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A review of yelloweye rockfish *Sebastes ruberrimus* along the Pacific coast of Canada: biology, distribution and abundance trends

Examen du sébaste aux yeux jaunes (*Sebastes ruberrimus*) dans les eaux baignant la côte canadienne du Pacifique : biologie, répartition et tendances en matière d'abondance

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Abstract

This paper compiles information on the distribution, biology, and abundance trends of yelloweye rockfish *Sebastes ruberrimus,* in Canada, for use in a Committee on Endangered Wildlife in Canada (COSEWIC) status report. Yelloweye rockfish are found in the northeast Pacific from Baja California to the Aleutian Islands. In British Columbia (BC), there are two designatable units of yelloweye rockfish recognized in this report; an "inside" unit that is undefined but includes the Strait of Georgia and possibly north to Queen Charlotte Strait and an "outside" unit that extends from southeast Alaska through to northern Oregon and includes the whole of the BC offshore and central coast areas. Fisheries catch yelloweye rockfish between 19 and 251 metres in depth over an estimated 41,694 square kilometres in BC. Yelloweye rockfish are aged to 115 years in BC and 50% of individuals 18 years of age are sexual maturity. Generation time is defined as the mean age of reproductive females and is estimated at 37.5 years for the "inside" unit and 32.5 years for the "outside" unit. Females tend to be larger and older than males and reach a maximum size of 88 cm in BC. Total mortality rate ranges from 0.03 to 0.06 depending on the model used and natural mortality is estimated at 0.02 using catch curve analysis. Fishery dependant catch per unit of effort (CPUE) is heavily influenced by management actions applied to the fishery and can not be used to interpret population trends. Abundance trends may be determined from research surveys over the long-term, however, the time series of data to date may be too short to detect any trends.

Résumé

Ce document rassemble des données sur la répartition, la biologie et les tendances en matière d'abondance du sébaste aux yeux jaunes, *Sebastes ruberrimus*, au Canada. Cette information sera utilisée dans un rapport de situation du Comité sur la situation des espèces en péril au Canada (COSEPAC). On trouve le sébaste aux yeux jaunes dans le nord-est du Pacifique, de Baja (Californie) aux îles Aléoutiennes. En Colombie-Britannique (C.-B.), il existe deux unités désignables de sébaste aux yeux jaunes, reconnues dans le présent rapport; une unité « interne » qui n'est pas définie, mais qui inclut le détroit de Georgia et peut-être une partie vers le nord jusqu'au détroit de la Reine-Charlotte, et une unité « externe » qui s'étend du sud-est de l'Alaska jusqu'au nord de l'Oregon et qui englobe l'ensemble des zones côtières du centre et des zones hauturières de la C.-B. Les pêcheurs capturent le sébaste aux yeux jaunes entre 19 et 251 mètres de profondeur, sur une étendue approximative de 41 694 km^2 en C.-B. Le sébaste aux yeux jaunes peut atteindre 115 ans en C.-B. et 50 % des poisons ont atteint la maturité à 18 ans. La durée de génération se définit comme l'âge moyen des reproductrices et est estimé à 37,5 ans pour l'unité « interne » et à 32,5 ans pour l'unité « externe ». Les femelles sont généralement plus grosses et plus âgées que les males, atteignant une taille maximale de 88 cm en C.-B. Le taux de mortalité totale varie entre 0,03 et 0,06, selon le modèle utilisé et le taux de mortalité naturelle est estimé à 0,02 à l'aide de l'analyse de la courbe de captures. Les prises par unité d'effort basées sur la pêche sont fortement influencées par les mesures de gestion appliquées à la pêche et ne peuvent être utilisées pour interpréter les tendances de la population. Les tendances de l'abondance peuvent être déterminées à partir des relevés scientifiques à long terme; toutefois, la série chronologique est encore trop courte pour indiquer une tendance quelconque.

SPECIES INFORMATION

Name and classification

The yelloweye rockfish (*Sebastes ruberrimus*) is one of 102 species of rockfish in the genus Sebastes worldwide and one of 96 species of rockfish found in the North Pacific. The genus and species names are from the Greek *sebastos* (magnificent) and the Latin *ruberrimus* (very red) (Hart 1973). In Canada's Pacific waters 36 species of rockfish have been found (Peden and Gillespie unpublished manuscript). Yelloweye rockfish are referred to by many names including red snapper, red rock cod, rasphead rockfish, red rockfish, red cod, goldeneye rockfish, and turkey red rockfish (Lamb and Edgell 1986). Yelloweye rockfish are managed in BC as part of the "inshore" rockfish complex which includes quillback rockfish (*S. maliger*), copper rockfish (*S. caurinus*), China rockfish (*S. nebulosus*), black rockfish (*S. melanops*) and tiger rockfish (*S. nigrocinctus*).

Morphological description

Yelloweye rockfish are one of the largest rockfish reaching a maximum recorded length of 91 cm and 11.3 kg (Love et al. 2002). They are easily identified by their bright orange to red colouration and bright yellow eyes. Adults usually have a light to white stripe on their lateral line (Figure 1). Juveniles are more dark red in colouration than the adults and have two light stripes, one on the lateral line and a shorter one below the lateral line (Mecklenburg et al. 2002) (Figure 1). Yelloweye rockfish have 13 dorsal spines and the fins may have black tips (Kramer and O'Connell 1995).

Figure 1. Photographs of yelloweye rockfish taken from a submersible, adult (left panel) and juvenile (right panel). Photo credit K. L. Yamanaka.

Genetic description

Geographic variation accounted for less than 1% of the observed genetic variation in a microsatellite survey of 2500 yelloweye rockfish captured in coastal waters of British Columbia (BC) and southeast (SE) Alaska between 1998 and 2000 (Yamanaka et al. 2000). The genetic data did not refute the null hypothesis that all samples were

drawn from a single population. The level of polymorphism was high, with an average of 13 alleles observed at the 13 microsatellite loci. Moderate to high levels of expected heterozygosity in all samples (range 71.1% to 74.0%) also indicated that the effective population size for yelloweye in BC was large. Sample sites included in the study ranged from southeast Alaska to Vancouver Island, but all samples in BC were collected off the west coasts of the Queen Charlotte or Vancouver islands. Thus, no samples from coastal mainland sites, the straits of Georgia, Juan de Fuca or Queen Charlotte, or southern US waters were analyzed.

Samples obtained from Georgia and Queen Charlotte straits, mainland coastal BC (Calvert Island), Washington and Oregon between 2000 and 2005 (Table 1) have since been analyzed at nine of the 13 loci used in the original study (unpublished data). Analysis of variation at the nine loci over the entire data set was carried out using GDA (Lewis and Zaykin 2001), FSTAT (Goudet 2001) and Bottleneck (Cornuet and Luikart 1996).

Table 1. Yelloweye rockfish samples collected between 2000 and 2005 and included in the analysis of variation at nine microsatellite loci.

Sample location	**Site**	**Collection Date**	**Sample size**
Georgia Strait		July-Sept. 2000	57
Georgia Strait	Protection, Entrance Islands	July 2005	47
Queen Charlotte Strait	Discovery Passage – Queen Charlotte Strait	Sept 2004	23
BC Central Coast	Calvert Island	Jan 2001	91
Washington	Cape Flattery Spit	July 2003	82
Oregon	South/Central Oregon	July-Aug 2004	87

The analysis extended the observation of high levels of genetic diversity and little differentiation of yelloweye rockfish among sites to the mainland locations sampled in BC and the US (Table 2). For all samples except the 'inside' samples from the Georgia and Queen Charlotte straits, the level of genetic diversity (expected heterozygosity) at the nine loci ranged from 70.7% to 74.2% (average = 72.5%) and standardized allelic richness (for a sample size of 46 fish) ranged from 10.7 to 11.7. In contrast, the three samples from the inside waters of Georgia Strait and Queen Charlotte Strait showed significantly lower levels of heterozygosity (P=0.004) and allelic diversity (P=0.002). For all three samples combined, the expected heterozygosity was 62.7% and allelic diversity was 8.0. Allelic richness was also calculated without combining the three inside samples (reducing the standardization sample size to 18 fish). Allelic diversity levels for the Georgia Strait 2000, 2005 and QC Strait 2004 samples (6.5, 5.6, 5.4) were uniformly lower than for all other samples (mean 8.3, range 7.9 – 8.6). The distinctiveness of these samples is apparent in a neighbour-joining dendrogram based on Nei's standardized genetic distance (Figure 2).

Table 2. Levels of genetic variation at nine microsatellite loci in yelloweye rockfish collected between 1998 and 2005. All samples were combined for sites sampled multiple times. The level of genetic diversity is the expected heterozygosity (HE) expressed as a percentage. The allelic richness is the average number of alleles observed per locus standardized to a sample size of 46 fish.

Sample site	Sample size	Genetic Diversity	Allelic Richness
S.E. Alaska	88	71.9	11.1
Bowie Seamount	848	72.6	11.1
Tasu	264	74.2	11.4
Barber Point	402	72.8	11.2
Cape St. James	369	72.3	11.0
Calvert Island	91	72.6	11.1
Triangle	221	72.6	11.2
Topknot	224	72.3	11.2
Brooks Bay	73	72.8	10.7
Esperanza	46	73.0	11.0
QC/Georgia Strait	127	62.7	8.0
Washington	82	70.7	10.4
Oregon	87	72.2	11.7

The reduced heterozygosity and number of alleles observed in the QC/Georgia Strait yelloweye samples indicates that they were drawn from a yelloweye population with a smaller effective population size than all other samples. For neutral loci following an infinite alleles mode of mutation, the relationship between effective population size (N_e) and heterozygosity is expected to be: $H = 4N_e\mu/(1+ N_e\mu)$ (Kimura and Crow 1964) where μ is the mutation rate. This indicates that the effective population size of yelloweye rockfish in the waters inside Vancouver Island is about two thirds that of yelloweye rockfish in outside waters. Actual values of N_e depend on the mutation mode and rate of microsatellite loci in yelloweye.

Estimates of pairwise F_{ST} values among all outside sample sites ranged from less than zero to 0.0033 and averaged 0.00080 (Table 3). Pairwise values between QC/Georgia Strait samples and all other sites ranged from 0.0078 to 0.0240 and averaged 0.01685. Pairwise tests of differentiation based on allele frequencies between QC/Georgia Strait samples and other locations were all significant ($P<0.05$) except for the QC – Calvert Island comparison, whereas tests among other locations were nonsignificant except for the comparison of Tasu and Barber Point (Table 3). However, the inside samples contained no unique microsatellite (i.e. contained no alleles not observed in outside samples).

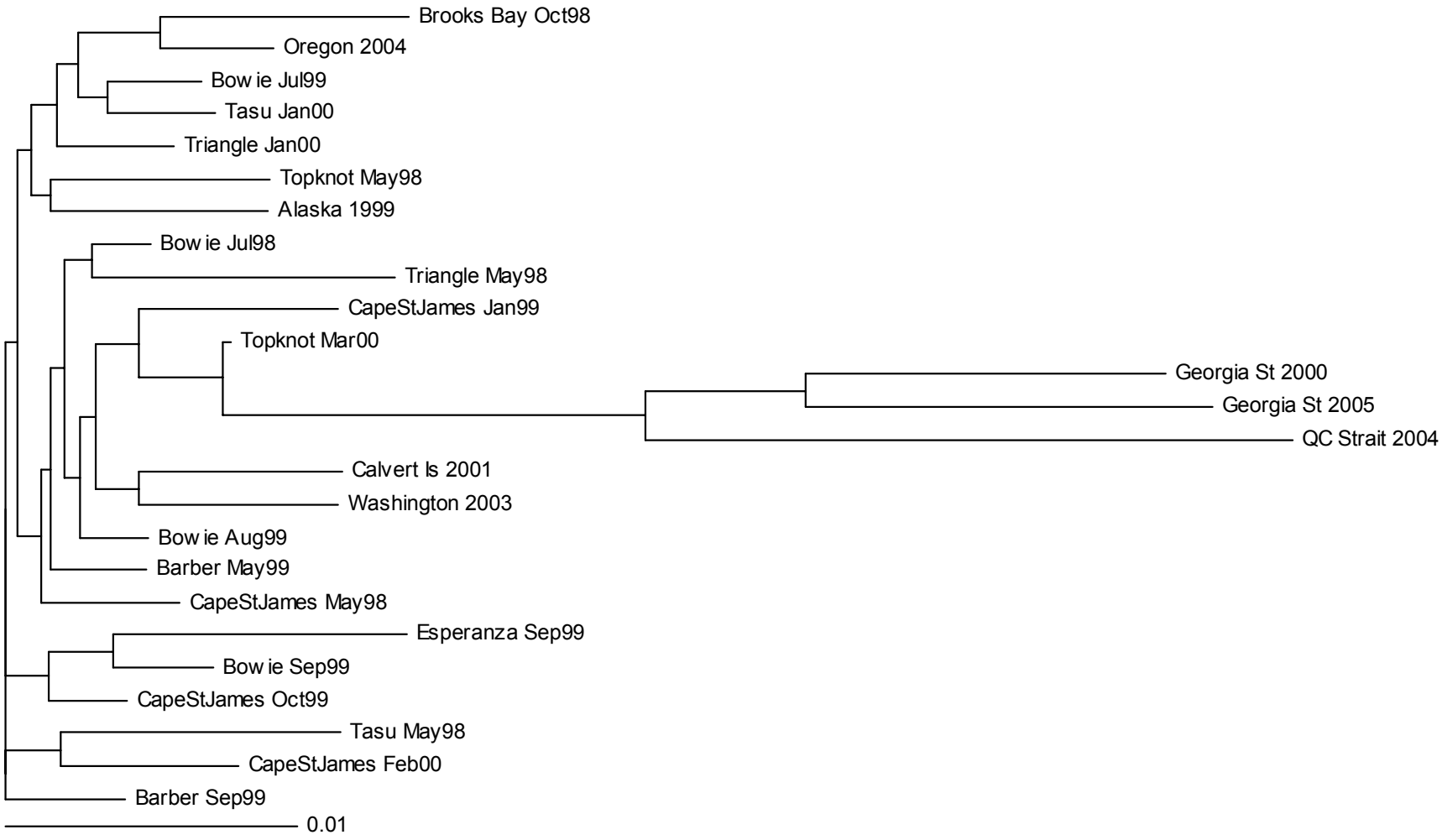

Figure 2. Neighbour-joining dendrogram of yelloweye rockfish samples collected between 1998 and 2005 between southeast Alaska to Oregon. The dendrogram was constructed based on Nei's (1972) standardized genetic distance (D_S) values.

Comparison of heterozygosity values observed in yelloweye samples with those expected under equilibrium conditions of mutation and genetic drift using Bottleneck indicated that all samples were in equilibrium under both an infinite allele and two-phase (combination of 70% single-step and 30% multiple-step mutation) model of mutation. This analysis provided no evidence that the inside population of yelloweye rockfish had experienced a recent severe reduction in number of breeding individuals.

Analysis of the total data set indicated that most (over 99%) of the genetic variation was still contained within samples, with very little due to differences among collection dates (0.11%) or collection sites (0.17%). This is consistent with the observation that the distinctiveness of the QC/Georgia Strait population apparently resulted from a loss of rare alleles, with little differentiation in allelic frequencies from other sites and the absence of unique allelic variants.

The results of this analysis indicate that at least two populations of yelloweye rockfish with limited genetic exchange exist in coastal North American waters between southeast Alaska and Oregon. The outside population extends over the entire range and includes all sites sampled except those in the waters between Vancouver Island and mainland BC. The extent of the inside population, characterized with two samples from southern Georgia Strait and one small sample from northern Georgia Strait and Queen Charlotte Strait, has yet to be accurately defined. The sample from Washington, collected from Cape Flattery Spit very near the mouth of Juan de Fuca Strait, indicates that the inside population does not extend to outside coastal sites in Washington. Additional sampling in the Juan de Fuca and Queen Charlotte straits (and Puget Sound) will be required to determine the population boundaries. Sampling of yelloweye rockfish in Hecate Strait is also required.

