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SLOSS (Single Large or Several Small) or Not? Factoring Wetland Size Into Decisions for Wetland Conservation, Enhancement, Restoration, and Creation

While species diversity tends to increase with wetland size, closer examination of species "nestedness" is required to determine whether species associated with smaller wetlands are simply a subset of the species pool typical of larger wetlands, or if they represent unique habitats needing protection to maintain diversity.

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Mitigation or replacement of several small impacted wetlands or sites with fewer large wetlands can occur deliberately through the application of functional assessment methods (e.g., Adamus 1997) or coincidentally as the result of market-based mechanisms for wetland mitigation banking (Bendor et al. 2009). Adoption of the concept that "bigger is better" was influenced by general knowledge of diversity-area curves from island biogeography, minimum area requirements for key species, and the logic that larger wetlands would have a greater capacity for flood reduction and nutrient retention. In the decades since the inception of the SLOSS (single large or several small) nature reserve debates, we have learned more about relationships between wetland area and wetland functions, and how these relationships depend on landscape context, watershed attributes, wetland position, wetland hydrogeomorphic type, specific wetland function, and biotic community type or key species targeted for protection. This overview reviews the current knowledge on these relationships. The discussion articles following this overview will address how these relationships should be factored into assessing wetland conservation successes.

Assessments of Species Nestedness

While species diversity tends to increase with wetland size (Baber et al. 2004; Matthews et al. 2005; Tales & Berreberi 2007; Angeler et al. 2008; Craig et al. 2008; Webb et al. 2010; Tsai et al. 2012), examination of species "nestedness" is required to determine whether species pools associated with smaller wetlands are simply a subset of the species pool typical of larger wetlands or if they contain unique species and thus represent unique habitats needing protection to maintain landscape-scale diversity. Thus far, species research on plants, macroinvertebrates, fish, and amphibians offers a mixed picture.

Species nestedness patterns for plants can develop from the combination of significant plant species-area relationships, a negative effect of wetland isolation on species diversity (particularly those that are dispersal-limited), and a tendency for conservative species to be associated with larger wetlands (Lopez et al. 2002; Matthews 2003; Boughton et al. 2010). For example, species nestedness has been demonstrated for sedge meadows (Matthews 2004), but not for calcareous montane fens (Peintinger et al. 2003). However, in human-modified landscapes, native species switch from dispersal-based community assembly to a species-sorting process, and recently introduced exotic species are more dispersal-limited (Ehrenfeld 2008; Boughton et al. 2010). Plant dispersal mechanisms have a critical role in determining landscape-scale diversity and in creating trade offs for increasing wetland density or interconnectedness in heavily disturbed landscapes because of the potential selection for exotic species.

The degree of nestedness for aquatic macroinvertebrates in playa systems was mixed (Craig et al. 2008), while nestedness was found for adult odonates in these temporary systems (Hall et al. 2004). Nestedness of wetland-dependent birds has not been assessed, although positive species-area relationships have been detected for birds in coastal marshes (Smith & Chow-Fraser 2010) and for both migrant and resident bird species in playas (Webb et al. 2010; Tsai et al. 2012). In peatlands, microhabitat heterogeneity is the most important predictor of bird diversity (Calmer & Desrochers 2000).

Landscape-level wetland fish diversity can be maintained by preserving, enhancing, and/or restoring wetlands with a range of hydroperiods and connectivity, which, in turn, are associated with fish species with differing tolerances for salinity, dissolved oxygen, and/or turbidity. Frequency and duration of connectivity with adjacent riverine (Miranda 2005) or lacustrine systems (Snodgrass et al. 1996; Baber et al. 2002; Bouvier et al. 2009) are the most important determinants of fish community structure, rather than wetland area.

For amphibians, evidence of nestedness is equivocal and may vary regionally (Hecnar & M'Closkey 1997; Snodgrass et al. 2000; Baber et al. 2004). Non-nested distributions of wetland-dependent amphibians may be created when risk of drying and predation are strong and vary in magnitude along a hydroperiod gradient (Baber et al. 2004; Snodgrass et al. 2000). Given the significant fraction of amphibian species at risk globally (Baillee et al. 2004), it may be more critical to develop wetland management strategies to protect populations at risk (Semlitsch 2002; Cushman 2006), rather than focusing on overall diversity and community assemblages as is done for plants and macroinvertebrates. Strategies for amphibian protection vary by species and must take into account not only wetland hydroperiod distribution and density, but also condition of the landscape matrix or dispersal corridors. In simulations, although size of ambystomid salamander metapopulations increases with patch area, in most landscapes with intensive land use, some amount of dispersal matrix protection is also necessary to ensure long-term species persistence (Bauer et al. 2010).

