Journal of Experimental Marine Biology and Ecology 485 (2016) 47–56

Contents lists available at ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

# Modification of nektonic fish distribution by piers and pile fields in an urban estuary

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ARTICLE INFO

*Article history:*
Received 9 December 2015
Received in revised form 8 August 2016
Accepted 9 August 2016
Available online 8 September 2016

*Keywords:*
Shoreline
Structure
Habitat
Shading
Fish
DIDSON

ABSTRACT

Large urban piers degrade habitat value for several estuarine benthic fish species by shading, but their effects on mobile nektonic species is less well understood due to sampling challenges. Dual Frequency Identification Sonar (DIDSON) allowed equal access to sampling in the water column of structured shaded and unshaded vs. open environments in both dark and light conditions by methods similar to video but without light. Sampling (n = 228, 5-min transects) occurred under and around four large municipal piers of varying dimensions in the Hudson River estuary during day and night from summer and fall in 2007–2009. The distribution of small (5–25 cm in length) and large (25–850 cm) fishes were analyzed separately in recognition of functional guild differences. Small fishes occupied open water, shaded under-pier, and un-decked relict piling habitats, but were significantly more abundant during the day in open unshaded water than under adjacent piers or in piling habitats. Small fish occurred under 3 of 4 piers of varying size and configuration at 10–20% of the median abundances of adjacent open water. However, while schools were rare under piers they could be very large, so that abundance greatly exceeded mean open water abundance variance so as to preclude confidence in differences among piers. The differences among habitats were not significant at night, and the difference among piers was also not significant at night. School membership for small fish appeared to mitigate adverse effects of shading and may influence scaling of their response to shading and could therefore influence pier design. Large (>25 cm) predatory fish were uncommon but responded similarly to habitat effects as did small fish. Habitats did not segregate fish by guild as small forage fish co-occurred in 65.8% of samples with large piscivores. Studies that provide species-specific and mechanistic interpretation of dynamic habitat use as well as further quantification of scaling effects could improve our understanding of how fishes respond to piers and other structures on urban shorelines.



## 1. Introduction

One of the most dramatic alterations to urban shorelines worldwide is through the construction of piers and their abandonment, dilapidation, and collapse. Experiments on pilings, floating structures, and armoring in several regions have tested the premise that these alterations locally enhance fish diversity and abundance through the provision of hard structure in otherwise soft-sediment environments with low relief and liken them to artificial reefs. Results, examined mechanistically as either shelter for juvenile reef fishes or food provisioning through the support of epibiont prey, have been weak or mixed (Caine, 1987; Hair and Bell, 1992; Coleman and Connell, 2001; Clynick et al., 2007; Moreau et al., 2008; Feary et al., 2011). Some but not all of those structures shaded habitat. When shading did occur, it was conjectured to have a negative effect (Hair and Bell, 1992) in contrast to shading effects in streams by banks, trees, docks, or bridges in shallow fresh water (Haeseker et al., 1996; Helfman, 1981; Le Pichon et al., 2015; Penaluna et al., 2015).

Previous research in the generally turbid Hudson River estuary extended over much of the shallow water habitat along the entire stretch of both the New Jersey and New York (Manhattan) portions of the estuary (Able and Duffy-Anderson, 2006), which is one of the most developed shorelines in North America (Squires, 1992). In general, these studies focused on benthic fishes inclusive of those that naturally occur in the open soft bottom habitat replaced or covered by the structures. These studies found that shade generally had a negative effect on several species of benthic fish while having no effect on nocturnal chemosensory feeders; however, the piers studied here are much more massive structures than marina docks and piers or even bridges previously studied and therefore may have different effects. This past research was valuable in pointing to shading by piers, not benthic invertebrate prey scarcity, as a critical factor impacting habitat value for small benthic fish. A multifaceted approach to evaluate the impacts of these alterations included: 1) quantifying the distribution and abundance of benthic fishes under piers, at pier edges, in pile fields, and in open

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http://dx.doi.org/10.1016/j.jembe.2016.08.004
0022-0981/

water areas (Stoecker et al., 1992; Able et al., 1998, 1999; Duffy-Anderson et al., 2003; Able and Duffy-Anderson, 2006); 2) feeding and growth of juvenile benthic fishes under and around piers (Able et al., 1999; Metzger et al., 2001); and 3) availability of benthic prey for fishes under and adjacent to large piers (Duffy-Anderson and Able, 1999). For juvenile fish, species diversity and species abundance were depressed under piers relative to nearby habitats (Able and Duffy-Anderson, 2006). However, all of these studies necessarily focused on small, primarily benthic oriented fish that would enter small traps, and growth studies were limited to selected species and early life stages within cages (Duffy-Anderson and Able, 1999; Able and Duffy-Anderson, 2006).

