An Overview of *Action Before Extinction*

Brian Harvey [1]

Setting the Stage

The idea for an international workshop on fish genetic conservation suggested itself in 1994 when I was reviewing global salmon gene banking for the Canadian Department of Fisheries and Oceans. Preparing the report (Harvey 1994) involved a lot of correspondence with contacts I already had, like the Norwegian Directorate for Nature Management, Washington State University, the National Institute of Aquaculture in Mie, Japan, and others. But it also involved meeting new people and learning about new programs, like the gene banks in Finland, Iceland, and Sweden, and the huge investment in genetic conservation that had gone on in the former Soviet Union until about 1992. Everyone I talked to or corresponded with agreed that we should all meet.

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But these were only the salmon people. I had begun my research career in the early 1980s on tropical species, and by 1994 World Fisheries Trust had become involved in several fish genetic conservation projects in developing countries where we were dealing with the technical and policy ends of gene banking a variety of migratory fishes in several South American countries. Everyone we worked with had the same problems and concerns as the salmon people farther North: selection of stocks, national and local policies (or, more commonly, the lack of them), technology, access and ownership, standards, data management, when to begin a gene banking program, even the public and professional perception of gene banking.

Clearly there was some global "common ground" here. In a very general way, Article 9 of the Convention on Biological Diversity had already acknowl-

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"By 1997, even the protection of habitat was no guarantee of fisheries recoveries"

edged an important role for *ex situ* conservation of genetic resources, even if it was plant genetic resources that were probably uppermost in the minds of those drafting it. By 1994 there had already been several international meetings on fish genetic conservation, including FAO's Expert Consultations in Rome in 1980 (FAO 1981) and 1992 (FAO 1992), and an ICLARM-FAO workshop in Rome in 1995 (Pullin and Casal 1996). The Rome meetings laid the conceptual foundation for global fish genetic conservation, and it was significant that the last two included representatives from the plant genetic resource community in recognition of the vast policy experience they could bring to bear on the problem. But there had to date been little opportunity for the people and institutions who were actually doing fish gene banking around the world to get together and compare notes, and none at all for them to do so in the company of policy makers and funders. This was the need that *Action Before Extinction* was intended to fill.

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Fisheries crises as a backdrop

By the time organization of *Action Before Extinction* began in earnest, several other things had become clear. First, the outlook for global fisheries was even grimmer than in 1992, and by 1997 freshwater biodiversity had become a much-debated topic, serving as the theme for the Third Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA). Just as clear was the realization that, in many countries, a drastic loss in aquatic genetic diversity by no means meant the automatic establishment of a gene banking program on anything like the scale in agriculture; despite the fact that delegates to SBSTTA in 1997 actually recommended establishment of fish gene banks, there was (and remains) debate about the proper contribution of *ex situ* genetic conservation, and in more than a few instances there was evidence of outright concern that *ex situ* conservation was an abdication of a higher responsibility, namely the protection of habitat. But then, by 1997, even the protection of habitat was no guarantee of fisheries recoveries: mounting evidence from around the world was beginning to force managers to accept that the effects of climate change on fish behaviour had now to be considered too. In Canada, huge declines in ocean survival of some salmonids were beginning to be considered as important as habitat loss and overfishing in causing the disappearance of stocks.

In short, by 1997 we certainly knew that aquatic biodiversity was eroding, but we were becoming acutely aware that there would be no simple explanations for why this was happening, and we were feeling less and less confident that we knew how to stop it.

Action Before Extinction was conceived in the untidy environment of global fisheries in the 90s, with the aim of putting practitioners and policy makers together for three days to review past achievements, discuss future imperatives, and perhaps even agree on some present actions. As organizers, World Fisheries Trust tried to keep the meeting from being all-policy, a role much better played three months later at the ICLARM-FAO Bellagio conference (Pullin et al. in preparation), or all-technique (that was taken care of by the special session on cryopreservation at the World Aquaculture Society Annual Meeting, held on the same dates as *Action Before Extinction*). In WFT's view, fish genetic conservation encompassed far more than *ex situ* preservation, was as important for conservation as for aquaculture, and certainly wasn't just a matter of collecting some samples of fish sperm and freezing them.

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Participants and venue

The best way to keep the agenda balanced was of course to invite the right mix of people. We decided to try and cater to the following broad categories:

- *Established fish genetic conservation programs* (Ananiev, Chebanov, Harvey, Isaksson, Kopeika, Piironen, Ponniah, Thorgaard, Walso);
- *Genetic conservation programs in early or planning stages* (Diaz, Foresti, Godinho, Wada, Zaniboni);
- *Agencies and funders* (Bartley, Braga, Davy, Fischer, Fortier, Pullin, Raymond, Windsor).

