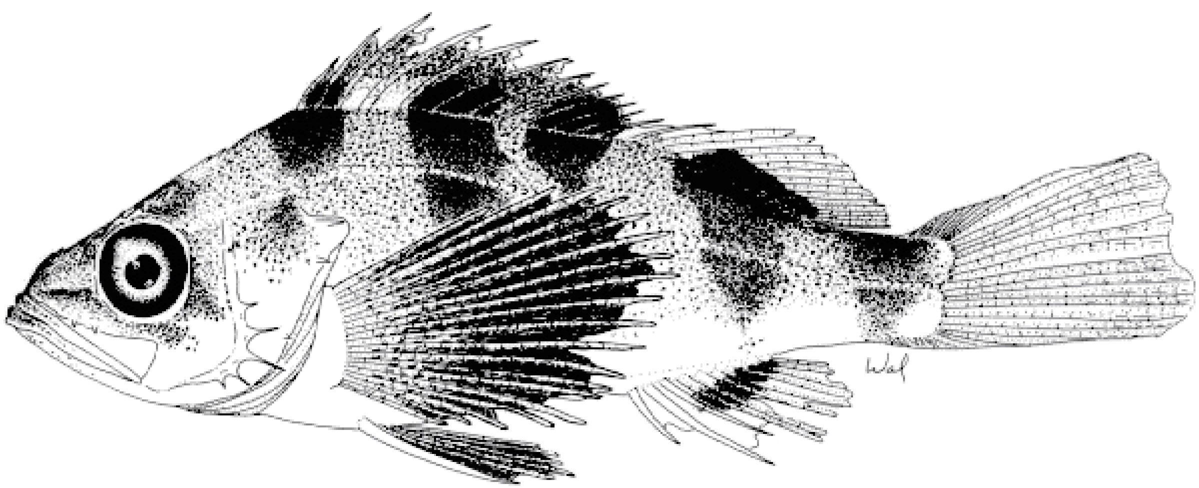
# COSEWIC
# Assessment and Status Report

on the

# Darkblotched Rockfish
*Sebastes crameri*

**in Canada**



**SPECIAL CONCERN**
**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 Darkblotched Rockfish *Sebastes crameri* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 48 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Production note:
COSEWIC acknowledges Andrea L. Smith for writing the status report on the Darkblotched Rockfish *Sebastes crameri* in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Howard Powles, Co-chair, and Robin Waples, Handling Member, 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 tacheté (*Sebastes crameri*) au Canada.

Cover illustration/photo:
Darkblotched Rockfish — Matarese *et al.* 1989.


Catalogue CW69-14/590-2010E-PDF
ISBN 978-1-100-15060-4

Recycled paper

# COSEWIC
# Assessment Summary

**Assessment Summary – November 2009**

**Common name**
Darkblotched Rockfish

**Scientific name**
*Sebastes crameri*

**Status**
Special Concern

**Reason for designation**
This long-lived species (maximum age 100 years; generation length 23 years) demonstrates episodic recruitment events. The species is taken at relatively low levels in fisheries targeting more abundant rockfishes. Research surveys show no clear abundance trends, although information on abundance trends has relatively high uncertainty. In adjacent US waters, the species declined 84% from 1928 to 1999 and is considered overfished, although there has been some recent population recovery. Recent surveys do not account for population declines from foreign fishing prior to the 1970s.

**Occurrence**
Pacific Ocean

**Status history**
Designated Special Concern in November 2009.

**COSEWIC**
**Executive Summary**

# Darkblotched Rockfish
*Sebastes crameri*

## Species information

The Darkblotched Rockfish, a member of the family Sebastidae (rockfishes), is found along the Pacific coast of North America, with over 60 other species of rockfish (over 35 of which occur in British Columbia). Its common names include “blackblotched rockfish”, “blackmouth rockfish” and “blotchie”. In French it is called Sébaste tacheté or Sébaste crameri. Adults are distinguished by four to five discrete dark blotches on their back, and range in colour from white to pink or red. Darkblotched Rockfish have venom glands in their spines. Males grow faster than females, but females are larger once mature. The maximum length of the species is 58 cm. No genetic studies have been conducted on Canadian populations, but research along the US west coast (northern California to Washington) show that significant genetic structure exists and that gene flow is restricted to neighbouring populations. Overall levels of genetic differentiation, however, are low among these US populations. A single population or designatable unit is present in Canada.

## Distribution

Darkblotched Rockfish range from Alaska to California, but are most abundant from British Columbia to central California. Within Canada, they are widespread in continental shelf and slope waters along the BC coast. The species is caught in high densities along the shelf northwest of Vancouver Island and in Moresby Gully, southeast of the Queen Charlotte Islands. The area of occupancy of Darkblotched Rockfish in Canadian waters is estimated to be 9000-31 000 $km^2$.

## Habitat

Immature Darkblotched Rockfish are pelagic and occur offshore in surface waters. Juveniles settle into benthic habitat and may be associated with either soft muddy or rocky bottom habitat. As individuals increase in size and age, they migrate to deeper waters, but remain as bottom dwellers, usually in areas of cobbles or boulders. Adults are typically caught between 150-435 m in British Columbia. Based on the species’ apparent depth and substrate preferences, approximately 43 000 $km^2$ of potential habitat is estimated to exist for Darkblotched Rockfish in Canada.

The continental shelf habitat associated with Darkblotched Rockfish is subject to intense fishing acitivity in BC, most notably commercial bottom trawling. Very little of this offshore area receives habitat protection. The species was declared overfished in Washington, Oregon and California in 2000, and as such in those states receives habitat protection in rockfish conservation areas that are off limits to fishing. Similar areas established to protect other groundfish species in Alaska and Canadian waters may also offer some protection to Darkblotched Rockfish habitat.

## Biology

Limited research has been conducted on Darkblotched Rockfish. The species has a protracted reproductive period, with mating occurring from August-December, fertilization from October-March and the release of live young from November-June (peaking in February in BC). Each female gives birth to between 20,000 and 610,000 young in a single event each season.

The age and size at which Darkblotched Rockfish mature appears to vary latitudinally. In BC, most individuals mature at approximately eight to nine years of age. The maximum age recorded for the species is 48 years old in Canada and 105 years old in the US. The generation time (average age of parents in the population) is 23 years.

Darkblotched Rockfish associate with several other groundfish, including Pacific Ocean Perch, Arrowtooth Flounder, and Yellowmouth Rockfish. Adults feed mainly on invertebrates. Juvenile Darkblotched Rockfish are eaten by Albacore, salmon and Pacific Hake. Like other rockfish, Darkblotched Rockfish have closed swim bladders, which make them vulnerable to injury when captured from deep water. Consequently, bycatch mortality is assumed close to 100%. Immature Darkblotched Rockfish have low dispersal capability (< 100 km) and adults appear to be highly sedentary.

## Population sizes and trends

Darkblotched Rockfish is a harvested species in Canada but is not subject to a species quota. Catch records have been relatively poor for groundfish over much of the fishery's history, up to the mid-1990s. The total coastwide catch by both domestic and foreign vessels since the 1930s has been at least 4200 tonnes (3 million fish). The average annual catch since dockside monitoring was implemented in 1994 is estimated at 74 tonnes. Catches of Darkblotched Rockfish are considerably higher in the US, averaging approximately 550 tonnes/year since 1994.

Research survey time series using methods well adapted to this species are generally too short to show trends. In other surveys, indices are highly variable, making it difficult to reliably estimate abundance of Darkblotched Rockfish in Canadian waters. Furthermore, surveys are not located in high density areas for the species. Commercial fishery catch per unit effort data from 1996-2006 were influenced by changes in the fishery and are not considered to track abundance well.

In the US, Darkblotched Rockfish showed an 84% decline in spawning stock between 1928 and 1999. The species is currently under a rebuilding plan and there has been some recent population recovery.

### Limiting factors and threats

Darkblotched Rockfish exhibit several life history traits which make them vulnerable to human activities, notably late maturation and long lifespan.

Commercial fishing is the primary threat to Darkblotched Rockfish. The species is caught mainly as a bycatch to Pacific Ocean Perch in the trawl fishery, in relatively small amounts. There is no directed fishery for Darkblotched Rockfish in Canada.

The lack of reliable historical and contemporary records on Darkblotched Rockfish abundance poses a challenge for determining the current population status of the species in Canada. A rebuilding plan was implemented for the species in the US in 2003 and a 2005 stock assessment shows gradual signs of recovery, although Darkblotched Rockfish spawning biomass is still at very low levels along the US west coast. Several areas of uncertainty exist in this stock assessment, which may lead to an underestimation of older fish in the population.

### Special significance of the species

The Darkblotched Rockfish is a commercially important species in the US, representing the fourth most common species caught by the commercial trawl fishery in 2004. In Canada, however, no directed catch of Darkblotched Rockfish exists and instead the species is caught as a bycatch in the Pacific Ocean Perch fishery. In the 2007-2008 fishing season, the total Canadian catch of Darkblotched Rockfish had a landed value of approximately $61 000.

### Existing protection

No specific protection exists for the species in Canadian waters, although general regulation of commercial fisheries is in effect. The Darkblotched Rockfish has been designated as overfished in the US and is currently managed under a rebuilding plan that regulates where, when, and by how much it can be harvested.

## 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.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

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

# COSEWIC Status Report

on the

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*Sebastes crameri*

**in Canada**

2009

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## SPECIES INFORMATION

### Name and classification

The Darkblotched Rockfish (*Sebastes crameri* Jordan, 1896) is a member of the order Scorpaeniformes and family Sebastidae. The genus *Sebastes* occurs worldwide but is concentrated along the Pacific coast of North America, where over 60 rockfish species have been identified (Clay and Kenchington 1986). Other common names for the Darkblotched Rockfish include blackblotched rockfish, blackmouth rockfish and blotchie (Love 2002). In French it is referred to as Sébaste tacheté or Sébaste crameri.

### Morphological description

Adult Darkblotched Rockfish range in colour from white to pink or red and are characterized by four to five discrete dark brown or black blotches on their backs which extend across the lateral line (Fig. 1). Juveniles are white with a dark patch on their gill cover, in addition to four to five brown to reddish-brown wide vertical bars, one of which is on the head, and the others extending from the dorsal fin almost to the belly (Love 2002). Adults have 7 to 8 head spines, as well as 13 dorsal and 3 anal spines. Darkblotched Rockfish have venom glands in their dorsal spines (Smith and Wheeler 2006).

Darkblotched Rockfish exhibit sexual dimorphism, with males achieving maximum length faster than females, but with mature females being larger at any given age than males (Love 2002). Males, however, tend to have longer spines, fin rays and upper jaw length (Lenarz and Wyllie Echeverria 1991). Maximum length is 58 cm (Love 2002).

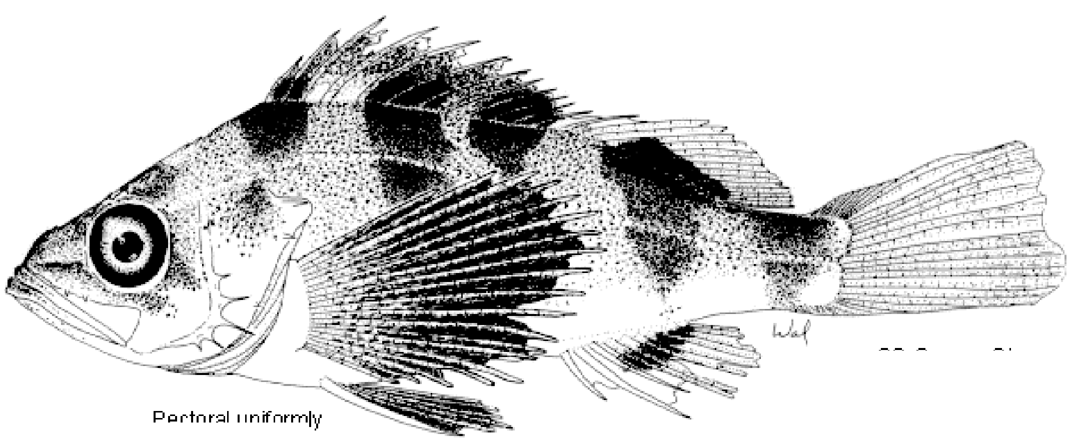


Figure 1. Line drawing of Darkblotched Rockfish adult (Matarese *et al.* 1989).

## Genetic description

No genetic studies of Darkblotched Rockfish populations have been conducted to date in British Columbia. Based on life history characteristics (see Biology section below) and genetic surveys of US populations of the species, however, populations in British Columbia are unlikely to be panmictic. Gomez-Uchida and Banks (2005) found that Darkblotched Rockfish populations from northern California to Washington showed low but significant genetic structure in three microsatellite loci ($F_{st}$ = 0.001, Fisher's $P$ = 0.0017) and exhibited an isolation-by-distance model of gene flow, indicating that genetic exchange was restricted to nearby populations ($r$ = 0.16, $P$ = 0.04). The low level of genetic differentiation among populations and lack of obvious phylogenetic groups identified with UPGMA trees suggest that occasional long-distance dispersal events may occur among geographically isolated populations.

## Designatable units

A single population or designatable unit is considered to exist in Canada.

# DISTRIBUTION

## Global range

The Darkblotched Rockfish is found in the northeast Pacific Ocean from the southeast Bering Sea and Aleutian Islands (Alaska) to Santa Catalina Island (California) (Allen and Smith 1988) (Fig. 2). It is most abundant from British Columbia to central California (Rogers 2005).

Figure 2. Global distribution of the Darkblotched Rockfish (indicated by area within line; Love 2002).

## Canadian range

Data from research trawl and submersible surveys indicate that the Darkblotched Rockfish is widespread in continental shelf and slope waters along the entire coast of British Columbia (Fig. 3; Wilkins *et al.* 1998; Fleischer 2005; Yamanaka 2005; Haigh and Starr 2008). Information on the historical distribution of the species is lacking, since it was often grouped with other rockfish species in research surveys and commercial catch records. Based on distribution data collected by onboard observers in the groundfish trawl fleet between 1996 and 2007, the highest concentrations of Darkblotched Rockfish are found along the shelf northwest of Vancouver Island and in Moresby Gully southeast of the Queen Charlotte Islands (Haigh and Starr 2008). The species is recorded both from Pacific Rim National Park and Gwaii Haanas National Park and Haida Heritage Site. Throughout its Canadian range the species is most commonly captured between depths of 150 and 435 m (Fig. 4).

Using CPUE (catch per unit effort) data from observed commercial trawl tows collected from 1996 to 2007, and a grid cell of 0.1$^0$ longitude x 0.075$^0$ latitude, the area of occupancy (AO) for this species was calculated as 30 760 km$^2$ (Fig. 3)[1]. Grid cell area varies latitudinally with this method but covers approximately 59 km$^2$ (7.7 km x 7.7 km). Using the same CPUE data with a Universal Transverse Mercator (UTM) grid cell size of 2 km x 2 km yields an AO of 9 232 km$^2$. The discrepancy between methods arises from the fact that, while a trawl tow covers tens of kilometres, it is represented in the data by only one or two points (i.e., at the start and possibly end of the tow) (Table 1). The smaller grid cell size may not coincide with either of these sampling points (Haigh and Starr 2008).

