Applying Science to Hatchery Management	
Lars Mobrand, Team Leader, Mobrand Biometrics, Inc. and Chair, Hatchery Scientific Review Group (HSRG)	Moderator
Trevor Evelyn, Ph.D., Department of Fisheries and Oceans Canada (retired) and Member, HSRG	"Hatchery Reform Project/ Regional Review Process"
Don Campton, Senior Scientist/Geneticist, USFWS and Member, HSRG	"Integrated and Segregated Hatchery Programs"
Lars Mobrand, Mobrand Jones and Stokes, and Chair, HSRG	"Using Science to Manage in the Face of Uncertainty"

Session Introduction

Barbara Cairns

Executive Director, Long Live the Kings

> ***"With state and tribal scientists, they developed those decision support tools and in doing so they gave to the co-managers a pretty complete package – the science, the recommendations, and the tools to help make it happen."***
>
> ***– Barbara Cairns***

Billy Frank, Jr. and Jeff Koenings have now set the frame for today. We understand anew the importance of what it is we're about here. Let's see if we can't make the case and fill in the story. We begin with the Hatchery Scientific Review Group presentation and as they are taking their seats, let me just say this about the HSRG.

This project started in 2000 when Congress created an independent science panel. Their purpose was to conduct a scientific re-examination of the hatchery programs in Puget Sound and Coastal Washington. They did much more than that. They understood that in order to make hatchery reform fully operational, there would need to be decision support tools that would enable the co-managers to make decisions about hatcheries: whether or not there should be one in a particular watershed, what sort of hatchery it should be, how it should be managed and evaluated over time. So with state and tribal scientists, they developed those decision support tools and in doing so they gave to the co-managers a pretty complete package – the science, the recommendations, and the tools to help make it happen.

The moderator for this session is Lars Mobrand who has been the Chair of the HSRG for the past five years. He's been working on these issues in one way or another for 30 years. By Billy's standards, he's kind of an amateur, but we know him to be a brilliant thinker and he's been a terrific Chairman. He's joined by Trevor Evelyn from the Department of Fisheries Oceans Canada (retired) and Don Campton, the Senior Geneticist from USFWS.

Moderator Remarks

Lars Mobrand
Team Leader, Mobrand Jones and Stokes, and Chair, Hatchery Scientific Review Group

"The conclusion we have come to is that this indeed is a critical time for salmon stocks in this region and hatcheries are a very important part of maintaining the genetic resources we have and we need to deal with that responsibly."
– Lars Mobrand

Thank you, Barbara. I'm Lars Mobrand. I have the honor of moderating the next session, which is titled **Applying Science to Hatchery Management**. This panel is going to try and shed some light on the modern paradigm, or scientific paradigm, for hatchery management. I will be joined by Trevor Evelyn and Don Campton to present most of the details of this session.

The work we're reporting on, the scientific paradigm that we've developed, has very much been a collaborative effort with the state and tribal co-managers. We've had the privilege and the opportunity to spend a lot of time over the past five and a half years thinking about the role of hatcheries, but much of the work has been done over a long period of time by many folks.

We've heard often through this five year period that "hatchery reform didn't start when you came along. We've been doing it for a long time." I think that's a true statement. The HSRG came along, and we were given the opportunity to think about these things and to synthesize information and try to articulate the information in a concise and useful way.

The basis for this paradigm is sound biological principles; nothing particularly extraordinary or new, but basically sound biological principles when it comes to genetics, ecology and management. For instance – we talked a lot about local adaptation, about the importance of allowing hatchery fish to adapt to the environment in which they are reproduced, whether that's the hatchery or the natural environment. You will hear quite a bit about that today and that's one of the issues we think that is important. That is, to manage the root stock, manage the genetics of the stocks in a way that hatcheries are basically benign or an improvement to the environment. We have to look at hatcheries not as a fish factory, but as a component of the natural environment. They have been here awhile, as we've heard. It's our strong belief that hatcheries have a very important role into the future, both for conservation and for meeting harvest goals.

As tools, they are important or right only if they are, in fact, the best way to meet a given set of goals; best in the sense of benefits and risks. If other methods are available that create better benefits and less cost, less risk, those should be chosen. They should also be part of a comprehensive, integrated strategy that involves habitat, harvest management, all the tools that we have in our tool box to manage the resource, to accomplish the vision that Billy has set before us of a resource that's healthy long into the future.

The conclusion we have come to is that this indeed is a critical time for salmon stocks in this region. Hatcheries are a very important part of maintaining the genetic resources we have and we need to deal with that responsibly.

