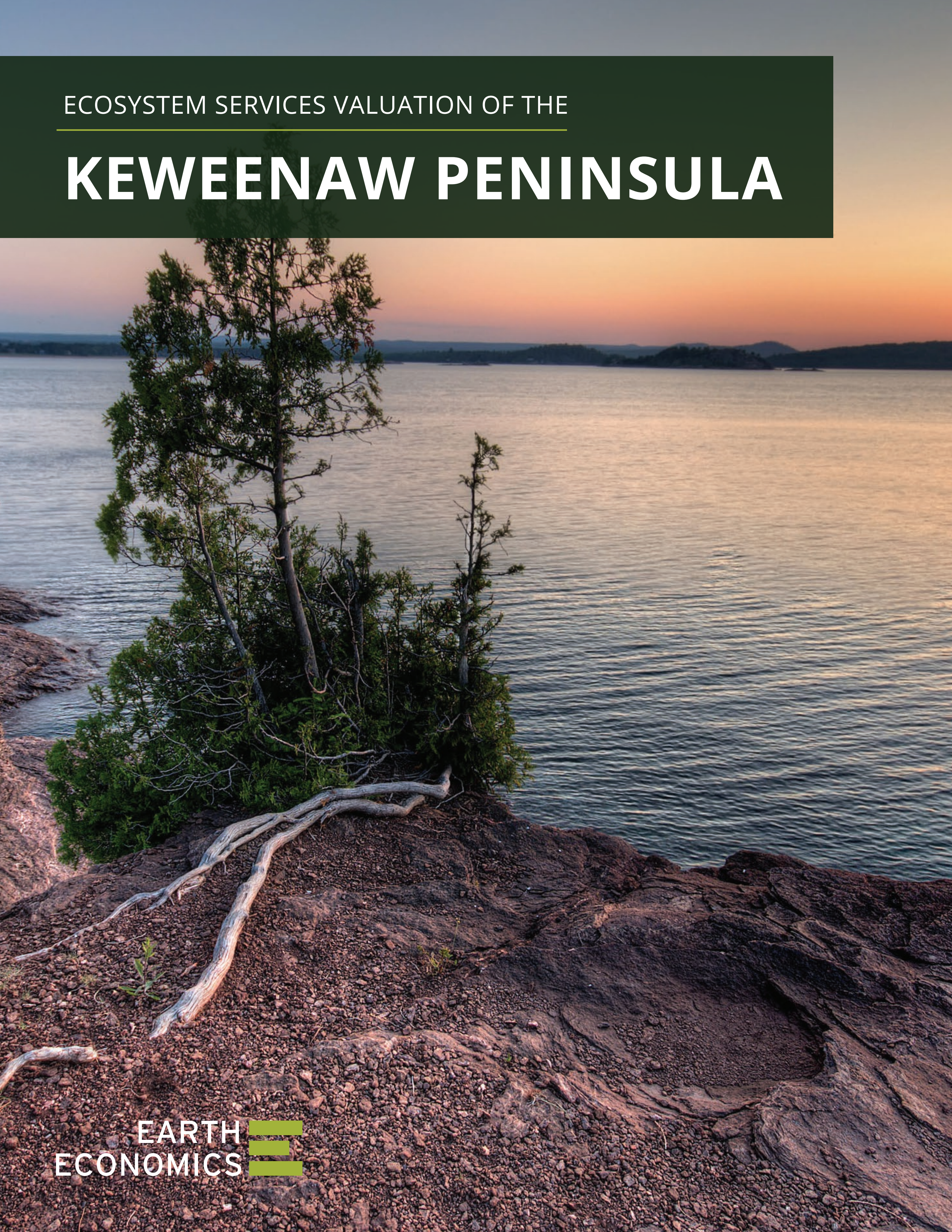
ECOSYSTEM SERVICES VALUATION OF THE

KEWEENAW PENINSULA



EARTH ECONOMICS

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The authors are responsible for the content of this report.

Earth Economics is a leader in ecological economics and has provided innovative analysis and recommendations to governments, tribes, organizations, private firms, and communities around the world.

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EARTH ECONOMICS

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EXECUTIVE **SUMMARY**

The goal of this report is to measure the indirect economic values that are provided by ecosystem services in the Keweenaw Peninsula region — the northernmost part of Michigan's Upper Peninsula. Pine forests and sandy beaches on the shores of Lake Superior foster productive ecosystems that provide water, clean air, and food, as well as sustain local economies and communities with dollars from various industries, including tourism. While they are valuable on their own, when ecosystems are threatened with degradation, we often fail to account for the indirect values of ecosystem goods and services that nature provides at no cost to society. By taking nature into account, we can better inform decision-making. Currently, the ecosystems around the Keweenaw Peninsula risk being impaired by mining waste called stamp sands. Gaining a better understanding of the economic value of the services provided by these ecosystems will provide important information to be taken into account in management decisions, including the restoration efforts targeted at removing or containing these stamp sands in the Keweenaw Peninsula.

Along the Keweenaw Peninsula, copper mines and mills dotted this "Copper Country" at the turn of the 20th century. These mines produced tailings called stamp sands — sand in both coarse and fine particle sizes left over from processed ore — from 1860 until 1968. During that time, miners dumped millions of metric tons of stamp sands along rivers, waterways, lakes, and the shores of Lake Superior on the Keweenaw Peninsula. These stamp sands left behind from historic mining activities are now having significant environmental effects.

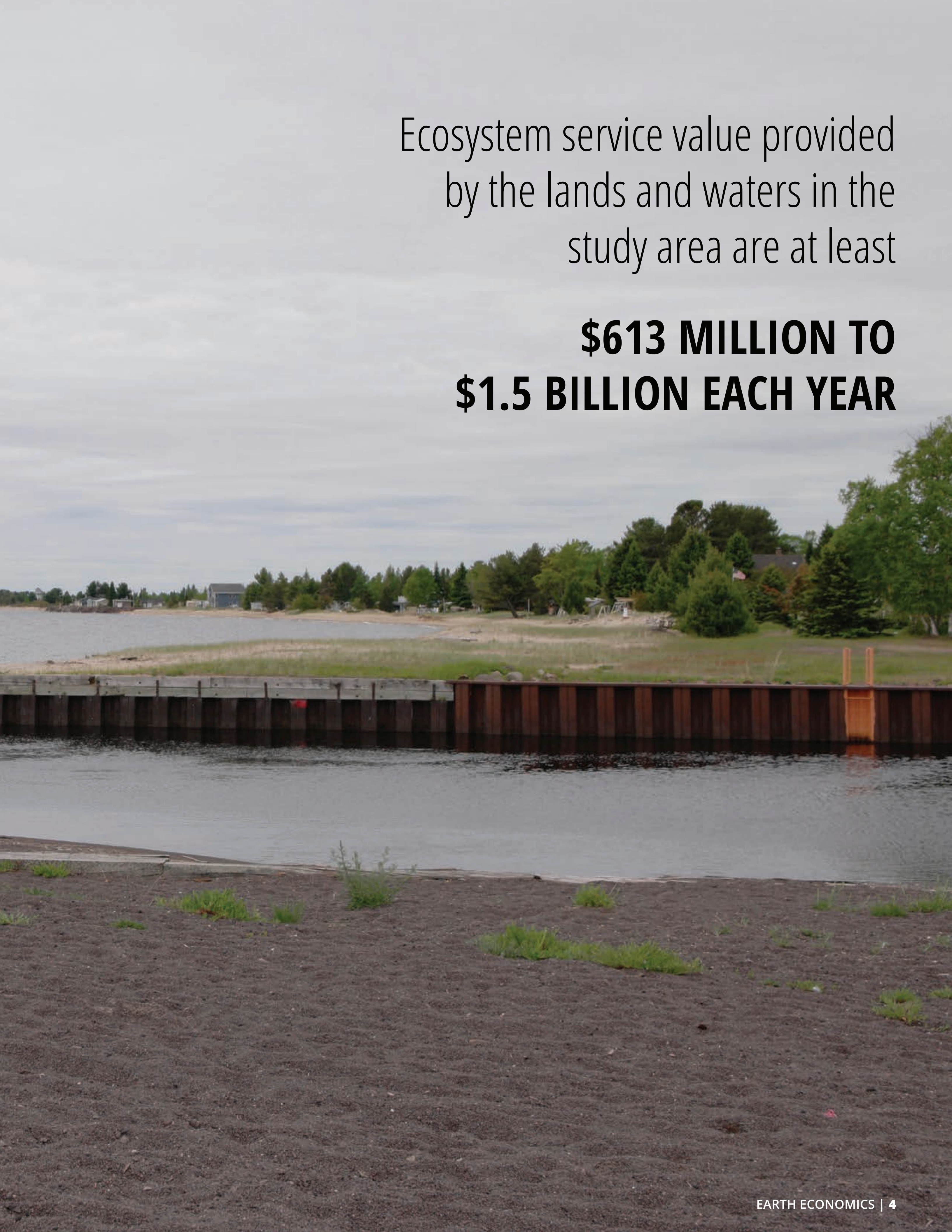
Stamp sands contain toxic levels of copper for aquatic ecosystems, as well as contain a host of other metals that can be harmful, including silver, arsenic, cadmium, cobalt, chromium, mercury, manganese, nickel, lead, and zinc.[1] These metals seep into and contaminate soils and groundwater. In aquatic environments, metals leach from stamp sand substrates and enter the water column. Areas contaminated by stamp sands become biological dead-zones as a result of contamination from chemicals and sedimentation that covers natural habitat.

Stamp sands can become airborne. While copper is not easily absorbed through skin contact, ingesting high levels of copper may lead to gastrointestinal distress and even liver damage. Children face greater risk of exposure to toxic levels, especially during critical growth stages. Assessments of exposure are based on target behaviors treated in isolation (e.g., exposure during one activity and location, without consideration of cumulative effects from other exposure pathways).[2]

While productive ecosystems are fundamental to functioning economies and communities, in economic development plans, conservation efforts, and legislative decisions, we often fail to account for the value nature provides. Knowing where to develop or invest — identifying cost-effective and resilient means of managing natural capital and protecting built infrastructure — requires the most complete economic information available. By taking nature into account, we can make better-informed and more strategic decisions that lead to long-term prosperity.

This study finds that the indirect, non-market values of ecosystem services provided by the Keweenaw Peninsula region are substantial. Under the analysis in this report, the total ecosystem services value provided by the lands and waters in the study area are at least $613 million to $1.5 billion each year. Over 100 years, these benefits total at least $21 billion to $52 billion using a 2.75 percent discount rate, or $61 billion to $149 billion using a 0 percent discount rate. Still, due to gaps present in the analysis, these values represent underestimates of the total indirect value of these benefits. Additionally, there are other types of economic benefits provided by natural resources in the area. The values in this report don't include market transactions and spending associated with these natural resources, or the jobs they support in the region.

The values presented in this report reveal the breadth and magnitude of the indirect economic benefits provided by the study area in its current condition. These results provide a broad sense of the economic importance of these lands and waters and show that there are significant benefits to restoring natural capital in the Keweenaw Peninsula. Understanding the value of these ecosystem services can help build shared goals, sustainable funding mechanisms for management, and better decision-making.



Ecosystem service value provided by the lands and waters in the study area are at least

$613 MILLION TO $1.5 BILLION EACH YEAR

INTRODUCTION

PURPOSE OF THIS REPORT

The purpose of this report is to provide information on the current non-market economic values of ecosystem services in the Keweenaw Peninsula region, with an emphasis on areas impacted by the encroachment of stamp sands originating at the Gay, Mich. stamp sand pile.

The numbers we provide in the report are intended to increase awareness of the economic benefits of healthy natural lands and resources in the Keweenaw Peninsula. They can be incorporated into decision-making processes and are meant to fill a gap that is often overlooked in that process. While it is difficult to quantify the specific effects of stamp sands on many of the ecosystem services provided by these natural lands, by estimating the benefits provided by healthy natural ecosystems in the area, we can get a sense of the scale of benefits at risk from lands and resources contaminated from stamp sands.

This report focuses on non-market benefits provided by natural areas. Therefore, there are many other values this report does not consider. For example, the values presented do not include jobs or expenditures related to the use of these natural resources. These values also do not include the importance of the natural resources in this area to the rights and culture of tribes. However, placing economic value on important cultural activities and resources can be inappropriate and controversial. Regardless of dollar value, subsistence rights should always be the primary consideration. The dollar values in this report should be regarded as comprising one type of value, and as a very small portion of the true, total value of natural resources in the area.

REPORT ORGANIZATION

This report is organized as follows: The current chapter discusses the environmental issues with stamp sands in the Keweenaw Peninsula region and describes the area of analysis; the next chapter defines ecosystem services and provides concrete examples of ecosystem services in the study area, as well as examples of how stamp sands could affect ecosystem services provisioning; the third chapter details the methods and results of the non-monetary ecosystem services valuation; the final chapter discusses overall conclusions of this report. Appendices cover the limitations of this report, sources used for valuation, and further reading not pertaining to the non-monetary benefits provided by natural capital in the study area.

