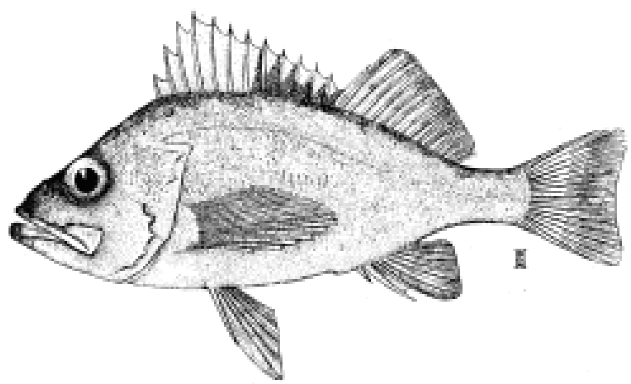
COSEWIC
Assessment and Status Report

on the

Canary Rockfish
Sebastes pinniger

in Canada



THREATENED
2007

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC
Assessment Summary

Assessment Summary – November 2007

Common name
Canary rockfish

Scientific name
Sebastes pinniger

Status
Threatened

Reason for designation
A comparatively large (maximum weight 5.7 kg), orange-yellow fish that typically inhabits rocky bottoms at 70-270 m depths from the western Gulf of Alaska south to northern California. Its late maturity (13 years for females), long maximum lifespan (84 years), and long generation time (20-30 years) are characteristic of species that are slow to recover following population decline. The species is treated as a single designatable unit. Two surveys in the southern part of its Canadian range considered the most reliable indicators of population trend, and show abundance index declines of 78% and 96% over 30 years and 17 years respectively. Survey indices from the northern part of the range and commercial catch per unit effort indices show no consistent trends but are of relatively short duration and are in some cases based on methods which do not adequately sample areas inhabited by the species. There is uncertainty due to high variability in the various index series (characteristic of trawl surveys) and the unknown degree to which abundance trends in the southern part of the Canadian range reflect abundance trends throughout the species' range in Canadian waters. Fishing is the most likely cause of the observed decline. Changes to management since 1995 include 100% observers or video monitoring coverage and implementation of individual transferable quotas, which are expected to improve control of fishing. Rescue from contiguous populations to the south is unlikely given that current abundance in the US is estimated at 5-10% of unfished levels, and rescue from populations to the north is uncertain because their status is not well known.

Occurrence
Pacific Ocean

Status history
Designated Threatened in November 2007. Assessment based on a new status report.

COSEWIC
Executive Summary

Canary Rockfish
Sebastes pinniger

Species information

Canary rockfish (French: sébaste canari) (*Sebastes pinniger*) is one of 102 species of the genus *Sebastes*, of which at least 36 species are present in B.C. waters. Canary rockfish have been managed in B.C. waters as two principal stocks: a southern or west coast of Vancouver Island stock and a central, or Queen Charlotte Sound stock north of Vancouver Island. Although there is evidence for a biogeographical boundary at the north end of Vancouver Island, which could be considered a boundary between northern and southern populations of canary rockfish, this report treats canary rockfish as a single designatable unit in B.C. waters. Fishers report that canary rockfish are abundant in more northern areas, particularly off the west coast of the Queen Charlotte Islands; but landings from these areas have been limited owing to the lack of trawlable ground. The B.C. population probably overlaps to some extent with U.S. populations.

Distribution

Canary rockfish are found from the western Gulf of Alaska (Shelikof Strait) to northern Baja California. Populations are most abundant between B.C. and northern California. They are broadly distributed in continental shelf and coastal waters of B.C.

Habitat

Larvae and pelagic juvenile canary rockfish occupy the top 100 m for up to 3-4 months after live-birth (parturition) and then settle to a benthic habitat. Adults typically inhabit rocky bottom in 70-270 m depth on the continental shelf. Canary rockfish are a marine and sub-tidal species; thus, all Canadian habitat is within Federal waters. Most of these waters are currently exploited by commercial, recreational, and First Nations' fishers.

Biology

Maximum observed length, weight, and age for canary rockfish from B.C. waters are 68 cm, 5.7 kg, and 84 y, respectively. Average weight in commercial samples 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. The *M* for females appears to increase as they mature with an overall 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 an array of planktonic items. Adults and subadults primarily eat krill and small fishes. Significant predators probably include lingcod (*Ophiodon elongatus*). Like all rockfish, they have closed swim bladders and will usually die if released after routine capture. Tagging work in Oregon indicated that at least some individuals can move over 100 km. Trawl catches indicate a seasonal depth migration from 160-210 m in late winter to 100-170 m in late summer. The role and importance of canary rockfish in the ecosystem have not been examined.

Population sizes and trends

Surveys and commercial harvests suggest a current adult abundance of at least several million fish. In the southern part of the species' range in Canada, the U.S. triennial bottom trawl survey (1980-2001) indicates a decline of 96%. The catch rates in a long-term (1975-2006) shrimp trawl survey off the west coast of Vancouver Island show high variability but a statistically significant decline over this period of 78%. Commercial bottom trawl catch rates in the same region appear stable since 1996. Age data from this region show little long-term trend in mean age of females but a decline in mean age of males from 1980-1990, followed by no trend. Inferred estimates of *F* (the instantaneous rate of fishing mortality) from catch curve analysis do not indicate overexploitation. The contiguous population in the USA is at a very low level (5-10% of unexploited) and was declared “overfished” in 1999; directed fishing was closed as part of a rebuilding plan.

For the northern part of the species' range in Canada (Queen Charlotte Sound), there is no long-term index available, and available indices are considered of low reliability for this species. Two recently initiated surveys indicate increasing abundance since 1998 and 2003, respectively. Trawl catch rates appear stable since 1996; size and age composition provide no evidence of overexploitation. Fishers have long reported significant unexploited populations of canary rockfish further north, particularly off the west coast of the Queen Charlotte Islands, but no abundance trend is available for that population. Status of populations to the north (Alaska) is unknown.

A combined analysis of the two most reliable index series (US triennial, west coast of Vancouver Island shrimp survey) shows a decline of 86% in 30 years or 1 – 1.5 generations in the southern part of the Canadian distribution. Reported catches are consistent with this level of decline and plausible biomass estimates, indicating that fishing can explain the decline. Reduced recruitment may have contributed to the decline but there is no clear evidence that this occurred.

Limiting factors and threats

Fishing is the major known anthropogenic threat. Commercial fisheries are managed by harvest quotas, which are essentially unchanged in the most important fishing areas since the mid-1990s, and 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 had an impact on abundance in Canadian waters, but since the declaration in 1999 of an "overfished" status for canary rockfish for Washington-California waters, fishing effort and catches have been drastically reduced.

Mobile fishing gear may impact canary rockfish habitat, but the canary rockfish trawl grounds have been fished for 3-6 decades and, since the introduction of Individual Vessel Quotas in 1997, trawl activity has been limited to core areas. Oil and gas exploration could impact habitat but this is currently under moratorium on the B.C. coast. No other threats to habitat are known.

Special significance of the species

Canary rockfish are a significant economic component of the commercial fisheries (>800 t/y since 1995), 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.

Existing protection or other status designations

Landings are currently constrained in the commercial fisheries through a variety of harvest controls, and are well monitored. Catches in the recreational fishery are controlled through bag limits for "rockfish" and by Rockfish Conservation Areas.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2007)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as “Vulnerable” from 1990 to 1999, or “Rare” prior to 1990.

** Formerly described as “Not In Any Category”, or “No Designation Required.”

*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

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Canary Rockfish
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in Canada

2007

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SPECIES INFORMATION

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 has been interpreted to mean “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

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).

[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

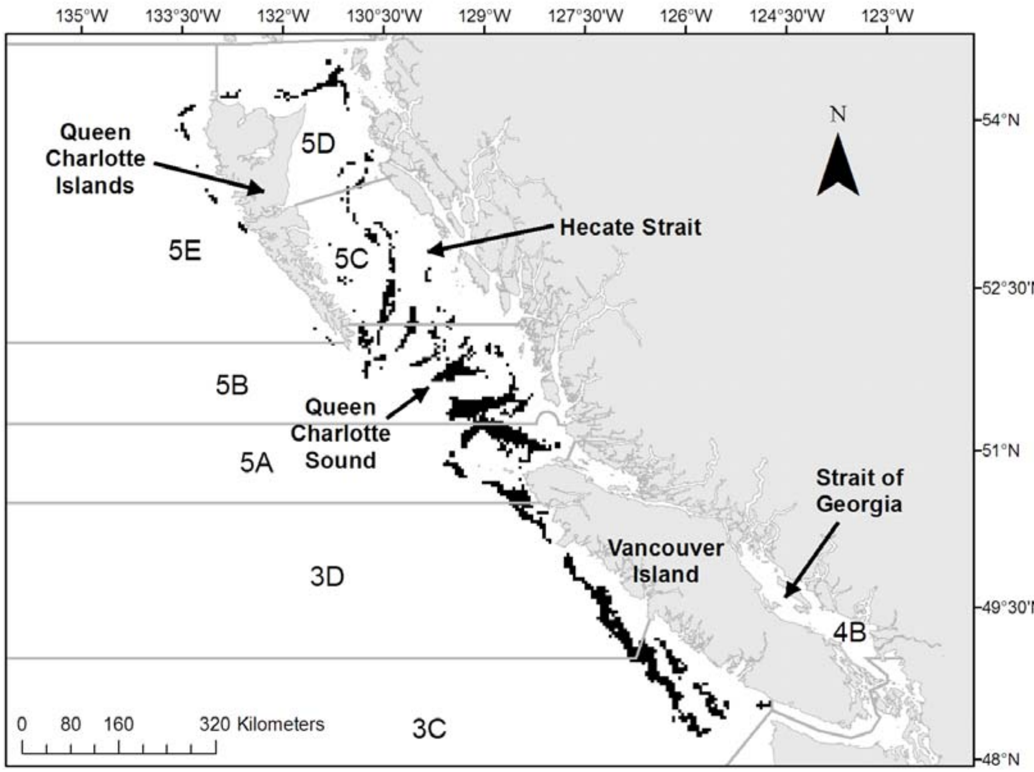

Figure 1. Spatial distribution of catches of canary rockfish in B.C. as recorded in commercial trawl observer logbooks (1996-2004). Also shown are the Pacific Marine Fisheries Commission (PMFC) Area designations.

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). Some populations of groundfish on either side of this boundary do not seem to vary synchronously: for example 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).

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, but 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).

Although canary rockfish to the north and to the south of the northern tip of Vancouver Island might be considered two populations (consistent with stock separation for fishery management purposes), there is presently no basis to assign more than one designatable unit for canary rockfish and the species is considered to be a single designatable unit in Canada's Pacific waters for this report.

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 metres (Fig. 3). This translates to an extent of occurrence 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 area of occupancy of >32,000 km^2.

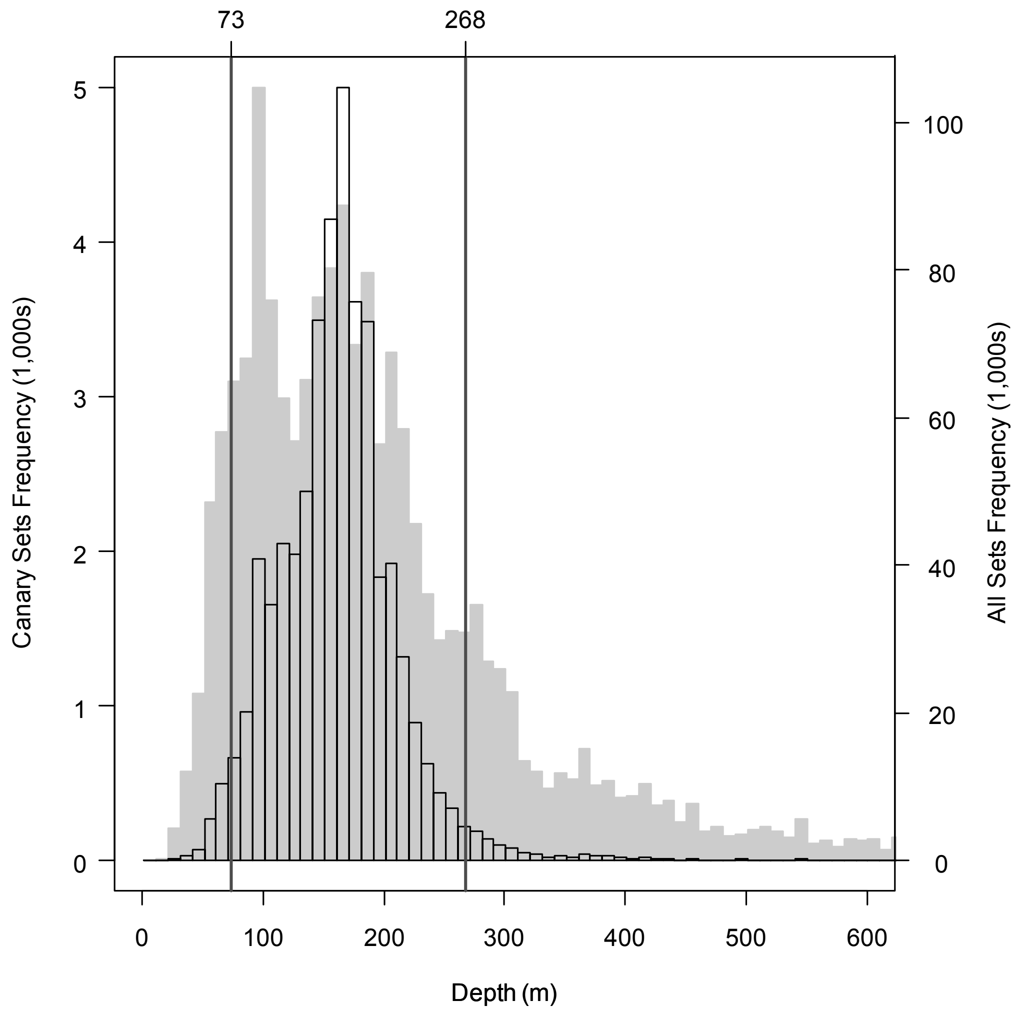

Figure 3. Histogram of the frequency of occurrence of canary rockfish in commercial tows by depth-of-capture as recorded in observer logbooks from the British Columbia commercial trawl fleet (bottom trawls only). The vertical lines denote the 2.5% and 97.5% quantiles of the observations and are located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

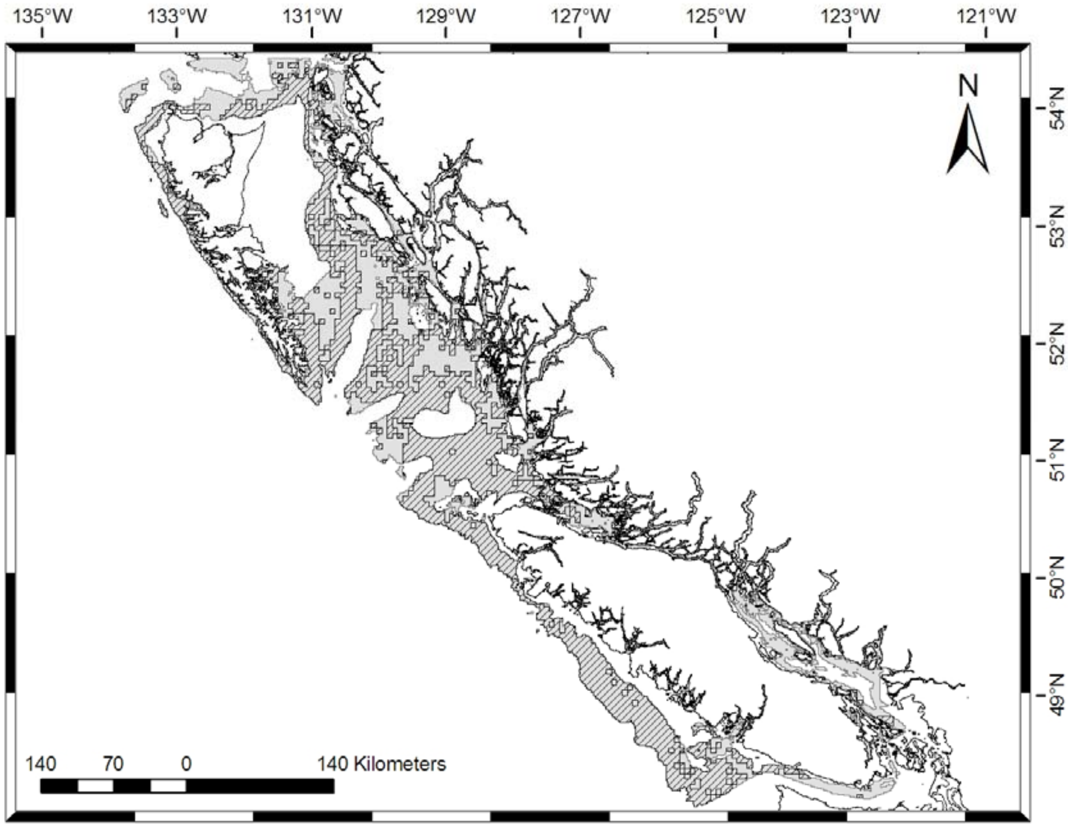

Figure 4. Canary rockfish habitat in British Columbia. The grey shaded region defines the potential maximum area (=60,043 km^2) of canary rockfish habitat based on depth-of-capture in the commercial trawl fleet. The hatched zone indicates within this region, the area where canary rockfish were actually 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 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 Conservation Areas in the Strait of Georgia and the outer coast.