Naturally, assignment to any one of these categories is restrictive and imprecise for several participants, and impossible for Chris Wood and Blair Holtby, whose paper on defining conservation units had generic, overall relevance. And of course the list was incomplete; although the scope of fish genetic conservation is still fairly limited, keeping the number of participants below 25 meant ignoring many other potentially excellent contributors. China, for example, is not represented, nor is Africa.

Holding the meeting in Vancouver meant gathering in a place where interest in salmon issues is intense and fisheries debate is a daily (often rancorous) media event. Canada, although respected internationally for the quality of its fisheries research, has seen its share of fisheries catastrophes in the past decade. The costly demise of the Northern cod still looks irrevocable, and, despite the closure of the commercial fishery for Atlantic salmon, escapements for many stocks continue to worsen—another example of a fishery that has not responded to a ban on fishing. To maximize the opportunity for exchange of ideas, we also invited interested local biologists, man-

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agers, First Nations and NGOs to attend; these people, who are listed in Appendix 1, did not present papers but took part in all discussions.

In February 1998, when the meeting was held, the continued decline in ocean survival of BC coho salmon was much in the news. A month after the workshop the Government of British Columbia announced a living gene bank for steelhead salmon and, as this chapter is written in May, fishing communities are in turmoil over an outright ban on coho harvest that will profoundly affect fishing for other salmonid species as well. *Action Before Extinction* could hardly fail to be relevant in this climate, a fact to which the wide variety of sponsors willing to underwrite the meeting also attests. To further underscore the local relevance of what was, after all, an international meeting, the keynote address that opened *Action Before Extinction* was delivered by Hon. John Fraser, who is not only Canada's Ambassador for the Environment but has also contributed enormously over the years, both officially and privately, to the understanding and resolution of the many problems that beset Canadian fisheries.

The participants in *Action Before Extinction* spoke in their personal capacities. Their views do not necessarily represent or constitute the official position of their organization. The papers presented in these Proceedings are excellent and discussion was lively. My overview introduces each paper and then summarizes the discussion that followed each presentation, as well as general discussion that occupied the final afternoon, according to a half dozen or so recurring themes.

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Summary of Papers

The meeting was organized so that authors representing agencies and funders first presented an overview of fish genetic conservation; they were then followed by presentations that described genetic conservation programs of greater or lesser magnitude in a number of countries. A general discussion, based on themes that became evident during the presentations and the brief discussion that followed each, occupied most of the final day of the meeting. My overview follows roughly the same sequence.

Opening addresses

The meeting opened with addresses from **Hon John Fraser,** Canada's Ambassador for the Environment, and **Jamie Alley**, Director of Fisheries, B.C. Ministry of Fisheries. Mr. Fraser spoke of what he termed the "disconnect" between the facts that science can provide to society and the story that is often presented to the public, and he provided many examples from the areas of climate change and fisheries. He also provided a valuable synopsis of comments on the status of Pacific salmon stocks, particularly coho, provided by the federal Department of Fisheries and Oceans Science Branch.

Mr. Alley provided an overview of management of B.C. fisheries from the perspective of the Province of British Columbia and listed a number of new provincial initiatives for inventorying fishery resources and protecting habitat to promote *in situ* conservation of biodiversity.

Agencies and funders

Presentations by **Roger Pullin, Devin Bartley** and **Ruth Raymond** set the stage by highlighting the interdependencies in philosophy, methods, and in some cases policy, between the international plant, animal and fish genetic resource communities. The International Centre for Living Aquatic Resource Management (ICLARM—Pullin) and the International Plant Genetic Resources Institute (IPGRI—Raymond) are both members of the Consultative Group on International Agricultural Resources (CGIAR); as such, both work closely with the Food and Agriculture Organization of the United Nations (FAO—Bartley) to promote, regulate and develop policies for collection, management and sharing of the world's genetic resources. Any eventual global coherence to fish genetic conservation will depend on joint planning, coordination and sharing of expertise among these key agencies, and indeed *Action Before Extinction* carried on a tradition, begun with the FAO Expert Consultation on Fish Genetic Resources in Grottaferrata in 1992, of including all three institutions in international discussion of fish genetic conservation.

Roger Pullin and co-authors, in attempting to place aquatic genetic conservation in a global context, suggest a very broad definition of gene bank, namely "any collection of genetic material kept to ensure the future availability of that material for conservation, study or production purposes." Their paper compares gene banking for plants and aquatic organisms, in terms of what has been done and what can be done in the future. ICLARM's own involvement with gene banking aquatic organisms is described for the Genetic Improvement of Farmed Tilapia (GIFT) project as well as establishment of several marine protected areas. The authors argue that protected areas should be used as *in situ* gene banks or "gene parks", and that they should be set up sooner rather than later.

