Volume 1: Spring 2014: pp. 1-9.

REVIEW

Wetlands and mining: A case study of "NorthMet"

Carsten Knutsen

Abstract

Estimates have global wetland area at roughly nine percent of Earth's total land area. Already wetland's global area has been halved by human activity. As wetlands provide environmental services such as water filtration and carbon sequestration they are of importance to the environment. Wetlands are very sensitive to disturbances; this creates a problem for conservation in the face of development. In Northeastern Minnesota mining in particular threatens wetlands. NorthMet, a copper-nickel mine proposed by Polymet and under review by the state of Minnesota, provides a model for examining wetland management, including potential damages, assessment of the damages, and mitigation of damage caused by mining to surrounding wetlands. Although wetland assessment is improving, because wetlands vary greatly, health indicators must be determined area-by-area. Mitigation techniques are improving, but cannot completely restore the function of a natural wetland. Future research is needed on wetland management to ultimately achieve responsible land use.

*Biology Department, University of Minnesota Duluth

Introduction

Wetlands, areas where vegetation and animals have adapted to soil saturated with water, currently make up roughly nine percent of Earth's land cover. The extent of wetlands has been halved due to actions by humanity (Zedler and Kercher 2005). Seen as waterlogged and isolated, many people think these swamps, bogs and meadows are of little value. Because of this, wetlands are targeted as areas of future development further accelerating loss of wetlands. However, wetlands provide many benefits to the environment and society.

Water filtration
Wetlands trap chemicals, nutrients, and various sediments preventing them to enter nearby bodies of water and groundwater. This keeps waters clean for humans, and other life.

In temperate areas, wetlands provide **water filtration**, **carbon sequestration**; and sustain high biodiversity (Brinson and Malveraz 2002). Their natural control of water flow provides protection from floods. Wetlands store nutrients and waste from both natural and **anthropogenic** sources (Barbier 1994). Besides environmental benefits, wetlands provide economic benefits to surrounding areas through tourism and recreation, like hunting and fishing. Wetland areas are not only important to our environment but directly benefit our society.

Because of their sensitivity and reliance on water, wetlands are susceptible to danger from land use. As wetlands lay near bodies of water, their form is determined by their watershed (Hopkinson and Vallino 1995). Changes in land use cover can greatly disturb these watersheds. First, fluctuations in volume of water can change the form and function of a wetland (Zedler and Kercher 2005). Also, changes in water quality have a negative impact on the biodiversity and local species that live in impacted wetlands. Finally, these disturbances in habitat give

Corresponding Author:
Carsten Knutsen
knuts635@d.umn.edu

Carbon sequestration
Wetlands contain many fast growing plants that capture carbon from the atmosphere in order to grow. Carbon taken up by the oxygen deficient soil of wetlands is trapped for thousands of years.

Anthropogenic
Originating from human activity.

Polymet
A publicly traded mining company focused on developing the NorthMet project.

conditions for invasive species to move in and thrive (Zedler and Kercher 2005). Weighing the loss of wetland services and the economic benefits of development is key to the fundamental question of responsible land use.

Different developments can affect wetlands in different ways. In Northeastern Minnesota mining is a primary concern. **Polymet's** project "NorthMet" provides an opportunity to examine the process of wetland management in conjunction with land use, specifically mining. This proposed project would affect wetlands in the Embarass and Partridge River watersheds. Both of these rivers flow into the St. Louis River, which has had problems with heavy metal pollution (MPCA 2014). By viewing potential damage to wetlands, how the damages are monitored, and the potential of mitigation it is possible to gain an environmental perspective on wetland management in conjunction with land use.

