Hatcheries and Management of Aquatic Resources (HaMAR)

Considerations for Use of Hatcheries and Hatchery-origin Fish

American Fisheries Society—2014

Contents

Background iii
Formation of the Steering Committee iii
Scoping Survey iv
Symposia iv
Preparation of Deliverables v
Acknowledgments 1
Considerations for Use of Hatcheries and Hatchery-origin Fish 1
Summary of findings from PFIRM 1
Priority shifts identified during HaMAR 2
Habitat restoration and management efforts as companions to stocking 2
Establishing appropriate uses for hatchery-origin fish and defining expectations for stocking programs 3
Understanding the limitations of hatchery-origin fish and stocking programs 3
Monitoring and flexible/adaptive management of stocking programs 5
Hatchery operation and propagation techniques 6
Types of enhancements and complementary modes of hatchery operation 6
Emerging concerns for hatchery operation 8
Culture of imperiled species and conservation hatcheries 10
Fish health and access to disease management tools 11
Biosecurity 12
Strategies to maintain genetic integrity and diversity in hatchery-origin fish 13
Biological and other interactions between wild and hatchery fish 14
Risk assessment and decision-making 15
Final thoughts 17
Effective communication 17
Issues yet to be resolved 17
References 18
Bibliography 21
Appendix I, Considerations for the Use of Propagated Fishes in Resource Management A-1
Appendix II, Selected Abstracts from HaMAR Symposia A-52

Background

The American Fisheries Society (AFS) is the oldest, largest, and most influential professional organization devoted to fisheries conservation, and, in this capacity, the AFS has routinely assessed the contributions of hatcheries to natural resource management and issued recommendations to guide natural resource managers in best uses of hatchery-origin fish. The Society has explored these issues in a formalized process initiated in 1985 to periodically assess contemporary issues related to hatcheries and management of aquatic resources. Representatives of the Fish Culture and Fisheries Management Sections came together in Lake of the Ozarks, Missouri, in 1985 to answer the question "Fish culture—fish management's ally?" in a symposium entitled "The Role of Fish Culture in Fisheries Management" (Stroud 1986). In 1994, AFS re-examined the issues of fisheries enhancement in the context of emerging ecosystem-based approaches to resource management in a symposium and workshop entitled "Uses and Effects of Cultured Fishes in Aquatic Ecosystems" (Schramm and Piper 1995). A similar process was undertaken in 2003-2004 to once again review the uses of hatchery-origin fish and new scientific findings in the course of a symposium, web-based survey of fisheries professionals, and a facilitated workshop, collectively referred to as "Propagated Fishes in Resource Management (PFIRM)".

In 2012, the AFS initiated the next cycle in this iterative process, dubbed "Hatcheries and Management of Aquatic Resources (HaMAR)". Each of the previous cycles yielded a proceedings book (Fish Culture in Fisheries Management [1986], Uses and Effects of Cultured Fishes in Aquatic Ecosystems [1995], and Propagated Fishes in Resource Management [2004]), and most recently a guidance document, "Considerations for the Use of Propagated Fishes in Resource Management" (Mudrak and Carmichael 2005; Appendix I). The "Considerations" guide, published by the AFS in 2005, provided resource managers with general recommendations for decision-making and successful implementation of fisheries supplementation, rehabilitation, and restoration programs. This document represents an update and expansion of the previous "Considerations" publication, providing aquatic resource managers with timely and comprehensive guidance regarding hatcheries and their products, including finfish, crustaceans, molluscs, reptiles, and other aquatic biota.

Formation of the Steering Committee

In response to fisheries management policy changes that have occurred, newly available information on supplementation and rehabilitation, and fisheries issues that have arisen since the previous cycle, AFS President William Fisher established the HaMAR Steering Committee in 2012, to reengage the AFS in addressing issues related to hatchery operation and the role of hatchery-origin fish in aquatic resource management. Initially co-chaired by Jesse Trushenski and Don MacKinlay, the Steering Committee comprised Doug Bradley, Tom Flagg, Kurt Gamperl, Jeff Hill, Christine Moffitt, Vince Mudrak, George Nardi, Kim Scribner, Scott Stuewe, John Sweka, Gary Whelan, and Connie Young-Dubovsky who were nominated to represent interested AFS Sections and the perspectives of state and federal agencies. The Steering Committee was subsequently joined by Jay Hesse and Ken Leber, Kai Lorenzen, and Lee Blankenship to represent tribal/First Nation perspectives and the Science Consortium for Replenishment of the Oceans (SCORE), respectively. Collectively, this group worked to develop, organize, and

implement the HaMAR process. Following completion of a scoping survey and fact-finding symposia (see below), Chair Trushenski and members Blankenship, Flagg, Hesse, Leber, Lorenzen, MacKinlay, Scribner, Sweka, and Whelan continued their service by preparing and reviewing the current "Considerations" guidance document with assistance from organizer of the HaMAR special publication module, Des Maynard, and Past-President of the Fish Culture Section, Jim Bowker.

Scoping Survey

A scoping survey was conducted to help develop a fact-finding sessions to elucidate current and emerging issues related to the use of hatchery-origin organisms in aquatic resource management. In consultation with their 'constituencies', the HaMAR Steering Committee members prepared a series of topics regarding hatchery operation and use of hatchery-origin fish. These topics formed the basis of a scoping survey that asked respondents to rank them with respect to their importance. The respondents were also asked to comment on the current relevance of the PFIRM-era "Considerations" guide, and provided with the opportunity to write in additional comments. Requests to complete the survey were distributed by various means, including AFS and AFS unit listservs, the Association of Fish and Wildlife Agencies (AFWA) listserv, and by other mechanisms.

Nearly 450 responses were received, representing employees of state and federal agencies, academics, tribal/First Nation authorities, and representatives from the private sector and nonprofit groups/NGOs and a wide range of AFS unit affiliations (Figure 1). Responses were received from 48 states and three Canadian provinces. Respondents identified habitat restoration and management efforts as critical companions to fish stocking programs. The most important contemporary issues related to hatcheries and hatchery-origin fish included: monitoring and adaptive management of stocking programs; development of propagation techniques that result in genetically appropriate, healthy hatchery-origin fish; fish health and access to disease management tools; and understanding the limitations of hatchery-origin fish and stocking programs (Figure 2). These and the other highest-ranking topical areas became the central foci of the planned fact-finding symposia, forming the basis of this document. Respondents indicated that the core considerations identified in the PFIRM process were still relevant, but that the relative importance of each changed with greater priority being given to: the creation of comprehensive fishery management plans; consideration of biological and environmental feasibility; and risk/benefit analysis (Figure 3). The new structure and focus of the present "Considerations" guide was chosen, in part, to reflect these apparent shifts in fisheries professionals' priorities.

Symposia

Based on the priority topics identified by the scoping survey conducted during the previous reporting period, presentations were solicited for the AQUACULTURE 2013 conference (Nashville, TN, Feb. 21-25). Ten papers were presented on topics such as hatchery reform in Washington, Idaho, and South Carolina; emerging disease issues and how these affect hatchery operation; and the effectiveness of non-traditional restoration partnerships. Many participants also presented in related sessions organized by others involved in hatchery operation and use of hatchery-origin fish.

A larger symposium was developed for AFS 2013 (Little Rock, AR, Sept. 8-12). Underwritten by the Fish Culture, Introduced Fishes, and the Fisheries Management Sections and organized with help from the Fish Habitat, Fish Health, Fisheries Administration, Genetics, Marine Fisheries, Physiology, and Water Quality Sections, the 2 ½-day symposium featured topics related to each of these disciplines and others such as tribal/First Nation trust responsibilities and human dimensions.

Preparation of Deliverables

The HaMAR Steering Committee worked to distill the symposia into the current guidance document. This process included multiple rounds of drafting and revision by the HaMAR Steering Committee members. The final draft was then reviewed and recommended by the AFS Management Committee to be considered by the 2013-2014 AFS Governing Board. The present document was approved by the Governing Board on August 16, 2014.

Concurrent with the development of the present document, manuscripts were prepared for a HaMAR-themed special issue of the North American Journal of Aquaculture. Guest-edited by Des Maynard and Jesse Trushenski, the special issue featured primarily papers derived from HaMAR-related symposium presentations.

Acknowledgments

A great number of individuals and organizations contributed to the Hatcheries and Management of Aquatic Resources (HaMAR) process and its deliverables and are gratefully acknowledged by the American Fisheries Society (AFS). The members of the HaMAR Steering Committee were instrumental in providing the knowledge, expertise, and work ethic necessary to develop and implement the HaMAR process, as well as to represent their appointed 'constituencies' from 2012-2014.

2012-2013: Jesse Trushenski (co-Chair), Don MacKinlay (co-Chair), Doug Bradley (Water Quality Section), Tom Flagg (federal agency perspective), Kurt Gamperl (Physiology Section), Jeff Hill (Introduced Fishes Section), Vince Mudrak (Fish Culture Section), Christine Moffitt (Fish Health Section), George Nardi (Marine Fisheries Section), Kim Scribner (Genetics Section), Scott Stuewe (Fisheries Administration Section), John Sweka (Fish Habitat Section), Gary Whelan (state agency perspective), and Connie Young-Dubovsky (Fisheries Management Section).

2013-2014: Jesse Trushenski (Chair), Lee Blankenship (Science Consortium for Ocean Replenishment, SCORE), Jim Bowker, Tom Flagg, Jay Hesse (tribal/First Nation perspectives), Ken Leber (SCORE), Kai Lorenzen (SCORE), Don MacKinlay, Des Maynard, Christine Moffitt, Vince Mudrak, Kim Scribner, Scott Stuewe, John Sweka, Gary Whelan, and Connie Young-Dubovsky.

Underwriting for the HaMAR process and its deliverables was graciously provided by the AFS, as well as the AFS Fish Culture Section, Fisheries Management Section, and Introduced Fishes Section. The Programming Committees of the AQUACULTURE 2013 and AFS 2013 meetings were very helpful in accommodating the various HaMAR-related symposia. Of course, these symposia would not have occurred if not for the thought-provoking and insightful contributions of the presenters.

AQUACULTURE 2013: Tom Flagg, Desmond Maynard, Jeffery Gislason, Peter Paquet, Jay Hesse, H. Lee Blankenship, Peter F. Galbreath, Paul A. Kline, Christine Kozfkay, David Fast, Eric Stark, Erick Sturm.

AFS 2013: Jesse Trushenski, Gary Whelan, Thomas Flagg, Brian Leth, Jeff Heindel, Mike Peterson, Jay Hesse, Cory M. Kamphaus, Desmond Maynard, Barry Berejikian, David Fast, Douglas Hatch, Michael Matthews, Elizabeth Fairchild, Steve Lochman, Kenneth Leber, Kai Lorenzen, James Johnson, Troy Zorn, Kathleen Fisch, Christine Kozfkay, Joshua Sakmar (presented by Michael Matthews), Jody L. Callihan, Jim Bowker, Theresa Tomas Cody, Anita Kelly, Scott Stuewe, Thomas Johnson, Ed Eisch, Christine Moffitt, Becky Johnson (presented by Jay Hesse), Ed Camp, Taryn Gainer, Shelley Edmundson, Lee Blankenship, and Brie Elking (poster).

The HaMAR process extended over several AFS presidencies, and would not have been successful had Past-President Bill Fisher, Past-President Boreman, President Bob Hughes not remained committed to completion of this comprehensive, time-consuming exercise. Their diligence in seeing HaMAR through was essential. Finally, the strengths of HaMAR are derived, in large part, from the foundational work of its predecessors, most recently Propagated Fishes in Resource Management (PFIRM). Many of those acknowledged above were also involved in the previous cycles and we thank them, as well as Pat Mazik, for their assistance in developing the HaMAR process and providing historical context.

Considerations for Use of Hatcheries and Hatchery-origin Fish

Summary of findings from PFIRM

The PFIRM process identified seven primary concepts that should be considered when stocking fish: 1) comprehensive fishery management plans, 2) biological and environmental feasibility, 3) risk and benefit analysis, 4) economic evaluation, 5) public involvement, 6) interagency cooperation, and 7) other administrative considerations (Mudrak and Carmichael 2005). The participants in PFIRM also addressed several narrower topics, some which were considered somewhat controversial at the time: risk and resource assessment, outbreeding depression, propriety of stocked fishes, and fisheries management terminology. Some of these issues are highlighted below, but readers are encouraged to review the PFIRM "Considerations" document, located in **Appendix I** or here, for more in-depth discussion of the PFIRM-era topics.

- Comprehensive fishery management plans - comprehensive fishery management plans should guide resource managers through the choice to stock fish, evaluate stocking programs, and manage fisheries in an adaptive, responsive fashion. The comprehensive management planning process should recognize and consider alternatives to stocking and include inputs from various resource partners. When stocking is delineated, specific goals and objectives should be considered. Objectives should be specific, measurable, accountable, realistic, and time-fixed (Meffe et al. 2002).
- Biological and environmental feasibility - Decisions to stock propagated fishes should be predicated on science-based evaluations that indicate the environment can support the stocked fish and stocking will achieve the identified management objective(s).
- Risk and benefit analysis - Scientific evaluations should be conducted to determine what effects stocked fishes may have on the environment, native and naturalized biota (including humans), and what benefits and risks various approaches may yield.
- Evaluate potential beneficial or harmful effects of increased and directed public use of aquatic environments on biotic (including human) communities - Particular caution should be exercised if introducing fish to an area where they did not occur previously.
- Economic evaluation - benefits and costs should be comprehensively evaluated and quantitatively described as accurately as possible.
- Public involvement - Keep the public informed about pending changes in fisheries management, encourage dialogue on potential changes, and provide a forum for public input. Moreover, when appropriate, educate the public on legal and interjurisdictional issues, including First Nation treaty rights and responsibilities.
- Interagency cooperation - Share technical science-based fisheries information to strengthen interagency coordination and interjurisdictional fisheries monitoring programs. Recognize regulatory and legal differences for the United States, Canada, United States of Mexico, tribes, provinces, states, territories, and federal lands such as national parks and military reservations.

The PFIRM considerations provided a good summary of issues considered important at the time for fisheries managers to use in their comprehensive planning process and subsequent decisions involving

the potential use of stocked fishes. We consider these key PFIRM considerations issues to still be a primary need for resource managers in developing fisheries management plans that include stocking propagated fish. However, much scientific progress has been made in the intervening decade since the PFIRM recommendations on issues of hatcheries and hatchery fish. The HaMAR process was initiated to attempt to capture the current prevailing information on the stocking of propagated fish and to examine how the related issues and priorities have changed.

Priority shifts identified during HaMAR

The HaMAR scoping survey respondents were asked to assess the current relevance of the major elements identified in the PFIRM "Considerations". More specifically, they were asked to identify which three of the seven elements they considered to be the most important in terms of contemporary stocking programs. Whereas the relevance of all seven elements remains, the creation of comprehensive fishery management plans, consideration of biological and environmental feasibility, and risk/benefit analysis were emphasized as the highest priorities (Figures 2 and 3). For example, establishing appropriate uses for hatchery-origin fish, defining expectations for stocking programs, and understanding the limitations of both are integral to the creation of a comprehensive fishery management plan, as is consideration of complementary habitat rehabilitation and other management efforts. Similarly, developing propagation methods that ensure the genetic integrity and health of hatchery-origin fish is essential to success. The importance of risk/benefit analysis was directly reaffirmed in the context of risk assessment and decision-making. From these results, it is clear that the PFIRM "Considerations" remain relevant, but there is now even more emphasis on integrated management and a need for greater specificity in considering the use of hatcheries and hatchery-origin fish. In the following sections, each of the priority topics identified during the HaMAR process are addressed in detail.

Habitat restoration and management efforts as companions to stocking

Whereas the focus of the present "Considerations" guide is the use of hatcheries and hatchery-origin fish, it is imperative to note that stocking is just one leg of the 'three-legged stool' of fisheries management: stocking for supplementation is unlikely to be successful in the absence of complementary habitat rehabilitation and harvest management strategies. Increasingly, management approaches must also be inclusive of strategies to control or eradicate competing invasive species. Walters and Martel (2004) noted a few instances when supplementation went wrong, and these were primarily related to a disconnection between stocking, habitat, and harvest control. These include replacement of wild fish with hatchery recruits with no net increase in stock size; excessive fishing following stocking, resulting in overfishing of wild fish; overexploitation of available forage by the stocked species (i.e., exceeding carry capacity of the system); and genetic effects on the long-term viability of the wild stock. These authors stress the importance of identifying relevant metrics/benchmarks, closely monitoring the effects of stocking, and the collection of targeted data on stocking effectiveness or ineffectiveness. This information is essential to adaptive management and

engaging regulatory authorities and stakeholders in scientifically justifiable decision-making (LEBER, LEBER ET AL.).

Establishing appropriate uses for hatchery-origin fish and defining expectations for stocking programs

Hatchery-origin fish are used to achieve a number of management objectives that are discussed further in "**Hatchery operation and propagation techniques**" below. Appropriate propagation and stocking methods vary based on the intended use of the fish and it is impossible to apply the principles of adaptive management if goals and objectives are not clearly articulated and agreed to by decision-makers and stakeholders. Stocking may or may not be an effective management action, depending on the targets identified for the fishery and the current status of the receiving system. If quantitative assessments indicate stocking is advisable, species selection processes should take a broad range of biological, economic, and risk management criteria into consideration as described in **Summary of findings from PFIRM** above (GAINER ET AL.). Lorenzen et al. (2010) describe a series of recommended steps for implementing stocking programs that should be considered in identifying uses of hatchery-origin fish and defining expectations:

- Stage I: Initial appraisal and goal setting. In this stage, decision-makers and stakeholders establish a decision-making process, evaluate the potential for enhancement to further fisheries management goals, prioritize species for enhancement based on biological criteria, and assess the potential economic and social costs/benefits of enhancement.
- Stage II: Research and technology development, including pilot studies. In this stage, the 'nuts and bolts' of hatchery operation and fish production are established, including identification of proper rearing systems, husbandry methods, and release protocols. During this phase, genetic resource management and fish health management plans are developed and implemented to ensure the genetic and physiological integrity of the cultured fish.
- Stage III: Operational implementation and effectiveness analysis. In this stage, management plans are defined and implemented so that the effects of stocking are monitored and decision points/metrics are established and used to best meet program objectives.

These steps reflect the recommendations identified in the PFIRM Considerations document in many ways, but the full document (Mudrak and Carmichael 2005) provides a greater level of detail and specific guidance to decision-makers and resource managers (see Lorenzen et al. 2010 for further information)(LEBER, LEBER ET AL.).

Understanding the limitations of hatchery-origin fish and stocking programs

Hatcheries and hatchery-origin fish are an essential component of many fishery management plans. However, there are limitations to stocking, and failure to recognize and address these limitations is likely

to yield less than desired results and unintended consequences. In the 19th century, hatcheries were viewed as technological marvels that would turn degraded waters, newly formed reservoirs and impoundments, and underused waterways into bountiful sources of food (frequently non-native species from the country/countries of origin of the residents) and recreation along with addressing declining catches in established fisheries (MOFFITT). Today, it is still tempting to view hatchery-origin fish as a 'quick fix', but like other quick fixes, they are unlikely to resolve systemic issues unless applied as part of a comprehensive solution. If not implemented responsibly, enhancement may lull regulatory authorities into false confidence or dissuade them from addressing the root cause of the identified problem (Leber 2013).

Successful enhancement programs are closely connected to the fishery management process, and are integrated with ongoing fishery monitoring programs. Flexible/adaptive management of hatcheries, conducted in concert with that of fisheries management plans, enables refinement, progress, and success in stocking programs. Lorenzen et al. (2010) identified several common weaknesses that can limit the success of enhancement programs:

- Lack of a clear fishery-management perspective;
- Lack of fishery stock assessments and modeling to explore the potential positive and negative effects of stocking;
- Ignoring the need to establish a structured decision-making process;
- Stakeholders are not involved in the planning and execution of the stocking program from the beginning; and
- Flexible/adaptive management is not well integrated into enhancement plans

Leber (2013) underscored these issues, emphasizing the need for better integration between hatcheries and the fisheries management programs they are intended to support, and suggested that greater stakeholder awareness of the issues, pitfalls, progress, and opportunities related to a stocking program will lead to more realistic expectations and better fisheries for all.

In the Pacific Northwest, the Congressionally-established Hatchery Scientific Review Group (HSRG, http://www.hatcheryreform.us/) described three foundational principles for best management practices for operation of hatcheries (Mobrand et al. 2005, HSRG 2009, Paquet et al. 2011):

- Principle 1: Every hatchery stock must have well-defined goals in terms of desired benefits and purpose. Goals and objectives should be well defined and explicit and include: 1) the intended number of fish to be harvested, 2) the number of fish returning to a hatchery or spawning naturally in a watershed (i.e., escapement), and 3) the expected results of any associated scientific research. Goals must reflect the purpose and desired benefits of the program (e.g., harvest, conservation, research, education) and monitoring plans need to be in place to track progress.
- Principle 2: Hatchery programs must be scientifically defensible. The goals of hatchery program and the day-to-day operations of hatcheries must be scientifically defensible. Once the goals for a program are established, the scientific rationale for the design and operation of the program must be explicitly described so that they may be understood by all personnel and, ideally, the

general public. The approach must represent a logical progression to achieve the management goals, and should be based on knowledge of the target ecosystem and the best scientific information available. Scientific oversight and peer review should be integral components of every hatchery program.

- Principle 3: Hatchery programs must be flexible and respond adaptively to new information. Scientific monitoring and evaluation (M&E) are necessary for all stocking programs and should be evaluated annually to allow timely programmatic adjustments. Hatcheries should be managed flexibly/adaptively to respond to new goals, new scientific information, and changes in the status of natural stocks and habitat. Evaluations should include assessment of survival, contributions of hatchery-origin adults to harvest and natural reproduction, and assessments of genetic (e.g., inbreeding depression, outbreeding depression) and ecological (e.g., competition, predation, disease transmission) interactions between hatchery- and natural-origin fish.

The HSRG also emphasized that maintaining healthy habitat is critical not only for viable, self-sustaining natural populations, but also to adequately control risks of hatchery programs and realize the benefits of hatcheries to recover populations and sustain healthy harvests in an increasingly populated world.

Monitoring and flexible/adaptive management of stocking programs

As noted above, it is absolutely essential that fishery management plans include pre-established timelines and criteria for evaluating enhancement and deciding whether to continue, modify, or terminate the stocking program. Such recurrent decisions require the adoption of a formal adaptive management framework (Williams et al. 2007). The specific objectives and benchmarks of effectiveness will vary from one situation to another depending on the stakeholders involved and their values. Stocking may be conducted in perpetuity to support a put-and-take fishery, but such an approach would not be an appropriate benchmark for enhancement efforts intended to (re)establish a self-sustaining population. Decision points/triggers must be developed and accepted by regulatory authorities and stakeholders before they are needed. The decision to continue or discontinue a long-standing stocking program can be fraught with political discord without agreed-upon criteria and quantitative measures to reference, leading to the decision-making process being easily delayed or derailed, resulting in lost time and resources as well as low cost/benefit ratios (JOHNSON ET AL.).

Monitoring provides decision-makers with the evidence needed to objectively evaluate enhancement effectiveness. Walters and Martel (2004) identified a series of recommendations for evaluation of fishery enhancement as follows:

- Mark all, or at least a known proportion, of the fish released from hatcheries;
- Mark as many wild fish as possible of the same size/at the same location as hatchery fish being released;
- Experimentally vary hatchery releases over a wide range from year to year and from area to area, rotating stocking annually to break up the confounding of competition/predation effects with shared environmental effects;

- Monitor changes in total recruitment, production, and fishing effort in targeted fish populations, not just the percentage contribution of hatchery fish to production;
- Monitor changes in the fishing mortality rates of both wild and hatchery fish directly, through carefully conducted tagging and recovery programs that measure short-term probabilities of capture;
- Monitor reproductive performance of hatchery-origin fish and hatchery-wild hybrid crosses in the wild using genetics information from both hatchery and wild fish. (LEBER, LEBER ET AL., and HESSE ET AL.)

These requirements emphasize marking of hatchery-origin fish. Marking or tagging all hatchery releases so they can be easily distinguished from conspecific wild fish is an especially valuable tool for broodstock management, selective fisheries, and evaluating the ecological and genetic implications of stocking. However, identifying hatchery-origin fish with physical tags or external marks may be costly, affect post-stocking fitness, or be inconsistent with stakeholder beliefs, particularly those of some Native peoples. Minimizing intrusive marking and handling of fish supports cultural and spiritual beliefs, respect for the fish, and maximizes survival. Alternative means of identifying hatchery-origin fish, such as genetic 'fingerprinting' (parentage based tagging), thermal otolith marking, and otolith micro-chemistry, are becoming increasingly popular as maintaining and cross-referencing genetic databases of hatchery broodstock becomes increasingly feasible and cost-effective. Such marking techniques can also be valuable in assessing the fate of hatchery-origin fish with large home ranges or complex life histories (i.e., anadromous stocks; ISRP/ISAB 2009). Hatchery programs with multiple releases should consider tagging a portion of each group released (constant fractional marking strategy), while recognizing that the number of tagged fish influences the rigorousness and statistical power of the analysis.

Hatchery operation and propagation techniques

Types of enhancements and complementary modes of hatchery operation

Not all fish tolerate the same environmental conditions, and husbandry methods vary substantially among the hundreds of finfish species that are reared throughout the world. Just as propagation techniques vary from fish to fish, what constitutes "best management practices" for a hatchery depends on the operation's requirements. Examples include: taxa to be raised; the size requirement by managers; and the expectation of whether the fish will recruit to the fishery in the future following release, or are they stocked simply to satisfy angler demand for catchable-sized fish? The answers to these and related questions will determine what propagation methods, fish quality and genetic requirements, and operational standards are appropriate for the hatchery.

