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The Importance of Isolated Wetlands as Habitat for Rare and Endangered Species in Comparison to Riparian Wetlands

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THE IMPORTANCE OF ISOLATED WETLANDS AS HABITAT FOR RARE AND ENDANGERED SPECIES IN COMPARISON TO RIPARIAN WETLANDS

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Introduction

The number of wetlands in North America has been drastically reduced since European settlement. In Canada, 15% of the original wetlands have been lost, whereas in the United States, over half of the original wetlands have been drained and used for development or agriculture (Moore et al., 1989; Murdock, 1994; Lovett Doust and Lovett Doust, 1995). Because of the high amount of losses of these ecosystems, wetlands should be conserved. However, in 2001, the United States Supreme Court ruled that only "navigable" waters were to be included for protection under the U.S. Clean Water Act (CWA), issued in 1972, in *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers* (SWANCC). This ruling drastically affects the wetland communities of the nation, many of which are isolated from other bodies of water, and therefore are not considered "navigable." Under this ruling, these isolated wetlands are no longer protected by the CWA (Zedler, 2003; Tiner, 2003; Leibowitz and Nadeau, 2003; Leibowitz, 2003; Sharitz, 2003; Gibbons, 2003; Comer et al., 2005). Since this ruling was made, many ecologists have been in an uproar to find evidence for the need for conservation of isolated wetlands.

The term "isolated wetland" is slightly misleading, because it implies that these wetlands are completely separated from any other bodies of water. However, that is typically not the case. Many of these "isolated" wetlands are actually connected to others via ground water, and can occasionally be connected above ground during brief flooding periods. These wetlands are also connected via terrestrial corridors which many species use to migrate. Because these wetlands are isolated from other bodies of water, they cannot receive water from other wetlands, and therefore rely on precipitation and runoff as their main sources of water. For these reasons, many scientists describe these ecosystems as *geographically* isolated wetlands (Tewksbury et al., 2002;

Tiner, 2003; Gibbons, 2003; Leibowitz, 2003; Sharitz, 2003; Leibowitz and Nadeau, 2003; Mulhouse et al., 2005; Comer et al., 2005; Schalk and Luhring, 2010). Today, we know that isolated wetlands are vital ecosystems with many functions: wetlands help reduce flooding, filter nutrients, and serve as critical habitats to many rare and endangered species (Lovett Doust and Lovett Doust, 1995; Leibowitz and Nadeau, 2003; Leibowitz, 2003; Sharitz, 2003; Gibbons, 2003).

Both isolated and riparian (directly connected to other bodies of water) wetlands have incredibly high biodiversity, and are the preferred habitats for many rare, endangered, and even some endemic species (Bartgis and Lang, 1984; Franzreb, 1987; Moore et al., 1989; Murdock, 1994; Lovett Doust and Lovett Doust, 1995; Semlitsch and Bodie, 1998; Pollock et al., 1998; Bornette et al., 1998; Zimmerman et al., 1999; Dudgeon, 2000; McCune et al., 2002; Tewksbury et al., 2002; Tiner, 2003; Zedler, 2003; Leibowitz, 2003; Leibowitz and Nadeau, 2003; Sharitz, 2003; Gibbons, 2003; Comer et al., 2005; Menzel et al., 2005; Laliberte et al., 2007; Liner et al., 2008; Stroh et al., 2008; Graeter et al., 2008; Attum et al., 2008). Because of the isolation of some of these wetlands, these species cannot migrate easily to other habitats that might be suitable for them. The importance of migration to these species indicates that the areas surrounding wetlands are just as important as the wetlands themselves. Corridors between wetlands are also being developed, and this could have even more drastic effects on the habitat and wildlife by decreasing gene flow and increasing the probability of inbreeding depression (Tewksbury et al., 2002; Gibbons, 2003; Leibowitz, 2003; Sharitz, 2003; Leibowitz and Nadeau, 2003; Menzel et al., 2005; Laliberte et al., 2007; Graeter et al., 2008).

If these wetlands are drained for agricultural or industrial use, extinction of many rare and endangered species would be inevitable (Bartgis and Lang, 1984; Franzreb, 1987; Moore et al., 1989; Murdock, 1994; Lovett Doust and Lovett Doust, 1995; Semlitsch and Bodie, 1998; Zimmerman et al., 1999; Dudgeon, 2000; Edwards et al., 2001; McCune et al., 2002; Luken, 2005; Comer et al., 2005; Soons, 2006; Winne et al., 2007; Czapka and Kilgo, 2011). Although both isolated and riparian wetlands have been assessed as vital habitats for many rare and endangered species, no comparisons have been made between the two wetland types to see whether one is more important. In this paper, I will review the literature on the factors contributing to the presence of rare or endangered species, the species found in each wetland type and what threatens them, and the views on how to and why we should conserve these habitats. I will also provide data analyses on the importance of isolated wetlands as habitats for rare and endangered species in comparison to riparian wetlands, and present my own views on the topic.

Literature Review

Factors contributing to the presence of rare or endangered species

Studies have shown that the number of rare, endangered, or endemic species increases with the total native species richness of wetlands (Moore et al., 1989; Mills and Schwartz, 2005; Stohlgren et al., 2005). Since wetlands have a very high biodiversity, it is therefore likely that wetlands also contain many rare, endangered, or endemic species (Bartgis and Lang, 1984; Franzreb, 1987; Moore et al., 1989; Murdock, 1994; Lovett Doust and Lovett Doust, 1995; Semlitsch and Bodie, 1998; Pollock et al., 1998; Bornette et al., 1998; Zimmerman et al., 1999; Dudgeon, 2000; McCune et al., 2002; Tewksbury et al., 2002; Tiner, 2003; Zedler, 2003; Leibowitz, 2003; Leibowitz and Nadeau, 2003; Sharitz, 2003; Gibbons, 2003; Comer et al., 2005; Menzel et al., 2005; Laliberte et al., 2007; Liner et al., 2008; Stroh et al., 2008; Graeter et al., 2008; Attum et al., 2008). Many factors can influence the amount of species richness in a habitat. Connell (1978) found that disturbance plays a large role in species richness. He found that species richness was highest when there was an intermediate amount of disturbance, thereby coining the phenomenon as the Intermediate Disturbance Hypothesis. This phenomenon is now widely recognized as true, and is used in many biodiversity experiments and papers. Pollock et al. (1998) found that wetland plant species richness was highest in wetlands that had an intermediate flood frequency (Figure 1a). Another common determination of species richness is the Intermediate Productivity Hypothesis, which was discovered by Huston (1979). Pollock et al. (1998) also found that wetland plant species richness was highest in wetlands with an intermediate amount of productivity (Figure 1b).

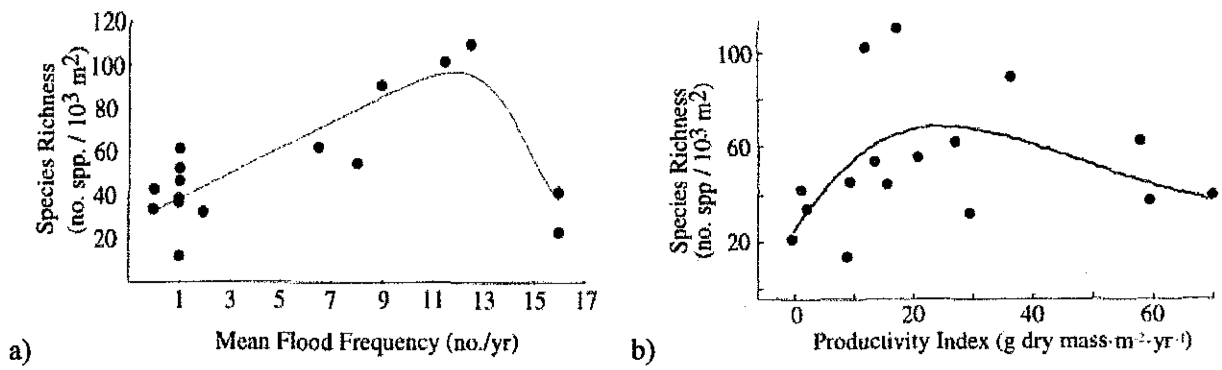

Figure 1: a) Relationship between wetland plant species richness and the mean flood frequency; b) Relationship between wetland plant species richness and the productivity index. Courtesy of Pollock et al. (1998)