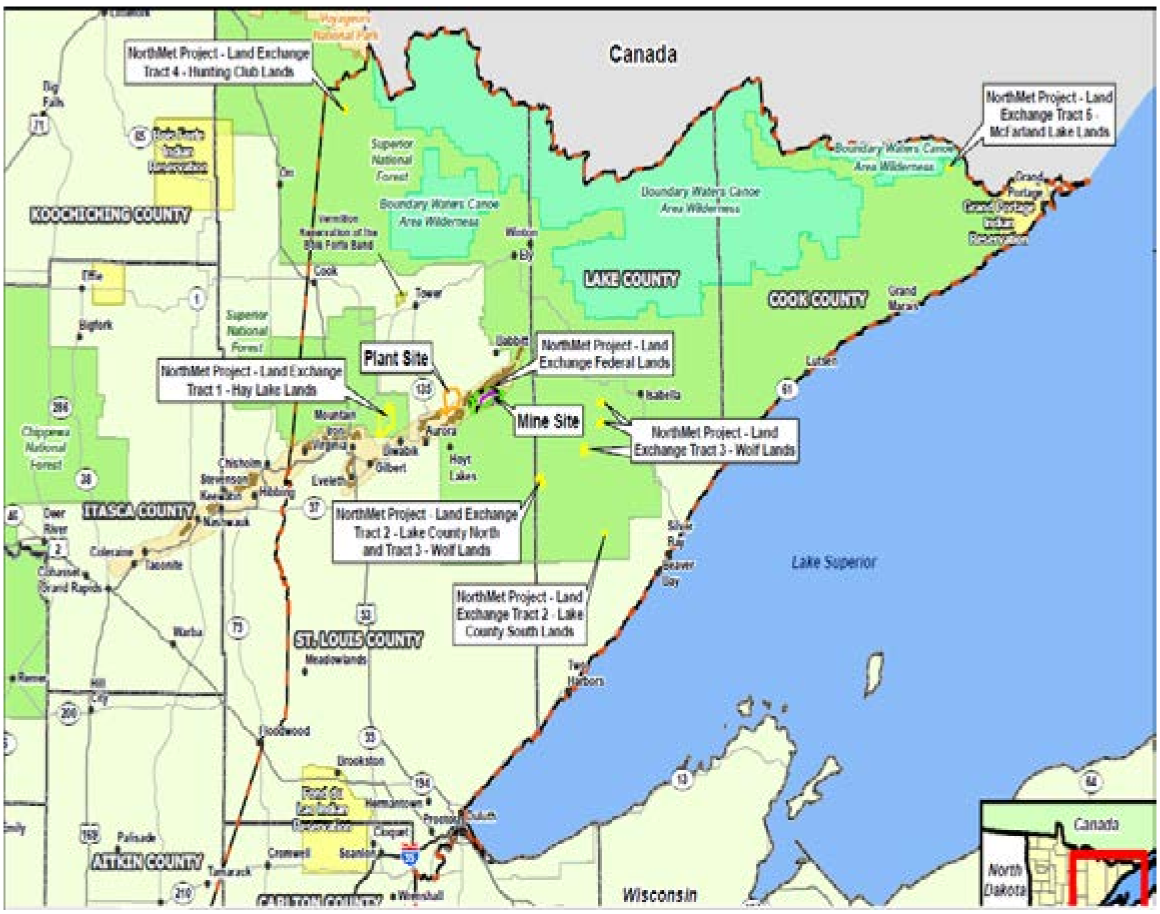

Figure 1. Map of proposed Polmet project "NorthMet". This map shows the areas involved in the NorthMet project. This includes the land exchange as well as the mine and its associated infrastructure. Areas of interest including mine site, plant site, and area of land exchanges are labeled on the figure. Figure from (MNDNR 2013).