The outside population is characterized by moderately high levels of polymorphism, extensive gene flow among sites and an apparently large effective population size. The inside population possesses a reduced level of polymorphism and smaller effective population size apparently resulting from limited genetic interchange with the outside population. However, the inside population possesses no unique genetic variants and is closely related to the outside population. It is not clear whether the restriction of gene flow between the two populations has a long history (perhaps since postglacial colonization of the inside waters) or is more recent. The levels of heterozygosity and allelic diversity in the inside population are still relatively high and not indicative of an extreme bottleneck. However, the samples in this study were adult fish, with a likely average age of 30 years. Thus, any reduction in genetic diversity resulting from more recent low abundances of yelloweye rockfish would not be captured in this survey. These results indicate that two designatable units of yelloweye rockfish should be recognized in the waters of British Columbia.

Table 3. Pairwise values of F_{ST} between yelloweye rockfish samples from sites between Alaska and Oregon are shown above diagonal. The significance of pairwise tests of differentiation (of allele frequencies) between samples (with Bonferroni corrections for multiple tests) is shown below the diagonal. For these tests, NS indicates that there were no differences in allelic frequencies between sites and an asterisk (*) indicates that the allele frequencies in the two samples differed (P<0.05).

	Alaska	Bowie	Tasu	Barber	St Ja	Calvert	Trian	Topknt	Brooks	Esperan	G2000	G2005	QC 04	Wash	Oregon
S.E. Alaska	-	0.0006	0.0008	0.0001	0.0007	0.0032	0.0019	0.0006	0.0015	0.0008	0.0144	0.0196	0.0148	0.0033	-0.0001
Bowie	NS	-	0.0002	0.0006	0	0.0012	0.0004	0.0008	0.001	-0.0011	0.0177	0.0210	0.0140	0.0004	-0.0002
Tasu	NS	NS	-	0.0012	0.0007	0.0016	0.0014	0.0007	0.0014	-0.0001	0.0191	0.0240	0.0155	0.0019	0.0009
Barber Pt	NS	NS	*	-	0.0003	0.0013	0.0008	0.0006	0.0017	0.0003	0.0162	0.0191	0.0133	0.0015	0.001
C St. James	NS	NS	NS	NS	-	0.0005	0.0006	0.0005	0.001	-0.0019	0.0145	0.0185	0.0104	0.0006	0
Calvert Isl.	NS	NS	NS	NS	NS	-	0.001	0.0007	0.0014	0.0009	0.0173	0.0236	0.0112	-0.0004	0.0009
Triangle	NS	NS	NS	NS	NS	NS	-	0.0004	0.0012	0.0006	0.0187	0.0185	0.0117	0.0007	0.0001
Topknot	NS	NS	NS	NS	NS	NS	NS	-	0.0012	0.0019	0.0150	0.0171	0.0078	0.0009	0.0009
Brooks Bay	NS	NS	NS	NS	NS	NS	NS	NS	-	0.0016	0.0208	0.0206	0.0147	0.0025	-0.0018
Esperanza	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	0.0179	0.0229	0.0146	0.0007	0.0004
Georgia2000	*	*	*	*	*	*	*	*	*	*	-	0.0063	0.0089	0.0202	0.0169
Georgia2005	*	*	*	*	*	*	*	*	*	*	NS	-	0.0071	0.0219	0.0198
QC 2004	*	*	*	*	*	NS	*	*	*	*	*	NS	-	0.0115	0.0117
Washington	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	*	-	0.0008
Oregon	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	*	NS	-

Designatable units

Two designatable units of yelloweye rockfish in BC are recognized in this report. The “inside” unit is undefined but includes the Strait of Georgia (between Vancouver Island and the mainland coast) and possibly north to southern Queen Charlotte Strait. The “outside” unit, extends from SE Alaska to Northern Oregon and includes the whole of the BC offshore coast. Similar to DFO stock assessments, biological data and population indices are summarized separately for the “inside” and the “outside” units.

DISTRIBUTION

Global range

Yelloweye rockfish are found only in the northeast Pacific and have been observed from as far south as Ensenada, northern Baja California to south of Umnak Island, Aleutian Islands (Phillips 1957) (Figure 3).

Figure 3. Global distribution of yelloweye rockfish reprinted with permission from Love et al. (2002).

Canadian range

Yelloweye rockfish range throughout the marine waters of BC on Canada’s Pacific Coast. Commercial hook and line and trawl fisheries operating in BC report catches by species and location to Fisheries and Oceans Canada (DFO). These data are archived in the DFO databases PacHarvHL and PacHarvTrawl. Groundfish research survey data are archived in the DFO database GFBio. The distribution of both the commercial and

research survey catch records for yelloweye rockfish, for the years 1996 to 2004, are shown in Figure 4. This distribution of yelloweye rockfish in the commercial fisheries as well as groundfish research surveys depicts the Canadian range of the species.

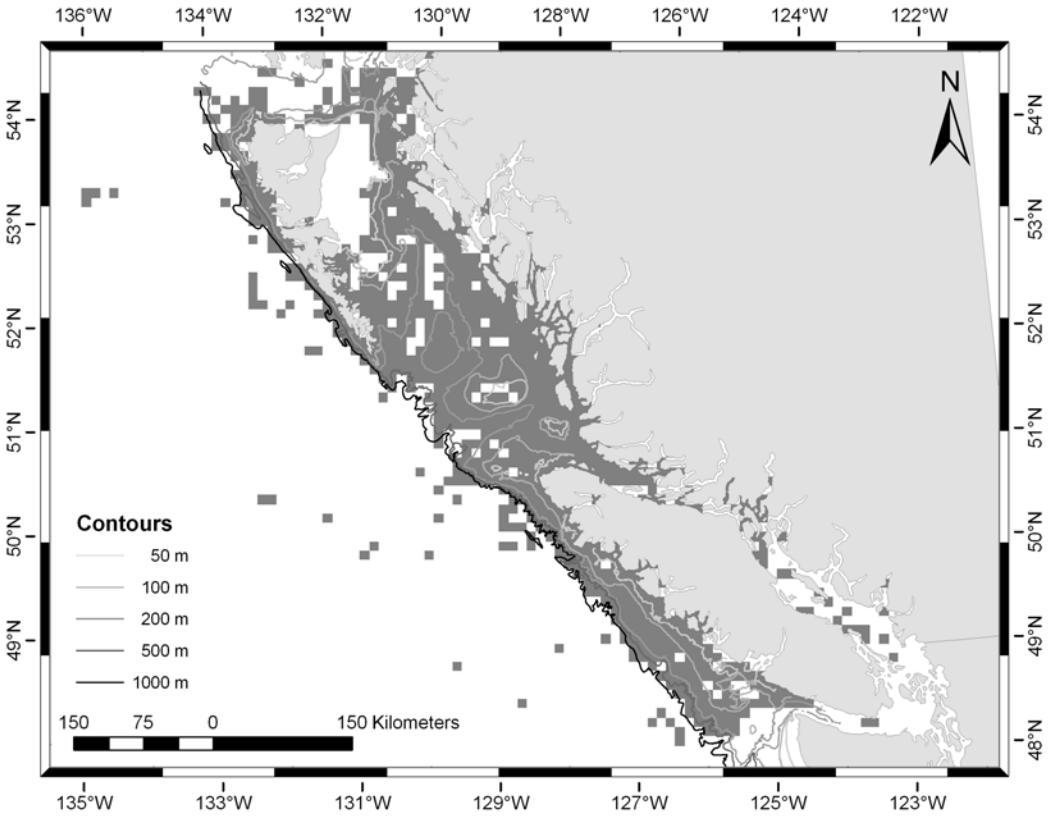

Figure 4. Distribution of yelloweye rockfish in B.C. from commercial hook & line and trawl catch records and groundfish research surveys (1996-2004) summarized on a 10 by 10 km coastwide grid.

A generalized distribution of catch (commercial hook & line and trawl and groundfish research surveys) by depth interval is derived by overlaying bathymetry on the catch records and summarizing data over a 10 X 10 km grid. Area occupied by yelloweye rockfish is shown in Table 4 for the outside area and Table 5 for the inside area. Yelloweye rockfish are most commonly caught in the 51-100 m and 101-200 m depth. They are widely distributed and recorded as caught in all depth intervals and overall occupy 66% and 32% of the total surface area outside and inside, respectively. This species is not endemic to Canada and its Canadian distribution is approximately 20% of their global range (Love et al. 2002).

Table 4. For the outside area, the total surface area (km^2) of marine water by depth interval (m) from 1 to 2000 m (based on map bathymetry), area with yelloweye rockfish commercial and research survey catch recorded and the percentage of the total surface area with yelloweye rockfish catch recorded for the years 1996 – 2004 combined.

Depth Interval (m)	Total Area (km^2)	Occupied Area (km^2)	Percent Occupied
1-50	18,620	9,809	52.7
51-100	18,128	15,468	85.3
101-200	32,399	28,164	86.9
201-500	22,836	15,626	68.4
501-1000	7,277	4,412	60.6
1001-1500	8,475	2,313	27.3
1501-2000	10,631	1,793	16.9
Total:	118,366	77,585	65.5

Table 5. For the inside area, the total surface area (km^2) of marine water by depth interval (m) from 1 to 2000 m (based on map bathymetry), area with yelloweye rockfish commercial and research survey catch recorded and the percentage of the total surface area with yelloweye rockfish catch recorded for the years 1996 – 2004 combined.

Depth Interval (m)	Total Area (km^2)	Occupied Area (km^2)	Percent Occupied
1-50	2,947	720	24.4
51-100	2,003	775	38.7
101-200	3,970	1,703	42.9
201-500	3,629	927	25.5
501-1000	192	57	29.7
Total:	12,741	4,182	32.8

Temporal changes in distribution

The distribution of yelloweye rockfish is examined, for all depths combined, by year to determine temporal changes. The percent of total area with yelloweye rockfish commercial catch is determined annually for the outside and inside areas from 1996 to 2004 (Table 6).

Table 6. The total number of blocks (10 x 10 km grid) fished, the total number of blocks with a recorded yelloweye rockfish catch (commercial fisheries and research surveys) and the percent of blocks with yelloweye rockfish catch for the outside and inside areas by year (1996-2004).

Year	Area	Blocks Fished	Blocks Occupied	Percent
1996	Outside	1129	652	57.8
1997	Outside	991	586	59.1
1998	Outside	959	539	56.2
1999	Outside	1006	585	58.2
2000	Outside	1038	542	52.2
2001	Outside	1330	616	46.3
2002	Outside	1177	559	47.5
2003	Outside	1089	519	47.7
2004	Outside	1017	471	46.3
1996	Inside	185	80	43.2
1997	Inside	79	61	77.2
1998	Inside	80	56	70
1999	Inside	66	50	75.8
2000	Inside	81	63	77.8
2001	Inside	281	101	35.9
2002	Inside	139	35	25.2
2003	Inside	246	76	30.9
2004	Inside	132	75	56.8

In 2001, new logbooks for the Schedule II fisheries (directed lingcod and dogfish by hook & line gear) were implemented and compiled in PacHarvHL for the first time. This effectively increased the number of blocks fished by the commercial fisheries but yelloweye 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. As a result, the percent of occupied blocks in 2001 appears to be lower than in years prior to 2001 but may not be indicative of a contraction of area occupied by yelloweye rockfish. For the outside area, occupied area has been stable since 2001. For the inside area, occupied area has increased since 2002.

Catch quotas for yelloweye rockfish declined dramatically between 2001 and 2002; by 50% in the outside area and 75% in the inside area. 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 yelloweye rockfish catch in logbooks. It is uncertain whether the declines in the percent distribution of yelloweye rockfish are real or a result of significant management actions applied to the commercial fisheries.

Occupied habitat

Examining the depth of capture for yelloweye rockfish recorded on commercial hook and line and trawl fishery logbooks and groundfish research surveys, 95% of all

observations lie between 19 and 251 meters in depth (Figure 5). An estimate of the maximum potential habitat area for yelloweye rockfish was derived by applying this preferred depth range (surrogate for habitat), to bathymetry coastwide. Summarizing over a 5 x 5 km grid, an estimate of maximum potential habitat is 83,596 km^2 coastwide in B.C (Figure 6). The habitat area with yelloweye rockfish catch, or occupied habitat area, is estimated at 41,694 km^2 or 50 percent of the maximum potential habitat area.

This estimate of maximum potential habitat does not differentiate between bottom types (it includes them all) and is likely an overestimate of the true habitat area as yelloweye rockfish associate only with hard bottom substrates within their depth range. The occupied habitat area is likely underestimated with this analysis because not all potential habitat areas have been fished.

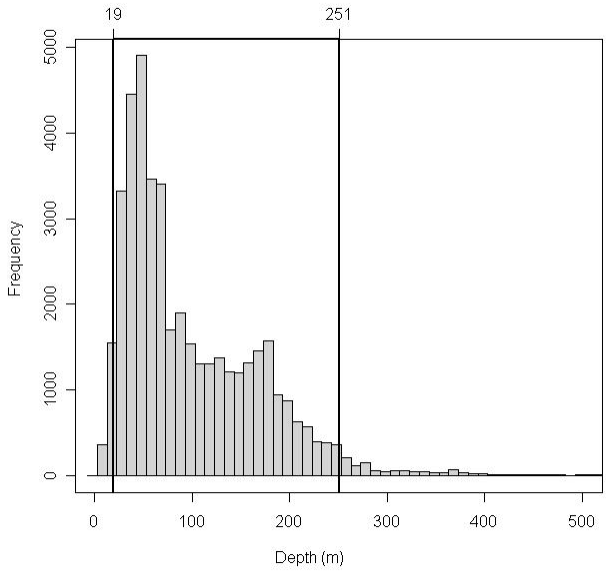

Figure 5. Histogram of the capture depth of yelloweye rockfish in the commercial hook & line and trawl fisheries in B.C. between 1996 and 2004. Vertical lines denote the 2.5% and 97.5% quartiles of the data.

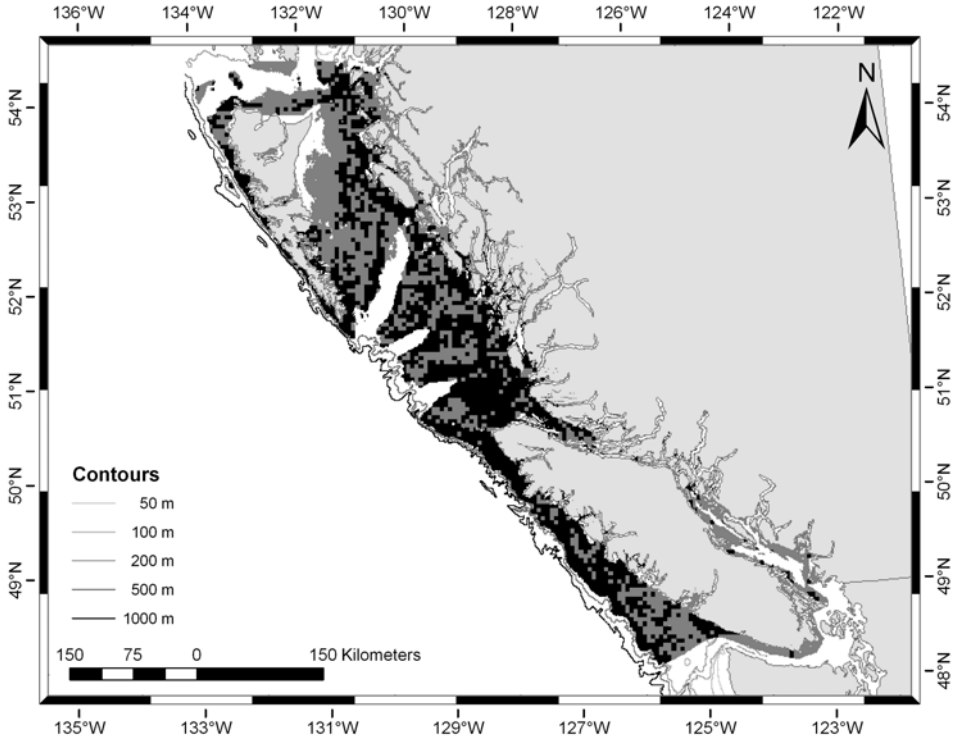

Figure 6. Maximum potential habitat of yelloweye rockfish in Canadian waters, based on the depth of capture range of 19 to 251 m, over a 5 x 5 km grid, is 83,596 square kilometres. The occupied habitat based on commercial fishing records and research surveys, for the years 1996 – 2004 combined, is 41,694 square kilometers, or 50 % of the potential habitat.

