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Do Freshwater Macroinvertebrates Select for Different Substrates Used in Fisheries Habitat Enhancement?

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ABSTRACT

Habitat enhancement projects are commonly used for augmenting fisheries in lakes and reservoirs, but a dearth of research exists regarding how habitat enhancements influence lower trophic levels. Structures used for habitat enhancement may be comprised of a range of natural and artificial materials and thus present different substrates for macroinvertebrates. We examined whether motile, grazing macroinvertebrates from the genera *Baetis*, *Ischnura*, *Pachydiplax*, and *Trichocorixa* exhibited different selection for substrates commonly used in fisheries habitat enhancement projects. Substrates evaluated included natural pine wood with bark, polyvinyl chloride plastic (PVC; a common frame material for artificial fish cribs), and the composite plastic of a commercial fish attractor. Counts of individuals on each substrate were recorded at one-minute intervals for 30 minutes in a common garden style aquarium experiment where all substrate types were equally available. Substrate selection differed among the macroinvertebrate taxa tested. Natural wood was not selected more often than artificial substrates. *Trichocorixa* rarely selected for the wood substrate over artificial substrates. *Ischnura* selected the light colored PVC substrate most often and *Pachydiplax* selected the darker artificial composite most often. Our results suggest that selection of different substrates may be taxon specific and not heavily influenced by material composition.

Keywords: Artificial Habitats, Behavior, Habitat Selection, Macroinvertebrates, *Baetis*, *Ischnura*, *Pachydiplax*, *Trichocorixa*

INTRODUCTION

The addition of artificial aquatic habitats to enhance fisheries in lakes and reservoirs is common practice (Tugend et al., 2002; Bolding et al., 2004). Added habitats range from natural materials such as whole trees, tree stumps, brush piles, aquatic vegetation, and rocks, to artificial materials like tire bundles, plastic-log cribs, concrete, hay bales, stake beds, spawning boxes, and a host of commercially produced plastic fish attractors (Bolding et al., 2004). The goal of placing artificial or natural habitat additions is most commonly to increase angler catch rates by providing refuge or resources for adult and juvenile fishes (Bolding et al., 2004). Habitat structures have been related to increases in angler catch rates, relative abundance of fish, and spawning activity (Wilbur, 1978; Johnson & Lynch, 1992; Wills et al., 2004). While the goal of these enhancements is to increase fish habitat and improve catchability of fish, added structure also changes habitat available for macroinvertebrates.

Macroinvertebrates are not evenly distributed throughout freshwater ecosystems (Downing, 1991; Malmqvist, 2002; Detmer et al., 2017). Structural heterogeneity of littoral environments supports diverse assemblage of invertebrate species with different factors driving habitat selection (Diehl, 1992: Schneider & Winemiller, 2008). Macroinvertebrate selection for habitat structures is dependent on feeding strategy (e.g., detritivores, grazers, planktivores, predators; e.g., Heino, 2008), and resource availability (food or substrates for attachment by predators, e.g., Schramm & Jirka, 1989: Diehl, 1992). There has been particular focus on understanding macroinvertebrate selection for differing levels of habitat complexity and the role of this complexity for avoiding predation pressure from fish and other invertebrates (e.g., Crowder & Cooper, 1982: Gilinsky, 1984: Diehl & Kornijów, 1998: Huang & Sih, 1990). Substrate type may also influence macroinvertebrate community structure through a variety of other mechanisms. For example, invertebrate selection of macrophytes (Lauridsen & Lodge, 1996; Warfe & Barmuta, 2004; Hanson, 1990) and woody debris (Czarnecka et al., 2014) affects vulnerability to predation. Less is known regarding differences in macroinvertebrate use of natural and artificial substrates (e.g., plastics). However, differences in periphyton growth between artificial and natural substrates (Lamberti & Resh, 1985; Hao et al., 2017) can in turn regulate habitat selection by macroinvertebrate grazers through differences in resource availability (Braccia et al., 2014). Thus, the material composition of different structures used for habitat enhancements may determine their viability as macroinvertebrate habitat.