Much progress has been made towards defining common stocking strategies (Trushenski et al. 2010, Lorenzen et al 2010, HSRG 2009). However, standardized terminology and definitions remain elusive. We encourage the use of the following terms to broadly characterize managers' expectations of the hatchery origin fish and help to frame the principles of hatchery operation and propagation methods.

- Harvest augmentation: fish stocked with little-to-no expectations beyond return to the creel; also referred to as put-and take, put-grow-take, and sea ranching

- Supplementation: recurring release of juvenile fish to compensate for poor recruitment caused by limitations related to habitat quantity or quality, environmental quality, or intense harvest pressure; also referred to as restocking or stock enhancement, and related to terms including conservation, and captive broodstock
    - *Note—harvest augmentation and supplementation stockings may be conducted to address ecosystem balance, as well as population-level concerns*
- Re-introduction: short-term releases to reestablish a locally extinct or extirpated population
- Integrated hatchery program: a program that produces fish that are genetically similar to the wild population and requires, as a long-term goal, a self-sustaining, naturally-spawning population capable of providing adult fish for broodstock each year
- Segregated hatchery program: a program that produces a distinct hatchery-supported population that is reproductively isolated from wild populations. A segregated program creates a new, hatchery-adapted population intended to meet goals for harvest or other purposes (e.g., research, education)
- Experimental: fish are stocked to conduct or facilitate research projects or hypothesis testing

These terms can be used to broadly characterize managers' expectations of the hatchery-origin fish, and help to frame the principles of hatchery operation and propagation methods.

Harvest augmentation or production hatcheries use industrialized rearing techniques and are focused on the efficient low cost production of large numbers of fish to increase demographic numbers in a receiving system. These operations do not necessarily focus on genetic management or mimicking natural rearing conditions. Fish originating from such facilities can be genetically or behaviorally distinct from wild fish, and may not exhibit local adaptations or maximum fitness post-stocking. As a result, these types of hatcheries are best suited to supplying fish for put-and-take or put-grow-take management plans.

Supplementation hatcheries often use the same rearing systems as production hatcheries, but they differ in that the fish they produce are generally intended to become naturally-spawning individuals post-stocking. These types of hatcheries generally use gametes from wild-origin broodstock and follow strict breeding and release protocols to minimize loss of genetic diversity and artificial selection in the hatchery environment. Fish originating from supplementation hatcheries are raised to be similar to wild fish, and are best suited to management plans intending to increase the number of naturally-spawning individuals or increase recruitment.

Conservation hatcheries are an extreme form of supplementation hatcheries, and follow protocols to intensively manage the genetic integrity of the broodstock as well as the overall fitness of the progeny. Culture methods are typically modified to mimic natural conditions to the extent feasible. Fish originating from conservation hatcheries have been raised to be as genetically and behaviorally similar as possible to wild fish, and are best suited to management plans focused on the restoration of imperiled populations. Conservation hatcheries also serve increasingly important roles as refugia for rare species or genetic profiles.

Many hatcheries are functional hybrids, operating as harvest augmentation, supplementation, or conservation hatcheries by turns or simultaneously to produce various fishes in a manner consistent

with their intended uses. Clear and well-documented objectives are essential for all hatchery programs, especially facilities rearing fish for different uses.

Emerging concerns for hatchery operation

Conflicting mandates: balancing the use of hatcheries to support both conservation and harvest objectives (FLAGG)

During development and operation of hatchery programs, managers are often faced with having to address competing and often conflicting objectives or mandates. For instance, in the Pacific Northwest almost two-dozen stocks of Pacific salmon are now listed as threatened or endangered under the U.S. Endangered Species Act (ESA) and require federal protection and rebuilding. At the same time, hatchery programs release almost 300 million fish to support harvest requirements associated with legally binding federal treaties, treaty trust responsibilities, and court mandates. Achieving a scientifically defensible but socially acceptable balance between harvest and conservation has proved to be challenging, both politically and biologically. During the last decade, the Hatchery Scientific Review Group (HSRG) was charged by the U.S. Congress to examine and suggest possible solutions regarding conservation and harvest conflicts in the Columbia River Basin (HSRG 2009, Paquet et al. 2011). The HSRG review examined over 178 hatchery programs and 351 individual hatchery and wild salmon and steelhead populations to determine mechanisms for achieving manager's goals for conservation and sustainable fisheries. The HSRGs' approach was to use the best available science and key principles of explicit goal identification, scientific defensibility, and flexible/adaptive management to change the focus of the Columbia River hatchery system from an agrarian or aquaculture-based paradigm to a renewable natural-resource paradigm. Best management "practices" should be applied as "principles" which 1) maintain site-specific flexibility, 2) integrate biological, legal, and political perspectives, and 3) ensure adaptive management based on program performance data (HESSE AND JOHNSON).

The HSRG approach used modeling based on the size and biological importance of a wild population, the size and location of the proposed hatchery release, the fraction of hatchery fish (pHOS) in the natural spawning escapement (NOR) and the fraction of natural-origin parents in the hatchery broodstock (pNOB) over time. The HSRG then calculated the proportionate natural influence (PNI) as a measure of the relative influence of the natural and hatchery environments on the mean phenotypic values of a population at equilibrium based on the relative rates of gene flow between the two environments ($0 < PNI < 1.0$). The HSRG recommended standards for each population designation regarding the allowable levels of hatchery influence on naturally spawning populations in terms of pHOS and PNI, whereby "primary populations" would need to experience the lowest level of hatchery influence (pHOS should be less than 5% of the naturally spawning population, unless the hatchery population is integrated with the natural population; for integrated populations, pNOB should exceed pHOS by at least a factor of two, corresponding to a PNI value of 0.67 or greater and pHOS should be less than 0.30), "contributing populations" an intermediate level of influence (pHOS should be less than 10% of the naturally spawning population, unless the hatchery population is integrated with the natural population; for integrated populations, pNOB should exceed pHOS, corresponding to a PNI value of 0.50 or greater and pHOS

should be less than 0.30), and "stabilizing populations" would not require modification (no criteria developed for pHOS or PNI)(Paquet et al. 2011).

Using these parameters and precautions, the HSRG solutions were able to project improved conservation status for many Columbia River populations, usually exceeding the co-managers' conservation goals for these populations, while at the same time providing for increased harvest (HSRG 2009, Paquet et al. 2011). An important key for these solutions was the use of the underlying assumption that the biological principles used to manage hatchery populations and programs had to be the same principles that are used for managing natural populations. Hatcheries and hatchery operations must be considered in context of the ecosystem and should be as small as possible, while still achieving conservation and harvest goals. The HSRG review emphasized that hatcheries and hatchery fish cannot replace lost or damaged habitat or the natural populations that rely on that habitat. Hatchery programs must be viewed not as surrogates or permanent replacements for lost habitat, but as tools that can be managed as part of a coordinated strategy to meet watershed or regional resource goals, in concert with actions affecting habitat, harvest rates, water allocation, and other important components of the human environment. To be considered successful, hatcheries should be used as part of a comprehensive strategy where habitat, hatchery management, and harvest are coordinated to best meet resource management goals that are defined for each population in each watershed.

Controlling the costs of hatchery operation

In the U.S. alone, state and federal fish hatcheries produce roughly 1.75 billion fish annually, corresponding to a production volume of more than 20 million kg (Halverson 2008). Tribal/First Nation and private hatcheries also produce fish for use in natural resource management. Hatchery operation involves both economic and environmental costs, much of which is associated with feeding practices. Even assuming high feed conversion efficiencies, rearing large volumes of fish requires even larger amounts of nutrient-dense aquaculture feeds and yields solid and dissolved wastes. Feed cost and effluent management are increasingly critical constraints for hatcheries: flat or declining budgets and stricter oversight of water usage make the prospect of producing the same or greater numbers of fish a difficult, if not impossible, proposition.

Unlike terrestrial livestock, fish demand diets rich in proteins and lipids (fats and oils), which increases the price of aquaculture feeds compared to forage or prepared diets used in poultry, swine, or cattle production. To meet these requirements, feed manufacturers traditionally used nutrient-dense ingredients like fish meal and fish oil (produced by rendering small marine pelagic fishes such as anchovies, herrings, etc.) as primary ingredients. However, the price of such ingredients has increased dramatically, having grown by 400% over the last 20 years, including a two-fold increase since 2004 (FAO 2008). To control feed prices, fish meal and fish oil can be replaced with lower cost, terrestrial-origin ingredients, such as derivatives of soy, corn, wheat and various rendered animal products. However, these alternative ingredients do not provide the same nutritional value as fish meal and fish oil, and may not be as palatable or digestible to cultured fish. Consequently, replacing marine-origin ingredients with terrestrial-origin ones may help to control feed costs, but may limit fish growth and performance as well as complicate water quality management and limit effluent discharges.

The costs of hatchery operation will continue to increase as a result of increasing feed prices and/or the need to implement more robust water treatment methods (EISCH, EISCH) or transition to more intensive, water reuse-based rearing systems. Research and development related to fish nutrition and low-cost, low-effluent feeds, water treatment technology, and energy efficiency has yielded incremental progress, but the growing financial burden of hatcheries jeopardizes the ability of agencies to operate these facilities and use their essential products and services in natural resource management. While reductions in effort or hatchery closures may offer short-term savings, it is important to recognize that curtailing hatchery programs will undoubtedly have broader economic consequences. Beyond the intangible value of imperiled species restoration and strengthening of native fish assemblages, hatcheries support recreational fishing, which is valued at more than $61 billion in total economic impact and is associated with more than 587,000 jobs in the United States (Southwick Associates 2011). In assessing of their costs, the value of hatchery programs and their products must also be considered.

Culture of imperiled species and conservation hatcheries

The operational approaches and measures of success for a conservation hatchery may differ considerably from those of harvest augmentation/production or supplementation hatcheries. The mission of a modern conservation hatchery is two-fold: gene pool preservation and recovery. Flagg and Nash (1999) described a generalized 'decision tree' for implementation of conservation hatchery strategies that include the status of the population, its genetic composition, rate of decline, and the impact of any actions on native fish. Each conservation program will therefore be site specific and depend on the physical and management limitations of each individual hatchery. Consequently, the exact application of conservation hatchery strategies will depend on the particular stock of fish, its level of depletion, and the biodiversity of the ecosystem.

Once a conservation hatchery approach has been selected, program operation requires application and integration of a number of rearing protocols, which are known to affect the inherent fitness of the fish to survive and breed in its natural environment. Fish husbandry in a conservation hatchery must be conducted in a manner that 1) mimics natural life history patterns, 2) improves the quality and survival of hatchery-reared juveniles, and 3) lessens the genetic and behavioral influences of propagation techniques on hatchery fish and, in turn, the genetic and ecological impacts of hatchery releases on wild stocks (Flagg et al. 2004). Operational guidelines for conservation hatcheries (Flagg et al. 2004) may include 1) mating and rearing designs that reduce risk of domestication selection and produce minimal genetic divergence of hatchery fish from their wild counterparts to maintain long-term adaptive traits; 2) simulating natural rearing conditions through incubation and rearing techniques that approximate natural profiles and through increasing habitat complexity (e.g., cover, structure, and substrate in rearing vessels) to produce fish more wild-like in appearance and with natural behaviors and survival similar to wild fish upon release; 3) conditioning techniques such as antipredator or increased water flow conditioning to increase postrelease behavioral fitness; 4) programming aspects of release size, stage, and condition to match the wild population in order to reduce potential for negative ecological interactions and to promote homing; and 5) aggressive monitoring and evaluation to determine success of conservation hatchery approaches. High priority must be given to basic scientific research to meet

three principal goals: 1) maintain genetic integrity of the population, 2) increase juvenile quality and behavioral fitness, and 3) increase adult quality ("quality" being a somewhat plastic metric, determined on a case-by-case basis).

In the future, creation of gene banks using cryopreservation and other biotechnological tools for reproduction (e.g., gynogenesis, androgenesis, cloning) may be increasingly important in the preservation or production of rare aquatic organisms. Gene banking allows for gametes or other genetic resources to be stored indefinitely or for near-indefinite periods of time. Gene banking may be particularly beneficial for increasing effective population size when broodstock are limited (e.g., intergenerational crossing) or when husbandry methods have not been adequately established beyond gamete collection and preservation (Harvey 2000). Gene banking and other reproductive biotechnologies are more refined in the agricultural sectors (including aquaculture, Hiemstra et al. 2006) and in restoration of imperiled terrestrial species (Leibo and Songsasen 2002), but these approaches may prove essential to preventing future losses of genetic diversity or extinctions.

Fish health and access to disease management tools

The goals of a model aquatic animal health program should include:

- Keeping mortality low and maximizing production for each facility;
- Ensuring that hatchery-origin fish are fit and have a high likelihood of survival post-stocking;
- Preventing the introduction of pathogens to naïve receiving waters and producing immunologically competent fish able to withstand exposure to pathogens found in the wild; and
- Ensuring that wild populations are not exposed to different or greater densities of pathogens as a result of stocking.

Establishing a relationship with or having a qualified fish health professional or veterinarian on staff is paramount to achieving these goals. Successful hatchery programs take a comprehensive approach to aquatic animal health, including use of biologics (i.e., vaccines and bacterins), biosecurity measures, and other preventative strategies; use of therapeutants and other disease management techniques; broodstock conditioning and spawning; marking progeny; and reducing handling stress. Many of these activities require administration of fish drugs, including antimicrobials, spawning aids, marking agents, and sedatives. Virtually all hatchery-origin fish are considered to be food fish or fish that may be caught and consumed (though species that are listed as threatened or endangered at the state or federal level are generally considered to be the exception to this rule). As a result, the only drugs that can be legally used to treat hatchery-origin fish are those that have been approved by the U.S. Food and Drug Administration (FDA). Only nine drugs are currently approved by the FDA for use on food fish. Drugs may be approved for specific groups of fish (e.g., freshwater salmonids) or for specific purposes (e.g., to control mortality caused by furunculosis associated with *Aeromonas salmonicida*). There is considerable confusion and misinformation regarding legal and judicious use of drugs in fish culture, fisheries management, and research. To maximize the effectiveness of drug treatments and remain compliant with relevant regulations and aquatic animal health plans, hatcheries have a responsibility to ensure

staff know what drugs are legal and how to apply them correctly. The FDA Center for Veterinary Medicine is the authoritative source of information on the legal and judicious use of all animal drugs (http://www.fda.gov/AnimalVeterinary/default.htm), but fish culturists may find the U.S. Fish and Wildlife Service Aquatic Animal Drug Approval Program website (http://www.fws.gov/fisheries/aadap/) and the Fish Culture Section Guide to the Use of Drugs, Biologics, and Other Chemicals in Aquaculture (http://fishculturesection.org/) to be more readily accessible resources.

Therapeutic drugs use can be minimized using comprehensive fish health management plans that include administration of biologics. Vaccines contain live organisms (bacteria or viruses) or killed viruses, whereas bacterins contain inactivated cultures of bacteria. Both are used to increase the natural ability of the animal to resist the disease caused by the organism from which the biologic product is derived. There are a number of licensed, commercially available veterinary biologics that are currently approved for use in fish. Autogenous vaccines are a specific subset of biologics that are derived from specific pathogens associated with a specific facility. As with drugs or any other compound used in aquaculture, it is recommended to seek professional advice about the specific biologic product you are interested in using before using it for the first time. The U.S. Department of Agriculture Animal and Plant Health Inspection Service Center for Veterinary Biologics is the authoritative source of information on licensed biologics, but this information may be more readily accessed in the USDA APHIS Program Aid No. 1713 "Veterinary Biologics: Use and Regulation" (http://www.aphis.usda.gov/publications/animal_health/content/printable_version/vet_biologics.pdf), "Use of Vaccines in Finfish Aquaculture" (http://edis.ifas.ufl.edu/pdffiles/FA/FA15600.pdf) and the Fish Culture Section Guide to the Use of Drugs, Biologics, and Other Chemicals in Aquaculture (http://fishculturesection.org/).

The Fish Health Section of the AFS maintains an online registry of certified Fish Health Pathologists and Aquatic Animal Health Inspectors who can help provide hatcheries with guidance regarding the development and implementation of aquatic animal health plans (http://www.afs-fhs.org/certification.php). The American Veterinary Medical Association also maintains an online registry of licensed veterinarians with knowledge of aquatic animal health (http://www.aquavetmed.info/); the American Association of Fish Veterinarians is establishing a similar registry (http://fishvets.org/).

Biosecurity

Biosecurity refers to practices used to prevent the introduction and spread of disease-causing organisms and nuisance/invasive species. Although many common fish pathogens and parasites are present in virtually all environments and are difficult or impossible to eradicate, others have a regional distribution or are easier to avoid or contain. In any event, biosecurity is an essential 'first line of defense' against introduction or transmission of undesirable organisms. Biosecurity is commonly associated with disinfection, but comprehensive biosecurity plans can go well beyond simple disinfection procedures to include everything from facility layout and design, to livestock sourcing and quarantine, to records-

keeping. Biosecurity practices vary from one situation to the next, based on the potential risks associated with the type of facility, culture species, and pathogens or invasive/nuisance species that are involved.

For more information about biosecurity, users can refer to an aquaculture biosecurity manual and accompanying annotated presentation that were developed for Illinois aquaculture facilities, "Biosecurity Protection for Fish Operations" which focuses on Arkansas aquaculture operations, or the North Central Regional Aquaculture Center "Biosecurity for Aquaculture Facilities in the North Central Region" fact sheet. Although originally developed with regional facilities and biosecurity concerns in mind, the strategies described in these resources are largely applicable to hatchery facilities throughout the U.S. Users may also wish to review "Sanitation Practices for Aquaculture Facilities" for further information.

Strategies to maintain genetic integrity and diversity in hatchery-origin fish

Proper genetic management of and spawning strategies for hatchery-origin fish are critical to maintaining genetic diversity, minimizing inbreeding, maximizing effective population size, and reducing artificial selection (FISCH ET AL., KOZFKAY ET AL.). The degree to which these elements are intensively managed depends, in part, on the type of hatchery and intended use of the hatchery-origin fish (see **Hatchery operation and propagation techniques**). Various spawning strategies can be employed in hatcheries that can maintain genetic diversity, minimize inbreeding, maximize effective population size and reduce adaptation in captivity and upon supplementation of these fish into wild populations (FISCH ET AL., KOZFKAY ET AL.).

Genetic management is particularly complex for supplementation stocking programs, where stocked fish are either intended to interbreed with wild fish or may have the unintended opportunities to do so. Two approaches are commonly applied in these situations: 1) hatchery-origin fish are managed as a distinct genetically segregated population focused on keeping hatchery-origin and wild fish reproductively isolated (segregated hatchery program); or 2) hatchery-origin fish are managed as a genetically integrated component of a natural population with a focus on minimizing the consequences of interbreeding between hatchery-origin and wild fish (integrated hatchery program)(Trushenski et al. 2010). Whereas maintaining genetic diversity is an important element of both approaches, the specific protocols involved differ (Mobrand et al. 2005). A segregated program creates a new, hatchery-adapted population intended to divert harvest pressure away from the wild population. Gene flow is minimal between the hatchery-origin and wild populations, and over time, a genetically distinct hatchery-origin population develops. An integrated hatchery program strives to increase the demographic size of the wild fish population while minimizing the genetic influence from hatchery rearing by maximizing gene flow between the hatchery-origin and wild populations. By continually supplementing the broodstock with wild-origin fish, the hatchery-origin population remains integrated with and ideally indistinguishable from the wild population. Mobrand et al. (2005) described these two genetic management options in detail, and additional information can be found on the Hatchery Scientific Review Group [HSRG] websites (http://www.hatcheryreform.org/; and http://hatcheryreform.us/).

Biological and other interactions between wild and hatchery fish

Much of the concern over interactions between hatchery and wild fish has centered on genetic effects of hatchery fish on wild populations (Hindar et al. 1991; Lynch and O'Hely 2001) and hatchery management strategies are often in place to minimize genetic risks. However, ecological effects may be just as important as genetic effects (Weber and Fausch 2003) and should be considered when releasing hatchery origin fish into the wild. Ecological impacts of hatchery fish on wild populations have been reviewed by Weber and Fausch (2003) and Kostow (2009). Large releases of hatchery fish can increase competition with wild fish and increase density-dependent mortality. Hatchery fish may also exhibit different behavior than their wild counterparts. For example, hatchery salmonids may not out-migrate, remaining resident in areas where they were stocked, and become precocious with the ability to spawn shortly after release. Spawning by these individuals may alter the typical life history of the wild population. Alternatively, outmigrating hatchery fish may not be as adept at homing due to altered electromagnetic imprinting (Putman et al. 2014) and may stray upon return from the ocean. Studies aimed at evaluating the effects of competition between hatchery and wild fish have shown mixed results with some showing hatchery fish to have a competitive advantage, some showing wild fish have a competitive advantage, and others showing neither have a competitive advantage. Competition is difficult to experimentally evaluate and the mixed results seen in the literature are likely due to differences in experimental design and conditions under which they were conducted (Weber and Fausch 2003). Nevertheless, responsible use of hatchery fish in sympatry with wild fish should strive to minimize risk of negative interactions with wild populations.

Kostow (2009) provided several management strategies to mitigate ecological risks from hatchery programs. Some of the strategies proposed by Kostow (2009) were specific to anadromous salmonids. Below are summaries of the strategies that would be applicable to any propagated species.

- *Operate hatchery programs within an integrated management context.* Hatchery operational plans need to be developed specific to the populations with which they interact and focus on restoring naturally producing populations. Operational plans should be formulated so that they are consistent with broader management objectives.
- *Only implement hatchery programs that provide a benefit.* Recent scientific studies have questioned the benefits of hatchery programs. Agencies should review hatchery programs periodically to determine if they still provide a benefit toward reaching management objective and discontinue programs that no longer serve a social or biological need.
- *Reduce the number of hatchery fish that are released.* Many of the risks associated with the release of hatchery fish are due to the sheer numbers released. Decisions regarding the number of fish released should incorporate biological/ecological metrics as well as social demands and legal responsibilities.
- *Scale hatchery programs to fit carrying capacity.* Agencies need to monitor wild populations and scale hatchery programs such that natural reproduction is not depressed by the addition of hatchery fish.

- *Limit the total number of hatchery fish that are released at a regional scale.* Ecological impacts can extend beyond immediate release sites and into major migration routes and even the ocean. Releases of the total hatchery fish from multiple facilities should be coordinated among managers from multiple jurisdictions.
- *Locate large releases of hatchery fish away from important natural production areas.* This strategy helps to minimize negative interactions with wild fish and also helps to decrease harvest risks to wild populations.
- *Time hatchery fish releases to minimize ecological risks.* The timing of release and outmigration should be considered. Multiple releases could be made over time which allow dispersal from a release site and minimize concentrations that attract predators. Releases could also be timed to avoid predation on wild species during critical time.
- *Restrict the number of hatchery adults allowed into natural production areas.* Reproductive segregation of hatchery and wild fish minimizes genetic risks. Some methods used to reduce entry into natural spawning areas include removal at dams or weirs, selective fishing, and release locations away from natural spawning areas.
- *Be able to identify hatchery-origin fish and monitor the effects of hatchery programs.* Adequate monitoring and evaluation of a hatchery program requires hatchery fish to be identifiable in order for risks to wild fish to detected and managed. There are a number of approaches which can be used to physically mark or otherwise identify hatchery-origin fish after release.

Additional recommendations for minimizing risks may be found in HSRG (2014), Cowx et al. (2009), and FAO (1994).

Risk assessment and decision-making

Risk assessment is the process by which the likelihood of an event occurring and the severity of its consequences are described. Risk itself is defined as the product of these two factors—likelihood of occurrence and negativity of consequences. Thus, scenarios involving unlikely events with only moderately negative consequences are considered low risk; scenarios involving events that are very likely or have very serious consequences would be considered moderately risky; and scenarios involving highly negative events that are likely to occur are considered high risk. Risks should be delineated and integrated into the decision-making process in as quantitative a manner as possible, including the consequence of taking no action. Potential benefits should also be considered as a part of such an assessment. Benefits often relate to society, such as angling days, fish yield, and public access, but may also include ecosystem function, stability, cultural value, productivity, and others.

Depending on the elements of the scenario and the availability of quantitative information, risk assessment can be a straightforward assembling of facts and figures, or it can be a challenging process involving considerable uncertainty. The latter is perhaps more common in risk assessments involving fisheries resources, where information is often incomplete or imperfect (i.e., stock assessments may be available for some but not all species, effects of an action may be unknown or known only in a different type of ecosystem) or difficult to quantify or predict with certainty (i.e., historical stock structure of non-game fish, ecosystem responses to ecosystem change, the intangible value of fisheries to stakeholders).

Assessing potential consequences and cumulative risk is complex. Acceptable risk levels and desired benefits vary across user and management entities; application of a structured decision-making process is recommended (see **Monitoring and flexible/adaptive management of stocking programs**). Management decisions tend to be risk-averse in pristine habitats dominated by native species where the primary management goal is species conservation. Management decisions tend to be more risk-tolerant, however, in more altered habitats dominated by nonnative fishes where the primary management goal is exploitation of a fishery.

These challenges should not dissuade resource managers from attempting to assess the relative risk of proposed actions, including stock enhancement, with the caveat that decisions will still need to be made even when risks are not completely understood. In other words, stakeholders are not likely to be satisfied with tabling an important decision until a comprehensive risk assessment can be completed. Steps should be taken to reduce uncertainty, but it cannot be completely eliminated from the decision-making process. It is equally important to understand that all management actions, including the decision to do nothing, involve risk; whether that level of risk is acceptable to stakeholders is separate question. Risk assessments can provide quantitative or semi-quantitative estimates of risk associated with stocking or other elements of a fishery management program, but decision-makers must engage with stakeholders to determine proper thresholds for risk.

