockfish” category. We suggest that, on a coast-wide basis, First Nations’ canary rockfish catches are very small in comparison with the catches of canary rockfish in other fisheries, although catches may be significant in some specific locales and may have a significant cultural role.

RECREATIONAL FISHERIES

Description of Fisheries

There is no directed recreational fishery for this species; adult canary rockfish usually inhabit water too deep to be commonly caught in the recreational fishery. When taken, canary rockfish are almost always bycatch from effort targeting halibut and lingcod on the west coast of Vancouver Island and to a lesser degree the north coast of B.C. (Jeremy Maynard, pers. comm.).

The annual creel survey of the recreational fishery catch in the SoG indicates wide variations in the annual canary rockfish catches from 1986-2004 (Table 1, data source: South Coast Creel Database). The variation of two orders of magnitude in the catch estimates in consecutive years indicates that these catch estimates are unreliable. The species identification was probably poor and inconsistent so we did not consider a CPUE analysis. Not only are the catch estimates unreliable, but the recent changes to bag limits make it inadvisable to draw inference about abundance trends from either the creel survey catch or CPUE.

The national mail-in survey of Recreational Fishing, conducted every five years by DFO, in cooperation with all regional, provincial and territorial fisheries licensing agencies, has no record of canary rockfish catches[3].

SUMMARY OF CATCHES

Prior to the imposition of commercial catch restrictions of the 1980’s, coast wide reported landings of canary rockfish averaged about 1,000 t/y from 1967-1979. There is evidence that significant exploitation on this species in the Canadian continental shelf started at least in 1960, probably rising slowly to 1967-1979 levels. Catches were driven largely by market conditions, abundance, or availability. Landings since the early 1980’s have been limited by regulation. Total reported landings ranged from 626-1,817 t with an average of 1,315 t from 1980 to 1995. Full dockside monitoring was implemented for trawlers in 1994 and hook-and-line fishers in 1996. Full observer coverage in the trawl fishery was implemented in 1996. Total reported commercial catches (landings plus discards for trawl, and landings only for hook-and-line) have averaged 840 t from 1996-2004. In summary, canary rockfish on the Canadian continental shelf have been exploited since at least 1960, with catches probably increasing to about 1,000 t/y in the 1967-1979 period. Since then, reported catches have averaged over 840 t/y, not including minor amounts of unreported catches in the non-trawl sectors.

[3] http://www.dfo-mpo.gc.ca/communic/statistics/recreational/index_e.htm

FISHERIES MANAGEMENT

Canary rockfish in B.C. waters is managed as four separate stocks among approximately 70 groundfish stocks of commercial importance and over 100 more fish populations that are affected by groundfish harvesting. However, since the introduction of 100% observer coverage in the trawl with Individual Vessel Quotas, it is no longer possible to search for and catch canary rockfish without risking overruns in the catches of other species, and vice versa. This explains the occasional quota shortfalls in some years, as fishers sometimes must leave annual quota of canary rockfish (or other species) “in the water” owing to quota limitations on other species (or canary rockfish) (Table 2).

Official management plans should be examined for details on fishing regulations[4]. To summarize, 87.7% of the canary rockfish quota is allocated to trawl (T license), 11.77% to outer coast rockfish fishers (ZN-outside license), and 0.53% to halibut fishers (L-license). Catches in the trawl fleet are constrained by annual quota divided into vessel specific quotas. Hook-and-line catches were constrained by annual quotas and trip limits. As of 2006, there will be 100% monitoring of all remaining groundfish sectors (see 2006/2007 Integrated Fishery Management Plan: http://ops.info.pac.dfo.ca/fishman/Mgmt_plans).

Groundfish catches in the recreational fishery are constrained by a bag limit (for “all rockfish” combined) which varies by area. Catches may be constrained in the First Nations' fisheries but it would vary among First Nations.

Area specific quotas adopted by DFO were largely based on advice provided in stock assessment documents (Table 2). The most recent advice from Stanley (1999) which was presented for the 2001/2002 fishing year, commented:

> “While the variety of conclusions is disappointing, they are consistent in indicating there is no massive underexploited stock of fish in the traditional grounds of 3C-5B. We see no basis for arguing for increased harvests in the traditional canary rockfish fishing grounds of Areas 3C+3D and 5A+5B….. ….We suggest that managers do not consider yields in excess of [*average*] historical levels for these traditional fishing areas. Therefore, maximum [*defined as high risk*] recommended yields for Areas 3C+3D and 5A+5B are 700 and 350 t, respectively.
>
> In view of the expected poor 1990's' year classes, declining U.S. populations of canary rockfish, the dependency of the age analysis on the assumption of stable recruitment and the low estimates generated by Walters and Bonfil (1999), we suggest a minimum [defined as low risk] harvest no more than 50% of the average yield. This translates to 350 t and 175 t for Areas 3C+3D and 5A+5B, respectively.”

[4] http://ops.info.pac.dfo.ca/fishman/Mgmt_plans.

Table 2. Canary rockfish recommended harvest, quota, and catch (t), by year and management region, 1997 to 2004. "Total" column also includes catches from unknown areas and Area 4B (Strait of Georgia). Catches do not include HL discards, First Nations' and Recreational catches.

Year		Region				Total
		3C+3D	5A+5B	5C+5D	5E	
1997/98	Recommended Harvest[a]	350-525	200-400	[b]	[b]	550-925
	Trawl Quota[c]	503	345	81		929
	Quota (HL)[c]	[e]				[e]
	Catch (trawl and HL)	449	198	46	29	747
1998/99	Recommended Harvest[a]	350-525	200-400	[b]	[b]	550-925
	Trawl Quota[c]	503	345	81		929
	Quota (HL)[c]	74				74
	Catch (trawl and HL)	443	302	49	20	833
1999/00	Recommended Harvest[a]	350-525	200-400	[b]	[b]	550-925
	Trawl Quota[c]	499	342	80		921
	Quota (HL)[c]	76				76
	Catch (trawl and HL)	574	324	47	19	976
2000/01	Recommended Harvest[d]	350-700	175-350	50-150	100-200	675-1400
	Trawl Quota[c]	555	277	106	159	1097
	Quota (HL)[c]	92				92
	Catch (trawl and HL)	479	227	80	27	821
2001/02	Recommended Harvest[d]	[d]	[d]	[d]	[d]	[d]
	Trawl Quota[c]	529	265	101	151	1046
	Quota (HL)[c]	[e]				[e]
	Catch (trawl and HL)	505	239	77	20	852
2002/03	Recommended Harvest[d]	[d]	[d]	[d]	[d]	[d]
	Trawl Quota[c]	529	265	101	151	1046
	Quota (HL)[c]	140				140
	Catch (trawl and HL)	576	242	67	9	896
2003/04	Recommended Harvest[d]	[d]	[d]	[d]	[d]	[d]
	Trawl Quota[c]	529	265	101	151	1046
	Quota (HL)[c]	140				140
	Catch (trawl and HL)	514	250	73	24	865
2004/05	Recommended Harvest[d]	[d]	[d]	[d]	[d]	[d]
	Trawl Quota[c]	529	265	101	151	1046
	Quota (HL)[c]	140				140
	Catch (trawl and HL)	525	206	68	10	809

[a] Stanley (1995)
[b] Not specified in Stanley (1995)
[c] see http://ops.info.pac.dfo.ca/fishman/Mgmt_plans/
[d] Stanley (1999), advice not updated for 2001/2002-2004/2005
[e] Not specified

Note that the expressions of risk were qualitative and intended to convey the uncertainty of the advice and thereby allow managers flexibility within a suggested range.

POPULATION SIZES AND TRENDS

Population Size

Average recent total landings of at least 840 t/y with a mean weight of landed canary rockfish of 2.03 kg, equates to over 413,000 pieces landed each year, composed predominantly of mature individuals (GFBio: unpublished data). The population has sustained a continual harvest of this magnitude for over 30 years. In the absence of evidence of imminent collapse in the abundance trends, or size and age composition (see below), it seems likely that the current standing population of adults is at least in the low millions. Certainly it cannot be in the low 100,000s. While an estimate of abundance with this uncertainty falls well short of characterizing the status of the population, we assume that it assists the discussion of whether the population is at risk to such issues as genetic drift.

An alternative low or underestimate of the standing population can be made by summing the area-expanded bottom trawl catch rates in recent B.C. surveys (WCVI: unpublished data for 2004; QCSd: see Table 6; HS: unpublished data for 2005). These surveys are designed to monitor relative abundance of bottom dwelling fish species. They are conducted with Atlantic Western IIA bottom trawls and use a random stratified design. They survey bottom depths from 50-500 m, spanning the depth range of adult canary rockfish (Fig. 11; Table 3).

The resulting biomass estimate of 2,563 t assumes a catchability (between the trawl doors) of 1.0. U.S. research by Millar and Methot (2002) indicates a likely range for canary rockfish catchability in the U.S. triennial survey of 0.15-0.35. Applying this range to the B.C. surveys expands the 2,563 t to 7,300-17,100 t of canary rockfish biomass in B.C. survey areas. This does not include populations on the west coast of the QCI and inshore waters, which implies that this estimate is likely to be low. Given a mean weight of trawl caught canary rockfish of 2.03 kg, the range of expanded biomass estimates translates into a current abundance of 4 to 8 million adults in B.C. waters, given that the majority of the canary rockfish catch in the survey (by weight) is composed of mature fish.

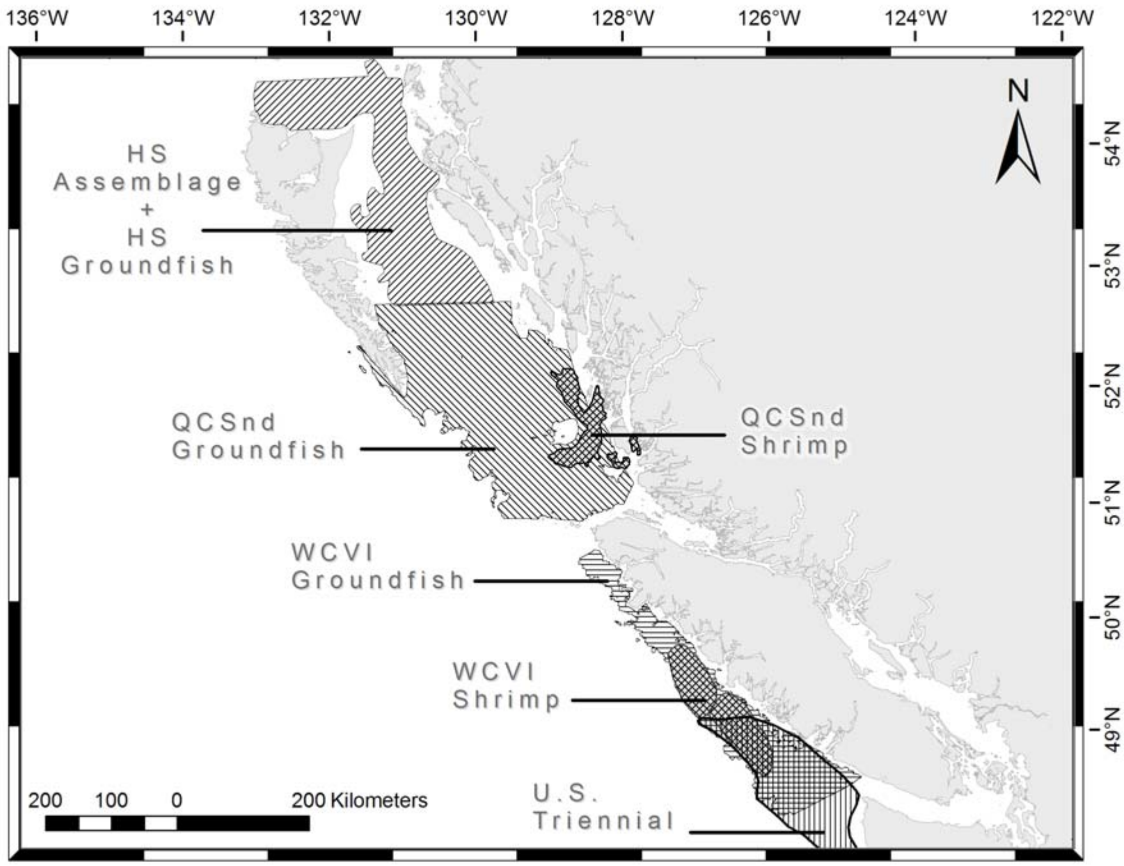

Figure 11. Locations of trawl surveys that provide indices of canary rockfish abundance. All surveys target groundfish except two shrimp trawl surveys conducted in QCSd and off the WCVI.

Table 3. Fishery independent trawl surveys conducted in B.C. and referenced in this document.

Survey	Start Year	End Year	Number of Surveys	Depth Range (m)	Bottom Trawl Gear Used
West Coast Vancouver Island Shrimp[1]	1975	2005	31	15-258	NMFS Standard Shrimp
West Coast Vancouver Island Groundfish	2004	2004	1	46-750	Atlantic Western IIA
U.S. Triennial[2]	1980	2001	8	55-477	Noreastern
Queen Charlotte Sound Shrimp	1999	2004	6	15-309	NMFS Standard Shrimp
Queen Charlotte Sound Groundfish	2003	2005	3	37-543	Atlantic Western IIA
Hecate Strait Assemblage[3]	1984	2003	11	18-232	Yankee 36
Hecate Strait Groundfish	2005	2005	1	11-230	Atlantic Western IIA

Notes:

[1] Survey started in 1972 but rockfish catch not recorded until 1975.

[2] Information only for those surveys conducted in Canadian waters.

[3] Survey was substantially redesigned in 2005, thus this series effectively ends in 2003.

Start and end years refer to the surveys used in this document, not necessarily the complete survey series.

Population Trends From Surveys in B.C. Waters

The following discussion summarizes existing indices that can be used to infer abundance trends for canary rockfish in Canadian waters. These indices are:

1. U.S. triennial bottom trawl survey (U.S. triennial survey)
2. West Coast Vancouver Island shrimp trawl survey (WCVI shrimp survey)
3. Queen Charlotte Sound shrimp trawl survey (QCSd shrimp survey)
4. Queen Charlotte Sound bottom trawl survey (QCSd groundfish survey)
5. Hecate Strait Assemblage survey (HS assemblage survey)

U.S. Triennial Survey

The U.S. triennial survey began in 1977 and typically covered northern California to the U.S./Canada border in northern Washington (Weinberg et al. 2002). For the years 1980, 1983, 1989, 1992, 1995, 1998, and 2001, it also extended into southern B.C. waters. The first two of these surveys extended to 49°15' N; the latter five surveys extended further north to 49°40' N (Fig. 12).

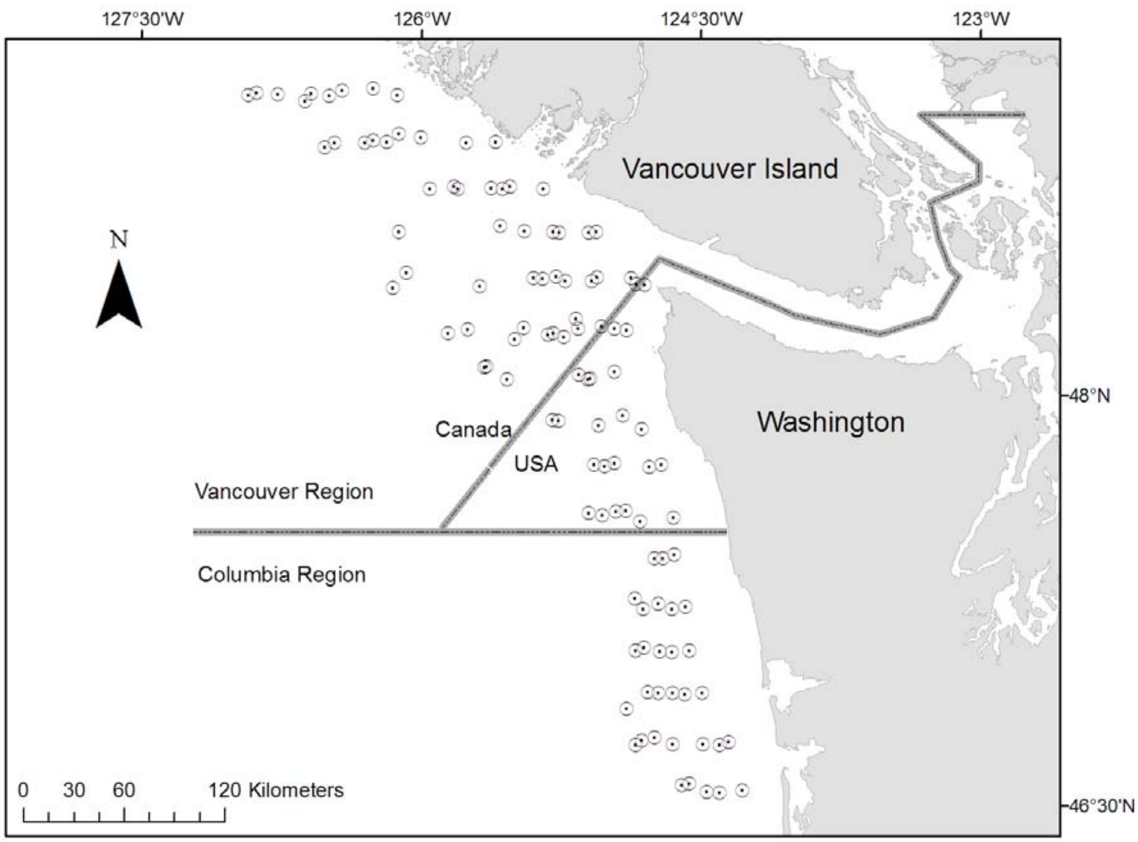

Figure 12. Set locations from the U.S. triennial survey conducted in 2001.

The U.S. triennial survey indices for canary rockfish show a declining trend over the period of the survey, with the amount of decline depending on which area is considered (Fig. 13, Table 4, and Appendix 2).

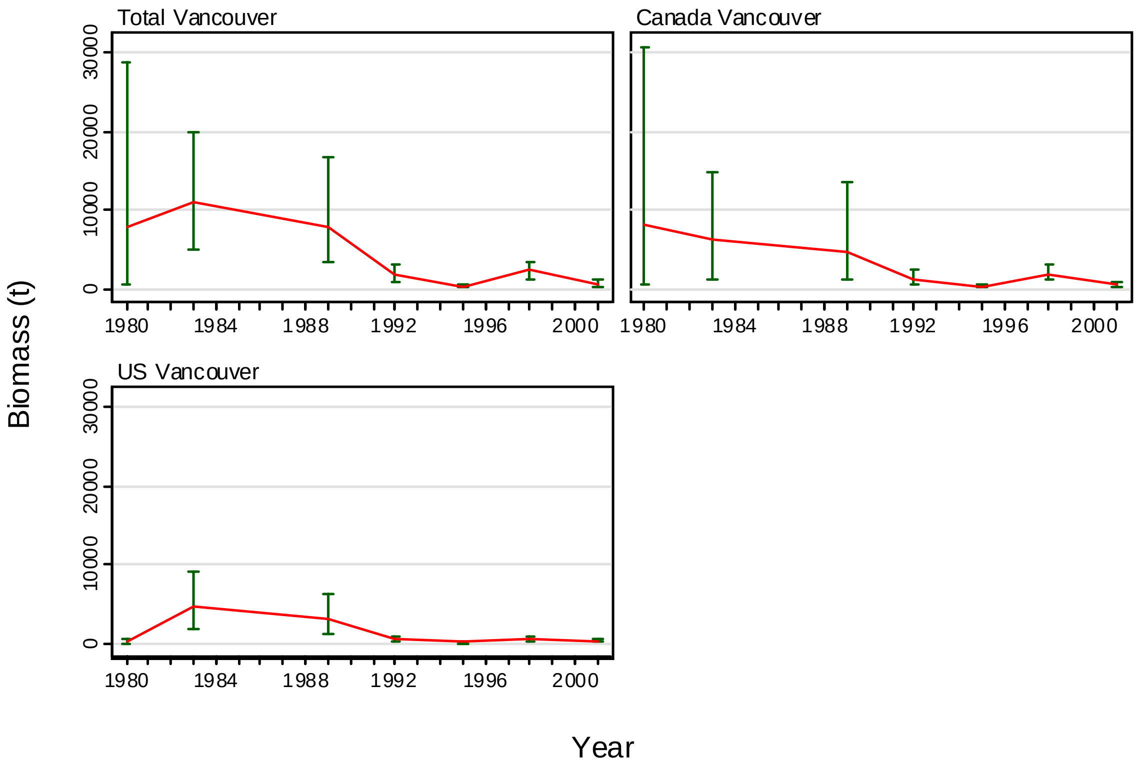

Figure 13. Three biomass estimates for canary rockfish in the INPFC Vancouver region (total region, Canadian waters only and U.S. waters only) with 95% bias corrected error bars estimated from 5,000 bootstraps.

Table 4. Biomass estimates for canary rockfish in the Vancouver INPFC region (total region, Canadian waters only and U.S. waters only) with 95% confidence regions based on the bootstrap distribution of biomass. Additional details and alternative derivations are shown in Appendix 2. The bootstrap estimates are based on 5,000 random draws with replacement.

Area	Year	Mean bootstrap biomass	Lower bound biomass	Upper bound biomass
Total Vancouver	1980	7,633	427	28,611
	1983	11,063	4,976	19,812
	1989	7,918	3,389	16,711
	1992	1,654	801	2,884
	1995	293	109	594
	1998	2,233	1,275	3,472
	2001	622	271	1,151
Canada Vancouver	1980	8,082	306	30,811
	1983	6,241	1,078	14,815
	1989	4,814	1,303	13,362
	1992	1,310	555	2,469
	1995	253	88	504
	1998	1,805	957	2,888
	2001	351	75	850
US Vancouver	1980	158	0	390
	1983	4,647	1,726	8,963
	1989	3,104	1,106	6,165
	1992	344	138	801
	1995	40	12	103
	1998	427	242	707
	2001	271	102	508

The trend for this species from the US-Vancouver section is -7% per year since 1980 while the trend in the Canada-Vancouver section is -14% per year, for an overall decline of about 95% (Fig. 14). The overall trend for the total Vancouver section is also a decreasing trend of -4% per year. While survey data are considered the most reliable method for monitoring demersal marine species, the large error bars indicate that the apparent trends are associated with high variability and may not represent the population trajectory accurately. Annual biomass estimates can be highly leveraged by 1-2 large tows (see Appendix 2: Figure 2).

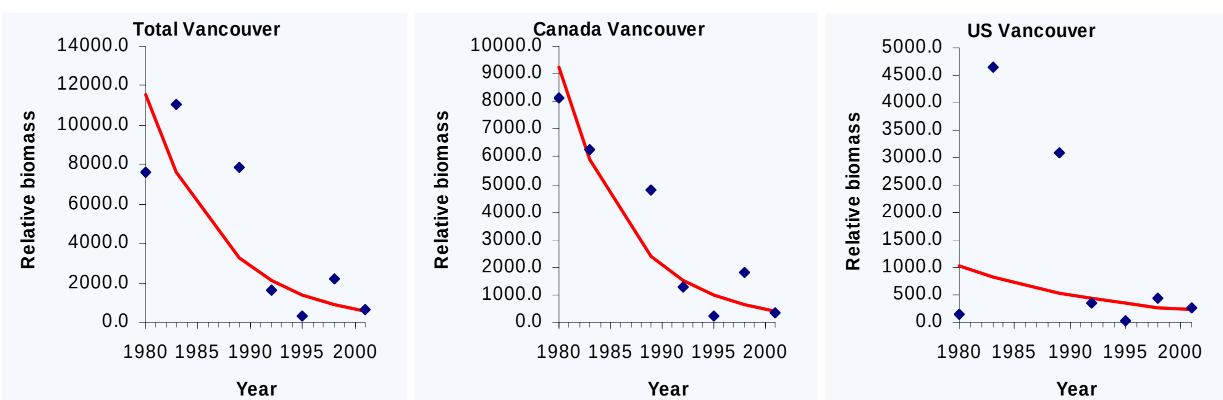

Figure 14. Biomass estimates for canary rockfish from the U.S. triennial survey grouped for the different zones. The lines represent an exponential fitted curve through the point estimates.

Note the improbable change in the U.S. Vancouver series from 1980 to 1983. It shows that this survey for this species can easily indicate population changes over the short term that are extremely unlikely. Even the low end of the error range for 1983 requires at least a 4X increase from the upper end of the 1980 estimate. There was no evidence of a large year class entering the fishery at this time. It is reasonable to infer from this survey that the population of canary rockfish has declined in the Canada Vancouver area over this time period but there is large uncertainty over the size of the decline.

West Coast Vancouver Island Shrimp Survey

Survey indices for canary rockfish from the WCVI shrimp survey which spans 1975 to 2005 (Fig. 15, Appendix 3). This is the longest series available to monitor this species in Canadian waters and was conducted nearly annually over the entire period of record. These survey data were analysed, following the recommendations made by Starr et al. (2002), by post-stratifying the data into two areas, Areas 124 and 125, and treating the tows as having been randomly selected (Appendix 3). Tows were selected in areas that had been consistently covered across depths over all years and the analysis was confined to a consistent set of vessels and survey months.

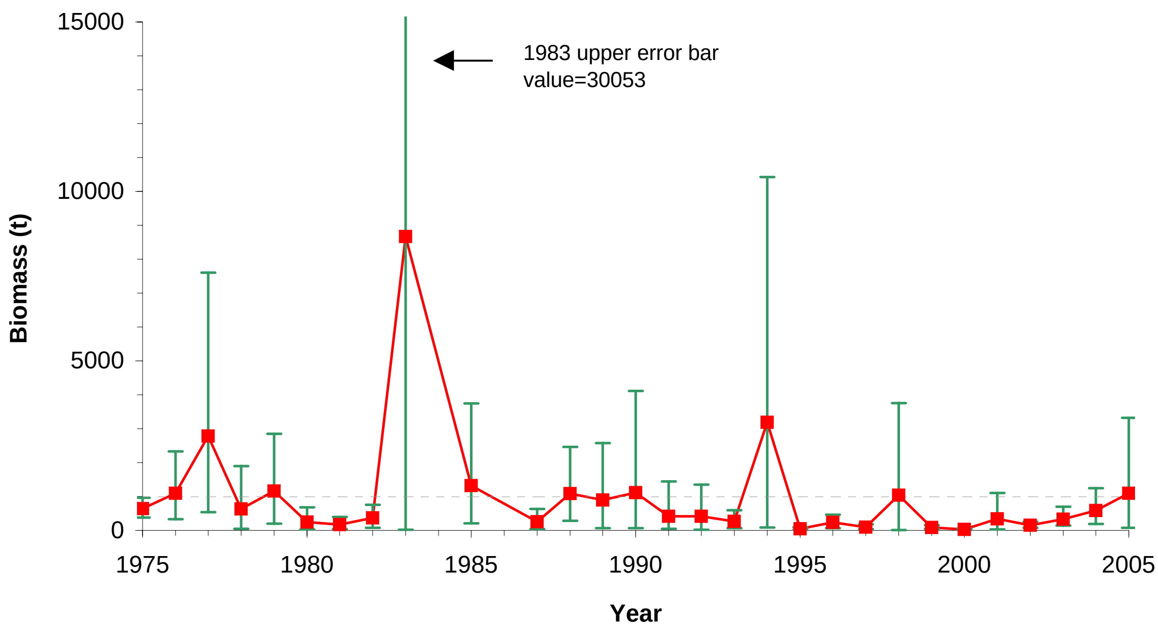

Figure 15. Plot of biomass estimates for canary rockfish from the WCVI shrimp survey for the period 1975 to 2005. Bias corrected 95% confidence intervals from 1,000 bootstrap replicates are plotted. Upper error bar for the 1983 index truncated for clarity. Mean index value for series is shown as a dotted horizontal line.

The survey data were analysed using equations consistent with a random stratified survey and uncertainty was estimated by resampling the survey data with replacement for 1,000 bootstrap iterations. Area stratum 125 was not surveyed in two of the survey years (1989 and 1991) so the mean catch rate from area stratum 124 in those years was used in its place to ensure comparability over all survey years.

Estimated biomass levels for canary rockfish from the WCVI shrimp survey appear to have been relatively consistent throughout the history of this survey, with the exception of some years with relatively high biomass estimates associated with high levels of relative error (e.g. 1977, 1983, 1994). Biomass levels appear to be gradually increasing since the late 1990's, but these indices also have high uncertainty. The proportion of tows with canary rockfish shows an even more consistent trend towards increasing canary rockfish in recent years, such that the proportions are now above the long term average (Fig. 16).

This latter treatment of the data is not presented as a preferred view of the biomass trend, simply as an alternative. There is no basis for selecting which of the two indices tracks canary rockfish abundance better, but there is evidence that the frequency of non-zero catches is a valid alternative index and may sometimes be superior (Bannerot and Austin 1983).