Inside

The spatial distribution and catch rate of yelloweye rockfish on the inside waters from combined longline survey data collected in 2003, 2004 and 2005 is shown in Figure 7. Yelloweye rockfish occur from Queen Charlotte Strait in the north to Darcy Island in the gulf islands in the south. The survey on the inside covers 2359, 2x2 km blocks of potential yelloweye rockfish habitat. Of these blocks, 233 were surveyed and 101 had yelloweye rockfish catch which is 43.3 % occupied habitat. Yelloweye rockfish were not caught in the fishing sets made in Juan de Fuca Strait and this may denote the southern boundary to the inside population unit.

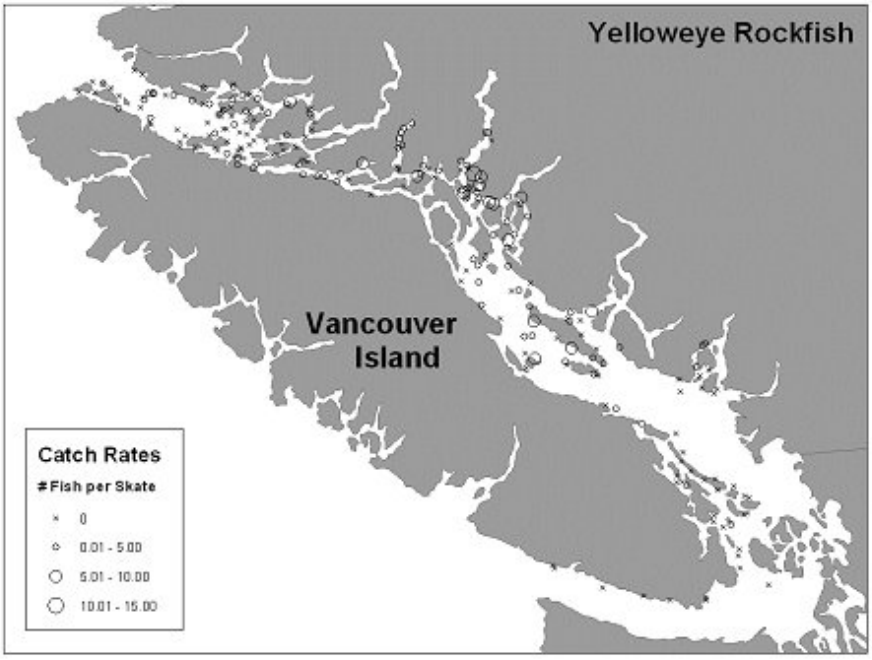

Figure 7. Spatial distribution of catch rate for yelloweye rockfish during the research longline surveys conducted in 2003, 2004 and 2005 combined.

HABITAT

Habitat requirements

Yelloweye rockfish are habitat specialists, exhibiting a solitary, demersal existence over substrates that are hard, complex and have some vertical relief, such as broken rock, rock reefs, ridges, overhangs, crevices, caves, cobble and boulder fields (Yamanaka unpublished data, Richards 1986, O'Connell and Carlile 1993, Murie et al. 1994, Yoklavich et al. 2000, Love et al. 2002). Information on the habitat of yelloweye rockfish from California through BC and in Alaska has come from direct *in situ* observations from submersibles.

Habitat trends

There are no data to substantiate habitat trends for yelloweye rockfish. It is assumed that there have been no net changes to the habitat (19-251 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

(http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/fisheriesmgmt/rockfish/default_e.htm). RCAs were developed in consultation with stakeholders and are used as a spatial management tool to protect a portion of the rockfish population from harvest. These RCAs are aimed at protecting rockfish by identifying 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 has closed 20% of rockfish "habitat" within RCAs for the outside area in 2005 and has targeted 30% of rockfish "habitat" closed for the inside area in 2006.

BIOLOGY

Yelloweye rockfish have been sampled for biological data (length, weight, sex, maturity, age) by the Department of Fisheries and Oceans (DFO) intermittently since 1980. These data are archived in the DFO database GFBio. Historically, biological samples were taken opportunistically from commercial landings and in more recent years large samples are collected during research surveys. Research fishing surveys have provided the majority of the samples used here to characterize populations and the 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 yelloweye rockfish biology that have not been directly studied in BC.

Life cycle and reproduction

Female yelloweye rockfish produce between 1.2 and 2.7 million eggs annually (Love et al. 2002). Although other rockfishes display courtship behaviors, this is undocumented for yelloweye rockfish. In BC the mating season for yelloweye rockfish is most likely in November when males gonads are known to be in "running ripe" condition and may extend into the winter months. 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 yelloweye rockfish in B.C. occurs between April and September with a peak in May and June.

The duration of the pelagic larval phase of yelloweye 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 these pelagic larval-juvenile and benthic settlement phases.

Typically, rockfish juveniles settle to nearshore hard bottom habitats at shallower depths than their conspecific adults. This appears to hold true for yelloweye rockfish observed from submersibles at all coastal B.C. locations surveyed. 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, Lea et al. 1999). Some benthic rockfishes are known to have limited home ranges and may defend some portion of their territories (Love et al. 2002). Yelloweye rockfish are more or less solitary, benthic dwellers and are likely to exhibit these behaviours. There is no direct evidence from tagging to substantiate a home range for yelloweye rockfish.

Submersible surveys conducted in BC have observed yelloweye rockfish at various locations coastwide in 1984, 2000, 2003 and 2005 (Richards 1986, Murie et al. 1994, Yamanaka 2005, Yamanaka unpublished data). Sub-adult and adult yelloweye rockfish (>20 cm forklength) have been observed from submersibles in BC hovering near or settled upon rock ridges or outcrops and occupying crevices in rock substrates or boulders patches from 30 to 232 m in depth with a median of all observations of 79 m (Table 7).

Table 7. Minimum (min), 25th percentile (25%), median, 75th percentile (75%), maximum (max) depth and number (n) of sub-adult and adult yelloweye rockfish greater than 20 cm in forklength observed during submersible surveys coastwide and by site.

Yelloweye Rockfish			Depth in meters			
(>20cm)	min	25%	median	75%	Max	n
Coastwide all locations	30	71	79	103	232	1350
Bowie Seamount	49	71	78	102	232	1132
Juan Perez Sound	37	55	69	121	170	32
Desolation Sound	30	70	100	140	207	113
Jervis Inlet and Area	36	60	90	115	197	68
Southern Gulf Islands	159	165	171	179	197	5

Juvenile yelloweye rockfish (<20 cm in forklength) have also been observed from submersibles in a shallower depth range than the adults, 30 to 168 m with a median of all observations of 73 m (Table 8). 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.

Table 8. Minimum (min), 25th percentile (25%), median, 75th percentile (75%), maximum (max) depth and number (n) of juvenile yelloweye rockfish less than or equal to 20 cm in forklength observed during submersible surveys coastwide and by site.

Yelloweye Rockfish			Depth in meters			
Juveniles (≤20cm)	min	25%	median	75%	Max	n
Coastwide all locations	30	68	73	87	168	601
Bowie Seamount	54	72	79	92	160	374
Juan Perez Sound	32	43	48	50	81	21
Desolation Sound	30	51	68	80	160	149
Jervis Inlet and Area	35	57	78	90	152	56
Southern Gulf Islands	168	n/a	n/a	n/a	168	1

Age and Growth

Yelloweye rockfish have been aged to 115 years in B.C. and 121 in Alaska (Yamanaka and Lacko 2001, Munk 2001)). Half of individuals between 42.1 – 49.1 cm in forklength and 17.2 – 20.3 years of age are sexually mature (Kronlund and Yamanaka 2001). The average age of mature females, assessed through historical biological samples for the outside area, taken between April and June, is 32.5 (std dev = 17.78, n = 1,590). For the inside, the average age of mature females, taken between April and July, is 37.5 (std dev = 15.74, n = 71). These are estimates of generation time for yelloweye rockfish as all mature individuals contribute to annual cohorts from the year they first produce larvae, until their death.

Biological sample data is summarized for two areas; “outside” waters to the West of Vancouver Island and extending North and South to the U.S. boundaries and “inside” waters to the East of Vancouver Island. In the yelloweye rockfish population, there are equal numbers of males and females, the average age of females is older than the males and the maximum age of both sexes is 115 years for the outside area and 87 for males and 101 for females for the inside area (Table 9). Yelloweye rockfish are one of the largest species within the genus Sebastes. The average forklength of males is longer than that for females but the maximum forklength of females is greater than that for males (Table 9). Length – weight relationship is shown in Figure 8 and length – age fit to a von Bertlanffy growth function are shown in Figure 9. Sexual dimorphism is common among rockfishes with females most commonly larger in size than the males (Wyllie Echeverria 1986).

Table 9. Summary of biological sample data for yelloweye rockfish, including descriptive statistics on sex, age and forklength (source: DFO GFBio database 23/09/2005).

Yelloweye Rockfish	outside area		inside area	
	males	females	males	females
Number sexed	11334	11402	599	584
mean age (yrs)	27	31	27	30
std dev of age	14.1	17.6	14.2	15.3
Number aged	7036	6930	468	467
Maximum age (yrs)	115	115	87	101
mean forklength (mm)	540	534	476	469
std dev of forklength	87.7	93.5	118.0	112.1
Number of lengths	10657	10830	603	593
Maximum forklength (mm)	812	884	785	804

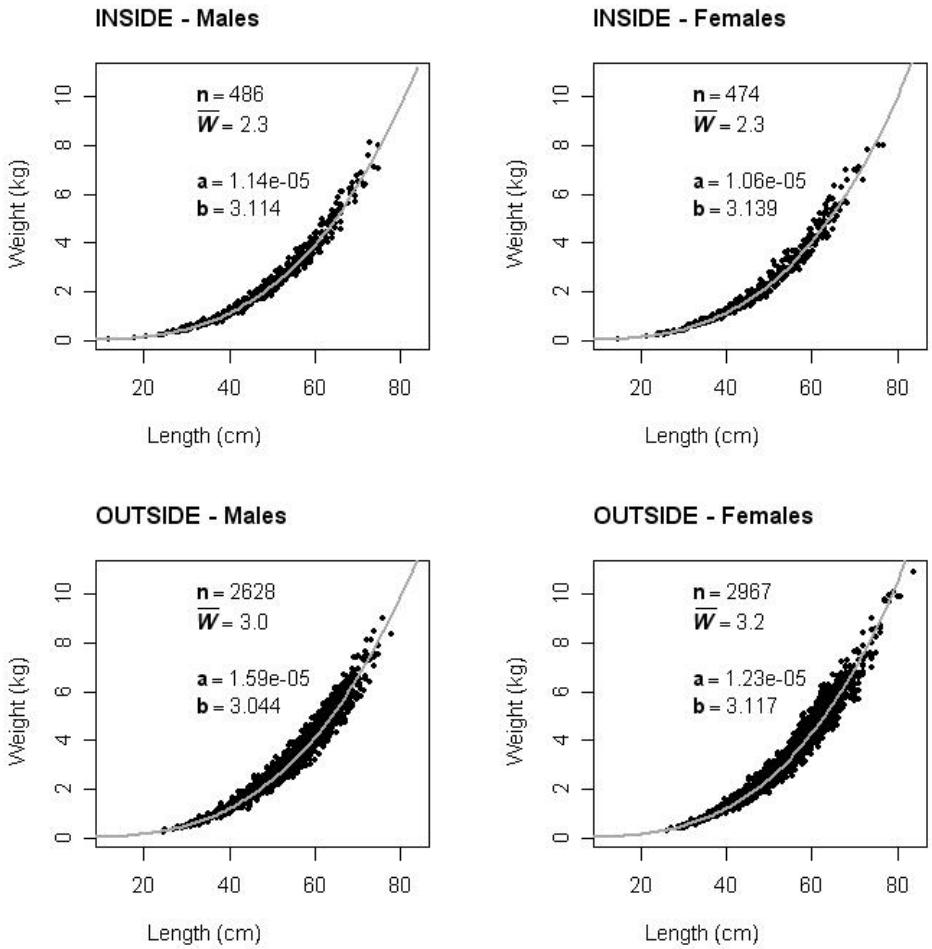

Figure 8. Yelloweye rockfish forklength (L in cm) vs weight (W in kg) by area and sex $W = aL^b$.

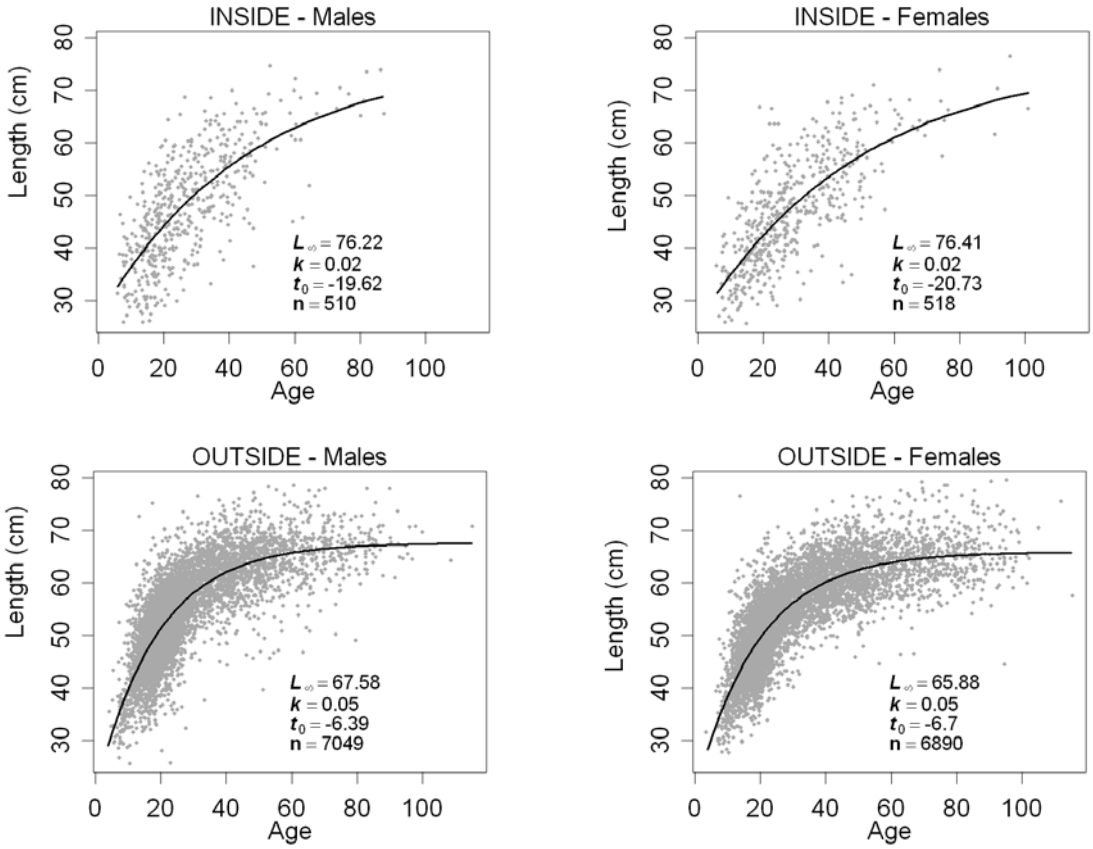

Figure 9. Yelloweye rockfish forklength (cm) at age (yrs) fit to the von Bertalanffy growth function by area and sex.

Mortality Rates

Simple catch curves were used in 2001 (Yamanaka and Lacko) to estimate Z from 1997/98 research survey data. Using data from additional research surveys, simple catch curves were used to estimate total mortality rates shown in Table 10. (Appendix A). Depth of capture for the DFO research charters was filtered to include only the depths between 80 and 225 m.

Table 10. 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
outside	1997/98	DFO research charters	0.051	0.8789
outside	2002/03	DFO research charters	0.055	0.7952
outside	2003	IPHC SSA charters	0.040	0.6915
inside	2003	DFO research longline	0.036	0.5966

Catch curve methods of Schnute and Haigh (2006), incorporates variable and estimate total mortality. These methods are applied to the same age data sets used in the simple catch curve analyses in Table 10 above. Total mortality for yelloweye rockfish from the research survey data are shown in Figure 10 and 11 and Table 11.

