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Developing British Columbia's Inshore Rockfish Conservation Strategy

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Abstract.—The hook-and-line fishery for inshore rockfishes *Sebastes* spp. in British Columbia is diverse, with participants in directed commercial, recreational, and Aboriginal fisheries, as well as other incidental fisheries coastwide. Rockfish species targeted in this fishery are yelloweye rockfish *S. ruberrimus* and quillback rockfish *S. maliger*. Expansion of the fishery outpaced management's effort controls, and catch quotas were implemented in the early 1990s. Conservation concerns largely based on life history traits resulted in restrictions to the directed fishery, but other fisheries remained unmanaged. A growing mismatch between the demands of fishery management and the difficulties of inshore rockfish stock assessment led to the development of a conservation strategy in 2001. The strategy included the following four components: comprehensive catch monitoring; dramatically reduced fishing mortality; extensive fishery closed areas; and improved stock assessment and monitoring. Targets were met in 2002 by reducing the fishing mortality rate by 75% in the protected waters east of Vancouver Island (inside area) and by 50% in the remaining open-coast waters (outside area). Research survey programs were reinstated by the provision of funds in 2003. An intricate catch accounting and monitoring proposal from industry set the rules in a pilot groundfish licensing integration program launched in 2006. Progress continues to be made on this difficult task. Areas closed to all fishing were implemented in 30% of the rockfish habitats throughout the inside area and in 20% of the outside area in 2007. Key to the development of the strategy was the consultation process. Consensus-based decision making within the Department of Fisheries and Oceans and the organization and commitment of industry participants contributed to this success. Open communication and respectful conduct brought participants to the table and kept them engaged. Without the consultation process and the benefits from this exchange, the conservation strategy would not have been possible.

Early 1999 marked a turning point in the management of inshore rockfishes *Sebastes* spp. in British Columbia. With the realization that traditional fisheries management use of catch quotas was insufficient to conserve inshore rockfish, steps were taken to reconcile the longstanding mismatch in scale between the demands of fishery management and the difficulties of inshore rockfish stock assessment. The rapid growth of the fishery had outpaced all management measures to limit effort. Fear of overharvesting the stock was inferred largely from rockfish life history characteristics and was exacerbated by stock assessment data that were insufficient to determine sustainable total allowable catches (TACs). Scientists advocated precautionary assessment and management strategies that were independent of the estimation of biomass and TACs, and managers initiated spatial effort controls into the management of the directed fishery.

The Department of Fisheries and Oceans Canada (DFO) maintains science and management within separate branches that work closely together to conduct fisheries in British Columbia. Managers are responsible for developing and implementing fisheries management plans based on stock assessment advice from scientists and in consultation with various users of the resource. Through the advisory process, stakeholders reinforced the notion that only controlling the effort of the directed fishery for inshore rockfishes was not adequate when incidental catches were allowed in other fisheries. Anecdotal information from the advisory process led to further overharvesting concerns. In 2001, science advice to managers recommended a range of measures across all gear types (hook and line, trap and trawl) and sectors (commercial, recreational, and Aboriginal) to improve catch monitoring and assessment and to incorporate areas closed to fishing as a spatial management tool.

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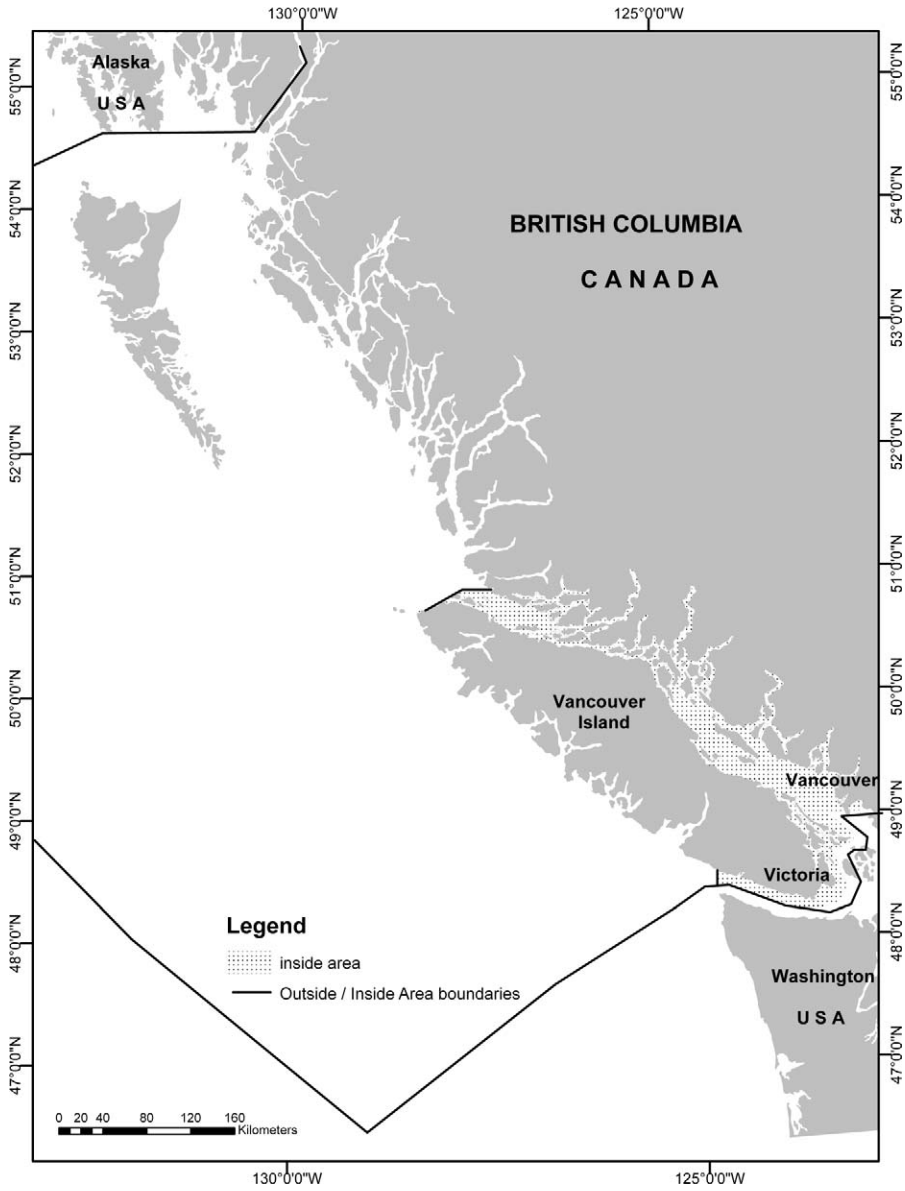

FIGURE 1.—British Columbia coastal waters, divided into the inside (stippled) fishery management area (protected waters between Vancouver Island and the mainland) and the outside fishery management area (the remainder of the coast).

These components shaped an inshore rockfish conservation strategy (hereafter referred to as "the strategy") that was designed to reverse the declines in abundance and enable the rebuilding of stocks. Science advice, innovative management tactics, and intensive consultations all shaped the strategy. British Columbia's attempt to develop this comprehensive management plan for data-limited rockfish species is reviewed, and the process for decision making is discussed.

History of the Inshore Rockfish Fishery

Inshore rockfish are commonly found aggregated over rocky habitats to 200 m and are readily caught with hook-and-line gear. Like all rockfish, they possess a closed swim bladder and suffer severe barotrauma when brought to the surface (Rummer and Bennett 2005). Discarded rockfish suffer a high mortality rate from these decompression effects (Hannah et al. 2008). Target species in the fishery are yelloweye rockfish

TABLE 1.—Estimated annual British Columbia quillback rockfish *Sebastes maliger* and yelloweye rockfish *S. Ruberrimus* landings (metric tons) from 1951 to 2008. Annual landings are shown for the inside area east of Vancouver Island, for the remaining British Columbia area (outside), and for total landings coastwide.[abcd]

	British Columbia coast area		
Year	Inside, metric tons	Outside, metric tons	Total, metric tons
1951	79.1	169.1	248.2
1952	60.4	115.4	175.8
1953	74.7	43.4	118.1
1954	46.6	46.3	92.9
1955	46.0	37.4	83.4
1956	43.8	33.9	77.7
1957	75.6	63.3	138.9
1958	109.9	40.1	150.0
1959	113.1	46.1	159.2
1960	91.8	67.9	159.7
1961	68.4	75.1	143.5
1962	110.8	105.7	216.5
1963	84.5	107.0	191.5
1964	50.9	47.3	98.2
1965	45.9	45.5	91.4
1966	36.9	49.4	86.3
1967	57.0	72.1	129.1
1968	61.6	45.6	107.2
1969	72.1	89.8	161.9
1970	87.6	149.7	237.3
1971	74.7	100.5	175.2
1972	82.7	161.3	244.0
1973	101.6	99.6	201.2
1974	50.1	166.2	216.3
1975	40.1	189.4	229.5
1976	48.8	138.0	186.8
1977	137.1	191.0	328.1
1978	155.3	210.3	365.6
1979	276.3	305.2	581.5
1980	190.1	285.6	475.6
1981	216.6	210.8	427.4
1982	276.3	111.3	387.6
1983	279.0	137.7	416.6
1984	321.5	217.8	539.3
1985	371.6	314.2	685.8
1986	481.1	719.0	1200.0
1987	452.9	793.0	1246.0
1988	507.6	776.2	1283.8
1989	515.9	976.5	1492.4
1990	489.6	1327.0	1816.5
1991	485.6	1337.5	1823.1
1992	196.3	1204.8	1401.1
1993	223.4	1279.8	1503.2
1994	302.1	884.2	1186.3
1995	236.1	877.9	1114.1
1996	220.0	661.8	881.8
1997	184.8	646.0	830.8
1998	178.7	701.5	880.1
1999	177.5	511.0	688.5
2000	163.4	598.5	761.9
2001	167.1	586.9	754.0
2002	27.5	432.1	459.6
2003	44.8	271.1	362.4
2004	32.3	255.2	316.3
2005	27.4	275.4	334.7
2006	30.7	308.9	364.3
2007	36.5	310.4	383.8
2008	24.7	306.0	378.8

[a] Commercial hook-and-line rockfish landings between 1951 and 1995 are derived from sales slips that include records of "red cod" and "rock cod" (1951–1975), "rockfish" (1976–1981), and "red snapper" and "other rockfish" (1982–1995).

