COSEWIC
Assessment and Status Report

on the

Quillback Rockfish
Sebastes maliger

in Canada

THREATENED
2009

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:

COSEWIC. 2009. COSEWIC assessment and status report on the Quillback Rockfish *Sebastes maliger* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 71 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Production note:
COSEWIC would like to acknowledge K. Lynne Yamanaka, Lisa C. Lacko, Chris Grandin, Janet Lochead, Norm Olsen, Jonathan C. Martin and Scott Wallace for writing the status report on the Quillback Rockfish *Sebastes maliger* in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Howard Powles, Co-chair and Lou Van Guelpen, Handling Member for the COSEWIC Marine Fishes Species Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le sébaste à dos épineux (*Sebastes maliger*) au Canada.

Cover illustration/photo:
Quillback Rockfish — Photo by Lynne Yamanaka.

Catalogue CW69-14/589-2010E-PDF
ISBN 978-1-100-15059-8

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – November 2009

Common name
Quillback Rockfish

Scientific name
Sebastes maliger

Status
Threatened

Reason for designation
This species is part of an inshore rockfish complex, with 95% of commercial catch records occurring between 14 and 143m depth. Maximum recorded age is 95 years, age at 50% maturity is 11 years and generation time is over 30 years. No overall estimate of decline is possible, however all survey indices have declined, some by 50-75% since the mid-1980s. Commercial catch per unit effort indices show inconsistent trends and are probably affected by changes in fishing practices. Commercial and recreational fisheries are the principal threats, however, commercial fishing pressure has been reduced as a result of strengthened management regimes established in the mid-1990s, including introduction of closed areas and decrease in commercial harvest quotas. Management measures for recreational fisheries (bag limits) do not restrict catches and the impact of such catches on the species is less understood.

Occurrence
Pacific Ocean

Status history
Designated Threatened in November 2009.

COSEWIC
Executive Summary

Quillback Rockfish
Sebastes maliger

Species information

The Quillback Rockfish (*Sebastes maliger*) is one of 102 species of rockfish belonging to the genus *Sebastes* of which 96 are found in the North Pacific. The scientific names are from the Greek *sebastos* (magnificent) and the Latin *malus* and *gero* meaning “mast” and “to bear”, translating into “I bear a mast” referring to the high dorsal fin. Quillback Rockfish are classified as “inshore” rockfish together with yelloweye rockfish, copper rockfish, China rockfish, black rockfish and tiger rockfish and exist primarily over rocky habitats at depths less than 200 m.

There is presently no genetic basis to assign multiple designatable units for Quillback Rockfish within British Columbia (BC). The fishery for inshore rockfish has traditionally been managed separately for the inside (water between the east side of Vancouver Island and the mainland) and the outside (remainder of the coast). Quillback Rockfish are managed within a species aggregate which includes other inshore rockfish species. The fishery is managed to a total allowable aggregate species catch for the inside and the outside areas.

Distribution

Quillback Rockfish have been reported from Kodiak Island, Gulf of Alaska to Anacapa Passage, southern California. They are present throughout the coastal waters of BC.

Habitat

Quillback Rockfish have been observed from submersibles in depths from 16 to 182 m over substrates that are hard, complex and have some vertical relief, such as broken rock, rock reefs, ridges and crevices. Fisheries have caught Quillback Rockfish over an estimated 27,370 km^2 in BC.

Biology

Quillback Rockfish, like all rockfishes are matrotrophically viviparous, supplying nutrients to the developing embryos. Mating takes place in December, females may store the sperm for weeks prior to fertilization, and parturition occurs in April and May. A prolonged pelagic larval phase may last for up to two months, after which settlement occurs to benthic habitats. Juveniles usually occur in shallower waters than their conspecific adults.

Quillback Rockfish have been aged to 95 years in BC and reach 50% maturity at about 11 years of age. On average, females tend to be larger and older than the males and can reach a maximum length of 50 cm in BC. Natural mortality rate has been estimated at M=0.02 for Quillback Rockfish in BC, although for other rockfishes estimates of 0.05 are considered appropriate. Total mortality rate estimates range from 0.05 to 0.09 based on simple catch curve analysis, and from 0.06 to 0.12 using a more complex model. Generation time is estimated at 30-60 years, depending on estimate of natural mortality used. The mean age of reproductive females in recent years has been 22.8 years.

Population and trends

Several total estimates are available but these only represent parts of the species' distribution. A minimum biomass estimate for Quillback Rockfish from bottom trawl surveys is 407 t in a small part of outside waters. Estimates of abundance derived from visual assessments conducted both within the Strait of Georgia (inside waters) and in Juan Perez Sound (outside waters), Queen Charlotte Islands is estimated at 2.23 million Quillback Rockfish in the 527 km^2 survey area in the Strait of Georgia and 2.08 million over the 218 km^2 study in Juan Perez Sound. A minimum biomass estimate for Quillback Rockfish from visual surveys is 4.4 million individuals.

All surveys that reliably index the population show declining abundance trends. The research survey charters conducted in 1997/98 and 2002/03, primarily to index yelloweye rockfish in the outside area show a significant declining trend for Quillback Rockfish CPUE. Surveys conducted within the inside waters show significant declining trends and significantly higher CPUE in the northern portions surveyed in 2003/04 when compared with the southern portion surveyed in 2005. Significant declines in Quillback Rockfish counts per transect in visual surveys were evident between 1984 and 2003. A significant declining trend in jig fishing CPUE between 1986 and 2004 (58% decline in 18 years) was observed, as were significant declines in jig fishing CPUE in the southern portion between 1993 and 2005. Fishery independent longline surveys in the outside waters show no trend in CPUE between 1995 and 2003/04 but these are in waters deeper than those usually inhabited by Quillback Rockfish. Fishery dependant CPUE is heavily influenced by management actions applied to the fishery and is not considered to show trends representing the popuation.

Limiting factors and threats

Limiting factors, which increase the vulnerability of Quillback Rockfish to human activities, include late maturation and slow growth, and episodic recruitment dependent on favourable environmental factors. Fishing is the principal known threat, as the species has been harvested in commercial, recreational and Aboriginal fisheries. The inshore, relatively shallow distribution of this species means that it has been fished for many decades, particularly in inside waters between Vancouver Island and the mainland. Historical information on harvests is imprecise, but information has improved substantially since the mid-1990s with 100% dockside monitoring, at-sea observer programs and video monitoring of catches on non-observed vessels. Catch from the recreational sector is estimated for portions of the coast annually and coastwide every five years, but these estimates are considered imprecise.

Special significance

Quillback Rockfish is a prized food fish that is targeted in commercial, recreational and Aboriginal fisheries coastwide. Quillback Rockfish is a preferred species for the local live-fish markets and maintains a premium price over the fresh (dead) product. Given the accessibility of this species to harvest, they have likely always been an important component of Aboriginal fisheries.

Existing protection

Quillback Rockfish do not have any international status designations. Puget Sound Quillback Rockfish were petitioned in 1999 but did not warrant listing under the *Endangered Species Act* (Stout *et al.* 2001). In Canada it receives no individual species protection and is managed by DFO under the groundfish hook and line fishery management plan.

Quillback Rockfish is managed in aggregate with copper, China and tiger rockfishes. Total allowable catches (TAC) are set for the species aggregate. BC's Rockfish Conservation Strategy has decreased the TAC of this inshore rockfish aggregate by 50% outside and 75% inside between 2001 and 2002. The coastwide commercial TAC for this rockfish aggregate in 2005/06 is 161 t. The recreational fishery is managed by bag limits.

Rockfish Conservation Areas (areas closed to all commercial and recreational hook and line fishing) protect 20% of rockfish habitats outside, and consultations to protect 30% of rockfish habitats on the inside were completed in 2007. A commercial groundfish integration process is underway and implementation of 100% at-sea monitoring for all commercial groundfish fisheries was attained in 2006. This new program will account for the catch (landed and discarded) of all rockfish, including quillback throughout the entire commercial groundfish fishery (trawl, hook and line and trap).

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 (2009)

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.

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2009

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SPECIES INFORMATION

Name and classification

The Quillback Rockfish (*Sebastes maliger*) is one of 102 species of rockfish belonging to the genus *Sebastes* of which 96 are found in the North Pacific. The scientific names are from the Greek *sebastos* (magnificent) and the Latin *malus* and *gero* meaning “mast” and “to bear” (Hart 1973), translating into “I bear a mast” referring to the high dorsal fin (Love *et al.* 2002). In Canada’s Pacific waters 36 species of rockfish have been found (Peden and Gillespie MS). Quillback Rockfish have been referred to by other names including speckled rockfish, orange-spotted rockfish, and yellow backed rockfish (Lamb and Edgell 1986). From a Canadian management perspective, Quillback Rockfish are classified as “inshore” rockfish and are managed alongside yelloweye rockfish (*S. ruberrimus*), copper rockfish (*S. caurinus*), China rockfish (*S. nebulosus*), black rockfish (*S. melanops*) and tiger rockfish (*S. nigrocinctus*).

Morphological description

Quillback Rockfish are most readily distinguished from other rockfish by their high, deeply incised first dorsal fin (Hart 1973; Love *et al.* 2002) (Figure 1). Adults are primarily brown with yellow to orange anterior blotches and with light coloured dorsal saddle patches that extend into the first dorsal fin (Love *et al.* 2002). Their heads may be speckled with orange and brown dots which extend ventrally to just past the pectoral fins. Quillbacks found in Puget Sound do not have the speckled pigmentation (Love *et al.* 2002). All fins are dark in colour with the exception of the first dorsal fin which has a lightly coloured band extending from the saddle patch.

Figure 1. Photograph of a Quillback Rockfish taken in the Strait of Georgia, BC. Photo credit: Lynne Yamanaka.

Genetic description

Geographic variation accounted for less than 1% of the observed genetic variation in a microsatellite survey of over 1,500 Quillback Rockfish captured in coastal waters of British Columbia (BC) and in Puget Sound in Washington State (Yamanaka *et al.* 2006). The genetic data did not refute the null hypothesis that all samples were drawn from a single population.

Sample sites included in the study ranged from Puget Sound to the Queen Charlotte Islands, with samples both on the west and east coasts of Queen Charlotte Islands and Vancouver Island. Allele frequency distributions showed that there was little differentiation of coastal Quillback Rockfish along the coast of BC, and that the most distinctive sites were found within Puget Sound. Analysis of gene diversity among the 16 quillback samples indicated that over 99.5% of the observed genetic variation occurred within samples and less than 0.5% was attributable to differentiation among samples. Although no significant effect of region was apparent from the AMOVA (Analysis of Molecular Variance), a neighbour-joining dendrogram clustered sites into three regions: Queen Charlotte Islands/North Coast Vancouver Island, West Coast Vancouver Island, and Puget Sound. Estimates of pairwise F_{ST} values among sample sites ranged from less than zero to 0.013 and averaged 0.0032. The most distinctive region along the coast was Puget Sound, with pairwise F_{ST} values between sites in Puget Sound and QCI averaging 0.0067 and WCVI averaging 0.0053, over two times the levels of differentiation observed within Puget Sound. However, only a small percentage of the individual comparisons were statistically significant.

From the results of this analysis, we cannot reject the null hypothesis that only a single population of Quillback Rockfish exists within British Columbia. Although not entirely statistically supported, it was clear that the Puget Sound sites were the most distinctive sites analyzed, but further work based on greater sample sizes and multi-year sampling would be required to confirm this. The data were consistent with the findings of a US review (Stout *et al.* 2001), which showed that the Puget Sound Basin Proper was distinctive from coastal Washington sites, but which observed no significant differences among coastal sites.

In Washington State, three distinct population segments (DPS) for Quillback Rockfish are recognized, based largely on biogeography, ecological and habitat factors and genetic population structure (Stout *et al.* 2001). These are defined as a Puget Sound proper DPS, a northern Puget Sound DPS and a coastal DPS but the boundaries are uncertain. Genetic evidence from allele and microsatellite analyses by Seeb (1998) and Winberger *et al.* (in prep) were used to support the DPS scenario for Quillback Rockfish. Seeb (1998) found some evidence that Quillback Rockfish in Puget Sound may be genetically isolated from those along the Pacific Coast.

Designatable units

There is presently no justification for multiple designatable units for Quillback Rockfish within BC. Two management areas have been used for inshore rockfish, including Quillback Rockfish: inside (water between the east side of Vancouver Island and the mainland) and outside (the remainder of the coast).

DISTRIBUTION

Global distribution

Quillback Rockfish have been reported from Kodiak Island, Gulf of Alaska (Mecklenberg *et al.* 2002) to Anacapa Passage (Love and Lea 1997), southern California (Figure 2).

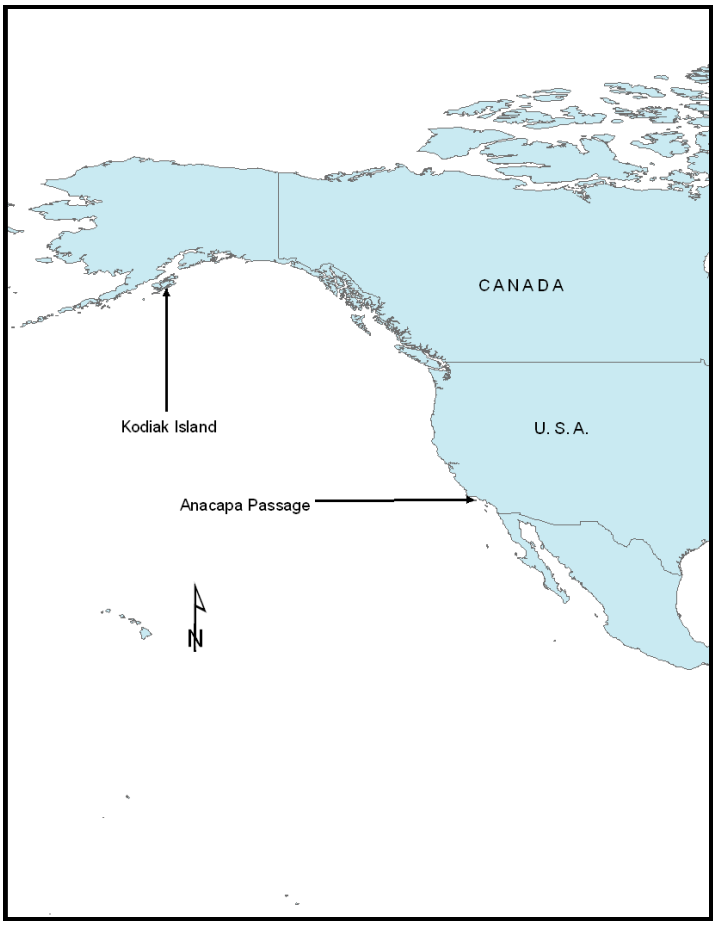


Figure 2. Global distribution of Quillback Rockfish.

Canadian range

Quillback Rockfish range throughout the marine waters of BC on Canada's Pacific Coast. The distribution of commercial catch records for Quillback Rockfish, for the years 1996 to 2004, is shown in Figure 3. This distribution of Quillback Rockfish in the commercial fishery depicts the Canadian range of the species.

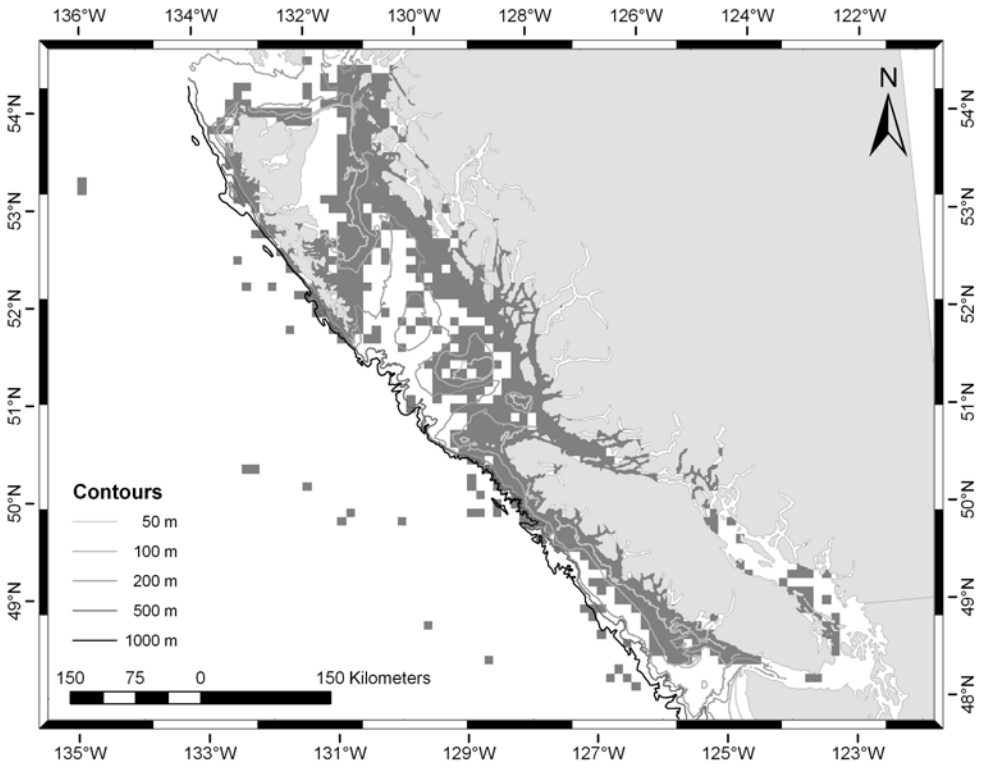


Figure 3. Distribution of Quillback Rockfish in BC from commercial hook & line and trawl catch records (1996 - 2004) summarized on a 10 by 10 km coastwide grid.

A generalized distribution of commercial catch (hook & line and trawl) by depth interval is derived by overlaying a bathymetric grid on the catch records and summarizing data over a 10 X 10 km grid. Area occupied by Quillback Rockfish is shown in Table 1. Quillback Rockfish are most widely caught in the 51-100 m depth range where catches are recorded in 84.5% of the area. This species is not endemic to Canada and its Canadian distribution is approximately 25% of their global range (Love *et al.* 2002).

Table 1. The total surface area (km^2) of marine water in BC by depth interval (m) from 1 to 2000 m (based on map bathymetry), area with Quillback Rockfish commercial catch recorded and the percentage of the total surface area with Quillback Rockfish catch recorded for the years 1996 – 2004 combined.

Depth Interval (m)	Total Area (km^2)	Occupied Area (km^2)	Percent Occupied
1-50	23,254	13,540	58.2
51-100	20,311	17,170	84.5
101-200	36,432	21,182	58.1
201-500	26,510	7,775	29.3
501-1000	7,473	1,492	20.0
1001-1500	8,480	1,207	14.2
1501-2000	10,679	780	7.3
Total:	133,139	63,146	47.4

The percent of total area with Quillback Rockfish commercial catch, determined annually from 1996 to 2004, was used to examine changes in distribution (Yamanaka et al 2006) (Table 2). The commercial hook & line and trawl fisheries have been established for many years prior to 1996 and logbook records have been routinely compiled for the hook & line rockfish and trawl fisheries (Yamanaka and Lacko 2001).

Table 2. The total number of blocks (10 x 10 km grid) fished, the total number of blocks with a recorded Quillback Rockfish catch (commercial hook and line and trawl) and the percent of blocks with Quillback Rockfish catch by year (1996 - 2004).

Year	Blocks Fished	Blocks Occupied	Percent
1996	1307	583	44.6
1997	1120	521	46.5
1998	1133	517	45.6
1999	1128	493	43.7
2000	1173	484	41.3
2001	1621	583	36.0
2002	1405	420	29.9
2003	1324	422	31.9
2004	1227	386	31.5

The percent of occupied blocks in 2001 to 2004 appears to be lower than in years prior to 2001 but may not indicate a contraction of area occupied by Quillback Rockfish. In 2001, new logbooks for the Schedule II fisheries (directed lingcod and dogfish by hook & line gear) were implemented for the first time. This effectively increased the number of blocks fished by the commercial fisheries but Quillback Rockfish were likely under reported in the new Schedule II logbook records due to the mandatory non-retention of rockfish in this fishery. Incidental rockfish catches were likely discarded at-sea and not reported on logbooks.

Catch quotas for Quillback Rockfish were lowered dramatically, by 50% in outside areas and 75% within inside waters, between 2001 and 2002. In general, the lowering of catch quotas would have the effect of lowering fishing activity (blocks fished as well as blocks occupied) but may also increase the non-reporting of quillback catch in logbooks. It is uncertain whether the declines in the percent distribution of Quillback Rockfish are real or a result of significant management actions applied to the commercial fisheries.

Depth of capture for Quillback Rockfish, recorded on commercial hook and line and trawl fishery logbooks, show that 95% of all observations lie between 14 and 143 metres in depth (Figure 4). An estimate of the maximum potential habitat area for Quillback Rockfish was derived by determining the size of the area in BC that falls between these depth intervals. Summarizing over a 5 x 5 km grid, an estimate of maximum potential habitat is 56,278 km^2 coastwide in BC (Figure 5). This is likely an overestimate of the true habitat area as Quillback Rockfish associate only with hard bottom substrates within their depth range. The habitat area with Quillback Rockfish catch, or occupied habitat area, is estimated at 27,370 km^2 or 48.6 percent of the maximum potential habitat area.