COPPER COUNTRY AND STAMP SANDS

The Keweenaw Peninsula is part of Michigan's so-called "Copper Country," which was one of the largest mining regions in North America at the turn of the 20th century. As the name suggests, copper mining was prevalent there between 1845 and the late 1960s. The region held large deposits of native copper and was the second-largest producer of copper in the world during that time.[3,4] More than 140 mines and 40 mills produced and processed ore.[5] During this time, the mines of the Keweenaw Peninsula produced the majority of the United States' copper.[6]

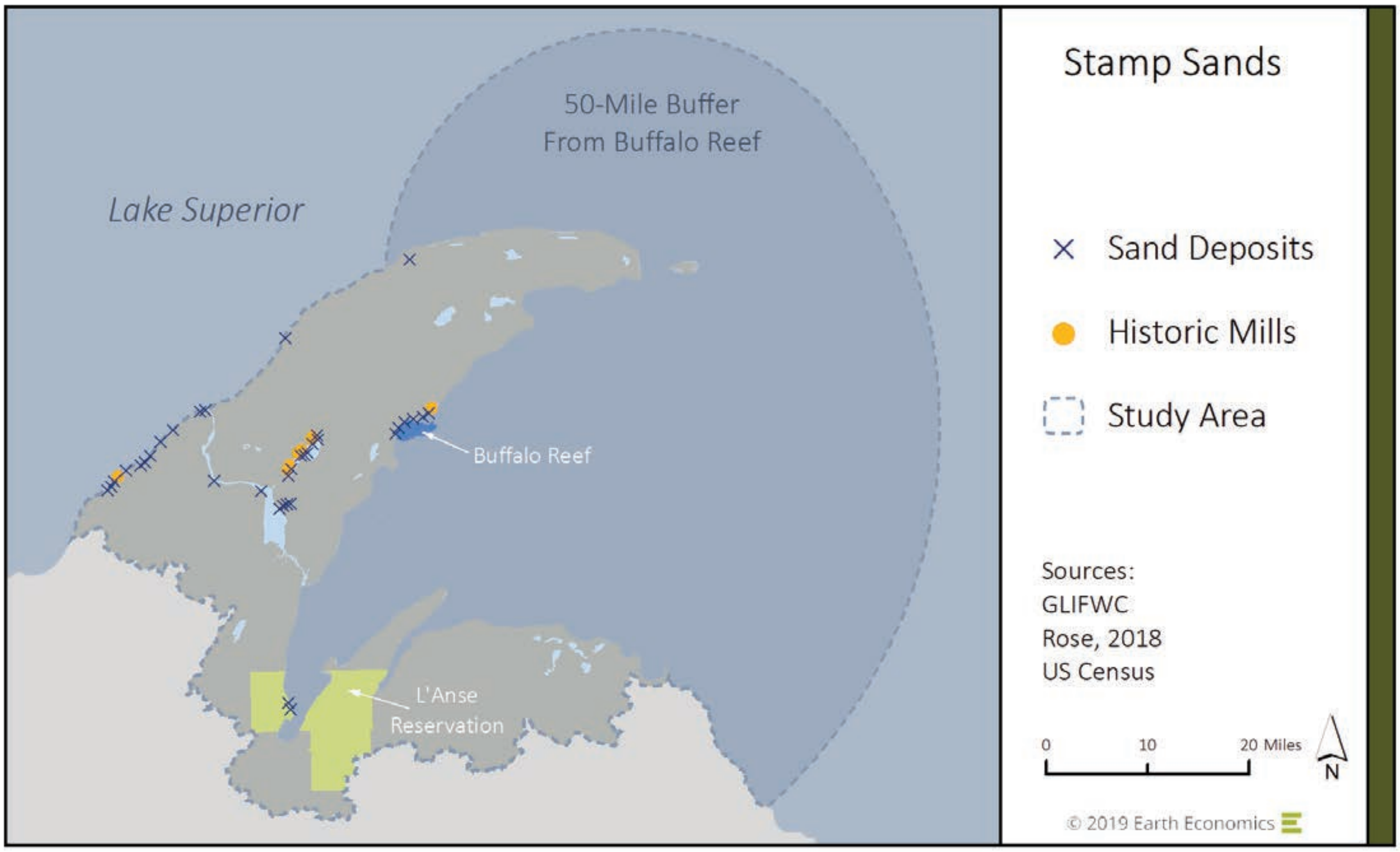
This report's limited scope assesses the non-market benefits provided by natural areas, but it does not account for economic values such as jobs or tribal subsistence and cultural activities related to natural resources.

The mines in Copper Country produced tailings called stamp sands — sand in both coarse and fine particle sizes left over from ore that has been processed in a stamp mill. Many millions of metric tons of stamp sands were dumped along rivers, waterways, lakes, and the shores of Lake Superior in the Keweenaw Peninsula. Stamp sand dump sites include Torch Lake, Boston Wetland, Freda-Redridge, and the Town of Gay. Almost 23 million metric tons of stamp sands were deposited at the Town of Gay. Torch Lake has piles of stamp sands and is classified as a superfund site — a polluted location requiring long-term clean-up of hazardous materials. Altogether, roughly 500 million tons of stamp sands were dumped in the region.[5]

Stamp sands are of environmental concern because they contain levels of copper that are toxic for aquatic ecosystems, and a host of other metals that can be harmful, including silver, arsenic, cadmium, cobalt, chromium, mercury, manganese, nickel, lead, and zinc.[1] These metals seep into and contaminate soils and groundwater. In aquatic environments, metals leach from stamp sand substrates and enter the water column. As stamp sands erode, the fine stamp sand particles are transported into deep water habitats, while coarser particles are deposited close to shore. Areas contaminated by stamp sands become biological dead-zones as a result of this sedimentation that covers natural habitat and chemical contamination.

GAP COARSE- AND FINE-GRAINED STAMP SANDS LOCATED AT THE MAIN PILE AT GAY, MICHIGAN. IMAGE CREDIT: ESTEBAN CHIRIBOGA, GREAT LAKES INDIAN FISH AND WILDLIFE COMMISSION

FIGURE 1 LOCATION OF STAMP SANDS AND STAMP MILLS IN THE KEWEENAW AREA



Stamp sands can also become airborne from human activity. While copper is not easily absorbed through skin contact, ingesting high levels of copper may lead to gastrointestinal distress and even liver damage. Children face greater risk of exposure to toxic levels, especially during critical growth stages. Assessments of exposure are based on target behaviors treated in isolation (e.g., exposure during one activity and location, without consideration of cumulative effects from other exposure pathways).[2]

Some piles of these toxic tailings are not stationary and have been eroding and spreading along shorelines and into Lake Superior. The stamp sand pile at the Town of Gay is eroding at approximately 25 feet per year.[8] In 2008, only 13.5 percent of the original stamp sands remained in the pile. These sands have covered approximately five miles of shoreline, including approximately 400 acres of nearshore land and 2,816 acres of aquatic habitat. Not only are they toxic, but migrating sands smother rocky nursery areas used by fish and have covered native white sand beaches. The U.S. Army Corps of Engineers has ranked stamp sands as a 1 on a 10-point habitat scale (where a 10 represents the highest habitat value and 0 represents no habitat value).[7] Stamp sands are sterile and unsuitable for terrestrial — and aquatic — habitat due to their toxic nature.

In addition to the consequences on ecosystems alone, these environmental issues threaten local economies through their impact on natural resources. Recreational and commercial fishing are crucial industries in the area around the Keweenaw Peninsula, both of which depend on fish habitat provided by reefs that are threatened by the stamp sands. The Keweenaw Bay Indian Community, whose reservation is approximately 25 miles south of Buffalo Reef, maintains both commercial and subsistence fisheries in the area. The Bad River and Red Cliff Bands of Ojibwa also fish this area. Since stamp sands threaten treaty rights in the ceded waters and territories — rights that are fundamental to the tribes' culture and way of life — all of the Great Lakes Indian Fish and Wildlife Commission's (GLIFWC) 1842 treaty signatory tribes are concerned about the loss of spawning habitat due to stamp sands.

Each of GLIFWC's 11 tribes[i] entered into a treaty with the United States that formally reserved each tribe's sovereign hunting, fishing, and gathering rights in these ceded territories. The United States, as a treaty signatory, must live up to its treaty obligations regarding those ceded territory rights. Therefore, the federal government has legal and trust responsibilities toward those tribes to protect the ecosystems that support the natural resources subject to treaty rights. In short, the tribes maintain that the United States has the obligation to restore and protect the habitats that maintain the Lake Superior treaty fishery, including areas impacted by stamp sands.[9]

In the early 2000's, tribal fishermen expressed concerns to GLIFWC about stamp sands moving closer to tribal fishing grounds. In 2005, GLIFWC commissioned a study to document the location of stamp sands relative to these areas and, with the concerned tribes, began to raise awareness of the issue. Since then, much work has been done to gain more information about the threats posed by stamp sands in the region, especially at the Gay pile. The results of this work led the EPA, in 2017, to endorse the formation of a task force comprised of state, federal, and tribal agencies, academic institutes, and private entities to address the issue. Currently, proposed alternatives are being investigated to stabilize or remove the stamp sands at Gay and will involve restoration and protection of aquatic and terrestrial habitat.

[i] The GLIFWC member tribes are: in Wisconsin -- the Bad River Band of the Lake Superior Tribe of Chippewa Indians, Lac Courte Oreilles Band of Lake Superior Chippewa Indians, Lac du Flambeau Band of Lake Superior Chippewa Indians, Red Cliff Band of Lake Superior Chippewa Indians, St. Croix Chippewa Indians of Wisconsin, and Sokaogon Chippewa Community of the Mole Lake Band; in Minnesota -- Fond du Lac Band of Lake Superior Chippewa, and Mille Lacs Band of Ojibwe Indians; and in Michigan -- Bay Mills Indian Community, Keweenaw Bay Indian Community, and Lac Vieux Desert Band of Lake Superior Chippewa Indians.

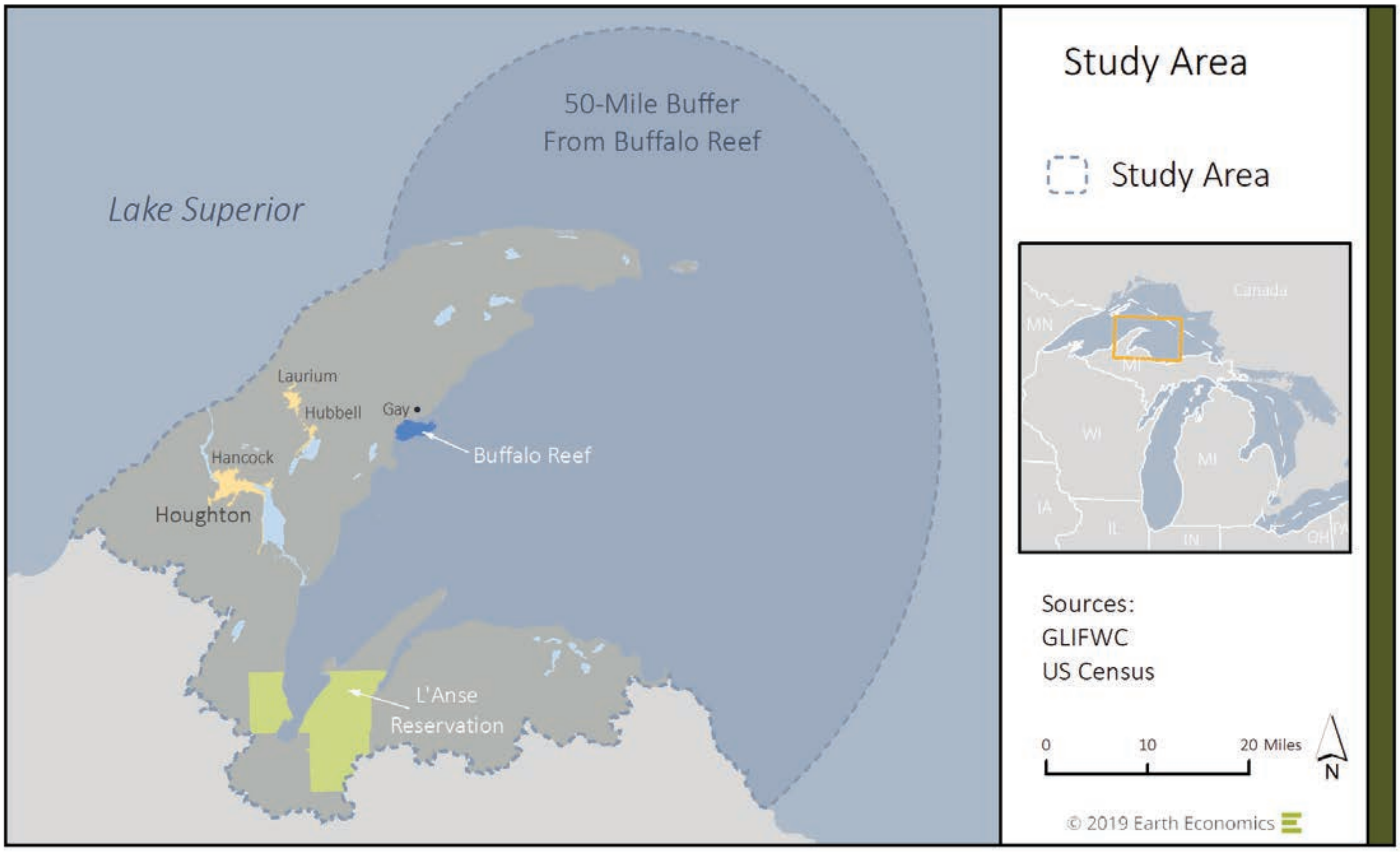
AREA OF ANALYSIS

To achieve the purpose of this report, we sought to include the important natural resources of the area that may be affected by stamp sands. Stamp sand fines and water with altered chemistry move from the watersheds into Lake Superior. The transport of mine-influenced sediment and water into Lake Superior have formed a copper "halo" around the Keweenaw Peninsula.[10] The study area for this report encompasses the major stamp sand deposits of the Keweenaw and the drainage basins potentially impacted by those deposits. In addition to the Keweenaw Peninsula, the study area extends into areas of the Upper Peninsula of Michigan that include the Keweenaw Bay Indian Community, the Ojibwe Band most heavily affected by stamp sands. Figure 2 shows the study area boundary, as well as key ecological and demographic features within the study area.