We tested the selection of different substrate materials used in habitat enhancements by four common macroinvertebrate taxa. Our goal was to assess selection of different substrates in the absence of food (i.e., substrates were not conditioned). Substrate materials consisted of white pine (*Pinus strobus*) as a woody substrate with bark (hereafter called wood), polyvinyl chloride (PVC), and a composite plastic material from a commercial fish attractor (Mossback®). The wood and composite substrates were both dark in coloration and had rough surfaces, while the PVC substrate was white in coloration and had a smooth surface. Previous studies have examined macroinvertebrate colonization rates for substrata types used by detritivores and other infauna (Williams & Mundie, 1978; Lamberti & Resh, 1985; Schmude et al., 1998). In contrast to those studies, we sought to examine substrate selection by motile, epibenthic macroinvertebrates that do not permanently colonize surfaces. Macroinvertebrate taxa tested included a mayfly (*Baetis* spp.), a damselfly (*Ischnura* spp.), a dragonfly (*Pachydiplax* spp.), and a water boatmen (*Trichocorixa* spp.). We hypothesized that macroinvertebrates would preferentially select natural, dark-colored materials with rough surfaces because they offer more camouflage from predators and rough surfaces are conducive to attachment. Therefore, we predicted that for all macroinvertebrate taxa examined preference from highest to lowest, would be wood, composite plastic material, and PVC. Understanding the response of these macroinvertebrate taxa could help managers make informed decisions about which combination of materials and structural features promote use by macroinvertebrates and fish.

METHODS

Experimental tank and substrates. Trials to assess substrate selection were conducted within 38-L glass aquaria filled with filtered, dechlorinated tap water at a temperature of 20-23 °C. Substrates were provided as flat patches (5 cm x 8.5 cm) that were affixed with aquarium-safe 100% silicone adhesive to an acrylic sheet cut to fit the bottom of the aquarium. Nine substrate patches (three of each substrate type) were provided, and three different substrate arrangements were used randomly among trials to minimize confounding factors such as proximity to tank corners or glass walls and the arrangement of substrates. The PVC substrate was obtained from a Cresline® brand 7.6-cm diameter pipe that was heated, and flattened. The composite plastic substrate was from unused limbs of Mossback® Safe Haven artificial trees. Safe Haven artificial trees resemble pine trees and consist of a 102-cm tall trunk and 18 flexible and textured limbs. The wood substrate consisted of white pine bark and wood removed together from logs cut from a living tree and flattened. Tanks were drained of water, rinsed, and refilled between trials to reduce potential confounding effects of residual infochemicals from prior occupants. Following the completion of each trial, the substrates were air dried to prevent conditioning of the materials (i.e., breakdown of substrates or growth of periphyton or fungus).

Experimental procedure. Habitat selection was quantified during 30-minute trials with macroinvertebrates collected from Lake Shelbyville and nearby, connected waterways (Moultrie County, IL, USA). All individuals were collected using D-frame nets with 500-μm mesh. Following collection, macroinvertebrates were sorted and either used in trials the same day or maintained overnight inside the lab in aerated holding aquariums (separate from experimental tanks) prior to use in trials the following day. Ten trials were conducted for each taxon.

Trials were conducted using five individuals of a single taxon collected at random and acclimated for 30 minutes within the experimental tank in a 500-mL glass jar filled with 250 mL of water from their holding tank and 250 mL of water from the experimental tank in which the trial was subsequently run. Experimental tanks were aerated with air stones throughout to ensure fully oxygenated conditions, and the air stone was removed upon the start of each trial. Each trial was begun by pouring the organisms slowly and evenly just over the surface of the water in a lateral motion along the long axis of the tank, uniformly introducing the organisms across the area of the aquarium. Following addition of focal taxon, the trial observer began a stopwatch and recorded locations of organisms within the tank every one minute for 30 minutes. Use of substrates (e.g., physical contact with the surface of a substrate patch) was recorded along with behaviors and locations not associated with use of a substrate (e.g., swimming or grasping to tank walls).