Some studies have shown that wetland fertility plays a large role in the number of rare species found there. Moore et al. (1989) found that the total species richness for wetlands drastically increased for those with a lower standing crop, and then decreased for wetlands with a higher standing crop (Figure 2a). The researchers also found that the number of rare species was higher in wetlands with a low standing crop (Figure 2b). These results provide more evidence that the number of rare species increases with total species richness. The results also show that infertile wetlands are much more likely to have rare species than fertile wetlands. Moore et al. (1989) states that wetland conservation priorities are typically focused on fertile wetlands in order to maximize wildlife productivity. The scientists argue that infertile wetlands should have a higher conservation value than fertile wetlands due to their overwhelmingly higher species richness and presence of rare and endangered species. Moore et al. (1989) speculate that in order to preserve genetic diversity (which is one goal of nature conservation), we should conserve the habitats that have the highest species richness and highest numbers of rare species.

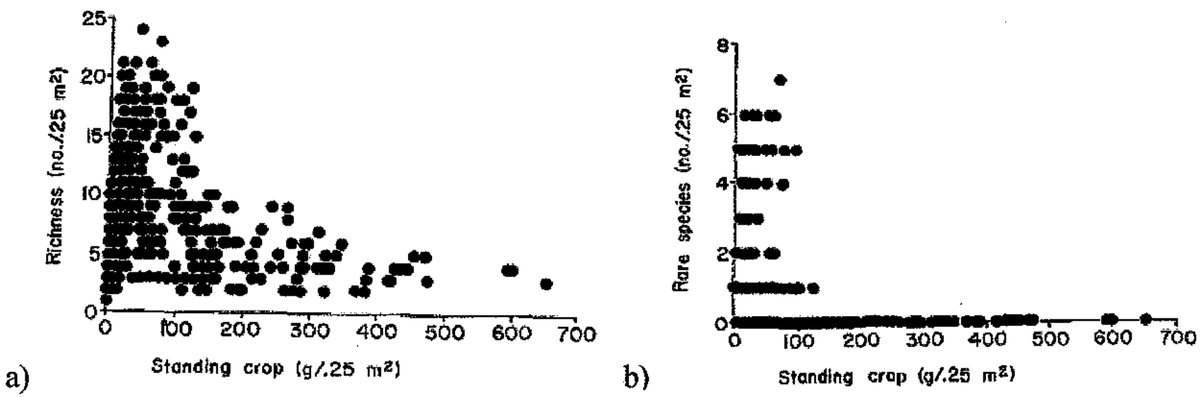

Figure 2: a) The correlation between species richness and the amount of standing crop in wetlands; b) the correlation between the number of rare species and the amount of standing crop in wetlands. Courtesy of Moore et al. (1989)

Mills and Schwartz (2005) studied the distributions of two classifications of rare species in North America: suffusively rare and endemic species. The researchers defined a suffusively rare species as one that has a geographically wide range, but has very small local populations and are locally rare throughout its geographic range. Mills and Schwartz (2005) grouped the suffusively rare and endemic species into 11 regions in North America (north of Mexico) for analysis (Figure 3). The researchers found that 22.6% of all native North American species are endemic, whereas only 2% are suffusively rare. Their data also show that 31.9% of the entire North American flora are designated as wetland specific, and suffusively rare species are more likely to be located in wetlands than endemic species (Table 1). The researchers' findings show a much higher percentage of suffusively rare than endemic species is located in wetlands. However, the importance of wetlands to endemic species is not to be underestimated, as the data indicate a number of endemic species much larger—more than three and a half times larger—than the number of suffusively rare species found in wetlands.

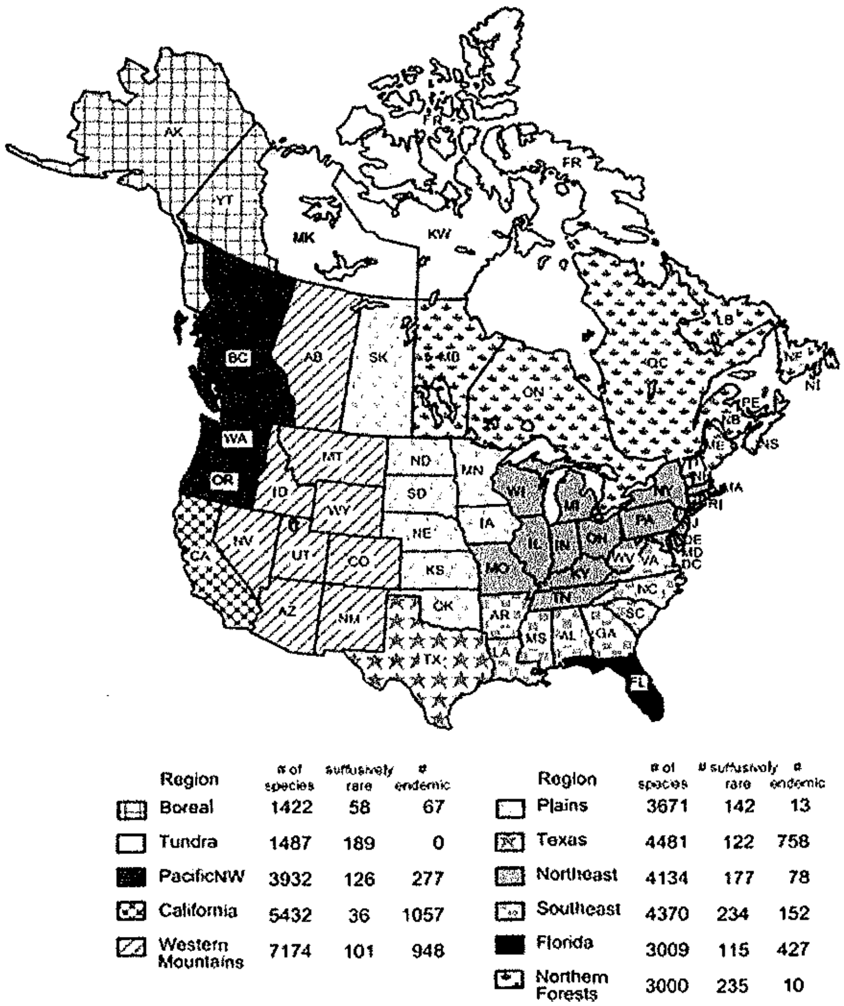

Figure 3: The number of native, suffusively rare, and endemic species for each of the 11 regions studied. Courtesy of Mills and Schwartz (2005).

Number of suffusively rare species	% of suffusively rare species	Number of endemic species	% of endemic species
137	46.7	489	17.5

Table 1: Numbers and percentages of suffusively rare and endemic species found in wetland habitats. Data courtesy of Mills and Schwartz (2005).

Mills and Schwartz (2005) found that more suffusively rare species are in the southeastern United States and in the far northeastern United States and Canada. The scientists speculate that the southeastern U.S. localization is probably due to the wide geographical range of similar habitat types within the southeastern coastal plain, which has not been interrupted by glacial events for long periods of time. The scientists argue that the northeastern localization of suffusively rare species is influenced by low variation in climate and types of biomes in this region. Mills and Schwartz (2005) attribute the high number of endemic species in Florida, Texas, and California to the highly varying habitat types within those states. The researchers state that because endemic species are restricted by their range size, they are at a high risk of extinction, due to the increased likelihood of experiencing a disastrous event. Endemic species are therefore the most commonly used species to define areas that should be protected by law. Mills and Schwartz (2005) argue that suffusively rare species are also very prone to extinction due to their small local population sizes, and should also serve as criteria for areas to be protected.