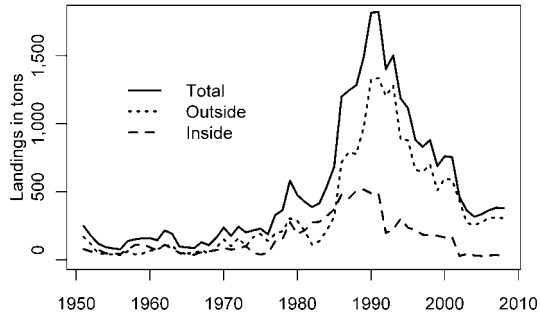

FIGURE 2.—Estimates of annual British Columbia inshore rockfish landings (metric tons) from 1951 to 2008 (solid line). Landings for the inside area east of Vancouver Island (dashed line) and the remaining outside area (dotted line) are shown. Data sources are presented in Table 1.

Sebastes ruberrimus and quillback rockfish *S. maliger*, with other, less-common rockfish species also landed (copper rockfish *S. caurinus*, China rockfish *S. nebulosus*, tiger rockfish *S. nigrocinctus*, and black rockfish *S. melanops*). Yelloweye rockfish and quillback rockfish are slow growing and extremely long lived, reaching 115 and 95 years, respectively, in British Columbia (Yamanaka and Lacko 2001).

Inshore rockfish were an incidental catch in the lingcod *Ophiodon elongatus* fishery that developed on the British Columbia coast in the mid 1800s (Cass et al. 1990). This fishery supplied fish to markets in Victoria from nearby fishing grounds (Figure 1). A directed hook-and-line rockfish fishery began to expand in the late 1970s in response to the development of a lucrative market for live rockfish in Vancouver (Table 1; Figure 2). The target species for the live market is the quillback rockfish, and the target for the fresh market is the yelloweye rockfish.

In the early 1980s, the fishery was unrestricted by any management controls (Richards and Cass 1986). Annual assessments for British Columbia's commercially exploited inshore rockfish stocks began in 1986, coincident with the establishment of a directed hook-and-line rockfish license (Table 2). The DFO managed the British Columbia fishery as two areas: (1) the "inside" or protected waters east of Vancouver Island and (2) the "outside" or open-coast waters (Figure 1).

[b] Commercial trawl landings between 1968–1995 for quillback rockfish and yelloweye rockfish are from logbook records.

[c] Commercial hook-and-line and trawl catch data from 1996 to October 2008 for inshore rockfish species are derived from dockside monitoring programs and logbook records.

[d] Recreational landings are converted (3.22 kg for yelloweye rockfish and 0.7 kg for quillback rockfish) from numbers of fish reported in creel surveys for the years 1986–2007.

TABLE 2.—Chronology of British Columbia inshore rockfish fishery management actions by area. Asterisks denote management milestones (TAC = total allowable catch; RCA = rockfish conservation area).

Year	Area	Management action
<1986	Coastwide	Unrestricted fishery
1986	Coastwide	Introduced a category "ZN" license* for the directed hook-and-line rockfish fishery with a voluntary logbook program
	Inside	Feb 15 to Apr 15 closure
1987	Inside	Jan 1 to Apr 15 closure
	Inside	Provisional 75-metric-ton quota, area 12
1988	Inside	Year-round commercial closure, area 13 Discovery Pass
	Inside	Jan 1 to Apr 30 closure
1990	Inside	Jan 1 to Apr 30 and Nov 1 to Dec 31 closure
	Outside	Provisional 650-metric-ton quota
	Outside	Portions closed, area 7
	Outside	Jan 1 to Apr 30 closed west coast of Vancouver Island
1991	Coastwide	Area licensing,* 592 inside and 1,591 outside
	Inside	Trawl closure
	Inside	Live rockfish fishery only
	Inside	Jan 1 to May 14 closure, with no incidental rockfish catch allowances
	Inside	2–3-d opening in area 13 Discovery Pass
	Outside	Rotational closure was initiated in area 7
	Coastwide	Limited-entry licensing program was announced
1992	Inside	Limited-entry licensing with 74 eligible inside licenses
1993	Outside	Limited-entry licensing with 183 eligible outside licenses
	Coastwide	TAC quota management* for "red snapper" and "other rockfish" by five management regions
	Coastwide	Region/time closures
1994	Coastwide	User-pay logbook program
	Coastwide	Trip limits for trawl species
	Coastwide	Incidental catch allowances
1995	Coastwide	User-pay dockside monitoring program*
	Coastwide	Aggregate species quota management for yelloweye rockfish, quillback rockfish, copper rockfish, china rockfish, and tiger rockfish
	Coastwide	Monthly fishing periods, monthly fishing period limits, annual landing options, and annual trip limits
	Coastwide	Relinquishment of period limit overages
1996	Coastwide	Change to species quotas,* yelloweye rockfish TAC, aggregate 1&2 TAC (quillback rockfish, copper rockfish, china rockfish, and tiger rockfish)
1997	Coastwide	Initiate 5% quota allocation for research purposes
1998–1999	Outside	92% of commercial rockfish TAC allocated to the trawl sector, 8% to hook-and-line sector
	Inside	100% of commercial rockfish TAC allocated to the hook-and-line sector
1999–2000	Coastwide	10% at-sea observer coverage
	Coastwide	Quillback rockfish, copper rockfish, china rockfish, tiger rockfish TAC reduced by 25%
	Coastwide	Selected area closures: rockfish protection areas, closed fishing areas to commercial groundfish hook-and-line gear types*
2000–2001	Coastwide	Allocation of rockfish species between the Pacific halibut and hook-and-line sectors
2001–2002	Inside	Limited amount of at-sea observer coverage
	Outside	License option elections before fishing season, monthly fishing period limits
2002–2003	Inside	75% reduction of inshore rockfish TAC from 2001*
	Outside	50% reduction of inshore rockfish TAC from 1997–1998*
	Coastwide	Expansion of catch monitoring programs
	Coastwide	Introduced 1% interim areas of restricted fishing, closed to all commercial groundfish fisheries (both hook-and-line and trawl gear types)
2004–2005	Coastwide	RCAs expanded to 8% of rockfish habitats
2005–2006	Inside	RCAs expanded to 30% of rockfish habitats
	Coastwide	Introduce groundfish license integration pilot program: 100% catch monitoring*
2006–2007	Outside	RCAs expanded to 20% of rockfish habitats

At this time, there were no restrictions on catch, but a 2-month closed season was imposed. Scientists recommended that if a quota was to be established, it should be based on historic landings until additional biological data became available (Richards 1986). Research jig surveys targeting quillback rockfish in the inside waters were initiated and conducted annually between 1986 and 1988. Management measures applied to the fishery in the late 1980s were designed to limit effort of the fleet, but these "input" controls did not slow the rapid expansion of the fishery.

British Columbia rockfish landings quadrupled between 1986 and 1990, largely due to increases in yelloweye rockfish landings in outside waters (Figure 2). License limitation was imposed in the early 1990s together with the implementation of the first "output" control, in the form of TACs (Table 3). These TACs were based on prior fishery catch and were set at a level designed to cap the catches. Implicit in this shift from input to output controls is the requirement of accurate and timely stock assessment advice to set TACs, as well as a fishery monitoring system to manage TACs

TABLE 3.—Annual British Columbia rockfish hook-and-line total allowable catch (TAC) quotas (in metric tons) by species or species category and management area. Subsequent to the implementation of the rockfish conservation strategy, TACs were reduced in 2002 and have remained at this level.