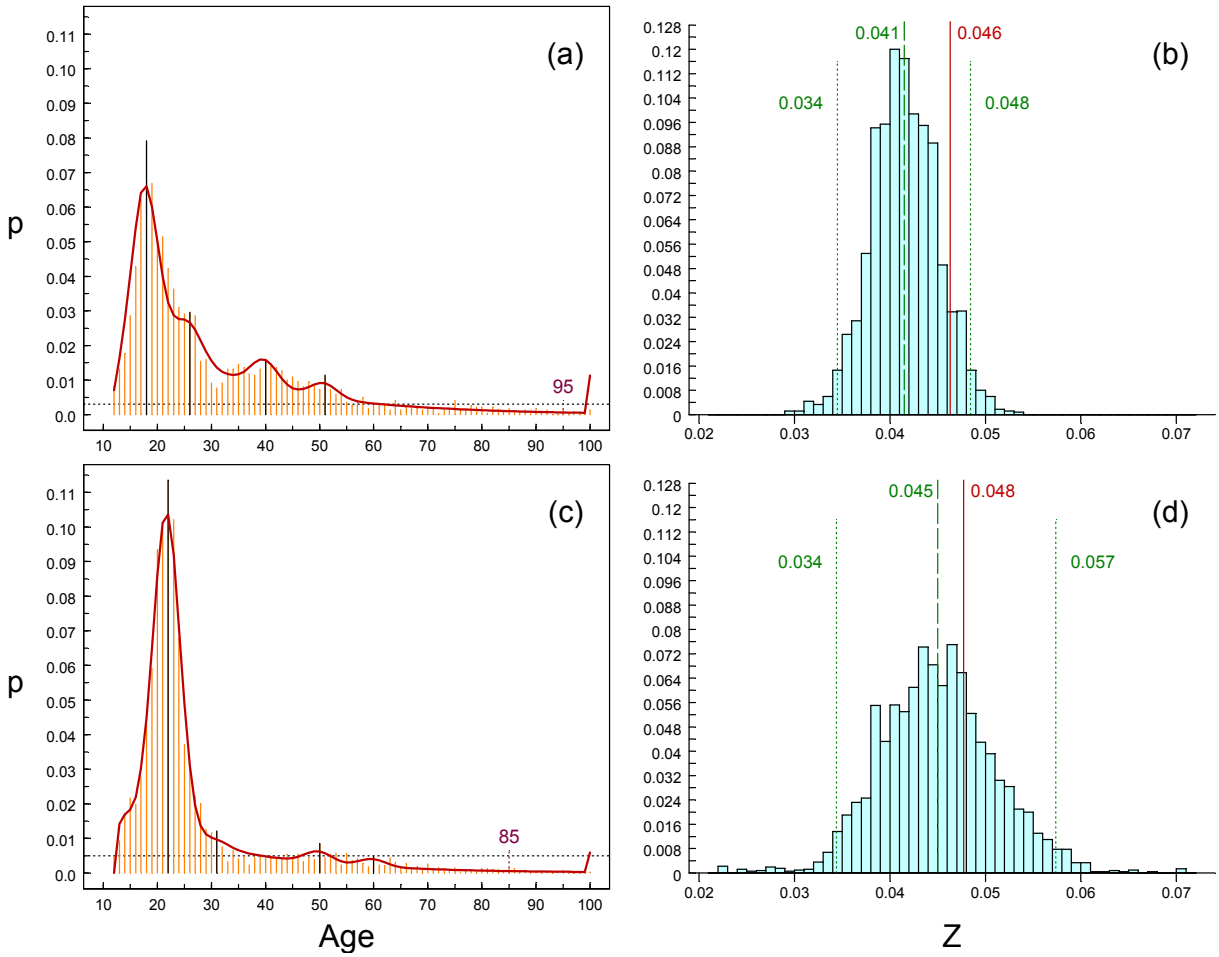

Figure 10. Catch curve analysis for the research charter surveys in 1997/98 (a and b) and in 2002/03 (c and d). Observed proportions-at-age (vertical bars) and predicted (solid curves) using the catch curve model in Schnute and Haigh (2006) (a and c). The recruitment anomalies assumed are highlighted as dark vertical bars. Posterior samples of Z as histograms (b and d). Solid vertical lines indicate the mode from the model fits. Dashed vertical lines indicate the mean Z-values, dotted vertical lines indicate the 2.5% and 97.5% quantiles.

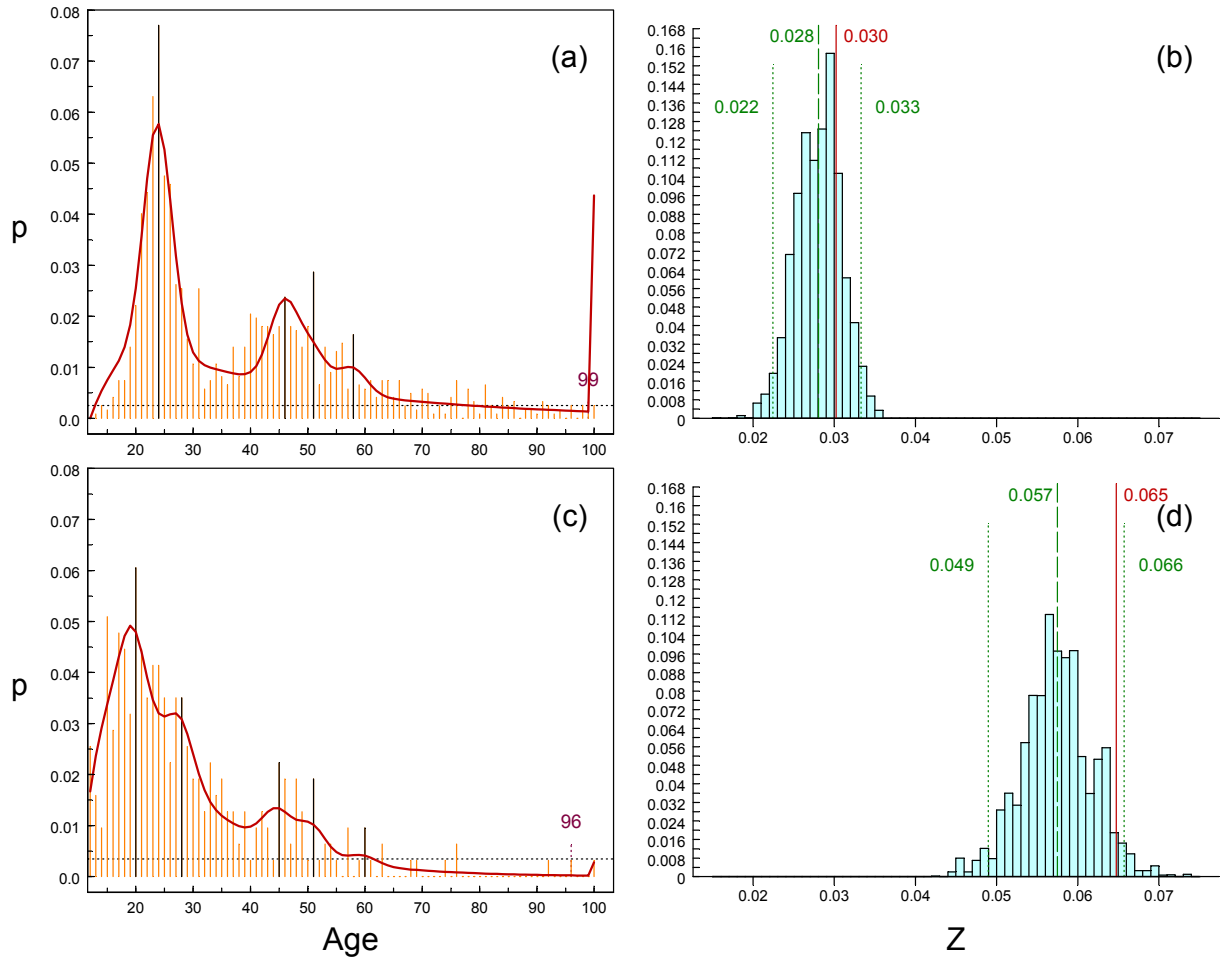

Figure 11. Catch curve analysis for the IPHC SSA survey in 2003 on the outside (a and b) and the DFO longline survey in 2003 on the inside (c and d). Observed proportions-at-age (vertical bars) and predicted (solid curves) using the catch curve model in Schnute and Haigh (2006) (a and c). The recruitment anomalies assumed are highlighted as dark vertical bars. Posterior samples of Z as histograms (b and d). Solid vertical lines indicate the mode from the model fits. Dashed vertical lines indicate the mean Z-values, dotted vertical lines indicate the 2.5% and 97.5% quantiles.

Table 11. Total mortality estimates (Z) from Schnute and Haigh (2006) 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 2006)			
Area	Year	Survey	2.5%	mean	mode	97.5%
outside	1997/98	DFO research charters	0.034	0.041	0.046	0.048
outside	2002/03	DFO research charters	0.034	0.045	0.048	0.057
outside	2003	IPHC SSA charters	0.022	0.028	0.030	0.033
inside	2003	DFO research longline	0.049	0.057	0.065	0.066

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). Fishes are the major food item for yelloweye rockfish, juveniles and adults, in Alaska. Diets include other rockfish (S*. emphaeus, S. maliger, S. helvomaculatus, S. proriger* and juvenile *S. ruberrimus*), juvenile gadids, sand lance (*Ammodytes hexapterus*) and herring (*Clupea pallasi*) (Rosenthal et al. 1988). Other prey items consumed are shrimp (*Caridea spp., Pandalus spp.)*, lithodid crab (*Acantholithodes hispidis*, *C. oregonensis),* green sea urchin *(Stongylocentrotus droebachiensis),* and lingcod (*Ophiodon elongates)* eggs. Major food items off Oregon included cancroid crabs, cottids (*Artedius* spp.), righteye flounders, adult rockfish and pandalid shrimps (Steiner 1978).

Predation

Observations of B.C. resident killer whale predatory behaviour has confirmed that adult yelloweye rockfish are taken as prey (Ford et al. 1998). In the Strait of Georgia, predation by harbour seals has been estimated at 112 t for all rockfish species in 1988 (Olesiuk et al. 1990). These rockfish were not identifiable to species but may be significant relative to the all fishery harvest of 172 t in the Strait of Georgia in 1988. In Alaska, adults are preyed upon by seals, sharks and dolphins whereas the juveniles are taken by birds, porpoises, and fishes such as rockfish, lingcod, cabezon and salmon (ADFG).

Physiology

All rockfish have physoclistic swim bladders (lack a pneumatic duct) and must rely on a gas gland to fill the bladder unlike other species such as salmon and lingcod. This gland is a highly vascularized and can push oxygen into the gland even against some very high pressures. To release gas from the swim bladder, the fish opens a set of constrictor muscles that allows the gas to escape the bladder and diffuse into the blood stream. Rockfish cannot rapidly accommodate changes in pressure and gas expansion in the swim bladder when brought to the surface from depth. Yelloweye rockfish suffer from severe barotrauma that is assumed to be fatal. Rockfish discarded at sea are considered part of the total catch.

The ambient temperature and salinity were measured during submersible surveys conducted in 2003 and 2005 and are summarized for all observations of yelloweye rockfish in Table 12. The observed temperature ranged from 8.1 to 12.1^{o}C and salinity ranged 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 overall physiological tolerance of the species.

Table 12. Summary of temperature (^{o}C) and salinity (parts per thousand) measured for all observed yelloweye rockfish during submersible surveys in a portion of the Strait of Georgia and Juan Perez Sound in 2003 and 2005.

Yelloweye rockfish	Temperature	Salinity
Mean	9.21	32.07
Standard Error	0.0407	0.1350
Median	9.19	30.99
Minimum	8.06	28.16
Maximum	12.10	35.04
Count	208	208

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 300 nmi 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 yelloweye rockfish. The actual dispersal distance for yelloweye rockfish is unknown.

Repopulation of yelloweye rockfish through the dispersal of larvae from adults living outside of Canada is likely as there are no physical barriers to dispersal in the marine environment. Yelloweye rockfish exist both to the north and south of B.C.

Interspecific interactions

There are no known interspecific interactions that limit the survival of yelloweye rockfish in Canada.

Adaptability

Yelloweye rockfish have been fished from the wild then held in aquaria for display purposes but there is no known captive breeding/grow-out aquaculture operation for this species in Canada or elsewhere.

FISHERIES

Yelloweye rockfish are caught primarily by demersal hook and line gear types in Aboriginal, recreational and commercial fisheries coastwide (Yamanaka and Lacko 2001). Common gear types used are rod and reel rigged with single or multiple hooks 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 set directly on the bottom. The largest commercial landings of yelloweye rockfish are

taken in the directed commercial halibut and rockfish fisheries. Incidental catch occurs in other directed commercial fisheries, such as those for dogfish, lingcod and salmon and to a lesser extent in groundfish and shrimp trawl fisheries and prawn and sablefish trap fisheries. Trawl gear types, because of their use either off the substrate (mid-water) or over smooth substrates (bottom trawl) do not typically intercept yelloweye rockfish.

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 licences outside from over 2400 licenses coastwide in 1986.

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.

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. Incidental catch is not well known for unobserved commercial fisheries, especially where the landing of rockfish is either limited or prohibited by license conditions.

Inshore rockfish stock assessment has been hindered by the lack of reliable catch statistics and no available biomass estimate or exploitation rate. However, stock declines are evident through catch curve analyses which showed that natural mortality rates were low (~2%) and exploitation effects were large for rockfish populations from survey sites (1997 – 2003) in the outside area (Yamanaka and Lacko 2001). Stock monitoring programs to provide reliable abundance indices, biomass estimates and improved catch monitoring throughout all fisheries are required to improve the stock assessment of inshore rockfish.

A rockfish conservation strategy (RCS) (http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/fisheriesmgmt/rockfish/default_e.htm) 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 outside, together with the implementation of 28 RCAs (closed areas) 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 is set for the inside with consultations completed in 2006.

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 address 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 with implementation for 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. Fishermen 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 (TAC's) and other catch limits will be considered and implemented to be consistent with the precautionary approach for management.

In 2006, 100% at-sea monitoring standards will be in place for the entire groundfish fishery. This monitoring will eliminate unreported catch of rockfish throughout the commercial groundfish fishery and allow all rockfish to be accounted for within their TACs.

1. Commercial catch

Historic commercial catch statistics

Through the years the commercial yelloweye rockfish catch statistics were summarized under various species categories by the Dominion Bureau of Statistics (Canada 1818-1946) and DFO; “various kinds of fish” (1877-1881), “assorted fish” (1882-1889), “rock cod” (1890-1894), “mixed fish” (1895-1917), “red cod, etc.” (1918-1922), “red cod” (1923-1931), “red and rock cod” (1932-1974), “rockfish” (1975-1981), “red snapper” (1982-1994), and finally in 1995, was specifically recorded as yelloweye rockfish. The “official” DFO catch record starts in 1951 with the initiation of the sale slip system designed to track commercial catch by area and gear type.

Historic commercial catch statistics are detailed for Pacific salmon between 1828 and 1950 by Argue and Shepard (2005) and highlight the difficulty of deriving landed round weights of salmon by species and area of catch from Hudson's Bay Company and Canadian government summaries of salmon products produced. Substantial effort was required to convert from product weights back to round weights, allocate weights by species and trace the transfers of fish between areas. Numerous records of salmon catch and products were available to cross reference portions of the time series and allowed, to some extent, the verification of the derived data. Unfortunately, no substantive data for yelloweye rockfish are available to allow the allocation of weights by species for rockfish. A possible exception is the period between 1923 and 1931 with the species category "red cod" which may have been largely yelloweye rockfish. Similar to the catch statistics for salmon between 1930 and 1950, lingcod and rockfish reported as processed in the Fraser River and Howe Sound areas were not properly deducted and/or transferred back as catch from the North Coast and West Coast areas (Argue pers comm). If these statistics are not corrected there appears to be large catches of rockfish within the Strait of Georgia during the 40's, which are clearly in error.

There are many anecdotal records of the early catch of yelloweye rockfish in BC. In an 1886 expedition exploring fisheries resources in the North Arm of Burrard Inlet [Indian Arm, Strait of Georgia], the inspector of fisheries described the "large red rock cod" as being "plentiful" (Canada 1886). In 1888, the inspector of fisheries explained that of the 28 varieties of rockfish known at the time, "the most abundant and highly prized is what is known as the red cod or snapper" (Canada, 1888). These accounts verify that red cod or snapper were abundant in the Strait of Georgia in the late 1800's but are not sufficiently detailed to derive catch statistics for yelloweye rockfish from historic "assorted fish" categories.

