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ECOSYSTEM OVERVIEW:

PACIFIC NORTH COAST INTEGRATED MANAGEMENT AREA (PNCIMA)

APPENDIX G: GROUND FISH

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1.0 INTRODUCTION

Groundfish are fish species that spend most of their time on or near the sea bottom. They can be divided into four general groups with similar characteristics: roundfish, flatfish, rockfish and elasmobranchs. Many are habitat/site specific and the juveniles often occupy a different niche than the adults. They display a considerable amount of phenotypic plasticity with regard to reproduction. Some species spawn in late winter or early spring with eggs released and fertilized in the water column, others are batch spawners and have protracted spawning periods. Reproductive strategies vary among species as well. Some species maximize fecundity, while others maximize survival of their offspring with parental care. Elasmobranchs give birth to live young that are sustained by a yolk sac in the days following spawning, while rockfish undergo internal fertilization and release live larvae. They are all iteroparous – spawning many times during their lifetime likely because of the uncertainty of their oceanic environment. Individual life history characteristics determine how species will respond to exploitation and environmental perturbation. Flatfish species with their moderate growth and natural mortality rates are the most robust to over fishing whereas rockfish species, particularly the long lived species, are the least robust.

Groundfish species are harvested year round by trawl, longline, and trap, and form the most significant fishery in British Columbia (BC) in terms of landed catch weight. In recent years they have been increasingly targeted by the recreational sector, especially in the Strait of Georgia. The commercial fisheries catch a wide range of species that can be categorized in two ways: 1) species of commercial value that are retained for sale, and 2) species with no commercial value which are released at sea. In recent years the industry has significantly reduced the proportion of species in the latter category. Groundfish fishery managers rely on stock assessment advice provided by the Science Branch of Fisheries & Oceans Canada (DFO) to set TACs (Total Allowable Catch) for species caught in commercial fisheries. Data collection encompasses all species caught in all areas of the coast. Research and commercial fishery data are housed in two modern relational databases. Analysis of species abundance and distribution data incorporates both spatial and temporal features. Recent surveys have employed the use of visual methods to examine species density in relation to habitat type. This type of data remains limited for most species but is critical to understanding the role of habitat in marine ecosystems.

2.0 LIFE HISTORY

2.1 Roundfish

Roundfish species exhibit two general life history patterns: 1) opportunistic life strategy employed by forage fish and 2) intermediate strategy exhibited by larger, more long lived species. Forage fish species are discussed in Appendix H: Pelagic Fishes, and will not be discussed here. Intermediate strategists, including lingcod, true cod, tuna, mackerel

and hake exhibit life history traits that are intermediate between short-lived small forage fish with high growth rates, and long lived, slower growing rockfish species. For example, fish species in the intermediate category are typically larger and live longer than forage fish. Most do not live as long as rockfish and they may have large migratory ranges. Prey species for this group include euphausiids and fish.

2.2 Rockfish

Rockfish are generally long lived and slow growing; with maximum ages of over 100 years and age of maturity ranging between 5 and 20 years. They exhibit high fecundity, and have some parental investment. Most rockfish undergo internal fertilization and release live larvae in late winter or early spring. Rockfish are primarily piscivores. They have a pelagic larval or juvenile stage and adults inhabit ranges within subtidal, shelf, or slope benthic habitats. Rockfish have periodic high recruitment events, associated with favourable environmental conditions (King and McFarlane 2003). Compared with roundfish species, the abundance of rockfish populations fluctuate less frequently. Their longevity ensures more years of production per individual and provides insurance against unfavourable environmental conditions. Strong year classes occur on average about once a decade. Rockfish species including Pacific ocean perch, yellowmouth rockfish, silvergray rockfish, canary rockfish, and redstripe rockfish are very important to the commercial fishery. However, managing the commercial harvesting of rockfish is difficult, as long lived species are the least robust to fishing, and require an extremely long rebuilding period after depletion (several decades).

2.3 Flatfish

Flatfish, including halibut, and sole and flounder species, are also periodic strategists but show some differences in life strategy compared to rockfish (King and McFarlane 2003). Flatfish exhibit high fecundity and show little parental investment. Maximum age ranges between 20 and 45 years, and most mature between 3 and 5 years. Flatfish species have a relatively high intrinsic rate of increase and high reproductive output compared to most species. Thus they are more robust to fishing than most other groundfish species.

2.4 Elasmobranchs

Elasmobranchs are long lived, large in size and have delayed maturation. They are slow growing, have low fecundity, and in some cases long gestation periods (King and McFarlane 2003). They exhibit a high degree of parental investment, usually giving birth to live young that are sustained by a yolk sac in the days following spawning. Elasmobranchs include skate and shark species, and are high-order carnivores and piscivores inhabiting a wide range of habitat. Individuals of some species such as dogfish have been found to migrate large distances (McFarlane and King 2002), while others have a high degree of endemism. Elasmobranchs have a low intrinsic rate of increase that may require long periods for rebuilding due to their low reproductive output.

3.0 FISHERY

Groundfish fisheries target on both demersal and pelagic fish species caught on offshore fishing 'grounds'. Commercial species encompass all of the previously mentioned species groups. In addition, the catch includes non commercial species such as poachers, sculpins, gunnels, and eelpouts. There are three general gear types: trawl (all species), longline (rockfish and halibut), and trap (sablefish). The groundfish fishery has increased greatly in value over the last twenty years and provides employment for the fish processing industry all year.

The trawl fishery in BC began in the early 1900s (Wilderbuer *et al.* 2005), although trawling by Canadian vessels did not begin in earnest until after 1945. In the 1960s there were large removals by foreign vessels which operated on 'grounds' inside the 12 mile limit off the west coast until Canada declared extended jurisdiction in 1977. There were few regulations governing the fishery until DFO began to establish quotas and other catch limitation measures by species and areas in the late 1970s. Over time these measures have included license limitations, establishment of Total Allowable Catches (TACs), use of fishing area closures (time/area) and implementation of vessel trip limits for commercial species.

Since 1978, DFO managers have consulted with stakeholders prior to developing annual plans for the management of the groundfish fisheries. The current process includes all stakeholder groups in an atmosphere of co-management. In 1997 DFO and the groundfish trawl industry agreed on a plan to implement an Individual Vessel Quota (IVQ) system. The result was the most advanced fishery management system in the world (Branch *et al.* 2006). Transferable quotas were set for 25 different species in 55 different species area groups. Under this system fishermen have more flexibility to choose when, where, and how to fish. Discards at sea are also minimized and the IVQ system has resulted in full mortality accounting in the British Columbia groundfish fishery. Fishermen wanting additional quota for a given species can arrange to lease or buy quota from another holder.

Any marketable fish released at sea is deducted from the vessel's quota. In addition, since 1996, observers record comprehensive information on catch on every offshore trawl vessel while inshore vessels have electronic monitoring to validate their catch. This allows managers to accurately determine catch and bycatch levels, thereby strengthening their capability. The observer program provides comprehensive data from the fishery and valuable information on discards, locations of catch, time of catch, and species composition of the catch.

Overall, discard rates of marketable fish in the trawl fishery dropped from 25% in 1995 to 7% in 2005 (Branch *et al.* 2006). Prior to 1996 the amount of discards was unknown but some reports put it at more than double that in the IVQ inaugural year of 1996. The decrease in discards has been largely due to the IVQ fishery but also reflects the changing attitude of fishermen. The fishing industry is working to find markets for discarded species and is developing mitigation measures to reduce discards.

In 1999, DFO introduced at-sea observers in the halibut fishery and, in 2001, expanded this requirement to other groundfish longline fisheries. Bycatch in the longline industry has been a key issue with the advisory groups. Commercial sectors (Commercial Industry Caucus) are currently working toward an integrated groundfish industry. As of April 1, 2006, quotas were shared across gear types and one set of regulations and areas was used to manage the entire fishery. All vessels must retain observers or have electronic monitoring.

The current groundfish trawl fleet is composed of approximately 88 vessels landing approximately 140,000 tonnes annually, worth an estimated value of \$60-65 million. Twenty five species make up 95% of the landings by weight (Figure G.0, Table G.0, Figure G.1, Table G.1), with 77 species landed. To date 27 different groundfish stocks have been assessed and subject to annual allocations in eight different management areas.

As mentioned before, in addition to the trawl fleet, the Department also regulates the sablefish fleet, the ZN (rockfish) fleet and the halibut fleet. However, quotas for the halibut fleet are set by the International Pacific Halibut Commission. Locations and catch in the non-trawl groundfish fisheries are illustrated in Figure G.2, Table G.2, Figure G.3, and Table G.3.

