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Report Title *Functional Assessment of Alaska Peatlands in Cook Inlet Basin*

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Abstract

Peatlands in south central Alaska form the predominant wetland class in the lowlands that encompass Cook Inlet. These peatlands are also in areas of increasing human development in Alaska. Currently Alaska peatlands are extensive and largely pristine. This study focused on obtaining measures of functional aspects of these peatlands to help environmental managers and wetland scientists better understand processes and ecoservices that peatlands in this landscape provide. Measures of peatland processes will help determine expectations for wetlands of this area. Six tasks and their results included Task 1 which found the regional Cook Inlet Wetland Classification (CIC) to accurately classify peatlands into several subtypes by primarily ecohydrologic functional characteristics and the CIC did so relatively better than two other classification systems. Task 2 used piezometer wells to collect porewater for chemical characterization to help determine discharge/recharge function and interestingly revealed that peatlands on the Kenai Peninsula function hydrologically as bogs but are structurally characterized by plants and water chemistry as fens. Task 3 measured potential enzyme activities to describe constraints on nutrient acquisition and organic C decomposition for the first time in Alaska peatlands and revealed that enzymatic stoichiometry was useful for determining microbial P and N limitation and phenol oxidase was especially helpful in prediction of P and N acquisition in relationship to organic C decomposition. Task 4 used an end-member mixing model and water budget on a small watershed with anadromous fish support and found the contribution of peatland waters to summer baseflow was significant. Task 5 was an examination of historical and current aerial photographs over 45 years and found bogs in the area were neither expanding nor contracting. Task 6 measured dissolved arsenic levels in 260 porewater samples and found 30% or 8 of 27 different peatlands exceed the current drinking water standard of 10µgAs/L. These tasks bring a better conceptual understanding using quantitative and objective measures of ecosystem processes within peatlands and among peatlands in the watersheds where they occur. For the area of south central Alaska, management of wetlands shall be helped knowing there is a meaningful classification of the peatlands for this area and a variety of ecological functions that can be examined and measured. These shall support decision making about stressor effects on the peatlands, their ecoservices and how to continue to ensure the peatlands are sustainable.

(This abstract and report do not necessarily reflect U.S. EPA policy.)

Introduction

This report is a summary of is a FY10 RARE (Regional Applied Research Efforts) funded project titled *Functional Assessment of Peatlands and Role in Ecosystem Services* (Gracz 2010; 2011) and a MED (Mid-Continent Ecology Division) project under the exploratory research plan titled *Alaskan Peatlands Project* (Moffett 2012). The goal of this work is to improve our understanding of peatland functions, especially hydrological and peat decomposition and nutrient cycling processes.

Background

Peatlands are a type of wetland and are characterized by partially decomposed vegetation called peat which accumulates in the water-saturated sediments below living plants (sedges, mosses, or wetland tolerant shrubs and trees). Mineral soils lay 0.3 to several meters below the peat and water wets the peat from underground sources or precipitation depending upon the peatland hydrogeomorphology and climate. Nutrient status, pH and plant communities vary across peatland types and classification of peatlands across regions using the same classification attributes should not be done or done with caution. In the United States there are large areas of peatlands in the northern midwest (Minnesota, Wisconsin, Michigan), in the northeast (New York, Maine, New Hampshire, Vermont), in the southeast (Florida), in the southwest (California), and more than half of the U.S. peatlands are in Alaska. In this research we examined peatlands in one region of Alaska, the Cook Inlet area lowlands. Environmental management of this rapidly developing area is wanting for scientific knowledge of how wetlands in this area function and what ecoservices they provide.

Expansive areas of peatlands in the Cook Inlet lowlands (Figure 1) of Alaska currently are largely pristine yet highly varied in their functioning. These peatlands can be identified and classified by many factors independent of human disturbance. Simply scoring peatlands as “reference standard”, when there is no human disturbance evident, is not helpful to environmental managers. Currently there are no useful set of metrics to describe the function of the many large peatland complexes in the Cook Inlet basin. This research shall add to our understanding of the ecosystem services that these peatlands provide by better defining several of their functional attributes. Two specific aims will test conceptual models for hydrology and microbial enzymes use in biogeochemical processes in peat.