The study area also includes the stamp sand deposit at Gay, Michigan, which have already covered five miles of shoreline on the Peninsula. In this area, natural resources have already been impacted. While the resolution of available spatial data of the natural resources impacted by this deposit prevents additional analysis at the time of this report, it is important to include this area in this report as we know some degree of impact has already occurred on this site.

One of the important natural resources in this area is Buffalo Reef, a cobble reef of approximately 2,200 acres that lies to the east of Keweenaw Peninsula. The reef provides critical spawning habitat for whitefish (C. clupeaformis) and lake trout (S. namaycush), two fish species important to subsistence, commercial, and recreational fishing in the area.[11] This aspect of the reef is noted in the *Atlas of the Spawning and Nursery Areas of the Great Lakes, Volume 2*.[12] As the reef is only three miles south of the original stamp sand pile at Gay, the nearshore portion of the reef has already been impacted by stamp sand migration, and it is threatened by further movement of stamp sands, which smother nursery habitat and are toxic to the aquatic communities the reef otherwise supports. This report's study area includes the waters of Lake Superior up to 50 miles distant from Buffalo Reef, as the majority of fish spawned and reared on the reef are caught within that distance.[13] Most of this area covers the MI4 fishing unit in Lake Superior. Upland areas included in this study cover all watersheds on the Keweenaw Peninsula as well as those that drain into the MI4 fishing unit.

FIGURE 2 STUDY AREA BOUNDARY AND KEY FEATURES



NATURAL CAPITAL AND ECOSYSTEM GOODS AND SERVICES

All economies operate within and rely on the natural capital in surrounding landscapes. The healthier a landscape is, the more likely the economy and surrounding communities will thrive. Environmental degradation can cause economies to falter, and yet natural capital has generally been overlooked in economic accounting. Though its value is often unrecognized, natural capital provides immense value to communities and the economy in the form of ecosystem goods and services. This section introduces the concepts of natural capital and ecosystem goods and services.

WHAT IS NATURAL CAPITAL?

Natural capital is the foundation for all other forms of capital for economies. Our quality of life relies on five types of capital: natural, built, financial, human, and social. Together, these five building blocks create the conditions for a healthy, sustainable economy. A robust and resilient economy requires that all forms of capital are healthy and work productively and synergistically. Natural capital is particularly important, yet frequently overlooked. It consists of any "minerals, energy, plants, animals, ecosystems, [climatic processes, nutrient cycles, and other natural structures and systems] found on Earth that provide a flow of natural goods and services."[15]

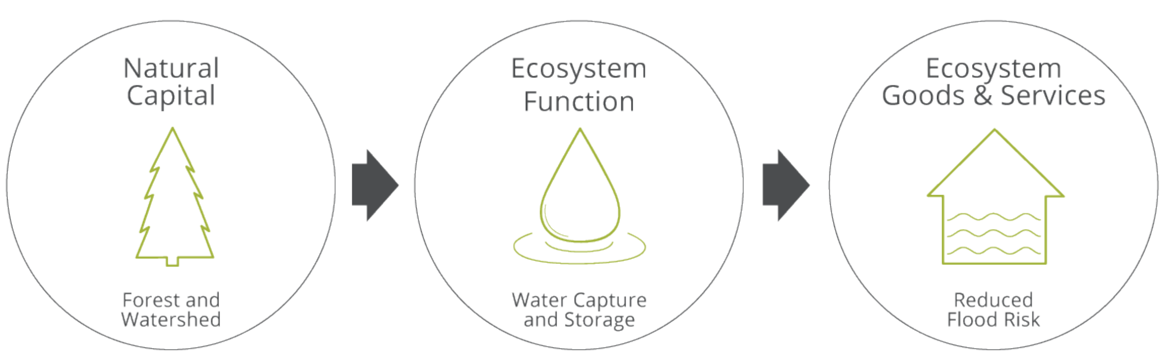
The five types of capital are described as follows:

- **NATURAL CAPITAL** All energy and materials from nature, including minerals, energy, plants, animals, and ecosystems.
- **BUILT CAPITAL** Technologies, machines, tools, and transport that are designed, built, and used by humans for productive purposes.
- **FINANCIAL CAPITAL** Shares, bonds, banknotes, and paper/electronic assets that enable other combinations of capital to be owned, traded, and allocated.
- **HUMAN CAPITAL** People, their education, technical and interpersonal skills, health, labor, knowledge, and talents.
- **SOCIAL CAPITAL** Organizations, institutions, laws, networks, and relationships for productive organization of the economy.

Like any form of capital, natural capital provides a flow of goods and services. The infrastructure and assets of any given ecosystem perform natural functions that provide goods and services that humans need to survive. For example, natural capital assets within a watershed (e.g., forests, wetlands, and rivers) perform critical functions such as intercepting rainfall and filtering water. This natural storage and filtration process supports a clean water supply, which is crucial to human survival.

FIGURE 3 CAPITAL FUNCTIONS

ILLUSTRATION OF THE RELATIONSHIP BETWEEN NATURAL CAPITAL ASSETS, ECOSYSTEM FUNCTIONS, AND THE PRODUCTION OF ECOSYSTEM GOODS AND SERVICES




CREDIT: BILL MATES, GLIFWC
THREE SUNS

WHAT ARE ECOSYSTEM GOODS AND SERVICES?

Ecosystem goods are tangible, physical products of a natural process that can be quantified using flow, volume, weight, or quantity measures. Drinking water, timber, fish, crops, and wildlife are all examples of ecosystem goods. Most goods are excludable, meaning that if one individual owns or uses a particular good, others are excluded from owning or using that same good. If one person eats an apple, for example, another person cannot eat that same apple. Excludable goods are easily traded and valued in markets. The gallons of water produced per minute or the board feet of timber cut in a 40-year rotation can be measured by the physical quantity an ecosystem produces over time. The current production of goods can be easily valued by multiplying the quantity produced by the current market price.

Ecosystem services are less tangible, defined as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life."[16] Flood protection, recreational value, aesthetic value, and water filtration are a few examples. Ecosystem services are difficult to value, yet they are indeed valuable and vital both to our quality of life and to economic production.

Many ecosystem services are non-excludable, meaning that they can be used by multiple individuals. The flood protection provided by upstream forested land benefits all downstream residents. One person benefitting from natural flood protection services will not inhibit other community members from gaining flood protection from the same forested land area. Ecosystem services such as oxygen production, soil regulation, and storm protection are not, and often cannot, be sold in markets. However, some ecosystem services are now valued and traded in markets; water temperature trading and carbon sequestration markets are examples.

Over the last 15 years, considerable progress has been made in systematically linking functioning ecosystems with human well-being. The work of De Groot et al., the Millennium Ecosystem Assessment (MEA), and The Economics of Ecosystems and Biodiversity (TEEB) marked key advancements in this task.[17, 18, 19] These studies laid the groundwork for a conceptual framework for valuing natural capital and ecosystem goods and services.

De Groot et al. were among the first to present a conceptual framework and typology for describing, classifying, and valuing ecosystem functions, goods, and services in a consistent manner. Recognizing the need for a standardized valuation framework, they began translating the complexity of ecological structures and processes into a limited set of ecosystem functions and subsequently identified how these functions provide people with valuable goods and services.

Around the time de Groot et al. initiated their work, an international coalition of over 1,300 scientists and experts from the United Nations Environmental Program, the World Bank, and the World Resources Institute assessed the effects of ecosystem change on human well-being. A key goal of the assessment was to develop a better understanding of the interactions between ecological and social systems, and to develop a knowledge base of concepts and methods that would improve our ability to "…assess options that can enhance the contribution of ecosystems to human well-being."[17] This study produced the landmark MEA, which classifies ecosystem services into four broad categories according to how they benefit humans: provisioning, regulating, supporting, and cultural services.

The conceptual framework initiated by de Groot et al. and developed through the MEA provided the impetus for several subsequent initiatives and programs, most notably TEEB. This global initiative aimed to help decision makers recognize and incorporate ecosystem service benefits in decision-making through a structured approach to valuation. TEEB involved three distinct phases of work and multiple reports on different aspects of ecosystem services valuation and its integration into policy-making.

Earth Economics' approach to valuation is adapted from the MEA's ecosystem service descriptions.[17] The adapted framework clearly articulates and values the vast array of critical services and benefits that natural capital provides. Under this framework, the four categories of ecosystem goods and services, which are now commonly used in the field of ecological economics, are as follows:

- **PROVISIONING GOODS & SERVICES** provide physical materials and energy for society that vary according to the ecosystems in which they are found. Forests produce lumber, while agricultural lands supply food, and rivers provide drinking water.
- **REGULATING SERVICES** are benefits obtained from the natural control of ecosystem processes. Intact ecosystems keep disease organisms in check, maintain water quality, control soil erosion or accumulation, and regulate climate.
- **SUPPORTING SERVICES** include primary productivity (natural plant growth) and nutrient cycling (nitrogen, phosphorus, and carbon cycles). These services are the basis of the vast majority of food webs and life on the planet.
- **INFORMATION SERVICES** are functions that allow humans to interact meaningfully with nature. These services include providing spiritually significant species and natural areas, natural places for recreation, and opportunities for scientific research and education.

WHY VALUE ECOSYSTEM SERVICES?

Understanding and accounting for the value of natural capital assets and the ecosystem services they provide can reveal the economic benefits of investment in natural capital. Natural systems have only recently begun to be viewed as economic assets that provide economically valuable goods and services. Yet when these valuable goods and services are lost, people are more susceptible to disasters such as flooding, and they face costly expenditures to replace lost services, such as water supply. When the ecosystem services that nature previously provided for free are damaged or lost, they must be replaced by costly, taxpayer-funded built structures. Tampering with a watershed, for instance, can inhibit or even eliminate natural flood protection, which in turn requires replacing natural protective services with pipes, levees, or other infrastructure. In some cases, lost ecosystem goods and services are irreplaceable.

Just as understanding the condition, production capacity, and value of built assets was important to economic progress in the 1900s, so too can valuing and accounting for natural capital assets and the ecosystem services they provide better inform investments in the 21st century. The benefits of ecosystem goods and services are similar to the economic benefits typically valued in the economy, such as the services and outputs of skilled workers, buildings, and infrastructure. While some goods are already valued and sold in markets, many other ecosystem services go unvalued within traditional accounting. To illustrate, when the flood protection services of a watershed are lost, economic damages from floods can include job losses, infrastructure repairs, reconstruction and restoration costs, property damages, and deaths.

Today, economic methods are available to value natural capital and many non-market ecosystem services. When valued in dollars, these services can be incorporated into a number of economic tools, including benefit-cost analysis, accounting, environmental impact statements, asset management plans, conservation prioritization, and return-on-investment calculations. Inclusion of these values ultimately strengthens decision-making. When natural capital assets and ecosystem services are not considered in economic analysis, they are effectively valued at zero, which can lead to inefficient capital investments, higher incurred costs, and poor asset management.[20]

EFFECTS OF STAMP SANDS ON ECOSYSTEM SERVICES IN THE KEWEENAW PENINSULA

In summary, natural capital provides what we need to survive. Without healthy natural capital, many of the services that we freely receive could not exist. Once lost, these services must be replaced with costly built capital solutions, which are often less resilient and shorter-lived.

There is a scarcity of quantitative research on how stamp sands affect many of the ecosystem services provided in the region. However, there is much anecdotal, qualitative, or non-monetary research that suggest there is, in fact, a negative consequences of stamp sands to many of these services. The following sections frame stamp sand impacts in terms of ecosystem service impacts, including examples of each ecosystem service in the Keweenaw Peninsula with supporting anecdotes on how stamp sands may threaten the service being provided.

ENERGY AND RAW MATERIALS

Many areas covered by stamp sands are either unable to support vegetation or remain devoid of plants for long periods.[21] That tree stumps are still found in stamp sand piles suggests that the scarcity of vegetation is a function of the stamp sands (likely metal toxicity), rather than preexisting site conditions.[22] Today, two-thirds of the Keweenaw Peninsula is forested, with more than half of that managed for commercial forestry. Yet, in the 1800s (before mining began), almost 90 percent was forest. While it seems probable that stamp sands displaced at least some native forests, changes in land use associated with European settlement — including commercial forestry — are likely to have been far more significant.[70]

FOOD

Providing food is one of the most important functions of ecosystems. As an important spawning reef in the region, Buffalo Reef supports fishing industries in the region by providing habitat for commercially caught species. Buffalo Reef supports lake trout and whitefish populations within about 50 miles of the reef. Both species are important to commercial fishing activity in the area.[7] Wetlands in the region also support wild rice, waterfowl, furbearing animals, and other species that are important for subsistence purposes.[23] Blueberries, cranberries, and other wild plants are harvested as food sources upland. Where stamp sands cover natural soils and substrates causing contamination of soils and water, wildlife populations could decline and threaten food provisioning.[7]

MEDICINAL RESOURCES

Traditional foods, including fish, other wildlife, and plants, are medicine for Native American communities. Today, Native Americans experience higher-than-average rates of diseases, such as diabetes and heart disease and endure a significantly lower health status

SUBSISTENCE GATHERING

A powerful symbol of cultural identity, food is more than an object or product to be consumed. Tribal people, such as the Keweenaw Bay Indian Community (KBIC), maintain their cultural identities with their food practices, values, and beliefs. According to Phil Schneeberger, Michigan Department of Natural Resources Lake Superior Basin coordinator, "... if the reef is lost, over $1 million in tribal fishing jobs would also be lost. There would be additional impacts to the recreational fishery, as well as to local businesses that rely on locally caught fish" (Pepin, 2017). Being a subsistence fishing tribe, more than two-thirds of KBIC Tribal members report consuming local fish at least once a month, while 18 percent of the Tribe report eating local fish three or more times a week (Gagnon, Nankervis, & Johnston, 2013).