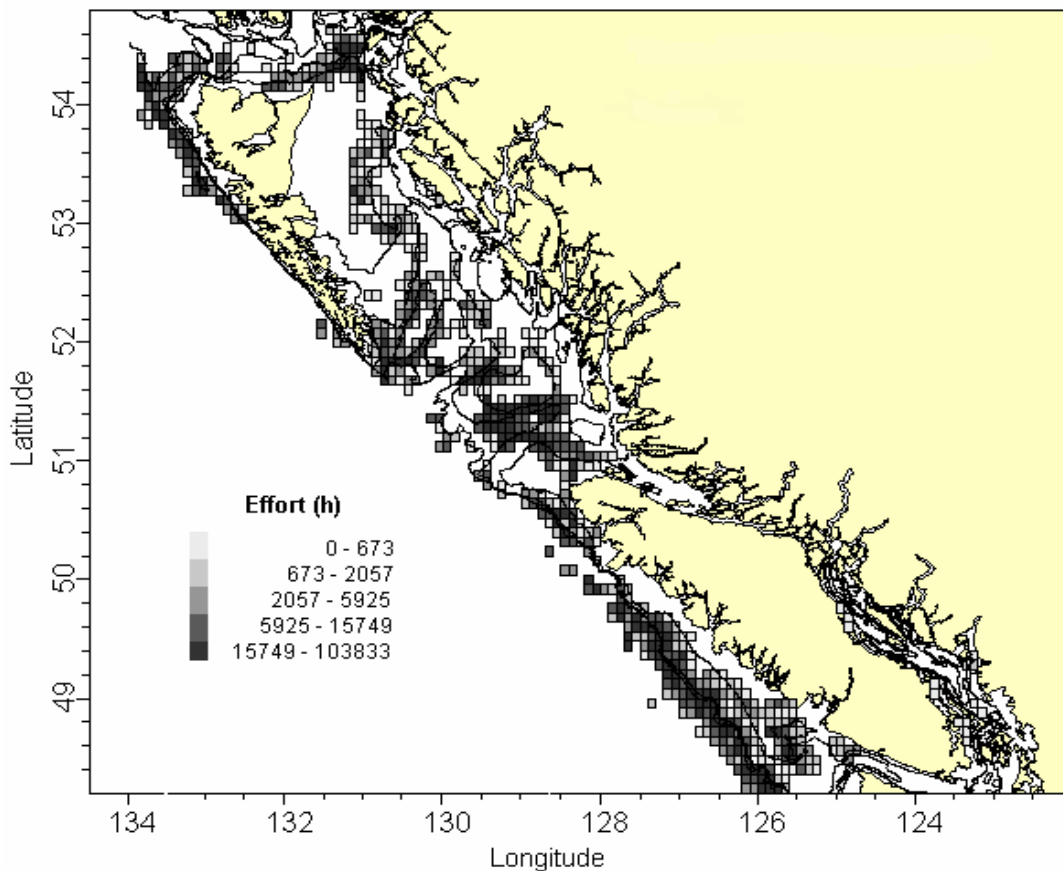


Figure G.0 Total fishing effort (hours year⁻¹) for the British Columbia trawl fishery in 2005.

The hook and line groundfish fishery involves the use of longline, troll, and hand line to catch rockfish, lingcod, dogfish, skate, Pacific cod, sole, and flounder. Rockfish are caught under the authority of trawl and ZN licenses while by catch of rockfish occurs in the salmon troll, halibut, dogfish, and sablefish (seamount only) fisheries (Yamanaka *et al.* 2004). The category ZN license was created in 1986. Prior to 1986, rockfish could be harvested commercially by hook and line gear by any vessel with a vessel-based license allowing the fisher to catch Schedule II – other species. In 1987, 1,935 ZN licenses were issued. The number of ZN licenses issued increased to a high of 2,395 in 1990. ZN licenses are not vessel-based licenses but personal licenses that must be designated to a fishing vessel each year upon license issuance.

Table G.0 Groundfish species that make up 95% of the landings from the British Columbia trawl fishery.

- **Rockfish**
 - Canary rockfish
 - Yelloweye rockfish
 - Redstripe rockfish
 - Sharpchin rockfish
 - Bocaccio
 - Widow rockfish
 - Silvergray rockfish
 - Redbanded rockfish
 - Pacific ocean perch
 - Shortspine thornyhead
 - Yellowmouth rockfish
- **Elasmobranchs**
 - Skates
 - Ratfish
 - Dogfish
- **Roundfish**
 - Sablefish
 - Lingcod
 - Pacific cod
 - Pacific hake
 - Walleye pollock
- **Flatfish**
 - Butter sole
 - Sand sole
 - Rock sole
 - English sole
 - Petrale sole
 - Flathead sole
 - Rex sole
 - Dover sole
 - Pacific halibut
 - Arrowtooth flounder

Table G.1 Species caught incidentally in the groundfish trawl fishery. These species make up the “Trace” category from Figure G.1.

- | | |
|--------------------------|-------------------------|
| Oreos | Pomfrets |
| Dragonfish and viperfish | Northern ronquil |
| Bristlemouth and fangjaw | Tubeshoulders |
| Lumpsuckers and skilfish | Barreleye |
| Slipskins | Javelin spookfish |
| Pacific sandfish | Myctophids |
| Hairtails | Dreamers |
| Medusafish | Opah |
| Pricklebacks | Clingfishes |
| Pacific barracuda | Pipefish and tubesnouts |
| White croaker | Cuskpout |
| Quillfish | Crested ridgehead |
| Gunnels | Toadfishes |
| Gobies | King-of-the-salmon |
| Giant wrymouth | Billfishes |
| Manefishes | |

The Groundfish Hook and Line Advisory Committee (GHLAC) was established in 1990 to advise DFO about issues concerning the groundfish hook and line fisheries. This committee is comprised of representatives of fishers, processors, the United Fisherman and Allied Workers' Union (UFAWU), First Nations, and the Province of BC. Rockfish area licensing (inside/outside) was implemented in 1991 with 2,183 ZN licenses issued: 592 Inside (Strait of Georgia) and 1591 Outside (remainder of the coast). Limited entry was implemented in the inside fishery in 1992, resulting in 74 eligible licenses, and the outside fishery in 1993, resulting in 183 eligible licenses. Maximum vessel length restrictions were included with the limited entry program.

Management measures for rockfish have been increasingly restrictive to ensure resource conservation. Management measures currently in place for the inside and/or outside rockfish fisheries include: area TACs, trip or fishing period limits, incidental catch allowances, relinquishment of limit overages, area/time closures (including Rockfish Conservation Areas), option selection, seabird avoidance measures, at-sea monitoring, and 100% dockside monitoring.

The inside rockfish fishery in 2003/04 season had 65 active licenses. Unlimited stacking of licenses is permitted for the Strait of Georgia resulting in a total of 26 vessels fishing in the 2003/04 season. The TAC is split evenly between all the eligible licenses (74). Fishing season is open between April 1 and March 31 every year.

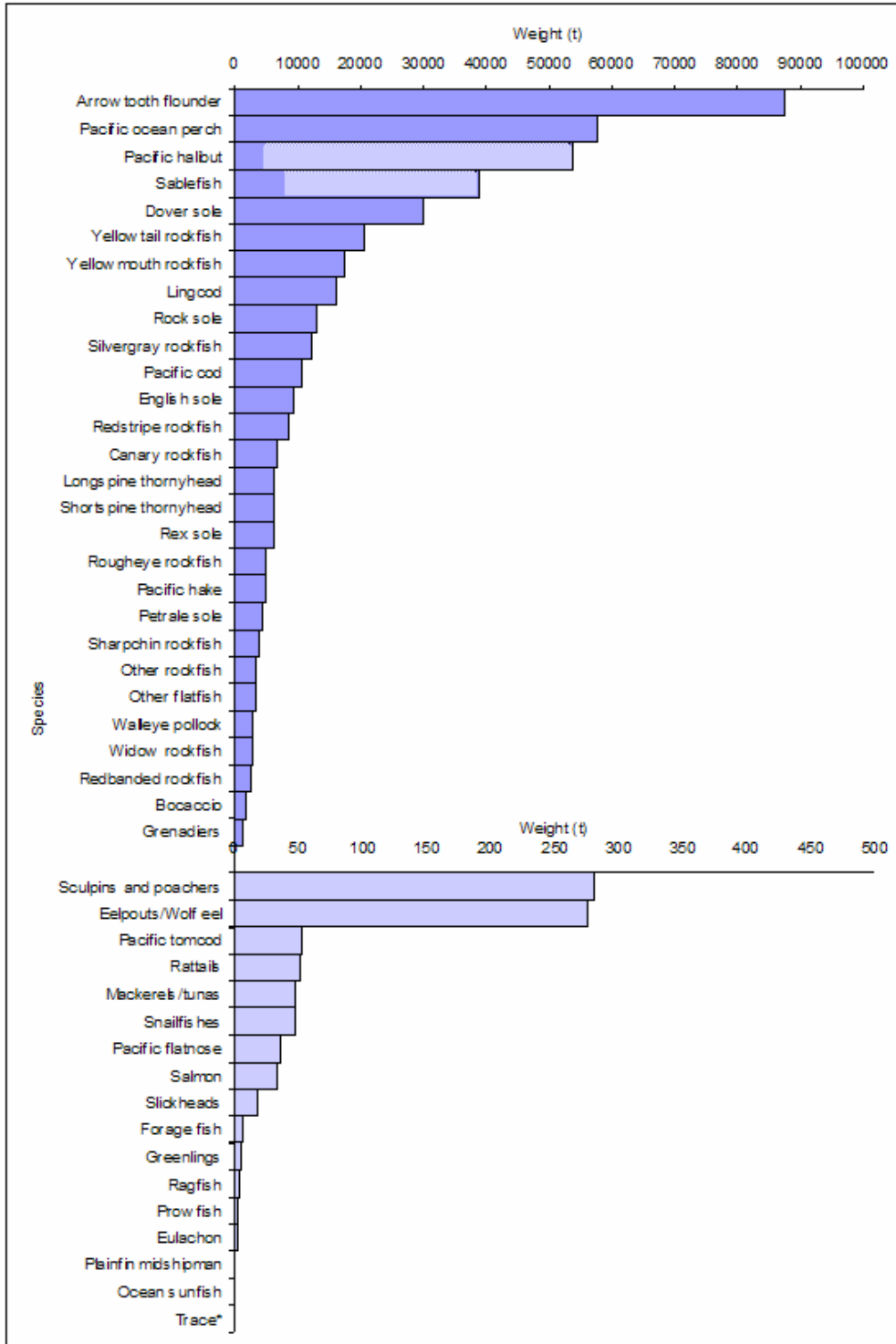


Figure G.1 Species catch by weight in the British Columbia trawl fishery from 1996 to 2005. Sablefish and halibut catch combines trawl (dark blue) and sablefish or halibut fishery (light blue) catches, respectively. Species included in the lower chart account for less than 1% of the cumulative catch by weight. Trace category includes catches of nearly 50 species.

