Small Wetlands and the Cumulative Impacts of Small Wetland Losses: A Synopsis of the Literature

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SMALL WETLANDS AND THE CUMULATIVE IMPACTS OF SMALL WETLAND LOSSES: A SYNOPSIS OF THE LITERATURE

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INTRODUCTION

Wetland regulation and classification systems typically are biased against small wetlands. Activities which fill small incremental amounts of wetlands are often considered inconsequential. Small fragmented wetlands in urban areas are especially vulnerable to loss from real estate development. While the national average for wetland loss is approximately 50 percent, in urban areas only an estimated 10-15 percent of the original wetland acreage now remains (Kusler 1988).. As small wetlands continue to be lost and degraded, we are beginning to understand the individual and cumulative significance of these wetlands for providing important functional values.

Small wetlands are inconsistently defined in the literature as anywhere between one and 10 acres. References to small wetlands in this report are to those two acres or smaller, unless otherwise noted. These wetlands perform valuable functions individually and also in combination with other aquatic and terrestrial features within a watershed. Although some small wetlands may not appear to provide significant functional values when assessed individually, they may be very important components of a larger natural system.

WETLAND FUNCTIONAL VALUES

Wetland functional values are those physical, biological and chemical functions a wetland performs and the benefits or value that society derives from them. Wetland water quality standards in chapter NR 103, Wisconsin Administrative Code, list such wetland functional values as wildlife support, aquatic life support, human use values, storm and flood water storage, hydrologic functions, water quality functions and shoreline anchoring. Chapter NR 115 and NR 117, Wisconsin Administrative Codes, which require zoning of shoreland-wetlands, also refer to these wetland functional values.

Wildlife And Aquatic Life Support

Wetlands support game species, including waterfowl, raccoon, beaver, muskrat, mink, deer, and pheasants, and non-game species, including migratory songbirds, small mammals, raptors, herptiles and other species that are important components of the food web. Isolated wetlands are used by 450 species of migratory birds, including 25 federally-endangered species. As of 1986, 209 animals were listed as federally endangered or threatened and about half of these species depend upon wetlands for their survival (Feirabend and Zelazny 1987).

Waterfowl

Waterfowl are the most economically important group of migratory birds in North America. North American wetlands provide habitat for 37 species of waterfowl that are important to a large number of hunters. The loss and degradation of habitat is the major waterfowl management problem in North America (US Fish and Wildlife Service 1986).

Small wetlands are critically important to waterfowl. Since breeding ducks are territorial, 10 one-acre wetlands provide habitat for more nesting ducks than one 10-acre wetland (Wildlife Management Institute 1995). Small wetlands generally thaw faster than larger wetlands, allowing nesting hens and juveniles to find an earlier and potentially larger source of invertebrates, which are a critical component of their diet (Eldridge 1990). The loss of all one-acre wetlands in the prairie pothole region would have a devastating impact upon waterfowl populations nationwide. This loss of habitat would result in a 50 percent reduction in the prairie pothole region's duck population (Wildlife Management Institute 1995). The decline in population would result in 10 to 20 fewer days of hunting per year, reduce the average annual duck harvest in the United States by 428,000 birds and cost more than $22.2 million in lost hunter expenditures.

Loss of small wetlands may concentrate waterfowl on the few remaining large wetlands during migration and molting (Smith and Higgins 1990). High concentrations of birds may cause more stress, degrade water quality, and increase disease susceptibility within the population (Friend 1981).

On a landscape scale, a diversity of wetland types is needed to maintain the diversity of invertebrate populations essential to waterfowl. Preliminary results from a study of eleven wetlands in Columbia and Sauk counties ranging in size from one-third acre to three acres indicate that invertebrate and amphibian diversity is linked to having a range of seasonally flooded wetlands in a region that dry down at different rates (Boorse in preparation).

Amphibians and Reptiles

One of the most significant wetland functions is the role wetlands play in biological support. Aquatic life support functions vary with the individual wetland, even small wetlands support aquatic life species critical for the survival of higher food chain organisms. Seasonally flooded wetlands which regularly dry down are often more valuable in the production of amphibian food resources, since water level fluctuations enhance primary productivity (Pechmann, et al. 1989).

