Getting the Message Out

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Abstract: Total Pacific salmon production as indicated by the total catch of all Pacific salmon-producing countries is at historic high levels. Most scientists agree that the current high levels of production result from favourable ocean and climate conditions. There also is agreement that the technology and international cooperation exist to establish an international program that will determine the processes that regulate Pacific salmon abundance and develop reliable forecasting models. Combining information on production of salmon from fresh water or hatcheries with an understanding of how ocean conditions regulate marine survival will identify for the first time the processes regulating recruitment. This understanding will provide regional fisheries managers with new models that more accurately link climate and physical processes to recruitment, abundance and distribution. An international team of researchers can carry out the required research within the organization established for the North Pacific Anadromous Fish Commission if private and public funds are available. In order to receive these funds, researchers need to convince funding agencies that they are committed, capable and accountable. Open, honest and direct communication with clients and patrons will establish the trust needed to carry out the long-term research that will provide managers with the models needed to manage Pacific salmon in a future dominated by the impacts of climate change.

Keywords: integrated ocean studies, communication of Pacific salmon research, North Pacific Anadromous Fish Commission

WHAT IS THE MESSAGE?

The first message is that Pacific salmon are at high levels of abundance. In fact, the catches by all countries were at historic high levels in 1995 and the second largest catch occurred in 2003 (Fig. 1A). Catches of all Pacific salmon in Alaska followed a similar pattern with historic high catches in 1995, 1999 and 2005 (Fig. 1B). This is important information for the large numbers of people around the rim of the North Pacific that care about Pacific salmon.

The second message is that climate profoundly affects the production of Pacific salmon. It is self-evident that the weather would affect the survival of Pacific salmon. However, it was only recently that it became known that the kind of climate variability that affects Pacific salmon occurs as trends rather than varying randomly. The recognition of the occurrence of trends in climate is important because the capacity of the ocean to produce salmon also changes in trends as evidenced by the large-scale synchrony in catch trends around the subarctic Pacific. The challenge of this discovery for salmon stewardship is two-fold. Firstly, there will be shifts from periods of high ocean survival to low ocean survival that will occur quickly. These shifts need to be predicted or at least quickly recognized when they occur to allow management to reduce catches and adjust enhancement programs. Secondly, the accumulation of greenhouse gases is expected to change climate in ways that will affect salmon. At this time, we do not understand what these changes will be.

The third message is that technology and international partnerships exist that can identify the processes that regulate Pacific salmon production. The picture of stock structure and migration timing that we see today resulted from the life-history strategy that the various species of Pacific salmon evolved to maximize their production in the naturally changing ocean and in fresh water. We now need to put together the pieces of the puzzling process (Ricker 1972, 1973) that regulates the abundance of Pacific salmon.

WHY THE MESSAGE NEEDS TO GET OUT

There is a general impression among the public and even some salmon biologists that Pacific salmon are following the same fate as some well-publicized species in the North Atlantic and other areas. It is true that some stocks of some species no longer exist and some stocks are in critically low abundance. However, these examples must be seen in the perspective of all Pacific salmon. When this is done, it becomes clear that the importance of Pacific salmon extends beyond individual stocks. Pacific salmon are the dominant group of fishes in the daytime in the surface waters of the subarctic Pacific (Beamish et al. 2005). Extensive surveys by Japanese, Russian, United

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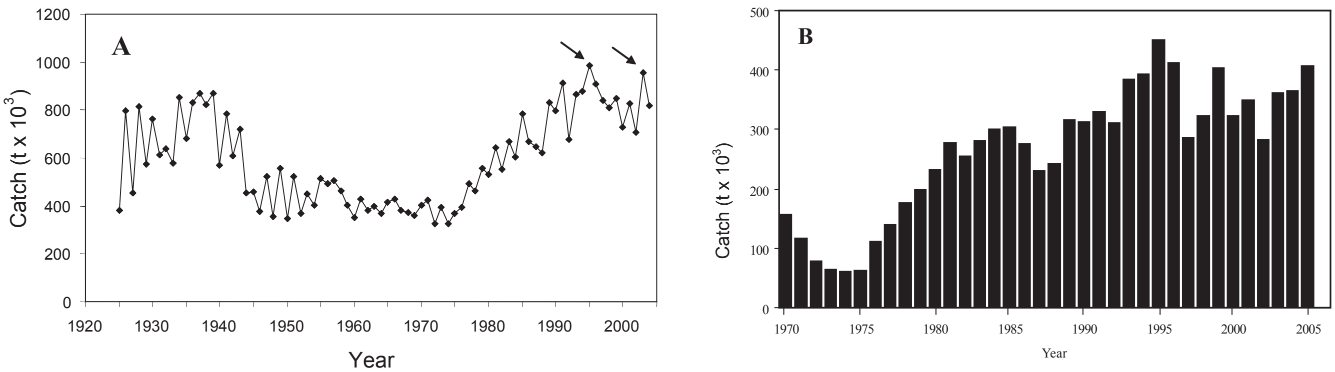