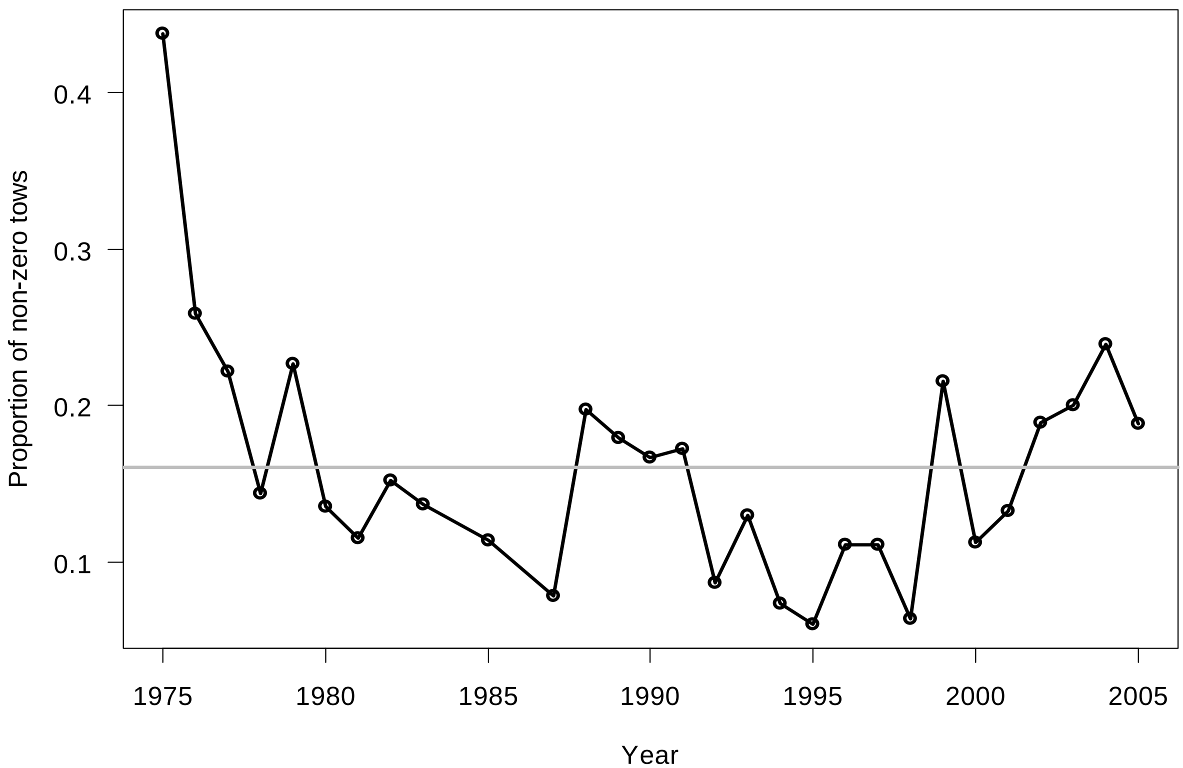

Figure 16. Proportion of tows with canary rockfish by year for the WCVI shrimp survey. The average proportion is shown by the solid line.

The trends in the WCVI shrimp survey catch rate indices were analysed following the methodology presented by Stanley and Starr (2004). The survey series was blocked into two or three periods of approximately equal length (Fig. 17 and 18). An alternative interpretation blocked the series into four periods (Fig. 19) which attempted to capture a beginning and ending cluster of 5 years, separated by two decadal groupings. The choice of the periods over which to summarize is obviously arbitrary, but it is easy to examine Figures 17-19 to assess the impact of using alternate groupings.

The average of the survey indices in each period was calculated in one of two ways: either as a simple average or by using the inverse of each survey CV (relative error) as a weighting factor (Table 5). This second approach down-weights indices which are associated with high relative error. Plots are presented for the two step, three step, and four step analyses using the inverse weighting assumption (Figs. 17-19). The analyses presented in this document estimate that recent abundance from this survey is 39% to 61% of the long term mean, or is 23% to 45% of the earliest period in the series (Table 5).

Table 5. Relative mean values for the shrimp survey canary biomass indices over the period 1975-2005, using three definitions to generate periods over which to compare survey indices. Two averaging schemes were used for each comparison period: a) a simple average for the period; and b) an average where each index is weighted by the inverse square of the survey CV to account for differences in survey reliability. The period averages are scaled either by the mean of the entire survey series or by the mean of the first period.

	1) Recent abundance relative to overall mean abundance		2) Recent abundance relative to abundance in earliest period	
	Simple average	Inverse weighting	Simple average	Inverse weighting
2-step	0.56	0.48	0.38	0.28
3-step	0.40	0.39	0.23	0.23
4-step	0.51	0.61	0.45	0.39

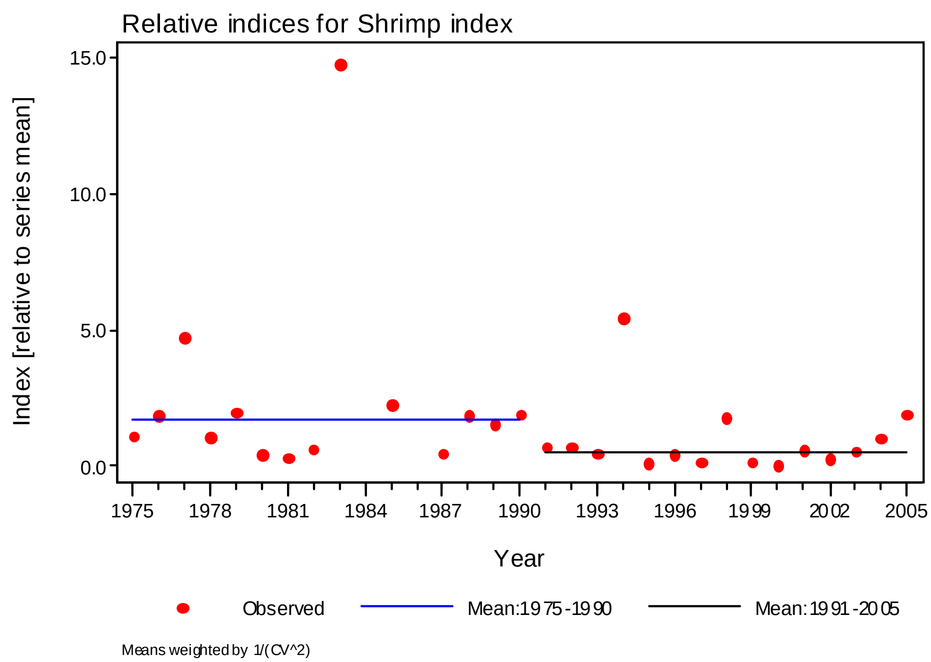

Figure 17. Two step function for the WCVI shrimp survey index, plotted relative to the mean of the survey series, weighted by the inverse of the CV^2 for each survey.

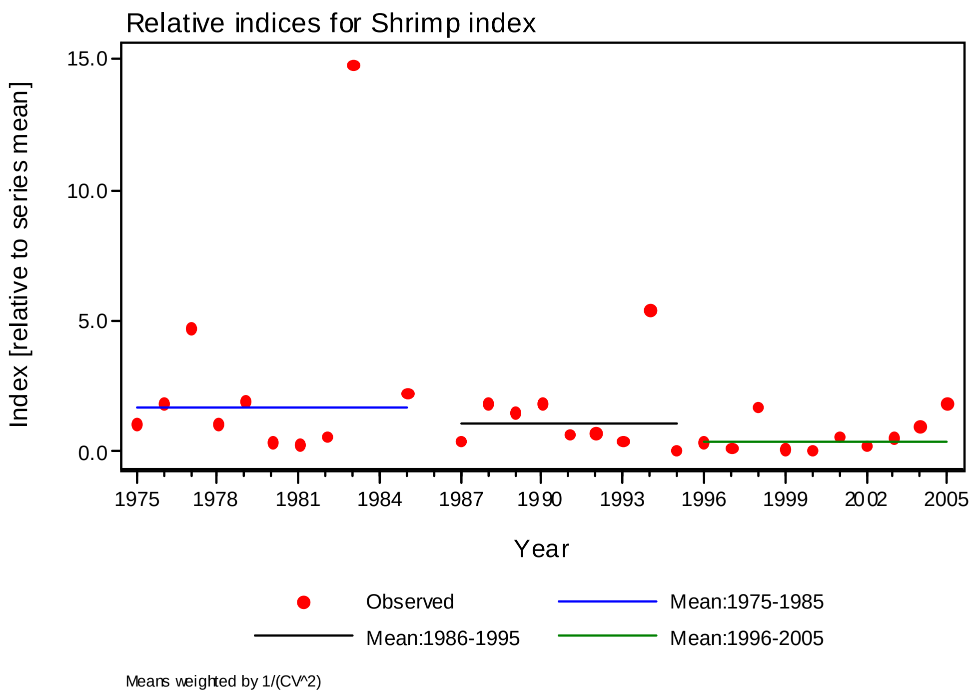

Figure 18. Three step function for the WCVI shrimp survey index, plotted relative to the mean of the survey series, weighted by the inverse of the CV^2 for each survey.

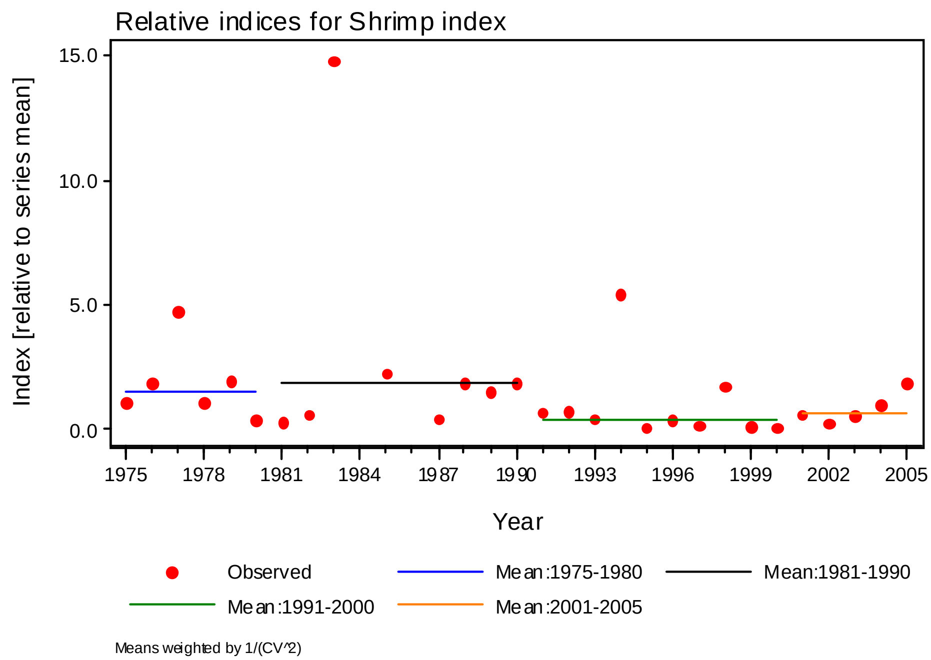

Figure 19. Four step function for the WCVI shrimp survey index, plotted relative to the mean of the survey series, weighted by the inverse of the CV^2 for each survey.

We recommend the step approach presented above in place of a simple regression to characterize trends over time. If simple linear regression is fit to the shrimp survey data, it indicates a point estimate of decline over the entire period (1975-2005) of about 80%, but this drops to 60% if the 1983 estimate is removed. Neither of these slopes is significantly different from 0, and the series is clearly not monotonic, so we suggest that fitting a linear regression to these indices is inappropriate. The approach summarized herein is preferred because it is more robust to the outlier index points which are present in this series and it makes fewer assumptions about the continuity of the series.

Queen Charlotte Sound Shrimp Survey

A swept-area shrimp survey of QCSd has also been conducted yearly since 1998 (Boutillier and Olsen 2000). Although the original design employs uniform sampling stations and uses spatial interpolation to estimate biomass, we re-analyzed the surveys as if they were randomly stratified to arrive at the canary rockfish biomass estimates given in Table 6 and Fig. 20 (see Appendix 4 for details). The points indicate a rising trend for the central coast since 1999, but the survey is obviously imprecise and, in common with the other surveys summarized in the following section, covers only a short time period.

Table 6. Canary biomass estimates (t) from the QCSd shrimp survey, 1999 to 2005. Confidence intervals are at the 95% level.

Year	Biomass (t)	Lower CI (t)	Upper CI (t)
1999	5.4	0.9	25.3
2000	0.8	0.0	2.3
2001	0.7	0.0	2.1
2002	9.5	2.9	22.6
2003	14.2	5.3	28.0
2004	2.4	0.0	7.3

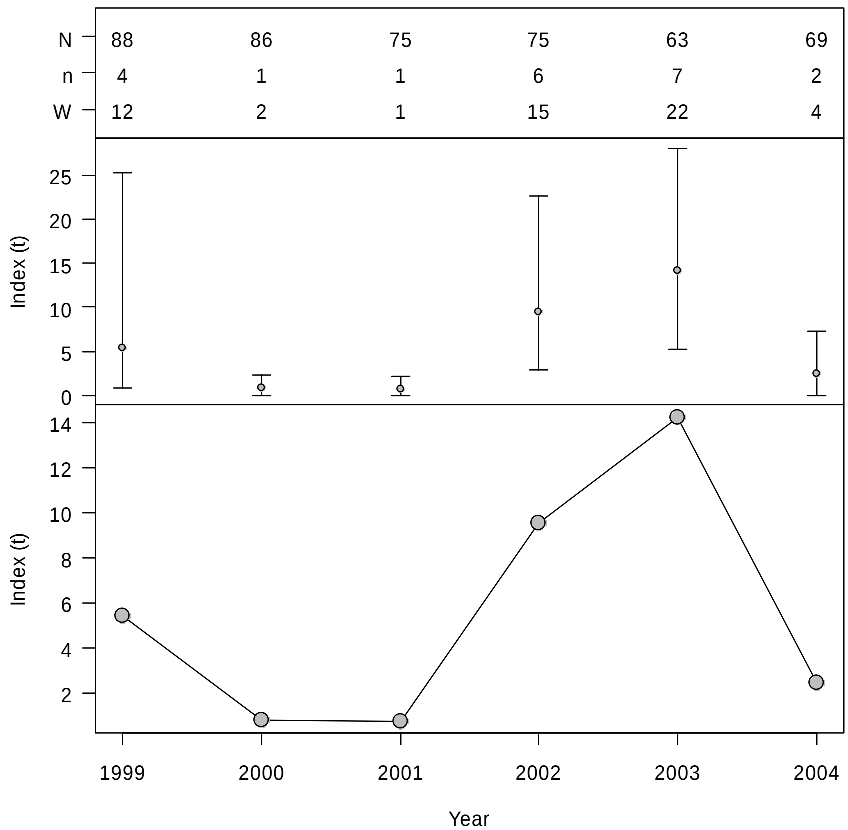

Figure 20. Bootstrapped biomass estimates (t, bottom panel) and biomass + 95% confidence intervals (t, middle panel) for canary rockfish caught in the QCSd shrimp survey, 1999 to 2004. The top panel indicates: N = the number of sets conducted; n = the number of sets in which canary rockfish were caught; W = the total weight (kg) of canary rockfish caught.

Queen Charlotte Sound Groundfish Survey

A large-scale groundfish bottom trawl survey of QCSd was initiated in 2003 and repeated in 2004 and 2005 (Fig. 11) (Stanley et al. 2004). Funded primarily by the trawl industry, the current plan is to continue it on a biennial rotation. The survey is based on approximately 240 successful tows. Results indicate an increasing trend over the three years (Table 7, Fig. 21) but, as with the other surveys for this species, is obviously imprecise, although it captures a much larger number of canary rockfish than other surveys.

Table 7. Canary biomass estimates (t) from the QCSd groundfish survey, 2003 to 2005. Confidence intervals are at the 95% level.

Year	Biomass (t)	Lower CI (t)	Upper CI (t)
2003	1,326	709	2,861
2004	1,493	784	3,313
2005	1,701	349	5,232

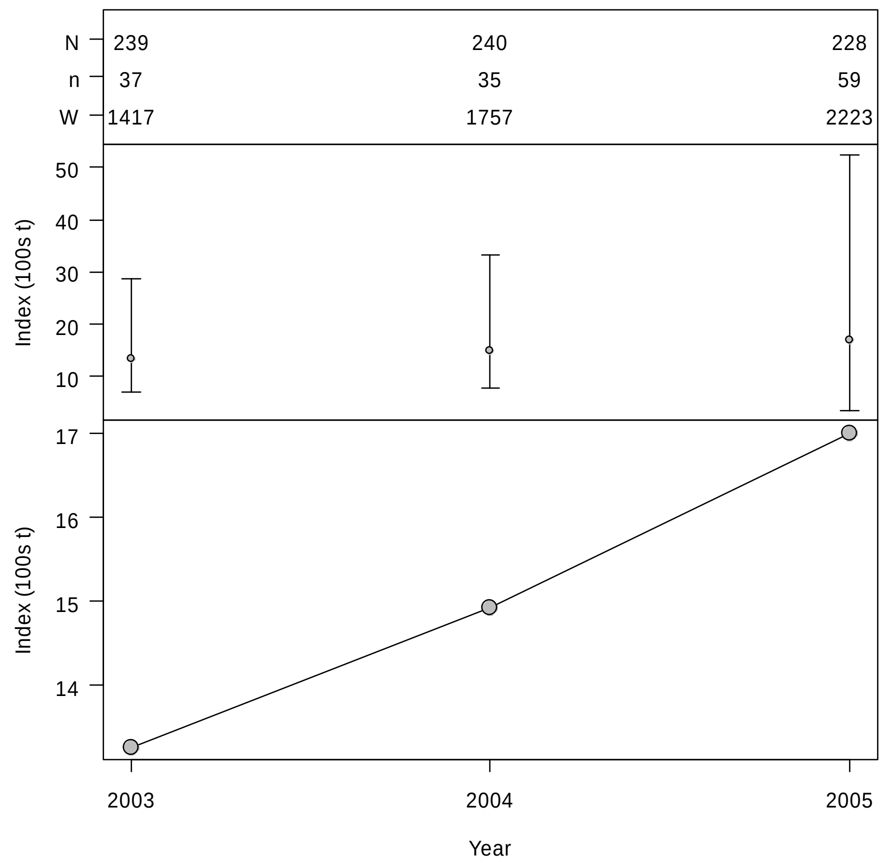

Figure 21. Bootstrapped biomass estimates (100’s t, bottom panel) and biomass + 95% confidence intervals (100’s t, middle panel) for canary rockfish caught in the QCSd groundfish survey, 2003 to 2005. The top panel indicates: N = the number of sets conducted; n = the number of sets in which canary rockfish were caught; W = the total weight (kg) of canary rockfish caught. The methods used to calculate the confidence intervals are the same as those used in the analysis of the QCSd shrimp survey and are detailed in Appendix 4.

Hecate Strait Assemblage Survey

DFO has conducted a bottom trawl “assemblage” survey in HS since 1984-2003. However, it was conducted in waters which are too shallow for canary rockfish, resulting in catch rates which are extremely low. Canary rockfish were observed in only 1-11 sets/y of the 85-146 sets/y. The trend, such as it is, is downwards, although heavily leveraged by one high point in 1984 and two low points in 2002 and 2003 (Table 8, Fig. 22). We attach little confidence to this trend owing to the low catch rates in the survey. This survey was re-designed in 2005, which added a few more tows in deeper water. It may prove to be more useful for tracking canary rockfish than the previous survey but it is still likely to be imprecise.

Table 8. Canary biomass estimates (t) from the HS assemblage survey, 1984-2003. Confidence intervals are at the 95% level.

Year	Biomass (t)	Lower CI (t)	Upper CI (t)
1984	246	79	913
1987	23	3	87
1989	32	5	124
1991	159	25	659
1993	49	14	196
1995	39	6	115
1996	14	2	57
1998	37	1	244
2000	57	10	202
2002	1	0	3
2003	5	1	14

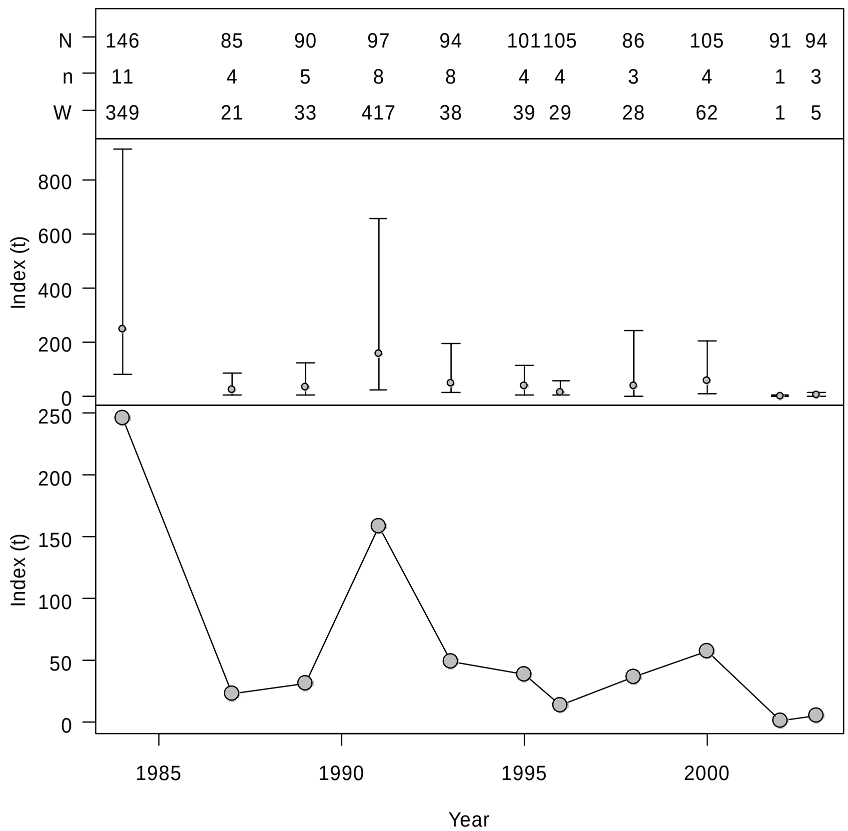

Figure 22. Bootstrapped biomass estimates (t) (bottom panel) and estimates + 95% confidence intervals (t) (middle panel) for canary rockfish caught in the HS assemblage survey between 1984 and 2003. The top panel indicates: N = the number of sets conducted; n = the number of sets in which canary rockfish were caught; W = the total weight (kg) of canary rockfish caught. The methods used to calculate the confidence intervals are the same as those used in the analysis of the QCSd shrimp survey and are detailed in Appendix 4.

Population Trends and Assessments in U.S. Waters

U.S. research staff have recently updated the assessment of canary rockfish (Methot and Stewart 2005). They treated the population from the Washington/B.C. border to southern California as one stock. Their data sources include catch, length- and age-frequency data from 10 fishing fleets and the U.S. triennial survey. These data were used in a catch-at-age analysis tuned with an index from the U.S. triennial survey, although in this case, the data from the entire triennial survey from California to the Canadian border were used. This series of survey data include additional surveys in 1977, 1986 and 2004 which did not venture into Canadian waters. Current stock status in the U.S. was summarized as:

> "Canary rockfish are estimated to have been relatively lightly exploited until World War II, when catches increased and a rapid decline in biomass began. The rate of the decline in spawning biomass accelerated during the late 1970's, and finally stabilized in the late 1990's in response to management measures. The canary rockfish spawning stock biomass reached an estimated low in 2000, but has been increasing since that time, with an estimated 1,850 t (95% interval 996-2,704) at the beginning of 2005. The estimated relative depletion level is 5.3% (2.7-7.9%) ... The stock remains depleted, although the spawning stock biomass appears to be increasing (Methot and Stewart 2005)".

There is a swept area survey conducted in southeastern Alaska but too few canary rockfish are captured to infer trends in abundance (Mark Wilkins, pers. comm.).

Abundance Trends From Canadian Commercial Trawl CPUE

We have restricted our analysis of commercial trawl CPUE to the period of April 1996 through to March 2005. The beginning date of this analysis corresponds to the start of at-sea observer records, and ignores the catch history that relied on fisher logs and sales slips. We argue that catch rate data prior to April 1996 are not comparable over time, owing largely to the significant and varying degrees of mis-reporting. Our concerns about this period are based on the reporting of a large number of landing events, known to the senior author and others, for which the fishing logs and sales slips were obviously falsified. It was apparent at the time that many, possibly the majority, of sales-slips (and logbooks) were completed match accommodate official species' trip limits. Furthermore, the trip limits were varied widely over time, thus the directions of the biases would vary from one year to the next, or over groups of years. The dysfunction in the catch reporting system and the resulting inability to manage to quotas was the primary reason that the Department imposed 100% observer coverage on the trawl fishery in 1996. While we acknowledge that the degree of misreporting was never documented in a manner which would support these concerns, we suggest that presenting catch rates as being reliable from this period would not be useful.

We present commercial CPUE trends for the 1996+ period, which marked the beginning of 100% observer coverage and more reliable catch data. However, it is with the caveat that CPUE can be expected to be "hyper-stable" within the context of an IVQ fishery (IVQ's were introduced in 1997). As canary rockfish abundance varies within a limited range, fishers in an IVQ fishery are likely to alternate between targeting and avoiding this species in response to changes in abundance, thus making CPUE appear to be stable. However, we assume this tendency towards hyper-stability would be overwhelmed by large-scale changes in abundance, particularly for declines because, at some point, IVQs will not be caught if abundance declines significantly. This should be manifest in the CPUE as well. Therefore, these analyses were conducted to examine whether there was evidence of a decline large enough to overcome the tendency for hyper-stability.

Trawl catch/effort data pertaining to canary rockfish from the DFO PacHarvTrawl database were analysed using two general linear regression models: one assuming a log-normal distribution based on the non-zero catches of canary rockfish and the other assuming a binomial distribution based on the presence/absence of this species in the catch (Appendix 5). This analysis begins from April 1, 1996 which represents the period when the quality of data had been vastly improved through the imposition of 100% observer coverage on all the major trawl operators. The analysis was also restricted to tows at optimal depths for canary rockfish and confined to vessels which had been in the fishery for at least three years for a minimum of five trips per year. The analysis considered two fisheries for canary rockfish: the WCVI (Areas 3C+ 3D) and QCSd (5A+5B). A comparison of the two areas for each type of GLM analysis shows that there are similarities between series across areas (Fig. 23).

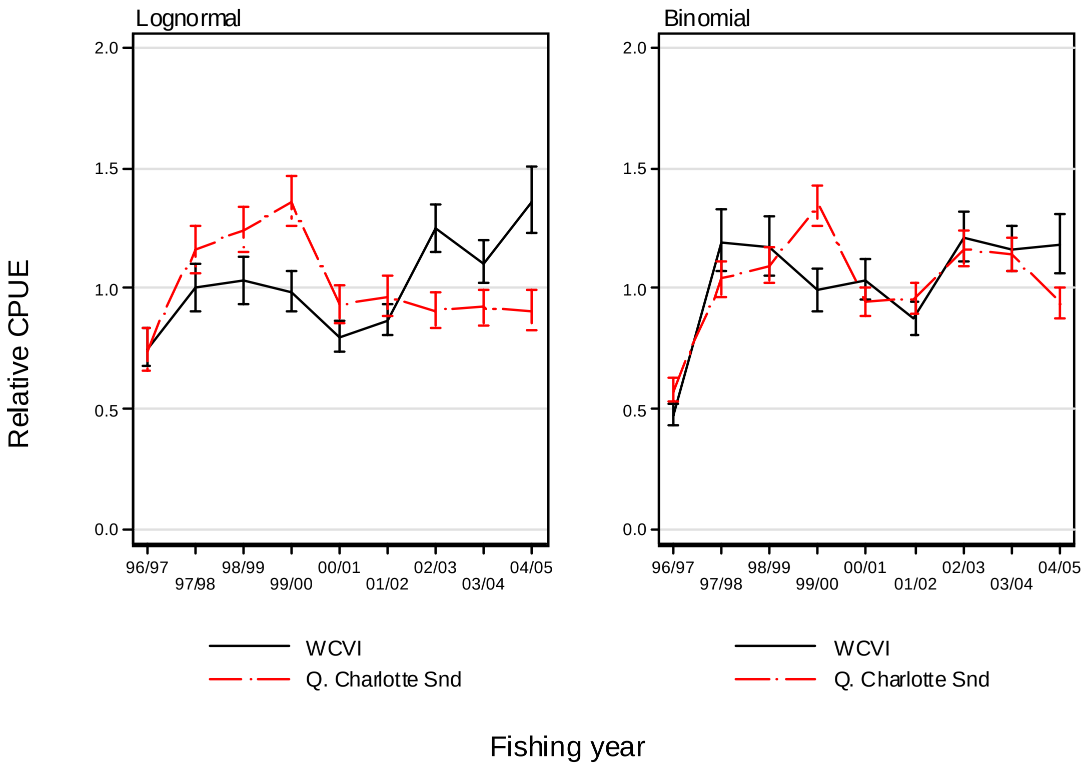

Figure 23. Comparison of two sets of CPUE indices each based on different regression model assumptions for each of three areas. Each series has been standardised relative to the geometric mean of the period 1996/97 to 2004/05. The error bars show ± 95% confidence bounds (see Appendix 5 for explanation of the binomial trend).

A comparison of the two areas for each type of GLM analysis shows that the binomial series are very similar for the two areas, with each area showing a strong increase between 1996/97 to 1997/98 and remaining fairly flat since. The QCSd binomial series shows a drop in the most recent fishing year while the WCVI series does not. The two sets of lognormal series differ more, with the QCSd series showing an increase in the first half of the series while the WCVI series shows an increasing trend in the latter half of the series. The WCVI canary fishery has a higher catch rate and a higher proportion of non-zero tows. These series of relative abundance indices should be interpreted with caution as they are derived from fishery dependent data and are subject to between-year effects which may originate from sources other than fish abundance.