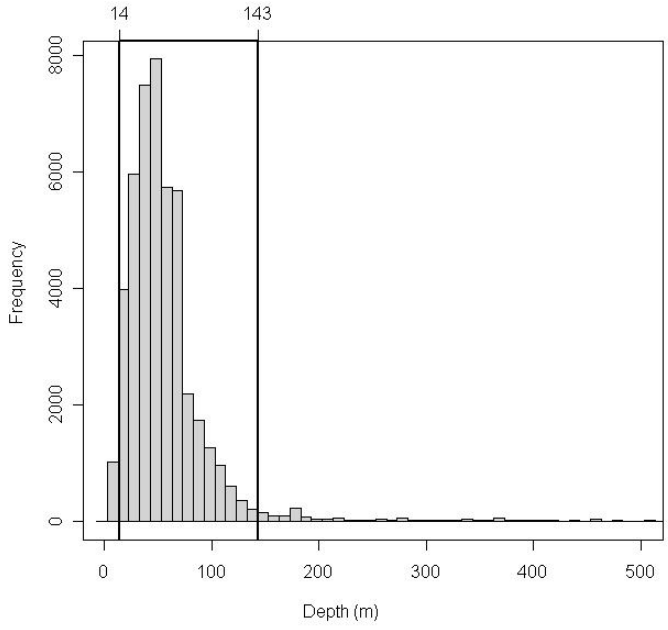


Figure 4. Histogram of the capture depth of Quillback Rockfish in the commercial hook & line and trawl fisheries in BC between 1996 and 2004. Vertical lines denote the 2.5% and 97.5% quartiles of the data.

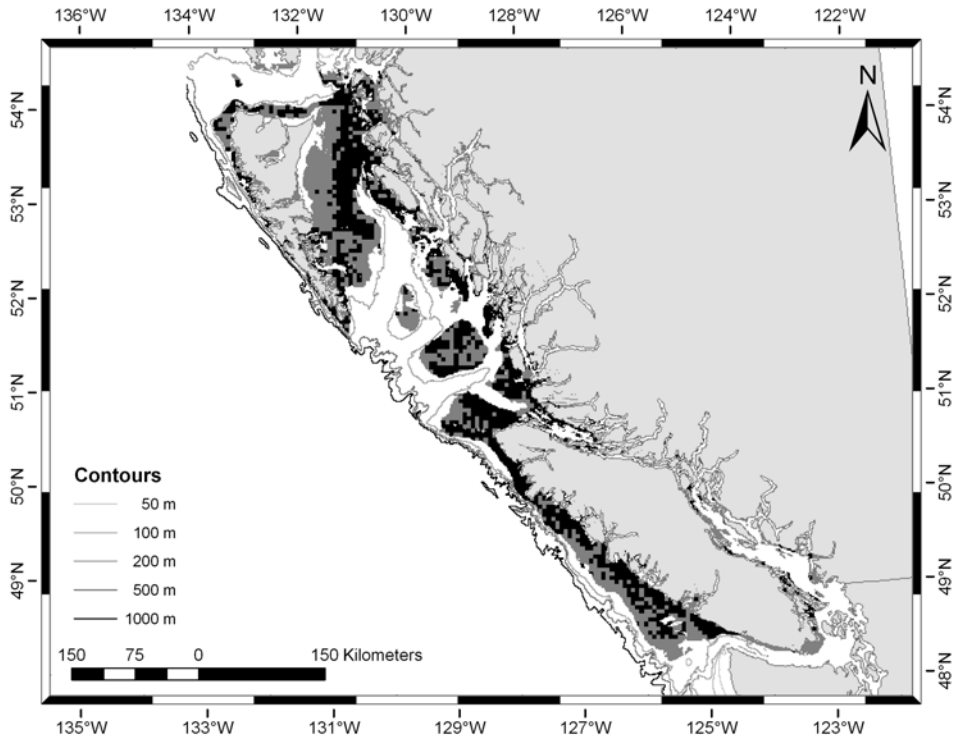


Figure 5. Maximum potential habitat of Quillback Rockfish in Canadian waters (black plus grey areas), based on the depths of 14 to 143 m, using a 5 x 5 km grid, is 56,278 square kilometres. The occupied habitat (black areas) based on commercial fishing records is 27,370 square kilometres, or 48.6% of the potential habitat.

HABITAT

Habitat requirements

Quillback Rockfish are habitat specialists, aggregating over substrates that are hard, complex and have some vertical relief, such as broken rock, rock reefs, ridges, crevices (Richards 1986, Matthews 1990, Murie *et al.* 1994). Information on the habitat of Quillback Rockfish from California through BC and in Alaska has come from direct *in situ* observations from submersibles, underwater towed cameras and divers using self contained underwater breathing apparatus (SCUBA).

Temperature and salinity were measured during submersible surveys conducted in 2003 and 2005 and are summarized for all observations of Quillback Rockfish in Table 3. The observed temperature ranges from 8.1 to 12.1^{o}C and salinity ranges from 28.2 to 35 parts per thousand. The submersible surveys were conducted over a limited range of habitats in B.C. and likely represent a subset within the physiological tolerances of the species.

Table 3. Summary of temperature (°C) and salinity (parts per thousand) measured for all Quillback Rockfish observed during submersible dives in 2003 and 2005.

Quillback Rockfish		
	Temperature	**Salinity**
Mean	9.13	32.83
Standard Error	0.0242	0.0708
Median	8.78	34.70
Minimum	7.96	28.19
Maximum	12.22	35.34
Count	1172	1172

Habitat trends

There are no data to substantiate habitat trends for Quillback Rockfish. It is assumed that there have been no net changes to the habitat (14-143 m depth range coastwide) since the last glaciation.

Habitat protection/ownership

Rockfish Conservation Areas (RCAs) are spatially defined areas where fishing is prohibited year round by both commercial and recreational sectors. RCAs were developed in consultation with stakeholders and are used as a spatial management tool to protect a portion of the inshore rockfish population from harvest. These RCAs are aimed at protecting inshore rockfish, including Quillback Rockfish, by identifying inshore rockfish habitat and closing a portion of these habitats to all harvesting activities. RCAs will remain closed into the future to support the rebuilding of inshore rockfish stocks. DFO closed 20% of rockfish habitat via RCAs for the outside area in 2005 and targeted 30% of rockfish habitat closed for the inside area in 2006. Currently 164 RCAs are in place (DFO 2007).

BIOLOGY

Fishing research surveys have provided most of the data used here to characterize populations, while submersible surveys have provided information on depth ranges for adult and juvenile fish. For other information in this section, research largely from the U.S. has been used to characterize aspects of Quillback Rockfish biology that have not been directly studied in BC.

Life cycle and reproduction

In BC the mating season for Quillback Rockfish is most likely in December when male gonads are known to be in “running ripe” condition, and may extend from November to February (Yamanaka unpublished data). Females can mate with several males and store sperm for several weeks prior to fertilizing the eggs (Wyllie Echeverria 1987). Rockfishes are matrotrophically viviparous, supplying nutrients to the developing

embryos late in their development (Boehlert and Yoklavich 1984, Yoklavich and Boehlert 1991). The gestation period is generally between one to two months for rockfishes (Love *et al.* 2002). Parturition for Quillback Rockfish in BC occurs between March and July with a peak in April and May (Yamanaka unpublished data).

The duration of the pelagic larval phase of Quillback Rockfish is unknown but *Sebastes*, in general, have a prolonged pelagic larval period lasting for one to two months. Larvae and juveniles occur in the upper mixed layer (<300 m) and are dispersed by physical transport processes (Loeb *et al.* 1995, Kokita and Omori 1999). In the pelagic environment the small (3-7 mm) larvae develop into pelagic juveniles (20 to 70 mm) prior to settling in benthic habitats (Bjorkstedt *et al.* 2002). *Sebastes* larvae are opportunistic feeders known to feed initially on copepod nauplii and invertebrate eggs, moving onto larger prey such as copepodites, adult copepods, and euphausiids as they grow (Moser and Boehlert 1991). Settlement occurs when the pelagic juveniles reach 3 - 9 cm and 6 - 9 months of age (Love *et al.* 2002). Benthic juveniles continue to feed on crustaceans but shift to larger prey from planktonic to benthic species then on to fish (Love *et al.* 1991).

The recruitment of rockfish is influenced to a large extent by their success during the pelagic larval-juvenile and benthic settlement phases. Quillback Rockfish populations experience highly variable annual recruitments. Rockfish are known to have periodic good recruitments with typically low recruitment in the intervening years. In a 1992 survey, 30% of the Quillback Rockfish caught were from the 1985 year class (Yamanaka and Richards 1993).

Typically, rockfish juveniles settle to near-shore hard bottom habitats at shallower depths than their conspecific adults. Rockfish move bathymetrically with age, hence the older (larger) rockfish tend to occupy the deeper depths within their specific depth range (Love *et al.* 1991). This appears to hold true for Quillback Rockfish observed from submersibles at all coastal BC locations surveyed (Table 4).

Adult Quillback Rockfish are known to have limited home ranges and have the ability to return to their home reef after displacements of 500 m (Matthews 1989). A study in Puget Sound found that adults moved within a range of 30-1500 m^2 within a year, but migrated between shallow and deep waters between years (Matthews 1989).

Submersible surveys conducted in B.C. have observed Quillback Rockfish at various locations coastwide in 1984, 2000, 2003 and 2005 (Richards 1986, Murie *et al.* 1994, Yamanaka unpublished data). Sub-adult and adult Quillback Rockfish (>20 cm forklength) have been observed from submersibles in BC hovering near or settled upon rock ridges and occupying crevices in rock substrates from 22 to 182 m in depth with the median of all observations of 60 m (Table 4).

Table 4. Minimum, 25th percentile, median, 75th percentile, maximum depth and number (n) of sub-adult and adult Quillback Rockfish greater than 20 cm forklength observed during submersible surveys coastwide and by site.

Quillback Rockfish							
>20cm	**Year**	**min.**	**25%**	**median**	**75%**	**max**	**n**
coastwide	all	22	45	60	88	182	568
Juan Perez Sound	2005	31	51	64	95	178	347
Desolation Sound	2003/05	22	31	40	60	178	121
Jervis Inlet	2005	24	46	62	88	178	85
Gulf Islands	2003	67	75	87	109	182	15

Juvenile Quillback Rockfish (<20 cm forklength) have also been observed from submersibles in a shallower depth range than the adults, 16 to 159 m, with a median of all observations of 48 m (Table 5). Juveniles occupy similar rock habitats to the adults but are seen in areas with smaller crevice space available for refuge, including cloud sponge formations, crinoid aggregations on top of rocky ridges and over cobble substrates. Young of the year Quillback Rockfish have been observed by SCUBA divers in shallow water (< 18 m) eel grass and kelp beds in the Strait of Georgia, BC during the late summer and early fall (Richards 1987).

Table 5. Minimum, 25th percentile, median, 75th percentile, maximum depth and number (n) of juvenile Quillback Rockfish less than or equal to 20 cm forklength observed during submersible surveys coastwide and by site.

Quillback Rockfish							
Juveniles (<=20cm)	**Year**	**min.**	**25%**	**median**	**75%**	**max**	**n**
coastwide	All	16	36	48	60	159	420
Juan Perez Sound	2005	30	43	49	52	121	82
Desolation Sound	2003/05	16	31	42	57	159	194
Jervis Inlet	2005	21	36	52	74	102	137
Gulf Islands	2003	41	48	58	76	120	7

Age and growth

Quillback Rockfish have been aged to 95 years in BC (Yamanaka and Lacko 2001). Size and age at 50% maturity are 29.3 cm (95% CI 28.9 – 29.7 cm) and 11 years (95% CI 10-12 yr; Yamanaka and Richards 1993). The average age of mature females, assessed through historical biological samples from April to July is 22.8 yr (std dev = 12.36, n = 1,776) (Yamanaka unpublished data). This is an estimate of current generation time for Quillback Rockfish as all mature individuals contribute to annual cohorts from the year they first produce larvae, until their death.

Generation time (G) in an unfished population can be estimated using the formula: G = A + 1/M, where A is the age at 50% maturity and M is the natural mortality rate. A is estimated from maturity ogives constructed from the female samples used above and is

11 years for the Quillback Rockfish in BC. M has been estimated as 0.02 by Yamanaka and Lacko (2001), which would give an estimate of generation time (G) of 61 years. This estimate of M is lower than that used for other rockfish species, typically around 0.05; using the latter value, generation time would be estimated at 31 yr.

In the Quillback Rockfish population, there are equal numbers of males and females; average age for both sexes is about 21, while maximum age of females is 95 years and of males is 80 years (Table 6). Females are slightly larger than males. Sexual dimorphism is common among rockfishes with females most commonly larger in size than the males (Wyllie Echeverria 1986). Forklength – weight relationship is shown in Figure 6 and forklength at age data fit to a von Bertalanffy growth function (von Bertalanffy 1938) is shown in Figure 7.

Table 6. Summary of biological sample data for Quillback Rockfish, including descriptive statistics on sex, age and forklength (source: DFO GFBio database 23/09/2005).

Quillback Rockfish	Males	Females
Number sexed	19677	19940
mean age	20.6	20.7
std dev of age	12.27	12.60
Number aged	6425	6683
Maximum age	80	95
mean forklength	308	313
std dev of forklength	98.9	95.3
Number of lengths	11746	11991
Maximum forklength	502	503

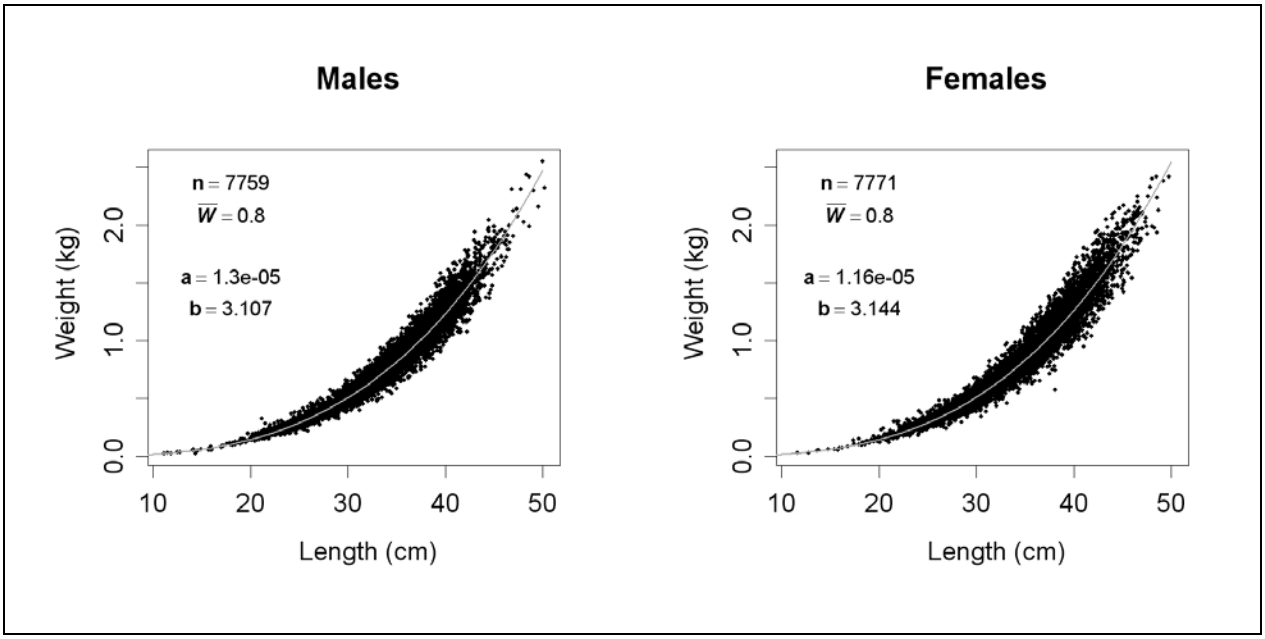


Figure 6. Quillback Rockfish forklength (L in cm) vs weight (W in kg) by sex, $W = aL^b$.

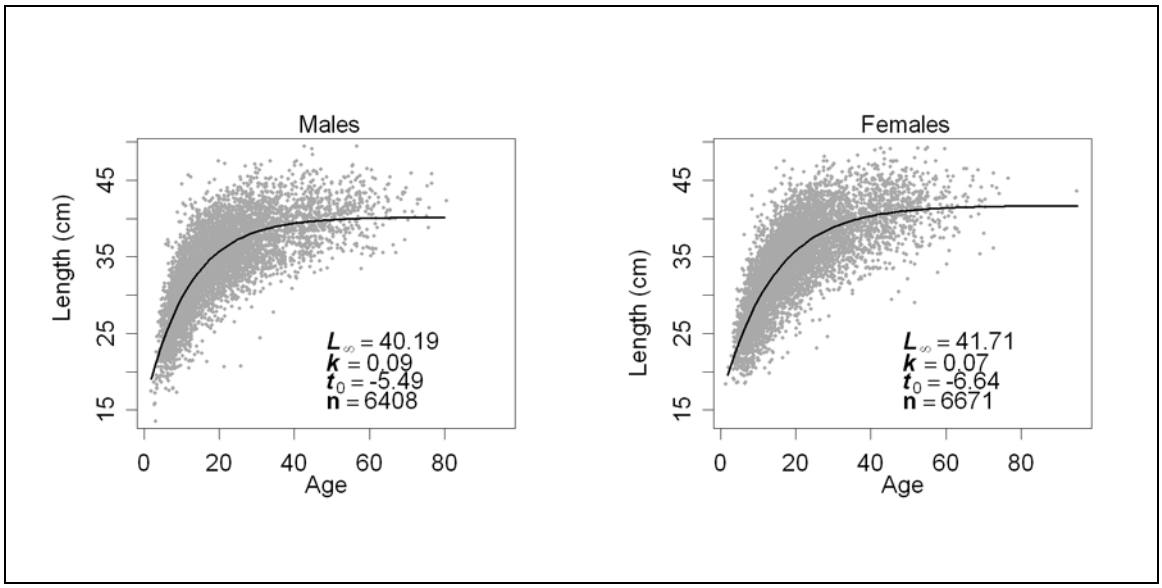


Figure 7. Quillback Rockfish forklength (cm) at age (yrs) fit to the von Bertalanffy growth function by sex.

Mortality rates

Rockfish total mortality rates are difficult to determine using simple catch curve analysis primarily because of highly variable annual recruitment and the effect that trends in recruitment can have on the mortality estimates (Ricker 1975). New methods developed by Schnute and Haigh (2007) recognize large year classes and try to account for these in the estimation of a total morality rate.

Simple catch curves have been used (Yamanaka and Lacko 2001) to estimate total mortality (Z) for Quillback Rockfish from jig survey age data collected from 1986 to 2001 and longline survey data from 2003/4. Z values ranged from 0.046-0.093 (Table 7) (methods are described in Appendix A).

Table 7. Total mortality estimates (Z) from simple catch curves (Appendix A) by area, year and survey and the r^2 statistic for the regression line.

		Total mortality estimate (Ricker 1975)		
Area	**Year**	**Survey**	**Z**	**r^2**
Inside	1986-88	DFO research jig fishing	0.063	0.759
Inside	1992	DFO research jig fishing	0.068	0.642
Inside	2001	DFO research jig fishing	0.093	0.662
Inside	2004	DFO research jig fishing	0.046	0.388
inside	2003/04	DFO research longline	0.078	0.872

The improved catch curve methods of Schnute and Haigh (2007) were applied to the same age data sets used in the simple catch curve analyses in Table 7. Z estimates from this method were similar but somewhat higher than those from simple catch curves, ranging from 0.057-0.109 (Table 8).

Table 8. Total mortality estimates (Z) from Schnute and Haigh (2007) by area, year and survey showing the mean, mode and 2.5 and 97.5 percentiles of the posterior Z distributions.

		Total mortality estimate (Schnute and Haigh 2007)				
Area	**Year**	**Survey**	**2.5%**	**mean**	**mode**	**97.5%**
Inside	1986-88	DFO research jig fishing	0.047	0.059	0.059	0.069
Inside	1992	DFO research jig fishing	0.051	0.071	0.073	0.092
Inside	2001	DFO research jig fishing	0.061	0.109	0.124	0.140
Inside	2004	DFO research jig fishing	0.061	0.106	0.135	0.150
inside	2003/4	DFO research longline	0.049	0.057	0.065	0.066

Using an estimate of the natural mortality rate (M) of 0.02 from Yamanaka and Lacko (2001) and mean total mortality (Z) estimates from Table 8 (Schnute and Haigh 2007), the fishing mortality rate (F) can be derived from F = Z – M. Quillback Rockfish in BC had an estimated F in 2003/04 between 0.037 and 0.086. The research jig fishing surveys between 1986 and 2001 showed an increasing trend in Z (F) over time. Between 2001 and 2004, this trend seems to be halted or reversed, coincident with the implementation of the Rockfish Conservation Strategy which imposed dramatic quota cuts and closed areas to fishing in 2002 (see Fisheries). Caution must be used in interpreting these data, since the mortality values represent averages over many year-classes, and thus events over many years, such that the data may not strongly support conclusions about changes in mortality over the short term.

Diet

Most rockfishes are opportunistic feeders that take prey readily available to them and substituting prey items of the same general size and type (Rosenthal *et al.* 1988). As larvae and after settlement, Quillback Rockfish feed on planktonic animals and eggs. As adults they consume a variety of prey, fishes, benthic and pelagic invertebrates, especially shrimp (CDFG 2001).