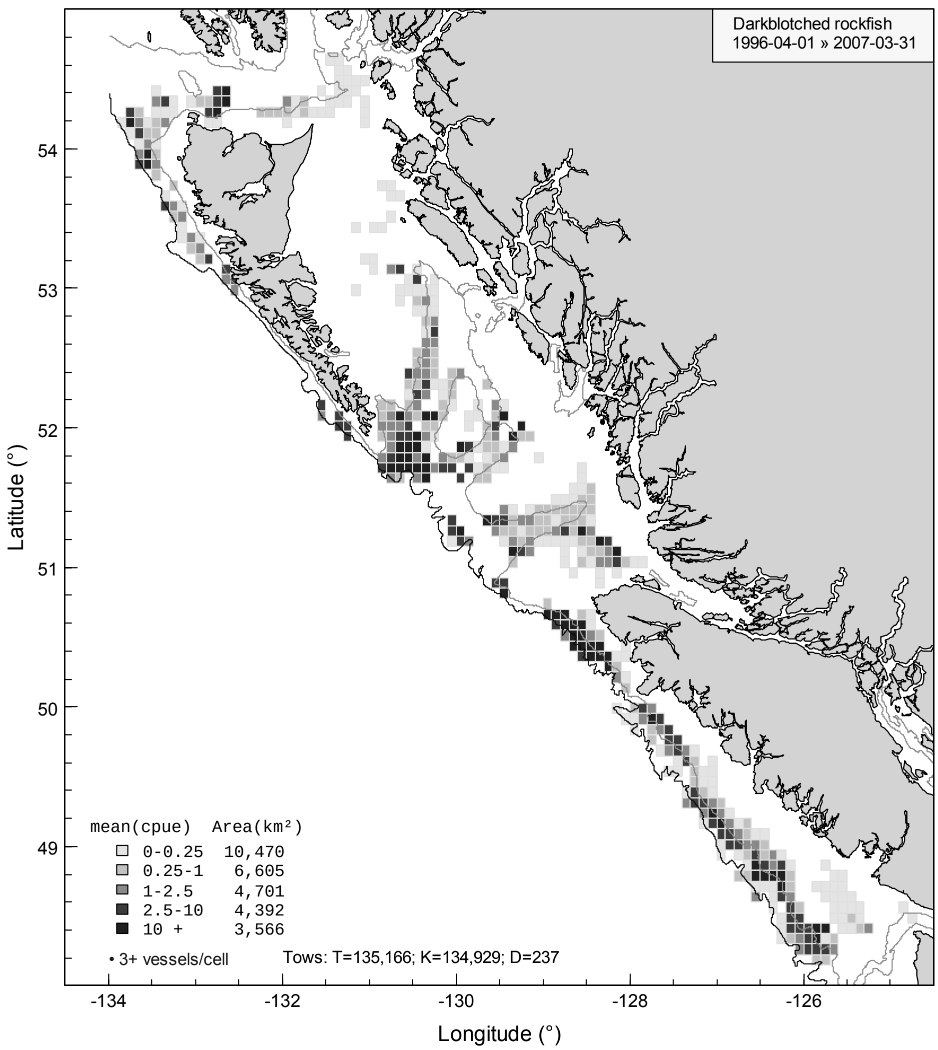


Figure 3. Mean CPUE (kg/h) of Darkblotched Rockfish caught by the trawl fishery in 0.10 x 0.0075 degree grid cells along the BC coast. Isobaths displayed are 200 m and 1000 m (from Haigh and Starr 2008).

[1] Note that, in all figures displaying AO, grid cells with fewer than three fishing vessels have been excluded due to privacy concerns. These grids are, however, included in all AO calculations.

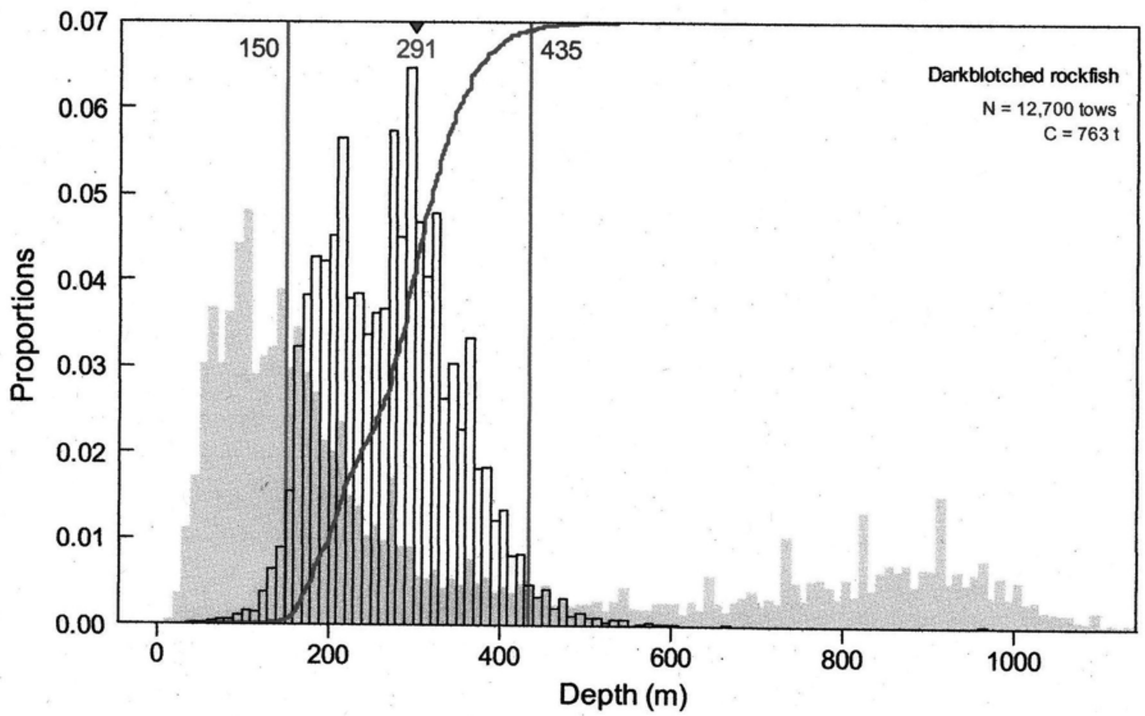


Figure 4. Depth frequency of tows that captured Darkblotched Rockfish from commercial trawl logs (1996-2007). The vertical solid lines denote the 2.5% and 97.5% quantiles. The shaded histogram indicates the relative trawl effort for all species. The cumulative catch of Darkblotched Rockfish, superimposed on the histogram in relative space (0 to 1), confirms that most of the darkblotched catch comes from these depths. The depth of median cumulative catch is represented by an inverted triangle at the top. 'N' = total number of tows; 'C' = total catch (t) (from Haigh and Starr 2008).

**Table 1. Estimates of area of occupancy (km$^2$) of Darkblotched Rockfish using two different grid scales: DFO geographic grid cell (0.1$^0$ longitude x 0.075$^0$ latitude) and COSEWIC UTM grid cell (2 km x 2 km) (from Haigh and Starr 2008).**

| Fishing Year | DFO | COSEWIC |
|---|---|---|
| 1996 | 15 361 | 2760 |
| 1997 | 13 544 | 2384 |
| 1998 | 11 935 | 2000 |
| 1999 | 14 055 | 2492 |
| 2000 | 13 161 | 2352 |
| 2001 | 11 659 | 2072 |
| 2002 | 11 281 | 2072 |
| 2003 | 9 698 | 1736 |
| 2004 | 11 902 | 2036 |
| 2005 | 11 273 | 1972 |
| 2006 | 12 258 | 2360 |
| 1996-2006 | 30 760 | 9232 |

# HABITAT

## Habitat requirements

Darkblotched Rockfish larvae and young-of-the-year juveniles are pelagic, typically occurring in offshore waters near the surface (Rogers 2005). Juveniles settle in benthic habitat, often on soft muddy bottoms, or perched on rocks or cobble (Love *et al.* 1991). Juveniles also have been observed at the base of deepwater oil platforms (Love 2002). In central California, young-of-the-year juveniles are commonly found on rocky outcrops at 9 to 20 m depths. As fish increase in size and age they remain demersal, but migrate to deeper water, with adults typically occurring at 140-210 m, although some have been documented in waters as shallow as 25 m and as deep as 900 m (Love 2002). Adults appear to prefer high-relief rocky habitat to low-relief soft sediment (Yoklavich *et al.* 2002). Individuals found in soft bottom habitats are usually associated with cobbles or boulders (Rogers 2005).

By identifying bottom bathymetry lying between 155 and 435 m (the depth range at which the highest trawl catch of Darkblotched Rockfish occurs), a rough estimation of potential habitat for Darkblotched Rockfish in British Columbia can be obtained (Fig. 5). Clearly not all bathymetry within this depth range is actual darkblotched habitat (e.g., Masset Inlet on Graham Island), and depths outside the 95% quantile range at which the species has been recorded are overlooked with this method. Nevertheless, the highlighted bathymetry (42 848 $km^2$) provides a broad overview of the spatial distribution of potential darkblotched habitat in the province, and can be used as a proxy for the species' extent of occurrence.

The surficial geology within the Queen Charlotte basin and Hecate Strait has been described by Barrie *et al.* (1991). Overlaying darkblotched fishing events (weighted by catch and standardized to a 1 $km^2$ grid) on the surficial geology of these areas allows a determination of frequency of occurrence of Darkblotched Rockfish over different bottom substrates (Haigh and Starr 2008). Unlike studies in US waters (which have darkblotched on soft sediment near to cobbles or boulders), the species was primarily found in areas with sand, gravel and till bottoms, at least in the Queen Charlotte basin (Table 2).

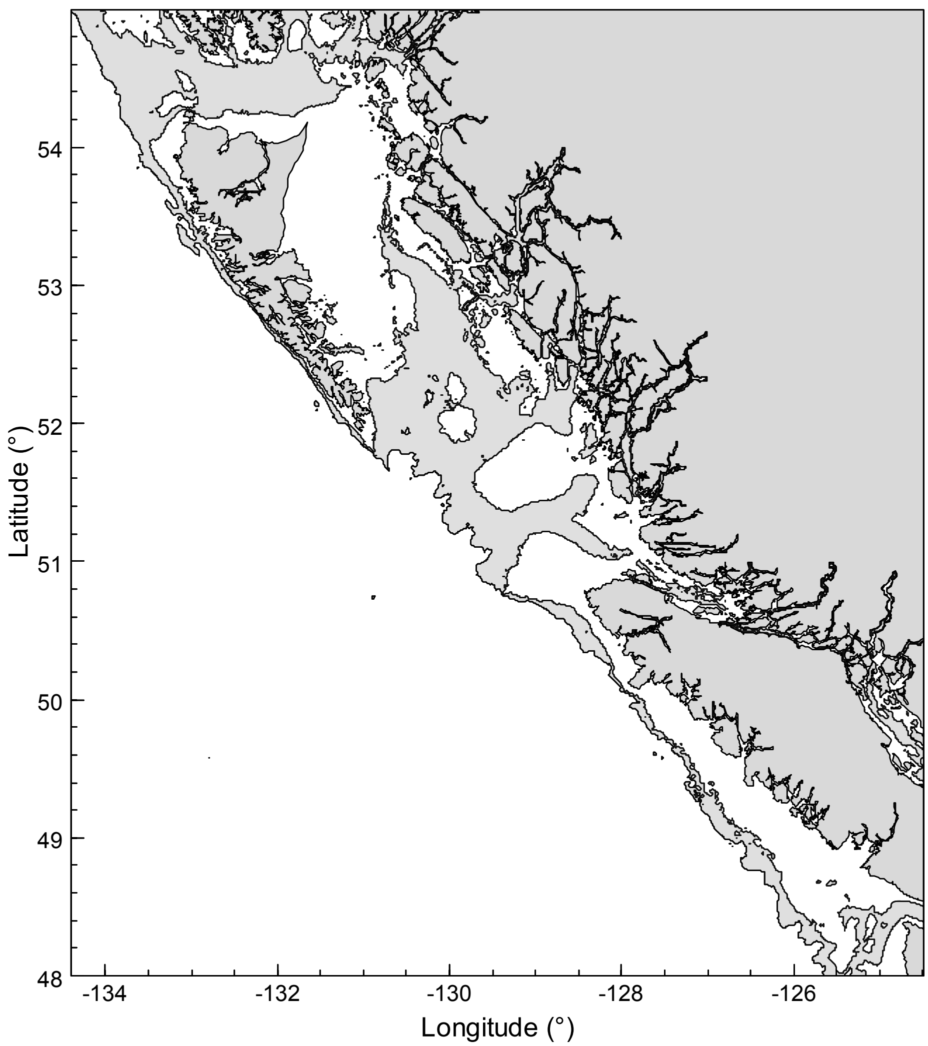


Figure 5. Potential Darkblotched Rockfish habitat along the BC coast, represented by shaded bathymetry between 150 and 435 m (from Haigh and Starr 2008).

**Table 2. Darkblotched Rockfish catch frequency in different surficial geology categories within the Queen Charlotte basin (from Haigh and Starr 2008).**

| Surficial geology category | % Frequency |
|---|---|
| Outwash sand & gravel | 20.8 |
| Till | 16.3 |
| Glaciomarine mud | 15.4 |
| Bedrock | 11.3 |
| Holocene sand & gravel | 10.3 |
| Holocene mud | 9.6 |
| Sand & gravel/ glaciomarine mud | 9.0 |
| Sand & gravel/ bedrock | 7.3 |
| Sand & gravel | 0.2 |

## Habitat trends

No specific information on trends in habitat availability currently exists for Darkblotched Rockfish. Marine waters within its Canadian range are subject to intense human activity, including effluents from industrial activities, shipping, and commercial fishing, all of which can have varying effects on marine habitat. Approximately 83% of British Columbia's continental shelf and slope is affected by human activity, with commercial bottom trawling having the largest impact (Ban and Alder 2008). High-relief rocky habitat associated with adult Darkblotched Rockfish distributions appears highly sensitive to bottom trawling (Bellman *et al.* 2005). Impacts of heavy trawling in such habitat can include reduced habitat complexity and loss of biodiversity (including rockfish species) (Engel and Kvitek 1998; Bellman *et al.* 2005). Very little of British Columbia's marine environment is currently protected, with only 1.5% of the province's exclusive economic zone and 4.7% of the continental shelf off-limits to commercial activities (Ban and Alder 2008).

## Habitat protection/ownership

In Canada, the Department of Fisheries and Oceans (DFO) has established Rockfish Conservation Areas (RCAs) along the BC coast since 2002, primarily to protect inshore rockfish and lingcod. A total of 164 RCAs were implemented for the 2007 fishing season, mainly close to shore (e.g., in the Strait of Georgia and Johnstone Strait). These areas may protect the habitat of juvenile Darkblotched Rockfish, but are unlikely to affect the habitat of adults, which generally occur in deeper water.

The Darkblotched Rockfish was declared overfished along the US west coast (Washington, Oregon, California) in 2000. As part of a conservation strategy for overfished groundfish, the Pacific Fishery Management Council (PFMC) established Rockfish Conservation Areas (RCAs) along the US west coast in 2002. RCAs are situated in areas known to contain the highest biomass of overfished species and are off limits to fishing (Roberts and Stevens 2006). RCAs vary by location throughout the year, and by gear type. For example, approximately 14 000 $km^2$ is closed to bottom-trawling on the continental shelf from 183-274 m along the entire US west coast (Roberts and Stevens 2006). California and Washington also have prohibited trawling for groundfish in state waters (which extend approximately four km out from the coast). Other RCAs extend from shore out to 450 m at different times of year (Roberts and Stevens 2006).

In Alaska, the North Pacific Fishery Management Council (NPFMC) has restricted or prohibited fishing activity in several areas affecting groundfish habitat. These include the Sitka Pinnacles Marine Reserve (groundfish harvesting prohibited), king crab closure areas around Kodiak Island (bottom trawling prohibited year-round in some areas and from February to June in others), the Gulf of Alaska Slope Habitat Conservation Areas (non-pelagic trawling prohibited), the Gulf of Alaska Coral Habitat Protection Areas (bottom contact gear prohibited) and Alaska Seamount Habitat Protection Areas (bottom contact gear prohibited) (NPMC 2006).

# BIOLOGY

Few studies have specifically examined the biology of Darkblotched Rockfish. The majority of these have focused on populations along the US west coast and in the Gulf of Alaska (e.g., Nichol and Pikitch 1994; Gunderson *et al.* 2003; Shanks and Eckert 2005). Since life history traits may vary latitudinally (Love 2002; Rogers 2005) caution should be exercised when extrapolating information to Darkblotched Rockfish populations in BC.