Three of the four sets of CPUE abundance series (two models: lognormal and binomial for each of two areas outlined above) show an increasing trend of 5-6% per year, depending on the area and the regression model applied. The QCSd binomial model has a decreasing trend of -1% per year. Simple two-parameter models should not be used as a substitute for a stock assessment model and are provided as one indicator of the overall trend over the analytical period. It is not possible to predict a "three generational" change for these populations because such a prediction would require a complex analysis and strong assumptions of stability over long periods which are unlikely to be met. Nevertheless, these data, with their limitations, do not indicate a decline in abundance in these areas, since 1996.

Other Stock Assessments of the Canadian Population(s)

Stanley (1999) provided stock assessment advice for canary rockfish. The author conducted a catch curve analysis after blocking the age observations into groups of years to account for ageing error. The resulting estimates of *Z* (instantaneous rate of total mortality) in all the periods for areas 3C+3D and 5A+5B (females: 0.046-0.10 and males: 0.03-0.07) were not significantly different from the range of possible M, indicating, by subtraction (F=Z-M), that the fishing impact was likely to be low. Even the most recent period (1996-1998) analyzed indicated that the estimates of *Z* were 0.092 and 0.095 for females from Areas 3C+3D and 5A+5B respectively and the *Z* estimates for males were 0.047 and 0.053 for the same two areas, indicating that the *Z* estimates continued to be near the plausible values for M. While the weaknesses of conducting catch curve analysis in isolation are well documented (Ricker 1975), the implied estimates of *F* in various epochs did not indicate an unsustainable level of fishing nor were they increasing over time for the two main regions. Thus, existing quotas at that time (Table 2) appeared sustainable and they have not been changed since then.

The recommended quota range tended to bracket historical mean landings. In the absence of quantitative risk analysis, the intent of the upper and lower bounds presented in Table 2 was to provide qualitative guidance to managers. Harvests less than the minimum level would incur negligible risk, while harvests above the maximum level could not be defended as being sustainable and may put the stock at risk.

Walters and Bonfil (1999) provide two alternative stock assessments of canary rockfish. The first was based on an expansion of catch rates in the commercial fishery and used an area-swept biomass approach. However, they had no knowledge of catchability of the trawls and commented that they were "less than satisfied with the technique". Nevertheless, they estimated "minimum" biomasses of 3,246-4,932 t for the years 1994-1996, for the areas that were heavily trawled.

Their second method involved a single stock Bayesian assessment procedure. This procedure modeled populations over various assumptions of starting biomass (B0) and was tuned to the 1980-1996 qualified commercial trawl CPUE, in spite of the fact that those authors noted that the data indicated unrealistic trends in CPUE. We note above, as was noted in the bocaccio assessment (Stanley et al. 2001), that catch and CPUE data were neither accurate nor comparable over this period owing to a variable management regime and trends in misreporting.

Walters and Bonfil provided a useful contribution by indicating the impact those trends would have as a tuning index for stock assessment but we continue to suggest (see Stanley 1999) that the results should be interpreted with caution. The canary rockfish assessment, along with the other assessments in that work, were highly leveraged by the sudden drop in CPUE near the end of the time series (mid-1990's) which was associated with improvements in the reporting of catch data, the advent of the dockside monitoring program (DMP) in 1994 and complete observer coverage in 1996. Nevertheless, their analyses suggested that the ratio of current biomass (B1996) to unfished biomass (B0) in 19 trawl localities was 0.29-0.77 with a mean proportion of 0.49.

Trends in Biological Characteristics

Length and age composition observations for commercial catches in Canadian waters are summarized in Figs. 5-8 and 24, shown separately for Area 3C+3D, 5A+5B, and 5E (there are too few data from 5C+5D). Since these data are collected "opportunistically" from the commercial fishery, the actual spatial distribution of these samples, within these areas, varies among years and may not be entirely representative of the fishery. This brings into question the comparability of these data over time and the specific possibility that stability in mean length or age might be an artefact of harvesters gradually finding relatively unexploited sub-stocks within these areas. However, this possibility is unlikely as the known areas of canary abundance in 3C+3D and 5A+5B are relatively small and have been continuously exploited since the late 1950's. Thus it is unlikely that serial depletion in recent decades would act to camouflage overall declining trends in mean size or age within these areas.

At larger spatial scales, however, this effect is more likely and this is why we have separated the data into regions. For example, Area 5E has only been fished since about 1977, thus pooling the samples from this area into a coastwide summary would cause the above artefact. Table 9 summarizes the available canary rockfish age samples and shows that the number of samples is too sparse to permit detailed exploration of how varying characteristics of each sample (see above), such as season, depth, or source (port sample versus at-sea) may influence comparability over time. However, the modest increase in presence of small fish in recent years (Figs. 6 to 8) may have resulted from some at-sea samples taken from shallower depths. Removing these samples results in larger mean sizes and ages in recent years (compare Figs. 6-8 with Fig. 24). Thus, while we argue above against a serial depletion effect, there is evidence of more catches coming from shallower water and affecting the comparability of samples over time. This underlines the weakness of trend analysis in samples taken from opportunistic sampling. The recently initiated set of fishery independent surveys will provide more comparability in population samples, although these will not be representative of commercial catches.

We also present both nominal (unweighted) and weighted trends in mean length and age composition. The weighted versions pool the same samples, while weighting each sample by the catch of canary rockfish associated with the sample (Figs. 25 and 26).

Table 9. Canary rockfish age samples from Area 3C+3D. Port = samples obtained at the offloading port; Observer = samples obtained at sea by on-board observers; Research = samples obtained at-sea during research cruises; n = the number of samples; N = the number of aged specimens.

	Port		**Observer**		**Research**		**Total**	
Year	**n**	**N**	**n**	**N**	**n**	**N**	**n**	**N**
1978					1	104	1	104
1979	2	201					2	201
1980								
1981								
1982	2	50					2	50
1983	2	225					2	225
1984	3	212					3	212
1985	1	296			3	75	4	371
1986					2	75	2	75
1987								
1988					1	50	1	50
1989	1	25					1	25
1990	1	33					1	33
1991	2	102					2	102
1992								
1993	3	151					3	151
1994	1	52					1	52
1995	4	211					4	211
1996	1	62	3	135			4	197
1997			4	117			4	117
1998	6	346	11	551			17	897
1999	2	108	7	321			9	429
2000	1	62	3	180			4	242
2001			3	165			3	165
2002	1	59	4	152			5	211
2003	2	113	2	94			4	207
2004	3	153	7	299			10	452
Total:	**38**	**2461**	**44**	**2014**	**7**	**304**	**89**	**4779**

Table 9 continued. Canary age samples from Area 5A+5B.

	Port		Observer		Research		Total	
Year	**n**	**N**	**n**	**N**	**n**	**N**	**n**	**N**
1978	4	387					4	387
1979	1	100					1	100
1980	1	100					1	100
1981	1	24					1	24
1982	1	27					1	27
1983	1	25					1	25
1984								
1985								
1986								
1987								
1988	2	166					2	166
1989								
1990	4	141					4	141
1991	4	206					4	206
1992	2	109					2	109
1993	1	81					1	81
1994	7	365					7	365
1995								
1996			1	40			1	40
1997	2	106	3	154			5	260
1998	1	59	1	48			2	107
1999	2	118	2	86	1	29	5	233
2000	3	165	1	49			4	214
2001	5	322	1	24			6	346
2002								
2003	2	109	2	60			4	169
2004	1	40	1	46			2	86
Total:	**45**	**2650**	**12**	**507**	**1**	**29**	**58**	**3186**

Table 9 continued. Canary age samples from Area 5E.

	Port		Observer		Research		Total	
Year	**n**	**N**	**n**	**N**	**n**	**N**	**n**	**N**
1978	1	100					1	100
1979								
1980								
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990								
1991								
1992								
1993								
1994								
1995								
1996								
1997	1	51					1	51
1998			2	93			2	93
1999								
2000	1	56	1	48	1	50	3	154
2001			2	158			2	158
2002								
2003								
2004	3	125					3	125
Total:	**6**	**332**	**5**	**299**	**1**	**50**	**12**	**681**

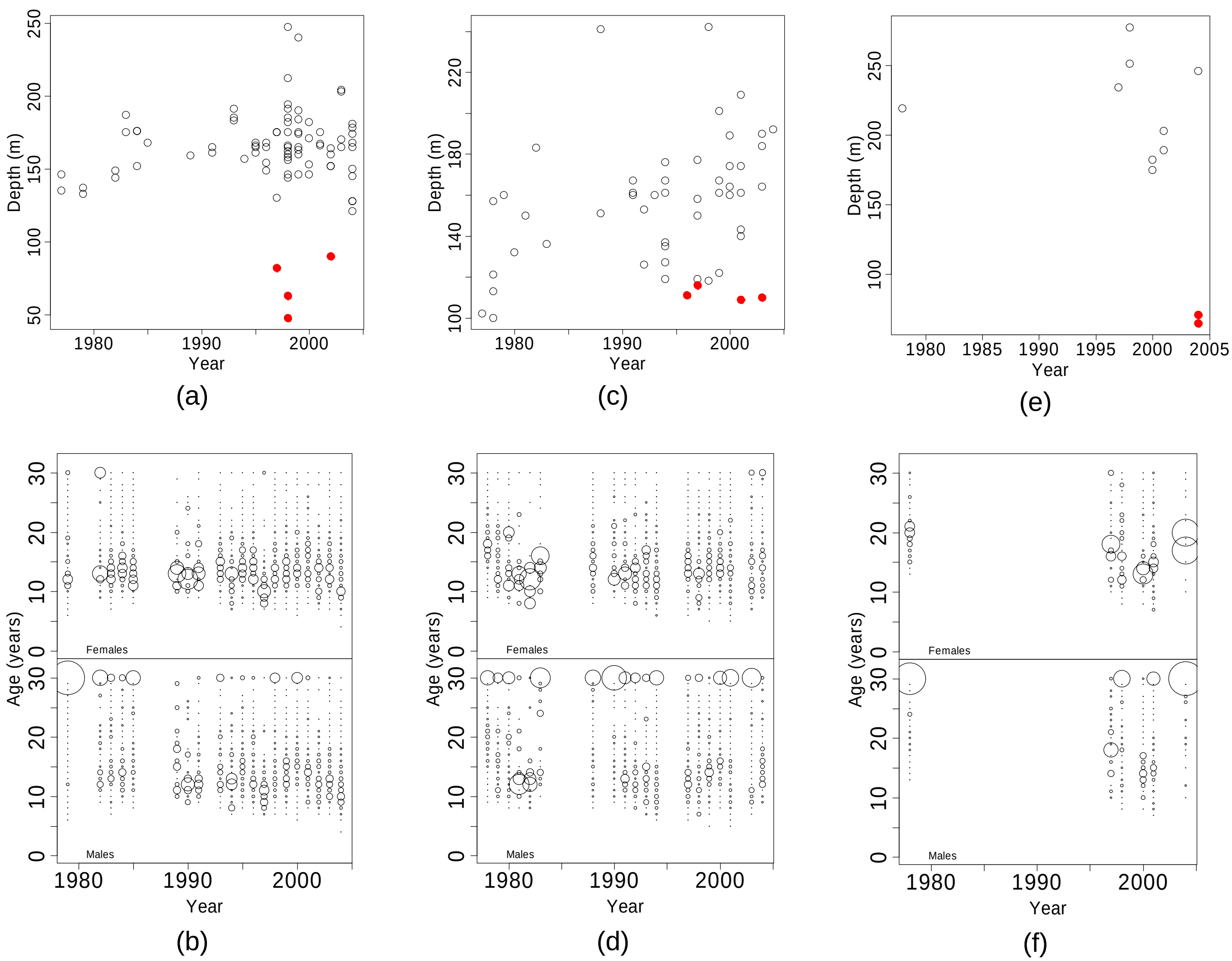

Figure 24. The effect of shallow samples on canary rockfish proportions-at-age. Panel (a) identifies 4 shallow samples from Area 3C+3D. Removal of these samples from the proportions-at-age analysis yields the figure shown in panel (b). Compared to the original proportions-at-age plot shown in figure 6, this plot has markedly fewer fish in the younger age classes, for the years in which the shallow samples were removed. A similar pattern exists for Area 5A+5B (panels (c) and (d)) and Area 5E (panels (e) and (f)).

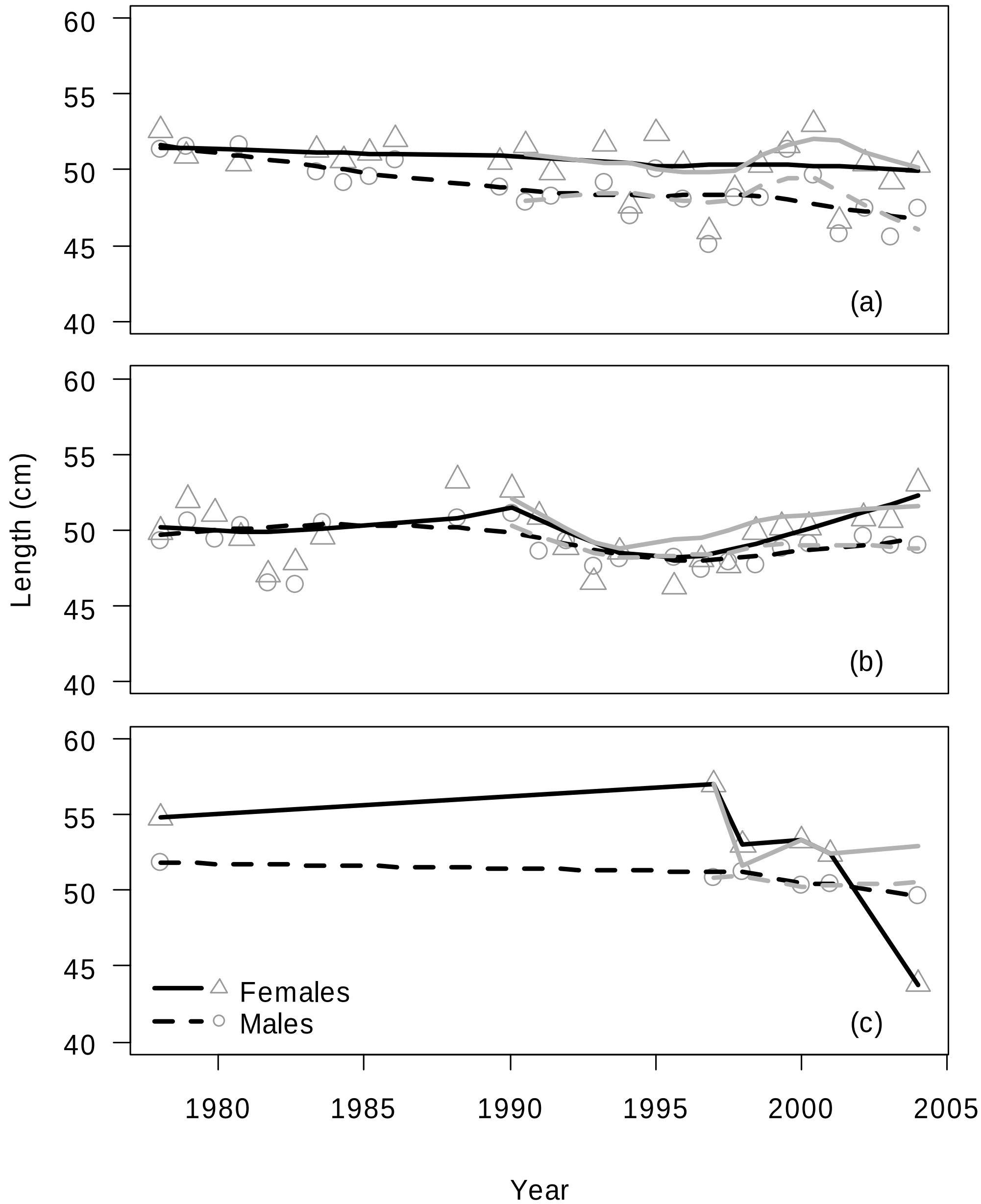

Figure 25. Trends in mean fork length for canary rockfish from (a) Area 3C+3D, (b) Area 5A+5B, and (c) Area 5E. The grey lines show the effect of weighting each sample by the total catch weight of canary rockfish from which the sample was taken. Sample catch weights are only available for more recent years.

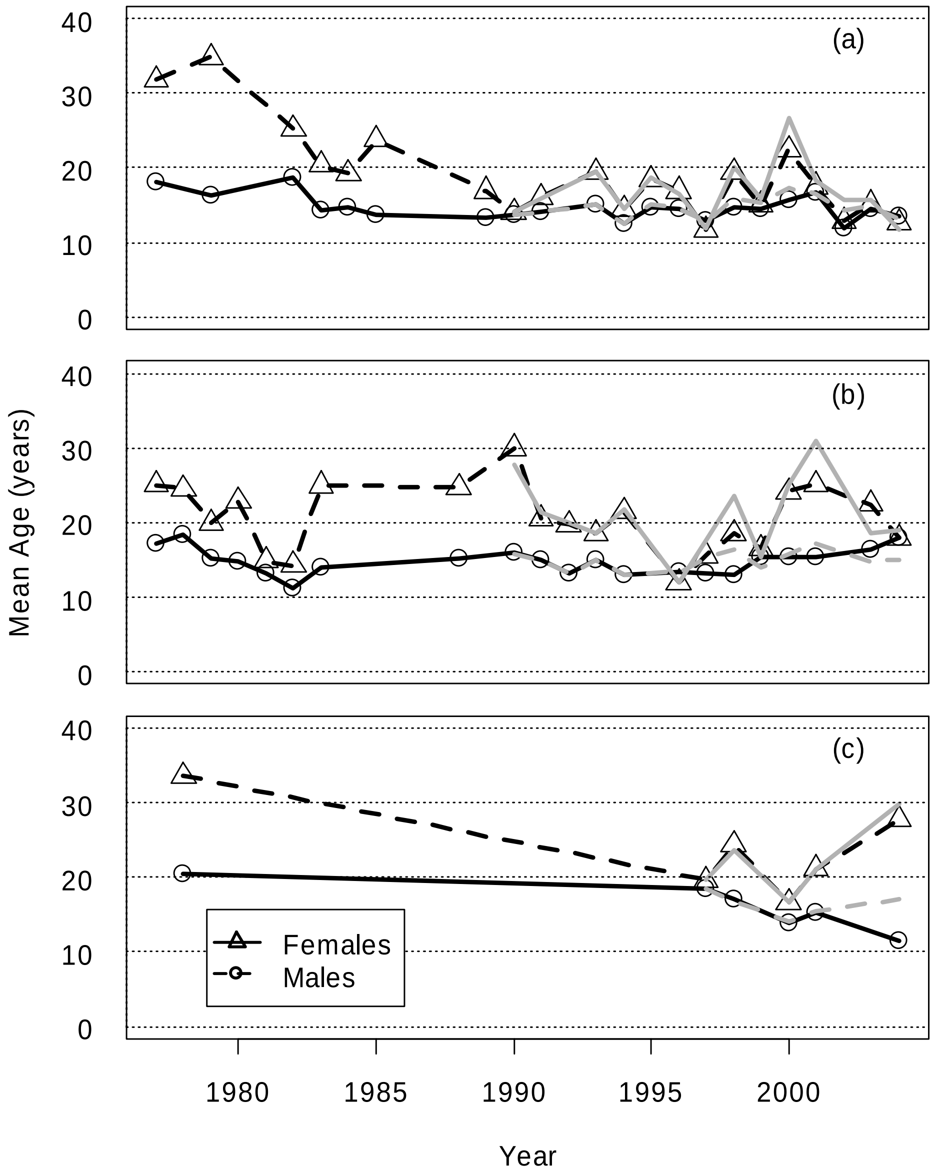

Figure 26. Mean age versus year for canary rockfish from (a) Area 3C+3D, (b) Area 5A+5B, and (c) Area 5E. The gray lines show the effect of weighting each sample by the total catch weight of canary rockfish from which the sample was taken. Sample catch weights are only available for more recent years.

There is an apparent decrease in mean length for males in Area 3C+3D, but not for Area 3C+3D females. There is no overall trend for Area 5A+5B in either sex, although mean length may be increasing in recent years. The time series is short for Area 5E.

Mean age in Area 3C+3D shows a decline for both sexes from late 1970's until 1990 then no trend. The Area 5A +5B is without trend. The mean age of 3C+3D is lower than Area 5A+5B in recent years, although it appears similar to Washington State collections (Fig. 27 in Methot and Stewart 2005). The one 5E sample collected in 1977 indicated an unexploited age composition. Samples from this area now show a lower mean age, which is generally consistent with areas to the south.

Summary of Current Abundance in B.C. Waters

Estimates of abundance inferred from annual landings and from trawl surveys indicate that adult canary rockfish abundance in Canadian waters is probably at least several million adults. With respect to trends in relative abundance, we have distinguished among regions, although the indices have been standardized to a common mean and are presented in combined graphs (Figs. 27-29). There is evidence of a partial natural stock boundary near the northern tip of Vancouver Island, separating the southern Coastal Upwelling Domain (Baja California to 50.5^{o} N) and the Coastal Downwelling Domain (50.5^{o} N to the Aleutian Islands) (Ware and McFarlane 1988, King 2005). Populations of groundfish on either side of this boundary do not seem to vary synchronously, given that recruitment between these regions is asynchronous for silvergray rockfish (Stanley and Kronlund 2000) and movement patterns for sablefish differ between these regions (Kimura et al. 1997).

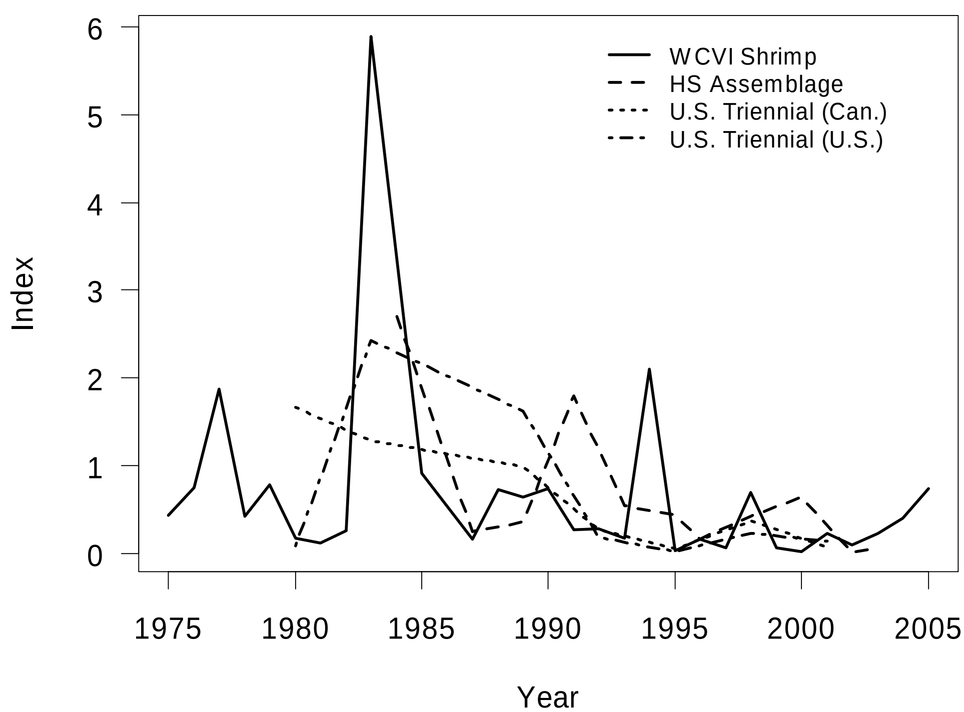

Figure 27. Relative biomass indices for canary rockfish from four longer term fishery independent surveys. All indices have been scaled such to a common mean calculated over the period 1983-2001.

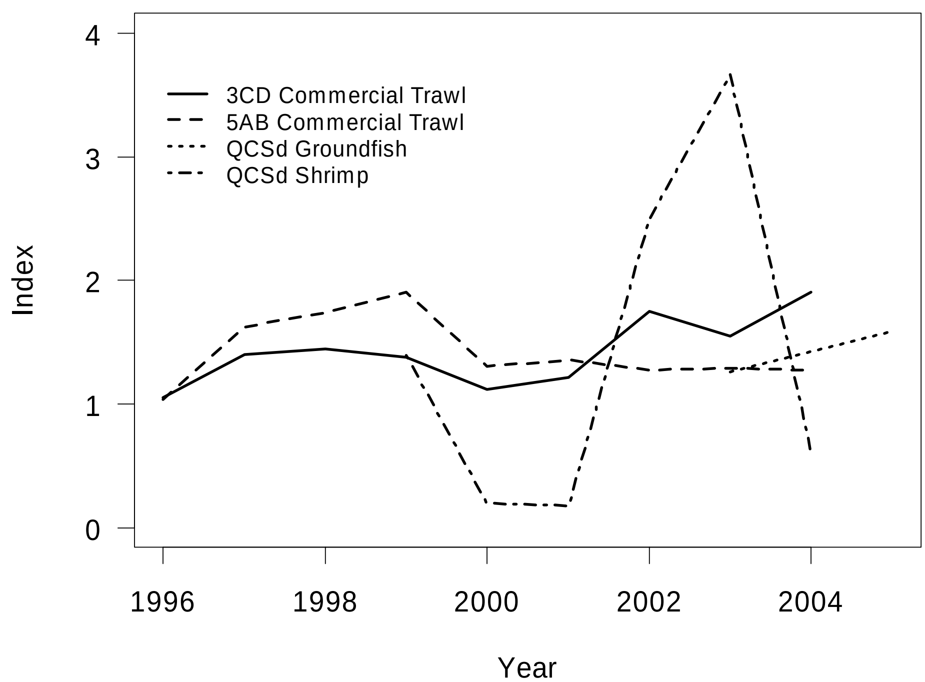

Figure 28. Relative indices for canary rockfish from shorter term commercial trawl data in Areas 3C+3D and 5A+5B and from two fishery independent surveys in QCSd. All indices have been scaled to a common mean calculated over the period 1999-2004.

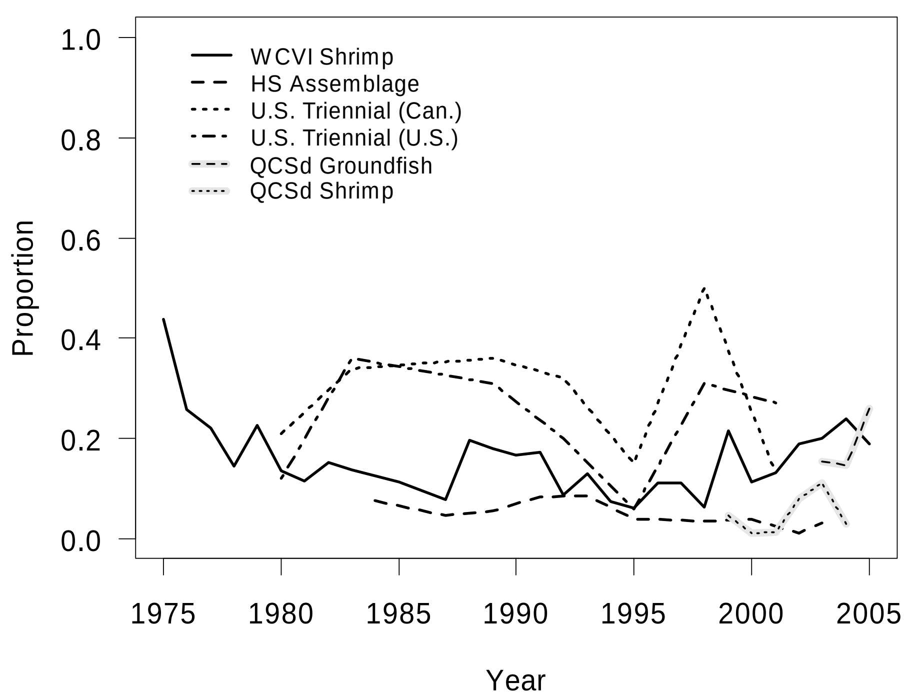

Figure 29. Proportions of non-zero tows of canary rockfish in six fishery independent surveys.

A step-function interpretation of the catch rate index from the annual WCVI-shrimp survey (from 1975-2005) indicates that recent abundance is 39-61% of the long term mean, or is 23-45% of the earliest period. However, examining the trend in the proportion of non-zero tows (Figs. 16 and 29) from the same survey indicates that the population is at the same or higher levels than it was at the beginning of the survey. The U.S triennial survey catch rate (Figs. 13 and 27) presents a more pessimistic view, showing a fitted decline of 95% (see earlier), while the average of four more recent surveys (1992-2001) in comparison with the average of the three surveys from 1980-1989 period indicates a decline of 92%. The estimated declines from the trend in the U.S. triennial survey are derived from only seven surveys compared to the 29 surveys for the WCVI shrimp survey and that there is great imprecision in both surveys owing to the occasional large tows which exert significant leverage on the annual survey estimates (Appendix 2: Fig.2). This effect is illustrated by the results in the US-Vancouver zone between 1980 and 1983, when the index rose from near zero to the largest index value of the time series. Note also that the time series of proportion of non-zero tows from this survey does not provide as pessimistic a view (Fig. 29).