SOURCES AND FURTHER READING:

- *Gagnon, V.S., Nankervis, P., & Johnston, E. 2013. Keweenaw Bay Indian Community Wildlife and Natural Resources' Survey Report Keweenaw Bay Indian Community Natural Resources Department & Hatchery.*
- *Pepin, J. 2017. The century-long journey from Mohawk to Buffalo Reef. Michigan Department of Natural Resources.*

compared with all other Americans.[24, 25] Much of the current state of Native American health can be traced back to historical practices that have displaced tribes and limited their access to healthy and traditional foods. As a result, consumption of Native foods has decreased, and tribes increasingly rely on less-healthy, store-bought food. The spread of stamp sands in the study region further exacerbates the problem. Stamp sands harm native flora and fauna used for this purpose, thus reducing natural areas' ability to provide these traditional medicines.[70]

ORNAMENTAL RESOURCES

Ornamental resources are those plants and animals that are valued for ceremonial purposes, for clothing, jewelry, or handicrafts, and for decoration. Culturally significant species include paper birch (B. papyrifera), and northern white-cedar (T. occidentalis).[26] For other area residents, the native tussock sedge (C. stricta) has proven suitable for landscaping.[27] We have found no studies documenting stamp sand impacts on these resources.

WATER STORAGE

Lake Superior has the largest surface area of any freshwater lake in the world, accounting for almost 10 percent of the planet's fresh surface water (9.2B acre-feet).[26] Wetlands are also known to store substantial amounts of freshwater, but as stamp sand piles migrate, they fill these low-lying areas. Changes to the bathymetry along the Gay stamp sand pile have also been shown to reduce natural wave attenuation, which has allowed sediment from the lake to further fill wetlands, reducing their water-storage capacity.[21]

AIR QUALITY

Natural vegetation has the ability to clean the air, removing pollutants such as particulate matter that is harmful to human health, and to produce the oxygen we breathe. While the Michigan Department of Environmental Quality (MDEQ) has determined there is no risk of air exposure of stamp sands at the Gay tailings pile, the risk to people in other stamp sand infected areas is not as clear.[28] Stamp sands can become airborne due to human activity, including recreation, excavation work, or by vehicle traffic on roads where stamp sands were applied.[29]

BIOLOGICAL CONTROL

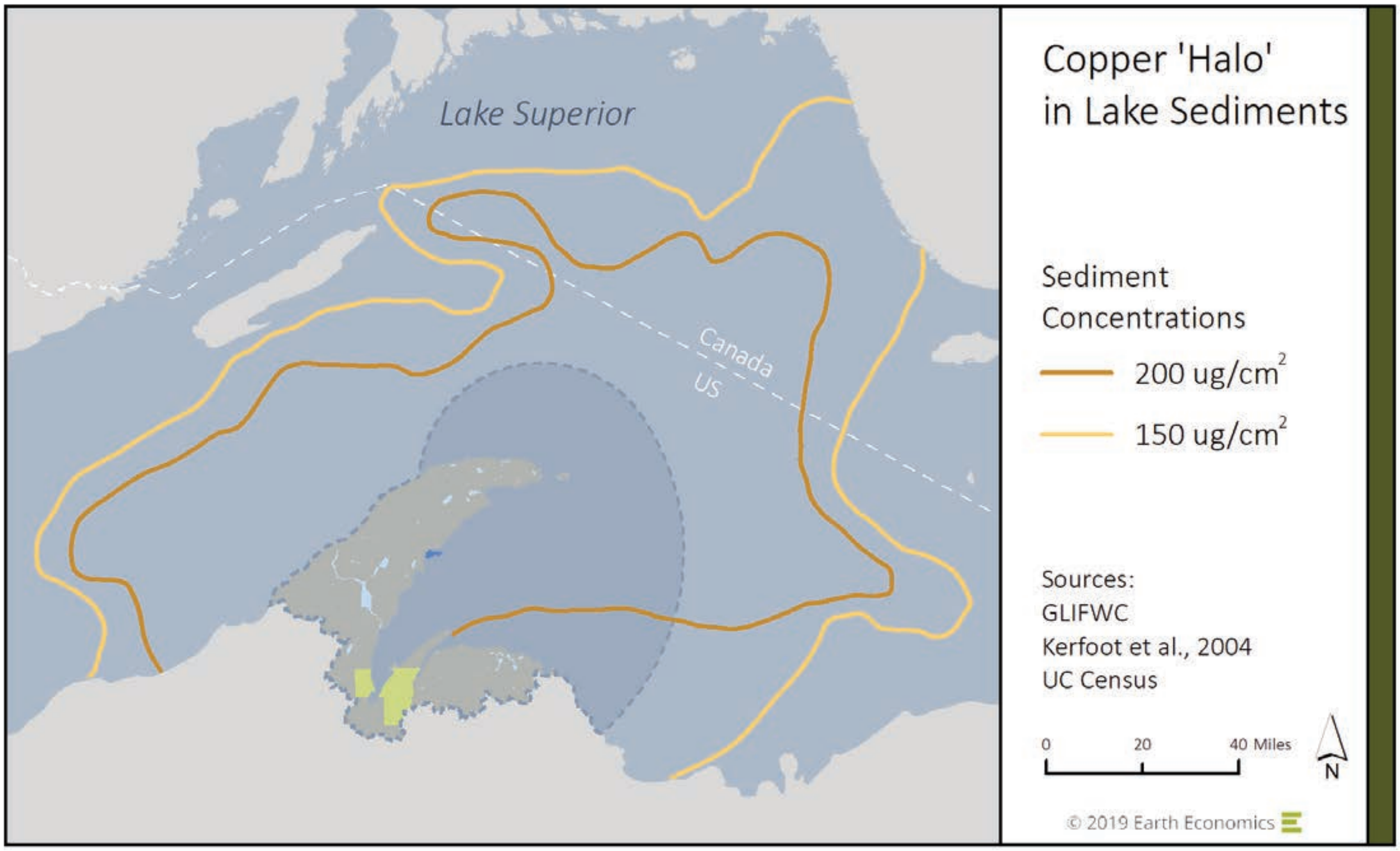
Resilient ecosystems are characterized by networks of interactions in which no single species is able to destroy or significantly degrade the ability of populations of other species to survive. In this way, both predator-prey relationships and disease resistance can promote a dynamic balance between populations and the resources required to sustain them. Stamp sands negatively impact both terrestrial and aquatic ecosystems at an immediate level.[8,21] Though there may be local effects (e.g., fish may shift feeding to areas richer in benthic invertebrates),[8] there is no evidence to suggest that these effects have led to trophic imbalances or disease outbreaks in Lake Superior.

CLIMATE STABILITY

Ecosystems help regulate local and global climate stability. This process is facilitated by the capture and long-term storage of carbon. Natural lands including forests, grasslands, and wetlands play essential roles in absorbing carbon and mitigating the damages of climate change.

Wetlands are especially important in global carbon dynamics since they can store large quantities of carbon in the soil. Great Lakes coastal wetlands like the ones located on the Keweenaw Peninsula can accumulate carbon at a rate of 1.42 tons of carbon per hectare, per year.[29] That carbon can then be stored in soil for centuries.

FIGURE 4 COPPER "HALO" IN LAKE BOTTOM SEDIMENTS PRODUCED BY COPPER MINING ON THE KEWEENAW PENNINSULA



KEWEENAW'S COPPER HALO

Around the Keweenaw Peninsula, the fine silt-clay portion of the stamp sands is transported through wave action and disperses far across the coastal shelf into Lake Superior. The deposition of stamp sands over deep-water sediments has formed a "copper halo" that illustrates anthropogenic changes in copper sediment concentrations throughout a large portion of Lake Superior. This stamp sand transport has been documented through LiDAR, MSS, high-definition sonar, as well as photography. Water samples at stamp-sand contaminated locations in Lake Superior have average copper concentrations 36 percent higher than natural sand, and 83 percent higher copper concentrations in surface water samples (Haak 2011). This "copper halo" around the Keweenaw Peninsula potentially influences Lake Superior – an important source of fresh water – in ways yet to be researched.

SOURCES AND FURTHER READING:

- *Haak, D. M. 2011. Impact of copper mine tailings (stamp sand) on survival and development of aquatic organisms near Gay, Michigan (Master's Thesis). Michigan Technological University.*
- *Kerfoot, W.C., Hobmeier, M.M., Yousef, F., Green, S.A., Regis, R., Brooks, C.N., ... Reif, M. 2014. Light detection and ranging (LiDAR) and multispectral scanner (MSS) studies examine coastal environments influenced by mining. International Journal of Geo-Information 3(1): 66-95.*
- *McDonald, C.P., N.R. Urban, J.H. Barkach, and D. McCauley. 2010. Copper profiles in the sediments of a mining-impacted lake. Journal of Soils and Sediments 10: 343-348.*

DISASTER RISK REDUCTION

The ability of some ecosystems to resist the movement of soil, water, or wind is often a critical factor in reducing the negative impacts of widespread erosion, flooding, and storms. To the degree that the deposition and migration of stamp sands has filled and degraded wetlands, those lands' contribution to flood protection has been diminished. Similarly, the movement of stamp sands along coastal areas has been shown to reduce natural wave attenuation, leading to increased erosion along affected coastlines.[21]

POLLINATION AND SEED DISPERSAL

Pollination is essential for most of the plants in the world, including agricultural crops, trees, and flowers. Insects, birds, mammals, and the wind transport pollen grains to fertilize plants. People depend on pollination directly for food and fiber (such as wood, paper, and cloth), and indirectly as part of ecosystem productivity. Many plant species would go extinct without animal- and insect-mediated pollination. Pollination services by wild animals are also crucial for crop productivity for many types of cultivated foods, enhancing the basic productivity and economic value of agriculture. Notably, some plants have only a single species pollinator. The importance of wild pollinators to food crops means that wild habitats near croplands are necessary to provide sufficient habitat to keep populations of pollinators intact.

SOIL FORMATION

Soils are initially formed through physical, chemical, and biological weathering, but also move from one location to another by gravity, wind, and water. As a whole, these processes can increase the availability (and quality) of soils in a given location. The higher metal content of stamp sands has been shown to negatively affect plant and microbe metabolisms.[22] Wetlands can be important for soil formation sites, as deep-rooted plants draw minerals from subsoils and make them available for other surface plants. Stamp sands that migrate into wetland areas may diminish the biological basis of soil formation for those sites, but this potential is not well-studied.[21]

View toward Lake Superior in October 2017 from a flooded property north of the break wall at Grand Traverse Harbor. Storm-force winds push water onshore. Because stamp sand deposition has changed the bathymetry of the shoreline, waves do not dissipate as quickly as they do on the natural silica sand beaches. Image credit: Robert Regis of Northern Michigan University.