Commercial hook & line landings data are extracted from DFO sale slip records under the category of "red and rock cod" (1951-1974) and "rockfish" (1975-1981) and subset by gear type for only the hook and line gears, "red snapper" (1982-1995) by hook and line gear and from the integrated dockside monitoring and logbook DFO databases PacHarvTrawl and PacHarvHL for yelloweye rockfish for the years 1996-2004 (Table 13 and Figure 12).

Table 13. Coastwide catch of yelloweye rockfish by year (1951 to 2004) from the commercial hook and line (H&L) landings and trawl (T) catch (landings and discards), halibut (H) landings and recreational catch (kept and discarded) for the inside (I) and hook and line landings and trawl catch for the outside (O) areas. Commercial H&L and T catch between 1951 and 1995 are from sale slips records, between 1996 and 2004 are from PacHarvHL and PacHarvTrawl. Recreational catch data are converted (3.2 kg) from numbers of fish recorded in the Strait of Georgia Creel Survey for the years 1981 to 2004.

Year	H&L I	T I	H I	REC I	H&L O	T O	H O
1951	47.60	0.00	0.00	0.00	165.50	0.00	0.00
1952	14.20	0.00	0.00	0.00	112.90	0.00	0.00
1953	29.40	0.00	0.00	0.00	42.70	0.00	0.00
1954	10.80	0.00	0.00	0.00	44.60	0.00	0.00
1955	17.30	0.00	0.00	0.00	34.50	0.00	0.00
1956	11.80	0.00	0.00	0.00	30.90	0.00	0.00
1957	11.20	0.00	0.00	0.00	58.40	0.00	0.00
1958	9.70	0.00	0.00	0.00	35.30	0.00	0.00
1959	22.70	0.00	0.00	0.00	40.00	0.00	0.00
1960	17.50	0.00	0.00	0.00	56.70	0.00	0.00
1961	16.00	0.00	0.00	0.00	58.10	0.00	0.00
1962	11.00	0.00	0.00	0.00	73.80	0.00	0.00
1963	17.50	0.00	0.00	0.00	65.60	0.00	0.00
1964	17.20	0.00	0.00	0.00	38.60	0.00	0.00
1965	19.60	0.00	0.00	0.00	37.90	0.00	0.00
1966	9.20	0.00	0.00	0.00	40.60	0.00	0.00
1967	15.40	0.00	0.00	0.00	54.50	0.00	0.00
1968	13.70	0.00	0.00	0.00	34.10	0.00	0.00
1969	13.80	0.05	0.00	0.00	62.60	0.24	0.00
1970	26.50	0.00	0.00	0.00	84.80	0.00	0.00
1971	25.70	0.00	0.00	0.00	69.50	0.00	0.00
1972	23.10	0.00	0.00	0.00	69.70	0.10	0.00
1973	66.20	0.00	0.00	0.00	64.90	0.00	0.00
1974	12.90	0.00	0.00	0.00	89.10	0.00	0.00
1975	10.40	0.00	0.00	0.00	132.00	0.00	0.00
1976	8.20	0.00	0.00	0.00	83.90	0.00	0.00
1977	46.30	0.10	0.00	0.00	112.30	0.55	0.00
1978	47.50	0.18	0.00	0.00	133.00	4.38	0.00
1979	90.50	26.04	0.00	0.00	190.00	14.48	0.00
1980	59.00	11.25	0.00	0.00	168.50	9.18	0.00
1981	49.10	4.97	0.00	0.00	122.30	5.90	0.00
1982	22.20	12.98	0.00	0.00	48.70	2.01	0.00
1983	26.80	0.88	0.00	0.00	67.30	1.85	0.00
1984	46.40	1.24	0.00	0.00	124.80	37.39	0.00
1985	82.00	3.97	0.00	0.00	235.50	8.93	0.00
1986	93.90	0.18	0.00	26.28	592.60	13.36	0.00
1987	100.60	0.35	0.00	46.79	578.70	31.61	0.00
1988	130.80	0.01	0.00	40.80	620.40	15.83	0.00
1989	125.50	0.01	0.00	35.68	838.00	36.17	0.00
1990	135.20	0.00	0.00	14.35	1033.70	48.19	0.00
1991	114.90	0.00	0.00	8.99	1041.40	32.16	0.00
1992	30.10	0.06	0.00	12.75	925.90	38.50	0.00
1993	41.60	0.01	0.00	17.02	1040.70	45.31	0.00
1994	86.40	0.36	0.00	21.05	660.80	81.60	0.00
1995	38.00	0.05	0.65	13.24	643.90	46.47	44.15
1996	24.50	0.00	1.01	47.64	357.10	19.96	70.46
1997	25.70	0.02	1.92	24.74	357.20	19.40	52.19
1998	24.20	0.00	5.75	13.71	309.50	15.80	220.38
1999	22.80	0.00	1.10	29.97	267.40	14.78	102.22
2000	23.80	0.00	0.44	20.24	228.50	16.93	214.81
2001	24.90	0.00	0.83	28.43	206.50	13.33	240.57
2002	0.60	0.01	0.01	10.82	135.10	12.59	165.66
2003	5.10	0.00	0.00	12.23	74.70	13.39	141.45
2004	3.20	0.02	0.19	9.92	63.30	9.55	127.33

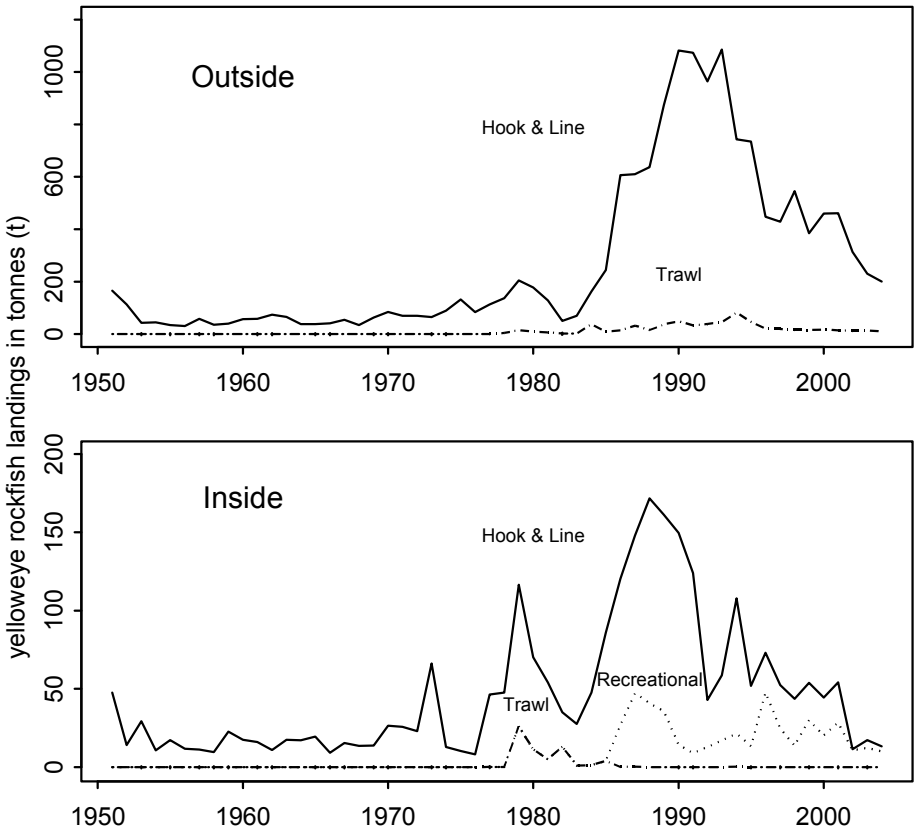

Figure 12. Total cumulative landings of yelloweye rockfish, by gear for the outside (top panel) and inside (bottom panel) areas, from 1951 to 2004. Data sources from 1951 to 1994 is the DFO sale slip data and from 1995 to 2004 is the DFO PacHarv database. The solid line represents landings by hook and line gears, dash-dot line represents catch by trawl gear, light dots represents catch by recreational gear.

The 2005 coastwide commercial annual total allowable catch is 236 t allocated to the outside ZN hook and line rockfish fishery (147 t), halibut fishery (76t), trawl fishery (7t), and the inside ZN hook and line rockfish fishery (6 t). TACs have remained at this low level since 2002 and more areas closed to fishing, Rockfish Conservation Areas (RCAs) have been implemented coastwide. Prior to the implementation of the Rockfish Conservation Strategy in 2001, the landed commercial catch of yelloweye rockfish coastwide was almost 600 t. In the early 1990's the yelloweye rockfish catch peaked at about 1200 t.

2. Recreational Catch

Their large size and relatively shallow preferred depths (less than 100 m) make yelloweye rockfish an important species to the recreational fishery. While it is often a primary target of individual anglers, it is more frequently encountered as incidental catch in the pursuit of lingcod and halibut in the North coast and West coast Vancouver Island recreational fisheries (Maynard pers. comm. 2005). In the Strait of Georgia, the fishing effort directed towards yelloweye rockfish has declined due to both the low abundance as well as an overall reduction in fishing effort (Maynard pers. comm. 2005). In the Strait of Georgia, since 2001, the recreational catch of rockfish is estimated to be larger than the commercial catch (Table 13).

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 (http://www.dfo-mpo.gc.ca/communic/statistics/recreational/canada/2000/index_e.htm). 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 14).

Table 14. 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. Yelloweye rockfish are estimated from this survey by applying a 5% proportion to the overall rockfish catch (Collicutt and Shardlow 1990, 1992) then converting numbers to weight by applying an average weight (3.2 kg). Yelloweye rockfish catch in the Strait of Georgia creel survey is shown in Table 13, and is approximately 10 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 yelloweye rockfish catch extrapolated in the same way as the Strait of Georgia creel survey show the National survey estimate for the inside fishery as 85 t whereas the Pacific Region survey estimates 20 t in the same year (2000). This is a concern as the majority of the

yelloweye catch on the inside is taken by the recreational fishing sector.

An estimate of recreational catch from the National Survey for the outside area is 56 t based on the same extrapolation as the inside in 2000.

3. Aboriginal Catch

There is no information available to understand either present day or historical traditional use of yelloweye rockfish to the several coastal First Nation bands along BC's coast and therefore this aspect of the report is incomplete. Yelloweye rockfish has likely always been an important species to all coastal First Nations. Early ethnographers all recognized the importance of the "various specimens of cod" as important to a variety of coastal First Nations (Boas 1895). Explicit reference to rockfishes as a subgroup is absent in the early ethnographies (Stewart 1975). Archaeological records of *Sebastes sp.* based on the presence of otoliths, skulls, and pelvic girdle bones are typically only classified to the genus (i.e., *Sebastes*).

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

Catch Summary

Prior to 1982, catch records for yelloweye rockfish were not species specific and typically lumped with other rockfish, groundfish and other fish. Anecdotal evidence and early catch statistics confirm that yelloweye rockfish harvests did occur in the Strait of Georgia, West coast of Vancouver Island and the North coast prior to "official" DFO sale slip records beginning in 1951. The tonnage of yelloweye rockfish catch is not derivable from existing sources of data primarily due to the lack of information on species compositions.

The discarding of rockfishes, including yelloweye rockfish, is unknown prior to 100% observer programs for commercial trawl fisheries in 1995 and partial observer coverage for commercial hook and line fisheries in 1999. Because yelloweye rockfish is a highly prized food fish, discarding of this species is probably less than other rockfishes but the economics of fishing varies between fisheries and over time and discarding levels are difficult to assess retrospectively. The mortality associated with discarding is unknown for all the fisheries and at this time is considered 100%.

Estimated cumulative catches of yelloweye rockfish coastwide from DFO sources are shown in Table 13 and Figure 12. Estimates of recreational catch and effort by species can not be estimated on an annual basis for all areas of the coast. This is a concern, as is the lack of catch statistics from the Aboriginal fisheries.

POPULATION SIZES AND TRENDS

Search effort

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

Abundance

Research longline fishing as well as visual surveys directed for yelloweye rockfish index abundance but there are no additional data, such as catchability of the longline gear, area swept calculations in visual surveys or probability of detection functions available to directly apply the relative abundance indices to assess absolute abundance of yelloweye rockfish in BC. Trawl surveys, however, use an area swept expansion to estimate biomass for yelloweye rockfish. Area swept bottom trawl survey data should be considered a minimum biomass estimate as the bottom trawl gear is not able to survey rocky reef habitats where yelloweye rockfish primarily aggregate (Jagielo et al. 2003). Figure 13 illustrate the areas surveyed on the BC coast and Table 15 shows the corresponding biomass estimates from the bottom trawl surveys.

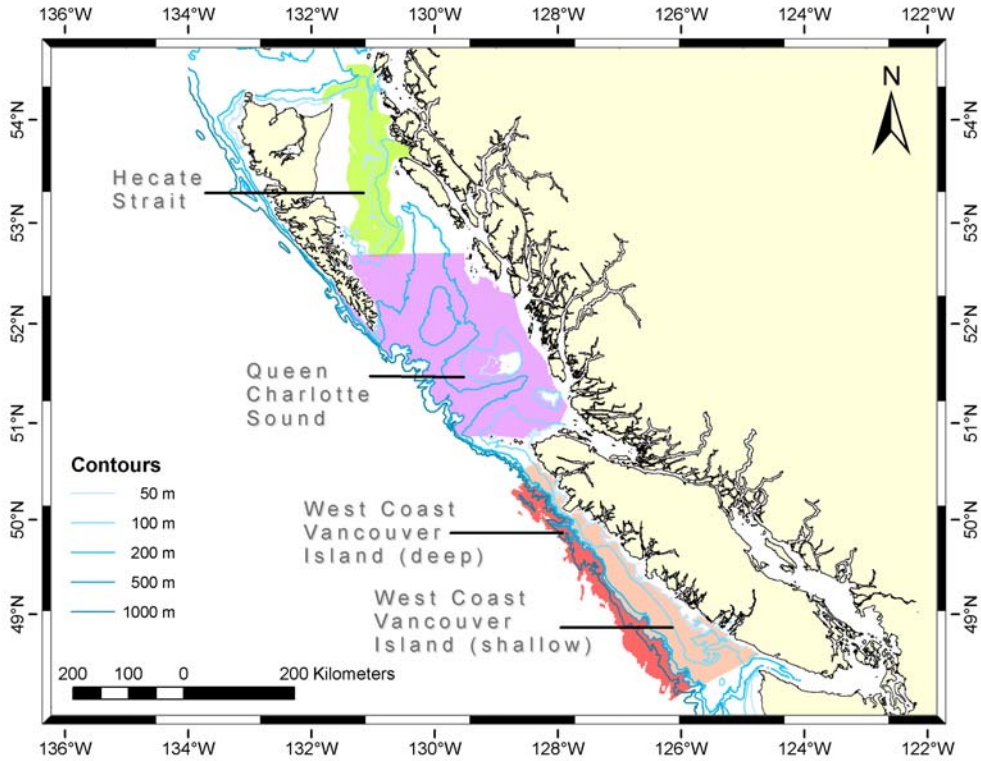

Figure 13. Trawl survey areas for the outside area.

Table 15. Biomass estimate (area expanded) from bottom trawl surveys. Minimum estimate for yelloweye rockfish based on trawlable bottom only. Yelloweye rockfish occur primarily over hard, untrawlable bottom.

Survey	Year	Index (tonnes)	Std. Dev.
West Coast V.I. (shallow)	2004	249	109
West Coast V.I. (deep)	2003	0	0
Queen Charlotte Sound	2004	471	247
Hecate Strait	2003	0	0

Fluctuations and trends

1. Coastwide commercial catch data

1a. Commercial hook and line rockfish (ZN)

Population trends for yelloweye rockfish can be constructed from the commercial ZN fishery catch and effort data recorded on logbooks (1986 – 2004). This is the longest time series of catch per unit of effort (CPUE) data available. The majority of the fishing outside of the Strait of Georgia management region is conducted with longline gear. Inside the Strait of Georgia the fishery is conducted largely with handline gear. Catch per unit effort data from the directed commercial rockfish (ZN) fishery are shown in Figure 14 by gear type and area.

There are many problems with interpreting abundance trends derived from fishery CPUE data. The most significant of these, for yelloweye 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 limited the number of licences in the ZN fishery. Particularly high CPUE, prior to 1991, may be due to an increased effort to record landings and become eligible for a license. 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 yelloweye rockfish have steadily declined from 1991 to 2002 (~1000 t to 236 t). As with other fishery dependent catch indices, CPUE is affected by the catch, lowering TACs will lower CPUEs. Fishermen claim that decreasing TACs result in lowered CPUE as fishing becomes more non-directed and yelloweye 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 suppy a constant supply of fish to the live market. CPUE indices from this commercial catch data are likely uninformative and reflect changes in management rather than population trends.