## Life cycle and reproduction

Like other rockfish species, the Darkblotched Rockfish is viviparous, meaning that it has internal fertilization of eggs, maternal nourishment of developing embryos and gives birth to live young (Wourms 1991). The reproductive period is protracted, with insemination occurring from August to December, fertilization from October to March and parturition from November to June (Nichol and Pikitch 1994). In BC the release of larvae peaks in February and has been recorded as late as June (Westrheim 1975; Love 2002). The exact gestation period for Darkblotched Rockfish is unknown; however, in most rockfish species it lasts one to two months (Wourms 1991). Darkblotched Rockfish have one brood per year and release larvae all at once (Shanks and Eckert 2005). Fecundity per female ranges from 20,000 to 610,000 larvae in BC and 19,000 to 500, 000 larvae in Oregon (Nichol and Pikitch 1994; Love 2002). Fecundity increases with female age and size (Roberts and Stevens 2006). The older the female the earlier larvae are released in the season. Successful recruitment may occur within a relatively narrow window within the spawning period (Nichol and Pikitch 1994).

Rockfish larvae are 4-9 mm in length at parturition and are relatively well developed (Wourms 1991). However, they are weak swimmers and their survival is strongly linked to environmental factors, such as ocean currents and upwelling events (Shanks and Eckert 2005). As a result mortality is high during the early life stages. Rockfish have a long pelagic larval duration, extending on average from late December through August on the US west coast (Shanks and Eckert 2005). The pelagic phase varies from several months to a year in different rockfish species, during which time the larvae transform into juveniles, which then settle on the ocean floor (Wourms 1991). Data from BC indicate that Darkblotched Rockfish mature from May to November (Haigh and Starr 2008).

Rockfish species typically exhibit highly variable inter-annual recruitment success. In BC exceptional recruitment episodes are estimated to occur every 15 to 20 years for inshore rockfish (Yamanaka and Lacko 2001).

Age and size at maturity vary with geographic location. In Oregon, 50% maturity is achieved at approximately five years old for males (29.6 cm total length) and eight years old for females (36.5 cm total length) (Nichol and Pikitch 1994). In California 50% maturity in females may be reached at four years old (Roberts and Stevens 2006). In BC 50% maturity is reached at approximately 8 years for males (32.1 cm total length) and 9 years for females (35 cm total length) (Fig. 6**;** Haigh and Starr 2008).

Westrheim (1975) found that size at 50% maturity decreased with increasing latitude from Oregon to Alaska. Along the US west coast south of Canada the opposite trend (size at 50% maturity increased with increasing latitude) seems to occur since fish caught in California are generally smaller than fish caught at the equivalent age in Oregon and Washington (Rogers 2005). The size difference between these populations, however, is not statistically significant (Rogers 2005).

In BC the maximum recorded age for the species is 48 years (Archibald *et al.* 1981). The von Bertalanffy growth coefficient (k) for Darkblotched Rockfish has been estimated as 0.25 for males (n = 1505) and 0.20 for females (n = 1263) based on a limited age range (1-40 years; Rogers 2005)[2]. Haigh and Starr (2008) calculated von Bertalanffy growth curves from 99 specimens caught by bottom trawl in BC in 1969 (Fig. 7). All otoliths were analyzed by surface readings, which unlike the break and burn technique, tend to underestimate fish age (Munk 2001). Using otoliths to age deepwater fish such as rockfish is notoriously difficult (Caillet *et al.* 2001). Nevertheless, otoliths have been used to determine a maximum age of 105 years for Darkblotched Rockfish south of $48^0$ N (Love 2002).

Gunderson *et al.* (2003) estimated the instantaneous natural mortality rate (M) of Darkblotched Rockfish as between 0.05-0.30 using three different models. The mortality rate based on longevity (M = 0.05) was outside the 95% confidence intervals for the other two models, based on reproductive effort (M = 0.11) and growth rate (M = 0.30). The US National Marine Fisheries Service (NMFS) recommends that 0.07 is an appropriate value for M in Darkblotched Rockfish (Rogers 2005). Based on the estimates for age at 50% maturity in BC (A = 8-9 years) and natural mortality (M = 0.07) generation time (G = A + 1/M) is approximately 23 years.

Data from the NMFS triennial bottom trawl survey of groundfish resources indicates that the sex ratio of Darkblotched Rockfish is fairly even off the US west coast and BC (Fig. 7). The age composition is skewed, however, toward individuals less than 20 years old, for both males and females. Most individuals were aged under five years of age, while the maximum recorded age in this survey was 64 years old (Fig. 8). Groundfish generally become available to survey and commercial trawl gear between three and six years of age. Before that they are only detected by surveys if present in sufficiently high quantities.

[2] Rogers (2005) restricted her calculations to a limited age range because the von Bertanlaffy curve poorly fits the growth of Darkblotched Rockfish.

Little is known about the feeding strategy of immature Darkblotched Rockfish. Adults feed mainly at midwater depths on amphipods, copepods, euphausiids, gammarids, salps and occasionally on other fish and octopus (Love 2002). Euphausiids were found to be the dominant food for Darkblotched Rockfish from Vancouver Island to northern California (Brodeur and Pearcy 1984).

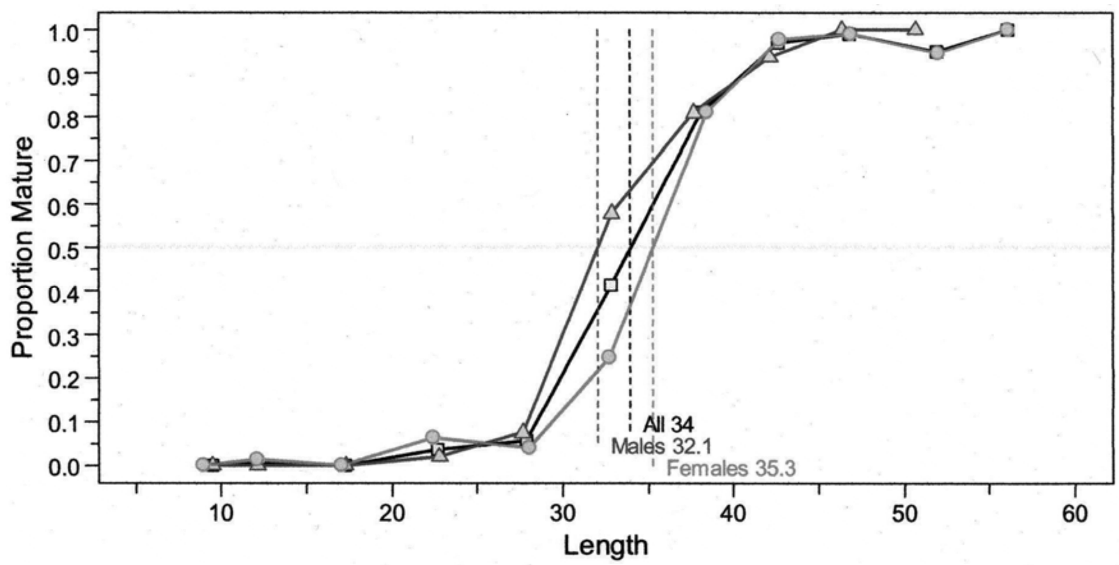


Figure 6. Maturity ogives for Darkblotched Rockfish using length grouped at 5-cm intervals. The length of each group is expressed as the mean of the observed lengths in each group. Vertical dashed lines indicate lengths at 50% maturity for males, females, and all available specimens, including those lacking a sex determination (from Haigh and Starr 2008).

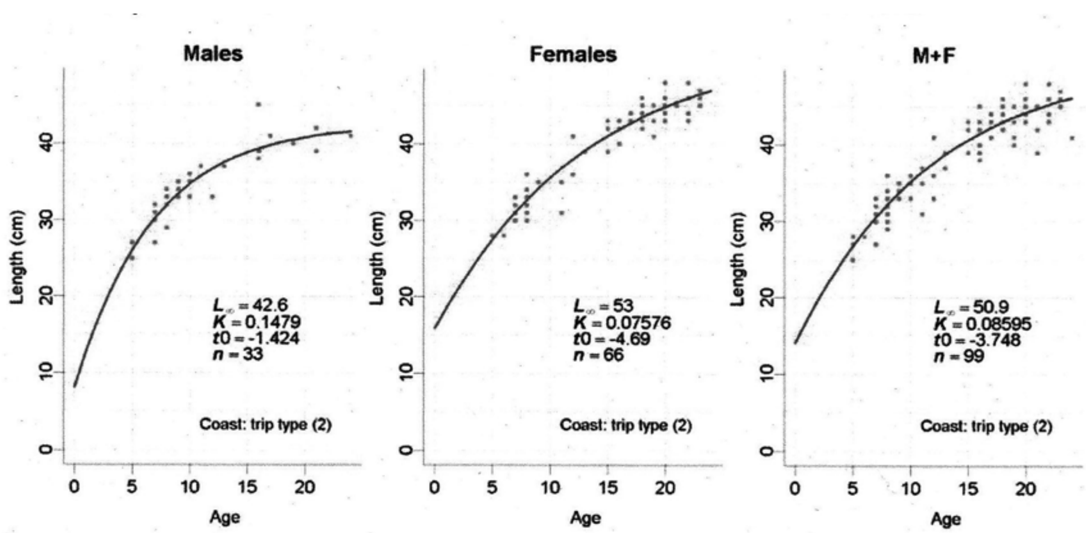


Figure 7. Length-at-age relationships for Darkblotched Rockfish collected on non-observed domestic commercial trips, using the von Bertalanffy growth equation. M+F = male and female specimens combined; *n* = number of specimens (from Haigh and Starr 2008).

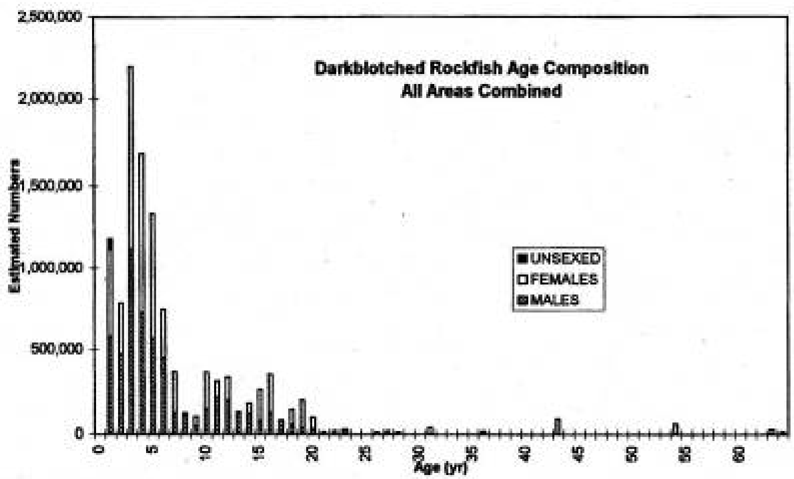


Figure 8. Age composition of Darkblotched Rockfish collected by bottom trawl off California, Oregon, Washington and British Columbia in 1995 (from NMFS triennial bottom trawl survey, Wilkins *et al.* 1998).

## Predation

Juvenile Darkblotched Rockfish are preyed upon by Albacore (*Thunnus alalunga*), Chinook Salmon (*Oncorhynchus tshawystscha*), and Pacific Hake (*Merluccius productus*) (Love 2002; Harvey *et al.* 2008). Juvenile rockfish species comprise a significant portion of seabird diets in the California Current System (Mills *et al.* 2007).

## Physiology

All *Sebastes* rockfish have physoclistic or closed swim bladders that are unable to adjust to rapid changes in pressure. Consequently, rockfish are extremely susceptible to barotrauma when captured from deep water, including swim bladder rupture and arterial embolisms (Jarvis 2007). Bycatch mortality is considered to be close to 100% for most rockfish species (Fort *et al.* 2006).

## Dispersal/migration

Darkblotched Rockfish have dispersive larval and young-of-the year juvenile stages. The timing of their pelagic duration exposes immature individuals to both winter downwelling and spring/summer upwelling events. As a result, net alongshore drift may be minimized (Shanks and Eckert 2005). Using population density estimates and genetic isolation-by-distance data, Gomez-Uchida and Banks (2005) calculated the average dispersal distance of immature Darkblotched Rockfish to be 0.87 km. The density estimates, however, assume uniform abundance, which may not be realistic for rockfish populations. The authors also employed an alternative dispersal function independent of density, resulting in an estimate of dispersal distance of immature Darkblotched Rockfish of 100 km. The apparently low dispersal of this species suggests that oceanographic and/or behavioural mechanisms play a role in larval retention despite the relatively long pelagic early development phase (Gomez-Uchida and Banks 2005). In general, once mature rockfish settle in an area they tend to be extremely sedentary (Roberts and Stevens 2006).

Bottom trawl catches of Darkblotched Rockfish were reduced at night along the upper continental slope of the US west coast (Washington, Oregon and California), suggesting that this species may exhibit diurnal vertical migration (Hannah *et al.* 2005).

### Interspecific interactions

Darkblotched Rockfish occur in multispecies assemblages with a variety of other groundfish species. In the Gulf of Alaska, they associate with Bocaccio (*S. paucispinis*), Chilipepper (*S. goodei*), Greenstriped Rockfish (*S. elongates*), Harlequin Rockfish (*S. variegates*), Pygmy Rockfish (*S. wilsoni*), Redbanded Rockfish (*S. babcocki*), Redstripe Rockfish (*S. proriger*), Sharpchin Rockfish (*S. zacentrus*), Silvergray Rockfish (*S. brevispinis*), Splitnose Rockfish (*S. diploproa*), Stripetail Rockfish (*S. saxicola*), Vermilion Rockfish (*Sebastes miniatus*) and Yellowmouth Rockfish (*S. reedi*) (Roberts and Stevens 2006). Off the US west coast, Darkblotched Rockfish aggregate with Bank Rockfish (*S. rufus*), Greenspotted Rockfish (*S. chlorostictus*), Pacific Ocean Perch (*S. alutus*), Rosethorn (*S. helvomaculatus*), Sharpchin Rockfish, Shortspine Thornyhead (*Sebastolobus alascanus*), Splitnose Rockfish, Squarespot Rockfish (*S. hopkinsi*), Widow Rockfish (*S. entomelas*), Yelloweye Rockfish (*S. ruberrimus*) and Yellowmouth Rockfish (Jay 1996; Yoklavich *et al.* 2002; Rogers 2005). In BC the depth range at which Darkblotched Rockfish are most commonly captured (150-435 m, 1.7% of total catch weight in trawl tows) is dominated by Pacific Ocean Perch (36.0%), Arrowtooth Flounder (*Atheresthes stomias*; 20.6%), Yellowmouth Rockfish (6.4%) and Dover Sole (*Microstomus pacificus*; 5.6%) (Haigh and Starr 2008).

### Adaptability

Over evolutionary time, Darkblotched Rockfish may have been well adapted to extended periods of environmental stress because of their longevity and viviparity. However, their longevity now make the species vulnerable to recruitment overfishing (excessive removal of spawners from the population which decreases the probability of successful recruitment events) (Roberts and Stevens 2006). Viviparity improves the survival of developing embryos and larvae, and in highly fecund species such as rockfish, may promote the colonization of new habitats (Wourms 1991). Nevertheless, colonization of unpopulated areas may be rare in Darkblotched Rockfish because of their apparently low dispersal distances.

## POPULATION SIZES AND TRENDS

### Search effort

Information on population sizes and trends of Darkblotched Rockfish in BC comes from both the commercial trawl fishery and research surveys. However, because this rockfish is not a targeted species, and because monitoring programs for rockfishes have generally been inconsistent and incomplete until recently, robust historical data on Darkblotched Rockfish abundance are lacking. Furthermore, none of the research surveys along the coast occur in known high density areas for the species (i.e., along the northwest shelf of Vancouver Island and in Moresby Gully southeast of the Queen Charlotte Islands).