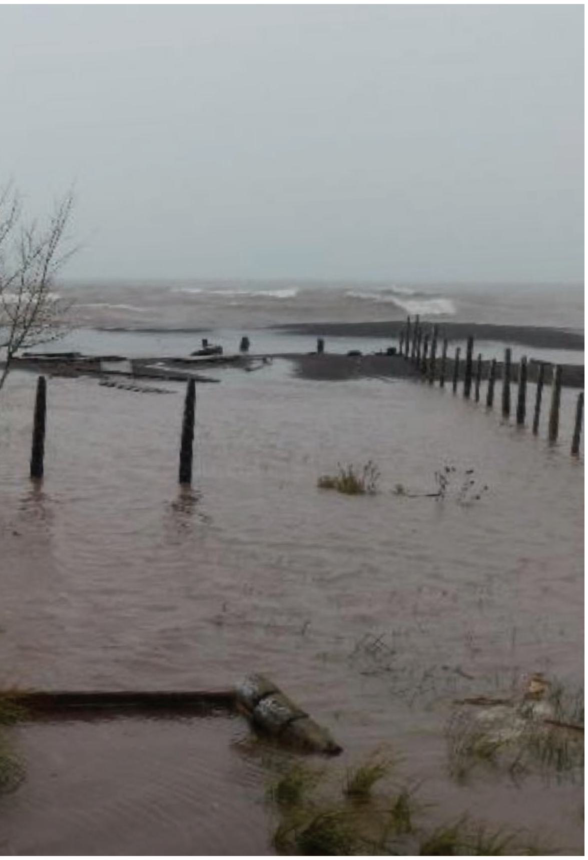
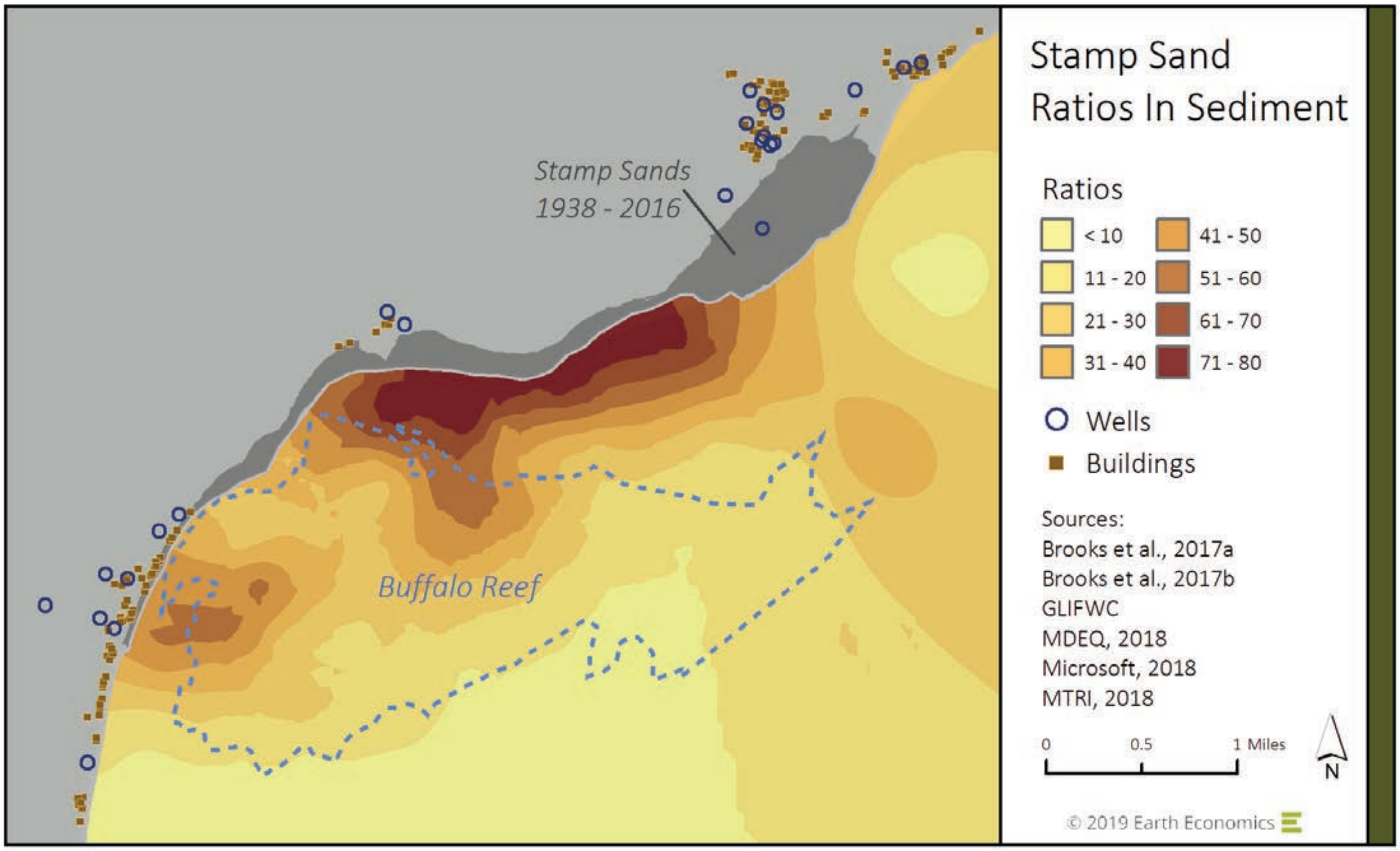


FIGURE 5 STAMP SAND PERCENTAGES FROM 2013 & 2016 PONAR SAMPLES



WATER QUALITY AROUND BUFFALO REEF

In stamp sands, copper occurs at levels considered toxic for aquatic ecosystems. Higher concentrations of stamp sands are also associated with a lower density of benthic organisms. Copper exposure in humans can occur through many forms, both in toxic and nontoxic levels. The data shown in Figure 5 confirms copper contamination of the lakebed sediment around Buffalo Reef. The highest concentration of stamp sands, and the corresponding concentrations of copper are located along the beach.

SOURCES AND FURTHER READING:

- *Agency for Toxic Substances and Disease Registry. (n.d.) Center for Disease Control. Retrieved on February 11, 2019 from https://www.atsdr.cdc.gov/toxprofiles/tp132-c2.pdf*
- *Mausolf, G., Perkey, D., Gailani, J., Kerfoot, W.C., et al. (n.d.) Overview of Environmental Issues (white paper).*
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SOIL QUALITY

Soil quality is critical for plant growth and maintaining vegetative communities. Soil biota can remediate contaminants and keep soils healthy. When stamp sands cover natural areas, it turns them into biological dead zones for plants and animals, meaning nothing can survive on stamp sand-contaminated sediment, including those flora and fauna that promote healthy soils.[10]

SOIL RETENTION

Wind and water move stamp sand particles through both terrestrial and aquatic environments. While stamp sands are not living soils, their particles — especially small, silt-sized grains — can be deposited significant distances from their sources. The deposition of stamp sands not only smothers aquatic habitats, the chemical composition of those displaced particles is known to be toxic to benthic organisms.[21,30,10] Moreover, bathymetric changes caused by the migration of the Gay stamp sands has reduced natural wave attenuation, leading to increased coastal erosion during storms.[21]

WATER QUALITY

Ecosystems have the ability to process waste and render it harmless to humans. For example, natural vegetated areas provide valuable water filtration services that improve water quality for human and wildlife consumption, as well as for habitat purposes. These services remove a variety of pollutants and can maintain a level of water quality that is relatively clean, although some contaminants do still require mechanical filtration for purification of potable water. Stamp sands are known to leach copper and other metals into the water column,[31] creating toxic conditions for insects, zooplankton, and bacteria.[22] While testing near the Gay stamp sand pile showed levels remained below hazardous levels for human physical contact, use of wells for human consumption was considered to pose an unacceptable risk because of detected concentrations of aluminum and manganese higher than the drinking water criteria.[21] Sustained ingestion of copper can produce gastrointestinal problems and liver disease, and safe exposure levels are lower for children, especially during critical developmental stages.[2] The toxicity of stamp sands may also hinder the growth of vegetation that naturally filters water.[21]

WATER CAPTURE, CONVEYANCE, AND SUPPLY

Plant communities capture precipitation for their own metabolic needs (releasing it through transpiration) but may also facilitate infiltration into groundwater. To the degree that stamp sands eliminate plant life (temporarily or permanently), they can diminish these processes. But since sand is highly pervious, it is also likely to allow precipitation to pass into groundwater – indeed, the potential for stamp sands to contaminate

DREDGING COSTS

Grand Traverse Harbor has been dredged four times in recent history to prevent stamp sands from entering the harbor channel to allow for easy boat access. Dredging must be completed every three to seven years due to drifting sediment and stamp sands. The cost of dredging in 2003, 2009, 2017, and 2018 was $122,900, $280,900, $246,230 and $3.1 million[i], respectively (USACE, 2014). Within the last 15 years, more than $3.7 million has been spent on dredging Grand Traverse Harbor at an average cost of $250,000 per year. This expense is expected to continue for the foreseeable future unless a stamp sand containment option is implemented. According to Steve Casey, district supervisor for the Michigan Department of Environmental Quality's Water Resources Division, dredging only temporarily buys time for the harbor. "We need to develop a long-term, adaptive management plan, a solution, for the Gay stamp sands problem," he explained.

SOURCES AND FURTHER READING:

[i] *Costs for 2018 include dredging the trough.*

- *"Grand Traverse Bay Dredging Gets Green Light." 2018. Dredgingtoday.com. Retrieved on February 20, 2019, from https://www.dredgingtoday.com/2018/03/26/grand-traverse-bay-dredging-gets-green-light/*
- *DNR Task Force and Steering Committee. Retrieved on February 20, 2019, from https://www.michigan.gov/dnr/0,4570,7-350-79136_79236_80245_85494-461161--,00.html*

STAMP SANDS AT GRAND TRAVERSE HARBOR. IMAGE CREDIT: MICHIGAN DEPARTMENT OF NATURAL RESOURCES.

groundwater is a key concern, especially where residents rely on wells for drinking water.[1]

NAVIGATION

The Great Lakes Navigation System is a complex deep-water navigation system that supports thousands of miles of traffic routes.[32] There are 140 harbors on the U.S. side of the Great Lakes, including those for recreational and commercial use. Navigation is an important economic driver in the region — an average of 145 million tons of commodities are transported between Great Lakes ports each year, and great lakes traffic accounts for 10 percent of all U.S. waterborne traffic.

Three recreational harbors support waterborne traffic in MI4 — Lac La Belle Harbor, Keweenaw Waterway, and Grand Traverse Bay Harbor. Recreational and charter fishing boats operate out of these harbors. Lac La Belle Harbor and Keweenaw Bay are also important harbors of refuge during storm events. The Keweenaw Waterway is a part-natural, part-artificial waterway allowing passage through the peninsula. It includes a shipping lane, and historically allowed freighters to haul copper from the many mines on the peninsula and goods to be shipped to those mines.

Stamp sands threaten the navigational capacity at Grand Traverse Bay — stamp sands are beginning to wash over the breakwater of the harbor and, in a few years, will migrate past the breakwater.[7] The harbor contains a boat launch and day-use dockage on two piers. The sands will fill the channel, requiring additional dredging for navigational use.

HABITAT

Ecosystems provide shelter from predators, food availability, and appropriate living conditions for wildlife. Nursery areas are a subset of habitats where juveniles of species occur. Species use nursery areas to spawn, lay eggs, and rear their young. Without the appropriate habitat, species populations that are integral to the provision of ecosystem services would die out.

Buffalo Reef is one of 115 fish spawning reefs in Lake Superior, and one of 15 spawning reefs in the study area. The reproductive potential of Buffalo Reef is estimated to be excellent.[12] It accounts for a quarter to a third of all lake trout yield in the Michigan waters of Lake Superior, but many other species use the reef as well. Waterways and wetlands also provide important habitat for terrestrial and aquatic wildlife. South of Grand Traverse Harbor are natural white sand beaches which still have the original morphology. These natural beaches provide important foraging habitat for many shorebirds, including nesting habitat for federally endangered species such as the piping plover.[34]

Stamp sands cause habitat loss by covering these natural areas through erosion. Stamp sands are beginning to migrate onto Buffalo Reef, currently covering one-quarter of its surface. Not only are the stamp sands toxic to aquatic organisms, this movement of stamp sands is also filling in and destroying key whitefish nursery areas located in shallow water between Buffalo Reef spawning areas and the shore. It is estimated that within 10 years, 60 percent of the Reef will be covered by at least one inch of stamp sands.[35] If these sands are allowed to erode further, they will eventually reach the natural beaches south of Grand Traverse Harbor, covering and changing the natural morphology of this beach habitat. Finally, waterways and wetlands have been filled and other areas are also at risk of being filled by stamp sands.

AESTHETIC INFORMATION

Stamp sands are black in color, in stark contrast to the native white sand beaches of the Upper Peninsula. As property values are often influenced by its viewshed, these are often used in determining the importance of aesthetic information of ecosystems. There is a public perception that stamp sands are “inferior” to native beaches, which is believed to impact property values for nearby homes.[36,37] Aesthetic appreciation of nature is not limited to homeowners, of course. Anyone can experience this service by simply enjoying the views around them. Unfortunately, published research on this subject is extremely limited, and public perceptions on aesthetic impacts of stamp sands are complicated.

LAKE TROUT CREDIT: K. STEIGER MEISTER, UNITED STATES FISH AND WILDLIFE SERVICE MIDWEST REGION

WHITE FISH CREDIT: BILL MATTES, GLIFWC

WHITE FISH CREDIT: BILL MATTES, GLIFWC

STAMP SAND EFFECTS ON FOOD WEBS

In stamp sands, copper occurs at levels considered toxic for aquatic ecosystems. Higher concentrations of stamp sands equal a lower density of benthic organisms, which equates to an unhealthy environment. In 2016, a U.S. Army Corps of Engineers and Michigan Technological University survey found that 35 percent of the 2,200-acre Buffalo Reef was already covered in stamp sands. Wisconsin Department of Natural Resources estimates the entire Buffalo Reef, a major fish habitat, could be completely covered in less than 50 years. Complete coverage would cause the reef to die, which would render it no longer viable spawning ground. Data suggests that eroding stamp sand will contribute more copper to Lake Superior than the wave-washed stamp sand (Haak, D. 2011). This, in turn, has the potential to harm fish species, particularly those using Buffalo Reef as a spawning site. Should fish populations lose Buffalo Reef and the surrounding area, generations of fish would be lost and a severe break in the food web would occur.