Nektonic fishes are an important part of estuarine fish assemblages (Hagan and Able, 2003; Able and Fahay, 2010) but were not included in these prior studies in large part due to sampling difficulties. These include small schooling planktivorous species such as Atlantic silverside *Menidia menida* (Fam. Atherinidae), bay anchovy *Anchoa mitchilli* (Fam. Engraulidae) and clupeiforms as well as larger predatory fish. Artificial harbor shoreline structures are used as spawning substrate and perhaps shelters for nektonic fishes including *M. menidia* (Caine, 1987; Balouskus and Target, 2012), but at reduced levels and on a very different scale. The development of small high frequency sonars, such as the Dual Frequency Identification Sonar (DIDSON) provided a means to move into the highly structured habitats of large commercial piers to do fish surveys by using video transect sampling models in a way that nets and traps could not (see Able et al., 2013, 2014; Martignac et al., 2014). Further, DIDSON does not depend on light to produce images and thus eliminates a potential bias when an understanding of light/shading effects is the study objective (Able et al., 2014; Becker et al., 2013). Study of response by nektonic fishes to shading began at the fine scale by examining distribution across the shade/light interface of the largest pier (355 × 251 m) in New York Harbor, Pier 40 (Able et al., 2013). Both small and large nektonic fish in that study responded to shading, although somewhat differently. Small forage species, primarily bay anchovy and Atlantic silverside, avoided the shaded under-pier habitat during both day and night. The abundance of large predatory fish such as striped bass (*Morone saxatilis*) increased slightly just inside the edge relative to the sunlit water away from the pier, but fell away quickly at distances of >10 m under the edge where light was almost extinguished during both day and night. Incident light was less under the pier even during the day than the adjacent open water was at night, suggesting that light was an important factor in determining the response of nektonic fishes as it was for benthic species. However, the pier also provides vertical structure, which may attract or repel nektonic fishes, and few piers may be as consistently dark underneath as this large pier. Therefore, it remains to experimentally separate the influences of light and structure and to examine less severely shaded piers of different size and structure.

The objective of this study was to evaluate nektonic fish use of pier habitat relative to adjacent structured but unshaded habitats (piling fields) and also open water habitats on a broader scale. Acoustic imaging again provided an approach that was relatively unbiased to light level or to differently structured habitats. More specifically, fish preference was determined for under pier, piling field, and adjacent open water habitats during the day and night and among piers of different size.

## 2. Methods

### 2.1. Study site

The study was carried out along the eastern (Manhattan, New York) shore of the Lower Hudson River estuary (Fig. 1). The area has a long history of modification with very little natural shoreline remaining (Squires, 1992). Bulkheads now form most of the shoreline. A shallow river bench of 1.5 to 5 m depth (at low tide) extends about 300 m from the shoreline to a sharp channel edge dropping to at least 18 m depth before sloping to the main channel depths in excess of 30 m. Piers of various configurations extend from the shoreline to the channel edge, crossing the bench and thereby delineating small embayments of shallow water. Many of these are further split by piling fields remaining from previously removed piers. The piling fields have similar length-to-width dimensions as some of the existing piers (Table 1) and are all arrayed in the same compass direction. Surveyed habitat included under piers, among uncovered piling from relict piers, and open water areas in between the piers and piling fields. Sampled piers included those with large and small length-to-width ratios ranging from nearly 1 to about 0.125 (Table 1, Fig. 1). Additionally, clustered pilings that act as bumpers but do not support overhead structure were examined near Pier I. These were classified the same as relict piling fields because they were uncovered but had substantial eddy fields around them (Table 1, Fig. 1).

Piers were built to different designs and only some could be accessed underneath for sampling. Of these, Pier 40 is the largest pier along this shoreline and nearly square in configuration with a small extension from the southwest corner. The perimeter, with the exception of the little extension, is a multistory building that casts shade several meters beyond the northern side. Pier 54 is small and low, with no supported building. It is similar in length and width to Pier 57, which does support a tall building. All three of these, and also Pier I, have very different supporting structure. Pier 54 was (at sampling time, since modified) supported by very dense and decrepit wooden pilings which are further interlaced by cross braces and wooden walls, some collapsed. Galleries, the openings between rows of pilings, are narrow (approaching 2 m). In contrast, Pier 40 has orderly rows of smooth concrete pilings spaced about 2 m apart until well under the pier where there are some obstructions. Pier I is high and narrow and without a building so that it receives abundant light underneath and pilings are few and widely spaced. Pier 57 is supported by 3 large buoyant cassions that are anchored to the bottom by short pilings. The cassions take up most of the pier's footprint and block access to its underside except for 3 galleries of ~6 m wide between adjacent concrete cassion walls. Two of these are partially blocked by a concrete structure and all have wooden pilings approximately 2 m apart forming a “fence” across the gallery entrance.

### 2.2. Sampling techniques

Dual Frequency (1.8 MHz and 1.1 MHz) Identification Sonar (DIDSON) (Sound Metrics Corp., Seattle, WA) was used to image nektonic fishes in different habitats, although only the higher frequency was applied. Resolution varies with distance from the DIDSON lens so that, for example, fishes of >300 mm length were resolved by 140 pixels in length in the near field and 35 pixel length at the extreme down-range. Sampling was at a rate of 5–12 frames per second, dependent on range as this affected processing speed. Moderate frame rate helped to discern moving fishes from a moving (relative to moving viewer) background. The high frequency multiple beams allow visualization of diagnostic features such as fins and swimming behavior (Holmes et al., 2006, Boswell et al., 2008). The thickness of the body, position and size of dorsal fins, and caudal fin fork were especially useful in distinguishing between different species of larger fish such as striped bass, bluefish, and Atlantic menhaden (Able et al., 2014).

The DIDSON was mounted under a kayak (~4 × 1 m) for easy, quiet access to transects under and around the structures. A splash-proof laptop computer in the kayak cockpit allowed real-time viewing so that the paddler could adjust focus and direction for closer inspection of potential targets. Tilt of the DIDSON unit was set at 23 degrees for an optimum viewing range based on earlier trials (Able et al., 2013; Able et al., 2014). The set angle was sufficient to allow the DIDSON beams to reach the bottom at all sites until near the edge of the bench, and then not for any sites. This was possible because the operator could change the window length in order to keep the bottom reflection near the distal end of the frame, thus continually maximizing spread within the field. As the