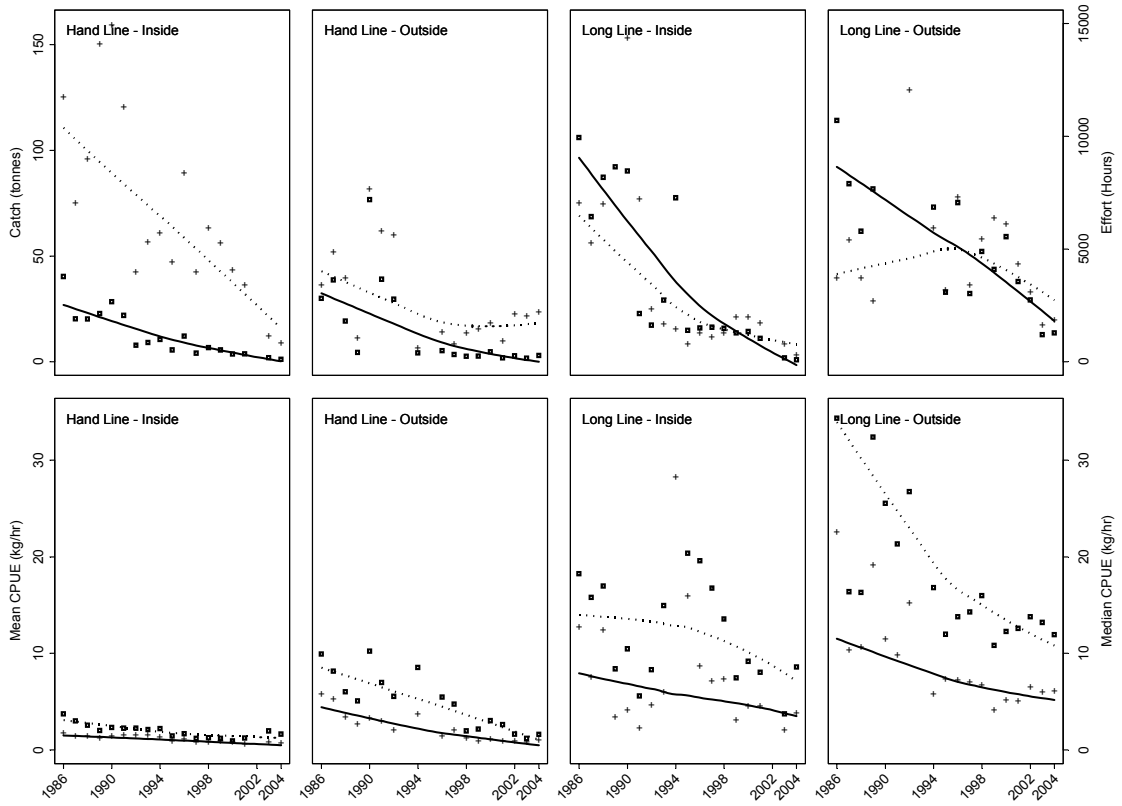

Figure 14. Commercial catch data by gear type (handline and longline) and area (inside and outside) for yelloweye rockfish in the directed ZN fishery. Upper panels display catch (square) and effort (plus). Solid line is a local regression fit of catch, dotted line is a local regression fit of effort. Lower panels display mean (square) and median (plus) catch per unit of effort. Solid line is a local regression fit of median CPUEs, dotted line is a local regression fit of mean CPUEs.

1b. 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 15). Yelloweye 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 instead reflect avoidance of species by fishers.

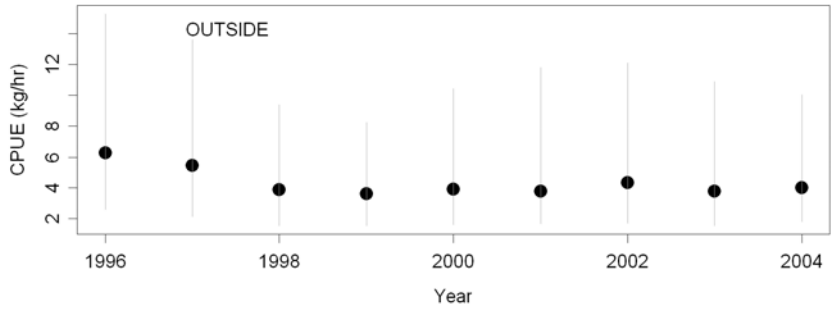

Figure 15. Commercial trawl fishery observed yelloweye rockfish catch per unit of effort (kg/hr) by year.

2. Trends in size and age

Trends in forklength and age by sex and area for yelloweye are shown in Figure 16. Yelloweye rockfish proportion-at-age data by year, sex and area are shown in Figure 17. Long-term trends are difficult to interpret from this data as sampling of yelloweye was sporadic and generally of low sample size up until the first surveys were conducted on the outside in 1997. Size at age generally increases with increasing latitude for yelloweye rockfish and trends may not be apparent without a consistent sampling strategy (Kronlund and Yamanaka 2001, Yamanaka and Lacko 2001). The proportion-at-age-data from the outside area show the progression of ages from the late 1990's which is reflected in increasing mean lengths and ages from 2000 (Figures 18 and 19). It appears that there is good recruitment of yelloweye rockfish progressing through the fishery in the outside area.

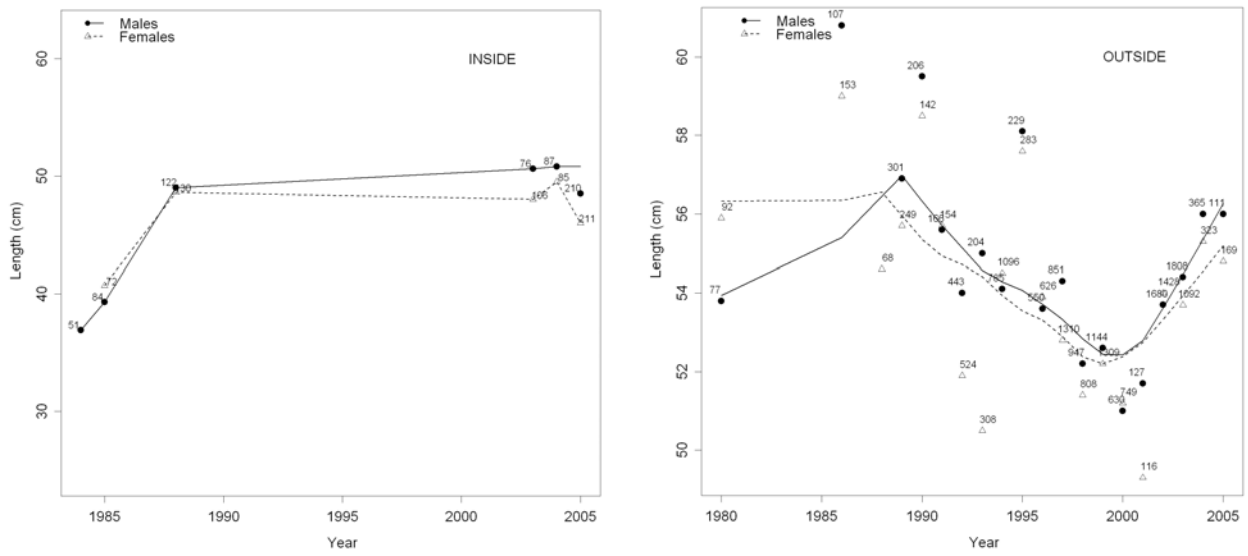

Figure 16. Mean lengths by year for yelloweye rockfish (males solid line, females dotted line) for the outside (left panel) and inside (right panel) areas. The lines shown are produced from the best-fit locally weighted regression of mean length by year.

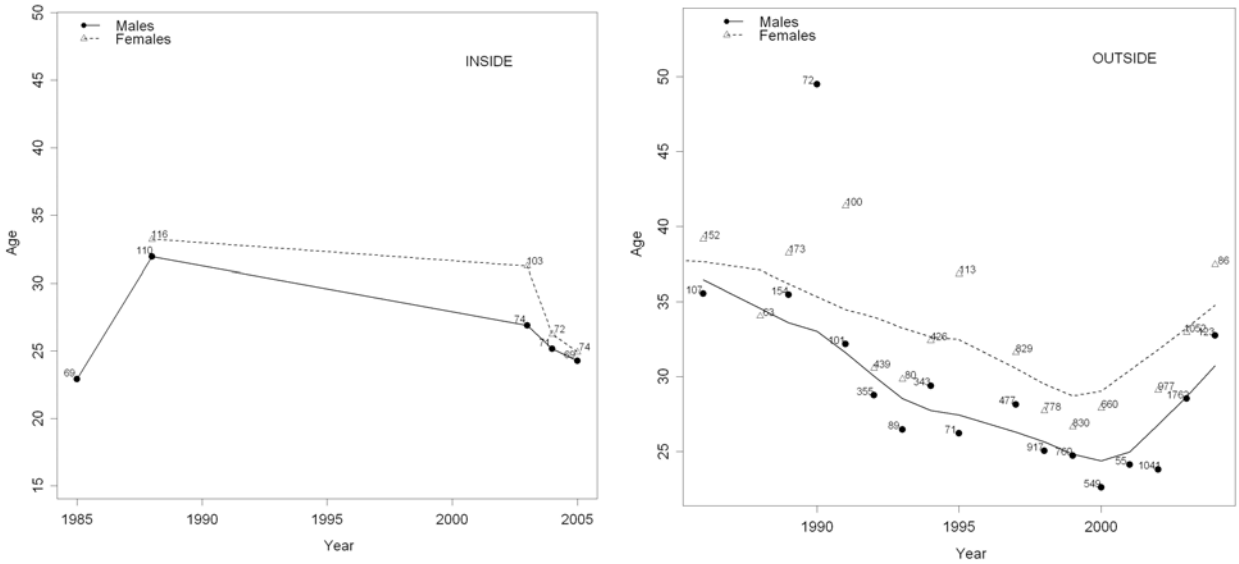

Figure 17. Mean ages by year for yelloweye rockfish (males solid line, females dotted line) for the outside (left panel) and inside (right panel) areas. The lines shown are produced from the best-fit locally weighted regression of mean length by year.

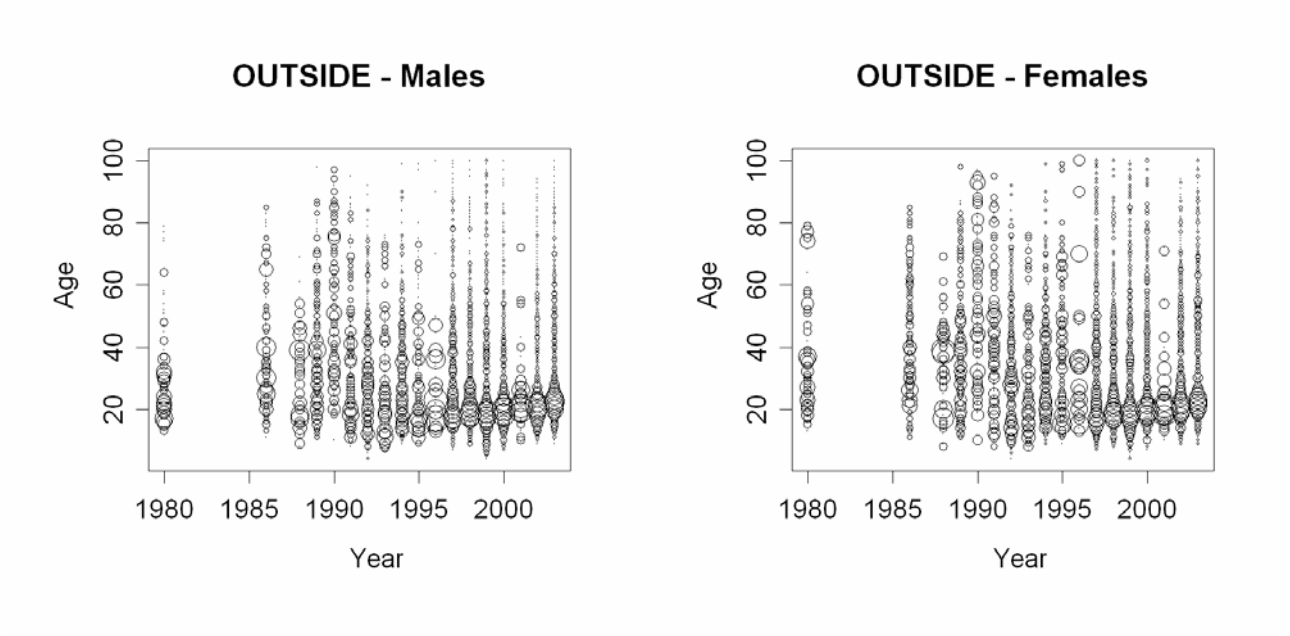

Figure 18. Outside area yelloweye rockfish proportions at age by year (males left panel, females right panel).

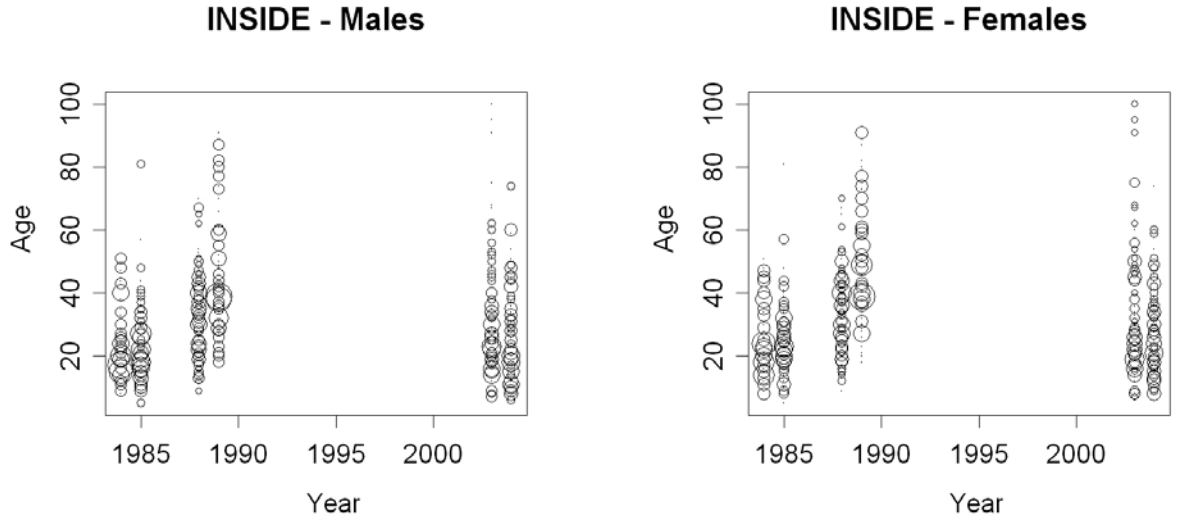

Figure 19. Inside area yelloweye rockfish proportions at age by year (males left panel, females right panel).

3. Outside surveys

3a. Research Charters Surveys

Chartered commercial fishing vessels conducted research surveys to index yelloweye rockfish abundance and collect biological samples for stock assessment purposes (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 20.). These were followed five years later by the same survey conducted in September 2002 and May 2003. CPUE indices are shown in Figure 21 and Table 16. There is no trend in the CPUE data between 1997 and 2004.