SOURCES AND FURTHER READING:

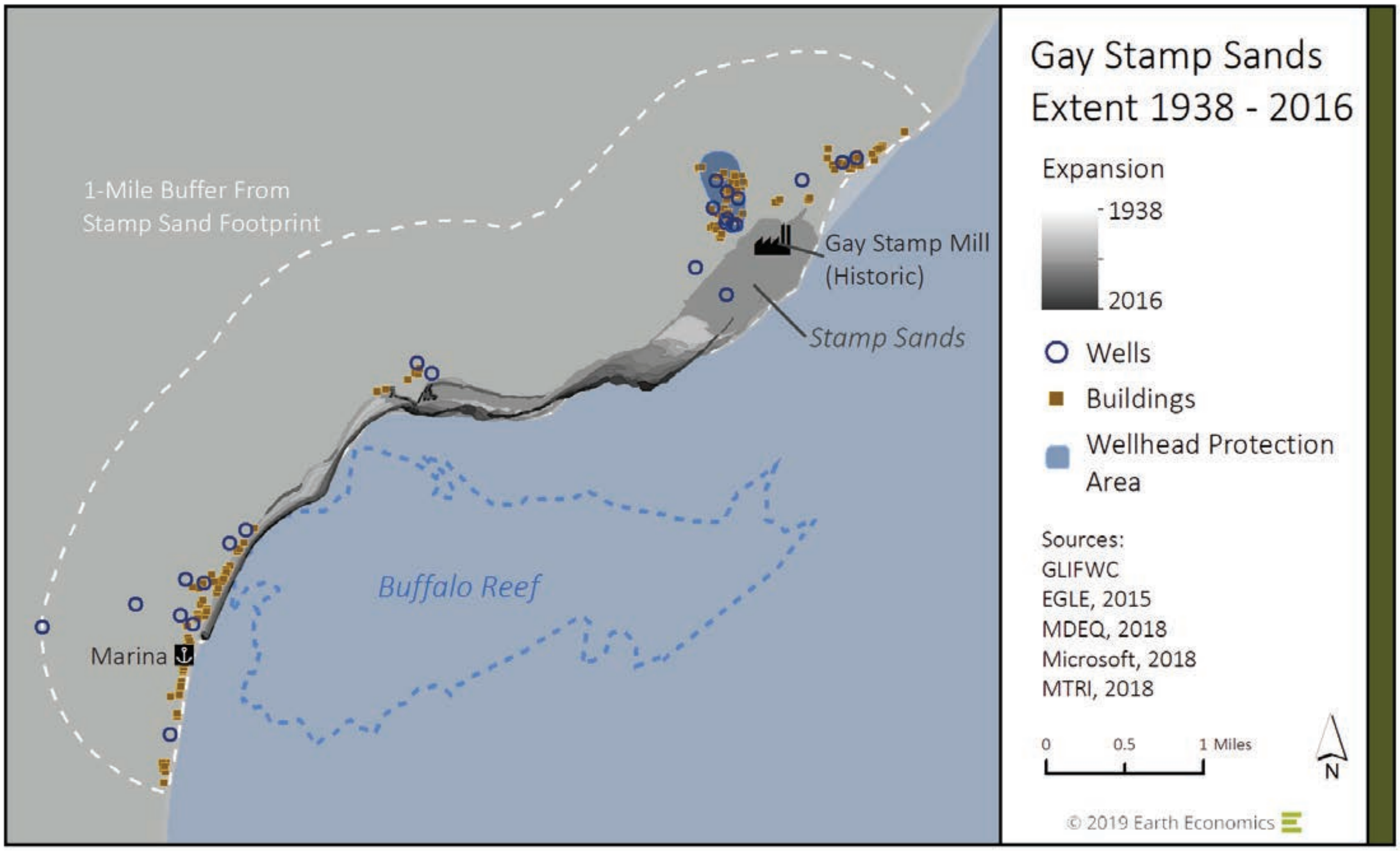
- *Haak, D.M. 2011. Impact of copper mine tailings (stamp sand) on survival and development of aquatic organisms near Gay, Michigan (Master's Thesis). Michigan Technological University.*
- *Michigan Department of Natural Resources. 2019. "History of Buffalo Reef." Retrieved on February 25, 2019 from https://www.michigan.gov/dnr/0,4570,7-350-79136_79236_80245_85494-461163--,00.html*

STAMP SAND BEACH *CREDIT: ESTEBAN CHIRIBOGA, GREAT LAKES INDIAN FISH AND WILDLIFE COMMISSION.*

STAMP SANDS AND THE HOUSING MARKET

It is not uncommon for public discussions about stamp sands to turn to their possible effect on nearby property values. A 2007 study of the Great Lakes region (more than 11 million households) estimated that remediating all official Areas of Concern (e.g., Torch Lake) could raise home values in the broader region $12 billion to $19 billion — and more than $50 billion if commercial properties were included (Austin 2007). But the process by which AOCs would be remediated is neither simple or straightforward; cleanup efforts have faced resistance from local officials, concerned about potential effects on tourism and property values (EPA 2018). Some have also expressed concern that removing or capping stamp sands would destroy local mining history (Urban et al. 2018). Still, remediation presents a significant economic opportunity to the Keweenaw Peninsula, which has seen waterfront property values rise five-fold over the past two decades. To the degree that removing stamp sand deposits has the potential to expand the supply of buildable sites, remediation may produce direct economic benefits to the local real estate market (HCPC 2018). Unchecked Gay stamp sand migration is believed to threaten existing home values (Neese 2016).

FIGURE 6 LOCATION OF BUILDINGS WHOSE VIEWSHEDS COULD BE IMPACTED BY STAMP SANDS AT GAY, MICHIGAN



SOURCES AND FURTHER READING:

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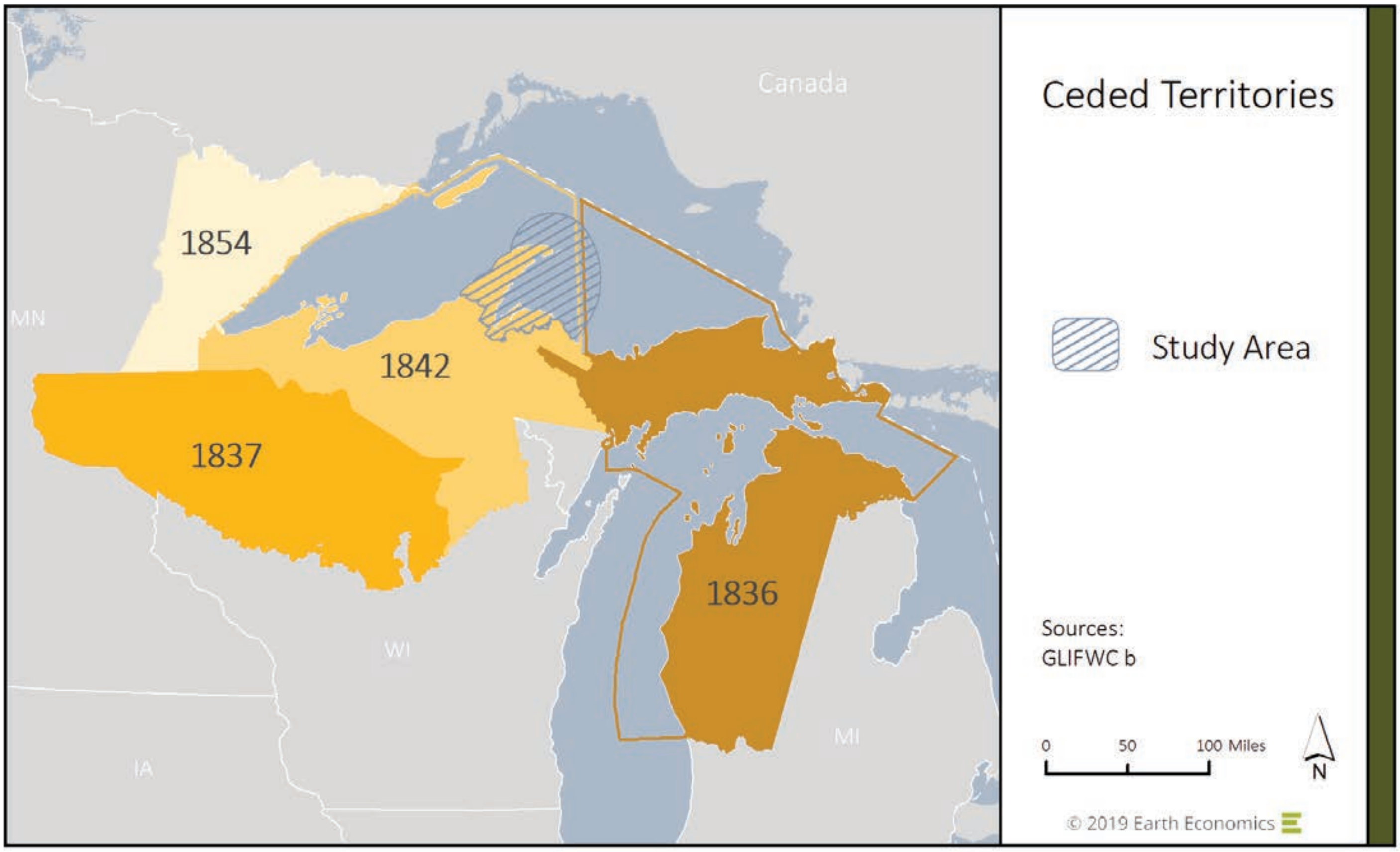
- *EPA. 2018. EPA Requesting Property Owners to Add Deed Restrictions (Public Announcement), Torch Lake Superfund Site. US Environmental Protection Agency, Houghton County, MI.*
- *HCPC. 2018. Houghton County Master Plan (Master Plan). Houghton County Planning Commission, Houghton County, MI.*
- *Neese, G. 2016. UP Township Needs Help with Shifting Stamp Sands. The Daily Mining Gazette.*
- *Urban, N.R., MacLennan, C.A., & Perlinger, J.A. 2018. An Integrated Assessment of Torch Lake Area of Concern (Great Lakes Research Center No. 53). Michigan Technological University.*

FIGURE 7 MAP OF CEDED TERRITORIES



CULTURAL VALUE

Many natural areas have special, spiritual importance to tribes. The study area lies in the 1842 ceded territory, where tribes reserve rights to fish, hunt, and gather in the land and water. The Keweenaw Bay Indian Community is also approximately 25 miles south of Buffalo Reef. Courts have also found that tribes reserved rights to fish in Lake Superior by virtue of the location of their reservations on the shore of the lake itself. It must be emphasized that these ceded territory rights were not given or granted by the United States, but are sovereign rights that were reserved by the tribes for themselves. The exercise of these rights was and continues to be fundamental to the tribes' culture and way of life and explains their insistence on explicitly reserving them in the treaties. Stamp sands threaten this ancestral relationship between people and the environment, and the reserved treaty rights in the area.[70]

SCIENCE AND EDUCATION

Ecosystems and landscapes can be important to both science and education, to the degree that they are the subject and context for study. While the dynamics of stamp sand piles — and their potential to affect surrounding ecosystems and populations — is of significant concern for many area residents, the scientific literature remains quite limited. Aside from the Michigan Tech Research Institute, current scholarly interest in the stamp sands and their impacts appears small.

RECREATION AND TOURISM

Attractive landscapes, clean water, and wildlife populations form the basis of the recreational experience. Fishing, swimming, bird-watching, and hunting are all activities that can be enhanced by healthy natural capital. A strong recreational fishery is maintained in the region, as well as many miles of beach that allow a variety of recreational activities. However, stamp sands already cover miles of shoreline in the area. The Gay pile, alone, covers about 4 miles of shoreline. If these tailings eliminate local fish populations, they will eliminate angling as well. Furthermore, as the sands migrate south of the break wall at Grand Traverse harbor, not only will it be costly to dredge the navigation channel at the harbor for marine traffic, but the public beach access south of the harbor would be covered by stamp sands.

CREDIT: ESTEBAN CHIRIBOGA, GLIFWC

THE RECREATION MARKET

In 2017, tourism expenditures within the four counties adjoining the Buffalo Reef study area (i.e. Keweenaw County, Houghton County, Baraga County, and Marquette County) totaled more than $332 million and accounted for 4,185 direct jobs providing $282 million in labor income. Buffalo Reef is one of three major spawning reefs in the mid-Lake Superior area that accounts for roughly one-third of lake trout and whitefish spawning (Goodyear et al. 1982). Buffalo reef contributes to the fishery (tribal, subsistence, recreational) in terms of population, harvest and genetic resiliency. Buffalo Reef is therefore a critical component of Lake Superior's fish habitat (Larimer 2018). These numbers are noteworthy and depend on the overall ecological health of Buffalo Reef and the greater Lake Superior region.

SOURCES AND FURTHER READING:

- *Goodyear, C.S., Edsall, T.A., Ormsby-Dempsey, D.M., Ross, G.D., and Polanski, P.E. 1982. Atlas of the spawning and nursery areas of Great Lakes fishes. Vols. 1-13. U.S. Fish and Wildl. Service, Wash. D.C. FWS/OBS-82/52.*
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- *Larimer, W. 2018. Permit Issued for Removal of Stamp Sands. International Dredging Review. Retrieved on January 15, 2019, from https://www.dredgemag.com/2018/05/14/permit-issued-for-removal-of-stamp-sands/*

VALUATION AND NON-MARKET ECOSYSTEM SERVICES

METHODOLOGY

The economic value of ecosystem services in this section is estimated both on an annual basis and as an asset value. For many of the ecosystem services, we take a land cover-based approach, which calculates the value of ecosystem services per acre depending on the ecosystem type of that acre (e.g., whether each acre is grassland, forest, or wetland). Therefore, the first step in determining these benefits is to identify what land cover exists throughout the study area. Next, we create a dataset of ecosystem service values using the benefit-transfer method. These datasets are combined to produce the final valuation results. Valuation methods not using this acre-based method are also described below.