Predation

Quillback Rockfish larvae are preyed upon by jellyfish and arrow worms and the juveniles are preyed upon by fishes, marine birds, pinnipeds and the adults by larger fish, sea lions, seals and possibly river otters (CDFG 2001). In the Strait of Georgia, predation by harbour seals was estimated at 112 t for all rockfish species in 1988 (Olesiuk *et al.* 1990). These rockfish were not identified to species but this marine mammal harvest may be significant relative to the total fishery harvest of 336 t in the Strait of Georgia in 1988.

Physiology

All rockfish have physoclistic swim bladders (lack a pneumatic duct) and must rely on a gas gland to fill the bladder. Accordingly, rockfish cannot rapidly accommodate changes in pressure and gas expansion in the swim bladder when brought to the surface from depth.

The mortality rate suffered by discarded rockfish is unknown but considered to be high, especially when brought to the surface from depth. Based on shallow water fishing with handline gear and holding experiments, estimates of 30% mortality rate at 1-month post catch have been made for Quillback Rockfish (Berry 2001). Long-term mortality rates are likely higher for these fish as visible eye damage alone was noted for 55% of the catch. Rockfish discarded at sea are considered part of the total catch.

Dispersal

Rockfish are known to passively disperse with ocean currents during their extended pelagic larval stage. *Sebastes* larvae were found to concentrate over the continental shelf and slope west of the Queen Charlotte Islands, up to 600 km from shore (LeBrasseur 1970). From the composition of otolith microstructure, there is evidence that dispersal may be less than 120 kms for black rockfish (*Sebastes melanops*) (Miller and Shanks 2004). Dispersal of larvae would immediately follow parturition which occurs from April to September for Quillback Rockfish. The actual dispersal distance for Quillback Rockfish is unknown.

Interspecific interactions

There are no known interspecific interactions that limit the survival of Quillback Rockfish in Canada.

Adaptability

Quillback Rockfish have been captured from the wild and held in aquaria for sale and for display purposes but there are no known captive breeding programs or grow-out aquaculture operations for this species in Canada.

FISHERIES

Quillback Rockfish are caught primarily by hook and line gear in Aboriginal, commercial and recreational fisheries coastwide (Yamanaka and Lacko 2001). As an inshore rockfish species inhabiting relatively shallow coastal waters, Quillback Rockfish (along with other species in the inshore rockfish complex) has been targeted by fisheries for many years, certainly decades and probably centuries. Aboriginal peoples in British Columbia are known to have harvested coastal rockfishes historically, and recreational fishing for coastal rockfishes has existed since the late 1800s.

In commercial fisheries, they are targeted in a fishery that supplies a high-value live product to local fish markets. Common gear types include rod and reel rigged with single or multiple hooks and operated manually by the fisher or longline systems with multiple hooks that are operated hydraulically. Rod and reel gear is jigged just off the bottom and longline gear is demersal. The majority of the harvest in the “outside” management area is with longline gear. Inside the Strait of Georgia is largely a handline fishery.

Quillback Rockfish are taken as incidental catch in all other commercial hook and line fisheries, such as those for halibut, dogfish, lingcod and salmon, as well as groundfish and shrimp by trawl gear and prawn and sablefish by trap gear. Incidental catch is not known for fisheries where the landing of rockfish is either limited or prohibited by licence conditions.

The directed commercial fishery for Quillback Rockfish in the Strait of Georgia developed in the late 1970s in response to a growing demand for live fish in markets around Vancouver. Premium prices are paid for live rockfish, at least five times the price for fresh (dead) rockfish. The live market continues to thrive in the lower mainland. Fishery management for the Strait of Georgia management region (inside waters) is focused solely on a live rockfish fishery, in contrast to the outside area where there is more of a mix between live and fresh rockfish landed.

The commercial fishery for Quillback Rockfish is managed by aggregate species TACs. Quillback Rockfish are managed in an aggregate together with copper, china and tiger rockfishes. Quillback Rockfish, within inside waters east of Vancouver Island, make up 40 to 80% of the catch by weight in the aggregate species quota (Kronlund and Yamanaka 1997).

The directed commercial hook and line fishery for rockfish was licensed in 1986 (Yamanaka and Lacko 2001, Kronlund and Yamanaka 1997, Yamanaka and Kronlund 1997). Area licensing (inside or outside the Strait of Georgia Management Region) and catch quotas for each of five management regions were introduced in 1991. Limited entry licensing was implemented for the inside (Strait of Georgia) management region in 1992 and for the remainder of the coast (outside) in 1993. Limited entry licensing reduced the number of licences to 74 in the Strait of Georgia and to 183 outside from over 2400 licences coastwide in 1986.

Within the aggregate total allowable catch (TAC), allocations have been made to the various commercial fisheries; trawl, directed hook and line rockfish and hook and line halibut. A history of annual TACs is shown in Table 9.

Table 9. Quillback Rockfish, aggregate catch quotas (t) by management year, gear type, management region and total allowable catch (TAC).

Management	Trawl	Hook and Line						Aggregate
Year	Coastwide	Inside[3]	CC[4]	PR[5]	QCI[6]	WCVI[7]	Coastwide[8]	TAC
1991[1]		300	100	20	100	150		670
1992[1]		130	100	20	100	150		500
1993[1]		140	100	60	100	150		550
1994[1]		150	100	60	54	150		514
1995[1]		150	105	63	76	144		538
1996[1]		150	105	63	76	144		538
1997[1]		143	110	59	40	144		496
1998/99[2]		23	99	51	38	133		344
1999/00[2]	0	102	70	36	21	96		325
2000/01[2]	10	102	70	36	21	96	36	371
2001/02[2]	10	102	70	36	21	97	15	351
2002/03[2]	5	26	42	33	13	58	20	197
2003/04[2]	5	26	40	21	12	55	15	174
2005								160

[1] January 1 to December 31
[2] April 1 to March 31
[3] Inside area, Pacific Fishery Management Area (PFMA) 12 to 20, 28 and 29 (see DFO management plans)
[4] Central Coast, PFMA 6 to 10 and 106 to 110
[5] Prince Rupert, PFMA 3 to 5 and 103 to 105
[6] Queen Charlotte Islands, PFMA 1, 2, 101 and 102
[7] West Coast Vancouver Island, PFMA 21 to 27, 11, 121 to 127 and 111
[8] Allocation to the halibut fishery

Recreational harvests are managed by bag limits. In 1986 an eight rockfish daily bag limit was implemented coastwide for the recreational fishery. In 1992 the daily bag limit for the Strait of Georgia recreational fishery was reduced from eight to five rockfish. Further reductions were implemented in 2002, from eight to five rockfish per day outside and from five to one rockfish per day inside.

In 1995, dockside monitoring of all commercial groundfish landings was initiated together with 100% at-sea observer monitoring for the commercial groundfish trawl fishery. Partial at-sea observer coverage for the commercial hook and line groundfish fleet was initiated in 1999.

A rockfish conservation strategy (RCS) was announced by the Minister of Fisheries and Oceans in 2001 and focused on four principles:

1. account for all catch (landed and discarded)
2. reduce fishing mortality
3. areas closed to all fishing (Rockfish Conservation Areas (RCAs))
4. stock assessment

Strong management measures were implemented in 2002, including increased at-sea observer coverage on commercial hook and line fleets, commercial TAC and recreational daily bag limit reductions by 50% for areas outside and 75% for the inside, together with the implementation of 28 Rockfish Conservation Areas (RCAs) coastwide. Consultations in 2003/04 resulted in the closure of 20% of the rockfish habitat on the outside and a goal of 30% rockfish habitat closed was set for the inside with consultations completed in 2006. In 2002, overall TACs for the aggregate that includes Quillback Rockfish were 148 t for the outside and 57 t inside.

In response to the Department's Rockfish Conservation Strategy, Pacific Fisheries Monitoring and Reporting Framework and Selective Fishing Policy as well as the *Species at Risk Act*, the commercial groundfish industry formed a committee, the Commercial Industry Caucus (CIC) to develop a pilot groundfish integration proposal that addresses these issues and others, to ensure a unified and sustainable groundfish fishery into the future (Diamond Management Consulting Inc. 2005). The CIC is committed to ecologically and economically sound practices and supports the general principles of the *Oceans Act*. The CIC has worked on this proposal since 2003, and implementation began with the 2006 fishery.

The CIC is guided by the following five principals:

1. All rockfish catch must be accounted for,
2. Rockfish catches will be managed according to established rockfish management areas,
3. Fishers will be individually accountable for their catch,
4. New monitoring standards will be established and implemented to meet the above 3 objectives, and,
5. Species of concern will be closely examined and actions such as reduction of total allowable catch (TACs) and other catch limits will be considered and implemented to be consistent with the precautionary approach for management.

With integrated groundfish management, 100% at-sea monitoring standards are in place for the entire groundfish fishery, eliminating unreported catch of rockfish throughout the commercial groundfish fishery and allowing all rockfish to be accounted for within their TACs. Specifically for rockfish, 100% video monitoring of logbook records is in place for the commercial groundfish hook and line fisheries which include the directed halibut, dogfish and rockfish fisheries. The logbook data, backed up by onboard video monitoring, provides the catch data required for stock assessment.

Commercial catch

Commercial hook & line landings and trawl catch (landings and discards) data were obtained from DFO records for the years 1996-2004 (Figure 8 and Table 10) (Yamanaka et al 2006). Quillback Rockfish catch weights were estimated from reported sales slip weights of “other rockfish” and logbook data in the years prior to 1995. Hook and line at-sea discards of Quillback Rockfish, assessed using partial at-sea observer data (1999-2001), is estimated at 22% of the Quillback Rockfish caught by weight in the halibut fishery and 13% in the hook and line rockfish fishery (Yamanaka and Lacko 2001). However, no attempt was made to account for discards in the catch figures provided below.

The 2005 commercial TAC for the Quillback Rockfish species aggregate was 135 t outside and 25 t inside.

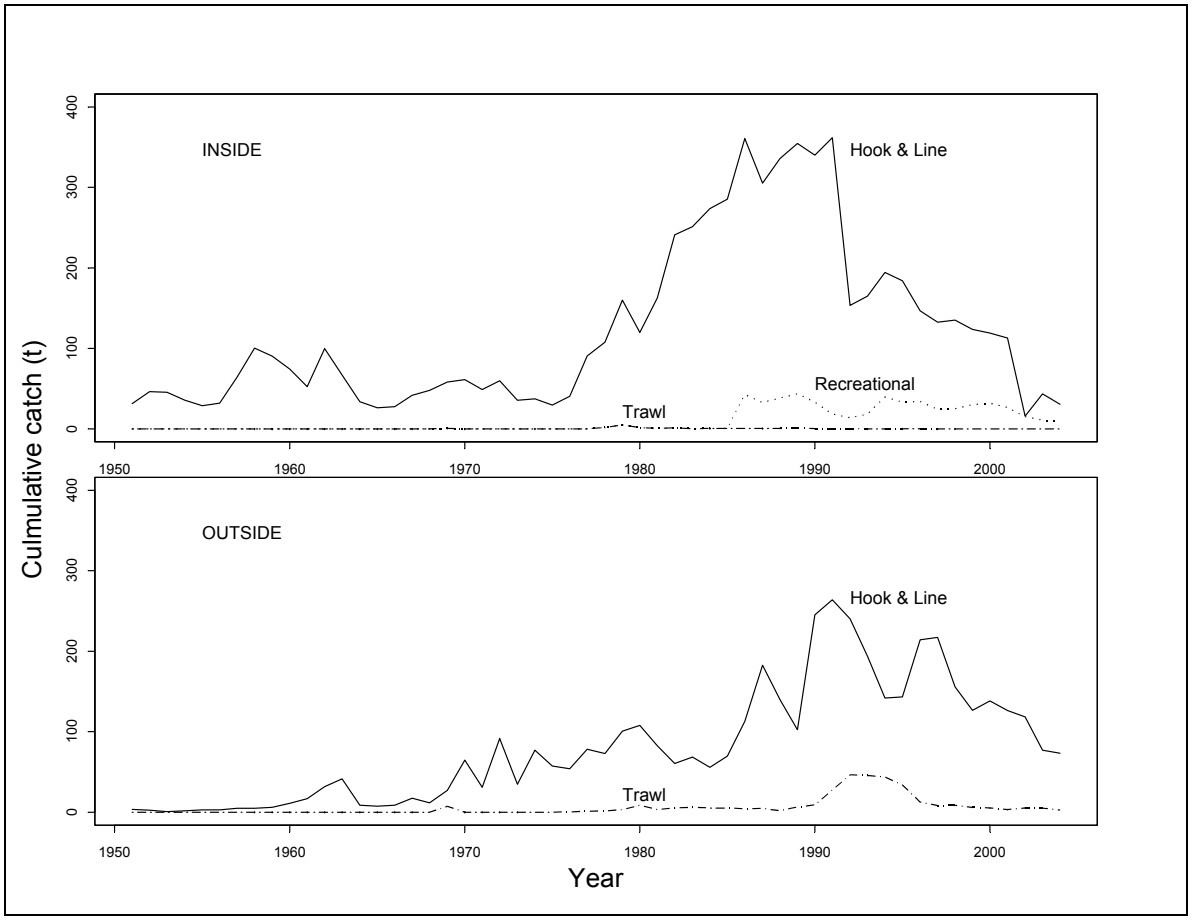


Figure 8. Quillback Rockfish landings for the inside (top) and the outside (bottom) by fishery, commercial hook and line and trawl fisheries and the recreational fishery. The solid line represents the hook and line fishery, dash-dot is trawl, light dots are recreational.

Table 10. Coastwide landings of Quillback Rockfish 1951 to 2004 from commercial hook and line (H&L), trawl, halibut and recreational (Rec) fisheries, tabulated by year for the inside and outside areas. Commercial H&L and trawl landings between 1951 and 1995 are from saleslip records, between 1996 and 2004 are from PacHarvHL and PacHarvTrawl. Commercial halibut landings between 1995 and 2004 are from PacHarvHL. Recreational landings are converted (0.7 kg) from numbers of fish reported in the Strait of Georgia Creel Survey for the years 1986 to 2004.

Year	Inside management region				Outside management region			TOTAL
	H&L	trawl	halibut	Rec[1]	H&L	trawl	halibut	
1951	31.5	0.0	0.0	0.0	3.6	0.0	0.0	35
1952	46.2	0.0	0.0	0.0	2.5	0.0	0.0	49
1953	45.3	0.0	0.0	0.0	0.7	0.0	0.0	46
1954	35.8	0.0	0.0	0.0	1.7	0.0	0.0	38
1955	28.7	0.0	0.0	0.0	2.9	0.0	0.0	32
1956	32.0	0.0	0.0	0.0	3.0	0.0	0.0	35
1957	64.4	0.0	0.0	0.0	4.9	0.0	0.0	69
1958	100.2	0.0	0.0	0.0	4.8	0.0	0.0	105
1959	90.4	0.0	0.0	0.0	6.1	0.0	0.0	97
1960	74.3	0.0	0.0	0.0	11.2	0.0	0.0	86
1961	52.4	0.0	0.0	0.0	17.0	0.0	0.0	69
1962	99.8	0.0	0.0	0.0	31.9	0.0	0.0	132
1963	67.0	0.0	0.0	0.0	41.4	0.0	0.0	108
1964	33.7	0.0	0.0	0.0	8.7	0.0	0.0	42
1965	26.3	0.0	0.0	0.0	7.6	0.0	0.0	34
1966	27.7	0.0	0.0	0.0	8.8	0.0	0.0	37
1967	41.6	0.0	0.0	0.0	17.6	0.0	0.0	59
1968	47.9	0.0	0.0	0.0	11.5	0.0	0.0	59
1969	57.6	0.6	0.0	0.0	19.9	7.1	0.0	85
1970	61.1	0.0	0.0	0.0	64.9	0.0	0.0	126
1971	49.0	0.0	0.0	0.0	31.0	0.0	0.0	80
1972	59.6	0.0	0.0	0.0	91.5	0.0	0.0	151
1973	35.4	0.0	0.0	0.0	34.7	0.0	0.0	70
1974	37.2	0.0	0.0	0.0	77.1	0.0	0.0	114
1975	29.7	0.0	0.0	0.0	57.4	0.0	0.0	87
1976	40.6	0.0	0.0	0.0	54.0	0.1	0.0	95
1977	90.7	0.0	0.0	0.0	76.9	1.2	0.0	169
1978	106.0	1.6	0.0	0.0	71.5	1.4	0.0	180
1979	155.0	4.8	0.0	0.0	97.5	3.2	0.0	260
1980	118.5	1.3	0.0	0.0	99.5	8.4	0.0	228
1981	161.7	0.8	0.0	0.0	79.4	3.2	0.0	245
1982	240.2	0.9	0.0	0.0	55.3	5.3	0.0	302
1983	251.2	0.1	0.0	0.0	62.5	6.0	0.0	320
1984	273.5	0.4	0.0	0.0	50.3	5.3	0.0	330
1985	285.2	0.4	0.0	0.0	64.7	5.1	0.0	355
1986	318.2	0.5	0.0	42.0	108.7	4.3	0.0	474
1987	272.6	0.5	0.0	32.1	178.0	4.7	0.0	488
1988	297.9	0.5	0.0	37.6	138.3	1.7	0.0	476
1989	311.3	0.7	0.0	42.7	95.8	6.5	0.0	457
1990	306.8	0.1	0.0	33.1	236.0	9.1	0.0	585
1991	343.3	0.0	0.0	18.4	236.1	27.8	0.0	626
1992	139.6	0.2	0.0	13.6	194.1	46.3	0.0	394
1993	146.7	0.0	0.0	18.1	148.3	45.5	0.0	359
1994	154.6	0.0	0.0	39.7	98.0	43.8	0.0	336
1995	151.3	0.1	0.1	32.7	106.9	33.7	2.8	327
1996	112.5	0.2	0.3	33.8	196.8	12.6	4.9	361
1997	108.3	0.0	0.0	24.1	206.7	8.0	2.5	350
1998	110.0	0.0	0.1	24.9	140.1	8.4	7.3	291
1999	93.8	0.0	0.0	29.8	116.2	5.9	4.5	250
2000	87.3	0.0	0.0	31.6	123.4	5.1	9.8	257
2001	86.3	0.0	0.2	26.4	112.6	3.1	10.8	239
2002	1.0	0.0		15.1	98.0	5.2	15.5	135
2003	32.6	0.0		10.7	57.7	5.0	14.3	120
2004	21.8	0.0	0.0	8.7	56.9	2.5	13.9	104

[1]converted to weight using 0.7 kg

Recreational catch

The distribution of Quillback Rockfish in relatively shallow coastal waters has made this species a regular quarry of recreational fishers, especially in the Strait of Georgia. Although they can be caught all year round, most of the catch is taken in the summer months when participation in the recreational fishery peaks. Quillback Rockfish are taken in directed recreational fisheries targeting rockfishes, or as bycatch associated with the targeting of other species, primarily salmon.

In recent years the number of Quillback Rockfish caught in the recreational fishery may have declined due in part to the lower overall abundance in inside waters but also from a combination of reduced overall effort (participation) in the Strait of Georgia recreational fishery, lowered bag limits throughout all of British Columbia, and the recent implementation of Rockfish Conservation Areas (Maynard pers. comm. 2005).

Recreational catch is assessed annually in the Pacific region through a creel survey in portions of the Strait of Georgia and assessed coastwide every five years nationally through a mail-in survey of recreational fishing in Canada. For the first time in 2000, the National Survey of recreational fishing reported the catch (in numbers of fish) of rockfish (all species combined) by management region (Table 11).

Table 11. National Survey of recreational fishing reported catch of rockfish (all species), in numbers of fish for 2000.

Outside	**Total number of rockfish (all species)**	**346,022**
	Queen Charlotte Is.	30,421
	North Coast	51,060
	Central Coast	68,582
	Barkley Sound	80,899
Inside	**Total number of rockfish (all species)**	**530,630**
	Johnstone Strait	84,099
	Strait of Georgia	446,531

The Strait of Georgia creel survey has provided an annual estimate of recreational catches (in numbers of fish), primarily for salmon but secondarily for groundfish and other species, since 1986. The number of months and landing sites surveyed over the years has varied but as many as 50 landing sites are monitored throughout the Strait of Georgia from Sooke in the south to Brown's Bay in the North. Quillback Rockfish are estimated from this survey by applying a 32% proportion to the overall rockfish catch (Collicutt and Shardlow 1992) then converting numbers to weight by applying an average weight (0.7 kg). Quillback Rockfish catch estimated in the Strait of Georgia creel survey was approximately 9 t in 2004.

There is a discrepancy in the recreational catch estimates, in 2000, between the National Survey and the Pacific Region Strait of Georgia Creel Survey, but there are no independent means of verifying catch in this fishery. Estimates of Quillback Rockfish catch extrapolated (numbers multiplied by 32% proportion of all rockfish that are Quillback Rockfish, multiplied by an average weight of 0.7 kg) from the National Survey for the inside fishery are on the order of 119 t whereas the Pacific Region Creel Survey estimates 32 t. The 2004 estimate of Quillback Rockfish caught in the recreational creel survey in the Strait of Georgia is 9 t.

An estimate of recreational catch for the outside area, in 2000, based on extrapolations from the National Survey is 78 t.

Overall there are many sources of uncertainty affecting estimates of catch of this species in recreational fisheries, and thus the effectiveness of recreational fishery management is difficult to assess.

