Rearing Origin and Distribution of Atlantic Salmon Post-Smolts in Penobscot Bay and the Near-shore Waters of the Gulf of Maine, USA

Russell W. Brown, Ruth Haas-Castro, Craig A. Tinus, and **Erin Livensparger**
NOAA Fisheries, Northeast Fisheries Science Center,
166 Water Street, Woods Hole, Massachusetts 02543 USA

Keywords: Atlantic salmon, post-smolt, rearing origin, mortality, trawl

Wild Atlantic salmon populations on the east coast of the United States have failed to recover despite sustained efforts to improve rearing conditions, reduce high seas fishing mortality and supplement populations with hatchery fish. Currently, differential mortality of cohorts and life history stages from factors such as competition, predation, pollution and disease is poorly understood. The smolting process (migration and transition from freshwater to marine environments) has been identified as a critical period and a potential population bottleneck for Atlantic salmon and other salmonids. The success of the transition to marine habitats by emigrating Atlantic salmon smolts is poorly understood because attempts to sample and monitor smolts in estuarine and near-shore marine areas have been extremely difficult.

The Penobscot River (Maine, USA) has hosted 75% of documented adult returns to East Coast US Rivers since 1986. Atlantic salmon smolts from the Penobscot River originate from natural spawning by adult escapement and hatchery releases of fry, parr and age 1+ smolts. The relative contribution of each source to smolt populations is unknown, but scale analyses indicate that adults originating from age 1 and 2-year smolt stocking have represented in excess of 85% of returning adults in recent years. The survival rates of hatchery smolts have declined by 10-fold over the past 15 years, resulting in sharp declines in adult returns, and has heightened concerns about progress on restoration goals. To provide future direction for coordinated management strategies, basic questions about the riverine, estuarine, and marine survival of each cohort need to be addressed. Partitioning of riverine, estuarine and marine mortality sources for smolts and post-smolts represents an important step that may allow for the identification of population bottlenecks.

In an effort to track individual cohorts with differing in-river rearing times, NOAA Fisheries has developed a coordinated research program focused on hatchery and naturally reared Atlantic salmon smolts in the Penobscot watershed. This coordinated program involves the elastomer marking and release of 170,000–180,000 age 1+ hatchery smolts annually, a rotary screw trap monitoring program at the head of tide, an estuarine and near-shore marine trawl survey program, and recovery of elastomer marks from returning adults trapped at a head-of-tide dam. In May 2001, NOAA Fisheries implemented a pair-trawl sampling approach to the capture and live release of post-smolts based on technology developed by investigators in Norway and Canada. We pair-trawled a modified mid-water trawl with an aluminum live box at the cod end throughout Penobscot Bay and near-shore waters of the Gulf of Maine. Atlantic salmon post-smolts were captured at 49 of 61 stations (80%) sampled during the survey and a total of 1458 Atlantic salmon post-smolts were captured. Recovery of 355 elastomer-marked fish allowed for evaluation of the relative contribution of different hatchery release groups to the post-smolt population. Analysis of scale samples indicates that post-smolt populations were dominated by age 1+ hatchery smolts (97%) and few naturally reared fish (smolts originating from natural spawning or fry and parr releases) were detected. However, the proportion of naturally reared fish increased in samples collected further offshore, suggesting that either naturally reared fish were migrating earlier, were moving more quickly to offshore waters, or that differential mortality was occurring between hatchery and naturally reared fish. Hatchery smolts are easily distinguished from naturally reared smolts, but a potentially confounding factor is the difficulty in distinguishing smolts originating from natural spawning from smolts surviving from fry and parr releases. Expansion of marking programs and refined image analysis approaches are being utilized to improve identification of smolts from these sources.

Effects from pollution, river acidification and other sources of physiological stress may negatively affect the timing of physiological transitions required to successfully osmoregulate in saltwater. The release of batch-marked smolts at different times and at different locations in the river is allowing for analysis of migration timing and measurement of enzymatic indicators of physiological transition. Sequential testing of Na+, K+, ATPase and citrate synthase levels in hatchery smolts prior to release, in the river at the head of tide during migration, and in estuarine and near-shore marine areas, is providing a continuum of data to allow for better understanding of this physiological transition. Ultrasonic telemetry studies in other US systems provide evidence that smolts that are not fully capable of osmoregulating in saltwater may hold in areas of lower salinity, possibly increasing their vulnerability to predation. In addition, the presence of multiple hydro-electric projects and associated impoundments in the

All correspondence should be ddressed to R. Brown.
e-mail: Russell.brown@noaa.gov

watershed may delay the timing of emigration to marine systems. Although hatchery smolts are released in main stem areas below the majority of dams, naturally reared smolts are required to migrate through up to 6 hydro-electric projects prior to reaching estuarine areas. Current migration data suggest that smolts begin seaward migration at 10°C, but that in many years water temperatures quickly reach 18°–20°C in lower river areas. Rapidly warming river water temperatures can potentially result in increased physiological stress and predation from warm-water predators. Delayed migration can further increase smolt exposure to these potential mortality sources.

The early marine phase likely represents a critical growth period since suitable prey are abundant in near-shore marine waters. Diet samples collected from smolts and post-smolts as they move down river and into marine waters suggest that upon entering marine waters post-smolts begin feeding immediately and predominantly on herring larvae, which occur in high densities. As part of the continuing research we intend to evaluate this further by calculating relative growth rates using RNA/DNA ratios and additional stomach content analysis.

Heavy sea lice infestation potentially contributes to higher mortality of post-smolts. However, in our samples we found no sea lice infestation on post-smolts, though closely related lice species were documented on other species (e.g. lumpfish). A follow-up cruise in Spring 2002 will expand spatial and temporal coverage to further define migration pathways and near-shore distribution and to test hypotheses related to differential mortality of post-smolts originating from hatchery and naturally reared sources.