

Aquatic degradation in shallow coastal plain lakes: Gradients or thresholds?

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ABSTRACT

The establishment of introduced species in aquatic and wetland habitats is often associated with human-related environmental degradation. In the blackwater streams of the New Jersey Pinelands, the presence of nonnative species drives the relationship between community composition and watershed disturbance associated with developed land and upland agriculture. Most Pinelands lakes are shallow, artificial stream impoundments. In this study, we determined if land-use gradients or thresholds were associated with the presence of nonnative-herbaceous-plant, woody-plant, fish, and anuran species in 30 Pinelands stream impoundments. Correlation and regression analyses indicated that the response of all four taxonomic groups to watershed disturbance was an increase in the number of nonnative species and the proportion of total species richness represented by nonnative species. Native-anuran richness decreased along the watershed-disturbance gradient. We found both linear and nonlinear responses when relating species-richness attributes to the percentage of altered land (combined percentage of upland agriculture and developed land) in the associated watersheds, but the nonlinear responses cannot be considered land-use-related degradation-threshold responses. The breaks in the regression lines describing the relationship between the percentage of total species richness represented by nonnative plants and fish and altered land in our Pinelands watersheds did not represent a degradation threshold because, with the exception of the percentage of total species richness represented by nonnative-anuran species, a progressive decline in aquatic integrity was observed before the break points. Kruskal–Wallis ANOVA revealed significant differences in species-richness attributes only among stream impoundments with contrasting altered-land profiles, providing further evidence that aquatic degradation was progressive. Logistic regression identified the point along the watershed-disturbance gradient at which the probability of encountering nonnative bullfrogs was greater than that for native carpenter frogs.

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1. Introduction

The establishment of introduced species in aquatic and wetland habitats is often associated with human-related environmental degradation (Moyle, 1973, 1986; Ehrenfeld, 1983; Ehrenfeld and Schneider, 1991, 1993; Moyle and Light, 1996; Ashton and Mitchell, 1989; Owen, 1999; Galatowitsch et al., 2000; Green and Galatowitsch, 2002; Marchetti et al., 2004; Zedler and Kercher, 2004; Burton et al., 2005). The concept of degradation thresholds has been used to describe the level of urbanization and associated impervious surface that results in stream impairment (Arnold and Gibbons, 1996; May et al., 1997; Paul and Meyer, 2001; Gergel et al., 2002; Stepenuck et al., 2002). The concept is valid in areas dominated by urban-land use, however it fails to account for the effect of agriculture on the ecological integrity of surface waters in areas with mixed-land uses since both urban land and agriculture

can result in water-quality degradation (Johnson et al., 1997; Carpenter et al., 1998; Herlihy et al., 1998; Rhodes et al., 2001) and associated changes in the composition of aquatic communities (Lenat and Crawford, 1994; Wang et al., 1997; Waite and Carpenter, 2000). In the New Jersey Pinelands, the extent of both developed land and upland agriculture must be considered to adequately explain variations in stream-water quality (Conway, 2007; Zampella et al., 2007). Ten-percent altered land, defined as the percentage of developed land and upland agriculture in a drainage basin, has been described as the threshold at which a significant deviation from reference-site water-quality conditions occurred in a major Pinelands watershed (Zampella et al., 2007).

Although the relationship between the presence of nonnative species and aquatic degradation associated with upland-agricultural and developed-land uses is well documented in the blackwater streams of the New Jersey Pinelands (Morgan and Philipp, 1986; Zampella and Laidig, 1997; Zampella and Bunnell, 1998, 2000; Zampella et al., 2001; Bunnell and Zampella, 2008), the land-use-related degradation threshold at which the occurrence of nonnative species might occur has not been established. The

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purpose of this paper is to determine if altered-land-use gradients or thresholds are associated with the presence of nonnative plants, fish, and anurans in Pinelands stream impoundments.

2. Methods

2.1. Land use and study-site selection

Most Pinelands lakes are shallow, artificial stream impoundments that were created for sawmills, ironworks, papermaking,

and cranberry production (Patrick et al., 1979; Wacker, 1979). We selected 30 impoundments that represented a range of watershed conditions characterized by the percentage of developed land and upland-agricultural land (Fig. 1). Mean lake area (± 1 SD) was 16.2 (± 11.6) ha. Land-use/land-cover and impervious-surface profiles for watersheds associated with the impoundment were prepared using ArcView software (Environmental Systems Research Institute Inc., Redlands, CA, 1999–2006) and digital data, obtained from the New Jersey Department of Environmental Protection, 2000, which classifies land uses using a modified Anderson et al. (1976) system.