LAND-COVER ANALYSIS

We used Geographic Information Systems (GIS) data to calculate the extent of each land-cover type (e.g., forests, wetlands, stamp sands) within the study area, which was itself defined based on HU12 units (subwatersheds) within the Watershed Boundary Dataset.[38] The base land cover for this analysis is the most recent National Land Cover Database (NLCD) dataset,[39] combined with the National Hydrology Dataset,[40] spatial data on Michigan's commercial forest land,[41] the Gay stamp sand pile, and Buffalo Reef. Building footprints within the study area are from Microsoft's U.S. Building Footprints dataset.[43]

THE BENEFIT TRANSFER METHOD

This report uses the benefit-transfer method (BTM) to identify appropriate economic values for ecosystem services provided by Buffalo Reef and surrounding areas. Benefit-transfer methodology, broadly defined as "… the use of existing data or information in settings other than for what it was originally collected," is frequently used to indirectly estimate the value of ecological goods or services.[44] BTM is often the most practical option available to quickly generate reasonable estimates at a large scale and at a fraction of the cost of conducting local, primary studies. This methodology is widely used in the field of ecosystem service valuation.[45]

The BTM process is similar to a home appraisal in which the value and features of comparable, neighboring homes (e.g., two bedrooms, garage, one acre, recently remodeled) are used to estimate the value of the home in question. In our analysis, the BTM process identifies previously published ecosystem service values from comparable ecosystems and transfers them to our study site.[46] As with home appraisals, the BTM results can be somewhat rough, but they quickly yield values appropriate for policy work and analysis.

Primary studies were selected from Earth Economics' Ecosystem Valuation Toolkit (EVT). The EVT is one of the most robust repositories of published, peer-reviewed primary valuation studies, reports, and gray literature on the value of ecosystem services. The EVT contains more than 200 data elements associated with each value estimated in a study, including study scale and location, a detailed description of the ecosystem and ecosystem service assessed, methodology used, and type of economic value produced. In addition to the EVT, a wealth of information on biophysical carbon sequestration and storage rates can be found in published scientific literature for most ecosystems. This analysis combines biophysical carbon sequestration from these studies and the social cost of carbon to provide accurate estimates of the economic value of climate stability.

The BTM process begins by selecting appropriate ecosystem service values within this database. Before a value is selected for inclusion in the valuation dataset, we examined the degree of correspondence, or the similarity of location and socioeconomic indicators from the primary data and the applied study region.[48] Conducting a defensible benefit transfer requires careful thought, research, and choices, particularly with regard to the transferability between the study site (the site of the original published literature) and the transfer site (the site to be valued through benefit transfer). To reduce double-counting issues, we used a set of strict criteria based on best practices outlined in the valuation literature. The following criteria apply to the transferability of literature values from the EVT to the study site.

Similarity of ecosystem goods and services: The basis of a valid transfer lies with the same types of uses or non-use connections being present at the study site and the transfer site. The similarity of uses, goods, and services at the study and transfer sites is critical for a valid transfer.[48,49,50,51]

Similarity of ecosystems: Like the previous criterion, the similarity between ecosystems at both sites is important. Errors associated with benefit transfers are lessened as the similarity between the study site and the transfer site increases.[46,48,52] Only literature conducted on ecosystems occurring on land-cover types existing in the study area were included in the dataset.

Literature is of sound methodology: The original valuation methodology of a study must be assessed to ensure quality of the original valuation estimate. Studies must meet data quality conditions, including adequate sample size, sound empirical technique, and the use of accepted economic methodologies.[48,49,53,54] All studies included in the dataset undergo a double review process that assesses validity of the methodology used.

Additionally, studies using primary valuation methods were prioritized for inclusion into our dataset over those using secondary methodologies (i.e., methodologies that use data not collected by the researcher publishing the results, such as another benefit transfer study or meta-analysis). Where gaps existed in the primary literature, a secondary valuation study was used.

Transferability of ecosystem services: Some ecosystem services are more easily transferred than others. Ecosystem processes with large or even global benefits, such as carbon sequestration, are highly transferable. Other services with more local effects, like habitat for specific species or aesthetic views, are not as transferable. Table 2 portrays the transferability of each ecosystem service.

Regardless of transferability, ecosystem service values from studies conducted within the study area are given priority over other estimates. However, many gaps exist in the valuation literature in these areas, in which Earth Economics utilized case studies from other parts of the United States and Canada. For services with low transferability, we transferred values only from studies conducted within Michigan, Minnesota, and Wisconsin. We assessed values representing services with medium and high transferability on a case-by-case basis for relevance when derived from similar regions outside of the study area.

TABLE 2 TRANSFERABILITY OF ECOSYSTEM SERVICES

Ecosystem Service	Transferability Across Sites
Aesthetic Information	Low
Air Quality	High
Biological Control	High
Climate Stability	High
Cultural Value	Low
Disaster Risk Reduction	Medium
Energy and Raw Materials	High
Food	High
Habitat and Nursery	Low
Medicinal Resources	Low
Navigation	High
Ornamental Resources	Medium
Pollination and Seed Dispersal	Medium
Recreation and Tourism	Low
Science and Education	High
Soil Formation	Medium
Soil Quality	Medium
Soil Retention	Medium
Water Capture, Conveyance, and Supply	Medium
Water Quality	Medium
Water Storage	Medium

Adapted from: Liu, S., Costanza, R., Farber, S., Troy, A. 2010. Valuing ecosystem services: Theory, practice, and the need for a transdisciplinary synthesis. Annals of the New York Academy of Sciences 1185: 54–78.

Similar demographics and cultural attitudes: Benefit transfers are more accurate when the demographic characteristics, attitudes, and beliefs of consumers at the transfer and study sites are similar.[49,55,56] It is difficult to determine cultural attitudes of sites from published valuation literature, as this is not often recorded in academic research. Also, this information is not often recorded. To partially address these effects, we limited the geographic range of valuation studies under the assumption that geographies in proximity have similar cultural attitudes toward environmental services. Therefore, we considered for the dataset only valuation studies from the United States, Canada, or in the case of highly transferable services, global averages.

Using criteria outlined above, we selected the most appropriate values for each land cover and ecosystem services combination. We excluded from the valuation dataset studies that did not meet the five criteria. Appendix B lists the studies included in the analysis.

This ecosystem services valuation analysis uses the low and high values for each combination to present a range in valuation estimates. The selected values represent variability in the location, methods, and socioeconomic characteristics of the primary studies. Combining these values into a single dataset produces the best available approximation of ecosystem services values based on available primary literature. This approximation will improve as new primary analyses become available in the future. Individual primary study values are adjusted and standardized for units of measure, inflation, and land-cover classification to generate an "apples-to-apples" comparison. The unit of measure for this analysis is dollars per acre, per year, adjusted to 2017 United States dollars using the World Bank GDP inflation and deflation factors.

Table 3 summarizes the land cover/ecosystem services combinations that could be valued based on available, suitable primary literature. A combination not included in the analysis does not necessarily mean that the ecosystem does not produce that service or that the service is not valuable, but rather shows a lack of primary, peer-reviewed data for that service. For example, shrubland provides highly valuable services such as recreation, habitat, and carbon sequestration, yet there are few valuation studies of this land-cover type. Caution should be exercised when comparing total ecosystem services values across land covers, as the difference in values could stem from an information gap rather than true differences in ecosystem services value. Continued investment in local primary valuations is an ongoing need necessary to fill in this valuation's gaps. See Appendix A for a detailed discussion on study limitations.

Earth Economics valued most ecosystem services using the acre-based land-cover analysis and transferred point values using the benefit-transfer process. The valuation of some services differed slightly based on available data and are described in the following sections.[ii]

TABLE 3 ECOSYSTEM SERVICES AND LAND COVER COMBINATION VALUED IN THE STUDY AREA

ECOSYSTEM SERVICES BY LAND COVER TYPE	OPEN WATER	DECIDUOUS FOREST	EVERGREEN FOREST	MIXED FORESTRY	COMMERCIAL FORESTRY	SHRUB/ SCRUB	GRASSLAND/ HERBACEOUS	PASTURE/ HAY	CULTIVATED CROPS	WOODY WETLANDS	EMERGENT HERBACEOUS WETLANDS
Aesthetic Information	●										
Air Quality		●	●	●			●				
Biological Control		●	●	●	●	●		●	●		
Climate Stability		●	●	●		●		●		●	●
Disaster Risk Reduction										●	●
Energy & Raw Materials					●						
Existence Value											●
Food								●	●		
Habitat											●
Pollination & Seed Dispersal		●	●	●		●	●				
Recreation & Tourism	●						●			●	●
Soil Formation						●		●	●		
Soil Retention						●	●	●	●		●
Water Capture, Conveyance, and Supply		●	●	●	●					●	●
Water Quality		●	●	●			●			●	●
Water Storage										●	●

● = VALUE COMBINATION INCLUDED IN ESV DATASET

STAMP SAND ENCROACHMENT AFTER STORM
CREDIT: CHARLES KERFOOT

BUFFALO REEF HABITAT VALUE

We estimated the habitat value of Buffalo Reef through the replacement cost method. The replacement cost method estimates the value of environmental goods and services by assuming a substitute can be found with a human engineered system that could replace the good or service being estimated. For this method to be valid, that substitute must: provide similar functions to the ecosystem service being estimated; be the least-cost alternative; and, be the alternative the costs of which beneficiaries would be willing to pay for if the service were no longer available. The method assumes that the service would be worth at least what people would pay to replace the service.

For Buffalo Reef, we assume its habitat value may be approximated by estimating the restocking costs for the lake trout and whitefish fisheries supported by the reef.[iii] This includes both the tribal and state commercial fisheries, as well as the recreational fishery. First, we estimated the average annual harvest from those three fisheries that are supported by the reef. We gathered these data from GLIFWC and the Michigan DNR creel reports.[57] Next, we estimated the number of harvestable pounds that could be lost due to the destruction of habitat on Buffalo Reef due to stamp sands. We translated this value into the number of adults and yearlings needed to replace those lost to that habitat destruction. Finally, we estimated the replacement costs of these fish by using hatchery production costs estimated for the Great Lakes region.[58]

AESTHETIC VALUES OF LAKE SUPERIOR

Benefits of viewsheds are commonly valued through housing price analysis in the literature. The basic idea is that these prices are related to its characteristics, such as the number of rooms, square footage, etc., but also whether that home has a view of some resource. The impact of shorelines and water bodies has been well-studied in the Great Lakes region, and there is much literature available for benefit transfer. To quantify the benefits of the aesthetic value of ecosystem services, we determined the number of homes in the study area and applied appropriate dollar-per-household values from the literature.

Earth Economics estimated the number of coastal homes by identifying structures larger than 500 square feet that are also located within one mile of Lake Superior.[43] This approach was intended to exclude smaller outbuildings (e.g., garages, boat houses), and it was visually confirmed from a cursory review of satellite imagery. Once the number of households that may benefit from aesthetic views of Lake Superior was established, we used benefit transfer to identify an appropriate estimate of property value increase due to proximity to shorelines. These values are often difficult to translate into a per-acre value, hence the need for valuation of different units for this service. We measured this value in dollars per household per year and applied this measurement to the appropriate number of households to find an annual estimate of aesthetic views of Lake Superior.

ASSET VALUATION

Asset values provide a measure of the expected benefits flowing from the study area's natural capital over time and are useful for comparing benefits produced at various points in the future. The asset value of built capital can be calculated as the net present value of its expected future benefits. Provided Buffalo Reef and its

[ii] Methodology and results for recreational angling may be found in Appendix C. While this ecosystem service value is included in the total results for the study area, details are presented separately since similar values for tribal fishing could not be included. Placing economic values on important cultural activities and resources can be inappropriate and controversial. Regardless of dollar value, subsistence rights should always be the primary consideration.

[iii] Other species of fish utilize Buffalo Reef and the waters of the study area for habitat. We chose to focus on these two species for the valuation exercise because of their importance to fishing in the area. However, if Buffalo Reef habitat were to be lost, other species of fish would be impacted as well.

surrounding areas do not degrade further, the annual flow of ecosystem services will continue into the future, and those benefits can be included in the asset value. In order for this to be accomplished, a discount rate must be used.

Discounting allows for sums of money occurring in different time periods to be compared by expressing the values in present terms. In other words, discounting shows how much future sums of money are worth today. Discounting is designed to consider two major factors:

1. **Time preference:** People tend to prefer consumption now over consumption in the future, meaning a dollar today is worth more than a dollar received in the future.

2. **Opportunity cost of investment:** Investment in capital today provides a positive return in the future.

However, due to disagreement among experts, the rate at which natural capital benefits should be discounted is uncertain.[59,60] Public and private agencies vary widely in their standards for discount rates. The choice of discount rate is critical, however, as it heavily influences the outcome of the present values of benefits that occur over a long period of time. This report uses two discount rates: 2.75 percent, which is certified by the U.S. Department of the Treasury for water-based projects,[61] and a 0 percent discount rate. The use of multiple discount rates allows for comparison of the sensitivity of the asset value calculated.

Net present values can be calculated over different timeframes depending on the purpose of the analysis and nature of the project. In the case of natural capital valuations, ecosystems, if unimpaired, are self-maintaining, display long-term stability, and are continuously productive. We chose a 100-year timeframe to reflect the longevity of ecosystems' stability and productivity. If kept healthy, Buffalo Reef and the surrounding natural areas can provide benefits for much longer than 100 years.

