SALMONINE REPRODUCTION AND RECRUITMENT

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Introduction

Fostering self-sustainability and protecting the genetic diversity of fish stocks are key features of the goals and guiding principles in the fish-community objectives for Lake Michigan (Eshenroder et al. 1995). Reliance on natural feedbacks between predator and prey to control recruitment can provide more-effective self-regulation, leading to greater system resilience and stability, than external actions, such as stocking or harvest, which entail time lags (Christie et al. 1987). The genetic fitness of self-sustaining populations likely exceeds that of stocked populations (Berejikian et al. 1999, 2001; Kostow et al. 2003), because self-sustaining populations benefit from natural selection and are able to adapt to unique and specific conditions in localized environments (Falkner and Falkner 2000).

Natural recruitment of Lake Michigan salmonine populations has been quantified historically by mark-and-recapture studies of hatchery-released fish, by counting out-migrating wild smolts in tributary streams, and, more recently, by surveys of lake trout eggs and fry on spawning reefs. Because hydrologically stable, groundwater-fed streams most conducive to natural reproduction of anadromous salmonids (Carl 1983; Seelbach 1985) are generally found in just the northern and eastern areas of the lake's basin, measures of smolt out-migration or of returning adults in streams can be

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difficult to translate into the whole-lake population, which also comprises stocked fish. In contrast, if recruitment of wild fish is quantified through recreational fisheries and independent assessments in the open lake, information regarding stream-specific influences on the lakewide population is not obtained. Given limited monitoring efforts, the recruitment dynamics of salmonines continues to be incompletely understood. Here we report on natural recruitment of four of the lake's major salmonines: coho salmon, Chinook salmon, steelhead, and lake trout. We do not report on brown trout because, although it is a major salmonine, its level of natural reproduction is minimal (Keller et al. 1990).

Progress

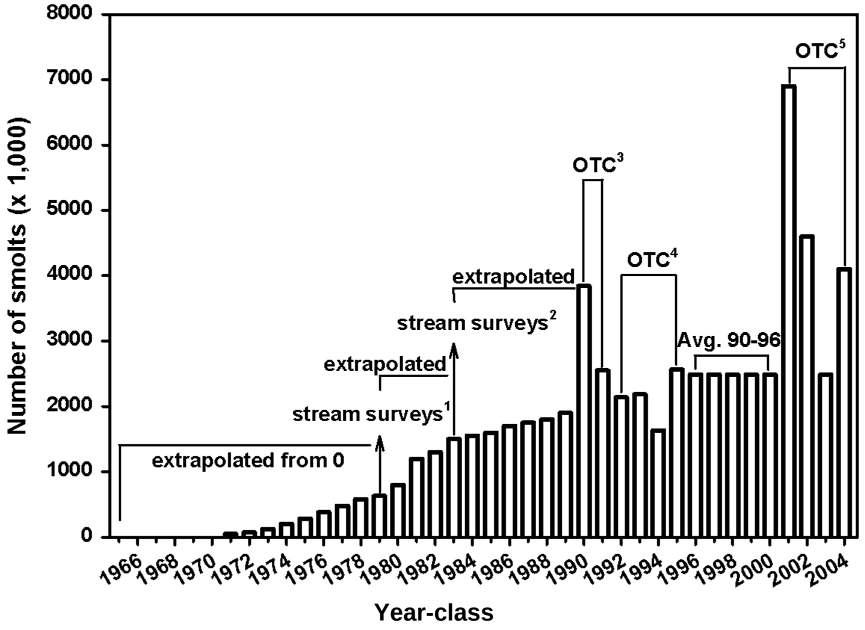
Coho Salmon

Spawning of coho salmon in the wild was encouraged as early as the fall of 1967 when adults were transferred to seven Michigan streams (Borgeson 1970). Reproduction was detected the following year in at least two of the streams, the Boyne and Boardman Rivers (see frontispiece for location of rivers) (Borgeson 1970), and since then has been observed in many tributaries (Taube 1974; Carl 1983; Seelbach 1985; Rutherford et al. 1999; T. Newcomb, personal communication, 2005). In 1979, all stocked coho salmon in Lake Michigan were fin clipped, allowing Patriarche (1980) to estimate that wild coho comprised 9% of the lakewide population. In recent years, smolt production has been measured in individual rivers, but there are no current efforts to estimate lakewide production.

Chinook Salmon

Five investigations conducted over the past 35 years suggest that natural recruitment of Chinook salmon, the most productive of the lake's salmonines, has increased (Fig. 13). By the late 1970s, approximately one decade after stocking began, lakewide smolt production was estimated at 600,000 smolts. By the early 1990s, smolt production was estimated at 2.5 million, and estimates in recent years indicate more than 4 million smolts have been produced annually (Fig. 13). Data from lakewide surveys and smolt monitoring in indicator streams suggest recruitment levels can vary from three- to fourfold in any given year, due in part to changes in stream flow during the three- to four-month nursery period after hatch (Zafft 1992; ESR, unpublished data). Management objectives for production of wild fish relative to stocking needs have not been determined for Chinook salmon.