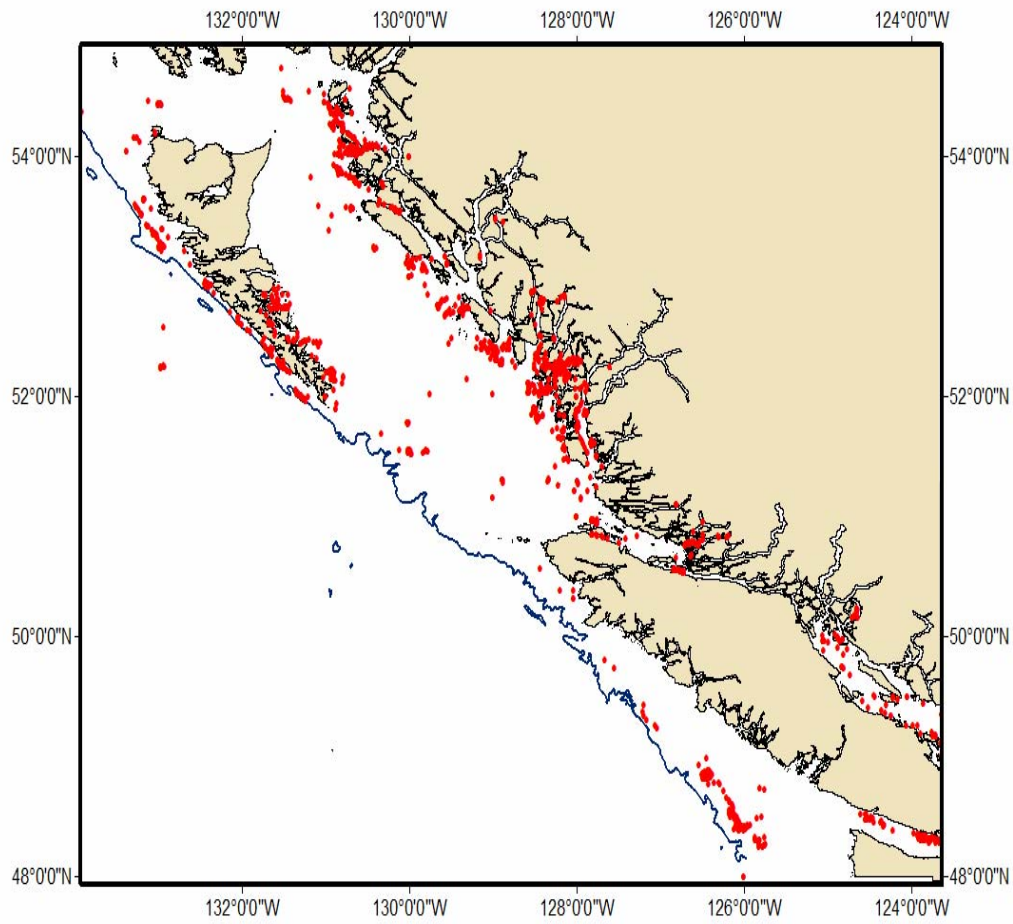


Figure G.2 Set locations for the British Columbia ZN (rockfish) and Schedule II (other species) fisheries in 2002.

Table G.2 Groundfish species caught in the hook and line fishery. Species listed comprise 95% of the landings.

- **Rockfish**
 - Rougheye rockfish
 - Yelloweye rockfish
 - Quillback rockfish
 - Redbanded rockfish
 - Silvergray rockfish
 - Shortraker rockfish
 - Copper rockfish
 - China rockfish
 - Canary rockfish
 - Yellowmouth rockfish
 - Black rockfish
 - Tiger rockfish
 - Bocaccio
 - Vermilion rockfish
 - Shortspine thornyhead
 - Yellowtail rockfish
 - Redstripe rockfish
 - Widow rockfish
 - Pacific ocean perch
 - Rosethorn rockfish
 - Greenstriped rockfish
 - Blue rockfish
 - Dusky rockfish
- **Elasmobranchs**
 - Spiny dogfish
 - Skates
- **Roundfish**
 - Pacific cod
 - Sablefish
 - Lingcod
 - Greenlings
- **Cottids**
 - Sculpins
 - Cabezon
- **Flatfish**
 - Pacific halibut
 - Rock sole
 - Arrowtooth flounder

The outside rockfish fishery is divided into several Options: Option A targets quillback, copper, china, and tiger rockfish for the live rockfish market; Option B is primarily a yelloweye rockfish fishery that delivers to a ‘fresh’ market; Option C lands primarily deep-water species such as shortraker rockfish, rougheye rockfish, and redbanded rockfish; and Option D is a combination fishing program for vessels licensed for both halibut and outside rockfish. Fishers must select their options prior to the season. Only one license is permitted per vessel. For 2004/05 fishing season, of the 191 eligible licenses, 43 chose Option A, 16 Option B, 21 Option C, and 111 Option D.

Inshore rockfish are caught in longline fisheries coastwide. Historically, the largest component of the catch has been taken by commercial fishers. However, catches from the recreational sector have increased significantly in recent years in the Strait of Georgia. Catch records from the commercial fishery are taken from logbook reporting, dockside monitoring, and onboard observer programs. Recreational fisheries are monitored in various locations on the coast through creel surveys and logbook programs.

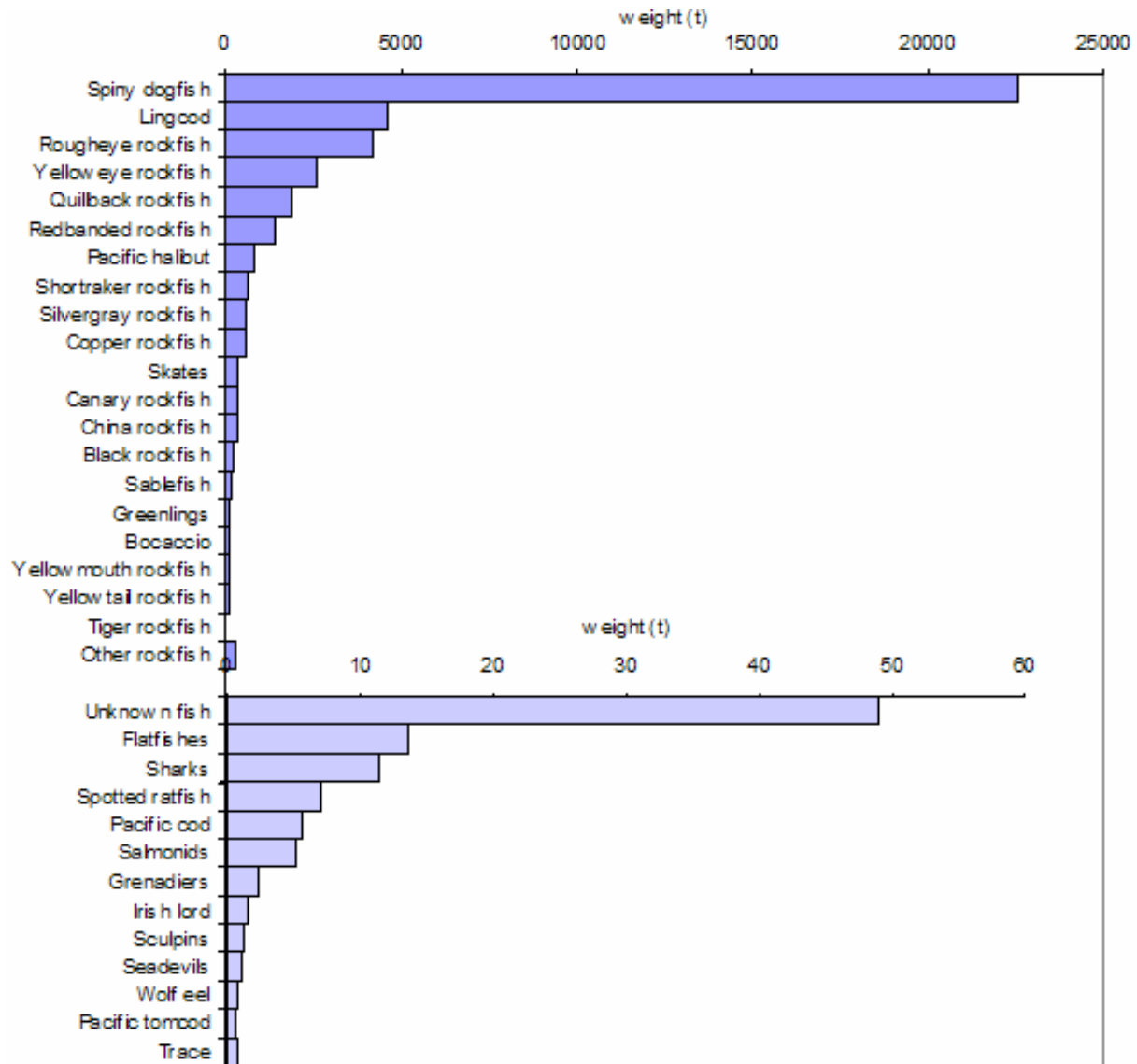


Figure G.3 Species catch by weight in the BC hook and line fishery, 1996 to 2005. Species included in the lower chart account for less than 1% of the cumulative catch by weight. Trace category includes small catches of 15 species.