Changes to hatchery programs in response to scientific recommendations can be successfully implemented only with concurrent integration of associated non-technical factors and risks, including but not limited to:

- Legally authorized and mandated mitigation obligations,
- Tribal/First Nation treaty-reserved fishing rights ,
- Logistical challenges and infrastructure constraints, and
- Funding and operating budgets for implementing the changes and monitoring their effectiveness.

The decision to implement a hatchery program, and what type of hatchery program to implement, should stem from a structured decision making framework (Gregory et al. 2012). Structured decision making is formal decision-making process in which management objectives are defined based on stakeholder values and alternatives are evaluated and selected based upon predictive models. Adaptive management is a type of structured decision making used for recurrent decision-making that is becoming typical in fisheries management (Williams et al. 2007). Within an adaptive management framework, models can be employed that account for uncertainty, risk, and constraints resulting from legal, economic, and logistical considerations to decide which of the possible alternatives has the greatest chance to achieve management objectives. An adaptive management framework also incorporates monitoring and evaluation to determine the accuracy of original predictions from models, where model can be improved, and where uncertainty should be reduced to better inform the decision-making process, and in some cases, where uncertainty may have little bearing on the decision. Without an adaptive management framework, decisions on the use of hatcheries may appear arbitrary or

unjustified to stakeholders. A formal adaptive management process maintains transparency and objectivity in the decision-making process.

Final thoughts

Effective communication

HaMAR and its predecessors were made possible by the willingness of a wide range of fisheries professionals to come together to discuss, fully understand and resolve issues related to the use of hatchery-origin fish in the management of aquatic resources. Though the need for cooperative management, inclusive planning, and interdisciplinary approaches may seem self-evident today, this was not always the case. The issues surrounding hatcheries were once hotly debated by individuals with widely different and largely inflexible views, both within AFS and in other contexts. The use of hatcheries and hatchery-origin fish remains contentious at times, but fisheries professionals now recognize the need for hatcheries and their products, as well as the need to closely monitor, critically evaluate, and frankly discuss stocking programs to ensure their effectiveness. Those participating in HaMAR exemplified a willingness to engage those with differing views and focus on science-based decision-making, both of which are essential to the creation of effective fisheries management plans, including the use of hatcheries and hatchery-origin fish.

Issues yet to be resolved

Like any scientific endeavor, HaMAR effectively addressed many questions, but raised others. Several of these questions are listed below. Whereas some of them may find quantitative responses or solutions in the future, it may not be possible to address all of them in the context of traditional fisheries science. Although we are unable to offer responses to these at this time, we offer them to the reader and future participants in AFS evaluations of hatcheries and hatchery-origin fish.

- Where's the progress in quantifying socio-economic impact of fisheries enhancement?
- Why are state fisheries managers reluctant to resist stakeholder demands to judge stocking programs simply by the numbers of organisms stocked?
- Is there an urgent need to increase seafood production in the USA? And be better prepared to maintain sportfishing?
- Why isn't there more assessment of success in existing marine stock enhancement programs?
- Hatchery-based fisheries enhancement isn't going away; so, despite differing opinions what can be done to make this field more effective?
- It appears that hatchery –natural population interactions are approached very differently between anadromous fish and freshwater and marine fishes. If this is true, why?
- Why has there been very little evaluation of supplementation for freshwater/marine species?

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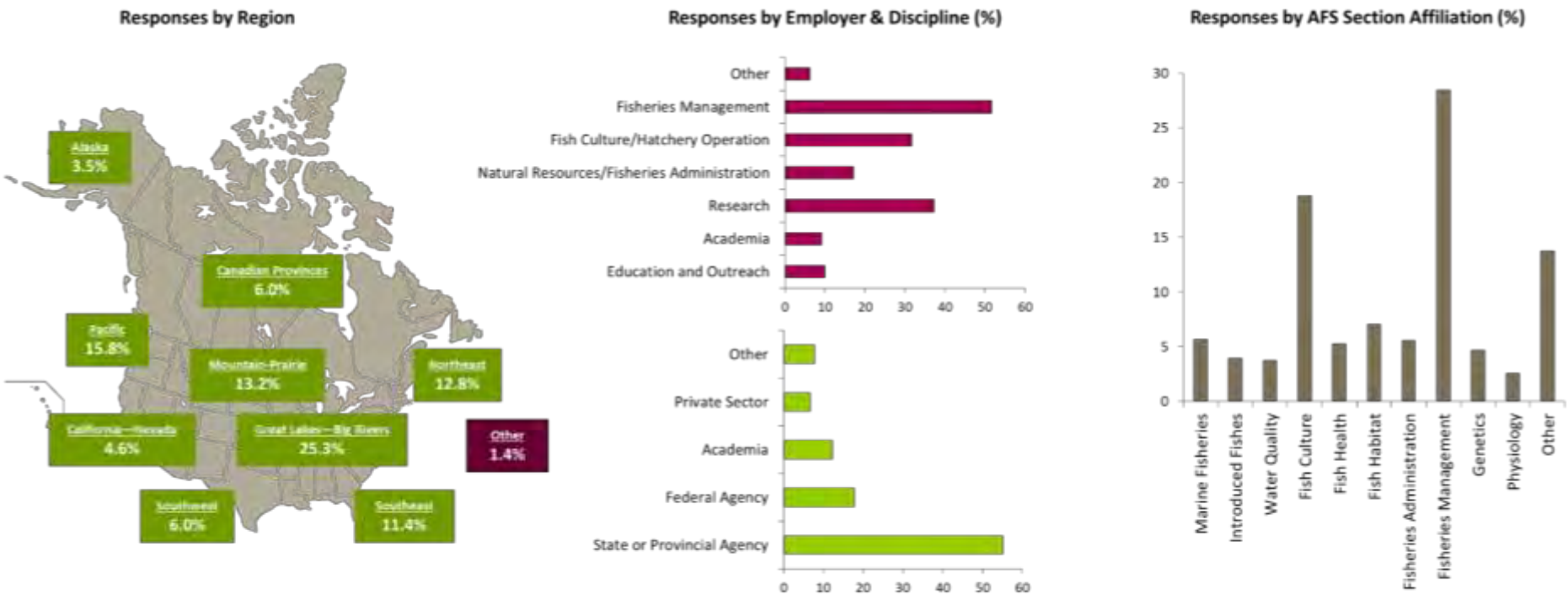

Figure 1. Demographics of respondents to HaMAR scoping survey conducted in 2012. Results are summarized by geographic regions, employer types, major fisheries disciplines, and affiliation with American Fisheries Society Sections. A total of 431 responses were received by the response deadline. Mexican states were targeted during the survey process, but no responses were received.

Topic	Rank
Habitat restoration and management efforts as companions to stocking	4.2
Monitoring and adaptive management of stocking programs	4.1
Development of propagation techniques that result in genetically appropriate, healthy hatchery-origin fish	4.1
Fish health and access to disease management tools	4.0
Understanding the limitations of hatchery-origin fish and stocking programs	4.0
Biological interactions between wild and hatchery fish	3.9
Defining appropriate uses for hatchery-origin fish, defining expectations and understanding the limitations of hatchery-origin fish and stocking programs	3.9
Culture of imperiled species and conservation hatcheries	3.8
Risk assessment and decision-making	3.8
Genetic integrity of hatchery-origin fish	3.7

Figure 2. Top ten topics identified by scoping survey. Approximately 40 topics were ranked by respondents on a scale ranging from 0 (not important) to 5 (extremely important). Values represent average ranks.

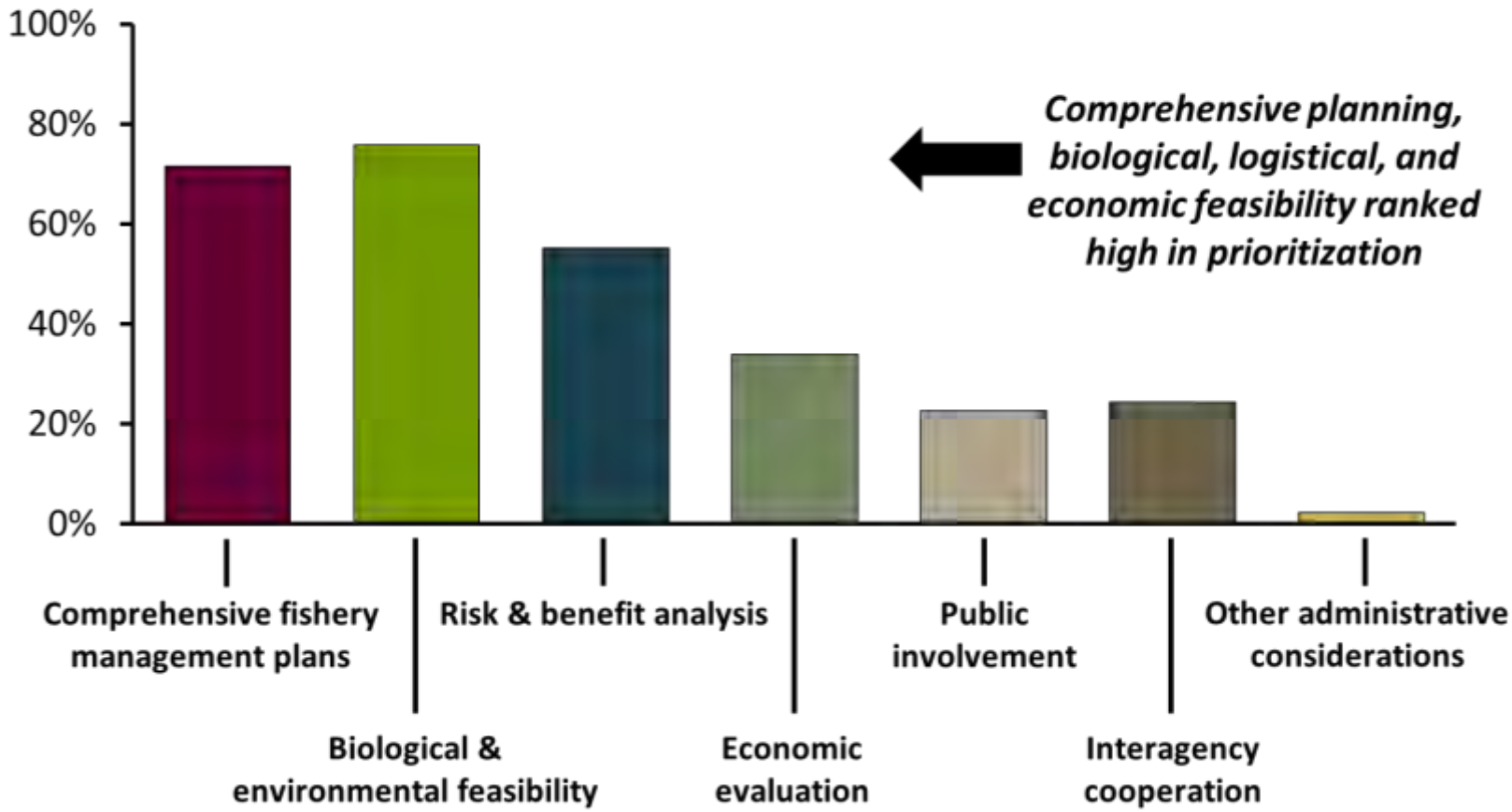

Figure 3. Elements of decision-making process described in "Considerations for the Use of Propagated Fish in Resource Management" ranked according to the priorities identified by respondents to the scoping survey. Values represent the percent of respondents indicating the various elements were among the three most important considerations in determining whether or not to initiate a stocking program.

Appendix I, Considerations for the Use of Propagated Fishes in Resource Management

In the following tan-colored pages, the full-text of "Considerations for the Use of Propagated Fishes in Resource Management" (Mudrak and Carmichael 2005) resulting from the "Propagated Fishes in Resource Management (PFIRM)" process is provided.

Considerations for the Use of Propagated Fishes in Resource Management

Vincent A. Mudrak and Gary J. Carmichael

American Fisheries Society

Bethesda Maryland

2005

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Preface

The stocking of propagated fishes has been a fisheries management tool for North American resource managers for more than a hundred years. During that time, the roles of propagated fish have been deemed to be important for addressing and enhancing opportunities to improve recreational fishing and restore depressed fish populations. However, over the last 30 years, some of these efforts have been challenged as being environmentally risky or ineffective and have thus been under careful scrutiny. The American Fisheries Society (AFS) proceeded to examine emerging issues dealing with the risks and benefits of fish stocking practices. The Fish Culture Section and Fisheries Management Section responded by conducting a symposium to answer the question "Fish culture—fish management's ally?" Accordingly, the first of three major symposia directed at this issue took place in 1985, at Lake of the Ozarks, Missouri. It was titled "The Role of Fish Culture in Fisheries Management" (Stroud 1986).

Nine years later, AFS decided to formally revisit the same issues. The rationale for conducting a second symposium resulted from advances in scientific capabilities and information and continued declines in fisheries resources. Increased political pressure from the scientific community demanded that resource management should be based on science. Moreover, resource management was being looked at comprehensively from an ecosystem approach. This new approach included the evaluation of complex relationships between fishes and their aquatic habitat and interactions of target species with the full assemblage of life forms within the biological community. Accordingly, AFS again stepped forward to address the risks and benefits associated with fish stocking practices. This time, AFS decided to address the fisheries issues using a two-step approach. To accomplish the first step, a symposium, "Uses and Effects of Cultured Fishes in Aquatic Ecosystems," was conducted March 1994 in Albuquerque, New Mexico. The second step was accomplished by inviting all North American fisheries resource management agencies to participate at a facilitated workshop, July 1994, in Denver, Colorado. The final product was a comprehensive set of considerations, endorsed by AFS, for the use of cultured fishes (Schramm and Piper 1995).

At the turn of the millennium, AFS asked the question "Was it time to revisit the issues again?" The answer from the 2001 AFS Governing Board was affirmative, largely due to continued advances in knowledge and new scientific capabilities to analytically study fishes and their population dynamics. It was also due to the

subsequent changes in resource management philosophy that more strongly embraced conservation genetics and other conservation values associated with an ecosystem management approach. The American Fisheries Society decided to repeat the 1990s two-step process. But this time, AFS also made the determination to ensure that all symposium and workshop information would be backed by scientific data. The American Fisheries Society appointed a steering committee to guide the process. Ten AFS sections focused on the theme of science-based fisheries management and ensured that science-based decision making would be emphasized as the primary goal for quality assurance in fisheries management. Participating sections were Estuaries, Fish Culture, Fish Health, Fisheries Administrators, Fisheries Management, Genetics, Introduced Fish, Marine Fisheries, Physiology, and Water Quality. The symposium steering committee generously provided their time, energy, and abilities to accomplish the successful symposium and follow-up workshop.

The papers from the symposium "Propagated Fish In Resource Management" (PFIRM) were peer reviewed and published by AFS (Nickum et al. 2004). The symposium papers represent state-of-the-art knowledge for the effective use of fish culture as a tool for fisheries resource management. These papers, coupled with interactive dialog at the symposium, were used to create an Internet Web survey to set the stage for the second step of the fact-finding process—the PFIRM workshop.

The AFS workshop "Propagated Fishes In Resource Management" was conducted June 2004 in San Antonio, Texas, and resulted in this publication. The science-based findings from the symposium and workshop serve to not only define appropriate roles for propagated fishes, they also delineate biological constraints. Accordingly, the question posed 30 years ago, "Fish culture—fish management ally?," can be answered in the affirmative. But the findings also demonstrate that the affirmative may involve a caveat: stocking programs should be well planned and aligned with comprehensive, science-based, fisheries resource management plans.

Vincent A. Mudrak

Co-Chair, PFIRM Steering Committee

Vincent A. Mudrak was Co-Chair of the AFS Steering Committee for Propagated Fish in Resource Management (Co-chaired with Gary Carmichael). He is the Director of the Warm Springs Regional Fisheries Center, U.S. Fish and Wildlife Service, Warm Springs, Georgia. He has been actively involved in the effective use of fish propagation strategies for resource management, especially as they relate to species recovery, rehabilitation of depleted native populations, and enhancement of fishery restoration programs.

Acknowledgments

Dedicated efforts of many folks were needed to plan, prepare, and stage this workshop and to prepare or update a set of functional and useable guidelines concerning the use of propagation in fisheries management. The 2003 symposium, Web survey, and follow-up 2004 facilitated workshop, "Propagated Fishes in Resource Management," were a success due to diligent hard work and commitment of the steering committee and many volunteers. Sponsors were the American Fisheries Society (AFS), U.S. Fish and Wildlife Service, and Canada Department of Fisheries and Oceans. Group Solutions, Inc. of Alpharetta, Georgia served as paid consultants to the workshop and hosted Web surveys, served as computer technologists, and facilitated the San Antonio, Texas meeting.

I had the pleasure of continuing to work with Vincent A. Mudrak as co-chair of this effort. His self-motivation, positive outlook, and professional work ethic helped guarantee success of the project. He went the extra kilometer—from Apache Tears, Arizona to White Sturgeon, Idaho; Riverwalk, Texas; and beyond. His energy supported me and the steering committee and his knowledge of the AFS governing board and the fisheries professional community led to the workshop and guidelines rewrite successes. His consensus-building nature allowed for very disparate viewpoints to be in the same venue, and he once again allowed various engines to be muffled with civility while advocating science-based resource management. His attention to detail insured the devil out.

Thanks go to AFS section representatives who served as steering committee members during the workshop: Estuaries, Dorothy Leonard; Fish Culture, Pat Mazik; Fish Health, Chris Moffitt; Fisheries Administrators, Virgil Moore; Fisheries Management, Dirk Miller; Genetics, Anthony Gharrett; Introduced Fishes, Cindy Kolar; Marine Fisheries, Mary Fabrizio; Physiology, Don MacKinlay; and Water Quality, Tom LaPointe. The AFS at-large representative was S. Adam Fuller. Ex-officio members of the steering committee were AFS Executive Director Gus Rassam, AFS President Ira R. Adelman, and past presidents Fred Harris, Ken Beal, and Carl Burger.

Texas Department of Parks and Wildlife and AFS Texas Chapter served as workshop hosts. As Phil Durocher's representatives, Paula Hawkins, Gary Garrett, and Todd Engeling did an outstanding job of coordinating the local arrangements for the symposium. Additional assistance with local arrangements was provided by Bill Provine, Mike Ray, Gerald Kurten, Larry McKinney, and Gary Saul.

The workshop committee deserves special thanks for all the tasks of team-leading and coordination as well as guidelines revision. Virgil Moore, Cynthia Kolar, Pat Mazik, John Nickum, Dirk Miller, S. Adam Fuller, and Don D. MacKinlay contributed enormous amounts of time, skill, and technical expertise to group leadership and evaluations of group outputs. AFS staff members Betsy Fritz and Aaron Lerner also made very valuable contributions of time and talent.

Workshop and publication finances were coordinated by AFS Executive Director Gus Rassam, Betsy Fritz, and steering committee co-chair Vince Mudrak. Contributors include the Canada Department of Fisheries and Oceans, the U.S. Fish and Wildlife Service, the International Association of Fish and Wildlife Agencies (Multi-State Conservation Grant), and the AFS governing board. Also, several AFS sections contributed to steering committee member travel.

Gary Carmichael

Co-Chair, PFIRM Steering Committee

Gary Carmichael was Co-Chair of the AFS steering committee for "Propagated Fish In Resource Management." He was the Research Leader at the U. S. Department of Agriculture, Agricultural Research Service, Catfish Genetics Research Unit, Stoneville Mississippi and then Director of the Mora National Fish Hatchery and Technology Center, U.S. Fish and Wildlife Service, Mora, New Mexico prior to his retirement from Government service in December 2002. Like Vince Mudrak, he has been actively involved in the effective use of fish propagation in resource management, especially as it relates to species recovery, rehabilitation of depleted native populations, and enhancement of fishery restoration programs. He now serves society as a farmer at Doe Run Farms and Conservation, Doe Run, Missouri.

Background

The American Fisheries Society (AFS), in its professional capacity as an organization devoted to fisheries conservation, has been continuously working with fisheries managers to evaluate issues surrounding the effective use of propagated fishes in aquatic resource management. This evaluation work is not new. Indeed, it began more than 20 years ago in 1985, at Lake of the Ozarks, Missouri, where fish culture and fisheries management sections responded by conducting a symposium to answer the question "Fish culture—fish management's ally?" It was titled "The Role of Fish Culture in Fisheries Management" (Stroud 1986). Again, in 1993, AFS re-examined the fish stocking issues, based on a "new" ecosystem approach to resource management. This examination was accomplished at the symposium and workshop entitled "Uses and Effects of Cultured Fishes in Aquatic Ecosystems" (Schramm and Piper 1995). Then, at the turn of the century, AFS decided again to review the stocking issues, based on new scientific findings. Accordingly, AFS formed a new steering committee, which selected a multi-faceted process to examine the issues. That process included three important information gathering components: (1) a symposium, (2) an Internet Web survey, and (3) a facilitated workshop. The following descriptions characterize the process.

Symposium and Proceedings

The American Fisheries Society worked with the U.S. Fish and Wildlife Service, Idaho Department of Fish and Game, and Canada Department of Fisheries and Oceans to hold a symposium that challenged fisheries management paradigms involving the use of cultured fishes. This symposium, "Propagated Fish In Resource Management" (PFIRM), was conducted June 2003 in Boise, Idaho. The symposium identified information gaps in technical knowledge and debated the propriety of assumptions and current theories being used to make resource management decisions. It also attempted to reconcile philosophical differences that have become an obstacle to science-based resource management. Ten AFS sections collaborated in this effort that showcased several themes:

- Decision Making and Risk Evaluation in Fish Stocking.
- Fishery Perspectives and Managing for Multiple Goals.
- Managing for Imperiled Species and Introduced Species.
- Differences between Propagated Fish and Wild Fish.

- Fish Health, Environmental Health, and Hatchery Reform.
- Propagated Fish and Resource Management—Science and Agency Perspectives.

The Boise symposium was much less controversial than the 1994 symposium in Albuquerque, where fisheries professionals with markedly different resource conservation views often "butted heads." Boise symposium participants worked toward a common goal of achieving fishery resource benefits while minimizing associated risks through rational and comprehensive management practices. The manuscripts from the PFIRM symposium have been published by AFS as a symposium proceedings (Nickum et al. 2004). The symposium showcased 84 presentations that led to the publication of 52 peer-reviewed publications in the proceedings.

PFIRM Web Survey

The PFIRM symposium discussions identified several issues that remained contentious or controversial to fisheries managers. These issues were captured and expanded as fisheries management scenarios. Invitations were sent out by AFS to fisheries management agencies and others, and survey responses came from states, provinces, tribes, industry, AFS units, and federal agencies from the United States and Canada. The findings from the Web survey were used as the starting point for formal discussions and group interactions at the PFIRM facilitated workshop.

Responses to the Web survey were compiled by an AFS contracted facilitator (Group Solutions Inc.). Results of the Web survey were analyzed and prepared by Group Solutions Inc. for an interactive Web conference. Accordingly, the results were further reviewed by the AFS steering committee and by a core of invited representatives from tribes, industry, academia, and government agencies. Initial findings identified several fisheries resource management issues that never reached consensus and needed clarification and/or required additional scientific scrutiny.

The compiled results from the Web survey were summarized and chart-graphed. They reflected the philosophical and professional ideals of the individuals who completed the survey. These findings from the Web survey set the stage for the facilitated workshop by characterizing specific areas for facilitated group discussions and other contentious issues (see Appendix 1).

PFIRM Facilitated Workshop

The PFIRM workshop was hosted by Texas Parks and Wildlife and AFS Texas Chapter, June 2004, in San Antonio, Texas. The workshop was professionally facilitated by Group Solutions Inc. (facilitation was funded by a grant from the International Association of Fish and Wildlife Agencies). More than 40 participants worked in harmony, through focus group interactions and through computer-assisted media. The participants included representatives from 10 AFS sections and also included resource management people from a diverse cross section of North America (see Appendix 2). Group Solutions Inc. used consensus building techniques to assist the PFIRM workshop participants in the development of a first-draft revision of AFS guidelines for the use of propagated fishes in resource management.

AFS Symposia

1. Fish Culture in Fisheries Management (1986)
2. Uses and Effects of Cultured Fishes in Aquatic Ecosystems (1995)
3. Propagated Fish in Resource Management (2004)

I. Introduction

The American Fisheries Society established a steering committee that included two co-chairs and official representation from 10 AFS sections. This steering committee (listed below) was charged with the responsibility to review and evaluate the status of fisheries management in 2003–2004, as related to the stocking of propagated fishes in resource management.

The specific purpose of this work was to refine, revise, and update the AFS guidelines delineated and written in 1994, entitled "Considerations for the Use of Cultured Fishes in Fisheries Resource Management" (Schramm and Piper 1995).

The desired goal was to provide fisheries resource managers with a contemporary tool with which they can strengthen their repertoire of management options. This publication, "Considerations for the Use of Propagated Fishes in Resource Management," is meant to serve as an aid in decision making and comprehensive resource planning.

Resource managers are encouraged to use these findings as a tool and to recognize the Propagated Fishes in Resource Management workshop as an important event that helped to improve and harmonize science-based fisheries management.

AFS PFIRM Steering Committee Co-Chairmen

Vincent Mudrak and Gary Carmichael

AFS Sections and Their Representatives for the PFIRM Workshop

Estuaries	Dorothy Leonard
Fish Culture	Patricia Mazik
Fish Health	Christine Moffitt
Fisheries Administrators	Virgil Moore
Fisheries Management	Dirk Miller
Genetics	John Epifanio, Anthony Gharrett, and Adam Fuller (at large)
Introduced Fish	Cindy Kolar
Marine Fisheries	Mary Fabrizio
Physiology	Don MacKinlay
Water Quality	Tom LaPointe

The AFS steering committee convened June 2004 in San Antonio, Texas, with a body of invited fisheries professionals that represented a diverse cross section of North American fisheries interests—federal, state, province, tribal, academia, industry, and nongovernment organizations. Through a professionally facilitated process, these men and women spent long hours addressing stocked fish issues and then reviewing and refining the AFS guidelines. Although 11 years had transpired since the initial process took place in 1994, the final recommendations for new AFS guidelines were surprisingly similar. Other than additional wording for clarification, and some reorganization of content, substantive changes to the guidelines were relatively minimal. Nevertheless, the facilitator captured group dynamics and participant dialog that demonstrated the need to include addenda that corresponds to workshop findings and statements-of-need. The workshop findings are reported as separate sections in this document, but a concise analysis is provided below.

