Chapter 29
The Future of Fisheries Science on Canada's West Coast Is Keeping up with the Changes

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Abstract A look back at the issues in fisheries management on Canada's Pacific coast identifies a history of surprises. "Expect the unexpected," was the advice of W.E. Ricker. Surprises will always occur, but fisheries science needs to be in a position to minimize their economic impacts and explain the causes to the people who manage and care about fish and fisheries. For example, we now recognize the critical role of climate and the ocean in the regulation of recruitment. However, we do not understand the mechanisms that link climate to the life-history strategies of key commercial species. We know that marine ecosystems off British Columbia are warming and we know that marine ecosystems can change rapidly. However, without a better understanding of the processes that link climate to fish abundance, fisheries science will be restricted in the advice it provides to managers and patrons. We also know that human populations will continue to grow and increase the demand for seafood. Expansion of marine aquaculture and ocean ranching is the only way to meet this demand. There are excellent aquaculture-related opportunities in the coastal communities of British Columbia, but the impacts on natural resources are not clear and poorly researched. Wild fish and shellfish, properly harvested and properly managed, will likely continue to command premium prices. These conditions and others will affect the kind of fisheries science we do on the Pacific coast of Canada. Effective fisheries science organizations in the future will be the ones whose leaders adapt the fastest to new knowledge and new issues by forming teams of researchers that combine experience, curiosity, and new thinking. An independent fisheries science research advisory board will help make the best use of all available fisheries science in the province. With this approach, surprises may become learning experiences.

Keywords British Columbia · pacific coast · fisheries management

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29.1 Introduction

In the early 1900s much of the early science related to marine fisheries on the west coast of Canada was conducted by scientists at the Pacific Biological Station in Nanaimo, British Columbia. By the 1960s, the reputation of the science and scientists was highly regarded around the world. However, despite the strong scientific support, the history of Canada's Pacific coast fisheries has been punctuated by major surprises. In this chapter, we describe a few of the key surprises to show that there is an unexpected side to fisheries science that will become more problematic as climate change compounds an already variable environment, and future environmental conditions interact with the cumulative effects of fishing. We speculate about the future issues in fisheries science on Canada's Pacific coast as a way of encouraging colleagues, managers, fishermen, and the general public to prepare for an uncertain future and the complexity associated with sustaining both fisheries and natural resources.

The hindsight and foresight relating to the complexities of fisheries science and management may not be clear, but it is good enough to show that there are two distinct approaches for the future. One approach would be to stay the course, hoping that future impacts of climate on fisheries and ecosystems can be managed with little change in how we do our science. According to this scenario, whatever science is available (sometimes called "the best available science" or "the weight of evidence") should be adequate to make timely biological and social adjustments when making management decisions. The second approach, which we think evolves logically from the lessons of the past, is to learn from the past but recognizes that future environments and social pressures will be different from those in the past. We suggest that it is necessary to rethink what science is needed, how we manage and conduct our science, and that a more adaptive approach is needed to navigate fisheries science through the uncharted waters of the future.

29.2 Examples of Surprises

The major fisheries on Canada's Pacific coast have been targeted on spiny dogfish (*Squalus acanthias*), Pacific herring (*Clupea pallasi*), Pacific sardine (*Sardinops sagax*), the aggregate of Pacific salmon species (*Oncorhynchus* spp.), Pacific halibut (*Hipploglossus stenolepis*), and recently Pacific hake (*Merluccius productus*) (Beamish et al. 2008a). Most fisheries research has focussed on Pacific salmon because this group of six major species are highly valued as commercial and recreational species. They provide food, and social and ceremonial values to First Nations, and are iconic as general indicators of ecosystem health. It is difficult to assign budgets to species, but a good guess is that about 70% of the fisheries research dollars assigned to Pacific coast fisheries have been spent on Pacific salmon.

29.2.1 Pacific Salmon

In 1954, W.E. (Bill) Ricker published his famous paper on stock and recruitment of Pacific salmon (Ricker 1954). Yet despite the improved understanding of the dynamics of Pacific salmon that resulted from Ricker's insights, Canadian catches of Pacific salmon did not increase in the 1960s and 1970s (Fig. 29.1a). This was sufficiently puzzling that in 1973 Bill published another famous paper in which he wrote, "a puzzling problem of Pacific salmon ecology is why the runs of major river systems, when brought under the best available management, rather consistently fail to produce levels close to what has generally been expected of them on the basis of their past history" (Ricker 1973). The concern was that Pacific salmon abundances and the resulting catches were not rebuilding as expected from the stock and recruitment models. We now know that the ocean rearing areas were in a period of reduced capacity to produce Pacific salmon (Beamish and Bouillon 1993; Beamish et al. 2004, 2008b). It was not until after the 1977 regime shift (Beamish and Bouillon 1993, 1995; Francis and Hare 1994; Mantua et al. 1997; Zhang et al. 1997; Minobe 2000) that the productivity and catches of Pacific salmon increased off the west coast of Canada (Fig. 29.1a). In fact, the highest Canadian catch in history occurred in 1985 which surprised everyone.

At about the same time as Ricker published his paper in 1973, other scientists studying Pacific salmon suggested that the failure of Pacific salmon to rebuild to historic abundances was a consequence of insufficient juveniles being produced in freshwater. One well-known researcher wrote that there seemed to be lots of headroom for expansion of salmon populations before the rearing areas of the ocean became a limiting factor. This consensus that juvenile Pacific salmon abundance was limiting total abundance led to the establishment of the Salmon Enhancement Program (SEP), a massive hatchery and artificial salmon rearing program (Fisheries and Environment Canada 1978) that still exists. However, after 1985, Pacific salmon catches declined steadily and now are approximately one half the historic average. As Canadian catches declined, the total catch by all other countries increased (Fig. 29.1b). Canadian commercial catches declined from average levels in the late 1960s and early 1970s of about 19% of total catches of all countries before SEP (1977) to about 3% of the total catches from the mid-1990s to 2005 (Fig. 29.1c). Included in this decline was the total collapse of a major recreational fishery for coho salmon in the Strait of Georgia (Beamish et al. 1999).

It is now recognized that climate profoundly affects the ocean carrying capacity for Pacific salmon (Beamish and Bouillon 1993; Francis and Hare 1994; Mantua et al. 1997; Beamish et al. 2000; Finney et al. 2000, 2002; Ruggerone and Goertz 2004; Briscoe et al. 2005). The climate effects are shown as trends (Trenberth 1990; Trenberth and Hurrell 1994; Mantua et al. 1997; Thompson and Wallace 1998; Minobe 2000; Yasunaka and Hanawa 2002) and are not random as was originally assumed. It is also recognized that adding artificially reared salmon to the ocean is tricky (Beamish et al. 2008a) and may even result in the replacement of wild stocks (Hilborn and Eggers 2000). The target of SEP to double the Pacific salmon catch has not been met and