Seasonally flooded wetlands are the only viable habitat for many amphibians. Small isolated seasonal wetland ponds for that hold water for short periods of time and dry down later in the year are unsuitable for predatory fish and invertebrates that prey on amphibian eggs and juveniles (Duellman and Trueb 1986). The ephemeral nature of these wetlands allows them to support a higher density and diversity of amphibians (Wilbur 1984). Small isolated seasonal wetlands can serve as refuges that support amphibian source populations that provide out-migrants to more permanent aquatic systems. Increases in wetland size can also negatively affect survival and growth rates in amphibians (Pearman 1993). Because of a decreasing ratio of edge to interior habitat, competition between individuals is greater in larger wetlands.

Amphibians and reptiles make up a large portion of the wildlife populations in many freshwater habitats, often comprising enormous populations and reaching significant biomass levels. For example, as many as 88,000 amphibians were captured in a single year at a two and a half acre temporary pond in South Carolina (Savannah River Ecology Laboratory 1980). Freshwater turtles are known to represent the majority of vertebrate biomass in many aquatic habitats (Congdon, et al. 1986; Congdon and Gibbons 1988).

The large numbers of amphibians and reptiles play a critical role in the food webs of the ecosystems they inhabit. Recent studies (e.g., Schabetsberger and Jersabek 1995) suggest that amphibians are often the top predators in some aquatic systems. In other aquatic systems, amphibians are important food items in the diets of waterfowl, fish, raptors, and predatory mammals - one researcher has commented that "almost everything eats amphibians". Amphibian populations influence primary and secondary productivity, nutrient influx, and competition in freshwater systems (Seale 1980; Osborne and McLachlan, 1985). The potential significance of freshwater turtles as a dispersal mechanism for seeds among temporary aquatic habitats has also been suggested (Congdon and Gibbons 1988).

Amphibians do not necessarily require large or floristically diverse wetlands. A study of created and restored wetlands in southeastern Wisconsin showed amphibian species diversity to be more dependent on landscape features than on wetland size (Kline 1997). Small, structurally simple wetlands often have high values for amphibian habitat (Richter and Azous 1995). In a study of 19 wetlands in the Puget Sound area, no relationship was found between amphibian species richness and wetland size. Moderate to high species richness was found in four of the smallest wetlands, suggesting that even the smallest wetlands are viable habitats for some amphibians.

Fish Support

Small wetlands with connections to surface waters can provide important fish support functions. Wetlands are critical spawning and nursery areas for many species of sport and forage fish, and do not necessarily have to be large to provide this function. Northern pike (*Esox lucius*), an important sport fish, is truly a wetland-dependent fish. It deposits eggs in shallow water wetlands on dense mats of short aquatic vegetation, such as wetland grasses, sedges, rushes and other shallow-water plants found in lake-fringe and stream headwater wetlands (Clark 1950; Forney 1968). After hatching, the fry attach themselves to this vegetation by means of a sucker on their head. Northern pike fry and juveniles use these wetlands for protection from predators and for foraging (Franklin and Smith 1963; Frost and Kipling 1967). Other species, including some walleye (*Stizostedion vitreum*) populations regularly use wetlands for spawning when available. Lake-fringe and headwater wetlands can extend the nursery area available to the young of muskellunge (*Esox masquinongy*) since they can use a combination of emergent, submergent and floating-leafed vegetation as a nursery area (Craig and Black 1986). Juvenile walleye, bass (*Micropterus spp.*), perch (*Perca spp.*), bluegill (*Lepomis spp.*), and various minnow species also use these wetlands as nursery habitat providing both forage and protection from predators.

As lake shorelines have been developed, wetlands have been filled, drained or cut off from lakes and streams making them unavailable to fish. Shoreline development has also resulted in loss or simplification of near-shore fish habitat. In southeastern Wisconsin, where wetland loss and shoreline development have been extensive, northern pike populations have drastically declined and the average size of individual fish has become smaller. Surveys of 16 Southeast Wisconsin lakes between 1951 and 1992 showed northern pike population declines averaging 72 percent (Paul Cunningham pers. comm.). Bryan and Scarnecchia (1992) demonstrated that the cumulative effect of shoreline development resulted in lower fish and aquatic vegetation abundance along developed shorelines as compared to undeveloped shorelines of the same Iowa glacial lake. Wisconsin Department of Natural Resources (WDNR) fish biologists have also noted the same relationship between developed and undeveloped shorelines during fish surveys (Mike Vogelsang pers. comm.).