1. Participants recognized and endorsed the philosophy that fisheries management strategies should reflect the needs of the aquatic habitat and its extant biological community. In this regard, a concept was developed by a workgroup to help characterize the risks of stocking, as related to the current biological community and habitat conditions. (Subsequent AFS workshops might reexamine this issue and possibly use this management concept to set the stage for improved dialog among dissenting individuals.)

2. Participants accepted, with caution, a second management option aligned with management of different quality habitats. This option was the acceptance of the careful stocking of nonindigenous fishes in highly altered environments where resident aquatic species assemblages have become markedly different (from prealtered ecosystem habitat) and the traditional fisheries species are no longer represented in the aquatic community. (Subsequent AFS workshops could reexamine this as a dynamic issue.)

3. Participants debated whether or not they should expand the focus of the guidelines to include the full spectrum of propagated aquatic species that might be used for resource management purposes. The steering committee noted that the term fishes was meant to be inclusive. Accordingly, in the 2005 AFS guidelines that follow, the term "fishes" means fish, shellfish, and other aquatic propagated species that might be stocked for resource management purposes. (Subsequent AFS workshops could reexamine this issue.)

4. Participants reacted differently to the use of the word "naturalized." Several participants continued to challenge the propriety of using the terms "native"

and "naturalized" fish populations in the same sentence. Participants agreed that the terms are not equivalent entities, and consensus was reached that each may have a legitimate place in resource management—manifesting different sets of risks, benefits, and costs. Each of the terms were retained in the same sentences, as per the 1994 AFS guidelines. (Subsequent AFS workshops should reexamine this issue and give consideration to the term "established.")

5. Participants at the PFIRM workshop (as well as respondents to the PFIRM Web survey) were not always in agreement with terminology meanings. At times, subtle but important communication voids occurred. The root of the problematic issue was the inconsistent use of some fisheries management terms. This publication attempts to clarify the management terms that might be misleading. Terms like recovery, restoration, rehabilitation, wild, native, and naturalized have drawn particular attention, and these are addressed in this publication (Appendix 3). Accordingly, until management definitions are standardized by AFS, and until their acceptance is universal among North American fisheries professionals, the steering committee cautions that strong consideration should be given to clearly defining the chosen management terms intended for use in comprehensive fisheries resource management. (Subsequent AFS workshops should reexamine this issue.)

6. Participants concluded that managing an ecosystem for biological productivity andfunction is difficult, especially while preserving highly imperiled populations. Such management decisions may not be ours (as fisheries professionals) to make. In many cases, society has already given direction or made choices through legal mandates— such as the U.S. Endangered Species Act. The team recommended that our fisheries management responsibility in these situations is to minimize the human impacts on aquatic resources until other opportunities arise or until an informed decision has been made to "give up" on the species. Participants were unable to define criteria for determining when it is time to "give up." But fisheries managers agreed that they can assist threatened and endangered species conservation by assessing population status and by providing costs, benefits, and likely outcomes to proposed management options. (Subsequent AFS workshops should reexamine this issue.)

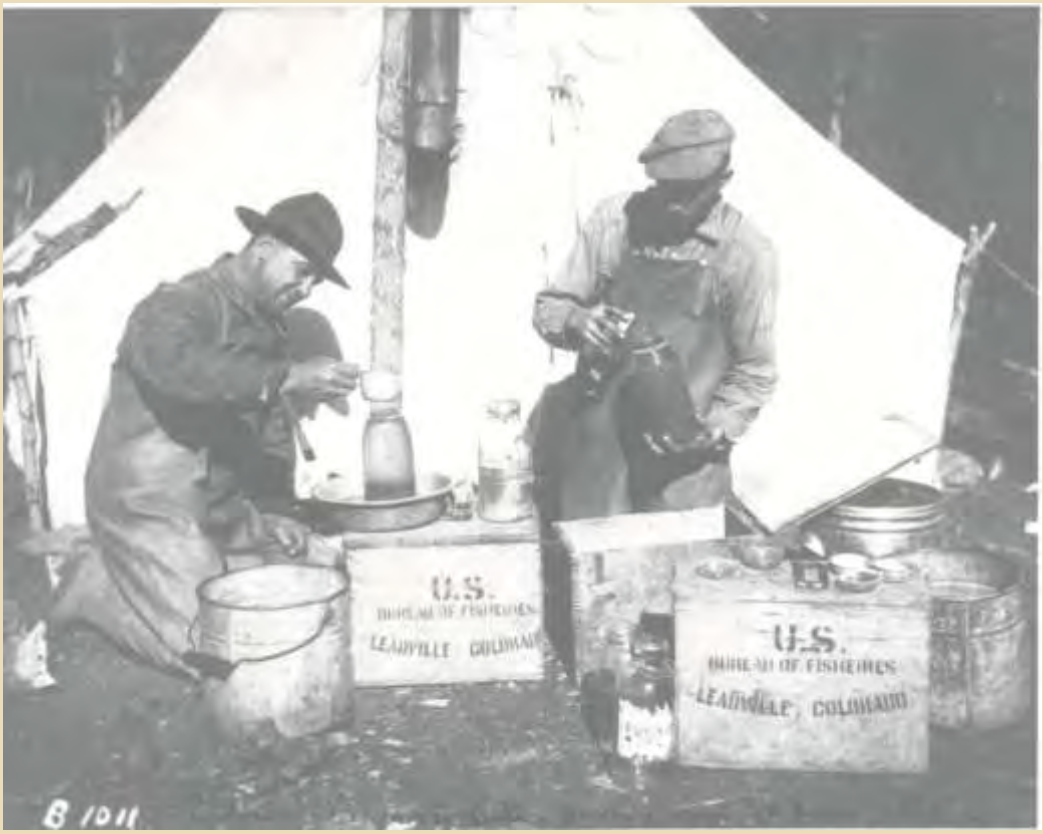
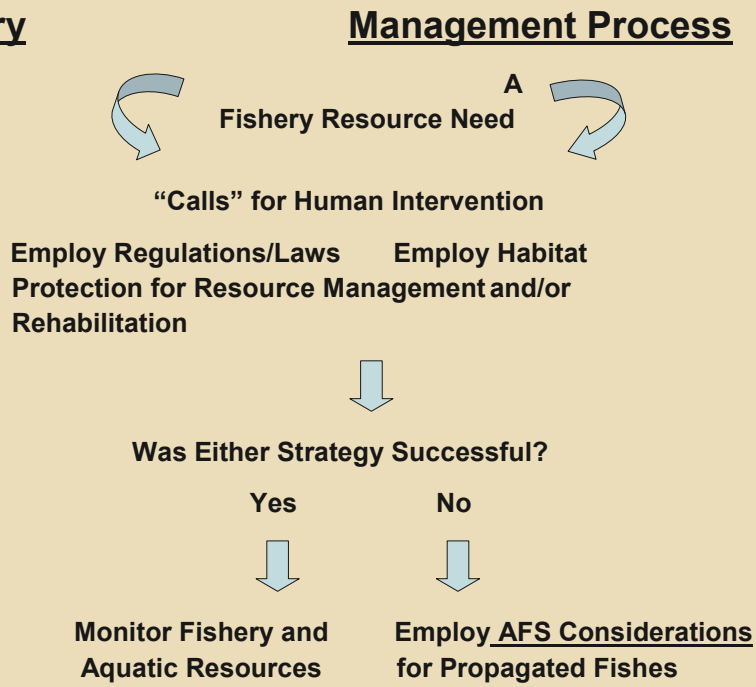


Figure 1. Leadville Colorado hatchery operations, early 1900s. Photograph from D.C. Booth Historic National Fish Hatchery, Spearfish, South Dakota.

II. Considerations for the Use of Propagated Fishes in Resource Management



Comprehensive Fishery Management Plans

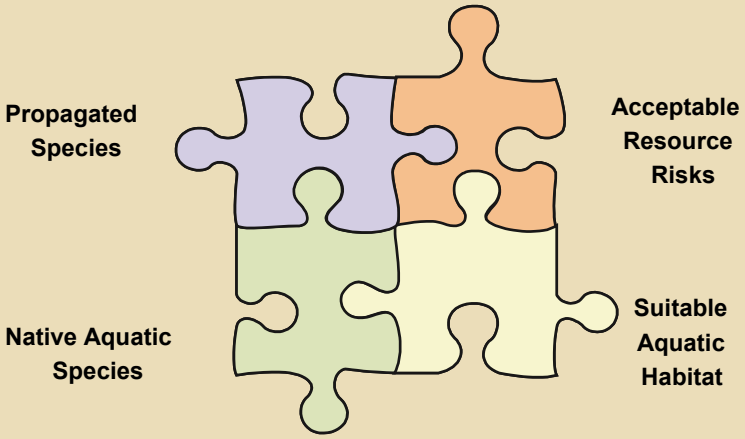
Decisions to stock propagated fishes are determined by the management authority that has legal jurisdiction over the aquatic system. The management authority is encouraged to use a comprehensive fishery and aquatic resource management planning process. The comprehensive management planning process should recognize and consider alternatives to stocking and include inputs from various resource partners. When stocking is delineated, specific goals and objectives should be considered. Objectives should be specific, measurable, accountable, realistic, and time-fixed (Meffe et al. 2002).

Some considerations for comprehensive planning are as follows:

1. Determine who needs to be included in a comprehensive fishery and resource management planning process (general public, local agencies, states or provinces, federal government, tribes, nongovernment organizations, impacted or impacting industries, etc.).

2. Establish clear, measurable management goals and consider possible courses of action that might be taken in lieu of stocking.
3. Include considerations of the benefits, costs, and risks.
4. Evaluate project feasibility in terms of biological, economic, and political factors. Reassess benefits as reconciled against potential effects—both positive and negative.
5. Articulate management goals using consistent terminology and describe objectives clearly in a format that the general public can understand.
6. Define measurable objectives for the management goal (whether put-and-take fishery, put-grow-and-take fishery, fishery restoration, population rehabilitation, etc.) and provide a clear statement on whether the stocking program is intended to be long-term or short-term.
7. Employ an adaptive management process that includes monitoring of the work and objectives and provides an opportunity to adjust the stocking process, based on scientific evaluation and management inputs.

Biological and Environmental Feasibility Involves a Comprehensive Analysis



Biological and Environmental Feasibility

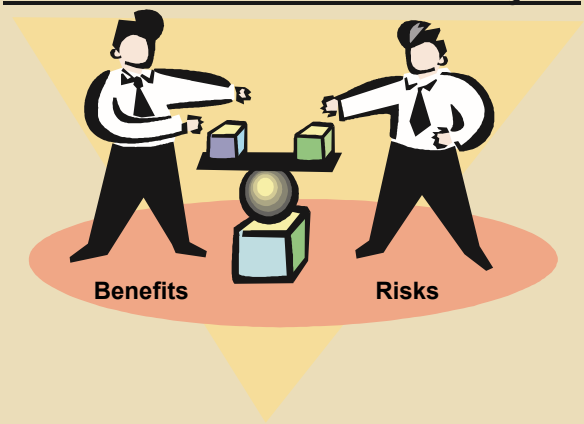
Decisions to stock propagated fishes should be predicated on science-based evaluations that determine whether the environment can support the propagated fish and whether stocking will achieve positive management objectives. The

following considerations will help determine whether the management objectives will be achieved using stocked fishes.

1. Complete watershed surveys and fish population assessments to determine the status of fish populations, carrying capacity, and other environmental and biological considerations.
2. Consider the overriding questions: "What is the driving force to stock propagated fish into the existing biological system, and is there a compelling need that warrants the decision to stock propagated fishes in a particular aquatic habitat?"
3. Evaluate the status and trends of existing fish populations to determine whether there is a need for stocking.
4. Determine which fish species to stock that is most appropriate and compatible with existing native species and is a species that will achieve desired management benefits, while also bringing the risk of negative genetic impact and ecological interactions to acceptable levels.
5. Conduct pilot studies or review data from similar stocking programs in similar habitats to evaluate survival, growth, and reproduction of stocked fish, to presumptively identify positive or negative impacts of stocking, and to develop stocking protocols.
6. Ensure that selected propagated fishes are appropriate for conservation programs dealing with species recovery, population rehabilitation, or fishery restoration propagated fish. (Example: for such conservation programs that employ stocked diadromous fishes, a recruitment bottleneck may be in another ecosystem [ocean, migration corridor, or freshwater].)
7. Monitor harvest and biological community of aquatic systems to predict carrying capacity and stocking rates.
8. Determine opportunities for habitat restoration to ensure that native and naturalized fish populations are sustained.
9. Where habitat restoration and native species management are unlikely due to highly altered environments, consider native species first before introduction of compatible nonindigenous species.
10. Compare environmental requirements of cultured species considered appropriate candidates for stocking with habitat conditions (inducing fish populations) to predict the suitability of the habitat for the candidate species.

11. Assess hatchery production capability to meet fishery management objectives, while including benefit-cost-risk analysis.

A Prerequisite for Propagated Fishes Involves Benefit & Risk Analysis



Risk and Benefits Analysis

Scientific evaluations should be conducted to determine what effects stocked fishes may have on the environment, native and naturalized biota, and humans. The following considerations may be useful in determining the potential positive or negative effects of stocking cultured fishes. These considerations should be reconciled under a comprehensive management plan that assesses various management strategies (including stocking) and weighs aligned risks, benefits, and costs.

1. Consider most probable beneficial or harmful effects on diversity of native fishes and their aquatic habitat, with particular emphasis on threatened and endangered species.
2. Identify and evaluate potential beneficial or harmful genetic effects on native fish if interbreeding of cultured fish with native fish if possible.
3. Evaluate potential beneficial or harmful effects (physiological, behavioral, health, genetic) of cultured fishes on population abundance and population variables, such as size structure, growth rate, recruitment rate, and mortality rate, of native and desired naturalized fishes.

4. Evaluate the history of target stocked species and other fish transplants into the fishery to determine the history and genetic composition of existing fish populations.
5. Determine the potential for propagated fishes to introduce virulent disease agents to native fishes and desired naturalized fishes. Where appropriate, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the International Council for the Exploration of the Sea guidelines should be consulted (CITES 1975; ICES 2005).
6. Evaluate the disease susceptibility of wild fish populations (host, pathogen, environment) and determine the potential for pathogenic agents to establish a disease epizootic in the wild.
7. Evaluate the relative occurrence of fish disease agents in the wild and their potential interactions and impacts on propagated fishes.
8. Evaluate potential interspecific and intraspecific behavioral interactions, such as competition, predation, changes in reproductive behavior, that would have significant adverse effects on native and desired naturalized fishes.
9. Determine the potential for stocked fish to invade nontarget areas or expand their range to nontarget habitats.
10. Identify potential beneficial or harmful environmental effects of fish propagation, such as water discharge, broodfish collection, and fish escapement, on the local aquatic community.
11. Evaluate potential beneficial or harmful effects of increased and directed public use of aquatic environments on biotic communities and human communities.
12. Evaluate public health issues possibly important for hatchery operations and propagated fishes, as might be related to external factors, such as bioaccumulation of chemical contaminants and control of hatchery mosquitoes with West Nile virus.
13. Evaluate the potential for the stocked fish to persist and flourish without continued stocking.
14. If the cultured fish will be a previously untried introduction, American Fisheries Society Position Statement #15 (see Appendix 4) on introductions of aquatic species (Kohler and Courtenay 1986) should be considered.

15. Consider specific guidelines, such as CITES, and/or a risk management process like the adoption of the Hazard Analysis and Critical Control Point approach used by the U.S. Fish and Wildlife Service (http://haccp-nrm.org) to minimize the potential for introduction of nontarget species (i.e., native, nonnative, or exotic species brought in with shipments of target species.)

16. Implement and continue monitoring activities to evaluate effects after stocking.

17. Develop an adaptive management process to acquire data to answer set of questions that will determine if fish stocking goals are being accomplished responsibly and in the most cost efficient manner.

18. Ensure that species stocked into altered habitats are compatible with the physical, chemical, and biotic conditions of the altered habitat. In determining the species to be stocked,

    — primary consideration should be given to native species;
    — if no native species can meet management goals, select the nonnative species best suited to use the productivity of the altered habitat;
    — if nonnative species are used in the altered habits, consider their impacts to existing native species and desired naturalized species; —consider the option of stocking sterile fishes.

Economic Evaluations Should Include Many Different Factors

Economic Evaluation

Fisheries management strategies have benefits, risks, and costs. Benefits often relate to society, such as angling days, fish yield, and public access. Benefits also include ecosystem function, stability, cultural value, and productivity. Costs include operations, staff, and capital investment, and depending on the impacts of stocked fish, costs of biological, habitat, or social effects may also be incurred. Although some measurements remain difficult (such as what a "species" is worth), benefits and costs should be comprehensively evaluated. Similarly, associated risks also need to be delineated and integrated into the decision-making process.

1. Consider comprehensive analysis of benefits and costs for fish propagation operations and the resultant stocking, and ensure that a full spectrum of management and economic issues are included in the analysis. (Examples: cost or detriment of stocking to other programs; social expectations and economic loss associated with doing nothing; management costs associated with escapement of nontarget species; and political realities and value of public opinions).
2. Use a fishery management planning process that includes the assessment of risk, benefits, and costs. Recommend the stocking of propagated fish where benefits are cost effectively achieved within an acceptable level of risk.
3. Economic assessments for managing stocked fisheries in highly altered habitats should consider the special interests of the entities that are currently benefiting from the alteration (Example: mitigation stocking programs).

Our Public Clients Have Both a Right and Responsibility to Be Involved in Aquatic Resource Management

Public Involvement

The public has the right to make value judgments concerning fisheries management. Along with fisheries managers, the public also has the right and responsibility to enjoy, protect, enhance, and conserve fisheries resources. As such, the public has a role to assist resource agencies in the decision-making process to use (or not use) propagated fishes for fisheries resource management. The following considerations are intended to help resource managers maintain or increase public acceptance of stocking propagated fishes as an effective management tool.

1. Keep the public informed about pending changes in fisheries management, encourage dialogue on potential changes, and provide a forum for public input. Moreover, when appropriate, educate the public on legal and interjurisdictional issues, including Native American treaty rights and responsibilities.
2. Make efforts to inform the public about the biological and social benefits of stocking fishes or not stocking fishes. Ensure that the public understands the fishery management prognosis for the full range of potential alternatives—each with different outcomes, costs, and risks.
3. Determine public consumptive and nonconsumptive uses of the fishery. If fishes are stocked for recreational fishing, then angler preferences, angler accessibility, uniqueness of the fishing opportunity, and potential changes in public use should be considered.
4. Broaden the support base for propagation of fishes for restoration of harvest fisheries, rehabilitation of unique fish populations, and recovery of highly imperiled aquatic species. Public taxpayers and resource managers should communicate the values and goals of these conservation programs, which may differ markedly from the values and goals of recreational fishing programs.
5. Develop outreach programs and encourage public participation in fish stocking programs. Use fish stocking events as outreach opportunities to explain the fisheries management plan and stocking objectives to the general public.
6. Ensure that the evaluation of stocking programs includes outside peer review and public input and that the authorized management agency communicates to partners a prospective timetable when the stocking will be evaluated.

7. Ensure that public education and public input are part of the administrative and regulatory process used for decision making, whenever a comprehensive resource management plan includes the stocking of propagated fishes.

Good Interagency Cooperation Involves Respect for Political, Social, and Economic Differences

Interagency Cooperation

Stocked fishes, or the propagation operations that produce fish for stocking, can have direct and indirect biological, social, and economic effects on other political or geographic jurisdictions. The following considerations may help develop cooperative management strategies and contribute to achieving management objectives when such cases occur.

1. Share technical science-based fisheries information to strengthen interagency coordination and interjurisdictional fisheries monitoring programs. Recognize regulatory and legal differences for Canada, the United States, Mexico, tribes, provinces, states, and territories.
2. Encourage jurisdictional authorities that have control over commercial harvest to communicate with fishing industry, and recognize that economic pressures to harvest target fishes prior to achieving their desired restoration population level must be addressed before stocking programs are put in place.
3. Inform and seek concurrence from other fisheries management jurisdictions where resources may be impacted by stocked fish. Determination of

jurisdictions solicited for concurrence should consider possible migration or movement patterns of the stocked species.

4. Use existing interjurisdictional fisheries management processes to ensure that stocking programs are cost effective and compatible with the management goals of all potentially affected stakeholders.

Interjurisdictional Fisheries Management Includes High-Level Administrative Communications

Other Administrative Considerations

The aforementioned considerations identify specific biological, social, economic, and political issues that should be considered by fisheries managers in their comprehensive planning process and subsequent decisions involving the potential use of stocked fishes. The following list of issues are redundant but are important and re-emphasized. They may be particularly useful as an administrative reminder for resource managers developing fisheries management plans that include stocking propagated fish as part of an interjurisdictional management strategy.

1. Define specific management objectives to be accomplished by stocking propagated fishes, and identify criteria to determine how success or failure will be determined in terms that can be understood by all stakeholders.

2. Recognize that various authorities may have established legislated processes which have legal primacy to fully govern the requirements of some fisheries

management plans and objectives. Examples include Endangered Species Act issues; tribal/First Nation fishing rights; and Canadian, U.S., and Mexican compacts.

3. Identify regulations and other management actions that are needed to maximize the chances of successful use of propagated animals in the context of ecosystem management.

4. Develop and maintain administrative and operational guidelines for fish stocking.(What if target endangered species recovery objectives impact another listed species? How will experimental population assessment be conducted within interjurisdictional U.S.–Canadian waters?)

5. Require agencies that produce fish for stocking to have comprehensive management plans that encompass genetic characterization of hatchery fishes, avoidance of fish pathogens, and minimized risk of infestation with an undesirable nuisance species.

6. Recognize the complexity of interjurisdictional fisheries management, and consider all resource partners (federal, province, state, tribal/First Nation, etc.) and their existing fishery resource agency strategic plans, guidelines, policies, regulations, and laws, prior to engaging in fish-stocking programs.

7. Measure stocking effectiveness through scientific evaluations, and make subsequent management decisions commensurate with evaluation findings and fishery management goals (such as discontinuation of supplemental stocking if self-sustaining populations have achieved levels sufficient to meet management goals).

8. Avoid using management terms that might be misleading. Terms like recovery, restoration, rehabilitation, wild, native, and naturalized have specific meanings (see Appendix 3), and their misuse has drawn particular attention. Until management definitions are officially standardized, program administrators should clearly define their resource management terms, as used in comprehensive resource management plans.

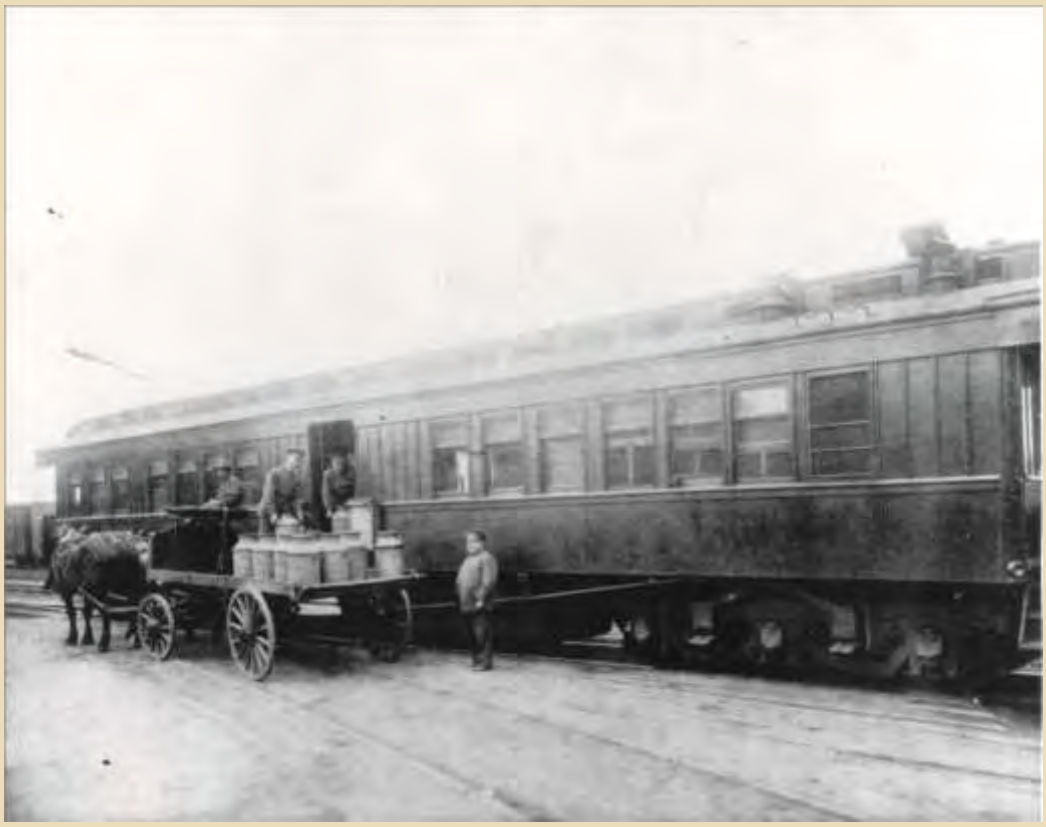


Figure 2. Railroad cars were used to transfer fish across North America in the early 1900s. Photograph from D.C. Booth Historic National Fish Hatchery, Spearfish, South Dakota.

