Foundations of Fisheries Science

Edited by

Greg G. Sass
Northern Unit Fisheries Research Team Leader
Wisconsin Department of Natural Resources
Escanaba Lake Research Station
3110 Trout Lake Station Drive, Boulder Junction, Wisconsin 54512, USA

Micheal S. Allen
Professor, Fisheries and Aquatic Sciences
University of Florida
7922 NW 71st Street, PO Box 110600, Gainesville, Florida 32653, USA

Section Edited by

Robert Arlinghaus
Professor, Humboldt-Universität zu Berlin and
Leibniz-Institute of Freshwater Ecology and Inland Fisheries
Department of Biology and Ecology of Fishes
Müggelseedamm 310, 12587 Berlin, Germany

James F. Kitchell
A.D. Hasler Professor (Emeritus), Center for Limnology
University of Wisconsin-Madison
680 North Park Street, Madison, Wisconsin 53706, USA

Kai Lorenzen
Professor, Fisheries and Aquatic Sciences
University of Florida
7922 NW 71st Street, P.O. Box 110600, Gainesville, Florida 32653, USA

Daniel E. Schindler
Professor, Aquatic and Fishery Science/Department of Biology
Harriett Bullitt Chair in Conservation
University of Washington
Box 355020, Seattle, Washington 98195, USA

Carl J. Walters
Professor, Fisheries Centre
University of British Columbia
2202 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada

American Fisheries Society
Bethesda, Maryland
2014

Section 5

Managing Fisheries Enhancements

Kai Lorenzen

5.1. SYNTHESIS

Articles in this section deal with the use of hatchery programs in fisheries enhancement and restoration—the third approach to managing fisheries after harvest and habitat management, and possibly the most controversial. Hatchery programs have been used successfully to maintain fisheries where natural recruitment of target species is low or absent, to enhance certain wild fisheries, and to conserve or restore threatened or endangered fish populations. At the same time, many hatchery programs have been associated with deleterious ecological or genetic impacts on wild fish populations and fisheries. In addition to biological interactions, hatchery programs have brought about varied and often significant human responses. Some have provided the impetus for fish conservation and habitat restoration initiatives, while others have encouraged overexploitation of wild stock components in mixed fisheries or masked fisheries impacts of habitat loss and thereby reduced incentives for restoration.

Even this brief introduction suggests that evaluating hatchery programs and using them effectively where potential exists for them to improve fisheries outcomes is a complex endeavor—quite the opposite of the "quick fix" that hatcheries are sometimes believed to offer. Among the issues that need to be considered are the dynamics of the fish population enhanced or created by stocking, hatchery techniques and their implications for post-stocking survival, strategies for releasing hatchery fish successfully into natural environments, genetic management, and the behavior of stakeholders and governance systems. Moreover, these facets need to be integrated into a coherent enhancement system framework to assess whether a hatchery program may meet its intended fisheries management goals and to design, implement, or reform the program where this is the case.

Hatchery programs have been used in fisheries management for well over a century, yet much of our current understanding of their potentials and limitations has emerged only over the past few decades. The articles assembled in this section are milestones that have advanced our understanding of hatchery programs through visionary and critical reviews that have defined the place of hatchery programs in fisheries management and the critical issues that need to be considered, and through primary research on these issues. This section aims to provide a unifying context for the selected, seminal articles and to point the reader to key subsequent studies that may have confirmed or challenged the conclusions of the selected articles.

Setting the Scene

The two articles in this section ask "what are hatchery programs useful for from a fisheries management perspective" and "what needs to be considered in order to make it work?" Both articles appeared around the same time and were motivated by a prevailing sense that many hatchery programs operated without a clear rationale, without consideration of key factors likely to be crucial to outcomes, and without evaluation. Cowx (1994) draws mostly on experience and examples from European freshwater systems where hatchery programs have been long established, while Blankenship and Leber (1995) focus on marine hatchery programs with a much shorter history. Cowx (1994) emphasized decision making frameworks such as flow charts, while Blankenship and Leber (1995) outlined a set of broad recommendations. The articles independently arrive at many of the same conclusions—the need for a strategic approach with defined objectives, targeted program design, and rigorous evaluation being the overarching one. Others include the need to consider stocking/release strategies, ecological interactions with wild fish, genetic management, and disease control. Some differences in approach are evident that may be traced to differences between freshwater and marine hatchery programs and the degree to which they have become part of operational management rather than research. Cowx (1994) differentiates between uses of hatchery programs (for mitigation, enhancement, restoration or creation of new fisheries) and emphasizes the need to quantitatively assess the status of the fishery (e.g., abundance relative to carrying capacity, size and age structure) to identify the need and scope for enhancement. At the time, such assessments were more practical in freshwater systems where empirical yield and stocking models had been developed from comparative studies across multiple lakes or streams than in marine systems where stocks were assessed individually using mathematical models that were not set up to deal with the issues surrounding stocking. This and other aspects of the disciplinary elements of hatchery programs are further explored below. As for overarching, strategic approaches to hatchery programs, the articles by Cowx (1994) and Blankenship and Leber (1995) have remained important points of reference. In 2010, Lorenzen, Leber, and Blankenship published a comprehensive update of the responsible approach that integrates and expands on key recommendations from both articles. The updated responsible approach has fifteen key elements arranged in three stages as follows: (Phase I) initial appraisal and goal setting; (Phase II) research and technology development including pilot studies; and (Phase III) operational implementation and adaptive management. Stages are ordered in this sequence to ensure that broad-based and rigorous appraisal of enhancement contributions to fisheries management goals is conducted prior to more detailed research and technology development and operational implementation.