BIOLOGY

Lifespan, life cycle, and reproduction

Aging 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 38-45).

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.

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[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.

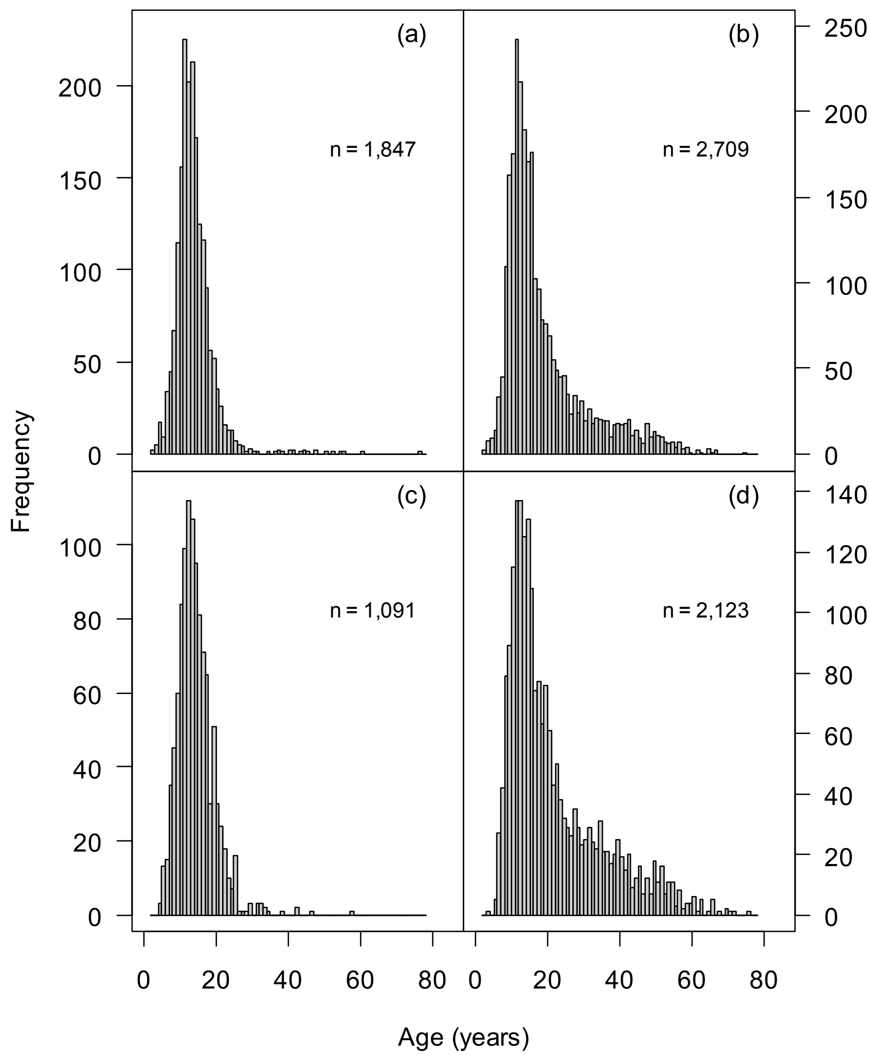

Figure 5. Histogram of canary rockfish ages (cutoff at 80y): (a) Females from Area 3C+3D; (b) Males from Area 3C+3D; (c) Females from Area 5A+5B; (d) Males from Area 5A+5B (Data from 5E are omitted owing to the large gap in years between samples, see Fig.8).

The 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).

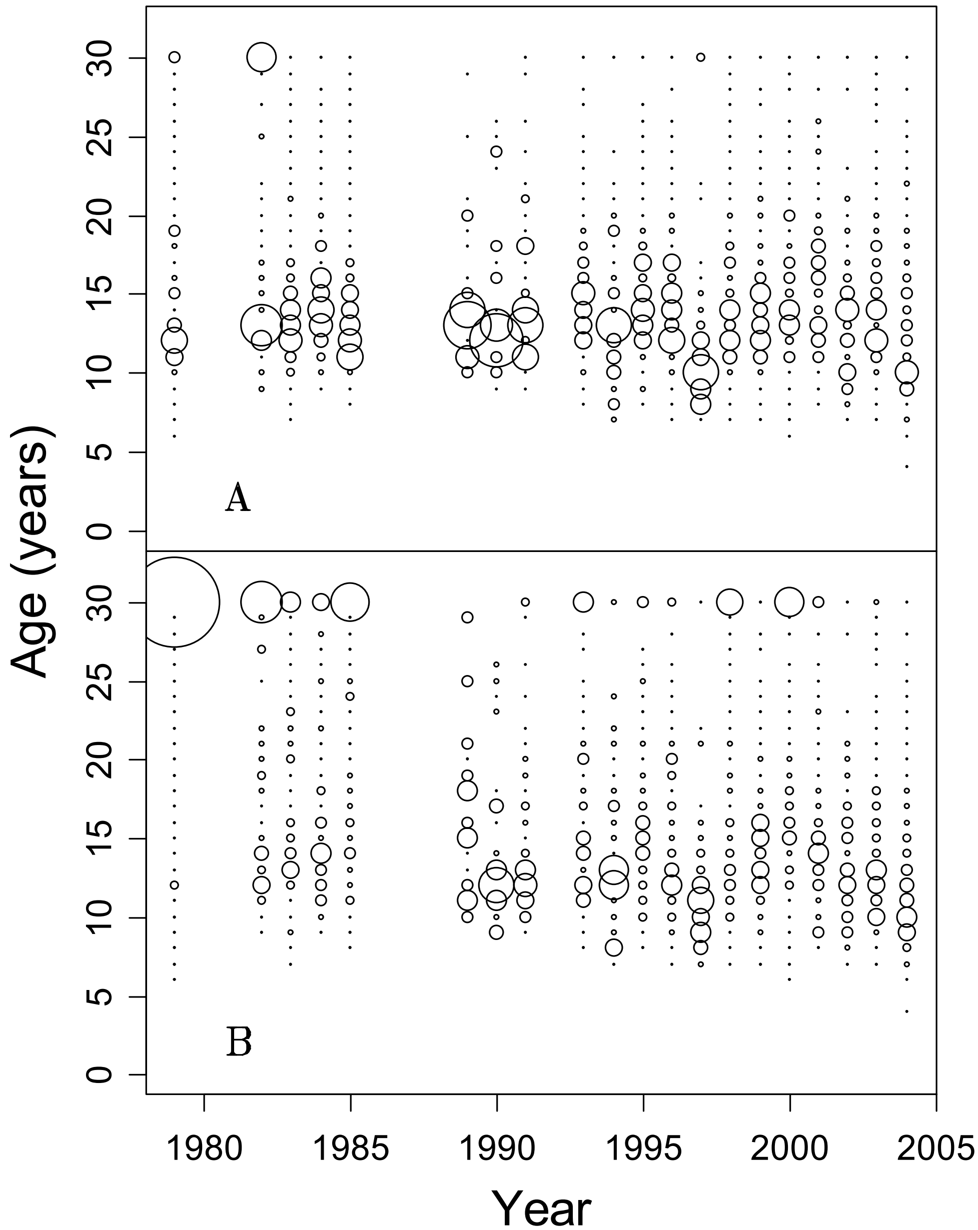

Figure 6. Proportions-at-age by year for (A) female and (B) male canary rockfish from Area 3C+3D. The radius of each circle is scaled relative to the proportion-at-age within each sex, age 30 = 30+ group. Commercial and survey samples combined.

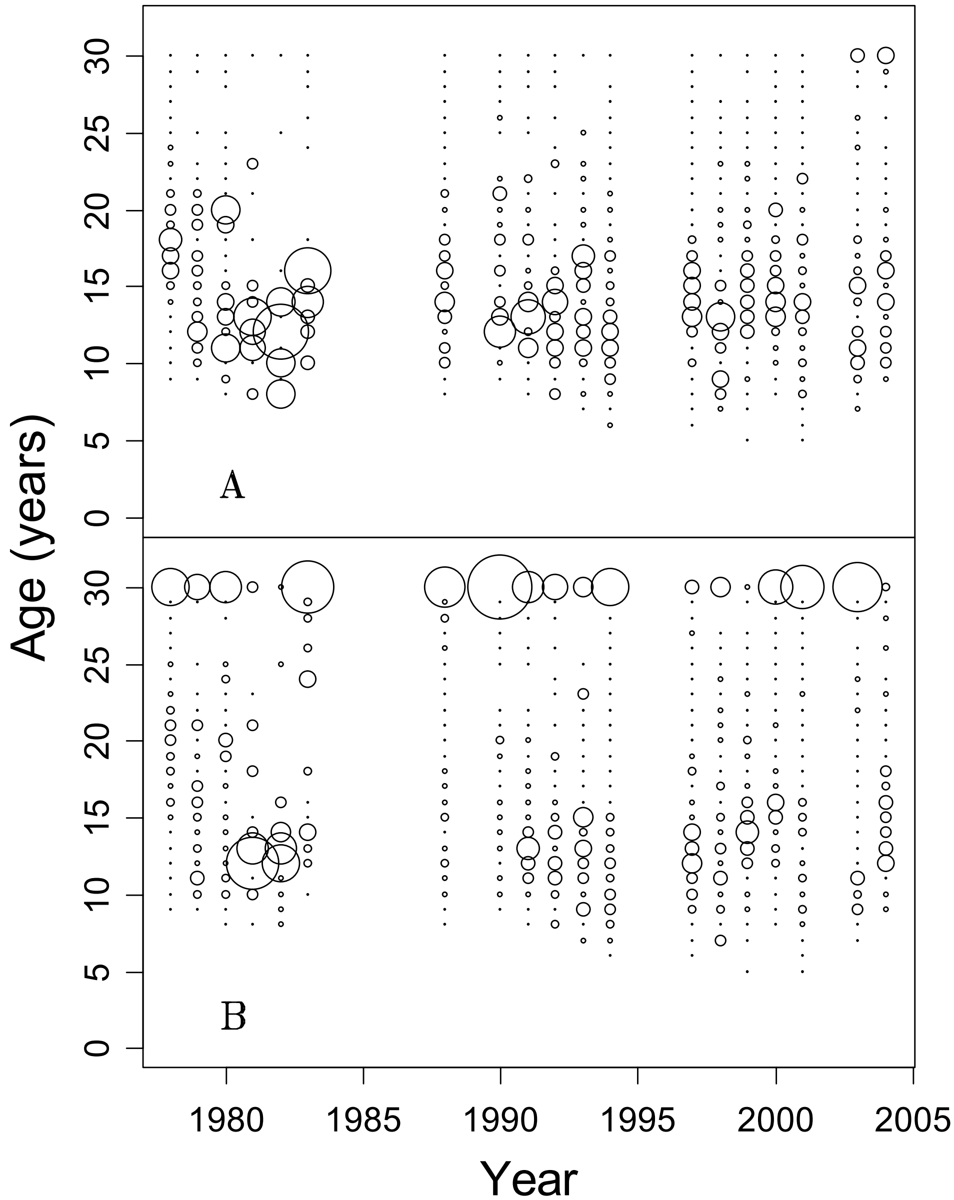

Figure 7. Proportions-at-age by year for (A) female and (B) male canary rockfish from Area 5A+5B. The radius of each circle is scaled relative to the proportion-at-age within each sex, age 30 = 30+ group. Commercial and survey samples combined (see Table 9).

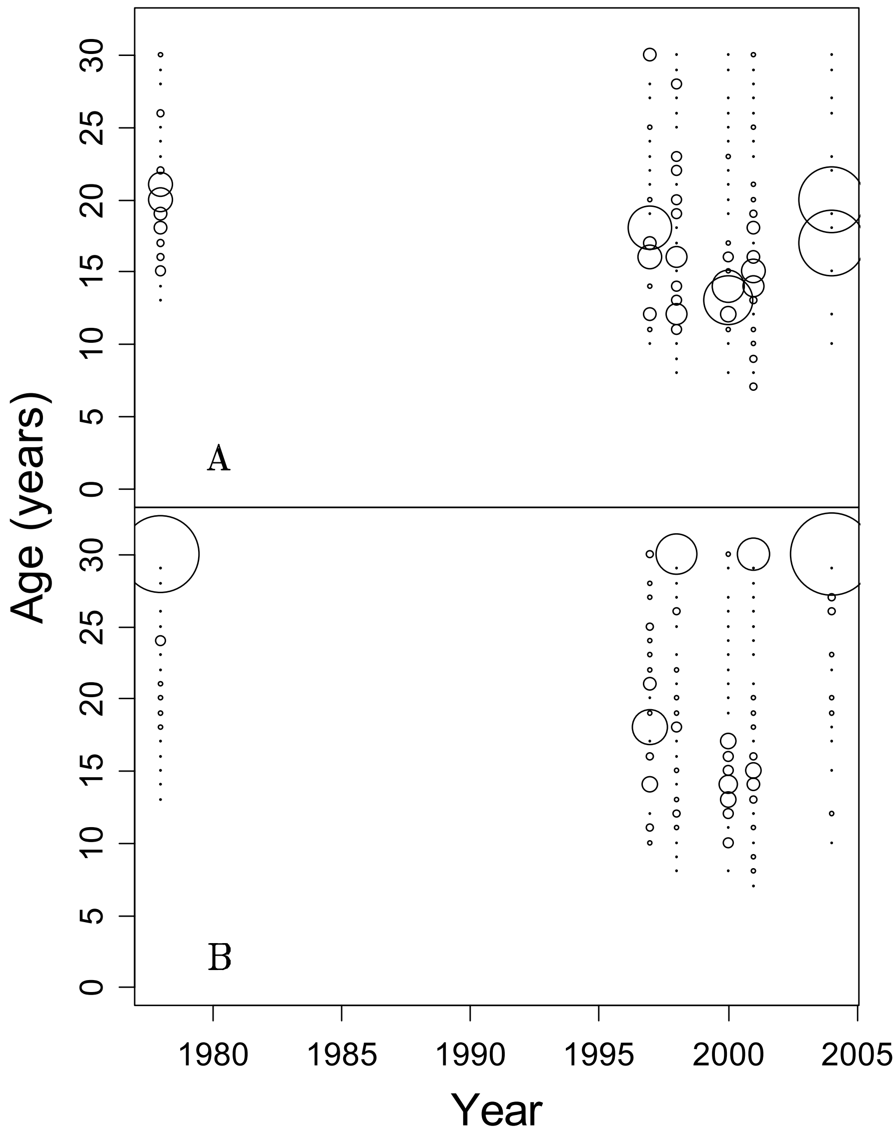

Figure 8. Proportions-at-age by year for (A) female and (B) male canary rockfish from Area 5E. The radius of each circle is scaled relative to the proportion-at-age within each sex, age 30 = 30+ group. Commercial and survey samples combined (see Table 7).

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). Based on an estimate of an age-averaged *M* 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).