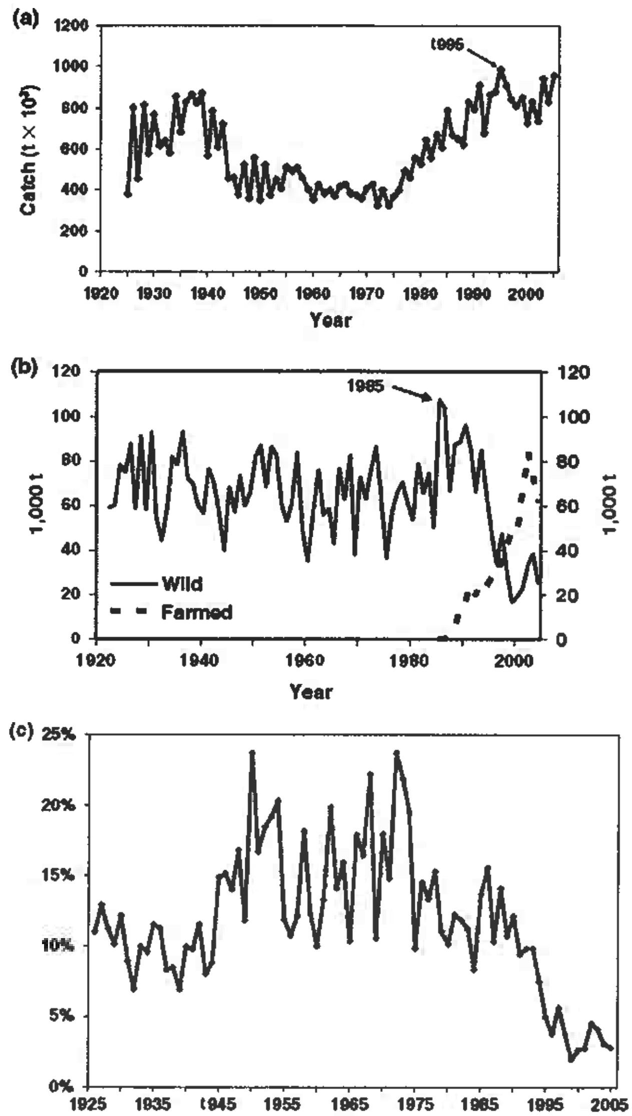

Fig. 29.1 (a) Total Canadian catch of Pacific salmon from 1925 to 2005. The annual production of farmed salmon is shown separately. (b) Total production of farmed salmon produced and wild salmon caught in British Columbia from 1924 to 2005. The largest total catches occurred in 1995, 2003, and 2005 with 985,100, 942,400, and 959,000t, respectively (for 1925–1992 data email Chrys.Neville@dfo-mpo.gc.ca; for 1993–2005 data, see http://www.npafc.org/new/pub_statistics.html). (c) Percentage of Canadian salmon in total Pacific salmon catch from 1925 to 2005

the program has not really adapted to the recognition that the original assumptions of unused and/or stable ocean capacity are invalid. Perhaps the biggest surprise is that everyone remains puzzled by the current low Pacific salmon catches in Canada when the total Pacific salmon catches by all other countries are at historic high levels. After decades of research, monitoring, and analysis, our ability to explain the determinants of Pacific salmon production in British Columbia remains surprisingly limited.

29.2.2 Aquaculture

As the wild and hatchery Pacific salmon catches were declining, production from salmon farming was increasing (Fig. 29.1b). There was no vision of the potential of Atlantic salmon farming in the 1960s and 1970s and the concept of culturing fish off the coast of British Columbia was unheard of. A well-known researcher advised in the late 1960s that aquaculture might equal the efficiency of rearing chickens, but it could scarcely surpass it. Today, the food conversion ratio (dry weight of food to wet weight of fish) for salmon farming is 1.2:1, compared to 2–3:1 for chickens (Brown et al. 2001). Atlantic salmon (*Salmo salar*) production in British Columbia is now two and one half times larger than wild Pacific salmon catches and the comparative value (Fig. 29.2) is about four times greater (BC Seafood Industry Year in Review 2006, available at www.env.gov.bc.ca/omfd/reports/YIR-2006.pdf). The industry in 2002 provided about 4,700 full-time jobs in many areas of the province needing employment (BCSFA 2003).

Aquaculture generally and salmon farming in particular are controversial for a variety of reasons, but the main reason is that the rapid development of the industry was a surprise to most people. As the industry developed, management agencies did not establish monitoring programs and advisory bodies. Impacts of salmon farming on wild Pacific salmon were not researched until environmental groups alarmed the public (Morton et al. 2004). In the absence of an established research program,

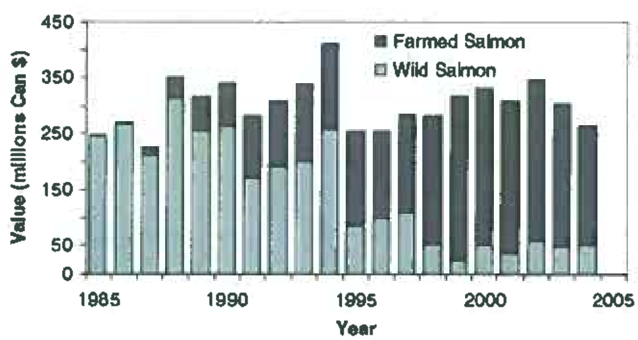

Fig. 29.2 Value of wild and farmed salmon in British Columbia from 1985 to 2004

ideological debates flourished. Hindsight shows us that it was a mistake not to take aquaculture and salmon farming seriously when Atlantic salmon farming was approved in British Columbia in the early 1980s. It was unfortunate that the salmon farming industry did not recognize that culturing an exotic species of salmon in British Columbia would be so controversial. It was equally unfortunate that fisheries scientists, who have a responsibility to provide management advice, did not have research programs that evaluated the impacts of salmon farming or other forms of aquaculture.

29.2.3 Pacific Herring

The Pacific herring fishery has always been a major fishery on Canada's Pacific coast. After the collapse of the sardine fishery in the late 1940s (MacCall 1979; Beamish et al. 2008b; McFarlane and Beamish 1999), Pacific herring were actively fished for reduction to fish meal and fish oil (Fig. 29.3). The annual increases in catch did not appear to affect recruitment resulting in several well-known scientists reporting that it was not possible to overfish herring. In less than 10 years after this statement was made, the Pacific herring fishery was closed (Fig. 29.3). The collapse of the Pacific herring fishery is now recognized as resulting from too high a fishing mortality at a time of continual poor recruitment into the fishery (Beamish el al. 2001). The Pacific herring fishery resumed in the early 1970s (Fig. 29.3) as a roe fishery that has been sustained to the present. The recent fishery is considered to be well managed with a series of regulations that prevent overfishing. However, the mechanisms that caused the herring recruitment failure are still not clearly understood. In fact, after about 70 years of research, the factors affecting year-class strength of Pacific herring off Canada's Pacific coast are still very poorly understood.

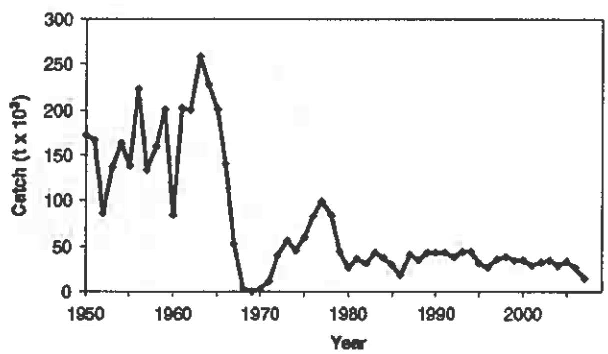

Fig. 29.3 Canadian catch of Pacific herring from 1950 to 2007

29.2.4 Groundfish

In the 1960s, groundfish were considered a relatively minor fishery. The rapid increase in catches beginning in the mid-1980s (Fig. 29.4) was not expected. Thus, it was a surprise that the value of the groundfish fishery today is about $300 million, exceeding the combined value of Pacific salmon and Pacific herring fisheries (BC Seafood Industry Year in Review 2006, available at www.env.gov.bc.ca/omfd/reports/YIR-2006.pdf). We know of no study or even an opinion that recognized this possibility.