Population Dynamics

The central aim of most hatchery programs is to increase the abundance of fish populations to enhance, rebuild, and/or conserve small fisheries. Hence, understanding and predicting the dynamics of fish populations subject to stocking is crucial to managing hatchery programs effectively.

Experimental stocking studies have been conducted in freshwater systems since the early 20th century, often for the dual purpose of studying fundamentals of production ecology and developing stocking strategies. Of these studies, Homer Swingle's experiments on the management of fisheries in farm ponds in the southeastern United States are the most well-known and influential. In the article reproduced here, Swingle (1951) designed a stocking regime that quite reliably produced a good annual crop of harvestable size fish from a predator-prey community of Largemouth Bass *Micropterus salmoides* and Bluegill *Lepomis macrochirus* stocked into small impoundments. The study systematically applied ecological concepts and quantitative indicators Swingle had developed earlier through a large number of pond experiments (Swingle 1950), and which are well laid out in the introduction of the article reproduced here. The article makes several important contributions to the development of fisheries enhancement science. First, it sets out to use stocking for a specific fisheries management goal (a balanced fish community yielding good catches) that, in small impoundments, cannot reliably be achieved by harvest or habitat management alone. That is a far cry from the many *ad hoc* hatchery programs that have motivated Cowx (1994) and Blankenship and Leber (1995) to call for systematic and responsible approaches to enhancement. Secondly, in addition to using his community indices to guide stocking strategies, Swingle carefully analyzed survival and the effects of stocking regimes and inter-specific interactions upon it, making this an early empirical study of population dynamics of stocked fisheries. Swingle's studies, with some extensions and modification, have continued to inform the management of small impoundments in the southeastern United States to this day.

Pacific Salmon *Oncorhynchus* spp. stocks have been subjected to the world's largest and longest-running hatchery programs. The relative ease of quantifying abundance of juveniles and spawners during their migrations out of and into their natal rivers means that some of the best quantitative data on enhanced populations are available for these stocks. Hilborn and Eggers (2000) took advantage of such long-term data for Alaskan Pink Salmon *O. gorbuscha* stocks and most importantly, evaluated the impact of hatchery programs by comparing long-term variation between enhanced stock and non-enhanced controls. While the focal hatchery program in Prince William Sound was associated with a substantial increase in salmon catches, similar increases were observed over the same period in stocks not enhanced with hatchery fish—suggesting that catch increases were due to large-scale changes in ocean conditions and that a substantial contribution of hatchery fish to catches in Prince William Sound signified displacement of wild by hatchery fish rather than a net positive contribution to catches. The study sparked some debate (Wertheimer et al. 2001; Hilborn and Eggers 2001), which served to further highlight the risk of displacing the wild stock component in enhanced fisheries, and the importance of adopting a sound experimental design with non-enhanced controls and replication when evaluating enhancements experimentally.

While experimental and comparative observation studies have played a major role in informing the management and enhancement of freshwater and anadromous fisheries, such approaches are less suited to marine fisheries and those in larger freshwater systems which rely on fewer, larger stocks and offer only limited opportunities for replicated experiments. Population dynamics modeling, therefore, is the primary tool for assessing management options in such fisheries. The same approach holds promise for assessing the potential or actual contribution of hatchery releases to fisheries management goals. However, the dynamic pool models commonly used in fisheries assessment are based on a simplified representation of population dynamics that is appropriate to the assessment of harvesting of recruited fish, but precludes the evaluation of enhancements. Lorenzen (2005) extended the