Statistical analysis. We used a two-way repeated measures analysis of variance (ANOVA) to identify whether counts of macroinvertebrates were different among the three substrate types. Only data for observations of animals that occupied one of the three substrates were included in the analysis, while counts of animals swimming or on the tank walls were not included (range 0.3—12% of counts). Factors in the model were macroinvertebrate taxon (four levels), substrate type (three levels), and their interaction. Groups of macroinvertebrates were treated as a random factor to account for repeated measurements taken from each group over each trial. Differences in macroinvertebrate counts were compared among taxa using a Holm-Sidak post hoc test to control for multiple comparisons. All data were analyzed using the Statistical Analysis System, version 9.4 (SAS Institute, Cary, North Carolina, USA).

RESULTS

Number of macroinvertebrates was significantly different among substrate types ($F_{2,\ 3576}$ = 27.11, P < 0.0001) and taxa ($F_{3,\ 3484}$ = 71.01, P < 0.0001), with a significant interaction between macroinvertebrate taxon and substrate type ($F_{6,\ 3576}$ = 82.76, P < 0.0001). *Trichocorixa* and *Ischnura* counts were highest on the PVC material (Figure 1), with *Ischnura* using this material most often compared to the other three taxa (Table 1, Figure 1). *Trichocorixa* counts differed across all three substrate types (Table 1). *Trichocorixa* selected for PVC most often, followed by the composite material, with the wood substrate having the lowest number of water boatmen (Figure 1). *Ishnura* count also differed across all substrate types (Table 1), with next highest number after PVC being found on the wood substrate (Figure 1). *Baetis* counts were low on PVC and wood substrates compared to the composite material (Table 1, Figure 1). *Pachydiplax* was the only taxon with-out a single, clearly used substrate type (Table 1), having its highest counts on both the wood and composite materials (Figure 1).

DISCUSSION

Substrate selection differed among the macroinvertebrate taxa tested. In contrast to our hypothesis, the wood substrate was not selected more overall than artificial PVC and composite substrates. While previous research has indicated darker colors and increased complexity and rugosity (i.e., roughness) of surfaces tend to be more attractive to macroinvertebrates (Warfe & Barmuta, 2004), these features were poor predictors of substrate use for most taxa examined in our experiment. Out of all taxa examined, only *Pachydiplax* selected the wood substrate more often than PVC substrate. Thus, factors other than material composition (i.e., wood or plastic) or surface qualities (e.g., color and rugosity) may be more important for macroinvertebrate selection of structures added for fish habitat.

Trichocorixa was the only taxon that exhibited greater selection for both artificial substrate types compared to the wood substrate. Trichocorixa (Family Corixidae) are often prey for a wide variety of macroinvertebrate and vertebrate consumers (Kelts, 1979), and can be an important food source for fish in freshwater lakes and ponds if other resources are scarce. Cryptic coloration and background color matching have been shown to play an important role in avoiding fish predation for Corixidae (Popham, 1943). As such, selection for the lightest-colored treatment material (white PVC) was contrary to expectations, as most Corixidae possess dark-colored dorsal features (Stonedahl & Lattin, 1986). Additionally, Corixidae carry gas bubbles stored on the abdomen which function as physical gills (Popham, 1960), and possess forelegs specially adapted for grasping underwater objects to prevent their floating to the surface (Short 1953). Given this, it again seems counterintuitive that *Trichocorixa* selected PVC over the composite substrate and pine bark (wood) substrate because these substrates provide a far greater complexity of surface upon which to grasp. If Corixidae do prefer PVC to more natural materials, its inclusion in fishery enhancements may facilitate greater capture of poorly camouflaged taxa such as *Trichocorixa* (Stevens & Merilaita, 2011), increasing resource availability for fish.

