EFFECTS OF A MUNICIPAL PIER ON GROWTH OF YOUNG-OF-THE-YEAR ATLANTIC TOMCOD: A STUDY IN THE LOWER HUDSON RIVER ESTUARY

A Final Report of the Tibor T. Polgar Fellowship Program

Charles V. Metzger

Polgar Fellow

Marine Science Program
Richard Stockton College of New Jersey
Pomona, NJ 08201

Project Advisers:

Janet Duffy-Anderson
Kenneth W. Able
Rutgers University Marine Field Station
Tuckerton, NJ 08087

Metzger, C., J. Duffy-Anderson, K.W. Able. 1999. Effects of a municipal pier on the growth of young-of-the-year Atlantic tomcod: A study in the lower Hudson River Estuary. Section VII: 19 pp. *In* W.C. Nieder & J.R. Waldman (eds.), Final Reports of the Tibor T. Polgar Fellowship Program, 1998. Hudson River Foundation.

ABSTRACT

In two 10-day field experiments conducted during May and June 1998, I investigated the effect of a large municipal pier on the growth of young-of-the-year Atlantic tomcod (*Microgadus tomcod*) in the lower Hudson River estuary. Fish were caged along a transect ranging from outside the pier to underneath comprising three stations: 40 m beyond the edge in open water, at the pier edge, and 40 m underneath the pier. In both experiments, fish grew at all transect stations, compared to negative growth among laboratory-starved controls. In the first experiment, growth rates under the pier were $+0.02 \pm 0.004$ d^{-1}, at the edge were $+0.04 \pm 0.006$ d^{-1}, and outside were $+0.03 \pm 0.005$ d^{-1}. For the second experiment, growth rates were similar, with $+0.02 \pm 0.002$ d^{-1}, $+0.03 \pm 0.002$ d^{-1}, and $+0.03 \pm 0.003$ d^{-1} at the underneath, edge, and outside stations, respectively. Results show that juvenile Atlantic tomcod are capable of positive growth underneath piers, though at reduced rates compared to edge or open water habitats. Although piers may be detrimental to the growth of some fish species, others such as Atlantic tomcod may be better able to exploit them as habitat. However, because growth of juvenile Atlantic tomcod was lower under piers compared to at the edge and outside, under-pier areas may be suboptimal habitat even for species that are able to utilize them.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

New York Harbor is a large urban estuary, and a nursery area for juvenile fishes. However, anthropogenic influences in the region have altered or destroyed most of the natural fish habitat (Squires 1992), often replacing it with man-made structures such as wrecks, abandoned pile fields, bulkheads, and piers. There is evidence that some of these man-made structures may be used as habitat by juvenile fish (Able *et al.* 1998), though it appears that not all structures are suitable for all species. Previous work has demonstrated that abundances of fishes and crustaceans are depressed under large, municipal piers (Able *et al.* 1998), and that growth rates of juvenile winter flounder *(Pseudopleuronectes americanus)* and juvenile tautog (*Tautoga onitis*) are negative when these animals are caged there (Duffy-Anderson and Able in press; Able *et al.* in review). This has led to speculation that under-pier areas are poor quality habitats for juvenile fishes in general. However, American eel and Atlantic tomcod are repeatedly collected under piers (Stoecker *et al.* 1992; Able *et al.* 1998), suggesting that for some species, under-pier areas may represent better quality habitat.

Habitat quality is difficult to assess, but species abundance (Szedlmayer and Able 1996), species richness (Heck *et al.* 1995), and species distribution (Sogard and Able 1994) have all been employed to quantify its value. However, measurements of growth rate may be best suited to examining habitat value among juveniles since growth is very rapid during this period and therefore readily quantified. Sogard (1992) used growth rates to demonstrate that vegetated areas may be more suitable for growth of juvenile tautog than open water sites, and Rountree and Able (1992) used growth to determine that salt-marsh creeks were important habitats for young-of-the-year summer flounder

(Paralichthys dentatus). I assessed the value of under-pier areas as habitat for juvenile Atlantic tomcod (*Microgadus tomcod*), a species commonly collected under large piers, by determining differences in growth rates among fishes caged under piers, at pier edges, and in open waters beyond piers.