Although permits are required for some of these activities in Wisconsin, effective implementation and enforcement of shoreland zoning ordinances and navigable waters regulations has been difficult to achieve (Bernthal and Jones). As littoral habitat is degraded, whatever accessible and suitable habitat remains, including lake-fringe and headwater stream wetlands, becomes even more essential for the reproductive success of fish populations. Managers must resort to stocking hatchery-raised fish, installing artificial fish habitat structures and tightening fishing regulations to maintain populations of sport fish when natural reproduction falls below a sustainable level. Unfortunately, these efforts have failed to restore the abundance of sportfish to levels similar to those that existed before the extensive wetland losses occurred (Paul Cunningham pers. comm.). Consideration of the cumulative effects of small wetland losses, and an understanding of the condition of the fishery resource in a watershed are essential to evaluating the significance of a proposal affecting even small amounts of wetland.

Human Use Values

Human use values are those values that humans attribute to wetlands. Though more difficult to quantify, these are often quite substantial. Human use values include recreational, aesthetic, and educational values.

Recreation in wetlands is economically important. Wetlands are the basis for more than $10 billion spent annually on nature study, fishing, hunting, swimming and other outdoor recreation (Feierabend and Zelazny 1987). In a North Dakota study, an estimated 56 percent of the $54.3 million of gross business volume generated by hunters was attributed to the existence of wetlands (Sorenson 1975). The amount of money expended by hunters is theorized to be minor compared to the amount of money spent by non-consumptive recreation such as bird watching (US Fish and Wildlife Service 1986).

Small wetlands can be invaluable classrooms for many subjects, from ecology to art. For example, fourth and fifth grade elementary classes in a Madison, Wisconsin school have been studying a small wetland for the past two years to learn basic ecosystem functions and develop an understanding and appreciation for the natural world (Wirth and Maas 1995). If a class can walk to a wetland near school, it is more likely to become part of the curriculum than a wetland for which more complex transportation must be arranged.

A group of small wetlands in an urban area may be significant for education and recreation because they are more accessible to a large number of people. Even wetlands with monotypic flora can be valued by urban dwellers as open space, aesthetic relief and buffers between incompatible land uses (Holland, et al. 1995). They can become community natural areas and attract citizen involvement in research or restoration efforts.

Storm and Flood Water Storage

Wetlands usually occupy low areas of the landscape, resulting in a greater opportunity for wetlands to perform storm and flood water storage functions. While a larger wetland may have a greater individual impact upon flood storage, many small wetlands may cumulatively reduce peak flooding significantly. Knight (1993) argues that small wetlands can have higher rates of evapotranspiration, making them more efficient for reducing runoff water volume than large wetlands (Millar 1971). Even isolated wetlands can store stormwater that would otherwise run off the land after a rainfall. One study in North Dakota found that depressional wetlands stored 72 percent of the total runoff in the largest storm that occurred every two years (Kantrud, et.al. 1989).

Cumulatively, wetlands can be very economically significant in providing flood control. A study by the US Army Corps of Engineers of the Charles River Basin found that protecting 8,400 acres of wetlands would prevent $17 million in flood damages (Thibodeau and Ostro 1987). The city of Bellevue, Washington found that constructing stormwater facilities for flood control would be 130 percent more expensive than maintaining natural wetlands. Studies in the Midwest have shown that flood flows were reduced by 80 percent in basins with wetlands compared to those without wetlands (Feirabend and Zelzany 1987). One analysis shows that an increase in wetland loss would result in about a 50 percent increase in predicted mean flow, 36 percent increase in predicted maximum daily flow, and 70 percent increase in predicted mean during-spring flow (Brun, et al., undated).

Discussions of wetland restoration priorities for flood control also suggest the cumulative importance of small wetlands. DeLaney (1995) notes that larger downstream wetlands will function more effectively for flood attenuation if there are wetlands (most likely smaller) located in the upper reaches of the watershed. Knight (1993) suggests that in situations where restoration opportunities only exist in the lower reaches of a watershed, a series of smaller wetlands adjacent to the channel would perform better for flood attenuation than a single wetland downstream.