		TAC region	
Year	Species or category	Inside,[a] metric tons	Outside,[b] metric tons
1991	Red snapper	50	630
1992	Red snapper	59	630
1993	Red snapper	70	853
1994	Red snapper	70	711
1995	Yelloweye rockfish	62	700
1996	Yelloweye rockfish	26	700
1997	Yelloweye rockfish	24	577
1998	Yelloweye rockfish	23	381
1999	Yelloweye rockfish	23	315
2000	Yelloweye rockfish	23	315
2001	Yelloweye rockfish	23	315
2002	Yelloweye rockfish	7	277
1991	Other rockfish	300	370
1992	Other rockfish	130	370
1993	Other rockfish	140	436
1994	Other rockfish	150	418
1995	Aggregates 1 and 2	150	345
1996	Aggregates 1 and 2	150	373
1997	Aggregates 1 and 2	143	353
1998	Aggregates 1 and 2	130	322
1999	Aggregates 1 and 2	102	223
2000	Aggregates 1 and 2	102	223
2001	Aggregates 1 and 2	102	223
2002	Aggregates 1 and 2	26	194

[a] Protected inside waters east of Vancouver Island.
[b] Remaining outside, open-coast waters of British Columbia.

and close fisheries (Walters and Pearse 1996). Advice was sought from science on "sustainable" TACs, but the data were insufficient to provide defensible harvest levels.

Symptoms of overfishing (e.g., declining catch rates) together with anecdotal information on local area depletion of stocks and at-sea discarding practices led to reductions in TACs in most of the years since license limitation and TACs were introduced (Table 2; Figure 3). The lack of science advice for sustainable TACs continued to exacerbate management problems. By mid-1990, user-pay logbook, 100% dockside monitoring, and partial at-sea observer programs were implemented in an attempt to address catch monitoring concerns (Table 2).

Increasing conservation concerns prompted the development of spatial management measures intended to protect a portion of the inshore rockfish stock from harvest. Closed areas were identified through consultation with industry and were closed to the commercial groundfish hook-and-line gears in 1999. During consultation with industry, it became apparent that these closures could not fully protect rockfish stocks because other fisheries that caught rockfish (e.g., commercial salmon troll, groundfish and shrimp trawl, and invertebrate trap fisheries) were not excluded from fishing. Similarly, reducing TACs for the directed commercial fishery but allowing uncontrolled catch by the recreational fishery would not meet conservation goals. For management to be effective, all fisheries that intercept rockfish need to be assessed and managed.

In March 2001, nongovernmental conservation organizations (NGOs) launched a campaign calling for the conservation of groundfish stocks, particularly within the Strait of Georgia (inside area). Critical of the DFO's management of groundfish stocks, NGOs lobbied for actions to protect inshore rockfish. Within the DFO, policy statements from the American Fisheries Society also raised awareness of the need for conservative and robust management for Pacific rockfish (Parker et al. 2001).

Elements of the Strategy

Scientists' advice to managers reiterated that the data and the assessment methodology were insufficient to meet the existing management objectives, and they recommended adopting precautionary management measures to ensure conservation. Management needed to be robust to both the uncertainties in the fishery catch and the incomplete knowledge of stock abundance. Scientists' advice set the following four specific measures for the strategy (Yamanaka and Lacko 2001): (1) account for all catch; (2) decrease fishing mortality; (3) establish areas closed to all fishing; and (4) improve stock assessment and monitoring.

In November 2001, a multi-stakeholder meeting including fishery stakeholders, the Province of British Columbia, NGOs, and interested members of the public was convened to present the evidence for the inshore rockfish conservation concern and to solicit opinions about the proposed conservation measures. The resulting consensus about the importance of developing and implementing conservation measures to protect inshore rockfish prompted the Minister of Fisheries to announce a commitment to develop a plan to reverse the inshore rockfish decline and ensure stock rebuilding. In addition, a broad consultation process would be implemented to seek input from harvesters and other interested parties to develop conservation measures.

Specific objectives for each component of the strategy were developed through internal DFO deliberations between groundfish science and management. These four objectives were announced by the minister in a May 2002 news release and are summarized below.

Account for All Catch

Catch monitoring is required to account for the total mortality of inshore rockfish, both landed and released,

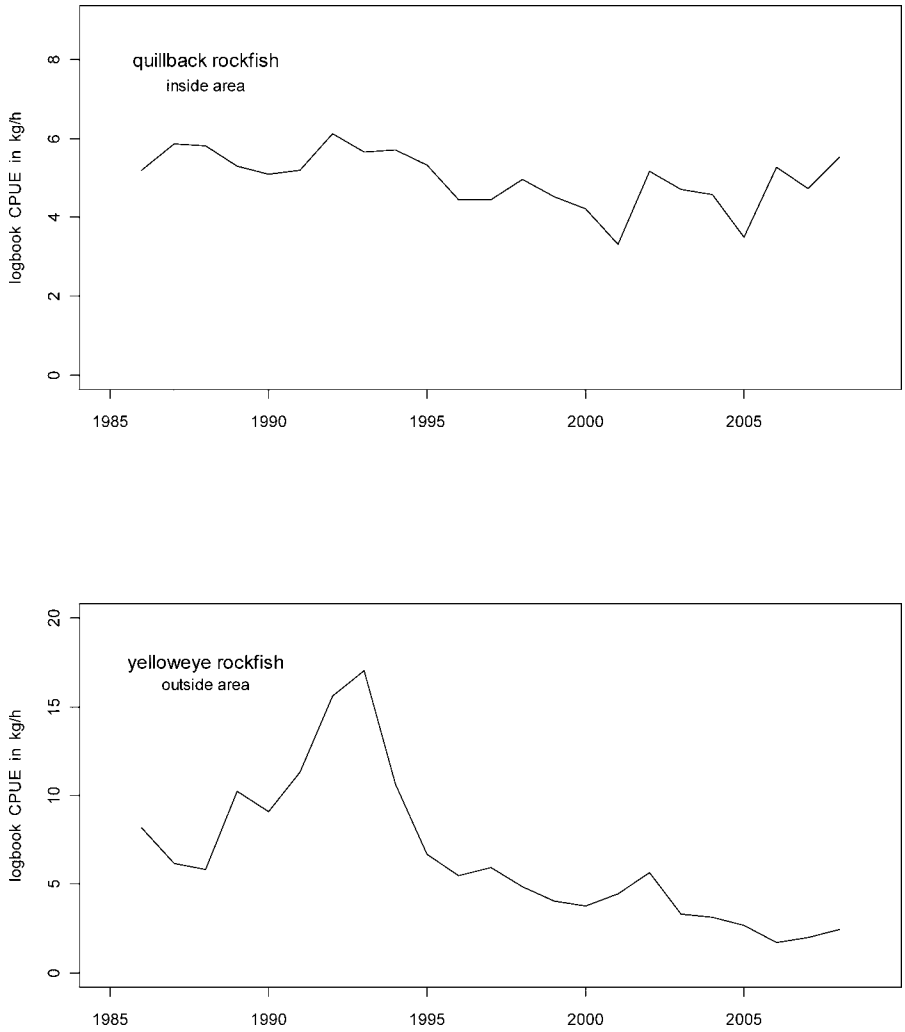

FIGURE 3.—Catch per unit effort (CPUE; kg/h) from logbook records for quillback rockfish from the British Columbia inside management area and for yelloweye rockfish from the outside management area.

from all commercial, recreational, and Aboriginal fisheries in order to monitor the influence of fisheries and management measures on inshore rockfish stocks.

Decrease Fishing Mortality

Harvest mortality must be significantly decreased to less than natural mortality to halt stock declines and allow for rebuilding. A precautionary sustainable fishing mortality rate of 2% or less is required.

Establish Areas Closed to Fishing

Extensive inshore rockfish habitat must be protected to provide a buffer against scientific uncertainty and contribute to the protection and rebuilding of rockfish stocks. Proposed targets for closure from all fishing were up to 50% of rockfish habitat within the inside area and 20% of the outside area (Figure 1).

Improve Stock Assessment and Monitoring

The effectiveness of management measures requires monitoring over time to ensure that conservation and rebuilding objectives are achieved. This will require the development of habitat-based survey methods to estimate population abundance. These survey methods will inform future stock assessment.

Preparing for Consultations

The elements of the strategy were easily understood. The challenge was to identify management actions that were comprehensive enough to meet these objectives.

A broader DFO team (hereafter referred to as "the team"), including enforcement and communications staff and a member from the Province, was assembled to reflect all fisheries that directly or incidentally catch inshore rockfish in British Columbia. These early meetings were intended to bring all managers up to date on the development of the strategy, to request opinions on appropriate management measures, and to develop cooperative approaches to addressing these coastwide. Team members reviewed fishery information and developed management measures for discussion in a document to inform the consultations (DFO 2002). Consultations would reiterate the conservation concern, present the components of the strategy and management measures for discussion, and solicit input from all parties.

Team members were asked to identify groups for consultation as all harvesters and provincial and community members were to be engaged in the process of developing a comprehensive management plan. Because inshore rockfish are caught in directed rockfish hook-and-line fisheries (commercial, recreational, and Aboriginal) and incidentally in all other hook-and-line (Pacific halibut *Hippoglossus stenolepis*, sablefish *Anoplopoma fimbria*, spiny dogfish *Squalus acanthias* and lingcod *Ophiodon elongatus*), trawl (groundfish and shrimp), and trap (prawn and sablefish) fisheries, the consultation process needed to reach all sectors and gear types. Furthermore, public concern for groundfish had increased due to campaigns by NGOs. The DFO had existing advisory bodies for each of these individual fisheries by sector and had a newly formed Marine Conservation Caucus that included all NGOs. However, nonfishing, nonenvironmental parties were difficult to reach but were important for inclusion in the discussion of area fishing closures. Provincial contacts for land trusts, island trusts, and landowner groups were identified, and public notices in local newspapers were used to engage community members.