METHODS

Site Description / Target Species

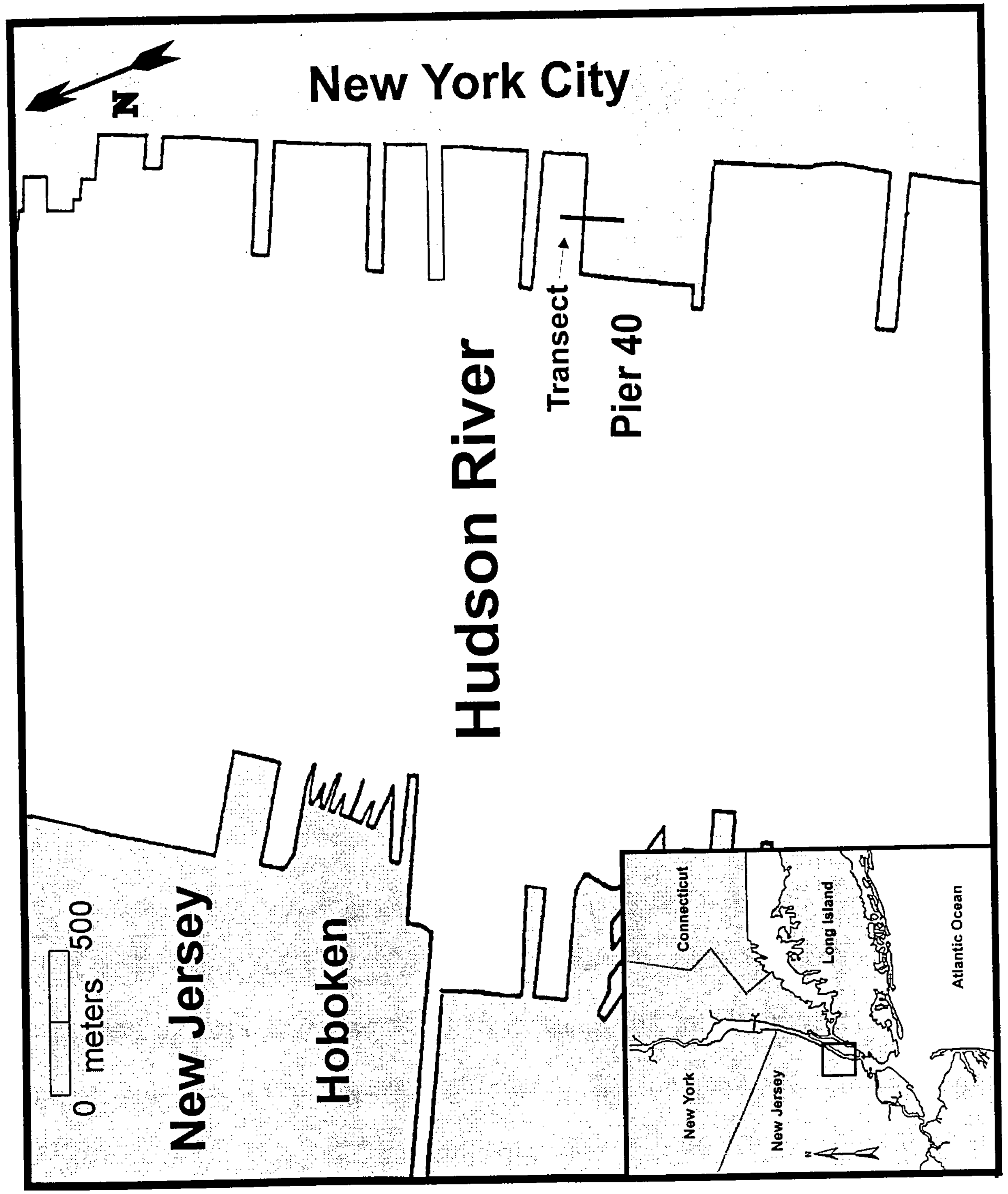
Marine and Aviation Pier 40 was selected as the study site (Figure 1). It was selected because of its accessibility to the interior by boat, and because it was previously used by Able *et al.* (1998) in an earlier study of habitat quality. The pier is on the Manhattan side of lower New York Harbor, across from Hoboken, NJ, and currently supports multiple decks for parking.. Its top is solid concrete, measuring approximately 250 m x 350 m.

The transect used in this study was established on the northern side of the pier, primarily because it was closed to public. Three stations were set up along the transect: 40 m beyond the edge of the pier in open water (+40 m), the pier edge (0 m), and 40 m underneath the pier (-40 m).

Physical Parameters

Water temperature (^{0}C), salinity (ppt), dissolved oxygen level (mg L^{-1}) and depth (m) were recorded at regular intervals at both the –40 m and +40 m stations using Datasonde 3 dataloggers (Hydrolab Corp.). The dataloggers were attached to concrete blocks to prevent movement, and therefore were approximately 25 cm above the substrate.