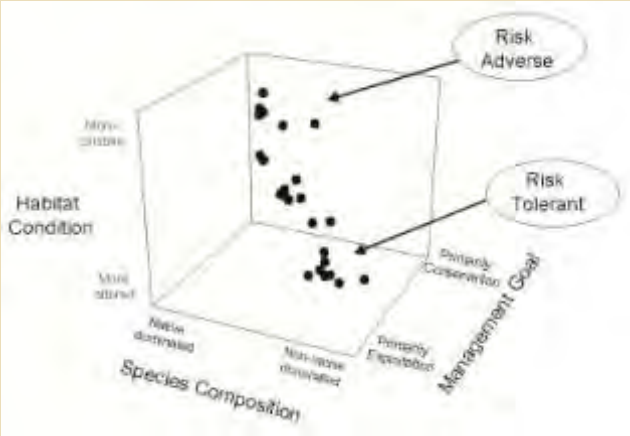
III. Work Group Findings

A team of more than 40 North American stakeholders met in San Antonio, Texas to resolve contentious issues dealing with stocked fishes in resource management. This team represented a broad array of resource management interests and opinions. A professional facilitator was hired to guide the team which was challenged with many pages of Web survey findings and hot topics that emerged from the 2003 PFIRM symposium in Idaho.

The team used an interactive process that enabled participants to simultaneously and anonymously comment on issues via personal computer. The team split into subgroups to explore individual assignments. These included the following topic issues: (1) Risk and Resource Assessment; (2) Outbreeding Depression; (3) Propriety of Stocked Fishes; and (4) Fisheries Management Terminology.

Risk and Resource Assessment

The team led by Virgil Moore and Cindy Kolar considered risk management to be a function of the resources at risk, and the relative values placed upon habitats and their biological communities. The team considered a relationship for fish management that evaluated habitat variation (from pristine to highly altered) and the biological fishery resource community (from self-sustaining native species to stocked nonindigenous species). The team expressed this function graphically with a model based on two criteria: habitat condition (from pristine to altered) and type of introduction (native or nonnative). Within this continuum, the habitat environments house both native and nonnative species. Thus, a pristine environment may be dominated by either native or nonnative species, much the same way that a highly altered biological environment may be. This produces four distinct types of biological environment: pristine native, pristine nonnative, altered native, and altered nonnative. Depending upon the culture action (type of fish being introduced), the risk to the habitat and existing species may range from low to high. For example, in the case of sport fish, the introduction of a nonnative stock to a pristine, native fish environment could be considered a high risk, but the introduction of nonnative stock to a highly altered nonnative fisheries environment might reasonably be considered low risk.



Graphic by Cindy Kolar

Each introduction of aquatic organisms carries some risk of unintended consequences such as spread beyond the intended area, stock contamination, genetic effects on native species, or detriment to native species by predation, competition, or disease introduction. Some introductions of aquatic species result in populations that will persist for hundreds of years (e.g., common carp *Cyprinus carpio* or brown trout *Salmo trutta* in North America). Because of the potential for unintended consequences, risks associated with an introduction should be identified and considered prior to the activity, whether or not a formal risk assessment procedure is used. The AFS Policy Statement on Introductions of Aquatic Species (see Appendix 4) should be used as a guide to determine whether an introduction is appropriate.

Although the relative risk of a given introduction is situational, there are identifiable patterns in the level of risk that managers typically accept. Three important factors that affect the willingness of managers to release fishes into the environment include the condition of the habitat, composition of the current fish community, and the goal of fisheries management for the system. Management decisions tend to be risk adverse in pristine habitats dominated by native species where the primary management goal is species conservation. Management decisions tend to be more risk tolerant, however, in more altered habitats dominated by nonnative fishes where the primary management goal is exploitation of a particular harvest fishery.

All introductions require a minimum level of evaluation before the event and monitoring afterward. Accordingly, not all of the considerations listed in this document will need to be addressed. Some situations, however, have inherently higher risk associated with the release of aquatic animals. These situations require more thorough assessments to support a decision to proceed with the introduction.

In addition, more thorough monitoring should be conducted after the introduction to document any unintended consequences—not only for adaptive management to affect future management decisions, but also to determine whether further management intervention is necessary to minimize detrimental effects. In higher risk situations, therefore, more of the considerations listed in this document should be addressed. The specific considerations listed in this document that should be addressed for a given introduction should be determined by fisheries management professionals having knowledge of the potential risks.

Outbreeding Depression

The team led by Dirk Miller, Anthony Gharrett, and Adam Fuller considered the phenomenon of outbreeding depression as a genetic risk in fisheries management. The team leaders opened the discussion by explaining why outbreeding depression was elevated as a contentious issue for workgroup review.

The belief that "outbreeding depression" is a real and major genetic risk to wild fisheries resources was presented toward the end of the PFIRM symposium in Boise by a member of the AFS Genetics Section. This individual explained a viewpoint that outbreeding depression was a real and dangerous risk to wild populations especially when using propagated (and subsequently stocked to the wild) fishes in resource management. The individual went on to explain that "outbreeding depression" is very real and a potentially larger risk than "inbreeding depression" in the genetic make-up of wild populations. Scant scientific evidence was presented in proof that outbreeding depression had been widely proven in many fishes or in various and different resource management scenarios. Several members of the symposium audience took exception to the validity and scientific proof that outbreeding depression had been proven for fishes in North America. They argued that such an unproven concept, or concept minimally supported by scientific literature, was just another example of the "Chicken Little (the sky is falling) school of fisheries management." Participants were not offered proof of the magnitude of genetic risk with which outbreeding depression threatened wild fish populations. The symposium ended before any scientific papers were presented in support of or contradiction to the specific concept of outbreeding depression. These statements led to an emotionally intense discussion on scientific validity of this genetic concept, which was vehemently and emotionally argued by proponents and antagonists. Accordingly, outbreeding depression (as a genetic risk to wild fisheries resources)

was brought forward for review and discussion by workshop participants, consisting of fisheries scientists, managers, and administrators.

The symposium and workshop steering committee noted that this one issue, above any other, provided perhaps the greatest controversy offered by the symposium; yet no direct scientific evidence was offered in proof or rebuttal at the symposium. All members of the steering committee unanimously agreed that the controversial issue of outbreeding depression merited further discussion at the PFIRM facilitated workshop, to be held in 2004. The steering committee, therefore, included the outbreeding depression genetics topic in surveys to fisheries managers and administrators prior to the workshop. Specific fisheries management scenarios used to set management issues included outbreeding depression.

To ensure that the Genetics Section and workshop steering committee had representatives well versed in the scientific basis of and for outbreeding depression, the steering committee approached the Genetics Section to provide a potential list of scientists to represent the topic. The steering committee also approved the presence of an at-large workshop participant. This participant was selected because he has an extensive population and molecular genetics background yet has remained neutral in advocacy of population genetics issues. This selection was made to ensure that both sides of the audience from the Boise symposium would be represented. The at-large participant conducted a literature search on outbreeding depression in North American fishes and wild fish populations. A workshop workgroup was appointed to include both the genetics section member and the at large representative. This workgroup was charged by the steering committee to fully develop the issue in a manner such that AFS could be sure that the topic received fair and full discussion that was up to date with available scientific evidence. The intent was to remove the emotional effects of human bias and advocacy.

Scientific Background on Outbreeding Depression

Outbreeding depression is defined as a reduction in fitness, either through reduced survival or lowered reproductive success, of progeny from distant parents (Templeton 1987). There are two fundamental ways this phenomenon can occur. The first is by breaking down local adaptations by the "swamping" of any locally adapted genes. This occurs when adaptive gene complexes in one environment or population are simply displaced by the immigration of genes that are adapted a different environment or population. For example, selection in one population

might produce a large body size, whereas in another population small body size might be more advantageous. Gene flow between these populations may lead to individuals with intermediate body sizes, which may not be adaptive in either population. A second way outbreeding depression can occur is by the breakdown of physiological or biochemical compatibilities between genes themselves in the different populations. Both of these fundamental mechanisms of outbreeding depression have the potential to be operating at the same time. However, determining which mechanism is more important in a particular population is very difficult.

That vascular plants exhibit outbreeding depression has been well documented in many different species of plants (Fischer and Matthies 1997, Fenster and Galloway 2000, Keller et al. 2000, Montalvo and Ellstrand 2001, and Quilichini et al. 2001, to name a few). There have been but a few documented examples of this phenomenon in fish, such as in Gharrett et al.(1999). Yet, the phenomenon is heavily referenced as a potential causative agent responsible for many problems associated with restoration stocking programs—without any scientific investigations.

According to current scientific literature, does outbreeding depression exist? Can it affect any species? Is it an important consideration? How important? These were questions and topics put to the workshop subgroup. The subgroup achieved 100% consensus reaching conclusions that (1) Outbreeding depression can be real and that potentially any species could be affected, (2) The extent of outbreeding depression effects is difficult to predict, (3) Outbreeding depression is one of many potential genetic issues to be considered by managers, and (4) It is not necessarily of primary concern to fisheries resource managers.

While there is currently a nascent state of knowledge, the potential for outbreeding depression is a valid consideration, especially with regard to species conservation programs. Outbreeding depression offers little or no concern in put-and-take fisheries. The degree of risk would be dependent on specific management goals. With current technology, managers have the potential to identify genetic differences that may not represent meaningful biological differences. Conversely there may be observed biological differences that cannot be identified as a genetic difference. Managers need to identify and employ most appropriate genetic analysis. The degree of risk of outbreeding depression would be dependent on specific management goals.

The appropriate application of these guidelines is dependent upon the management context and the use of the best available science. The American Fisheries Society's genetics related guidelines are still acceptable (Schramm and Piper 1995). "When a species is stocked that has potential to interbreed with native or naturalized populations, appropriate genetic and biological analyses of existing populations should be conducted."

Propriety of Stocked Fishes

The team led by Pat Mazik and John Nickum was challenged with two questions.

1. Resource managers often desire fish that are physiologically and behaviorally adapted to certain environmental conditions. In terms of hatchery management, how can we ensure that stocked fish are appropriate for their fishery management plan?
2. Consider hatchery management practices in terms of benefits, risks, and costs involved with the stocking of appropriate fish. How do we know when the stocked fish are appropriate? What is inappropriate?

Discussions concerning the propriety of stocked fishes assume that the related decision of whether or not it is appropriate to stock fish at all has been answered affirmatively. Having decided that fish are going to be stocked in a given situation, fishery managers and fish culturists must then address several additional questions. These may include which species, what size, how many, which genetic characteristics, what behavioral characteristics and appearance, and whether or not the fish carry disease agents not established in the area to be stocked.

The first step in determining the characteristics desired in stocked fish is a specific management plan for the fishery. The management plan must be realistic biologically. It should describe attainable, overall goals for the fishery, as well as measurable objectives that are expected to result from the stocking program and associated management practices. Given detailed objectives, fish culturists and managers can determine exactly which fish and which characteristics are needed. Further, they can take actions to ensure that the fish selected for stocking have been reared using techniques that will not destroy their inherent propriety.

The fact that there is controversy concerning the propriety of stocked fishes seems to develop from more than one root cause. In some situations, anglers may want fish that simply will not survive in a given location, or they may want fish that have

been shown to disrupt ecological balances in the receiving waters. The presence of management plans with clearly stated and understood goals and objectives can ensure that appropriate fish are stocked. Inappropriate visual appearances and behaviors of fish may be artifacts of inappropriate rearing methods rather than inherent characteristics of the fish.

Recent research by the U.S. Fish and Wildlife Service Bozeman Fish Technology Center has demonstrated that it is possible to rear fish in a hatchery and still have them look and act like wild fish. Various practices ranging from the low density, high cost techniques of the "NATURES" system developed at the National Marine Fisheries Service Manchester Laboratory, to systems that vary from standard systems only in diet formulations, provision of cover in raceways, and absence of hand feeding have been shown to produce fish that look and act wild. In all such systems, attention is given to producing fish that are physiologically adapted to the waters into which they will be stocked.

Questions can still remain concerning genetic propriety and whether or not the propagated fish are carriers of disease agents that are not endemic to the waters into which they will be stocked. Advances in genetic testing, broodstock management, and fish health management appear to have solved most problems related to genetic propriety and disease management. However, new questions concerning the absence of natural selection processes in hatcheries, whether propagated stocks can maintain local adaptations, and related concerns about outbreeding depression have been raised. Discussions of these concerns have led to a currently acceptable consensus that these concerns may be realistic in some situations with certain species, but probably are not applicable to all situations, or even most situations.

Fishery managers generally agree that stocking propagated fish, even with total appropriate characteristics, is not appropriate if nature can provide a productive, sustainable fishery. The relative amount of effort and funds to be spent on habitat and population restoration compared with the amount spent to maintain a fishery with propagation and stocking is a related issue.

The workgroup articulated the need to assess and characterize the existing fishery resource and then develop a management plan that clearly defines specific and measurable objectives needed to accomplish a management goal. The determination of what is an appropriate fish stocking practice would be justified in a comprehensive management plan, and the results would be monitored and evaluated

so that adaptive management practices could be employed (with commensurate adaptive stocking).

The workgroup considered hatchery management options to produce fish that manifest traits that are compatible with the watershed targeted for stocking. They discussed the "NATURES" system as being implemented in the Pacific Northwest, where hatcheries mimic natural conditions. Some members postulated that simple changes, using hatchery existing systems, can probably produce the equivalent desired results. The workgroup members felt that in many cases, hatchery management modifications could be undertaken—such as improving diets, modifying feeding strategies, and/or adding structure within the raceway environment.

Workgroup members also raised several questions. How sure is management that hatchery changes they desire are warranted? How did management come to their conclusions? At what level of certainty should managers base their management decisions? Although the workgroup did not make any recommendations, they felt that hatchery management needs could be articulated, and that hatchery management practices could be adapted to match clearly defined fishery resource requirements.

The workgroup also explored the issue of how appropriate fishes might be propagated through adaptive hatchery management practices. They listed parameters that could be measured and included in the fish stocking considerations for a comprehensive fisheries management plan. Time was spent examining traditional fish hatchery management practices that would help ensure that stocked fishes would be genetically, physiologically, and behaviorally adapted for their specific environment.

Fisheries Management Terminology

The team led by Don MacKinlay was charged with establishing common working definitions for a number of terms that have multiple meanings. The team expanded the charge and identified a long list of terms to be clarified for fisheries. But many definitions were deemed to be daunting and difficult to achieve partial consensus. However, for the purposes of ensuring some agreement for this document, a partial list of definitions was subsequently prepared (including the fisheries management terms "recovery," "rehabilitation," "restoration," "naturalized," and "native"). These

are found in Appendix 3 and are provided as a reference point until the definitions are addressed again in the future.

Figure 3. Handling fish eggs and newly hatched larvae was a tedious process. Photograph from D.C. Booth Historic National Fish Hatchery, Spearfish, South Dakota.

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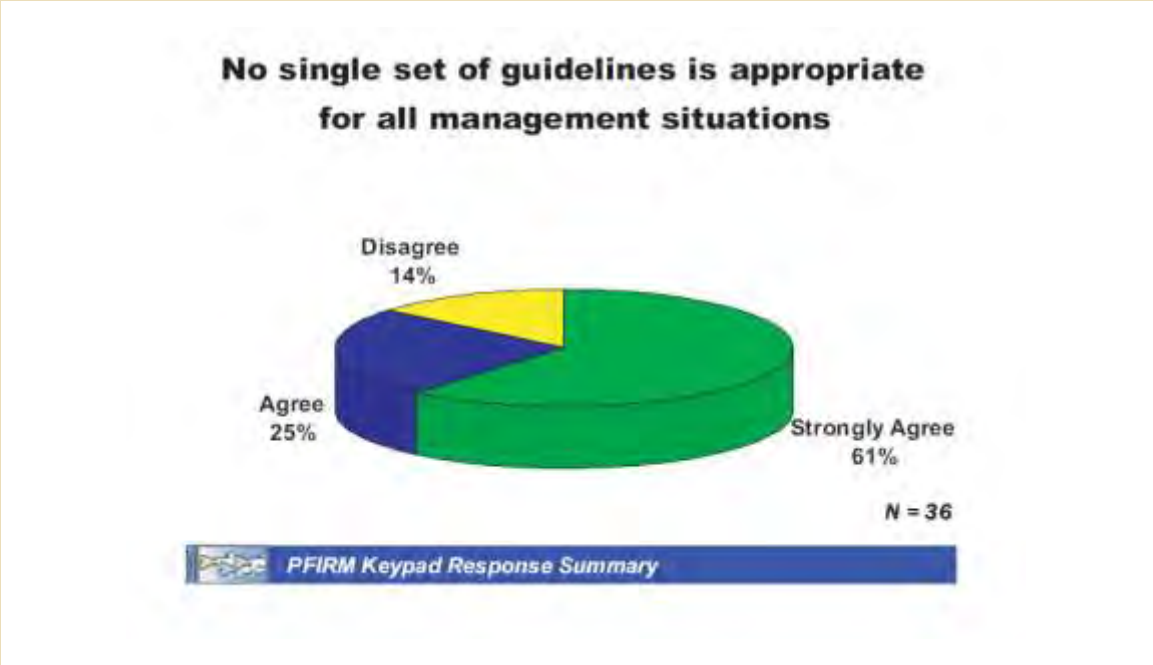
Figure 4. Old-timers enjoyed and respected their hatchery work as a strong contribution to conservation. Photograph from D.C. Booth Historic National Fish Hatchery, Spearfish, South Dakota.

V. Appendices

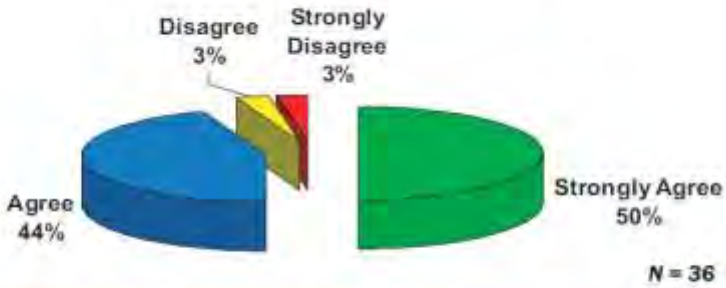
Appendix 1 Web Survey Analysis

Internet Web survey findings analysis presented in workshop forum.

The Web survey discussions identified several issues that remain contentious or controversial to fisheries managers. The following 11 graphic analyses represent response of the workshop participants to those issues. These results parallel the diverse range of prevailing management opinions in 2004.

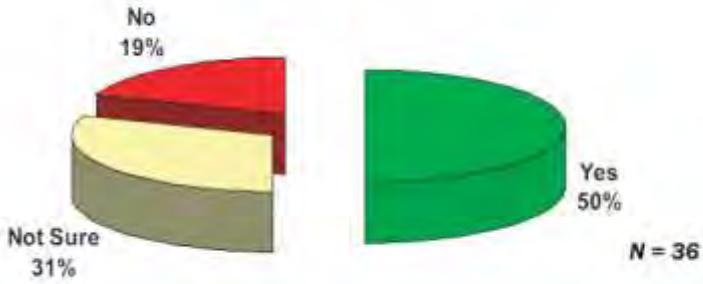


In the future, we are very likely to face management situations where certain fish might conceivably be considered as biological pollutants



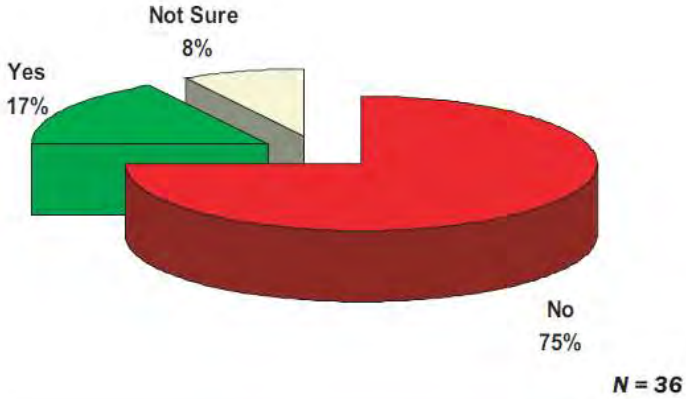
PFIRM Keypad Response Summary

Is it appropriate to stand back if environmental changes that are NOT man-made are threatening a species?



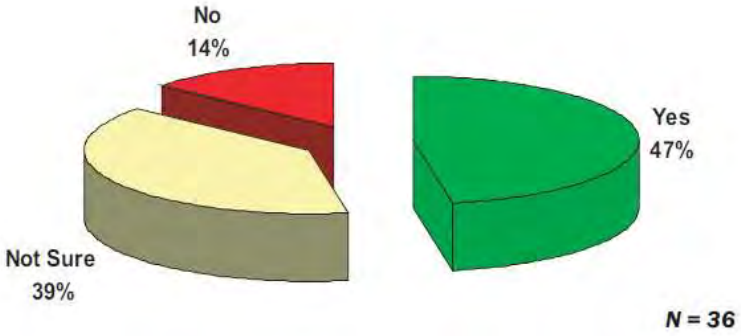
PFIRM Keypad Response Summary

Introduction of nonnative species should ALWAYS be avoided



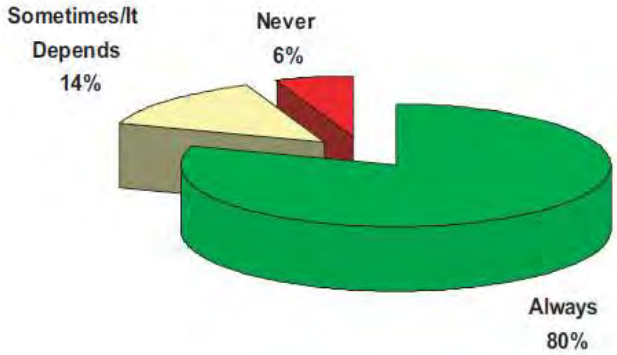
PFIRM Keypad Response Summary

Is it better to accept low-productive rivers with natural fisheries instead of augmented fisheries with higher productivity that could threaten other resources?



PFIRM Keypad Response Summary

Should we manage for the historical heritage of what the environment and species used to be and what we would someday like it to become?



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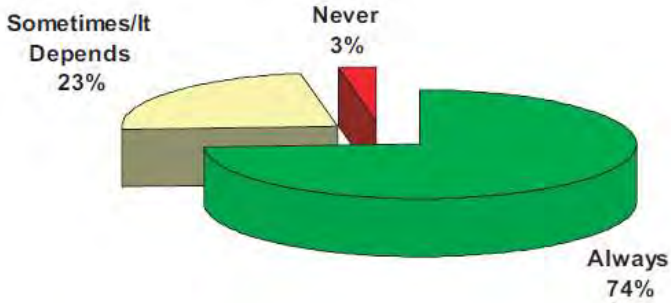
PFIRM Keypad Response Summary

Should we manage fisheries resources for the functionality of existing environmental conditions?



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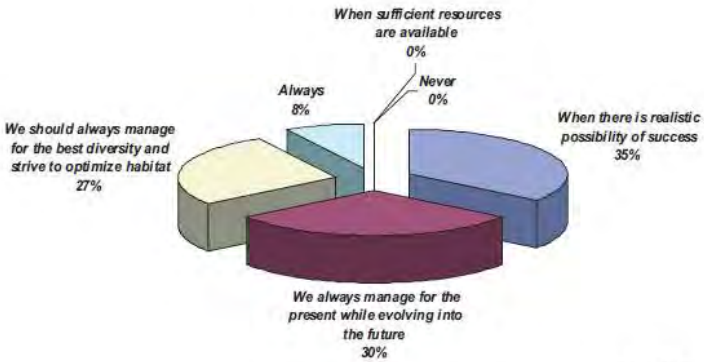
PFIRM Keypad Response Summary

It is most appropriate to manage for what we would someday like the environment and species composition to be when...



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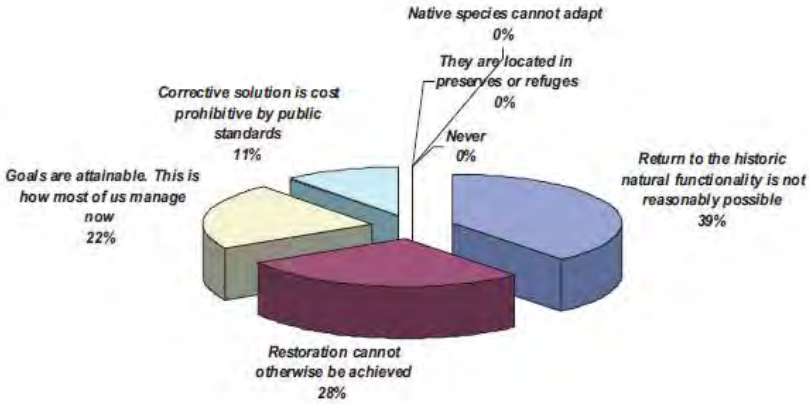
PFIRM Keypad Response Summary

It is MOST appropriate to manage for the functionality of adapted environmental conditions when...



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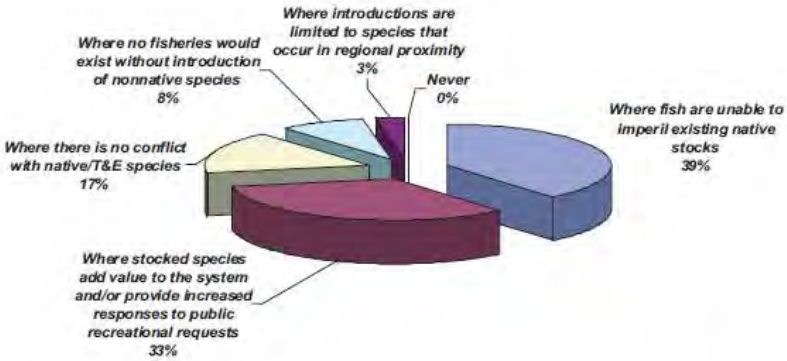
PFIRM Keypad Response Summary

Where is a fishery management approach that that uses nonindigenous fish species that are physiologically adapted for the altered environment MOST appropriate?