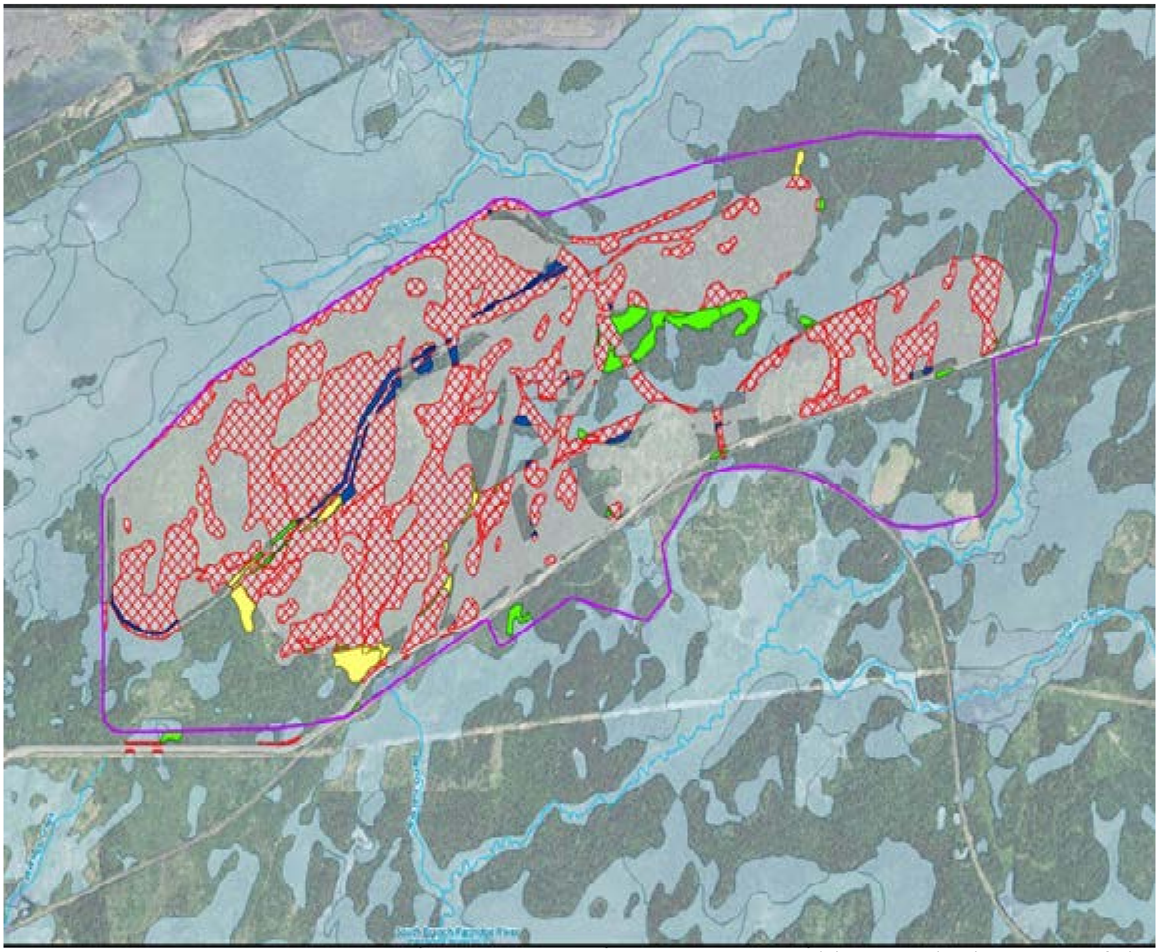

Figure 2. Map of directly impacted wetlands at mine site. This map depicts part of the 912.5 acres of wetland areas lost directly to the project at the mine site. The area outlined in purple is the mine site, red checkered areas represent wetlands directly lost. The light blue areas represent wetlands surrounding the mine that include those indirectly affected. Figure from (MNDNR 2013).

Background on "NorthMet" project

Polymet is proposing opening a copper-nickel mine in Northeastern Minnesota. Entitled "NorthMet", the proposed mine would lay 6 miles south of Babbitt MN, on the eastern edge of the Mesabi Iron Range. The plant for processing the ore would be on a former industrial site in Hoyt Lakes MN. There would be 6,650 acres of land on the south boundary of the Superior National Forest transferred from public ownership to Polymet. In turn, 6,722 acres would transfer from private to public ownership (Figure 1). In total the project would entail a mine, processing plant, **tailings basin**, and a seven mile stretch of railroad connecting the mine and processing plant. Each part of the project has potential negative effects on wetlands.