Riparian Wetlands

Rare species and their threats

Riparian wetlands are adjacent to bodies of water, be they lentic or lotic. This connectivity provides pathways for many species to migrate and colonize other habitats. For rare species, this is essential for local populations, as the connectivity allows these populations to migrate from one area to the next, increasing the numbers of the species. The connectivity to deeper bodies of water adds another class of vertebrates that could possibly contain rare or endangered species not found in isolated wetlands: fish. Fishes can be incredibly diverse, and since they are often exploited for food, can contain many rare or endangered species. Dudgeon (2000) discusses the decline of giant catfish (*Pangasianodon gigas*), an endemic species in Asia: commercial catches decreased from 69 fish in 1990 to 18 in 1995. In five years, this species almost disappeared due to overfishing, and is still in danger of going extinct. Dudgeon (2000) also mentions the over exploitation of the clown loach (*Botia macranthus*), which he argues is the most important wild-caught aquarium fish in the world. Clown loaches are only found in a few locations in Borneo and Sumatra, and little is known about its actual biology, making it a species of concern for Asia.

The deeper waters associated with riparian wetlands are also home to completely aquatic species that are not fish. Dudgeon (2000) discusses the three species of river dolphins found in Asia that are endangered: *Platanista gangetica*, *Platanista minor*, and *Lipotes vexillifer*. He mentions that these species—three of only five in the world—are endangered because of various human activities: population fragmentation due to the damming of the rivers, accidents with boat traffic, fisheries by-catch, directed hunting, and pollution. He also discusses other more aquatic species that are not typically associated with isolated wetlands, such as large herpetofauna. Eight of the global 23 species of crocodiles, gharials, and alligators are located in Asia, and all are endangered (Dudgeon, 2000).

There are also many rare and endangered herpetofauna in North America. In the wetlands of the southern Appalachian Mountains, populations of the bog turtle (*Clemmys muhlenbergii*) have declined due to habitat destruction and degradation. This is causing the wetlands they inhabit to become more and more isolated, and this species cannot find more suitable habitat, even though the turtle can migrate along streams, due to the increased distance between wetlands (Murdock, 1994). Murdock (1994) also discusses the importance of these wetlands to several rare and endangered amphibians: the mole salamander (*Ambystoma talpoideum*), the four-toed salamander (*Hemidactylium scutatum*), the mountain chorus frog (*Pseudacris brachyphona*), the seepage salamander (*Desmognathus aeneus*), the longtail salamander (*Eurycea longicauda*), and the mud salamander (*Pseudotriton mantanus*). Riparian wetlands serve as the primary breeding habitat for these amphibians, and the continued disappearance of this essential habitat will lead to the eventual extinction of these species (Murdock, 1994).

Franzreb (1987) discusses the importance of riparian wetlands to many bird species in California, both endangered and not. She mentions that these habitats are vital to many nesting and migrating birds, and that the densities and species richness of the avifauna associated with riparian wetlands demonstrate how important these habitats are for the birds. Franzreb (1987) also mentions that the riparian avifauna increase the diversity of avian species in adjacent habitats. She discusses the major threat to the riparian avifauna of California is continued habitat loss and fragmentation (Franzreb, 1987).

Many rare or endangered terrestrial mammals are associated with riparian wetlands (Murdock, 1994; Dudgeon, 2000). In the southern Appalachians, Murdock (1994) briefly mentions the presence of the star-nosed mole (*Condylura cristata parva*) and the southern bog lemming (*Synaptomys cooperi*). She also mentions that no extensive surveys have been conducted for the faunal communities associated with these wetlands (Murdock, 1994). In Asia, Dudgeon (2000) discusses the many terrestrial mammals associated with riparian wetlands. He mentions several nominally-terrestrial species that are considered "vulnerable" on the International Union for the Conservation of Nature (IUCN) red list: river otters (*Lutra*, *Lutragale*, and *Aonyx*), otter civets (*Cynogale* spp.), and fishing cats (*Prionailurus planiceps* and *P. viverrinus*). These species are vulnerable due to the destruction of their habitats. He also discusses various other flagship species that are associated with riparian wetlands. The proboscis monkey (*Nasalis larvatus*) is dependent upon riparian wetlands for the trees they use to sleep in. Malayan tapirs (*Tapirus indicus*) are incredibly adapted to life in riparian wetlands, and can migrate during different seasons, but rely on the wetlands for protection and food. The loss of riparian wetlands also affects many other endangered species: the orangutan (*Pongo pygmaeus* and *P. albelii*), the siamang (*Hylobates syndactylus*), the Sumatran rhinoceros (*Dicerorhinus sumatrensis*), the Sumatran tiger (*Panthera tigris sumatrae*), and the clouded leopard (*Pardofelis nebulosa*) (Dudgeon, 2000).

Murdock (1994) briefly states that the rare Baltimore butterfly (*Euphydryas phaeton*), one of the checkerspot butterflies, is found within the riparian wetlands of the southern Appalachians. Not much research has been conducted on the diversity of invertebrates within wetlands (Murdock, 1994; Dudgeon, 2000), so there isn't enough information to include many of them here.

Dudgeon (2000) also briefly discussed the large number of plant species in Asia. He mentions that the Malaysian Peninsula has over 800 plant species associated with swamp forests, just one type of riparian wetland. The high number of plant species indicates that there is probably a high number of rare, endangered, or even endemic species. Dudgeon (2000) specifically mentions Ramin (*Gonystylus bancanus*), which is an endemic species important commercially. He states that the composition of vegetation varies between different habitat types—especially those with differing amounts of species richness—and that blackwater streams that drain swamp forests have not been studied well in order to give a good estimate of rare species diversity (Dudgeon, 2000).

Moore et al. (1989) found a total of 14 rare species within riparian wetlands of eastern Canada: eight in Nova Scotia, five in Ontario, and one in Quebec (Table 2). Of these species, 11 were listed as nationally rare, one as nationally threatened, and two as nationally endangered. The species listed as threatened (*Sabatia kennedyana*) and endangered (*Coreopsis rosea* and *Hydrocotyle umbellata*) were all found in wetlands located in Nova Scotia. The researchers argue that the threat to these species is mainly due to the fact that the infertile wetlands in which they reside are not being conserved (Moore et al., 1989).

Location	*Species*[a]	*Status*
Nova Scotia		
Wilsons Lake	*Coreopsis rosea*	c
	Solidago galetorum	a
	Habenaria flava	a
	Hydrocotyle umbellata	c
	Panicum longifolium	a
	Rhexia virginica	a
	Sabatia kennedyana	b
	Xyris difformis Chapm.	a
Ontario		
Georgian Bay area	*Panicum rigidulum* Nees. var. *rigidulum*	a
	Rhexia virginica	a
	Xyris difformis Chapm.	a
Presqu'ile	*Aristida longespica*	a
	Scleria verticillata	a
Westmeath	—	—
Quebec		
Luskville	*Lindernia dubia*	a

Table 2: Status of rare species found in riparian wetlands of eastern Canada. a=nationally rare; b=nationally threatened; c=nationally endangered

Within the Appalachian region of the U.S., many rare plant species occur within riparian wetlands (Bartgis and Lang, 1984; Murdock, 1994). Bartgis and Lang (1984) studied the distributions of rare plant species in marl wetlands within West Virginia. A marl wetland is one with a thick deposit of calcium carbonate underneath a layer of organic matter. The researchers found 27 rare species within ten marl wetlands, one of which contained 25 rare species. Bartgis and Lang (1984) state that grazing by animals and human development are the main factors contributing to the destruction of these habitats, and therefore threatening the species. There is a railroad traversing one of the wetlands, which also used to support a mill; another is the main source of water for a printing products plant; one is being quickly overrun by invasive species; one was significantly drained for agriculture; another was used for mill races and aquaculture ponds (Bartgis and Lang, 1984).