In the mid-1990s, 100% at-sea and dockside monitoring of all rockfish catch was implemented, leading to major improvements in data quality. Prior to this, no record of dumping, discarding or mis-reporting in groundfish fisheries occurred. In 1997 the Individual Vessel Quotas (IVQ) system was introduced for the BC trawl fishery, setting area-specific annual catch (retained and discarded) limits on species for which TACs (total allowable catches) were set, for each vessel. Although Darkblotched Rockfish is a non-TAC species, without a set total allowable catch, its catch levels are affected by trip limits for total non-TAC rockfish in various fisheries. For example, in the trawl fishery, a maximum of 15,000 lbs. of non-TAC rockfish (including darkblotched) are permitted per trip.

Darkblotched Rockfish catch records are only available back to 1977. Before then, the species was lumped together with “other rockfish” in fishery catch statistics. To estimate catches prior to 1977, 1996-2006 trawl fishery data on the proportion of Darkblotched Rockfish caught to other rockfish (DBR/ORF) and on the proportion of Darkblotched Rockfish discarded to retained (DBRd/DBR) were applied to historical catch records. While these ratios have remained relatively constant over the ten-year period it is probably unrealistic to assume that modern ratios, taken from a modern IVQ fishery, resemble past fishery patterns. Historical abundance estimates were made using this method for both US vessels fishing in BC waters from 1930 to 1975 and Canadian vessels from 1945 to 1982. Catch estimates are more difficult to calculate for the large Soviet and Japanese trawling fleets, which operated along the BC coast from 1965 to 1976, since information on species composition and locality of catches are unavailable (Haigh and Starr 2008). However, employing the above DBR/ORF ratio used for domestic fisheries to the largest year of the Soviet fishery (1966) provides a rough estimate of this fishery’s impact on the Darkblotched Rockfish population.

Contemporary abundance estimates for Darkblotched Rockfish were obtained from a variety of research surveys (e.g., bottom trawl, mid-water shrimp tows) and commercial catch-per-unit-effort (CPUE) from the trawl fishery.

Synoptic bottom trawl surveys operate biennially within Queen Charlotte Sound (QCS synoptic bottom trawl survey; north Vancouver Island to southern Hecate Strait), along the west coast of Vancouver Island (WCVI synoptic bottom trawl survey), and west of the Queen Charlotte Islands (WQCI synoptic bottom trawl survey). These surveys target all groundfish species using random tow allocations per stratum and cover depths of 50 to 1300 m.

Tow-by-tow data are available from the *G.B. Reed* historical Queen Charlotte Sound surveys for nine years between 1965 and 1984 (i.e., 1965-1967, 1969, 1971, 1973, 1976, 1977 and 1984). Although these surveys cover various geographic areas both within and outside British Columbia, to ensure consistency between surveys, only tows from Goose Island Gully (i.e, tows between 50.9$^0$ N and 51.6$^0$ N; Fig. 9) were used for abundance estimates. Since few individuals were captured at depths shallower than 146 m, estimates are based on tows conducted between 146-256 m. The resulting data cover seven years from 1967 to 1984 (1965 and 1966 surveys omitted).

Two shrimp trawl surveys provide additional tow-by-tow abundance data along the west coast of Vancouver Island (WCVI shrimp trawl survey; Fig. 10) and within southern Queen Charlotte Sound (QCS shrimp trawl survey; Fig. 11). The WCVI shrimp trawl survey covers 33 years from 1972 to 2007. Rockfish were only identified to species beginning in 1975. As such, this data set represents the longest time-series available in Canadian waters for Darkblotched Rockfish abundance patterns. Trawl coverage within the 80-100 m and 160-180 m depth zones was sporadic in the WCVI survey. Analysis was limited to the 80-160 m depth range in all survey years, which probably means that juveniles rather than adult Darkblotched Rockfish were more prevalent. The QCS shrimp trawl survey has operated since 1999 and consistently samples depths up to 220 m. This survey is divided into three aerial strata: stratum 109 (west of the outside islands and extending into Goose Island Gully), stratum 110 (south of Calvert Island and the mainland) and stratum 111 (between Calvert Island and the mainland). Stratum 111 was omitted from the abundance analysis because this inshore area is unlikely habitat for Darkblotched Rockfish (Fig. 11; Haigh and Starr 2008).

NMFS triennial bottom trawl surveys along the US west coast extended into Canadian waters in seven years between 1980 and 2001. The surveys cover the Vancouver International North Pacific Fisheries Commission (INPFC) region (Fig. 12), which is divided by NMFS into strata. The size and definition of these strata has varied over time. To standardize survey data, strata not surveyed consistently from year to year were omitted in the analysis, and indices from two years (1980 and 1983) were scaled up so that their area coverage was comparable to later years (Haigh and Starr 2008).

A general linear model (GLM) analysis of commercial trawl CPUE was calculated for April 1996 through March 2007, using only bottom trawl data. The start date of the analysis coincides with the initiation of the At-Sea Observer Program. Much of the previous catch rate data is considered unreliable due to mis-reporting and variation in trip limits over time.

Because commercial fisheries aim to maximize harvesting rates of target species, and are governed by existing fishery regulations, their CPUE indices may not necessarily accurately reflect fish abundance, especially for non-TAC species, such as Darkblotched Rockfish. A number of factors may account for the observed variability in CPUE values, including date of capture, capturing vessel, depth and location of capture and fishing behaviour (e.g., avoidance fishing) (Schnute *et al.* 1999). However, if the spatial distribution of Darkblotched Rockfish closely matches that of other quota species (e.g., such as Pacific Ocean Perch, which is highly likely), then CPUE estimates may represent abundance trends reasonably well (Haigh and Starr 2008).

Only bottom tows were used in the CPUE analysis and all observations in which Darkblotched Rockfish were absent were removed. While these zero-tows may provide important information, the lognormal model used for the analysis required positive values for the dependent observations (Haigh and Starr 2008).

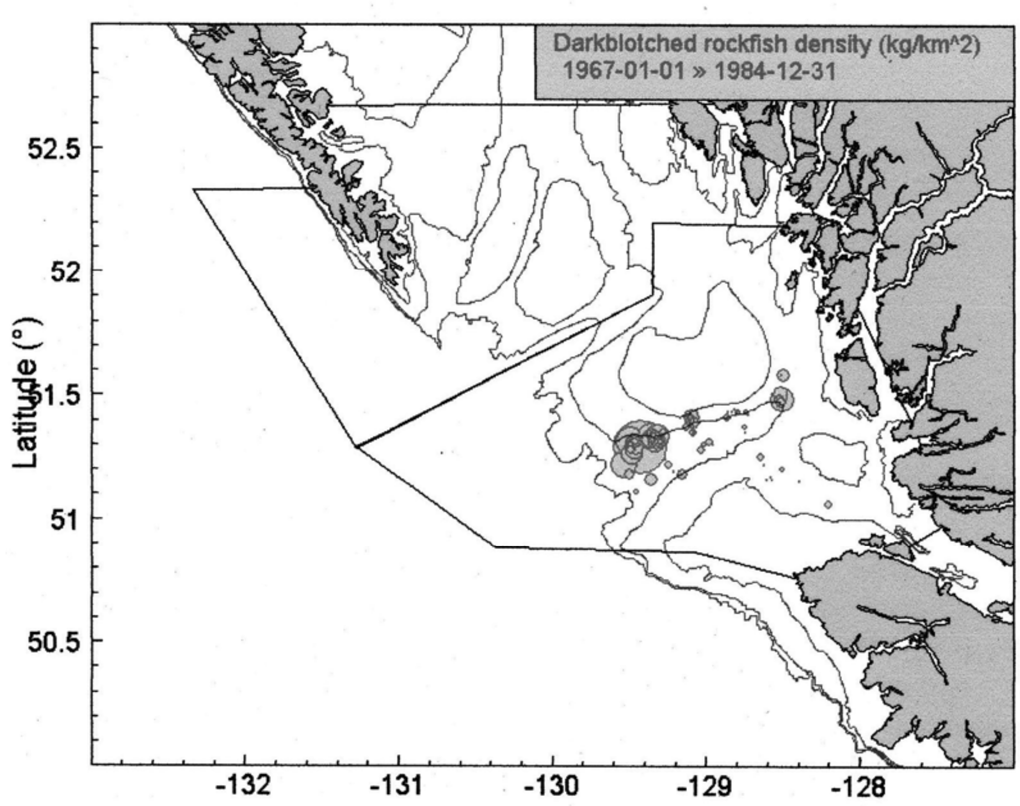


Figure 9. Locations of all trawls from the *G.B. Reed* trawl survey (1967-1984) which caught Darkblotched Rockfish. Only tows in the Goose Island Gully which were used in the biomass index calculation are shown. Circles are proportional to catch density (largest circle = 0.57 kg/km$^2$). The 100, 200 and 300 m isobaths are also shown (from Haigh and Starr 2008).

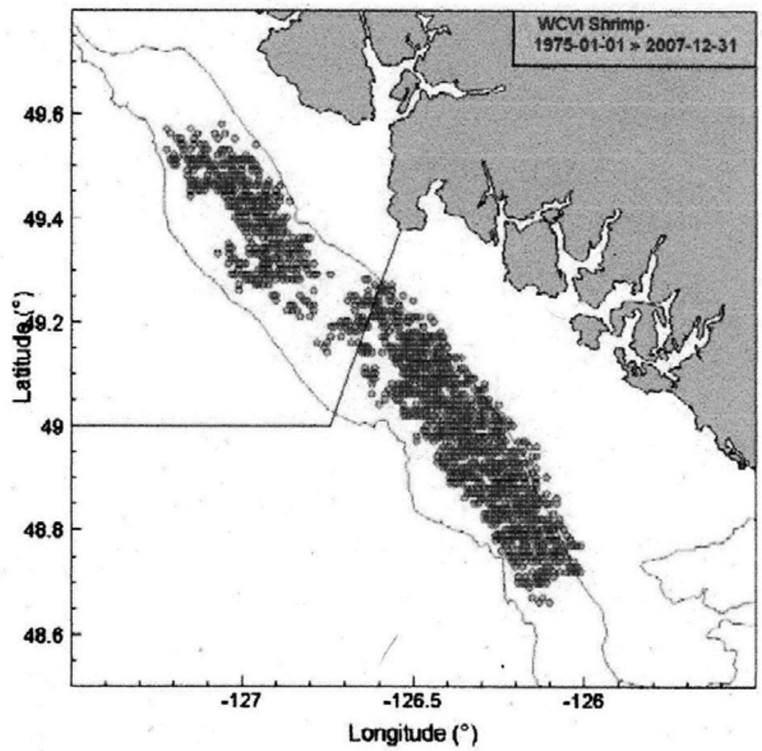


Figure 10. Locations of all trawls in the west coast Vancouver Island shrimp trawl survey (from Haigh and Starr 2008).

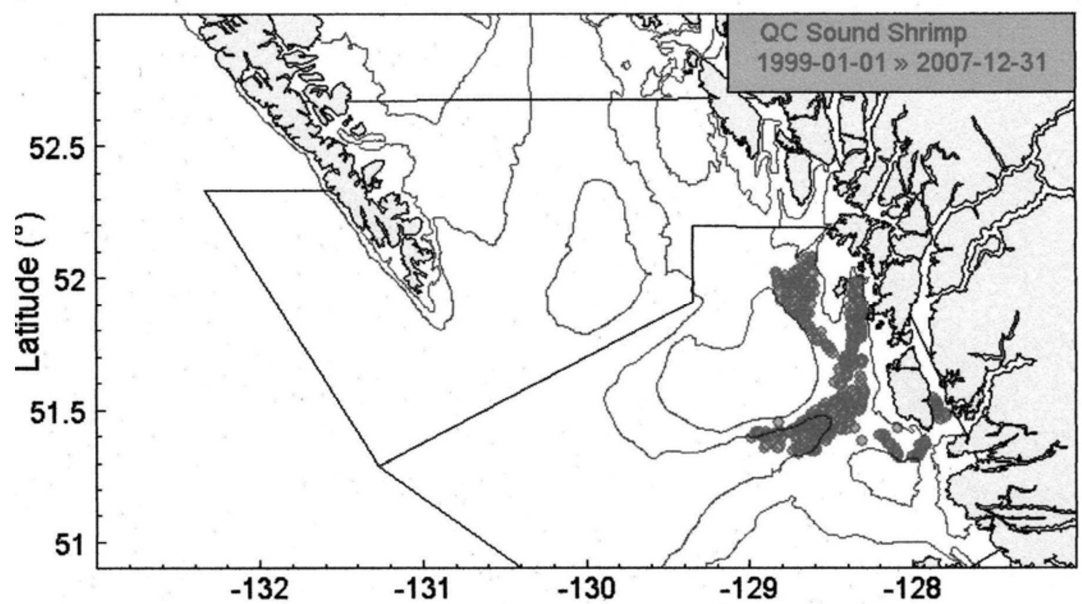


Figure 11. Location of tows conducted by the Queen Charlotte Sound shrimp survey (1999-2007). The tows on the inside of Calvert Island represent Stratum 111 which was not used in the analysis for Darkblotched Rockfish (from Haigh and Starr 2008).

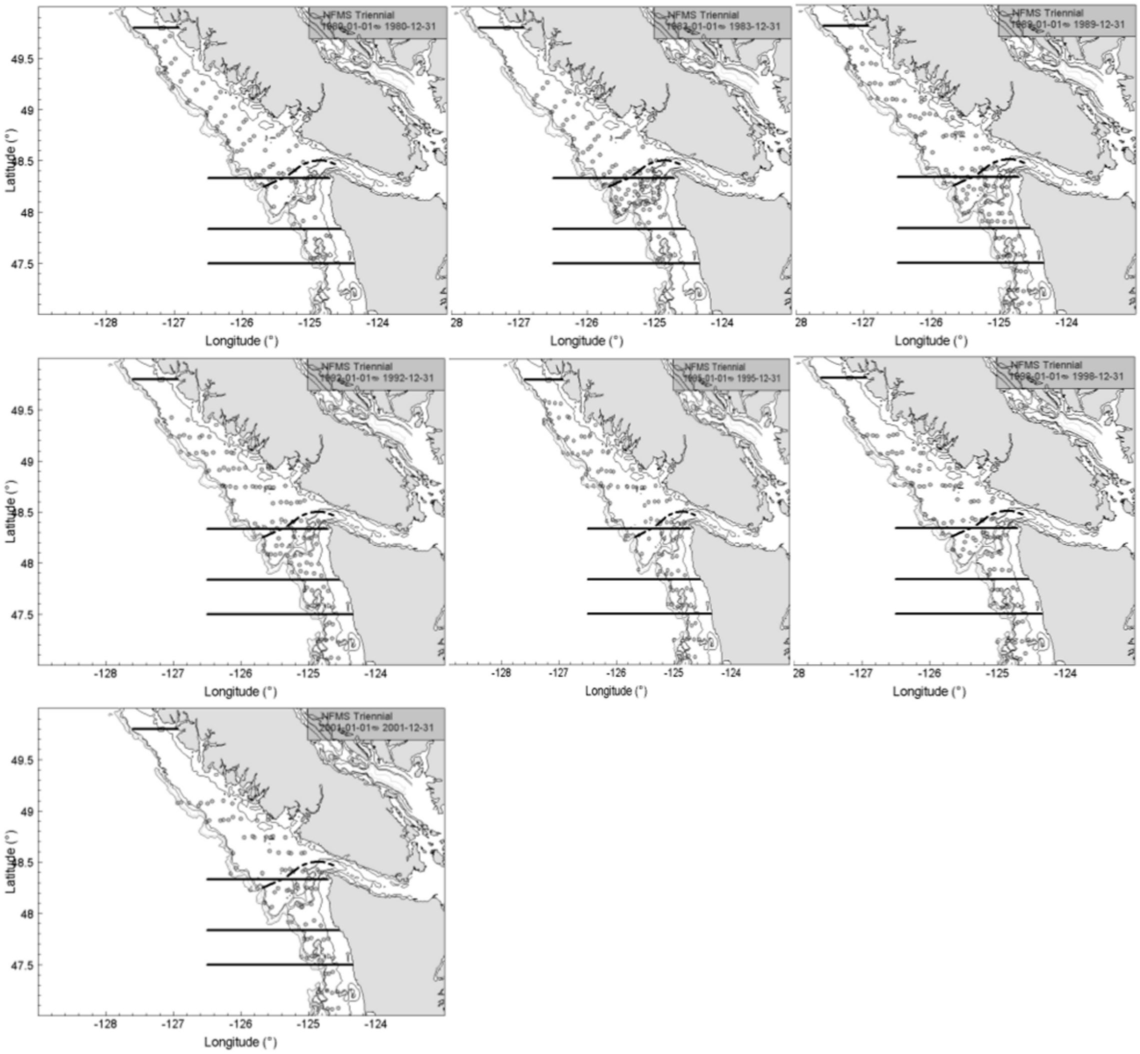


Figure 12. Tow locations in the Vancouver INPFC region for each of the seven US NMFS triennial surveys covering Canadian waters. The approximate position of the US/Canada marine boundary is shown (dashed line). The horizontal lines are the stratum boundaries: $47^{0}$30’, $47^{0}$50’, $48^{0}$20’, and $49^{0}$50’. Tows south of the $47^{0}$30’ line were excluded from the analysis. Isobaths are the stratum depth boundaries at 55, 183, 220, 366, and 500 m (from Haigh and Starr 2008).