There are 59 species in the current groundfish fishery and it is noteworthy that about 30 species have maximum ages exceeding 30 years (Beamish et al. 2006). It was not until the 1980s that it was recognized that many species were substantially older than previously thought (Beamish et al. 1983). Leaman and Beamish (1984) proposed that the length of life of a species is related to the length of time over the evolutionary history of a species that climate-related conditions were unfavorable for reproduction. Thus, the importance of climate and climate trends in both the life-history strategy and the stock and recruitment relationships for groundfish species have been recognized only recently. However, it is still unknown whether older fish in a population are needed for a species to adapt to climate changes. Fishing down the age composition or "longevity overfishing" is still a developing concept (Beamish et al. 2006).

There were a number of surprises associated with the success of the groundfish fishery. One example worth noting relates to spiny dogfish, as they could play a key role in the future. One of the first major fisheries off Canada's Pacific coast was for spiny dogfish with landings from the Strait of Georgia from 1870 to 1950 that exceeded the landings of Pacific salmon (Beamish et al. 2008c). The fishery collapsed in 1950 when synthetic vitamin A became available (Ketchen 1986).

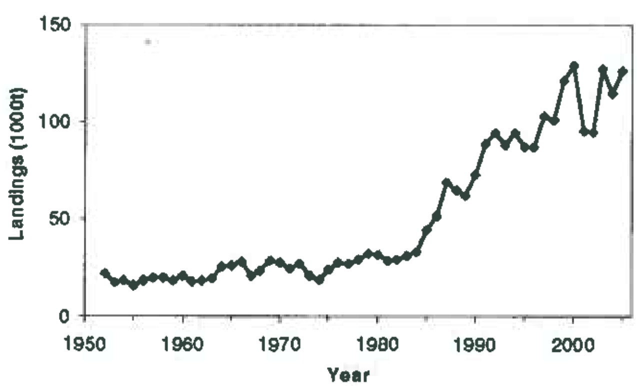

Fig. 29.4 Groundfish catches off the coast of Canada from 1951 to 2005

From 1950 to 1972, there were a number of attempts by both government and industry to eradicate spiny dogfish, largely because people did not like them (Beamish et al. 2008c). There were stories about the harm spiny dogfish did to more charismatic species, although there was no scientific proof. The facts are that spiny dogfish are very slow growing and thus consume only between 1.5 and 2 times their body weight a year (Brett and Blackburn 1978), thus they are not voracious predators. Spiny dogfish mature at an average age of 30 years for females and produce 3–11 "pups" about every 2 years (Beamish et al. 2008c; McFarlane and Beamish 1986; Ketchen 1975). Maximum ages are about 100 years (Beamish et al. 2006). Thus, some spiny dogfish that survived the "liver fisheries" in the 1930s and 1940s could still be alive today. The scientific issue today is that after more than 100 years of exploiting this slow-growing, long-lived fish, we know little about the animal. It is surprising that one of the major species in our west coast fisheries has survived massive fishing pressures and 20 years of eradication attempts, yet there is no understanding of why they are currently so abundant, what regulates their abundance and what their role is in the marine ecosystem.

29.3 Future Issues in Fisheries Science on Canada's Pacific Coast

Species evolve life-history strategies to survive in a naturally changing environment, but how do these strategies adapt when humans intervene and/or their environment changes? Unexpected events in fisheries science are to be expected as Bill Ricker advised. We think that fisheries science should be prepared to expect even more surprises as the impacts of global warming and climate change increasingly affect the poorly understood life-history strategies.

In Section 29.4 we present our vision of the future issues in fisheries science on Canada's Pacific coast. We begin with the key species and a brief assessment of their potential responses to changes in climate. We then select ten issues that we suggest will affect fisheries research on Canada's Pacific coast. We conclude by suggesting how to make more efficient use of the scientific effort that is available.

29.4 The Species

29.4.1 Pacific Salmon

Pacific salmon will remain the most important group of species even though their commercial catch and value have declined. The values of wild commercially caught and sport caught salmon may well increase with the development of new markets and specialty products, but we expect the catch to remain much reduced from historic values, a result of biological production and management/allocation decisions.

Beamish and Noakes (2004) and Beamish et al. (2008b) examined the impact of climate on the past, the present, and the future of the key Pacific salmon species in British Columbia. Beamish and Noakes (2004) speculated that there would be a general increase in Pacific salmon production in the subarctic Pacific, but production in British Columbia would decline. They also suggested that Pacific salmon will move into the Canadian Arctic in increasing numbers. Pacific salmon stocks south of about 55°N will probably be most adversely affected by a warmer climate as there appears to be an oscillation of productivity about this latitude (Hare et al. 1999). Sockeye salmon (*Oncorhynchus nerka*) in the Fraser River will be severely affected as the species is virtually at its southern limit (Rand et al. 2006). Pink (*O. gorbuscha*) and chum (*O. keta*) salmon will likely be less affected because of their reduced dependence on freshwater ecosystems and their use of mainstem channels. However, the marine ecosystem will also have an important influence on these two species (Beamish et al. 2008a). Coho (*O. kisutch*) and chinook (*O. tshawytscha*) salmon are not at their southern limits in British Columbia, but they enter the ocean later than the other salmon species and could be impacted by a trend toward earlier plankton production. In general, over the next 30 years, there will be much greater variability in Pacific salmon production in British Columbia that, in contrast to the past, will be mainly related to climate impacts in the ocean and in freshwater rather than the effects of fishing. The impacts of economic development and water use will likely exacerbate the effects of climate, again increasing uncertainty and competition among resource industries.

29.4.2 *Pacific Herring*

Beamish et al. (2008b) concluded that Pacific herring would likely continue to fluctuate in abundance over the next 30 years. Earlier plankton production should favor improved juvenile survival, but an increase in predators offshore, such as Pacific hake, would reduce recruitment. Pacific herring fisheries are conservatively managed (Schweigert 2001), so it is quite unlikely that overfishing will be a direct factor in Pacific herring production. The warming trend in the Strait of Georgia could become a problem (Fig. 29.5). Research is needed to determine how an additional degree Celsius will affect spawning behavior and prey availability for first-feeding larvae. Pacific herring off the west coast of Vancouver Island may be in low abundance because of predation from Pacific hake, which may increase in abundance as the ocean warms off Vancouver Island.

29.4.3 *Pacific Halibut*

Pacific halibut off British Columbia are virtually all recruited from waters off Alaska. Thus, it is the conditions in the Gulf of Alaska and perhaps the Bering Sea that most affect the abundance of Pacific halibut off British Columbia. Furthermore,

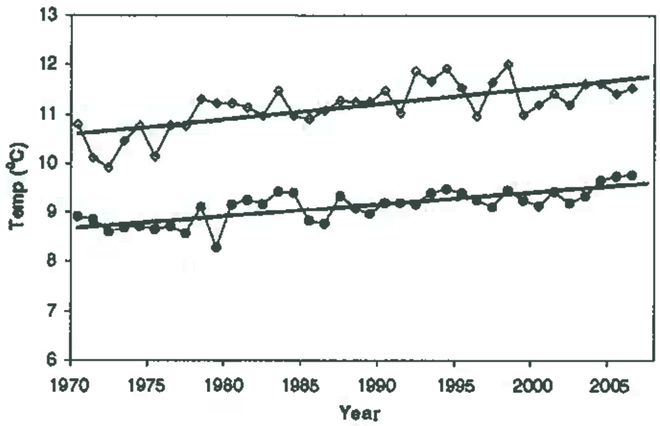

Fig. 29.5 Annual bottom (solid dot) and surface (open diamond) temperatures from 1970 to 2007 at the Nanoose Station in the Strait of Georgia

changing ocean conditions may reduce the southward migration of Pacific halibut into the waters off Vancouver Island. If there is a strengthening of the Aleutian Low as identified by Mote et al. (1999), then Pacific halibut production may be either similar to that of the past 30 years or even increase. By contrast, if there is a weakening of the Aleutian Low (Overland and Wang 2007), Pacific halibut production would be expected to decline. Pacific halibut are managed conservatively through the International Pacific Halibut Commission and it is unlikely that overfishing in the directed fishery would occur. However, the mortality of juvenile Pacific halibut as bycatch off Alaska remains high (Salveson et al. 1992). The inability to reduce this bycatch along with climate-induced changes in behavior may require a rethinking of Pacific halibut management strategies in Canada.