Developing the Strategy

Subsequent to the initial multi-stakeholder and ministerial announcements, 5 months were spent on the coastwide consultation process. Ten public coastal community meetings and over 50 regional and area consultation meetings were held with the commercial, recreational, and Aboriginal fishing sectors; NGOs; the Province of British Columbia; municipalities; and community groups. Stakeholders were encouraged to provide feedback in developing conservation measures directly to groundfish management staff or through a website (DFO 2008). Progress to date is summarized below for each of the strategy components.

Account for All Catch

Catch monitoring has been the most difficult operational component of the strategy. Inshore rockfish are caught, retained, and discarded (assumed 100% mortality rate) by many different gear types and fishing sectors coastwide. Monitoring programs to estimate catch (retained and discarded) in all these fisheries were required to manage an overall TAC for inshore rockfish. From the data-collection side, gaps in the reporting of catch (especially discards) were identified in all sectors of the fishery. To fill gaps, catch reporting programs were initiated for many of the incidental fisheries, and recreational catch monitoring programs were expanded. By far, the most extensive catch monitoring solution has been for the commercial groundfish sectors.

In 2002, existing recreational catch monitoring programs, including creel surveys and logbook reporting from guides and lodges, were expanded spatially and temporally to better account for rockfish catch. Recreational logbook and creel survey programs have expanded into most of the outside areas of the coast, and summer season programs were expanded to include more months of the year. Information on rockfish species retained and released is recorded, and these figures are used to estimate the total catch of rockfish in the recreational fishery. Existing reporting and catch monitoring frameworks remained largely the same, but faster data processing provided in-season creel survey catch estimation on a bi-monthly basis.

In the commercial fisheries other than groundfish, rockfish species catch reporting has been incorporated into existing at-sea observer programs for the spot prawn *Pandalus platyceros* trap fishery and salmon troll fishery and through logbooks for unobserved trips. These reports are forwarded to the groundfish managers for inclusion in TAC monitoring.

In the commercial groundfish fisheries, 100% dockside catch monitoring was in place, but the at-sea discards of rockfish was unknown for the directed hook-and-line rockfish fleet. Management was complex, with rules that resulted in discarding of catch to meet landing (species trip limits or quotas) and single-species licensing (regulation) requirements. The entire commercial groundfish industry began to work toward eliminating the discarding of nondirected catch through an initiative from members of the directed rockfish hook-and-line fishery. The central concept would turn all discarded, nondirected catch into catch that would then be landed and sold. For this to happen, the existing single-species or gear type licensing structure in the groundfish fisheries needed to be integrated or relaxed. This integration scheme would protect indi-

vidual directed licensed fisheries (groundfish trawl fisheries; sablefish trap fishery; and sablefish, Pacific halibut, lingcod, dogfish, and rockfish hook-and-line fisheries) but would allow the transfer of fish quotas across these fisheries to cover the nondirected catch and hence eliminate discarding.

The DFO worked with the industry in 2003 to form a Commercial Groundfish Integrated Advisory Committee (CGIAC), with wide participation from government (federal and provincial), commercial fisheries, coastal communities, NGOs, recreational fisheries, and Aboriginal fisheries. The CGIAC provides advice on strategic approaches to management and addresses operational concerns to improve current management (Koolman et al. 2007). An industry-only subcommittee of the CGIAC, the Commercial Industry Caucus (CIC), was formed and convenes monthly to coordinate planning within the commercial fisheries. The CIC is guided by the following five criteria:

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

The CIC worked to resolve these issues and consulted with the DFO on specific aspects of their plan. The groundfish license integration initiative devised solutions to the accounting and monitoring problems in dramatic, intricate, and ingenious ways. Details of this process are described by Koolman et al. (2007). The two foundations of the initiative are individual transferable quotas for all species with TACs and 100% monitoring programs for the entire commercial groundfish fleet. Individual transferable species quotas are allocated by vessel and are transferable both across vessels within a single licensed groundfish fishery and across licensed fisheries up to a predefined limit to eliminate nondirected catch. The entire groundfish fleet is monitored at sea by observers or video cameras and is monitored by dockside monitoring programs when the catch is landed. Fishers are individually accountable for their catches and must either possess or buy species quotas to cover their total catch before their next fishing trip. A data system that enables managers to monitor the fishery through dockside landing reports, logbooks, at-sea video review audits, and observer logs is also being developed by the CIC and DFO. A pilot groundfish license integration program was launched in 2006 and is presently in its third year of operation.

Decrease Fishing Mortality

An overall TAC that would meet a fishing mortality rate (F) of less than 2% was set by the DFO and presented in the consultations. The mortality rate was based on recommendations for "remaining rockfish" in the USA by the Scientific and Statistical Committee (SSC), which evaluated the suitability of the Pacific Fishery Management Council's default harvest rates for groundfish. The SSC recommended risk-neutral proxies for the F at maximum sustainable yield (F_{msy}) and precautionary F based on 0.75 times the natural mortality rate (M) and $0.50–0.70 \cdot M$, respectively (SSC 2000).

For inshore rockfish in British Columbia, the total mortality rate (Z), M, and F were estimated by using catch curve analyses and derived with $Z = M + F$ (Ricker 1975). Research survey samples of yelloweye rockfish at Triangle Island were selected as representative of the outside fishery in 1997–1998 and were used to estimate Z, and Bowie Seamount samples were representative of an unfished population and were used to estimate M (Figure 4). For quillback rockfish on the inside, survey samples from research sites taken before the fishery (June 1986) were used to estimate M and samples taken from the same sites in 2001 were used to estimate Z (Figure 5). Fishing mortality was simply derived by subtracting M from Z.

Reductions in TACs were made commensurate with the required reductions in F to attain F_{msy} (i.e., $0.75 \cdot M$). To reach the target F, the total fishery catch (retained and discarded over all fisheries) was reduced in proportion to the estimated required reductions in F estimated for British Columbia. For the outside yelloweye rockfish, F was equal to $2 \cdot M$; for the inside quillback rockfish, F was equal to $4 \cdot M$. Total allowable catches needed to be reduced by 50% for the outside area and by 75% for the inside area. These TAC reductions were announced in the consultations and would apply to all catch of yelloweye rockfish and quillback rockfish across all fisheries, unlike previous years during which TACs were only applied to the directed rockfish and Pacific halibut commercial fisheries.

Through the consultations, the magnitude of the reductions was generally accepted, and the focus of discussion became the application of the reduction and the total catch from which to apply the reductions. Agreement was made to apply reductions separately to

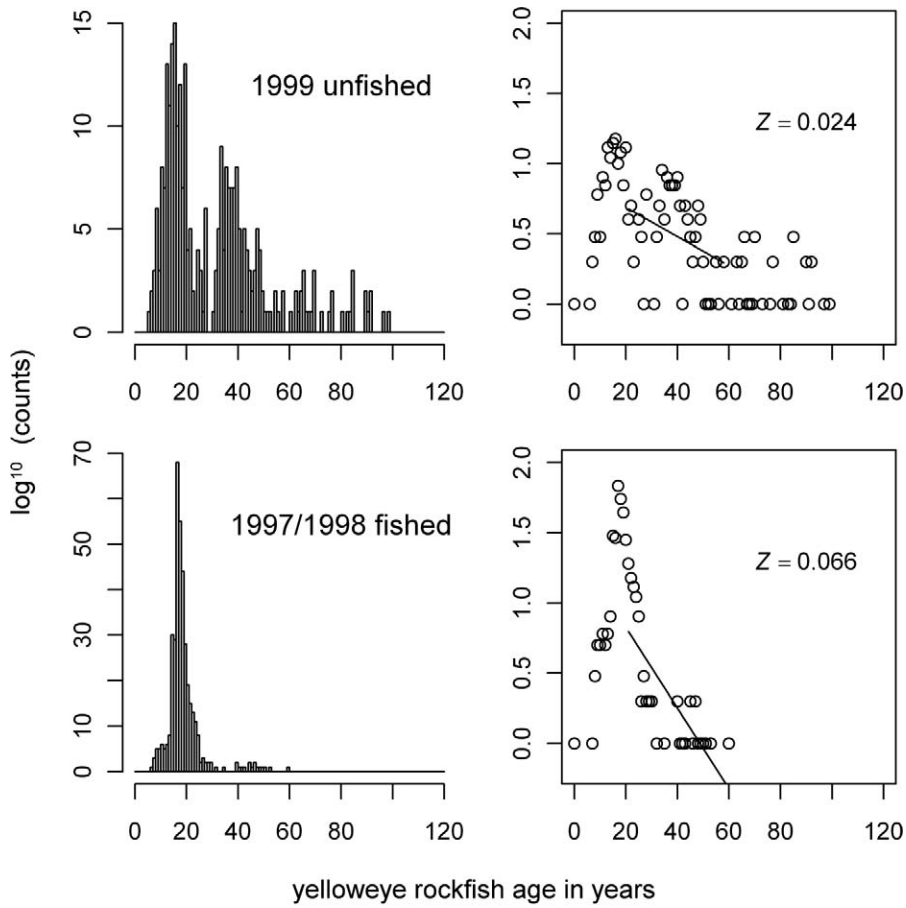

FIGURE 4.—Yelloweye rockfish age frequencies (left panels) and catch curves (right panels; Z = total mortality rate) from index site research surveys at the fished Triangle Island (British Columbia) site in 1997–1998 (top panels) and the relatively unfished Bowie Seamount area in 1999 (bottom panels).

each fishery (commercial and recreational) and to apply the reductions to total catch in the year the samples were taken to estimate Z. For yelloweye rockfish on the outside, commercial landings and discards estimated from at-sea observer data for the 1997–1998 fishing year were used to apply the 50% reduction. Similarly, for quillback rockfish, commercial landings and estimated discards in 2001 were used to apply the 75% reduction. To meet these reductions in the recreational sector, daily bag limits and seasons were adjusted. The recreational bag limit was reduced from 5 to 1 rockfish on the inside; for the outside, recreational bag limits were reduced from 10 to 5 rockfish (with no more than three yelloweye rockfish) in the north and from 5 to 3 rockfish (with no more than two yelloweye rockfish) on the west coast of Vancouver Island.