## Abundance

The estimated total coastwide catch of Darkblotched Rockfish since the 1930s in Canada (including all Canadian and US fisheries) is approximately 4200 tonnes (Appendix 1) or three million fish (using the mean weight $\hat{w}$ of Darkblotched Rockfish caught by the observed commercial trawl fishery: $\hat{w}$ =1.32 kg, $\sigma$ = 0.41, n = 208; Haigh and Starr 2008).

No estimate of effective population size exists for Canadian populations of Darkblotched Rockfish. However, along the US west coast between Washington and northern California, the breeding population is estimated to be several orders of magnitude smaller than its census population size ($N_e$ = 9157 compared with N = 24 376 210; Gomez-Uchida and Banks 2006). The small $N_e$/N ratio likely arises from a combination of highly variable reproductive success among individuals, genetic structure and demographic disturbances caused by overfishing. In particular, historical fishing practices along the US west coast have truncated the age structure and diminished the size of populations (Gomez-Uchida and Banks 2006).

### Fluctuations and trends

Two experimental programs were conducted in the 1980s to assess adaptive management strategies for Pacific Ocean Perch stocks. One of these programs showed that Darkblotched Rockfish, like other species, could be depleted by intensive harvesting (Leaman and Stanley 1993), but otherwise these experiments were not directly relevant to Darkblotched Rockfish status assessment.

The three synoptic bottom trawl surveys have been conducted over relatively short periods, and have high coefficients of variation (CVs) on biomass estimates (there is essentially no significant difference between indices in the various survey years; Figs. 13 and 14). The biomass indices assume a catchability quotient of q = 1 (i.e., every individual in the path of the trawl is taken) which is probably too high for Darkblotched Rockfish, although catchability is unknown for the species. As a result, survey values are likely underestimates of actual abundance levels (Haigh and Starr 2008).

Darkblotched Rockfish were caught at relatively low and constant levels in the *GB Reed* surveys in Goose Island Gully (Fig. 15, Appendix 2), except for a high catch in 1976. Biomass estimates from all years had high CVs (at least 30%), with some years approaching or exceeding 60% (i.e., 1969, 1973, 1976). The proportion of tows containing Darkblotched Rockfish varied from 35-50% over the first six years of the survey, but declined below 20% in 1984. Darkblotched Rockfish were mainly captured along the 200 m depth contour and within the trench of the gully (Fig. 9). A log-linear regression of the time series provided a non-significant slope estimate of -0.023 yr-1 (p=0.76).

Biomass estimates of Darkblotched Rockfish caught in the WCVI shrimp trawl survey increased non-monotonically until the late 1990s, but have since been declining (Fig. 16, Appendix 3). However, the CVs are large for these indices and in most cases catches are not significantly different from year to year. Darkblotched Rockfish were captured in greater abundance in Area 124 than in Area 125 (Fig. 17) and primarily at depths of 120-160 m. Biomass estimates from the QCS shrimp trawl survey have also been highly variable and relatively low, except for high catches in 2001 and 2002 (Fig. 18, Appendix 4). The proportion of tows catching Darkblotched Rockfish have also been variable (Haigh and Starr 2008). Catches of Darkblotched Rockfish over the nine-year survey were concentrated along the trench of Goose Island Gully and along the shelf edge of the outside islands (Fig. 19), primarily at depths of 150-210 m. A log-linear regression of the time series provided a non-significant slope estimate of -0.13 yr-1 (p=0.52).

Data from the NMFS triennial bottom trawl survey show a non-significant increasing trend in relative biomass estimates for Darkblotched Rockfish in the Canadian section of the INPFC Vancouver region, but no similar trend is found in the US section (Fig. 20, Appendix 5). The largest catch for this species occurred in 2001 in US waters. Consistently over time a higher proportion of tows with Darkblotched Rockfish were recorded in the US than in the Canadian portion of the survey (i.e., 23-37% of tows in the US compared with 11-33% in Canada; Haigh and Starr 2008). Overall no reliable pattern is evident in the dataset. All abundance indices for Darkblotched Rockfish derived from this dataset were highly variable. Furthermore, the bootstrapped coefficient of variation (CV) values do not account for the expanded ratios applied to 1980 and 1983 surveys. Thus, the uncertainty in these estimates is likely greater than what is indicated. A log-linear regression of the time series provided a non-significant slope estimate of -0.032 yr-1 (p=0.66).

A combined log-linear regression of the different survey time series was conducted using the *G.B Reed*, NMFS triennial survey, Queen Charlotte Sound and West Coast Vancouver Island shrimp surveys. An analysis of covariance was used with separate intercepts for the survey series and a common slope. The slope estimate was not statistically significant (0.04 +- 0.044, p<0.075). Over the 40-year time period covered by the surveys, this would indicate a five-fold increase in biomass.

Commercial CPUE indices are uniformly low for Darkblotched Rockfish, averaging <50 kg/h towed (Haigh and Starr 2008). Highest CPUE values were concentrated along the northwest coast of Vancouver Island, within Goose Island and Moresby Gullies, and along the north and northwest coast of the Queen Charlotte Islands. As mentioned before, caution should be exercised when interpreting CPUE indices, since they may be affected by fishing practices. In this case, two distinct management strategies have operated at different times over the course of the CPUE time-series. From February 1996 to March 1997, a trimester system was used for the commercial trawl fishery, in which vessels chose two out of three trimesters to maximize their rockfish catch. Thus, during this period, Darkblotched Rockfish could have been targeted simply because it represented part of the total rockfish harvest. In contrast, following the implementation of the IVQ system in 1997, Darkblotched Rockfish may suddenly have been avoided as vessels switched to targeting individual quota species instead (Haigh and Starr 2008). The apparent annual decline of 3.9% in Darkblotched Rockfish CPUE between 1996 and 2006 (Fig. 21) is not considered representative of population abundance because it is primarily determined by the first two points in 1996-7, following which the changes described above occurred in the fishery; there is essentially no trend in the index after 1997. A lower than average CPUE is typically observed from June through August, and highest CPUE values occur at depths of 150-375 m (Fig. 22).

Intermittent information on trends in Darkblotched Rockfish length over time is available from research, charter and observer commercial trawl surveys since 1967 (Fig. 23). In general, most individuals captured are between 30-40 cm in all years, although the 2005 charter data indicate an increase in juveniles (~10 cm) caught in this year.

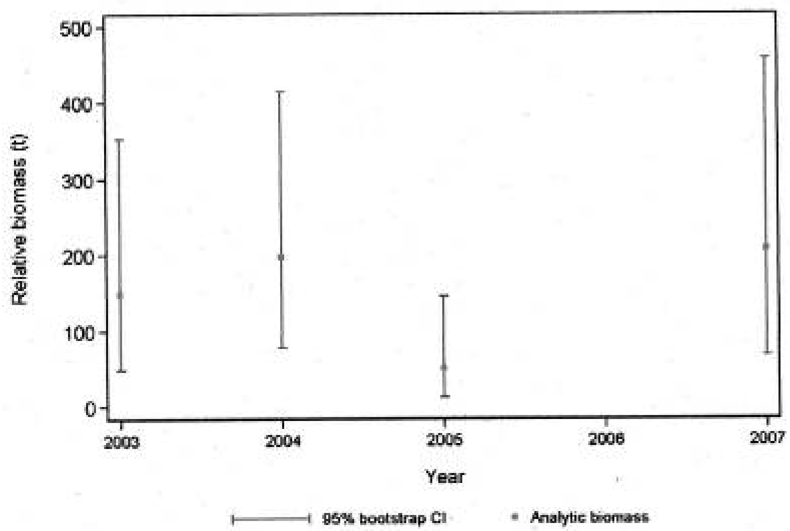


Figure 13. Relative biomass index for Darkblotched Rockfish in Queen Charlotte Sound from the QCS synoptic bottom trawl survey. Vertical bars indicate 95% confidence intervals based on 1000 bootstrap replicates (from Haigh and Starr 2008).

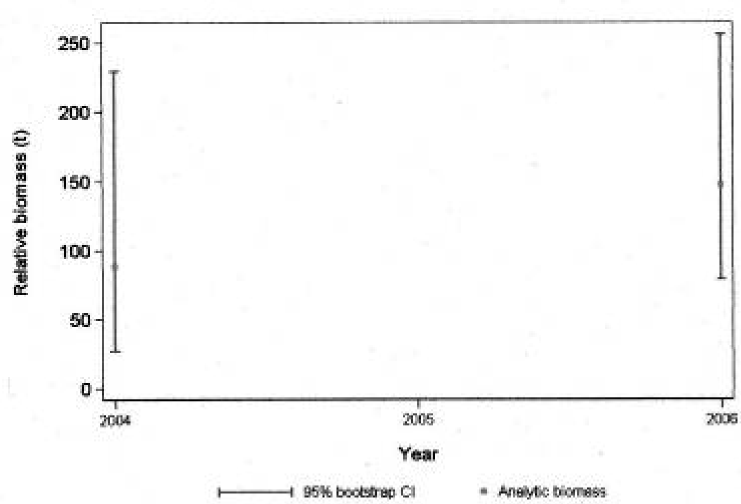


Figure 14. Relative biomass index for Darkblotched Rockfish on the west coast of Vancouver Island from the WCVI synoptic bottom trawl survey. Vertical bars indicate 90% confidence intervals based on 1000 bootstrap replicates (from Haigh and Starr 2008).

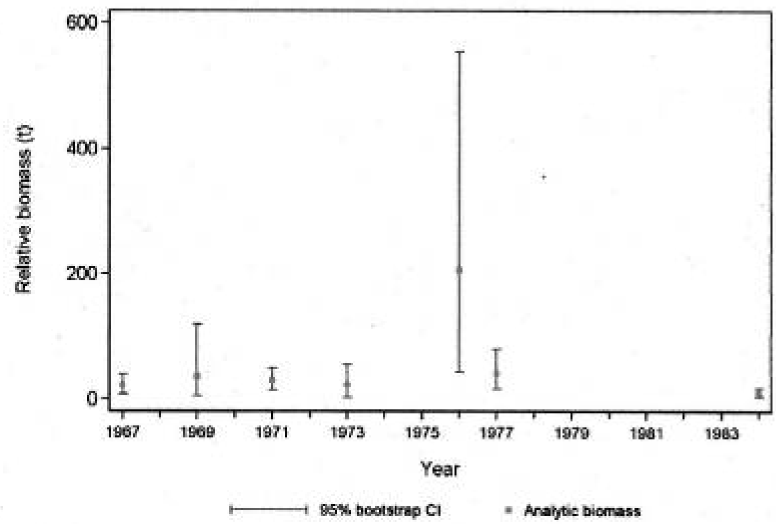


Figure 15. Relative biomass estimates for Darkblotched Rockfish from the Goose Island Gully *G.B. Reed* trawl surveys (1967-1984). Bias corrected 95% confidence intervals derived from 1000 bootstrap replicates are plotted (from Haigh and Starr 2008).

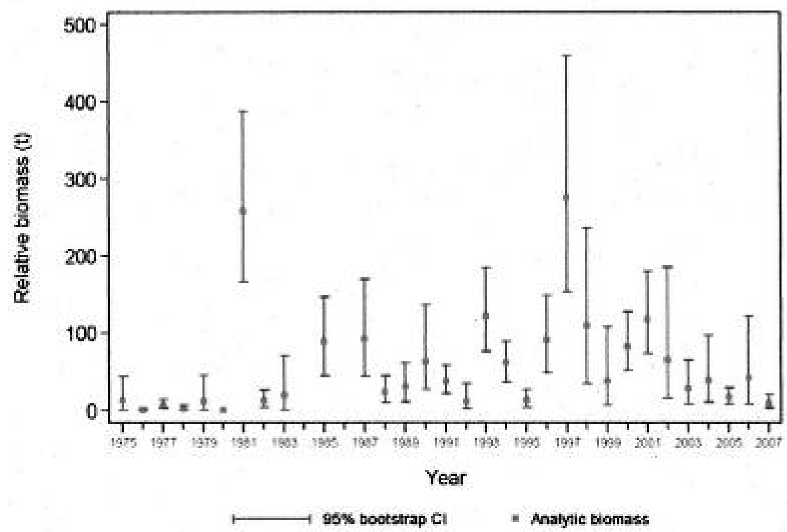


Figure 16. Relative biomass estimates for Darkblotched Rockfish from the WCVI shrimp trawl survey (1975-2007). Bias corrected 95% confidence intervals from 1000 bootstrap replicates are plotted (from Haigh and Starr 2008).

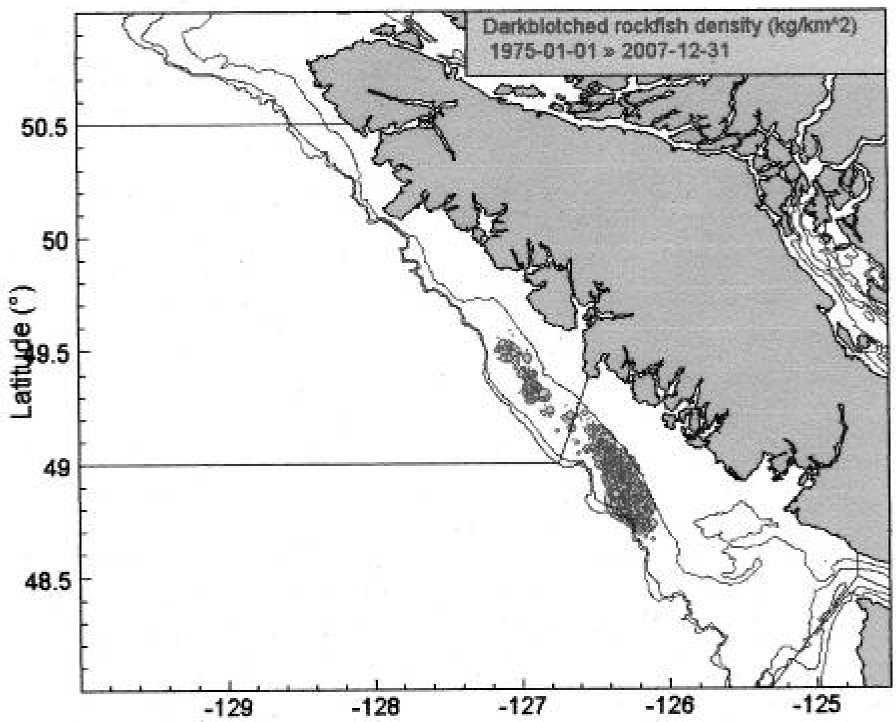


Figure 17. Location of all trawls from the WCVI shrimp trawl survey (1975-2007) catching Darkblotched Rockfish. Circles are proportional to catch density (largest circle = 2.2 kg/km$^2$). The PFMC major area boundaries for Areas 123 and 124 are shown, as well as the 100, 200 and 300 m isobaths (from Haigh and Starr 2008).