Murdock (1994) found a total of 81 rare plant species associated with riparian wetlands within the Appalachians. She discusses several plant species which have been drastically reduced in number: the mountain sweet pitcher plant (*Sarracenia rubra* spp. *jonesii*), the green pitcher plant (*Sarracenia oreophila*), bunched arrowhead (*Sagittaria fasciculata*), swamp pink (*Helonias bullata*), bog asphodel (*Narthecium americanum*), and the white fringeless orchid (*Platanthera integrilabia*). *Sarracenia rubra* has only ten small populations left, and is considered one of the rarest species in its genus. It is known that 16 populations have been degraded due to various forms of human development, such as draining, highway and railroad construction, agriculture, and aesthetic purposes. *S. oreophila* has 35 remaining populations, half of which have less than 50 individuals. The main threats to this species are the continued degradation of its habitat for human development and the further isolation of the wetlands. Isolation drastically affects the genetic diversity of this species, due to the fact that the bees which pollinate it do not fly further than one mile from their hive, so many populations are considered genetically isolated. *Sagittaria fasciculata* exists in only 19 populations, and is threatened by the same issues as *Sarracenia rubra*. *Helonias bullata*, *Narthecium americanum*, and *Platanthera integrilabia* are all affected by the aforementioned issues (Murdock, 1994).

Mountain wetlands of the western U.S. also have rare species, particularly lichens (McCune et al., 2002). McCune et al. (2002) found 27 rare species of lichen within riparian wetlands in Oregon. The researchers found that rare species were 75% more likely to occur near fish-bearing streams smaller than fifth-order than in the uplands, 57% more likely to occur in larger than fifth-order streams than in the uplands, and 24% more likely to occur along intermittent and non-fishing bearing streams than in the uplands. These species are generally threatened by habitat destruction, typically logging and urbanization (McCune et al., 2002).

Riparian wetlands are not only found in areas characterized by water. Some are actually found in arid landscapes, and still contain high numbers of rare plant species (Zimmerman et al., 1999; Stohlgren et al., 2005). Stohlgren et al. (2005) surveyed the plant species found in riparian wetlands within the Grand Staircase-Escalante National Monument in Utah, and found that most of the plants in the monument were rare, 37 of them were endemic. The researchers found that both native and nonnative species richness were higher in mesic soils, whereas endemic species richness was higher in xeric soils. Stohlgren et al. (2005) and Zimmerman et al. (1999) argue that the biggest threats to the many rare species found in these riparian wetlands are those of invasive species and loss of habitat.

The main threat to these rare species and their habitats is habitat destruction (Bartgis and Lang, 1984; Franzreb, 1987; Moore et al., 1989; Zimmerman et al., 1999; McCune et al., 2002; Murdock, 1994; Lovett Doust and Lovett Doust, 1995; Dudgeon, 2000; Stohlgren et al., 2005). This degradation is associated with multiple factors, but mainly ones that are due to human activities. Murdock (1994) and Lovett Doust and Lovett Doust (1995) explain some of these activities in depth. The researchers discuss how channelization of streams adjacent to the wetlands can lower the water table, which dries out the wetlands and allows for a quick succession of shrubs. Murdock (1994) also mentions that the vast majority of riparian wetlands (in the Appalachians) are near agricultural fields, so herbicide drift and fertilizer runoff can be a major threat to many rare species (Murdock, 1994; Lovett Doust and Lovett Doust, 1995). Herbicide drift can decimate many rare plants, whose populations are small to begin with, and have drastic effects on the species. Fertilizer runoff can play a major role in drying out the sphagnum moss of these wetlands, which is detrimental to many rare species, both plants and animals (Murdock, 1994; Lovett Doust and Lovett Doust, 1995). Murdock (1994) discusses that sphagnum moss is the keystone species to these riparian wetlands, as it conserves the amount of water in the wetlands during times of drought. She says that many rare species live in the sphagnum and use for breeding: *Sarracenia rubra*, *S. oreophila*, *Clemmys muhlenbergii*, and *Hemidactylium scutatum* (Murdock, 1994). This shows that not just the wetland itself needs to be conserved, but the surrounding areas as well. The upland is just as important to wetlands as the wetlands themselves.

Conservation

As mentioned above, Moore et al. (1989) state that the main goal for conserving nature is to preserve genetic diversity, and that the best way to do so is to conserve the systems that have the highest species richness and numbers of rare species. This follows the approach of conserving "hotspots" that Myers et al. (2000) suggests. These researchers agree that conserving the areas with the largest amount of at risk species is the quickest, easiest, and cheapest way to conserve biodiversity (Moore et al., 1989; Myers et al., 2000). Dudgeon (2000) relates that biodiversity is an important aspect to the quality of the habitats, and that it should be a major concern in conservation, but rarely is considered as such in Asia. He argues that flagship species and keystone habitats should be identified and conserved to help maintain biodiversity within the riparian wetlands of Asia (Dudgeon, 2000). However, there are researchers who disagree with this hotspot approach, and have evidence to defend their case (Zimmerman et al., 1999; Stohlgren et al., 2005). Zimmerman et al. (1999) found rare species in areas of low biodiversity that would not be protected if the hotspot approach was taken. The researchers argue that high versus low diversity does not indicate ecological quality (Zimmerman et al., 1999). Stohlgren et al. (2005) found that the hotspots of endemism in their study area were less threatened by invasive species than native species. The researchers argue that since almost all rare species occur in fragmented populations, conservation efforts should be geared toward larger areas to provide enough area for maintaining effective pollination, establishment, and persistence (Stohlgren et al., 2005). Both researchers argue that the best way to conserve rare species is not via hotspots, as this approach rarely protects more than a few individuals or populations of at risk species (Zimmerman et al., 1999; Stohlgren et al., 2005).

There are many more approaches to conserving rare species. McCune et al. (2002) discusses two of these: the fine-filter and coarse-filter approaches. The fine-filter method uses the presence of particular rare species to determine whether a habitat is protected, but is subject to compromising with human development. The coarse-filter method depends on the importance of a particular site to various at risk species, and relies on the identification of key habitats for these species. The researchers argue that in order for the coarse-filter approach to succeed, more must be known about the habitat requirements for rare species that are in danger of becoming extirpated. McCune et al. (2002) state that in most cases, a combination of the two approaches is needed in order to successfully conserve many rare species. The researchers argue that this is because some species are easier to protect individually, and some are easier to protect by protecting their habitats (McCune et al., 2002).

Along with various approaches of conserving these rare species, many scientists provide steps that will help determine whether a specific habitat type should be conserved (Moore et al., 1989; Lovett Doust and Lovett Doust, 1999). Moore et al. (1989) provide three steps for the reevaluation of infertile wetlands as habitats that should be conserved for the continuance of several rare and endangered species: research, site selection and evaluation, and management. The researchers state that more research needs to be conducted on the functions of infertile wetlands and how these habitats respond to distress. The researchers then state that the wetland evaluation systems currently in place need to be revised to place a greater importance on higher species richness and the presence of rare and endangered species. Finally, Moore et al. (1989) argue that wetlands should be managed with varying techniques, depending on their differing functions, instead of the current management approach, which treats all wetlands as the same, and uses only a small number of techniques to manage them. Lovett Doust and Lovett Doust (1999) give four suggestions for conserving rare wetland species. The scientists first suggest that the conservation of wetlands in terms of quantity and quality is a priority. The researchers believe this is best achieved via federal legislation. Secondly, the scientists suggest that there may be differences between central and peripheral populations, which can cause conflict between differing views on how to conserve these habitats. The researchers then state that in order to conserve rare species, genetic and demographic approaches must be taken. Lovett Doust and Lovett Doust (1999) finally suggest the use of rare species as sites of habitat recovery in their presence or impairment in their absence.