Tailings basin
Land on which byproduct of purifying mineral product is stored.

Potential Damages from mining

The mine, processing plant, and infrastructure associated with the project are set to directly destroy wetland habitat, contribute to water pollution, and indirectly damage the environment (MNDNR 2013).

Direct Loss of Habitat

The NorthMet site would destroy 912.5 acres of wetlands around the mine site, along the transportation and utility corridor, and around the plant site(Figure 2) (Figure 3) (MNDNR 2013). This land would be lost due

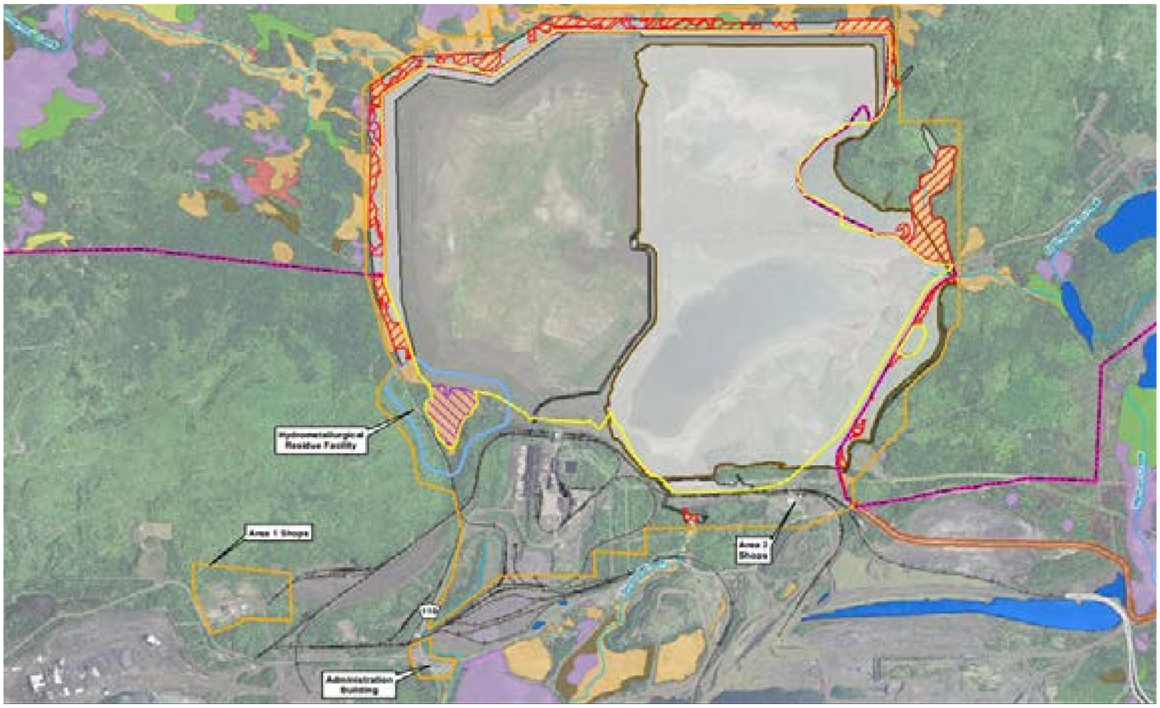

Figure 3. Map of directly impacted wetlands at plant site. This map depicts part of the 912.5 acres of wetland areas lost directly to the project, at the plant site. The area outlined in orange is the plant site, andred checkered areas represent wetlands directly lost. The various other shaded areas represent different wetland types surrounding the plant that include those indirectly affected. Figure from (MNDNR 2013).

to mining activities including excavation, filling, and installing a containment system within the wetland boundary.

This direct loss of wetlands is a loss of habitat for many animals and vegetation, includingnine plants Minnesota listed as threatened. These effects are irreversible, and result in the permanent loss of the services of the wetlands (MNDNR 2013).