First Nations fisheries and Aboriginal traditional knowledge

There is little detailed information on present-day or historical traditional use of Quillback Rockfish by the several coastal First Nations along British Columbia's coast. Given the accessibility of this species to fishing, they have likely always been an important component of Aboriginal fisheries. Quillback Rockfish were probably caught both intentionally as well as incidentally while pursuing other fish resources including other rockfish species, halibut and lingcod. Early ethnographers all recognized the importance of the "various specimens of cod" as important to a variety of coastal First Nations (Boas 1895), but according to Stewart (1975) explicit reference to rockfishes as a subgroup is absent in the early ethnographies. Archaeological records of *Sebastes sp.* 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).

Catch summary

In summary, the early history of catch records for Quillback Rockfish, and all rockfishes in general, is not species specific and typically lumped with other groundfish or other rockfish. Discarding of rockfishes, including Quillback Rockfish, has most likely occurred in the past but the level of discarding prior to 100% observer programs for commercial trawl fisheries in 1995, partial observer coverage in hook and line fisheries in 1999, and full video monitoring of logbooks in 2006, is unknown. The mortality associated with discarding is known to be high for all the fisheries and at this time is considered 100%. Landings generally peaked in the late 1980s in inside waters, and in the early 1990s in outside waters, and have subsequently declined (Fig. 10). Recreational catch and effort by species can not be estimated on an annual basis for all areas of the coast, and catches in Aboriginal fisheries are not known.

POPULATION SIZES AND TRENDS

Information Sources

Commercial catch and effort data recorded on logbooks from the directed rockfish hook and line fishery are stored in the DFO database PacHarvHL. Research fishing survey data are stored in the DFO database GFBio. Submersible survey videos and visual observations are contained within the DFO database PacGFVideo.

Abundance

Area swept bottom trawl surveys

Trawl surveys conducted in BC have been used to estimate biomass for Quillback Rockfish. These expansions from area swept bottom trawl survey data should be considered a minimum biomass as trawls are not able to survey in rocky reef habitats, the primary habitat type for Quillback Rockfish. Catchability for Quillback Rockfish in trawls is <1. Figure 9 illustrates the areas surveyed by trawls on the BC coast and Table 12 shows the corresponding stratified random bootstrapped biomass estimates from these bottom trawl surveys. A minimum biomass estimate from the trawl surveys for Quillback Rockfish for the outside waters is 407 t.

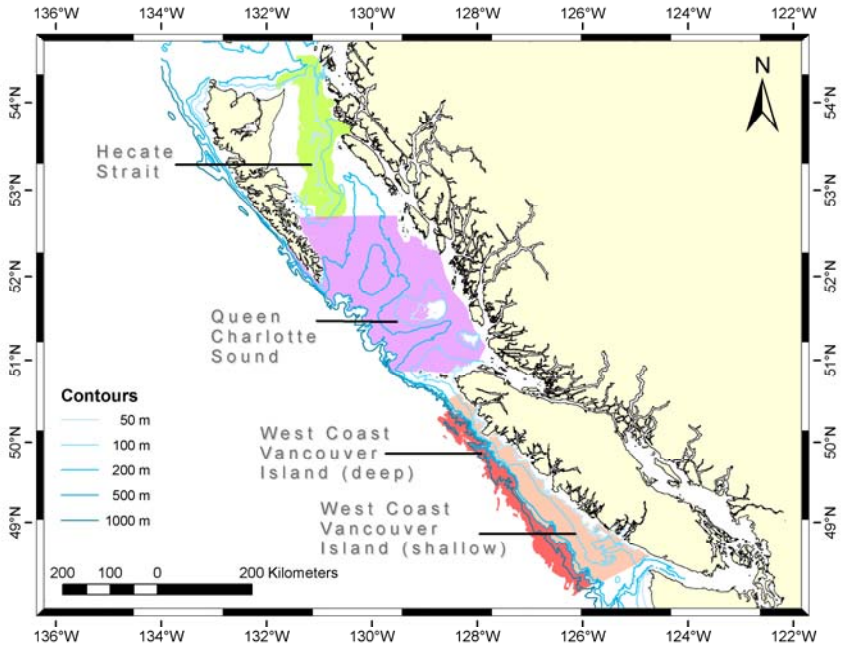


Figure 9. Trawl survey areas in British Columbia.

Table 12. Stratified random bootstrapped biomass estimate from bottom trawl surveys. Relative error is the CV of the bootstrapped estimates. This is considered a minimum estimate based only on trawlable bottom.

Survey	Year	Median Index (t)	Lower C.I.	Upper C.I.	Relative Error
West Coast V.I. (shallow)	2004	61	23	182	0.49
West Coast V.I. (deep)	2003	0	0	0	-
QC Sound Synoptic	2004	230	94	732	0.51
Hecate Strait	2003	116	45	338	0.50

Hecate Strait assemblage trawl survey

The Hecate Strait trawl survey is stratified by area and depth with fixed stations within depth strata (Choromanski *et al.* 2002). The sampling grid (10 nm^2) extends throughout Hecate Strait, between the Queen Charlotte Islands and the mainland, from Dundas Island in the north to Juan Perez Sound in the south (Figure 10). Between 82 and 105 trawl tows were made during the 11 surveys conducted between 1984 and 2003. A small proportion of the tows catch Quillback Rockfish in this survey because of the low relief (trawlable) bottom types targeted in this trawl survey. Quillback Rockfish aggregate over rocky reef habitats and are not typically found in these low relief areas.

Biomass estimates for Quillback Rockfish from trawl surveys are shown in Table 13. These should be considered minimum estimates as the survey does not cover the primary rocky reef habitat for Quillback Rockfish. Biomass as low as 14 t and as high as 258 t are estimated for the Hecate Strait survey area.

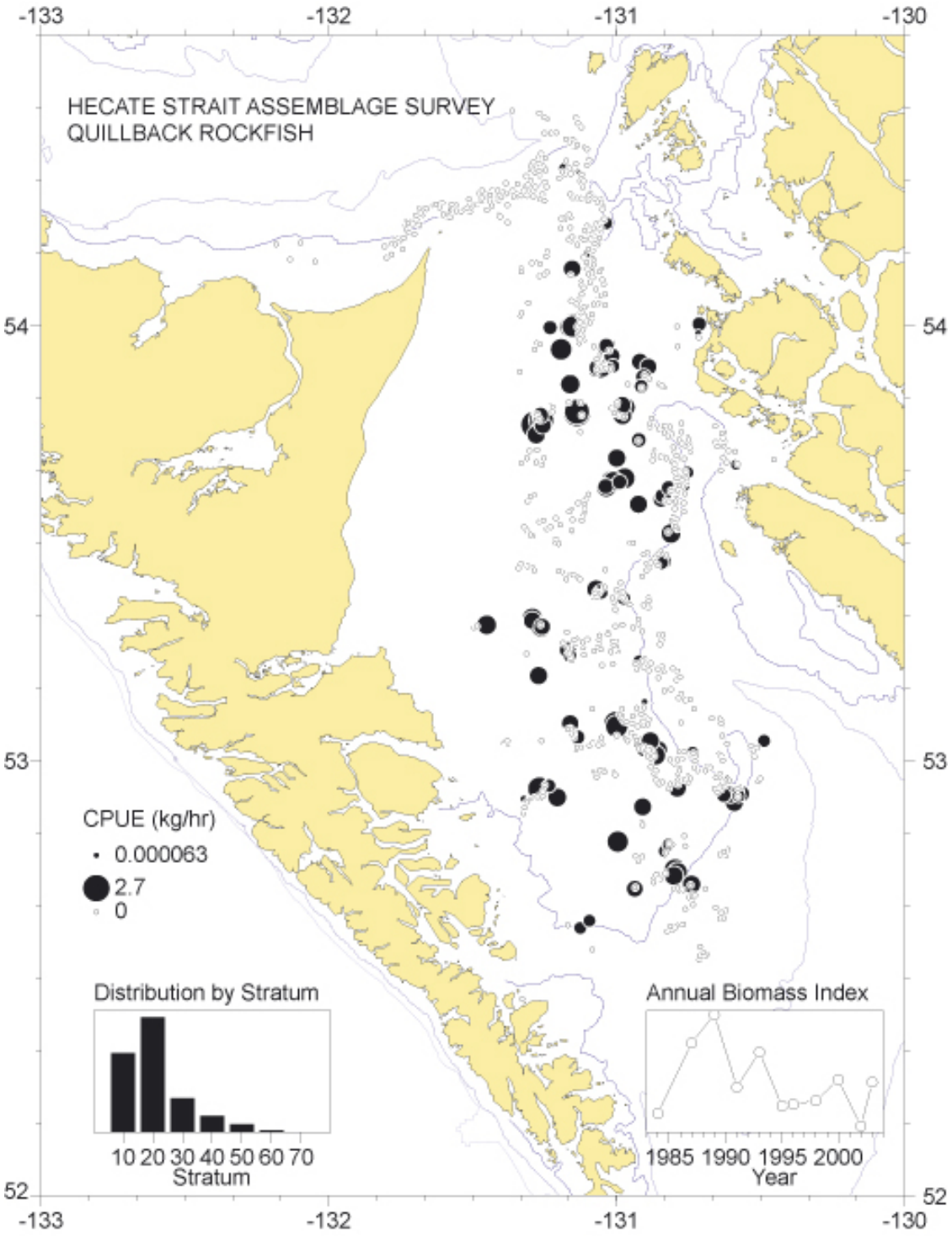


Figure 10. Hecate Strait assemblage survey 1984 – 2003 area showing the distribution and catch rates of Quillback Rockfish caught. Latitude and longitude are shown outside the chart.

Table 13. Quillback Rockfish biomass in tonnes by year from area swept trawl estimates from the Hecate Strait assemblage survey. Median biomass (t), 95% lower and upper confidence values are presented.

Year	Median	Lower CI	Upper CI
1984	43	14.19	114.68
1987	194	68.06	631.22
1989	258	72.40	718.35
1991	98	25.26	282.15
1993	184	43.12	715.53
1995	60	25.88	155.14
1996	64	29.05	125.84
1998	71	27.96	202.44
2000	124	44.12	301.25
2002	14	4.01	28.30
2003	116	40.92	315.01

Visual towed camera survey in the Strait of Georgia

A video survey was conducted in 2003, in a portion of the Strait of Georgia (Figure 11). A depth-stratified random design was employed where the survey area was divided into two depth strata of 10-50 m and 51-100 m and overlain with a 1 km^2 grid (Martin and Yamanaka 2004). Twenty-two blocks were randomly selected from each depth stratum. Transects within the block were targeted in areas of hard bottom and/or high slope.

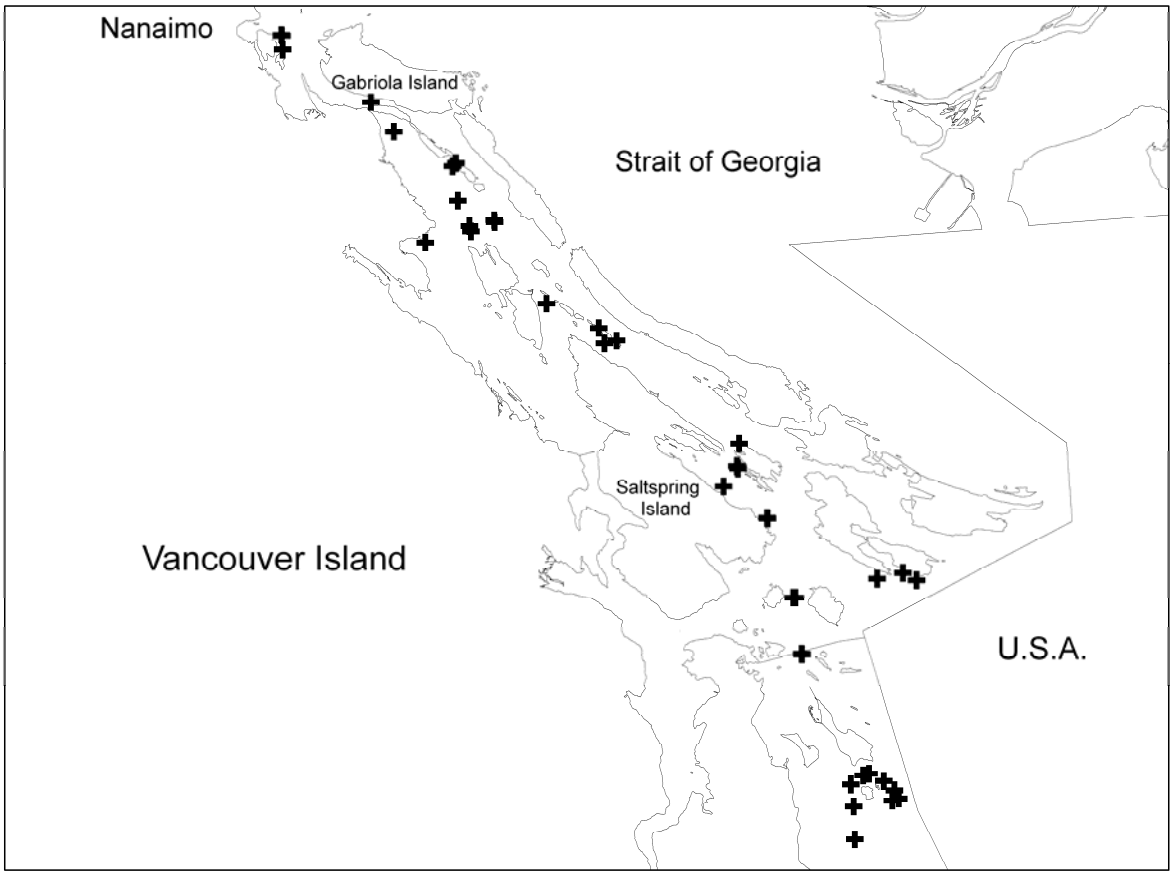


Figure 11. Locations of the towed camera transects in the Strait of Georgia in 2003.

Quillback Rockfish density over all 42 transects for combined habitat types was approximately 4226 individuals km^{-2}, though habitat-specific densities for bedrock and boulder were 12283 individuals km^{-2} and 7632 individuals km^{-2}, respectively. Summary statistics for these densities are shown in Table 14. Using the density estimate over all habitat types, Quillback Rockfish abundance is 2.23 million over the survey area (527 km^2).

Table 14. Quillback Rockfish densities estimated from visual fish counts using an ROV in the Strait of Georgia in 2003.

Density # per km²	Bedrock	Boulder	Cobble	Mixed Coarse	Sand	All Habitat Types
Mean	12,283	7,632	252	405	5,506	4,226
Std Error	6,239	2610	252	110	5,506	1,364
Median	0	0	0	146	0	0
Std Dev	24,163	14,059	758	594	18,264	8,521
Range	69,988	50,789	2275	2370	60,576	45,902
Minimum	0	0	0	3	0	0
Maximum	69,988	50,789	2,275	2,373	60,576	45,902
95% CI	13,381	5,348	582	226	12,270	2,762

Visual submersible survey in Juan Perez sound

A submersible survey was conducted in Juan Perez Sound on the east side of the Queen Charlotte Islands in May 2005 (Figure 12) (Yamanaka unpublished data). The area was divided into a survey grid of 2 km^2, each grid block was stratified by habitat type then randomly selected grid blocks were surveyed. Dive transects were conducted within the grid block, using the submersible Aquarius, to visually enumerate Quillback Rockfish. Line transect methods were used to estimate rockfish density and abundance (Buckland *et al.* 1993). Probability density functions (PDF) are constructed from fish observations and used in conjunction with estimates of line length to estimate the density of Quillback Rockfish populations (Thompson 1992).

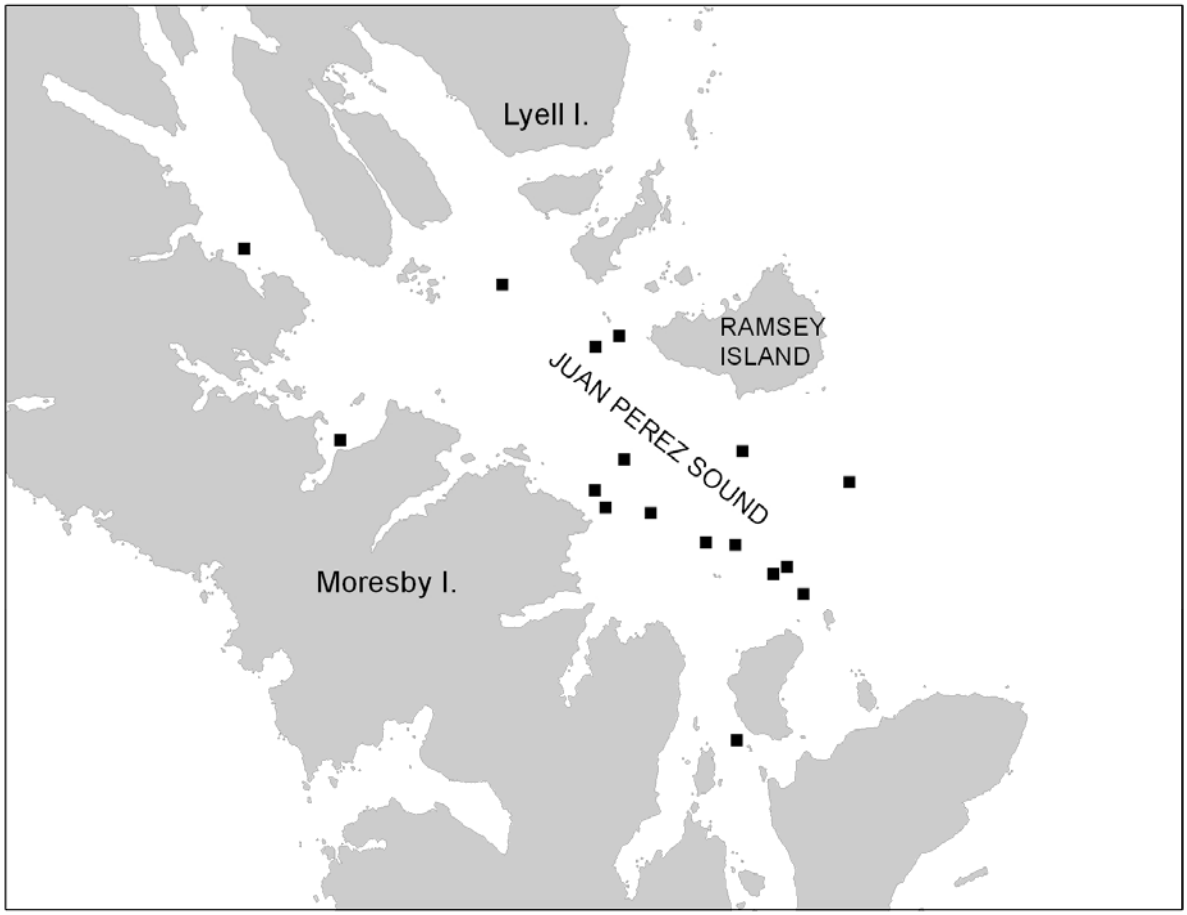


Figure 12. Locations of the 2005 submersible dives conducted in Juan Perez Sound, Queen Charlotte Islands.

Habitat was assessed using a bathymetric position index (BPI) derived from multibeam bathymetry and enhanced with a backscatter filter (Weiss 2001). Fine and coarse scale BPI values identified ridge tops and ridges and with the addition of the backscatter, soft bottom areas were filtered out of the analysis. Three habitats were identified, rock ridge tops, rock ridges and all other low slope habitat areas.

Submersible transects were overlain on the habitat maps and partitioned by habitat type. PDFs were constructed from the Quillback Rockfish observations by habitat type and densities estimated (Yamanaka and Grandin unpublished data). These densities were then expanded to an abundance estimate over each habitat area within Juan Perez Sound. By adding together the abundance estimates by habitat type, the total abundance of Quillback Rockfish for the survey area (217.63 km^2) in Juan Perez Sound is 2,078,160 fish (Yamanaka and Grandin unpublished data).

In summary, estimates of Quillback Rockfish abundance from the trawl surveys are very low in comparison to those from the visual surveys. This is due to the preferred habitat of these rockfish, which is complex, rocky reef habitats which are untrawlable. The trawl surveys were conducted over low relief, soft, trawlable habitats and the visual surveys were conducted over untrawlable habitats.

The abundance estimates from the visual surveys are from two small areas; one in the southern Strait of Georgia that has a long history of exploitation and the other in the Queen Charlotte Islands where there is relatively little fishing. At a minimum, there are 4.4 million individuals, 2.1 million in Juan Perez Sound and 2.3 million in the Strait of Georgia based on visual surveys.

Fluctuations and trends

Research surveys

IPHC SSA surveys

The International Pacific Halibut Commission (IPHC) conducts a Standardized Stock Assessment (SSA) longline survey annually to assess Pacific halibut stock abundance. In 1995 and annually since 2003, catch data for species other than halibut have been collected (Yamanaka *et al.* 2004, Lochead *et al.* 2006). The survey set locations differed in 1995 from those in 2003/04 (shown in the left panel of Figure 13). Only those sites common in all years were used to calculate a CPUE index (shown in the right panel of Figure 13).

This survey covered depths greater than those typically inhabited by Quillback Rockfish, and accordingly catches were low (Figure 14) and variability around mean abundance high (Figure 15). No trend in abundance was observed over the survey years (Figure 15).