Hatchery Reform Project/Regional Review Process

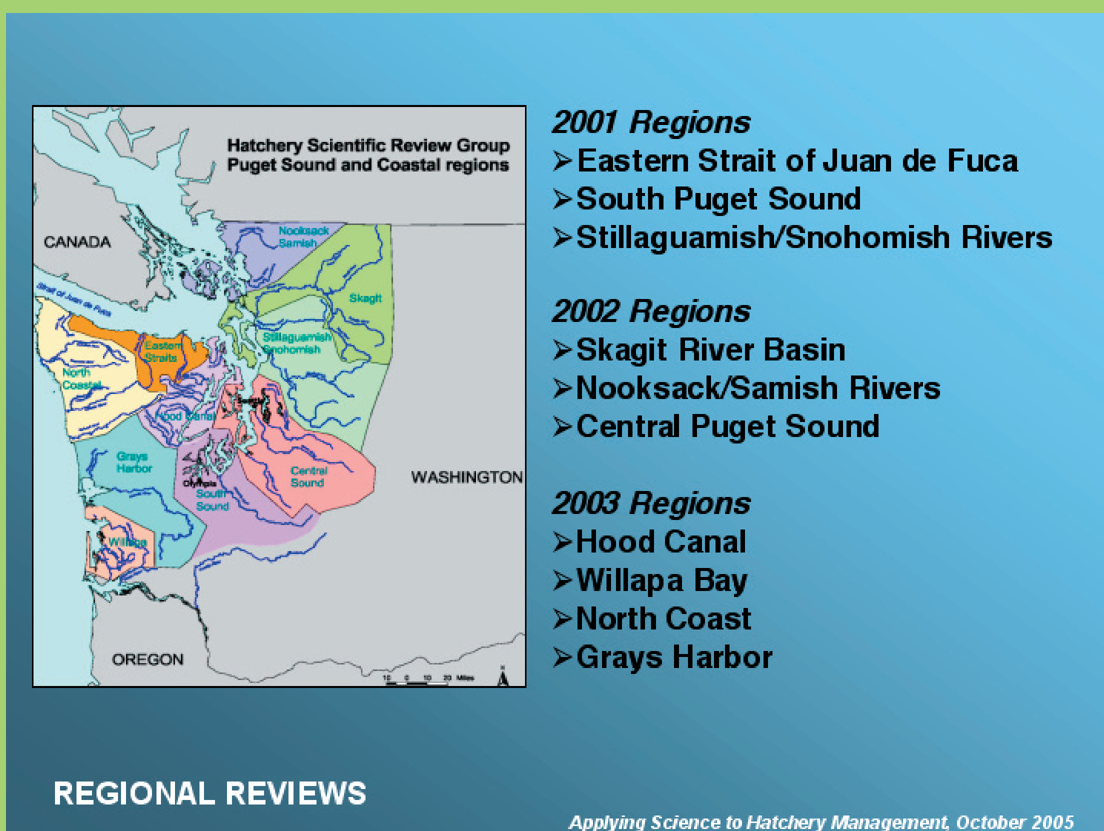
Trevor Evelyn, Ph.D., Department of Fisheries and Oceans Canada (retired) and Member, HSRG

> ***"One of the HSRG's major accomplishments was to cut through the ongoing debate over whether hatcheries are "good" or "bad," and build from the premise that hatcheries are tools to be used when they are the best strategy for meeting the goals for a salmon resource, when judged from a risk-benefit standpoint." — Trevor Evelyn***

Good morning. My task is to provide some brief background on the Hatchery Reform Project and how we went about carrying through with the review of the hatcheries. Washington State, amazingly enough when you consider places like Japan and China, has one of the largest hatchery systems in the world.

The Puget Sound and coastal Washington hatchery system is large and complex, with more than 100 facilities operated by the co-managers (the Washington Department of Fish and Wildlife and the treaty Indian tribes). Three additional hatcheries are operated by the US Fish and Wildlife Service (USFWS). This hatchery system produces more than 100 million juvenile salmon and steelhead annually.

Figure 1 — Regional Review



The hatchery system is important economically and culturally. Seventy percent of the recreational catch in Puget Sound originates from hatcheries. The production from hatcheries is important to commercial harvest and also in helping to meet tribal treaty harvest obligations. However, past hatchery practices earned hatcheries a bad reputation. Hatcheries have been identified as one of the factors potentially contributing to the decline of salmon populations, leading to Endangered Species Act listings.