Devin Bartley describes how fish gene banks can be used to implement articles of the FAO Code of Conduct for Responsible Fisheries and the Convention on Biological Diversity. He cites the precautionary approach to development as important in deciding on acceptable levels of risks and "trigger points" for establishing gene banks for particular stocks. As first hand experience he describes the FAO gene banking project for ship sturgeon *Acipenser nudiventris* in the Caspian Sea, where habitat cleanup efforts are unlikely to be in time to prevent catastrophic loss of biodiversity.

Ruth Raymond argues that plant, animal and fish genetic resources have enough in common to warrant common legal and policy frameworks. Her paper is particularly important in providing the rationale for fish genetic conservation to "learn from" several decades of accumulated experience with plants—although there are clearly many historical and technical differences. Those interested in developing local and national policies on the utilization and exchange of fish genetic resources will find the paper's discussion of bilateral and multilateral arrangements very useful and will find lessons with obvious applicability to fish. Pros and cons of restrictive exchange arrangements, such as are tending to emerge from many countries as a result of the Convention on Biological Diversity, are discussed. Her paper should be essential reading for fisheries policy makers.

Brian Davy (International Development Research Centre, IDRC) presented a funder's view of aquatic biodiversity and described specific programs and projects that promote conservation of fish genetic diversity. Within IDRC's overall mission of "empowerment through knowledge", aquatic genetic conservation is contained in the Sustainable Use of Biodiversity program along with agricultural biodiversity, and the emphasis is on ensuring food security and equitable sharing of the benefits of genetic resources. IDRC's programs have a strong community flavour and in this area focus on the intersection between wild genetic diversity, capture fisheries and aquaculture. IDRC funds research, promotes development of policies for sharing biological diversity, and funds meetings like the present one (IDRC was the lead sponsor of *Action Before Extinction*).

The World Bank is a lending institute with a responsibility to help borrowing countries comply with provisions of the CBD, including those that relate to freshwater biodiversity. With a total water resource portfolio of US $33 billion over the last decade there are many opportunities for the Bank to invest in conservation of freshwater biodiversity, and projects that specifically target this area are showing up in increasing numbers in the Bank's portfolio. **Isabel Braga** outlines the kinds of impact on freshwater habitat that result from most water development projects and recommends that genetic diversity should not decline as a result. To achieve this, she argues that scientists be involved in project planning; that genetic diversity considerations be incorporated into project planning right from the start, not as after-the-fact mitigation; and she provides a "Recommended Approach" to the *in situ* conservation of freshwater biodiversity in development projects. She also gives some examples of past and present World Bank initiatives in conserving freshwater biodiversity, including direct investments in conservation, workshops, publications, inclusion of freshwater biodiversity in lending activities, and support for strategic global partnerships like the Global Water Partnership and the World Water Council.

The North Atlantic Salmon Conservation Organization (NASCO) is a treaty organization that contributes to conservation and management of Atlantic salmon stocks in Canada, Denmark, the European Union, Iceland, Norway, the Russian Federation and the United States. **Malcolm Windsor** and **P. Hutchinson** describe the importance of genetic diversity in survival of Atlantic salmon and the variety of threats—especially the threat of genetic contamination from farmed salmon—to which the species is presently subjected. They stress the precautionary or conservative approach, especially in the light of continued stock declines despite cessation of commercial fishing (this has been the experience with Canada's Atlantic salmon). Examples of this approach include establishment of gene banks such as the Norwegian Atlantic Salmon Gene Bank. NASCO's own guidelines for establishing and operating salmon gene banks are included in the paper—an example of multi-party standards that aid in coordinating activities of the various members of NASCO. These standards will be of interest to those interested in establishing a gene banking program.

An indigenous perspective on conserving genetic diversity of Pacific salmon is provided by **Fred Fortier,** representing the Shuswap Nation Fisheries Commission and the B.C. Aboriginal Fisheries Commission. Salmon stocks in Shuswap traditional territory have experienced severe declines in the past decade, with many coho stocks in particular being at critically low escapements. Fortier describes the various costs of these declines, from lost fishing opportunity to the financial cost of maintaining a gene bank of selected stocks. The Shuswap Nation, with technical assistance from World Fisheries Trust, began a gene banking program in 1993; cryopreserved sperm from six stocks is currently held in trust pending an action plan for its use in rebuilding stocks. Fortier's paper provides important insights into indigenous attitudes toward stewardship and exploitation of biodiversity, and proposes policies for the conservation and management of genetic diversity. (All fishing on Thompson and Skeena coho stocks, including those in Shuswap territory, has been declared closed by the Department of Fisheries and Oceans as this is written. The aims of the Shuswap program are similar to those of the Nez Perce Tribe in Idaho, USA, who are pursuing a long-term gene banking program for chinook and sockeye salmon in tributaries of the Columbia River—Eds.).