29.4.4 *Sablefish*

Sablefish (*Anoplopoma fimbria*) currently are the second most valuable of the west coast groundfish fisheries ($30.5 million in 2006), behind Pacific halibut ($53.9 million in 2006), with Pacific hake ranking third ($26.9 million in 2006; BC Seafood Industry Year in Review 2006, available at www.env.gov.bc.ca/omfd/reports/YIR-2006.pdf). Sablefish are a long-lived (a maximum of 113 years, McFarlane and Beamish 1983, 1995), deepwater species (Beamish et al. 2006) and thus have survived periods of unfavorable ocean conditions over evolutionary time. If care is taken in their management and older age classes are protected (Beamish et al. 2006), then it is possible that sablefish will continue to sustain a fishery as they have over the past 30 years. However, relatively little is known about the linkages between climate and recruitment. It would be wise to acquire this information as quickly as possible in case there is a "sablefish surprise" around the corner.

29.4.5 *Pacific Hake*

Pacific hake currently support the largest fishery, by weight, in British Columbia (about 100,000t [BC Seafood Industry Year in Review 2006, available at www.env.gov.bc.ca/omfd/reports/YIR-2006.pdf]). Most Pacific hake are caught off the west coast of Vancouver Island. There is a relatively large and separate population of smaller Pacific hake in the Strait of Georgia that receives very little fishing pressure. Over the past 50 years the Pacific hake population in the Strait of Georgia has increased and is now the dominant biomass there. It is likely that they will continue as the dominant species over the next 30 years. This is important because they are also the major food source for harbor seals (*Phoca vitulina*; P. Olesiuk, personal communication 2007 Nanaimo, BC) that can be significant predators on other species including Pacific salmon. An emphasis on ecosystem-based management in the Strait of Georgia will require a much improved understanding of the relationship among the species that have direct trophic relationships with Pacific hake.

The impacts of climate change on the offshore population of Pacific hake will affect the production and the number that migrate into waters off British Columbia. It is possible that a warmer climate will result in larger spawning populations off the coast of California and more migration into the Canadian zone. If this occurs, there will be greater predation by Pacific hake on species such as Pacific herring and salmon as well as larger fisheries for Pacific hake.

29.4.6 *Pacific Ocean Perch and Other Rockfish*

It is remarkable how little we know about climate impacts on Pacific ocean perch and the large group of other rockfish species in the groundfish fishery. These species are generally long-lived and thus are able to survive long periods of ocean conditions unfavorable for reproduction. However, they are relatively easy to overexploit because of their schooling behavior. It is probable that a management strategy may be to close large areas to fishing. Such a strategy, would at a minimum, require more monitoring of the rockfish fishery. Preferably, more research into how climate affects recruitment would be needed. When wild fish command premium prices in the future, rockfish could become one of the most valuable groups of species in British Columbia. Thus, it is in the long-term interest to manage these species conservatively now. Their future will be determined mainly by the amount of fishing and our ability to manage the harvest at least over the next 30 years.

29.4.7 *Pacific Cod*

Pacific cod (*Gadus macrocephalus*) used to be one of the key groundfish species. We know that warmer bottom temperatures are detrimental to the early development of juvenile Pacific cod (Alderdice and Forrester 1971). It is possible that the current bottom temperatures in the Strait of Georgia (Fig. 29.5) are already too warm for their continued survival and it is likely that Pacific cod will all but disappear in the Strait of Georgia and off the west coast of Vancouver Island over the next 30 years.

The Species at Risk Act (SARA) may be imposed as a way to provide protection for these disappearing Pacific cod stocks. If this were the case, other fisheries would be affected. Clearly, there is a need for research to determine if the current and expected declines are a natural response to climate change, in which case it is unlikely that stocks could be rebuilt unless climate change impacts are reversible in the long term, which is also unlikely.

29.4.8 *Spiny Dogfish*

Spiny dogfish currently are worth more per kilogram than pink salmon. Who would have thought that a hated pest would become a sought-after species? There is no indication that spiny dogfish populations are overexploited; but they need to be carefully managed, because SARA can be used to protect stocks that are in low abundance. If this happened, other fisheries for other species could also be impacted. One difficulty is that very little is known about how to manage spiny dogfish. We do not understand the mechanisms that affect recruitment, control abundance, or even where and when reproduction occurs. If the demand for spiny dogfish continues, we have a lot of catching up to do to understand its population ecology.

29.4.9 *Shellfish*

Geoduck clams (*Panope abrupta*), Dungeness crabs (*Cancer magister*), and spot prawns (*Pandalus playtceros*) are the major species in Pacific shellfish fisheries. There is very little information about the factors affecting their production. Larval crabs are a key prey species of many species including Pacific salmon, particularly in the Strait of Georgia. A focus on ecosystem-based management will require a much improved understanding of the dynamics of shellfish, in general, and crab and shrimp species, in particular. The landed value of shellfish (wild and cultured) in British Columbia was $127 million in 2006 which represented 16% of the total landed value of all seafood. Prawns, geoducks, and crabs were the most valuable species, with landed values in 2006 of $38.7, $33.0, and $23.1 million, respectively. Harvests have remained relatively stable for prawns and geoducks from 2004 to

2006 (BC Seafood Industry Year in Review 2006, available at www.env.gov.bc.ca/omfd/reports/YIR-2006.pdf). Annual catches of Dungeness crabs have been relatively stable in the Strait of Georgia, but variable in other areas. The reasons for the stability and variability are not known. Dungeness crabs, spot prawns, and geoducks are at about their center of distribution in British Columbia; thus, any initial increases in temperature would not be expected to have a major impact. It is the change in currents and the availability of bottom habitat that could have the greatest impact through the larval stages. In general, there is not enough known about the factors that regulate recruitment of these species to determine how they will respond to climate changes over the next 30 years. It is possible that there may be greater variability in recruitment and continued uncertainty about the causes of such variability.

29.5 Future Issues in Fisheries Research

We selected ten issues that we think will drive fisheries science on Canada's Pacific coast over the next few decades and possibly longer. Issues in ocean and climate sciences also need to be considered and integrated into fisheries science, but these considerations are outside the scope of this chapter.

29.5.1 Issue 1: Climate Change

Climate change is clearly the key factor affecting the future of fisheries science and resource trends along Canada's Pacific coast. In British Columbia, for example, the Strait of Georgia has warmed almost 1°C over the past 40 years (Fig. 29.5). Currently, the impacts of this warming are not understood much beyond speculation.

Only over the last 20 years has the importance of climate in the dynamics of fish and fisheries been fully appreciated. In the future, climate will rule. It probably is fair to conclude that we cannot confidently identify how any one species in the Pacific coast fishery will respond to climate change. Informed speculation is useful, but impact assessments need to become more quantitative if we are to move from alarming the public and ourselves to identifying management actions. An extensive effort is needed to understand how climate will impact fish and fisheries. Initially, retrospective analyses using statistical models will help to identify possible responses of species and stocks to change, but mechanistic models are needed to predict climate change impacts. Retrospective studies are helpful in providing insights into past relationships, but it is unclear how the records from the past will represent the future.