Table G.3 Species caught incidentally in the groundfish hook and line fishery. These species make up the “Trace” category from Figure G.3.

Drums	Walleye pollock
Bigfin lanternfish	Barracudinas
Pacific hake	Snailfishes
Skilfish	Rockweed gunnel
Surfperches	Wrymouths
Striped marlin	Sturgeons
Prickleback	Hagfishes
Tubenoses	

4.0 DATA SOURCES

Groundfish data collection began at ports of landing in the early 1950s. From 1954 to 1995 port samplers collected information from a voluntary logbook program. However, some fishermen did not participate in the logbook program and some withheld information. Historically, commercial fishery data was housed in a database, GFcatch, with individual records corresponding to spatial/temporal scales. Information was pooled by fishing ground and not resolved by individual haul. In the early 1990s, work commenced on two modern relational databases. The first, PacHarv, houses all commercial fishery data collected since 1996. The second, GFbio, contains all of the data that has been collected on research cruises over the last 50 years. These two databases provide the comprehensive information required for stock assessment and research work.

5.0 STOCK STATUS AND MONITORING

5.1 Research surveys

The need for research surveys arose because of the bias that exists in data collected from the commercial fishery. Fishermen do not sample the resource in a random fashion. Fishery CPUE (catch per unit effort) was a proxy for species abundance since the monitoring of fisheries began. Over time, regulatory effects and increasing vessel efficiency made these data less reliable. In response to this, scientists developed and implemented research surveys that meet the strict requirements for data analysis. A series of synoptic surveys were established starting in 2001 to provide CPUE data and biological data to meet the increasing demand for stock assessment, *Species At Risk Act* (SARA) mandate, and ecosystem work (Figure G.4).

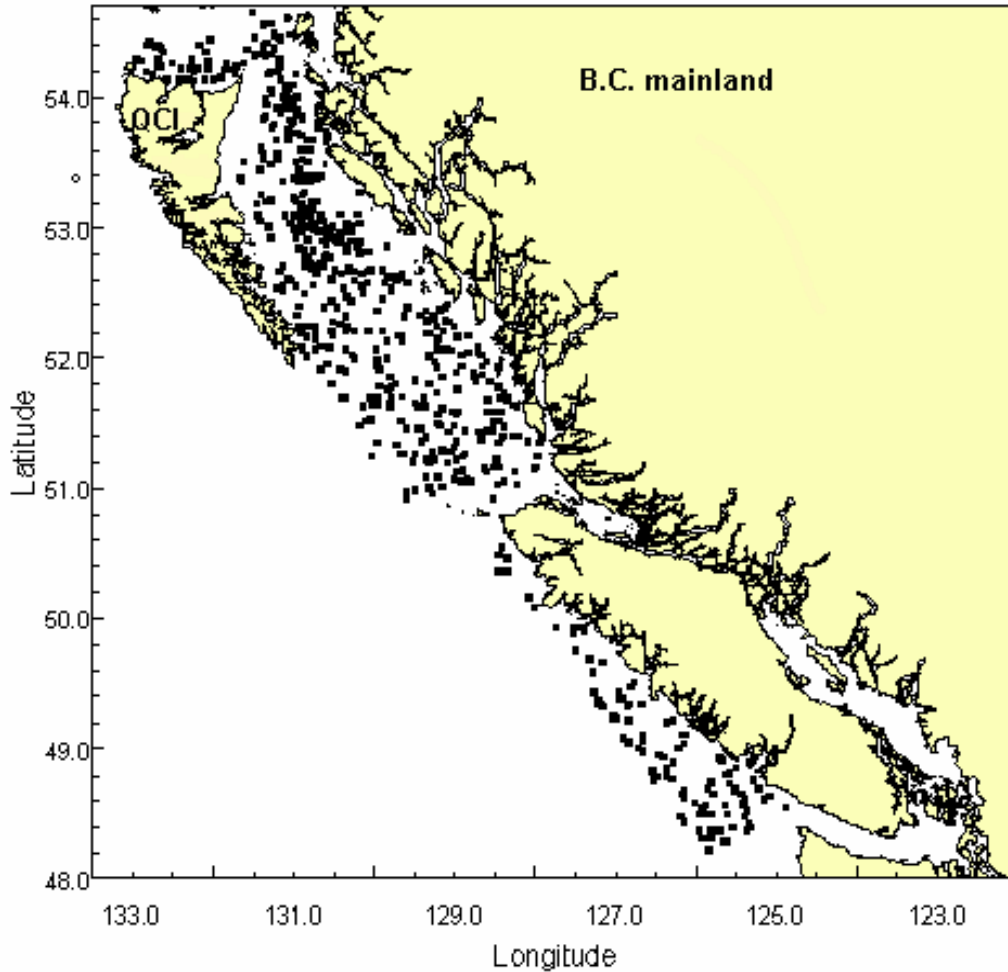


Figure G.4 Locations of stations occupied during DFO Science synoptic surveys, 2001 to 2005.

The distributions of individual species were categorized for potential relative indexing in stratified random surveys (Fargo and Tyler 1992). Type 1 species were characterised by consistent overall distribution and areas of peak density among years. Mean catch rates for these species were relatively similar in winter and in summer, with little seasonal difference in depth distribution, and little difference in depth distribution by size of individual. Type 1 species were therefore had stable distributions in space and time, making them appropriate candidates for abundance monitoring. Type 2 species were characterized by relatively consistent overall distribution, but variability in density. Mean catch rates and distribution of type 2 species varied by season. Type 3 species were characterized by a high degree of variability in density by season and year. These species exhibited schooling behaviour and, although they were present throughout the survey area, their overall distribution may vary widely in time and space. These species were the least suitable candidates for abundance monitoring. Species associations with depth, temperature, and bottom type have also been described (Figure G.5) accounting for seasonal and ontogenetic variability.