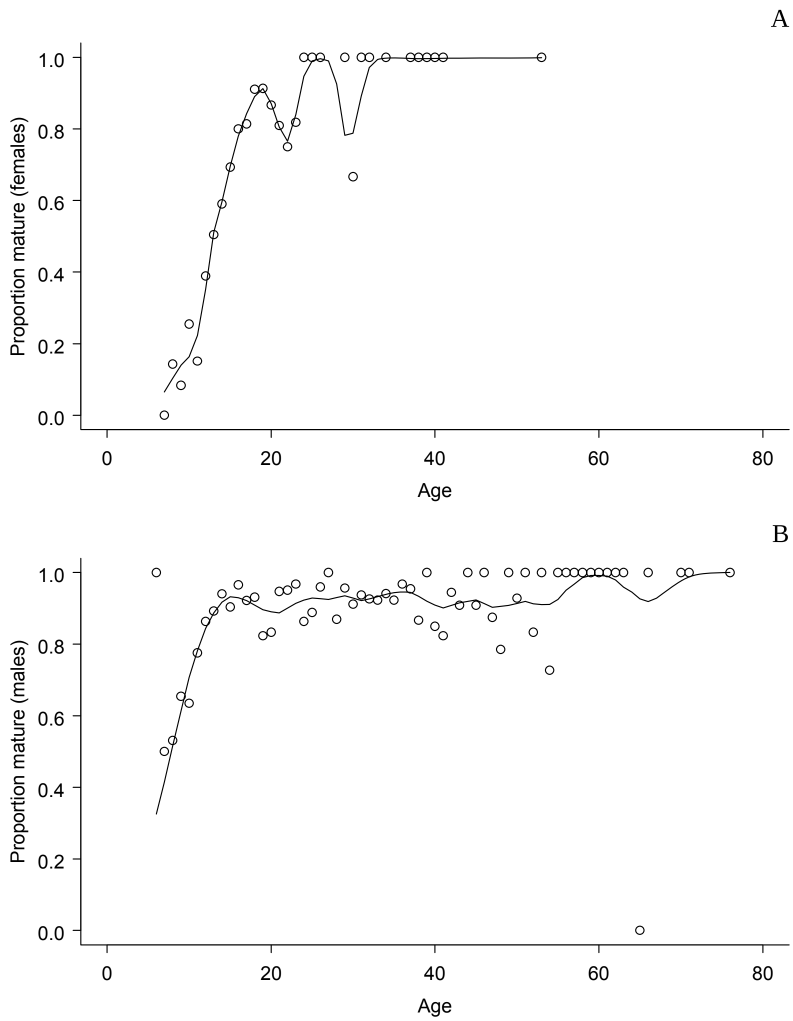

Figure 9. Age-at-maturity for (A) female and (B) male canary rockfish.

Diet

Love *et al*. (2002) report 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.

DESCRIPTION OF FISHERIES

Commercial fisheries

The U.S. trawl fishery moved northward to Area 3C+3D in the 1950s and reached central coast areas (5A+5B+5C) in the early 1960s 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 1970s, although this region is largely untrawlable at canary rockfish depths.

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

	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 1960s and Japanese vessels in the 1970s, 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-1990s 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 the 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.

Estimated landings should only be used to characterize the approximate magnitude of the harvest over the 1967-1996 period (Table 1). Actual values are only reliable since the introduction of 100% observer coverage in the trawl fishery in 1996. Even for the more recent period, 1996-2006, there are no discard estimates for the hook-and-line fleets, although these fleets have now moved to 100% monitoring (2006/2007). Therefore, population trends should not be inferred from trends in total landings and catch per unit effort (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). 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 prior to 2006. 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 for hook and line fisheries.

Catches of canary rockfish in the south coast salmon troll fisheries were projected from observer data for 1998-2001 (Wrohan *et al*. 2002). 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 1990s, 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.).

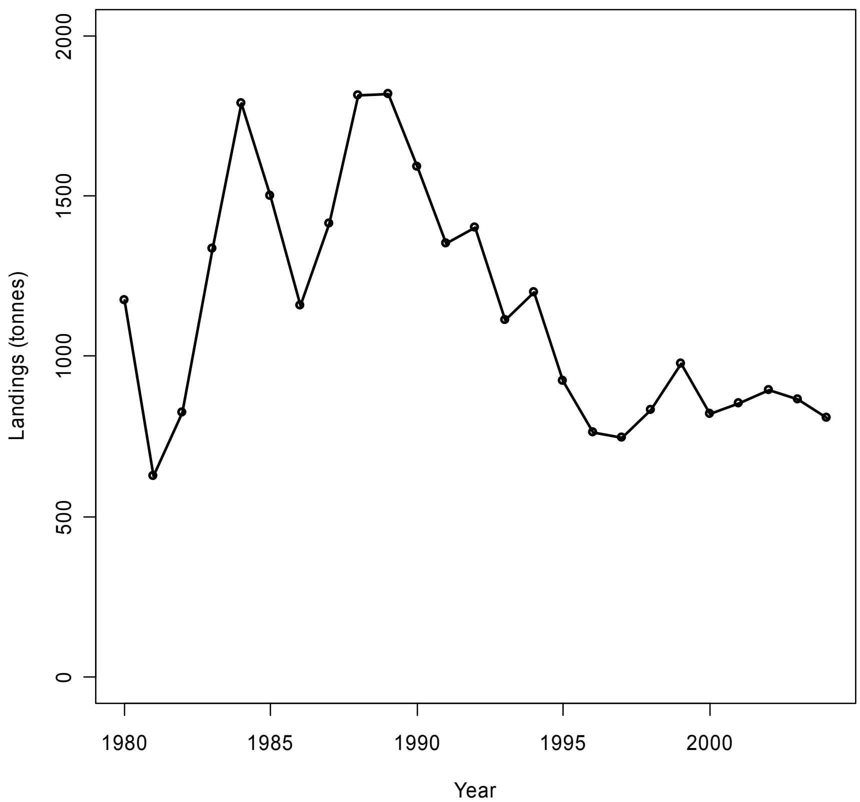

Figure 10. Total landings by year of canary rockfish in British Columbia waters.

First Nations' fisheries

Consistent with the COSEWIC guidelines for the collection of Aboriginal knowledge, the only required Wildlife Management Board contact, the Nisga'a Joint Fisheries Management Committee, was consulted during preparation of this report. They reported "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. 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.

No quantitative estimates of the catches of canary rockfish by First Nations are available, as available data only indicate the “rockfish” category. On a coast-wide basis, First Nations’ canary rockfish catches are probably very small in comparison with the catches of canary rockfish in other fisheries, although catches may be significant in some specific locales.

Recreational 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 Strait of Georgia (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 no CPUE analysis was considered. 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 in the 1980s, coastwide 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 1980s 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.

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

FISHERIES MANAGEMENT

Prior to extended jurisdiction (1977) fisheries impacting this species were largely conducted by foreign fleets (USA, USSR, Japan) with relatively poor reporting of catches and few restrictions on fishing. Canadian fleets progressively replaced foreign fleets, in particularly the US fleet, in the late 1970s. Only Canadian vessels exploited this species from 1982.

There are many reports of dumping at sea and misreporting in the mid-1980s to mid-1990s, but the magnitude of this error is unknown. Many fishers argue that the discards were large relative to the total amount landed, but there were also cases of landed overages that were misreported as other species. Reported catches could be 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.

The lack of confidence in the landings figures and the resulting difficulty in applying quota management for rockfish led DFO to mandate 100% dockside monitoring for all fleets exploiting groundfish in 1994 and 100% observer coverage for the trawl fleet in 1996. Observer coverage was particularly important for canary rockfish since most of the catch is from trawl vessels. Individual transferable quotas (ITQs) were introduced in 1997.

Additional management changes were introduced in 2006 in response to the problems of incidental catch in an area of high species diversity. Non-directed catch was a growing concern because the catches that exceeded allowable limits for each gear type were discarded at sea, often with high levels of mortality. Since discards were for the most part unreported, the total removals and subsequent mortality for many species of groundfish were largely unknown. As of 2006, all species were under quota and an electronic audit system was introduced on all vessels which were not required to carry observers. Using the video-based system, 10% of trips are audited to verify if logbook records are accurate and sanctions are applied if discrepancies are found. Logbooks remain the principal monitoring tool but the audit system is the “speed trap” to ensure compliance with logbook maintenance.

All monitoring measures (100% dockside monitoring, 100% observer coverage on trawl vessels, the electronic audit system) are funded by industry.

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.

Canary rockfish in B.C. waters is now 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. Since the introduction of 100% observer coverage in the trawl fleet 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).

Of the total canary rockfish quota, 87.7% is allocated to trawl (T licence), 11.77% to outer coast hook and line rockfish fishers (ZN-outside licence), and 0.53% to halibut fishers (L-licence). 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. Official management plans should be examined for details on fishing regulations[4].

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 have been largely based on advice provided in stock assessment documents (Table 2). Advice for data-poor species such as canary rockfish has been developed by examining historical catches and biological factors such as CPUE trends, trends in age composition, catch curve analysis, and comments from fishers (Stanley 1999). The most recent advice on this species (Stanley 1999) suggested a range of TACs from a maximum based on not exceeding historical catch levels to a minimum based on 50% of the historical level:

> “... 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.”

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

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.

Quotas have generally been set between the “maximum” and “minimum” levels in the biological advice; for example for a range of 525-1050 t/yr recommended for areas 3C+D and 5A+B (Stanley 1999) recent quotas have ranged between 647 (1997/8) and 898 (1999/2000) t/yr with most quota levels between 700 and 800 t/yr (Table 2).

Further details on stock assessment approaches is provided under “Other stock assessments of Canadian populations”.

In summary, there has been considerable improvement in monitoring and control of harvests in the past decade, and industry is making major contributions to the fisheries management system, but management of this species is not based on an analytical risk-based assessment of harvesting strategies related to species abundance.

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 abundance, 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, it assists the discussion of whether the population is at risk to such issues as genetic drift.

Table 2. Canary rockfish recommended harvest, quota, and catch (t), by year and management region, 1997 to 2007. "Total" column also includes catches from unknown areas and Area 4B (Strait of Georgia). Catches do not include HL discards until 2006/7.

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
2005/06	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)	601	231	95	11	943
2006/07	Recommended Harvest[d]	[d]	[d]	[d]	[d]	[d]
	Trawl Quota[c]	529	265	101	151	1046
	Quota (HL)[c]	147				147
	Catch (trawl and HL)	479	241	51	4.5	777
2007/08	Recommended Harvest[d]	[d]	[d]	[d]	[d]	[d]
	Trawl Quota[c]	529	265	101	151	1046
	Quota (HL)[c]	147				147
	Catch (trawl and HL)	na	na	na	na	na

[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 2001/2002-2007/2008
[e] Not specified

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.

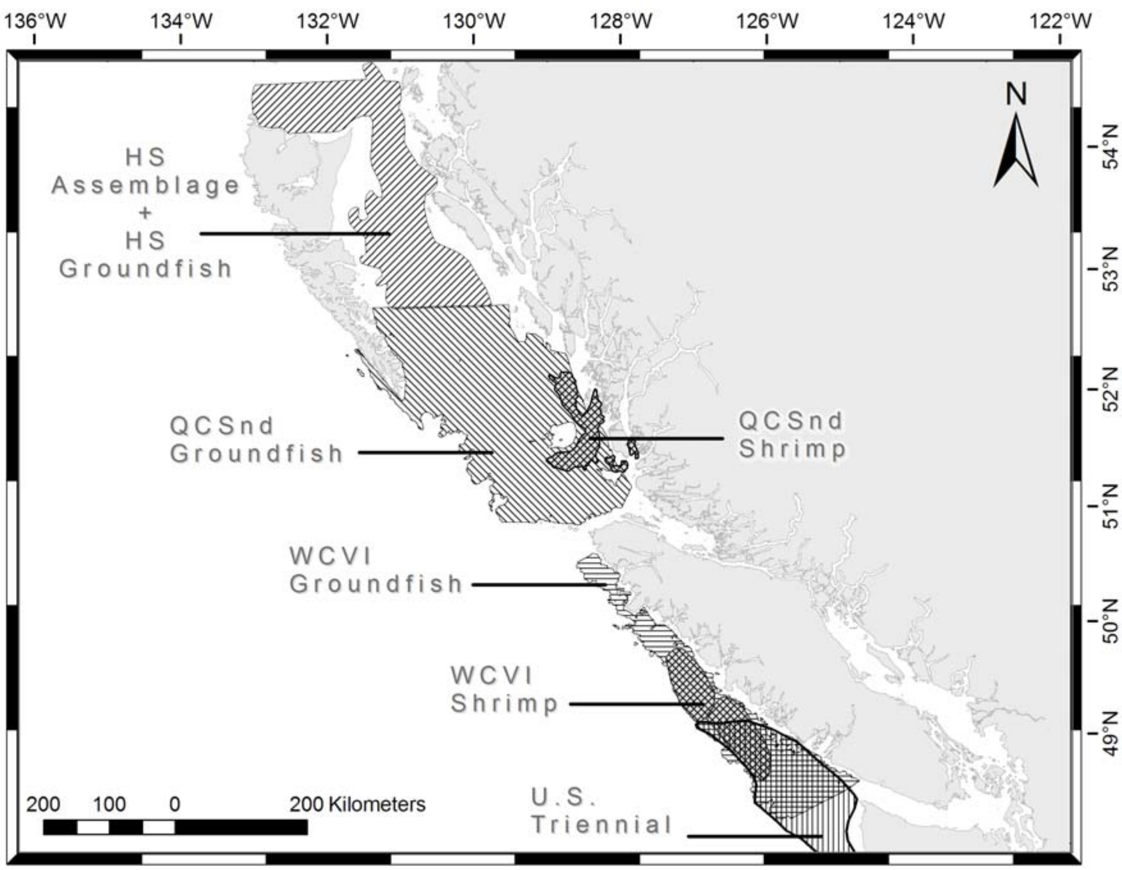

Figure 11. Locations of trawl surveys that provide indices of canary rockfish abundance. All surveys target groundfish except two shrimp trawl surveys conducted in QCSd and off the WCVI.

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
Goose Island Gully Pacific O. perch	1966	2005	16	146-218	various
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.

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)
6. Goose Island Gully Pacific Ocean perch 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).

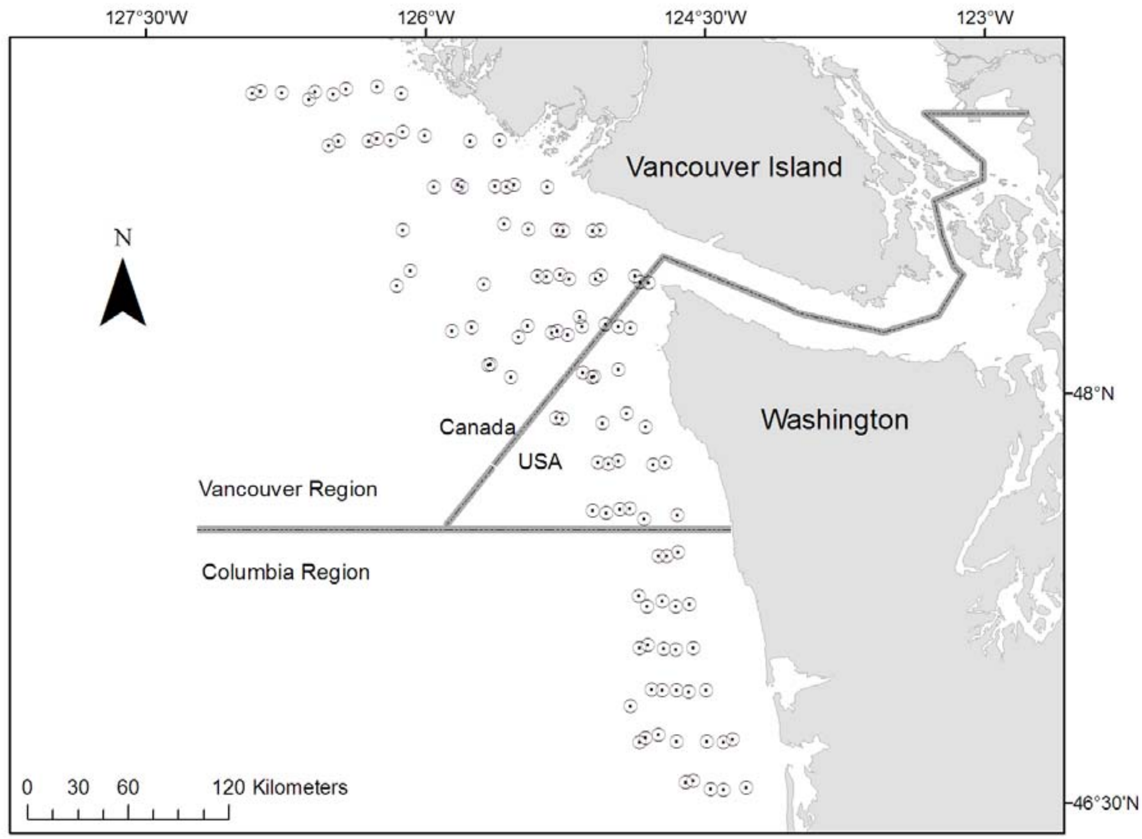

Figure 12. Set locations from the U.S. triennial survey conducted in 2001.

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).