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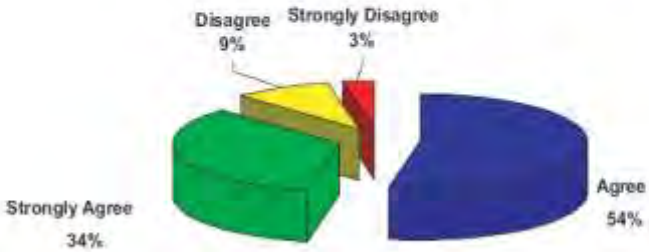
PFIRM Keypad Response Summary

Alternatives to NATURES-based hatchery programs exist, and these can deliver equivalent product to meet fisheries restoration and/or recovery needs.



N = 32

PFIRM Keypad Response Summary

Figure 5. Gentlemen display catch while fishing Link River rapids, 1891. Maud Baldwin photograph provided by the Klamath County Museum.

Appendix 2 List of Registered Workshop Participants

Last Name	First Name	Affiliation
Brader	Don	Arkansas Game and Fish Commission
Carmichael	Gary	Doe Run Farms & Conservation
Curry	Robert	NC Wildlife Resources Commission
DeHart	Douglas	US Fish & Wildlife Service
Durocher	Phil	Texas Parks & Wildlife
Engeling	Todd	Texas Parks & Wildlife
Frew	Tom	Idaho Fish & Game
Fuller	Adam	US Fish & Wildlife Service
Galbreath	Peter	Columbia River Inter-Tribal Fish Commission
Gharrett	Tony	University of Alaska Fairbanks
Hershberger	Bill	US Dept Agriculture, ARS NCCCWA
Hewett	Steve	Wisconsin DNR
Horton	Chris	BASS / ESPN Outdoors
Jennings	Daryl	US Fish & Wildlife Service
Kolar	Cindy	USGS Upper Midwest Environ Sci Cntr
Kurten	Gerald	Texas Parks & Wildlife
La Point	Tom	University of North Texas
Leonard	Dorothy	AFS Estuaries Section
MacKinlay	Don	Fisheries & Oceans Canada
Martel	Gary	VA Dept of Game and Inland Fisheries
Martin	Mallory	NC Wildlife Resources Commission
Mayeaux	Maxwell	US Dept of Agriculture
Mazik	Pat	USGS/WV Coop Fish & Wldlf Unit
McKinney	Larry	Texas Parks & Wildlife
Meritt	Don	University of Maryland
Miller	Dirk	Wyoming Game and Fish Dept
Moffitt	Chris	Idaho Coop F&W Research Unit
Moore	Virgil	Idaho Fish & Game
Mudrak	Vince	US Fish & Wildlife Service
Nelson	Kent	NC Wildlife Resources Commission
Nickum	John	USFWS-retired senior scientist
Nickum	Mary	AFS Special Editor
Preacher	Jim	USGS Biological Resources
Provine	Bill	Texas Parks & Wildlife
Pruitt	Tom	US Fish & Wildlife Service, Ennis NFH
Rassam	Gus	American Fisheries Society
Ray	Mike	Texas Parks & Wildlife
Saul	Gary	Texas Parks & Wildlife
Stone	Mike	Wyoming Game and Fish Dept

Last Name	First Name	Affiliation
Stout	Dave	US Fish & Wildlife Service
Talbot	Andre	Columbia River Inter-Tribal Fish Commission
Woodward	Spud	Georgia Department of Natural Resources
Zimmerman	Brian	Confed.Tribes of Umatilla Indian Reserv.

Figure 6. Transfer of Atlantic salmon eggs to the Craig Brook hatchery. U.S. Fish and Wildlife Service photograph.

Appendix 3 Definitions

PFIRM Terminology

Draft Steering Committee Definitions

(Workshop and Web-Survey Clarifications)

Population Rehabilitation

For the purposes of PFIRM, propagation and stocking under a rehabilitation plan use strategies that involve the protection and enhancement of specific native fish populations. Where rehabilitation is employed, the primary goal is to safeguard the genetic legacy of the native species within its habitat-specific historic range. Under rehabilitation, sustainability of the unique population for its ecosystem function is the primary objective, and harvest may or may not be a secondary management objective. Accordingly, rehabilitation is generally considered a genetic conservation strategy. Rehabilitation is typically employed for enhancing the specific population, where species abundance is insufficient to meet human harvest expectations or where an imperiled population has not been given formal federal protection under the Endangered Species Act.

(Bottom Line—Rehabilitation actions help to rebuild a specific natal population.)

Species Recovery

For the purposes of PFIRM, propagation and stocking under a recovery plan use strategies that involve the protection and enhancement of specific native fish populations. Where recovery is employed, the primary goal is to protect the status of the species and to ensure sustainability. Similar to rehabilitation, recovery is a conservation strategy designed to safeguard the genetic legacy of the species within its habitat-specific historic range. Under recovery, all management actions are governed by a formal species Recovery Plan, and the primary objective of the plan is to improve the population status to a measurable level that will allow the species to be *de-listed*. Additionally, under recovery, bycatch (unintentional harvest), as well as intentional "take," may be regulated by law.

(Bottom Line—Recovery actions help to delist a federally listed species.)

Fishery Restoration

For the purposes of PFIRM, propagation and stocking under a restoration plan use strategies that involve the protection and enhancement of native fish populations. Where restoration is employed, the primary goal is to increase the abundance of a particular species of fish within its historic range. Under restoration, sustainability of the population is the objective (similar to rehabilitation), but ensuring a harvestable surplus of animals for humans is the management goal. Accordingly, restoration is primarily a fishery management strategy. Under restoration, hatchery propagation and stocking might opt to use the best available genetic material that is similar to, but not specific for, the restoration river or water body.

(Bottom Line—Restoration actions help to rebuild a viable fishery.)

Native Species and Nonnative Species

For the purposes of PFIRM, species native to North America are regarded as those species that resided within North America prior to European colonization in the early 1600s. And moreover, within North America, there are specific ranges for native species (e.g., eastern brook trout and west coast rainbow trout). Comparatively, nonnative species are defined as those species that were subsequently introduced by humans, deliberately or accidentally, during or post colonization. The definitions portray a static view of the world. In reality, as climate and landscapes changed over the millennia, species probably moved to latitudes and altitudes that match the conditions to which they were adapted, or the species may have remained and evolved to adjust to the changing climate and environmental conditions.

Naturalized Species

For the purposes of PFIRM, a naturalized species refers to a displaced native (nonindigenous) species and/or nonnative species that has achieved self-sustaining status in the natural environment. The naturalized species may have become established outside its native range through intentional or accidental human actions. There is no intent by the PFIRM Steering Committee to designate naturalized populations at the same intrinsic value as applied to native species. Nevertheless, naturalized species may provide important economic benefits for fisheries management and serve as surrogates for native species by providing functional

biological benefits within natural and altered ecosystems. (An example is a self-sustaining brown trout and/or smallmouth bass in many streams and rivers of the northeast.) In many cases, the term "established" has been used as a synonym for naturalized.

Feral Fishes

For the purposes of PFIRM, feral fish refer to fishes that originated from human captivity and found their way into the natural environment that had been in captivity and originated from human introductions—intentionally or accidentally. The fishes may originate from dedicated stocking, from hatchery escapement, or from some other human action. Feral fishes can be a native species, or a nonindigenous species. Moreover, feral fishes can provide an important fishery in some waters. Besides population supplementation, they could be associated with put-and-take fisheries and put-grow-and-take fisheries. (Examples include stocked hatchery trout in west coast streams and escaped farm-raised salmon in west coast waters.)

Wild Fishes

For the purposes of PFIRM, wild fishes are fishes that originated from natural reproduction in the natural environment—as opposed to hatchery fishes or fishes derived from human intervention in the spawning process. Wild fishes might be native or naturalized nonindigenous species. Because the term "wild fish" tends to cause debate, PFIRM steering committee urges resource managers to qualify its use. (Example: the state's wilderness trout fishing program is highly successful because of management's two-tiered approach to their "wild-trout" fishery: (1) the state capitalized on the high intrinsic value of the historic native brook trout fishery; and (2) the state recognized the desire of anglers to seek out large trophy brown trout that have become naturalized in the region.)

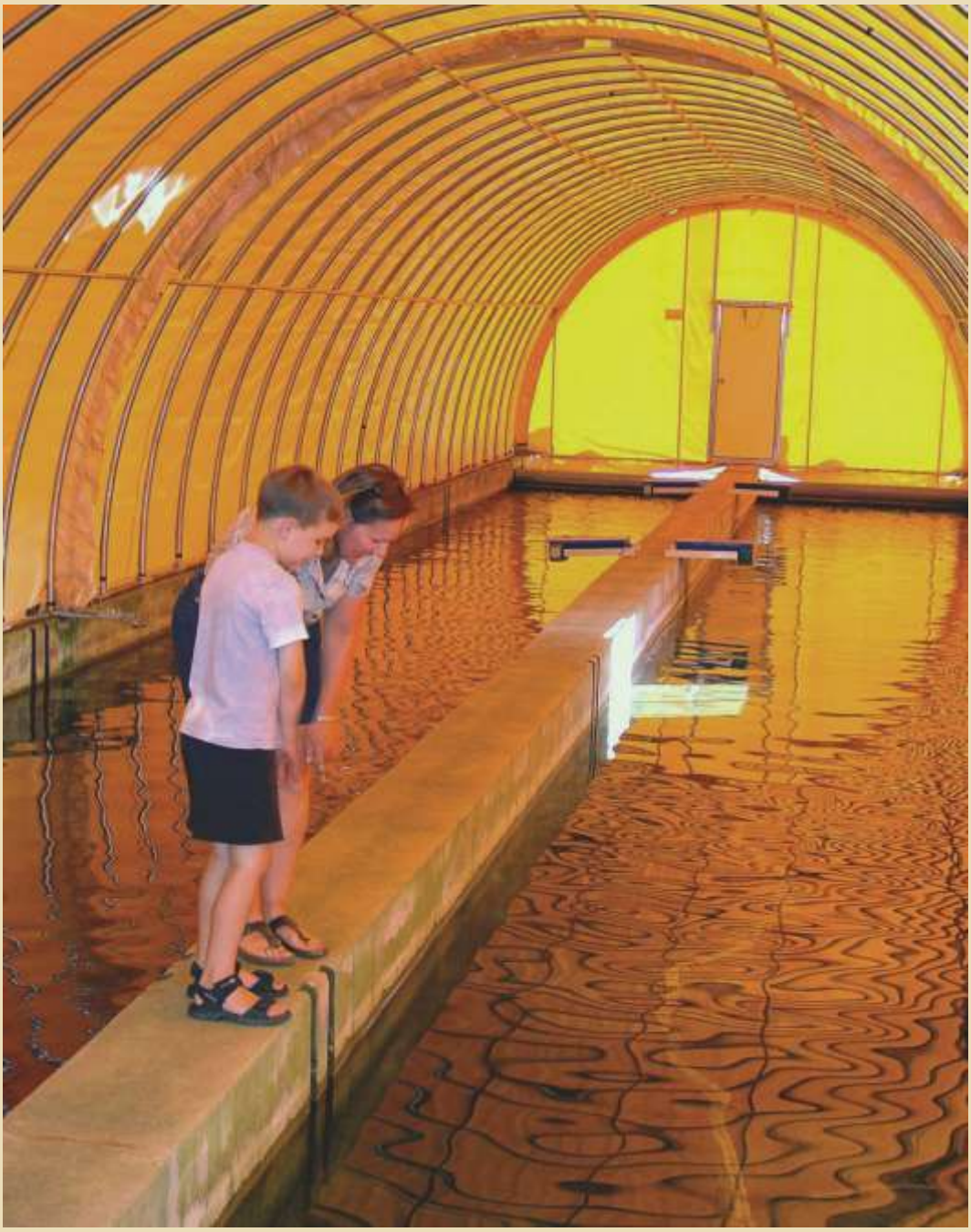


Figure 7. Fish hatchery facilities have evolved and include many different technologies. Photo by Michael E. Barnes.

Appendix 4 AFS Policy Statement #15: Introductions of Aquatic Species (Abbreviated)

The AFS policy regarding introduction of aquatic species is to:

1. Encourage fish importers, farmers, dealers, hobbyists, and ship owners to prevent the accidental or purposeful introduction of aquatic species into local ecosystems.
2. Urge that no city, county, state, province, or federal agency introduce, or allow to be introduced, any species into any waters within its jurisdiction that might contaminate any waters outside its jurisdiction without official sanction of the exposed jurisdiction.
3. Urge that only ornamental aquarium fish dealers be permitted to import such fishes for sale or distribution to hobbyists. The "dealer" would be defined as a firm or person whose income derives from live ornamental aquarium fishes.
4. Urge that importation of fishes for purposes of research not involving introduction into a natural ecosystem, or for display in public aquaria by individuals or organizations, be made under agreement with responsible government agencies. Such importers should be subject to investigatory procedures currently existing or to be developed, and species so imported shall be kept under conditions preventing escape or accidental introduction. Aquarium hobbyists should be encouraged to purchase rare ornamental fishes through such importers. No fishes should be released into any natural ecosystem upon termination of research or display.
5. Urge that all species considered for release be prohibited and considered undesirable for any purposes of introduction into any ecosystem unless that species has been evaluated upon the following bases and found to be desirable:
   - *Rationale*. Reasons for seeking an import should be clearly stated and demonstrated. It should be clearly noted what qualities are sought that would make the import more desirable than native forms.
   - *Search*. Within the qualifications set forth under *Rationale*, a search of possible contenders should be made, with a list prepared of those that appear most likely to succeed, and the favorable and unfavorable aspects of each species noted.
   - *Preliminary Assessment of the Impact*. A preliminary assessment should go beyond the area of *Rationale* to consider impact on target aquatic ecosystems, on game and food fishes or waterfowl, on aquatic plants, and on public health. The published information on the species should be reviewed and the species should be studied in preliminary fashion in its biotype.
   - *Publicity and Review*. The subject should be entirely open and expert advice should be sought. It is at this point that thoroughness is in order. No importation is so urgent that it should not be subject to careful evaluation.
   - *Experimental Research*. If a prospective import passes the first four steps, a research program should be initiated by an appropriate agency or organization to test the import in confined waters (experimental ponds, etc.).

— *Evaluation or Recommendation*. Complete reports should be circulated among interested scientists and presented for publication.

— *Introduction*. With favorable evaluation, the releases should be effected and monitored, and the results should be published or circulated.

6. Urge that international, national, and regional natural resource agencies endorse and follow the above stated AFS policies.
7. Encourage international harmonization of guidelines, protocols, codes of practice, and so forth, as they apply to introduction of aquatic species.
8. Urge fisheries professionals and other aquatic specialists to become more aware of issues relating to introduced species.

Appendix II, Selected Abstracts from HaMAR Symposia

INTRODUCTION TO HATCHERIES AND MANAGEMENT OF AQUATIC RESOURCES (HaMAR)

Jesse T. Trushenski , Center for Fisheries, Aquaculture, and Aquatic Sciences, Southern Illinois University Carbondale, Carbondale, IL

For the past several decades, AFS has coordinated forums to discuss the role of hatcheries in natural resources management and address evolving concerns surrounding the use of hatchery-origin fish. AFS has coordinated "Hatcheries and Management of Aquatic Resources" (HaMAR), to reengage AFS in addressing current issues related to hatchery operation and the role of hatchery-origin fish in aquatic resource management. A scoping survey of fisheries professionals highlighted habitat restoration and management as complements to stocking; monitoring and adaptive management of stocking programs; rearing genetically appropriate fish; fish health and access to disease management tools; defining appropriate uses and expectations, and understanding the limitations of hatchery-origin fish; biological interactions between wild and hatchery fish; culture of imperiled species; and risk assessment and decision-making as the most critical, contemporary issues related to hatcheries and hatchery-origin fish. Fact-finding symposia have been organized to bring these challenging issues before a body of fisheries professionals to distill the associated discourse into the next set of guiding principles regarding hatcheries and aquatic resource management. This presentation will review the aforementioned survey and themes from a recently held presentation series, and will set the stage for the HaMAR symposium.

WHY HATCHERIES: THE LIKELY RELEVANCE OF PUBLIC FISH PRODUCTION SYSTEMS IN THE COMING DECADES

Gary Whelan , Michigan DNR Fisheries Division, Lansing, MI

Public fisheries agencies across the landscape are struggling with declining revenues which make large infrastructure systems vulnerable to budget reductions. Initial minimum estimates of the total installed state and federal fish production infrastructure is approximately $3.7 billion dollars with an estimated annual operation cost of $370 million dollars which makes it a large value economic asset to move to other purposes. While this may be an attractive option to balance current fiscal issues, the rapid land use conversions currently occurring in the U.S. and other countries to support increased row crop, in particular corn production along with future land use change opportunities created by large scale climate change should make fisheries agencies take pause to consider this decision which is nearly impossible to restore from once taken. It is clear that the conversion of over 12 million acres of CRP land into row crops, mostly corn, in the last 5 years will create water quality and material input issues across

the continent and will reduce fish habitat quality. Additionally, all of the climate models show large scale warming trends that will certainly cause human populations to increase, rapidly increasing urbanization, and will move agricultural conversion of grass and forest lands northward. The recent National Fish Habitat Board's Assessment of the Nation's Fish Habitat clearly showed that increasing amounts of urbanization and agricultural conversion will increase the stress on our nation's fish habitat, likely reducing its quality and allowing invasive species to gain new footholds. Given these likely degraded habitat scenarios, it is foolish to think that we will not need properly designed and operated fish production systems which must use sound genetics and fish management policies. Public fish production systems will provide the needed lifeline to species that are in danger of losing their current homes to climate and land use changes, likely buying time against extinction, and will be needed to maintain economically important sport and commercial fisheries. The role for public fish production system in the future should be to: restore extirpated species; rehabilitate depressed fish populations; provide ecosystem balance; and provide for enhanced fishing opportunities. We must maintain sufficient public fish hatchery infrastructure that when combined with habitat protection (protecting the best of what remains) and rehabilitation of degraded system, and proper harvest allocation provide the keys to keep ecosystem benefits flowing from our aquatic systems in the face of climate and land use change.

CAN ALTERNATIVE HATCHERY REARING PRACTICES LESSEN FITNESS LOSS IN STEELHEAD TROUT?

Barry Berejikian, Behavioral Ecology, NOAA Fisheries, Manchester, WA

Hatchery rearing environments may affect behavioral, physiological or morphological development that can influence breeding success or induce selection that results in genetically based fitness loss. The relative fitness of hatchery-origin salmon and steelhead is generally less than that of natural-origin fish. Differential breeding success, offspring fitness, or both may contribute to lower fitness of hatchery fish, and these effects vary depending on the species, type of hatchery, and broodstock type. Studies of steelhead trout indicate greater reductions in fitness than in other species after a single generation of hatchery culture. Studies of one steelhead population steelhead have demonstrated a genetic basis for a rapid decline in fitness after one generation. Two subsequent published studies implementing similar 'common garden' study designs for coho salmon and Chinook salmon have not detected a genetic basis for fitness loss, although fish reared in the hatcheries suffer significant fitness loss when they return as adults, implicating developmental effects of the hatchery environment. Fitness loss in steelhead is hypothesized to result from accelerated growth regimes and associated selection for fish that grow rapidly under hatchery conditions. Evidence of selection on body size after

release comes from studies in the Columbia River and Snake River Basins. Experimental hatchery growth regimes that more closely mimic natural age-at-smoltification (e.g., age-2) appears to reduce viability selection on growth rate by providing the time for a greater percentage of the hatchery population to achieve thresholds for successful migration. Research is underway to determine whether two-year steelhead rearing programs can lessen the degree of hatchery-induced selection and fitness loss.

THE PARADIGM SHIFT TO SELECTIVE FISHERIES FOR PACIFIC SALMON IN THE PACIFIC NORTHWEST

Lee Blankenship, NW Marine Technology, Tumwater, WA

There are over 200 state, federal and tribal salmon and steelhead hatcheries in Washington, Oregon and Idaho. The vast majority of the Chinook, coho and steelhead harvest on the west coast of the United States is from hatchery production. One negative consequence of their success has been the over-harvesting of wild fish. Another negative consequence has been the reduced productivity of wild fish caused by hatchery adults spawning with wild fish. Managers are generally faced with two alternative options to counter these negative consequences of successful hatchery production. Either greatly reduce hatchery production or selectively harvest hatchery production. While reducing the output from hatcheries is an attractive alternative from strictly the conservation view point, the economic and social value derived from sustainable commercial, tribal and recreational harvest is very important. With nineteen stocks being listed for protection under the Endangered Species Act (ESA), selective fishing strategies have become increasingly important in the Pacific Northwest. Historically, selective fisheries employed time and area closures to protect certain stocks of fish. However, these methods have proven to be less effective than desired because ESA listed and other weak stocks are co-mingled with healthy hatchery stocks in most fisheries. In the mid-1980s managers started looking for methods to increase selective fishing opportunities. Washington State passed legislation in 1995 to mass mark hatchery coho and Chinook released from state operated facilities. Federal legislation followed which called for implementation of mass marking all federally funded, hatchery released coho, Chinook and steelhead intended for harvest. The adipose clip was the marking method chosen to identify harvestable hatchery fish which set the stage for a new era of selective fisheries. Today mark-selective regulations are the standard for most Chinook, coho and steelhead recreational fisheries. The Washington Department of Fish and Wildlife and the Colville Tribe have made great progress in developing, testing, and implementing new commercial gear for mark-selective fisheries.

MYTHBUSTERS: WHAT'S REAL AND WHAT'S NOT WHEN IT COMES TO USING FISH DRUGS

Jim Bowker, Aquatic Animal Drug Approval Partnership Program, U. S. Fish and Wildlife Service, Bozeman, MT

Successful fish culture programs take a comprehensive approach to disease management, broodstock conditioning and spawning, marking progeny, and reducing handling stress. Occasionally, drugs are needed to facilitate these tasks, and the only drugs legally available for use are those that have been approved for such use by the U. S. Food and Drug Administration (FDA). A lack of understanding of the approval process and the realities of how these products are actually used in fish culture has led to unfounded concerns regarding potential human health issues, unsafe drug residue levels in fish stocked into public waters, and discharge of elevated concentrations of drugs in hatchery effluents. The rigorous drug approval process requires extensive data to demonstrate that a drug is safe and effective for fish, as well as safe to humans and the environment, manufactured and packaged properly, and labeled to avoid misuse. It is incumbent upon fisheries professionals to use approved drugs judiciously. However, the rigors of the approval process assume a naive user—if inexperienced personnel can be expected to apply these products successfully, experienced fisheries professionals certainly can. This presentation will address concerns regarding drug use in fish culture from a fishery biologist's perspective.

GROWTH AND MORTALITY OF HATCHERY-REARED STRIPED BASS STOCKED INTO NON-NATAL SYSTEMS

Jody L. Callihan, Biology, North Carolina State University, Raleigh, NC

Charlton Godwin, North Carolina Division of Marine Fisheries, Elizabeth City, NC

Kevin Dockendorf, NC Wildlife Resource Commission, Elizabeth City, NC

Jeffrey A. Buckel, Department of Biology, North Carolina State University, Morehead City, NC

Due to practical constraints (costs, hatchery proximity) and/or difficulties obtaining local broodstock (for endangered or imperiled populations), stocking programs often utilize fish from non-local sources for the purpose of population enhancement. This practice of cross-stocking could be counter-productive; fish from different populations may be ill-suited for a given system whose environmental conditions differ from those of the natal habitat to which stocked fish are adapted. However, few studies have evaluated this possibility, especially in coastal environments. Here, we used tag-return data (1990-present) to compare the growth and mortality of striped bass fingerlings of Roanoke River (North Carolina, USA) origin stocked into three different systems: 1) the Albemarle Sound estuary (natal system), 2) the Tar-Pamlico

River, and 3) the Neuse River. Growth in non-natal systems (Tar-Pamlico and Neuse) was similar to that in the natal estuary (von Bertalanffy K's=0.54-0.62). Total instantaneous mortality was significantly higher in non-natal (Z=0.48-0.51 year-1) vs. natal (Z=0.33 year-1) systems, but we suspect this was due to greater anthropogenic stressors (e.g., fishing mortality) rather than the population origin of stocked fish. Our results illustrate that depleted populations can be enhanced by stocking fish from nearby populations. Still, there are genetic concerns with this practice that need to be considered in the context of long-term population resiliency.

PAST, PRESENT, AND FUTURE CONTRIBUTIONS OF HATCHERY-REARED WALLEYES TO POPULATIONS IN NORTHERN GREEN BAY, LAKE MICHIGAN

Troy Zorn, Fisheries Division, Michigan Department of Natural Resources, Marquette, MI

Darren Kramer, Fisheries Division, Michigan Department of Natural Resources, Gladstone, MI

Jessica Mistak, Fisheries Division, Michigan Department of Natural Resources, Gladstone, MI

Hatchery-reared walleyes have played an important role in rehabilitation of Great Lakes walleye populations. For example, stocking efforts to rehabilitate remnant walleye populations in northern Green Bay, Lake Michigan began in 1969, after populations nearly collapsed. Some natural reproduction was documented as early as 1988, but no quantitative data existed for assessing contributions of hatchery- and naturally-produced fish. This data gap and the changing environment of northern Green Bay have hindered efforts to define the extent of population recovery and the future role of hatchery fish. We used oxytetracycline (OTC) marking to determine the relative contribution, growth, and survival of stocked walleyes for the 2004-9 year classes of walleyes in Little and Big bays de Noc in northern Green Bay. Marking study results, combined with spatial information on juvenile walleye abundance and historic harvest data, provide insight into the past, present, and future walleye management potential of each bay. This information provides the basis for ecosystem-specific management that makes cost-effective use of hatchery-reared walleyes. Such an approach can be applied to other nearshore areas to help optimize use of hatchery resources.