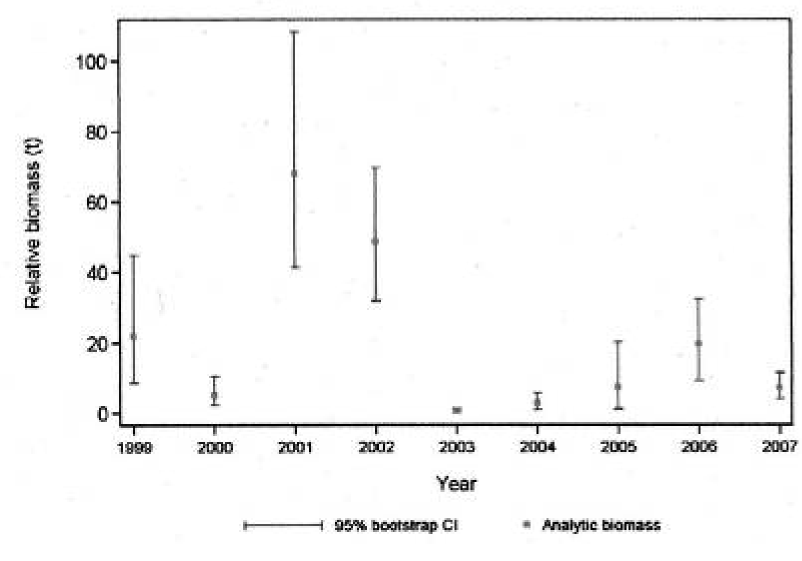


Figure 18. Relative biomass estimates for Darkblotched Rockfish from the QC Sound shrimp trawl survey (1999-2007). Bias corrected 95% confidence intervals from 1000 bootstrap replicates are plotted (from Haigh and Starr 2008).

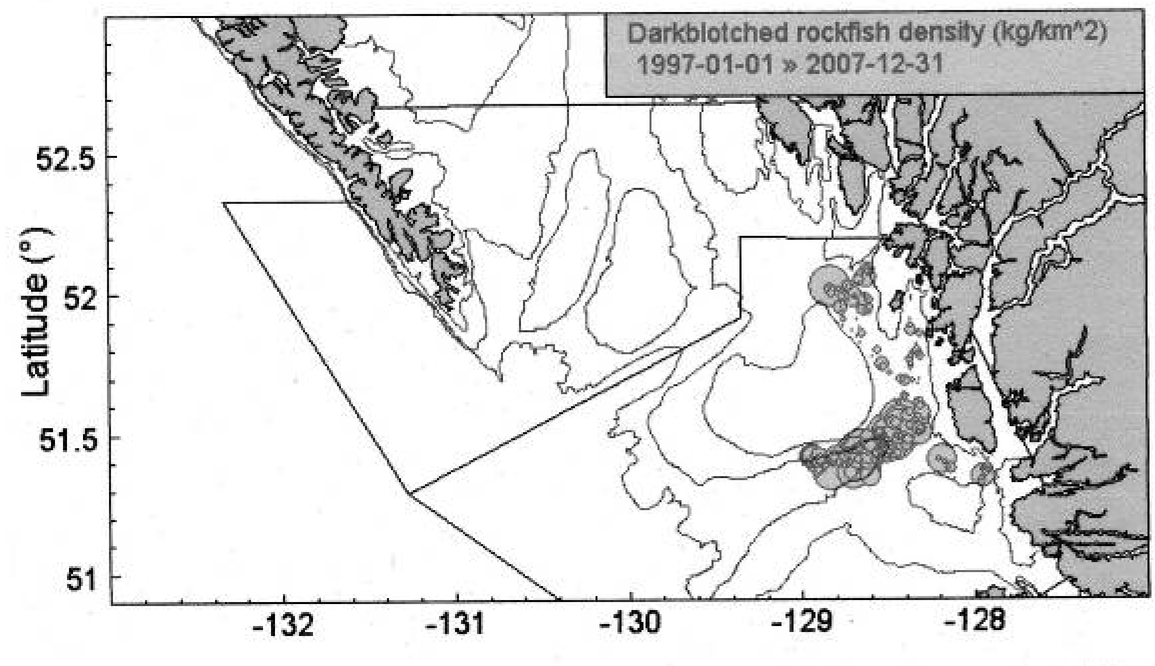


Figure 19. Location of all trawls from the Queen Charlotte Sound shrimp trawl survey (1999-2007) catching Darkblotched Rockfish. Circles are proportional to catch density (largest circle = 0.35 kg/km$^2$). The area stratum boundaries for the Queen Charlotte Sound synoptic bottom trawl survey, as well as the 100, 200, and 300 m isobaths, are also displayed (from Haigh and Starr 2008).

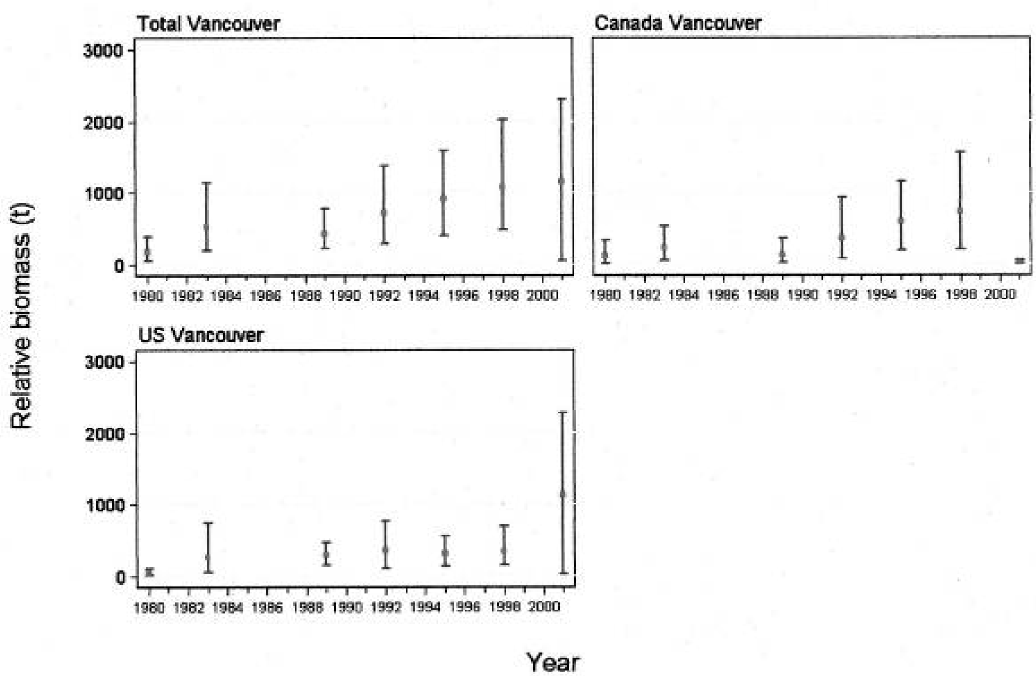


Figure 20. Relative biomass estimates for Darkblotched Rockfish in the INPFC Vancouver region taken from the US NMFS triennial survey (total region, Canada only, and US only) with 95% bias corrected error bars estimated from 5000 bootstrap replicates (from Haigh and Starr 2008).

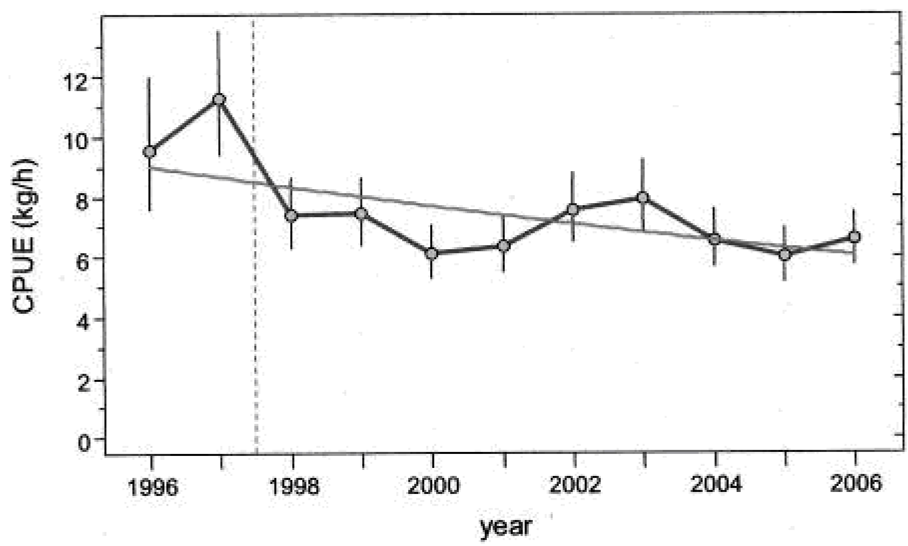


Figure 21. Annual index in Darkblotched Rockfish commercial trawl CPUE data (1996-2006). The error bars show 95% confidence intervals. The vertical dashed line indicates an adjustment phase during which a trimester system was used, followed by the introduction of the individual quota program (IVQ) (see text for details; from Haigh and Starr 2008).

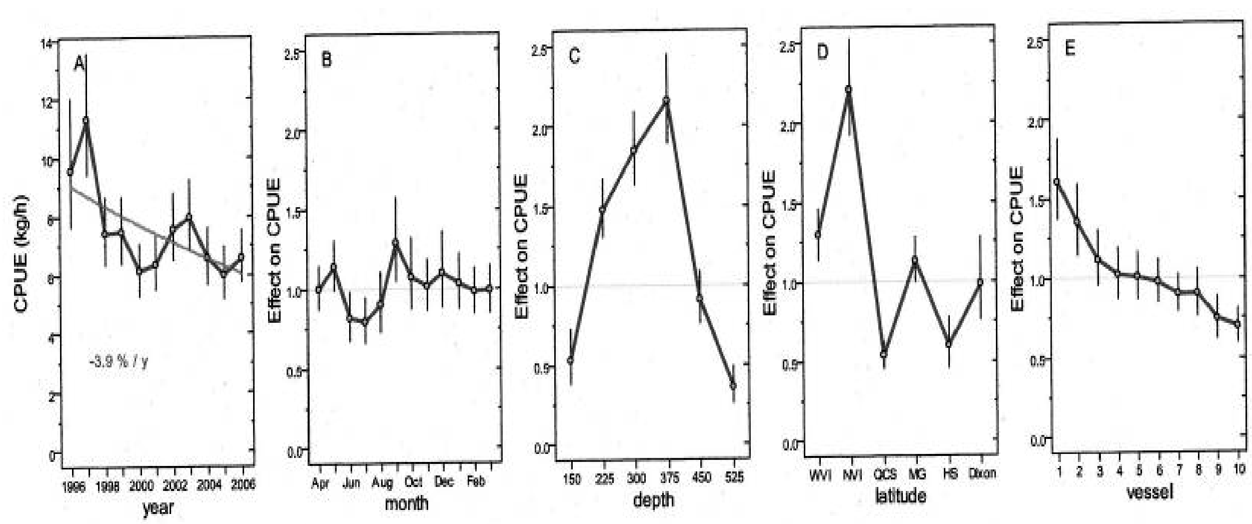


Figure 22. Annual index trend and factor coefficients for the GLM analysis of Darkblotched Rockfish commercial trawl CPUE data (April 1996-March 2007). (A) annual CPUE indices by fishing year, with fitted curve indicating instantaneous decline; (B) month effect on CPUE; (C) depth effect on CPUE, where depth is divided into 75-m depth zones between 75 and 525 m; (D) latitude effect on CPUE, where WVI = $48^0$N to $50.1^0$N, NVI = $50.1^0$N to $50.8^0$N, QCS = $50.8^0$N to $51.6^0$N, MG = $51.6^0$N to $52.2^0$N, HS = $52.2^0$N to $53.8^0$N, and Dixon = $53.8^0$N to $54.8^0$N; (E) vessel effect on CPUE where vessels accounted for $\geq$ 3% of the darkblotched catch over the period of the analysis. Error bars show 95% confidence intervals (from Haigh and Starr 2008).

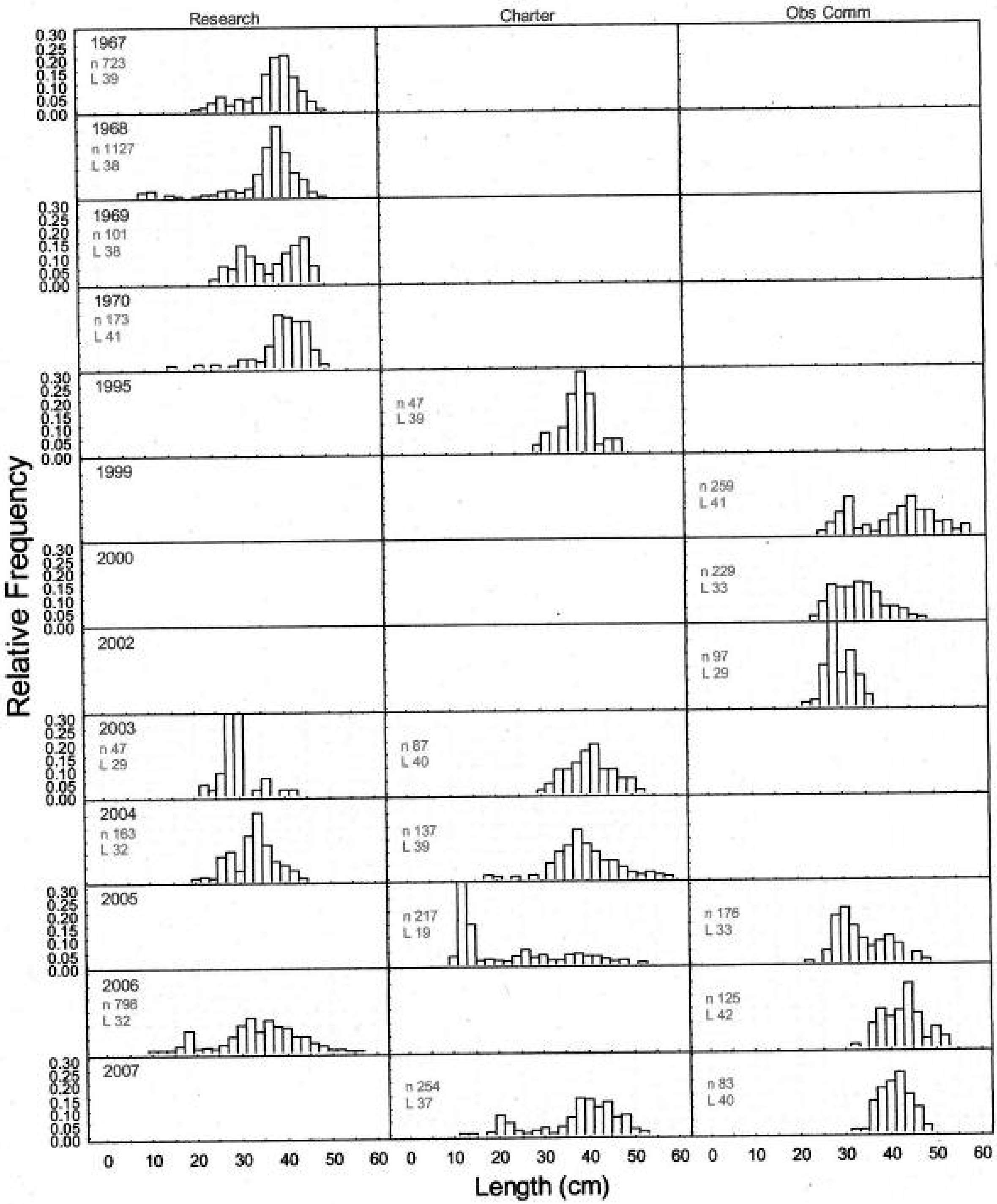


Figure 23. Relative frequency of Darkblotched Rockfish lengths (cm) by calendar year and trip type (Research = Research vessel, Charter = Charter vessel and Obs Comm = Observer Commercial Trawl). Lengths are grouped using 2-cm intervals; n = number of fish, L = mean length (cm) (from Haigh and Starr 2008).