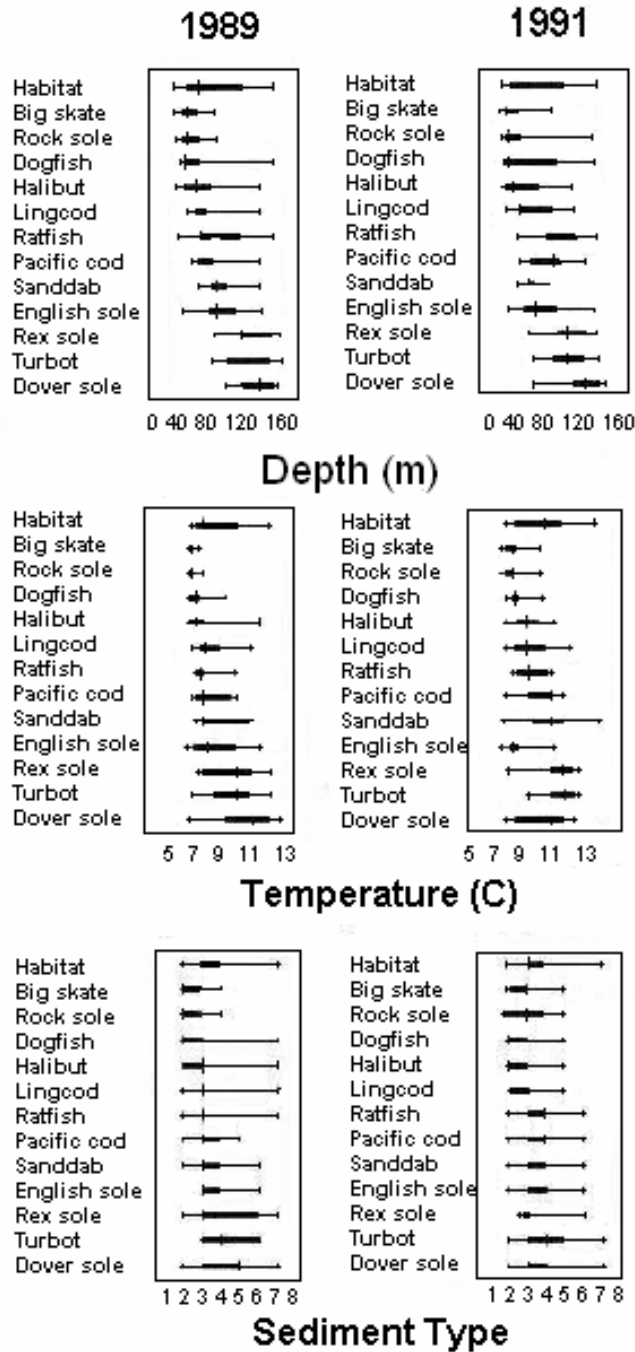


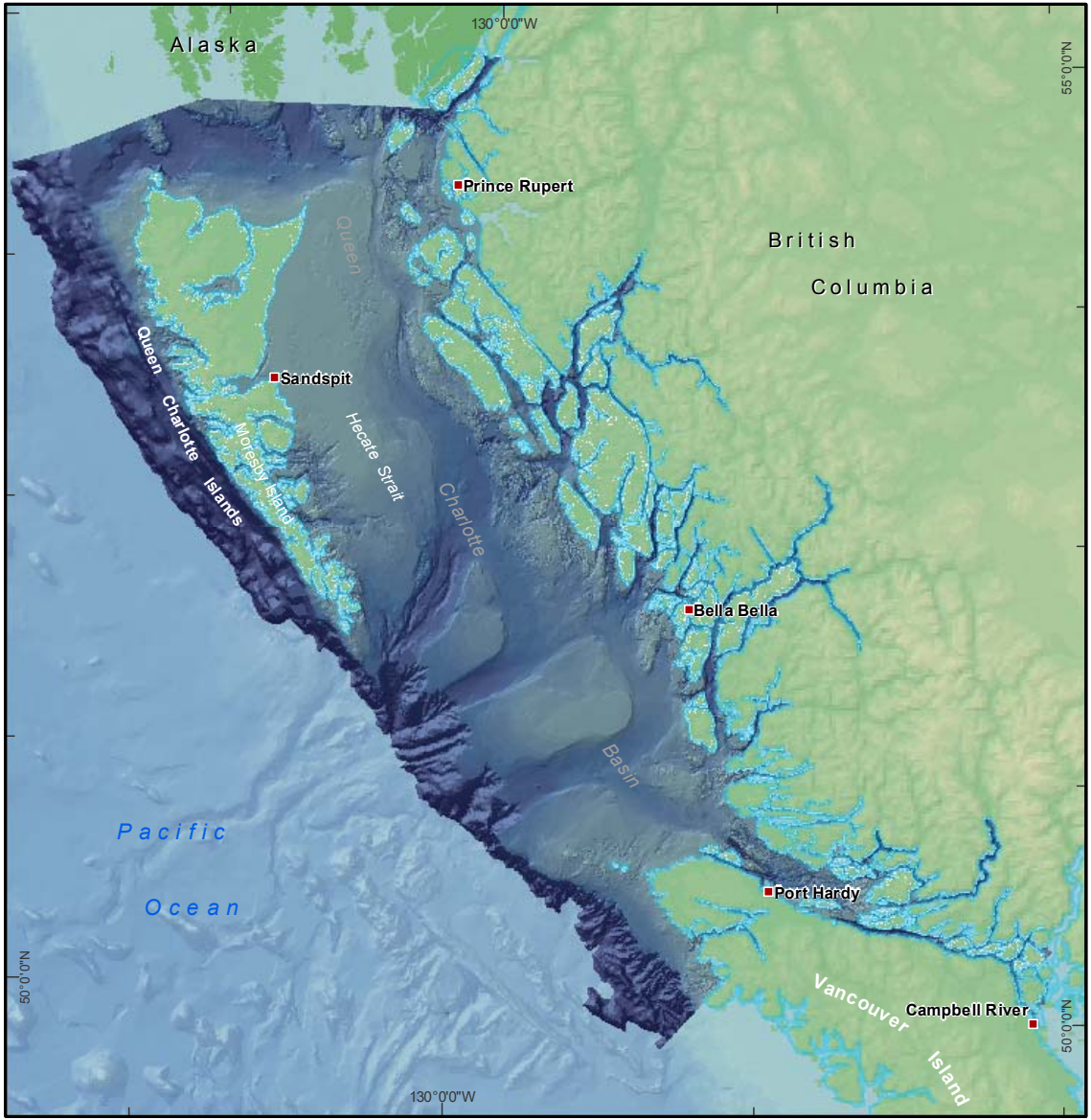
Figure G.5 Quartile plots of the distribution of available habitat and groundfish species as sampled May-June 1989 and 1991. Species such as Dover sole and big skate exhibited relatively narrow depth, temperature, and sediment type preferences, while species such as lingcod and dogfish had distributions that were not significantly different from random on depth, temperature, and sediment type. Sediment type categories are: 1) gravel, 2) very coarse sand, 3) coarse sand, 4) medium sand, 5) fine sand, 6) very fine sand, and 7) silt (figure reproduced from Perry *et al.* 1994).

5.2 Ecosystem/multispecies considerations

Several different approaches to ecosystem/multispecies work have been used by principal investigators over the last decade.

1. **Mass-balanced models.** These models are driven by trophically linked biomass ‘pools’ consisting of species groups or ecological guilds. Data requirements include: biomass estimates, total mortality estimates, consumption estimates, diet compositions, and fishery catches.
2. **Assessment and management by critical species.** Maintenance of the diversity of an entire assemblage may result from normal catch quota management of a group of species. The persistence of all species in the area during the conduct of a fishery is perceived as a legitimate goal here.
3. **Species interaction models.** Modelling of species interactions may provide estimates of joint-species yields or provide insight into particular management oriented questions.
4. **Management by trophically linked species or guilds.** Cohabiting, resident species with strong trophic linkages have properties of integrated productivity that are assessed to develop species-group quotas and may be conceptualized as production units.
5. **Total system yield estimates using particle size dynamics theory.** Evidence has accumulated that there is a relationship between animal body size and the sustainable number of animals of a particular size (Sheldon *et al.* 1982). This theory has been developed for pelagic species but not for demersal fish species.

Most recently, scientists have focused attention on ecosystem mass-balanced models. One study area on the Pacific coast has been Hecate Strait (Figure G.6; <http://www-sci.pac.dfo-mpo.gc.ca/sa-hecate/>). Existing data for that region includes 50 years of commercial fishery data, 20 years of multispecies survey data, physical and biological oceanographic data and habitat type. Areas of study in this project included phytoplankton/zooplankton productivity, ocean circulation, species abundance and distribution, species habitat association/utilization, and food resource division. Three distinct fish communities dominated by flatfish species were identified and characterized by bathymetry and habitat type (Figure G.7). Three types of species components were associated with each community: a) regular components were always associated with the community and had no seasonal or temporal variability in overall distribution, b) seasonal components were present in the community during summer or winter only due to migrations, and c) transient components had highly variable distributions and moved freely between communities.



Legend

Fisheries and Oceans Canada / Pêches et Océans Canada
 PNCIMA Boundary
 Communities
 Alaska

0 30 60 120 Kilometers

Notes:
 Source Information:
 - BC Altimetry provided by NOAA
 - Pacific North Coast Integrated Management Area Boundary and Offshore Bathymetry provided by DFO.
 - Communities provided by NRCAN
 - Lakes / Rivers provided by BC MOE

Projection: BC Albers, NAD 83
 Production Date: June 18, 2007
 Produced By: OHEB GIS Unit, DFO

Figure G.6 PNCIMA region showing locations and features of BC waters.

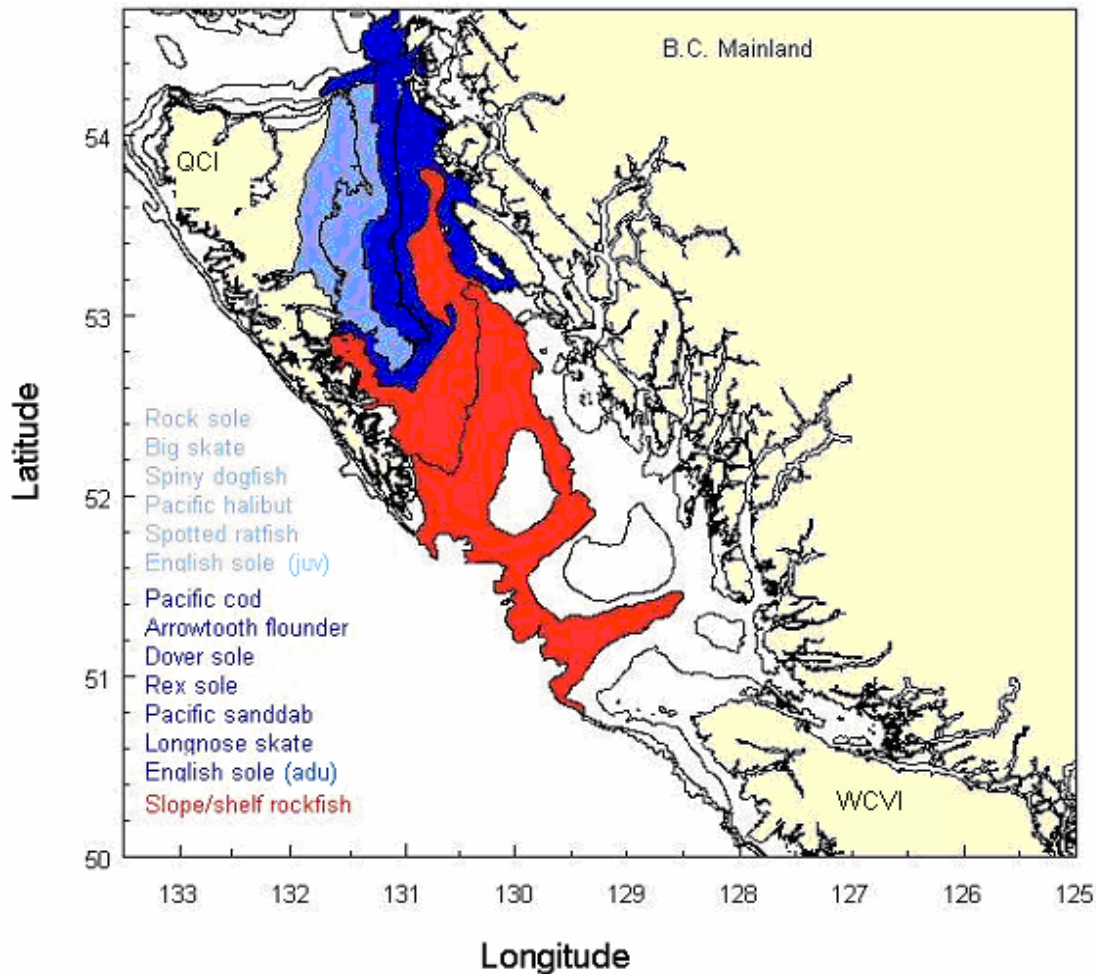


Figure G.7 Key components of fish communities in the Queen Charlotte Basin were characterized by bathymetric boundaries shown (light blue 0-50 m, dark blue 51-160 m and red >160 m, juv = juvenile, and adu = adult) and habitat type. Fish communities in white areas are less well known.