The Puget Sound and Coastal Washington Hatchery Reform Project is a systematic, science-driven effort to ensure that hatcheries contribute positively to two goals: 1) conservation of naturally spawning populations, and 2) support of sustainable fisheries. The project has been fortunate to enjoy bipartisan support throughout its history, including Congressman Norm Dicks, Senator Patty Murray, former Senator Slade Gorton; current and former Washington Governors Christine Gregoire and Gary Locke; Salmon Recovery Funding Board Chair Bill Ruckelshaus; and the directors of WDFW, the Northwest Indian Fisheries Commission (NWIFC), USFWS' Northwest Regional Office and NOAA Fisheries' Northwest Regional Office. In addition to that, it is getting strong support from the Hatchery Reform Coalition (a coalition of recreation, sports fishing and conservation organizations and advocates, representing over 250,000 members, who have come together to support hatchery reform as recommended by the HSRG).

The heart of Hatchery Reform Project is the HSRG. The HSRG is funded by Congress and composed of five unaffiliated scientists selected from a pool of candidates nominated by the American Fisheries Society's Past Presidents' Council. In addition, there are four scientists designated by WDFW, NWIFC, NOAA Fisheries and USFWS. Those scientists were given the freedom by their respective organizations to focus on science and were not expected to represent the particular interests of their organizations. Their value to the group was pivotal, because they knew the inner workings of the organizations that were evaluated. The breadth and depth of the membership's knowledge helped make the HSRG an exceptionally effective group. The group had a broad range of experience and expertise from biology to genetics, ecology, fisheries management, biometrics, fish culture and also fish health.

One of the HSRG's major accomplishments was to cut through the ongoing debate over whether hatcheries are "good" or "bad," and build from the premise that hatcheries are tools to be used when they are the best strategy for meeting the goals for a salmon resource, when judged from a risk-benefit standpoint. From 2000-03, the HSRG developed a scientific framework and review tools, divided Puget Sound and the coast into ten regions, and evaluated the effectiveness of hatchery programs against their stated goals and in context of the quality of habitat and status of stocks in each region. The HSRG carefully reviewed the actual operations of the hatcheries.

The co-managers did a tremendous amount of work to provide written briefing books about their programs, which ran to hundreds of pages. HSRG members did field tours and met in person with the managers in each of the regions, developing relationships with the people who would be involved with hatchery reform and were responsible for hatchery management in the regions. It was apparent from the start that the decision to divide the state into 10 regions was worthwhile, because each region had unique challenges and the managers had to have goals that were appropriate to those challenges.

Results of the Regional Review Process

In April 2004, the HSRG produced a report for Congress containing the outcome of the reviews, as well as recommendations for improving the hatchery system. The HSRG reviewed approximately 100 hatcheries, which operated about 200 programs. The HSRG presented roughly 1,000 specific recommendations for changes to current hatchery programs—fine tuning in some cases, more substantial in others. The report also contained 18 system-wide recommendations for achieving successful hatchery programs and three important principles that are absolutely necessary for effective hatchery management.

The three principles developed by the HSRG are:

1) **Well-Defined Goals**: Goals for all stocks must be quantified, where possible, and expressed in terms of values to the community (harvest, conservation, education, research, employment, etc.);

2) **Scientific Defensibility**: Managers must explain how each hatchery program expects to achieve these goals. The purpose, operation and management of each program must be scientifically defensible, consistent with current scientific knowledge. Where there is uncertainty, hypotheses and assumptions should be articulated;

3) **Informed Decision Making**: Decisions must be informed and modified by continuous evaluation and new scientific information. Hatcheries can then be managed in a more flexible and dynamic manner, responding to changing environmental conditions, new science, economic value of the resource, etc. The hatchery system should be structured to allow innovation and experimentation.

Institutionalizing the principles and recommendations developed by the HSRG is critical to achieving meaningful, long-term reform. If the principles and recommendations do not become second nature within the hatchery system, hatchery reform will likely not succeed.

Integrated and Segregated Hatchery Programs

Don Campton, Senior Scientist/Geneticist, USFWS and Member, HSRG

"The HSRG recognized... that there are only two fundamental ways that genetic broodstock management can be conducted within hatchery programs in a scientifically defensible manner.... Either strategy, when properly implemented, should lead over time to hatchery and natural populations that survive at higher rates." — Don Campton

As most of you know, one of the major concerns related to hatcheries over the last three decades has been the genetic effects of hatcheries on hatchery fish, and how those hatchery fish affect natural populations. Many scientific papers over this period have addressed these questions, both from an empirical standpoint (studying natural populations) and from a theoretical standpoint (using mathematical models). The HSRG recognized early on that one of the first problems that would have to be to be addressed in reforming hatcheries was how hatchery broodstocks could be managed to achieve the goals of salmon recovery and sustainable harvest, while at the same time not creating negative genetic or ecological impacts on natural populations.