Water Pollution associated with sulfide mining

A large environmental consequence of mining is pollution of surrounding waters. NorthMet is set to extract copper, nickel and precious metals from an open pit mine. This type of mining is known to have an effect on water quality. The metals are not found in their elemental form, but as a part of **sulfide ores**. The ores in the NorthMet project have an estimated 0.15 percent sulfide, miniscule compared to 40 percent sulfide of other mines, but still a potential for risk as 533 million tons of rock predicted to be excavated (MNDNR 2013).Wasterock is discarded as the metals are purified from the ores and stored in a tailings basin, which in the case of NorthMet is set to be located on wetlands. The waste rock contributes to **acid rock drainage**, a major problem in sulfide mining. This drainage leaches into the soil and can contaminate groundwater and surrounding watersheds. The acidic drainage results in a net lowering of pH in surrounding water (Nordstrom et al. 2000). Besides being very acidic, the runoff from the tailings basin contains various heavy metals. Chemicals such as mercury, aluminum and over 20 other solutes have been identified as adding non-negligible amount of pollutants to surrounding watersheds. Wetlands are rich in organic matter and readily take up these metals (Kablitz and Wennrich 1998). Metals such as mercury have a high toxicity in plants (Sharma 2000). These conditions

Sulfide ores
Ores containing a metal or mineral and S^{2-} anion. When exposed to air and water these compounds react to form sulfuric acid (H_2SO_4) which can acidify surrounding watersheds.

Acid rock drainage
Outflow of acidic water laced with heavy metals leached from sulfide wasterock associated with mining.

greatly impact the vegetation of wetlands, and hurt the organisms that directly rely on the water.

The NorthMet mine will also add to pre-existing water quality problems in the wetlands in Embarass and Partridge river watersheds (MNDNR 2013). These rivers are estuaries to the St. Louis River which flows directly into Lake Superior. The size, distribution, and makeup of wetlands cumulatively affect surrounding streams hydrology (Johnston et al. 1990). Shifts in the mosaics of wetlands can affect uptake of inorganic suspended solids, and nutrients. "NorthMet" would add to the cumulative effect of mines on the Iron Range adding to already impaired waters.

Damages from land cover changes

Mining, and its associated infrastructure, also has various indirect effects on surrounding wetland habitats. Habitat fragmentation that results from infrastructure directly affects life within the wetland. The NorthMet projects is set to fragment habitat for wolves, moose, the federally protected lynx as well as many other animals in that reside in and depend on wetlands in Northeastern Minnesota. This fragmentation can contribute to genetic bottlenecks in local populations (Gerlach and Musolf 2000). Dust from infrastructure and road use will also impact wetlands. The dust can slowly acidify the surrounding soil, reducing vegetation (MNDNR 2013). Dust pollution has been associated with loss in CO_2 exchange in wetlands, reducing carbon sequestration abilities (Niadoo and Niadoo 2005). NorthMet will increase road travel near various wetlands, which causes a direct loss in biodiversity (Findlay and Boudages 2000) Infrastructure also affects the water table. By shifting how rainfall flows, the form and function of wetlands is altered. Fluxes in groundwater can have a large impact on the ecological makeup of a wetland basin (Todd et al. 2006). As species have adapted for their specific environments even small shifts in habitat makeup can greatly affect biodiversity.

Hydrogeologic
The study of how groundwater moves and is distributed through soil and rocks.

Assessment of Wetland Health

Assessing wetland health provides a baseline on which to evaluate future projects such as NorthMet. Mining needs to be monitored and controlled long-term, even after the mine closes. Water treatment is considered necessary for 500 years after NorthMet is closed. Wetlands could be impacted on a long time scale. To insure their safety, a method to quantify their health is vital. There are no formulated ecological or environmental tests for assessing an aquatic ecosystem's health (Brooks et al. 2007). Indicators must be found on an area-by-area basis. Three major facets of identifying wetland health are testing of wetlands' water, measuring the distribution of flora and fauna, and monitoring land cover. A picture of wetland health develops by weighing these environmental factors (Brooks et al. 2007). Monitoring of wetland areas requires a combination of data sets.