Finally, a change of scene from salmon was provided by **Carlos Fischer** of the Brazilian Ministry of Natural and Renewable Resources (IBAMA), who described the regulation of fishing in Brazil, the growing recognition of the importance of freshwater biological diversity, and the belief that maintenance of habitat is essential and that regulation of fishing alone cannot be counted on to halt declines in numbers of fish (see also **Godinho**, this volume, for a discussion of the ineffectiveness of fishing closures in Brazil). The scope of the problem is huge, not only in terms of species (Brazil has more than 3,000 freshwater fish species) but also from the standpoint of a regulatory structure in which, up till 1989, each State set its own standards for gear size, catch, reporting and enforcement; there were 28 such regulations for the Amazon basin alone. His paper describes IBAMA's post-1990 efforts to re-orient fisheries management according to hydrographic basin and to include input from all groups that use the resource. Sport fishing is a big industry, representing, for example, 75 per cent of the catch in the Pantanal region. There are also more than 2,500 unregulated pay-fishing ponds in Brazil, compounding the threat of introduction of exotic species that already exists from aquaculture. IBAMA is currently working with local governments, fishermen and industry to develop fisheries management strategies that recognize these threats.

Established fish genetic conservation programs

The "established" fish genetic conservation programs represented at *Action Before Extinction* do not comprise a complete global list, but they include most of the better-known ones (which is not to say that significant programs were not overlooked). Programs in Russia (Ananiev, Chebanov, Kopeika) and Norway (Walso) have been established for a decade, and the gene banks in Finland (Piironen) and Iceland (Isaksson) took the lead from Norway's. Gene banking in Canada (Harvey) and the USA (Thorgaard) is more recent. The National Bureau of Fish Genetic Resources in India is the oldest national program, having been in operation since 1983.

The Norwegian Gene Bank Program for Atlantic Salmon is described by **Øyvind Walsø.** It has operated since 1986 and was established to preserve and eventually re-establish the genetic diversity of Norwegian salmon stocks threatened by acid rain, parasite infestations, water development projects and escaped farmed salmon. Initially a frozen sperm bank only, the gene bank has expanded to include three "living gene banks" or broodstock stations. The stations facilitate conservation of genetic diversity by using frozen milt and by maintaining several year classes. Mating schemes in the living gene banks incorporate the use of samples of cryopreserved milt that now number over 6,000 individuals from 155 stocks. The cost for roughly a decade's operation of the program has been about CAD$14.6 million, a substantial figure that primarily represents expenditures on the living gene banks and was justified without hesitation by the author as a demonstration of the deep significance of salmon to Norwegians.

Jorma Piironen's paper on genetic conservation of endangered fish stocks in Finland is a lucid description of how another Nordic country has come to grips with the problem of conserving aquatic biological diversity at risk from habitat alteration, overfishing, unplanned stocking and disease. Only two of eighteen original Atlantic salmon populations remain in

Finland, and sea trout have declined similarly. His paper clearly lays out the roles the State has decided to play, as well as those it has not, and is explicit about the role of State-controlled fish culture in Finland as the means to preserve fish genetic diversity. In accord with the Finnish national plan of action to preserve biodiversity there are State-run living and cryopreserved gene banks for a variety of species including Atlantic salmon, char, sea trout, brown trout, whitefish and grayling, all with the aim of establishing breeding stocks in which the genetic makeup is as close as possible to that found in the remaining wild fish. Frozen milt is incorporated in breeding schemes as a means of further broadening the genetic base. As an example, the milt banking program and the associated living gene bank for Tana (Tenojoki) River salmon is described in some detail, including practical linkages with the Norwegian Atlantic Salmon Gene Bank.

Fish genetic conservation in another Nordic country, Iceland, is described by **Árni Ísaksson.** In general, and partly due to a ban on ocean harvest of salmon since 1932, Icelandic stocks are in good condition. Acid rain has not affected Icelandic rivers as it has Norway's, and the greatest concern is that straying of farmed stocks will be detrimental to wild ones which are the basis of a large sport fishing industry. To this end a small gene bank of cryopreserved salmon sperm was established by the Reykjavik Angling Club in 1989, but its activities have declined since sea cages were removed from the areas of greatest concern.

In India as in Norway and Finland there is a national plan specifically for preservation and sustainable use of fish genetic resources. The mandate and activities of the Indian National Bureau of Fish Genetic Resources are described in detail by **A.G. Ponniah,** who, like Pullin and Raymond, makes comparisons to plant genetic resource conservation. Pros and cons of fish gene banking (including living and cryopreserved banks) are discussed, along with the ways in which such banks can be used in a practical way to conserve and sustainably use Indian fish genetic resources. Species selected for gene banking are chosen on the basis of economic importance and endangered status, and cooperation between the private sector, local communities and the State is encouraged in NBFGR programs. The bureau also has a significant research function that includes genetic analysis of wild and cultured stocks so that decisions about what to conserve are made rationally. The NBFGR milt gene bank has operated since 1989 and uses low-cost field cryopreservation methods.