This investigation quickly illuminated a critical point—very few hatchery programs had clear genetic management plans or strategies for their broodstocks. Typically, the way hatcheries were managed was that adults were trapped to provide fish for broodstock and, in most cases, the origin of those adults was unknown. It was unclear if they were fish of hatchery- or natural-origin. Further, if they were hatchery-origin fish, it was unclear if they had been produced in the same hatchery where they were trapped for broodstock.

Basic animal husbandry dictates that the genetic background of the animals being bred must be known in order to achieve breeding goals. The HSRG recognized this disconnect and concluded that there are only two fundamental ways that genetic broodstock management can be conducted within hatchery programs in a scientifically defensible manner. These two methods are referred to as integrated and segregated (or isolated) genetic management. The concepts behind these methods are straightforward.

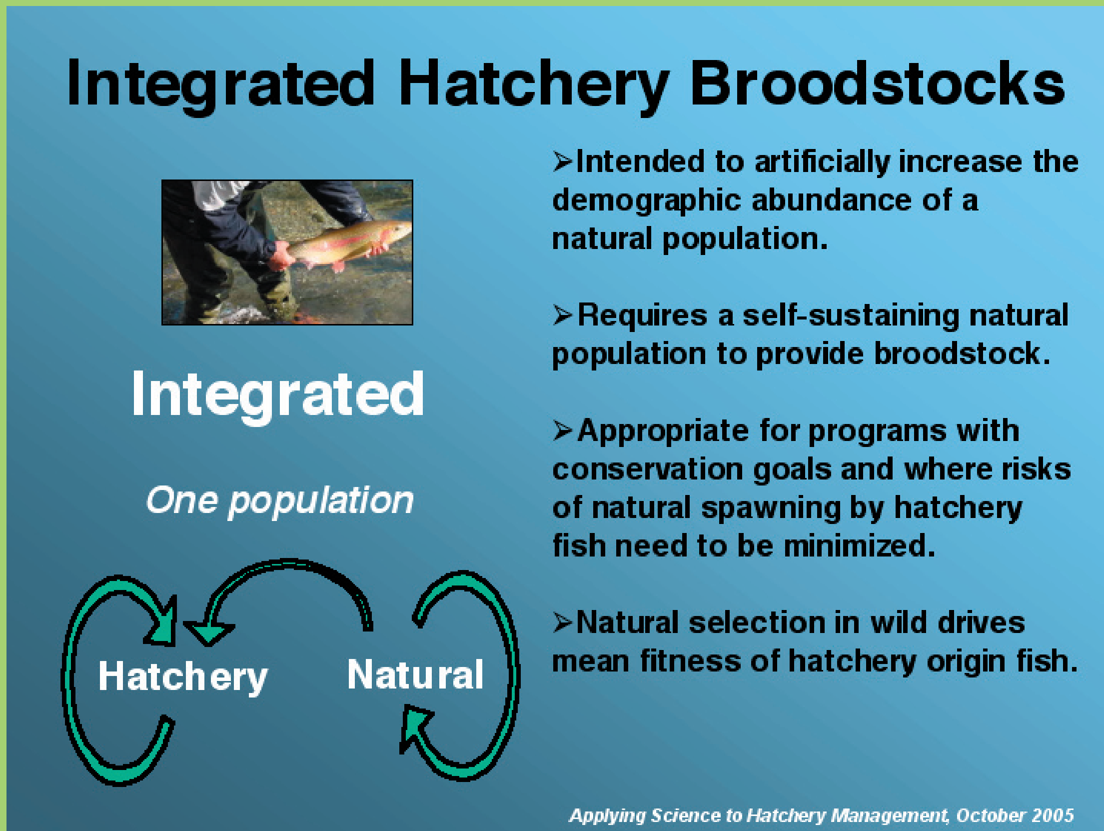
Integrated Broodstock Management

The goal of the integrated strategy is essentially to use the hatchery as an artificial extension of the natural habitat. This means an existing natural population can be increased in terms of the total number of juveniles produced, and the total number of adults that return, that reflect the genetic make-up of the natural population. In this situation, you have one population that spawns in two environments—a hatchery environment and a natural environment. In order to have only one population or gene pool, the fish that are spawning in these two different environments cannot be reproductively isolated from each other.

Under the integrated strategy, the intent is to ensure that the natural environment (not the hatchery environment) drives natural selection of biological characteristics and the genetic constitution (or "fitness") of both hatchery- and naturally-spawning fish. A simple genetic model quantifies mathematically that one of the easiest ways to achieve this is to include wild fish in the hatchery broodstock in a systematic manner, on an annual or generational basis.

Figure 1 illustrates the two environments—hatchery and natural. The arrows represent the gene

Figure 1 —Integrated Hatchery Broodstocks



flow between those environments when some of the progeny of naturally-spawning adults are included in the hatchery broodstock. That's the integrated approach.