General Approach

To improve our understanding of peatland functions, this research began by measuring proxies for some important hydrological functions to ultimately relate these to other wetland characteristics, functions, and ecosystem services. By definition, hydrology is the primary driver in all wetlands and potentially controls much of wetland structure and function. Other wetland functions (e.g., nutrient cycling, sedimentation, and habitat) respond to hydrology. To define the hydrology, this project tested methods to measure hydrologic recharge and discharge function. Where possible, hydrology was examined along measures of peatland water chemistry including nutrients and arsenic. Hydrology was related to baseflow support for streams and to microbial ecoenzyme activities in the peat.

Tasks

There were six tasks completed for this project.

Task 1. Test the performance of the Cook Inlet Wetland Classification against other classification systems.

Task 2. Measure recharge and discharge patterns through the peat profiles of extensive peatlands using hydraulic head and water chemistry.

Task 3. Describe the role of nutrient cycling in extensive peatlands with enzymatic analysis of peat sediment.

Task 4. Evaluate the possible contributions of extensive peatlands to stream flow during the summer low flow period using a water budget and an end-member mixing analysis (EMMA).

Task 5. Determine whether bog area is expanding, contracting or in equilibrium by comparing historical with modern aerial photographs.

Task 6. Measure the concentration of the arsenic (As) in peatland porewaters to determine the presence and possible exceedance of current drinking water standards.

Methods

All methods are detailed in a Quality Assurance Project Plan (QAPP) for portions done for the cooperative agreement (Gracz 2011) and in a Mid-Continent Ecology Division (MED) Exploratory Research Plan (ERP) for work done by MED (Moffett 2012). These plans and their associated documents, e.g. standard operating procedures, can be obtained from the product and project contact, Mary Moffett. These documents cover methods for the entire project and describe how each task was accomplished. General methodology for each task is summarized as follows.

Task 1. The classification task was done by statistically comparing the similarity of three wetland classification systems for the wetlands in south central Alaska. These were the U.S. Fish and Wildlife Service National Wetland classification (NWI)(Cowardin et al. 1979), the hydrogeomorphic modified wetland classification called the (LLWW) of Tiner (2003), and the Cook Inlet Wetland classification (CIC) of Gracz (2012).

Task 2. Recharge and discharge patterns were measured by installing piezometers, either temporarily or permanently (for multiseasonal comparisons) in 24 wetlands and measuring head, specific conductance, O-18 isotope, anions and cations in the porewater at different depths and in the wetland surface water (Figures 2 and 3).

Task 3. Nutrient cycling was measured by assimilation of C, N and P through the use of enzyme assays of peat sediment samples taken near piezometer well sites at the surface (just under the top green plant layer) and from well depths sampled by coring.

Task 4. A small watershed with two tributaries (locally called Limpopo Creek) of the larger Anchor River system was used for calculating the hydrologic contribution of peatland water to summer low-flow by doing a water budget in mid-summer and measuring O-18 and several other conservative chemical parameters. An End-Member-Mixing Model Analysis

(EMMA) was performed to determine the percentages of hydrologic contributions from three possible end-members: tertiary deposits, glacial till, and peatland.

Task 5. A visual comparison and measurements from historical (1960) and recent (2005) aerial photographs of one exemplary area with bogs in south central Alaska was done.

Task 6. All samples of peatland surface water, all depths of porewater, and Limpopo Creek stream water taken at low-flow were measured for total arsenic by standard furnace atomic absorption methods. Comparisons were made to measures of arsenic in streams and wells in this same region of south central Alaska reported in by U.S. Geologic Survey (2001).

Study Location Peatlands of the Cook Inlet basin in south central Alaska were studied. Two subregions were sampled, namely, in the Matanuska River valley and in the lowlands of the Kenai Peninsula, located north and south of Anchorage, respectively (Figure 1).