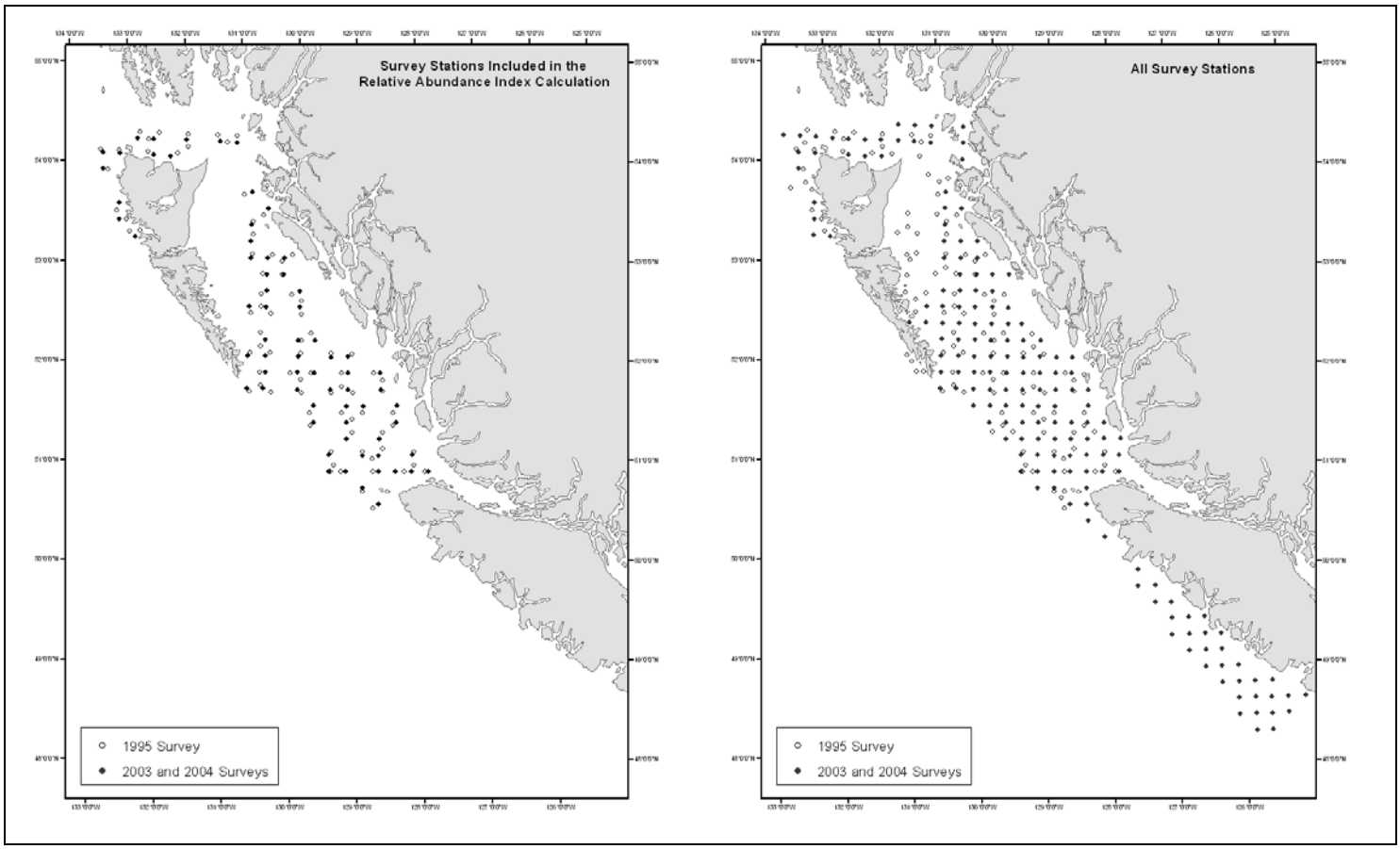


Figure 13. IPHC SSA survey locations for 1995, 2003 and 2004 surveys in BC (left panel). Open circles represent survey sites in 1995, filled circles represent survey sites in 2003 and 2004. Overlapping sites surveyed in all years that were included in the CPUE index (right panel).

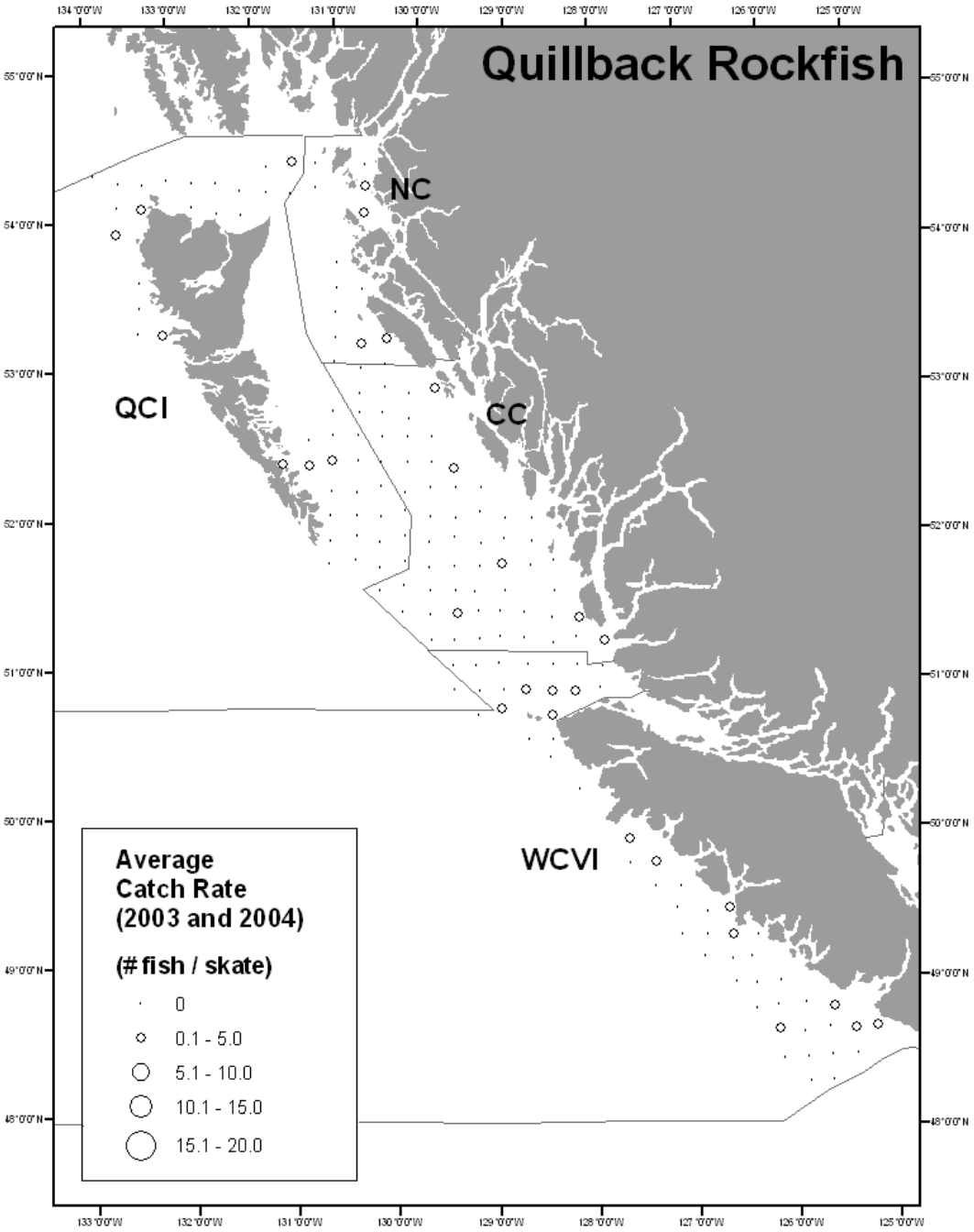


Figure 14. Spatial distribution of Quillback Rockfish catch rates from the IPHC SSA survey in BC for the years 2003 and 2004 combined.

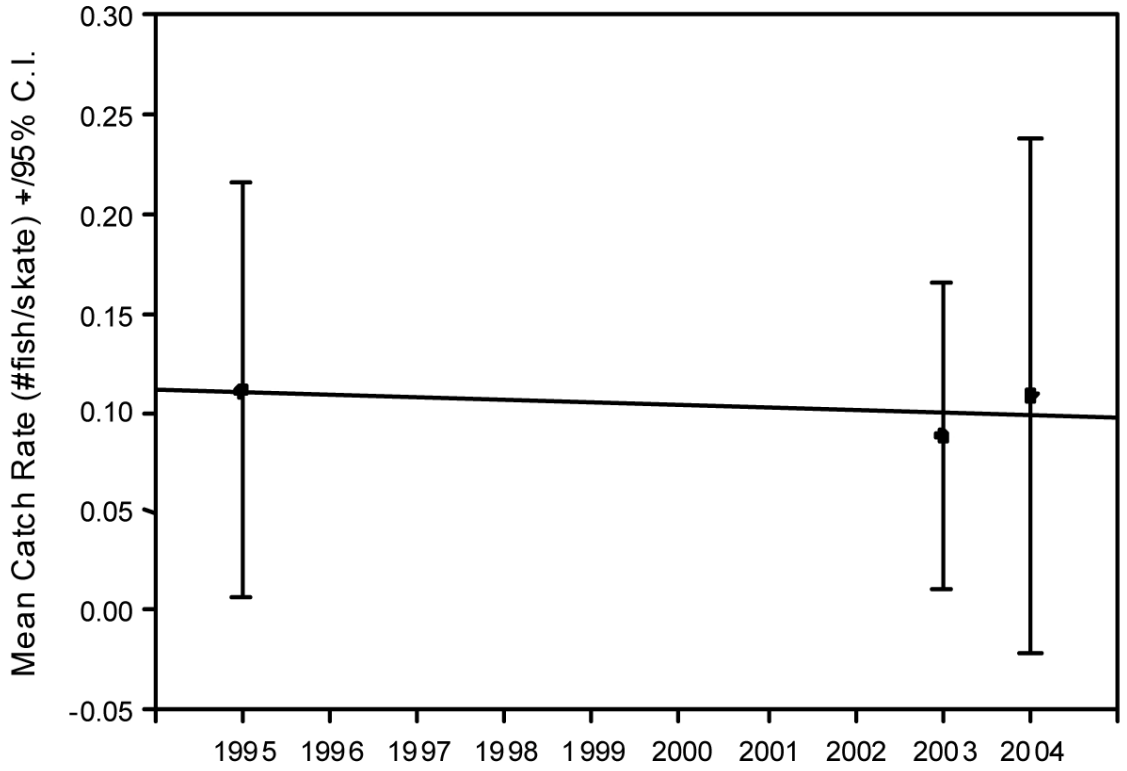


Figure 15. Quillback Rockfish mean catch rates and 95% confidence intervals (CI) by year for the IPHC SSA survey. Slope of regression line is not significantly different from zero (r^2 = 0.0001, F = 0.03, df = 1,213, p = 0.86).

Table 15. Summary statistics for the quillback catch rate in numbers of fish per skate of fishing gear for the IPHC SSA survey by year in BC.

Catch Rate (#fish/skate)	1995	2003	2004
Mean	0.11	0.09	0.11
Standard Error	0.05	0.04	0.06
1st Quartile	0	0	0
Median	0	0	0
3rd Quartile	0	0	0
Mode	0	0	0
Standard Deviation	0.48	0.32	0.53
Sample Variance	0.23	0.10	0.28
Minimum	0	0	0
Maximum	2.80	1.50	3.75
Total Number of Sets	81	67	67
Confidence Interval (95.0%)	0.11	0.08	0.13

Research Charter Survey for yelloweye rockfish

Research charters conducted to index yelloweye rockfish in 1997/8 and 2002/03 also intercepted Quillback Rockfish (Kronlund and Yamanaka 2001, Yamanaka *et al.* 2004). The first surveys were conducted in September 1997 and May 1998 in four study areas; two on the west side of the Queen Charlotte Islands and two on the upper west coast of Vancouver Island (Figure 16). These were followed five years later by surveys conducted in September 2002 and May 2003. CPUE indices for Quillback Rockfish are shown in Figure 17 and Table 16. The CPUE index is highly variable but there is a significant negative trend in catch rate over the survey series from 1997 - 2003.

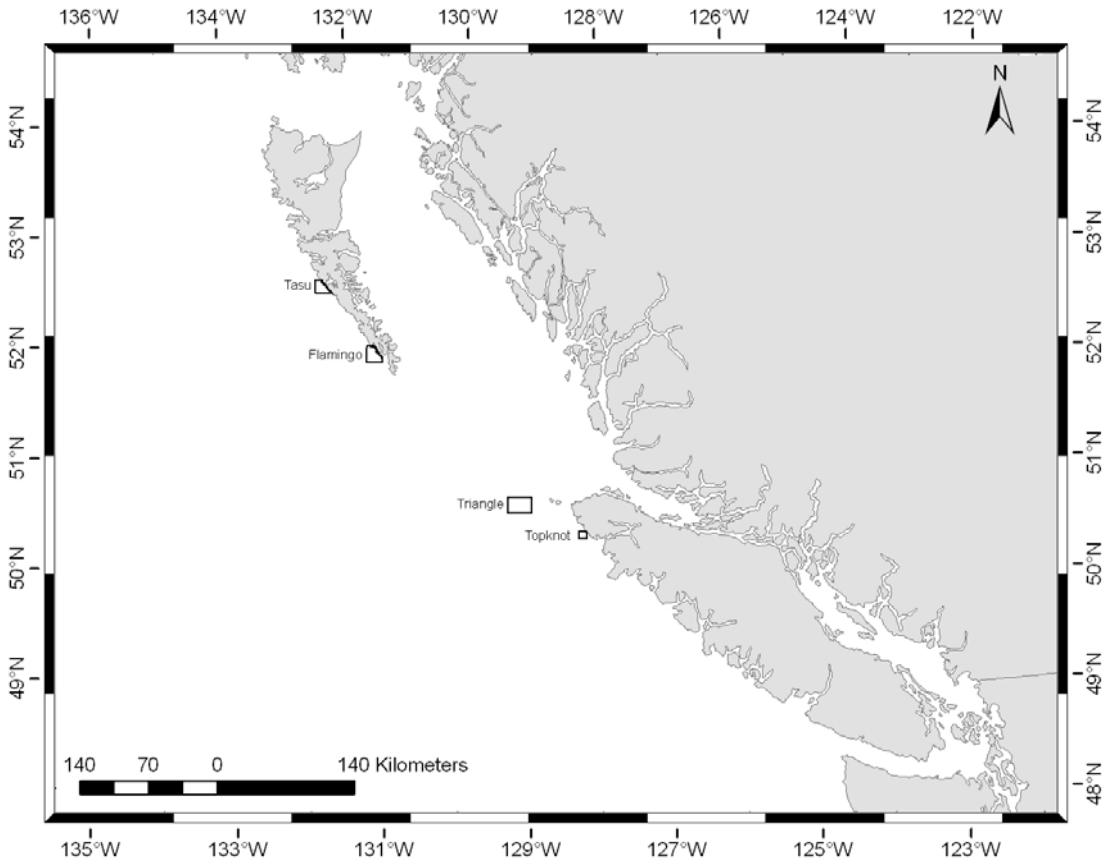


Figure 16. Four study sites surveyed for yelloweye rockfish by chartered fishing vessels in 1997/98 and 2002/03. Paired sites, lightly and heavily fished, off the Queen Charlotte Islands (Tasu and Flamingo) and the North West of Vancouver Island (Triangle and Topknot).

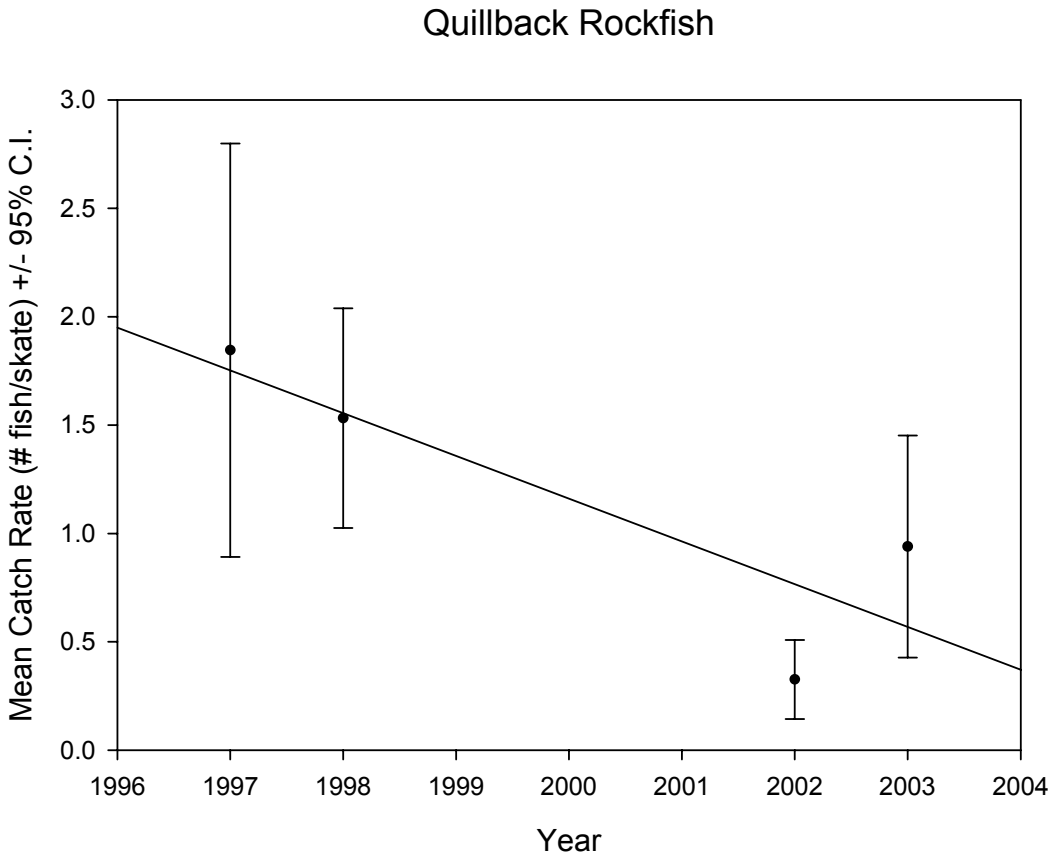


Figure 17. Quillback Rockfish mean catch rates and 95% confidence intervals from the charter vessel surveys in the outside area. Slope of the trend line is significantly different from zero (r^2 = 0.075, F = 13.37, df = 1,165, p = 0.003 *).

Table 16. Summary statistics for the quillback catch per unit effort for the research charters.

Quillback Rockfish	Fall 1997	Spring 1998	Fall 2002	Spring 2003
Mean	1.85	1.53	0.33	0.94
Standard Error	0.4670	0.2518	0.0906	0.2537
1st Quartile	0	0	0	0
Median	0.80	0.80	0.00	0.20
3rd Quartile	2.60	2.50	0.40	0.70
Mode	0	0	0	0
Standard Deviation	2.6004	1.7262	0.6144	1.6639
Sample Variance	6.7619	2.9796	0.3775	2.7686
Minimum	0	0	0	0
Maximum	9.40	6.00	2.60	6.60
Total Number of Sets	31	47	46	43
Confidence Interval (95.0%)	0.9538	0.5068	0.1825	0.5121

Hecate Strait assemblage trawl survey (see Abundance section)

The CPUE index for Quillback Rockfish derived from the Hecate Strait assemblage trawl survey is shown in Figure 18. Two and three stage averages of the CPUE series show a declining trend through the series from the mid-1980s to the mid-2000s (Figure 19).

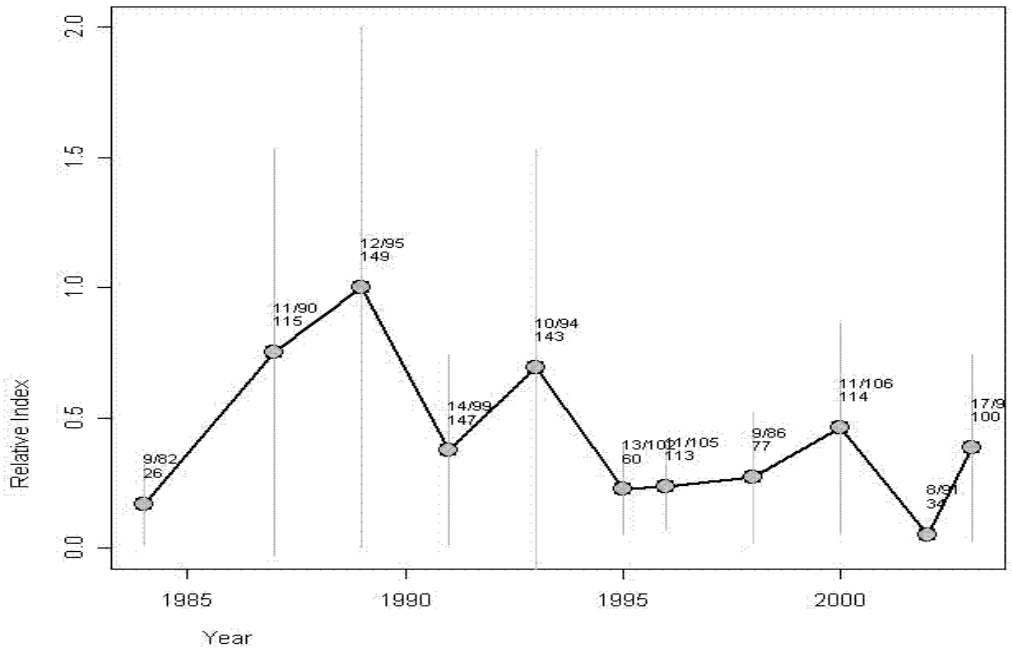


Figure 18. Relative indices (median bootstrapped) for Quillback Rockfish from the Hecate Strait multi-species assemblage survey. The bootstrapped 95% confidence limits are shown as vertical lines. The numbers above each point indicate the number of sets in which Quillback Rockfish were caught and the total number of sets in the survey (top numbers), and the total catch weight (kg) of Quillback Rockfish (bottom number).