Pacific salmon may be the first species to be impacted because of their relatively short life span. There is some understanding of climate-related impacts on salmon in freshwater but, even though Pacific salmon spend most of their life in the ocean, our understanding of the linkages between climate and productivity in the marine environments is at best rudimentary. The importance of understanding this linkage has never been more evident than when one examines the salmon returns to British Columbia in 2006 and 2007. Pacific salmon that entered the sea during 2005 suffered extremely poor survival as evidenced by: (a) very poor returns of pink salmon to British Columbia and southeast Alaska in 2006; (b) poor spawning returns of coho salmon to southern British Columbia in 2006; (c) extremely poor returns of age-4 sockeye salmon from the Fraser River north to the Skeena River in 2007; and (d) poor returns of age-4 chinook salmon to the Fraser River and southern British Columbia in 2007. However, while British Columbia had the poorest ever returns of Pacific salmon, catches of Pacific salmon in Japan, Russia, and most of Alaska are, in aggregate, at record high levels (Fig. 29.1b). Understanding the spatial and temporal impacts of climate change on the population ecology of Pacific salmon is a challenge to the scientific community. The overwhelming problem is the inadequate logistical capability to conduct coastal marine ecosystem research, let alone participate in any international, open-ocean studies.

29.5.2 Issue 2: Wild Salmon Policy

A policy for the conservation of wild Pacific salmon was adopted in 2005 (Fisheries and Oceans Canada 2005). The policy was developed as a management framework to conserve Pacific salmon in an uncertain future while continuing to provide a range of benefits to Canadians. Under the Wild Salmon Policy (WSP), wild salmon will be maintained by identifying and managing Conservation Units that reflect both their geographic and genetic diversity, and defining two benchmarks to assess the status of each Conservation Unit. The upper benchmark or reference point defines a unit that is healthy and capable of sustaining harvest; the lower benchmark defines a Conservation Unit that may be at risk and should be managed with conservation in mind. The lower benchmark is precautionary through a significant "buffer" that will differentiate the benchmark from conditions under which a Conservation Unit is at risk of extinction. The policy also begins to implement ecosystem-based management for salmon and requires the development of habitat and ecosystem (freshwater and marine) assessment frameworks in the Yukon and British Columbia. While the WSP required nearly a decade of drafts and public consultations, its completion is timely and its effective implementation is likely to dominate the management of Pacific salmon for the next decade.

We have identified climate change as the key issue in the immediate future; however, no one can predict either the rate or magnitude of change. The WSP includes the elements needed for effective conservation, but requires a commitment to full implementation, including: assessment and monitoring programs (Strategies 1–3), development of an effective regional advisory structure (Strategy 4) for communities that participate in resource decisions, and an independent review process (Strategies 5 and 6). Implementation is a logistical challenge by itself. Climate change is likely to exacerbate this challenge by increasing debate over resource uses (e.g., forestry, water allocation, fishing), access to salmon, and how risk-averse society chooses to be. The first public review is scheduled for 2010 and the outcome of that review will determine the midterm agenda for the WSP.

The hatchery/wild Pacific salmon interaction debate (Meffe 1992; Hilborn and Eggers 2000; Levin et al. 2001; Myers et al. 2004; Zaporozhets and Zaporozhets 2004) is one issue that will continue, particularly if social science decisions are made that support recreational fisheries using artificially produced Pacific salmon. The definition of "wild" in the WSP was problematic, but an aggregation of Pacific salmon that spawns naturally and has offspring that spawn naturally is considered wild. In other words, enhancement could be used to increase the spawning abundance of Pacific salmon, but the effectiveness of enhancement to the WSP will be assessed based on its net benefit (including interactions) to natural production. Implementation of the policy requires a significant commitment to better monitoring and support for science.

29.5.3 Issue 3: Pacific Salmon Hatcheries

Our Canadian Pacific salmon hatcheries will continue to produce salmon for the next 30 years, and will require resources to repair an aging infrastructure. Most biologists now recognize that adding more juvenile Pacific salmon to the ocean will neither double the total catch nor even guarantee sustainable catches. The use of major hatcheries and spawning channels is a complicated issue with both successes and failures, but with extraordinary public support (PFRCC 2005). Even recently, with increasing evidence of concerns for chinook and coho hatchery production, the idea of using hatchery fish to sustain recreational fisheries through mark-selective fisheries is increasingly popular. A recent study of hatchery and wild coho salmon in the Strait of Georgia showed that climate is linked to marine survival through the amount of early marine growth (Beamish et al. 2008a). It was proposed that the impacts were greater on hatchery coho salmon because of their later release dates. There were other differences in the population ecology of hatchery and wild coho salmon, indicating that the two types are not identical in the ocean. As climate change negatively impacts the production of natural chinook and coho salmon in the southern part of British Columbia, we foresee that hatchery fish will be used experimentally to support recreational fisheries in fishing zones that depend on hatchery fish, particularly in the Strait of Georgia. The difficulty, however, continues to be that the impact of hatchery fish on wild fish is not even close to being understood. Future research may show that there is competition between wild and hatchery salmon that affects early marine growth and ultimately marine survival and that the effect of interactions varies with environmental conditions. When marine conditions are good for the production of salmon, there may be no concern for such interactions. However, when conditions are poor such interactions could be substantial, with lasting impacts on wild stocks.

After 30 years of the Salmonid Enhancement Program in Canada very little has been learned about hatchery/wild salmon interactions. The debate between enhanced and natural salmon has been largely fueled by beliefs *versus* knowledge, a result of a lack of research investment. This situation will need to change in the immediate future if the determinants of marine survival are to be understood within an increasingly uncertain climate, particularly within the WSP. Possibly, the social science decision to enhance the expectation of catching coho and chinook salmon in the recreational fishery will result in additional resources for research. In the absence of a strategic plan, however, efforts to support such recreational fisheries with marked hatchery fish constitutes nothing more than costly trial and error. Studies are also urgently needed to determine the causes of the early marine mortality in salmon generally. It is remarkable that most salmon that enter the ocean die, yet we know very little about what kills them.

29.5.4 *Issue 4: Certification*

Certification is a relatively new initiative in world fisheries but its short history suggests some success involving consumer purchasing power to generate change and promote environmentally responsible stewardship of the world's fisheries. Certainly, the most widely known certification process is that of the Marine Stewardship Council (MSC) (http://eng.msc.org/) established in the late 1990s. In a bid to reverse the continued decline in the world's fisheries, the MSC developed environmental standards for sustainable and well-managed fisheries and a product label (eco-labeling) to identify environmentally responsible fisheries and management practices. Consumers concerned about overfishing and its environmental and social consequences can choose seafood products, which have been independently assessed against the MSC standard and identified if the standards are met. The MSC's mission statement succinctly summarizes their concept: "To safeguard the world's seafood supply by promoting the best environmental choice" (web site above). Their web site now reports that as of September 2007 there are 857 MSC-labeled seafood products sold in 34 countries worldwide. Over 7% of the world's edible wild-capture fisheries are now engaged in the program, either as certified fisheries (22 fisheries) or in full assessment (30 other fisheries) against the MSC standard for a sustainable fishery. In British Columbia, four sockeye salmon fisheries received conditional certifications in 2007.

The potential power of consumers and marketing has been further developed by specification of seafood products from "sustainable" fisheries as identified by environmental organizations. Examples are: SeaChoice (http://seachoice.org/) and Seafood Watch (http://www.mbayaq.org/cr/seafoodwatch.asp).