Genetic conservation of the rich and in many cases threatened fish fauna of the former Soviet Union is reviewed by **Eugeny Kopeika** (Ukraine), **Valentin Ananiev** and **Michail Chebanov** (Russia); the latter concentrates specifically on sturgeon status and recovery efforts. Papers by Ananiev and Kopeika concentrate on the use of cryopreservation methods, developed in

Russia and the Ukraine, to conserve genetic diversity from a wide variety of species; they argue that cryopreservation is a cheap and practical way of preserving genetic diversity while efforts to remedy the root causes of its loss continue. This strategic approach was embodied in the Low Temperature Gene Bank of Marketable, Rare and Endangered Species, begun in 1990 and comprising cryobanks in several locations that accumulated a considerable number of accessions until the collapse of the Soviet Union and subsequent funding crises made it extremely difficult to continue, and in some cases led to the loss of stored samples of genetic material.

Chebanov's paper describes genetic conservation of sturgeon in Russia, all species of which have now been placed in Appendix II of CITES. Existing methods of repopulation focus on captive breeding which, Chebanov argues, must be informed by a thorough understanding of local population structures. Effects of dam construction on sturgeon in the Sea of Azov are described, along with programs for enhancement that include living and cryopreserved gene banks. Together, the papers from the former Soviet Union paint a vivid picture of a complicated fish fauna under threat, significant investment in ex situ conservation theory and practice, and an acute need for funding to keep even some of these conservation programs alive.

Brian Harvey relates the experiences of World Fisheries Trust in *ex situ* banking of fish genetic resources in Canada and South America. Since 1993, World Fisheries Trust has used portable field equipment to cryopreserve sperm from wild fish. Programs in Canada include collaborative field work with various First Nations in British Columbia and a two-year pilot gene banking program for the federal Department of Fisheries and Oceans. In South America, WFT has worked on adaptation of field genetic conservation methods to migratory fishes in Colombia and Venezuela, and is presently managing a three year project to train Brazilian biologists from government, academia and the private sector in genetic conservation theory and practice. WFT is also active in policy development with various agencies in Canada.

Gary Thorgaard and co-authors provide a picture of *ex situ* fish genetic conservation in the United States against a complicated management backdrop in which several agencies may have conflicting responsibilities—not unlike the situation in some parts of Brazil. As examples they discuss gene banking programs for Columbia River salmon, Colorado River fishes and sturgeon. Their point—that complexity of government structure tends to make it unclear who is ultimately responsible for preventing extinction, and that divided responsibility leads to confusion and inaction—is one that surfaced frequently in other papers. They also bring up two other common themes of the conference: that gene banking is perceived to be costly, and that some biologists see gene banking as an abdication of a more basic responsibility to protect habitat.

Genetic conservation programs in early or planning stages

Since about 1990 the effects of pollution and habitat alteration (especially dams) on large migratory fish species in South America have stimulated more and more local interest in genetic conservation, especially as captive breeding for restocking forms such an important part of recovery efforts. Two countries with an exceptionally rich migratory fish fauna, Brazil and Colombia, are represented in *Action Before Extinction*, and their technical papers (policies in Brazil have already been covered, by Carlos Fischer), give readers unfamiliar with the subject a fascinating first look at a problem of enormous magnitude.

Papers by **Hugo Godinho** and **Evoy Zaniboni** describe the fish themselves, their habits, threats to which they are presently subject and measures that are being taken to conserve their genetic resources and habitat. These two papers cover two different geographic areas: Godinho's concentrates on the São Francisco basin, already much-developed for hydroelectric power generation, and Zaniboni's on the Uruguai, where major development is planned but not yet underway. Both authors talk about reproductive patterns and the effects of dams, and particularly about the practice of restocking reservoirs and the difficulty of ensuring that such programs have access to a wide range of genetic diversity at a time when it is becoming harder and harder even to locate broodstock. Gene banking of cryopreserved sperm from a variety of migratory species is one tool that is now being introduced in both these areas.

Silvio Toledo and **Fausto Foresti** present an overview of Brazilian research in conservation genetics at the State University of São Paulo and the University of São Paulo; their paper concentrates on studies aimed at understanding the genetic makeup of populations of migratory fish using cytogenetic, allozyme and DNA techniques. Results of their studies are provided to fishery managers and aquaculturists and help set a rational course for hatchery programs and restocking, much as the work described by Wood and Holtby (this volume) is used to help determine management strategies in Canada. Note especially the genetic analysis of pacu *Piaractus mesopotamicus* populations in the Pantanal wetlands to identify *in situ* gene banks for the species—this is the broader application of gene banking mentioned by Pullin and co-authors.