**Table 3. Summary of existing biomass indices for Darkblotched Rockfish in British Columbia.**

| Index name | Type | Years | Decline or pattern | Reliability |
|---|---|---|---|---|
| QCS synoptic bottom trawl survey | Research vessel survey | 2003-2007 | No trend (Fig. 13) | Short time series, high variability |
| WCVI synoptic bottom trawl survey | Research vessel survey | 2004-2006 | No trend (Fig. 14) | Short time series, high variability |
| WQCI synoptic bottom trawl survey | Research vessel survey | 2006 | No trend | Short time series, high variability |
| *GB Reed* historical QCS survey | Research vessel survey | 1967-1984 | No significant trend (Fig 15) | Highly variable index, proportion of tows with darkblotched varied from <20% - >50% |
| WCVI shrimp trawl survey | Research vessel survey | 1975-2007 | No significant trend (Fig. 16) | High CVs, catches generally not significantly different from year to year, may target juveniles due to shallower water coverage |
| QCS shrimp trawl survey | Research vessel survey | 1999-2007 | No trend (Fig. 18) | High CVs (ranging from <20% - 65%) and highly variable proportion of tows with darkblotched |
| NMFS triennial bottom trawl survey | Research vessel survey | 1980-2001 | Increasing non-significant trend in Canadian waters 1980-1998 (Fig. 20) | High CVs, high variability in proportion of tows with darkblotched (11-33%) |
| Combined log-linear regression: *G.B. Reed*, NMFS, QCS, WCVI | Research vessel surveys combined | 1967-2007 | Increasing non-significant trend | As for individual surveys; best possible analysis of combined survey information |
| Commercial trawl CPUE | Commercial CPUE | 1996-2007 | Index declined 3.9% per year (Fig. 21) | Index influenced by changes in fishing practices over survey period |

### Rescue effect

Darkblotched Rockfish along the US west coast are considered a single stock from California to Washington and are caught primarily through bottom trawling. The stock has shown a long-term declining trend, with an estimated 84% decline in spawning stock (i.e., age 1+ individuals) between 1928 and 1999 (Rogers 2005). Much of the decline occurred as a result of large-scale harvesting by foreign fleets in the 1960s and increased domestic catches in the 1980s and 1990s (Rogers 2005). The spawning output of the species has been below the current management target of 40% of unfished biomass (S40%) since 1984. S40% is PFMC's default proxy for spawning output at which the maximum sustained yield is obtained and is estimated as 10660 x $10^7$ eggs for Darkblotched Rockfish. In 1989 spawning output fell below the minimum threshold of 25% of unfished biomass (S25%), at which stocks are considered overfished. The stock is now considered to be at approximately 16% of unfished biomass (Roberts and Stevens 2006).

Given the low dispersal behaviour of Darkblotched Rockfish (i.e., maximum 100 km dispersal range along US west coast; Gomez-Uchida and Banks 2005), it appears unlikely that individuals from either Alaska or US west coast populations would successfully colonize habitat in BC in the event of Canadian extirpation of the species, at least in the short term (e.g., < 50 year period). Furthermore, due to current low population levels along the US west coast, this area does not seem a promising source of future colonists to Canadian waters.

## LIMITING FACTORS AND THREATS

Several life history traits of the Darkblotched Rockfish make for low resilience in the face of mortality from human activities. The apparently low dispersive ability of juvenile individuals, and the highly sedentary nature of adults, combined with delayed maturity and very slow growth, mean that Darkblotched Rockfish populations may not readily recover from stressors such as overfishing and habitat degradation or loss. Additionally, variable oceanographic conditions influence survival at the pelagic larval stage, leading to significant variation in reproductive success. Ultimately, this may result in a small number of individuals from each generation passing on their genes to the next generation, and low genetic diversity can be further exacerbated by fishing activity, as is evidenced by the low $N_e/N$ ratio estimated for populations along the US west coast (Gomez-Uchida and Banks 2006).

Commercial fishing is currently the main threat to Darkblotched Rockfish, although the species is not targeted and catches are small relative to other species. As for other rockfish, intensive fishing practices may disproportionately target the largest, oldest and most fecund individuals, potentially leading to a truncated age distribution, loss of spawning biomass and diminished recruitment success (Berkeley and Markle 1999), while bottom trawling may degrade the high-relief habitat associated with the species.

The species is primarily caught in the trawl fishery, as a bycatch in the harvest of Pacific Ocean Perch, although small numbers are also taken by the hook and line and halibut fisheries (Appendix 1). The average annual catch since dockside monitoring was initiated for the trawl fishery (1994) is approximately 74 tonnes (Appendix 1).

The trawl fishery for slope rockfish began in the mid 1930s in BC and the Darkblotched Rockfish has always been a minor bycatch species, as is evidenced by its relatively constant mean annual catch by decade (Fig. 24). The fishery was dominated by foreign vessels until the mid-1970s. In particular, US vessels were active from the start of the fishery until the mid-1970s, and Japanese and Soviet ships targeted BC slope rockfish from 1965 to 1976. The Soviet 1966 trawl fishery caught between 29 000 and 63 000 tonnes of groundfish in BC. Assuming the darkblotched to other rockfish ratio calculated for contemporary domestic trawls, this translates to approximately 400-800 tonnes of darkblotched caught in the 1966 fishery. This amount is an order of magnitude higher than average annual catch levels since 1994 by domestic vessels (Haigh and Starr 2008). Catches in the United States are considerably higher than in Canada. Triennial trawl surveys in the Gulf of Alaska show a highly variable annual catch between 1984 and 1999, ranging from 6 to 272 tonnes, with an annual average of approximately 153 tonnes (Heifetz *et al.* 2000 cited in Haigh and Starr 2008). Similarly, along the US west coast, annual catches fluctuated between 1994 and 2004, ranging from 127 to 1041 tonnes, with an annual average of approximately 550 tonnes (Table 4), over seven times greater than in BC.

Darkblotched Rockfish were designated as overfished along the US west coast in 2000. A rebuilding plan for Darkblotched Rockfish was implemented in the US in 2003. Conservation measures include year-round and temporal area closures, gear restrictions and regulations and extremely restricted landing limits (close to 0 along the California to Washington coastline) (Roberts and Stevens 2006). The 2005 stock assessment indicates that Darkblotched Rockfish are showing gradual signs of recovery. Spawning biomass has approximately doubled since 1999 (from 2136 x $10^7$ eggs to 4453 x $10^7$ eggs), although it is still at very low levels. The PFMC estimates that the target S40% biomass will be restored with 90% probability by 2030.

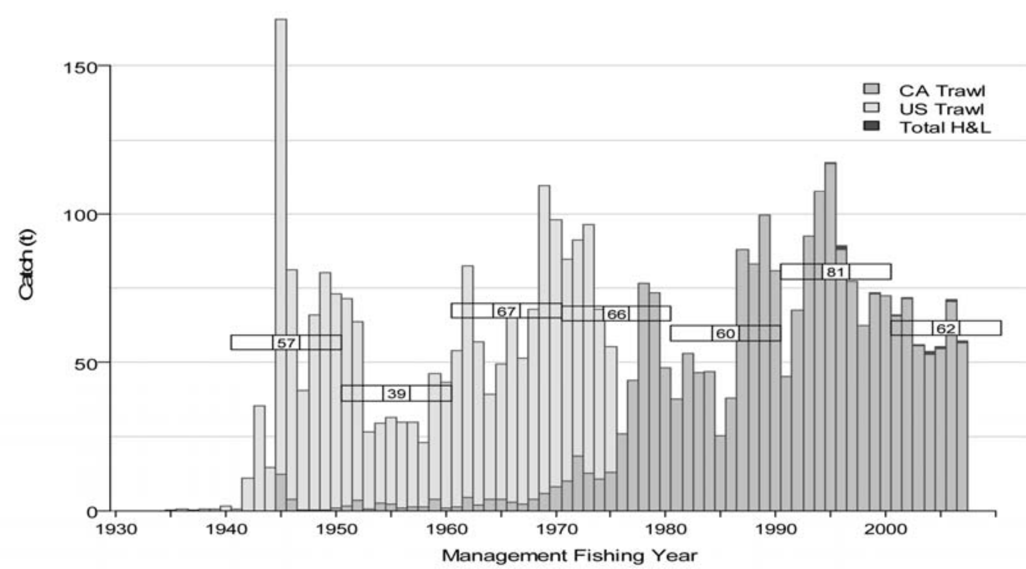


Figure 24. Catch history of Darkblotched Rockfish by US and Canadian fleets along the BC coast. Mean annual catches by decade are displayed in the horizontal boxes (from Haigh and Starr 2008).

**Table 4. Annual catches of Darkblotched Rockfish in the US bottom trawl fishery along the California, Oregon and Washington coasts (from Rogers 2005).**

| Fishing Year | Total catch (t) |
|---|---|
| 1994 | 918 |
| 1995 | 790 |
| 1996 | 790 |
| 1997 | 862 |
| 1998 | 1041 |
| 1999 | 434 |
| 2000 | 436 |
| 2001 | 272 |
| 2002 | 192 |
| 2003 | 127 |
| 2004 | 227 |

## SPECIAL SIGNIFICANCE OF THE SPECIES

Darkblotched Rockfish has always been a bycatch of the Pacific Ocean Perch fishery in Canada, although catches in Canada have been substantially lower than in the US. In the 2007-08 fishing season, the Canadian trawl fishery landed 55 t of Darkblotched Rockfish, representing a landed value of approximately $61 000 based on a $0.50/lb. market price (DFO 2008). In contrast, the Darkblotched Rockfish has been a major component of the US groundfish fishery. For example, in 2004 it was the fourth most common species caught along the US west coast by commercial trawlers (Roberts and Stevens 2006).

## EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The status of the Darkblotched Rockfish has not been ranked by NatureServe (NatureServe 2008), by the BC Conservation Data Centre (Prescott pers. comm. 2007), or by IUCN's Species Survival Commission (IUCN Red List).

No specific fishery management measures exist for Darkblotched Rockfish in Canada; the fishery for the species is regulated collectively with other non-TAC rockfish. The current management measures for all rockfish species include commercial fishery quotas for combined non-TAC species, with measures to control commercial fishing gear and seasons, recreational bag limits, and Rockfish Conservation Areas (although since these are mainly inshore, they would have relatively little impact on Darkblotched Rockfish). Management of the commercial multi-species rockfish fishery has been substantially strengthened since the mid-1990s through increased observer coverage, dockside monitoring, and on-board video monitoring of catches and discards on vessels which do not carry observers. In the US the species is currently considered overfished and is managed under a rebuilding plan that regulates where, when and by how much it can be harvested along the US west coast.

# TECHNICAL SUMMARY

*Sebastes crameri*
Darkblotched Rockfish — Sébaste tacheté
Range of Occurrence in Canada: Marine waters along BC's continental slope

**Demographic Information**

| | |
|---|---|
| Generation time (average age of parents in the population)<br>▪ based on 50% maturity reached at 8.5 years and an instantaneous natural mortality rate of 0.07 | 23 yrs |
| Observed percent reduction in total number of mature individuals over the last 10 years or three generations:<br>▪ see table of indices (Table 3)<br>▪ no consistent, significant trends in research surveys<br>▪ commercial CPUE has declined but is influenced by fishery changes | No significant trends observed |
| [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]. | Unknown |
| [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. | Unknown |
| Are the causes of the decline clearly reversible? | No decline observed |
| Are the causes of the decline understood? | No decline observed |
| Have the causes of the decline ceased? | Not applicable |
| [Observed, inferred, or projected] trend in number of populations | Not applicable – single population |
| Are there extreme fluctuations in number of mature individuals? | No |
| Are there extreme fluctuations in number of populations? | Not applicable |

**Extent and Area Information**

| | |
|---|---|
| Estimated extent of occurrence | 43 000 km² |
| [Observed, inferred, or projected] trend in extent of occurrence | Unknown |
| Are there extreme fluctuations in extent of occurrence? | Probably not |
| Index of area of occupancy (IAO) | 9000- 31 000 km² |
| [Observed, inferred, or projected] trend in area of occupancy | Unknown |
| Are there extreme fluctuations in area of occupancy? | Probably not |
| Is the total population severely fragmented? | No |
| Number of current locations | Not applicable (continuous distribution) |
| Trend in number of locations | Not applicable |
| Are there extreme fluctuations in number of locations? | Not applicable |
| Trend in area and/or quality of habitat | Unknown |

**Number of mature individuals in each population**

| Population | N Mature Individuals |
|---|---|
| | |
| | |
| Total | Unknown |
| Number of populations (locations) | Not applicable |

**Quantitative Analysis**

| | |
|---|---|
| Not carried out | |

**Threats (actual or imminent, to populations or habitats)**

| |
|---|
| Commercial harvest is the main known threat, since this species is harvested in commercial fisheries targeting other species, but catches are small. Bottom trawling may impact the rocky high-relief habitat associated with the species. |

**Rescue Effect (immigration from an outside source)**

| | |
|---|---|
| Status of outside population(s)?<br>USA: Population in Washington, Oregon and California declared overfished in 2000 due to approximately 84% decline in spawning stock from 1928-1999. Spawning biomass has approximately doubled since 1999 but is still at very low levels. | |
| Is immigration known? | Possible at pelagic larval stage, although dispersal ability reported to be limited |
| Would immigrants be adapted to survive in Canada? | Probably |
| Is there sufficient habitat for immigrants in Canada? | Probably |
| Is rescue from outside populations likely? | Unlikely, as adjacent population depleted and dispersal ability may be limited |

**Current Status**

| |
|---|
| COSEWIC: Special Concern (November 2009) |

**Status and Reasons for Designation**

| | |
|---|---|
| **Status:**<br>Special concern | **Alpha-numeric code:**<br>Not applicable |
| **Reasons for Designation:**<br>This long-lived species (maximum age 100 years; generation length 23 years) demonstrates episodic recruitment events. The species is taken at relatively low levels in fisheries targeting more abundant rockfishes. Research surveys show no clear abundance trends, although information on abundance trends has relatively high uncertainty. In adjacent US waters, the species declined 84% from 1928-1999 and is considered overfished, although there has been some recent population recovery. Recent surveys do not account for population declines from foreign fishing prior to the 1970s. | |

**Applicability of Criteria**

| |
|---|
| **Criterion A** (Declining Total Population): Not met – no consistent indications of decline in available abundance indices |
| Criterion B (Small Distribution, and Decline or Fluctuation): Not met – extent of occurrence and area of occupancy larger than thresholds |
| **Criterion C** (Small Total Population Size and Decline): Not met – population size estimate not available but certainly larger than threshold |
| **Criterion D** (Very Small Population or Restricted Distribution): Not met |
| **Criterion E** (Quantitative Analysis): Not undertaken |

## ACKNOWLEDGEMENTS AND AUTHORITIES CONSULTED

The report writer is grateful to Rowan Haigh (Department of Fisheries and Oceans) and Paul Starr (Canadian Groundfish Research and Conservation Society) for their much appreciated assistance in the writing of this report. Environment Canada provided funding and support.

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## COLLECTIONS EXAMINED

No collections were examined for this report.