While we believe that the educational value of these initiatives will continue to be important, we suggest that a better understanding of the state of the world's fishery resources combined with the response of management agencies will actually reduce the market value of certification and eco-labeling. These initiatives have been important in bringing greater exposure of overfishing and ecosystem impacts of fishing to the public, but there are clear indications that the risks of overfishing and related ecosystem impacts are being recognized and acted upon. Market values may very well adjust to availability, quality, and preference for products but we think that fisheries will be adjusted before market pressures require it. It is certainly possible, however, that the profitability of some fisheries will depend on market responses and how well those fisheries succeed in becoming more sustainable. We suggest this for three reasons. First, the state of marine resources, the risks associated with overfishing, and the need for change have been prominent in recent legislation in Canada and the United States, particularly in the US re-authorization of the Magnuson-Stevens Fishery Conservation and Management Act of 2006 (http://www.nmfs.noaa.gov/sfa/magact/), and the Oceans Act and the Species at Risk Act in Canada. It is particularly notable that the Magnuson-Stevens Act sets a deadline for ending overfishing in the United States by 2011. Second, the emergence of ecosystem-based management as a new paradigm in resource management has significantly broadened debate about the impact of overfishing and the impacts of fishing on habitats. While the literature on ecosystem-based management is expanding rapidly, papers describing the concept include the National Research Council (1999), Pikitch et al. (2004), and Sinclair et al. (2002). In general, we expect the need to consider ecosystem-based impacts will reduce fishing rates that were previously based on single-species assessments and improve sustainability. However, there is a major concern regarding the latter – the likelihood of recovery of overfished marine resources. Third, reviews of the recovery of overfished marine fish populations indicate that recovery may be protracted and highly uncertain (Hutchings and Reynolds 2004; Hutchings 2000). Consequently, the impacts of overfishing may be more prolonged than previously assumed. We suggest that this will become a significant issue providing support for more precautionary approaches toward fishing marine resources.

Assuming that resource managers and policy makers are similarly motivated to improve the state of our marine resources, there is an adequate scientific basis for acting to improve the sustainability of fisheries, long before the market pressures discussed above stimulate the industry to change. The importance of certification to Canadian west coast fisheries may very well rise and fall over the next 30 years.

29.5.5 Issue 5: Species at Risk Act

In Canada the Species at Risk Act (SARA, Government of Canada 2003) is now law. Under this legislation, any citizen can request a review of the status of a wildlife species (a species, subspecies, variety, or a geographically or genetically distinct population; paragraph 2 of the Act). If through a prescribed peer-review process, the species is recommended for listing (i.e., protection) and if the Federal government accepts the recommendation, then the responsible management agency must by law protect the species and its habitat, and establish procedures to restore its abundance. For British Columbia fishes and fisheries, given our history of development and fishing, SARA will increasingly pose limitations on future development, land and water uses, and fishing. This may be particularly true for Pacific salmon, because within the WSP over 400 Conservation Units will likely be defined. For other important species such as sablefish or Pacific halibut, there are few definitions of stocks or conservation unit subgroups. As these stock units are identified there will be major impacts on traditional fishing practices as SARA is used to provide protection.

Under a climate change scenario, however, SARA may become increasingly restrictive without any guarantee of successful protection. We expect that the number of wildlife species requiring protection will increase as climate impacts affect their survival. As it may not be possible to reverse the impacts of climate change, government officials will have to produce a recovery plan for any listed species, but with less and less assurance that the species can be secure, even with full protection of its habitat. Thus, if a species or stock declines in abundance because of climate change, the decline should not be any more reversible than climate change itself. SARA may need to be revisited to account for the impacts of climate change.

SARA is directed at single wildlife species and its associated habitat. Such a focus is inconsistent with the development of ecosystem-based management strategies and directives. Whether through development effects, climate change, or both, ecosystems are dynamic and will change continually (e.g., mountain pine beetle impacts, aquatic invasive species, water budgets). As ecosystems change, we can also anticipate human populations and cultures to adjust. The singular focus of a SARA listing will undoubtedly come into conflict with climate and ecosystem changes and human responses. Even if the rationale for SARA continues to be accepted, the variability associated with climate-related impacts will most likely result in mind-numbing debates about causes and effects. If the listings continue under the legal requirement to restore species, then there will need to be many more biologists working to understand the population ecology of a diversity of stocks and species. It appears that fisheries science is just beginning to feel the effects of SARA. In the medium term, however, we expect that SARA will be rethought and revised. An ecosystem approach that establishes marine protected areas could be integrated into SARA. For example, instead of establishing small areas for protection, larger areas such as the entire Strait of Georgia could be a marine protected area, but with fishing allowed in specific areas. A species needing protection would simply not be made available and would respond naturally to the changing ecosystem.

29.5.6 Issue 6: Aquaculture and Ocean Ranching

In September 2006, the Food and Agriculture Organization (FAO) reported that "While in 1980 just 9 per cent of the fish consumed by human beings came from aquaculture, today 43 per cent does, ..." (FAO Technical Report No. 500, 2006; available at http://www.fao.org/docrep/009/a0874e/a0874e00.htm).

Where will anybody who eats seafood caught on Canada's Pacific coast get their seafood in the future? We propose that the public acceptance of cultured seafood will facilitate increased investment and provide employment in aquaculture in coastal areas where jobs are needed. The FAO reports that there will be a world increase in seafood consumption of about 25% over the next 30 years (FAO 2007). Fish farming is the world's fastest growing food production sector, exceeding the annual rate of livestock production by a factor of 3 (FAO 2007). Approximately half of all fish consumed by humans is now raised on farms. Within 25 years, the world population is expected to consume about 83 million tons of farmed fish, up from 46 million tons in 2004 (FAO 2007). A limitation to the growth of aquaculture and the aquafeeds industry is the virtually fixed supply of fish oil and fish meal. We speculate that technology will be developed to genetically engineer plants to produce the proteins needed in the various diet formulations. This technological advance will reduce the cost of aquaculture resulting in a supply of inexpensive seafood that is certified as safe to eat and safe for the environment. With an affordable and plentiful supply of safe seafood, management agencies will be able to reduce fishing rates and thus rebuild overfished stocks. In British Columbia, for example, wild seafood could become a premium product, changing the nature of fisheries for many species, but for rockfish in particular. It is also possible that the added value for wild species may result in more fisheries research being supported by the private sector. Salmon farms will continue to be the major supplier of salmon to the world as it becomes a more affordable and safe food source. Salmon farming will also achieve ecological sustainability through reduced ecological impacts. However, like all farming, there will be new challenges related to climate impacts, diseases, and perhaps invasive species. All challenges will require research support and if the Canadian Department of Fisheries and Oceans is not seen to be providing the appropriate research, then aquaculture will be moved to another agency. Certification of products from salmon farming will become more important than eco-labeling of wild seafood products.

We think that private ocean ranching will be authorized. It is probable that the initial pilot projects will be approved in areas with limited natural Pacific salmon production, perhaps associated with First Nations' groups. Russia, Japan, and the United States already have major hatchery programs that release billions of young salmon into the common feeding areas for Pacific salmon on the high seas. These countries recognize the opportunities of ocean ranching. Canada will eventually follow their lead. There are opportunities for Canada to culture species and stocks such as "summer" chum salmon. The science in support of these pilot projects may be conducted outside of government, but government experts will be needed to evaluate proposals and review reports. There is an obvious linkage between hatcheries and the WSP that needs to be agreed upon and managed.