South coast commercial trawl catch rates, as elsewhere, appear to be stable, if not increasing, since 1996. However, any observed trend in commercial trawl CPUE may be an artefact of the target/avoidance response by fishers within the context of an ITQ fishery. Biological samples from the southern coast appear to indicate a decrease in mean size and age over the long term, but are stable in recent years. Catch curve analysis does not indicate overfishing.

The apparent longer term decline in abundance indicated by the two WCVI surveys may have resulted from a sustained period of poor recruitment in the 1990’s that has been reported for many groundfish stocks in the Washington-California area (King 2005). An equivalent recruitment failure has not been identified for more northerly rockfish populations.

There is no long-term index available for the central coast (Area 5A+5B). The QCSd groundfish survey indicates an possible increasing trend over the first three survey years (2003-2005) (Figs. 21 and 28), while the QCSd shrimp survey is more variable. Commercial trawl catch rates appear to be stable since 1996, although the same caveat presented for 3C+3D also applies to these commercial data.

The point estimates of minimum biomass for QCSd from the 2005 groundfish survey (assuming a catchability of 1.0) indicate that there is likely to be at least 1,795 t (95% confidence range: 433-5,668 t) in 2005 compared to the 738 t (95% confidence range: 417-1,390 t) estimated for the WCVI in 2004. While catchabilities cannot be assumed to be equal among both areas; the nominal results imply that there is a larger biomass of canary rockfish in the central region.

Biological samples from the central coast do not indicate a trend in mean size or age over the long term. Catch curve analysis indicated that current removals appear to be sustainable. Fishers have long reported that there is a significant population of canary rockfish in the north coast (Area 5E), although northern waters have generated few landings. Their opinions are based on significant acoustic sign of rockfish over untrawlable bottom in canary rockfish depths. This acoustic “sign” has also been noted by research staff and partially confirmed with tows of canary rockfish during numerous research trips. There are only a few places where canary rockfish can be captured by trawl, given the rough bottom topography, but fishers report that the low quotas in this area have prevented expansion of this fishery. Canary rockfish are frequently encountered when hook-and-line fishing in this region.

Biological samples from the north coast (from the West Coast of the Queen Charlotte Islands) are limited. Comparison of recent samples with one sample collected in 1978 possibly indicates that there has been an impact from exploitation. Current mean size and age are similar to southern and central coast samples. However, this interpretation may be affected by how the samples were obtained.

RESCUE EFFECT

The low biomass levels in U.S. waters to the south reduces the likelihood that these populations could assist recovery of Canadian canary rockfish in the short-term through dispersal of mature adults. However, even a small spawning biomass in these waters may produce a large year class which could spill into Canadian waters. Canary rockfish populations in Southeast Alaska could also provide a rescue effect for B.C. populations although the status of this population is unknown (Victoria M. O'Connell, pers. comm.).

Mobile fishing gear may have a broad-scale impact on canary rockfish habitat and therefore abundance; but these trawl grounds have been fished for 2-6 decades. Since introduction of IVQ's in 1997, trawl activity has tended to be restricted to core areas. Other than fishing gear impacts and possible impacts from oil and gas exploration (should the moratorium be lifted), there does not appear to be any scope for remedial habitat measures, except on a highly localized basis.

LIMITING FACTORS AND THREATS

Canadian fisheries are well monitored. All commercial groundfish fisheries have 100% dockside validation. The trawl fishery on the continental shelf has effectively 100% observer coverage since 1996 and the remaining commercial fisheries, as of 2006/2007 also have 100% at-sea monitoring. Fishers will choose between observers or video recording. Video monitoring has been demonstrated to be an acceptable alternative especially if combined with 100% retention of all species of rockfish. The latter regulation will also will be introduced in April 2006. Recreational and First Nations' catches are less well monitored but will probably remain negligible in the short term, except in localized areas.

We are not aware of any imminent or changing threat to canary rockfish habitat. The continental shelf is not currently exposed to industrial activities. We assume that fishing gear has some impact, although trawl activity continues to be concentrated on virtually the same areas for the last few decades. Future oil and gas exploration may have some impact, but there is currently a moratorium on this activity.

In addition to improved catch monitoring, a number of surveys have been implemented since 2000 to improve tracking of canary rockfish abundance. Large scale bottom trawl surveys have now been implemented for most of the traditional trawl areas: WCVI started in 2004; QCSd started in 2003, a revamped version for HS started in 2005 and a new survey started for the WCQCI starting in 2006. New or improved hook-and-line surveys have also been initiated. Catch composition is extensively sampled from commercial catches (landings and at-sea) as well as during surveys. In 2004, DFO obtained 74 samples of canary rockfish representing 1,460 specimens.

U.S. fisheries may have an impact on abundance in Canadian waters. Since the declaration of "overfished" status for canary rockfish for Washington-California waters in 1999, a number of management measures have been implemented to reduce harvest and fishing effort. These have included closing the continental shelf to trawling shallow of 137 m and non-retention in hook-and-line fisheries. Reported catches for 2004 were less than 38 t, which include estimates of discarding. This compares with a peak catch of over 5,000 t/y in the early 1980's. The principal monitoring tool for this population, the U.S. triennial survey, is now conducted annually instead of the previous triennial frequency.

SPECIAL SIGNIFICANCE OF THE SPECIES

We are not aware of any special significance of canary rockfish outside of its economic importance in the commercial fisheries and modest role in recreational fisheries. As far as we know, catches are small in First Nations' fisheries, but its cultural significance may be larger than is reflected by the size of the catches.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Landings are currently controlled within the commercial fisheries using a variety of harvest controls including area-specific yearly quotas, and ITQ's. Discarding is now (as of 2006/2007) currently monitored and regulated in the hook-and-line fisheries. Catches in the recreational fishery are somewhat constrained through bag limits for "rockfish" and Rockfish Conservation Areas.

TECHNICAL SUMMARY

Sebastes pinniger

Canary rockfish — Sébaste canari

Range of Occurrence in Canada: widespread in the coastal waters of British Columbia

Extent and Area Information	
• *Extent of occurrence (EO)(km²)- in Canada*	>60,000 km²
• *Specify trend in EO*	stable
• *Are there extreme fluctuations in EO?*	no
• *Area of occupancy (AO) (km²)- in Canada*	>32,000 km²
• *Specify trend in AO*	stable
• *Are there extreme fluctuations in AO?*	no evidence
• *Number of known or inferred current locations*	widespread, continuous in distribution
• *Specify trend in #*	appears stable
• *Are there extreme fluctuations in number of locations?*	no evidence
• *Specify trend in area, extent or quality of habitat*	probably stable

Population Information	
• *Generation time (average age of parents in the population)*	20-30 years (22.8 U.S. estimate)
• *Number of mature individuals*	> 1,000,000

• *Total population trend:*	South coast • shrimp survey catch rate index indicates overall decline since 1975; shrimp survey proportion of zeros index indicates no net change since 1975, currently higher than average; • U.S. triennial survey catch rate index indicates decline since early 1980; triennial survey catch proportion of zero tow index indicates no net change since early 1980; • Commercial trawl CPUE is stable since 1996; • Size and age composition provide no evidence of overexploitation. Central coast • Shrimp and groundfish surveys, and commercial CPUE indicate stable or increasing trend within the last decade; • Size and age composition provide no evidence of overexploitation. North coast • Limited history of fishing on WCQCI (5E), harvester reports of significant biomass; • Possible decline east of Queen Charlotte Islands (5C+5D-HS) but the survey catches very few fish; • Size and age composition too limited for inference.
• *% decline over the last/next 10 years or 3 generations.*	South coast • shrimp survey catch rate index indicates overall decline of 29-77% since 1975; shrimp survey proportion of zeros index indicates no net change since 1975, currently higher than average • triennial survey indicates 92-95% decline since early 1980s; triennial survey proportion of zeros index indicates no net change; • commercial trawl CPUE stable over last decade. Central coast • Shrimp and groundfish surveys, and commercial CPUE indicate stable or increasing in the last decade. North coast • No trend analysis for 5E • Possible decline east of Queen Charlotte Islands (HS assemblage survey) but few fish in this survey
• *Are there extreme fluctuations in number of mature individuals?*	No evidence of this over 30 years
• *Is the total population severely fragmented?*	No evidence of this
• *Specify trend in number of populations*	Not applicable

• *Are there extreme fluctuations in number of populations?*	Not applicable
• List populations with number of mature individuals in each:	Not applicable

Threats (actual or imminent threats to populations or habitats)
1. Fishing

Rescue Effect (immigration from an outside source)	
• U.S. waters: Adjacent population to the south has been declared over fished and thought to be about 5% of the unfished population. While the fishery has almost been eliminated and rebuilding in U.S. waters is thought to be occurring, the low population levels in U.S. waters would reduce likelihood of a "rescue effect" by movement of juveniles or adults from U.S. populations. Larval immigration leading to recruitment is possible.	
• *Is immigration known or possible*	Yes
• *Would immigrants be adapted to survive in Canada? Yes*	Yes
• *Is there sufficient habitat for immigrants in Canada?*	Yes
• *Is rescue from outside populations likely?*	Low likelihood at the present time, given current U.S. biomass

Quantitative Analysis	
There is no quantitative basis for estimating the probability of extirpation in a specified period.	Not applicable

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ACKNOWLEDGEMENTS

We appreciate the assistance of the various respondents from the commercial, native and recreational fisheries and other agencies. Mark Wilkins of NOAA provided data from the U.S. triennial survey. The document was much improved through reviews provided by Lara Cooper, Jamie Gibson, Jeff Hutchings, Howard Powles, Peter Shelton, and Alan Sinclair.

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Rick Stanley has a B.Sc. and M.Sc. in Zoology from the University of British Columbia. For the past 21 years, he has worked as a stock assessment biologist within the Groundfish Section, Fisheries and Oceans, Canada at the Pacific Biological Station in Nanaimo, B. C. Principal duties have focused on (1) designing, conducting and reporting on basic fisheries research in support of rockfish stock assessment, (2) providing annual stock assessment of shelf rockfish and, (3) supervising development of catch and biological databases for all groundfish species. The co-authors have a combined experience of 20 years in maintaining groundfish catch and biological databases.

Paul Starr has a Bachelor of Arts from Yale University (1968) and a M. Sc from the University of British Columbia (1973). Paul worked for the Department of Fisheries and Oceans from 1976 to 1991, primarily as a chinook salmon assessment biologist for the Pacific Biological Station. Paul moved to New Zealand in late 1991 to become a stock assessment advisor to the New Zealand Fishing Industry Board, a statutory body overseeing the New Zealand fishing industry. In 2000, Paul left his position as Chief Scientist for the New Zealand Seafood Industry Council (the successor to the NZ FIB) to become a consulting fisheries scientist. In that capacity, Paul has been funded by the Canadian Groundfish Research and Conservation Society to participate as contributing scientist in the Pacific Stock Assessment Review Committee (PSARC) Groundfish Sub-committee. Paul has had extensive experience in both New Zealand and Canada as a groundfish stock assessment scientist, including performing stock assessments on a range of groundfish species, and designing and implementing groundfish surveys and fishery catch sampling programs.

Norm Olsen has a B.Sc. in biology from the University of Victoria. For the past 11 years he has worked as a stock assessment biologist in the Groundfish and Shellfish stock assessment sections, Fisheries and Oceans Canada, at the Pacific Biological Station in Nanaimo, B.C.

Kate Rutherford has a B.Sc. in biology from the University of Victoria. For the past 18 years she has worked as the manager of the catch and biological databases in the Groundfish stock assessment section, Fisheries and Oceans Canada, at the Pacific Biological Station in Nanaimo, B.C.

Scott Wallace has a Ph.D. from the Fisheries Centre at the University of British Columbia. He presently works as an independent consultant and educator on several marine conservation topics including marine reserves, species at risk, and sustainable fisheries.

COLLECTIONS EXAMINED

No collections were examined.

DATA SOURCES

AKFIN. U.S. commercial landings from Alaska, 1991-1998 (www.psmfc.org/akfin/Reports/reports.html).

PACFIN. U.S. commercial landings from Washington, Oregon and California, 1981-2000 (www.psmfc.org/pacfin/data.html).

GFBio. Biological samples and research cruise database, Groundfish Section, Stock Assessment Division, Science Branch, Fisheries and Oceans, Canada. Pacific Biological Station. This data archive includes most of the groundfish specimen data collected since the 1950's. It therefore includes data from a variety of sources (port and at-sea commercial sampling, research cruise sampling) by a variety of investigations for different reasons.

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APPENDIX 1. Terms of Reference

National Advisory Process meeting to review marine species subject to upcoming assessment by COSEWIC

November 1-2, 2005
Pacific Biological Station
Nanaimo, B.C.

Chairpersons: Lara Cooper and Alan Sinclair

A. Background

The implementation of the Species at Risk Act (SARA), proclaimed in June 2003, essentially begins with an assessment of species' status by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an arm's-length scientific advisory body. This assessment initiates the regulatory process whereby the competent Minister must decide whether to accept COSEWIC's designation and add a species to Schedule 1 of SARA, which will result in legal protection for the species under the Act.

DFO, as the primary generator and archivist of information on marine and aquatic species, will be expected to support the work of COSEWIC by providing the best information available on the status of species to be assessed. DFO also benefits from this activity, because COSEWIC can assess the status of species most accurately when all relevant information is made available to those assessing status.

A National Advisory Process (NAP) meeting will be held November 1-2 to review the Pacific Ocean rockfish species listed on COSEWIC's Call for Bids (March 2005).

B. General objectives

This advisory meeting will be held to peer-review DFO's information that would be relevant to determining a COSEWIC status designation for five species of rockfish including canary rockfish (*Sebastes pinniger*). For the information that is reviewed for use by COSEWIC, non-DFO information will not be considered. The intent of this part of the meeting was to review and provide information from DFO to COSEWIC.

C. Specific objectives

The purpose of the meeting will be to ensure that species information held by DFO is made available to COSEWIC, including the authors of the respective status reports, and the Chairs of the appropriate COSEWIC Species Specialist Subcommittee. In the case of the canary rockfish, the same authors will be responsible for the COSEWIC and present document.

For each species, the meeting will review information on life history characteristics, distribution, and abundance in Canadian waters, along with threats, which could be used by COSEWIC to determine, following its assessment guidelines and criteria, the appropriate risk category. Discussion on each species will consider the available information on population differentiation, which could support a COSEWIC decision of which populations would be suitable for assessment and designation.

Documentation produced by this part of the meeting includes a Research Document summarising the available information on these species and Proceedings documenting discussions at the meeting.

A detailed description of the information to be produced for each species follows. In addition, information that can be made available on life history and ecological characteristics will be reviewed for each species to allow a general assessment of the resilience or general vulnerability of the species. Therefore, the following information will be reviewed to the extent that it is available:

Life history characteristics—

- Growth parameters : age and/or length at maturity, maximum age and/or length
- Fecundity
- Early life history pattern (e.g. duration of planktonic larval life, and major egg, larval, and juvenile transport mechanisms)
- Specialised niche or habitat requirements

For all species:

1. **Review the population structure—** see COSEWIC 2004 "Guidelines for Recognizing Designatable Units below the Species Level" (attached).

2. By stock, by Ocean Region (i.e. Atlantic, Pacific, Arctic), for species in Canada as a whole, and for ESUs identified in 1 (if on a scale finer than stocks), and using information in the most recent assessments:

COSEWIC Criterion— **Declining Total Population**

a. Summarize overall trends in population size (both number of mature individuals and total numbers in the population) over as long a period as possible and in particular for the past three generations (taken as mean age of spawners). Additionally, present data on a scale appropriate to the data to clarify the rate of decline. **Calculate rate of decline over last 10 years or three generations, whichever is greater.**

b. **Identify threats to abundance**— where declines have occurred over the past three generations, summarize the degree to which the causes of the declines are understood, and the evidence that the declines are a result of natural variability, habitat loss, fishing, or other human activity

c. Where declines have occurred over the past three generations, summarize the evidence that the declines have ceased, are reversible, and the likely time scales for reversibility.

COSEWIC Criterion— <u>Small Distribution and Decline or Fluctuation</u>: by stock, for species in Canada as a whole and for ESUs identified in 1 (if on a scale finer than stocks) and using information in the most recent assessments:

a. Summarise the current extent of occurrence (in km^2) in Canadian waters
b. Summarise the current area of occupancy (in km^2) in Canadian waters
c. Summarise changes in extent of occurrence and area of occupancy over as long a time as possible, and in particular, over the past three generations.
d. Summarise any evidence that there have been changes in the degree of fragmentation of the overall population, or a reduction in the number of meta-population units.
e. Summarise the proportion of the population that resides in Canadian waters, migration patterns (if any), and known breeding areas.

COSEWIC Criterion— <u>Small Total Population Size and Decline</u> and <u>Very Small and Restricted</u>: by stock, for species in Canada as a whole and for ESUs identified in 1 (if on a scale finer than stocks), and using information in the most recent assessments:

a. Tabulate the best scientific estimates of the number of mature individuals;
b. If there are likely to be fewer than 10,000 mature individuals, summarize trends in numbers of mature individuals over the past 10 years or three generations, and, to the extent possible, causes for the trends.

3. Summarise the options for combining surveys to provide an assessment of status, and the caveats and uncertainties associated with each option.

4. For transboundary stocks, summarise the status of the population(s) outside of Canadian waters. State whether rescue from outside populations is likely.

As time allows, review status and trends in other indicators of the status of each of the species that would be relevant to evaluating the risk of extinction of the species. This includes the likelihood of imminent or continuing decline in the abundance or distribution of the species, or that would otherwise be of value in preparation of COSEWIC Status Reports.

D. Documentation

The meeting will produce the following documentation:

1. At least one Research Document for each of the species to be considered, summarising the overall status of the species and the data and information held by DFO which could be used by COSEWIC in making status designations. These Research Documents will cover the information called for in the Terms of Reference above.

2. Proceedings summarising the decisions, recommendations, and major points of discussion at the meeting, including a reflection of the diversity of opinion present in the discussions.

APPENDIX 2. Canary rockfish catch statistics

Table 1. Catches (t) of canary rockfish by trawl gear (1967-2004).

	4B							
	Bottom Trawl			Midwater trawl				Total
Year	Can landed	US landed	Can discarded	Can landed	Can discarded	J/V	N/S	
1967	0.4	-				-	-	0.4
1968	0.0	-				-	-	0.0
1969	1.1	-				-	-	1.1
1970	1.7	-				-	-	1.7
1971	0.8	-				-	-	0.8
1972	0.1	-				-	-	0.1
1973	0.0	-				-	-	0.0
1974	2.3	-				-	-	2.3
1975	2.1	-				-	-	2.1
1976	tr.	-				-	-	0.0
1977	0.4	-				-	-	0.4
1978	0.1	-				-	-	0.1
1979	0.6	-				-	-	0.6
1980	0.0	-				-	-	0.0
1981	0.3	-				-	-	0.3
1982	0.5	-				-	-	0.5
1983	tr.	-				-	-	0.0
1984	0.6	-				-	-	0.6
1985	0.0	-				-	-	0.0
1986	0.1	-				-	-	0.1
1987	0.0	-				-	-	0.0
1988	tr.	-				0.0	0.0	0.0
1989	tr.	-				0.0	0.0	0.0
1990	0.0	-				0.0	0.0	0.0
1991	tr.	-				0.0	0.0	0.0
1992	0.9	-				0.0	-	0.9
1993	0.0	-		tr.		0.0	-	0.0
1994	tr.	-		tr.		0.0	-	0.0
1995	tr.	-		tr.		0.0	-	0.0
1996	tr.	-	tr.	0.0	0.0	0.0	-	0.0
1997	0.0	-	0.0	0.0	0.0	0.0	-	0.0
1998	0.0	-	0.0	0.0	0.0	0.0	-	0.0
1999	0.0	-	0.0	0.0	0.0	0.0	-	0.0
2000	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
2001	tr.	-	0.0	0.0	0.0	0.0	-	0.0
2002	tr.	-	0.0	0.0	tr.	-	-	0.0
2003	0.0	-	tr.	0.0	0.0	-	-	0.0
2004	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0

Notes:

- Can landed: 1967-1995 GFCatch; 1996-2004 PacharvTrawl (“Official” resolved catch). Calendar year until 1995. 1996 contains Jan-Mar 1997. Fishing year (Apr-Mar) from 1997-2004.
- US landed: 1967-1979 Tagart & Kimura; 1980-1982 are amounts from Stanley 1999.
- Can discarded: 1996-2004 PacharvTrawl. Calendar year until 1995. 1996 contains Jan-Mar 1997. Fishing year (Apr-Mar) from 1997-2004.
- J/V: only available from 1988, by calendar year but fishery generally occurs May-Sep (GFBio).
- N/S: occurred in 1988-1991, 2000, 2004, by calendar year but fishery generally occurs May-Sep (GFBio).
- Shrimp trawl: no records of canary or other rockfish; used excluders since 2000.

Table 1 continued.

	3C							
	Bottom Trawl			Midwater trawl				Total
Year	Can landed	US landed	Can discarded	Can landed	Can discarded	J/V	N/S	
1967	6.2	219.2				-	-	225.4
1968	4.0	323.3				-	-	327.3
1969	4.4	145.0				-	-	149.4
1970	5.6	166.6				-	-	172.2
1971	51.7	347.1				-	-	398.8
1972	0.2	97.5				-	-	97.7
1973	0.0	46.5				-	-	46.5
1974	9.9	26.8				-	-	36.7
1975	6.7	205.0				-	-	211.7
1976	55.2	208.3				-	-	263.5
1977	99.6	135.8				-	-	235.4
1978	14.5	202.4				-	-	216.9
1979	32.5	63.8				-	-	96.3
1980	17.7	-				-	-	17.7
1981	12.1	-				-	-	12.1
1982	40.8	-				-	-	40.8
1983	151.0	-				-	-	151.0
1984	307.2	-				-	-	307.2
1985	177.3	-				-	-	177.3
1986	200.9	-		0.3		-	-	201.2
1987	215.7	-		2.3		-	-	218.0
1988	480.9	-				0.1	5.8	486.8
1989	435.4	-		1.4		1.3	8.4	446.5
1990	226.9	-		4.2		1.6	tr.	232.7
1991	166.1	-		2.7		2.4	0.4	171.6
1992	296.3	-		4.7		1.3	-	302.3
1993	244.5	-		tr.		3.3	-	247.8
1994	212.3	-		3.2		14.7	-	230.2
1995	171.5	-		2.5		2.5	-	176.5
1996	148.3	-	2.7	1.0	tr.	4.3	-	156.3
1997	113.5	-	1.7	0.3	tr.	1.7	-	117.2
1998	73.4	-	0.4	7.7	0.0	2.2	-	83.7
1999	92.3	-	0.8	3.1	0.0	1.0	-	97.2
2000	90.8	-	0.2	0.8	0.0	0.5	tr.	92.3
2001	137.2	-	0.6	1.3	0.1	2.0	-	141.2
2002	117.9	-	0.3	5.8	tr.	-	-	124.0
2003	166.3	-	0.5	6.6	tr.	-	-	173.4
2004	111.5	-	0.2	10.2	tr.	0.9	0.0	122.8

Table 1 continued.

	3D								US 3C+3D
	Bottom Trawl			Midwater trawl				Total	from Stanley
Year	Can landed	US landed	Can discard	Can landed	Can discarde	J/V	N/S		
1967	3.9	351.9				-	-	355.8	
1968	18.7	502.1				-	-	520.8	
1969	46.1	597.4				-	-	643.5	
1970	17.8	713.1				-	-	730.9	
1971	14.5	524.5				-	-	539.0	
1972	0.0	192.9				-	-	192.9	
1973	0.0	443.3				-	-	443.3	
1974	16.3	577.7				-	-	594.0	
1975	7.0	452.6				-	-	459.6	
1976	137.6	186.9				-	-	324.5	
1977	96.5	222.2				-	-	318.7	
1978	53.0	860.6		1.1		-	-	914.7	
1979	100.4	250.7				-	-	351.1	
1980	107.5	-				-	-	107.5	477.0
1981	50.7	-				-	-	50.7	249.0
1982	215.0	-				-	-	215.0	133.0
1983	694.9	-				-	-	694.9	
1984	882.4	-				-	-	882.4	
1985	726.9	-				-	-	726.9	
1986	462.1	-		57.4		-	-	519.5	
1987	415.2	-		94.2		-	-	509.4	
1988	543.7	-		31.4			tr.	575.1	
1989	704.6	-		16.7		tr.	3.1	724.4	
1990	502.5	-		30.4		1.2	0.3	534.4	
1991	470.8	-		8.3		0.1	0.1	479.3	
1992	450.1	-		16.2		0.0	-	466.3	
1993	553.6	-		25.9		0.1	-	579.6	
1994	512.8	-		36.9		0.3	-	550.0	
1995	423.5	-		25.2		0.0	-	448.7	
1996	265.3	-	0.9	50.6	0.4	0.0	-	317.2	
1997	233.2	-	3.4	82.5	2.4	0.0	-	321.5	
1998	254.7	-	0.8	81.7	0.4	0.0	-	337.6	
1999	293.4	-	0.3	151.6	0.4	0.0	-	445.7	
2000	273.2	-	0.4	89.2	4.6	0.0	0.0	367.4	
2001	313.7	-	2.6	34.7	0.0	0.0	-	351.0	
2002	393.9	-	0.8	47.8	tr.	-	-	442.5	
2003	284.3	-	0.3	45.1	tr.	-	-	329.7	
2004	357.2	-	0.3	35.7	0.1	0.0	-	393.3	

Table 1 continued.

				5A				
	Bottom Trawl			Midwater trawl				Total
Year	Can landed	US landed	Can Discarded	Can landed	Can discarded	J/V	N/S	
1967	29.5	88.1	-		-	-	-	117.6
1968	44.9	607.0	-		-	-	-	651.9
1969	58.4	355.0	-		-	-	-	413.4
1970	3.0	90.2	-		-	-	-	93.2
1971	11.7	35.5	-		-	-	-	47.2
1972	0.4	33.5	-		-	-	-	33.9
1973	17.5	113.5	-		-	-	-	131.0
1974	2.7	180.1	-		-	-	-	182.8
1975	2.8	4.7	-		-	-	-	7.5
1976	20.1	208.3	-		-	-	-	228.4
1977	23.5	60.0	-		-	-	-	83.5
1978	106.3	8.1	-	2.3	-	-	-	116.7
1979	48.5	18.8	-	0.0	-	-	-	67.3
1980	20.3	-	-	0.0	-	-	-	20.3
1981	46.0	-	-	0.0	-	-	-	46.0
1982	158.6	-	-	0.0	-	-	-	158.6
1983	119.3	-	-	0.0	-	-	-	119.3
1984	215.6	-	-	0.0	-	-	-	215.6
1985	140.6	-	-	0.0	-	-	-	140.6
1986	96.2	-	-	0.0	-	-	-	96.2
1987	181.3	-	-	0.2	-	-	-	181.5
1988	186.5	-	-	0.0	-		0.0	186.5
1989	137.9	-	-	0.2	-	0.0	0.0	138.1
1990	164.8	-	-	1.8	-	0.0	0.0	166.6
1991	204.3	-	-	0.4	-	0.0	0.0	204.7
1992	212.2	-	-	3.0	-	0.0	-	215.2
1993	80.6	-	-	2.2	-	0.0	-	82.8
1994	101.4	-	-	4.0	-	0.0	-	105.4
1995	66.0	-	-	2.7	-	0.0	-	68.7
1996	53.8	-	0.2	5.5	0.0	0.0	-	59.5
1997	75.7	-	0.3	1.4	0.0	0.0	-	77.4
1998	146.0	-	0.3	5.6	0.0	0.0	-	151.9
1999	105.5	-	0.2	2.9	tr.	0.0	-	108.6
2000	66.8	-	0.1	4.7	0.0	0.1	0.0	71.7
2001	78.1	-	0.5	7.4	tr.	0.0	-	86.0
2002	77.7	-	0.9	17.8	tr.	-	-	96.4
2003	72.3	-	0.3	10.3	0.2	-	-	83.1
2004	92.3	-	0.1	7.6	0.0	0.0	-	100.0

Table 1 continued.