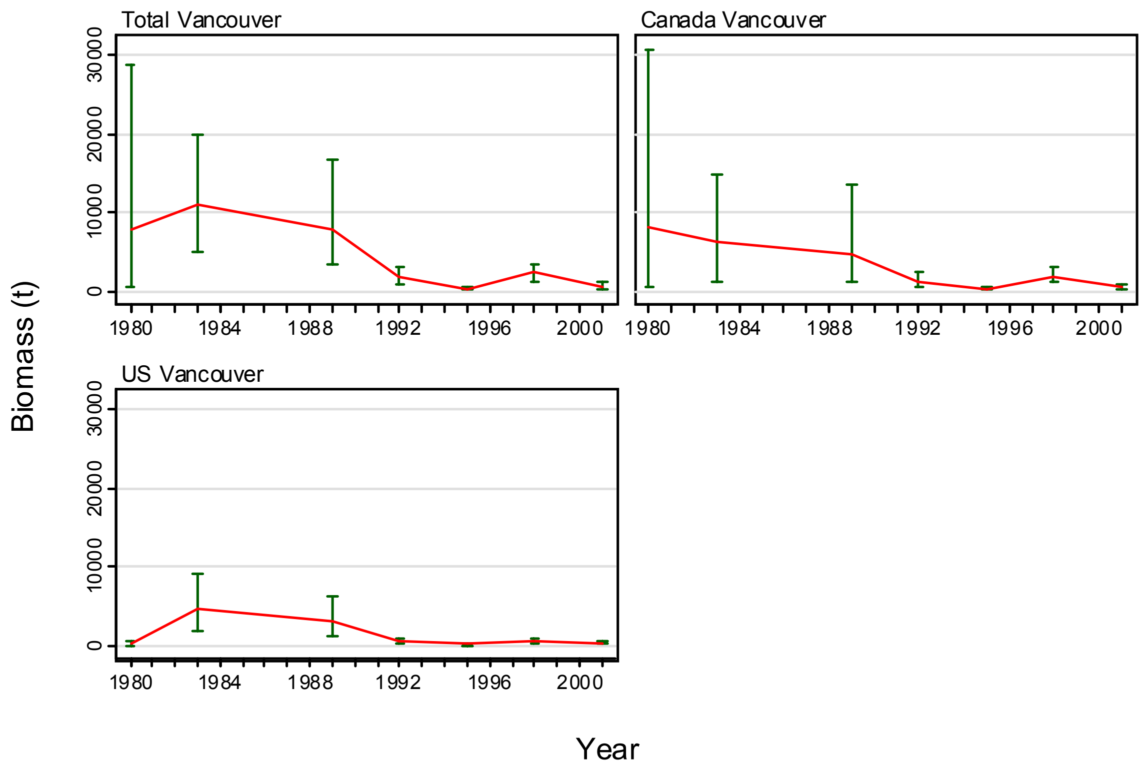

Figure 13. Three biomass estimates for canary rockfish in the INPFC Vancouver region (total region, Canadian waters only and U.S. waters only) with 95% bias corrected error bars estimated from 5,000 bootstraps.

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.

Fitting a log-linear regression to the Canada-Vancouver index values gives a regression significantly different from 0 and an overall decline of 96% over the series. Survey data are considered the most reliable method for monitoring demersal marine species, but typically (as here) give large error bars. Annual biomass estimates can be highly leveraged by 1-2 large tows. However, despite these caveats, this survey is considered to be a reliable index of population status in this area.

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. 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
U.S. 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

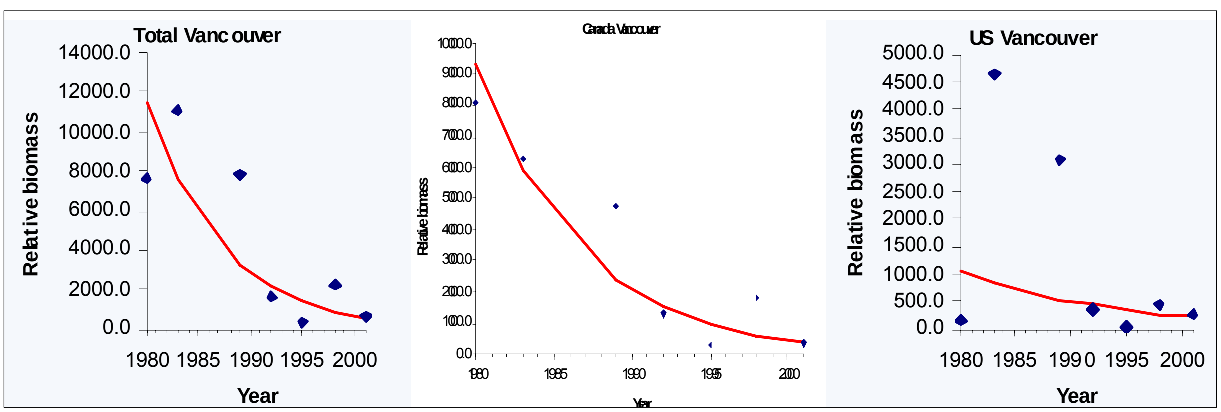

Figure 14. Biomass estimates for canary rockfish from the U.S. triennial survey grouped for the different zones. The lines represent an exponential fitted curve through the point estimates.

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.

West Coast Vancouver Island shrimp survey

Survey indices for canary rockfish are available from the WCVI shrimp survey which spans 1975 to 2006 (Fig. 15). 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. 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.

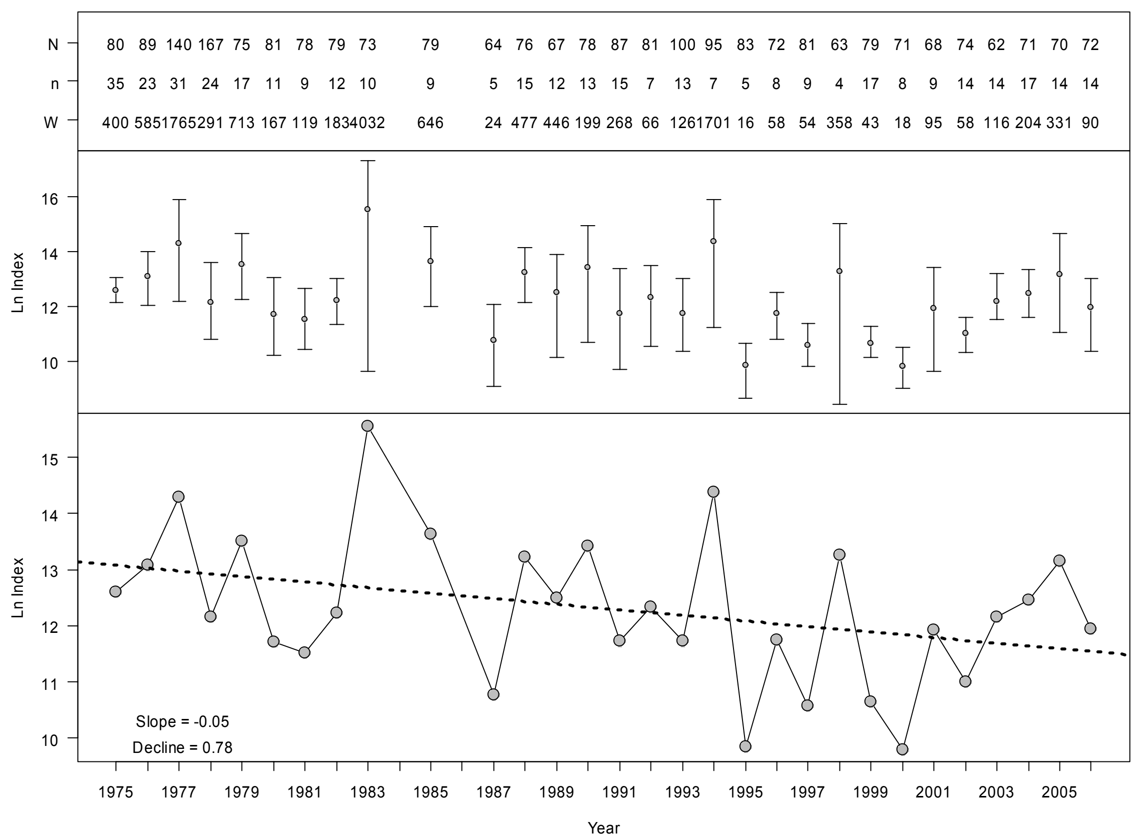

Figure 15. Canary rockfish index from the west coast Vancouver Island shrimp survey, 1975 to 2006. The bottom panel plots the index on the Ln scale, with the dotted line showing the least squares linear fit. The middle panel plots the same index but includes the 95% confidence intervals around each point. The top panel lists the total number of tows (N), the number of tows that captured canary rockfish (n), and the weight of canary rockfish captured (W, in kg) in each year of the survey.

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 have declined throughout the history of this survey, although there is considerable variability around the trend line, with some years of 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 1990s, but these indices also have high uncertainty, and there have been periods of increase or stability earlier in the series followed by a continuing decline.

Fitting a log-linear regression to the series of indices provides a regression significantly different from zero and an overall decline over the period of 78%, consistent with the pattern observed in the triennial survey.

The proportion of tows with canary rockfish shows a consistent trend towards increasing canary rockfish in recent years, following a period of decline, such that the proportions are now above the long term average (Fig. 16). The power of this index to detect real changes in abundance is unknown, although there is evidence that the frequency of non-zero catches is a valid alternative index and may sometimes be superior (Bannerot and Austin 1983). For this assessment, the biomass estimates are considered more reasonable as an index of abundance.

Trends in the WCVI shrimp survey catch rate indices were analysed following a step function 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).

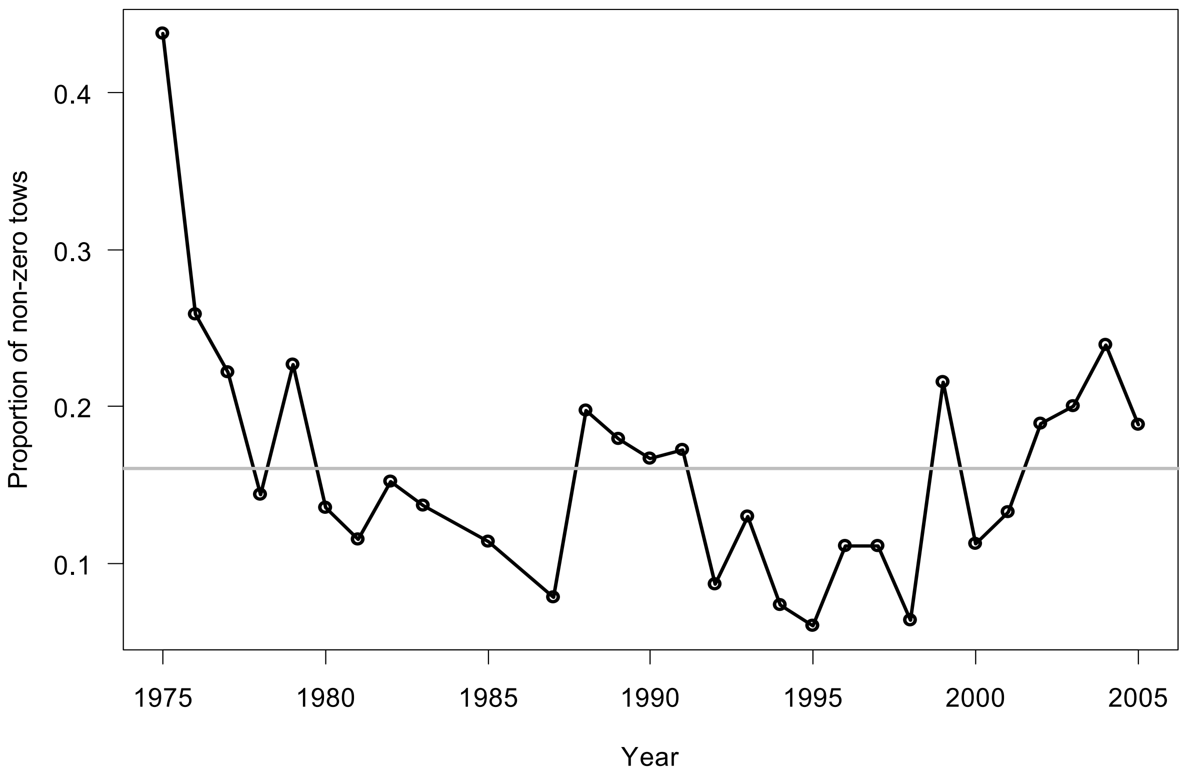

Figure 16. Proportion of tows with canary rockfish by year for the WCVI shrimp survey. The average proportion is shown by the solid line.

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

The step approach presented above represents an alternative to 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% (consistent with the log linear analysis noted above), but this drops to 60% if the 1983 estimate is removed. The series does not appear monotonic, so the rationale for fitting a linear regression can be questioned. The step function approach may be more robust to the outlier index points which are present in this series and it makes fewer assumptions about the continuity of the series.

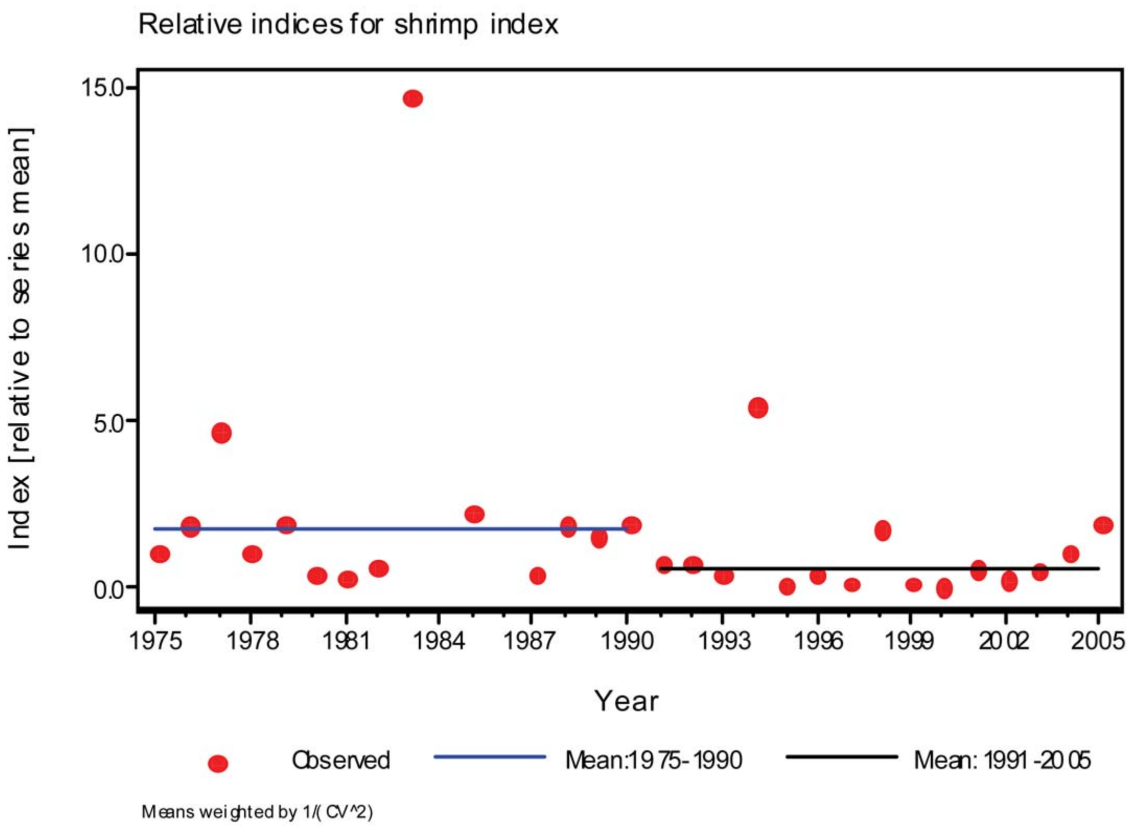

Figure 17. Two step function for the WCVI shrimp survey index, plotted relative to the mean of the survey series, weighted by the inverse of the CV^2 for each survey.