Figure 1. Location of study area in New York Harbor.



Stowaway Light Intensity dataloggers (OnSet Corp.) were fastened to deployment cages at the same two stations to record light levels hourly over a 10-day period.

Relative net water movement was determined at the –40 m and +40 m stations by comparing plaster dissolution rates (also known as clod card method). A mixture of plaster of Paris ($CaSO_4 \bullet \frac{1}{2} H_2O$; Fisher Scientific) was prepared and molded according to Angradi and Hood (1998). The plaster standards (clods) were sanded to a constant initial weight (mg) and attached to petri dish lids using marine silicone. Eight clods and lids were attached to a concrete block and two blocks were deployed to each station, for a total of sixteen clods at each station. Clods were left in the field between 24 – 48 hours. Upon retrieval, they were removed from the petri dish lids and allowed to dry for no less than 96 hours, after which final weights were recorded. Three replicate trials were conducted throughout the summer.

Growth Experiment

Juvenile Atlantic tomcod (40 mm – 70 mm total length) were either collected by benthic traps in the lower Hudson River or were seined from Little Neck Bay (Long Island, NY) and Princess Bay (Staten Island, NY). Fish were held in the laboratory in 4 ft diameter flow-through tanks for approximately one week and were fed *Artemia* nauplii and chopped clams. They were maintained on a 14 hour light : 10 hour dark photoperiod, during which temperature and salinity levels were 16 - 19 °C and 21 – 25 ppt, respectively.

Two separate 10-day field experiments were conducted. Two days prior to an experiment, the feeding regime was stopped to allow the fish to eliminate gut contents.

One day prior to deployment, fish were weighed and placed in 1 L containers with flow-through mesh lids.

Cages used in the experiments were welded steel frames (0.85 m x 0.85 m x 0.45 m), from which a 3 mm mesh bag was hung in the interior. The mesh retained the fish, but allowed passage of water, sediment, and potential prey items. For a more complete description, see Able *et al.* (in review). On the day of an experiment, the fish were transported to the site in water-filled coolers. Once at the pier site, one fish was transferred to each cage and the cage was lowered to the bottom. During the first trial, eight cages were deployed to +40 m, seven cages to 0 m, and eight cages to –40 m. During the second trial, only five cages were deployed to each station due to logistical constraints. Fish remained in the field for 10 d, after which the cages were retrieved and the fish were transported back to the laboratory live for final weight determination. Experiments were conducted from May 29 - June 8, 1998 and June 9 - 19, 1998.

Simultaneous with the above procedures, five fish were chosen at random to serve as controls. These fish were held in the laboratory without food for the duration of the field experiment. They were weighed at the beginning and end of each experiment. The controls provided growth rates under true starvation conditions.

Statistical Analysis

Growth rate in weight (G_w) was assumed to be exponential, and was calculated according to :

$$G_W = (\ln W_f - \ln W_i) / t$$

where W_i = initial weight prior to deployment, W_f = final weight after experiment, and t = the duration of the experiment in days. Differences in growth rates between the three stations were analyzed using ANOVA procedures. Tukey multiple comparison tests were used to show where the differences were, and inference was made at $\alpha = 0.05$. Differences in mass loss between clods at –40 m and +40 m were analyzed using a two-sample t-test.