Fishing mortality targets were met in 2002 for the commercial sector and by 2003 for the recreational sector coastwide. Catch allocations are made to Aboriginal, commercial, and recreational fisheries. Aboriginal fisheries have the first access to fisheries, subject only to conservation considerations. Aboriginal fishery allocations are deducted from the TACs, and allocations are then made between the commercial and recreational sectors. As a precautionary measure in 2007, with the reopening of the inside recreational lingcod fishery, the recreational rockfish fishery no longer remains a year-round fishery and instead opens and closes with the lingcod fishery (June 1 to October 1).

Establish Areas Closed to All Fishing

Discussions on the size of closed areas took place within DFO groundfish science and management. Based on literature reviews and workshop results, the science recommendations were 20% of rockfish habitat

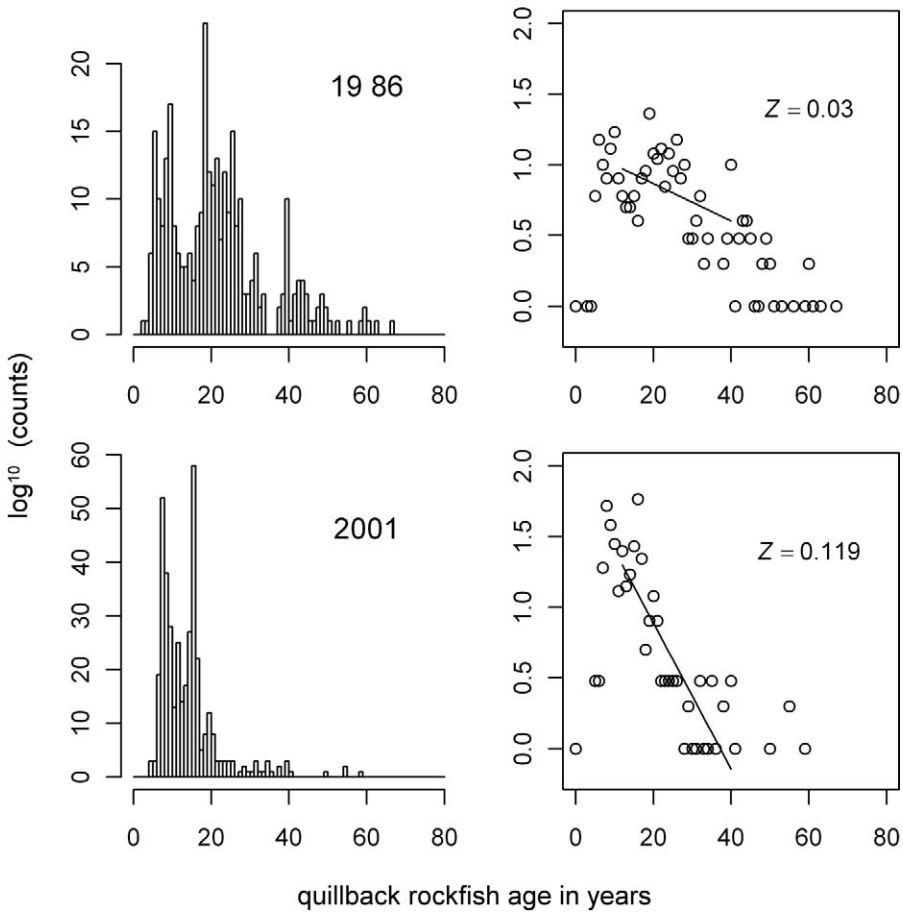

FIGURE 5.—Quillback rockfish age frequencies (left panels) and catch curves (right panels; Z = total mortality rate) from research jig-fishing surveys in the British Columbia inside management area in 1986 (pre-fishery; top panels) and 2001 (bottom panels).

throughout the outside management area and 50% of inside habitat. From 20% to 30% of the ocean area (encompassing all marine habitats) had been proposed as a guideline for conservation (Ballentine 1997; Bohnsack 2000). For inshore rockfish, a calculation over the entire ocean area would not consider the quality of habitat within the area. Habitat quality criteria are important for evaluating individual sites for closure and are a requirement for selecting areas that are biologically meaningful for inshore rockfish. However, the spatial distribution of inshore rockfish habitats coastwide is unknown.

A practical measure of area is a proportion of the fishing ground or vulnerable area (Walters and Parma 1996). A recommendation of a 50% closed area was proposed to sustain fisheries with no fishery management in the open fishing areas (Yoklavich 1998). Closed-area targets were refined through discussions and review of management within the two British Columbia management areas (outside and inside). The outside management area largely hosts a commercial fishery, and the inside management area is evenly split between commercial and recreational fisheries. Commercial fisheries are managed largely by TACs, and landings are well known through dockside monitoring. Recreational fisheries are managed by bag and possession limits, and landings are estimated through logbook and creel survey programs. Because of the existing management and nature of the fisheries, a closed-area target of up to 20% was set for the outside management area; due to the greater conservation concern, a target of up to 30% was set for the inside.

The activities allowed within closed areas were reviewed by the team, and coastwide fishing activities that were likely to incidentally or directly catch inshore rockfish were not permitted. Salmon troll and shrimp

trawl fisheries are not permitted within rockfish conservation areas (RCAs); fisheries that are spatially or temporally limited and intensively monitored, such as the roe herring (Pacific herring *Clupea pallasi*) and invertebrate hand-pick or trap fisheries, were exempt. A decision was also made to avoid restricting fisheries on the basis of their removal of rockfish prey (i.e., the prawn fishery).

A comprehensive consultation process was the focus to developing closed areas coastwide. The process evolved from the interaction with interested participants at the multi-stakeholder meeting and initial coastwide consultations and expanded to include all groups from harvesters to local property owners. The team worked closely with science, management, and regional staff to develop a closed-area strategy that progressed through the following steps with broad consultations at each step: (1) data gathering for the identification of specific closed-area proposals; (2) internal DFO review of proposals and verification with fishery catch data; and (3) DFO rockfish habitat analysis to meet the 20% outside and 30% inside targets.

Data gathering.—During the initial 5 months of consultation in 2002, charts were taken to meetings and groups were asked to identify inshore rockfish habitat. Quillback rockfish habitats were generally described as between 0 and 100 m in depth. Year-round adult habitat consists of high-relief rocky substrates, summer adult habitat is low-relief rock with kelp cover, and young-of-the-year habitat consists of kelp forests, blade kelp slopes, and eelgrass *Zostera marina* (Love et al. 2002). Year-round yelloweye rockfish habitat was described as between 50 and 200 m in depth, with boulders, broken rock, pinnacles, and rock overhangs (Love et al. 2002). Participants were asked to draw areas on the charts where (1) quillback rockfish and yelloweye rockfish were present; (2) spawning, nursery, or feeding grounds were present; and (3) historically productive but presently depleted fishing areas were located.

These various rockfish habitats were identified and proposals for closed areas were highlighted together with the reasons for each. In addition, other groundfish, salmon, herring, and shellfish fishing grounds were identified and noted as areas that were socioeconomically important to fishers and not recommended for closure. These habitat areas and proposals were digitized and entered into a geographical information system (GIS).

Stakeholder consultations in 2002 identified 148 proposals for area closure. Through several meetings, all 148 proposals were reviewed and 32 were selected based on unanimous agreement of the closure among all those consulted. Other considerations for area closures were the ease of description in fishery regulations, clear recognition by the public, and ease of monitoring and enforcement. Boundaries were adjusted and parties were consulted when changes affected their area proposals. These 32 areas were identified as interim areas of restricted fishing (IARFs). Permitted fishing activities within these IARFs were restricted to invertebrate fisheries in which harvesting methods included hand picking or traps. The IARFs represented about 1% of the entire coastal waters and were established in August 2002 as the first areas to be closed to fishing under the strategy.