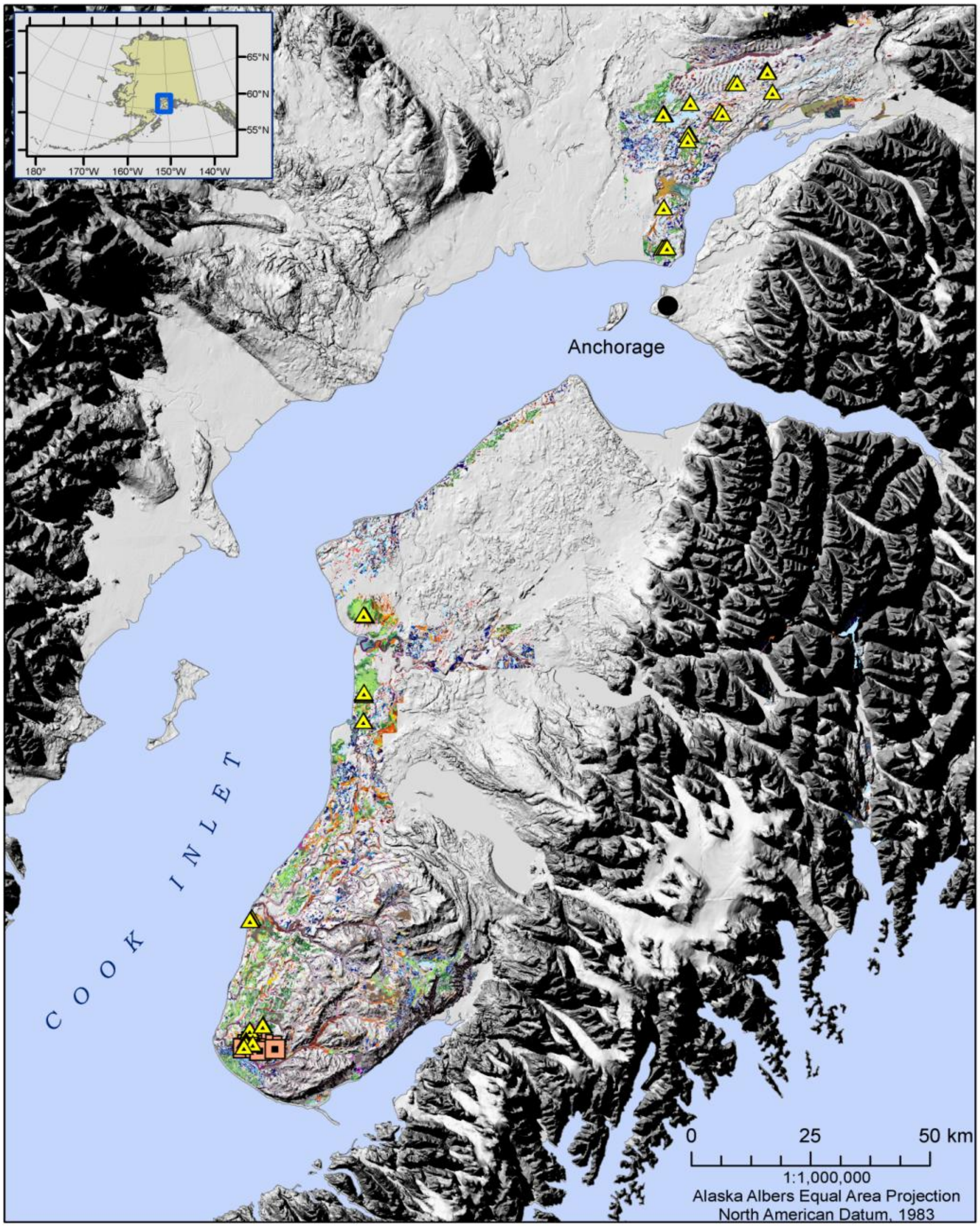

Figure 1. Location of 24 peat sampling sites (yellow triangles) in wetlands (colored areas) that have been mapped by the Cook Inlet Wetland Classification. (Gracz et al. 2008; http://www.kenaiwetlands.net/)

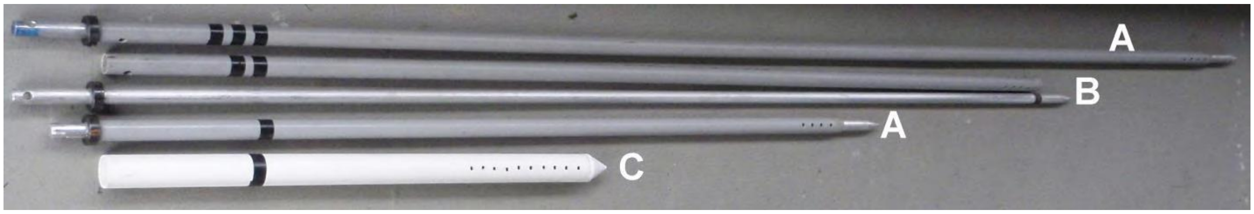

Figure 2. Portable piezometer assembled (A), dissembled (B), and a permanent piezometer (C).