Hydrologic Testing

The large volume of water has impacted all life within the wetland, knowing the quality of the water is important. Taking samples of water from the wetland back to the laboratory to be tested for its solutes, suspended compounds, as well as other chemical properties provides a quantifiable amount for some pollutants in the water. Knowing water quality can provide a scope to the damage done to the wetland. Chemical load is not the only important trait of water measured. **Hydrogeologic** data is important to determining the biotic composition, structure, and function of aquatic wetlands. Factors such as well placement and flow of water are taken into account when assessing the degree of hydrologic alteration(Richter et al 1990). Mining impacts wetlands' hydrology, it must be assessed over a long time scale to prevent large damage to surrounding ecosystems.

Flora and Fauna surveys

The health of the life within the wetland is key to the wetlands' overall health. As wetlands vary in climate, hydrologic, and other environmental conditions, the diversity of species within it also varies. Vegetation is regularly identified as a defining feature in wetlands (Zedler and Kercher 2005). As a primary producer in the environment, vegetation uptakes nutrients, minerals, and heavy metals dispersing them throughout the food web (Stoltz and Greger 2002). As different plants deal with changes to habitat in different ways a survey of local vegetation is needed. Impact from land use is measured by finding abundance and distribution of various known plants and accompanying it with hydrologic data (Johnston et al. 2009). Through similar methods, fauna can be used as a stressor indicator. Benthic invertebrates are a common choice for use as a **focal assemblage**. As benthic invertebrates live in soil that may be affected from land use and in water, they are very directly affected by chemical changes in habitat (Wesolek et al 2010). Amphibians are also commonly used. Frogs are commonly chosen as are diverse, and some species of frog are known to absorb heavy metals through their skin (Knutson et al. 1999). Fish are also used as they spend their whole life in the water. Though birds do not live directly in the water, they experience **biomagnification** and accumulate hazardous minerals making them useful in measuring wetland health (Niu et al. 2013). Surveys of wildlife have been taken in the areas that are predicted to be impacted by NorthMet. These surveys provide a baseline to the biodiversity, as well as determining if especially threatened species will be impacted. As life is a big part of what makes wetlands unique, being able to assess biodiversity is important for measuring wetland health.

Focal assemblage
A species or group of species studied to determine the health of an ecosystem as a whole.

Biomagnification
The accumulation of chemicals in species as the concentration, of a chemical, progressively increases up the food web.

GIS and Remote Monitoring

Wetlands can prove to be difficult to access. Without ease of access, it is hard to get consistent sampling on foot or boat. Satellite images and GIS (Geographical Information System) have proven viable alternatives. By comparing images over a period of time with variables, it is possible to predict a baseline of wetland health. Variables chosen include condition of wetland, extent of wetlands compared to historic extent, habitat cover, and wetland disturbances, \(Papastergiadou et al. 2007). Land use cover has a negative correlation with biotic diversity (Roth et.al 1996). GIS provides an easy way to assess changes in ecosystems whether it is through hydrologic changes or land use. By overlaying images of existing wetlands with the planned areas of development, NorthMet has used GIS technology in which to estimate shifts in hydrology, and also to predict direct and indirect damages.

Monitoring of wetlands is a vital connection between discovering our impact on our environment and for developing a method to mitigate our damage. Assessing wetland health provides a baseline on which to base future projects such as "NorthMet" and to assess damages of our past and current infrastructure.

Mitigation and Restoration

Wetlands are a value to their surrounding ecosystem. However, their loss to development cannot be totally avoided. Mitigation of damage is the final part of wetland management. A combination of conservation and restoration is the best way to maintain habitat as well as access natural resources.