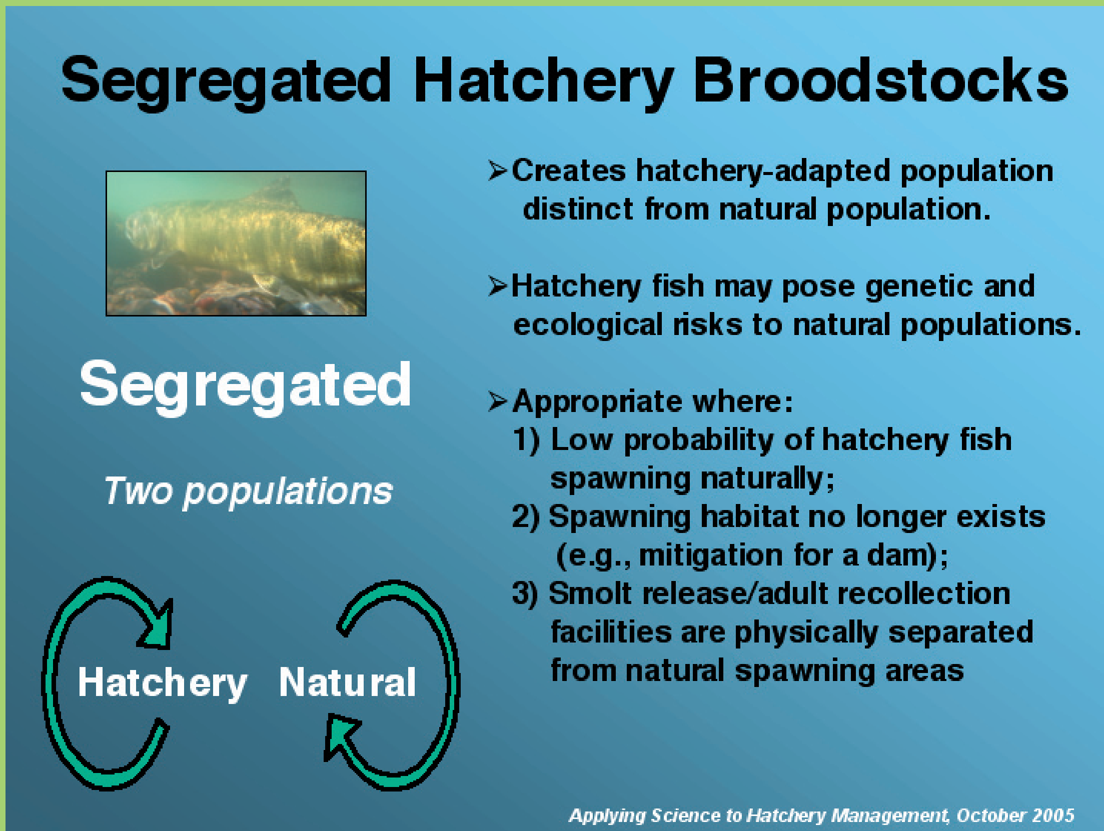
Segregated Broodstock Management

The segregated approach is fundamentally different. Here, the goal is not to maintain one population in two environments. Instead, it is to use a hatchery as a totally separate environment that produces a separate population of fish, in order to provide whatever benefit is intended by the program. Under the segregated strategy, the goal is for no gene flow to occur between the hatchery and wild population. The intent of the segregated strategy is to optimize the hatchery environment, and the population characteristics of its stock, to meet the programs' specific management goals. In this situation, the hatchery environment will drive natural selection in the hatchery population, and the fitness of hatchery fish will be optimized for the hatchery environment. Figure 2 shows no arrow from the hatchery to the natural environment because it is rarely a goal for fish from a segregated hatchery program to spawn naturally. Because some hatchery fish inevitably end up spawning naturally, zero gene flow is not realistic. But gene flow from segregated programs must be minimal.

Choosing Between an Integrated or Segregated Management Strategy

Hatchery managers must identify which of the two strategies is most appropriate given the status of the natural environment, risk of hatchery fish escapement, and management goals associated with the program. Either strategy, when properly implemented, should lead over time to hatchery and natural populations that survive at higher rates than populations influenced by improper integration and segregation.

Figure 2 —Segregrated Hatchery Broodstocks



It is important to note that under both integrated and segregated management strategies, natural spawning by hatchery fish is not considered desirable unless the hatchery program is specifically intended to help rebuild or restore a naturally spawning population via supplementation. However, the integrated strategy can reduce the risk that hatchery fish pose to wild fish when they do spawn in the wild.

