EFFECTS OF SUMMER TEMPERATURES ON THE GROWTH AND CONDITION OF JUVENILE ATLANTIC TOMCOD, *MICROGADUS TOMCOD*

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

Atlantic tomcod, *Microgadus tomcod*, is a small anadromous gadid whose southernmost spawning population inhabits the Hudson River and smaller adjacent estuaries. Prior studies suggest that growth of juvenile Hudson River tomcod slows during summer as a result of warm temperature, however, this has not been experimentally evaluated. The objectives of this study were to (1) estimate the effects of temperature on growth and condition of juvenile tomcod in the laboratory, and (2) evaluate seasonal changes in length, weight, and condition of tomcod in the Hudson River. We exposed populations of laboratory-reared juvenile tomcod to three water temperature regimes that mimicked cool, moderate, and warm summers. Tomcod growth rates were suppressed and their condition deteriorated when temperatures exceeded 20°C, but were unaffected by temperatures below 20°C. Two summer surveys of the lower Hudson River between the Battery and West Point (rkm 0 to 80) using a 4.9-m otter trawl were also conducted. Tomcod were collected in all regions sampled and were more abundant and smaller in size in June than in July. Abundance was highest at the upriver stations where temperatures exceeded those that retard growth as determined in the laboratory. Although our experimental estimates of juvenile tomcod growth rates are similar to earlier field-based estimates, they are free of the confounding factors typical of field collections and are the first to unambiguously link warm summer temperatures to reduced growth rate in juvenile tomcod.

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INTRODUCTION

Atlantic tomcod, *Microgadus tomcod*, is a small anadromous gadid distributed principally along the Atlantic coast of North America from southern Labrador to the Hudson River that occurs incidentally as far south as Virginia (Scott and Crossman 1973). Tomcod inhabiting the Hudson River estuary represent the southernmost spawning population of the species (Dew and Hecht 1976). The Hudson River population is largely self-contained and is an important member of the Hudson River biota. It is a dominant component of the ichthyofauna, a resident species whose status is indicative of the system's health, and a critical prey resource for a variety of predators including juvenile bluefish, *Pomatomus saltatrix*, and striped bass, *Morone saxatilis* (Klauda et al. 1988, McLaren et al. 1988, Juanes et al. 1993). Furthermore, Hudson River tomcod has been relatively well studied in nature because it has been the subject of numerous monitoring programs (Dew and Hecht 1994, Dew 1995).

Tomcod spawn in the Hudson River from mid December through January in low salinity (<10 ppt), upstream habitats (Klauda et al. 1988). Eggs are demersal and hatch 4 to 6 weeks after fertilization. Young larvae are transported downstream by the current during the spring. From mid May to October, juvenile tomcod are widely dispersed throughout the river with the area of highest abundance shifting from higher salinity (>10 ppt), downstream habitats to lower salinity (<10 ppt), upstream habitats during the summer (Klauda et al. 1988, CHGEC 2000). In fall, juveniles mature into adults and aggregate to spawn during their first winter. Few adults survive to spawn again in their second winter.

Earlier studies have proposed that summer water temperatures in the Hudson are too warm to sustain high tomcod growth rates (McLaren et al. 1988). Length-at-date data for juvenile tomcod collected in the Hudson River appear to show that tomcod increase in size rapidly in the spring and fall, but display little if any growth during July and August. This reduction in growth rate may mean that optimal temperatures for growth are exceeded during the summer (Grabe 1978, McLaren et al. 1988). McLaren et al. (1988) report that growth rates of juveniles, inferred by changes in length-frequency distributions, were highest from mid May through June, after which they were suppressed

by warm water temperatures in July and August. The upper lethal limit of tomcod, based on laboratory trials, is reported to be ~ 26.5°C (Ecological Analysts 1978).

The pattern of decelerated tomcod growth during periods of warm water temperature has yet to be experimentally evaluated. Current estimates of growth have been based on size-at-date information from field collections. Those size-at-date data, however, may reflect several processes in addition to temperature-dependent growth, including sampling artifacts, size-specific habitat shifts, size-dependent predation, and gear selectivity. As a result, it may be premature to conclude that the seasonal changes in tomcod sizes referred to above reflect solely the effects of temperature on growth rate. In addition, seasonal changes in sizes-at-date provide, at best, an indirect measure of the functional relationship between temperature and growth rate. This study was designed to provide a more direct assessment of the effects of temperature, specifically summer temperatures, on growth rate and condition of juvenile tomcod.

Objectives

The objectives of this study were to (1) estimate the effects of temperature on growth and condition of juvenile tomcod in the laboratory, and (2) evaluate seasonal changes in length, weight, and condition of tomcod in the Hudson River. Because this study used both laboratory and field data to estimate growth and condition, we also sought to compare estimates between these two sources and with estimates from previously reported tomcod length data.