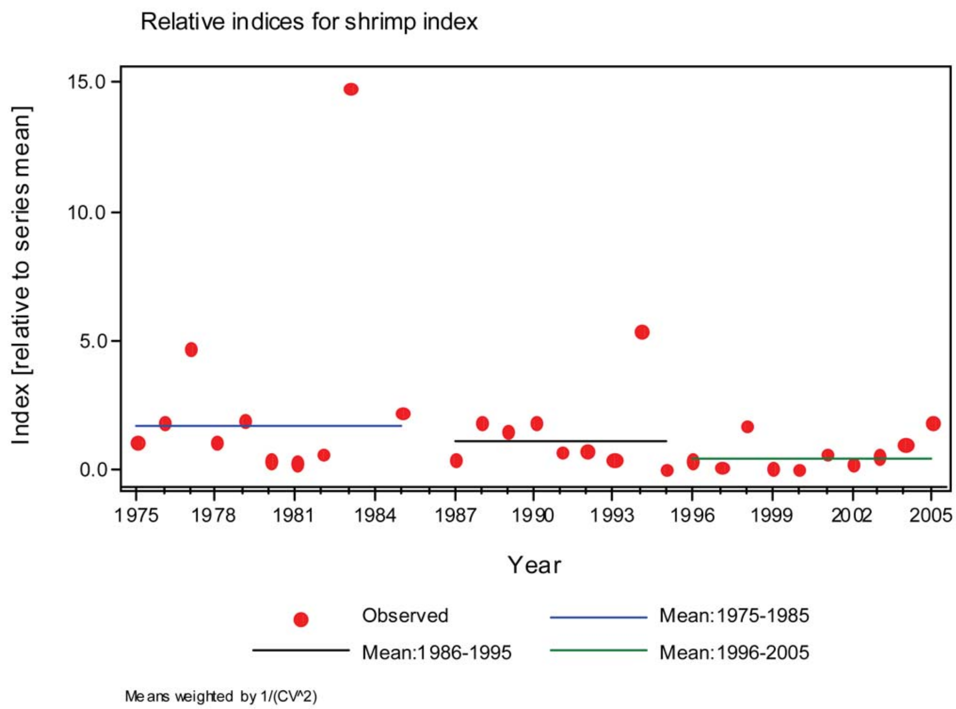

Figure 18. Three step function for the WCVI shrimp survey index, plotted relative to the mean of the survey series, weighted by the inverse of the CV^2 for each survey.

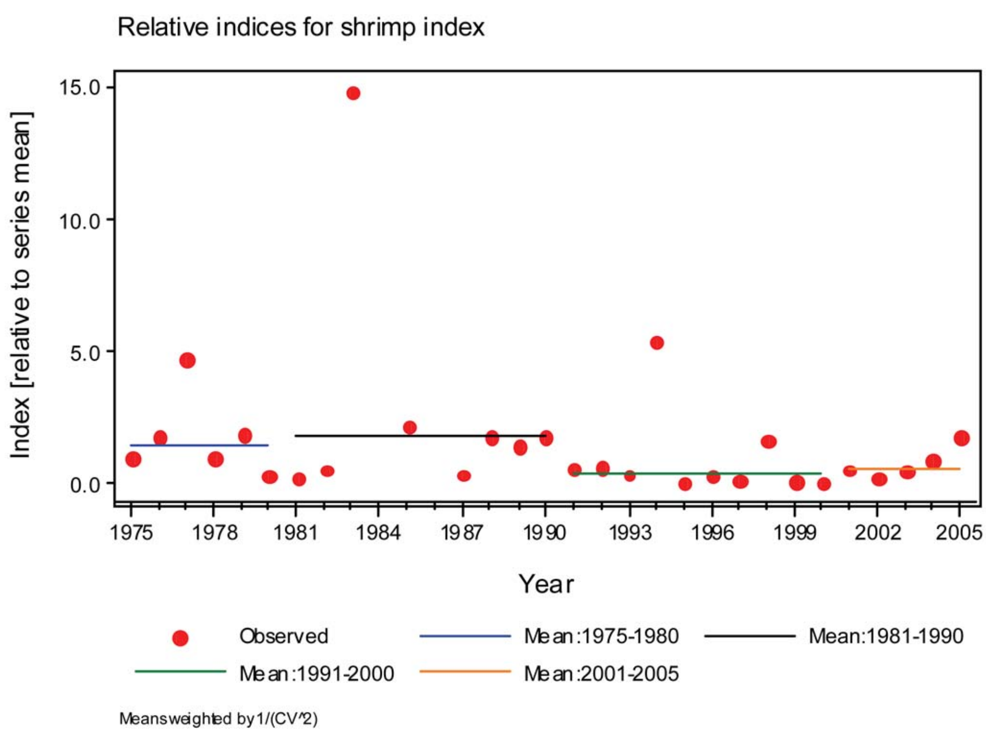

Figure 19. Four step function for the WCVI shrimp survey index, plotted relative to the mean of the survey series, weighted by the inverse of the CV^2 for each survey.

Regression analysis of triennial survey and WCVI shrimp survey

Population indices from the WCVI shrimp survey and the U.S. Triennial survey were analysed with a log linear regression model to estimate the rate of decline of canary rockfish as indexed by these surveys. The slope estimates were statistically significant in both cases at $p < 0.05$. The WCVI index indicated a decline of 78% over the 31 year time series. The triennial survey indicated a 96% decline over the 22 year time series. An analysis combining both indices indicated no significant difference in slope between the surveys, and the estimated decline was 86% over the 31 year time period covered by both surveys.

Queen Charlotte Sound shrimp survey

A swept-area shrimp survey of QCSd has 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-analysed the surveys as if they were randomly stratified to arrive at the canary rockfish biomass estimates given in Table 6 and Fig. 20. The points indicate a rising trend for the central coast since 1999, but the survey is obviously imprecise, took canary rockfish in a low proportion of sets, 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

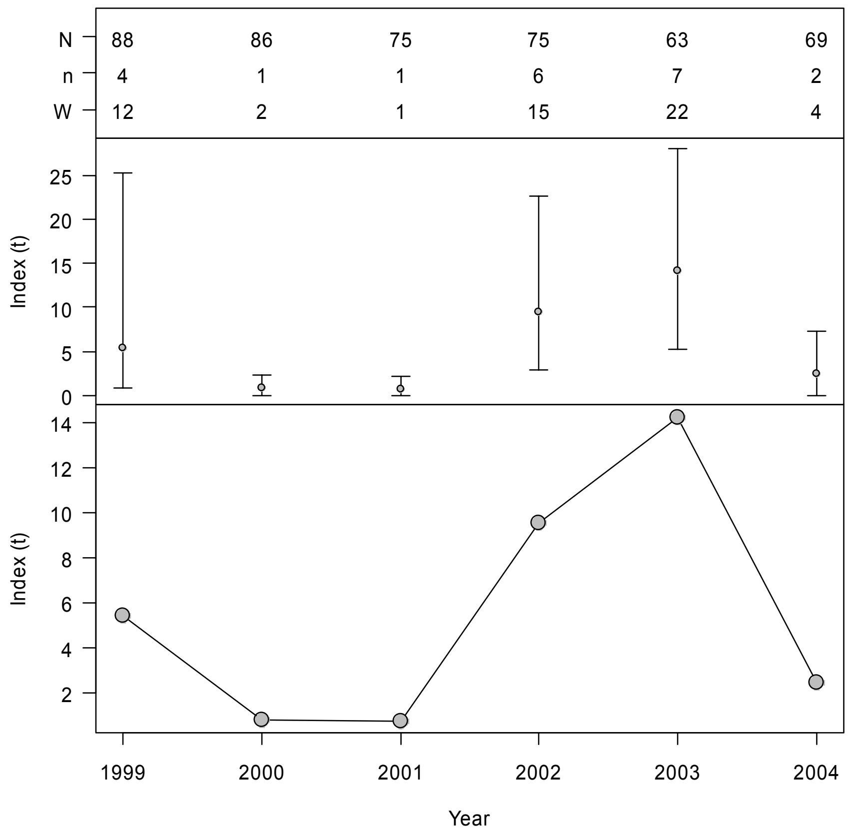

Figure 20. Bootstrapped biomass estimates (t, bottom panel) and biomass + 95% confidence intervals (t, middle panel) for canary rockfish caught in the QCSd shrimp survey, 1999 to 2004. The top panel indicates: N = the number of sets conducted; n = the number of sets in which canary rockfish were caught;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

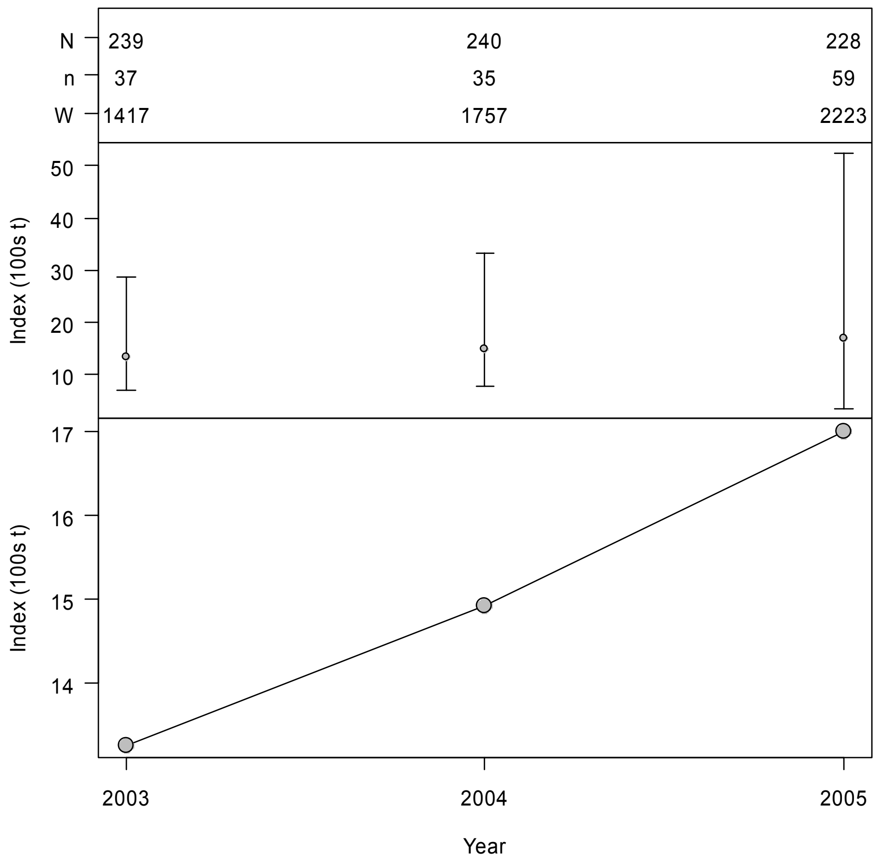

Figure 21. Bootstrapped biomass estimates (100’s t, bottom panel) and biomass + 95% confidence intervals (100’s t, middle panel) for canary rockfish caught in the QCSd groundfish survey, 2003 to 2005. The top panel indicates: N = the number of sets conducted; n = the number of sets in which canary rockfish 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.

Hecate Strait assemblage survey

DFO conducted a bottom trawl “assemblage” survey in HS in 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

Goose Island Gully Pacific Ocean perch survey

A Pacific Ocean perch (POP) survey in the Goose Island Gully of QCSd was conducted with reasonable frequency and the same design, vessel and gear from 1966 until 1984[5]. It was then abandoned for 10 years, to be restarted in 1994 with different vessels, gear, and design, but then stopped again in 1995 (Hand *et al*. 1995; Yamanaka *et al*. 1996).

More recently, DFO and the trawl industry have initiated a much larger-scale multiple-species survey in 2003, which was repeated in 2004 and 2005 and will be continued on a biennial frequency starting in 2007 (Olsen *et al*. 2007).

The original POP survey was mostly in waters too deep for significant catches of canary rockfish. The low catches of canary rockfish, the long gaps, and the problematic assumption of constant catchability in the face of numerous re-designs discouraged us from exploring these data. However, the lack of survey information on population trends in the northern part of B.C.'s coast merits an examination of these data. This survey may also throw light on the question of whether the foreign trawl fisheries (USSR and Japan) in the 1960s and 1970s may have depleted the canary rockfish population in B.C. waters.

[5] Note an additional survey was conducted in 1970 but these data have not yet been converted to electronic format.

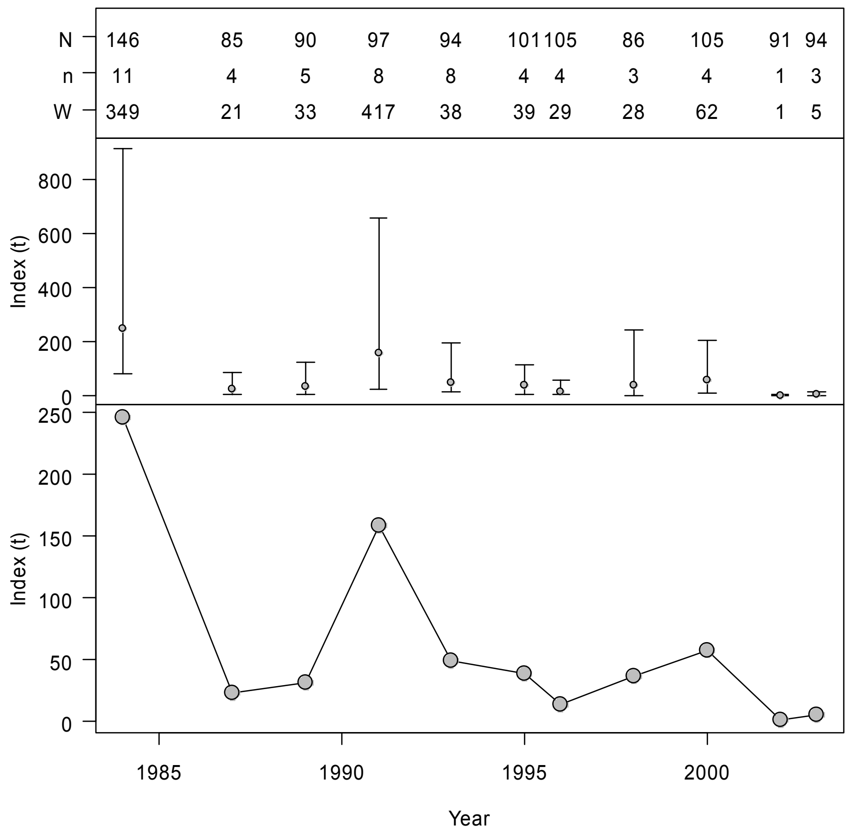

Figure 22. Bootstrapped biomass estimates (t) (bottom panel) and estimates + 95% confidence intervals (t) (middle panel) for canary rockfish caught in the HS assemblage survey between 1984 and 2003. The top panel indicates: N = the number of sets conducted; n = the number of sets in which canary rockfish 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.

The area common to all years corresponds to Goose Island Gully[6] (Figure 23) from depths of 146-218 m. Our attempt to standardize fishing power were limited to correcting for doorspread and average speed (Table 9, Figure 24).

Assuming a mean size of 2 kg, total catch ranged from about 8-370 fish over the entire time period. There were catches of canary rockfish in 2-16 tows from 1966-2005. The low catches of an aggregating species contribute to the implied large interannual variance.

The nominal results indicate a 56% decline based on the log-regression. The recent point for 2005 exerts significant leverage. Without it, the data indicate a 23% decline.

[6] Gazetted name is Otter Trough.