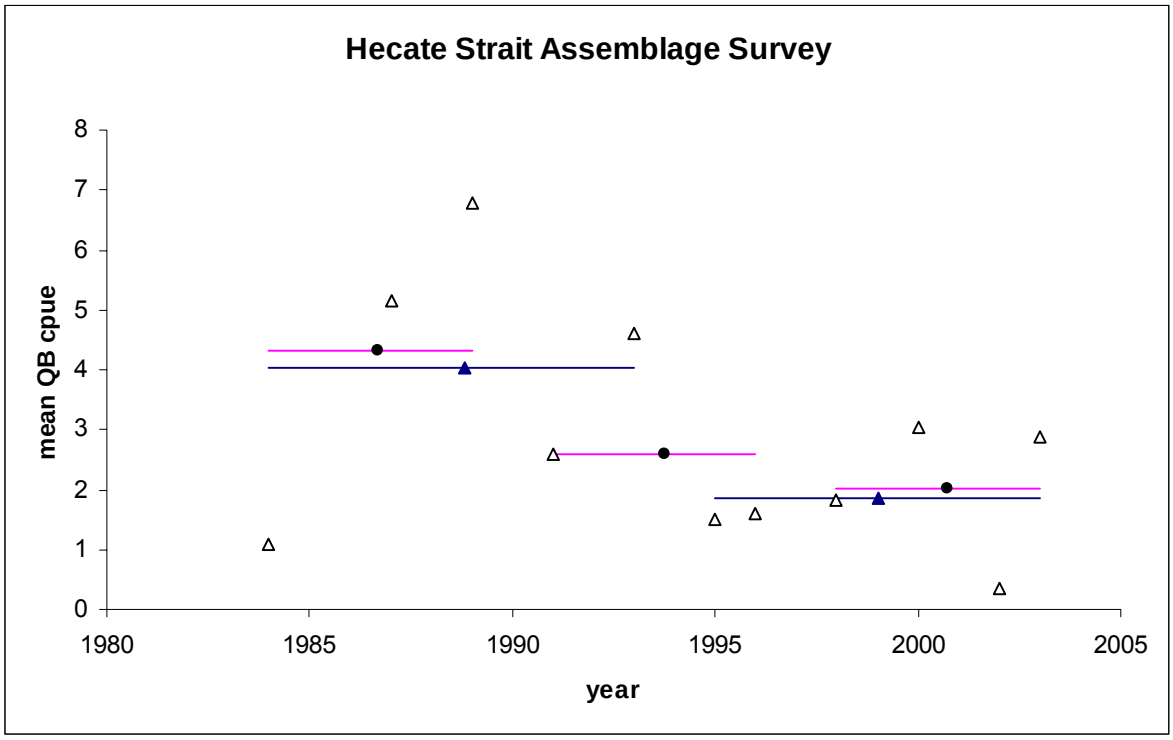


Figure 19. Relative indices for Quillback Rockfish from the Hecate Strait multi-species assemblage survey CPUE series (from Figure 18) averaged in two and three stages.

Longline survey Strait of Georgia

Longline surveys were initiated in the Strait of Georgia to develop a fishery independent abundance index and provide biological data for the assessment of population parameters for this area (Lochead and Yamanaka 2004, 2006, 2007). This survey was conducted in 2003 and 2004 in DFO statistical areas (SA) 12 and 13 and in SA 14 through 20, 28 and 29 in 2005 (Figure 20). No differences in CPUE from the two surveys in areas 12 and 13 are detected (Lochead and Yamanaka 2006). However, the CPUE is significantly lower for Quillback Rockfish in the southern portion (surveyed in 2005) when compared with the northern portion (surveyed in 2004) of the Strait of Georgia (Figure 21 and Table 17).

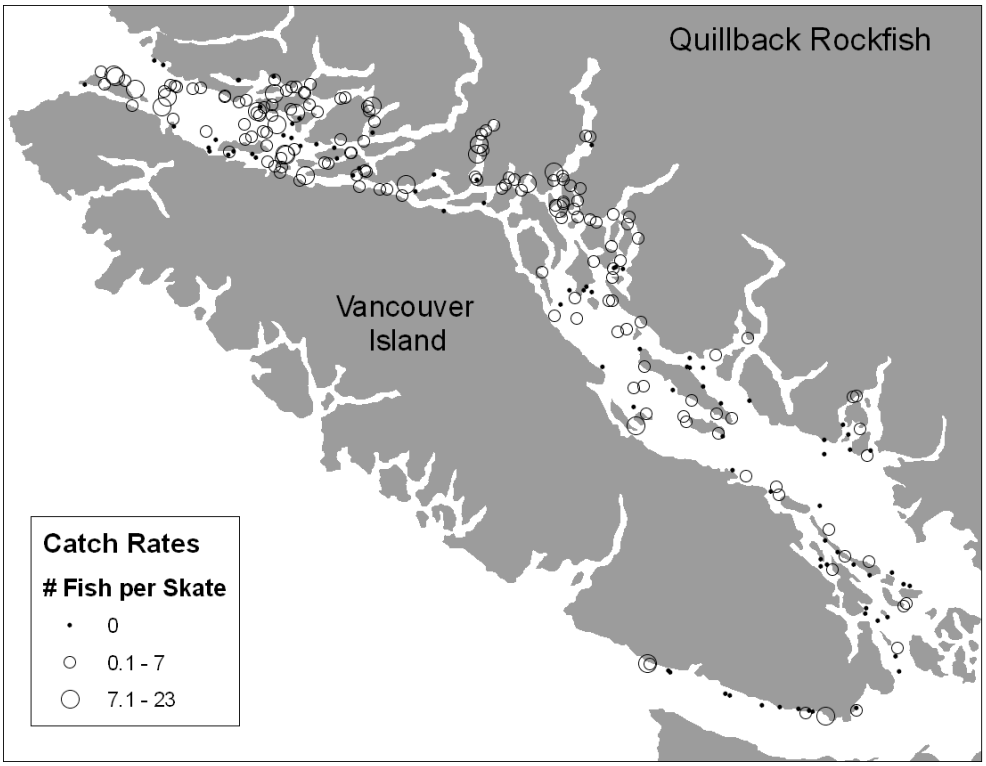


Figure 20. Longline survey catch rates (Quillback Rockfish per skate of gear) by fishing set locations. Survey was conducted in the northern portion in 2003 and 2004 and in the southern portion in 2005.

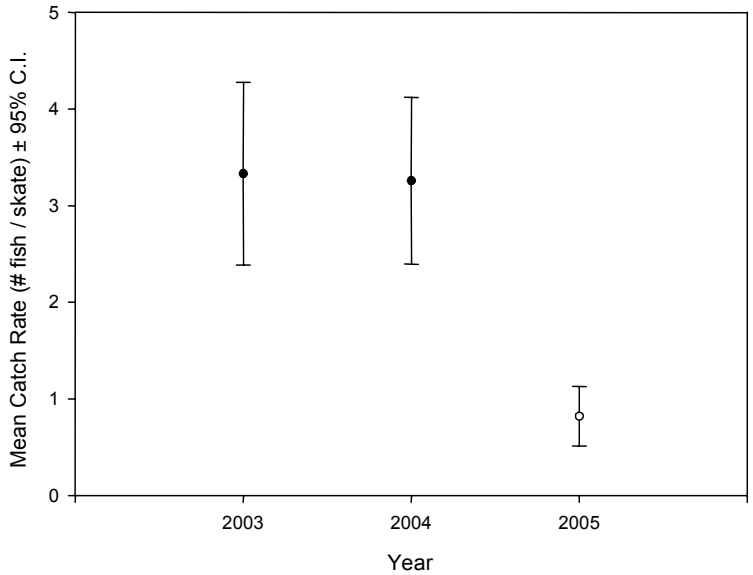


Figure 21. Longline survey CPUE by year in the Strait of Georgia. The survey was conducted in the north (SA 12 and 13) in 2003 and 2004 and in the south (SA 14 through 20, 28 and 29) in 2005, which could influence relative catch rates.

Table 17. Summary statistics for the Quillback Rockfish catch rate in the longline survey in the Strait of Georgia by year. The survey was conducted in the northern portion of the Strait of Georgia in 2003 and 2004 and in the southern portion in 2005.

Quillback Rockfish	2003	2004	2005
Mean	3.33	3.26	0.82
Standard Error	0.4751	0.4320	0.1552
1st Quartile	0	0.50	0
Median	1.75	2.00	0
3rd Quartile	4.50	5.00	1.00
Mode	0	0	0
Standard Deviation	4.2493	3.4561	1.4641
Sample Variance	18.0566	11.9444	2.1434
Minimum	0	0	0
Maximum	23	13.5	9
Total Number of Sets	80	64	89
Confidence Interval (95.0%)	0.9456	0.8633	0.3084
Difference among years: Kruskal-Wallis test, H = 35.3324, p <0.0001**, df = 2			

Submersible survey in Strait of Georgia

Submersible surveys were conducted in 1984 and 2003 to index abundance of inshore rockfish in the Desolation Sound and Sechelt areas of the Strait of Georgia (Figure 22 and Table 18) (Richards and Cass 1985, Yamanaka *et al.* 2004). A comparison of the numbers of fish observed per transect between the three common sites and depths surveyed between 1984 and 2003 are shown in Figure 23. A significant decline ($p<0.001$) in Quillback Rockfish counts per transect were found between the two surveys.

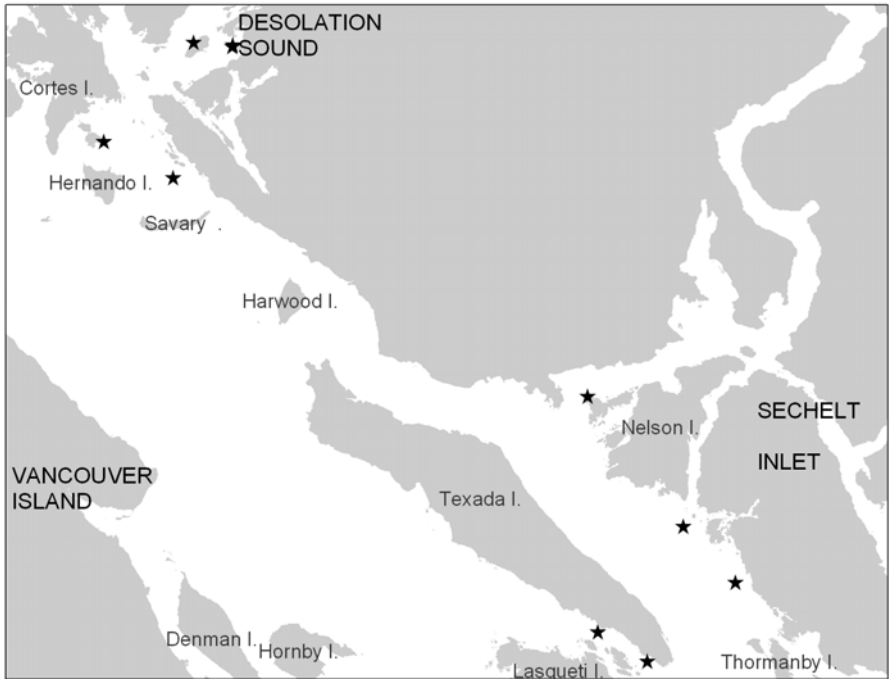


Figure 22. Location of submersible survey dives conducted in 1984 and 2003 in the Strait of Georgia.

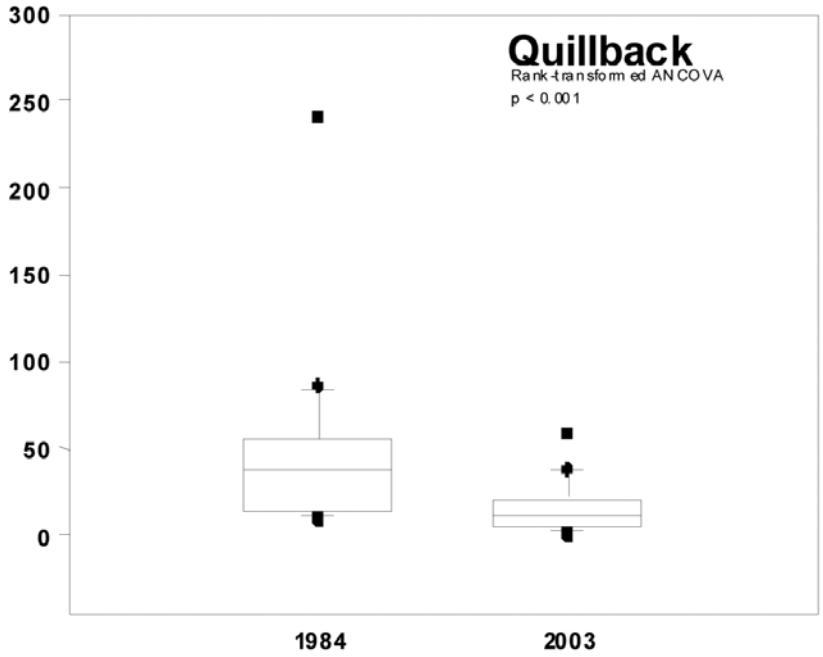


Figure 23. Visual counts of Quillback Rockfish per transect during submersible survey dives conducted in 1984 and 2003 in the Strait of Georgia (Yamanaka *et al.* 2004).

Table 18. Summary statistics for Quillback Rockfish counts per transect during the 1984 and 2003 submersible surveys (Yamanaka *et al.* 2004).

Counts per transect	Quillback	
	1984	**2003**
Mean	47.4	16.7
Standard Error	10.79	3.36
Median	38	11.5
Standard Deviation	49.44	15.01
Sample Variance	2443.95	225.19
Range	232	59
Minimum	9	0
Maximum	241	59
Confidence Level (95.0%)	22.50	7.02

Jig surveys

Johnstone Strait

Jig fishing surveys were conducted in 1986, 1987, 1988, 1992 and 2004 at 10 study sites in the Johnstone Strait area of the Strait of Georgia (Figure 24) (Hand and Richards 1989, Yamanaka and Richards 1993, Yamanaka unpublished data). Quillback Rockfish are targeted in these surveys. CPUE data from these surveys are used to index abundance of Quillback Rockfish and are shown in Figure 25 and Table 19.

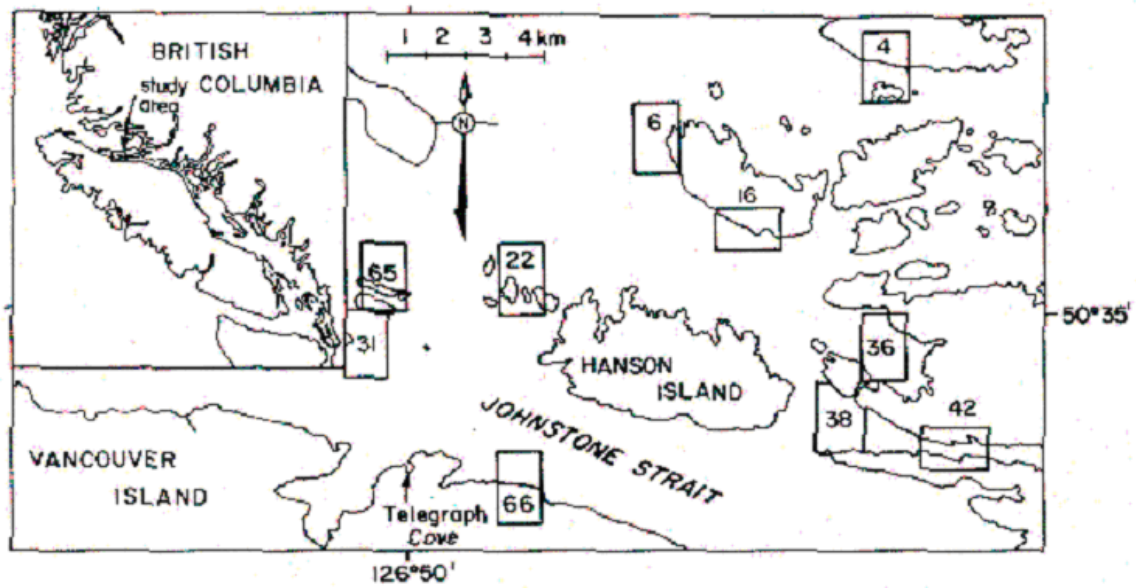


Figure 24. Jig survey sites in Johnstone Strait from Yamanaka and Richards (1993).

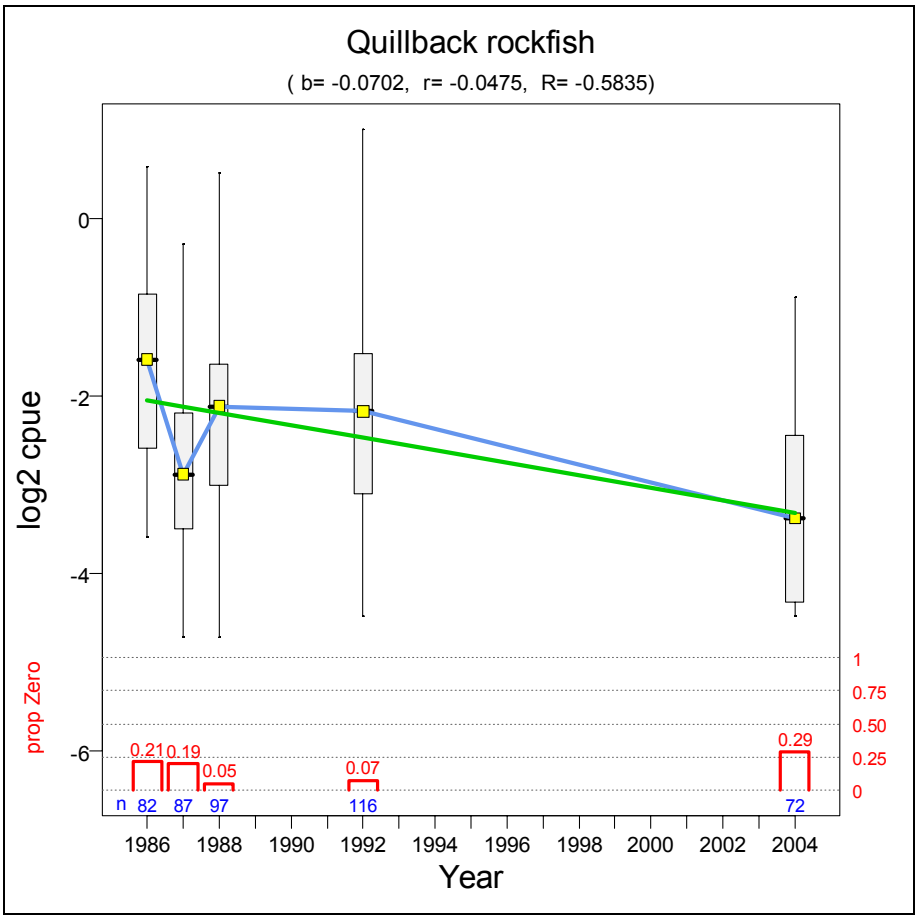


Figure 25. Johnstone Strait jig survey Quillback Rockfish median $\log_{(2)}$CPUE (number of non-zero Quillback Rockfish per minute fished) and 95% confidence intervals over all sites and depths by year. Slope of the regression line (b), annual rate of change (r) and series rate of change (R) are shown above the graph. The proportion of zero records is shown below the boxplots in red along with the total number of non-zero fishing sets (n) in blue.

Table 19. Quillback Rockfish CPUE (number of Quillback Rockfish per minute fished) summary statistics over all depths from the jig surveys conducted at study sites in Johnstone Strait.

Quillback Rockfish	1986	1987	1988	1992	2004
Mean	0.316	0.139	0.245	0.262	0.088
1st Quartile	0.091	0.042	0.120	0.100	0.000
Median	0.200	0.119	0.217	0.200	0.051
3rd Quartile	0.500	0.208	0.320	0.350	0.140
Minimum	0.000	0.000	0.000	0.000	0.000
Maximum	1.500	0.818	1.429	2.000	0.543
Total Number of Sets	106	108	102	125	101

Quillback Rockfish CPUE in the early surveys 1986-88 are highly variable and as the time series progresses, a significant declining trend is evident. The decline rate over the series from 1986 to 2004 is 58%. The decline in catch rate over time is likely not linear over the 18-year period given the reduction in catch quota between 1991 and 2004 and in particular since 2002 when quotas were reduced by 75% from the previous year.

Strait of Georgia

Jig fishing surveys targeted to index the abundance of lingcod were conducted in the southern Strait of Georgia in Statistical Areas 18 and 19 (Figure 26). Jig fishing was conducted at two depth intervals, a shallow 1-25 m and a deep 25-50 m in survey sites in 1993 and again in 2005. Surveys were examined for Quillback Rockfish catch rates (Figure 27 and Table 20) (Yamanaka and Murie 1995, Haggarty and King 2005). There were significant declines in CPUE between 1993 and 2005 (Kruskal-Wallis $p=0.003$ shallow and $p<0.001$ deep Haggerty and King 2005).