Pearsall and Fargo (Pearsall and Fargo 2007) determined that there were 5 main feeding strategies in Hecate Strait (outlined in Table G.4). Within a category, some species had widely variable diets, such as Pacific cod, arrowtooth flounder, and dogfish; while other species showed a high degree of dependence on a few prey items, such as the planktivore yellowtail rockfish. In general, the greatest diet breadth was found in piscivores, and the lowest diet breadth was found in planktivores and benthivores.

Similarities in diet preference were noted within groups; for example, many of the flatfish species had similar diets, as did the skate species. The 5 main feeding strategies were:

- 1) Fish feeders fed mainly on forage fish (herring and sandlance), flatfish, and shallow water benthic fish;
- 2) Shrimp feeders fed mainly on *Crangon* species and *Pandalus* species;
- 3) Crab feeders fed primarily on crabs, bivalves, and anomurans;
- 4) Annelid feeders fed primarily on annelids, with lesser amounts of echinoderms, echiurans, and cnidaria;
- 5) Plankton feeders showed the least varied diets, feeding primarily on euphausiids with a preference for *Thysanoessa spinifera*, except for eulachons and yellowtail rockfish for which *Euphausiida pacifica* was most important.

Table G.4 Feeding strategies for some marine fish species in Hecate Strait.

Plankton feeders

Pacific ocean perch (adult and juvenile)
Eulachon
Yellowtail rockfish
Sablefish
Pacific sanddab

Shrimp feeders

Walleye pollock
Speckled sanddab
Flathead sole
Black skate

Annelid feeders

Dover sole (adult and juvenile)
English sole (adult and juvenile)
Rex sole
Rock sole (adult)

Fish feeders

Arrowtooth flounder (adult and juvenile)
Petrale sole
Dogfish
Pacific cod (adult and juvenile)
Sand sole
Silvergray rockfish
Flathead sole
Black skate

Crab feeders

Big skate
Longnose skate
Redbanded rockfish
Ratfish

Seasonal and spatial diet patterns were discerned for some groundfish species, with seasonal differences being more common than spatial differences. Species demonstrating seasonal variation included a greater volume of fish in their diet in the fall and winter than in the summer. Annelid and crab feeders generally showed less spatial and temporal variability than fish feeders. Fish feeders generally demonstrated a greater degree of ontogenetic variability than species with other prey strategies.

Although the term 'food chain' has entered into common usage, in most ecosystems food chains do not exist. Trophic interactions are considerably more complex than a series of linear steps (Figure G.8). Trophic levels identify the kind of food an organism uses. The total number of trophic levels depends upon the location and number of different species in the ecosystem. The highest trophic level is occupied by adult animals with no

predators of their own. For example, killer whales (Orcas) occupy the highest trophic level in BC waters. Most organisms have more than one predator and the diet of most animals shifts as they develop. An example of this shift is Pacific cod and English sole adults occupying a higher trophic level than juveniles (Figure G.8). The presence of two or more competitors feeding on the same prey items may alter the availability of energy to higher trophic levels.

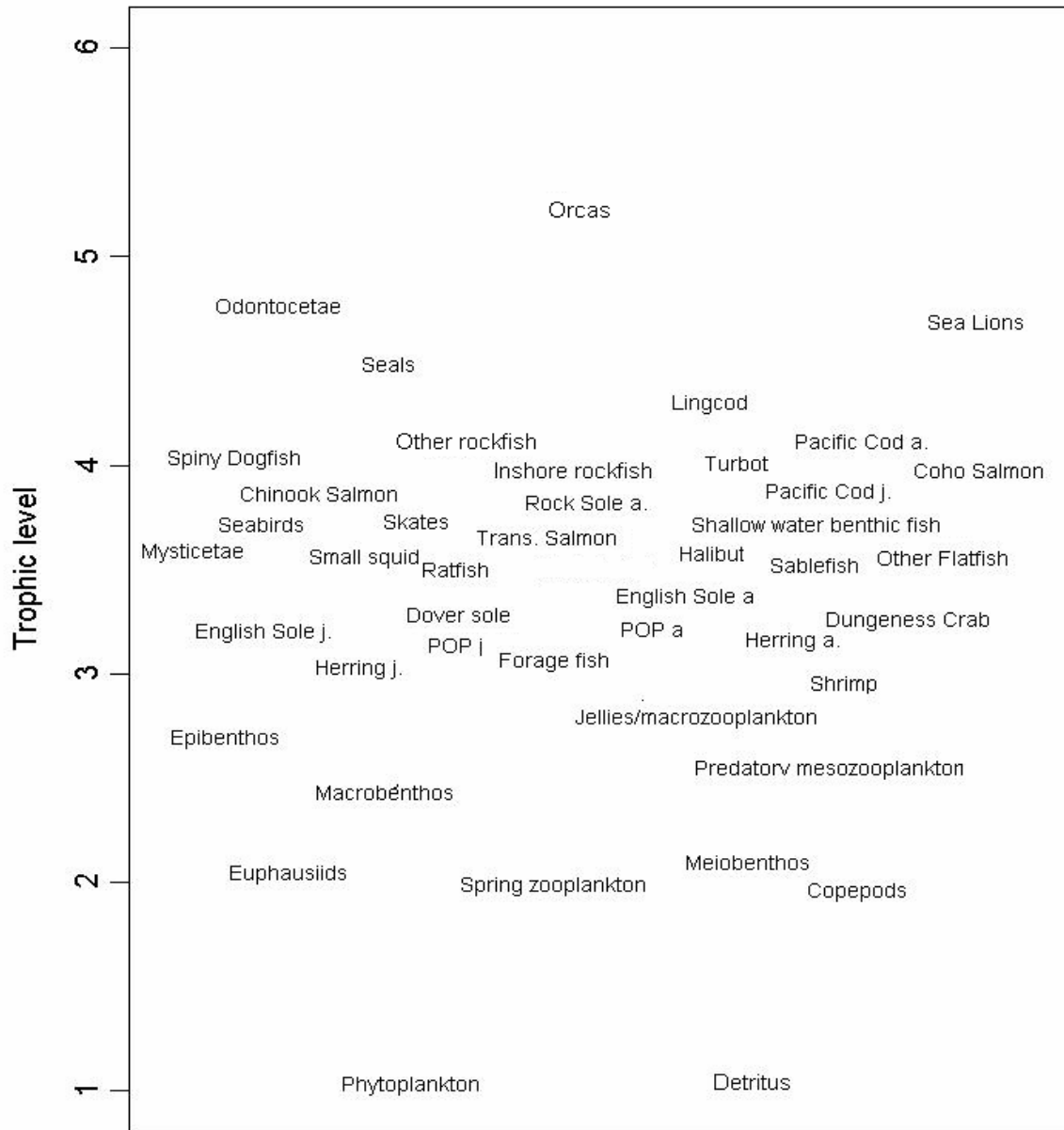


Figure G.8 Output from Ecopath/Ecosim illustrating trophic levels in the Queen Charlotte Basin. Note that groundfish species occupy more than one trophic level. For example, Pacific ocean perch (POP) is a planktivore (level 2-3), English sole feeds primarily on annelids (level 3-4), and Pacific cod and lingcod are piscivores (level 4). Adults of a species are indicated with the addition of the letter a, juveniles by j, transients by trans.

The flow of nutrients in a food web is cyclical. A pool of nutrients resides in a trophic level until animals die, excrete waste, are eaten, or are removed in fisheries. During primary production, inorganic nutrients are incorporated into cells during photosynthesis and chemosynthesis. Energy is captured by primary producers and transferred to higher trophic levels. At each transfer, only a fraction of the energy is passed on and much is lost. Total available energy declines at each trophic level. This places a limit on the number of trophic levels that can exist. At some point, there is too little energy available to sustain further transfers. Typical transfer efficiency from primary producers to planktivores is about 20%, while efficiencies between higher levels are about 10%. Secondary production refers to the total amount of animal biomass produced in all trophic levels above the primary producers.

Using an Ecopath/Ecosim model (Christensen and Pauly 1992), 6 trophic levels were determined from groundfish diet data (Figure G.8). Using this information, we were able to produce a simplified food web depicting species interaction and energy transfer between the trophic levels. Figure G.9 illustrates the energy flow for the marine community in the Queen Charlotte Basin. It consists of species with varied life history traits, from forage fish and planktivores, such as eulachon and Pacific ocean perch, to higher order piscivores, including dogfish, Pacific cod, and arrowtooth flounder. Consequently, groundfish species are present in several different trophic levels.

In the following discussion the term ‘guild’ is used to denote a group of trophically linked species. In the shallow guild, the spatial and diet overlap suggested that competition could occur between halibut and big skate. Based on depth preferences and diet, these two species would interact and could compete over the summer months. Halibut moves from a summer mean depth of 100 m to a winter mean of about 250-300 m. Skates tend to remain at a mean depth of 100 m year round. The seasonal diet variation for Pacific halibut, rock sole, and big skate was examined to try to determine whether the movement of dogfish out of the environment in winter has any impact on these other species. However, breadth of diet did not appear to increase for any of these species over the winter period.

In the intermediate guild, results suggested that spiny dogfish and Pacific cod could compete with one another during the summer months but are unlikely to compete with one another in winter. Similarly, English sole, Dover sole, and rex sole may impact one another during summer months. Competition is also likely between ratfish and English sole throughout the year, and between ratfish, rex sole, and Dover sole during summer. The transient habits of arrowtooth flounder and dogfish may be critical to community structure within the different spatial regions within Hecate Strait, since these two species have the highest biomass in Hecate Strait (Fargo and Tyler 1991). The diet breakdown suggests that dogfish could impact the abundance of herring, salmon, rock sole, and English sole in Hecate Strait. Arrowtooth flounder could impact herring, walleye pollock and inshore rockfish based on diet composition and could compete with dogfish, Pacific cod, petrale sole, and halibut for herring.