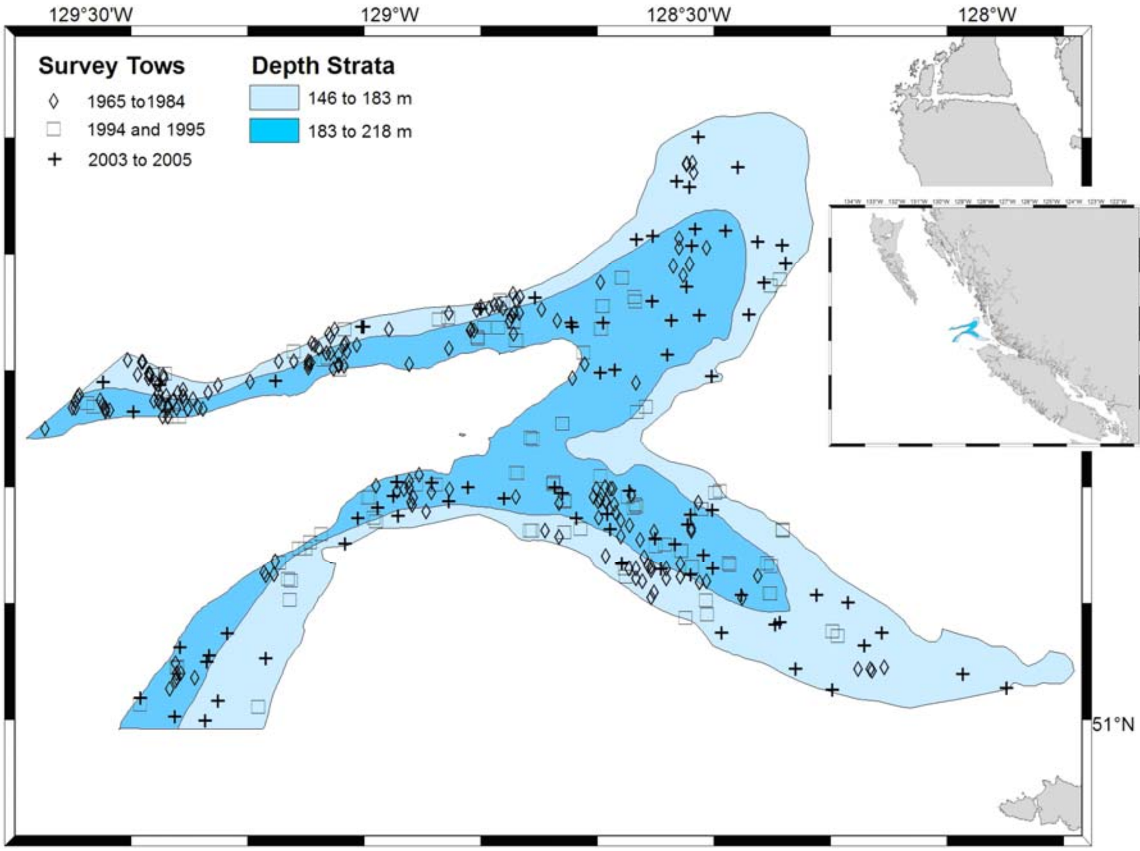

Figure 23. Goose Island Gully depth strata and tow locations within those strata, from historic POP surveys. The box inset shows the location of Goose Island Gully on the B.C. coast.

Table 9. Canary rockfish indices from historic Goose Island Gully POP surveys.

Year	Index (t)	Bootstrap Results (t) Mean	Median	Lower CI	Upper CI	RE	Num. Tows	Canary Tows	Catch Weight (kg)	Doorspread (m)	Speed (km/h)
1966	198	199	198	0	565	0.81	8	2	246	62	5.6
1967	66	66	66	23	113	0.35	14	10	54	62	5.6
1969	87	87	82	33	226	0.47	18	9	163	62	5.6
1971	42	43	41	23	88	0.33	18	8	61	62	5.6
1973	88	88	85	18	294	0.67	18	8	104	62	5.6
1976	42	42	40	12	122	0.57	17	5	40	62	5.6
1977	422	417	400	87	1,348	0.59	25	16	737	62	5.6
1979	60	60	58	24	165	0.46	28	5	184	71	5.9
1984	75	76	74	25	150	0.41	23	10	105	59	5.9
1984	118	122	124	31	152	0.20	6	4	70	43	5.6
1994	51	51	47	7	210	0.74	32	4	106	54	5.9
1995	274	277	267	16	884	0.67	32	6	416	54	6.1
1995	408	410	388	112	1,093	0.53	34	8	464	53	4.8
2003	29	29	28	7	107	0.65	31	7	61	72	5.7
2004	44	44	44	0	166	0.89	17	2	46	72	5.7
2005	10	10	10	3	29	0.55	25	5	17	72	5.7

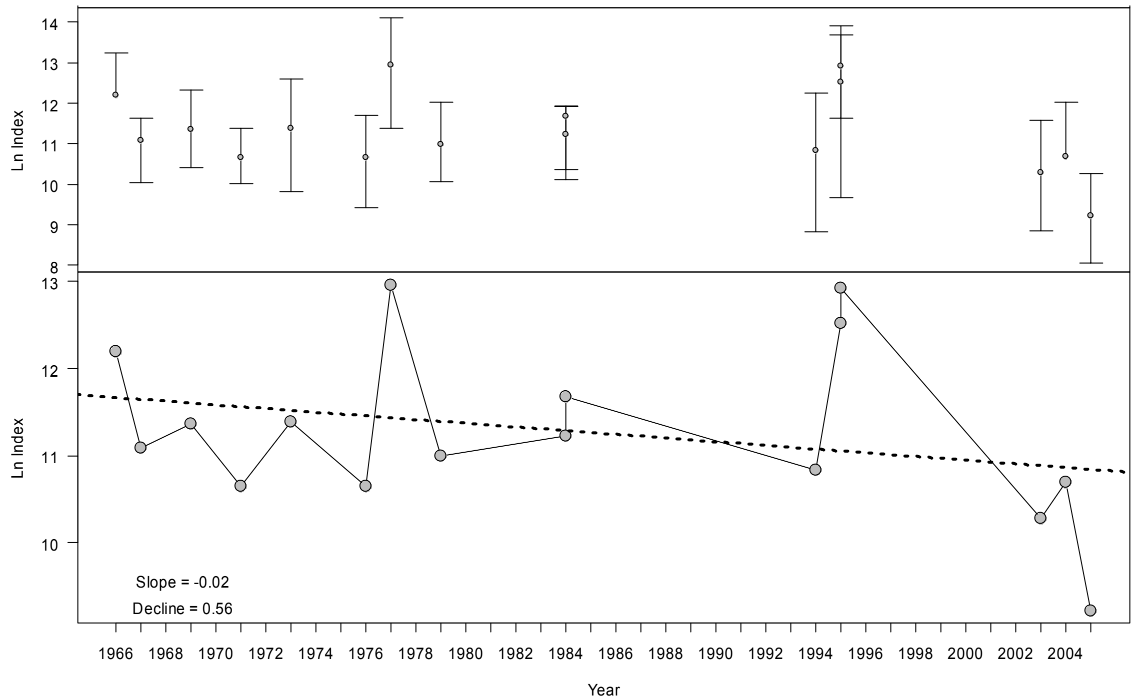

Figure 24. Biomass estimates from the Goose Island Gully Pacific Ocean perch survey and the QCSd groundfish survey (1966-2005). Data standardized only by doorspread and towing speed.

The most reliable or comparable portion of the time series indicates no change from 1966-1984 (1% increase). As this period spans the period of foreign fishing, it can be inferred that the foreign fleets did not significantly deplete the stock, at least in QCSd. Using the survey data is obviously problematic; nevertheless it provides the only insight into a long term trend for the central coast.

Abundance trends from Canadian commercial trawl CPUE

Analysis of commercial trawl CPUE has been restricted to the period April 1996 through March 2005. The beginning date of this analysis corresponds to the start of at-sea observer records, thus ignoring the earlier period of catch history that relied on fisher logs and sales slips. Catch rate data prior to April 1996 are not comparable over time, owing largely to the significant and varying degrees of misreporting. During this period a large number of landing events exist 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 to 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 of Fisheries and Oceans imposed 100% observer coverage on the trawl fishery in 1996. While the degree of misreporting was never documented in a manner which would support these concerns, catch rates from this period are not considered reliable.

Even with good catch data in the period 1996+, CPUE can be expected to be "hyper-stable" within the context of an individual vessel quota (IVQ) fishery (IVQs were introduced in 1997). As canary rockfish abundance varies, 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 (GLM): 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. 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. 25).

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 are not 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.

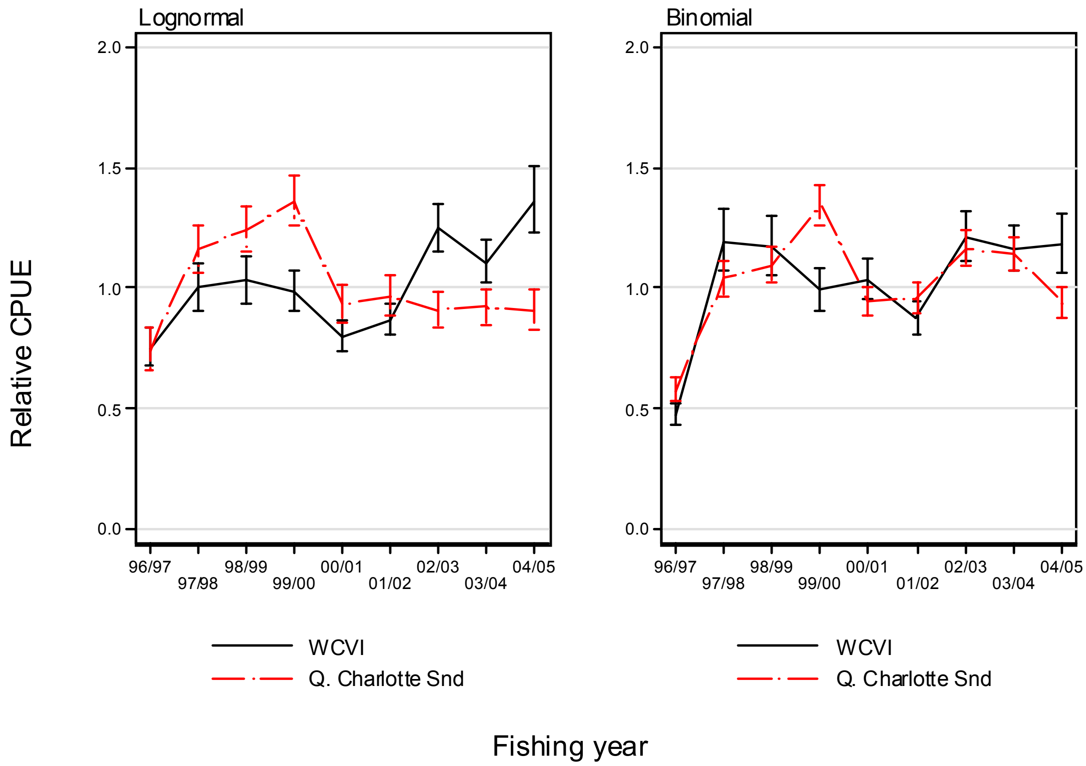

Figure 25. Comparison of two sets of CPUE indices each based on different regression model assumptions for each of three areas. Each series has been standardized relative to the geometric mean of the period 1996/97 to 2004/05. The error bars show ± 95% confidence bounds.

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 aging 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 modelled 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. As noted above (and in the bocaccio assessment, Stanley *et al*. 2001), 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 results should be interpreted with caution (Stanley 1999). 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-1990s) 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 26, 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 1950s. 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 the data have been separated 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 10 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. 26). Thus, while a serial depletion effect is unlikely to be present, 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.

Both nominal (unweighted) and weighted trends in mean length and age composition are presented. The weighted versions pool the same samples, while weighting each sample by the catch of canary rockfish associated with the sample (Figs. 27 and 28).

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 1970s 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 (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.

Table 10. 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 10 (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 10 (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**

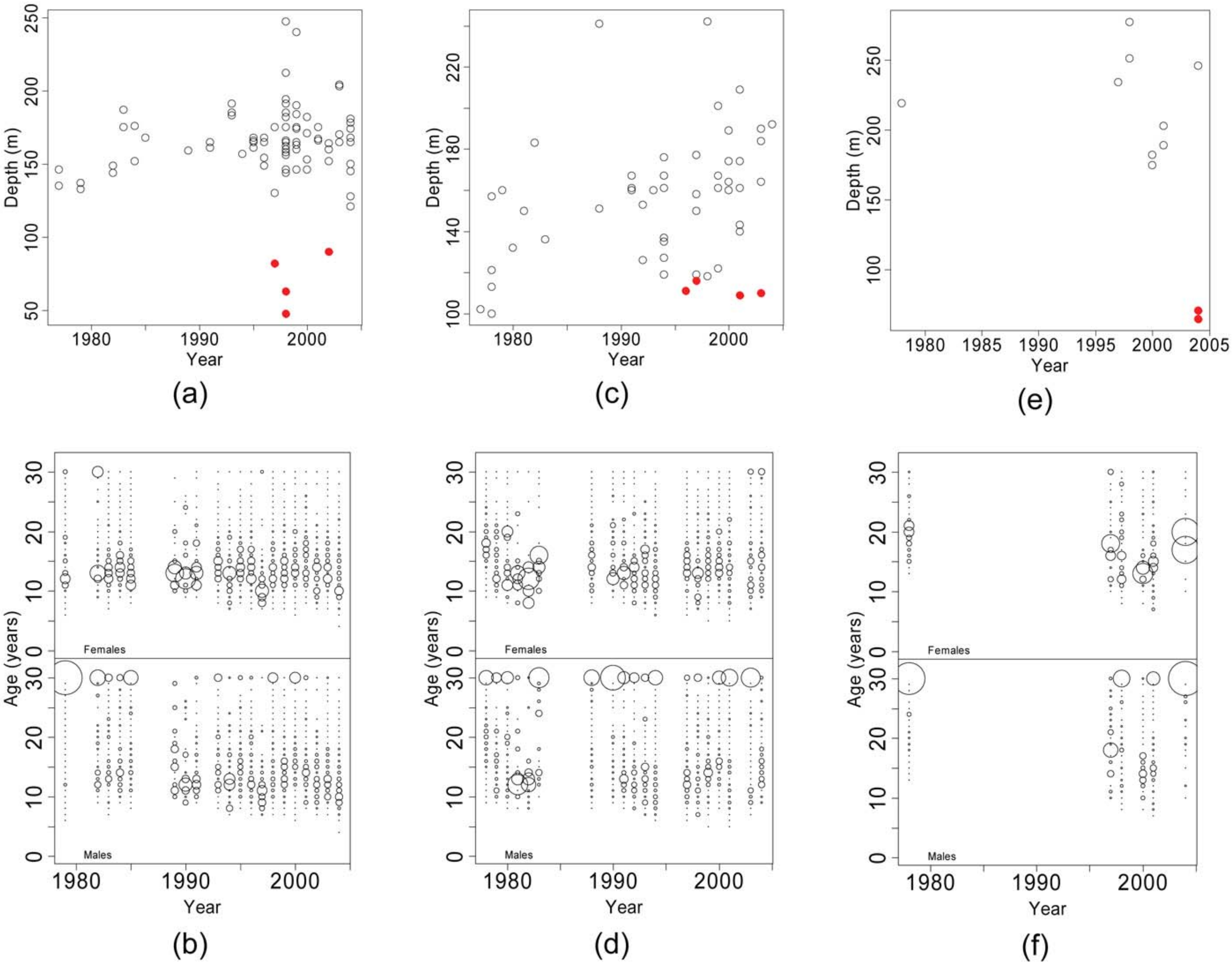

Figure 26. The effect of shallow samples on canary rockfish proportions-at-age. Panel (a) identifies 4 shallow samples from Area 3C+3D. Removal of these samples from the proportions-at-age analysis yields the figure shown in panel (b). Compared to the original proportions-at-age plot shown in Fgure 6, 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)).

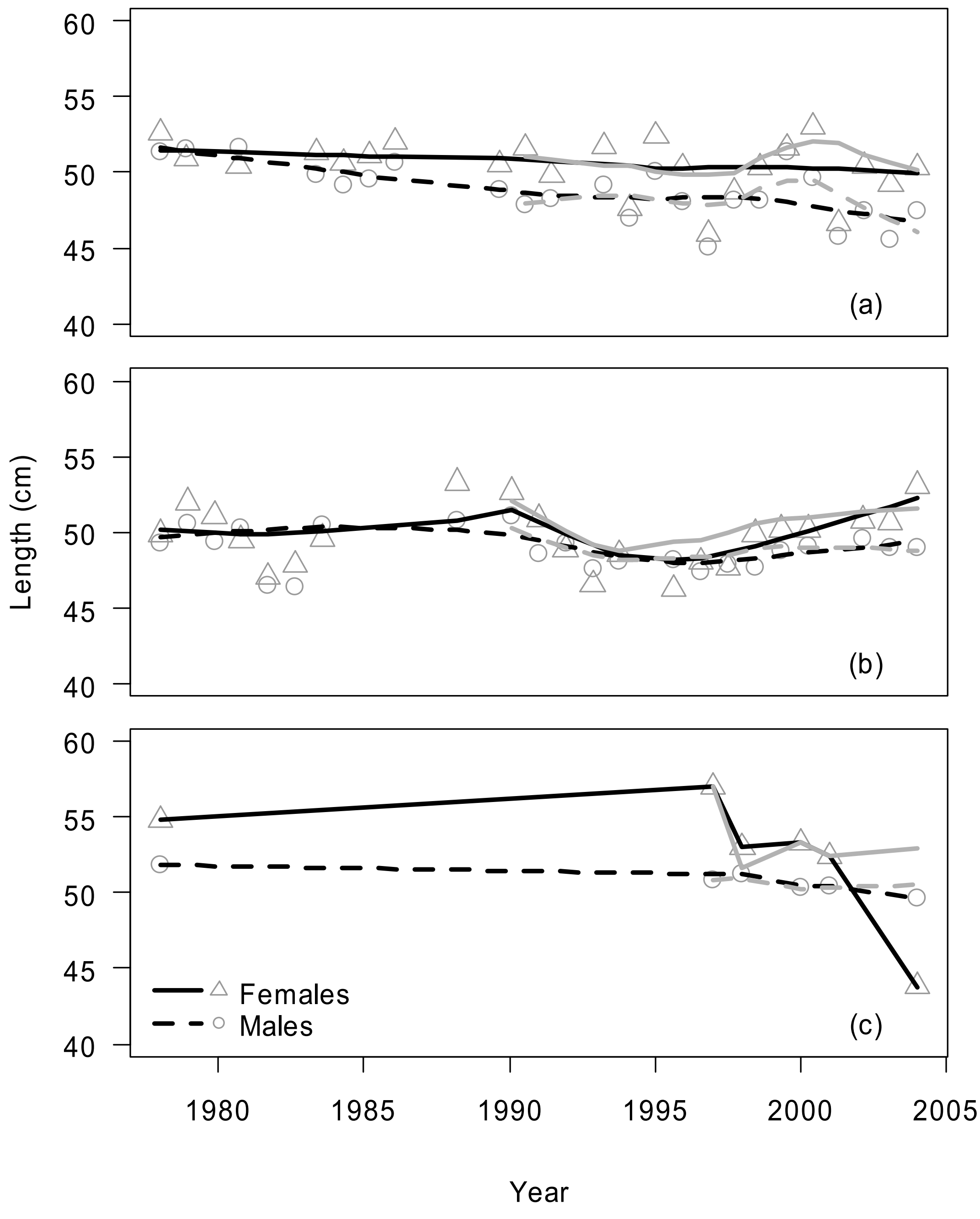

Figure 27. Trends in mean fork length for canary rockfish from (a) Area 3C+3D, (b) Area 5A+5B, and (c) Area 5E. The grey lines show the effect of weighting each sample by the total catch weight of canary rockfish from which the sample was taken. Sample catch weights are only available for more recent years.