Fig. 13. Estimates of wild Chinook salmon smolt production from Lake Michigan tributaries, 1965–2004. OTC refers to the recapture of adults marked as smolts with oxytetracycline ([1]Carl 1982; [2]Keller et al. 1990; [3]Hesse 1994; [4]ESR and DFC, unpublished data; [5]RMC and J. Johnson, unpublished data).



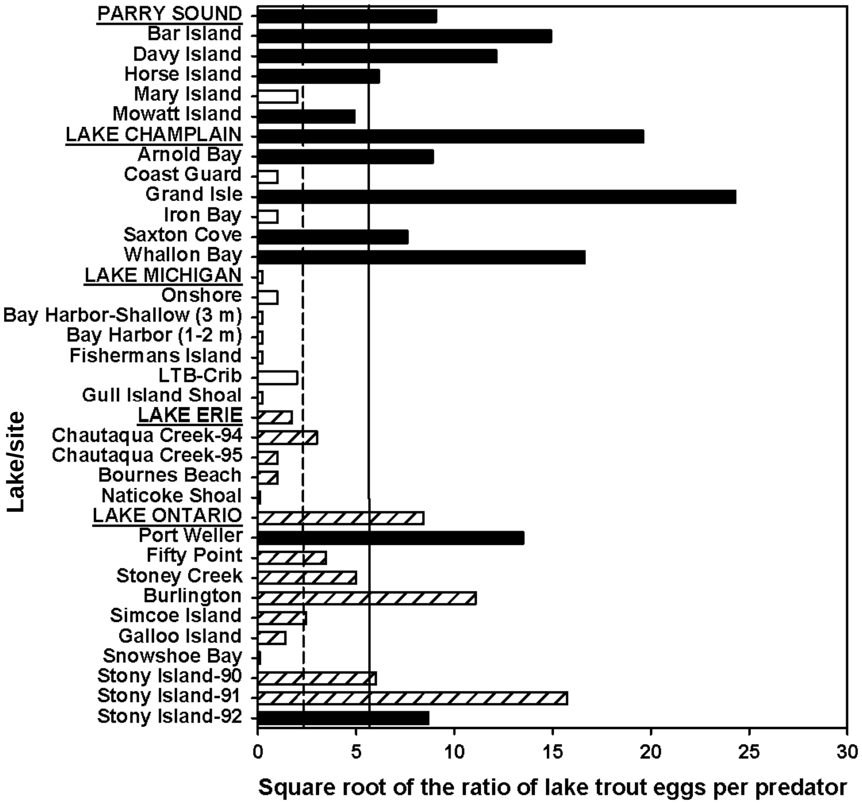
Steelhead

Production of wild steelhead in Lake Michigan is relatively simple to estimate because differential growth patterns on scales can be used to distinguish hatchery from wild fish (Seelbach and Whelan 1988). Current annual recruitment estimates average 250,000 to 300,000 smolts, but, as with Chinook salmon, recruitment varies three- to four-fold annually due to fluctuations in temperature in tributary nursery habitats and in stream flows (Seelbach 1987a, b; Newcomb 1998; Woldt and Rutherford 2002). The majority of investigations into steelhead recruitment dynamics have been river-specific (e.g., Seelbach et al. 1994; Newcomb 1998; Rutherford et al. 1999; Woldt and Rutherford 2002; Swank 2005), but some lakewide estimates have been made. As with Chinook salmon, management objectives for production of wild steelhead relative to stocking needs have not been established. To better inform management, factors influencing recruitment success, with an emphasis on forecasting and prediction, need to be investigated. Changes in stocking practices (fingerlings to yearlings) have greatly improved survival of stocked steelhead. Estimated percentages of hatchery steelhead in the lakewide population have increased from 4.1% during 1979-1982 to 83.2% during 1993-1997 (Rand et al. 1993; Bartron and Scribner 2004). Recent genetic and demographic studies of steelhead indicate naturalized steelhead populations have growth, survival, and maturity schedules specific to stream environments, suggesting they have evolved quickly both within Lake Michigan and among the Great Lakes (Bartron and Scribner 2004; Swank 2005). Given these findings, the role of stocking will need to be reconsidered.