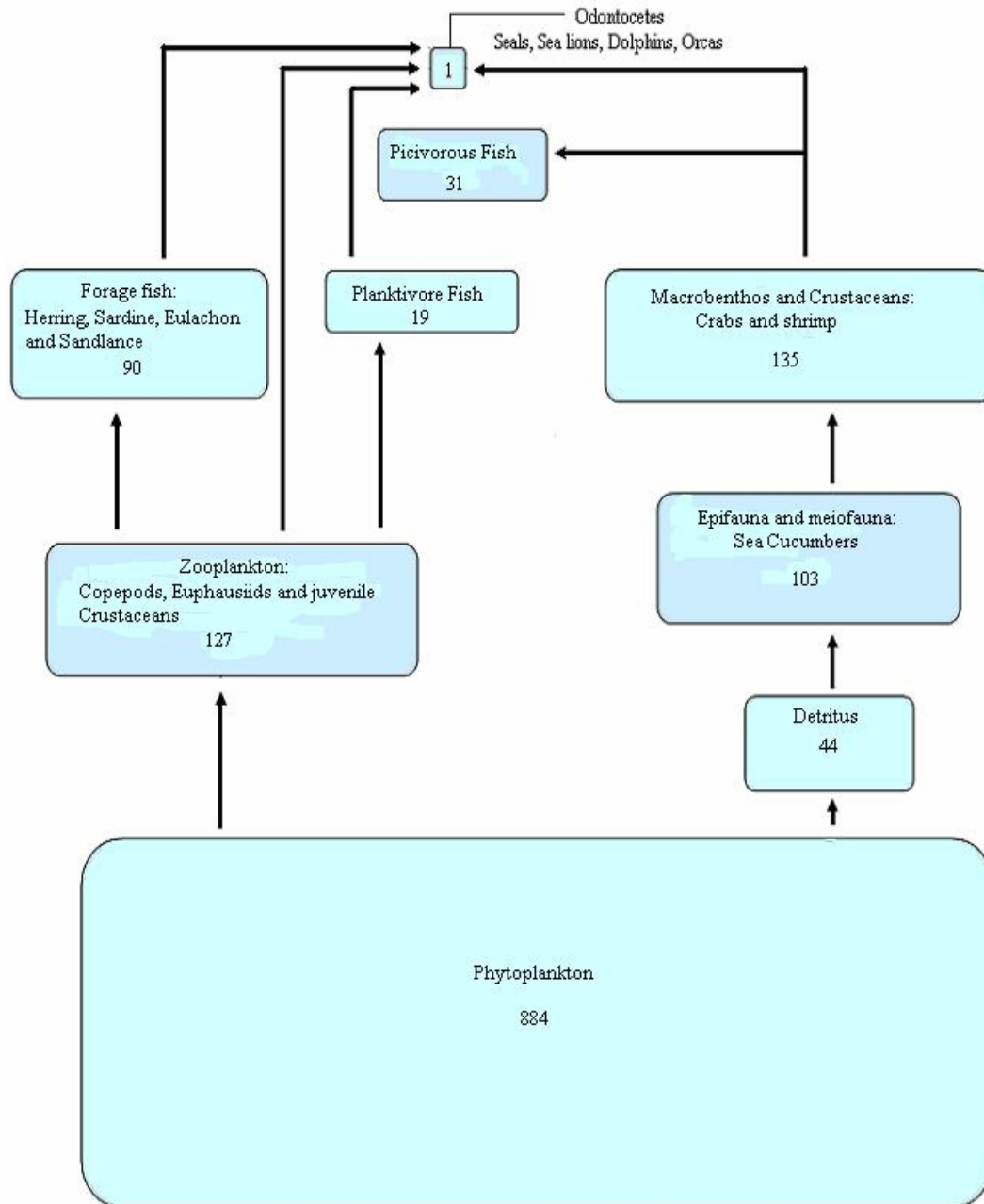


Figure G.9 Energy flow for the Hecate Strait region. Boxes are proportional to group biomass in $t\ km^{-2}\ year^{-1}$.

5.3 Stock assessment

There are approximately 409 known species of marine fish resident off the coast of British Columbia. At least one individual of 200 of these species has been caught in the groundfish fishery over the last ten years. In this complex fishery, more than 50 species of fish are landed while 27 different groundfish species/stocks have been assessed and are subject to annual allocations in eight different management areas.

Stock assessments in recent years have been much more detailed than a decade ago. They have included decision tables where the risk associated with particular management options is quantified. This has resulted in fewer annual assessments. The recently implemented (2002) groundfish synoptic surveys will eventually provide the biological and catch-rate data that is needed to assess numerous species that have not been assessed in the past.

Issues involving groundfish fisheries have increased greatly over the last decade. The delivery of science advice now includes co-management, co-research, and stakeholder groups from industry, recreational, and conservation groups. Science partnerships have become essential for meeting the mandate of DFO and delivering core programs. These include academics in universities and scientists from other agencies. Settlement of First Nations claims may also affect management and stock assessment strategies for Pacific groundfish stocks.

6.0 EFFECT OF FISHING GEAR ON HABITAT

Habitat altered or destroyed by fishing gear produces a significant effect on the marine ecosystem. Most of the studies to date have focused on the trawl fishery, however, the longline and trap/pot fisheries also have an impact and longline and trap/pot gear is set over a larger area than that the trawl fishery occupies. Some areas of sensitive habitat have been closed to trawling (Figure G.10, Figure G.11). This encompasses the unique glass sponge reefs in the Queen Charlotte Basin (see Appendix A: Geology, Figures A.19 and A.21) and an area of gorgonian habitat in deep water off the west coast of Moresby Island in the Queen Charlotte Islands. These area closures are augmented by Marine Protected Areas, Marine parks, and Rockfish Conservation Areas.

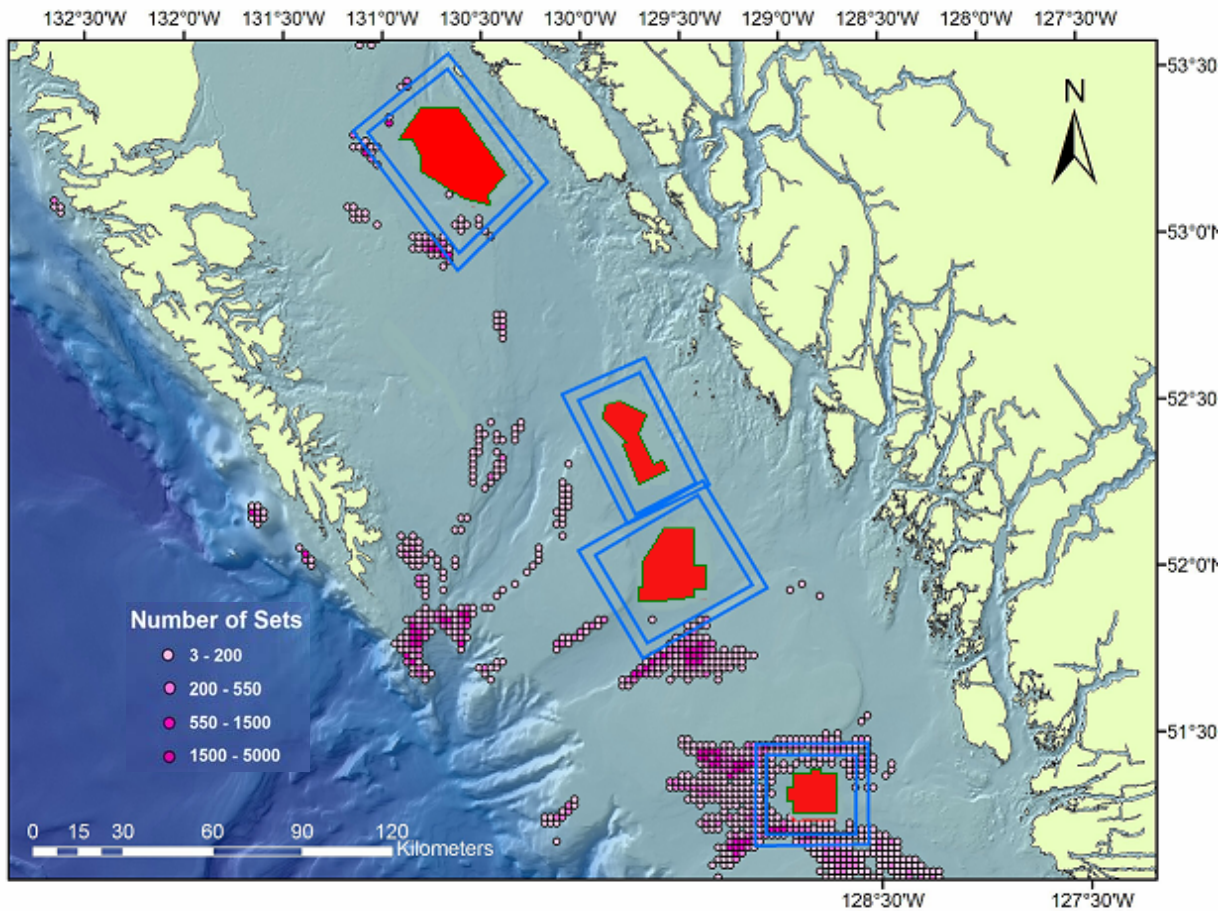


Figure G.10 Total fishing effort for the trawl fishery from 2003-2005. Shaded squares indicate fishing locations (the darker the square the greater the effort). The red areas show the location of unique glass sponge reefs in the Queen Charlotte Basin. The blue rectangles are proposed buffer boundaries for the closed areas. These areas were closed to commercial trawling in 2003.