Conserving preexisting wetlands is the most successful means of impact. Natural wetlands behave differently in many functions compared to restored areas, mainly due to soil composition (Bantilan et al. 2009). Maintaining buffer zones upland of wetlands provides an increased biodiversity, as shown by assemblages such as turtles (Burke and Gibbons 2002) Conservation of small areas of wetlands can have a large impact in biodiversity (Gibbs 1993). These small areas can provide habitat for localized populations; however they have also been noted to have a net loss of biodiversity over time. If there is a corridor of natural habitat between fragmented areas biodiversity is shown to be higher compared to isolated habitats (Gilbert-Norton et al. 2010). Placement of NorthMet infrastructure is optimized within its area to minimize damages to the surrounding environment. Additionally, the processing plant and the transportation and utility corridor would be located on land previously used for industrial purposes. This reuse would avoid the need to disturb additional wetlands and would further reduce environmental effects. Conservation is seen as a process based approach by some researchers (Euliss et al. 2008). They see as land usage increases, ecological systems of wetlands need to be optimized by the services they provide. Conservation and land use are difficult to juggle, techniques to minimize effects of fragmentation and disturbance are key to conserving wetlands in conjunction with land use.

Mitigation of destroyed wetlands accompanies proposed land usage. Mitigation of affected wetlands is required in the NorthMet proposal. USACE (United States Army Corps of Engineers) have a base compensation of 1.5:1 replacement with a minimum of 1:1 acres. This depends on damages done to wetlands by the project as well as quality of restored wetlands. Mitigation proposed by Polymet is on a 5-10 year scale (MNDNR 2013). That is that the effects on wetlands caused by NorthMet would be offset within that time frame. This includes wetlands created around the mine site after the mine is closed. Wetland mitigation sites have been recognized as not necessarily fitting the predicted pattern set up from models (Mitsch and Wilson 1996). Wetland restoration is a balance of providing the services wetlands provide such as nutrient uptake and flood control, while also providing biodiversity. (Zedler 2000).While restored wetlands provide some offset to damage, restoration is a complicated process with no guarantee to provide the function of natural wetlands.

Conclusions

In order to grow as a society, natural resources will continue to be utilized. Continued land use threatens more and more wetlands. Projects such as NorthMet must be weighed. Wetlands are very sensitive ecosystems, making them at risk from development. Future mines, such as NorthMet could potentially destroy wetlands, change their water quality and hydrology, and cause various other negative effects. Are the short-term economic benefits worth the lasting environmental impacts? Measuring damages to wetlands by testing water, taking surveys of life, and using technologies like GIS will provide the data to answer questions such as these. While more research is needed to accurately assess wetland health. With some wetlands remote area and inaccessibility a clearer picture of what types wetlands and the area they cover is needed. Increased mapping of wetlands is an important step for conservation. Still, research is needed to produce accurate inventories of wetlands using congruent classification schemes, assessments of condition, and information on rates of both loss and restoration. Techniques such as those used in projects such as the EPA funded EaGLe (Estuarine and Great Lakes Environmental indicator program) used to develop environmental stressor gradients for wetlands should be implemented on a wider scale. Wide implementation of mapping projects such as these would give policy makers and citizens a more detailed assessment to make land use decisions. As each area of wetlands is unique local data is needed in many areas. This is not done just by researchers. Many universities are looking for volunteers to take basic measurements in their area. If you are interested in making an impact, contact a local university and volunteer.

Acknowledgements

I would like to thank Dr. David Beard, Dr. Jennifer Liang, Dr. Shannon Stevenson, and Dr. Elizabetheda Wright for advising, editing, and coordinating DJUB. I would also like to thank Jill Jenson of the Writing Studies department of UMD for helping me review my manuscript. Lastly, I would like to thank the Natural Resource Research Institute for fostering my interest and curiosity in natural resource development.

Author Biography

Carsten Knutson is a junior pursuing his B.S. in Biology with a minor in chemistry. His research interests include sustainable natural resource use, nutrient cycling, and biotechnology. In his free time he enjoys hiking, kayaking, rock climbing, and playing music.

References

Barbier EB. 1994. Valuing environmental functions - tropical wetlands. Land Econ 70(2):155-73.