	5B								US 5A+5B
	Bottom Trawl			Midwater trawl				Total	from Stanley
Year	Can landed	US landed	Can discarded	Can landed	Can discarded	J/V	N/S		
1967	8.8	126.5	-		-	-	-	135.3	
1968	1.9	330.3	-		-	-	-	332.2	
1969	8.5	63.4	-		-	-	-	71.9	
1970	3.2	129.4	-		-	-	-	132.6	
1971	6.5	147.0	-		-	-	-	153.5	
1972	0.0	27.6	-		-	-	-	27.6	
1973	11.6	184.1	-		-	-	-	195.7	
1974	0.5	77.4	-		-	-	-	77.9	
1975	20.0	184.0	-		-	-	-	204.0	
1976	71.8	238.4	-		-	-	-	310.2	
1977	95.7	228.0	-	1.9	-	-	-	325.6	
1978	154.1	0.0	-	0.0	-	-	-	154.1	
1979	230.0	43.3	-	tr.	-	-	-	273.3	
1980	257.1	-	-	0.0	-	-	-	257.1	88.0
1981	138.7	-	-	0.0	-	-	-	138.7	
1982	200.8	-	-	0.0	-	-	-	200.8	
1983	240.8	-	-	0.2	-	-	-	241.0	
1984	297.7	-	-	0.0	-	-	-	297.7	
1985	254.3	-	-	0.0	-	-	-	254.3	
1986	183.8	-	-	0.0	-	-	-	183.8	
1987	381.8	-	-	0.0	-	-	-	381.8	
1988	391.5	-	-	7.7	-		0.0	399.2	
1989	337.9	-	-	26.3	-	0.0	0.0	364.2	
1990	428.6	-	-	5.9	-	0.0	0.0	434.5	
1991	312.3	-	-	0.7	-	0.0	0.0	313.0	
1992	265.0	-	-	tr.	-	0.0	-	265.0	
1993	107.4	-	-	0.8	-	0.0	-	108.2	
1994	188.5	-	-	0.0	-	0.0	-	188.5	
1995	101.8	-	-	1.0	-	0.0	-	102.8	
1996	81.4	-	6.9	1.9	0.1	0.0	-	90.3	
1997	109.6	-	1.3	1.6	0.0	0.0	-	112.5	
1998	135.6	-	0.2	0.7	0.0	0.0	-	136.5	
1999	204.9	-	0.4	0.7	0.0	0.0	-	206.0	
2000	143.2	-	1.2	0.1	0.0	tr.	0.0	144.5	
2001	134.5	-	0.2	2.3	tr.	0.0	-	137.0	
2002	134.2	-	0.1	5.5	0.0	-	-	139.8	
2003	143.5	-	tr.	13.3	0.0	-	-	156.8	
2004	91.6	-	0.1	tr.	0.0	0.0	-	91.7	

Table 1 continued.

	5C							
	Bottom Trawl			Midwater trawl				Total
Year	Can landed	US landed	Can discarded	Can landed	Can discarded	J/V	N/S	
1967	0.0	-				-	-	0.0
1968	0.7	-				-	-	0.7
1969	4.0	-				-	-	4.0
1970	0.3	-				-	-	0.3
1971	0.2	-				-	-	0.2
1972	0.4	-				-	-	0.4
1973	0.0	-				-	-	0.0
1974	tr.	-				-	-	0.0
1975	0.0	-				-	-	0.0
1976	0.9	-		1.9		-	-	2.8
1977	6.9	-		0.0		-	-	6.9
1978	93.3	-		0.0		-	-	93.3
1979	115.8	-		0.0		-	-	115.8
1980	202.1	-		0.0		-	-	202.1
1981	115.9	-		0.0		-	-	115.9
1982	57.0	-		0.0		-	-	57.0
1983	114.9	-		0.0		-	-	114.9
1984	68.9	-		0.0		-	-	68.9
1985	187.1	-		0.0		-	-	187.1
1986	44.1	-		0.0		-	-	44.1
1987	90.8	-		0.0		-	-	90.8
1988	79.8	-		0.0			0.0	79.8
1989	111.3	-		0.0		0.0	0.0	111.3
1990	134.8	-		0.0		0.0	0.0	134.8
1991	113.8	-		0.0		0.0	0.0	113.8
1992	107.1	-		0.0		0.0	-	107.1
1993	52.2	-		0.0		0.0	-	52.2
1994	102.8	-		0.0		0.0	-	102.8
1995	53.9	-		tr.		0.0	-	53.9
1996	53.2	-	0.1	tr.	0.0	0.0	-	53.3
1997	34.5	-	0.4	tr.	0.0	0.0	-	34.9
1998	39.3	-	1.2	0.0	0.0	0.0	-	40.5
1999	33.8	-	0.1	tr.	0.0	0.0	-	33.9
2000	70.1	-	0.1	0.0	0.0	0.0	0.0	70.2
2001	70.1	-	0.1	0.0	0.0	0.0	-	70.2
2002	62.5	-	tr.	tr.	0.0	-	-	62.5
2003	68.8	-	tr.	0.0	0.0	-	-	68.8
2004	59.4	-	0.2	tr.	0.0	0.0	-	59.6

Table 1 continued.

	5D							
	Bottom Trawl			Midwater trawl				Total
Year	Can landed	US landed	Can discarded	Can landed	Can discarded	J/V	N/S	
1967	6.1	-	-		-	-	-	6.1
1968	0.0	-	-		-	-	-	0.0
1969	1.4	-	-		-	-	-	1.4
1970	19.1	-	-		-	-	-	19.1
1971	27.1	-	-		-	-	-	27.1
1972	1.5	-	-		-	-	-	1.5
1973	8.1	-	-		-	-	-	8.1
1974	0.0	-	-		-	-	-	0.0
1975	1.2	-	-		-	-	-	1.2
1976	4.8	-	-		-	-	-	4.8
1977	8.5	-	-		-	-	-	8.5
1978	7.6	-	-	0.6	-	-	-	8.2
1979	9.2	-	-	tr.	-	-	-	9.2
1980	3.1	-	-	0.0	-	-	-	3.1
1981	11.3	-	-	0.0	-	-	-	11.3
1982	2.6	-	-	0.0	-	-	-	2.6
1983	4.0	-	-	0.0	-	-	-	4.0
1984	4.7	-	-	0.0	-	-	-	4.7
1985	3.3	-	-	0.0	-	-	-	3.3
1986	0.4	-	-	0.0	-	-	-	0.4
1987	12.1	-	-	0.0	-	-	-	12.1
1988	3.8	-	-	0.0	-		0.0	3.8
1989	10.7	-	-	0.0	-	0.0	0.0	10.7
1990	18.9	-	-	0.0	-	0.0	0.0	18.9
1991	39.0	-	-	1.5	-	0.0	0.0	40.5
1992	18.4	-	-	0.0	-	0.0	-	18.4
1993	21.3	-	-	0.3	-	0.0	-	21.6
1994	9.1	-	-	0.1	-	0.0	-	9.2
1995	6.2	-	-	0.2	-	0.0	-	6.4
1996	15.3	-	0.1	0.1	0.0	0.0	-	15.5
1997	6.5	-	0.1	0.1	0.0	0.0	-	6.7
1998	3.1	-	0.1	tr.	0.0	0.0	-	3.2
1999	8.0	-	0.1	tr.	0.0	0.0	-	8.1
2000	8.5	-	tr.	tr.	0.0	0.0	0.0	8.5
2001	2.8	-	tr.	tr.	0.0	0.0	-	2.8
2002	1.8	-	tr.	tr.	0.0	-	-	1.8
2003	2.3	-	tr.	0.3	0.0	-	-	2.6
2004	5.6	-	0.1	0.5	0.0	0.0	-	6.2

Table 1 continued.

	5E							
	Bottom Trawl			Midwater trawl				Total
Year	Can landed	US landed	Can discarded	Can landed	Can discarded	J/V	N/S	
1967	0.0	-	-		-	-	-	0.0
1968	0.0	-	-		-	-	-	0.0
1969	0.0	-	-		-	-	-	0.0
1970	0.0	-	-		-	-	-	0.0
1971	0.0	-	-		-	-	-	0.0
1972	0.0	-	-		-	-	-	0.0
1973	0.0	-	-		-	-	-	0.0
1974	0.0	-	-		-	-	-	0.0
1975	0.0	-	-		-	-	-	0.0
1976	0.0	-	-	0.0	-	-	-	0.0
1977	0.6	-	-	0.0	-	-	-	0.6
1978	8.3	-	-	0.0	-	-	-	8.3
1979	0.4	-	-	0.1	-	-	-	0.5
1980	0.5	-	-	0.0	-	-	-	0.5
1981	2.4	-	-	0.0	-	-	-	2.4
1982	18.3	-	-	0.0	-	-	-	18.3
1983	10.4	-	-	0.0	-	-	-	10.4
1984	12.7	-	-	0.0	-	-	-	12.7
1985	9.4	-	-	0.0	-	-	-	9.4
1986	110.5	-	-	0.0	-	-	-	110.5
1987	12.6	-	-	0.0	-	-	-	12.6
1988	79.1	-	-	0.0	-		0.0	79.1
1989	19.5	-	-	0.0	-	0.0	0.0	19.5
1990	64.3	-	-	0.1	-	0.0	0.0	64.4
1991	29.0	-	-	0.0	-	0.0	0.0	29.0
1992	26.3	-	-	0.0	-	0.0	-	26.3
1993	21.7	-	-	tr.	-	0.0	-	21.7
1994	7.7	-	-	0.0	-	0.0	-	7.7
1995	3.5	-	-	tr.	-	0.0	-	3.5
1996	10.1	-	tr.	0.5	0.0	0.0	-	10.6
1997	19.6	-	0.5	0.0	0.0	0.0	-	20.1
1998	2.5	-	0.0	0.0	0.0	0.0	-	2.5
1999	7.0	-	0.1	0.1	0.0	0.0	-	7.2
2000	14.2	-	tr.	0.4	0.0	0.3	0.6	15.5
2001	2.0	-	0.0	0.0	0.0	0.0	-	2.0
2002	3.1	-	0.0	0.1	0.0	-	-	3.2
2003	18.5	-	tr.	0.1	0.0	-	-	18.6
2004	3.9	-	0.0	tr.	0.0	0.0	-	3.9

Table 1 continued.

	5U		
	Unknown trawl		Total
Year	Can landed	Can discarded	
1967	0.0	-	0.0
1968	0.0	-	0.0
1969	0.0	-	0.0
1970	0.0	-	0.0
1971	0.0	-	0.0
1972	0.0	-	0.0
1973	0.0	-	0.0
1974	0.0	-	0.0
1975	0.0	-	0.0
1976	0.0	-	0.0
1977	0.0	-	0.0
1978	0.0	-	0.0
1979	0.0	-	0.0
1980	0.0	-	0.0
1981	0.0	-	0.0
1982	0.0	-	0.0
1983	0.0	-	0.0
1984	0.0	-	0.0
1985	0.0	-	0.0
1986	0.0	-	0.0
1987	0.0	-	0.0
1988	0.0	-	0.0
1989	0.0	-	0.0
1990	0.0	-	0.0
1991	0.0	-	0.0
1992	0.0	-	0.0
1993	0.0	-	0.0
1994	0.0	-	0.0
1995	0.0	-	0.0
1996	tr.	0.0	0.0
1997	0.2	0.0	0.2
1998	0.0	0.0	0.0
1999	0.0	0.0	0.0
2000	tr.	0.0	0.0
2001	2.2	0.0	2.2
2002	0.0	0.0	0.0
2003	0.0	0.0	0.0
2004	0.0	0.0	0.0

Table 2. Landings (t) of canary rockfish from the dockside monitoring program (1995-2004).

	4B				3C			
Year	ZN LL Landed[1]	Troll[2]	Halibut Landed[3]	Total	ZN LL Landed	Troll	Halibut Landed	Total
1995	0.3		tr.	0.3	1.8		tr.	1.8
1996	0.2	0.0	tr.	0.2	3.0	0.0	tr.	3.0
1997	0.7	0.0	0.0	0.7	1.2	0.0	tr.	1.2
1998	0.2	0.0	tr.	0.2	2.9	0.0	tr.	2.9
1999	0.5	0.0	tr.	0.5	1.6	0.3	0.1	1.6
2000	1.0	0.0	tr.	1.0	4.1	tr.	-	4.1
2001	1.2	0.0	tr.	1.2	4.0	1.1	-	4.0
2002	0.1	0.0	0.0	0.1	1.7	0.6	-	1.7
2003	0.8	0.0	0.0	0.8	1.6	8.6	-	1.6
2004	0.2	0.0	tr.	0.2	0.8	2.3	-	0.8

	3D				WC	5A			
Year	ZN LL Landed	Troll	Halibut Landed	Total	Halibut Landed	ZN LL Landed	Troll	Halibut Landed	Total
1995	7.3		tr.	7.3		12.8		tr.	12.8
1996	17.4	0.0	tr.	17.4		7.5	0.0	0.1	7.5
1997	8.7	0.0	tr.	8.7		5.5	0.0	0.1	5.5
1998	18.5	0.0	0.3	18.5		10.6	0.0	0.4	10.6
1999	29.4	0.9	0.7	29.4		6.1	0.0	0.3	6.1
2000	12.9	0.1	-	12.9	2.1	6.8	0.0	-	6.8
2001	5.9	tr.	-	5.9	3.4	11.7	0.0	-	11.7
2002	2.9	4.0	-	2.9	5.4	3.2	0.1	-	3.2
2003	1.6	7.1	-	1.6	7.6	6.8	tr.	-	6.8
2004	1.8	8.5	-	1.8	5.9	11.2	0.4	-	11.2

	5B				CC	5C			
Year	ZN LL Landed	Troll	Halibut Landed	Total	Halibut Landed	ZN LL Landed	Troll	Halibut Landed	Total
1995	1.7		0.1	1.7		4.3		0.1	4.3
1996	2.4	0.0	0.4	2.4		3.2	0.0	0.3	3.2
1997	2.9	0.0	0.2	2.9		3.3	0.0	0.2	3.3
1998	2.9	0.0	0.3	2.9		4.8	0.0	0.4	4.8
1999	3.4	0.0	1.0	3.4		3.0	0.0	0.2	3.0
2000	3.2	0.0	-	3.2	0.5	0.3	0.0	-	0.3
2001	3.1	tr.	-	3.1	0.8	1.9	0.2	-	1.9
2002	1.4	0.0	-	1.4	1.2	1.4	0.0	-	1.4
2003	1.5	0.0	-	1.5	1.8	0.2	0.0	-	0.2
2004	2.1	0.0	-	2.1	0.9	1.2	0.0	-	1.2

Notes:

- 1ZN landed: from D_Official_Catch. Calendar year 1995-1996. 1997 from Jan 1/97 to Mar 31/98. Fishing year (Mar-Apr) 1998-2004.
- 2Troll: from Pacharv3 (Regional Data Unit). Calendar year 1996-2004, incidental to salmon fishery.
- 3Halibut landed: from DMP. Calendar year 1995-2004. 1995-1999 reported by PFMA, 2000-2004 reported by rockfish management regions.
- Rockfish Mgmt Regions: SG included with 4B, NC included with 5D. WC, CC and QC are separate columns.

Table 2 continued.

	5D				5E				QC
Year	ZN LL Landed	Troll	Halibut Landed	Total	ZN LL Landed	Troll	Halibut Landed	Total	Halibut Landed
1995	1.2		tr.	1.2	5.5		tr.	5.5	
1996	1.0	tr.	0.1	1.0	10.7	0.0	0.4	10.7	
1997	1.1	0.0	0.1	1.1	8.7	0.0	0.3	8.7	
1998	0.7	tr.	0.6	0.7	17.9	0.0	1.0	17.9	
1999	1.7	0.0	0.4	1.7	11.9	0.0	0.9	11.9	
2000	1.2	0.0	0.1	1.2	7.3	0.0	-	7.3	4.1
2001	2.1	0.1	0.1	2.1	10.7	0.9	-	10.7	7.0
2002	1.5	2.3	0.2	1.5	0.2	0.7	-	0.2	5.5
2003	1.0	1.7	0.2	1.0	0.1	1.1	-	0.1	5.5
2004	0.5	2.4	0.1	0.5	0.1	1.0	-	0.1	5.7

	Unknown area				All areas			
Year	ZN LL Landed	Troll	Halibut Landed	Total	ZN LL Landed	Troll	Halibut Landed	Total
1995	26.2		0.0	26.2	61.1	0.0	0.2	61.3
1996	11.3	0.0	0.0	11.3	56.7	0.0	1.3	58.0
1997	22.6	0.0	tr.	22.6	54.7	0.0	0.9	55.6
1998	17.9	0.0	0.0	17.9	76.4	0.0	3.0	79.4
1999	6.9	0.0	0.0	6.9	64.5	1.2	3.6	69.3
2000	6.2	0.0	tr.	6.2	43.0	0.1	6.8	49.9
2001	2.4	0.1	0.0	2.4	43.0	2.4	11.3	56.7
2002	1.2	0.0	0.0	1.2	13.6	7.7	12.3	33.6
2003	2.3	0.0	0.0	2.3	15.9	18.5	15.1	49.5
2004	0.8	0.0	0.0	0.8	18.7	14.6	12.6	45.9

Table 3. Recreational creel estimates of number of boat trips and captures by piece (kept + released) of canary rockfish and all rockfish (pieces) from the Strait of Georgia.

Year	Boat Trips	Canary Rockfish	All Rockfish
1986	540,208	502	285,603
1987	516,329	2,811	220,802
1988	649,762	1,967	337,731
1989	556,950	990	314,260
1990	523,269	2,264	314,549
1991	452,052	327	252,135
1992	447,522	162	219,457
1993	490,965	11	200,222
1994	462,847	2,520	282,761
1995	333,198	1,292	177,740
1996	290,857	1,064	155,157
1997	267,901	729	142,882
1998	162,909	209	122,577
1999	205,276	2,290	113,513
2000	251,153	681	100,879
2001	275,371	2,681	120,481
2002	289,557	222	69,185
2003	275,211	438	45,913
2004	236,769	266	39,200

Table 4. Observed bycatch (pieces) of canary rockfish and all rockfish in the south coast troll fisheries.

Canary rockfish

Area G West coast Vancouver Island

Year	Fishing Days	Observed # canary rf	% observer coverage	# Observed days	Catch rate canary rf	Expanded catch
1998	2245	0	8	179.6	0.0	0
1999	1609	225	2	32.2	7.0	11250
2000	1762	5	7	123.3	0.0	71
2001	2560	10	7	179.2	0.1	143

Area H Strait of Georgia

Year	Fishing Days	Observed # canary rf	% observer coverage	# Observed days	Catch rate canary rf	Expanded catch
1998	1054	4	8	84.3	0.0	50
1999	245	0	5	12.3	0.0	0
2000	1114	0	5	55.7	0.0	0
2001	1067	0	5	53.4	0.0	0

Troll Area G + Area H combined

Year	Fishing Days	Observed # canary rf	% observer coverage	# Observed days	Catch rate canary rf	Expanded catch
1998	3299	4	8	263.9	0.0	50
1999	1854	225	2	37.1	6.1	11250
2000	2876	5	6	172.6	0.0	83
2001	3627	10	6	217.6	0.0	167

All rockfish

Area (West coast Vancouver Island

Year	Fishing Days	Observed # all rf	% observer coverage	# Observed days	Catch rate all rf	Expanded catch
1998	2245	18	8	179.6	0.1	225
1999	1609	580	2	32.2	18.0	29000
2000	1762	264	7	123.3	2.1	3771
2001	2560	354	7	179.2	2.0	5057

Area I Strait of Georgia

Year	Fishing Days	Observed # all rf	% observer coverage	# Observed days	Catch rate all rf	Expanded catch
1998	1054	284	8	84.3	3.4	3550
1999	245	11	5	12.3	0.9	220
2000	1114	252	5	55.7	4.5	5040
2001	1067	162	5	53.4	3.0	3240

Troll Area G + Area H combined

Year	Fishing Days	Observed # all rf	% observer coverage	# Observed days	Catch rate all rf	Expanded catch
1998	3299	302	8	263.9	1.1	3775
1999	1854	591	2	37.1	15.9	29550
2000	2876	516	6	172.6	3.0	8600
2001	3627	516	6	217.6	2.4	8600

APPENDIX 3. U.S. Triennial Survey

Introduction and Data

Tow-by-tow data from the U.S. triennial survey covering the Vancouver INPFC region were provided by the U.S. National Marine Fisheries Service (NMFS) (Marl Wilkins, pers. comm.) for the seven years that surveyed Canadian waters (Figure 1; Table 1). These tows are assigned to strata by the NMFS but the size and definition of these strata have changed over the life of the survey (Table 2). The NMFS also provided information in which country each tow was located. This information was plotted and checked against the accepted US/Canada marine boundary: all tows appeared to be appropriately located with respect to country, based on the tow start position (Figure 1). The NMFS designations were accepted for tows located near the marine border.

Table 1. Number of tows by stratum and by survey year for the U.S. triennial survey. Strata which are coloured grey have been excluded from the analysis due to incomplete coverage across the seven survey years or to locations outside of the Vancouver INPFC area (Table 2).

Stratum No.	1980		1983		1989		1992		1995		1998		2001	
	Can.	US	Can.	US	Can.	US	Can.	US	Can.	US	Can.	US	Can.	US
10		17		7										
11	48			39										
12			38											
17N						8		9		8		8		8
17S						27		27		25		26		25
18N					1		1							
18S						32		23		12		20		14
19N					58		53		55		48		33	
19S						4		6		3		3		3
27N						2		1		2		2		2
27S						5		2		3		4		5
28N					1		1		2		1			
28S						6		9		7		6		7
29N					7		6		7		6		3	
29S						3		2		3		3		3
30		4		2										
31	7			11										
32			5											
37N										1		1		1
37S										2		1		1
38N									1					
38S										2				3
39									6		4		2	
50		5		1										
51	4			10										
52			4											
Total	59	26	47	70	67	87	61	79	71	68	59	74	38	72

All usable tows have an associated net width and distance traveled, allowing for the calculation of the area swept by the tow. Biomass indices and the associated analytical CVs for canary rockfish were calculated for the total Vancouver INPFC region and for each of the Canadian and Vancouver sub-regions, using appropriate area estimates for each stratum and year (Table 2). Strata that were not surveyed consistently in all seven years of the survey were dropped from the analysis (Table 2), allowing the remaining data to provide a comparable set of data for each year from 1989 onwards (Table 3). The strata definitions used in the 1980 and

1983 surveys were considerably different than those used in subsequent surveys, particularly in Canadian waters (Table 3). Therefore, the 1980 and 1983 indices were scaled up by the ratio (1.24=9169 km2/7399 km2) of the total stratum areas relative to the 1989 and later surveys so that the coverage from the first two surveys would be comparable to the surveys conducted from 1989 onwards. The tow density was much higher in the U.S. waters although the overall number of tows was approximately the same for each country (Table 3). This is because the size of the total area fished was about twice as large in Canadian waters than in U.S. waters (Table 3).

Table 2. Stratum definitions by year used in the U.S. triennial survey to separate out the survey results by country and by INPFC area. Stratum definitions in grey are those strata which have been excluded from the final analysis due to incomplete coverage across the seven survey years or to locations outside of the Vancouver INPFC area.

Year	**Stratum No.**	**Area (km^2)**	**Start**	**End**	**Country**	**INPFC area**	Depth range
1980	10	3537	47°30	US-Can Border	US	Vancouver	55-183 m
1980	11	6572	US-Can Border	49°15	Can.	Vancouver	55-183 m
1980	30	443	47°30	US-Can Border	US	Vancouver	184-219 m
1980	31	325	US-Can Border	49°15	Can.	Vancouver	184-219 m
1980	50	758	47°30	US-Can Border	US	Vancouver	220-366 m
1980	51	503	US-Can Border	49°15	Can.	Vancouver	220-366 m
1983	10	1307	47°30	47°55	US	Vancouver	55-183 m
1983	11	2230	47°55	US-Can Border	US	Vancouver	55-183 m
1983	12	6572	US-Can Border	49°15	Can.	Vancouver	55-183 m
1983	30	66	47°30	47°55	US	Vancouver	184-219 m
1983	31	377	47°55	US-Can Border	US	Vancouver	184-219 m
1983	32	325	US-Can Border	49°15	Can.	Vancouver	184-219 m
1983	50	127	47°30	47°55	US	Vancouver	220-366 m
1983	51	631	47°55	US-Can Border	US	Vancouver	220-366 m
1983	52	503	US-Can Border	49 °15	Can.	Vancouver	220-366 m
1989&after	17N	1033	47°30	47°50	US	Vancouver	55-183 m
1989&after	17S	3378	46°30	47°30	US	Columbia	55-183 m
1989&after	18N	159	47°50	48°20	Can.	Vancouver	55-183 m
1989&after	18S	2123	47°50	48°20	US	Vancouver	55-183 m
1989&after	19N	8224	48°20	49°40	Can.	Vancouver	55-183 m
1989&after	19S	363	48°20	49°40	US	Vancouver	55-183 m
1989&after	27N	125	47°30	47°50	US	Vancouver	184-366 m
1989&after	27S	412	46°30	47°30	US	Columbia	184-366 m
1989&after	28N	88	47°50	48°20	Can.	Vancouver	184-366 m
1989&after	28S	787	47°50	48°20	US	Vancouver	184-366 m
1989&after	29N	942	48°20	49°40	Can.	Vancouver	184-366 m
1989&after	29S	270	48°20	49°40	US	Vancouver	184-366 m
1995&after	37N	102	47°30	47°50	US	Vancouver	367-500 m
1995&after	37S	218	46°30	47°30	US	Columbia	367-500 m
1995&after	38N	66	47°50	48°20	Can.	Vancouver	367-500 m
1995&after	38S	175	47°50	48°20	US	Vancouver	367-500 m

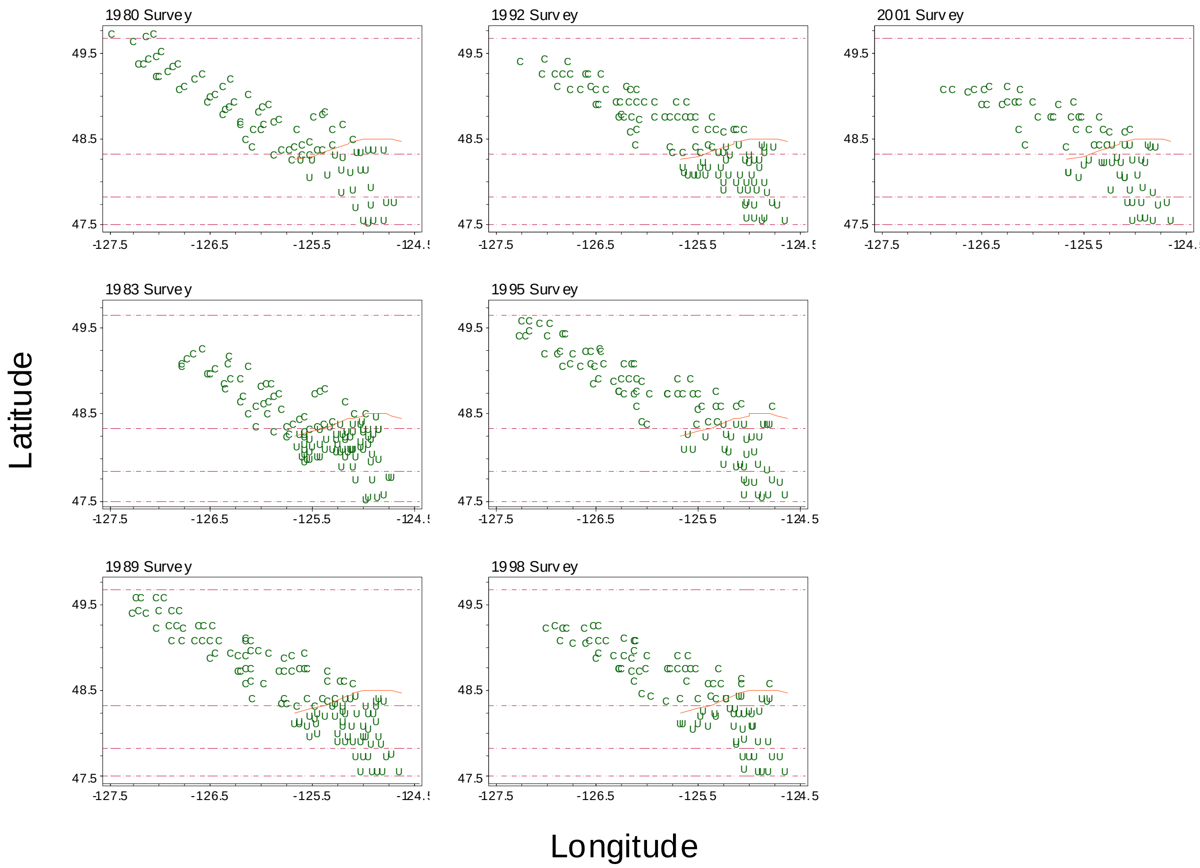


Figure 1. Plot of tow locations in the Vancouver INPFC region for each of the seven U.S. triennial surveys that surveyed Canadian waters. The approximate position of the US/Canada marine boundary is shown and each tow is coded with a “C” or a “U”, depending on to which nation the tow is assigned in the database. The horizontal lines are the stratum boundaries: 47°30’, 47°50’, 48°20’ and 49°40’.

Table 3. Number of usable tows performed and area surveyed in the INPFC Vancouver region separated by the international border between Canada and the United States. Strata 18N, 28N, 37, 38 and 39 (Table 2) were dropped from this analysis as they were not consistently conducted over the survey period. All strata occurring in the Columbia River INPFC region (17S and 27S; Table 2) were also dropped.

