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Effects of stereoscopic artificial floating wetlands on nekton abundance and biomass in the Yangtze Estuary

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HIGHLIGHTS

- The *Phragmites australis* stereoscopic artificial floating wetlands create new habitats for nekton in the Yangtze Estuary.
- Both the *P. australis* and palm sheets on the SAFWs alter the surrounding water characteristic.
- The *P. australis* SAFWs can be used as fisheries conservation and management tools in coastal and estuarine areas.

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ABSTRACT

Habitat degradation is one of the greatest existing threats to nekton biodiversity in estuarine and coastal habitats. Stereoscopic artificial floating wetlands (SAFWs) can provide new nekton habitats and have been widely used as conservation and management tools in freshwater and marine environments. In the current study, we constructed *Phragmites australis* SAFWs: the *P. australis* rhizomes were planted on the artificial floating beds, and palm slices were hung under the floating platforms to act as submerged plants. These SAFWs were anchored in the north channel of the Yangtze Estuary. To determine if SAFWs can serve as fish aggregation devices, fishes and crustaceans were sampled monthly using a bottom lift net during high-tide from July to October 2014. Our assessment was based on environmental parameters, nekton density, nekton species composition and the total length of the three most abundant fishes at the experimental and control sites. Nekton abundance was approximately three times greater in the SAFWs than that in the control habitats (108.2 ± 27.56 ind./m^2 vs. 28.37 ± 15.88 ind./m^2, respectively). There were no significant habitat-specific differences in the size distribution of the three most abundant fish species (*Acanthogobius ommaturus*, *Odontamblyopus rubicundus* and *Eleutheronema tetradactylum*) because most of the individuals sampled were juveniles. This study demonstrates that SAFWs can form stable environments for nekton and increase habitat available to juvenile fish.

1. Introduction

Fishes and crustaceans in estuarine and coastal habitats must maintain a balance between finding foraging opportunities and seeking shelter from predation. A lot of research has focused on nekton confined to small estuary marsh patches that can only sustain a limited number of individuals (Olden and Naiman, 2010), because these estuarine habitats have been adversely affected by human activities in recent years (Freon and Dagorn, 2000; Wang et al., 2006a). As a result, the rehabilitation of degraded fish and crustacean habitats has become a primary task of estuarine fisheries management and conversation. The goal of nekton habitat recovery projects in estuarine and coastal environments is to establish artificial habitats that supply spawning grounds, feeding, and winter habitats for fishes and crustaceans. However, nekton recovery in degraded habitats is a long-term project that requires significant financial inputs and technical support; moreover, cultural and/or demographic factors often hinder such projects(Mehdi et al., 2015; Mesa et al., 2015; Habersack et al., 2016).

Despite these limitations, some studies have focused on using fish aggregating devices (FADs) to rehabilitate functional habitats in

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degraded areas (Cech et al., 2012; O'Hanley et al., 2013). The three main rehabilitation methods used to construct nekton habitats are planting new vegetation, employing artificial structures, and constructing artificial floating wetlands. New vegetation has been planted to create new fishes and crustaceans habitats in several degraded areas (Rozas and Zimmerman, 2000; Thom et al., 2004; Weinstein et al., 2009; Putnam et al., 2010). Many studies have shown that nekton density is higher in these newly created marsh habitats compared with areas with no vegetation (Rozas and Zimmerman, 2000). Employing artificial structures, such as submerged trunks, brushwood bundles, industry structures and artificial reefs has been used to attract and concentrate fishery resources, enhance and provide habitat substrate for fish reproduction, increase shelter for juveniles, and create new habitats in structure-less ecosystems (Nash et al., 1999; Bolding et al., 2004; Winfield, 2004; Smokorowski and Pratt, 2007; Gois et al., 2012). For example, submerged trucks have been successfully used to construct artificial habitats that attract fish in abundance. Additionally, stereoscopic artificial floating wetlands (SAFWs) are a type of artificial ecosystem based on the principles of soilless cultivation techniques, which float on water and provide either a framework matrix or carrier on which plants can grow. It is a useful method for habitat recovery because the artificial floating bed has many important functions. Although the above methods have been used to attract fishes and crustaceans in all kinds of degraded habitats, most of these approaches cannot be used in estuary recovery because these environments are very complex.