Colombia shares both migratory species and problems with Brazil; the Magdalena River, for example, has shown a 78 per cent decline in landings over the past two decades. **Jaime Diaz** provides an excellent overview not only of the Colombian resource and the threats it faces, but also of Colombian legislation and policy that affect conservation. The importance of the Andean Decision of 1996, "Common Regime of Access to Genetic Resources" is rightly highlighted as crucial in the design of genetic conservation programs. The paper is especially useful in that ongoing policy development in Colombia is also described; policy will affect the strategies that are developed for fish genetic conservation and the sustainable use of those resources. Actual on-the-ground efforts at *ex situ* conservation using captive broodstocks and cryopreservation are just beginning in Colombia.

In Japan, certainly one of the world's most-developed countries, habitat loss and a very well developed aquaculture industry have clearly contributed to the loss of fish genetic diversity. However, while there is considerable technical expertise, activity in fish genetic conservation has to date primarily been in order to ensure continued seed production for aquaculture. Recently, though, as **Katsuhiko Wada** describes, a number of research programs funded by the Environmental Agency of Japan have begun to look at the genetics of endangered wild populations of several species of fish. There are several collections of cryopreserved fish sperm at universities and private aquaculture companies in Japan, but no coordinated national program.

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Defining conservation: how do we decide what to conserve?

Every paper presented at *Action Before Extinction* talks about threatened populations of fish and the pros and cons of a variety of methods for conserving their genetic resources. Several refer to *ad hoc* guidelines or criteria that provide the framework for making choices about which species or populations to select for conservation. But none offer a model or a line of reasoning that could be applied broadly, in many different situations, to ensure that there is a solid scientific basis for selecting one population over another. The paper by **Chris Wood** and **L. Blair Holtby** attempts this, taking Pacific salmon as a well researched example. Their thesis is that surveys of natural genetic variation can guide decisions about sampling design for two very different *ex situ* conservation objectives: archiving genetic diversity for the species as a whole, and preserving local adaptations for the restoration of wild populations. Strategies for archiving are discussed using genetic survey data for sockeye salmon.

Restoration of salmon runs means conserving local adaptations; Wood and Holtby argue that choosing the appropriate population unit to satisfy this objective means determining the spatial scale of local adaptations, and they propose terms for defining population (and conservation) units according to empirical estimates of gene flow based on actual genetic survey data. By way of a case study of this approach, they describe studies that have led to definition of population units of coho salmon in the Skeena River in northern British Columbia, where declines in numbers continue (all harvest on these and other B.C. coho stocks has been banned in 1998—Eds.), and relate their own conclusions to IUCN Red Book criteria. Although Wood and Holtby warn against the substitution of theoretical predictions for empirical evidence of local adaptation ("gumboot biology"), their paper has obvious and profound relevance for the rational development of any genetic conservation program.

Summary of Discussion, Common Themes and Recommendations

Individual presentations were followed by ten-to-fifteen minute discussions, and the final afternoon of the conference was devoted to discussion of common themes that had made themselves known as the presentations went along. What follows is a summary of discussion under these thematic headlines.

Definitions: What is genetic conservation? What is gene banking?

Action Before Extinction was not intended to be a gene banking meeting; whether it turned out to be depends on your definition of the term. For some, a fish gene bank is analagous to an agricultural seed bank; others are comfortable including broodstock collections as "living" gene banks; some suggest the term is very broad and includes "collections" of organisms within aquatic protected areas. The first two examples could be considered *ex situ* genetic conservation, and the latter i*n situ,* but, as Pullin pointed out, the definition of a gene bank for fish may need to be different from that for plants. **The approach most participants seemed comfortable with was to think instead of "genetic conservation", not gene banking, and use the definitions of genetic resources, *ex situ* conservation, *in situ* conservation and protected area as provided in the Convention on Biological Diversity.** The term "gene bank" means different things to different people and for some has connotations of sterile archives of biodiversity; "genetic conservation" is a less loaded, and already well defined, term. Following the CBD definitions has the added benefit of reference to a widely ratified document where the supporting role of *ex situ* conservation is unequivocal, a role that was endorsed by all participants.

Assistance from the plant genetic resource community

Broad overall similarities between plant genetic resource conservation and fish genetic resource conservation came up repeatedly during the meeting, and all participants recognized the enormous experience pool on the plant side. However, as Raymond, Bartley and Pullin pointed out, the two fields are anything but identical, and fish genetic conservation programs in the years to come will need to be selective about where they can learn and borrow from the plant people. Standardized data management is one area where fish genetic conservationists can get some immediate help; tools used by participants ranged from custom accessions management software like SpermSaver to various spreadsheet adaptations. In terms of technologies for genetic conservation there appeared to be much less crossover.

Probably the most fruitful area for learning from plant genetic conservation is in policy development, where there have been decades of international discussion and negotiation over just the same issues of access, ownership, compensation and sharing that fish genetic conservation is only now beginning to confront. **Participants recommended that a Working Group representing the fish genetic resource community establish formal, functional relationships with the plant genetic resource community. This would likely most easily be accomplished by using IPGRI as an entry point.**

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Who is responsible for conserving fish genetic resources?