**Appendix 1. Annual catch of Darkblotched Rockfish throughout British Columbia by various fisheries. Catches are rounded to the nearest tonne; entries marked '---' indicate no recorded catch (from Haigh and Starr 2008).**

| Year | CA Trawl | US Trawl | Zn HL | Shed II | Halibut | Total HL | Total |
|---|---|---|---|---|---|---|---|
| 1930 | --- | --- | --- | --- | --- | --- | --- |
| 1931 | --- | --- | --- | --- | --- | --- | --- |
| 1932 | --- | --- | --- | --- | --- | --- | --- |
| 1933 | --- | --- | --- | --- | --- | --- | --- |
| 1934 | --- | 0 | --- | --- | --- | --- | 0 |
| 1935 | --- | 0 | --- | --- | --- | --- | 0 |
| 1936 | --- | 0 | --- | --- | --- | --- | 0 |
| 1937 | --- | 0 | --- | --- | --- | --- | 0 |
| 1938 | --- | 1 | --- | --- | --- | --- | 1 |
| 1939 | --- | 1 | --- | --- | --- | --- | 1 |
| 1940 | --- | 2 | --- | --- | --- | --- | 2 |
| 1941 | --- | 1 | --- | --- | --- | --- | 1 |
| 1942 | --- | 11 | --- | --- | --- | --- | 11 |
| 1943 | --- | 35 | --- | --- | --- | --- | 35 |
| 1944 | --- | 15 | --- | --- | --- | --- | 15 |
| 1945 | 12 | 153 | --- | --- | --- | --- | 166 |
| 1946 | 4 | 77 | --- | --- | --- | --- | 81 |
| 1947 | 0 | 40 | --- | --- | --- | --- | 41 |
| 1948 | 0 | 66 | --- | --- | --- | --- | 66 |
| 1949 | 0 | 80 | --- | --- | --- | --- | 80 |
| 1950 | 1 | 72 | --- | --- | --- | --- | 73 |
| 1951 | 2 | 70 | --- | --- | --- | --- | 72 |
| 1952 | 3 | 60 | --- | --- | --- | --- | 64 |
| 1953 | 1 | 26 | --- | --- | --- | --- | 26 |
| 1954 | 3 | 27 | --- | --- | --- | --- | 29 |
| 1955 | 2 | 29 | --- | --- | --- | --- | 31 |
| 1956 | 1 | 29 | --- | --- | --- | --- | 30 |
| 1957 | 1 | 28 | --- | --- | --- | --- | 30 |
| 1958 | 1 | 22 | --- | --- | --- | --- | 23 |
| 1959 | 4 | 42 | --- | --- | --- | --- | 46 |
| 1960 | 1 | 43 | --- | --- | --- | --- | 43 |
| 1961 | 1 | 53 | --- | --- | --- | --- | 54 |
| 1962 | 5 | 78 | --- | --- | --- | --- | 83 |
| 1963 | 2 | 55 | --- | --- | --- | --- | 57 |
| 1964 | 4 | 35 | --- | --- | --- | --- | 39 |
| 1965 | 4 | 46 | --- | --- | --- | --- | 49 |
| 1966 | 3 | 63 | --- | --- | --- | --- | 66 |
| 1967 | 2 | 49 | --- | --- | --- | --- | 51 |
| 1968 | 4 | 64 | --- | --- | --- | --- | 68 |
| 1969 | 6 | 104 | --- | --- | --- | --- | 110 |
| 1970 | 8 | 90 | --- | --- | --- | --- | 98 |
| 1971 | 10 | 75 | --- | --- | --- | --- | 85 |
| 1972 | 19 | 73 | --- | --- | --- | --- | 91 |
| 1973 | 13 | 84 | --- | --- | --- | --- | 96 |
| 1974 | 11 | 57 | --- | --- | --- | --- | 68 |
| 1975 | 13 | 43 | --- | --- | --- | --- | 55 |
| 1976[L] | 26 | --- | --- | --- | --- | --- | 26 |
| 1977 | 44 | --- | --- | --- | --- | --- | 44 |

| Year | CA Trawl | US Trawl | Zn HL | Shed II | Halibut | Total HL | Total |
|---|---|---|---|---|---|---|---|
| 1978 | 77 | --- | --- | --- | --- | --- | 77 |
| 1979[L] | 73 | --- | --- | --- | --- | --- | 73 |
| 1980 | 48 | --- | --- | --- | --- | --- | 48 |
| 1981 | 38 | --- | --- | --- | --- | --- | 38 |
| 1982 | 53 | --- | --- | --- | --- | --- | 53 |
| 1983 | 47 | --- | --- | --- | --- | --- | 47 |
| 1984 | 47 | --- | --- | --- | --- | --- | 47 |
| 1985 | 25 | --- | --- | --- | --- | --- | 25 |
| 1986 | 38 | --- | --- | --- | --- | --- | 38 |
| 1987 | 88 | --- | --- | --- | --- | --- | 88 |
| 1988 | 83 | --- | --- | --- | --- | --- | 83 |
| 1989 | 100 | --- | --- | --- | --- | --- | 100 |
| 1990 | 81 | --- | --- | --- | --- | --- | 81 |
| 1991[D] | 45 | --- | --- | --- | --- | --- | 45 |
| 1992[L] | 68 | --- | --- | --- | --- | --- | 68 |
| 1993 | 92 | --- | --- | --- | --- | --- | 92 |
| 1994[D] | 108 | --- | --- | --- | --- | --- | 108 |
| 1995[T] | 117 | --- | 0.29 | --- | 0.08 | 0.36 | 118 |
| 1996[D,O] | 88 | --- | 1.07 | --- | 0.05 | 1.12 | 89 |
| 1997[Q,T] | 77 | --- | 0.13 | --- | 0.11 | 0.24 | 77 |
| 1998 | 62 | --- | 0.08 | --- | 0.12 | 0.21 | 63 |
| 1999 | 73 | --- | 0.09 | --- | 0.14 | 0.23 | 73 |
| 2000[T] | 72 | --- | 0.04 | --- | 0.08 | 0.12 | 72 |
| 2001 | 66 | --- | 0.15 | --- | 0.22 | 0.37 | 66 |
| 2002 | 72 | --- | 0.06 | --- | 0.29 | 0.35 | 72 |
| 2003 | 56 | --- | 0.14 | --- | 0.32 | 0.45 | 56 |
| 2004 | 53 | --- | 0.12 | 0.01 | 0.81 | 0.93 | 54 |
| 2005 | 55 | --- | 0.02 | --- | 0.47 | 0.48 | 55 |
| 2006 | 70 | --- | 0.00 | --- | 0.84 | 0.85 | 71 |
| 2007 | 57 | --- | 0.02 | --- | 0.53 | 0.55 | 57 |
| UNK | 76 | --- | --- | --- | --- | --- | 76 |
| Total | 2,313 | 1,897 | 2 | 0 | 4 | 6 | 4,216 |

[D] Dockside monitoring program (DMP) started: 1991 – halibut; 1994 – trawl; 1996 – ZN H&L
[O] Observer program started: 1996 – trawl
[L] Limited vessel entry: 1976 – trawl; 1979 – halibut; 1992 ZN H&L
[Q] Individual vessel quota (IVQ) system started for TAC species: 1997 – trawl
[T] Trip limits implemented: 1995 – ZN monthly limit on rockfish aggregate; 1997 – trawl trip limit of 15,000 lbs for combined non-TAC rockfish; 2000 – halibut option D with annual limit of 20,000 lbs of rockfish aggregate.

**Appendix 2. Relative biomass estimates for Darkblotched Rockfish from the Goose Island Gully *G.B. Reed* trawl surveys (1967-1984). Bias corrected confidence intervals and coefficients of variations (CVs) are based on 1000 bootstrap replicates (from Haigh and Starr 2008).**

| Survey Year | Relative biomass (t) | Mean bootstrap biomass (t) | Lower 95% bound biomass (t) | Upper 95% bound biomass (t) | Bootstrap CV | Analytic CV |
|---|---|---|---|---|---|---|
| 1967 | 21.1 | 21.2 | 7.9 | 39.4 | 0.395 | 0.396 |
| 1969 | 36.1 | 35.8 | 5.4 | 118.8 | 0.732 | 0.722 |
| 1971 | 28.8 | 28.9 | 14.4 | 49.0 | 0.323 | 0.320 |
| 1973 | 22.3 | 21.3 | 2.9 | 55.4 | 0.596 | 0.595 |
| 1976 | 204.6 | 205.7 | 43.4 | 554.4 | 0.657 | 0.649 |
| 1977 | 41.2 | 40.9 | 16.0 | 79.9 | 0.378 | 0.368 |
| 1984 | 9.6 | 9.8 | 3.5 | 18.2 | 0.378 | 0.378 |

**Appendix 3. Relative biomass estimates for Darkblotched Rockfish from the WCVI shrimp trawl survey. Bias corrected confidence intervals and CVs based on 1000 bootstrap replicates (from Haigh and Starr 2008).**

| Survey Year | Relative biomass (t) | Mean bootstrap biomass (t) | Lower 95% bound biomass (t) | Upper 95% bound biomass (t) | Bootstrap CV | Analytic CV |
|---|---|---|---|---|---|---|
| 1975 | 12.6 | 12.7 | 0.0 | 43.6 | 0.899 | 0.910 |
| 1976 | 0.7 | 0.6 | 0.0 | 1.8 | 0.704 | 0.705 |
| 1977 | 6.7 | 6.6 | 3.0 | 14.7 | 0.412 | 0.411 |
| 1978 | 1.8 | 1.8 | 0.2 | 6.4 | 0.834 | 0.790 |
| 1979 | 11.5 | 11.4 | 0.0 | 46.0 | 0.977 | 1.000 |
| 1980 | 0 | 0 | – | – | – | 0.000 |
| 1981 | 257.5 | 258.5 | 165.5 | 388.0 | 0.219 | 0.218 |
| 1982 | 12.1 | 12.0 | 3.2 | 26.2 | 0.493 | 0.479 |
| 1983 | 19.2 | 20.3 | 0.0 | 70.8 | 0.957 | 1.000 |
| 1985 | 88.8 | 90.6 | 44.2 | 146.3 | 0.298 | 0.306 |
| 1987 | 92.3 | 90.9 | 43.7 | 169.7 | 0.359 | 0.363 |
| 1988 | 22.9 | 23.1 | 9.3 | 44.2 | 0.372 | 0.358 |
| 1989 | 30.5 | 30.0 | 10.6 | 60.7 | 0.422 | 0.392 |
| 1990 | 63.2 | 64.1 | 26.7 | 136.7 | 0.422 | 0.417 |
| 1991 | 38.0 | 38.2 | 21.0 | 57.8 | 0.247 | 0.264 |
| 1992 | 11.0 | 10.4 | 1.2 | 35.1 | 0.760 | 0.754 |
| 1993 | 121.9 | 122.6 | 75.5 | 183.9 | 0.225 | 0.222 |
| 1994 | 61.7 | 62.0 | 35.3 | 90.0 | 0.230 | 0.239 |
| 1995 | 13.2 | 13.2 | 3.8 | 26.8 | 0.438 | 0.452 |
| 1996 | 91.4 | 91.6 | 48.6 | 149.0 | 0.280 | 0.279 |
| 1997 | 275.2 | 278.0 | 153.4 | 458.9 | 0.280 | 0.284 |
| 1998 | 110.3 | 111.7 | 34.4 | 236.3 | 0.459 | 0.468 |
| 1999 | 38.1 | 37.3 | 6.7 | 108.2 | 0.661 | 0.673 |
| 2000 | 82.8 | 82.2 | 51.3 | 127.7 | 0.232 | 0.226 |
| 2001 | 118.0 | 116.9 | 74.1 | 179.6 | 0.223 | 0.223 |
| 2002 | 65.1 | 63.7 | 16.3 | 185.5 | 0.651 | 0.666 |
| 2003 | 28.0 | 28.7 | 7.8 | 64.9 | 0.517 | 0.517 |
| 2004 | 38.4 | 38.4 | 10.1 | 97.2 | 0.560 | 0.579 |
| 2005 | 16.6 | 16.5 | 8.5 | 28.6 | 0.304 | 0.315 |
| 2006 | 42.3 | 43.4 | 7.0 | 121.5 | 0.708 | 0.698 |
| 2007 | 8.2 | 8.2 | 2.5 | 20.1 | 0.551 | 0.558 |

**Appendix 4. Relative biomass estimates for Darkblotched Rockfish from the QC Sound shrimp trawl survey (1999-2007). Bias corrected confidence intervals and CVs are based on 1000 bootstrap replicates (from Haigh and Starr 2008).**

| Survey Year | Relative biomass (t) | Mean bootstrap biomass (t) | Lower 95% bound biomass (t) | Upper 95% bound biomass (t) | Bootstrap CV | Analytic CV |
|---|---|---|---|---|---|---|
| 1999 | 21.9 | 21.9 | 8.6 | 44.7 | 0.408 | 0.403 |
| 2000 | 5.2 | 5.1 | 2.1 | 10.6 | 0.397 | 0.389 |
| 2001 | 68.0 | 67.2 | 41.3 | 108.2 | 0.247 | 0.241 |
| 2002 | 48.7 | 48.8 | 32.0 | 69.7 | 0.193 | 0.200 |
| 2003 | 0.7 | 0.7 | 0.2 | 1.4 | 0.418 | 0.403 |
| 2004 | 2.9 | 2.9 | 0.9 | 5.6 | 0.413 | 0.424 |
| 2005 | 7.3 | 7.1 | 1.2 | 20.1 | 0.641 | 0.656 |
| 2006 | 19.6 | 19.5 | 9.2 | 32.4 | 0.302 | 0.309 |
| 2007 | 7.3 | 7.3 | 3.8 | 11.4 | 0.261 | 0.271 |

**Appendix 5. Relative biomass estimates for Darkblotched Rockfish in the Vancouver INPFC region (total region, Canadian portion, and US portion) with 95% confidence regions derived from the bootstrap distribution of biomass. Estimates are based on 5000 bootstrap replicates (from Haigh and Starr 2008).**

| Estimate type | Survey Year | Relative biomass (t) | Mean bootstrap biomass | Lower bound biomass | Upper bound biomass | Bootstrap CV | Analytic CV |
|---|---|---|---|---|---|---|---|
| Total Vancouver | 1980 | 180 | 180 | 60 | 384 | 0.456 | 0.470 |
| | 1983 | 526 | 509 | 201 | 1,142 | 0.444 | 0.437 |
| | 1989 | 432 | 423 | 223 | 774 | 0.318 | 0.341 |
| | 1992 | 722 | 725 | 289 | 1,382 | 0.380 | 0.397 |
| | 1995 | 916 | 914 | 405 | 1,594 | 0.329 | 0.339 |
| | 1998 | 1,090 | 1,086 | 485 | 2,024 | 0.355 | 0.363 |
| | 2001 | 1,160 | 1,009 | 53 | 2,299 | 0.828 | 0.921 |
| Canada Vancouver | 1980 | 127 | 128 | 15 | 337 | 0.644 | 0.668 |
| | 1983 | 233 | 234 | 54 | 529 | 0.505 | 0.506 |
| | 1989 | 132 | 132 | 24 | 359 | 0.640 | 0.654 |
| | 1992 | 358 | 359 | 88 | 935 | 0.593 | 0.603 |
| | 1995 | 596 | 598 | 190 | 1,163 | 0.416 | 0.430 |
| | 1998 | 740 | 741 | 213 | 1,564 | 0.453 | 0.463 |
| | 2001 | 25 | 25 | 8 | 51 | 0.421 | 0.426 |

| Estimate type | Survey Year | Relative biomass (t) | Mean bootstrap biomass | Lower bound biomass | Upper bound biomass | Bootstrap CV | Analytic CV |
|---|---|---|---|---|---|---|---|
| US Vancouver | 1980 | 55 | 54 | 10 | 114 | 0.487 | 0.510 |
| | 1983 | 272 | 257 | 50 | 742 | 0.673 | 0.651 |
| | 1989 | 300 | 292 | 155 | 475 | 0.289 | 0.336 |
| | 1992 | 365 | 367 | 108 | 764 | 0.455 | 0.487 |
| | 1995 | 320 | 316 | 137 | 553 | 0.334 | 0.331 |
| | 1998 | 350 | 345 | 155 | 692 | 0.385 | 0.386 |
| | 2001 | 1,135 | 984 | 28 | 2,271 | 0.849 | 0.942 |