Fig. 1. (A) Total catch of Pacific salmon by all countries from 1925 to 2004. The largest catches occurred in 1995 and 2003 (arrows). From 1990 to 2004, catches of pink, chum and sockeye salmon represent an average of 95.7% of the annual total catch. Coho and chinook salmon represent an average of 4.7%. (B) Catch in Alaskan waters from 1970 to 2005. (data from the North Pacific Anadromous Fish Commission statistical yearbook, 2002, and historical data, http://www.npafc.org.)

States and Canadian scientists have documented the species composition of fishes living in the top 40 m of the waters north of the chlorophyll boundary (Fig. 2) which indicates the vastness of the potential feeding area. These studies show that, in general, pink (*Oncorhynchus gorbuscha*), chum (*O. keta*) and sockeye (*O. nerka*) salmon are the dominant group of fishes in the vast feeding area extending through the Bering Sea. The high catches of salmon over the past decade indicate that the climate and ocean processes in this feeding area have increased the capacity of the ocean to produce Pacific salmon. It is important that people know that these changes occurred so that they will understand the importance of identifying these processes that affect the capacity of this ocean area to produce salmon. Furthermore, it is of general interest to know the role that salmon play in these large marine ecosystems. The management philosophy in many countries is changing from a focus on single species to an ecosystem approach. This makes sense and is a long overdue approach to Pacific salmon stewardship. The difficulty is the cost of the required research. Thus, it makes sense to combine research efforts to make the best use of available funds. It is time for an international study of the processes that connect climate to salmon production in fresh water and in the ocean and to sort out the ecological relationships among salmon and with other species. The Bering-Aleutian Salmon International Survey (BASIS) program (North Pacific Anadromous Fish Commission 2001) and the resulting cooperation that developed among "salmon" scientists within the North Pacific Anadromous Fish Commission (NPAFC) is a foundation that will support fully integrated international studies that will resolve the long-standing mysteries of Pacific salmon production.

THE NEED FOR OPEN, HONEST AND CREDIBLE ADVICE

Feynman (1998) wrote that honesty in science was telling intelligent people what they needed to know to make intelligent decisions. Scientists traditionally debate interpretations in the peer-reviewed literature. Environmentalists take their messages to the public and politicians using the popular media. In the past, the two approaches proceeded along their own paths as funding for the work of scientists was usually adequate to support studies on the scale of enquiry at a single-species level. Scientists tended to talk within their own community, leaving the public communication of science to the environmental community. The recognition of the critical role of climate in the regulation of salmon abundances and the increasing levels of greenhouse gases essentially changes everything. Both groups now need to communicate more effectively among themselves and among the public.

The scientific community needs to carry out expensive, long-term research in the ocean that is linked to freshwater or hatchery production. Government agencies in Pacific salmon-producing countries can provide ships for internationally coordinated programs but all of the money for research is not available through the traditional government agencies.