Gary Thorgaard put it succinctly: divided responsibility for fish genetic resources leads to confusion and inaction; often, the resources simply do not get conserved. Many views on responsibility were presented, from clear State responsibility (for example the Nordic countries) to the confused situations with multiple agencies and regulations in Canada, the US and Brazil. Other participants referred to the Tragedy of the Commons, where a common property is allowed to disappear for lack of leadership. **In practical terms, participants recognized that to wait for consensus on collection and management of fish genetic resources within and between nations will take too long; what is now an environmental issue will rapidly become a food security issue, and action must be taken immediately.** Some kinds of national policies can, in fact, even work against conserving and using genetic resources, as recent experience has shown in countries that have created policies that severely limit the exchange of genetic resources.

Is gene banking an admission of failure?

Many participants referred to the view that gene banking is an admission that management has failed to protect the resource. Along with this sentiment go perceptions of gene banking as mitigation, as a license to despoil the environment, and as diverting funds away from habitat preservation. This view seems most commonly voiced by fisheries managers; it is not usually held by scientists or the public. Several participants referred to cases where managers resisted gene banking for these reasons, and all felt a need to respond to the fear that gene banking is an alternative to good management rather than a part of it. **Participants agreed that, in accordance with Article 9 of the Convention on Biological Diversity, *ex situ* genetic conservation supports rather than replaces *in situ* conservation, and is an example of using the precautionary approach to conservation.** Ísaksson pointed out that, in Iceland, concerns about a variety of risks stimulated formation of an Atlantic salmon gene bank that clearly embodies the precautionary approach—in this case gene banking went ahead even though the risks were still unclear. In the end, the following statement was accepted: **Gene banking is an admission of uncertainty.**

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Uses of ex situ collections of genetic resources; when to collect

Participants agreed that, however defined, gene banking is an important tool for archiving useful genetic adaptations for study and future use; for permitting the rebuilding of endangered populations using the widest possible genetic base; and for facilitating the development of breeding programs for enhancement and aquaculture, especially culture of native species. Only the first and last of these functions are analogous to plant genetic resource conservation and use; rebuilding populations is unique to fish. Also in contrast to plants, preservation of fish genetic diversity is particularly urgent in light of the very limited development of breeding programs at a time when genetic resources are threatened in many areas.

The two most commonly cited uses of genetic conservation—rebuilding threatened populations and improving breeding programs for aquaculture—tend to segregate into “conservation” and “commercial” applications, and there was discussion on whether such a segregation is a good thing. It was pointed out that, as in plants, wild genetic resources may have use down the road for aquaculture, although it’s not likely that society will fund collections on that basis. As Piironen pointed out, genetic resources are controlled by the State in Finland no matter what their eventual use; Walso argued for a separation of commercial and conservation gene banks. Funding, though, may only be obtainable when both functions are integrated, the strategy being followed in India. Pullin argued that, in situations where fish genetic resources are vanishing at unprecedented rates, for example the Philippines, the international community has a responsibility to ensure their conservation; this responsibility is also contained in the Convention on Biological Diversity.

“Participants agreed that… gene banking is an important tool for archiving useful genetic adaptations for study and future use; for permitting the rebuilding of endangered populations …and for facilitating the development of breeding programs”

Technology, cost, data management and standards

Participants treated the meeting as primarily a non-technical one, although many provide technical details of broodstock management and cryopreservation methods in their written papers. Standardization of cryopreservation methods is probably too much to hope for in the near term but there are many methods that work for a variety of species; previously untried species, for example the migratory fishes of South America, have proved amenable to experimentation. Little has been published on the results obtained with different collection and mating schemes used by living

"In short, cryopreservation can be cheap or expensive depending on how it's done."

gene banks, and several participants noted the need for such information as national programs are planned. There was little in the way of technical information on *in situ* conservation in aquatic protected areas.

About the cost of fish genetic conservation there are obviously different experiences and perceptions. Living gene banks or captive broodstock collections are acknowledged to cost much more than cryopreserved gene banks, and expenditures for some countries (Norway, India, Philippines) were provided by participants. The cost of cryopreservation, on the other hand, depends on *where* it is done (centrally or in the field), *how* it is done (with simple field equipment or using a programmable controlled-rate cooler) and even *who* does it (local trainees or consultants). Collection of wild genetic material seems to demand a field technique, as it is clearly impossible to carry sophisticated equipment into the bush in any country, and the logistics even of transporting chilled sperm collected in the field to a central cryopreservation facility, as is reported by Thorgaard and co-authors, break down if the distance is too great. **In short, cryopreservation can be cheap or expensive depending on how it's done.**

"As more and more fish genetic resources are collected…there is a need to develop codes of conduct and practice for such collections."