There are many threats to the conservation of riparian wetlands, most of which are non-scientific. These include the ignorance of many people, human population size, failing economies, and legislative efficiency (Murdock, 1994; Dudgeon, 2000). Dudgeon (2000) argues that the failing economy in Asia has set priorities on pulling the continent out of its economic slump, and the conservation of nature has been put on the backburner, or even completely ignored so that the government could use the natural resources to help the economy. This could be homologous with what the U.S. is currently experiencing. However, several conservational efforts have been made in the U.S. Murdock (1994) mentions how the U.S. Fish and Wildlife Service (USFWS), the Army Corps of Engineers, Charleston District, and the South Carolina Heritage Trust Program worked together to try and save a population of the endangered bunched arrowhead when it was buried under several thousand tons of dirt during a highway project in South Carolina. These groups attempted to remove the dirt and restore the original hydrology of the wetland, but the restoration failed. Murdock (1994) suggests that once a wetland is severely changed, it cannot be restored to its former state; however, wetlands that have not experienced such dramatic alterations can be restored.

Isolated Wetlands

Comer et al. (2005) found that 29% of wetland types in the U.S. are geographically isolated, and these geographically isolated wetlands represent 13% of all natural terrestrial ecosystems. The researchers also found that there is at least one type of isolated wetland in each state (Figure 4). The researchers found a total of 274 at risk species associated with isolated wetlands, and 35% of these species are endemic to isolated wetlands. 86 of these at risk species are either listed, or are candidates to be listed on the Endangered Species Act (ESA). These 86 species make up approximately 5% of all the species listed on the ESA, and 52% of these 86 species are endemic to isolated wetlands. Comer et al. (2005) also found that 43% of isolated wetlands have at least one species that is listed on the ESA.

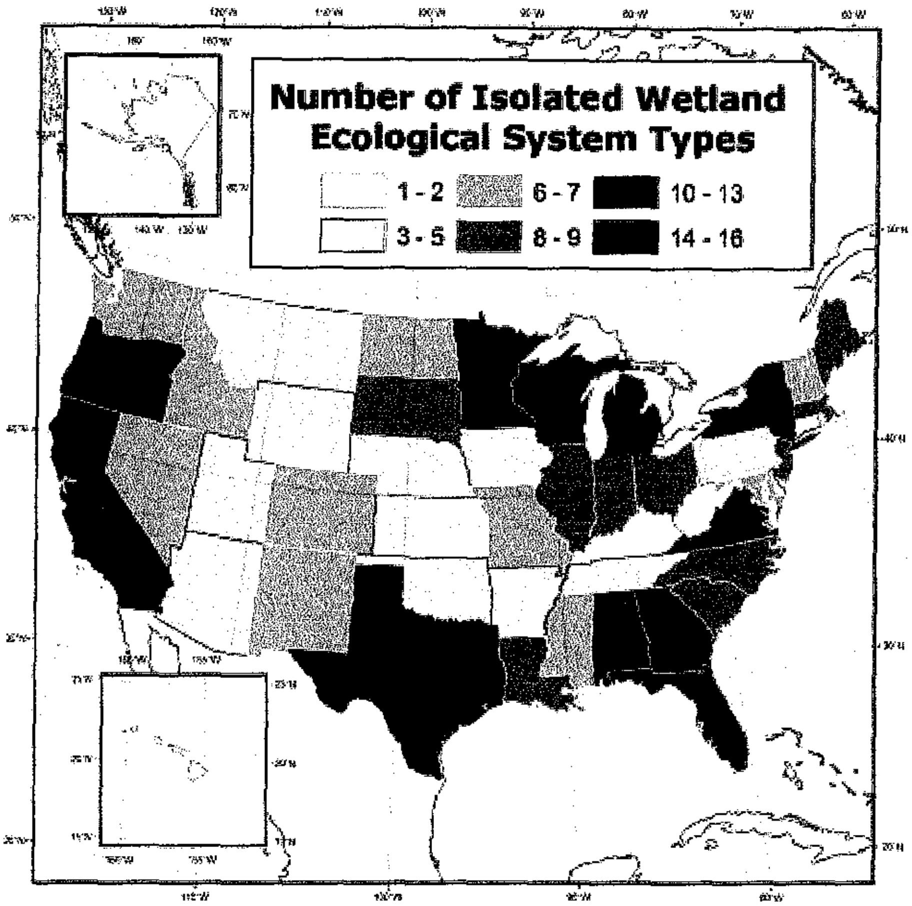

Figure 4: The number of isolated wetland types in each state. Courtesy of Comer et al. (2005)

Rare species and their threats

Although isolated wetlands are not connected via surface waters to other wetlands or streams and typically rely on precipitation for their water supply, there are some types that still contain fish species, and many are even rare (Tiner, 2003). Desert springs house several endangered species of pupfish, including: Owens pupfish (*Cyprinodon radiosus*), Devils Hole pupfish (*C. diabolis*), and Warm Springs pupfish (*C. nevadensis pectoralis*). Tiner (2003) states that the biggest threats to these endangered fish are the pumping of ground water for agriculture and urbanization and energy development. He mentions that the lowering of water levels in these springs due to the withdrawal of water for agriculture may expose spawning areas that these fish use (Tiner, 2003).

One of the groups of rare species associated with isolated wetlands that is commonly studied is herpetofauna. There are many herpetofauna that use these isolated wetlands as important breeding grounds, mainly due to the lack of fish predators (Semlitsch and Bodie, 1998; Sharitz, 2003; Gibbons, 2003; Zedler, 2003; Tiner, 2003; Attum et al., 2008). Coastal plain ponds are important habitats for the spotted turtle (*Clemmys guttata*), which are threatened by the development of these wetlands due to their close proximity to the coast (Tiner, 2003). Attum et al. (2008) found that two rare reptiles, the copper-bellied water snake (*Nerodia erythrogaster neglecta*) and Blanding's turtle (*Emydoidea blandingii*) were found in isolated wetlands that were typically closer to other wetlands than completely isolated. The researchers mentioned that these species are vagile, and can travel long distances to find suitable habitat. Attum et al. (2008) suggest that the upland corridors of these wetlands are vital for the migration of these rare species, and if the corridors are disturbed, or if the wetlands become more and more isolated, these species will be at risk of extirpation. Gibbons (2003), Sharitz (2003), and Tiner (2003) also argue the importance of the upland to endangered salamanders. Gibbons (2003) and Sharitz (2003) state that the flatwoods salamander (*Ambystoma cingulatum*) spends the majority of its life cycle in the uplands, beyond the edges of the defined wetland. Both researchers argue that many herpetofauna need the undisturbed upland region for terrestrial corridors between wetlands in order to migrate from one location to another, as well as for various aspects of their life cycles, including nesting, foraging, and hibernation (Gibbons, 2003; Tiner, 2003; Sharitz, 2003). Coastal plain ponds are the homes of many amphibious species of concern, such as the Pine Barrens treefrog (*Hyla andersonii*), Cope's gray treefrog (*H. chrysoscelis*), the eastern spadefoot toad

(*Scaphiopus holbrookii holbrookii*), and the spotted salamander (*Ambystoma maculatum*). These species are threatened by their proximity to the coast, which puts their habitats in danger of water drainage, pollution, and waste dumping from coastal development (Tiner, 2003). *Hyla andersonii* are also found in pocosins, which are being lost due to timber companies (Tiner, 2003).

The literature does not offer much information on rare and endangered species of birds or mammals, so they will not be discussed. Tiner (2003) discusses the rare Hessel's hairstreak butterfly (*Callophrys hesseli*), which is found in pocosins, and is threatened by the development of pocosins for agriculture and timber production.

Comer et al. (2005) found that 54% of the animal species found in isolated wetlands appear to be obligate species. The researchers found that the range of at risk animal species associated with isolated wetlands varied between 0-4% in each individual state (Figure 5), and mentions that these numbers could change as more information is found on the invertebrate species associated with isolated wetlands.