29.5.7 *Issue 7: Ecosystem-Based Management Will Lead to Regional Management*

Assessments of the abundance of commercially important species will continue to be made at the single-species level, but there will be a switch from single-species management to ecosystem-based management. Ecosystem-based management will need to include an evaluation of the role of a species within its ecosystem. This is a perspective that will require communication among management agencies, fishing interests, and those who want to see natural resources protected. It is likely that some areas will be closed to all fishing, except perhaps recreational fishing, for a few species. As previously indicated, we think that within the medium term, the Strait of Georgia probably will become a marine protected area, perhaps with fishing limited to First Nations and some recreational users. The strategy would be to close all fishing and open specific fisheries for species that are known to have surplus production within the ecosystem. A major new research activity will be the development of reliable models linking climate to the production of plankton through to fish production. The extension of fishery models to many non-fishery-related interests (e.g., industry, community development) will significantly broaden the range of groups involved in resource assessments, fishing allocations, and decision making. Stock assessment even at single-species levels will become more open and transparent via the use of web sites, standardized assessment models, and common data systems. It is likely that there will be virtual stock assessment agencies that use this standard software to produce internationally accepted stock assessments.

It would be the height of presumption to imply that humans can manage an entire ecosystem, but we can certainly alter the components of it. Ecosystem-based management is considered a new management paradigm and it explicitly involves human activities, communities, and values (Christensen et al. 1996). With continued human population growth and a changing climate we can anticipate increased conflict among resource users and between these users and the natural systems. However, if ecosystem-based management successfully involves more people in resource assessments and decisions, then more people may understand the complexities of the interaction of climate and recruitment, and fewer may immediately blame government officials when stocks decline. Improved public awareness will help promote what Robert Feynman (Feynman 1998) called, "honesty in science." According to Feynman, honesty in science is telling intelligent people what they need to know to make intelligent decisions, rather than giving them information that encourages them to support a particular message. An informed public will also recognize the inefficiencies of government agencies that maintain separate and even competing departments with overlapping responsibilities. A movement towards more regional management structures and processes (e.g., Strategy 4 of the Wild Salmon Policy; Fisheries and Oceans Canada 2005) will need to ensure that there are broader overall policies to resolve the trade-offs between resources and between users. The improved awareness of what we actually know and do not know probably would have the consequence of reducing the amount of fishing to account for uncertainty. However, as previously mentioned, we anticipate a substantial added value to the price of wild fish that are properly handled and processed, with a net result of less spent on fuel, more sustainable exploitation rates, and an increase in earnings.

29.5.8 Issue 8: Improved International Cooperative Research to Make Use of the Best Science

All species in the commercial fisheries off Canada's Pacific coast occur in the territorial waters of other Pacific Rim countries. Pacific salmon also share a common pasture in the waters beyond 200 miles. The science conducted by each country is shared among all scientists through the peer-reviewed literature, conferences, and workshops. We think that it is time to coordinate this science to ensure that information needed to manage exploited species in a changing climate becomes available to all countries, faster and cheaper. Existing organizations such as the North Pacific Anadromous Fish Commission (NPAFC 2001) and the North Pacific Science Organization (PICES) offer opportunities to share information and, in some cases, to plan research (also see Armstrong et al. [1998] for Atlantic salmon). In the future, these two organizations as well as others such as the International Pacific Halibut Commission need to integrate their activities to help understand how key species are responding to a changing climate.

In the future, we suggest that more Pacific salmon research be directed to the common feeding areas of Pacific salmon in cooperation with scientists from Russia, Japan, and the United States. Tremendous advances in genetic stock identification, new archival and acoustic tags, and effective capture methods provide the technologies needed to understand how climate affects the survival, distribution, and productivity of Pacific salmon stocks in the ocean, and issues of competition among salmon from the member countries. NPAFC has established a team approach through BASIS (Bering-Aleutian Salmon International Survey; NPAFC 2001) that can be further developed to improve greatly the ability to forecast returns reliably. The initial steps to extend the studies into the North Pacific will begin in 2008. Ultimately, NPAFC will have to establish principles of applying the best available science (as recently outlined by Nugent and Profeta [2006] for the United States) in the resolution of debates among these salmon-producing countries.

Canada and the United States communicate through the Pacific Salmon Commission (PSC, www.psc.org) to manage some stocks of mutual interest. The Commission supports a number of research projects, although there is no overall research plan. As climate impacts become more worrisome, it will become apparent that it is in each country's interest to have a science plan and a proposal granting process that recognizes the contributions from integrated teams. Further, the information that is collected from teams needs to be used according to a new code of ethics. As well a new reward system needs to be put in place for scientists in the teams.

29.5.9 Issue 9: The "Watson Effect"

Bill Ricker noted that everything appears simple once it is discovered. He called this the "Watson effect" after Mr. Sherlock Holmes' trusted assistant. Major discoveries often follow from major technological advances such as new kinds of microscopes or the use of coded-wire tags. In recent years, there have been a number of major advances in fisheries science. Satellites became operational, computers arrived and increased their power according to Moore's Law that computing power doubles every 18–24 months (see http://en.wikipedia.org/wiki/Moore's_Law), the Internet came into being, and genetic stock identification became DNA-based. In addition to these remarkable new technologies and techniques, we speculate that there will be new discoveries in the future that will change our thinking about the processes that regulate the organization of marine ecosystems.

Climate impacts occur on different scales, but the decadal scale is the most frequently observed. Decadal-scale shifts in climate are called regime shifts, which can be defined as climate-forced persistent changes in the marine ecosystems. The most dramatic regime shift in recent years occurred in 1977 (Trenberth 1990; Mantua et al. 1997; Zhang et al. 1997; Thompson and Wallace 1998; Beamish et al. 2000, 2004; Minobe 2000; Benson and Trites 2002; Yasunaka and Hanawa 2002). In British Columbia, this regime shift affected the trends in abundance of a number of fish species (Beamish and Bouillon 1993, 1995). Despite the major physical, biological, and economic impacts of this shift, there is still no understanding of the processes that caused the sudden shift in atmospheric circulation and wind intensity over the subarctic Pacific. The discovery of this mechanism will alert managers and scientists to expect changes in ecosystems years earlier than in the past. This information is important for a number of reasons but, for example, Beamish et al. (1999) suggested that periods of decreasing length of day (LOD) or a speeding up of the solid earth was associated with increased Pacific salmon production and a more intense Aleutian Low resulting in stormier winters.

One possible way to detect a regime shift is associated with energy transfer among the four shells (atmosphere, hydrosphere, solid earth, and core) of the planet. It is now possible to measure planetary processes accurately. As energy in a body rotating in a frictionless environment is conserved, and because the four shells of the planet rotate at different speeds, the energy lost from one shell must be transferred to one of the other three shells (Eubanks 1993). The index of energy transfer is the length of day (LOD). The LOD is the difference between the astronomically determined duration of the day and the standard LOD, which was established as exactly 86,400s on 1 January 1958. Changes in the LOD are expressed as the difference between the measured LOD relative to the standard LOD. It is generally believed that the energy associated with decadal-scale changes reflect core-mantle energy transfers (Eubanks 1993). Seasonal changes in the LOD (Fig. 29.6) are closely linked to the atmosphere, but the shifts in the trends of the seasonal changes may indicate when a decadal-scale shift occurred. If the next regime shift, which may be in 2008, is associated with a shift in the trend in the LOD, it may be possible to use the pattern of energy transfers to forecast regime shifts. Once the discovery is made it will then be necessary to understand if global warming affects the mechanism. One thing is clear; the discovery of the mechanism causing regime shifts will eventually be made and it will then become another example of the Watson effect.