METHODS

Temperature-dependent growth experiment

A laboratory experimental approach was used to quantify the effect of temperature on growth rate and condition of tomcod. Three different temperature regimes, each replicated twice, were chosen to mimic the summer temperatures experienced by tomcod throughout the species' range. The temperature regimes were simplified by forcing each to be a triangular distribution wherein all regimes began and ended at 15°C but differed in their peak temperatures. These three regimes were intended to reflect a warm (peak at 25.6°C), moderate (21.6°C), and cool (17.6°C) summer. The

continuously changing temperatures observed in nature were simplified in this experiment by increasing or decreasing temperatures every two or three weeks with interim temperatures held constant (Fig. 1). Water temperatures were monitored daily and adjusted when necessary (+/- 0.5°) by modifying the mixture of heated and ambient seawater, which filled the 1.2-m diameter fiberglass tanks. All tanks were maintained under flow-through conditions using seawater (20-24 ppt salinity) that was pumped into the laboratory from nearby Sandy Hook Bay.

Six experimental populations of laboratory-reared juvenile tomcod (n=150 tomcod per population) were established from a mixed group of offspring from crosses of three male and three female tomcod. These adult tomcod were collected using traps in the Hudson River at approximately river kilometer (rkm) 80, in Garrison, New York during January, 2000. All fish used in the experiment were drawn from a pool of tomcod that were of the same age (105 d post-hatch), comparable size (31.5 ± 2.27 mm total length, TL), and had been maintained under identical conditions prior to the experiment.

Growth of tomcod in the laboratory was estimated for each population from weekly samples of 20 fish from each of the six tanks. Measurements of TL were made to the nearest 0.1 mm using a dial caliper and wet weights (WW) were determined to the nearest 0.01 g. Ten of the 20 fish sampled were returned to the tank and 10 were frozen so that dry weights, otoliths, and lipid contents could be obtained at a later date. The robustness or leanness of fish was calculated as wet weight per unit length as an indicator of fish condition.

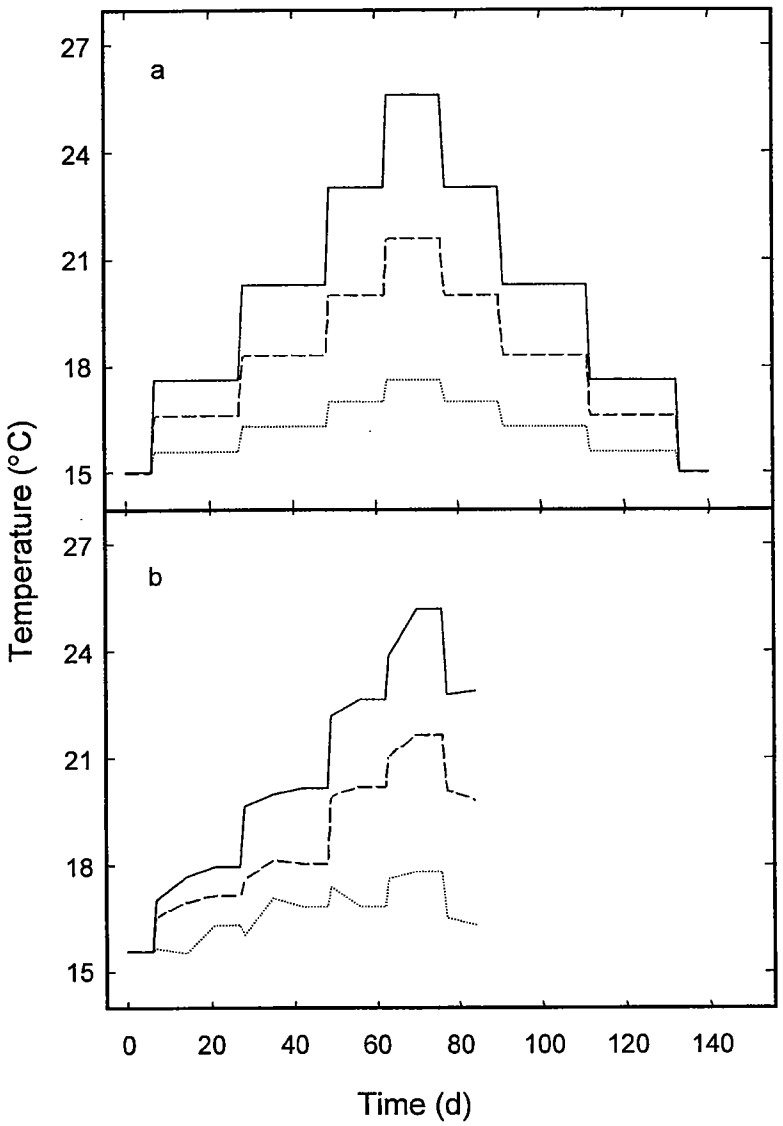

Figure 1. Targeted (a) and actual (b) temperatures for the three temperature regimes used in the tomcod growth experiment. The solid, long-dashed, and short-dashed lines represent the warm, moderate, and cool regimes, respectively.