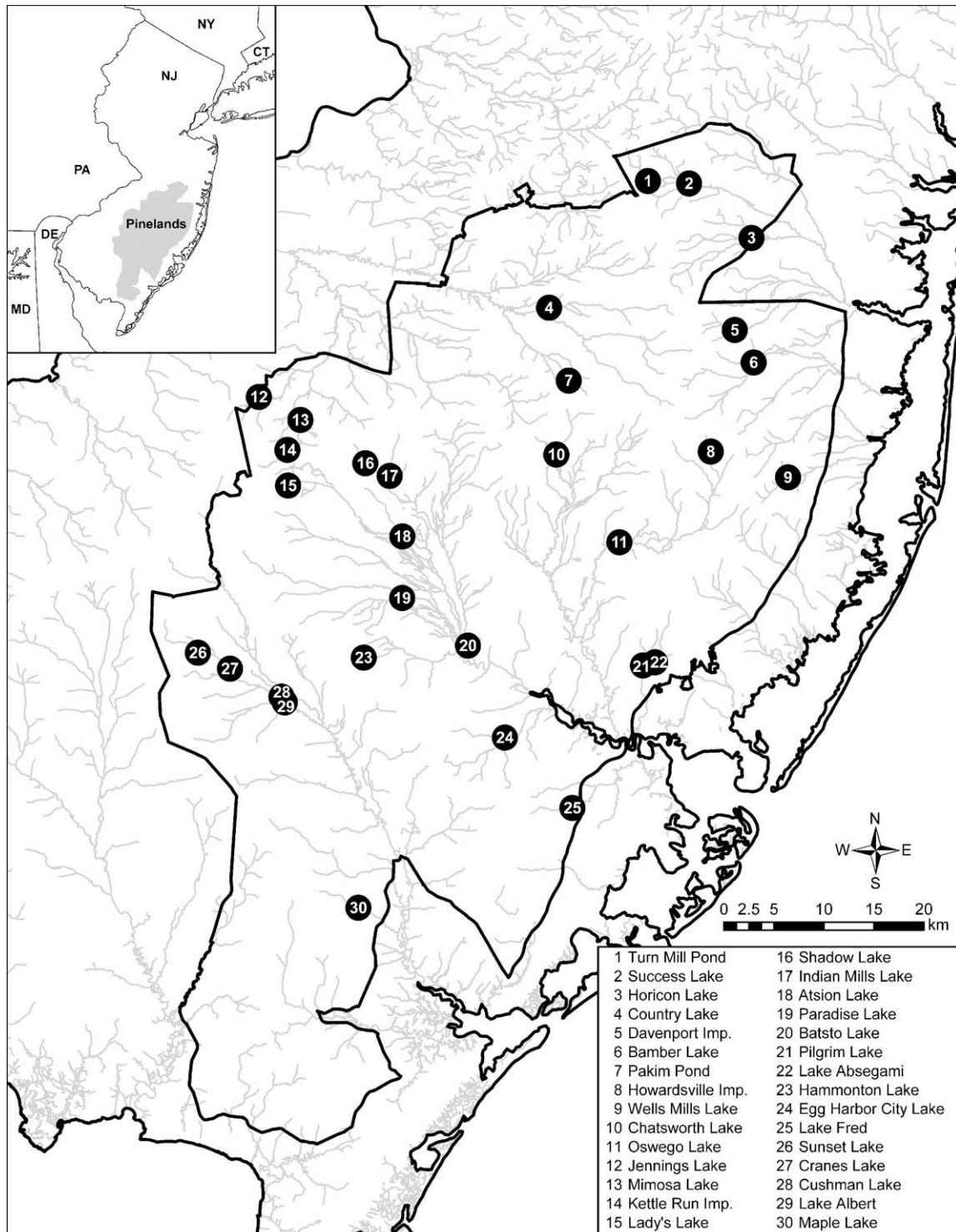


Fig. 1. Location of 30 Pinelands impoundments.

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