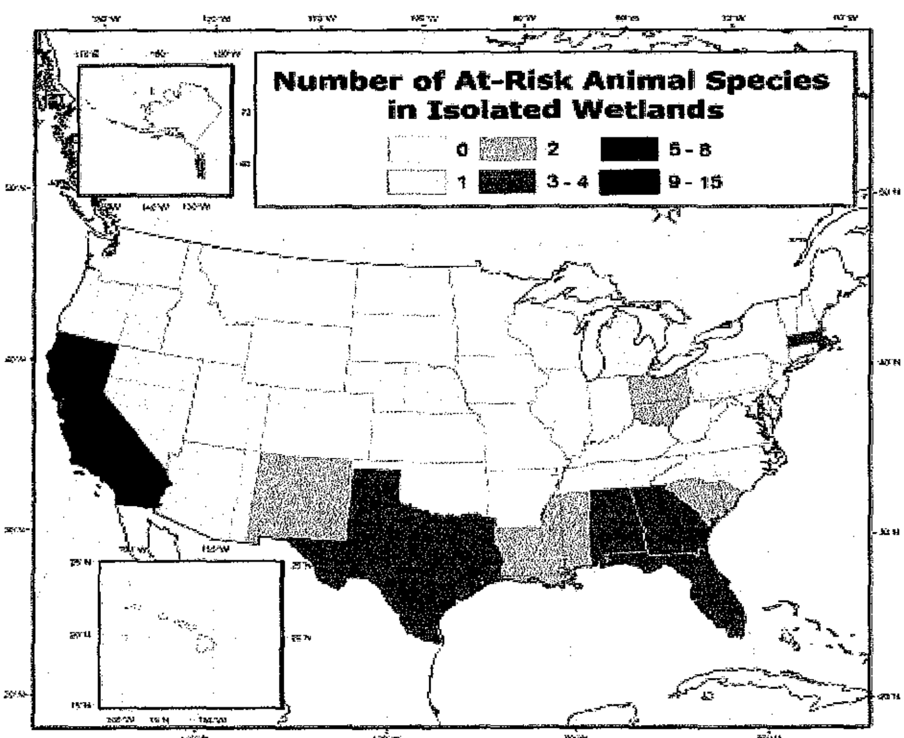

Figure 5: The number of at risk animal species associated with isolated wetlands in each state. Courtesy of Comer et al. (2005)

Comer et al. (2005) also found a total of 279 at risk vegetation associations are typical of isolated wetlands. These 279 associations make up 9% of all vegetation associations in the U.S. National Vegetation Classification. The researchers determined that 67% of these 279 associations are only found in isolated wetlands. Comer et al. (2005) determined that every state in the U.S. has at least one at risk species of plant (Figure 6), and that, on average, 6% of all at risk plant species within a particular state are associated with isolated wetlands. The researchers found a total of 241 at risk plant species that are associated with isolated wetlands, 73 of which are listed on the ESA. Fifty-one percent of these listed species are obligate to isolated wetlands (Comer et al., 2005).

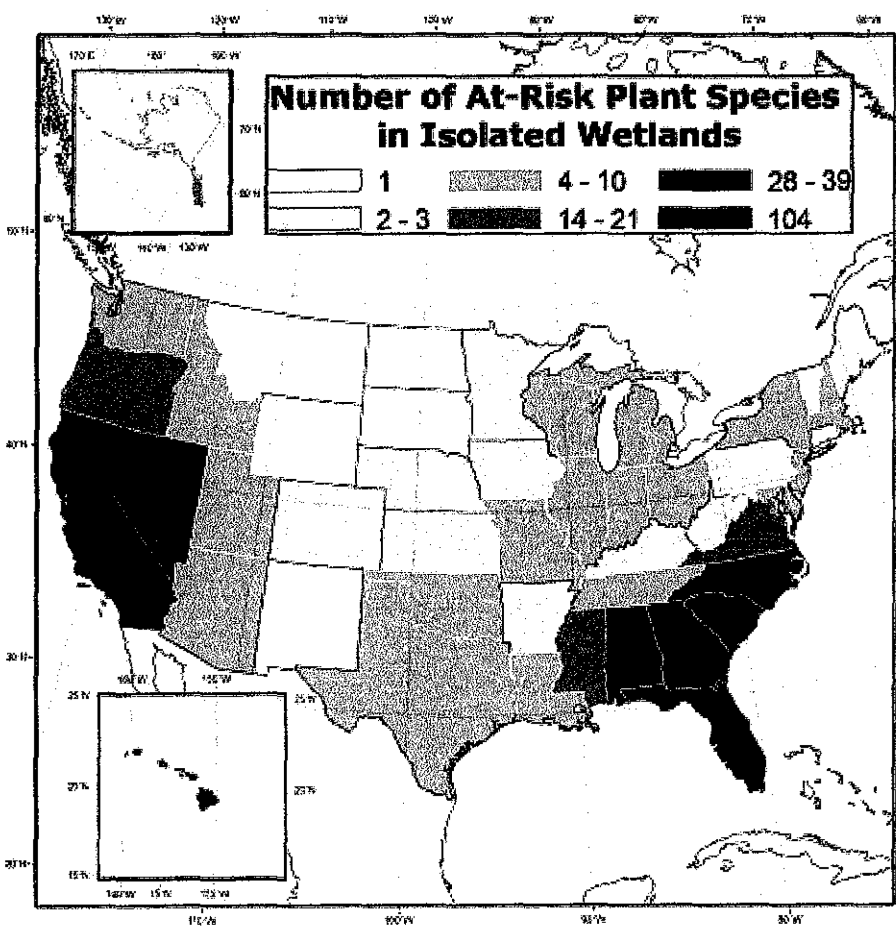

Figure 6: The number of at risk plant species associated with isolated wetlands in each state. Courtesy of Comer et al. (2005)

Many rare plant species are associated with isolated wetlands, as shown in Figure 6 (Semlitsch and Bodie, 1998; Edwards and Weakley, 2001; Zedler, 2003; Tiner, 2003; Comer et al., 2005). Vernal pools in the northwestern U.S. contain the second highest number of endangered plant species (Comer et al., 2005), including the water howellia (*Howellia aquatilis*), San Diego mesa mint (*Pogogyne abramsii*), Otay mesa mint (*P. nudiuscula*), Solano grass (*Tuctoria mucronata*), San Diego button-celery (*Eryngium aristulatum*), and Burke's goldfields (*Lasthenia burkei*) (Zedler, 2003; Tiner, 2003). The rare species associated with vernal pools are mainly threatened by grazing by cattle. Desert springs also contain several rare and endangered plants, such as the spring-loving centaury (*Centaurium namophilum*) and the Ash Meadows gumplant (*Grindelia fraxinopratensis*), which are in danger of losing their habitat from the pumping of ground water out of these springs. Rare species also inhabit the coastal plain ponds of the eastern U.S., including quill-leaf arrowhead (*Sagittaria teres*), pine barren bellwort (*Uvularia erula* var. *nitida*), rose tickseed (*Coreopsis rosea*), and creeping St. John's-wort (*Hypericum adpressum*). These species are threatened by coastal development of their habitats (Tiner, 2003). Laliberte et al. (2007) found four obligate plant species to the Carolina coastal plain in Carolina bays, and one endemic plant species: *Aristida stricta, Carphephorus bellidifolius, Vaccinium crassifolium, Zenobia pulverulenta* (obligates), and *Dionaea muscipula* (endemic).

Many rare and endangered species rely on sinkhole wetlands throughout the U.S. These species include the following: the northeastern bulrush (*Scirpus ancistrochaetus*), the Virginia sneezeweed (*Helenium virginicum*), smooth-barked St. John's-wort (*Hypericum lissophloeus*), karst pond xyris (*Xyris longisepala*), cypress-knee sedge (*Carex decomposita*), sharp-scaled manna-grass (*Glyceria acutiflora*), roundleaf water hyssop (*Bacopa rotundifolia*), Hall's bulrush

(*Schoenoplectus hallii*), and the dwarf burrhead (*Echinodorus tenellus*). These many species are threatened by water pollution from agricultural runoff, drainage, and timber harvest. Dune wetlands are inhabited by several rare and endangered species that are threatened by development of the wetlands due to their close proximity to the ocean. These species consist of Houghton's goldenrod (*Solidago houghtonii*), Lapland buttercup (*Ranunculus lapponicus*), the round-leaved orchid (*Amerorchis rotundifolia*), butterwort (*Pinguicula vulgaris*), horned bladderwort (*Utricularia cornuta*), and seaside arrow-grass (*Triglochin maritimum*) (Tiner, 2003).