Wetland Function-Area Relationships

Wetland function-area relationships depend on wetland hydrogeomorphic type and the function of interest. Floodplain wetlands associated with large rivers have critical size requirements associated with floods with different magnitude and recurrence intervals to maintain specific processes and functions (Opperman et al. 2010). Rivers with at least 2% of the watershed area with intact floodplains have significantly higher fisheries catch/unit effort for a given watershed size than those with less intact floodplain area (Welcomme 1985). Large areas of intact bottomland hardwood forest are necessary to maintain interior species and large carnivores (Gosselink et al. 1990).

Hydrologic functions of wetlands (flood peak reduction, baseflow maintenance) depend on the ratio of wetland-to-watershed area (Detenbeck et al. 2005). There is mixed evidence for variation of function with wetland size distribution (Bullock & Acreman 2003). However, hydraulic modeling of the Charles River by Ogawa and Male (1983) demonstrated that peak flows would increase exponentially with loss of floodplain wetlands. Increases were greater for fifth-order streams at < 50% floodplain wetland loss, but greater for first- and second-order streams at >75% floodplain wetland loss. Storm-surge protection by coastal wetlands increases with wetland continuity along a land-to-sea transect and vegetation roughness (Barbier et al. 2013).

Water-quality functions of wetlands also depend upon wetland-to-watershed area ratios, which affect hydraulic loading rate and retention time (Carleton et al. 2001). Both phosphorous removal efficiency (Richardson 1985) and nitrogen removal efficiency (Jordan et al. 2011) can become saturated at very high nutrient loading rates.

Assessing Wetland Conservation Success

Long-term strategies for conserving wetland functions should be developed for each region, taking into account landscape hydrogeomorphic profiles (Bedford 1996) and historical distributions of wetland size and hydroperiod. EPA currently supports the advance identification of disposal areas (ADID), a planning process used to identify wetlands and other waters that are generally suitable or unsuitable for the discharge of dredged and fill material. This process can improve predictability to the wetlands permitting process as well as better account for the impacts of losses from multiple projects within a geographic area. Advanced Identification methods (ADID; http://water.epa.gov/type/wetlands/outreach/fact28.cfm) incorporating alternatives analysis with optimization methods for multiple endpoints are more likely to reduce cumulative impacts of wetlands loss than decisions made on a case-by-case basis (e.g., Miller & Golet 2001; Transportation Research Board 2012) because effects are not simply additive. The effect of the modified landscape matrix in altering historical wetland area-function or wetland connectivity-function relationships also must be considered. The following discussion articles will address how wetland functions, hydrogeomorphic classifications, and community type should be incorporated into a framework for assessing likely success of single large or several small wetland conservation outcomes. How should newly evolving wetland monitoring programs at the state and national scale be designed and/or results analyzed to provide more definitive information on unique wetland types in need of protection or restoration given the incomplete information on species nestedness patterns? Designed to provide more information on the effect of the modified landscape matrix on wetland function relationships?

Current federal policies provide a mechanism for a systematic regional approach to wetlands mitigation. The avoid–minimize–mitigate sequence of actions involved in the wetlands permitting process is considered to be "satisfied where the proposed mitigation is in accordance with specific provisions of a Corps and EPA approved comprehensive plan that ensures compliance with the compensation requirements of the Section 404(b)(1) Guidelines (examples of such comprehensive plans may include Special Area Management Plans, Advanced Identification areas (Section 230.80) and State Coastal Zone Management Plans)." (U.S. EPA/U.S. Army Corps of Engineers 1990 Memorandum of Agreement, http://water.epa.gov/lawsregs/guidance/wetlands/mitigate.cfm). How can evolving science and lessons learned from the >71 completed or ongoing ADID projects, multiple Special Area Management Plans, and/or State Coastal Management Plans be combined to provide more general and comprehensive guidance and approaches for regional permitting activities?

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