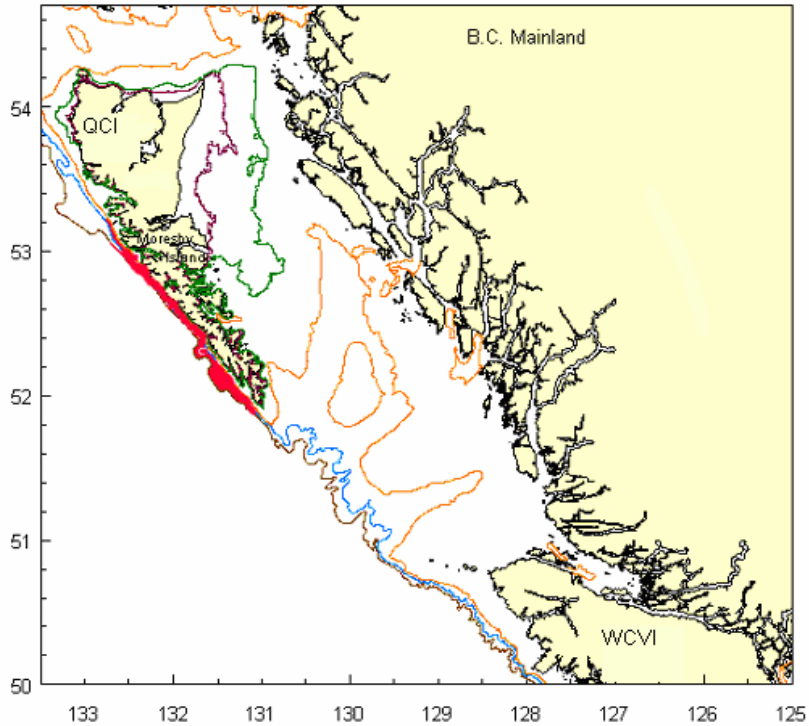


Figure G.11 Coral habitat closed to trawling (in red) off the west coast of Moresby Island in 2003.

7.0 CONSERVATION

In 1997 with the *Oceans Act* legislation, DFO made a commitment to develop a new approach to managing our oceans. An important part of this legislation has been the introduction of three principles - sustainable development, integrated management, and the precautionary approach to fisheries. We are now required to assess the effect of anthropogenic factors on marine ecosystems. The effect of fishing and loss of habitat are two important factors that can be managed by agencies like DFO. Species life history characteristics can serve as guidance for the level of sustainable exploitation for the resource.

The *Species At Risk Act* requires species conservation reports to be submitted to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). DFO staff have been directly or indirectly involved in the assessment of some groundfish species (Table G.5). COSEWIC sets priorities for species that have never been assessed or species with no recent assessment. This involves many rockfish species, which tend to be long-lived (*e.g.*, quillback to 76 years, yelloweye to 115 years). Their low rate of natural mortality and low productivity necessitates conservative harvest strategies. There are numerous examples of the depletion of rockfish stocks in the north Pacific. In BC, management regions for inshore rockfish are large, relative to stock distributions. This,

combined with their sedentary habits, makes them particularly vulnerable to over fishing. These stocks may require an extremely long rebuilding period after depletion (several decades). There is little biological information available for many of these stocks, although an on-board observer program initiated in 1997, along with a series of research synoptic surveys initiated in 2003, is providing much needed biological data.

Most groundfish stocks being monitored are in a healthy state. Others, specifically lingcod and inshore rockfish stocks in the Strait of Georgia, and Pacific cod in Hecate Strait, are a conservation concern, and rebuilding strategies have been implemented. Assessment of the status of these species will be an ongoing challenge requiring new techniques (especially for rockfish) and dedicated effort by both government and resource users.

Table G.5 Summary of PNCIMA groundfish species having SARA or COSEWIC assessments, along with their most recent status.

Group	Common Name	Scientific Name	Year Assessed	Status	
				SARA ¹	COSEWIC ²
Sharks	White shark	<i>Carcharodon carcharias</i>	2006		UR
	Basking shark	<i>Cetorhinus maximus</i>	2006		EN
	Bluntnose sixgill shark	<i>Hexanchus griseus</i>	2006		UR
	Brown cat shark	<i>Apristurus brunneus</i>	2006		UR
	Southern shark	<i>Galeorhinus galeus</i>	2006		UR
Skates	Sandpaper skate	<i>Bathyraja interrupta</i>	2006		UR
	Big skate	<i>Raja binoculata</i>	2006		UR
	Longnose skate	<i>Raja rhina</i>	2006		UR
Finfish	Green sturgeon	<i>Acipenser medirostris</i>	2004	1	SC
	Bocaccio	<i>Sebastes paucispinis</i>	2002	3	TH
	Longspine thornyhead	<i>Sebastolobus altivelis</i>	2006		UR
	Canary rockfish	<i>Sebastes pinniger</i>	2006		UR
	Rougheye rockfish	<i>Sebastes aleutianus</i>	2006		UR

¹SARA: *Species at Risk Act*. 1 = on Schedule 1 legal list of wildlife species at risk; 2 = not added to legal list; 3 = referred back to COSEWIC for further information or consideration (SARA 2006).

²COSEWIC: Committee on the Status of Endangered Wildlife in Canada. EN = Endangered: facing imminent extirpation or extinction, TH = Threatened: likely to become endangered if limiting factors are not reversed; SC = Special Concern: particularly sensitive to human activities or natural events but not endangered or threatened (formerly referred to as vulnerable), UR = report under review.

8.0 INTERNATIONAL TREATY FOR PACIFIC HAKE

This treaty, signed in 2003, will ensure the sustainability of the offshore stock of Pacific hake that is shared by the United States (US) and Canada. It is also consistent with the federal government's priorities to establish cooperative working agreements that fulfill our responsibilities for the joint stewardship of trans-boundary stocks. The treaty was ratified by the US in early 2007. Canada and the US are both operating 'in the spirit' of the agreement pending full implementation.

9.0 NEW TECHNOLOGY

New technology applications are required to improve existing stock assessment capability as well as to reduce the need for destructive sampling (resulting in fish mortality). For example, it has been possible to estimate the biomass of inshore rockfish stocks using non-traditional methods. Underwater video linking fish density to habitat type, combined with side-scan sonar estimates of habitat type abundance, offers a novel means to estimate fish biomass. In situ density estimates can be obtained for some species for the first time with the use of manned submersibles and remotely operated cameras. Side-scan and multibeam sonar are providing estimates of habitat type that can be used to refine in situ density estimates.

Current assessment activities in collaboration with the fishing industry are concentrated on mitigating the effect of fishing gear on habitat and developing modern surveys capable of providing biological and catch-rate data that can be used for assessment of a wide range of species across all areas of the coast. Partnerships with universities and stakeholders are essential to ensure product delivery here.

10.0 COOPERATIVE PARTNERS

Canadian Groundfish Research and Conservation Society, Vancouver, BC.
Canadian Pacific Sardine Association, Vancouver, BC.
Canadian Wildlife Service, Sidney, BC.
Commercial Sablefish Fishermen's Association, Vancouver, BC.
Council of Haida Nations
Institute for Ocean Sciences, Sidney, BC.
International Pacific Halibut Commission, Seattle, Wa. USA.
Northwest and Alaska Fisheries Science Center, Seattle, Wa USA.
Nuu-Chah-Nulth Nations
Pacific Geoscience Centre, Sidney, BC.
Pacific Halibut Management Association, Vancouver, BC.
Parks Canada, Sidney, BC.

Simon Fraser University (REM Faculty), Burnaby, BC.
University of British Columbia (Fisheries Centre), Vancouver, BC.
University of Victoria, Victoria, BC.
World Wildlife Fund, Vancouver, BC.

11.0 GLOSSARY

Annelid – Elongated, segmented invertebrate; including earthworms and leeches.

Anthropogenic – Caused or produced by humans.

Benthivore – Eat bottom-dwelling flora and fauna.

Carnivore – An organism that eats meat.

Chemosynthesis – Chemosynthesis is the biological conversion of 1-carbon molecules (usually carbon dioxide or methane) and nutrients into organic matter using the oxidation of inorganic molecules (*e.g.*, hydrogen gas, hydrogen sulfide) or methane as a source of energy, rather than sunlight, as in photosynthesis. Large populations of animals can be supported by chemosynthetic primary production at hydrothermal vents, methane clathrate cold seeps, and whale falls.

Cnidaria – An animal phylum that includes hydra, sea anemones, jellyfish, and hydrozoan colonies.

Demersal – Organisms that live on or near the ocean bottom.

Echiurans – Echinoderms, marine invertebrates with tube feet and five-part radially symmetrical bodies.

Fecundity – The potential reproductive capacity of an organism or population.

Guild – A group of species having similar ecological resource requirements or foraging strategies.

Iteroparous – Able to spawn many times during their lifetime.

Ontogenetic variability – The variability in the origin or development of an organism from embryo to adult.

Pelagic – Refers to fish and animals that live in the open sea, away from the sea bottom.

Phenotypic plasticity – Is non-genetic variation in organisms in response to environmental factors. Marine fish species have evolved many reproductive strategies including: batch and indeterminate spawners, brief to protracted spawning period, pelagic and demersal eggs, and differences in fecundity.

Piscivore – An organism that eats fish.

Planktivore – An animal which feeds primarily on plankton; plankton is the collective group of tiny plants and animals that float or drift near the surface of a body of water; plankton is very low on the aquatic food chain and therefore a vital element in that ecosystem.

Trophic – Pertaining to nutrition or to a position in a food web, food chain, or food pyramid.

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