RESULTS

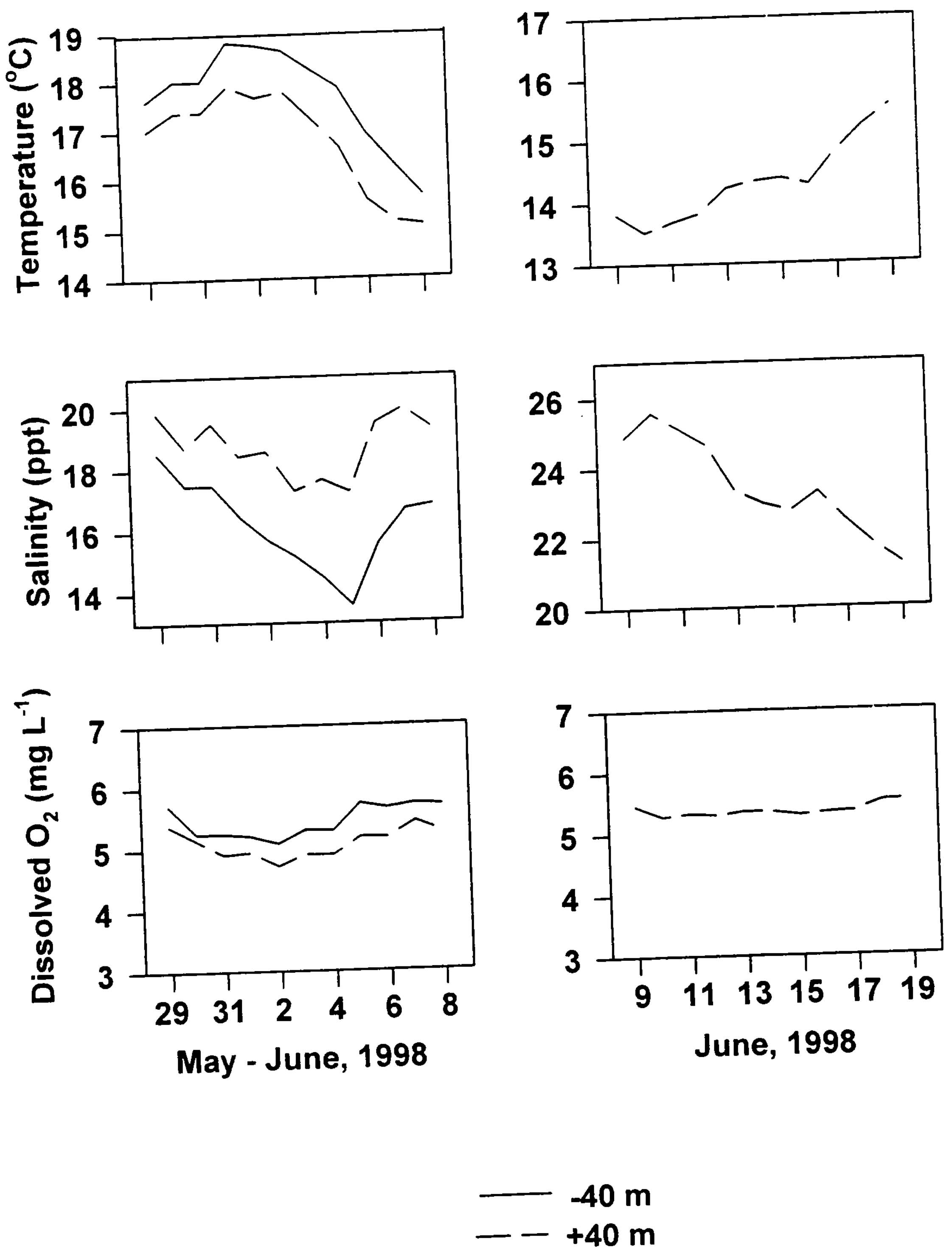
Physical Parameters

Average daily temperatures at depth ranged from 13 - 20 °C. Salinities ranged from 13 - 20 ppt, and dissolved oxygen levels ranged from 4 - 7 mg L^{-1} (Figure 2). Average depths at +40 m and –40 m were 4.5 ± 0.3 m and 3.0 ± 0.4 m, respectively (Table 1). Temperature, salinity, dissolved oxygen, and depth measurements at the –40 m station during the second trial were not recorded properly by the datalogger, however we expect that those measurements follow closely with those at the +40 m station, as in the first trial. Light intensities at +40 m were 0.64 ± 1.3 Lu m^{-2}, while at -40 m they were two orders of magnitude less, 0.002 ± 0.004 Lu m^{-2}. Average light levels were calculated for daylight hours only (6AM – 8PM) (Table 1).

Table 1. Depth and light intensities underneath (-40 m) and beyond (+40 m) Pier 40.

	-40 m	+40 m
Depth (m)	3.01 ± 0.38	4.48 ± 0.25
Light Intensity (lum/sqm)	0.002 ± 0.004	0.64 ± 1.30

Figure 2. Temperature, salinity, and dissolved oxygen levels underneath and beyond Pier 40.



All three experiments with the plaster of Paris clods show the same trend in net water movement, with clods at +40 m losing more mass than those at –40 m. This indicates that net water movement outside the pier is greater than underneath. Only differences in the first and third trials, however, were significant (Figure 3).

Growth Experiment

Percent recovery of caged Atlantic tomcod was very good; 86% for the first 10-d experiment and 95% for the second. Since none of the recovered cages were found with opened zippers or holes, unrecovered fish probably died and decomposed, rather than having escaped from the cages.