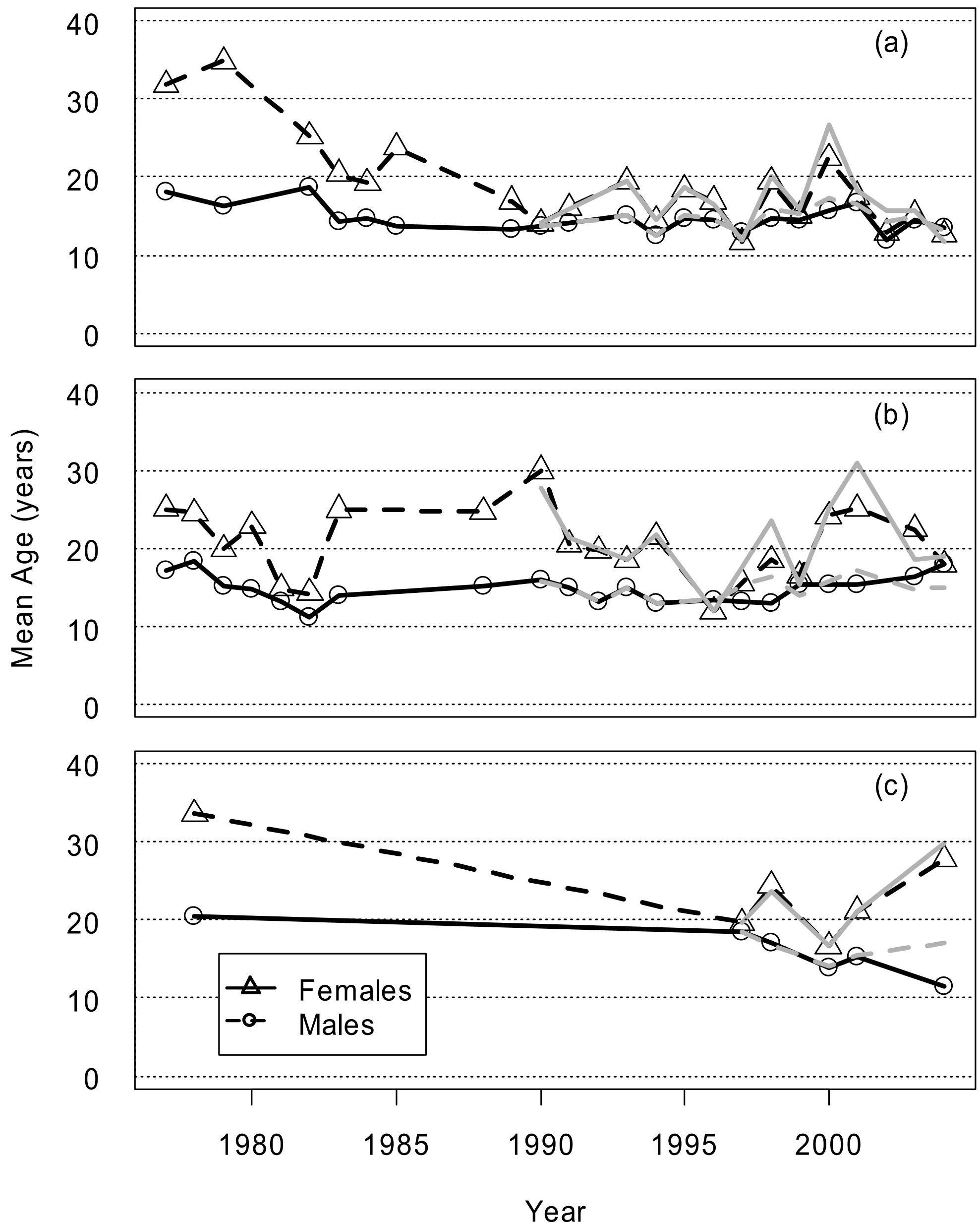

Figure 28. Mean age versus year for canary rockfish from (a) Area 3C+3D, (b) Area 5A+5B, and (c) Area 5E. The grey lines show the effect of weighting each sample by the total catch weight of canary rockfish from which the sample was taken. Sample catch weights are only available for more recent years.

Summary of current abundance and trends in B.C. Waters (Southern, Central and Northern areas)

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, information from different regions is presented, although the indices have been standardized to a common mean and are presented in combined graphs (Figs. 29-31).

Table 11. Summary of abundance indices for canary rockfish. All are based on trawling. Numbers 1-5: southern part of range; numbers 6-10: northern part of range.

Index	Units	Coverage	Signal	Weight/comments
1. US Triennial (Canada-Vancouver)	Biomass (t)	US border north to mid-Vancouver Island 1980-2001	Log-linear regression: Decline 96%	High (gear and design appropriate)
2. WCVI shrimp survey	Biomass (t)	Off west coast of Vancouver Island 1975-2006	Log-linear regression: Decline 78%	High (gear and design appropriate)
3. WCVI shrimp survey	Positive tows	Off west coast of Vancouver Island 1975-2005	Decline then increase – no overall trend	Low (power to detect abundance changes unknown)
4. WCVI shrimp survey	Biomass (t)	Off west coast of Vancouver Island 1975-2005	Step functions: varying levels of decline (to 23-45%)	Low (promising approach)
4. Combined 1 and 2	Index	As above	Log-linear regression: Decline 86%	High (as per individual surveys)
5. WCVI Commercial CPUE	Catch per unit effort	Off west coast of Vancouver Island 1996-2005	Inspection: Increase	Low (commercial catch rate influenced by factors other than abundance)
6. QCS shrimp survey	Biomass (t)	Queen Charlotte Sound 1999-2004	Inspection: Increase/no trend	Low (short time series)
7. QCS groundfish survey	Biomass (t)	Queen Charlotte Sound 2003-2005	Inspection: Increase	Low (short time series)
8. Hecate Strait assemblage survey	Biomass (t)	Hecate Strait 1984-2003	Inspection: Decline	Low (canary depths not covered)
9. Goose Island Gully Pacific ocean perch survey	Biomass index	Goose Island Gully 1966-2005	Log-linear regression: decline 56% (23% without last point)	Low (depths not covered, changes in sampling methods over time)
10. QCS commercial CPUE	Catch per unit effort	Queen Charlotte Sound 1996-2005	Inspection: No trend	Low (commercial catch rate influenced by factors other than abundance)

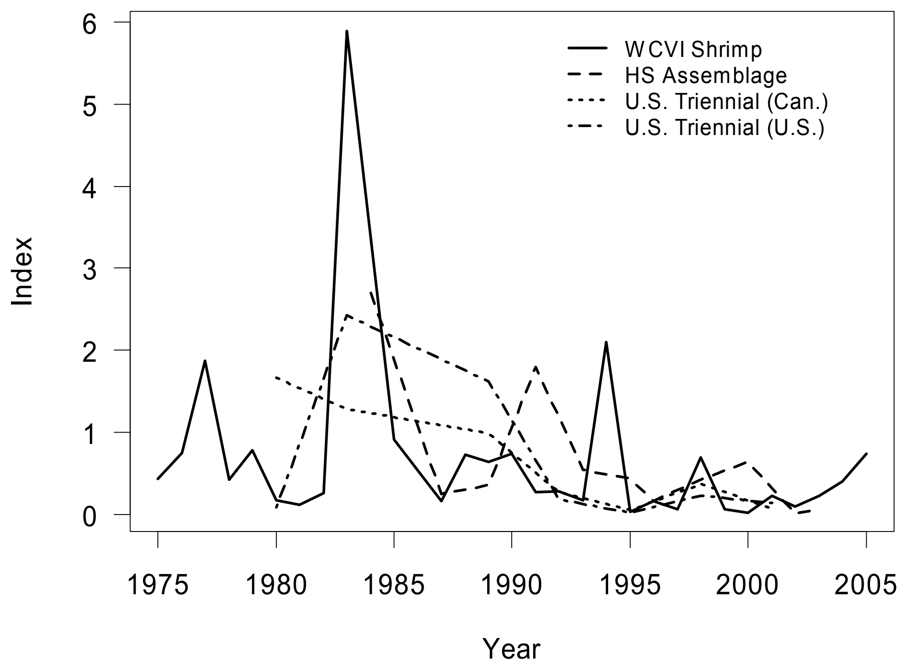

Figure 29. Relative biomass indices for canary rockfish from four longer term fishery independent surveys. All indices have been scaled such to a common mean calculated over the period 1983-2001.

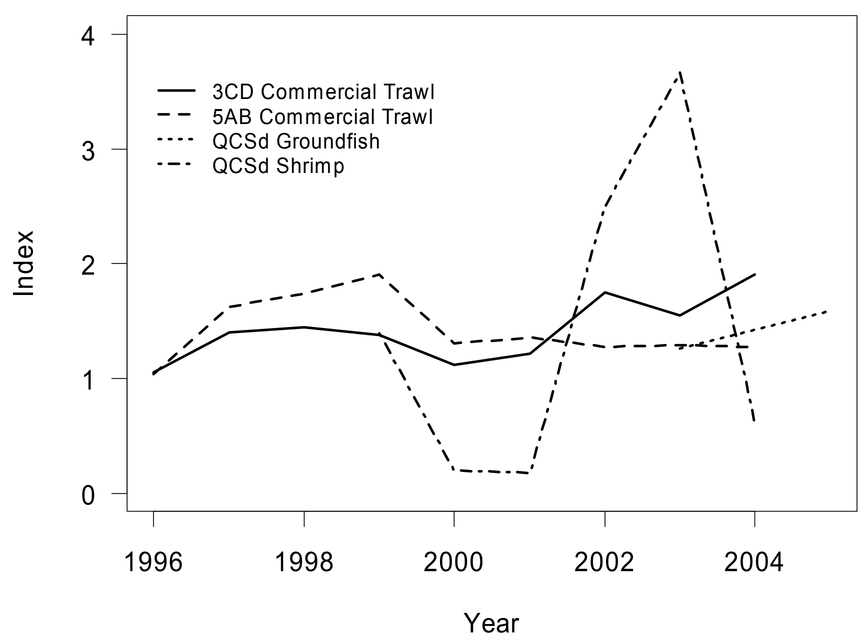

Figure 30. Relative indices for canary rockfish from shorter term commercial trawl data in Areas 3C+3D and 5A+5B and from two fishery independent surveys in QCSd. All indices have been scaled to a common mean calculated over the period 1999-2004.

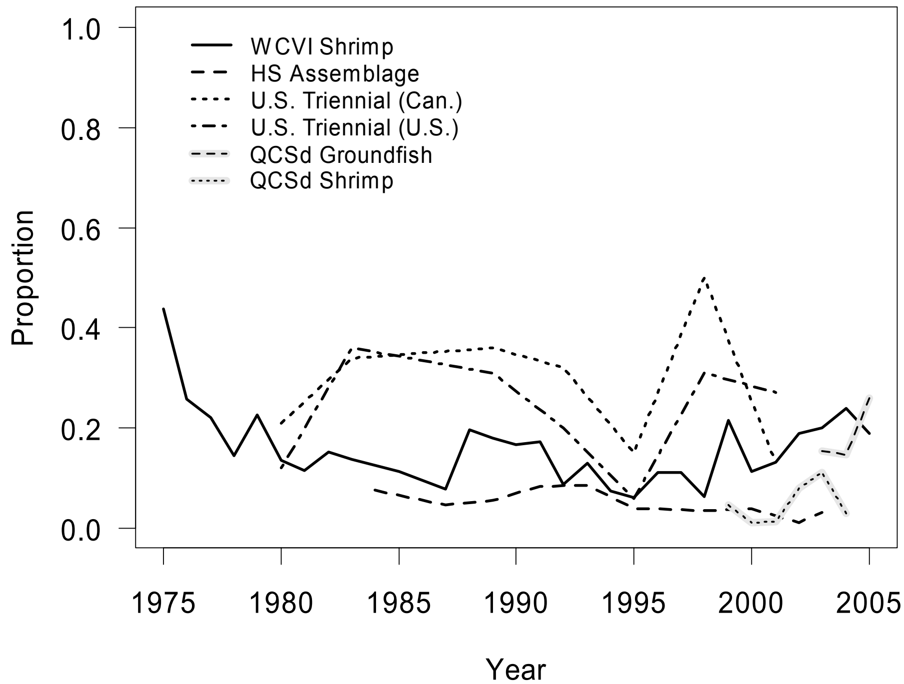

Figure 31. Proportions of non-zero tows of canary rockfish in six fishery independent surveys.

A log-linear regression analysis of the WCVI shrimp survey information shows a decline of 80% over the period (1975-2006). Step-function analyses of this index show recent values of 39-61% of the long term mean, or 23-45% of the earliest period. Examining the trend in the proportion of non-zero tows (Figs. 16 and 31) from the same survey indicates that the index 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 29) shows a fitted decline of 95%, 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%. Both surveys (as all trawl surveys for species which aggregate) are influenced by occasional large tows which exert significant leverage on the annual survey estimates. This effect is illustrated by the results in the U.S.-Vancouver zone between 1980 and 1983, when the index rose from near zero to the largest index value of the time series. The time series of proportion of non-zero tows from this survey has not shown a consistent strong decline (Fig. 31).

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.

There is no long-term index available for the central coast (Area 5A+5B), other than the Goose Island Gully series of surveys which is considered to sample canary rockfish poorly and whose design has changed over the years. The QCSd groundfish survey indicates a possible increasing trend over the first three survey years (2003-2005) (Figs. 21 and 30), 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. 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.

Summary of population status

The two most reliable survey indices come from the WCVI shrimp survey and the U.S.A. triennial survey. Analysed separately with a log-linear model, the WCVI shrimp survey indicates a decline rate of -0.051 yr-1 and the triennial survey has a decline rate of -0.15 yr-1 (Appendix 1). In an analysis of covariance of these two surveys, with survey as a categorical variable, the interaction term is not significant (i.e. different slopes between surveys) and the intercept term is significant. The common slope estimate for the analysis of covariance is -0.064 yr^{-1}, close to the WCVI survey index which has many more data points than the triennial.

The common slope (combined series) decline is considered to best represent the trend in population abundance. This gives a total decline of 86% over 30 years or 1.0-1.5 generations. Because information on numbers of mature individuals is not available over the entire time period for both surveys, total biomass is used here as a proxy for numbers of mature individuals. Given the apparent loss of older individuals over the period covered (Figure 6), the decline in biomass of mature individuals would probably be steeper than that observed for all individuals.