Water Quality Functions

Wetlands perform water quality functions that are related to, but not the same as their storm and floodwater storage functions. As surface water flows into a wetland, the combination of the flatter slope, the depressional shape of some wetlands, and dense emergent vegetation can slow or entirely retain surface water runoff. As water is stored in a wetland, the water-borne sediments with adsorbed nutrients and pollutants have the opportunity to settle out. Pollutants such as heavy metals and pesticides adsorbed to sediment particles are also stored when sediment particles are buried below the root zone in wetland soils (Elder 1987). Wetlands that trap sediments may remove 80-90 percent of the phosphorus attached to sediments (Tchobanoglaus and Culp 1980). Studies have shown 70 percent removal rates of nitrogen from water entering prairie basin wetlands (Kantrud, et.al. 1989).

Nitrogen and phosphorus are also stored seasonally in freshwater wetlands through the cycle of plant uptake during the growing season and released back into the water column in inorganic form through litter fall and leaching in fall and early spring (Van der Valk et al. 1979). The same wetland can act as a sink for the inorganic form of nutrients during the growing season and as a source of the organic forms of these nutrients during fall and early spring. Any particular wetland's ability to retain sediments and transform associated nutrients depends on the combination of the wetland's hydroperiod, and the slope, soil type, microbial composition, animal activities, and vegetation density of both the wetland and its watershed.

As with flood and storm water storage functions, small wetlands cumulatively have a potential to significantly affect downstream water quality. In discussing relative priorities for restoration objectives Knight (1993) suggests that restoring multiple small wetlands located in the upper reaches of a watershed is mainly beneficial for the purpose of improving water quality, rather than attenuating above normal flood episodes or providing wildlife habitat. In ranking priorities for water quality focused restorations of drained wetlands in an agricultural watershed, landscape position, rather than size was the chosen criteria, with wetlands in the upper reaches given a higher ranking (Bridson and Gatti 1997).

Other Hydrologic Functions

Wetlands may interact with groundwater locally or regionally. Some wetlands recharge groundwater. Others act as groundwater discharge areas. Some wetlands may be isolated from the groundwater. Many wetlands retain water in wet periods and contribute this water to maintain water levels in aquifers and surface waters during dry periods. Even in watersheds where wetlands have minimal groundwater contact, they may cumulatively perform important watershed functions. For instance, in Wisconsin's Pensaukee Priority Watershed Project area, a large percentage of the watershed's original wetlands were lost due to agricultural drainage. Restoration of wetlands is seen as a potential solution to augment stream base flows through slow release of surface and subsurface flows (Appleberry and Olson 1997). Restoring many small wetlands was seen as more feasible than restoring a smaller number of larger wetlands (Bridget Appleberry pers. comm.).

Most of the wetland types in Wisconsin generally do not play a very significant role in groundwater recharge (Novitzki 1982). In highly altered urban watersheds, however, small isolated surface water wetlands may be some of the only permeable areas that allow water infiltration.

Some groundwater discharge wetlands, such as calcareous fens, derive an extremely high value as natural areas from their unique hydrogeological conditions, despite their small size. Of 28 calcareous fen sites in southeastern Wisconsin studied by Reed (1985), 17 were two acres or smaller, 11 were one acre or smaller and seven were half an acre or smaller. Their unique, alkaline soil chemistry is typically the result of constant saturation by upwelling groundwater rich in calcium and magnesium bicarbonates which precipitate out at the surface (Curtis 1971). Only a select group of calcium-tolerant plants can survive these harsh conditions, making calcareous fens one of the most unique and rare plant communities in North America, supporting a disproportionate number of threatened and endangered plant species compared to other plant communities (Eggers and Reed 1987). For instance, a survey of the Bluff Creek Fen Natural Area in Wisconsin, which contains several small mounded fens within a complex of sedge meadows and spring-fed streams, yielded an extremely high rating for floristic quality (Swink and Wilhelm 1994; Wilhelm et. al. 1995 - unpublished data).