In both experiments, juvenile Atlantic tomcod showed positive growth when caged under the pier, though the fastest growth rates were recorded at the pier edge. Mean growth outside and under the pier was positive, while all control fish demonstrated negative mean growth (Figure 4). In the first experiment, growth rates under the pier were +0.02 ± 0.004 d^{-1}, at the edge were +0.04 ± 0.006 d^{-1}, and outside were +0.03 ± 0.005 d^{-1}. For the second experiment, growth rates were similar, with +0.02 ± 0.002 d^{-1}, +0.03 ± 0.002 d^{-1}, and +0.03 ± 0.003 d^{-1} at the underneath, edge, and outside stations, respectively. Differences in growth rates in the first experiment were significant between fish caged at –40 m and +40 m, while in the second experiment, differences were significant between –40 m and 0 m and between –40 m and +40 m. Growth of control fish was significantly different from all others in both experiments.

Figure 3. Relative current velocity underneath and beyond Pier 40 based on mass loss (g d^{-1} ± SE) of plaster of Paris clods.

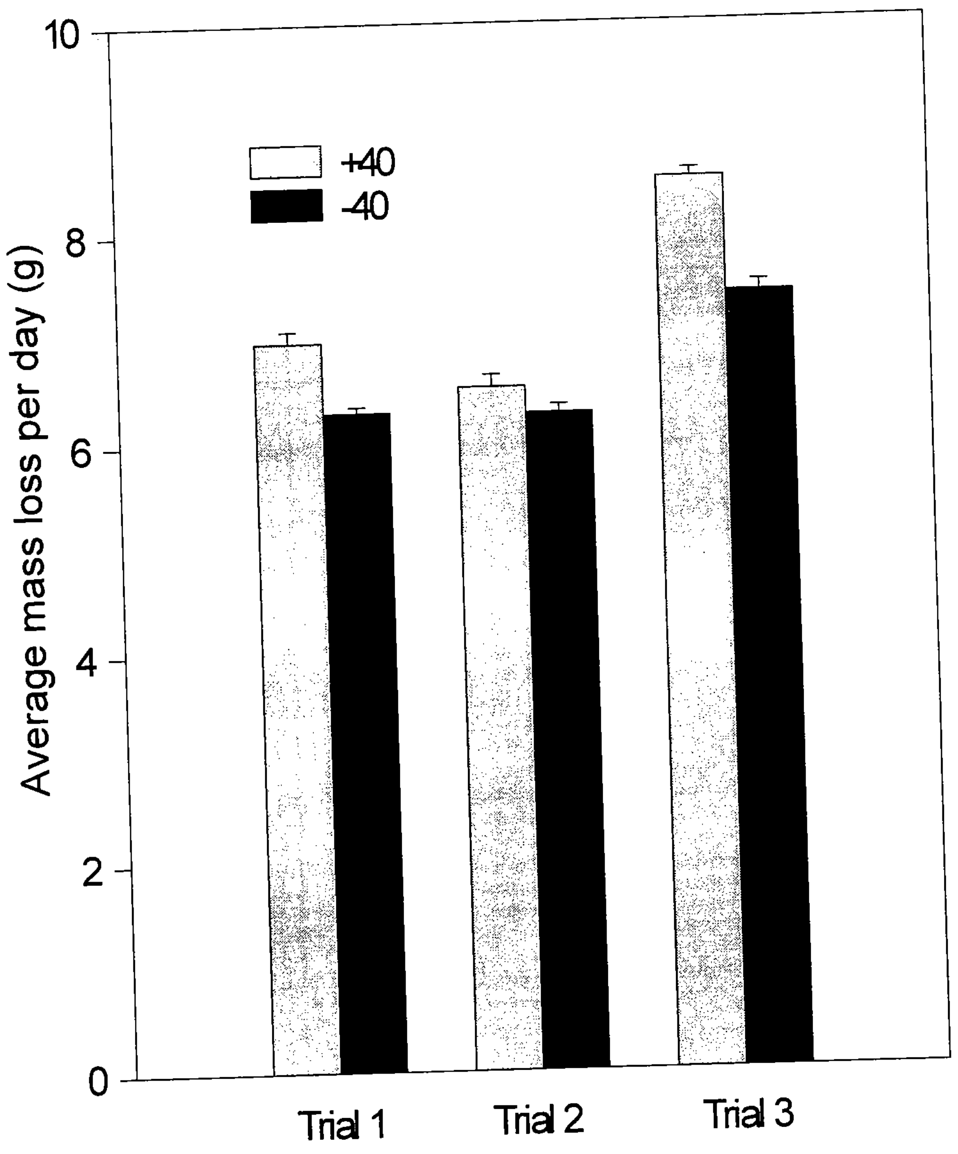
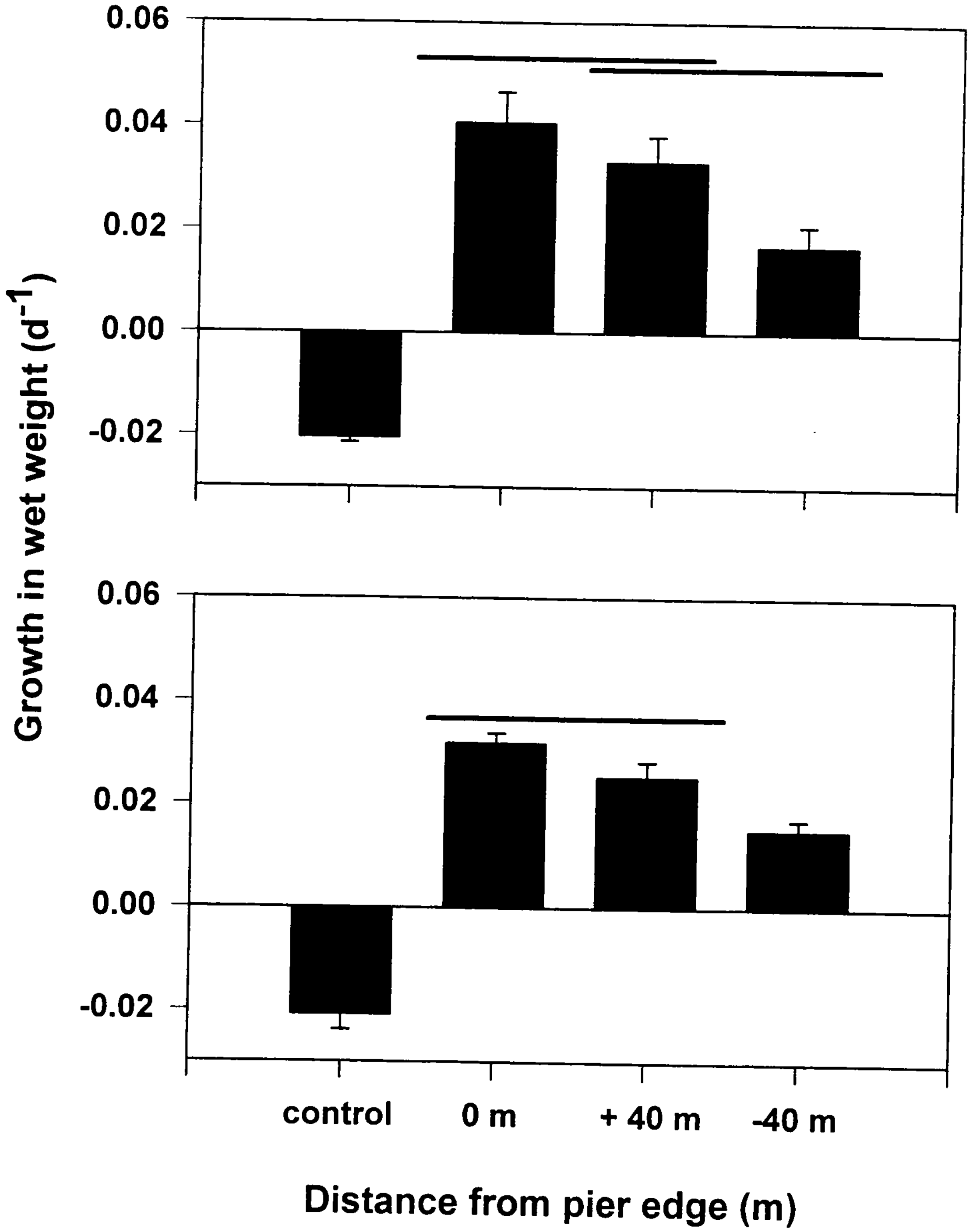


Figure 4. Mean (±SE) growth rate in weight (G_w) of *Microgadus tomcod* at transect stations and laboratory-starved control. Horizontal lines represent non-significant differences as determined by Tukey Multiple Comparison Tests.