Participants recognized the need to standardize the data on genetic material held in fish gene banks, especially when such resources begin to be shared between countries. As noted earlier, the plant genetic conservation community can provide models, for example the SINGER database developed at IPGRI; World Fisheries Trust's SpermSaver software was developed with input from IPGRI and uses standard gene banking terminology to catalogue accessions as they move in and out of a gene bank. Perhaps the first step to standardizing data reporting is the one recommended by Pullin, **namely the cataloguing of all known *ex situ* and *in situ* collections of fish genetic resources.** Such a project would make abundantly clear the variety of needs of different organizations and profitable ideas on standardizing data management are certain to suggest themselves.

As more and more fish genetic resources are collected and held in living and cryopreserved gene banks there is a need to **develop codes of conduct and practice for such collections.** Some models exist; there is a code of conduct for collection of plant germplasm as well as published gene bank standards, and NASCO has already developed international guidelines (code of practice) for collections of cryopreserved fish sperm. Participants agreed on the need for such codes; again, compiling a list of known gene banks may be the first practical step.

Threats to fish genetic diversity

The litany of threats to fish populations is extensive and well known; most of the papers in these Proceedings start out with some sort of recitation. Nevertheless there was some general discussion about the growing sense of urgency to conserve fish biodiversity, and in particular whether the effects of climate change on fish should be considered an exceptional stressor. In the end, participants agreed that the global complexity of the threats facing fish populations made it unwise to single out any single stressor in a meeting like this one. However, there remains a lively debate over the effect of climate change in specific cases; in British Columbia, for example, there is much scientific and media attention presently being paid to the controversial thesis that ocean warming is altering migration patterns of Pacific salmon and may be the explanation for record low marine survival.

"Currently the most comprehensive and long-running genetic conservation program is the Norwegian Atlantic Salmon Gene Bank."

Case studies of fish genetic conservation

For many participants, a few good case studies that consider pros, cons and outcomes would go a long way toward helping make decisions in their own countries about what kind of genetic conservation program to adopt. Currently the most comprehensive and long-running genetic conservation program is the Norwegian Atlantic Salmon Gene Bank. In operation for ten years, it comprises both living and cryopreserved banks and is beginning to compile a "track record" of conservation. There is also a history of banking Atlantic salmon in Finland and in other Nordic countries. Atlantic salmon provides the closest thing to a case study of genetic conservation, although many participants pointed out that as a luxury fish it is hardly representative of global fisheries, and several suggested common carp or Nile tilapia. Nevertheless, there is an informative history around Atlantic salmon throughout its range: protracted fishery declines, a variety of stressors, experience with the effects of limiting harvest, and complementary *in situ* and *ex situ* conservation.

What to conserve and when to start

"Managers need trigger points for genetic conservation and they need criteria for selection."

One of the thorniest problems facing managers designing a genetic conservation program is what to conserve, and when to start. True to the title of the meeting, participants urged action before it is too late (in line with the precautionary principle), but there is no getting around the fact that the tools for making the actual decisions about which species or populations to conserve, whether *in situ* or *ex situ*, need work. **Managers need trigger points for genetic conservation and they need criteria for selection.** Neither exists for fish, but there are potential models. IUCN criteria provide a starting point, and Allendorf *et al* (1997) have developed criteria for selecting salmon conservation units based on the IUCN model. Wood and Holtby, whose paper in this volume concerns using data on genetic variation to identify conservation units, suggested that the IUCN criteria were likely most applicable to fish when dealing with closed populations and could be used to trigger *ex situ* conservation.

"Where local and indigenous communities are involved in providing access to genetic resources, they will almost certainly wish to develop policies that protect their own rights and interests, which may be different from the State's."

The need for policy

With a few exceptions (Diaz, Fortier, Harvey), presentations did not include reference to any local or national policy that enables the preservation of fish genetic resources, although all participants were asked to include such references where possible. While such policies undoubtedly exist in a general sense, there still seem to be few examples of policy explicitly written for *ex situ* conservation—however, participants were able to share many examples where there was overlapping or conflicting management of fish populations. Such policies are, however, going to be needed, especially as various nations interpret the Convention on Biological Diversity in terms of exchange of genetic resources and benefit sharing. Where local and indigenous communities are involved in providing access to genetic resources, they will almost certainly wish to develop policies that protect their own rights and interests, which may be different from the State's.

In many countries the lack of policy may simply mean that genetic conservation does not occur. All participants agreed on the need for policy, and encouraged the efforts of the international workshop *Toward Policies for Conservation and Sustainable Use of Aquatic Genetic Resources* (Pullin et al. in prep.). They also agreed that to wait until policies were in place before acting to conserve genetic resources would in many cases be to wait too long. **This might, in fact, be fairly said to be the message finally emerging from the meeting—yes, there is a need for better criteria and for policy, but there are many cases where fish genetic diversity will vanish irrevocably unless action is taken now, and the longer we wait, the more expensive (financially and biologically) it will get.**

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