Internal DFO review.—In June 2003, an internal review of all 148 closed-area proposals was initiated. Georeferenced catch data records between 1995 and 2002 from commercial hook-and-line fishery logbooks, onboard observer programs, and recreational creel surveys were plotted in a GIS and were used to assess an arbitrary rockfish value of "high," "medium," or "data limited" for each of the area proposals. These values were verified through an internal DFO consultation, where the expertise of DFO's area managers and fishery officers with first-hand traditional knowledge was elicited. Results of this internal analysis were posted on the DFO website in August 2003. Participants from the first round of consultations were requested to review and comment again on these areas.

A subset of the team, with added participation from Parks Canada and British Columbia Parks, was involved in the closed-areas review. Members convened many times, discussed every comment (>400) posted to the website, and made revisions while considering all the concerns expressed throughout the consultations. Boundary changes were made to address socioeconomic concerns, such as to accommodate salmon troll fisheries or recreational fishing lodges. Participants were again consulted if boundary changes were made. The website was updated in November 2003, with a total of 89 selected areas for closure based on high or medium rockfish value or data-limited value where traditional knowledge indicated a higher rockfish value. These selections were again open to consultation through the website and through direct consultations until February 2004. The final revisions to the 89 closed areas, which included 22 of the previous 32 IARFs, were made and implemented in March 2004. Approximately 8% of the coast was now closed. These 89 areas were renamed RCAs, and the permitted activities within these areas were listed as invertebrate hand-picking fisheries, invertebrate trap fisheries, and seine, gill-net, and midwater trawl fisheries.

The DFO habitat analysis.—The final phase of identifying RCAs to complete the targets set for RCAs

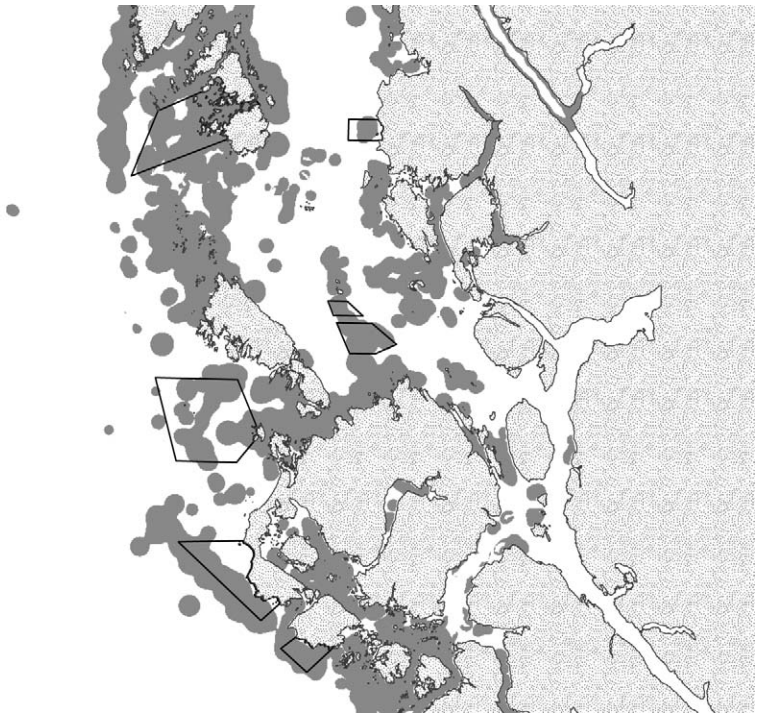

FIGURE 6.—Combined layers of catch density and complexity analyses used to model rockfish habitat (shaded areas) in British Columbia, with rockfish conservation areas outlined in black.

coastwide was based on a rockfish habitat model. Rockfish habitat was defined by depth from the distribution of quillback rockfish and yelloweye rockfish catches from fisher logbook records (from 1996 to 2003). A model was then developed in a GIS using rockfish catch (commercial and recreational) and available bathymetry data. Data sets overlapped to a large extent and in some areas complimented each another. Some areas of the coast have sparse bathymetry data available and, similar to the fishery data, not all areas have been fished. Fishery catch-per-unit-effort density analysis highlighted areas of high rockfish catch, and a complexity analysis highlighted areas where the rate of change in the slope of the bottom was high (second derivative of the slope; Ardron 2002; Iampietro and Kvitek 2002). These two layers were merged into one and used as a surrogate for rockfish habitat coastwide (Figure 6). The merged rockfish habitat layer was colored a monotonic green for the consultations due to the confidentiality of the fishery data.

The habitat model also provided the means to measure closed-area proportions and to ensure an equitable spatial distribution of closed areas coastwide. Measurements of the closed-area targets were based on the proportion of the rockfish habitat within the closed area divided by the total rockfish habitat for each management area. Using the model, further closed areas were selected by members of the team to meet the area targets (20% outside and 30% inside) and to ensure an even spatial distribution of areas throughout the coast.

An additional 13 outside and 112 inside closed-area proposals were developed by the team. All proposals were selected by using the model and considering proximity, size, and spatial distribution of areas, as well as traditional knowledge, common agreement among stakeholders, and socioeconomic concerns. Consideration was also given to creating RCAs adjacent to ecological reserves and land-based parks.

Rockfish conservation area proposals for the outside area were introduced through meetings with the harvesting sectors and web-based consultations in September 2004. These proposals represented the closed-area targets required for the strategy. Further boundary adjustments or revisions would need to achieve the same targets for closure. Proposals for the inside area were presented in the same way 1 year later. Consultation continued, and a suite of 164 RCAs was implemented in February 2007 (Figure 7). The

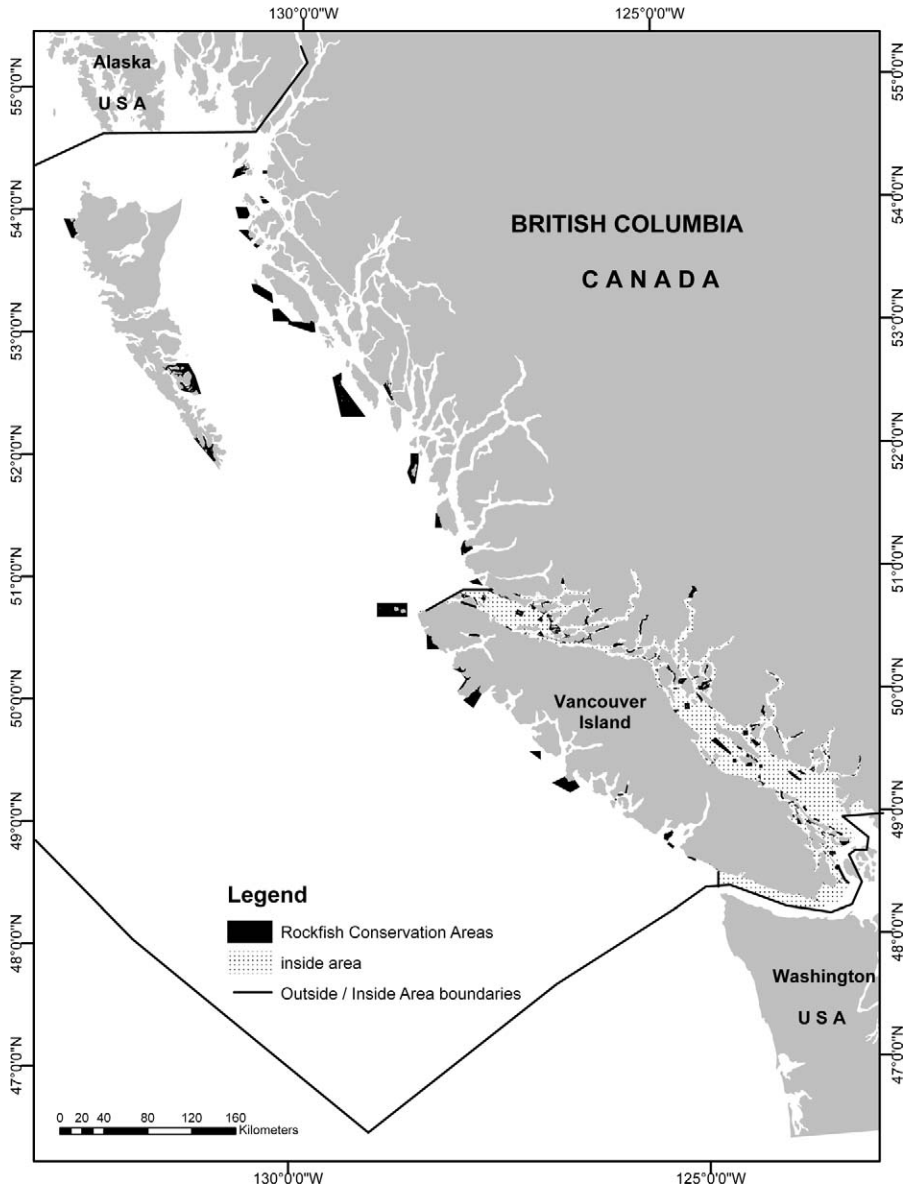

FIGURE 7.—Coastwide distribution of rockfish conservation areas in British Columbia.

geographical extent of the final RCAs was close to meeting target values of up to 20% on the outside and 30% on the inside (Table 4). Other closed-area initiatives (e.g., national marine conservation areas) are now underway and will result in further fishing closures in the outside area.