	Number tows			**Area surveyed (km^2)**		
Survey year	**Canadian waters**	**US waters**	**Total**	**Canadian waters**	**US waters**	**Total**
1980	59	26	85	7,399	4,738	12,137
1983	47	70	117	7,399	4,738	12,137
1989	65	55	120	9,166	4,699	13,865
1992	59	50	109	9,166	4,699	13,865
1995	62	35	97	9,166	4,699	13,865
1998	54	42	96	9,166	4,699	13,865
2001	36	37	73	9,166	4,699	13,865
Total	382	315	697	–	–	–

Methods

The data were analysed using the following equations. The biomass in any year y was obtained by summing the product of the canary rockfish CPUE and the area surveyed across the surveyed strata i:

$$B_y = \sum_{i=1}^{k_y} C_{y_i} A_{y_i} = \sum_{i=1}^{k_y} B_{y_i} \qquad \text{Eq. 1}$$

where C_{y_i} = mean CPUE density (kg/km^2) for canary rockfish in year *y* in stratum *i*

A_{y_i} = area of stratum *i* (km^2) in year *y*

k_y = number of strata in year *y*

B_{y_i} = biomass of canary rockfish in stratum *i* for year *y*

CPUE $\left(C_{y_i}\right)$ in stratum *i* for year *y* was calculated as a density in kg/km^2 by

$$C_{y_i} = \frac{\sum_{j=1}^{n_{y_i}} \left(W_{y_i j} \big/ D_{y_i j} w_{y_i j} \right)}{n_{y_i}} \qquad \text{Eq. 2}$$

where $W_{y_i j}$ = catch weight (kg) in year *y* in stratum *i* and tow *j*

$D_{y_i j}$ = distance traveled (km) in year *y* by tow *j* in stratum *i*

$w_{y_i j}$ = wingspread width (km) in year *y* for tow *j* in stratum *i*

n_{y_i} = number of tows in year *y* for stratum *i*

The variance of the survey biomass estimate V_{B_y} in year *y* is calculated in kg^2 as follows:

$$V_{B_y} = \sum_{i=1}^{k_y} \sigma_{y_i}^2 A_{y_i}^2 \big/ n_{y_i} = \sum_{i=1}^{k_y} V_{y_i} \qquad \text{Eq. 3}$$

where $\sigma_{y_i}^2$ = variance of CPUE (kg^2/km^4) for year *y* in stratum *i*

V_{y_i} = variance of canary rockfish in stratum *i* for year *y*

It was assumed that the variance and CPUE within any stratum was equal, even for strata that were split by the presence of the US/Canada border. The total biomass $\left(B_{y_i}\right)$ within a stratum which straddled the border was split between the two countries $\left(B_{y_{i_c}}\right)$ by the ratio of the relative area within each country:

$$B_{y_{i_c}} = B_{y_i} \frac{A_{y_{i_c}}}{A_{y_i}} \qquad \text{Eq. 4}$$

where $A_{y_{i_c}}$ = area (km^2) within country *c* in year *y* and stratum *i*.

The variance $V_{y_{i_c}}$ for that part of stratum *i* within country *c* was calculated as being proportional to the ratio of the square of the area within each country *c* relative to the total area of stratum *i*. This assumption resulted in the CVs within each country stratum being the same as the CV in the entire stratum:

$$V_{y_{i_c}} = V_{y_i} \frac{A^2_{y_{i_c}}}{A^2_{y_i}} \qquad \text{Eq. 5}$$

The partial variance $V_{y_{i_c}}$ for country *c* was used in Eq. 3 instead of the total variance in the stratum V_{y_i} when calculating the variance for the total biomass in U.S. or Canadian waters.

The CV for each year *y* was calculated as follows:

$$CV_s = \frac{\sqrt{V_{B_s}}}{B_s} \qquad \text{Eq. 6}$$

The biomass estimates (Eq. 1) and the associated standard errors were adjusted to a constant area covered by using the ratios of area surveyed provided in Table . This was required to adjust the Canadian biomass estimates for 1980 and 1983 to account for the smaller area surveyed in those years compared to the succeeding surveys. The biomass estimates from Canadian waters were consequently multiplied by the ratio 1.24 (=9,166/7,399) to make them equivalent to the coverage of the surveys from 1989 onwards.

Biomass estimates were bootstrapped for 5,000 random draws with replacement to obtain bias corrected 95% confidence regions for each year and for three area categories (total Vancouver region, Canadian Vancouver only and U.S. Vancouver only) based on the distribution of biomass estimates and using the above equations (Efron 1982).

Results

Canary rockfish were caught more frequently in the first three surveys, although the distribution by latitude was not consistent even in those three years (Figure 2). The northern extension of the survey has varied between years (Figure 2). This difference has been compensated for by using a constant survey area for all years. Coverage by depth has been consistent for all seven years of the survey (Figure 3).

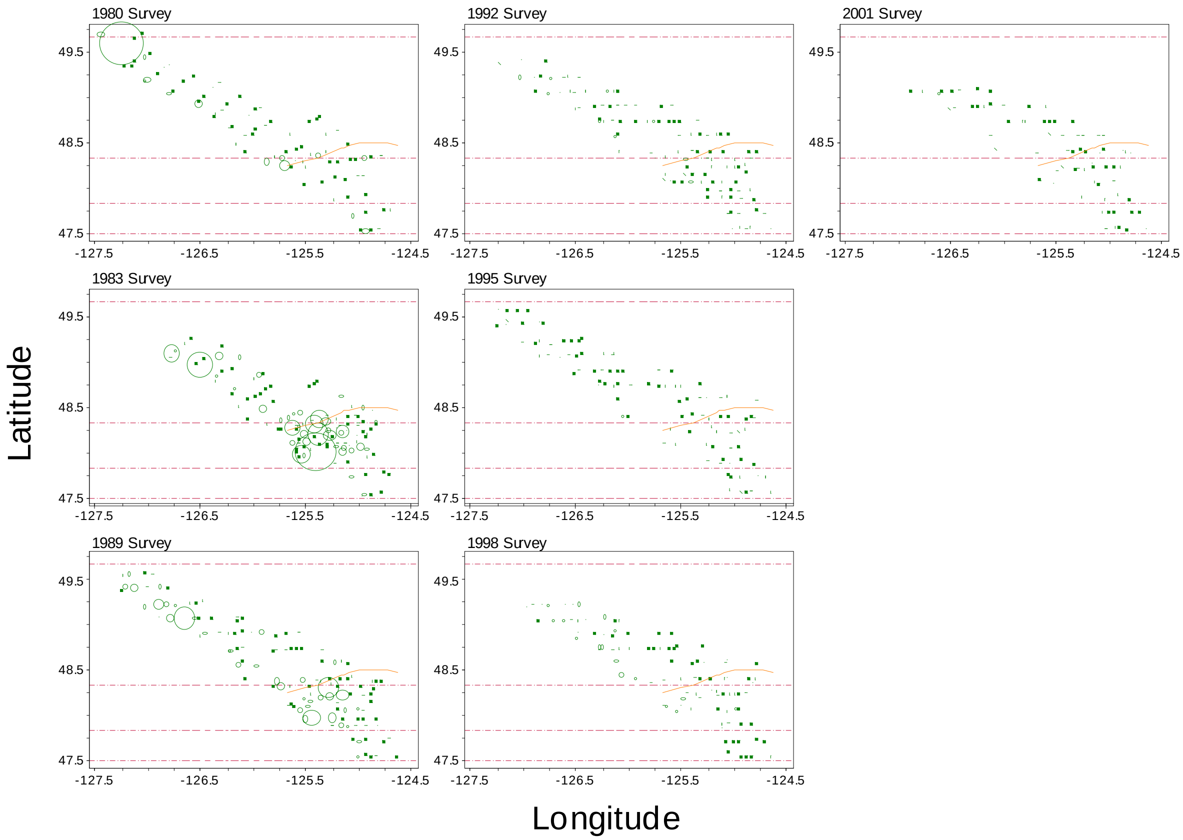


Figure 2. Plot of valid tows, weighted by the catch of canary rockfish, in the Vancouver INPFC region for the seven U.S. triennial surveys that surveyed Canadian waters. Catches in each year are scaled to the weight of the largest catch of canary rockfish (1,539 kg in 1980). Tows with zero catch of canary rockfish are coded with a "■". The approximate position of the US/Canada marine boundary is shown. The horizontal lines are the stratum boundaries: 47°30', 47°50', 48°20' and 49°40'.

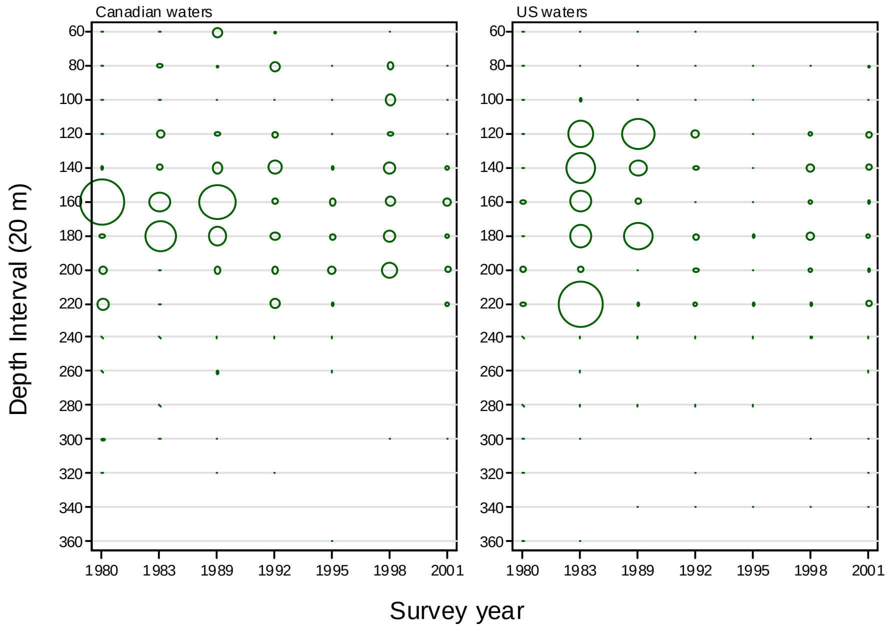


Figure 3. Distribution of canary rockfish catch weights for each survey year summarised into 20 m depth intervals for all valid tows (Table 2) in Canadian and U.S. waters of the Vancouver INPFC area. Depth intervals are labeled with the deepest limit of the interval. Maximum circle size=1,572 kg (Canadian waters).

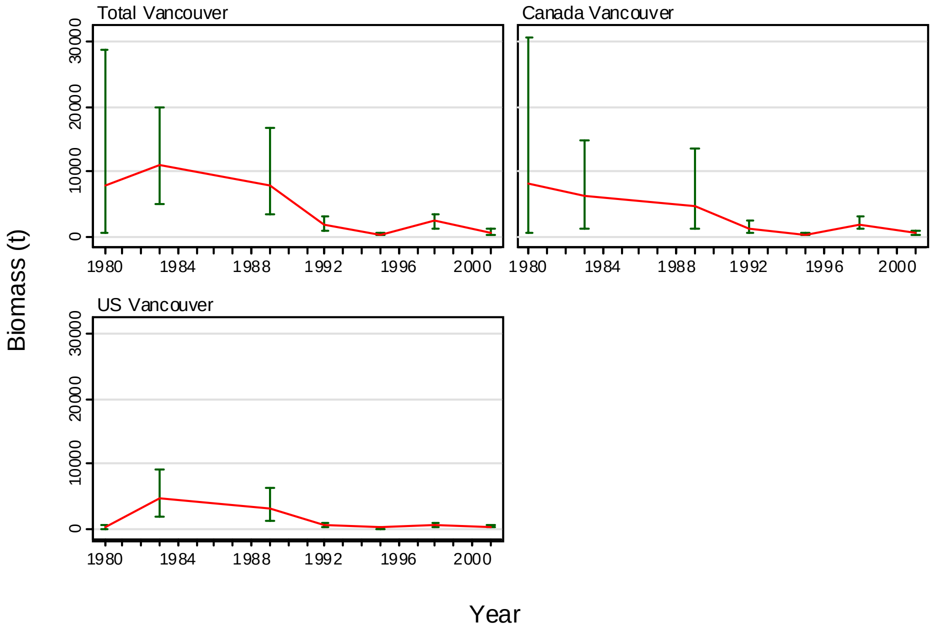


Figure 4. Three biomass estimates for canary rockfish in the INPFC Vancouver region (total region, Canadian waters only and U.S. waters only) with 95% bias corrected error bars estimated from 5000 bootstraps.

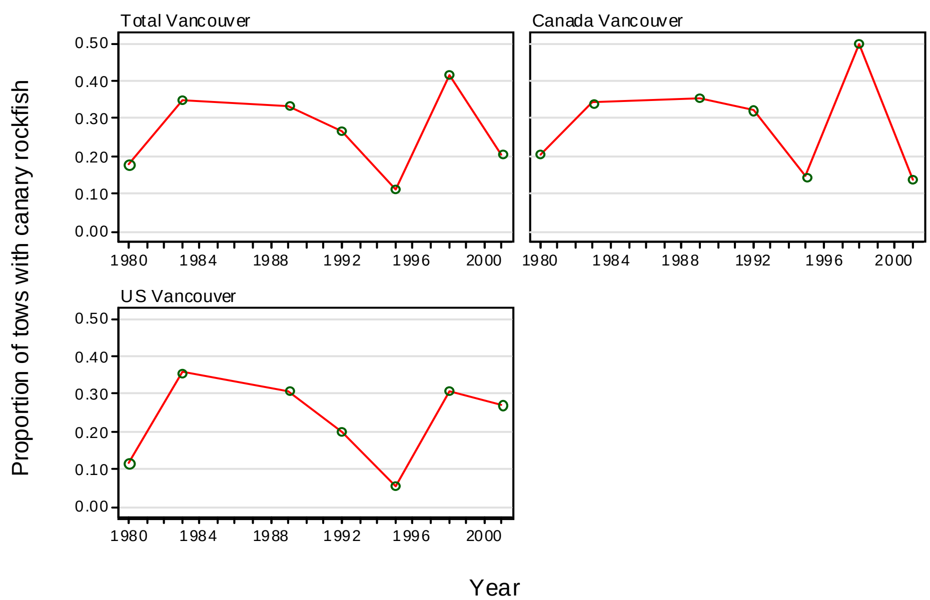


Figure 5. Proportion of tows with canary rockfish by year for the Vancouver INPFC region (total region, Canadian waters only and U.S. waters only).

Table 4. Biomass estimates for canary rockfish in the Vancouver INPFC region (total region, Canadian waters only and U.S. waters only) with 95% confidence regions based on the bootstrap distribution of biomass. Biomass estimates are calculated as in Eq. 1. The bootstrap estimates are based on 5000 random draws with replacement.

Estimate type	Year	Biomass (Eq. 1)	Mean bootstrap biomass	Lower bound biomass	Upper bound biomass	CV bootstrap	CV Analytic (Eq. 4)
Total Vancouver	1980	7,653	7,633	427	28,611	0.916	0.915
	1983	11,082	11,063	4,976	19,812	0.339	0.345
	1989	7,874	7,918	3,389	16,711	0.412	0.418
	1992	1,666	1,654	801	2,884	0.316	0.319
	1995	295	293	109	594	0.403	0.416
	1998	2,241	2,233	1,275	3,472	0.247	0.254
	2001	621	622	271	1,151	0.360	0.378
Canada Vancouver	1980	8,103	8,082	306	30,811	0.938	0.937
	1983	6,275	6,241	1,078	14,815	0.530	0.546
	1989	4,784	4,814	1,303	13,362	0.601	0.608
	1992	1,309	1,310	555	2,469	0.358	0.363
	1995	253	253	88	504	0.404	0.413
	1998	1,803	1,805	957	2,888	0.275	0.281
	2001	350	351	75	850	0.546	0.566
US Vancouver	1980	159	158	0	390	0.590	0.605
	1983	4,636	4,647	1,726	8,963	0.397	0.407
	1989	3,090	3,104	1,106	6,165	0.407	0.416
	1992	357	344	138	801	0.458	0.455
	1995	42	40	12	103	0.538	0.534
	1998	438	427	242	707	0.273	0.271
	2001	271	271	102	508	0.378	0.391

The biomass estimates and the associated annual CVs obtained from the above methods show a decreasing trend for the Canadian-Vancouver sub-region and also for the U.S.-Vancouver section of the region, if the first data point is not considered (Figure 4). The trend for the Total-Vancouver INPFC region is similar to the US-Vancouver series. The canary rockfish biomass estimates have very imprecise CVs, ranging from about 25% in 1998 to 92% in 1980 for the Total-Vancouver region (Table 4). This indicates that the confidence in the overall series trend should be low. Note that the bootstrap estimates of CV do not include any uncertainty with respect to the ratio expansion required to make the 1980 and 1983 survey estimates comparable to the 1989 and later surveys. Therefore, it is likely that the true uncertainty for this series is even greater than estimated.

One hundred ninety-one of the 697 tows in this data set caught canary rockfish over the entire history of the survey. The proportion of tows which contain canary rockfish has been relatively consistent at around 20-30% of the tows (Figure 5).

APPENDIX 4. West Coast Vancouver Island Shrimp Survey

Data Selection

Tow-by-tow data from the west coast Vancouver Island (WCVI) shrimp survey are available for 31 years spanning the period from 1972 to 2005. However, rockfish were not identified to the species level for the 1972 and 1973 surveys and 1974 is a missing year. Therefore, for rockfish species, this survey begins in 1975 and is the longest series available to monitor these species in Canadian waters.

These survey data were analysed following the recommendations made by Starr et al. (2002) in their reanalysis of the data from the same survey for WCVI Pacific cod (Gadus macrocephalus), with some modifications. These recommendations and modifications include:

a. Post-stratifying the data into two areas, Areas 124 and 125 (Figure 1) because these are the areas that have been monitored the most consistently over the history of the survey. The main modifications applied included dropping some tows which occurred in the most northerly part of Area 125 in 1975 and 1976 because these tows were not repeated in later surveys.
b. Moving tows east of the longitude 125° 54' from Area 124 to 123 as these tows were made in inshore waters and were spatially more closely associated with Area 123.
c. Only using tows made by the following vessels: G.B. Reed, W.E. Ricker, Sharlene K and the Frosti (Table 1). The latter two vessels are included because they are the only vessels which operated in 1989 and 2005 respectively. This vessel selection also rules out tows made in September 1977 and September 1978 which appear to be outside the scope of this survey.

The number of tows available for use in the analysis and the revised area weights in square km for the redefined strata are presented in Table 2.

There are almost no tows below 100 m in Area 125 (Figure 2) although there is reasonable coverage in the 80-100 m depth zone in Area 124. Coverage is continuous in all survey years up to the 140-160 m depth zone in both of the area strata, but the coverage in the 160-180 m depth zone is sporadic in many of the years. This analysis used 80-160 m as the depth range for all survey years. This should not affect the comparability of Area 125 because there is a consistent lack of tows in depths less than 100 m across all surveys (Figure 2). Stratum area weights were used which reflect the reduced area associated with the truncated depth range (Table 2).

No tows were recorded in Area 125 for the 1989 and 1991 survey years (Table 2). The catch rates estimated for Area 124 were also applied to the Area 125 stratum to ensure that the indices for these survey years were comparable to the indices in the years when Area 125 was surveyed.

Table 1. Number of sets made by each vessel involved in the WCVI shrimp survey.

Vessel & Year	April	May	June	July	August	September
Caligus						
1999		2				
2000		6				
2001		7				
Challenger						
1977						13
Deliverance						
1977						15
Frosti						
2005		94				
G. B. Reed						
1975		85				
1976		89				
1977		76		12		
1978		100				
1979		76				
1980		85				
1981		88				
1982		81				
1983		77				
1985		50	32			
Neo-Caligus						
2002		6				
2003	1	4				
2004		2				
2005		3				
Ocean King						
1978						81
Pacific Trident						
1977						21
Ricker						
1987					68	
1988	17	62				
1990	61	21				
1991	2	84				
1992		83				
1993	29	74				
1994	31	69				
1995		86				
1996	6	94				
1997		115				
1998		95				
1999		110				
2000		99				
2001		99				
2002	39	65				
2003	47	45				
2004	4	97				
Sharlene K.						
1989		67				
Sunnfjord						
1977						19

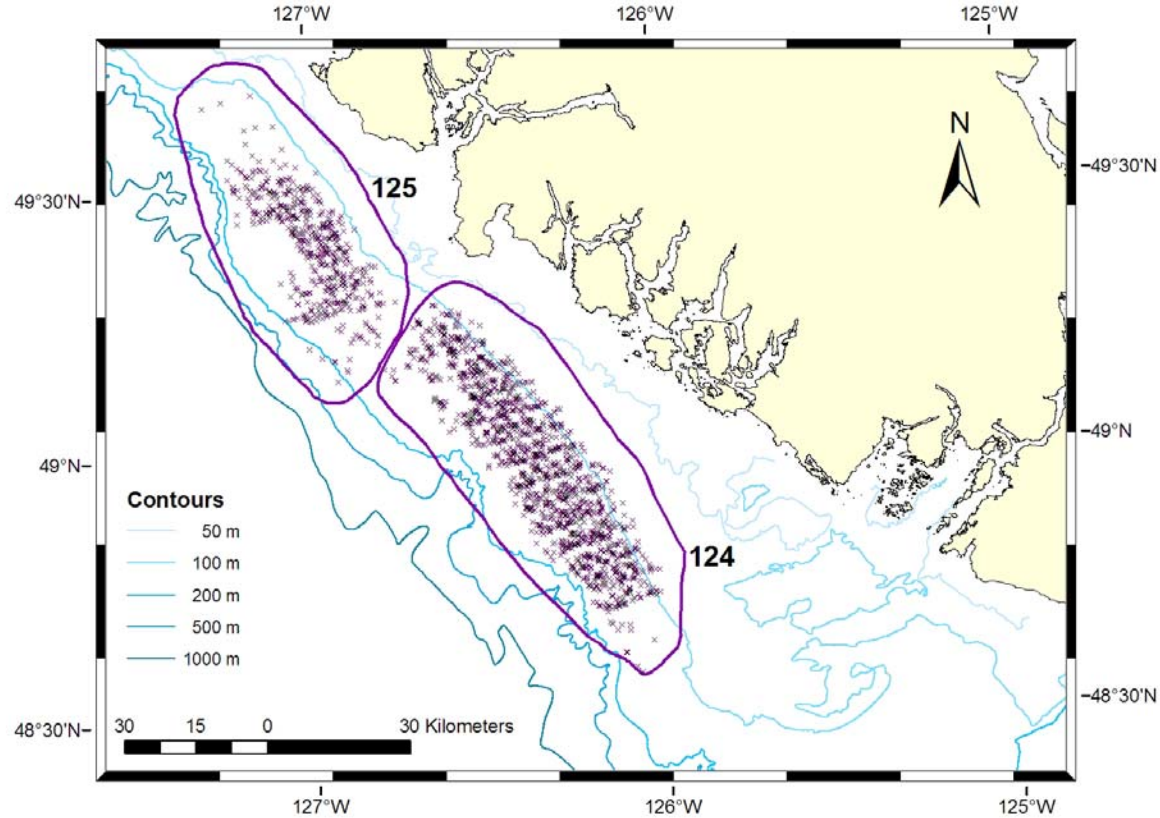


Figure 1. Map of the locations of all trawls in areas 123, 124, and 125 that were associated with the WCVI shrimp survey. Areas 124 and 125 are the strata that have been surveyed consistently over the history of the survey and which are in locations most likely to catch canary rockfish.

Table 2. List of tows used from the WCVI shrimp survey by survey year and stratum, including the number and weight of canary rockfish for tows dropped from the analysis and tows shifted from 124 to 123.

	Stratum		Total	Dropped tows		Shifted from 124 to 123	
Year	**124**	**125**	**tows**	**Number**	**Canary (kg)**	**Number**	**Canary (kg)**
1975	62	17	79	6	10.25		
1976	70	18	88	1	0		
1977	62	26	88	0	0		
1978	85	15	100	0	0		
1979	52	24	76	0	0		
1980	59	26	85	0	0		
1981	58	30	88	0	0		
1982	56	25	81	0	0		
1983	51	26	77	0	0		
1985	59	22	81	0	0		
1987	55	13	68	0	0		
1988	69	10	79	0	0		
1989	67	0	67	0	0		
1990	72	10	82	0	0		
1991	86	0	86	0	0		
1992	77	6	83	0	0		
1993	70	33	103	0	0		
1994	67	30	97	0	0		
1995	63	23	86	0	0		
1996	56	17	73	0	0	1	0
1997	61	21	82	0	0	2	0
1998	45	22	67	0	0	1	0
1999	51	31	82	0	0	1	0
2000	43	30	73	0	0	2	0
2001	49	22	71	0	0	2	0
2002	50	26	76	0	0	1	0
2003	46	19	65	0	0	1	0
2004	49	26	75	0	0	2	0
2005	46	25	71	0	0	1	0
Total	1860	718	2578	7	10.25	14	0
Area (km^2)[1]	2591	2065	4656				
Area (km^2)[2]	2166	1493	3659				

[1] Total area out to 260 m maximum depth
[2] Area out to 160 m maximum depth

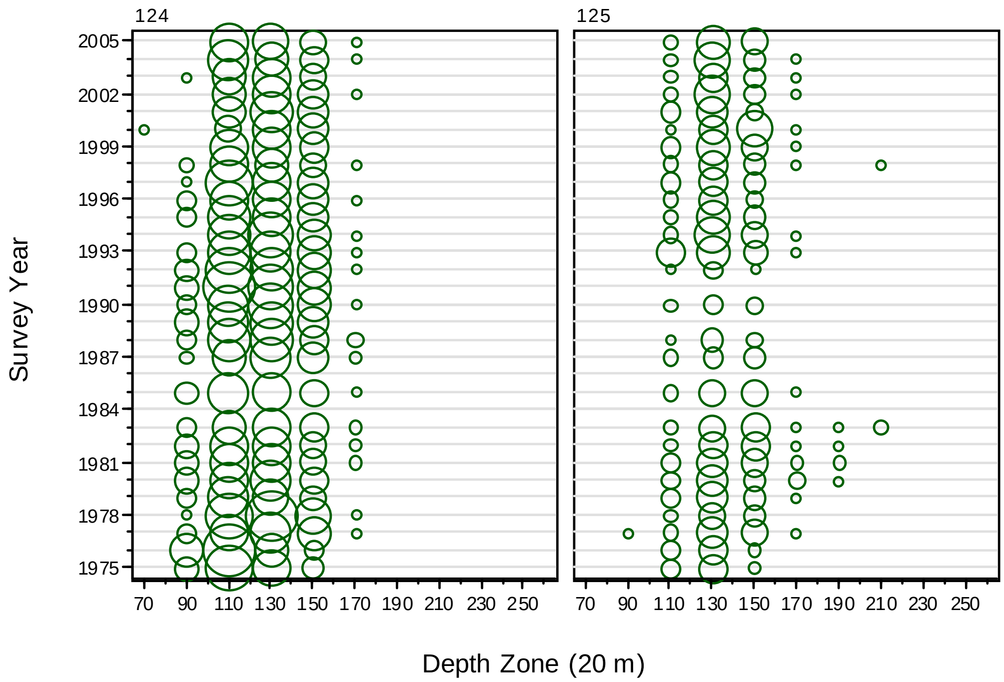


Figure 2. Distribution of tows in 20 m depth zones by survey year and area stratum for all selected tows. Each 20 m depth bin is indicated by the mid-point of the bin (i.e.: 110 m=100-120 m). Tow depth determined by the mean of the start and end depths. Circles are weighted by the number of sets observed in each depth bin.

Methods

These data were analysed using the following equations which assume that tow locations were selected randomly within a stratum relative to the biomass of canary rockfish. This was not an assumption made by the original survey design and the area stratification definition in Figure1 was not used when conducting the survey. The original survey design used latitudinal transects and selected the stations randomly along the transect. The biomass in any year *y* was obtained by summing the product of the CPUE and the area surveyed across the surveyed strata *i*:

$$B_y = \sum_{i=1}^{k} C_{y_i} A_i = \sum_{i=1}^{k} B_{y_i} \qquad \text{Eq. 1}$$

where C_{y_i} = mean CPUE density (kg/km^2) for species *s* in stratum *i*

A_i = area of stratum *i* (km^2)

B_{y_i} = biomass of canary rockfish in stratum *i* for year *y*

k = number of strata.

CPUE $\left(C_{y_i}\right)$ for canary rockfish in stratum *i* for year *y* was calculated as a density in kg/km^2 by

$$C_{y_i} = \frac{\sum_{j=1}^{n_{y_i}} \left(W_{y_i j} \big/ D_{y_i j} w_{y_i j} \right)}{n_{y_i}} \qquad \text{Eq. 2}$$

where $W_{y_i j}$ = catch weight (kg) for canary rockfish in stratum *i* for year *y* and tow *j*

$D_{y_i j}$ = distance travelled (km) by tow *j* in stratum *i* for year *y*

$w_{y_i j}$ = net opening (km) by tow *j* in stratum *i* for year *y*

n_{y_i} = number of tows in stratum *i*

The variance of the survey biomass estimate V_y for canary rockfish in year *y* is calculated in kg^2 as follows:

$$V_y = \sum_{i=1}^{k} \sigma_{y_i}^2 A_i^2 \big/ n_{y_i} = \sum_{i=1}^{k} V_{y_i} \qquad \text{Eq. 3}$$

where $\sigma_{y_i}^2$ = variance of CPUE (kg^2/km^4) for species *s* in stratum *i*

V_{y_i} = variance of canary rockfish in stratum *i* for year *y*

The CV for canary rockfish for each year *y* was calculated as follows:

$$CV_y = \frac{\sqrt{V_y}}{B_y} \qquad \text{Eq. 4}$$

One thousand bootstrap replicates with replacement were made on the survey data to estimate bias corrected 95% confidence regions for each survey year (Efron 1982).

Results

Estimated biomass levels for canary rockfish from the WCVI shrimp survey appear to have been relatively consistent throughout the history of this survey, with the exception of some years with relatively high biomass estimates associated with high levels of relative error (e.g. 1977, 1983, 1994; Figure , Table 3). Biomass levels appear to be gradually increasing since the late 1990's, but these indices also have high uncertainty and the trend is probably not significant (Figure 3). The proportion of tows which contain canary rockfish shows a lower incidence of canary rockfish in the 1990's, a decreasing trend at the beginning of the series, and an increasing trend at the end of the series (Figure 4).