Field collections of juvenile tomcod

We conducted monthly summer surveys of the lower Hudson River between the Battery and West Point (rkm 0 to 80) in order to (1) evaluate seasonal changes in length, weight, and condition of juvenile tomcod, (2) determine whether the spatial distribution of juvenile tomcod changed during the summer, and (3) correlate seasonal changes in fish size and distribution with water temperatures. Two sampling cruises in the Hudson River were conducted aboard the *NMFS R/V Gloria Michelle* during the summer of 2000. We sampled at six (June) or nine (July) stations with each station separated by approximately 10 km. The stations were chosen so as to cover the full salinity gradient (0-28 ppt) of the lower Hudson River (Fig. 2). One channel tow and two shoal tows on opposite sides of the channel were made at each station using a 4.9-m otter trawl. This sampling scheme enabled us to gather information about tomcod and water quality parameters from different depths at the same km on the Hudson River (depth 4-26.5 m).

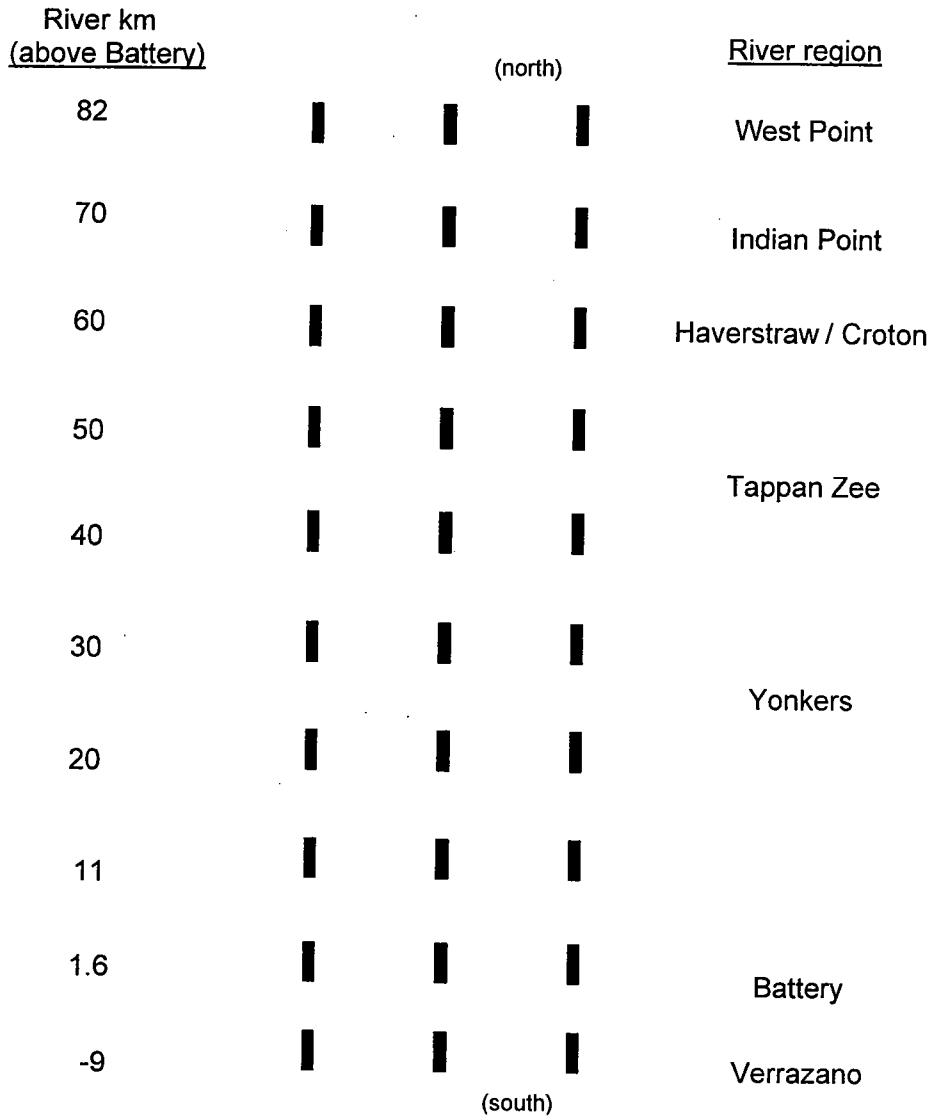

Figure 2. Hudson River otter-trawl sampling design for juvenile tomcod. Each bar represents a 5-min tow with a 4.9-m otter trawl.