Brinson MM, Malvarez AI. 2002. Temperate freshwater wetlands: Types, status, and threats. Environ Conserv 29(2):115-33.

Burke VJ, Gibbons JW. 1995. Terrestrial buffer zones and wetland conservation: A case study of freshwater turtles in a Carolina bay. ConservBiol 9(6):1365-9.

Findlay CS, Bourdages J. 2000. Response time of wetland biodiversity to road construction on adjacent lands. ConservBiol 14(1):86-94.

Gerlach G, Musolf K. 2000. Fragmentation of landscape as a cause for genetic subdivision in bank voles. ConservBiol 10(1) 1523-1739

Gibbs JP. 1993. Importance of small wetlands for the persistence of local-populations of wetland-associated animals. Wetlands 13(1):25-31.

Gilbert-Norton L, Wilson R, Stevens JR, Beard KH,\. 2010. A Meta-Analytic Review of Corridor Effectivness. Conserv. Biol. 24(3):660-668

Gilliam JW. 1994. Riparian wetlands and water-quality. J Environ Qual 23(5):896-900.

Hopkinson CS, Vallino JJ. 1995. The relationships among mans activities in watersheds and estuaries - a model of runoff effects on patterns of estuarine community metabolism. Estuaries 18(4):598-621.

Johnston CA, Detenbeck NE, Niemi GJ. 1990. The cumulative effect of wetlands on stream water quality and quantity a landscape approach. Biogeochemistry (Dordrecht) 10(2):105-42.

.Kalbitz K, Wennrich R. 1998. Mobilization of heavy metals and arsenic in polluted wetland soils and its dependence on dissolved organic matter. Sci Total Environ 209(1):27-39.

Knutson MG, Sauer JR, Olsen DA, Mossman MJ, Hemesath LM, Lannoo MJ. 1999. Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, USA. ConservBiol 13(6):1437-46.

Minnesota Department of Natural Resources (USA) United States Army Corps of Engineers (USA), United States Forestry Service (USA). NorthMet Mining Project and Land Exchange Supplemental Draft Environmental Impact Statement November 2013

Minnesota Pollution Control Agency (USA) 2014 Proposed Impaired Waters List. April 2014.

Mitsch WJ, Wilson RF. 1996. Improving the success of wetland creation and restoration with know-how, time, and self-design. EcolAppl 6(1):77-83.

Naidoo G, Naidoo Y. 2005. Coal dust pollution effects on wetland tree species in Richards

Bay, South Africa. Wetlands Ecol Manage 13(5):509-15.

Niu JY, Zou YA, Yuan X, Zhang B, Wang TH. 2013. Waterbird distribution patterns and environmentally impacted factors in reclaimed coastal wetlands of the eastern end of Nanhui county, Shanghai, China. ActaZoologicaAcademiaeScientiarum-Hungaricae 59(2):171-85.

Papastergiadou ES, Retalis A, Apostolakis A, Georgiadis T. 2008. Environmental monitoring of spatio-temporal changes using remote sensing and GIS in a mediterranean wetland of northern Greece. Water Resour Manage 22(5):579-94.

Roth NE, Allan JD, Erickson DL. 1996. Landscape influences on stream biotic integrity assessed at multiple spatial scales. Landscape Ecol 11(3):141-56.

Stoltz E, Greger M. 2002. Accumulation properties of As, Cd, Cu, Pb and Zn by four wetland plant species growing on submerged mine tailings. EnvironExp Bot 47(3):271-80.

Todd AK, Buttle JM, Taylor CH. 2006. Hydrologic dynamics and linkages in a wetland-dominated basin. Journal of Hydrology 319(1-4):15-35.

Wesolek BE, Szkokan-Emilson EJ, Gunn JM. 2010. Assessment of littoral benthic invertebrate communities at the land-water interface in lakes recovering from severe acid- and metal-damage. Hum Ecol Risk Assess16(3):536-59

Zedler JB, Kercher S. 2005. Wetland resources: Status, trends, ecosystem services, and restorability. Annual Review of Environment and Resources 30:39-74.