Shoreline Anchoring

Some shoreland wetlands can help protect against shoreline erosion. A wetland's vegetational root system may help anchor soils. Wetland vegetation may also dissipate wave energy reducing shoreline erosion. Although this function is very site-specific, many small wetlands may prove as valuable for shoreline anchoring as larger wetlands. A band of wetland vegetation as narrow 2.5 meters can provide some shoreline anchoring benefits (Wells 1988).

CUMULATIVE IMPACTS

We have frequently used the term "cumulative" in discussing the value of small wetlands and the impact of many piecemeal wetland losses. "Cumulative impact" describes the incremental effect of an impact added to other past, present, and reasonably foreseeable future impacts (Johnston 1994). When considering a proposed wetland fill project under federal law, reviewers must take into account the potential cumulative impacts resulting from the project. While filling a small wetland or filling a small area in a large wetland may seem insignificant, the activity must be considered in light of past wetland losses, other terrestrial and aquatic habitat losses, hydrologic changes in the watershed and potential future impacts. Impacts to one wetland may influence other wetlands and other natural systems, because of the way they interact through hydrological and ecological connections. Wetland impacts that may seem minor when considered individually, may become major if considered collectively over time and space.

Evaluation of any wetland's functional quality and evaluation of impacts should not be done only on an individual basis, but should take into account the hydrologic and biologic connections to lakes, streams, groundwater, other wetlands and terrestrial habitat. For example, while one wetland may provide resting habitat for migratory waterfowl, another may provide breeding and nesting habitat. These connections are not always immediately obvious. A small, isolated, seasonal pond, with low vegetation quality, may provide the optimal level and duration of ponded water for amphibian reproduction. The last bit of shallow marsh, lake-fringe meadow, or shallow vegetated ditch may be a productive northern pike spawning ground in wet years.

As these examples show, evaluating the overall cumulative impacts of small wetland losses and evaluating the functions of an individual small wetland can be difficult. Consideration should be given to the factors discussed below when doing either type of evaluation.

Wetland Complexes

A landscape with wetlands of varying size and types, intermixed with suitable upland habitat that allows frequent animal travel and seed dispersal between individual wetlands, forms what we will refer to here as a "wetland complex." Although individual wetlands within a wetland complex may not appear to provide significant functional values, the wetland complex as a whole may be especially critical to the support of wildlife or aquatic life, or for providing sediment and nutrient trapping, flood and stormwater storage, or groundwater recharge functions.

Waterfowl need a complex of wetlands to provide their life needs. Seasonally wet areas provide a rich source of invertebrates at the time a high protein diet is most needed by nesting hens and juveniles. When the seasonally wet areas dry down, wetlands with a more permanent hydrology are used (Hubbard 1988). Landscapes containing wetlands with varying dry-down rates appear to support a greater variety of invertebrate types (Boorse International Crane Foundation, in prep.). This diversity of hydrologic types provided in a landscape with many small wetlands produces high biomass and secondary productivity of macroinvertebrates, which guarantees a rich and diverse food source for waterfowl on a landscape scale (Bataille and Baldasarre 1993).

Wetland complexes are also important to amphibians. During years of high rainfall, larger and wetter wetlands may have low survival rates of amphibians, but during low rainfall years, the wetter wetlands are necessary for successful breeding (Stredl and Collins 1992).

Small wetlands play a greater role in the dynamics of wildlife populations than one might infer from the size of the wetland. Some animal populations depend upon migration and exchange of individuals between wetlands for recolonization.

Populations of plants and animals may exchange genetic material between two wetlands. As small wetlands are lost within an area, the distances between the remaining wetlands are increased and wildlife populations are increasingly isolated. This results in lower survival of dispersing individuals due to the greater risk of predation by humans and other animals (Johnston 1994). Local populations of animals in isolated habitats face a greater risk of extinction due to chance demographic events, disease, inbreeding or natural events (Soule 1986). When the loss of small wetlands was simulated in models, local populations of turtles, small birds and small mammals faced a significant risk of extinction (Gibbs 1993).

Wetland complexes generally provide better groundwater recharge and stormwater and floodwater storage functions than similar acreage of wetlands in a large, single basin (Hubbard 1988).