Improve Stock Assessment and Monitoring

Together with catch monitoring, abundance indices and biomass estimates were identified as requirements for stock assessment. Research plans were developed, and in 2003 funding was secured to carry out this component of the strategy.

Existing fishery-independent surveys in British Columbia were reviewed for their potential use as abundance indices and as a means to collect biological samples for quillback rockfish and yelloweye rockfish. The International Pacific Halibut Commission's (IPHC) standardized stock assessment (SSA) survey is conducted annually in British Columbia and was identified as a potential abundance index for yelloweye rockfish and quillback rockfish in outside waters. In

TABLE 4.—Proportion of modeled rockfish habitat area (km^2) within British Columbia rockfish conservation areas (RCAs) by statistical area or region for the inside and outside management areas.

Management area	Statistical area or region	Rockfish habitat area, km^2	RCA area, km^2	Percent within RCA
Inside[a]	12	1153.99	314.13	27
	13	454.37	133.16	29
	14	144.31	40.57	28
	15	242.64	72.45	30
	16	262.55	77.59	30
	17	282.82	82.22	29
	18	217.18	58.60	27
	19	186.04	55.40	30
	28	132.28	38.16	29
	29	83.00	25.13	30
	Total inside	3159.18	897.41	28
Outside[b]	North coast	2161.39	333.97	15
	Central coast	2721.69	503.44	18
	Queen Charlotte Islands	2384.78	353.85	15
	West coast of Vancouver Island	3660.53	471.68	13
	Total outside	10928.39	1662.94	15

[a] Protected inside waters east of Vancouver Island.
[b] Remaining outside open coast waters of British Columbia.

2003, a cooperative data collection program was developed with the IPHC and the commercial Pacific halibut industry whereby an additional technician records hook-by-hook catch data and carries out biological sampling on rockfish for all survey sets in British Columbia (Yamanaka et al. 2004b). Data on total catch by species have been collected from the annual SSA surveys since 2003, and estimates of catch from previous surveys were used to assemble an abundance time series from 1995 to 2007 (Obradovich et al. 2008). The IPHC SSA is the longest time series of fishery-independent catch rate observations for yelloweye rockfish and quillback rockfish in British Columbia outside waters. Declines in abundance since 1995 are evident, but there appears to be a reversal of this trend in the recent data between 2003 and 2007 (Figures 8, 9).

Two research surveys, last conducted in 1984 and

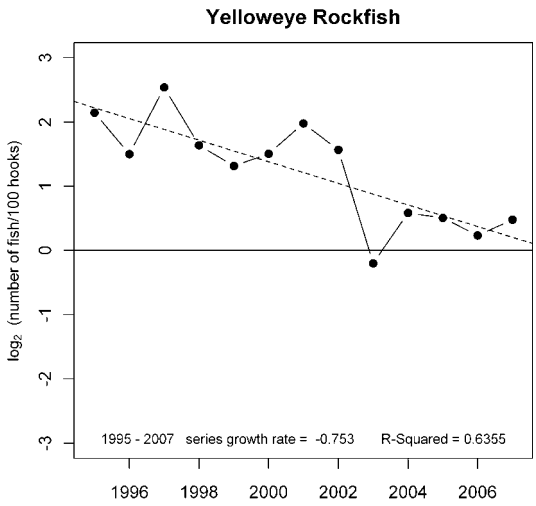

FIGURE 8.—Yelloweye rockfish catch per unit effort from the standardized stock assessment survey conducted by the International Pacific Halibut Commission in British Columbia outside waters from 1995 to 2007. Regression line is shown for all survey locations throughout the time series (dashed line). Figure is modified from Obradovich et al. (2008).

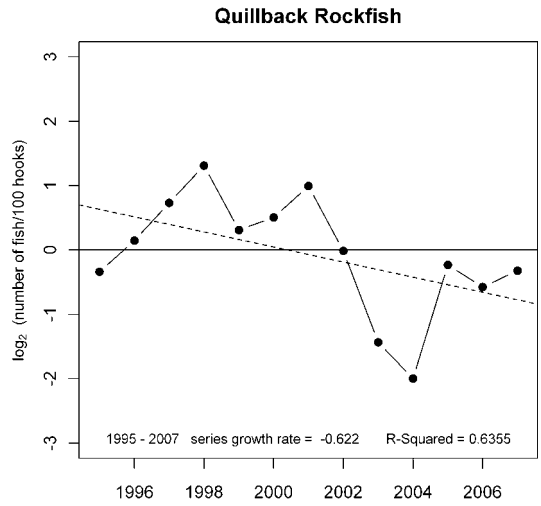

FIGURE 9.—Quillback rockfish catch per unit effort from the standardized stock assessment survey conducted by the International Pacific Halibut Commission in British Columbia outside waters from 1995 to 2007. Regression line is shown for all survey locations throughout the time series (dashed line). Figure is modified from Obradovich et al. (2008).

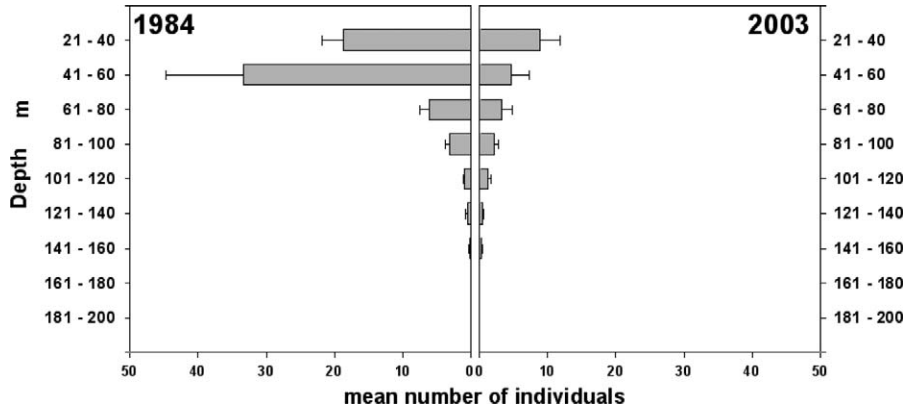

FIGURE 10.—Comparison of the mean number (±SE) of quillback rockfish observed per transect by 20-m depth intervals during submersible surveys conducted in British Columbia coastal waters in 1984 and 2003. Only sites and depths common to both years are included in the analysis. Figure is from Yamanaka et al. (2004).

1992, were resurrected to provide some information on the current stock status. Sites within the inside waters were resurveyed in 2003 by using a three-person submersible, similar to that used in the original surveys in 1984 (Richards and Cass 1985). Observed densities of quillback rockfish in 2003 were significantly lower than those in 1985 (Yamanaka et al. 2004a). Quillback rockfish were less abundant in 2003, particularly in the common fishing depths from 0 to 100 m (Figure 10). Index sites surveyed with jig fishing gear in 1986, 1987, 1988, and 1992 were also resurveyed in 2004 (Yamanaka and Lacko 2008). The relative abundance of quillback rockfish from these surveys shows a 58% reduction over the 18-year survey period. These surveys confirmed conservation concern for the stocks and reinforced a DFO commitment to develop the strategy.

New longline surveys employing a depth-stratified sampling design were planned for hard-bottom, untrawlable areas throughout the inside and outside waters of British Columbia. A 2-km grid was used coastwide, and blocks were included in the sampling frame if they fell within the commercial hook-and-line rockfish fishing areas between 40- and 100-m depths for inside waters and between 20- and 250-m depths for the outside waters. Areas of the grid were reviewed by fishermen, and blocks were added or removed based on local knowledge of bottom type. Sample sizes were derived from power tests, initially by using catches observed from the commercial fishery and then subsequent to the surveys were adjusted by using catches from the research surveys. Samples were allocated in proportion to the total number of blocks per area and depth strata and were selected randomly.

For the inside waters, annual longline surveys were initiated in 2003 by using a DFO research vessel (Lochead and Yamanaka 2004). The inside area is surveyed in portions, with each portion on a 3-year survey rotation (Figure 11). The outside area was surveyed through a cooperative program with commercial industry in years previous to the rockfish conservation strategy (Kronlund and Yamanaka 2001). In consultation with industry, these surveys were reconfigured to develop coastwide abundance indices. The outside area is surveyed in two portions: north and south. The northern half was surveyed in 2006 and 2008, and the southern half was surveyed in 2007, with plans for a survey in 2009 (Figure 12). Although expensive, the industry is committed to these surveys and advocates annual support by the DFO. Over the long term, these surveys will provide fishery-independent abundance indices for stock assessment.

The authors of other research to develop nonintrusive methods of assessment for inshore rockfish have investigated visual strip or line transect methods to estimate inshore rockfish densities by habitat type. Remotely sensed habitat features have been used in habitat models to investigate methods for the expansion of rockfish density to biomass. Submersibles, remotely operated vehicles, and towed cameras have been explored as tools for this research (Martin and Yamanaka 2004; Martin et al. 2006). These new nonintrusive survey tools are required for the monitoring and assessment of inshore rockfish stocks of low abundance and within areas closed to fishing. Collaborations with universities to develop visual survey methods and new stock assessment methods have also been launched in 2007 and 2008.