There are several points that indicate when and where the integrated strategy is appropriate, and the benefits this strategy confers. The proportion of natural-origin fish in a hatchery broodstock must exceed the proportion of hatchery-origin fish spawning naturally. Therefore, healthy habitat for natural spawning is required, in order to ensure a large enough population of natural-origin fish that some can be used for hatchery broodstock. For this reason, the maximum size of the integrated hatchery program (in terms of number of smolts released) would be determined by the abundance of returning natural-origin fish.

Typically, about five percent of returning adults would be "earmarked" for broodstock and subtracted from the "harvestable number" of wild fish. One generation later, five to ten times as many hatchery fish should be available for harvest and/or conservation. The integrated strategy is appropriate for programs that have conservation goals (because a separate population is not created), or where there is a risk of hatchery fish spawning in the wild.
By contrast, the segregated strategy creates a hatchery-adapted population that, over many generations, will develop characteristics that are not the same as the wild population's, as a result of the general process of domestication. Therefore, the proportion of natural spawners composed of hatchery fish is an extremely important parameter. Segregated programs are most appropriate when there is a very low probability of hatchery fish

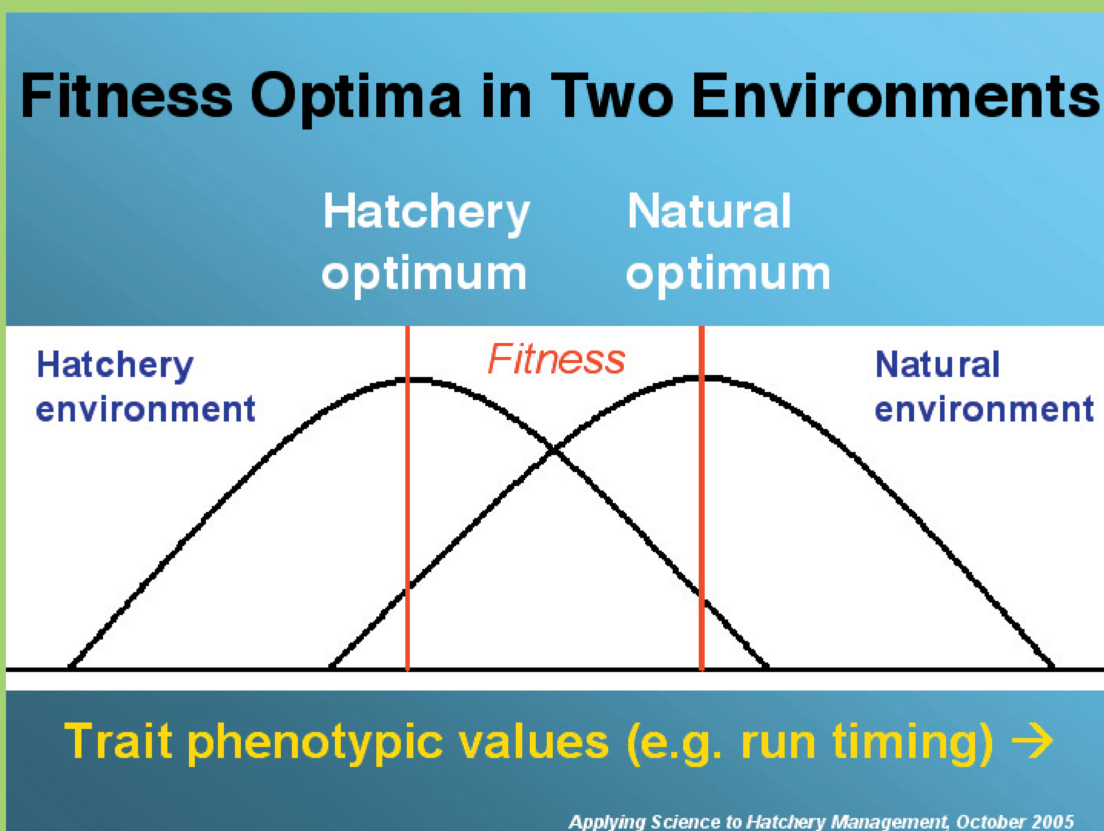
spawning naturally. Guidelines must be met that ensure hatchery fish do not pose unacceptable risks to natural populations. Population genetic modeling indicates that the genetic contribution of hatchery-origin fish from segregated broodstock to natural population must average less than five percent per year; otherwise, hatchery-origin fish can have a dominant genetic effect on a natural population after several generations. This can be most easily accomplished where there is an opportunity to recapture all of the hatchery adults returning to a watershed, before they can spawn naturally.