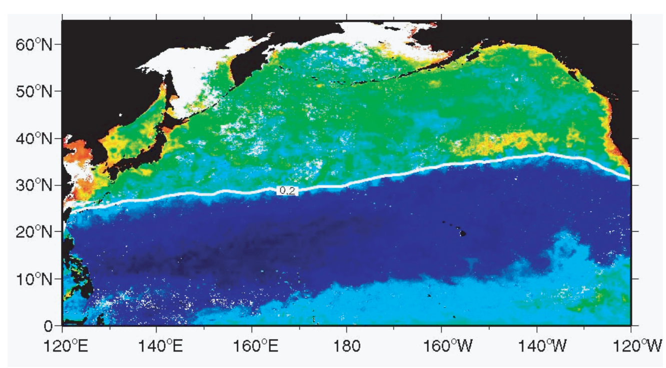

Fig. 2. Satellite imagery of surface chlorophyll *a* (from King 2005) showing the sharp boundary between the relatively high levels in the north (green) and the lower levels in the warmer sub-tropical regions (blue). The boundary between the two regions is the Transition Zone Chlorophyll Front. This boundary moves north in the summer and south in the winter. The average distributions of Pacific salmon (Beamish et al. 2005) are between 40° and 50ºN in the high chlorophyll *a* area.

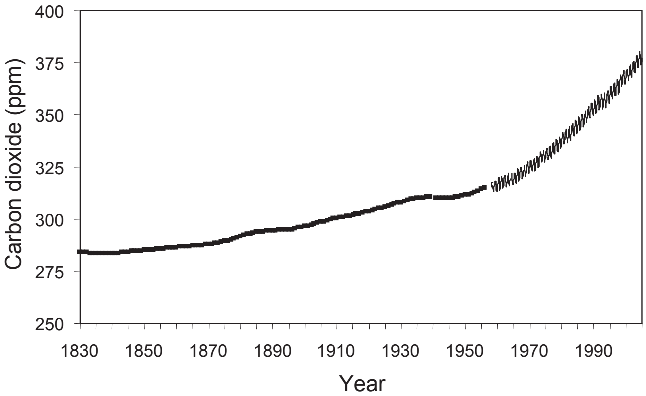

Fig. 3. Increase in atmospheric carbon dioxide levels from 1832 to 2004. Data from 1832 to 1958 are historical CO_2 data measured from Law Dome, East Antarctica ice cores and has been smoothed using 20-year running averages (Source: Etheridge et al. 1998). Monthly data from 1958 to 2004 are from Mauna Loa (Source: Keeling 2004).

Adequate funding would be available if philanthropic organizations were to enter into cooperative arrangements with government agencies. In the past these funding organizations favoured people who appeared independent of government. The reality is that for Pacific salmon stewardship, the future for both groups is all about climate and climate change. In the environmental movement there is debate about their future roles. One view is that the current approach to environmentalism must die so that a bold new direction is possible (Shellenberger and Nordhaus 2005). Proponents of the need to start over argue that the environmental movement is fragmented and generally unsuccessfully addressing the serious problem of global warming. There is no question that this is true for Pacific salmon. It is very hard to find scientific programs that are currently researching the impacts of global warming on Pacific salmon production. The problem of understanding climate change impacts on the dynamics of salmon in the ocean rearing area is not going to be solved by providing money to either groups that do not create new knowledge or individuals working on projects that are not part of integrated studies. It is time to do things differently. It is time for a trusted group of experts to speak openly, plainly and honestly to the public about what is known and what needs to be known about the factors affecting salmon abundance. The general public and funding organizations need to be directly involved with the researchers who are on the front line. The research that is needed to address the issues of global warming impacts will require the funding support of philanthropic organizations, and to get this, government researchers need to acquire the trust and support of the general public. People need to hear about Pacific salmon directly from the source. There is no dispute that CO_2 is increasing in the atmosphere (Fig. 3) and it is most likely that the increases will continue as the economies of countries such as China increase their energy demands. It has been reported (Elliot et al. 2002) that China expects to quadruple its economy in 30 years using new energy from burning coal that is equal to 50% of the current energy used in the U.S.A. Clearly, climate will be the major issue for Pacific salmon over the careers of at least several generations of biologists. Within NPAFC there is the understanding to know that change is needed. There is the technology to do the needed research. There are ships. There is an organization that is responsible, recognized and accountable. It is now time to expand the thinking and establish international research teams within the NPAFC.

WHAT SCIENCE NEEDS TO BE DONE?

My list of what needs to be done should be viewed as ingredients for discussion. The list does not include activities associated with the freshwater phase of Pacific salmon, but the anadromous life history of salmon requires an understanding of the factors affecting their dynamics in both fresh water and the ocean. It is important and preferable that any marine program is closely linked to the freshwater stages of the particular species and stocks; however, the following is a focus for marine research.