Fish aggregating devices (FADs) are artificial structures placed in the water to aggregate fishes and crustaceans to restore degraded ecological systems (Cech et al., 2012; O'Hanley et al., 2013). Artificial FADs have been experimentally deployed in reservoirs for a variety of purposes, such as to attract and concentrate fishery resources, enhance substrate for fish reproduction, increase shelter for juveniles. Some researchers have proposed that both anchored and drifting FADs alter the natural environment, e.g., tropical tunas aggregate around FADs (Dagorn et al., 2010; Sinopoli et al., 2012). FADs have become an important tool for assessing pelagic fish stock because both juveniles and adults tend to aggregate around floating objects (e.g. drifting algae, jellyfish, flotsam, and man-made objects). FADs are widely used throughout the Mediterranean to survey both adult and juvenile fauna associated with the devices (Massuti et al., 1999). FADs have been successfully used as fish management tools in lake and marine environments (Howson et al., 2012); however, they have seldom been employed in estuaries. Estuarine environments are complex and often highly variable, with extremes in salinity, high turbidity and well-mixed areas; they are also frequently dominated by seasonal winds and tides are diurnal with differing ranges.

In this study, we investigated whether the anchored SAFWs could be used as FADs for fisheries management along an estuary. We also assessed if this method could be used to survey the estuarine nekton assemblage and contribute to degraded habitats recovery. To evaluate the effects of the SAFWs, several metrics including environmental factors, and nekton community characteristics as indirect measures of habitat environment quality were investigated and compared. A primary aim of the present study was to explore whether the SAFWs could change the environmental variables (transparency, water velocity, and light intensity) in the experiment sites. The influence of artificial habitat types on nekton assemblage structure (species abundance and richness) was also investigated in the experiment and control habitats. The relationship between the environment and nekton species in both habitat types was also compared to determine if SAFWs could contribute to degraded nekton habitats recovery.

2. Materials and methods

2.1. Study area and SAFW construction

The study sites were located in the southern branch of the Yangtze Estuary (Fig. 1 a). The GPS coordinates of this estuary are 30°48′-32°6′ N, 120°0′-124°58′ E. The estuary's southern branch is separated into a northern and a southern channel, and extends to the Chongming, Changxing and Hengsha Islands. It is a partially mixed estuary characterized by semidiurnal tides, with a mean tidal amplitude of 2.8 m and tidal currents of 1.0–2.0 m/s. The average depth in the estuary is approximately 5 m and average salinity levels vary between 0 and 23 PSU. No plants grow in the experimental area because the soil at this location is covered by cement that was laid down for slope protection along the Qingchaosha reservoir.

In this study, we constructed SAFWs in the Yangtze Estuary outside the Qingchaosha reservoir according to Yao et al. (2014): the *Phragmites australis* rhizomes were planted on artificial floating beds and palm slices were hung under the floating platforms. The SAFWs were anchored in the northern channel of the southern branch of the Yangtze Estuary on the 1st February 2014 (Fig. 1b). The structure of each SAFW framework was divided into two parts: an artificial floating plant bed on the water surface and an artificial structure substrate below the surface (Fig. 1 c). Each frame structure unit was 16 m^2 in area and each SAFW habitat was constructed with 12 frame structure units; the total SAFW site area was 200 m^2.

2.2. Sampling design

The study sites were located outside the Qingcaosha reservoir in the Yangtze River. Four sites were designated SAFW sites (EA_1, EA_2, EA_3, and EA_4) and four other sites (NA_1, NA_2, NA_3, and NA_4) were selected as control sites (Fig. 1 b). The distance between the experimental site and each control site was approximately 3 km, both the SAFW and control sites were approximately 200 m^2 in area. Sampling was conducted on July 15–17th, August 16–18th, September 15–17th and October 16–18th, 2014. Within each study site, three replicate samples were collected on each sampling date.

2.3. Environmental characteristics

A suite of ten habitat characteristic variables was measured at the study sites (three replicates for each parameter per study site). The mean three random depths were measured (cm) each time a depth measurement was made. Water transparency (cm) at the experimental and control site was measured with a Secchi disc. Water velocity (m/s) was record with a SQ-FP111 (Global water, USA). Light intensity was measured with a ZDS-10W-2D (TES-1339R, China). Turbidity (NTU) was measured with a Turner Designs Aqua fluor® turbidimeter (Turner Designs, CA). Water quality parameters including temperature (T, °C), dissolved oxygen (mg/L), pH, total dissolved solids (TDS, mg/L) and salinity (PSU) were measured at both the SAFW and control sites using an YSI 85 handheld meter (YSI Incorporated, OH, USA).

2.4. Nekton sampling

Nekton sampling was conducted monthly at all study sites over 1 d sampling period. The fishes and decapod crustaceans were collected using a bottom lift net (20 m^2) suspended from a boom mounted on a 10.5 m boat. For each sample, the boat and sampler were traveled from the open water toward the study site and the sampler was released approximately 1 m inside the target areas. When the sampler failed to seal, the sample was abandoned and a