The asset value calculated in this report is based on a snapshot of the current land cover, consumer preferences, population base, and productive capacities. As such, it does not consider environmental degradation that may occur in the future, or changes in value due to scarcity. Rather, it assumes that the ecosystems in the study area remain the same over the entire duration of the calculation. For more information on the caveats of this report, see Appendix A.

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RESULTS

BUFFALO REEF HABITAT VALUE

Table 4 presents the results from the replacement cost analysis of spawning habitat on Buffalo Reef. Total tribal and commercial harvest of lake trout and whitefish within 50 miles of the reef is about 100,000 pounds and 326,00 pounds, respectively. Accounting for both lake trout and whitefish spawning habitat, we estimate the replacement cost of spawning habitat is worth $4.6 million every year.

Assuming this habitat is continued to be produced at the same rate, the total value of Buffalo Reef habitat over the next 100 years is about $159 million at a 2.75 percent discount rate, or $455 million at a 0 percent discount rate.

AESTHETIC VALUE OF THE LAKE SUPERIOR SHORELINE

Approximately 5,000 households lie near the shoreline of the study area that could benefit from aesthetic views of the lake. It is estimated that on an annual basis, property values benefit by about $337 per household, per year from these views. This means that Lake Superior contributes benefits of about $1.9 million annually to the area due to aesthetic views alone. Over 100 years, the total value discounted at 2.75 percent is $65 million, and $189 million at 0 percent.

OTHER NON-MARKET SERVICES

Overall, Earth Economics valued 16 ecosystem services on upland areas aside from the services described above (see Table 3 for the combinations valued). Table 5 shows the annual ecosystem services value provided by each land-cover type within the study area boundary.

TABLE 4 REPLACEMENT COST VALUE OF BUFFALO REEF HABITAT PER YEAR

Estimate	Lake Trout	Whitefish
Average annual Tribal commercial harvest in round pounds within 50 miles of Buffalo Reef from 1986-2017	100,317	221,823
Average annual State commercial harvest in round pounds	-	104,108
Total average harvest within 50 miles, 1986-2017	100,317	325,931
Average annual harvest pounds lost due to Buffalo Reef Habitat destruction (29% lake trout, 42% whitefish)	29,092	136,891
Weight Ave. of monitored - lbs./fish sampled	2.99	2.70
Number of adults needed to replace those lost to habitat destruction	9,730	50,700
Projected survival rate stocked yearlings to adult age 7 years	0.01	0.01
Number of Yearlings required to replace adults	972,974	5,070,038
Hatchery Production Costs - Great Lakes Region - Size 6-7 inches	$2.28	$0.46
Annual Production Value of Buffalo Reef	$2,218,381	$2,332,217
Total Annual Production Value of Reef	**$4,550,599**	

TABLE 5 ANNUAL VALUE OF ECOSYSTEM SERVICES BY UPLAND LAND-COVER TYPE (THOUSANDS OF 2017 USD)

NLCD Description	Acres	Low USD/Year	High USD/Year
Landlocked Open Water	28,761	14,094	15,964
Deciduous Forest	156,399	229,853	684,563
Evergreen Forest	45,878	67,416	212,163
Mixed Forest	68,034	99,972	314,618
Shrub/Scrub	16,272	8,032	8,259
Grassland/Herbaceous	41,461	18,300	20,128
Pasture/Hay	18,364	946	2,039
Cultivated Crops	10,788	538	1,417
Woody Wetlands	140,306	111,142	159,610
Emergent Herbaceous Wetlands	13,245	10,008	21,618
Commercial Forest	299,742	45,989	45,989

TABLE 6 ECOSYSTEM SERVICE VALUATION SUMMARY FOR KEWEENAW PENINSULA (THOUSANDS OF 2017 USD)

Source of Value	Low USD/Year	High USD/Year
Landlocked Open Water	14,094	15,964
Deciduous Forest	229,853	684,563
Evergreen Forest	67,416	212,163
Mixed Forest	99,972	314,618
Shrub/Scrub	8,032	8,259
Grassland/Herbaceous	18,300	20,128
Pasture/Hay	946	2,039
Cultivated Crops	538	1,417
Woody Wetlands	111,142	159,610
Emergent Herbaceous Wetlands	10,008	21,618
Commercial Forest	45,989	45,989
Reef Habitat Value	4,550	4,550
Aesthetic Value	1,867	1,867
Total Annual Value	**$612,708**	**$1,492,785**

TOTAL ANNUAL VALUE OF ECOSYSTEM SERVICES

The total ecosystem services value provided by ecosystems within the study region total $613 million to $1.5 billion each year. Given the limited availability of valuation studies across all ecosystem services and land-cover types present within the study area, these estimates only cover a portion of the total value of natural lands in the area. That is, if future valuation studies address the contribution of the absent services, these estimates are quite likely to increase. As such, they can be considered a conservative "minimal" estimation of the contribution of ecosystem services within the study area.

ASSET VALUE OF ECOSYSTEM SERVICES

Across all benefits, natural lands and waters in the study area provide about $21 billion to $52 billion over a 100-year timespan using a 2.75 percent discount rate. Under a 0 percent rate, this total comes to $61 billion to $149 billion.

TABLE 7 NET PRESENT VALUE OF ECOSYSTEM SERVICES (BILLIONS OF 2017 USD)

Discount Rate	Low	High
0%	61.3	149.3
2.75%	21.4	52.1

CONCLUSION

Productive ecosystems around the Keweenaw Peninsula provide fundamental elements to functioning local economies and communities, not least of which are water, clean air, and food. Yet, in economic development plans, conservation efforts, and legislative decisions, we often fail to account for the value nature provides. Knowing where to develop or invest — identifying cost-effective and resilient means of managing natural capital and protecting built infrastructure — requires the most complete economic information available.

This study finds that the non-market value of ecosystem services provided by the region are substantial. Yet, this is just one portion of the total benefits provided by natural resources in the area. It should be noted that these values do not include the economic activity generated by activities associated with use of natural resources as well as the jobs they support. Appendix D presents an example of one of the values outside the scope of this report; the appendix describes an analysis done by other parties on the market values of the commercial fishery of Buffalo Reef. While it is difficult to explicitly monetize the impacts stamp sands have on ecosystem services, it is clear from the abundant qualitative information available that stamp sands are negatively impacting ecosystem services in the area, which lead to economic costs. Appendix E provides a brief example of the types of costs of restoring ecosystems, and ecosystem services, for areas with contaminated sediments.

The values presented in this report reveal the breadth and magnitude of the non-market economic benefits provided by natural capital in the region. Despite constraints due to data gaps and granularity of the analysis, the obtained results provide a broad sense of the economic importance of these lands and waters. However, because of these gaps, the values presented in this report should be thought of as underestimates of the actual non-market values of ecosystem services. Still, understanding the scale of value of these ecosystem services can help build shared goals, sustainable funding mechanisms for management, and better decision making.

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By taking nature into account, we can make better-informed and more strategic decisions that lead to long-term prosperity.

APPENDICES

APPENDIX A: STUDY LIMITATIONS

Valuation exercises have limitations, yet these limitations should not detract from the core finding that ecosystems produce significant economic value for society. Like any economic analysis, the benefit transfer method (BTM) has strengths and weaknesses. Some arguments against benefit transfer include:

- Every ecosystem is unique; per-acre values derived from another location may be of limited relevance to the ecosystems under analysis.
- Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per-acre value is expected to increase, and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values).
- Gathering all the information needed to estimate the specific value for every ecosystem within the study area is not currently feasible. Therefore, the full value of all of the open water, habitat, shrubland, grassland, et cetera in a large geographic area cannot yet be ascertained. In technical terms, far too few data points are available to construct a realistic demand curve or to estimate a demand function.
- The prior studies upon which calculations are based encompass a wide variety of time periods, geographic areas, investigators, and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed too high or too low. In addition, only limited sensitivity analyses were performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels ("comps"): Even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.
- The objection to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. (1997)[62] of the value of all of the world's ecosystems. Even this is not necessary if one recognizes the different purpose of valuation at this scale – a purpose that is more analogous to national income accounting than to estimating exchange values.[63]

This report displays study results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services, it would be better to be approximately right than precisely wrong.

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APPENDIX C: RECREATIONAL ANGLING

Earth Economics quantified angling out of Keweenaw Bay and Traverse Harbor using the Michigan DNR Great Lakes Sport Fishing Report. This report tracks the number of fishing trips that anglers take out of each of these harbors each year for the purpose of recreational fishing. Annual trip data is combined with consumer surplus-per-trip for recreational fishing to estimate the non-market value of angling in the study area. Economists use consumer surplus, which measures the benefits beyond what people are already paying for access to the resource, to value the non-market benefits of goods and services. Recreational users receive these non-market benefits free of charge from their direct use of these resources.

Earth Economics used the benefit-transfer method to find appropriate per-trip consumer surplus values for angling in Lake Superior. We applied consumer surplus to the total number of annual trips to estimate the non-market benefits of angling in the study area.

An average of 13,000 angling trips are taken from Keweenaw Bay and Traverse Harbor each year for recreational angling. Michigan anglers gain consumer surplus of $52 to $137 per trip when participating in this activity, meaning the annual non-market value of angling from these harbors ranges from $690,000 to $1.8 million each year.

If angling activity continues at a constant rate over the next 100 years, the area will support a total of about $24 million to $63 million in value at a 2.75 percent discount rate over 100 years, or $69 million to $181 million at a 0 percent discount rate.

APPENDIX D: MARKET BENEFITS OF FISHERIES IN KEWEENAW BAY

This appendix presents an economic benefit analysis conducted by Jeff Ratcliffe, Executive Director of the Keweenaw Economic Development Alliance. The analysis collected tribal fish harvest data from the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) along with conversion factors for round pounds, dressed pounds and filet pounds. Surveys were conducted to ascertain price per pound prices and production costs including labor and operating costs. An industrial multiplier of 1.5 percent of the Total Value was applied. Recreational and Charter costs were obtained from MI DNR creel data and Charter Fishing Reports.

Commercial fish harvests generate revenue at several levels – first at the dockside, next after being sold by wholesalers, and finally as it is sold in retail to consumers. These sales support further economic activity as fishers and wholesalers use that revenue to make purchases from other industries. In this way, effects ripple throughout the economy, supporting further economic benefits. These estimates represent market values for the fishery and are not directly comparable to the non-market values presented in the main body of this report. They are, however, an example of the other types of economic values supported by Buffalo Reef and natural capital on the Keweenaw Peninsula.

TABLE 8 PARTICIPATION AND CONSUMER SURPLUS OF ANGLING IN THE STUDY AREA

Year	Total Annual Trips	Economic value per year	
		Low	High
2012	11,659	607,569	1,596,634
2013	15,071	785,373	2,063,888
2014	15,220	793,138	2,084,293
2015	16,292	849,001	2,231,097
2016	8,000	416,892	1,095,555
5-Year Average	13,248	690,395	1,814,293

TABLE 9 ESTIMATED ECONOMIC LOSS FROM STAMP SANDS MIGRATION AT GAY

Fish Harvest			
Fish	Round Pounds	Dressed Pounds	Filet Pounds
Whitefish - Tribal Fishers	173,524	148,311	74,156
Lake trout - Tribal Fishers	137,581	110,065	55,033
Whitefish - Non-tribal Fishers	63,915	54,628	27,314
Total Pounds	375,020	313,004	156,502

Market Values of Fish Harvest			
Fish	Price Per Pound	Total Pounds	Total Costs
Dockside Whitefish Price Round	$1.81	237,439	$429,764
Dockside Lake Trout Price Round	$0.69	137,581	$94,931
Wholesale Price Dressed	$4.00	313,004	$1,252,016
Retail Price Filets	$12.95	156,502	$2,026,701
Total Value of Fish			$3,803,412

Economic Industry Value of the Local Fishery			
Rate		Dockside Sales	Value
Labor Value of Fishers (56% of Dockside Sales)		$524,695	$293,829
Operating Cost of Fishers (40% of Dockside Sales)		$524,965	$209,878
Value of Fisher Labor and Operating Costs			$503,708
Industry Multiplier	1.5x Total Value		$755,561
Total Value of Fishers			$1,259,269
Recreational Fishing Costs			$165,543
Charter Fishing Costs			$210,000
Total Estimated Annual Market Value of the Fishery			$5,438,224

APPENDIX E: REMEDIATING CONTAMINATED SEDIMENT

Contaminated sediment is costly in both senses of time and money to repair. The costs associated with remediation of contaminated waterways and sediments include removal and disposal of the contaminated sediment, dredging, erosion control, and management costs, among others.

Though stamp-sand contaminated sediments are unique to the study area, harbors throughout the country have had problems with sediment contaminated with heavy metals. The Portland Harbor cleanup in Portland, Oregon saw 3 million cubic yards of contaminated sediment removed.[65] This project cost $1.05 billion. The Thea Foss waterway in Tacoma, Washington removed 425,000 cubic yards of sediment, costing $105 million.[66] In Muskegon Lake, Michigan, a project removed 48,870 cubic yards of sediment contaminated with petroleum hydrocarbons, lead, and other heavy metals.[67,68] This project cost $16 million and helped restore wetlands which now provide bird and fish habitat.

A current effort funded by the Great Lakes Restoration Initiative will remove roughly 80,000 cubic yards of stamp sands around Buffalo Reef and another 27,500 cubic yards from Grand Traverse Harbor. The project was awarded $2.8 million in 2018.[69] While this is just a beginning of the work needed to clean up the area and other stamp sand piles in the Keweenaw Peninsula, past projects can give a good sense of the time and effort required to remediate areas with contaminated sediments.

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