Wetland Scarcity

As wetlands are lost, the value of the remaining wetlands for certain functions may increase. Small wetlands may have more significant landscape functions for wildlife and aquatic life support where they remain as remnants of larger systems that were lost. In agricultural areas, noncultivated, isolated wetlands may be more critical to resident species as winter cover than wetlands of the same type within a complex (Hubbard 1988). Our discussion of fish habitat loss on developed lakes is a case in point. Remaining wetlands that provide spawning and nursery habitat become critical to preserve when other habitat is lost.

Hydrologic functioning on a watershed scale can also be greatly influenced by wetland loss. One study showed that small wetland losses would have a small effect on floodflow from watersheds containing 10-50 percent wetlands but a large effect on floodflow from watersheds with less than 10 percent wetlands (Johnston, et al. 1990). Watersheds with less than 10 percent wetlands had suspended solids-per-unit-area loading rates that were as much as 100 times greater than the loading rates from watersheds with more than 10 percent wetlands (Oberts 1981). As wetlands are lost in a watershed, the hydrologic regime of streams becomes less stable, with higher peak flows following storms and lower base flows between rains. This leads to deteriorating habitat quality in streams. Hey and Wickencamp (1996) documented this effect in a study of nine watersheds in southeastern Wisconsin, with watersheds containing less than 10 percent wetlands showing greater fluctutations in stream flow.

As wetlands become more scarce, particularly in urban areas, their value as green space and natural areas becomes more significant (Wells 1988; Wisconsin Department of Natural Resources 1992). Wetlands and other natural resource features are the focal points around which subdivisions can be designed to take advantage of their value as desired natural amenities. Arendt (1996) describes a process for site design following conservation development guidelines, allowing the same total number of lots as conventional "cookie cutter" designs, by arranging smaller lots in a cluster arrangement that allows access to common open space.

Fragmentation

Fragmentation of wetlands occurs when a small portion of a larger wetland system is lost. While the loss itself may seem inconsequential, a greater impact may result. Research in large forested areas shows that a sharp decline in songbirds is seen in forest fragments as compared to larger areas of continuous forest (Ehrlich, et al. 1988). Often these birds are area sensitive, requiring a large amount of suitable habitat to reduce nest parasitism and predation. As more edge is created, nest predators, such as blue-jays, American crows, grackles, and nest-parasitizing cowbirds gain greater access to nests. More than 20 species of birds found in southern Wisconsin floodplain forests are area sensitive. Of these species, the yellow-crowned night-Heron, red-shouldered Hawk, Acadian flycatcher, cerulean and Kentucky warblers are listed as threatened species on Wisconsin's Endangered and Threatened Species List (Mossman 1988).

Another type of fragmentation is the hydrologic isolation caused when fill cuts off a portion of a wetland from a larger wetland, lake or stream. The amount of fill involved may be small, but have serious impacts if the exchange of water, nutrients and species is eliminated (Mitsch and Gosselink 1986). For instance, a southeastern Wisconsin lake's natural northern pike reproduction was severely reduced when fish movement between the lake and the marsh was prevented by construction of a railroad dike (Welch pers. comm.).

CONCLUSION

Small wetlands provide important functional values, which often are difficult to measure if assessing a wetland in isolation from its landscape context. We suggest that the assumption that smaller size always implies lower functional values should not be uncritically accepted. Evaluations of any wetland's functional values should not rely on size alone. As wetlands become more scarce, and as aquatic and terrestrial habitat in general is degraded in a watershed, the remaining wetlands can become more important, and additional losses become more significant, especially in terms of human use values. Particularly for watersheds where the percentage of wetlands is near or below 10-15 percent, any proposed wetland loss should be closely evaluated, and alternatives to wetland loss should be vigorously pursued.

In some landscape contexts, assemblages of small wetlands play a critical role in providing wildlife habitat, with each small wetland playing a slightly different role in food webs. Research is showing that other factors, such as hydroperiod, soil chemistry, and landscape context, are often more important than size in determining the functions a particular wetland will provide. Cumulative losses of wetlands have resulted in societal costs of degraded water quality, increased flooding problems and degraded biological communities. When evaluating the short-term gain from a small wetland fill project proposal, one should fully evaluate the wetland loss from a cumulative impact perspective and weigh the costs to society from lost values. Some small wetlands, and small parts of wetlands may indeed prove to be some of the "parts" Aldo Leopold referred to when he wrote, "The first step of intelligent tinkering is to save all the parts."

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