As was the case with riparian wetlands, the many rare and endangered species associated with isolated wetlands are mainly threatened by habitat loss. The various causes of habitat loss include increased isolation and habitat fragmentation, excess nutrient runoff from agriculture, drainage for development, grazing by livestock, and timber harvest (Tiner, 2003; Zedler, 2003; Attum et al., 2008).

Conservation

Isolated wetlands, just like riparian wetlands, are areas with high biodiversity and high numbers of rare and endangered species. The main threat to rare and endangered species found in these wetlands is continued habitat destruction, isolation, and fragmentation (Semlitsch and Bodie, 1998; Edwards and Weakley, 2001; Gibbons, 2003; Sharitz, 2003; Leibowitz, 2003; Leibowitz and Nadeau, 2003; Tiner, 2003; Zedler, 2003; Comer et al., 2005; Laliberte et al., 2007; Attum et al., 2008). These habitats could, therefore, also be considered "hotspots" due the aforementioned reasons, and the hotspot approach could be used in conservation efforts (Myers et al., 2000). Many authors, however, point out several problems with this approach (Leibowitz, 2003; Leibowitz and Nadeau, 2003; Sharitz, 2003; Gibbons, 2003; Zedler, 2003; Soons, 2006). These authors point out that using the hotspot approach would only protect individual wetlands, when the broad regions of these ephemeral habitats need protection. These authors argue that protecting only the delineated wetland will not help any rare species, but would actually hinder their capabilities of surviving. Tewksbury et al. (2002) and Gibbons (2003) in particular claim that the surrounding upland habitat of isolated wetlands is just as important as the aquatic habitat. The researchers state that many amphibian species rely on these upland habitats for foraging, nesting, and hibernation—basically, every other aspect of their life cycles other than breeding (Tewksbury et al., 2002; Gibbons, 2003). Gibbons (2003) believes that the definition of a "wetland" does not only include the part of the land that has hydric soils, but the surrounding "dry" land as well, as it is very important to many species, as well as the habitat itself.

The surrounding upland is also important for many plant species (Tewksbury et al., 2002), especially those that disperse their seeds via wind (Soons, 2006). Soons (2006) states that most wetland plants rely on seed dispersal via water because water is more likely to deposit seeds in a suitable habitat for them to germinate and grow. She claims that most plants found in isolated wetlands—including rare and endangered species—rely on wind dispersal. Because of this, the upland habitat becomes the depositional area for these seeds, and should be protected so these species may continue to prosper (Soons, 2006).

The continued isolation and fragmentation of isolated wetlands makes it much more difficult for many rare and endangered species to migrate between wetlands. This can have drastic consequences on the populations of these species, including genetic isolation and an increased chance of extirpation (Lovett Doust and Lovett Doust, 1995; Gibbons, 2003; Zedler, 2003; Sharitz, 2003; Leibowitz, 2003; Leibowitz and Nadeau, 2003; Soons, 2006). This demonstrates the need for undamaged terrestrial corridors (Tewksbury et al., 2002; Gibbons, 2003; Zedler, 2003; Soons, 2006). Gibbons (2003) uses this to further his argument for the importance of upland habitats to many wetland species. Soons (2006) also mentions that the further isolation of wetlands will make it much more difficult for many of the wind-dispersing plants to scatter their seeds far enough for suitable habitat. Zedler (2003) argues that vernal pools rely on a balance of isolation and exchange between other pools. He claims that this balance is imperative for understanding the ecology and evolution of vernal pools. He also claims that local exchange and metapopulation dynamics might be essential parts to the systems of some isolated wetlands.

The presence of so many rare and endangered species in isolated wetlands should be taken into consideration for conservation as well. Lovett Doust and Lovett Doust (1995) mention that wetlands are seldom managed due to the presence of these rare species alone. However, many of these species are obligate or endemic species to these specific habitats, and if their habitat is not protected based on their presence alone, these species will go extinct. The continued degradation and loss of wetlands is sure to continue with human population growth, and the species in the most danger of going extinct because of this are the rare and endangered ones (Edwards and Weakley, 2001).

The 2001 SWANCC decision directly affects the protection of isolated wetlands. Because isolated wetlands are not protected under the CWA, these habitats rely on the endangered species that inhabit them for federal protection under the ESA. However, many of these isolated wetlands do not contain listed species, only rare ones. Therefore, other approaches are needed for the conservation of these species and their habitats (Zedler, 2003; Leibowitz, 2003; Leibowitz and Nadeau, 2003; Sharitz, 2003; Gibbons, 2003). Sharitz (2003) argues the merit of the biodiversity approach. She states that isolated wetlands—Carolina bays in particular—are essential for conserving regional diversity of habitats and species (Sharitz, 2003). Leibowitz (2003) and Leibowitz and Nadeau (2003) reason that since protecting species is not working for conserving these habitats, scientists should focus more on the functions of isolated wetlands for the surrounding habitat. The researchers argue that isolated wetlands have valuable functions for the land itself, and if these wetlands are lost, there could be detrimental effects on the surrounding areas (Leibowitz, 2003; Leibowitz and Nadeau, 2003). Zedler (2003) and Gibbons (2003) argue that if the federal government will not revise the CWA to include the protection of isolated wetlands, then individual states should put regulations into place in order to protect them. The researchers also discuss the importance of educating the public on the value of isolated wetlands. Zedler (2003) and Gibbons (2003) state that if the public sees and understands the functional and aesthetic values of these habitats, they can petition their states—or possibly even the federal government—to protect and conserve isolated wetlands.

Unlike riparian wetlands, restoration of isolated wetlands is actually possible. Many of these restored wetlands are even stable habitats for many species, and are often just as stable as naturally occurring habitats (Sharitz, 2003; Menzel et al., 2005; Ya-Fu et al., 2006). Ya-Fu et al. (2006) found that a restored isolated wetland in Taiwan still served as an important breeding ground for many amphibian species. Menzel et al. (2005) found that bat activity was highest in restored Carolina bays than naturally occurring Carolina bays that had yet to be restored. These studies indicate that the restoration of isolated wetlands is possible, and is generally successful. This could have beneficial impacts on many of the rare and endangered species that inhabit isolated wetlands.

Personal Views

When comparing the importance of isolated wetlands as habitats for rare and endangered species to riparian wetlands, extensive data is needed to obtain accurate results. Based on the limited data I could find, it is impossible to obtain the accuracy needed to argue that one is definitely more important than the other. However, Comer et al. (2005) and Mills and Schwartz (2005) provide enough data to give rough estimates for rare plant species. Comer et al. (2005) found a total of 241 at-risk plant species to be associated with isolated wetlands, while Mills and Schwartz (2005) found a total of 626 rare plant species to be associated with general wetlands. Since the estimates from Mills and Schwartz (2005) encompass both riparian and isolated wetlands, it is intuitive to subtract the isolated data from the general data in order to estimate the riparian data, which yields 412 rare plant species. It should be noted that I am considering the "at-risk" species are synonymous with rare species. These estimates yield 34% of rare plant species are associated with isolated wetlands, and 66% are associated with riparian wetlands. My estimates indicate that more rare plant species are found in riparian wetlands than isolated wetlands. However, this does not indicate importance. Comer et al. (2005) found that only 29% of wetland types are considered isolated wetlands. In this 29%, 34% of the rare wetland plant species occur (Figure 7a). Furthermore, Comer et al. (2005) found that isolated wetlands constitute just 13% of all naturally occurring terrestrial ecosystems, which increases the 34% value (Figure 7b). If so many rare wetland plant species are located in such a small amount of area, what does that say of the importance of that particular habitat to rare species?