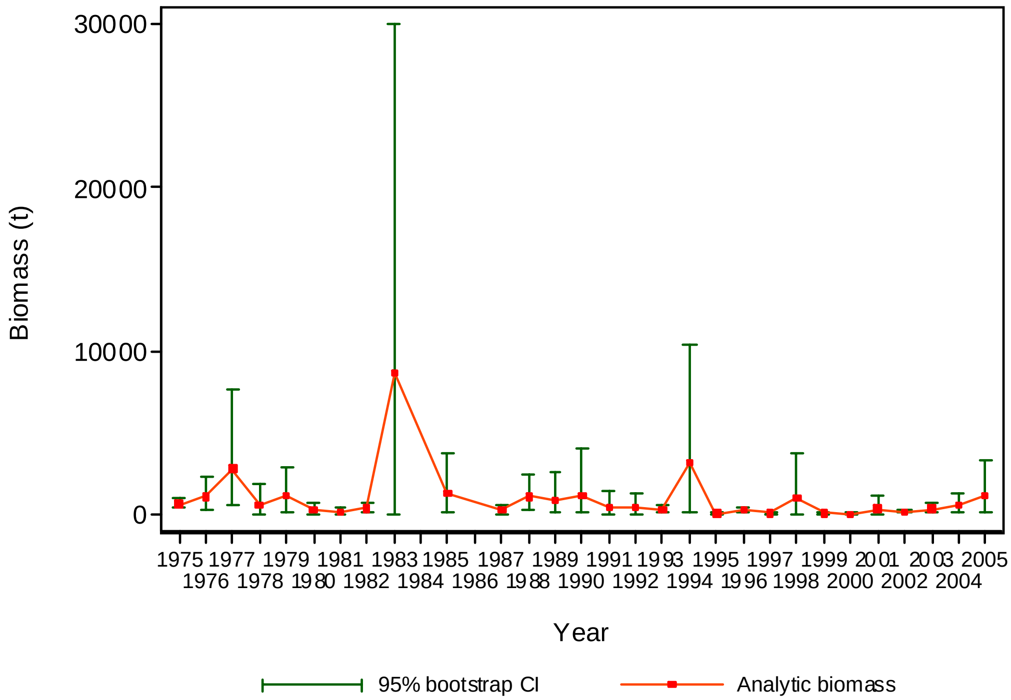


Figure 3. Plot of biomass estimates for canary rockfish from the WCVI shrimp survey for the period 1975 to 2005. Bias corrected 95% confidence intervals from 1,000 bootstrap replicates are plotted.

Table 3. Biomass estimates for canary rockfish from the WCVI shrimp survey for the survey years 1975 to 2005. Biomass estimates are based on a post-stratification of this survey into two strata (Figure 1) and by assuming that the survey tows were randomly selected within these areas. Bootstrap bias corrected confidence intervals and CVs are based on 1000 random draws with replacement. The analytic CV (Eq. 4) is based on the assumption of random tow selection within a stratum.

Survey Year	Biomass (t)	Mean bootstrap biomass (t)	Lower bound biomass (t)	Upper bound biomass (t)	Bootstrap CV	Analytic CV (Eq 4)	Proportion non-zero tows
1975	639	648	373	962	0.24	0.24	0.438
1976	1091	1105	331	2327	0.46	0.46	0.258
1977	2786	2760	542	7605	0.61	0.63	0.221
1978	628	632	44	1896	0.79	0.82	0.144
1979	1161	1148	203	2853	0.55	0.54	0.227
1980	241	250	32	681	0.73	0.75	0.136
1981	173	173	39	401	0.54	0.55	0.115
1982	371	378	74	755	0.45	0.44	0.152
1983	8673	8678	18	30053	0.94	1	0.137
1985	1320	1340	204	3749	0.66	0.66	0.114
1987	254	244	42	630	0.64	0.64	0.078
1988	1085	1074	288	2459	0.52	0.52	0.197
1989	899	948	67	2572	0.69	0.68	0.179
1990	1109	1083	62	4112	0.94	0.91	0.167
1991	417	408	49	1441	0.82	0.84	0.172
1992	420	420	22	1352	0.81	0.79	0.086
1993	265	260	68	593	0.49	0.49	0.130
1994	3191	3101	84	10426	0.89	0.89	0.074
1995	47	48	15	97	0.44	0.45	0.060
1996	237	237	63	458	0.43	0.43	0.111
1997	94	94	37	179	0.38	0.39	0.111
1998	1041	1030	5	3755	0.98	0.98	0.063
1999	87	88	45	151	0.3	0.3	0.215
2000	32	32	13	61	0.37	0.38	0.113
2001	340	333	30	1107	0.86	0.85	0.132
2002	152	150	71	259	0.32	0.31	0.189
2003	333	337	140	696	0.42	0.41	0.200
2004	586	586	186	1245	0.44	0.45	0.239
2005	1098	1095	76	3321	0.85	0.88	0.188

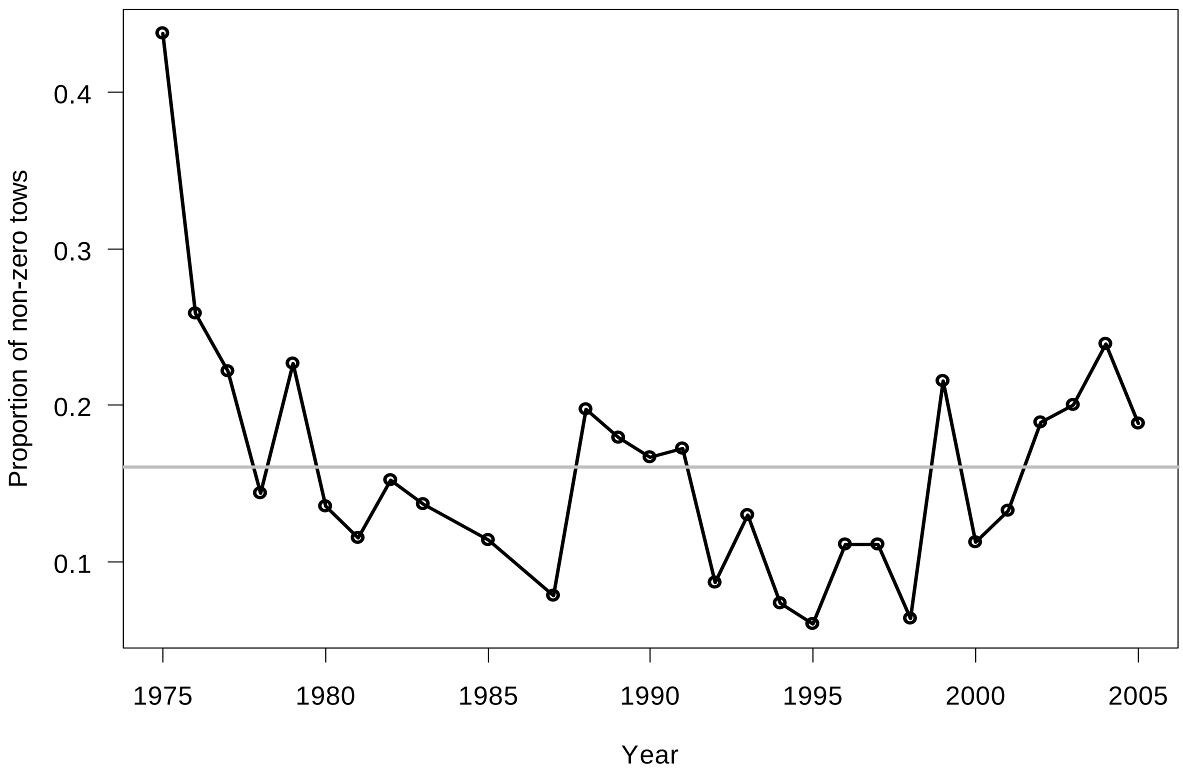
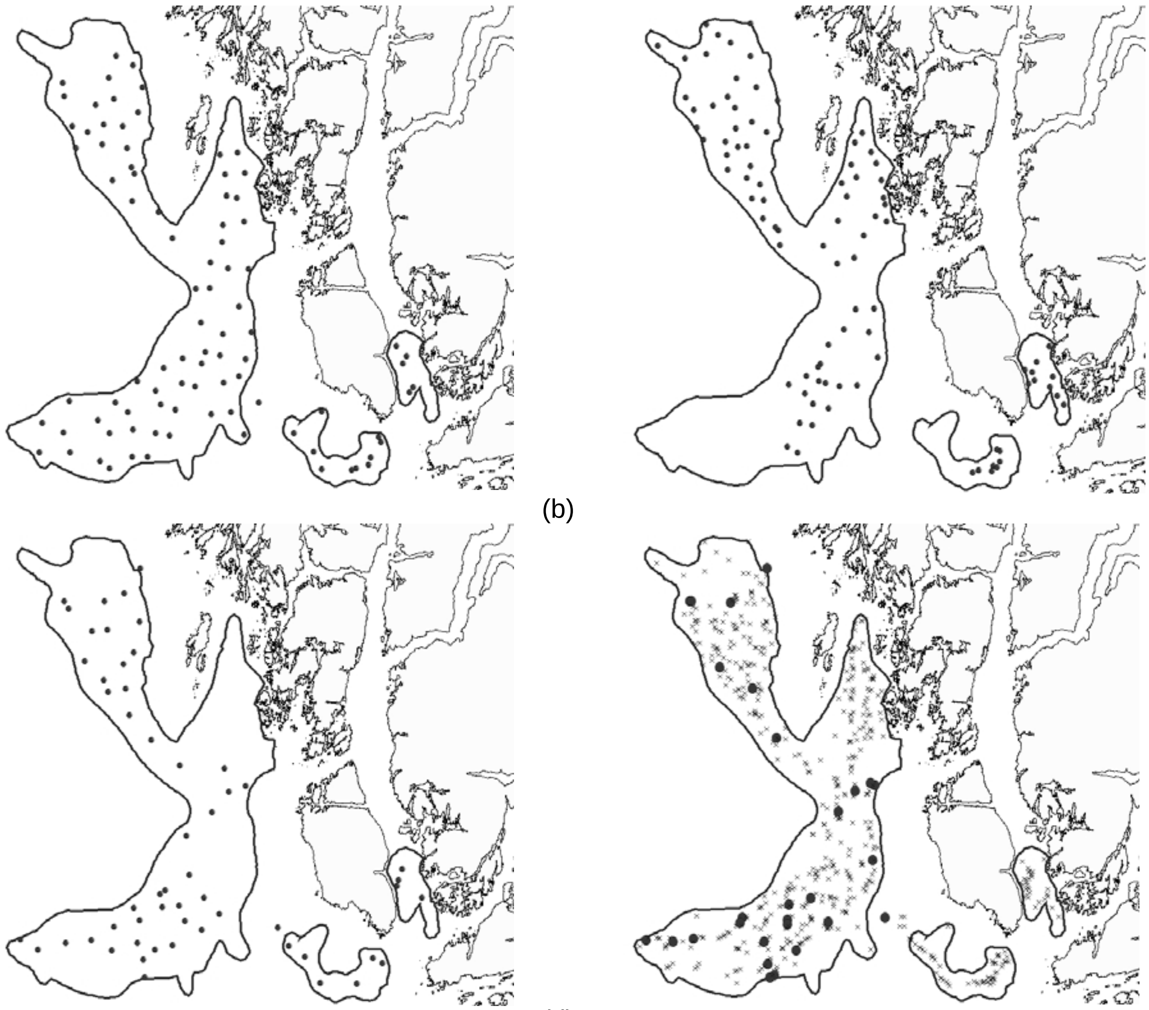


Figure 4. Proportion of tows with canary rockfish by year for the WCVI shrimp survey. The average proportion is shown by the solid line.

APPENDIX 5. Queen Charlotte Sound Shrimp Survey.

A swept-area shrimp survey of QCSd has been conducted yearly since 1998 (Boutillier and Olsen 2000). These data were analysed using the equations below which assume that tow locations were selected randomly within a stratum. This assumption was not part of the original survey which employed uniform sampling stations and used spatial interpolation to arrive at biomass estimates. We examined the set locations from each survey to ensure that spatial and depth coverage remained consistent over the history of the surveys. We concluded that the first survey conducted in 1998, and the most recent survey conducted in 2005 were sufficiently different to warrant their removal from the series. In particular, the set locations in 1998 extended further north than in subsequent years, and did not extend into the deeper regions of the south-west (Fig. 1-b). In 2005, the number of tows conducted was reduced due to time constraints and the area not surveyed coincided with regions where no canary rockfish had been encountered over the history of the survey (Fig. 1-d). We felt this could lead to an inflated estimate of mean catch density in 2005.



(a) (b) (c) (d)

Figure 1. Set locations from the QCSd shrimp survey (see map in Fig. 11 of main text). (a) Set locations conducted in 2003; this distribution is typical of the years 1999 to 2004. (b) Set locations conducted in 1998; note the limited distribution of sets to the south-west and increased coverage in the north. (c) Set locations conducted in 2005. (d) Canary rockfish catches (shaded circles) over the history of the surveys; zero catches are shown as small crosses.

The biomass in each year *y* was obtained by summing the product of the CPUE and the area surveyed across the surveyed strata *i*:

$$B_y = \sum_{i=1}^{k} C_{y_i} A_i = \sum_{i=1}^{k} B_{y_i} \quad \text{Eq. 1}$$

where C_{y_i} = mean CPUE density (kg/km^2) for species *s* in stratum *i*

A_i = area of stratum *i* (km^2), and

B_{y_i} = biomass of canary rockfish in stratum *i* for year *y*.

k = number of strata

CPUE $\left(C_{y_i}\right)$ for canary rockfish in stratum *i* for year *y* was calculated as a density in kg/km^2 by

$$C_{y_i} = \frac{\sum_{j=1}^{n_{y_i}} \left(W_{y_i j} \big/ D_{y_i j} w_{y_i j} \right)}{n_{y_i}} \qquad \text{Eq. 2}$$

where $W_{y_i j}$ = catch weight (kg) for canary rockfish in stratum *i* for year *y* and tow *j*

$D_{y_i j}$ = distance traveled (km) by tow *j* in stratum *i* for year *y*

$w_{y_i j}$ = net opening (doorspread; km) by tow *j* in stratum *i* for year *y*

n_{y_i} = number of tows in stratum *i*

One thousand bootstrap replicates with replacement were made on the survey data to estimate bias corrected 95% confidence regions for each survey year (Efron 1982).

APPENDIX 6. Commercial Trawl CPUE Analysis

Methods

A stepwise general linear model (GLM) regression procedure was used to derive a time series of the relative annual changes based on the relationship between commercial CPUE for canary rockfish and available predictive factors. The data were derived from the DFO PacHarvestTrawl and GFCatch commercial catch and effort databases. This approach is commonly used to analyse fisheries catch and effort data and has been described in Hilborn and Walters (1992) and Quinn and Deriso (1999).

We restricted the analysis to a main effects models. Interaction effects, such as a month versus depth, may be significant as many rockfish are known to undergo seasonal depth migrations (Stanley and Kronlund 2005). However, while more exhaustive treatments may have led to more appropriate model specification, we doubt it would have revealed a different trend. Future work will consider a more detailed treatment of this issue.

Quinn and Deriso (1999; page 19) described a general linear model based on the lognormal distribution:

$$U_{ijk} = U_0 \prod_i \prod_j P_{ij}^{X_{ij}} e^{\varepsilon_{ijk}} \qquad \text{Eq.1}$$

where U is the observed CPUE, U_0 is the reference CPUE, P_{ij} is a factor i at level j, and X_{ij} takes a value of 1 when the jth level of the factor P_{ij} is present and 0 when it is not. The random deviate ε_{ijk} for observation k is a normal random variable with 0 mean and standard deviation σ.

Taking the logarithm of Eq.1 yields an additive linear regression model:

$$\ln U_{ijk} = \ln U_0 + \sum_{i=1}^{p} \sum_{j=1}^{n_i - 1} X_{ij} \ln P_{ij} + \varepsilon_{ijk}$$

or Eq.2

$$Y_{ijk} = \beta_0 + \sum_{i=1}^{p} \sum_{j=1}^{n_i - 1} \beta_{ij} X_{ij} + \varepsilon_{ijk}$$

In the second form of the model, β_0 is the intercept of the model and β_{ij} is the logged coefficient of the factor j at level i under consideration.

The model described by Eq. 1 and Eq. 2 is overparameterised and constraints must be imposed to allow estimation of model parameters. A common solution is to setting a factor coefficient to zero, usually the first, whereupon the remaining n_i-1 coefficients of each factor i represent incremental effects relative to the reference level. Estimated coefficients will not be affected by the choice of constraint. Following the suggestion of Francis (1999), coefficients for factor i were transformed to "canonical" coefficients over all levels j calculated relative to their geometric mean $\bar{\beta} = \sqrt[n]{\prod_1^n \beta_j}$ (including the level where β_j=0), so that

$$\beta_j^{'} = \beta_j / \bar{\beta} \qquad \text{Eq.3}$$

As the analysis is done in log space, this is equivalent to:

$$b_j^{'} = e^{(\beta_j - \bar{\beta})} \qquad \text{Eq.4}$$

The use of the canonical form allows the computation of standard errors for every coefficient, including the fixed coefficient (Francis 1999). Ordinarily, the use of a fixed reference coefficient sets the standard error for that coefficient to zero and spreads the error associated with that coefficient to the other coefficients in the variable.

A range of factors (P_{ij}) are available in the data which may be used to account for variability in the observed CPUE. These include factors such as the date of capture (usually year and month), the capturing vessel, and the depth and location of capture. The year of capture is usually given special significance in these analyses: variations between years in this factor are interpreted as relative changes in the annual abundance of the fish species which is the subject of the analysis. The resulting series of 'year' or 'fishing year' canonical coefficients is termed the "Standardised" annual CPUE index $\left[Y_j^{'}\right]$ in this report.

A selection procedure (Vignaux 1993, Vignaux 1994, Francis 2001) was applied to determine the relative importance of these factors in the model. The procedure involves a forward stepwise fitting algorithm which generates regression models iteratively, starting with the simplest model (one dependent and one independent variable) and building in complexity subject to a stopping rule designed to include only the most important factors.

The following general procedure was used to fit the models, given a data set with candidate predictor variables:

1. Calculate the regression with each predictive factor (variable) against the natural log of CPUE (kg/h).
2. Generate the Akaike Information Criterion (AIC) (Akaike 1974) for each regression based on the number of model degrees of freedom. Select the predictor variable that has the lowest AIC. The AIC is used for model selection to account for variables which may have equivalent explanatory power in terms of residual deviance but require fewer degrees of freedom for the model (Francis 2001).
3. Repeat Steps 1 and 2, accumulating the number of selected predictor variables and increasing the model degrees of freedom, until the increase in R^2, for the final iteration, is less than 0.01. The selection of 0.01 as the threshold is arbitrary but adding factors which explain small amounts of the total variance has little effect on the year coefficients and other coefficients of interest.

Other annual indices can be generated from the catch and effort data used for the linear modelling described above. The simplest estimate of mean annual CPUE is given by:

$$R_j = \frac{\sum_{k=1}^{M_j} C_{jk}}{\sum_{k=1}^{M_j} E_{jk}} \qquad \text{Eq. 5}$$

where C_{jk} denotes that catch and E_{jk} denotes the effort for each record *k* in year *j*. The series of annual estimates is termed the "Arithmetic" CPUE index in this report.

Another annual index is specified by

$$U_j = \exp\left[\frac{\sum_{k=1}^{M_j} \ln\left(\frac{C_{jk}}{E_{jk}}\right)}{M_j}\right] \qquad \text{Eq. 6}$$

where U_j is the annual geometric mean of the CPUE observations. The resulting annual index is termed the "Unstandardised" CPUE index in this report. Annual estimates obtained using Eq. 6 are equivalent to the results obtained from a linear model where year is the only predictive factor.

Like the scaling described for the standardised index, the series specified by Eq. 5 and Eq. 6 can be scaled relative to their geometric means. This is done to provide comparability with the standardised indices. Given *n* years in each series, the geometric means of the arithmetic and unstandardised series are given by $\bar{R} = \sqrt[n]{\prod_1^n R_j}$ and $\bar{U} = \sqrt[n]{\prod_1^n U_j}$, respectively. Thus, each series can be scaled to the corresponding geometric mean as:

$$R_j^{'} = R_j / \bar{R} \qquad \text{Eq.7}$$

and

$$U_j^{'} = U_j / \bar{U} \qquad \text{Eq.8}$$

The procedures described by Eq. 1, Eq. 2 and Eq. 6 are necessarily confined to the positive catch observations in the data set as ln(0) is undefined. Observations with zero catch can be handled in a number of ways:

a. Zero catch records are frequently dropped from further consideration, usually because they are not accurately recorded. This is particularly true for catch records which are maintained by fishermen who frequently discount small amounts of catch as being inconsequential.
b. A small increment can be added to the zero catch records so that ln(0) can be calculated. This is not a satisfactory solution because model parameter estimates have been shown to be sensitive to the value selected for the increment.
c. A linear regression model based on a binomial distribution and using the presence/absence of the fish species as the dependent variable can be estimated using the same data set. Explanatory factors are estimated in the model in the manner described in Eq. 1 and Eq. 2. Such a model will provide another series of standardised coefficients of relative annual changes that is analogous to the series estimated from the lognormal regression. This approach has been followed for the data set based on observer records (PacHarvestTrawl after 1996) where it is felt that zero catch records are likely to have greater reliability (see below).
d. A combined model which integrates the two series of relative annual changes estimated by the lognormal and binomial models can be estimated using the delta distribution which allows zero and positive observations (Vignaux 1994). This approach was not followed in this analysis.

Data selection and model specification

Data were selected from the DFO PacHarvestTrawl database using the following criteria:

Tow start date between 1 April 1996 and 31 March 2005
Bottom trawl type
Fished in a valid outside DFO Major region (3C, 3D, 5A, 5B, 5C, 5D, or 5E)
Fishing success code <=1 (code 0= unknown; code 1= useable)
Catch of at least one fish or invertebrate species (no water hauls)
Valid depth field
Vessel had been in the fishery for at least three years with a minimum of five trips in each of those years
Valid latitude and longitude co-ordinates
Valid estimate of time towed that was greater than 0 hours and less than 24 hours

The following explanatory variables were offered to the model, based on the tow-by-tow information in each record for the data remaining after the selection procedure:

Fishing year (1 April–31 March)
Month
DFO locality (Rutherford 1999)
Latitude separated in 0.1° bands beginning with 48°N
Vessel
Depth aggregated into 50 m depth bands
DFO Major region (3C, 3D, 5A, 5B, 5C, 5D, or 5E)

Categories with relatively few observations were pooled into a single (“Plus”) category to reduce the number of parameters estimated.

Catches

Total annual landings and discards for canary rockfish are presented by major DFO region from 1979–80 to 2004–05 (Table 1). Landings from the PacHarvestTrawl database are considered more reliable than earlier landings from the GFCatch database as they are verified by the presence of an observer. Discard estimates are not available prior to 1996 and the establishment of the independent observer program.

The majority of rougheye catches have been from Area 5E (west coast Queen Charlotte Islands). However, there have been smaller but consistent catches from Areas 3C and 3D (WCVI) and Area 5B (upper QCSd). Catches in Area 5A (lower QCSd) have been more sporadic and there have been virtually no catches of this species from Areas 5C and 5D (HS).

Table 1. Total landed and discarded catches (t) for canary rockfish in the combined GFCatch/PacHarvestTrawl databases, as used in the GLM analysis, summarised by standard April 1 – March 31 fishing years for each of the major DFO reporting areas. Data from April 1, 1979 to December 27, 1995 are from the GFCatch database (Rutherford 1999). Data from February 16, 1996 to March 31, 2005 are from the PacHarvestTrawl database. The groundfish fishery was closed from December 28, 1995 to February 15, 1996. These catches have been processed without data selection criteria.

Fishing Year	**Major Area**							
	3C	**3D**	**5A**	**5B**	**5C**	**5D**	**5E**	**Total**
Landed catch (t)								
79/80	33.7	103.7	51.1	270.4	116.4	8.7	0.5	584.6
80/81	16.6	109.1	33.9	243.7	202	1.7	0.5	607.4
81/82	12.9	49.3	30.2	169.2	115.3	11.3	2.4	390.6
82/83	100.5	215.9	172.8	165.9	57.6	2.6	18.3	733.6
83/84	196.6	770.5	111.4	250.6	116.9	4.1	10.8	1,461.00
84/85	274.9	965.5	241.9	282.7	68.3	4.6	12.2	1,850.00
85/86	169.5	694.7	132.8	272.3	189	3.3	116.7	1,578.40
86/87	208.4	498.2	79.4	168.8	43.5	0.9	13.8	1,013.10
87/88	226.1	482.3	200.3	383	90.5	13	8.1	1,403.40
88/89	503.4	552.4	170.5	421.8	86.1	2.3	76.6	1,813.20
89/90	464.7	842.4	157.4	437.1	125.4	15.6	21.4	2,064.00
90/91	209.6	521.5	227.1	412.5	126.6	28	85.1	1,610.40
91/92	197.4	439.8	177.1	315.6	117.8	32.8	27.1	1,307.70
92/93	284.2	496.2	185.8	197.8	100.2	17.7	35	1,316.80
93/94	253.4	557.7	74.7	123	65.2	22.2	20.1	1,116.40
94/95	221.7	541.8	107	182.1	88.7	8.7	8.7	1,158.80
95/96	141.8	396.2	63.7	93.3	46.4	2	10.1	753.6
96/97	141.3	303.2	50.8	81.2	52.9	15.3	2.9	647.6
97/98	113.8	314.3	77.1	111.1	34.6	6.6	19.6	677
98/99	81	336.4	151.7	136.3	39.3	3.2	2.5	750.3
99/00	95.4	445.1	108.4	205.6	33.8	8	7.1	903.3
00/01	91.6	362.3	71.5	143.3	70.1	8.5	14.6	762
01/02	138.5	348.4	85.4	136.8	70.1	2.9	2	784
02/03	123.6	441.7	95.5	139.7	62.5	1.9	3.2	868.2
03/04	172.8	329.4	82.5	156.8	68.8	2.7	18.6	831.7
04/05	89.3	261.4	76.9	84.4	30.9	5	0.7	548.7
Total	4,562.90	11,379.60	3,017.00	5,585.10	2,218.80	233.8	538.8	27,535.90
Discarded catch								
96/97	2.6	1.2	0.2	7	0.1	0.1	0	11.3
97/98	1.7	5.8	0.3	1.3	0.4	0.1	0.5	10
98/99	0.4	1.1	0.3	0.2	1.2	0.1	0	3.3
99/00	0.8	0.6	0.2	0.4	0.1	0.1	0.1	2.3
00/01	0.3	4.9	0.1	1.2	0.1	0	0	6.5
01/02	0.7	2.6	0.5	0.2	0.1	0	0	4.1
02/03	0.3	0.8	0.9	0.1	0	0	0	2.1
03/04	0.5	0.3	0.5	0	0	0	0	1.3
04/05	0.2	0.3	0.1	0.1	0.2	0	0	0.9
Total	7.5	17.6	3.1	10.5	2.2	0.4	0.6	41.8

Area 3C+3D (West coast Vancouver Island):

The depth distribution of the selected data ranged from about 70 m to just under 400 m, with sporadic observations at deeper depths (Figure 1). The GLM model used all valid tows occurring between 50 and 400 m.

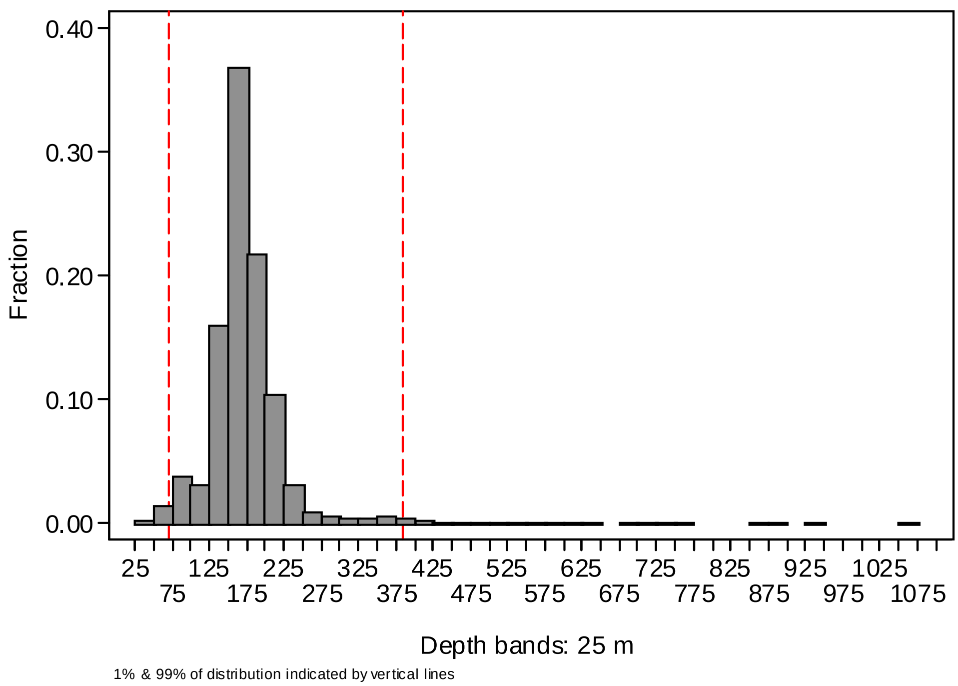


Figure 1. Depth distribution of canary rockfish catch for tows with landed catch in the combined Areas 3C and 3D from 1996/97 to 2004/05 in 25 m intervals. Each bin interval is labelled with the upper bound of the interval. Vertical lines: 1%=69 m; 99%=384 m. Data are Shown here to 25 m resolution; the analysis used 50 m intervals to reduce the number of parameters.