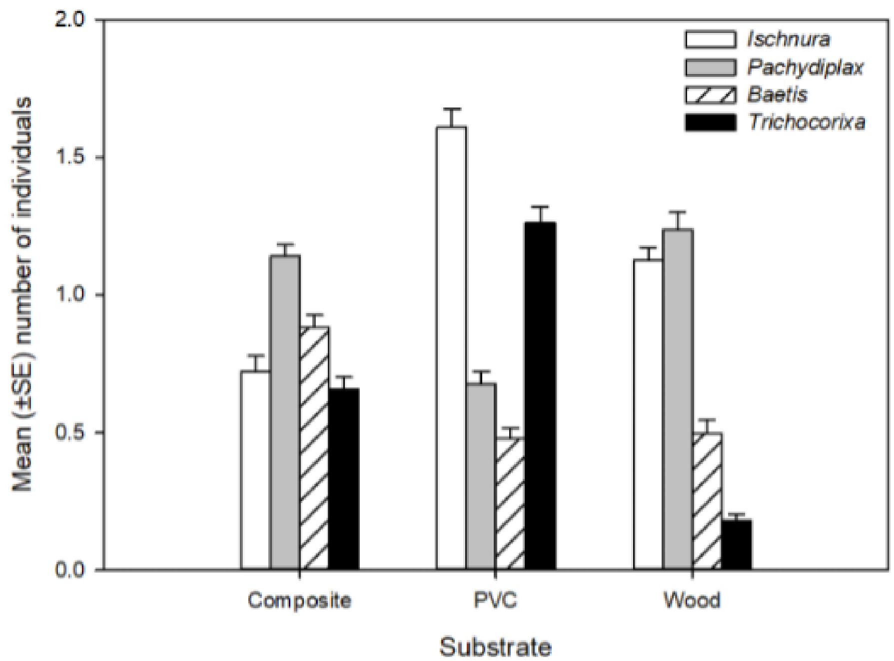

Figure 1. Mean count (number of individuals per substrate) of macroinvertebrate taxa on three substrate types. Error bars represent one standard error.

Table 1. Pairwise differences (Holm-Sidak) in macroinvertebrate counts (number of individuals) among substrate types.

Comparison	Mean Difference	*t*	*P*
All taxa			
Composite versus PVC	0.157	-4.62	< 0.0001
Composite versus Wood	0.090	-2.65	0.024
PVC versus Wood	0.247	-7.27	< 0.0001
Ischnura			
Composite versus PVC	0.887	-13.08	< 0.0001
Composite versus Wood	0.403	5.95	< 0.0001
PVC versus Wood	0.483	-7.13	< 0.0001
Pachydiplax			
Composite versus PVC	0.463	6.83	< 0.0001
Composite versus Wood	0.097	1.43	1.000
PVC versus Wood	0.560	8.26	< 0.0001
Baetis			
Composite versus PVC	0.403	5.95	< 0.0001
Composite versus Wood	0.383	-5.65	< 0.0001
PVC versus Wood	0.020	0.29	1.000
Trichocorixa			
Composite versus PVC	0.607	-8.95	< 0.0001
Composite versus Wood	0.477	-7.03	< 0.0001
PVC versus Wood	1.080	-15.98	< 0.0001

Previous research suggests that dark colored substrates are attractive to Odonata. However we found different patterns of selection between the two Odonates tested in this study. Odonata are lie-in-wait predators that use cryptic coloration and morphology to disguise themselves from prey (Cooper et al., 1985; Bailey, 1986; Merritt et al., 2017). Previous studies on substrate choice indicate both brown and green *Ischnura verticalis* larvae prefer brown substrates to green substrates, whether or not a predator is present, and that more prey are captured by larvae on brown substrates (Moum & Baker, 1990). *Ischnura* in our experiment, however, selected for white PVC substrate most often. Although selected for in equal proportion, *Pachydiplax* were most dense on both the composite and wood substrates. Both substrates were dark in color and selected more often than the white PVC. Selection for these substrates may be beneficial for prey capture but also for avoidance of predators if the organisms perceived the tank to be a dangerous environment.

Structure and conditioning of the substrates used in this study may be an important factor left unconsidered. Our design controlled for equal area of availability among all surfaces, but it did not represent the natural shape of materials (i.e., branches of wood, hollow space within PVC tubing) which may influence macroinvertebrate use and preference. In addition to varying structure, introduction of predator or prey organisms and/or chemical cues could also alter differential substrate choice and cryptic behavior in response (Chivers & Smith, 1998) as these factors would be present in a natural environment. Finally, conditioning, or allowing for the growth of periphyton and fungi on the substrates, was not evaluated because conditioning rates for each material may vary and fisheries habitat enhancements introduce materials unconditioned. We expect, however, that selection of different substrates would be affected by the colonization of periphyton and other important food resources for grazing macroinvertebrates and should be considered in future experiments. In the absence of conditioning, our experiment suggests that selection of different substrates may be taxon specific and not heavily influenced by material composition.

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