Fishing is the most likely cause for the observed decline; although a reduction in recruitment could have contributed, there is little clear evidence that this has occurred. Based on a simple production model, observed catches and plausible estimates of biomass early and late in the period of observed decline are consistent with the observed decline of 86% in the period for which information is available, suggesting that fishing alone could have caused the decline under "average" biological conditions. A sustained period of poor recruitment in the 1990s has been reported for many groundfish stocks in the Washington-California area (King 2005), and a period of poor recruitment for canary rockfish starting in the mid-1990s was anticipated in the most recent assessment (Stanley 1999). However, there is no strong indication of reduced recruitment in available age and length information (Figure 6). Thus although a reduction in recruitment due to environmental factors could have contributed to the decline, there is no strong evidence for such a reduction and it is not necessary to explain the decline.

There is substantial uncertainty in interpreting trend in population abundance in the most recent years (since 1995). The triennial survey stopped in 2001 (Figure 14); indices since the early 1990s were variable around a low level. The WCVI shrimp survey has provided annual indices over the entire period available (Figure 15). Because of the high year-to-year variability, indices from this survey since 1995 could be interpreted as continuing an earlier decline, stability, or even increasing.

Given the uncertainty about whether the decline has ceased, it appears that the most conservative and cautious interpretation of the trend is a continuing decline (as in the calculations of decline above and shown in Figure 15). Although there is some indication of an increase in younger individuals in recent years (Figure 6), there is no strong indication of increased recruitment which might drive an increase in abundance; and any increase in the index driven by an increase in young individuals would not reflect an increase in the mature population. Catches have not declined substantially over the past decade.

Because of the loss of older individuals over the time period covered, the observed declines would underestimate the decline in mature individuals, further suggesting that trend in recent years is most cautiously interpreted as a continuing decline.

There are several sources of uncertainty in interpreting population status. Uncertainty about recent trend in the most reliable index is discussed above. There is also uncertainty with respect to applying population trend indices from one part of the distribution (southwest, off the west coast of Vancouver Island) to the whole distribution. There is uncertainty about trends in biological characteristics (particularly age and length) since biological sampling has generally been at a low level, pattern has varied over time, and changes in fishing patterns could have influenced the data. Overall there is considerable variability in the information. However, the strong decline in two relatively reliable indices is considered to provide a relatively clear signal of population trend.

Population trends and assessments in U.S. waters

U.S. research staff have recently updated the assessment of canary rockfish from the Washington/B.C. border to southern California, which is treated as one stock (Methot and Stewart 2005). 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 (Methot and Stewart 2005 p. 10) as:

> “Canary rockfish were relatively lightly exploited until the early 1940’s, when catches increased and a decline in biomass began. The rate of the decline in spawning biomass accelerated during the late 1970s, and finally stabilized in the late 1990s in response to management measures. The canary rockfish spawning stock biomass reached an estimated low in 2000, but has been increasing since that time. The estimated relative depletion level in 2005 is 5.7% in the base model and 11.4% in the alternate model.”

The rebuilding plan for canary rockfish includes a number of measures including a closure on directed fisheries, closing the continental shelf to trawling shallow of 137 m and non-retention in hook-and-line fisheries. Estimated catches for 2004 were less than 38 t, which include estimates of discarding. The principal monitoring tool for this population, the U.S. triennial survey, is now conducted annually instead of the previous triennial frequency.

Catches from this population dropped from around 1,500 t/yr in the mid-1990s to 30-50 t/yr in 2003-2004. Catches were usually above 3,000 t/yr in the 1980s (maximum 5,400 t in 1982) and totalled 150,000 t over the entire time period covered by the assessment (1916 to the present). Unfished biomass was estimated at 35,000 t at the beginning of the period of the assessment (1916), with a steady decline to the present; biomass was around 15,000 t in the 1970s (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.).

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. The potential of canary rockfish populations in Southeast Alaska to provide a rescue effect for B.C. populations is uncertain, since status of this population is unknown (Victoria M. O'Connell, pers. comm.).

LIMITING FACTORS AND THREATS

Fishing, the principal known source of anthropogenic mortality, is managed by harvest quotas by areas. Coastwide harvest quotas have increased somewhat since the mid-1990s but this was due to allocating additional quota in little-exploited areas (5C+D, 5E); quotas in the traditional fishing areas (3C+3D, 5A+5B) have remained essentially constant. Total reported fishery removals have not shown a trend since 1995, varying between about 750t/yr and about 1000t/yr. Catch monitoring and control has improved substantially since 1996 and research surveys and studies initiated recently should help provide better information.

Despite these substantial improvements, there is not a formal risk-based fishery management strategy supported by an analytical stock assessment. The last assessment for this species, in 1999 (Stanley 1999), has provided the biological advice for harvest quotas. A new analytical assessment of this species is being developed which may support better analysis of risks from fishing.

There is no evidence of imminent or changing threat to canary rockfish habitat. The continental shelf is not currently exposed to industrial activities. Fishing gear may have some impact, although trawl activity continues to be concentrated on virtually the same areas for the last few decades and thus may leave other areas relatively undisturbed. Future oil and gas exploration may have some impact, but there is currently a moratorium on this activity.

U.S. fisheries may have had an impact on abundance in Canadian waters, but a number of management measures have been implemented to reduce harvest and fishing effort since the declaration of “overfished” status for canary rockfish for Washington-California waters in 1999 (see above “Population trends and assessments in U.S. waters”).

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 individual vessel quotas (IVQs). Removals in commercial fisheries are now essentially completely monitored. 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?*	probably not
• *Area of occupancy (AO) (km²)- in Canada*	>32,000 km²
• *Specify trend in AO*	stable
• *Are there extreme fluctuations in AO?*	probably not
• *Number of known or inferred current locations*	widespread, continuous distribution
• *Specify trend in #*	N/A – continuous distribution
• *Are there extreme fluctuations in number of locations?*	N/A – continuous distribution
• *Specify trend in area, extent or quality of habitat*	no known trends

Population Information

• *Generation time (average age of parents in the population)*	20-30 years (22.8 U.S. estimate)
• *Number of mature individuals*	4 to 8 million, minimal estimate
• *Total population trend*; *% decline over the last/next 10 years or 3 generations.* West coast Vancouver Island a. WCVI Shrimp survey b. US Triennial survey c. Pooled WCVI/Triennial d. Commercial CPUE Queen Charlotte Sound a. QCS shrimp survey b. QCS groundfish survey c. Hecate Strait assemblage survey d. Goose Island Gully POP survey e. Commercial CPUE North coast (west Queen Charlotte Islands)	 a. decline 78% 1975-2006 b. declined 96% 1980-2001 c. declined 86% 1975-2006 d. increasing since 1996 (low weight) a. Increasing/no trend (low weight) b. Increasing (low weight) c. Declining (low weight) d. Declining (low weight) e. No trend (low weight) No information on trends
• *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)

Fishing; controlled by quotas, well-monitored, but management not supported by risk analysis

Rescue Effect (immigration from an outside source)

• U.S. waters: Adjacent population to the south is estimated at 5-10% of unexploited abundance, has been declared overfished. 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?*	Possibly
• *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

Current Status

COSEWIC: Threatened, November 2007

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code**: Met criterion for Endangered, A2b, but Threatened, A2b, because the species is widely distributed, the population includes several million mature individuals, and changes in management since 1995 have improved control of the major threat
Reasons for Designation: A comparatively large (maximum weight 5.7 kg), orange-yellow fish that typically inhabits rocky bottoms at 70-270 m depths from the western Gulf of Alaska south to northern California. Its late maturity (13 years for females), long lifespan (84 years), and long generation time (20-30 years) are characteristic of species that are slow to recover following population decline. The species is treated as a single designatable unit. Two surveys in the southern part of its Canadian range, considered the most reliable indicators of population trend, show abundance index declines of 78% and 96% over 30 years and 17 years respectively. Survey indices from the northern part of the range and commercial catch per unit effort indices show no consistent trends but are of relatively short duration and are in some cases based on methods which do not adequately sample areas inhabited by the species. There is uncertainty due to high variability in the various index series (characteristic of trawl surveys) and the unknown degree to which abundance trends in the southern part of the Canadian range reflect abundance trends throughout the species' range in Canadian waters. Fishing is the most likely cause of the observed decline. Changes to management since 1995 include 100% observer or video monitoring coverage and implementation of individual transferable quotas, which are expected to improve control of fishing. Rescue from contiguous populations to the south is unlikely given that current abundance in the US is estimated at 5-10% of unfished levels, and rescue from populations to the north is uncertain because their status is not well known.	

Applicability of Criteria

Criterion A: (Declining Total Population): Meets criterion A2b for endangered. Meets criterion A2b for threatened.
Criterion B: (Small Distribution, and Decline or Fluctuation): Extent of occurrence and area of occupancy exceed threshold values.
Criterion C: (Small Total Population Size and Decline): Current population size over 1 million individuals, exceeds threshold values.
Criterion D: (Very Small Population or Restricted Distribution): Thresholds exceeded.
Criterion E: (Quantitative Analysis): Not undertaken.

ACKNOWLEDGEMENTS

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COLLECTIONS EXAMINED

No collections were examined.

DATA SOURCES

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APPENDIX 1

Reconciling Catch and Surveys for Canary Rockfish

Please note: Technical appendices on derivation of landings and abundance indices are available on demand.

The two most reliable survey indices come from the WCVI shrimp survey and the USA triennial survey. Analysed separately with a log-linear model, the WCVI shrimp survey indicates a decline rate of -0.051 yr-1 and the triennial survey has a decline rate of -0.15 yr-1 (Table 1). If one does an analysis of covariance survey as a categorical variable, the interaction term is not significant (i.e. different slopes between surveys) and the intercept term is significant. The common slope estimate for the analysis of covariance is -0.064 yr^{-1}, close to the WCVI survey index which has many more data points than the triennial.

If we accept the slope of the combined analysis is representative of the long term trend in canary rockfish biomass on the coast, how do we reconcile the historic catches with the stock productivity?

A very simple production model would be

$$B_{t+1} = gB_t - C_t$$

where B_t is biomass in year t, C_t is catch in year t, and g is the surplus production rate, in this case assumed to be time invariant and density independent. In the absence of fishing

$$g = \frac{B_{t+1}}{B_t}$$

Given guesses of g and the biomass at the beginning of the time series (B_0), it is possible to estimate B_t. The slope of the log linear regression over the time period can then be estimated. The question can be addressed by examination of the set of g and B_0 that gives a log linear slope equal to that observed in the combined survey analysis. The question then becomes; Are these consistent with what we know about canary rockfish?

The set of feasible g and B_0 values are negatively correlated, as g increases, B_0 declines (Table 2). A harvest rate of about 5% is considered sustainable, approximately equivalent to stating that a surplus production rate of 5% would be reasonable for this species if its biomass was in the region of maximum total production (i.e. MSY). The results indicate that with this growth rate and B_0 = 18,000 t, the required slope value can be obtained. The results for this scenario indicate a surviving biomass of close to 4,000 t in 2004 (Table 3). This is within the range of survey estimates of minimum biomass (actual biomass estimates depend on trawl catchability).

That the biomass appears to have declined throughout most if not all of this period indicates that the harvest rates experienced were not sustainable. The estimated harvest rates from the scenario in Table 3 are increasing in the most recent years. If we had some confidence in these estimates this could be a cause for concern. However, as indicated above, a constant surplus production rate and no density dependence were assumed for this model, which was done as a test of ranges, not as a population assessment.

The overall conclusion is that reported catches are consistent with plausible biomass estimates and the combined trend of the two more reliable indices. Thus, fishing can explain the observed decline.

Table A1. Results of log-linear analysis of long term trend in BC canary rockfish from the WCVI shrimp and USA triennial surveys.

a. Separate analyses			
Survey	N	slope	p val
WCVI	29	-0.051	0.0406
TRI	7	-0.15	0.0200
b. Combined analysis, separate slopes and intercepts			
Term		estimate	p val
intercept		206.5	0.0028
year		-0.10	0.0037
survey(TRI)		0.71	0.0055
year*survey		-0.049	0.1354
c. Combined analysis, common slope, separate intercept			
Term		estimate	p val
intercept		133.7	0.0041
year		-0.064	0.0062
survey(TRI)		0.68	0.0082

Table A2. The set of g and B0 values that give a slope of -0.064 between ln biomass and year for BC Canary rockfish.

B_0	g
10000	1.115
11000	1.103
12000	1.092
13000	1.083
14000	1.074
15000	1.067
16000	1.061
17000	1.055
18000	1.050
19000	1.045
20000	1.040
21000	1.036
22000	1.033
23000	1.029
24000	1.026

Table A3. Input data (catch) and estimated biomass for g = 1.05 and B0 = 18,000 t for B.C. canary rockfish.

		g	1.05		
		B_0	18000.0		
Year	Catch (t)		Biomass	ln Biomass	H Rate
1980	1173.3		17726.7	9.78	0.07
1981	626.4		17986.6	9.80	0.03
1982	826.6		18059.4	9.80	0.05
1983	1335.5		17626.8	9.78	0.08
1984	1789.8		16718.4	9.72	0.11
1985	1498.9		16055.4	9.68	0.09
1986	1156.8		15701.3	9.66	0.07
1987	1411.9		15074.5	9.62	0.09
1988	1814.3		14014.0	9.55	0.13
1989	1816.7		12897.9	9.46	0.14
1990	1590.9		11951.9	9.39	0.13
1991	1352.6		11197.0	9.32	0.12
1992	1401.8		10355.0	9.25	0.14
1993	1113.9		9758.8	9.19	0.11
1994	1198.9		9047.9	9.11	0.13
1995	924.2		8576.0	9.06	0.11
1996	761.6		8243.3	9.02	0.09
1997	746.7		7908.8	8.98	0.09
1998	832.7		7471.5	8.92	0.11
1999	975.8		6869.2	8.83	0.14
2000	821.2		6391.5	8.76	0.13
2001	852.0		5859.0	8.68	0.15
2002	896.4		5255.6	8.57	0.17
2003	864.7		4653.7	8.45	0.19
2004	809.2		4077.2	8.31	0.20

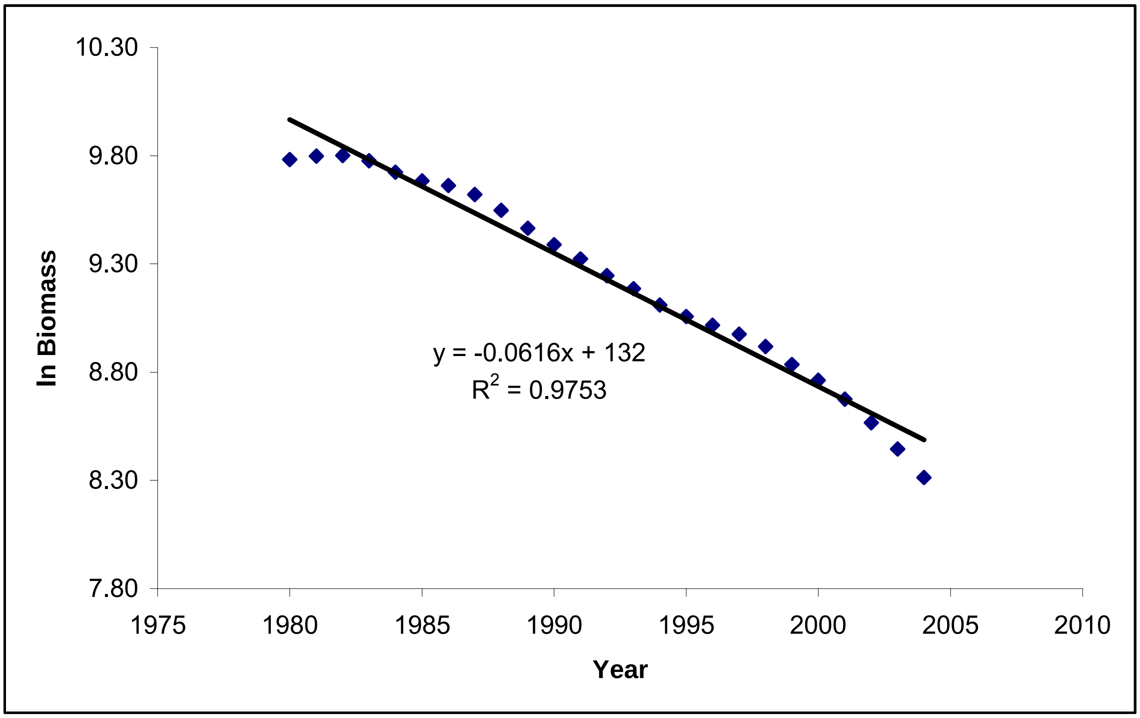

Figure A1. Log linear regression of biomass vs. year for the B.C. canary rockfish catch series and *g* = 1.05 and B_0 = 18,000 t.