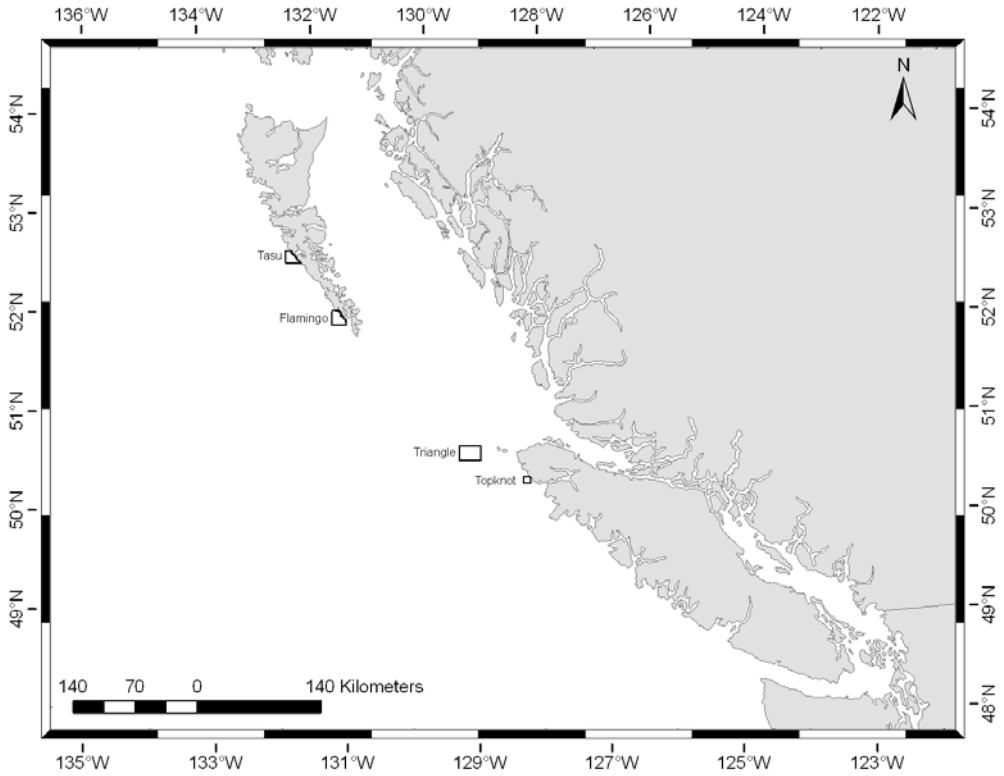

Figure 20. Four study sites surveyed for yelloweye rockfish by chartered fishing vessels in 1997/98 and 2002/03. Paired sites, lightly and heavily fished, off the Queen Charlotte Islands (Tasu and Flamingo) and the North West of Vancouver Island (Triangle and Topknot).

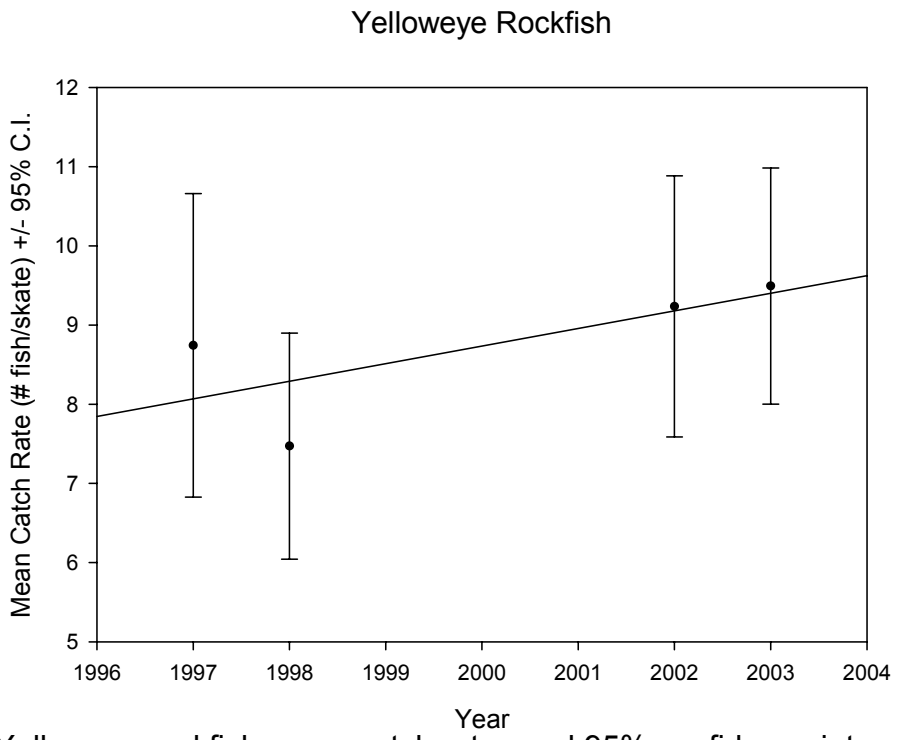

Figure 21. Yelloweye rockfish mean catch rates and 95% confidence intervals from the charter vessel surveys in the outside area. Slope of the trend line is not significantly different from zero (r^2 = 0.0122, F = 2.23, df = 1, 181, p = 0.1373).

Table 16. Catch per unit of effort statistics by year for yelloweye rockfish during the charter vessel research surveys.

Yelloweye Longline survey	Fall 1997	Spring 1998	Fall 2002	Spring 2003
Mean	29.3	26.2	34.8	35.8
Standard Error	2.8	3	3.2	3
1st Quartile	14.8	9.8	20.2	20
Median	28.3	20.8	29.5	32.9
3rd Quartile	42.2	41.2	42.5	41.2
Standard Deviation	15.4	20.4	21.3	19.7
Sample Variance	237.9	417.8	455.6	386.8
Minimum	6.1	2.8	7	9.3
Maximum	55.4	93.5	107.6	99.6
Total Number of Sets	63	80	45	43
Confidence Level(95.0%)	5.8	6.1	6.4	6.1

3b. IPHC SSA

The International Pacific Halibut Commission (IPHC) conducts a Standardized Stock Assessment (SSA) 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). The survey set locations differed in 1995 from those in 2003/04 (shown in the left panel of Figure 22). Only those sites common in all years, were used to calculate a cpue index (shown in the right panel of Figure 22).

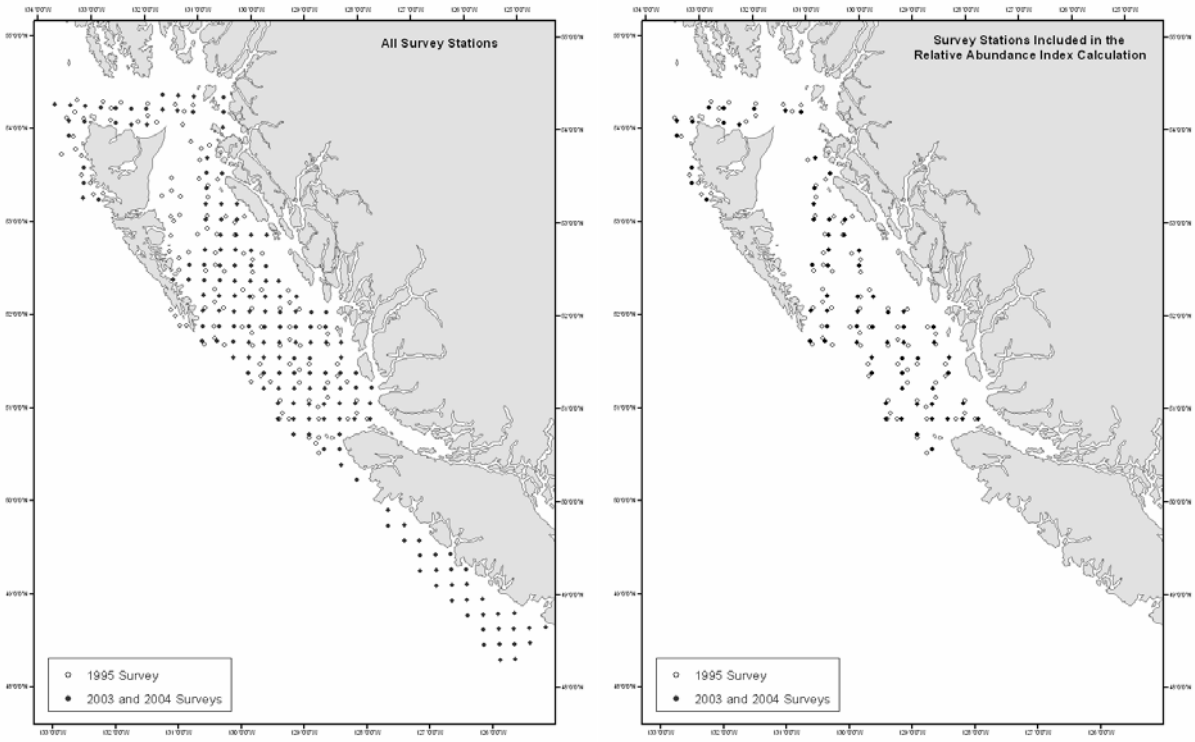

Figure 22. IPHC SSA survey locations for 1995, 2003 and 2004 surveys in BC (left panel). Open circles represent survey sites in 1995, filled circles represent survey sites in 2003 and 2004. Overlapping sites surveyed in all years that were included in the CPUE index (right panel).

Yelloweye rockfish are generally caught throughout the survey area. Catch rates vary widely and range from 0 to 20 fish per skate (Figure 23.) A catch rate index is constructed from survey sets that overlapped during the 1995, 2003 and 2004 surveys (Figure 24 and Table 17). There is no trend in catch rate detected over the 1995 to 2004 time series.

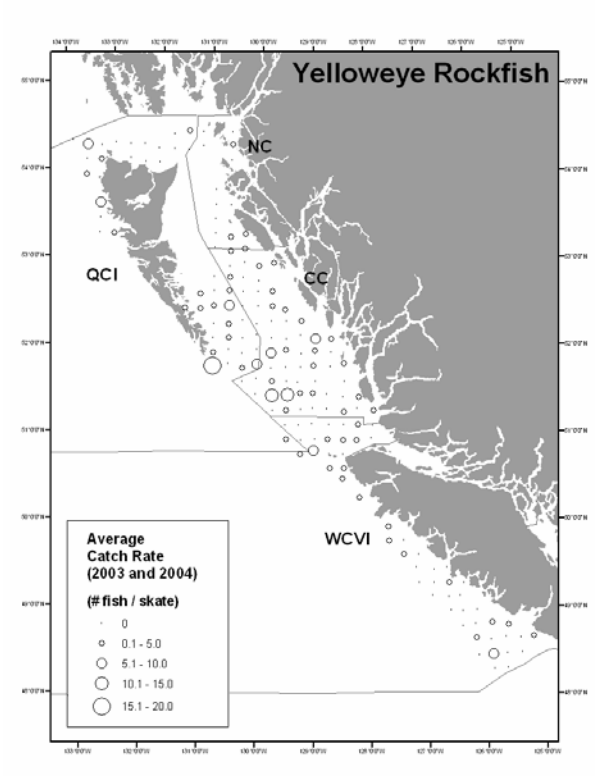

Figure 23. Spatial distribution of yelloweye rockfish catch rates from the IPHC SSA survey in BC for the years 2003 and 2004 combined.

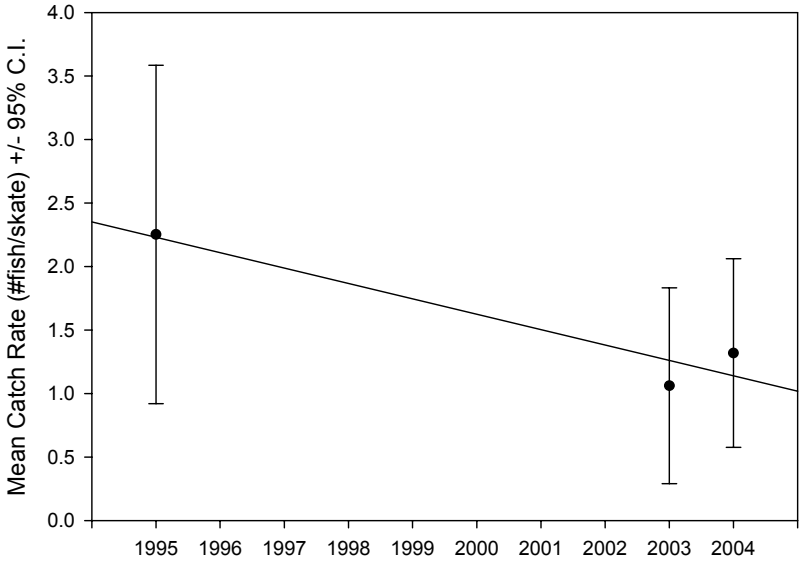

Figure 24. Yelloweye rockfish mean catch rates and 95% confidence intervals (CI) by year for the IPHC SSA survey. Slope of regression line is not significantly different from zero ($r^2 = 0.013$, $F = 2.77$, $df = 1, 213$, $p = 0.098$).

Table 17. Summary statistics for yelloweye rockfish 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	2.25	1.06	1.32
Standard Error	0.67	0.39	0.37
1st Quartile	0	0	0
Median	0	0	0
3rd Quartile	0.40	0.69	0.88
Mode	0	0	0
Standard Deviation	6.02	3.16	3.04
Sample Variance	36.27	10.00	9.27
Minimum	0	0	0
Maximum	33.80	22.88	16.88
Total Number of Sets	81	67	67
Confidence Interval (95.0%)	1.33	0.77	0.74

4. Inside research surveys

4a. Longline surveys

A new longline survey was initiated to provide an abundance index for inshore rockfish in the inside waters (Lochead and Yamanaka 2004, 2005). This survey has been conducted in 2003 and 2004 in the northern portion of the inside waters, DFO statistical areas (SA) 12 and 13, and in 2005 covered the southern portion of the inside waters, SA 14 through 20, 28 and 29 (Figure 25). No differences in CPUE from the two surveys in areas 12 and 13 are detected (Lochead and Yamanaka 2005). There appears to be no difference in overall catch rate for yelloweye rockfish among all the surveys throughout the inside area (Figure 26). Yelloweye rockfish CPUE indices are no different between the northern and southern portions of the inside area.

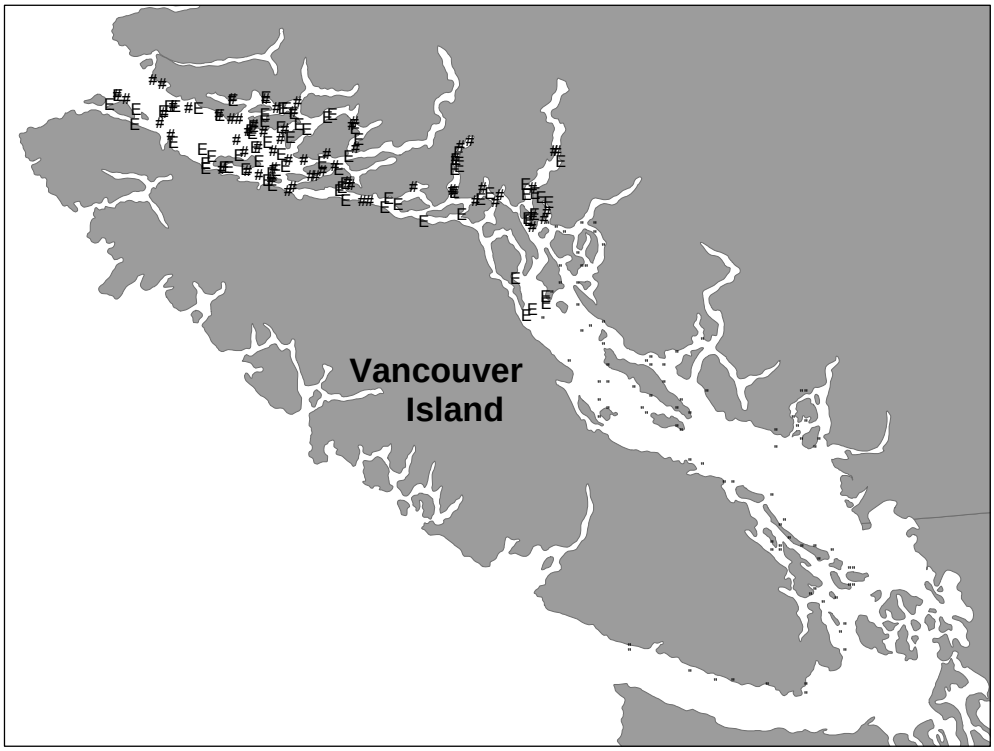

Figure 25. Longline survey set locations fished by year (plus = 2003, triangle = 2004, and square = 2005).