29.5.10 Issue 10: A New Approach to Fisheries Science

We suggest that it is time to rethink how we do fisheries science. Today and in the past, fisheries science was carried out mainly in universities, government agencies, and some private companies. University science was more curiosity-based and

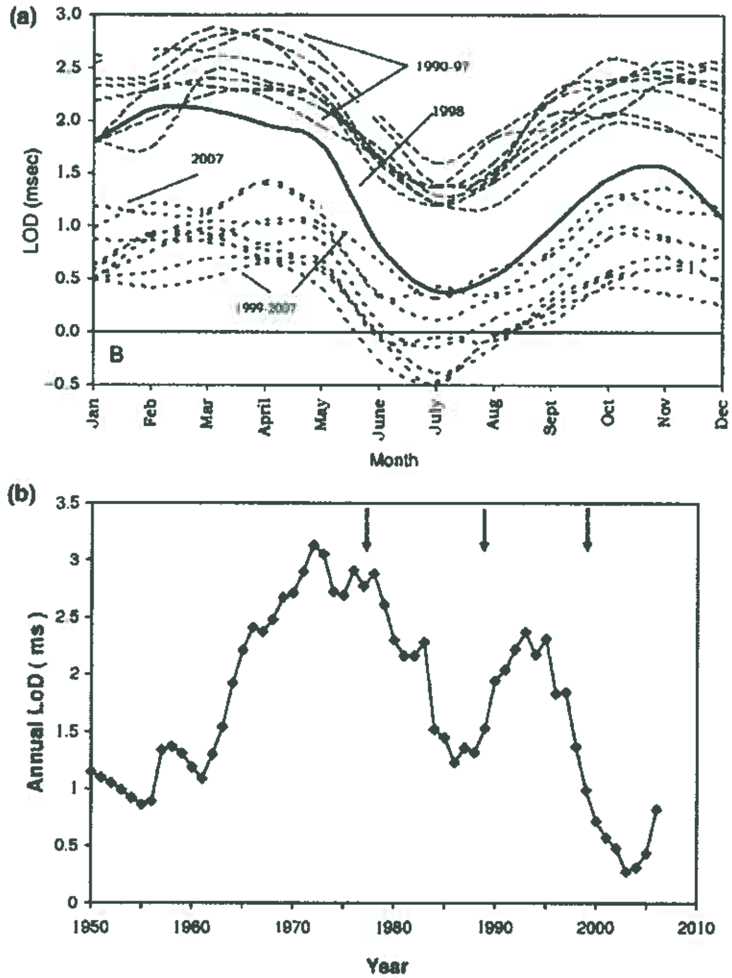

Fig. 29.6 (a) Seasonal length of day (LOD). The dashed lines show the seasonal trend in LOD with a slowing down of the solid earth in the northern hemisphere winter and a speeding up in the summer. The regime from 1990 to 1997 shifts in 1998 (thick solid line) about May and a new regime begins 1998–2007. (b) The annual trend in LOD. *Arrows* identify the 1977, 1989, and 1998 regime shifts. It is possible that regime shifts occur shortly after a change in the trend of the annual LOD

represented a number of independent areas of research. Government science was directed at solving management issues, maintaining long-term databases and providing advice on resource utilization. Both types of science contributed about equally to new knowledge. Some integration occurred, but multidisciplinary teams that operated for a number of years were hard to find.

We think that the science organizations that move faster and smarter in the future will provide the best advice. This means that more large-scale, multidisciplinary research needs to be carried out. It is unlikely that this will happen on its own. Universities and university researchers pride themselves on their independence; and federal and provincial organizations are at the mercy of government budgets. It is rare to find examples of fisheries research in British Columbia that has been integrated into a team. Consequently, it has been difficult to create teams of scientists, as the individual investigators do what is necessary to survive. Organizations do this too and are commonly thought of as "silo" organizations.

We suggest a new model. The new model does not touch existing structure; rather it adds an independent fisheries research advisory board that reports to the general public annually through the Federal and provincial ministers, perhaps not unlike the old Fisheries Research Board of Canada, but on a provincial scale. Initially a Board of Management was formed in 1898 with two major tasks: to prove its value to the Canadian government as an instrument of research in aid of Canadian fisheries, and to prove to the scientific community that it could operate a valuable laboratory for biological and fisheries research. The Fisheries Research Board of Canada replaced the Biological Board by an Act of Parliament in 1937 essentially to manage marine and freshwater research programs in Canada with a focus on fisheries-related research. The Board lasted until 1972 and the intriguing history was finally documented by Kenneth Johnstone (1977) in *The Aquatic Explorers*. Our fisheries science advisory board is not a management board. Its principal function is to identify the short-term and long-term research and monitoring requirements that will produce the advice needed by the managers of the marine ecosystems and associated fisheries. The board would review what is accomplished each year and identify what needs to be done in the future. The recommended research would apply to all fishery researchers in the province, including university researchers. The intent is to think strategically, but to recognize that the science needed to respond to climate change must be flexible and responsive. The fisheries science advisory board would be small, chaired by a prominent business leader, with three senior Fisheries & Oceans Canada scientists and three from universities (Fig. 29.7). The Head of federal government fisheries science and a Dean of Science should be on the board. Add a retired judge or someone who is experienced at understanding what is really going on. Members would rotate on 3-year terms, have no funds other than direct expenses, and be supported by government and universities. The board would ensure that the maximum use of all available fisheries research is available to work on the critical issues of the future. The board needs to have some teeth for government to listen which would come from the high profile of its members. The board would report annually to both the federal and provincial ministers responsible for fisheries and aquatic ecosystems in a manner originally envisaged for the Pacific Fisheries

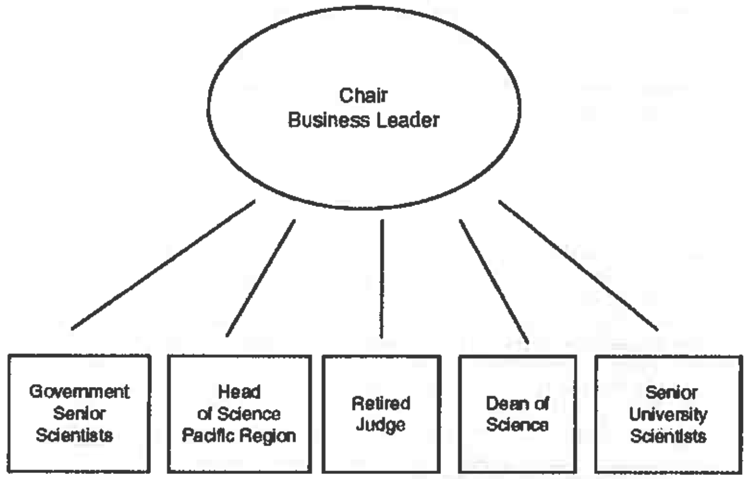

Fig. 29.7 Possible structure and composition of a fisheries science advisory board

Resource Conservation Council (2005; see http://www.fish.bc.ca/about_the_pfrcc). There are obvious difficulties with such a board, but we think that given the imminent impacts of climate change on the west coast fisheries and marine ecosystems, it is time to rethink how we do fisheries science.

29.6 Summary

We identified ten issues that we think will affect fisheries science on Canada's Pacific coast over the next 30 years. We could identify more but we think that the future of fisheries science in British Columbia will focus on the issues included here. All issues will be related to the impacts of climate on fisheries. We speculate that there will be greater variability in the populations of many species and stocks and that there will be continued uncertainty about the causes of such variability. A combination of modeling, monitoring, and a stable research program will be needed to manage resources on an ecosystem basis and to minimize the risk of overfishing. Improved climate models may eventually provide more accurate forecasts of regional climate changes, but the linkages with the population ecology of a species will remain elusive until the reasons for a particular life-history strategy are better understood. For some fisheries it may be necessary to change fishing methods altogether as the need to adapt to the impacts of climate change may challenge traditional approaches. It is unlikely that progress will be made quickly without changing how we do fisheries science. We think it is possible to have more of a business model for all fisheries science. We think that a new model for fisheries research will also provide the level funding that will be essential to ensure that good stewardship decisions are made.

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