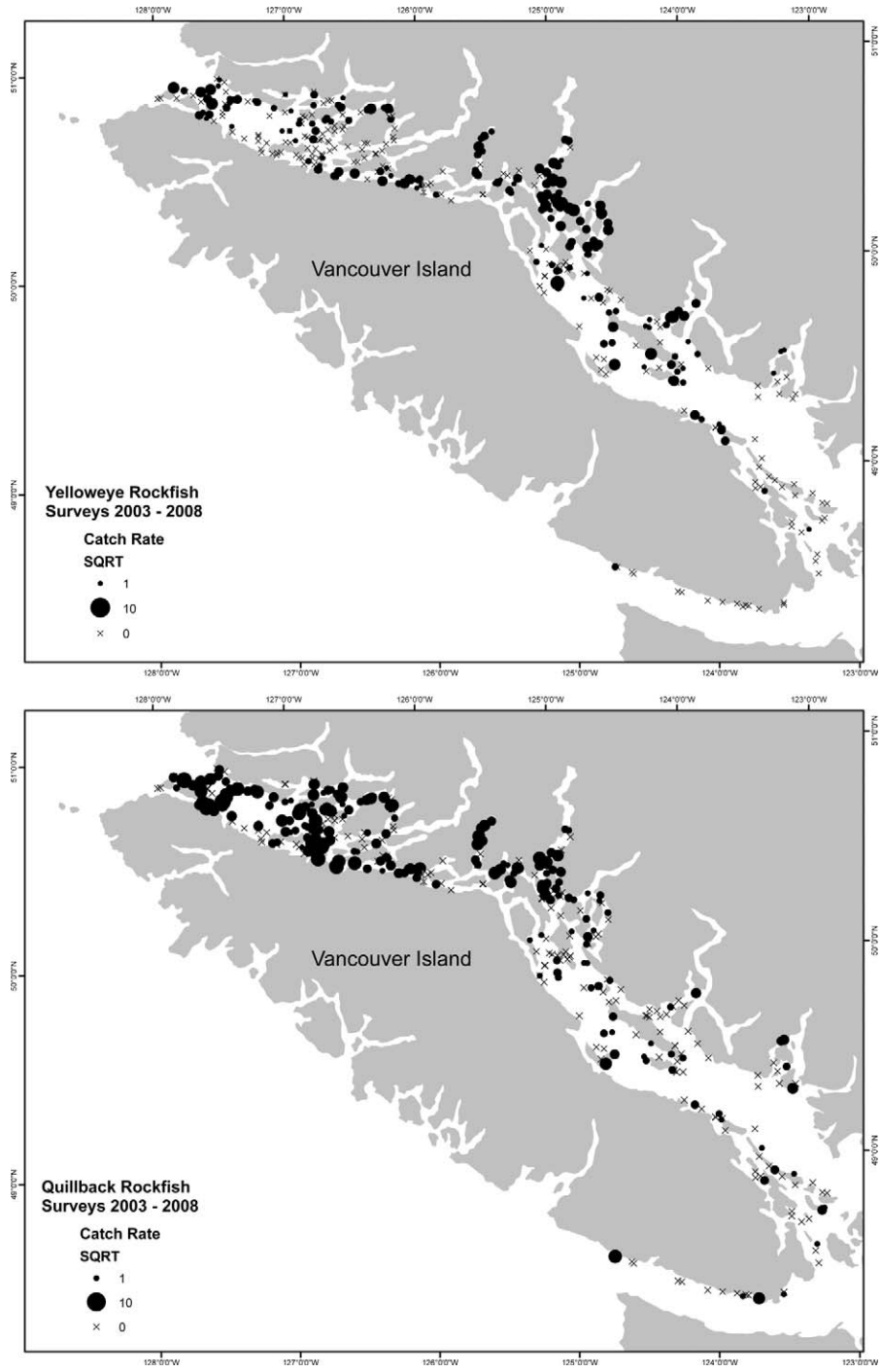

FIGURE 11.—Yelloweye rockfish (top panel) and quillback rockfish (bottom panel) catch rate (square root [SQRT] of the number of fish per 225 hooks) from Department of Fisheries and Oceans Canada longline surveys conducted throughout British Columbia inside waters from 2003 to 2008.

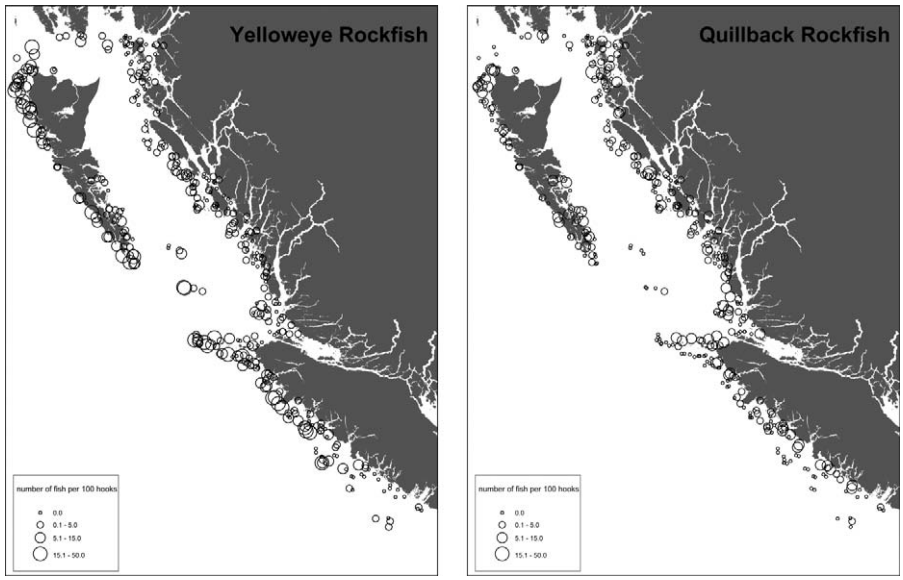

FIGURE 12.—Yelloweye rockfish (left panel) and quillback rockfish (right panel) catch per 100 hooks from longline research surveys conducted in the British Columbia outside management area with the Pacific Halibut Management Association.

Lessons Learned

The strategy identified four components required in a comprehensive management plan for these data-limited species. In light of the precautionary principle, bycatch reduction commitments made to Canadians and the international community, and conservation concerns voiced from fishers, NGOs, communities, and the public, the DFO had to move towards a more sustainable approach to management. Prescriptive science advice to develop a comprehensive management plan was delivered in 2001, and subsequent support by participants in a multi-stakeholder meeting elevated the strategy to a high priority within DFO. Encouraged by this support, management and science obtained personnel and funding (CAN$4.2 million over 5 years) required for intensive consultations and renewed science programs. At the onset, the operational plan was not known, but it was certain that the plan would have to be a dramatic shift from the status quo.

Development of the strategy within the DFO was facilitated by the assembly of a large team that covered the wide spread of departmental responsibilities with respect to inshore rockfish. Critical to the effectiveness of the team was a leader able to expedite decisions or operations within the team, as well as in other areas of the DFO by having a direct communication (reporting) link with senior managers. Consensus-based decision making required hours of deliberation but in the end allowed everyone to be heard and good decisions to be made. The team was able to communicate objectives of the strategy and provide a range of management measures designed to meet these objectives. These were fundamental to the success of the public consultations.

Bringing together a diverse group outside of the DFO to focus on inshore rockfish management was also a significant feat. The multi-stakeholder meeting at the onset of the consultations did much to broaden the individual perspectives of the participants and refocus their energy from pointing fingers and laying blame to collectively realizing the extent of the conservation concern and moving on to developing solutions. Open and respectful conduct also facilitated progress. Participants remained engaged in the consultation process when their comments were acknowledged and communication (feedback) mechanisms were provided and (more importantly) used by the DFO.

It has been several years since the minister's announcement of the strategy. All components of the strategy have been transformed into action—some due to the provision of funding (stock assessment research and surveys). Nevertheless, the strategy could have easily stalled had champions not emerged to take action and see tasks through. Surprisingly, work is still progressing on catch monitoring because of the unfailing commitment of individuals in the industry who have invested heavily (time and money) in the process (Koolman et al. 2007). The current manage-

ment plan, with some components still in progress, is more complex than previously imagined, but the participants involved in its creation are determined to work things through.

Although time consuming and arduous, engaging the DFO and fishery participants in developing the conservation strategy has been the key to our successes to date. Groundfish participants began this process as fragmented as the DFO but soon realized that many of their concerns were shared and that speaking with a unified voice would expedite work with the DFO. The creation of the CIC and the formation of the larger CGIAC were strategically significant moves. The CIC has fostered the groundfish license integration, which is the cornerstone of the operational strategy. Both the CIC and CGIAC are viewed as advisory bodies to the DFO, and groundfish management issues are vetted there as a means to management. In moving forward with components of the strategy, it could not have been politically or publicly possible without the intense and prolonged consultation process and resulting endorsements from participants, the CIC, and CGIAC.

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