DISCUSSION

The results of these experiments show that young-of-the-year Atlantic tomcod can grow under piers, though at reduced rates compared to edge or open water habitats. This result is in direct contrast with previous reports that consistently demonstrate that juvenile winter flounder and tautog show negative growth rates when caged under piers in New York Harbor (Duffy-Anderson and Able in press; Able *et al.* in review). These authors proposed that negative growth rates may have been related to reduced light levels under piers that acted to limit the ability of fishes to capture and consume prey. Indeed, I determined that light levels under piers were often two orders of magnitude below those in open water. However the ability of fishes to feed in darkness is species-specific. *Clupea harengus* (Batty *et al.* 1986), *Rutilus rutilus* (Diehl 1988), and *Anguilla rostrata* (Tesch 1977), are all capable of feeding efficiently in darkness, while feeding of *Esox lucius* (Frost 1954), *Cynoscion regalis* (Grecay and Targett 1996), *Tautoga onitis* (Olla *et al.* 1974), and *Pseudopleuronectes americanus* (Olla *et al.* 1969) is reduced by low-light conditions.

Many fishes possess heightened chemo- or mechanosensory abilities that may improve their ability to forage in low light. It has been shown that Atlantic tomcod rely on additional sensory cues to locate and consume prey (Herrick 1904), though it is not known whether these cues allow tomcod to do so in total darkness. Clearly however, I have shown that they were able to capture and consume prey under piers. The results of a trapping study in the lower Hudson River estuary indicate that 25% of the abundance (as catch per unit effort) of Atlantic tomcod occurred underneath piers, while 75% occurred in open water (Able *et al.* 1998). In contrast, winter flounder abundance underneath piers was 1.4% of the total. I propose that under-pier areas may only function as acceptable habitat to a few select species, perhaps those with supplementary sensory systems, while simultaneously being inhospitable to a variety of other estuarine species.

While winter flounder and tautog are primarily benthic feeders (Pearcy 1962; Grover 1982), Grabe (1978) has shown that juvenile Atlantic tomcod under 90 mm TL feed on planktonic organisms, primarily calanoid copepods. The fish used in this study were all under 90 mm TL, so it is likely that the dominant components of their diet during the experiments were planktonic prey. Comparative measurements of the current regime at the +40 m and –40 m stations revealed that water flow is slightly dampened underneath the pier, perhaps due to the presence of the supporting columns. The effect of decreased water movement may be to reduce the availability of planktonic prey to fishes caged under piers. Moreover, the mesh bag that retains the fish may also serve to reduce water movement, further reducing the availability of planktonic prey to fish caged inside. Despite these two factors, tomcod caged at –40 m consistently showed positive growth under piers. Although growth rates were lower than at the edge or in open water, it is reasonable to assume that a potential shortage of planktonic prey was not growth-limiting. Interestingly, growth rates were highest among fish caged at the pier edge. The reason for this is unclear, but it may be that flow patterns create small eddies adjacent to the pier pilings, therefore creating an accumulation of prey in areas surrounding the cages at the edge.

Atlantic tomcod are able to survive and grow underneath piers, though their growth potential seems to be higher at the pier edge and outside of the pier. Therefore, while it seems that tomcod are able to utilize under-pier habitats more effectively than some other species, under-pier areas are probably not optimal habitats for them. It is more likely that tomcod use under-pier areas intermittently, perhaps sacrificing the fastest rates of growth for increased refuge from predation. It has been shown that other species of fish will chose a lower quality habitat if it offers an increased chance of avoiding predators. For instance, Werner *et al.* (1983) showed that 30 mm - 40 mm *Lepomis macrochirus* will utilize the less profitable but safer habitat of *Typha spp.* in the presence of *Micropterus salmoides*. Additional behavioral studies are necessary to resolve whether Atlantic tomcod show this response, but they have been collected from submerged wrecks, pile fields, and in open water, suggesting that they do move among habitats of varied complexity (Able *et al.* in press).

CONCLUSION

Construction and restoration of municipal piers in estuaries is ongoing. Therefore, knowledge of their effects on the many fish populations in the Hudson River estuary is increasingly important. I have shown that growth of Atlantic tomcod was positive when caged at three transect locations, including the under-pier station. Growth under the pier implies that juvenile Atlantic tomcod can successfully capture and consume prey in this environment. I hypothesize that although piers may be detrimental to the growth of some fish species, others, such as Atlantic tomcod, may be better able to exploit them as habitat. However, because growth of juvenile Atlantic tomcod was lower under the pier compared to the edge and outside, I argue that under-pier areas may be sub-optimal habitat even for those species that are capable of utilizing them.

ACKNOWLEDGEMENTS

I wish to thank my advisors, Janet Duffy-Anderson and Kenneth Able. Thanks to Jenny Liming and Deborah Vivian for assistance in the field and laboratory. I would also like to thank Chuck Nieder of the NYS Department of Environmental Conservation and John Waldman of the Hudson River Foundation for comments on an earlier draft. Support for this project was provided by the 1998 Tibor T. Polgar Fellowship program.