SOCIOECONOMIC DYNAMICS AND SYSTEM-LEVEL EVALUATION OF ENHANCEMENT OUTCOMES

Ed Camp , Program of Fisheries and Aquatic Sciences, University of Florida, Gainesville, FL

Kai Lorenzen , School of Forest Resources and Conservation, University of Florida, Gainesville, FL

Stock enhancement is increasingly considered as a management strategy to improve outcomes of commercial and recreational fisheries. Assessing enhancement outcomes requires evaluating the entire system, including socioeconomic attributes (e.g., governance, economic dynamics, and stakeholder opinions and values). We synthesized information from studies of fisheries, enhancement, human dimensions, natural resource economics, and system change to describe system dynamics that are useful to consider. A key finding was that the economic outcomes of enhancement depend largely on the spatial scale considered (e.g., water body, regions or state), since enhancement may spatially redistribute economic benefits. We also found that system-level outcomes may depend as much on stakeholder perceptions and behavior as on biological dynamics. Our results further suggest that sometimes, enhancements may give rise to rapid, fishery system-level changes involving multiple biological, stakeholder and governance attributes.

FLORIDA'S FISH AND WILDLIFE HEALTH PROGRAM AND MARINE STOCK ENHANCEMENT

Theresa Tomas Cody, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Saint Petersburg, FL

Florida has long been committed to releasing healthy fish for marine stock enhancement, and the state's primary focus has been on red drum (Sciaenops ocellatus). The Fish and Wildlife Health research group within the Florida Fish and Wildlife Conservation Commission's (FWC) Fish and Wildlife Research Institute has a major role in ensuring this goal is met. Our activities include 1) monitoring the health of red drum at the FWC's marine hatchery throughout the rearing period, prior to release, and after recapture, 2) gathering baseline health data on red drum and other potential aquaculture species, 3) providing recommendations for treatment, 4) conducting applied research to promote health of stock, and 5) review of health certifications required under special activities licenses (SAL) issued to external facilities releasing aquatic organisms. Applicants must adhere to general guidelines outlined in the FWC SAL. Our near term challenge is to develop, with external partners, a health policy for the release of aquatic animals which will cover finfish and invertebrates.

PRIORITIZING CANDIDATE STOCKS FOR RECREATIONAL FISHERIES ENHANCEMENT IN FLORIDA

Taryn Gainer, School of Forest Resources and Conservation, University of Florida, Gainesville, FL

Kai Lorenzen, School of Forest Resources and Conservation, University of Florida, Gainesville, FL

Christopher Monk, School of Forest Resources and Conservation, University of Florida, Gainesville, FL

Kenneth Leber, Directorate of Fisheries and Aquaculture, Mote Marine Laboratory, Sarasota, FL

The state of Florida is seeking to expand its marine hatchery program for fisheries enhancement and conservation purposes. As part of this effort, a systematic process is being designed and implemented to prioritize candidate stocks for hatchery production and fisheries enhancement. The aim of this process is to identify stocks in which release of hatchery fish is likely to serve fisheries enhancement and/or conservation goals. Prioritization of candidate stocks is based on a broad set of criteria, including quantitative modeling of the enhanced fisheries based on stock assessments, likely ecological and genetic impacts on wild components of target and interacting non-target stocks, aquaculture capability or potential and cost-benefit considerations. The process involves five phases: 1) an initial workshop, where selection criteria are defined and assigned weights; 2) a stakeholder survey to solicit opinions on the selection criteria and generate a consolidated list of candidate stocks; 3) quantitative modeling of likely impacts of hatchery releases on fisheries management outcomes for the candidate stocks; 5) ranking of stocks through a web-based stakeholder process; and 5) a second workshop, in which the results of the quantitative prioritization process are synthesized. We present approaches and tools developed for the process and initial results.

PLATTE RIVER STATE FISH HATCHERY SETTLEMENT AGREEMENT COMPLIANCE HISTORY: 2000 TO 2008

Ed Eisch, Department of Natural Resources, Michigan Department of Natural Resources, Beulah, MI

Platte River State Fish Hatchery has served as the primary Pacific salmon hatchery for the State of Michigan since the inception of Michigan DNR's salmon management program. In the early years of the program, rearing numbers rose steadily and insufficient attention was paid to effluent management. This resulted in degradation of water quality in Big Platte Lake. In 1986, the Platte Lake Improvement Association (PLIA) filed suit against the hatchery for its effect on water quality. In March of 2000, a settlement agreement between the PLIA and MDNR was reached. The terms of the agreement included a calendar year net total phosphorus discharge limit of 175 pounds and a rolling three month limit of only 55 pounds, as well as a requirement that the hatchery provide all manpower and virtually all funding to conduct an extensive water sampling program aimed at understanding the phosphorus dynamics of the Platte River watershed and Big Platte Lake, in particular. In order to meet the discharge limits, a large scale renovation of the outdoor rearing system and installation of a more aggressive effluent

management system was completed in 2004. Since the beginning of the sampling program, over 40,000 phosphorus samples from the Platte River watershed have been developed. A comprehensive mass balance model of the system has been developed and various aspects of sampling methodology have been exhaustively evaluated. An Access database, with extensive reporting capabilities, holds all of the data from this watershed study.

PLATTE RIVER STATE FISH HATCHERY EFFLUENT MANAGEMENT IMPROVEMENTS: 2009-2010

Ed Eisch , Department of Natural Resources, Michigan Department of Natural Resources, Beulah, MI

Platte River State Fish Hatchery (PRSFH) serves as the primary Pacific salmon hatchery for the Michigan DNR. A major renovation of the outdoor rearing area was completed in 2004. The primary focus of the renovation was to improve effluent management. PRSFH is limited to twelve month net total phosphorus loading of 175 pounds and a rolling three month loading of 55 pounds. The twelve month loading in 2008 was in excess of 174 pounds. During calendar year 2009, the twelve month phosphorus loading was 244.6 pounds. The three month limit was also violated on multiple occasions, resulting in $118,000 in penalty fines. Waste water treatment plant operations experts were consulted regarding possible solutions. Multiple steps, both structural and operational, were taken to deal with the effluent issues. The pumping frequency of the clarifier was decreased and the duration of each pumping cycle shortened. Disc filter rotation speeds were modified to reduce bailing of process water and decrease flow to the clarifier. The sludge tank overflow was re-plumbed so it flowed back to the clarifier rather than to the settling pond. A ferric chloride delivery system was put in place to flocculate phosphorus in the clarifier. The five acre settling pond was dredged, returning it to an efficient operating depth. The twelve month net discharge for 2010 fell to 80.2 pounds and to only 47.4 pounds in 2011. In September 2010, the first ever zero net phosphorus discharge was reported for PRSFH. The cumulative net TP loading for 2012 was only 32.05 lbs., so it appears that the effect of the improvements is real. While the shotgun approach of implementing all of the changes precludes definitive determination of which changes had the greatest impact, it is believed that adding the ferric chloride system, dredging the settling pond and replumbing the sludge tank overflow provided the most benefit.

USING ECOSYSTEM ANALYSES AND HATCHERIES TO ENHANCE FISH POPULATIONS RESPONSIBLY

Elizabeth A. Fairchild , Biological Sciences, University of New Hampshire, Durham, NH

Stocking fish to augment natural populations is not a new technology, yet in many cases successful stocking strategies are defined retroactively by comparing different release strategies. Evaluating different scenarios pre-release, as opposed to post-release, may provide a more comprehensive and resource-saving mechanism to determine optimal release strategies. Several modeling programs are available for this purpose and can generate different stocking scenarios, depending on the input variables and desired outcome. However, in order for these programs to be effective, modelers must have valid input data for the release area(s). If a potential release area has not been the subject of other studies, or historic data are not available, modeling will not be fruitful. Alternatively, thorough pre-release sampling, termed ecosystem analyses, can generate meaningful information for stock enhancement programs and can resolve questions concerning best release site (both macro- and micro-locations), season, release time-of-day, size-at-release, release magnitude, as well as highlight potential problems that may be encountered. By incorporating ecosystem analyses results into both field and hatchery components of fish stockings, enhancement success increases. A case study on Martha's Vineyard, Massachusetts involving winter flounder, *Pseudopleuronectes americanus*, stock enhancement will be discussed.

EVALUATING SUPPLEMENTATION OF SPRING CHINOOK SALMON IN THE YAKIMA BASIN, WA

David Fast , Yakama Nation, Toppenish, WA

The Cle Elum Supplementation and Research Facility (CESRF) was designed to address uncertainties regarding the use of hatcheries to rebuild natural populations of salmon in the upper Yakima River in central Washington State. CESRF is a conservation hatchery that began operating in 1997 utilizing naturally produced adult spring Chinook salmon collected throughout the adults spawning run as broodstock. Spawning consists of factorial mating of each female with multiple males. Each female's eggs are divided into two equal components that are used as control and treatment for research groups. Approximately 800,000 juveniles are produced annually with half of the juveniles reared in nine treatment raceways and the other half in nine control raceways to allow statistical evaluation of each experiment. The fish are transported in late winter to three acclimation sites with six raceways (3 treatment groups and 3 controls) to increase statistical power and evaluate homing fidelity of returning adults to acclimation areas. Supplementation adults are not taken back into hatchery as broodstock, but allowed to spawn in the natural environment. All experiments evaluate the survival of out-migrating smolts at various mainstem Columbia River dams and also the survival to adults returning back to the Yakima. Experiments conducted to date include comparison of juveniles reared under semi-natural treatment (SNT) conditions with underwater feeders, overhead cover, and camouflage painted raceway walls against those reared under optimum

conventional technologies (OCT) with standard hand feeding, concrete walls and no cover. Another experiment varied the growth regimes in the hatchery rearing environment to create a treatment group of smaller size compared to larger smolts to evaluate production of precocial males that spawn as juveniles against smolt survival (larger smolts survive outmigration better than smaller ones). An artificial spawning channel was also constructed to conduct controlled RRS experiments. Variables include changing the density of adults in the channel, and varying the percentage of wild and supplementation fish in each experiment. All adults are genotyped and Peterson disk tags are inserted in the dorsal fin to allow visual observations. Subsamples of fry produced are genotyped to evaluate RSS. Genetic samples are also collected from each adult in the population as they return to the upper Yakima for Relative Reproductive Success (RRS) evaluations of the entire population.

GENETIC MANAGEMENT AND MONITORING OF CONSERVATION HATCHERIES: PART I

Kathleen Fisch , California Sea Grant Delta Science Program, San Diego, CA

Christine Kozfkay , Eagle Fish Genetics Lab, Idaho Department of Fish and Game, Eagle, ID

Jamie Ivy , San Diego Zoo, San Diego, CA

Oliver Ryder , Institute for Conservation Research, San Diego Zoo, San Diego, CA

Robin Waples , NOAA Fisheries / Northwest Fisheries Science Center, Seattle, WA

Artificial propagation has been widely used across western North America as a means to increase the natural abundance of salmonid populations. While artificial breeding is designed to preserve the genetic diversity and enhance the abundance of the target species, there are numerous studies that show there can be demographic and genetic risks to wild populations. There are also genetic changes that can occur in the captive fish through artificial propagation. However, with genetic management, and genetic monitoring and evaluation, many of the negative consequences may be reduced. There are numerous studies that provide recommendations during artificial propagation to reduce some of these risks. In this study, we provide an overview of some of the genetic management practices that can be implemented throughout different phases of captivity (choice of broodstock, spawning design, rearing and release of fish, monitoring of fish post-release). We also provide a framework for some of the genetic management practices that can be implemented depending on the goals of the program and some examples from different conservation programs throughout western North America. This is the first talk in a two part series that will provide an overview of hatchery genetic management. It will also report on the performance of different hatchery genetic management strategies based on the life history of the species, modeled using individual-based

demogenetic simulations, and their utility in preserving the genetic integrity of wild supplemented populations. This information can be used to help genetically manage and monitor salmonid hatchery propagation programs for at-risk species across North America.

GENETIC MANAGEMENT AND MONITORING OF CONSERVATION HATCHERIES: PART II

Christine Kozfkay, Eagle Fish Genetics Lab, Idaho Department of Fish and Game, Eagle, ID

Kathleen Fisch, UC Davis & Scripps Institution of Oceanography, La Jolla, CA

Jamie Ivy, San Diego Zoo, San Diego, CA

Oliver Ryder, Institute for Conservation Research, San Diego Zoo, San Diego, CA

Robin Waples, NOAA Fisheries / Northwest Fisheries Science Center, Seattle, WA

Artificial propagation has been widely used across western North America as a means to increase the natural abundance of salmonid populations. While artificial breeding is designed to preserve the genetic diversity and enhance the abundance of the target species, there are numerous studies that show there can be demographic and genetic risks to wild populations. There are also genetic changes that can occur to the captive fish through artificial propagation. However, with genetic management, and genetic monitoring and evaluation, many of the negative consequences may be reduced . There are numerous studies which provide recommendations during artificial propagation to reduce some of these risks. In this study, we provide an overview of genetic management practices that can be implemented throughout different phases of captivity (choice of broodstock, spawning design, rearing and release of fish, monitoring of fish post-release). We also provide a recommended framework for genetic management practices that can be implemented depending on the goals of the program, along with examples from different conservation programs throughout western North America. We also present results from a recent survey regarding the genetic management of conservation hatcheries throughout the Columbia River basin. The intent of this presentation to to provide guidelines for genetically managing and monitoring salmonid hatchery propagation programs for at-risk species across North America.

BALANCING ESA AND SUSTAINABLE FISHERIES: RESULTS OF THE HATCHERY SCIENTIFIC REVIEW GROUP'S COLUMBIA RIVER BASIN REVIEW

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The Pacific Northwest contains the largest number of hatchery programs for anadromous salmonids in the world. These hatchery fish provide for robust fisheries, however, they also have the potential to negatively affect the U.S. Endangered Species Act (ESA) salmon populations in the area. Achieving a scientifically defensible but socially acceptable balance between harvest and conservation has proven to be challenging, both politically and biologically. The Congressionally-established Hatchery Scientific Review Group (HSRG) reviewed the over 175 hatchery programs that release over 140 million anadromous salmon juveniles in the Columbia River Basin annually. The HSRG used stock specific information, the best available science, and key principles of explicit goal identification, scientific defensibility, and adaptive management to model potential solutions for comanager goals for the stocks. Overall, HSRG modeling indicated the potential to increase conservation of primary stocks of importance by about 25% for steelhead to over 70% for Chinook and coho salmon. At the same time, the modeling indicated the potential to increase overall harvest benefits by about 15% by shifting hatchery production away from key populations of concern and by focusing on selective fishing and by relocating some in-river harvest benefits.

SURVIVAL AND TRAITS OF RECONDITIONED KELT STEELHEAD *ONCORHYNCHUS MYKISS* IN THE YAKIMA RIVER, WASHINGTON

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We evaluated the traits and survival to release of reconditioned kelt steelhead Oncorhynchus mykiss in the Yakima River (Washington State, USA). From 2001-2011 we captured a total of 9,738 downstream migrating kelts at an irrigation diversion facility, on average about 27% of each annual wild steelhead return. Captured kelts were reared for 4.5-10 months in an artificial environment, treated for diseases and parasites, and fed both krill and pellets. Surviving reconditioned fish were released into the Yakima River coincident with the peak of upstream pre-spawn steelhead migration. Reconditioned steelhead kelts were predominantly (>92%)

female. Annual survival to release ranged from 20-62% and averaged 38% over the course of the study with surviving reconditioned kelts showing increases in fork length, weight, and Fulton's K condition factor. Kelts in good condition and those with bright coloration at the time of collection were more likely to survive. Post-release upstream migration timing of reconditioned kelts was spread out over several months and correlated well with run timing of upstream pre-spawn migrants. The empirical results we observed demonstrate the potential of kelt reconditioning to provide recovery benefits for imperiled wild repeat spawning populations in highly developed river systems.

SNAKE RIVER SOCKEYE SALMON RECOVERY: A TEMPLATE FOR CONSERVATION AQUACULTURE PROGRAMS

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Snake River sockeye salmon are one of the most depleted populations of salmonids in the world. The last known remnants of the Snake River population return to Redfish Lake in the Sawtooth Valley in central Idaho. In the ensuing two decades since the population was federally listed as endangered in 1991, many actions have been taken to conserve the population including the initiation of a hatchery-based gene rescue program. Over the course of the program, managers have rebuilt the captive broodstock annually and produced over 3.7 million fish or eggs for reintroduction to the habitat. Through these efforts, over 95% of the original founding genetic diversity of the population has been conserved and through 2011, over 4,200 anadromous sockeye salmon adults have returned to natal waters in Idaho. The chief aim of this presentation is to describe implementation of hatchery-based gene rescue activities, review present-day release strategies and associated adult returns, and describe a new effort underway to expand program production to more effectively address re-colonization and local adaptation objectives. In addition we describe achievable population dynamic triggers to allow the transition from a hatchery-based effort to an ecosystem-based effort that should allow natural population recovery to proceed.

BEST MANAGEMENT PRACTICES – A TOOL NOT A RULE

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Becky Johnson, Department of Fisheries Resources Management - Production Division, Nez Perce Tribe, Lapwai, ID

Salmon hatcheries in the Pacific Northwest were originally constructed to mitigate for impacts of human development (dam construction and habitat destruction). In the past twenty years hatcheries have evolved to meet both conservation and harvest objectives. Multiple expert panel reviews have produced generalized management principles for hatcheries aimed to minimize hatchery fish risks to natural populations. Recently two groups, the Hatchery Science Review Group (HSRG) and Hatchery Review Team (HRT), developed best management practice recommendations for hatcheries in the Columbia River basin. Even though the HSRG and HRT acknowledged that alternative actions exist and should be considered, policy and funding entities are considering adopting/requiring the HSRG and HRT recommendations. Many of the recommendations require additional funding for infrastructure modification and/or increased operational complexity. In most cases, implementing the full suite of best management principles (BMPs) is either cost prohibitive or logistically infeasible. Several common BMPs for recovering natural populations include: achieving 100% marking on hatchery production, implementing selective harvest regimes, maximizing natural origin fish utilized in hatchery broodstock, and minimizing hatchery fish on spawning grounds. Failure to fully implement one or all of these is commonly perceived as a death sentence for the natural population. We utilize ESA listed Snake River fall Chinook to explore "how good is good enough"? Only 50% of Snake River fall Chinook hatchery production is adipose fin clipped and 22% release unmarked; 30% or higher are subject to non-selective harvest; and utilization of natural origin fish in hatchery broodstocks was intentionally avoided for the first 30 years of the program. During the last ten years hatchery fish have constituted 67% of natural spawner escapement. Yet, natural origin abundance has increased 10 fold since the 1980's. The current 10 year geometric mean of natural origin abundance averages 5,000 fish; exceeding the recommended ESA delisting abundance criteria.

STEPS TO SUPPLEMENTATION SUCCESS

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Planning and implementation of hatchery programs involves coordination of program intent and evaluation of performance across various levels of technical, management, and policy representatives, from multiple organizations. Establishing transparent expectations for program intent and standardized reporting of program performance vertically within organizations and horizontally across organizations is needed. Hatchery production marking, genetic fitness, and management of adult return disposition are three topics commonly debated in hatchery program management. This presentation will provide success stories and recommendations for broader application associated with: 1) Snake River Fall Chinook marking, 2) Johnson Creek summer Chinook fitness, and 3) Lostine River spring Chinook adult disposition management. A comprehensive marking strategy was developed for Snake River fall Chinook hatchery programs. The mark strategy accounted for harvest mitigation, hatchery operation, and monitoring and evaluation. Fifty percent of the production is marked externally, 28% of the production is internally marked, and 22% is unmarked. Under this marking strategy, non-selective recreational and treaty harvest is occurring, natural-origin fish are being incorporated into the broodstock, and natural-origin abundance is being measured. The Johnson Creek summer Chinook supplementation project was initiated to avert extirpation. Adult return management consisted of using only wild fish in the broodstock with no restrictions placed on hatchery fish escapement to spawning grounds. With the use of genetic based parentage assignment we documented a 30% increase of natural origin adult returns, an equal reproduction rate between naturally-spawning hatchery fish and wild fish, and fitness of the natural population was maintained. Management of Lostine River spring Chinook salmon adult returns is guided by hatchery and harvest sliding scales. Allocation of adult returns is based on estimated abundance of wild returns and relative abundance of hatchery returns. Hatchery return disposition from this integrated mitigation/supplementation program has been 12% to consumption and 88% to conservation. Consumption consisted of harvest (6%) and distribution as food (6%). Conservation consisted of broodstock (6%), adult outplants to under-seeded habitat (7%), and natural spawning (75%).

HATCHERIES – FISH IN NETS AND FISH IN HABITAT

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Fish management is becoming increasingly complex, with multiple stakeholders having influence on: management decision making, management action implementation, and life stage specific fish survival mechanisms. The Nez Perce Tribe (NPT) is a stakeholder with treaty-reserved fishing rights. As a fishery co-manager, the NPT utilizes hatcheries as a tool to maintain harvest and restore healthy populations throughout its usual and accustomed area. Tribal policy success principles associated with the hatchery management tool include: fish on the table (or fish in nets), fish in the habitat, functional ecosystems, and ensuring active fish management role. Contemporary attributes of salmon and steelhead hatcheries in the Snake River basin will be described.

1) The social, cultural, and economic benefits of salmon and steelhead harvest are immense.

2) Hatcheries represent a promise – they are payment on the unfulfilled debt to mitigate for limiting factors (e.g., hydrosystem, habitat destruction).

3) Not all hatchery fish are the same. Most hatchery production occurs for harvest programs. Some (much less) have recently been operated for recovery.

4) Hatchery operations for both harvest and recovery have evolved and continue to be refined/reformed at an accelerated rate. Information from changed hatchery programs has only recently begun to be included in the published literature.

5) Modern hatchery programs can fulfill multiple objectives of supporting fisheries and re-introduction and recovery efforts (adult disposition management).

6) Hatchery actions are just one of many tools being applied to recover and restore populations.

7) Hatchery actions have associated risks to natural production; realized impacts vary by species and population.

8) Almost all hatchery fish in the Columbia Basin are marked in some way. The vast majority are adipose fin clipped.

9) Rigorous and coordinated research, monitoring, and evaluation is ongoing to adaptively manage and minimize risks.

10) Collaborative effort to evaluate hatchery effectiveness at regional scale needed.

ISSUES AND TRENDS IN PUBLIC FISH HATCHERY IMPROVEMENT PROJECTS

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The renovation and modernization of public fish hatcheries involves many biological and engineering issues including planning and design requirements, construction, operational testing and training, high costs and significant total project execution time frames. Case-history examples from a variety of state and federal fish hatchery improvement projects will used to highlight issues and trends in public hatchery design and construction. Imperiled fish species and a variety of aquatic animals have been added to the mixture of traditional sport species propagated in public hatcheries and provide new design challenges. Natural resource agencies continue to incorporate science-based decisions in the propagation and use of aquatic animal including genetics, biosecurity, animal health and controlled environments to produce high quality aquatic animals that meet strict product requirements. These factors have impacted facility improvement projects significantly. Other important factors impacting facility design include water conservation, energy reduction, labor and operational savings and discharge permit compliance. There continues to be a trend in public fish hatcheries toward more intensification and control of rearing systems by application of a variety process water treatment technologies that include dissolved gas management, screening and filtration, disinfection and temperature management. Public hatcheries are employing indoor recirculating aquaculture system (RAS) technology to provide improved environmental control, water conservation, pollution control and energy reduction. Facility improvement projects also include the use of modern communication and computer systems that provide process monitoring, alarm, and control functions. Specialized systems that provide automated feeding, grading, harvest and tagging of propagated aquatic animals are commonly included. Extensive pond production systems have evolved over time include improved harvest / water control structures, membrane liners, modern aeration and mixing systems, water quality monitoring, predator exclusion, water reuse and effluent discharge treatment. The case histories presented provide insight into the issues impacting the modernization of public fish hatcheries and the challenges of meeting the vital role that these facilities play in the management of aquatic resources.

PROGRESS TOWARD RESTORATION OF NATURALLY REPRODUCING TOP PREDATORS AND SELF REGULATION OF LAKE HURON'S FISH COMMUNITY, A CASE STUDY

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At the 2003 "Propagated Fish in Resource Management" symposium we presented case studies on role of stocking in rehabilitation of walleye and lake trout populations and biomanipulation of Great Lakes ecosystems. At that time (2003), lakes Huron and Michigan were reliant on stocking for maintenance of predator-prey balance and for sustaining recreational fisheries valued at nearly $1.7 billion/yr. Spawning stocks of lake trout, Chinook salmon, and walleyes had been re-established, but reproduction of these species remained low. More recently in Lake Huron, marking hatchery fish with oxytetracycline led to the finding that upwards of 80% of Chinook salmon of the 2000-2008 year classes were of wild origin. In 2004, alewives collapsed which caused the introduced Chinook salmon to decline but reproduction of native walleyes and lake trout to rise sharply. Relief from chronic thiamine deficiency caused by alewife-dominated diets probably contributed to rising reproduction. Central Lake Huron's walleye population is now considered to be recovered. Due to the decline of the Chinook salmon population, fishing effort fell and shifted from salmonids to percids. As reproduction rose and stocking success declined, agencies sharply reduced or ceased stocking of several species. If sustained, recent events will represent regime shift to a top-predator configuration resembling what prevailed prior to system collapse. The restoration of top-down controls could lead to a more resilient fish community with lower management costs to resource agencies, but also with lower economic benefits from its recreational fishery. Hatcheries have played a key role in this ecosystem recovery.