Standardised GLM:

The GLM analysis for Area 3C+3D selected 0.1° degree of latitude, depth band category, DFO locality and vessel as explanatory variables in addition to fishing year in the final model and accounted for 29% of the variation (Table 2).

Table 2. Order of acceptance of variables into the Area 3C+3D model of successful catches of canary rockfish by core vessels (based on the vessel selection criteria of at least 5 trips in three or more fishing years) with the amount of explained deviance (R^2) for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.

Variable	**1**	**2**	**3**	**4**	**5**	**6**
Fishing year*	**0.0114**					
0.1° Latitude bands*	0.1614	**0.1686**				
Depth bands*	0.1209	0.1354	**0.2527**			
DFO locality*	0.1420	0.1512	0.2111	**0.2717**		
Vessel*	0.0334	0.0420	0.1875	0.2692	**0.2870**	
Month	0.0128	0.0237	0.1802	0.2662	0.2840	0.2963
DFO Major region	0.0313	0.0421	0.1686	0.2527	0.2731	0.2883
Improvement in deviance		**0.1571**	**0.0841**	**0.0190**	**0.0153**	**0.0093**

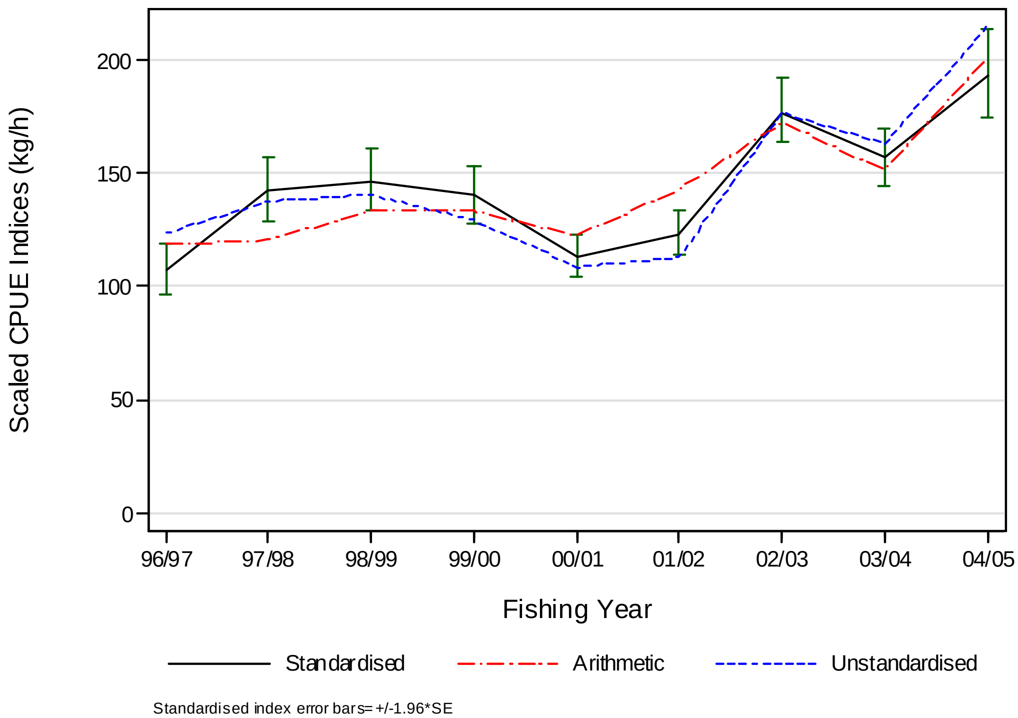


Figure 2. Three CPUE series for Area 3C+3D landed canary rockfish catches for the 1996/97 to 2004/05 fishing years. The solid line is a standardised analysis correcting for 0.1° latitude band, 25 m depth band, DFO locality and vessel effects. The arithmetic series is the sum of the non-zero catch divided by the sum of the associated effort (Eq. 5) and the unstandardised series is the geometric mean of all positive CPUE observations (Eq. 7).

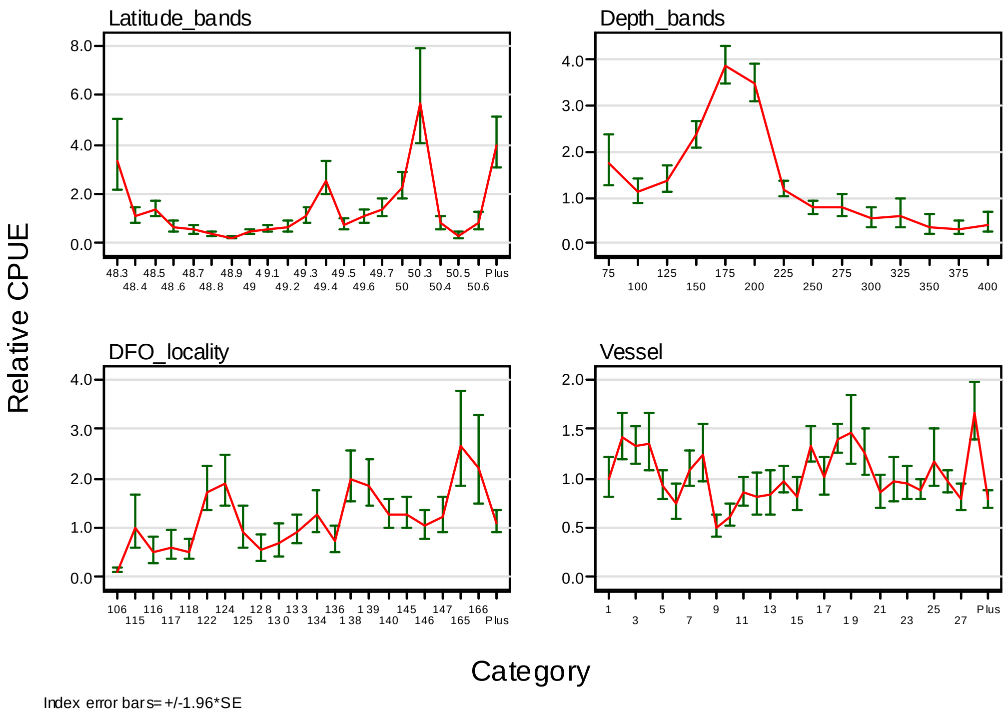


Figure 3. Plots of the coefficients for the categorical explanatory variables included in the standardised GLM analysis presented in
Figure 2 for Area 3C+3D.

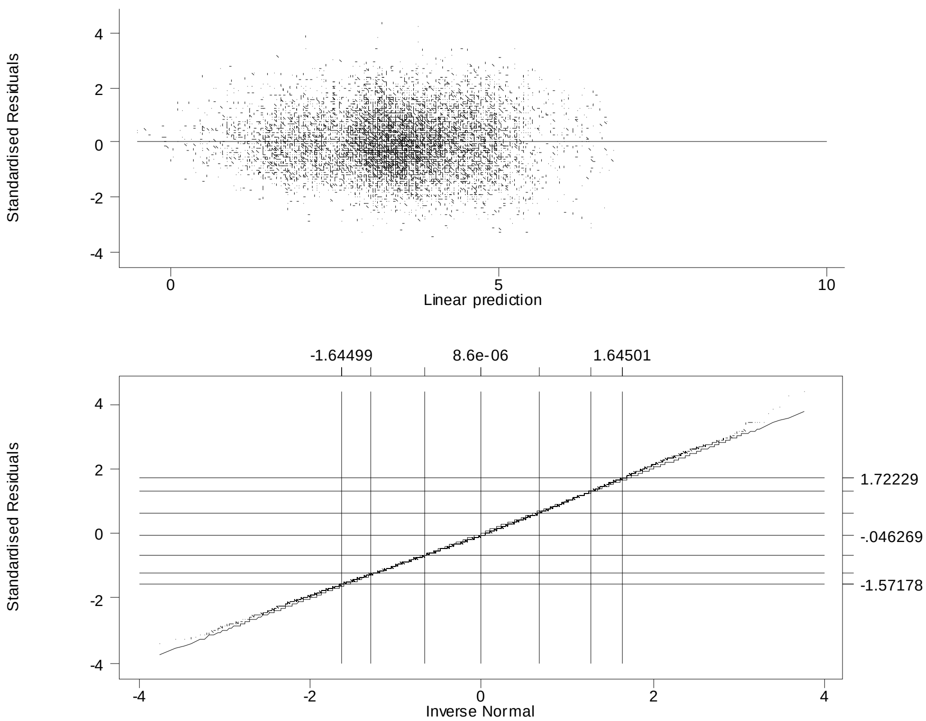


Figure 4. Standardised (Pearson) residuals for the Area 3C+3D GLM analysis presented in Figure 2. The outside horizontal and vertical lines represent the 5th and 95th percentiles of the theoretical and observed distributions.

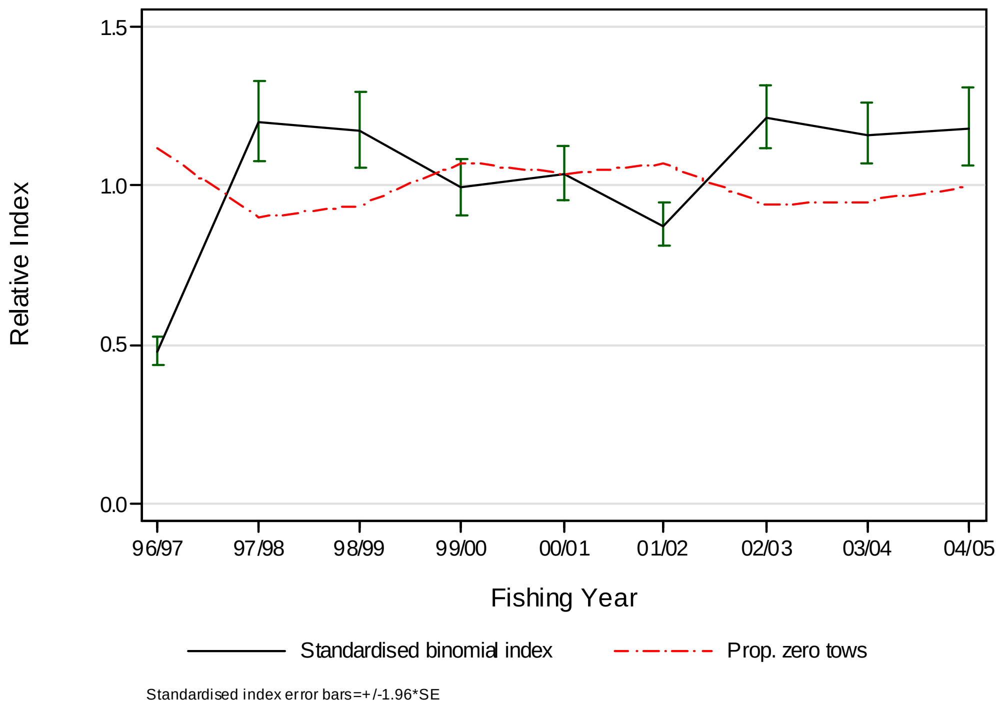


Figure 5. Year effects from a standardised binomial logit model fit to the presence/absence of canary rockfish using the same dataset that provided the lognormal regression model (Figure 2). Also shown is the relative proportion of tows with zero canary rockfish by fishing year (mean=0.53). Each series has been normalised to its geometric mean.

The selected lognormal model shows an increasing trend since the beginning of the series, but this seems more pronounced since 2000/01 (Figure 2 and Figure 3; Table 3). The standardised model did not vary much from the simple arithmetic mean CPUE or the geometric mean of the non-zero catches. Model residuals appear to fit the model assumption of log-normal error well throughout the entire distribution, with little deviation at either tail (Figure 4). A binomial model fit to the presence/absence of canary rockfish using the same dataset which provided the lognormal model shows a big jump in the annual effects between the first and second year of the series, but shows no trend subsequently (Figure 5). There has been little variation in the proportion of zero catch tows (Figure 5).

Table 3. Arithmetic and standardised CPUE indices with upper and lower bounds of the standardised indices and the associated standard error for the Area 3C+3D model of non-zero catches of canary rockfish. The standardised series has been scaled to the geometric mean of the arithmetic series.

Fishing year	Arithmetic	Standardised	Lower bound	Upper bound	Standard error
96/97	118.77	106.99	96.39	118.75	0.053
97/98	120.75	142.18	128.88	156.85	0.050
98/99	133.59	146.65	133.59	160.99	0.048
99/00	133.49	140.14	128.31	153.05	0.045
00/01	122.32	113.51	104.58	123.21	0.042
01/02	143.17	123.59	114.20	133.75	0.040
02/03	172.66	177.22	163.61	191.96	0.041
03/04	151.53	157.14	145.02	170.26	0.041
04/05	201.41	193.25	174.74	213.73	0.051

Combined Areas 5A and 5B (Queen Charlotte Sound):

The depth distribution of the selected data ranged from about 100 m to 700 m, with only sporadic observations at deeper depths (Figure 6). The GLM model used all valid tows occurring between 50 and 325 m.

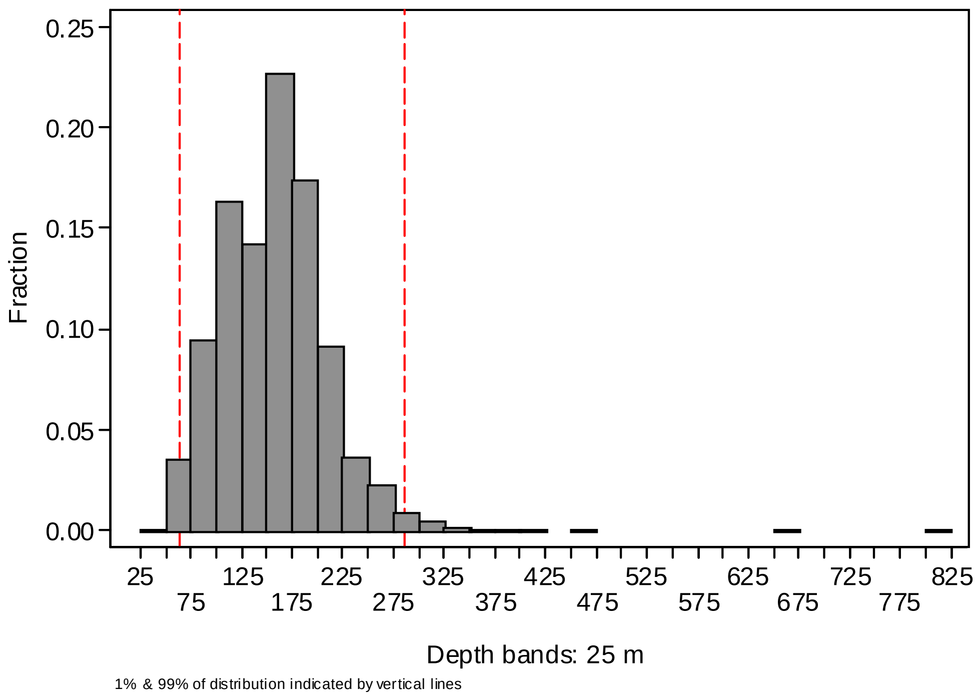


Figure 6. Depth distribution of tows with landed canary rockfish catch in the combined Areas 5A and 5B from 1996/97 to 2004/05 in 25 m intervals. Each bin interval is labelled with the upper bound of the interval. Vertical lines: 1%=64 m; 99%=287 m.

Standardised GLM:

The GLM analysis for Areas 5A, 5B, 5C and 5D selected DFO locality, depth band category, 0.1° latitude bands, and vessel effects in addition to fishing year as explanators in the final model and accounted for 25% of the variation (Table 4).

Table 4. Order of acceptance of variables into the Area 5A+5B model of successful catches of canary rockfish with the amount of explained deviance (R^2) for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.

Variable	**1**	**2**	**3**	**4**	**5**	**6**
Fishing year*	**0.0064**					
DFO locality*	0.1064	**0.1179**				
Depth bands*	0.0726	0.0788	**0.1941**			
0.1° Latitude bands*	0.0707	0.0808	0.1610	**0.2252**		
Vessel*	0.0335	0.0395	0.1386	0.2167	**0.2475**	
Month	0.0137	0.0216	0.1276	0.1995	0.2302	0.2518
DFO Major region	0.0023	0.0089	0.1182	0.1943	0.2264	0.2487
Improvement in deviance		**0.1116**	**0.0762**	**0.0311**	**0.0223**	**0.0043**

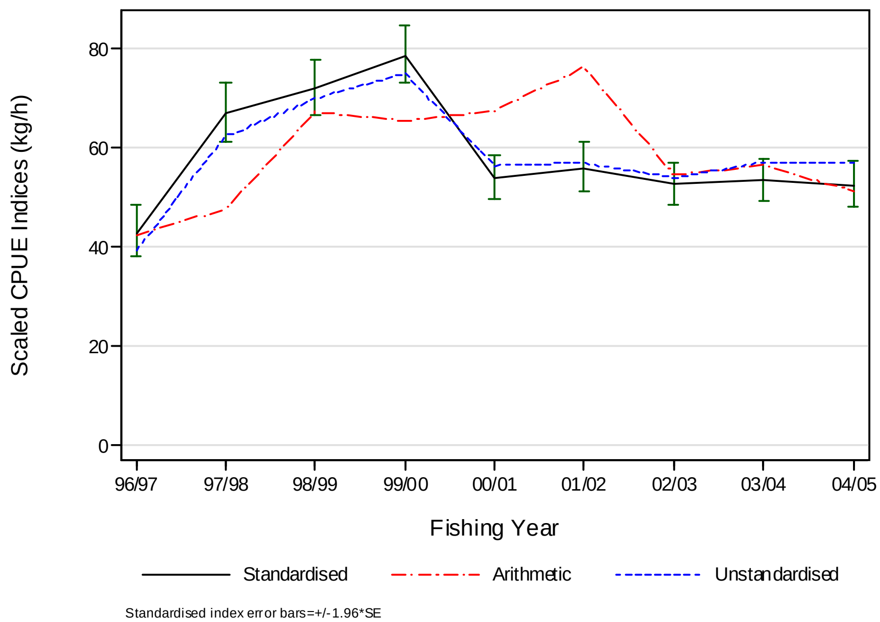


Figure 7. Three CPUE series for Area 5A+5B landed canary rockfish catches for the 1996/97 to 2004/05 fishing years. The solid line is a standardised analysis correcting for fishing year, DFO locality, depth band category, 0.1° latitude bands and vessel effects.

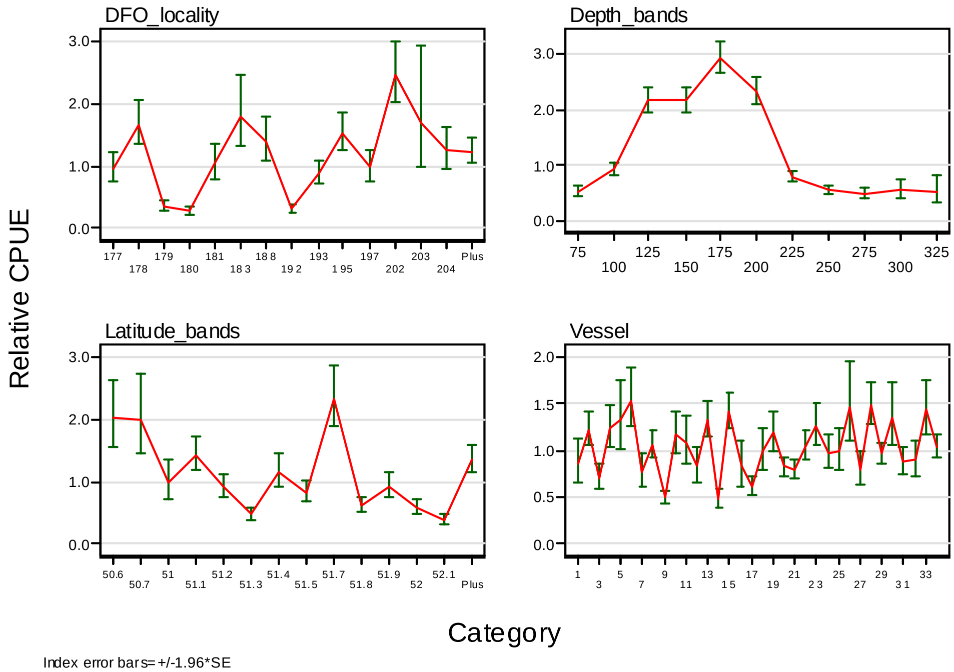


Figure 8. Plots of the coefficients for the categorical explanatory variables included in the standardised GLM analysis presented in Figure for Area 5A+5B.

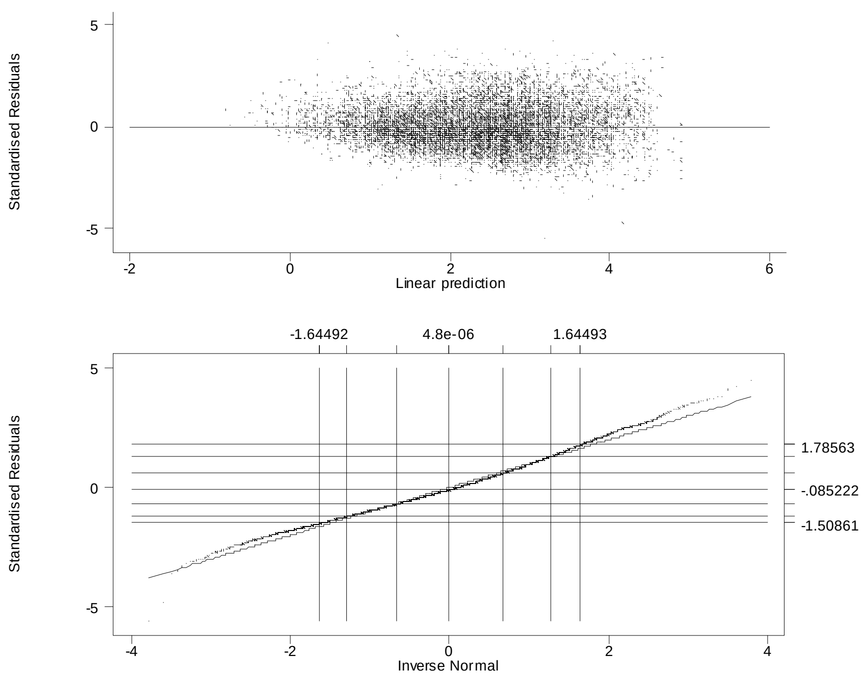


Figure 9. Standardised (Pearson) residuals for the Area 5A+5B GLM analysis presented in Figure . The outside horizontal and vertical lines represent the 5th and 95th percentiles of the theoretical and observed distributions.

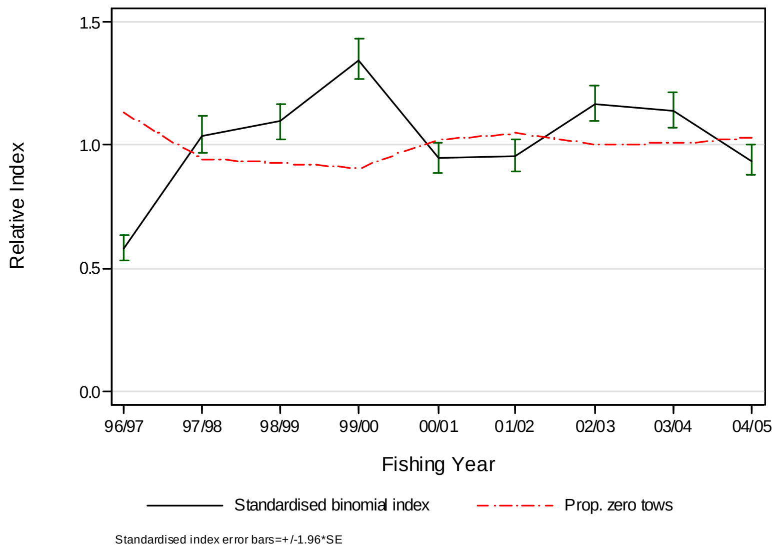


Figure 10. Year effects from a standardised binomial logit model fit to the presence/absence of canary rockfish in Area 5A+5B (using the same dataset that provided the lognormal regression model) (Figure). Also shown is the relative proportion of tows with zero canary rockfish by fishing year (mean=0.71). Each series has been normalised to its geometric mean.

The selected lognormal model shows an increasing trend in the first four years of the series and then drops to a relatively constant level which is slightly higher than the initial observation (Figure 7 and Figure 8; Table 5). Unstandardised catch rates stayed high for an additional two years before dropping to the same level as the standardised catch rates. Model residuals fit the model assumption of log-normal error reasonably well, with relatively small deviations at the tails of the distribution (Figure 9). A binomial model fit to the presence/absence of canary rockfish using the same dataset which was used for the lognormal model superficially shows similar trend to the lognormal series, with an initial increasing trend in the first four years (Figure 10). However, this series remains at a relatively higher level than the lognormal series in the last five years. There has been no change in the proportion to tows reported with zero catch (Figure 10).

Table 5. Arithmetic and standardised CPUE indices (kg/h) with standard errors and upper and lower bounds of the standardised indices for the Area 5A+5B model of non-zero catches of canary rockfish. The standardised series has been scaled to the geometric mean of the arithmetic series.

Fishing year	Arithmetic	Standardised	Lower bound	Upper bound	Standard error
96/97	42.31	42.94	38.02	48.49	0.062
97/98	47.69	67.06	61.48	73.15	0.044
98/99	67.29	71.91	66.54	77.72	0.040
99/00	65.56	78.78	73.21	84.78	0.037
00/01	67.51	53.96	49.72	58.56	0.042
01/02	76.33	55.93	51.21	61.08	0.045
02/03	54.60	52.68	48.68	57.01	0.040
03/04	56.53	53.37	49.36	57.70	0.040
04/05	51.34	52.54	48.17	57.30	0.044

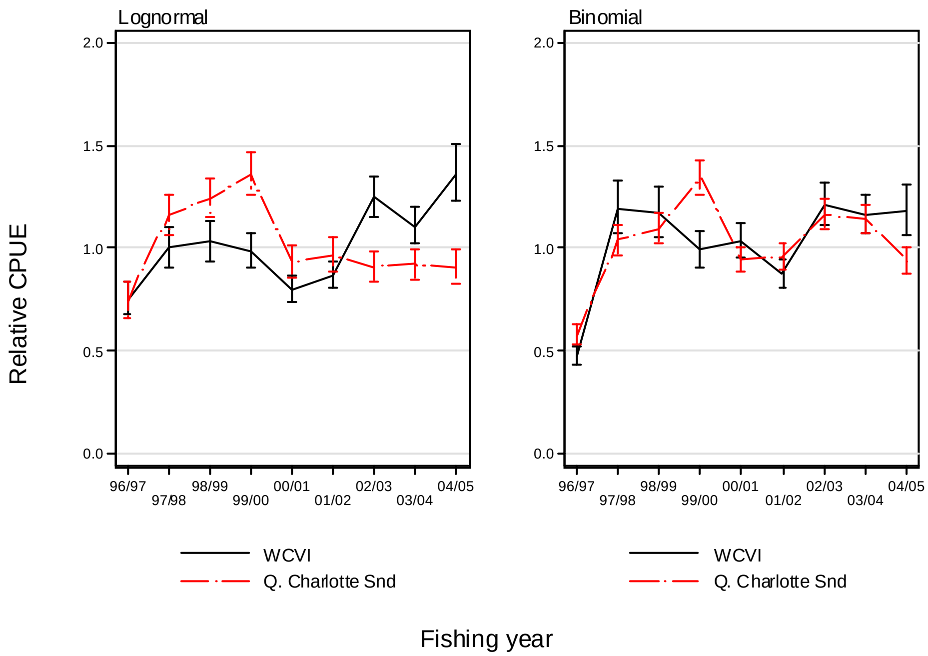


Figure 11. Comparison of two sets of CPUE indices each based on different regression model assumptions for each of the two areas. Each series has been standardised relative to the geometric mean of the period 1996/97 to 2004/05. The error bars show ± 95% confidence bounds.

Comparison of trend lines

Each of the two analysed areas has had two different types of CPUE analysis applied to it: one looking at only non-zero catches (lognormal GLM) and the other looking at the change in the proportion of successful catches (binomial GLM). A comparison of the two areas for each type of GLM analysis shows that the binomial series are similar for the two areas, with each area showing a strong increase between 1996/97 to 1997/98 and remaining fairly flat since then (Figure 11). The QCSd binomial series shows a drop in the most recent fishing year while the west coast Vancouver Island series does not. The two sets of lognormal series are more different, with the QCSd series showing an increase in the first half of the series while the WCVI series is more positive in the latter half of the series (Figure 11). The WCVI fishery has a higher catch rate (Table 3 and Table 5) and a higher proportion of non-zero tows (Figure 2 and Figure 7).