There is one caveat with my estimates though: the data from Mills and Schwartz (2005) includes rare wetland species found in North America north of Mexico, whereas the data from Comer et al. (2005) only includes rare wetland species found in the U.S. This indicates that the estimated percentages should actually be higher for isolated wetlands, and lower for riparian wetlands. So in reality, 29% of all wetland types—and 13% of all terrestrial ecosystems—contain greater than 34% of rare wetland plant species in the U.S. These estimates indicate that isolated wetlands are incredibly important habitats for rare wetland plant species.

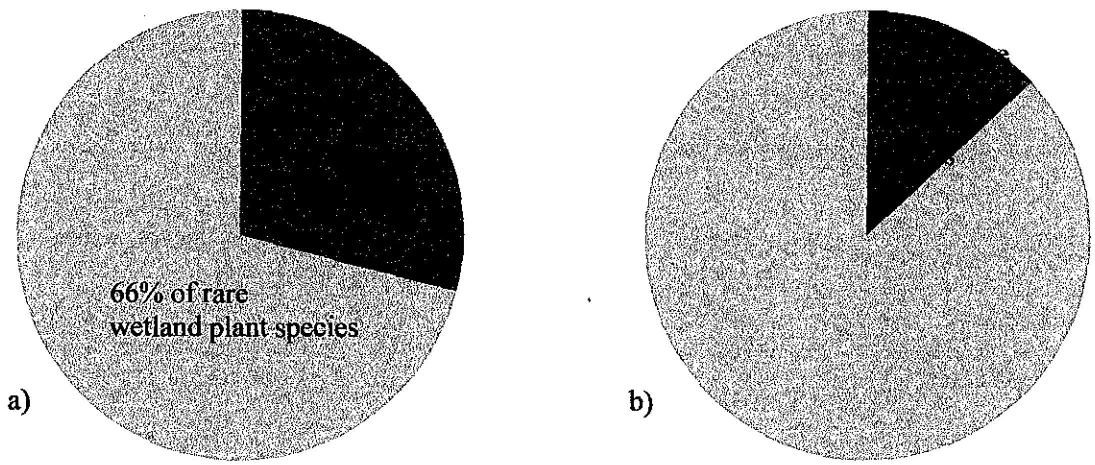

Figure 7: a) The visual representation of the estimates of the rare wetland plant species in the percentages of wetland types. b) The visual representation of the amount of rare wetland plant species within 13% of all terrestrial ecosystems.

While I consider isolated wetlands to be significant habitats to many rare and endangered species, and that these wetlands should be conserved as much as possible, I do not underestimate the importance of riparian wetlands to these species. Riparian wetlands still have more rare and endangered species inhabiting them than isolated wetlands, and that shows that riparian wetlands are just as important to rare and endangered species. I believe that if a habitat type has as many rare and endangered species as do both riparian and isolated wetlands, then both are significant habitats to these species, and both should be conserved. I also believe it makes sense that riparian wetlands would have more rare and endangered species than isolated wetlands. Riparian wetlands are interconnected, providing pathways for many species (particularly animals) to migrate between habitats, and the high amounts of water provide more hydration and food sources. The (usually) permanent waters allow for fish to inhabit these wetlands, which provides yet another category for rare and endangered species. Soils of riparian wetlands are likely more fertile than in isolated wetlands, so it is easier for many plant species to grow there, including rare and endangered ones.

I think the main difference in the rare and endangered species between riparian and isolated wetlands is that those of isolated wetlands have evolved to be more specialized to those conditions. As stated above, riparian wetland soils are more likely to be fertile than isolated wetland soils, so there are several species of plants that are not likely to inhabit riparian wetlands—and vice versa—due to their specific habitat requirements. Many rare and endangered plant species require the fertile soils in order to grow, but there are also many who require the less fertile soils so they can grow and not be overgrown and replaced by the plants who prefer fertile soil. Carnivorous plants are found in less fertile soils because they have evolved to be able to prey upon insects in order to acquire their vital nutrients. These specialized plants are not found in more fertile soils because the plants that are specialized for those soils overgrow the carnivorous plants. Many rare amphibians are more likely to be found in isolated wetlands than riparian wetlands as well due to the lack of fish, which prey upon eggs and juveniles. It is probably more likely, however, to find rare and endangered mammals in riparian wetlands, because there is a more reliable source of water and food in these wetlands. There are not enough data on the rare and endangered vertebrates and invertebrates from either wetland type, and more research should occur on these topics to enlighten science and the public on the importance of these ecosystems to rare and endangered species.

I believe that rare and endangered species located in isolated wetlands are in more danger of becoming extirpated or extinct than those in riparian wetlands. Riparian wetlands are federally protected, whereas isolated wetlands are not, and isolated wetlands are more threatened from development and agriculture than riparian wetlands. It also seems like isolated wetlands have only become a popular research topic in the last decade or so, and that not much is really known about them. I realize that riparian and isolated wetlands can be extremely different habitats, and therefore difficult to sample. However, if we were to accurately sample each wetland type for their rare and endangered species, we could more accurately determine if one wetland type is more important than the other. We need to know what these wetlands do for us, and what we are doing to them. I believe that more research should be conducted on these topics, not just for the wetlands, but for the rare and endangered species as well. This is imperative because the public just does not understand why these habitats and their species are important.

Conclusions

Wetlands are highly valuable ecosystems throughout the world, and have many functions. One of the most well-known of these functions is that they are important habitats for many rare and endangered species. In North America, the numbers of these critical habitats has been drastically reduced, and are still under threat from human development today. The United States has even decided that some wetlands—geographically isolated wetlands—are not worth protecting, and have taken away federal protection via the CWA. This is causing more and more of these habitats to disappear, and many rare and endangered species along with them (Bartgis and Lang, 1984; Franzreb, 1987; Moore et al., 1989; Murdock, 1994; Lovett Doust and Lovett Doust, 1995; Semlitsch and Bodie, 1998; Pollock et al., 1998; Bornette et al., 1998; Zimmerman et al., 1999; Dudgeon, 2000; McCune et al., 2002; Tewksbury et al., 2002; Tiner, 2003; Zedler, 2003; Leibowitz, 2003; Leibowitz and Nadeau, 2003; Sharitz, 2003; Gibbons, 2003; Comer et al., 2005; Menzel et al., 2005; Laliberte et al., 2007; Liner et al., 2008; Stroh et al., 2008; Graeter et al., 2008; Attum et al., 2008).

At least 34% of rare wetland plant species inhabit isolated wetlands in the U.S., and these wetlands make up only 29% of all wetland types. This indicates that these wetlands are incredibly important for many rare plants. Not enough research has been conducted on vertebrates and invertebrates to make any estimates on the numbers of each group found in each type of wetland.

The biggest threat to the rare and endangered species in both wetland types is habitat destruction. This creates less and less suitable habitat for these species, and the habitat fragmentation that is associated with habitat destruction causes many of these species to become more and more isolated from other suitable habitats as well as other populations. This increases the likelihood that the populations of the species will become extirpated, or the entire species will become extinct. Both habitat types should be protected and conserved for the continuation of these rare and endangered species, as well as for the various beneficial functions these wetlands provide humans (Bartgis and Lang, 1984; Franzreb, 1987; Moore et al., 1989; Murdock, 1994; Lovett Doust and Lovett Doust, 1995; Semlitsch and Bodie, 1998; Pollock et al., 1998; Bornette et al., 1998; Zimmerman et al., 1999; Dudgeon, 2000; McCune et al., 2002; Tewksbury et al., 2002; Tiner, 2003; Zedler, 2003; Leibowitz, 2003; Leibowitz and Nadeau, 2003; Sharitz, 2003; Gibbons, 2003; Comer et al., 2005; Menzel et al., 2005; Laliberte et al., 2007; Liner et al., 2008; Stroh et al., 2008; Graeter et al., 2008; Attum et al., 2008).

In the future, I think that scientists should conduct more studies on the rare and endangered species found in both wetland types, especially invertebrates. This information will help to more definitively determine whether one wetland type is a more important habitat for these species. I also believe that more research should be conducted on the other various functions of isolated wetlands, in order to better understand how these ecosystems benefit their surrounding environment and could possibly benefit us. The information gained from such studies could lead to federal protection of these habitats.

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