Figure 3. Piezometers installed in a wetland at 4 well depths (0.5, 1.0, 1.5 and 2.0 m).

Porewater was withdrawn from piezometer wells set at the same depths that peat was sampled. Porewater field measurements (pH & specific conductance) were taken. In the laboratory, anions (Cl and SO_4) and cations (Mg, Ca, K, Na), N and P were measured.

Figure 4. Water sampling locations in and around Limpopo Creek in the Anchor River watershed. Wetlands shaded according to type. Much of the area underlain by till has been logged. The elevation difference from source (right) to confluence (left) is approximately 215 m.

Results

Task 1. <u>Wetland Classification</u>

The Cook Inlet Wetland Classification (CIC) was found to have greater within group similarity of plots in oligotrophic peatlands of the Cook Inlet Basin, Alaska than the NWI, LLWW or an NWI+LLWW combined classification systems used on the same wetlands according to a multi-response permutation procedure (MRPP). The greater similarity produced demonstrates that the CIC is a sound method of classifying the peatlands of the region and preferable over a classification system developed in a distant and different geographical region. Because greater similarity in the variables may equate to greater functional similarity of wetlands, the findings support a central HGM concept that hydrology and geomorphology are akin to first principles of wetland function

Task 2. <u>Peatland Porewater</u>

Gradients in hydraulic head and specific conductance showed that many Kenai Peninsula peatlands are functioning hydrologically as bogs, despite their fen chemistry and plant species composition. This counter-intuitive conclusion is likely due to the chronic deposition of calcium-containing tephra from volcanoes in the subregion. The calcium allows fen indicator plants to survive, while chemically masking indications of bog hydrology.

Task 3. <u>Microbial Ecoenzymes</u>

The peatlands in the lowlands of south central Alaska were characterized for the first time with microbial enzyme activities which revealed information on the ecological processes of nutrient cycling within the underlying peat of these oligotrophic wetlands. Some of the biogeochemical measures displayed threshold depth effects demonstrating the significant difference between the aerobic surface layers with lower pH and anaerobic deeper peat layers with higher pH that would be decomposing organic matter differently. In a comparison of chemical ratios of C, N and P of the peat to enzyme activity ratios, there usually were no relationships and thus the chemical measures of the major nutrients would not be reliable measures of resource constraints in these peatland soils.

Enzyme stoichiometric relationships were strong and depicted much C-limitation throughout a peat profile and in the upper (acrotelm) layer of peat there was P-limitation. The enzyme assay for phenol oxidase was especially helpful to indicate the higher carbon quality present in the upper versus deeper layers of peat. When P acquisition increases, C acquisition increases significantly and the relationship is strongly predictive ($r^{2\,=}$ 0.92) when B-glucosidase and phosphatase activities are normalized for phenol oxidase activity (a measure of decomposability of organic C compounds). The same is true for N acquisition as measured by n-acetylglucosaminidase and leucine aminopeptidase. A key finding is that the microbial N and P acquisition and energy metabolism of C was tightly linked to oxidase enzymes capable of breaking down recalcitrant organic C in the peat.

Task 4. <u>EMMA Surface Water</u>

Peatlands in the watershed of an anadromous tributary (Limpopo Creek) to the Anchor River, Alaska were contributing approximately 55% of the flow during the summer dry period. Both a water budget analysis and a chemical mixing model (EMMA) pointed to substantial contributions from peatlands in hydrogeomorphic settings where extensive peat contributes diffuse porewater to streamflow. Thus the water in the wetlands provided significant baseflow support important to anadromous stream fisheries ecoservices.

Task 5. <u>Bog Expansion or Contraction</u>

Have bogs in the south central Alaska lowlands expanded or contracted over the past 45 years? Bogs were found to be neither expanding nor contracting in the Matanuska-Susitna Valley. When historic and modern photos were compared, bog area of both larger forested bog islands and small incipient bog cushions measuring on the order of a few meters across was found to be unchanged at several locations. The relative proportion of bogs and fens may be in equilibrium with effective precipitation (precipitation minus evapotranspiration). Whether this trend will continue over the course of next several decades in the face of climate change is unknown but the current comparison will serve as a baseline for future trend analyses.