1. Regime shifts change trends in the productivity of Pacific salmon, but what causes the shift in regimes? Recently, a task team of international scientists confirmed that regimes are real (King 2005). Their investigations confirmed the observations of others that regime shifts occurred in 1989 and 1998 as well as the now well-known 1977 regime shift. After the 1998 regime shift, biological productivity improved in the southern regions of the eastern North Pacific and in the northern regions of the western North Pacific. The existence of shifts in trends in biological production and the observation of synchronous trends in salmon catch are evidence that there is a carrying capacity for Pacific salmon. A recognition of a carrying capacity for salmon means that it is necessary to be able to determine when these shifts in productivity occur. One way to determine when regime shifts occur is to discover the physical mechanism that causes regimes to shift. Beamish et al. (1999, 2007) proposed that this mechanism is associated with solar cycles and thus has a connection to the physics of planetary energy distribution. If this is true, it may be possible to identify regime shifts by studying the causes rather than the impacts.
2. What are the key biological, climatic and oceanographic factors affecting long-term changes in Pacific salmon production and distribution? In 1973, W.E. Ricker noted that a puzzling problem of Pacific salmon ecology was that runs of salmon to major rivers could not be managed so that their abundances could be increased to levels that generally were expected based on their past history. We now know that the capacity of the ocean to produce salmon improved after the 1977 regime shift. The explanation to the puzzling problem was that climate and ocean conditions affected the capacity of the ocean to produce salmon non-randomly. It is now timely to determine what

these conditions are.

3. What are the similarities in production trends among salmon populations around the subarctic Pacific? This is a problem of indexing. Is it possible to identify small groups of salmon that are indices of the production trends of larger groups? It will never be possible to study the responses of all stocks, so it is important to find key aggregates of stocks that are indicators of production trends.
4. What are the seasonal migration patterns of salmon from each salmon-producing country? There is a common pasture in the ocean, but how much of this common pasture is used by how many stocks of what particular countries? This is particularly relevant to the question of how the enhanced production of one country might affect the production of another country.
5. How is the carrying capacity for salmon affected by trends in climate? There is a relationship between large-scale patterns in atmospheric circulation and Pacific salmon production (Beamish et al. 1999). What is not known is how changes in atmospheric circulation will affect biological productivity. How will global warming change atmospheric circulation, ocean currents and upwelling? For example, how will the chlorophyll boundary (Fig. 2) change? There are global climate change models of ocean temperature changes, but the large-scale changes in atmospheric circulation over the subarctic Pacific resulting from global warming need to be determined so that changes in ocean currents can be modeled.
6. What is the relationship between the dynamics of regional stocks and the dynamics of the species throughout its range? Each species of Pacific salmon has evolved to maximize its abundance by competing with other species of salmon for food and habitat. The success of a species may relate to the ability of some regional stocks to survive better than other regional stocks during specific climate and ocean conditions. This could mean that populations in one country will contribute to production in another country. This could be particularly important if future climate changes increase the ocean carrying capacity for salmon (Beamish and Noakes 2002). Research would also attempt to solve long-standing questions relating to cyclic dominance and stock biodiversity.
7. How will the distributions and abundances of species be affected by global warming? Will species at the southern limits of their distribution be affected first and will the impacts be greater in fresh water or in the ocean? Will some species establish new runs farther north and into the Arctic? Will hatchery-reared fish survive equally as well as wild fish?
8. How do we forecast trends in abundance and changes in migration timing? Recent controversies over sockeye salmon returning to the Fraser River (Fig. 4) indicate that there is an urgent need to improve our ability to forecast. Even when abundances are exceptional (Fig. 5), it is apparent that better forecasts will result in better use of fish surplus to spawning requirements.
9. How do we communicate effectively with the general public? All science has patrons. We must accept that an

Fig. 4. Example of some of the newspaper clippings in British Columbia in 2004.

investment of public and private funds must be matched by strategic thinking and accountability in science and in the communication of science.

10. How are teams of researchers selected, recognized and rewarded? Scientists are recognized for individual achievement and not for teamwork. New rewards systems are needed.

HOW DO WE DO IT?