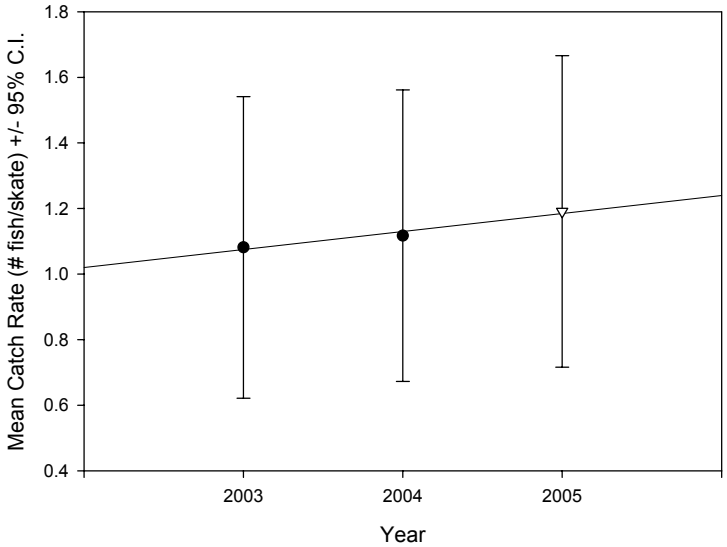

Figure 26. Yelloweye rockfish mean catch rate and 95% confidence interval (CI) for the inside area longline survey. The survey was conducted in SA 12 and 13 in 2003 and 2004 (filled circles) and in SA 14 through 20, 28 and 29 in 2005 (open triangle) (r^2 = 0.0005, F = 0.12, df = 1,231, p = 0.7288).

4b. Submersible surveys

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 27 and Table 18 (Richards and Cass 1985, Yamanaka et al. 2004). Comparisons of the number of fish observed per transect between common sites and depths surveyed between 1984 and 2003 are shown in Figure 28. No significant differences in fish observed per transect were found between the two surveys.

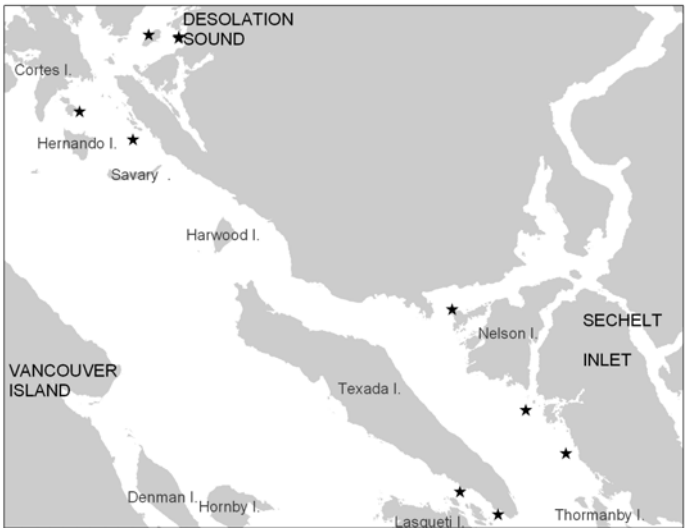

Figure 27. Submersible transect sites surveyed in 1984 and 2003 near Desolation Sound and Sechelt within the Strait of Georgia, inside area.

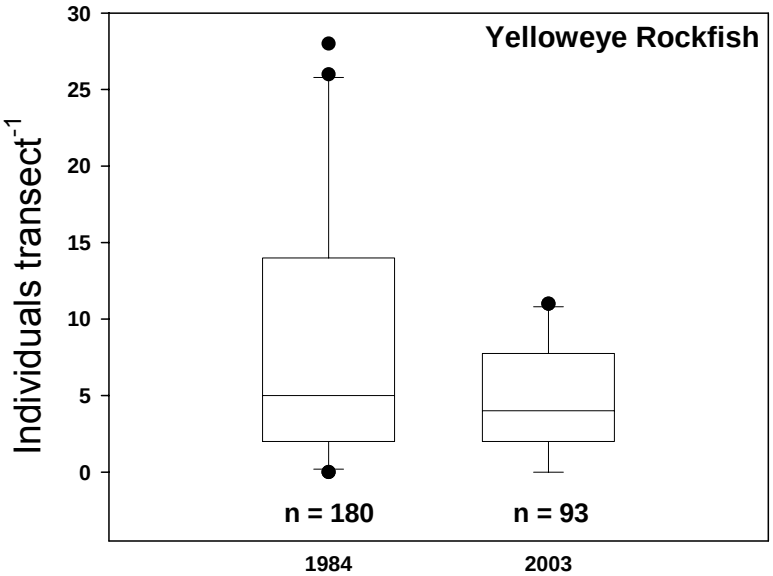

Figure 28. Boxplot of the number of yelloweye rockfish observed per transect at common sites and depths during submersible surveys conducted in 1984 and 2003.

Table 18. Summary statistics of yelloweye rockfish observed per transect during submersible dives in 1984 and 2003.

Numbers of yelloweye rockfish per transect		
	1984	2003
Number of transects	21	20
Mean	8.57	4.65
Standard Error	1.97	0.80
Median	5	4
Standard Deviation	9.03	3.56
Sample Variance	81.46	12.66
Range	28	11
Minimum	0	0
Maximum	28	11
Confidence Level(95.0%)	4.11	1.67

Summary of trends

The longest time series of relative abundance trends are derived from fishery dependant CPUE data recorded in logbooks. These are difficult to interpret over long periods of declining TACs and changes in management of the fishery. Biological data are also difficult to interpret due to low sample size prior to directed surveys in the outside area in 1997. A trend of increasing size, age and a progression of age proportions are evident in the samples from 1997 to 2004.

For the outside area, research survey CPUE data is also available through DFO's directed surveys on yelloweye rockfish and from the IPHC's SSA survey directed on halibut. There is no trend in CPUE between 1997 and 2003 in the directed surveys for yelloweye on the outside. The IPHC SSA survey shows no trend in CPUE from 1995 to 2004.

For the inside area, directed inshore rockfish longline surveys show no trend in CPUE over the three years of the survey, 2003 to 2005. There appears to be no difference in CPUE between the northern and southern portions of the inside area. Submersible surveys provided a visual index of abundance for yelloweye rockfish between 1984 and 2003. No differences in counts per transect were detected between these two surveys for yelloweye rockfish, although significant declines were detected for quillback rockfish (Yamanaka et al. 2004).

Rescue effect

Repopulation of yelloweye rockfish through the dispersal of larvae from adults living outside of Canada is likely as there are no physical barriers to dispersal in the marine environment. Yelloweye rockfish exist both to the north as well as the south of B.C. Yelloweye rockfish sampled along the coast from SE Alaska to Astoria Oregon are not genetically distinguishable and their habitats are similar. Repopulation rates are

unknown. Based on population status, repopulation of yelloweye rockfish from Alaska is more likely than from Washington.

1. Washington, Oregon and California

Yelloweye rockfish occur in American waters both to the north and south of BC. The U.S. west coast (Washington, Oregon and California) yelloweye rockfish stock declined sharply in the 1980's and early 1990's and the spawning biomass has been below the 40% of SB_0 since 1990 (Wallace et al. 2005). Yelloweye rockfish was declared "overfished" in 2002, and has been managed under a 2002 rebuilding plan (Methot and Piner, 2002). The recommended harvest level for yelloweye rockfish for the U.S. west coast is 26 t. The current spawning biomass is at 20.5% of unfished, down from 23.3% estimated in the last stock assessment in 2002 (Wallace pers. comm. 2005).

2. Alaska

Yelloweye rockfish are within an aggregate of demersal shelf rockfish (DSR) that 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 yelloweye rockfish estimated an exploitable biomass of 20,168 t for the SEO. The ABC for yelloweye rockfish for the SEO was set at 450 t (O'Connell et al. 2003). Yelloweye rockfish within State waters is managed to 50 t catch quotas for the NSEI and SSEI areas combined (O'Connell pers comm).

LIMITING FACTORS AND THREATS

Successive years of low recruitment are a natural limiting factor for rockfish populations. The link between successful rockfish recruitment and environmental factors has not been made in BC. In California, links have been made to oceanographic conditions such as upwelling and strong onshore drift (Yoklavich et al. 1996). Other natural limiting factors for yelloweye rockfish are tsunamis, such as the one resulting from the March 1964 earthquake in Anchorage, which lead to widespread mortalities from barotramatic effects. Yelloweye rockfish were seen floating at the surface in tide lines at the head of inlets along the west coast of Vancouver Island. (Andrew Amos pers comm, Alex Ward pers comm).

The fisheries are potential anthropogenic threats to the yelloweye rockfish population in BC but they are monitored assessed and managed by DFO. DFO's Rockfish Conservation Strategy, initiated in 2002, has implemented RCAs (closed areas) in 20% to 30% of rockfish habitats coastwide, decreased allowable catches by 75% and 50% between 2001 and 2002 and increased the monitoring and stock assessment research for yelloweye rockfish. Commercial fisheries are managed to total allowable catches through 100% dockside monitoring together with partial at-sea

observer programs (to be 100% monitored in 2006). Recreational fisheries are managed by bag limits and monitored by creel surveys in various areas coastwide. Recreational and Aboriginal harvests are not estimated on a coastwide basis.

SPECIAL SIGNIFICANCE OF THE SPECIES

The ecological role of yelloweye rockfish is not known but given their longevity, large size, and piscivorous habit, they are likely important in structuring near shore rocky reef ecosystems. Aside from their ecological significance, they are an important component in commercial, aboriginal, and recreational fishing sectors.

Legends of the Kwicksutaineuk-ah-kwaw-ah-mish First Nation situated on Gilford Island (Broughton Archipelago) involve an “underwater world” comprised of a variety of animals, one of which is “glowuksum” or yelloweye rockfish (Figure 29; Sewid pers. comm. 2005).

Figure 29. Photograph of a painting by artist Alan James depicting ‘glowuksum’ or yelloweye rockfish as part of the “underwater world” legends of the Kwicksutaineuk-ah-kwaw-ah-mish First Nation. Painting located on Gilford Island, British Columbia. Photo credit: S. Wallace

Sgan Gwaii on the southwest coast of the Queen Charlotte Islands directly translates as “yelloweye island” from “sgan” the Haida word for yelloweye rockfish (Jones 1999). The island is well known by the Haida for the abundance of yelloweye; it was said that yelloweye could be taken in any type of weather. The Ninstints site on the island of *Sgan Gwaii* was the main village of the Kunghit Haida and is now a United Nations World Heritage Site.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The yelloweye rockfish does not have any international status designations. In U.S. waters south of British Columbia, yelloweye rockfish have been declared “overfished”. In British Columbia, yelloweye are protected by various catch quota restrictions in both the commercial and recreational fishery. BC’s Rockfish Conservation Strategy has decreased the total allowable catch of yelloweye rockfish by 50% outside and 75% inside between 2001 and 2002. The coastwide overall sector total allowable catches for 2005/06 is 300 t. Rockfish Conservation Areas (areas closed to fishing) protect 20% of rockfish habitats outside and consultations to protect 30% of rockfish habitats on the inside will be complete for the 2006 fishery. These closed areas are intended to protect yelloweye rockfish.

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

1. The Surveys

a) Research charters

Research surveys were developed with the ZN industry in 1997 to determine the fishery's effect on catch rates and population demographics at selected index sites in the outside area. Industry members identified discrete pairs of fishing areas with contrasting fishing histories (lightly and heavily exploited), one pair off the South West Queen Charlotte Islands and the other pair off the North West Coast of Vancouver Island. The Tasu and Triangle sites were deemed lightly exploited and Flamingo and TopKnot sites, heavily exploited (Kronlund and Yamanaka 2001).

Two seasons were sampled, fall and spring, and no differences in catch rate and population demographics were determined so the data were combined to represent annual surveys (Yamanaka et al. 2004). Two depth intervals (37-110 m, 111-201 m) were surveyed at each site with 200 fish targeted at each depth. Data for both annual surveys were depth filtered to include only depths between 80 and 225 m.

b) IPHC SSA

The IPHC conducts their SSA survey annually to assess Pacific halibut from southern Oregon through BC to the Aleutian Islands. A fixed station survey design is fished by chartered commercial fishing vessels using standardized conventional gear. Since 2003, data on the total catch by species and biological samples for rockfish have been collected in the BC portion (IPHC Area 2B) of the survey (Yamanaka et al. 2004). Age data from the yelloweye rockfish collected during the 2003 and 2004 surveys were used for the catch curves. The age data were not depth filtered.

c) DFO longline survey

A longline survey directed for inshore rockfish was initiated in 2003 and surveyed the northern portion of the inside area (statistical areas 12 and 13) from Campbell River in the south to Hope Island in the north (Lochead and Yamanaka 2004). The survey uses a depth stratified (40 to 70 m and 71 – 100 m) random design. Data for the 2003 and 2004 surveys were used in the analysis, and the age data were not depth filtered.

2. Age data

Sagittal otoliths collected from surveys are assigned ages using a burnt section technique (MacLellan 1997) at the Pacific Biological Station Ageing Lab. Age data are stored in the PBS groundfish research database GFBio.

To standardize the ages, in each of the research charter paired surveys, one year

was added to the earlier survey data then both year's ages were combined for the analysis. For example, one year was added to the 1997 ages before combining the ages with the 1998 age data.

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. R^2 values are also presented for the regression line (Figure 1.).

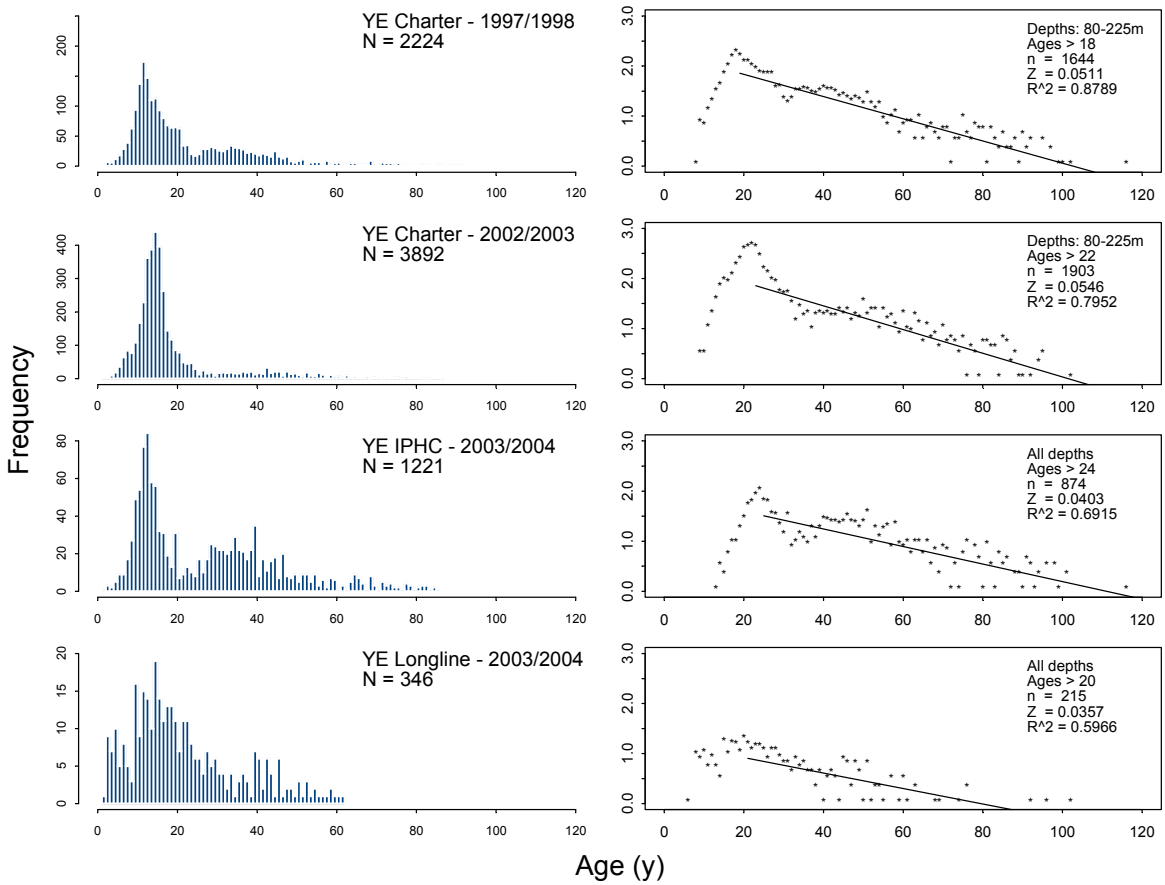

Figure 1. Age frequencies (left panels), log frequencies with regression line and calculated total mortality, Z and r^2 statistic for the outside research charters in 1997/98 (top), 2002/03 (second from top), outside IPHC SSA survey (second from bottom) and the inside DFO longline survey (bottom).