Segregated programs would also be appropriate if no natural spawning habitat exists; for example, if it has been lost to a dam. A segregated program is the only option if there is no place for wild fish to spawn.

The Concept of "Mean Fitness"

The concept of "mean fitness" provides insight into why controlling the genetic change associated with reproducing in two different environments is essential to achieve hatchery and conservation goals. In Figure 3, the horizontal axis represents the phenotypic value of a trait among individuals (e.g. day of spawning, breeding value for mean egg size, age at maturity), and the vertical axis represents the relative fitness of that phenotypic value for fish that are the product of reproduction in the respective environments. Substantial scientific data has indicated that the optimum value of any particular phenotype is not going to be the same within two different environments (like a hatchery and natural environment). This could be due to how we manage a hatchery, or just the environmental effects of artificial culture.

Figure 3 —Fitness Optima in Two Environments



This difference is illustrated in Figure 3, where the optimum phenotypic value in the hatchery environment (curve on the left) is not equal to the optimum value in the natural environment (curve on the right), though there is considerable overlap between the two. The distance between the two optima (vertical bars) is a measure of the strength of the domestication effect in that hatchery environment.

Anytime there is any gene flow from the hatchery to the wild environment, the mean fitness of the wild stock is driven toward the hatchery optimum. The higher the gene flow rate from the hatchery, the closer the population mean is going to be to the hatchery optimum. Conversely, the higher the gene flow rate from the wild environment to the hatchery environment (for example, if wild fish are used for broodstock), the more strongly natural selection will drive the mean fitness of the population towards the natural environment optimum.

The integrated and segregated strategies are based on this concept. Under the segregated strategy, we try to block off all gene flow, to allow one distinct population at the hatchery and one distinct population in the wild to exist. The integrated strategy controls the gene flow by ensuring that the flow from the natural environment is greater than the flow from the hatchery environment. Another way to move the mean fitness toward the natural optimum is to make the hatchery more like the natural environment.

In conclusion, the HSRG believes the first major step in hatchery reform is for every hatchery program to clearly describe its broodstock genetic goals as either integrated or segregated relative to naturally spawning populations in the watershed where fish will be released and adults trapped for broodstock. This requires explicitly specifying the desired values or limits of the gene flow rates between the two environments. It also requires a mechanism to distinguish hatchery and natural origin fish when adults are selected for broodstock and when natural escapement is estimated. Managers must decide which of the two broodstock strategies maximizes benefits and minimizes risks in a particular situation.

Using Science to Manage in the Face of Uncertainty

Lars Mobrand, Team Leader, Mobrand Jones and Stokes and Chair, HSRG

"Uncertainty is inevitable in the management of natural resources, but the lack of perfect knowledge should not prevent action." — Lars Mobrand

I'm going to make just a few quick points about uncertainty. Uncertainty is inevitable in the management of natural resources, but the lack of perfect knowledge should not prevent action. I want to talk about two concepts - two ways of dealing with uncertainty. One concept is the notion of a "working hypothesis." Regardless of uncertainty, a situation can always be assessed, biological principles applied, and a working hypothesis created that is based on what is known from biology and science.

Managers should always be able to spell out in some detail what the status, trajectory and goals of their programs are. This allows them to explain how a given action will lead towards those goals. For example, if investments are planned for a hatchery, the manager can explain the assumptions underlying that action. This level of detail allows managers to plan in a strategic way and to apply science. If assumptions are spelled out and recorded carefully, they can be reviewed as better information becomes available, in order to understand what makes sense and what does not. The idea of creating and documenting a working hypothesis is one of the underpinnings of this hatchery reform initiative.

In order to do that, a set of tools is necessary. Managers need the ability to organize and share information in a concise, transparent way, in order to make good management decisions and be accountable for the outcomes. The Managing for Success tool that the HSRG has developed in collaboration with the co-managers is designed to allow this and the co-managers have already taken steps in that direction to build such a "working hypothesis."

The second concept is that science is not static. Scientific knowledge will change over time, and one of the key elements of hatchery reform is the recognition that the process does not finish when one paradigm or one framework is selected. New information and new science will improve understanding over time. Therefore, it is necessary to take responsibility for developing and incorporating new science into management. The HSRG has struggled with how to foster such a system.

It is tempting to look for new ideas in science when critical decisions need to be made, as opposed to relying on an established framework. But the framework must be updated in a rational way, so that the new ideas do not prevent progress. It has, in part, been the responsibility of the HSRG to help construct the initial working hypothesis. The HSRG has agreed that as its work concludes, a need remains to provide scientists the opportunity, away from the day to day management, to both safeguard and evolve that hypothesis over time.

Question & Response

Question (Unidentified speaker): Lars, can you give an example of what you're talking about?