The North Pacific Anadromous Fish Commission established the Bering–Aleutian Salmon International Survey (BASIS) program in 2001 (North Pacific Anadromous Fish Commission 2001). The initial goal of the program was to determine how ocean conditions affected the survival and growth of Pacific salmon. The program resulted in unprecedented cooperation among salmon-producing countries and their researchers. Visiting scientists were welcomed on research vessels. Data and samples were freely exchanged. Each year, the preliminary results of the various cruises were provided to all interested researchers. Cooperation was so good that researchers at sea would accept email requests to collect data. This timely and open communication effectively provided millions of dollars of research information to all participating countries. The opportunity to work together resulted in a cooperative spirit that is characteristic of any successful team. The NPAFC currently has a science committee and an enforcement committee. I propose that a third committee is needed to manage the expanded ocean and climate impacts program. The expanded program would follow the model of BASIS but would include all areas of the ocean and would encourage research that links information from fresh water and hatcheries with ocean research. This third committee would be managed by an International Board consisting of representatives from each country (Fig. 6). Eventually, Board members would have to represent the interests of funding agencies and the general community of people who are passionate about Pacific salmon. There would be a science panel reporting to the management board that would be responsible for the coordination and reporting of research. The actual research would be carried out by teams (Fig. 6).

Fig. 5. Pink salmon carcasses on a beach in Alaska. Photo courtesy of Jim Lavrakas, Anchorage Daily News, Anchorage, AK 99508.

The Management Board would represent national governments and manage communications. The Board would be responsible for funding and would maintain the central research focus. The Board would request that a science plan be developed by the Science Panel. The Science Panel would consist of about 10-12 scientists that would represent a variety of disciplines as well as the participating countries. The Science Panel would include scientists not affiliated with the NPAFC. The Panel would elect a chair and would have administrative support. The Panel would establish a strategic research plan that would be approved by the Board. The Panel would establish research teams and associated support programs such as the use of ships. The Panel would maintain databases, review and write proposals and evaluate the results of privately funded research. Panel members would also be the communicators of research results by working within a communication strategy established by the Board. Each science team would conduct the directed research. Teams would usually contain an integrated and diverse group of experts that would reflect the need to link biology, oceanography, climatology, mathematics and common sense. Teams would use models wisely. Teams would meet as needed to continually assess what is known and what needs to be known. Teams would publish their results. The end point of fisheries science should be the ability to forecast salmon production at a level that protects stocks and sustains fisheries. The Management Board would ensure that forecasting is emphasized. If foundations provide funding, it will be expected that the resulting data are eventually made available to others. Thus a consequence of an international research program would require open and easy access to data.

CONCLUSION

For decades we have studied small pieces of the puzzling life-history strategy of Pacific salmon. We now have the tech-

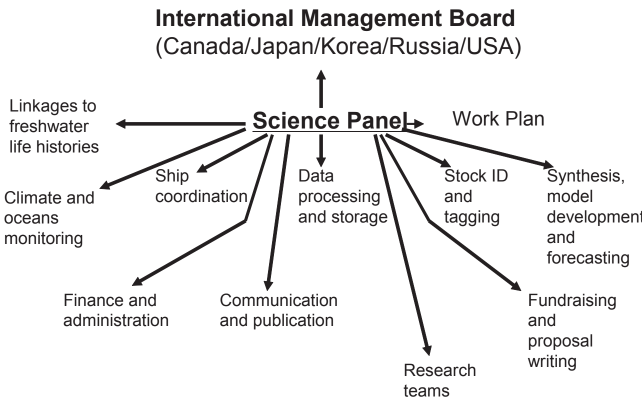

Fig. 6. Proposed organizations of a Committee within the NPAFC that would plan, coordinate and evaluate an international research program.

nology and cooperation needed to understand how recruitment of Pacific salmon is regulated. It is time to combine all of the resources available to finally put the pieces of the puzzle together. In order to secure the funding needed to support the international teams, it is necessary that the general public and funding agencies have a clear understanding of what is known and what needs to be known. Direct, open, honest and trustworthy relationships need to be established between front-line researchers, the general public and funding agencies. The NPAFC is perfectly positioned to coordinate a new international program, but environmental groups and funding agencies must be part of the coordinated effort. NPAFC will have to find ways to garner their support, perhaps through inclusion in the Management Board. Global climate change is the most serious threat to the future management of Pacific salmon stocks. The information needed to manage salmon through this period of climate change can now be obtained. It is a matter of money, leadership and teamwork.

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