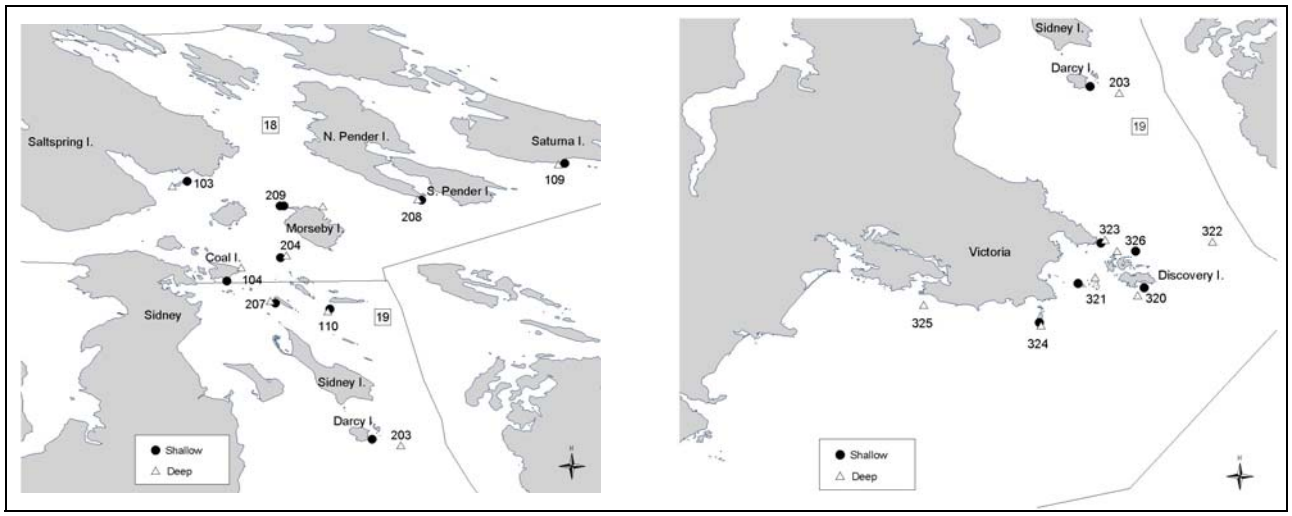


Figure 26. Lingcod jig fishing survey locations in the southern Strait of Georgia statistical areas 18 and 19 from Haggarty and King (2005).

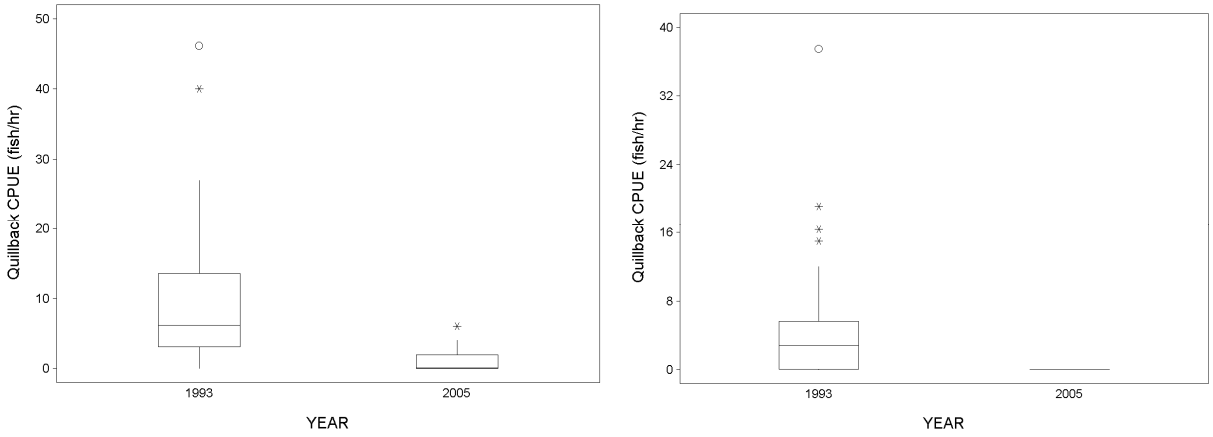


Figure 27. Quillback Rockfish catch rates in the lingcod jig surveys in the southern Strait of Georgia by year. CPUE in the shallow 1-25 m (left panel) and deep 25-50 m (right panel) depth intervals are shown by year from Haggarty and King (2005).

Table 20. Quillback Rockfish descriptive statistics for catch rate during the lingcod jig surveys (Yamanaka and Murie 1995, Haggarty and King 2005).

quillback CPUE	1993	2005	1993	2005
	Shallow depths		Deep depths	
N	52	16	52	18
LO 95% CI	2.4629	0.0	6.9844	0.1943
MEAN	4.335	0.0	9.645	1.1111
UP 95% CI	6.2071	0.0	12.306	2.0279
SD	6.7245	0.0	9.5566	1.8436
C.V.	155.12		99.083	165.92
MINIMUM	0	0.0	0	0
MEDIAN	2.795	0.0	6.16	0
MAXIMUM	37.5	0.0	46.15	6

Summary of survey abundance indices

A declining trend in abundance is noted for Quillback Rockfish in all surveys that reliably index the population (Table 21). Surveys with relatively high reliability are designed specifically to index shallow water reef species such as Quillback Rockfish. The Strait of Georgia jig and longline survey are directed for shallow water reef species but in the former the 2005 survey had a very low sampling rate, and in the latter, the time series is just starting, different areas were surveyed at the beginning and end of the time series, and reliability of this survey will improve over time with more observations. The IPHC longline survey, the only survey not to show a declining trend, samples areas deeper than those typical of Quillback Rockfish and as a result had few catches and high variability.

Given the long history of fishing for this species and its conservative life history characteristics, declines in abundance probably occurred prior to the period for which survey data are available. The observed declines occurred over less than one generation (about 25 years).

Table 21. Summary of surveys used to index the abundance of Quillback Rockfish in BC. Surveys are listed by gear, with information on the time period of the survey, the abundance index trend, comments on the relative reliability of the survey to index Quillback Rockfish, some comments on the assessment of reliability.

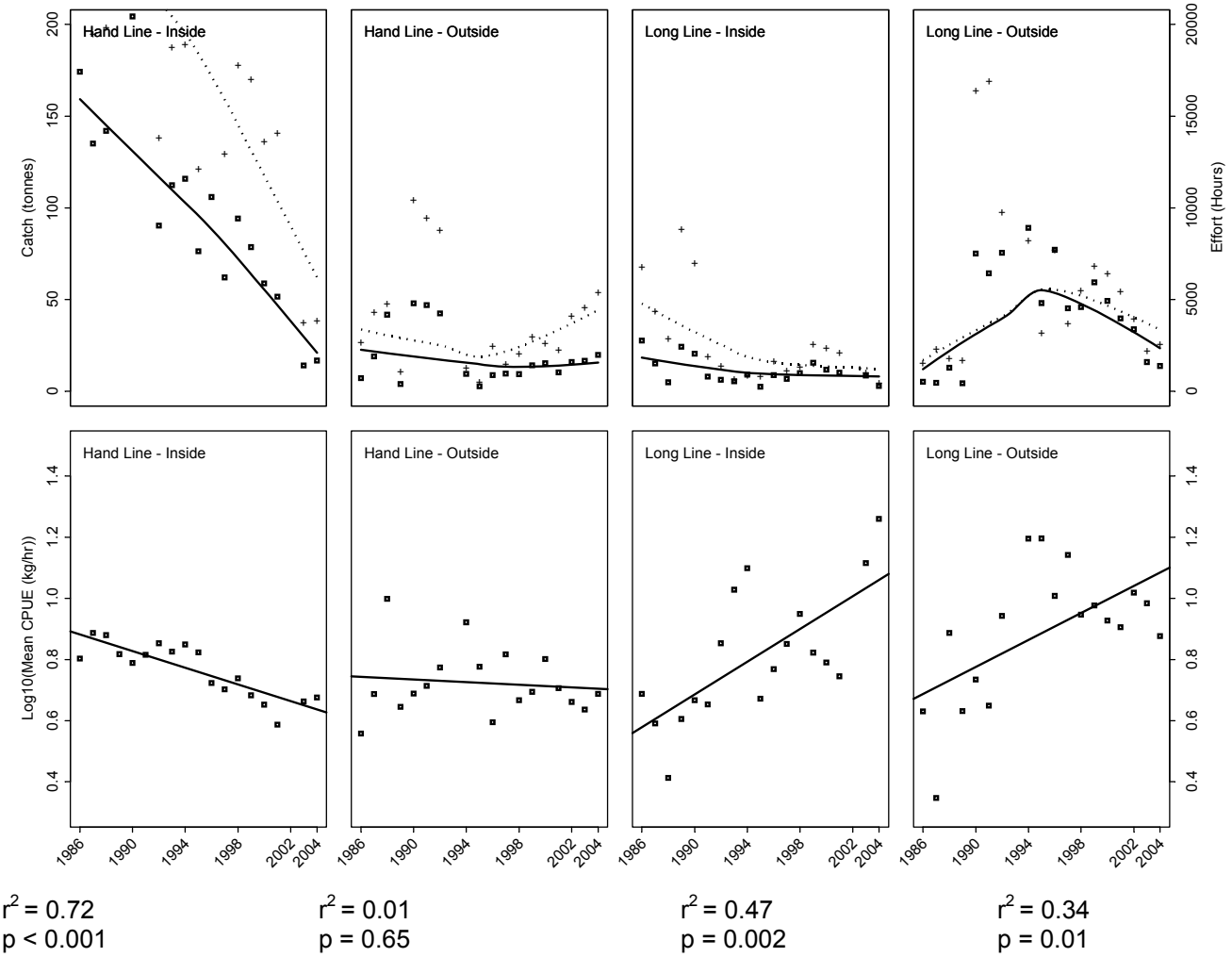
Survey	Gear	Time Period	Trend	Reliability	Comments
Johnstone Strait jig survey (F.27)	rod and reel	1986-88 1992, 2004	-58% over the time period	High	Directed survey, longest time series
Southern Strait of Georgia lingcod jig survey (F.29)	rod and reel	1993, 2005	Significantly lower in 2005	High	Appropriate sampling gear but low sample size in 2005
Strait of Georgia submersible survey (F.25)	3 person submersible	1984, 2003	Significantly lower in 2003	Medium	Directed survey, 20-year time difference, but low spatial coverage
IPHC SSA halibut survey (F. 17)	longline	1995, 2003, 2004	No trend	Low	Targets depths greater than those inhabited by Quillback Rockfish, generally low catches of Quillback, high variability
Research commercial charter survey (F.19)	longline	1997, 1998, 2002, 2003	Significant decline to 25% of original	Medium	Targets depths greater than those preferred by Quillback Rockfish
Strait of Georgia longline survey (F.23)	longline	2003, 2004, 2005	2005 lower than 2003, 2004	Low	Short time series, different area surveyed in 2005
Hecate Strait assemblage trawl survey (F. 20, 21)	trawl	1984 - 2003	Decline to 50% of original	Medium	Trawls do not sample high-relief hard-bottom habitats of Quillback Rockfish well

Coastwide commercial catch data

Commercial catch and effort

Population trends for Quillback Rockfish can be constructed from the commercial hook and line rockfish fishery catch and effort data recorded on logbooks. This is the longest time series of catch per unit of effort (CPUE) data available. Catch per unit effort data from the commercial hook and line rockfish fishery are shown in Figure 28 by gear type and area (Tables 22 and 23).

CPUE trends significantly declined in the inside handline fishery and significantly increased in the inside and outside longline fisheries (Figure 28).



$r^2 = 0.72$ $p < 0.001$ | $r^2 = 0.01$ $p = 0.65$ | $r^2 = 0.47$ $p = 0.002$ | $r^2 = 0.34$ $p = 0.01$

Figure 28. Commercial catch data by gear type (handline and longline) and area (inside and outside) for Quillback Rockfish in the commercial hook and line rockfish fishery. Upper panels display catch (square) and effort (plus). Solid line is a local regression fit of catch, dotted line is a local regression fit of effort. Lower panels display mean log(10) catch per unit of effort (kg/hr) fit with a regression line and regression statistics.

Table 22. Summary statistics for Quillback Rockfish commercial catch per unit of effort (kg/hr) for the hook and line rockfish fishery by year, handline gear and area.

	Handline - Inside					Handline - Outside				
Year	Mean	Variance	S. Dev	S. E.	n	Mean	Variance	S. Dev	S. E.	n
1985						9.8063	0.4200	0.6480	0.4582	2
1986	6.3581	23.6953	4.8678	0.0725	4509	3.6146	39.7711	6.3064	0.3611	305
1987	7.7069	34.1302	5.8421	0.1027	3237	4.8585	50.2079	7.0858	0.3072	532
1988	7.5728	38.6238	6.2148	0.1103	3176	9.9554	83.1775	9.1202	0.3622	634
1989	6.5722	29.2050	5.4042	0.0726	5543	4.4164	14.1469	3.7612	0.3156	142
1990	6.1390	22.7216	4.7667	0.0649	5391	4.8780	24.2724	4.9267	0.1310	1414
1991	6.5383	34.0810	5.8379	0.0809	5209	5.1668	22.5342	4.7470	0.1444	1080
1992	7.1303	21.6975	4.6581	0.1033	2035	5.9461	242.6031	15.5757	0.4953	989
1993	6.6898	23.1588	4.8124	0.0929	2684					
1994	7.0686	40.7713	6.3852	0.1165	3002	8.3516	65.3581	8.0844	0.6129	174
1995	6.6550	40.9684	6.4007	0.1452	1942	5.9801	42.1245	6.4903	0.8243	62
1996	5.2838	15.2828	3.9093	0.0690	3209	3.9340	23.5502	4.8529	0.2811	298
1997	5.0374	14.1832	3.7661	0.0844	1993	6.5556	43.8892	6.6249	0.4858	186
1998	5.4712	13.4814	3.6717	0.0704	2717	4.6432	18.7059	4.3250	0.2769	244
1999	4.8126	9.5253	3.0863	0.0610	2562	4.9433	17.8593	4.2260	0.2067	418
2000	4.4862	8.9118	2.9853	0.0669	1990	6.3353	45.1306	6.7179	0.3693	331
2001	3.8629	15.9133	3.9892	0.0936	1817	5.0791	29.0926	5.3938	0.3223	280
2002	0.6269	0.3607	0.6006	0.4247	2	4.5774	23.9150	4.8903	0.2305	450
2003	4.6007	33.4006	5.7793	0.2942	386	4.3283	18.5192	4.3034	0.2013	457
2004	4.7374	15.0669	3.8816	0.1905	415	4.8662	199.1104	14.1106	0.6011	551

Table 23. Summary statistics for Quillback Rockfish commercial catch per unit of effort (kg/hr) for the hook and line rockfish fishery by year, longline gear and area.

	Longline - Inside					Longline - Outside				
Year	Mean	Variance	S. Dev	S. E.	n	Mean	Variance	S. Dev	S. E.	n
1986	4.8718	26.0052	5.0995	0.1724	875	4.2719	34.5125	5.8747	0.4229	193
1987	3.8956	17.3330	4.1633	0.1912	474	2.2249	9.2915	3.0482	0.2006	231
1988	2.5846	10.5709	3.2513	0.1826	317	7.7020	76.9589	8.7726	0.6172	202
1989	4.0310	26.0455	5.1035	0.1522	1124	4.2753	41.2566	6.4231	0.5722	126
1990	4.6374	39.5874	6.2918	0.2107	892	5.4276	138.6012	11.7729	0.2776	1798
1991	4.4939	22.9837	4.7941	0.2672	322	4.4537	40.1570	6.3370	0.1439	1939
1992	7.1246	34.1243	5.8416	0.3665	254	8.7660	88.4052	9.4024	0.2752	1167
1993	10.6731	24.3613	4.9357	0.3866	163	7.7096	155.5834	12.4733	4.1578	9
1994	12.5491	206.1673	14.3585	1.3162	119	15.6751	434.8277	20.8525	0.6737	958
1995	4.6956	21.0439	4.5874	0.4354	111	15.6981	736.9396	27.1466	1.3694	393
1996	5.8666	36.6797	6.0564	0.4189	209	10.1903	304.2370	17.4424	0.5347	1064
1997	7.0833	70.6716	8.4066	0.7402	129	13.8527	212.8290	14.5887	0.6165	560
1998	8.8940	68.9333	8.3026	0.7397	126	8.8491	106.5161	10.3207	0.3789	742
1999	6.6462	26.2261	5.1211	0.3152	264	9.4720	136.7659	11.6947	0.3947	878
2000	6.1639	40.8501	6.3914	0.4083	245	8.4528	104.6934	10.2320	0.3467	871
2001	5.5554	42.8077	6.5428	0.4163	247	8.0398	98.6593	9.9327	0.3425	841
2002	14.8065	74.2901	8.6192	3.2577	7	10.4408	167.0138	12.9234	0.4857	708
2003	13.0479	273.7452	16.5452	1.4567	129	9.6417	169.1798	13.0069	0.7305	317
2004	18.1832	371.8910	19.2845	2.3919	65	7.5291	765.3958	27.6658	1.4268	376

There are many problems with interpreting abundance trends derived from fishery CPUE data. The most significant of these, for Quillback Rockfish, are the lack of independent catch data to verify log book recorded catch and effort data and the influence of management actions applied to the fishery. Changes in management of the fishery alters fisher behaviour which influences catch and effort data. Many significant management changes have occurred over the CPUE time series. In 1991, prior to limited entry, DFO announced its intention to limit the number of licences in the hook and line rockfish fishery. Particularly high CPUE, prior to 1991, may be due to an increased effort to record landings and become eligible for a licence. Landings may also have been inflated or incorrectly identified to species during this period as no dockside verification was in place. The implementation of a limited entry fishery for the inside in 1992 and the outside in 1993 reduced the number of licences (74 and 183 respectively) in both fisheries from over 2400 coastwide. Fishing effort decreased substantially. Prior to 1995 and the implementation of the 100% dockside monitoring program, landed weights by species could not be independantly verified on logbooks.

TACs for Quillback Rockfish have steadily declined from 1991 to 2005 (670 t to 160 t) (Table 9). As with other fishery dependent catch indices, CPUE is affected by the catch, lowering TACs will lower CPUEs. Fishermen state that decreasing TACs result in lowered CPUE as fishing becomes more non-directed and Quillback Rockfish is avoided. Between 2001 and 2002, TACs were dramatically reduced, as part of the Rockfish Conservation Strategy, by 50% in the outside area and 75% in the inside area. For the inside area, this fishery is also purposely drawn out to ensure a small amount of fish is constantly supplied to a year-round live market. This practice allows prices to remain high and live markets to maintain a consistant product. CPUE indices from this commercial catch data are likely uninformative, reflecting changes in management or marketing, rather than population trends.

Commercial groundfish trawl fishery (T)

Catch per unit effort time series can also be constructed from the commercial groundfish trawl fishery using at-sea observer recorded catch (Figure 29). Quillback Rockfish caught in the trawl fishery is not a significant portion of the overall catch. As with the hook and line fishery, catch rates are influenced by management measures, primarily declining TACs. Hence, declining trends in CPUE indices over a period of declining TACs is difficult to interpret and may not reflect declines in actual abundance but avoidance of species by fishers.

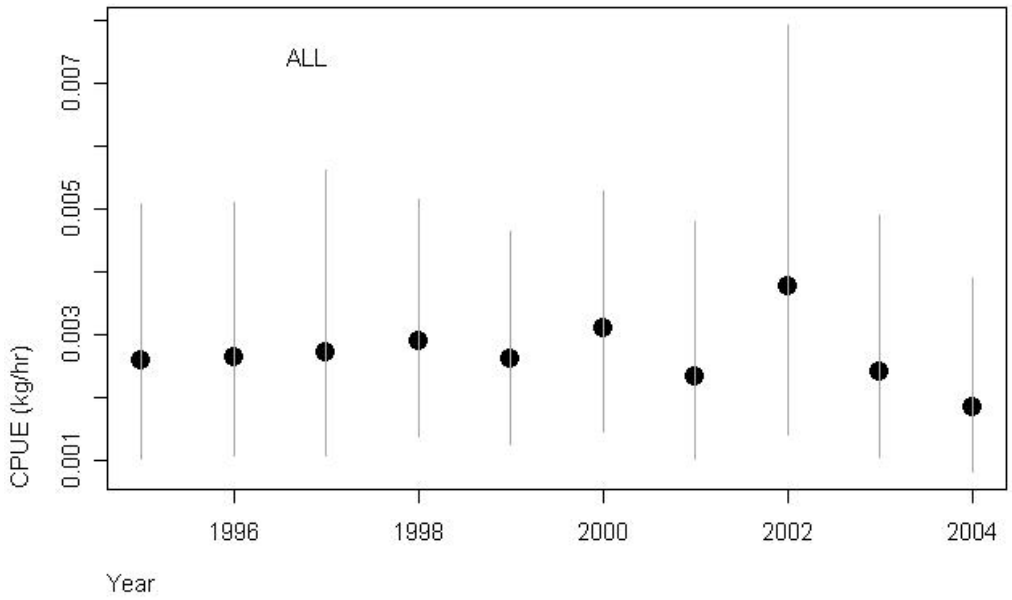


Figure 29. Commercial trawl observer recorded Quillback Rockfish CPUE (kg/hr) by year.

Trends in biological characteristics

Quillback Rockfish mean fork lengths and mean ages from commercial fishery and survey samples collected coastwide between 1983 and 2005 are shown in Figures 30 and 31. Both fork lengths and ages vary widely as a result of small sample sizes in some years. There is an increasing trend in fork length over the time series. Size at age varies by area and samples have not been consistently collected on a comparable spatial scale over the time series.