Response (Mobrand): My observation over the past several years as the recovery effort has been going on is that we have been reluctant to move forward because there may be something better, so we're caught between, unable to make decisions that need to be made. No action is a decision and it isn't necessarily the safest thing to do. When we set the standard for certainty too high, we tend to favor the "no action alternative." We favor status quo, as opposed to other alternatives that might be better or safer.

Question (Unidentified speaker): Do you think that has happened?

Response (Mobrand): The first listings of salmon happened around 1990, I think. I don't think we've made as much progress as we might have if we had maybe a different way of doing good science on the one hand. There's no doubt that science is critical to moving forward, but it can also be an impediment at times, if we set standards for certainty so high that we are unable to move forward at all.

Question (Tom Luce, Office of Congressman Norm Dicks): How do we set up the infrastructure for science and accountability like there was for the HSRG?

Response (Mobrand): I don't know that we're the appropriate folks to talk about institutional structures. We've asked ourselves about the role of science, and independent science in particular. We've heard from the co-managers and from others, that there has been value in having a group of independent scientist forward the thinking and assimilate and articulate the framework for management.

We haven't addressed management structure or policy issues or issues of that kind, specifically. There are things in scientific arena like maintaining the framework for how you describe the working hypothesis as well as prioritizing research. Those are things which are important to include as we look at investments into the future.

Question (Unidentified speaker): I would point out that hatcheries were built because of loss of natural habitat. So how about we do restoration and increase its productivity?

Response (Mobrand): That certainly is a correct observation, too.

Question (Unidentified speaker): How did you deal with hatchery carcasses?

Response (Evelyn): We recognized that there were certainly risks and benefits involved in using carcasses for nitrification. We actually wrote an article suggesting how it could be dealt with. Ideally, carcasses should be processed in such a way that you remove any serious infection risk. The next type of approach is being very judicious in how we handle the carcasses. If carcasses from a hatchery have languished a long time during the ripening process, it would be foolish to use those carcasses for lake or stream fertilization. Freezing destroys, to a considerable degree, though not 100%, many of the pathogens that could cause problems in fish. It will kill metazoan type pathogens almost 100%. It will knock down bacterial kidney disease population by about 70 or 80% in the tissues. We didn't make any hard and fast rules, but we made some recommendations as to how things might be done. One of these things was using carcasses that have come from "certified" stocks, especially with respect to viral-type pathogens. You can have a look at what's been written about it to get the full story.

Question (Larry Rutter, NOAA Science Center): I've heard about the integration framework. If you're going to have the wild population drive evolution, that will pose a practical limit on how big a hatchery can be.

Response (Campton): You're absolutely right, Larry. Larry's question was: Based on the integrated strategy, doesn't that put a limit on the size of your hatchery program because you are requiring wild fish for the brood stock? That is absolutely correct. When you do the calculations a simple rule of thumb emerges under the integrated strategy. The number of adults you spawn in a hatchery cannot exceed the number of natural origin adults returning to the watershed. It actually works out quite well as a working guideline, in terms of what might work in some places and what might not work in other places. In general, there's an assumption that there are probably hatchery fish spawning naturally. So, if you have a hatchery population that is four or five times larger than the number of natural origin adults returning to a watershed, it takes only a small percentage of those hatchery fish returning to spawn in the wild to overwhelm those natural spawners.

So when we went through all of our hatchery reviews, the first thing we had to understand was the goal of each program. Was the goal to basically have a hatchery population maybe for the primary purpose of just providing fish for harvest? Or was the goal for the hatchery to demographically increase the abundance of an existing wild population in a watershed? When we did that, in many cases we had to recommend that the size of the hatchery program be reduced.

Question (Rutter): In your calculations, have you found cases where hatcheries are much larger than the wild population can sustain?

Response (Campton): I don't know. Maybe Andy Appleby will speak to that. We're going to be going through some specific examples later on today, but it's in our report in terms of our conclusions and recommendations. Off the top of my head, I can't think of anything right now. I'll use a counter example though - our Warm Springs Natural Fish Hatchery on the Columbia which propagates spring Chinook salmon. From the outset, back in the late 1970s, it has been managed with the integrated strategy in mind. I don't remember the exact numbers, but I believe these should be fairly close. I believe the escapement goal for wild fish in the watershed is about 1,800 adults and the brood stock size is about 600 adults. So, by having that hatchery program associated with that natural population in an integrated manner, those hatchery fish can sustain a very high harvest, whereas on natural fish, that harvest has to be controlled in order to protect the natural spawners. The bottom line is that what the hatchery does in that situation is allow a much higher harvest for the stock as a whole then what you could sustain by the natural habitat by itself.