Task 6. Arsenic

Do peatlands in the Cook Inlet basin have arsenic in their porewater which could adversely affect provisioning of drinking water and wildlife? Measurable As (above 1.34µg/L) was found in many porewater samples (159 of 260 samples were positive for As). With respect to the number of wetlands samples, 40% or 6 of 15 wetlands in the Kenai Peninsula lowlands had measured concentrations >10µg/L in porewater. One wetland on the Kenai had As at 100µg/L. In peatlands of the Matanuska-Susitna Valley north of Anchorage, there was a lower occurrence but 17% of the wetlands or 2 of 12 had As >10µg/L which is the new EPA standard for As limits not to be exceeded in drinking water. As concentrations were significantly correlated to specific conductance (SC) measurements and thus SC may be a useful preliminary filter in the selection of waters to actually get a As analytical measurement done in the laboratory.

Outputs/products

1. This 2014 report which includes output from the EPA/MED Duluth efforts for the entire project titled *Functional Assessment of Alaska Peatlands in Cook Inlet Basin*.
2. The 2013 final report from the EPA Grant AE83482601written by the awardee.
3. A peer-reviewed manuscript being submitted in 2014 to the journal *Wetland Ecology and Management*. This paper includes is an application of the classification of sites from this study using a hydrogeomorphic classification system developed specifically for peatlands around Cook Inlet to differentiate ecological functioning of various peatland classes/subclasses. This manuscript also compares the Cook Inlet wetland classification system with other wetland classification systems.
4. A manuscript to be submitted in 2014 to the journal *Ecohydrology*, titled *The Contribution of Peatlands to Stream Flow during the Summer Dry Period in Cook Inlet Basin, Alaska*. This paper looked at a water budget and modeled conservative elements to demonstrate the significant hydrologic contribution that peatlands in a watershed make to associated streams. It showed the importance of the hydrologic and ecological functioning of undisturbed peatlands in the Cook Inlet Basin.
5. A completed poster presentation summarized the use of microbial enzyme assays to show the assimilation potential of C, N and P in Cook Inlet Peatlands of Alaska. Data showed the tight coupling of N and P assimilation to the availability of readily decomposable organic C in the peat.

Manuscripts for peer-reviewed journal publications from this study are attached here in their current state and are considered drafts. When manuscripts are in final published form, they will be resubmitted again to Region 10 to the RARE Regional Science Liaison, currently Bruce Duncan and to Matthew LaCroix, wetlands scientist at the Alaska Programs Operations Branch and co-principal investigator in this project for Region 10.

These products will inform environmental managers of this rapidly developing area in south central Alaska with scientific knowledge of how natural/pristine wetlands in this area function and how ecoservices they provide can remain as sustainable and healthy ecosystems. An improved conceptual model that uses functional measures (nutrient acquisition and hydrologic source modeling) and new metrics for classifying Cook Inlet lowlands by their hydrologic functions were finalized. With human activities increasing in the area and with ensuing global climate change, it has become important to find reliable methods to inform environmental managers on the sensitive ecological processes that occur within these peatlands, especially since peatlands are the predominant class of wetlands for this region. The testing and results of this study should provide resource managers and scientists with measures that will be useful in identifying characteristics of the peatlands that may be threatened by development or other changes.

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Attachments

Attached to this final summary report are the following outputs.

[Contact the report author to obtain the following outputs.]

1. Final report from cooperative agreement (EPA AE83482601) principal investigator, Michael Gracz, Kenai Watershed Forum, titled *Functional Assessment of Peatlands and Role in Ecosystem Services*, 30 September 2013.
2. A manuscript being submitted to the journal *Wetland Ecology and Management* in 2014, titled *A Test of a Newly Defined Hydrogeomorphic Classification for Freshwater Peatlands in the Cook Inlet Basin, Alaska*.
3. A manuscript being submitted to the journal *Ecohydrology* in 2014, titled *The Contribution of Peatlands to Stream Flow During the Summer Dry Period in Cook Inlet Basin, Alaska.*
4. A poster presented at the Society of Wetlands Scientists annual meeting in 2013, Duluth, MN, titled *Microbial Enzyme Activities of Peatland Soils in South Central Alaska Lowlands.*