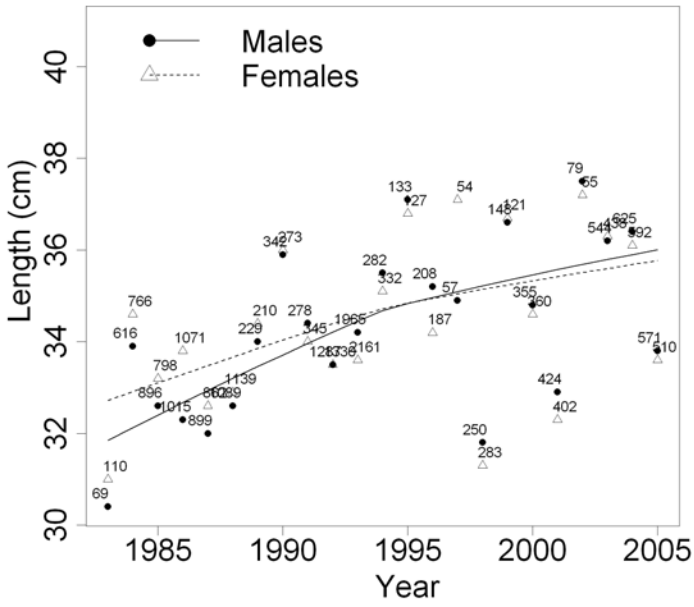


Figure 30. Mean fork lengths by year for Quillback Rockfish (males solid circles, females open triangles). Numbers of fish, by sex and year are shown. The lines shown are produced from the best-fit locally weighted regression of mean length by year (males solid line, females dotted line).

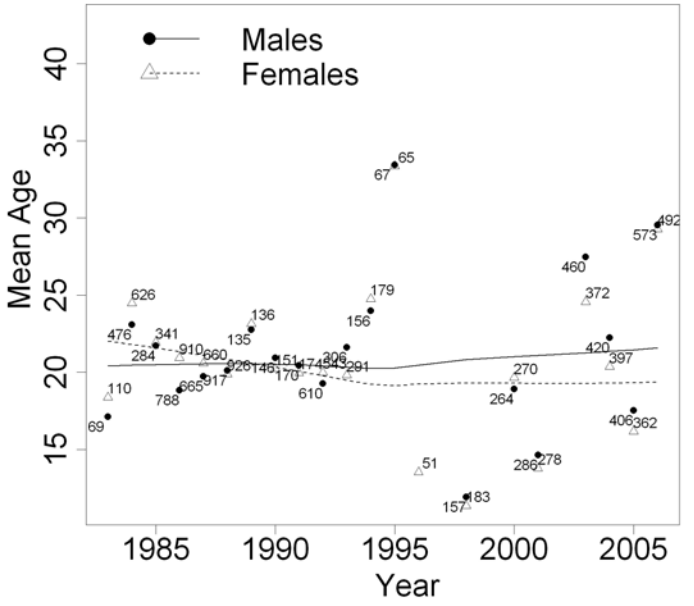


Figure 31. Mean ages by year for Quillback Rockfish (males solid circles, females open triangles). Numbers of fish, by sex and year are shown. The lines shown are produced from the best-fit locally weighted regression of mean length by year (males solid line, females dotted line).

Rescue effect

Dispersal of larvae from adults living outside Canada is likely, as there are no physical barriers to dispersal in the marine environment. Quillback Rockfish exist both to the north as well as the south of BC waters.

Alaska

Quillback Rockfish are managed within the demersal shelf rockfish aggregate (DSR) along with canary, China, copper, rosethorn, tiger and yelloweye rockfishes. DSR are managed jointly by the state of Alaska and the National Marine Fisheries Service in the Southeast outside subdistrict (SEO) and managed solely by the State in the internal state water subdistricts. The 2004 stock assessment for DSR is based on an exploitable biomass of 20,168 t for yelloweye rockfish, the dominant species of the DSR complex, for the SEO. The Allowable Biological Catch (ABC) for yelloweye rockfish for the SEO was set at 450 t which includes a 10% allowance for the other 6 species of DSR (O'Connell *et al.* 2004). Quillback Rockfish make up about 8% of the DSR catch. There is no Quillback Rockfish stock assessment in Alaska.

Washington

Puget Sound Quillback Rockfish were petitioned in 1999 but did not warrant listing under the *Endangered Species Act* (Stout *et al.* 2001). During this review three distinct population segments were determined; south Puget Sound, north Puget Sound, including the Canadian Gulf Islands and a coastal population. The Puget Sound Quillback Rockfish population is below historic levels and considered depressed but no assessment of stock size is available (Palsson pers. comm.). The Quillback Rockfish population on the outer coast has not been assessed.

LIMITING FACTORS AND THREATS

Limiting factors

Quillback rockfish are relatively long-lived and late-maturing, and as such are sensitive to mortality from human activities. Rockfishes are generally characterized by episodic recruitment, influenced by environmental conditions in the early life history (Yoklavich *et al.* 1996); for Quillback Rockfish this is confirmed by recruitment anomalies in catch curves (Figs 8, 9). Maintenance of a high population-level egg production may be important to maintain the potential to take advantage of episodically favourable environmental conditions; thus population depletion could act to reduce recruitment over the long term.

Threats

Fishing is the principal known threat to Quillback Rockfish in British Columbia. The species is particularly vulnerable to commercial and recreational fishing because of its inshore habitat and high desirability, including the potential to supply live specimens to markets. Aboriginal harvest (current and historical) is not known in detail but the species was probably harvested for subsistence for centuries. Quillback Rockfish were probably harvested recreationally from the late 1800s and are known from commercial and recreational harvests from the first half of the 20th century onwards. Fishery removals are essentially unknown prior to the 1950s and are poorly known to the mid-1980s, but could have been substantial. Fishing has had a longer history in the inside waters between Vancouver Island and the mainland, where human populations have grown rapidly over the past century, than in outside waters.

Fisheries in BC are monitored, assessed and managed by DFO. DFO's Rockfish Conservation Strategy, initiated in 2002, has implemented Rockfish Conservation Areas (closed areas) in 20% to 30% of rockfish habitats coastwide, decreased allowable catches by 50 to 75% between 2001 and 2002 and increased the monitoring and stock assessment research for Quillback Rockfish. Commercial fisheries are managed to total allowable catches through 100% dockside monitoring together with partial at-sea observer programs (100% monitored with groundfish integration). Recreational fisheries are managed by bag limits and monitored by creel surveys in various areas coastwide.

SPECIAL SIGNIFICANCE OF THE SPECIES

There is surprisingly little known about the role this species plays in structuring the shallow rocky reef ecosystem. Aside from their ecological significance, Quillback Rockfish are an important component in commercial, Aboriginal, and recreational fishing sectors. Quillback Rockfish are the most important species supplying the live fish market in BC's lower mainland. This live fish market is the main market for the Quillback Rockfish fishery in the Strait of Georgia and throughout BC.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The Quillback Rockfish does not have any international status designations. Puget Sound Quillback Rockfish were petitioned in 1999 but did not warrant listing under the *Endangered Species Act* (Stout *et al.* 2001). In Canada it receives no individual species protection and is managed by DFO under the groundfish hook and line fishery management plan.

In BC's commercial fishery, Quillback Rockfish are managed by TACs for an aggregate of rockfish species which also includes copper, China and tiger rockfishes (see Fisheries section). Since TACs were first introduced in 1991, they have decreased steadily over time with a significant decline of 50% in the outside areas and 75% for the inside area between 2001 and 2002, in response to the Rockfish Conservation Strategy (Table 13). The commercial coastwide total allowable catch for the aggregate in 2005/06 is 161 t (135 t on the outside and 25 t on the inside). The recreational fishery is managed by bag limits: one rockfish of any species within the inside waters east of Vancouver Island, three rockfish of any species, except no more than two yelloweye rockfish on the west coast of Vancouver Island and five rockfish of any species, except no more than three yelloweye rockfish on the north coast including the Queen Charlotte Islands. The recent creation of Rockfish Conservation Areas throughout 20 to 30% of rockfish habitats coastwide is intended to protect a portion of Quillback Rockfish populations from all harvests commercial and recreational.

TECHNICAL SUMMARY

Sebastes maliger
Quillback Rockfish Sébaste à dos épineux
Range of Occurrence in Canada : Marine waters of the Pacific Ocean from Alaska State border in the north to the Washington State boarder in the south, including the inside waters between Vancouver Island and the mainland.

Demographic Information

Generation time (average age of parents in the population) ▪ based on age at 50% maturity of 11 yr and natural mortality of 0.02 – 0.05	31 – 61 yrs
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 or 5 years, or 3 or 2 generations]. • see summary of indices, Table 21 • indices of higher reliability for the species show significant declines • substantial declines in abundance probably occurred prior to initiation of surveys in mid-1980s	Decline, not quantified overall; 50-75% since mid -1980s (less than 1 generation) in some indices
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 or 5 years, or 3 or 2 generations].	N/A
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 or 5 years, or 3 or 2 generations] period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible? ▪ if primarily due to fishing – yes ▪ if associated with decreased frequency of successful recruitment years – no	Yes (?)
Are the causes of the decline understood? ▪ fishing is the principal known threat and is believed to be associated with declines ▪ reduced frequency of successful year-classes due to changes in environmental conditions is a possible contributor but no information is available on mechanisms or impact	Yes (?)
Have the causes of the decline ceased? ▪ fishing pressure has been reduced through management measures, but fishing continues ▪ if environmental changes are involved, no information on whether these have ceased or not	No
[Observed, inferred, or projected] trend in number of populations	N/A
Are there extreme fluctuations in number of mature individuals?	No
Are there extreme fluctuations in number of populations?	N/A

Extent and Area Information

Estimated extent of occurrence	63,146 km²
[Observed, inferred, or projected] trend in extent of occurrence	Stable since 2002 (and probably prior)
Are there extreme fluctuations in extent of occurrence?	No
Index of area of occupancy (IAO) Extent of occurrence adjusted by depth range of 95% occurrence	27,370 km²
[Observed, inferred, or projected] trend in area of occupancy	None

Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented?	No
Number of current locations	N/A
Trend in number of locations	N/A
Are there extreme fluctuations in number of locations?	N/A
Trend in [area and/or quality] of habitat	Stable

Number of mature individuals in each population

Population	**N Mature Individuals**
The estimate below is from a small part of the range	
Total: much greater than	2.2 million
Number of populations (locations)	

Quantitative Analysis

Not done	

Threats (actual or imminent, to populations or habitats)

Fishing is the principal known threat to Quillback Rockfish populations; this inshore species has been fished for many decades. Commercial catches are monitored and managed to a TAC, recreational catches are managed by a non-restrictive bag limit. Fishing pressure has decreased since the mid-1990s due to new management measures.

Rescue Effect (immigration from an outside source)

Status of outside population(s)? USA: Alaskan population status is not known. Puget Sound Quillback Rockfish are depressed and the outer coast stock of the USA south of Canada is not assessed.	
Is immigration known?	Possible
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Possible

Current Status

COSEWIC: Threatened (November 2009)

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Threatened	A2bd

Reasons for designation:

This species is part of an inshore rockfish complex, with 95% of commercial catch records occurring between 14 and 143m depth. Maximum recorded age is 95 years, age at 50% maturity is 11 years and generation time is over 30 years. No overall estimate of decline is possible, however all survey indices have declined, some by 50-75% since the mid-1980s. Commercial catch per unit effort indices show inconsistent trends and are probably affected by changes in fishing practices. Commercial and recreational fisheries are the principal threats, however, commercial fishing pressure has been reduced as a result of strengthened management regimes established in the mid-1990s, including introduction of closed areas and decrease in commercial harvest quotas. Management measures for recreational fisheries (bag limits) do not restrict catches and the impact of such catches on the species is less understood.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Threatened A2bd as abundance indices have declined below threshold levels.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not met – area of occupancy and extent of occurrence above threshold levels.
Criterion C (Small and Declining Number of Mature Individuals): Not met – no population estimate available but certainly above threshold levels.
Criterion D (Very Small Population or Restricted Distribution): Not met – population and distribution above threshold levels.
Criterion E (Quantitative Analysis): Not undertaken

ACKNOWLEDGEMENTS

The report writers would like to thank the many DFO research scientists, biologists and technicians who over the years have planned and conducted research, and collected and archived data on Quillback Rockfish. Many DFO groundfish programs and personnel supported the research effort and data included in this report. Direct funding to write this report was provided by Environment Canada.

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K. Lynne Yamanaka graduated with a B.Sc. 1980 (Zoology) and M.Sc. 1989 (Interdisciplinary Studies) from the University of British Columbia. After working in groundfish management at DFO Regional Headquarters in Vancouver from 1989 to 1991, she began work as a research and stock assessment biologist in the Groundfish Section, Fisheries and Oceans, Canada at the Pacific Biological Station in Nanaimo, B. C. Principal duties have focused on (1) planning, designing, conducting and reporting on surveys and basic fisheries research in support of inshore rockfish stock assessment, (2) providing stock assessment of inshore rockfish and, (3) working with managers to develop, consult on and implement the Rockfish Conservation Strategy.

Lisa C. Lacko received her B.Sc.in Biology from Laurentian University (1989) and Computer Programmer and Analyst Diploma from CDI (1999). She began working for Fisheries and Oceans Canada in 1999 as the Shellfish Data Coordinator in the Stock Assessment Division at the Pacific Biological Station, Nanaimo, B. C. In 2000, Lisa started her current position in the Groundfish Division as a stock assessment biologist. Her responsibilities include database administration, spatial analysis in geographic information systems, and statistical analyses to support the inshore rockfish stock assessment program and Rockfish Conservation Area strategy.

Chris Grandin from Nanaimo, B.C. received a Bachelor of Science in Computing Science from the University of Victoria in 2002. He has been with the groundfish section of DFO stock assessment since 2000, initially working on database design and algorithm development. Since 2003 he has been a part of the Inshore Rockfish program, where he's been developing habitat-based stock assessment methods including a multibeam-based model. Chris is near completion of his Master of Science in Earth and Ocean Science at the University of Victoria.

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Scott Wallace runs a small consulting firm—Blue Planet Research and Education. His work focuses on the sustainability of marine fisheries, conservation of marine biological diversity, and ecosystem-based approaches to fisheries management. He is active in the conservation community where he is currently the Science Advisor to the Sierra Club of Canada, BC Chapter. In this capacity he reviews current fisheries practices, writes status reports, and sits on numerous subcommittees under the umbrella organization of the Pacific Marine Conservation Caucus. He holds a Ph.D. from the University of British Columbia's Fisheries Centre.

Appendix A. Total mortality estimated from Ricker catch curves (1975) for Quillback Rockfish age data collected from research surveys.

1. The Surveys

a) Research jig fishing

Research jig fishing surveys were conducted in 1986, 1987, 1988, 1992 and 2004 at ten research sites in Area 12, around Johnstone Strait in the northern portion of the inside or Strait of Georgia management region (Richards and Cass 1987; Richards and Hand 1987; Richards *et al.* 1988; Yamanaka and Richards 1993). In 2001, commercial fishing vessels were chartered to conduct research in Area 12 and fished many of the same jig fishing sites. Quillback Rockfish from this experiment were collected for aging structures and used in stock assessments.

b) DFO longline survey

A longline survey directed for inshore rockfish was conducted in 2003 and 2004. This survey covered the northern portion of the inside area (statistical areas 12 and 13) from Campbell River in the south to Hope Island in the north and employed a depth stratified (40 to 70 m and 71 – 100 m) random design (Lochead and Yamanaka 2004).

2. Age data

Sagittal otoliths collected from surveys are assigned ages using a burnt section technique at the Pacific Biological Station Ageing Lab. Age data are stored in the PBS groundfish research database GFBio.

To standardize three years of annual surveys into one age analysis, one year was added to the 1986 survey data and one year was subtracted from the 1988 survey data prior to combining ages for the analysis. Similarly, for combining two years of annual survey data, one year was added to the earlier survey to standardize ages for the analysis.

3. Catch curve methods (Ricker 1975 section 2.2 Simple catch curves p. 33)

Age frequencies are constructed in one year age bins and where the age frequency in an annual bin= 0, this age bin is removed. There is no binning of ages. Frequencies are $-\log_{10}$ transformed and the regression performed on all data after the age at which the maximum age frequency occurs. Total mortality, Z, is calculated from the slope of the regression line multiplied by 2.3026, as described by Ricker (1975). R^2 values are also presented for the regression line (Figures 1 and 2).

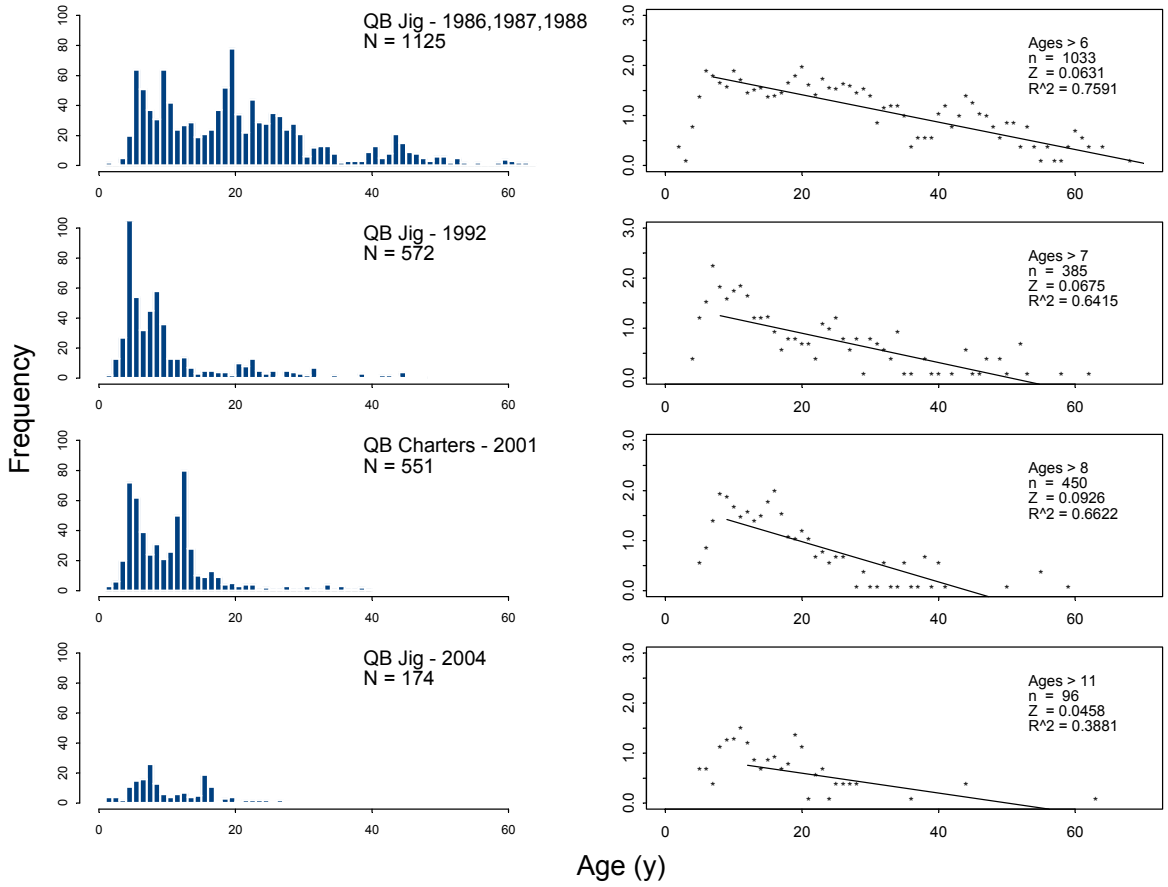

Figure A1. Age frequencies (left panels), log frequencies with regression line and calculated total mortality, Z and r^2 statistic for the research jig fishing surveys in 1986-88 (top), 1992 (second from top), 2001 research charter (second from bottom) and 2004 (bottom).

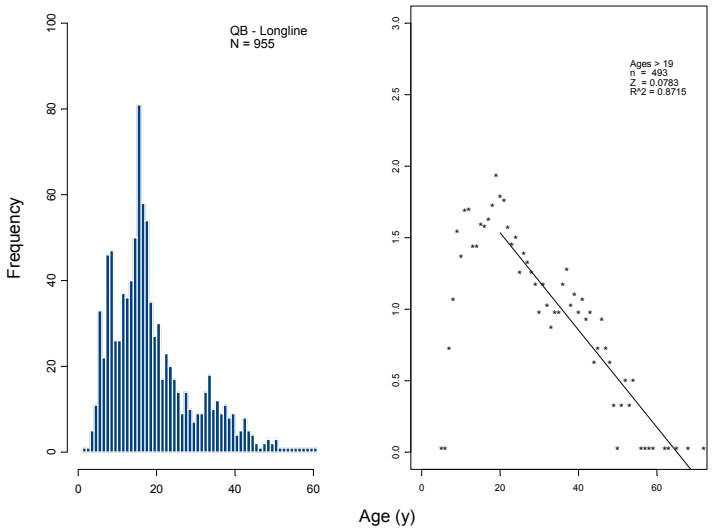

Figure A2. Age frequencies (left panels), log frequencies with regression line and calculated total mortality, Z and r^2 statistic for Quillback Rockfish from the research longline fishing surveys in Areas 12 and 13 in 2003 and 2004.

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