Lake Trout

The fish-community objective for lake trout is to "establish self-sustaining lake trout populations" (Eshenroder et al. 1995), and much time and effort have been spent toward rehabilitating this species, which was extirpated during the mid-1900s. Although egg deposition occurred and hatched fry were observed infrequently, no meaningful survival past age 1 has been detected. Revisions are being made to the 1985 rehabilitation plan for lake trout with the goal of enhancing production of wild lake trout (Bronte et al. 2008). Management targets have traditionally focused on abundance of spawning adults in gillnet surveys. Jonas et al. (2005b) have identified a better estimate of potential recruitment: the number of lake trout eggs deposited per egg predator on specified spawning habitats (Fig. 14). Egg-to-predator ratios at surveyed lake trout spawning reefs in Lake Michigan are well below those from sites where fry emergence was measurable (Fig. 14). Consequently, management should focus on achieving higher concentrations of spawning fish near the best habitat to increase the egg-to-predator ratio and the probability of increased recruitment (Bronte et al. 2003a).

Fig. 14. Suggested metric for measurement of success of lake trout spawning: the ratio of lake trout eggs deposited •egg predator^{-1}•m^{-2}. Bars next to site names represent the square root of average ratios for the site. Black bars indicate sites where emergence was detected, white bars indicate sites with no emergence, and hatched bars indicate sites where fry emergence was not assessed. The broken line represents the largest ratio where fry emergence was not detected, and the solid line represents the lowest ratio at sites with detectable fry emergence.



Recommendations for Revision of Salmonine Recruitment Objectives

Naturalized salmonines are a major component of the Lake Michigan fish community, and an understanding of their population dynamics is critical to developing effective lakewide management plans. Given the high temporal and spatial variation in survival rates of offspring from naturalized salmonines, improved methodologies for estimating and predicting natural recruitment and an improved understanding of factors causing variation (e.g., parent stock, stream discharge, stream temperature, and forage abundance) is increasingly important. Lake trout are currently the only species with defined stocking and reproductive targets. We recommend further refinement of lake trout rehabilitation targets by incorporating the egg-to-predator target discussed above. Management objectives for natural production of other salmonines need to be developed, and key questions are: (1) what level of natural recruitment is desirable? and (2) how should stocking rates be adjusted as targets for natural recruitment are approached? Consideration of species interactions, density-dependent responses, and the sustainability of the community should be included when establishing new management targets. Given the current understanding of genetic stock concepts, management objectives and stocking strategies should be revised to reflect more-recent findings. For example, stocking practices may inadvertently harm naturalized fish populations or, at the least, interfere with selective processes. Fishery managers should consider commitments to genetic stock concepts and revise stocking strategies accordingly. A long-term, multi-agency strategy for assessing natural reproduction on a lakewide basis should be developed.

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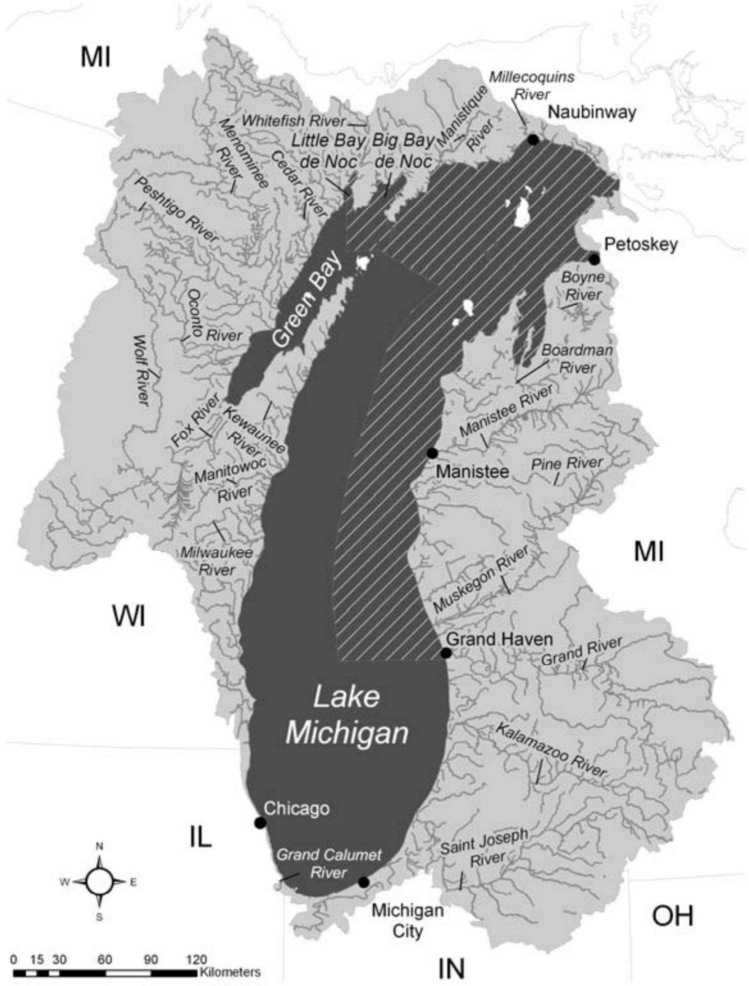

Lake Michigan depicting locations not otherwise identified in this publication. The lake basin is in grey, and treaty-ceded waters are depicted by diagonal lines.

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