REFERENCES

Able, K.W., J.P. Manderson and A.L. Studholme. 1998. The distribution of shallow water juvenile fishes in an urban estuary: the effects of man-made structures in the lower Hudson River. Estuaries 21(4B): 731-744.

Able, K.W., J.P. Manderson and A.L. Studholme. (In review) Habitat quality for shallow water fishes in an urban estuary: the effects of man-made structures on growth. Marine Ecology Progress Series.

Angradi, T. and R. Hood. 1998. An application of the plaster dissolution method for quantifying water velocity in the shallow hyporheic zone of an Appalachian stream system. Freshwater Biology 39: 301-315.

Batty, R.S., J.H.S. Blaxter and D.A. Libby. 1986. Herring (*Clupea harengus*) filter feeding in the dark. Marine Biology 91: 371-375.

Diehl, S. 1988. Foraging efficiency of three freshwater fishes: effects of structural complexity and light. Oikos 53: 207-214.

Duffy-Anderson, J.T. and K.W. Able. (In press) Effects of municipal piers on the growth of juvenile fish in the Hudson River estuary: a study across the pier edge. Marine Biology.

Frost, W.E. 1954. The food of pike *Esox lucius* L., in Windermere. Journal of Animal Ecology 23: 339-360.

Grabe, S.A. 1978. Food and feeding habits of juvenile Atlantic tomcod, *Microgadus tomcod*, from Haverstraw Bay, Hudson River. Fishery Bulletin. U.S. 76: 89-94.

Grecay, P.A. and T.E. Targett. 1996. Effects of turbidity, light level, and prey concentration on feeding of juvenile weakfish, *Cynoscion regalis*. Marine Ecology Progress Series 131: 11-16.

Grover, J.J. 1982. The comparative feeding ecology of five inshore, marine fishes off Long Island, New York. Doctoral Dissertation. Rutgers University, New Brunswick, New Jersey.

Heck, K.L., K.W. Able, C.T. Roman and M.P. Fahay. 1995. Composition, abundance, biomass, and production of macrofauna in a New England estuary: comparisons among eelgrass meadows and other nursery habitats. Estuaries 18: 379-389.

Herrick, C.J. 1904. The organ and sense of taste in fishes. Bulletin of the United States Fish Commission. Vol XXII for 1902: 239-272.

Olla, B.L., A.L. Bejda and A.D. Martin. 1974. Daily activity, movements, feeding, and seasonal occurrences in the tautog, *Tautoga onitis*. Fishery Bulletin. U.S. 72(1): 27-35.

Olla, B.L., R. Wicklund and S. Wilk. 1969. Behavior of winter flounder in a natural habitat. Transactions of the American Fisheries Society 98: 717-720.

Pearcy, W.G. 1962. Ecology of an estuarine population of winter flounder, *Pseudopleuronectes americanus* (Walbaum). Bulletin of the Bingham Oceanographic Collection, Yale University. 18: 1-78.

Rountree, R.A. and K.W. Able. 1992. Foraging habits, growth, and temporal patterns of salt-marsh creek habitat use by young-of-the-year summer flounder in New Jersey. Transactions of the American Fisheries Society 121: 765-776.

Sogard, S.M. 1992. Variability in growth rates of juvenile fishes in different estuarine habitats. Marine Ecology Progress Series 85: 35-53.

Sogard, S.M. and K.W. Able. 1994. Diel variations in immigration of fishes and decapod crustaceans to artificial seagrass habitat. Estuaries 17: 622-630.

Stoecker, R.R., J. Collura and P.J. Fallon Jr. 1992. Aquatic studies at the Hudson River Center Site. Pages 407-427 *In* Smith, C.L. (ed.). Estuarine research in the 1980s.

The Hudson River Environmental Society Seventh Symposium on Hudson River Ecology.

Squires, D. 1992. Quantifying anthropogenic shoreline modification of the Hudson River and Estuary from European contact to modern time. Coastal Management 20: 343-354.

Szedlmayer, S.T. and K.W. Able. 1996. Patterns of seasonal availability and habitat use by fishes and crustaceans in a southern New Jersey estuary. Estuaries 19: 697-709.

Tesch, F.W. 1977. The eel: biology and management of anguillid eels. Chapman and Hall, London.

Werner, E.E., J.F. Gilliam, D.J. Hall and G.G. Mittelbach. 1983. An experimental test of the effects of predation risk on habitat use in fish. Ecology 64(6): 1540-1548.