COHO REINTRODUCTION IN THE UPPER COLUMBIA RIVER-ADAPTIVELY MANAGING A FORGOTTEN SPECIES

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By the end of the 20thcentury, indigenous coho salmon no longer occupied the mid- and upper-Columbia river basins. Several factors contributed towards their extirpation, which included but not limited to construction of mainstem Columbia River hydropower projects, habitat degradation, irrigation, release locations, harvest management, and hatchery practices. Since this extirpation, attempts have been made to re-initiate production within the Upper Columbia but none of these efforts were intended to restore a species that had become a lessor priority with ESA listings of several depressed spring Chinook and steelhead stocks. In the mid-90's, Yakama Nation held a vision of restoring coho salmon with the primary focus of creating self-

sustaining populations that, over time, would have successfully adapted to their unique environmental conditions. Studies have been conducted to determine feasibility of reintroduction, which began in the Methow basin in 1996 followed by the Wenatchee basin in 1999. Reintroduction feasibility was focused on addressing two primary concerns from co-managers; 1) whether a broodstock could be developed from lower Columbia River coho stocks whose progeny could survive in increasing numbers to return as adults and 2) initiate natural reproduction in areas of low risk to sensitive species and in other select areas to study interactions risks with sensitive species. Since project initiation, feasibility questions have been answered with little to no adverse impacts to listed populations. A master plan, developed as the acting mandate for program guidance, emphasized adaptive management in order to develop a geographically isolated, population that was locally adapted and naturally reproducing. This distinct, phased approach is an attempt to develop that population over time through encouraging adaptation towards predicted habitats using biological 'benchmarks' to assess success. To date, the Methow program has met both broodstock development requirements while the Wenatchee is close to doing the same. The fall of 2013 will document a monumental program achievement as the Methow program begins to collect broodfish for an expansive, implementation phase that will encourage the naturalization process. Positive programmatic trends continue to be observed as coho adult escapement increases in both basins, as documented with the 2011 upper Columbia returns numbering over 30,000 individuals. This approach of species reintroduction is also occurring within other Yakama Nation programs (e.g.-Cle Elum sockeye and Yakima River summer Chinook) with the intent of returning fish that were once historically predominant and significant, not only culturally but to restoring ecological function to many of these systems.

ARKANSAS CERTIFIED COMMERCIAL BAIT AND ORNAMENTAL FISH PROGRAM: A METHOD TO NEGATE DISEASE IMPACTS ON WILD FISH

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In the United States, fish farms in Arkansas produce over 6 billion baitfish annually. These farms provide a reliable source of a few known species of fish that are already widely distributed. Fish are raised under controlled conditions in levee ponds, using groundwater. However, the farmed product must compete with wild-caught baitfish, and increasing concern has been voiced by many state and federal regulators regarding shipments of wild baitfish and their potential to spread exotic diseases. Farm raised baitfish producers in Arkansas believed they had a product that was superior to wild bait, but realized that verification was needed. In 2005, the Arkansas Bait and Ornamental Fish Growers Association worked with the state lawmakers to authorize a

comprehensive certification program that included fish disease, aquatic nuisance species, and farm biosecurity. This law provided for the State of Arkansas to set standards for participation in the certification program, inspect farms and farm records, evaluate biosecurity plans, and to oversee fish health inspection protocols. The certification program is fee-based, and farmers must also pay for veterinary supervision of sample collection and laboratory fees. More than 95% of all Arkansas bait and ornamental fish production acreage is undergoing the inspections needed for participation in this voluntary program. Fish Health Specialists at the University of Arkansas at Pine Bluff worked with the industry and the State to develop details of the bait and ornamental fish certification program and to provide the needed training for farmers and Arkansas Department of Agriculture Inspectors. Additionally, the Fish Disease Diagnostic Laboratory at the University of Arkansas at Pine Bluff (UAPB), an approved USDA/ APHIS laboratory for inspections of fish for export, provides laboratory testing. The Arkansas Certified Commercial Bait and Ornamental Fish program provides assurances that products from participating fish farms are free of listed pathogens. This program serves as a model for other state and national programs designed to prevent the spread of aquatic diseases.

DEVELOPMENT, USE AND ADVANCEMENT OF A RESPONSIBLE APPROACH TO USING HATCHERIES IN FISHERIES MANAGEMENT

Kenneth Leber , Directorate of Fisheries and Aquaculture, Mote Marine Laboratory, Sarasota, FL

By the late 1980's, following a century of stocking marine fishes to augment fisheries, not a single peer-review journal article had been published on the effects or effectiveness of stocking fishes that spawn in seawater. But by two decades later, science had grown rapidly in the field of marine fisheries enhancement. This was stimulated in large part by emerging new marine fish culture and tag technologies, experience gained in salmonid fisheries enhancement, and augmented by the publication in AFS Symposium 15 of a prescription for a science-based and responsible approach. Here we present the genesis, evolution and heuristic value of the Responsible Approach to marine stock enhancement, and show how awareness of it has fostered gains in the science underlying use of hatcheries in fisheries management worldwide and accomplishments made by incorporating such principles into stocking programs.

A RESPONSIBLE APPROACH TO MARINE STOCK ENHANCEMENT: AN UPDATE

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Kai Lorenzen, School of Forest Resources and Conservation, University of Florida, Gainesville, FL

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Marine stock enhancement is a set of management approaches involving the release of cultured organisms to enhance or restore fisheries. Such practices, including sea ranching, stock enhancement, and restocking, are widespread, of variable success, and often controversial. A set of principles aimed at promoting responsible development of restocking, stock enhancement, and sea ranching was proposed by Blankenship and Leber [American Fisheries Society Symposia 15: 167–175 (1995)], and has gained widespread acceptance as the 'Responsible Approach'. Fisheries science and management, in general, and many aspects of fisheries enhancement have developed rapidly since the responsible approach was first formulated. Here we provide an update to the Responsible Approach in light of these developments. The updated approach emphasizes the need for taking a broad and integrated view of the role of enhancements within fisheries management systems; using a stakeholder participatory and scientifically informed, accountable planning process; and assessing the potential contribution of enhancement and alternative or additional measures to fisheries management goals early on in the development or reform process.

IMPLEMENTING HATCHERY REFORM IN THE STATE OF IDAHO

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There is an established weight of evidence in the literature describing potential risks that hatcheries and hatchery-produced fish pose to natural populations of salmon and steelhead. Primary risks include competition for resources between conspecifics as well as potential reductions in the fitness of natural populations due to intraspecific genetic hybridization. Nevertheless, anadromous fish hatcheries have been part of the western landscape for over a century and continue to play an important role in addressing mitigations objectives established by a variety of legal actions and agreements. In the Columbia River drainage alone, over 200 hatchery facilities produce over 150 million juvenile salmon and steelhead annually. Approximately 15% of this production occurs within the state of Idaho.

Operating anadromous fish hatcheries within a framework that emphasizes hatchery reform is becoming standard operating procedure in the west. A number of regional efforts have improved the collective understanding of the potential risks hatcheries pose to natural populations. Recent work by the congressionally mandated Columbia River Hatchery Scientific Review Group provided specific "solutions" for operating hatcheries consistent with harvest and conservation goals. In this presentation, we describe efforts underway in the state of Idaho to operate hatcheries consistent with these principles.

A META-ANALYSIS OF FACTORS POTENTIALLY INFLUENCING CONTRIBUTION OF STOCKED LARGEMOUTH BASS TO A YEAR-CLASS

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We reviewed 135 stocking events from 21 published studies to identify factors that influence enhancement of largemouth bass populations with hatchery fish. Factors examined included system type and size, how hatchery fish were fed, size at stocking, stocking density, and marking and sampling methods. We used logistic regression to determine which factors resulted in a high contribution of hatchery fish to the year-class in the fall and spring following stocking, and whether these factors contributed to investigators deeming their stocking event successful. System size ranged from 1-8484 ha. Stocking size ranged from 23-315 mm. Stocking density ranged from 1-645 fish/ha. Contribution of hatchery fish to a year-class ranged from 0-100% and from 0-90% in the fall and spring, respectively. Median stocking contributions were 15% and 14% for the fall and spring, respectively. Logistic regression indicated that stocking fish raised on minnows was more likely to result in high fall contributions to the year-class, but this relationship disappeared by spring. Stocking larger fish was more likely to result in high fall contributions to the year-class, but again, this relationship disappeared by spring. How fish were marked and sampled were not related to year-class contribution. Stocking size and density were both related to whether an investigator felt the stocking event was successful. Events with high stocking density and relatively large stocking size were more likely to be deemed unsuccessful. Furthermore, mean stocking contributions did not differ significantly between events deemed successful and unsuccessful. Careful consideration of hatchery rearing methods and stocking program goals may aid in realizing stocking program success.

POPULATION DYNAMICS AND QUANTITATIVE ASSESSMENT OF HATCHERY-ENHANCED FISHERIES

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Quantitative assessment of the contribution a hatchery program can make to fisheries management goals, including synergies and tradeoffs with fishing regulations and habitat management, is a key requirement if enhancements are to be effective and sustainable. Over the past decade, population dynamics models commonly used in fisheries assessments have

been extended in various ways to allow evaluation of release programs. This includes 'unpacking' of the stock-recruitment relationship to describe dynamics in the pre-recruit stage explicitly; quantifying compensatory density-dependent processes in the recruited phase of the life cycle; accounting for differences in fitness between hatchery-released and wild fish; and explicitly modeling spatial dynamics. In several areas, such as the consideration of size-dependence in lifetime mortality schedules, models originally developed for enhanced fisheries have become widely used in the assessment of wild stocks. I provide a critical review of these developments and close by outlining best practice guidelines for quantitative assessment of enhancements and priorities for further research.

INTEGRATED HATCHERY AND POPULATION MANAGEMENT STRATEGIES FOR EFFECTIVE FISHERIES ENHANCEMENT AND RESTORATION

Kai Lorenzen, School of Forest Resources and Conservation, University of Florida, Gainesville, FL

Hatchery-based enhancement and restoration programs may be developed in a variety of fisheries situations and with a view to achieving different goals. Different situations and goals may call for very different combinations of hatchery practices, release and fishing regimes. For example, ranching systems operate for species that do not recruit naturally and may be managed to maximize biomass production or the abundance of catchable-sized fish, often manipulating populations in ways that could not be achieved in naturally recruiting populations. Because direct genetic interactions with wild stocks are absent, post-release fitness of cultured fish is primarily an economic rather than a conservation issue and such fisheries may even benefit from selective breeding to enhance return rates. Stock enhancement on the other hand involves the continued release of hatchery fish into a self-recruiting wild population, with the aim of sustaining and improving fisheries in the face of intensive exploitation and/or habitat degradation. Enhancement through release of advanced juveniles may increase total yield and stock abundance, but is likely to reduce abundance of the naturally recruited stock component through compensatory responses or overfishing. I discuss alternative enhancement system designs in the light of strategies for dealing with domestication issues and stock management.

A REVIEW OF SPAWNING FLORIDA LARGEMOUTH BASS "OUT OF SEASON" USING PHOTOPERIOD AND TEMPERATURE MANIPULATION TO PRODUCE ADVANCED SIZED FINGERLINGS

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Establishing a production – scale "Out of Season" (OS) spawning protocol to produce approximately 1,000,000 or more Florida Largemouth Bass Micropterus salmoides floridanus swim-up fry in a three to four week period in the fall was the objective of this research. This manuscript reviews five years of spawning trials and results attempting to establish an OS spawning method. The OS photo – thermal manipulation began each year approximately June 18th and was completed by September 20th. The idea was to simulate winter to spring temperatures and day length over a 90 d period to naturally induce gonad development without the use of hormones. Adult bass were stocked in the spawning raceways at a 1:1 and 2:3 male to female sex ratio (20 males to 20 or 30 females) and spawned in late September through mid October. Total number of spawns collected (2009, 2010, and 2011) were 193, 205, and 199 represented an average 1.4, 2.0, and 1.0 spawns per female. Spawning duration required to achieve production numbers were 26, 31, and 23 days. The OS spawning technique allows for bi-annual production seasons from the same broodstock population and the production of large numbers of 100 mm bass by March. Increased production, broodstock behavior, hatchery space efficiency, and temporal limitations are discussed.

A REVIEW OF SEMI-NATURAL REARING STRATEGIES FOR INCREASING OCEAN RANCHED AND STOCKED FISH SURVIVAL

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Thomas A. Flagg, Manchester Research Station, NOAA Fisheries Service NWFSC, Manchester, WA

Cultured fish released into the wild often lack the experience required to thrive in complex physical environments, successfully hunt elusive prey, and avoid predators. Providing cultured fish with some experience with the natural environment prior to release has been proposed as a tool to increase their post-release survival. Over the last 25 years many studies have been conducted evaluating this concept. Training fish to hunt by providing them live feeds, exposing them to limited predation, and rearing fish in a more natural environment have all been shown to improve behavioral responses in laboratory settings and sometimes survival in the wild. This presentation will review this research on semi-natural culture strategies to determine its effectiveness for increasing the post-release survival of ocean ranched fish and fish stocked into natural freshwater habitats. This literature review will focus on examining the work conducted since 2000 as an update to the reviews we conducted in 1995 and 2003.

THE DYNAMICS OF SOCIAL VALUES AND FISH CULTURE

Christine M. Moffitt, US Geological Survey Idaho Coop Fish and Wild Research Unit, University of Idaho, Moscow, ID

The applications of hatchery or aquaculture produced fish in fisheries management have a long history in human culture. This symposium helps us to reflect and re-assess the direction and consequences of our actions. The American Fisheries Society began as the Fish Culturists Association in 1870. Fish culturists are highly innovative and have utilized a variety of setting to increase the abundance of one species by reducing the natural mortality through intervening within the life history. In other cases, completely new fish communities have been established with non native species. Social values that are reflected in management actions have evolved, as culture reassessed the appropriate use and consequences of these propagation choices. American shad were widely introduced into waters of North American in the 1800s, and some populations became established in the large rivers of the Pacific coast. Angler groups intent on fishing for black bass have motivated resource agencies to introduce them into waters outside the historic range. German carp were celebrated as a great food source that would enhance waters across North America. What have been the consequences of these introductions? More recently conservation agencies and Tribes are using innovative tools in fish culture to restore endangered and threatened species. Our efforts in the future must include careful estimation of the true costs, benefits, and consequences of management actions. Superimposed on our understanding of the biology and sustainability of our choices are our dynamic social culture and its values regarding appropriate use, and conflicts for future allocations of water and economic resources. Using recommendations from previous symposia, and topics addressed in this symposium I propose a framework that could be helpful in facing future management choices.

CONTRIBUTION OF MATURING, CAPTIVE-REARED ADULT SALMON TO AID RECOVERY OF AT-RISK POPULATIONS

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Precipitous declines of Pacific salmon (Oncorhynchus spp.) have led to population levels that require prompt reactions to avoid extinction of some stocks. One rarely attempted strategy for reducing short term extinction risk and providing a demographic boost to natural populations is

to initiate conservation hatchery propagation programs that release captive adults to volitionally spawn in the natural environment. For these restoration efforts to succeed, captive adults must be able to successfully survive and reproduce in the wild. These programs require monitoring and evaluation components to describe reproductive success, determine the relative contribution of multiple release strategies and estimate subsequent abundance and productivity. We provide examples from two conservation hatchery programs in Idaho: Snake River sockeye salmon captive broodstock program and Snake River Spring Chinook salmon captive rearing program, which highlight some of the current evaluations. In both of these programs, we documented that captive- reared adults released into natural habitats successfully constructed redds, spawned, produced progeny that migrated to the ocean, and returned successfully as adults. We thus confirmed that captive-reared adults released into the freshwater environment contributed to the next generation of the natural population. These findings provide insight into the utility of using the captive propagation approach as a tool towards recovering severely depressed populations of salmon.

NOVEL USES OF GENETICS IN THE STOCKING AND CONSERVATION OF BLACK BASS IN FLORIDA

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In recent years, there has been a need to develop novel tools for addressing the challenges associated with management of valuable aquatic resources. The Florida Fish and Wildlife Conservation Commission (FWC) recognizes that endemic black bass (Florida largemouth Micropterus salmoides floridanus, shoal M. cataractae, spotted M. punctulatus, and Suwannee M. notius basses) are tremendous natural resources, enhancing the quality of life for citizens and tourists. Towards successful management of these important species, the FWC has incorporated robust policies designed to maintain the genetic integrity of hatchery reared finfish (i.e. Florida largemouth bass). These guidelines are the result of a series of science based discussions and workshops concerning fish genetic stocks in Florida. This work intends to discuss the status of fisheries genetics policies and programs employed by Florida and other state agencies. The results of a nationwide survey of current uses will be presented. This will be followed by a discussion of policy pertaining to the conservation of black basses in Florida, including a review of procedures leading to implementation. Topics will include the current use

of microsatellite markers in 1) genetic screening of hatchery broodfish 2) genetic tracking of hatchery releases 3) genetic conservation of endemic species and 4) creation of genetic management unts (GMUs). The discussion will also include ongoing projects addressing the potential for marker use in description of new species, mark-recapture, parentage analysis and broodstock development.

BIOSECURITY AND HATCHERY CHALLENGES TO ACHIEVE IT!

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Biosecurity in hatcheries can mean different things to different managers, depending upon what experiences they have had. It may be limiting the risk of disease (bacterial, viral or protozoan), or it could be preventing the introduction of an aquatic nuisance/invasive species, either onto the hatchery or from the hatchery during the distribution or stocking process. It could also mean the separation or isolation of specific species or "lots" of fish contained on the hatchery facility. Biosecurity is accomplished through process with the development of a plan, implementation of the plan, and use of technology. Hatchery managers have more technological options available to them than their predecessors had in the past that can now be utilized to make their facility more biosecure and limit the risk of infection or infestation. These technological options, including filtering, ultraviolet sterilization, use of ozone and chemical application will be presented, along with an overview of biosecurity practices that could be implemented to aid in the production of disease free, healthy and clean hatchery fish and mollusks.

SALMON AND STEELHEAD CONSERVATION AQUACULTURE AS MITIGATION FOR FEDERAL HYDROELECTRIC PROJECTS IN THE COLUMBIA RIVER BASIN: A HISTORICAL PERSPECTIVE

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Beginning with completion of Bonneville Dam in 1937, the Columbia River Basin in the Pacific Northwest region of the United States has been developed extensively by the U.S. Army Corps of Engineers and U.S. Bureau of Reclamation, as well as public and private utilities, to produce hydroelectric power. As mitigation for lost production attributed to federal hydro projects, the U.S Congress authorized construction of federally-funded Pacific salmon and steelhead hatcheries throughout the region. Despite artificial propagation, the commercial catch of Columbia River salmon declined by two-thirds between the mid-1930s and mid-1970s. A myriad of factors in addition to hydroelectric dams were responsible for decline in natural-

origin fish, notably overharvest, degraded tributary and estuary habitat, and poor ocean conditions. To help rebuild salmon and steelhead runs, the Columbia Basin Fish and Wildlife Program (Program) was initiated in 1982 to protect, mitigate, and enhance fish and wildlife affected by federal hydropower development in the Columbia Basin. However, in 1991, Snake River sockeye salmon (Oncoryhnchus nerka) were listed as Endangered under the U.S. Endangered Species Act (ESA), followed by listing of 12 more salmon Evolutionarily Significant Units or steelhead Distinct Population Segments over the next 14 years. Subsequently, captive broodstock programs and other conservation aquaculture projects were started under the Program to reduce extinction risk of at-risk populations of sockeye salmon, Chinook salmon (O. tshawytscha), chum salmon (O. keta), and steelhead (O. mykiss). An extensive conservation aquaculture research, monitoring, and evaluation program was also begun under the Program. In 2008, the National Marine Fisheries Service issued an ESA Section 7 Biological Opinion for the operation of the Federal Columbia River Power System (FCRPS) called for additional conservation aquaculture measures that are currently being implemented, including a significant effort to "reform" mitigation hatchery operations to reduce impacts on ESA-listed salmon and steelhead in the Columbia Basin. The Bonneville Power Administration, an agency of the U.S. Department of Energy that sells the power from the FCRPS, is the primary source of funding for operation of federal mitigation hatcheries and the conservation aquaculture programs established under the Program and FCRPS Biological Opinion.

TRANSPORTING ADULT SOCKEYE Oncorhynchus nerka FOR REINTRODUCTION ABOVE AN IRRIGATION STORAGE RESERVOIR IN THE YAKIMA BASIN IN WASHINGTON STATE

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Natural lakes in the Yakima basin historically produced approximately 200,000 returning adult sockeye to the watershed. Sockeye are the only Pacific salmon that require a lake environment for juvenile rearing. Each of these five lakes was dammed shortly before or after 1900 in order to create irrigation storage reservoirs to maximize water available for irrigation in the high desert of the Yakima basin. This was successful as the Yakima region became one of the major fruit, hops and grape producing regions of the United States. Unfortunately there was no fish passage included for either upstream or downstream passage of anadromous salmonids, and each lake population went extinct within one generation of construction. The Yakama Nation, in an effort to restore all anadromous salmon species historically present in the basin, began conducting research on the feasibility of reintroduction of sockeye into Lake Cle Elum in the mid 1990's after a century of absence. Research was conducted under a multi-agency work group with funding from the Bureau of Reclamation. A plywood flume was constructed down the face of the dam from one unblocked spillway to allow outmigration of smolts migrating on the

surface of the lake. Initial experiments were conducted using coho smolts as surrogates for the less plentiful sockeye. The coho successfully found the exit and migrated downstream. Due to the shortage of available sockeye smolts it was decided that the project would collect adult sockeye migrating up the Columbia River and transport them by truck to Lake Cle Elum, where they would be released into the lake and allowed to spawn naturally. These adults were returning to two watersheds in the upper Columbia, the Wenatchee (10 to 20% of the run) and the Okanogan (80 to 90%). A sliding scale was developed where more sockeye could be collected when greater numbers of adults were migrating to the upper Columbia. The first collection occurred in 2009 with 1000 adults collected and transported. This increased to 2500 in 2010, 4600 in 2011, and 10,000 fish transported in 2012 when a modern day record of over 400,000 sockeye returned. Genetic sampling is being conducted to determine which stock is more successful in recolonizing Lake Cle Elum, radiotelemetry is used to track adults after release into the lake, spawning adults are counted to determine survival from release to spawning, and estimates are made of smolts produced each year.

CONSERVATION STRATEGIES FOR NORTHWEST SALMON HATCHERIES - ESA AND SUSTAINABLE FISHERIES CONCERNS

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Development of the North Pacific salmonid hatchery system began in the late 19th century and has played a prominent role in enhancement of the salmonid resource in the Pacific Northwest. Today several billion hatchery-reared salmonids are released annually into the North Pacific. On the Columbia River alone, over 300 artificial production programs produce about 200 million hatchery fish. These hatcheries have played a major role in supplying salmon and trout to the common property fishery, benefiting commercial, sport, tribal, and nontribal fishers and now provide up to 80% of the fish in several of the key fisheries. Despite the great success of hatcheries in supplying fish, the philosophy of salmonid resource management has changed. Most public hatcheries in the Pacific Northwest were originally built to mitigate for loss of natural spawning habitat. Hatchery production goals focused on enhancing harvest of adults in commercial fisheries. The hatcheries were established at a time when wild salmon stocks were healthy and genetic diversity of stocks was not a concern. Today, many of the stocks are listed as threatened or endangered under the U.S. Endangered Species Act (ESA). The need to preserve biodiversity has brought about a new era of conservation of wild stocks that cannot help but impact the operation and management of production hatcheries and the traditional users of hatchery fish. A framework of Conservation Hatchery strategies to reduce potential impacts of artificial propagation on the biology and behavior of fish is discussed. These include: Mating and rearing designs that produce minimal genetic divergence of hatchery fish from their

wild counterparts to maintain long-term adaptive traits; Simulation of natural rearing conditions; Programming release size, stage, and condition to match the wild population in order to reduce potential negative ecological interactions and to promote homing; and Aggressive monitoring and evaluation. High priority must be given to basic scientific research to meet three principal goals: 1) Maintain genetic integrity of the population, 2) Increase quality and behavioral fitness, and 3) Reduce impacts to wild populations.

DO SALMON HATCHERIES PROVIDE MITIGATION TO THE NE PACIFIC ECOSYSTEM FOR SMOLT PRODUCTION LOST DUE TO ANTHROPOGENIC ACTIVITIES?

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The literature is reviewed to address the question do salmon hatcheries provide mitigation to the NE Pacific Ecosystem for smolt production lost due to anthropogenic activities. Hatcheries released about 5-6 billion smolts into the North Pacific each year during the 1990's. Although these fish made up only about 20% of the population going to sea, they were the majority of the population in the Southern portion of their range where permanent freshwater habitat loss has been significant. In the sea, most Pacific salmon inhabit the epipelagic zone of estuarine, coastal, and continental shelf waters where they exhibit selective feeding habits. Even though they consume less than 1% of the North Pacific's annual zooplankton production, they can significantly impact the macrozooplankton food base they depend upon. This has resulted in evidence of both intra- and interspecific competition being observed in salmon at sea. Species of special concern, such as rockfish and species important to regional fisheries (crabs) are part of this salmon food base. In turn, Pacific salmon are crucial prey for marine birds (e.g., terns and murres) and mammals (e.g., killer whales) that are also species of concern. Their crucial prey value, to species of special concern in the Southern portion of their range, indicates that artificial production may have ecological mitigation value for lost natural production. The conclusion is reached that if fishery manager's decisions are to conform with ecosystem management principles they should consider interspecific, as well as the intraspecific, effects when setting levels of artificial salmon production.