

**Paleoenvironmental Reconstruction and Landscape Interactions
in Lake Clark and other Southwest Alaska Lake Systems,
Southwest Alaska Inventory and Monitoring Network**

Summary of Progress: Outline Final Report

(2005 Annual Report)

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National Park Service
Southwest Alaska Network
Inventory and Monitoring Program

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Project Background and Objectives:

In order to fully understand the dynamics of any ecosystem, it is important to have some knowledge of how that ecosystem developed through time, how it has changed in the past, and how it may change in the future. Landscape history studies such as the timing of deglaciation, location and timing of hydrologic connections or barriers, and the history of lake level change will provide a framework for understanding salmon population dynamics in terms of colonization, isolation, and bottleneck effects, as well as for the ongoing efforts to locate and date early human settlements in the area. Paleoenvironmental reconstruction using pollen and other indicators from lake sediment cores will provide a history of ecological succession and vegetation change since the last ice age. Volcanic history, also obtained from lake sediment cores, will allow us to construct a regional tephra stratigraphy useful for dating inorganic lake sediments, landforms, and archeological sites. The potential effects of ash fall into different lake systems can also be investigated through the study of such events in the sedimentary record.

The main objective of this study is to reconstruct the landscape history of the SWAN parks in terms of the history of glaciers, lake level, volcanic eruptions and ecological change since the last ice age. More specifically:

1. Determine the timing and nature of deglaciation and lake formation in the Lake Clark and Naknek Lake systems and others as possible and in areas where such history will be useful in interpreting lake sediment records.
2. Reconstruct the extent and timing of major lake level changes and hydrologic changes in important stream systems.
3. Determine the timing and severity of volcanic ash fall events in Alagnak Wild River and in Katmai and Lake Clark National Parks and Preserves.
4. Reconstruct history of vegetation succession, changes, and ecosystem interactions since the last ice age by analyzing pollen found in sediment cores.
5. Determine, and differentiate between, multiple factors that could potentially influence the records of past changes in salmon abundance.

The multifaceted and interdisciplinary nature of this project has necessitated a division into several major sub-components, some of which are the major focus of at least two graduate theses. This summary (and the final report) will be broken into sections that follow along major project components as outlined below.

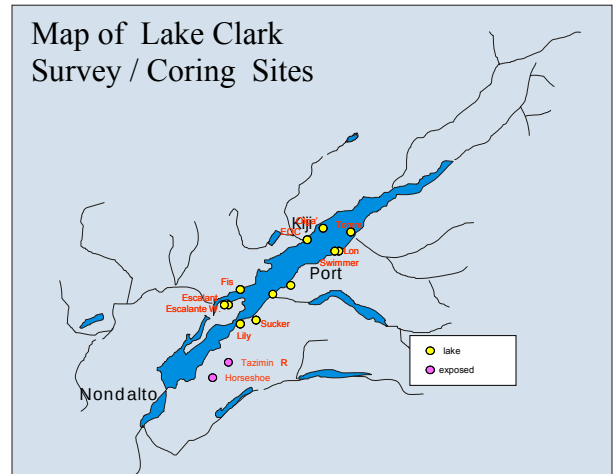
1. Lake Clark Glacial, Lake Level, and Watershed History (Heiser and Maglio)
2. SWAN Regional Lake Level History (Heiser and Finney)
3. Landscape Change and Lake Productivity (B. Cohn)
4. Tephra History and Stratigraphy in Lake Clark Valley (M. Bowes)
5. Paleoecology and Lake Level History in SWAN (Heiser and N. Bigelow)

Figures and maps provided in this summary report are examples of the type of graphic and other information that will be included in the comprehensive final report. A summary diagram at the end of this document graphically represents progress to date on each project component.

Lake Clark Glacial History and Lake Level Study

Objective: Determine the timing of ice retreat, lake level change and stream drainage changes in Lake Clark valley.

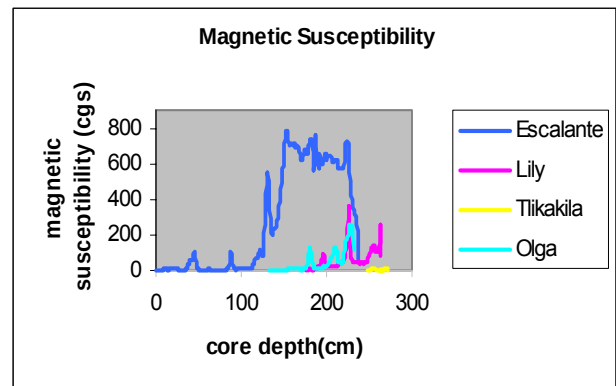
Project Summary: Small kettle lake basins within the shorelines of a larger “paleo Lake Clark” preserve a sedimentary record of the transition from a large glacial lake to a small pond as the larger lake receded below the elevation of the smaller pond. Using topographic profiles of raised beach sequences, the threshold elevation of these small ponds, and radiocarbon dating the sediment transition, a history of lake level change can be reconstructed. Basal dates from the small lakes and from selected bogs provide a limiting date on deglaciation of the valley.



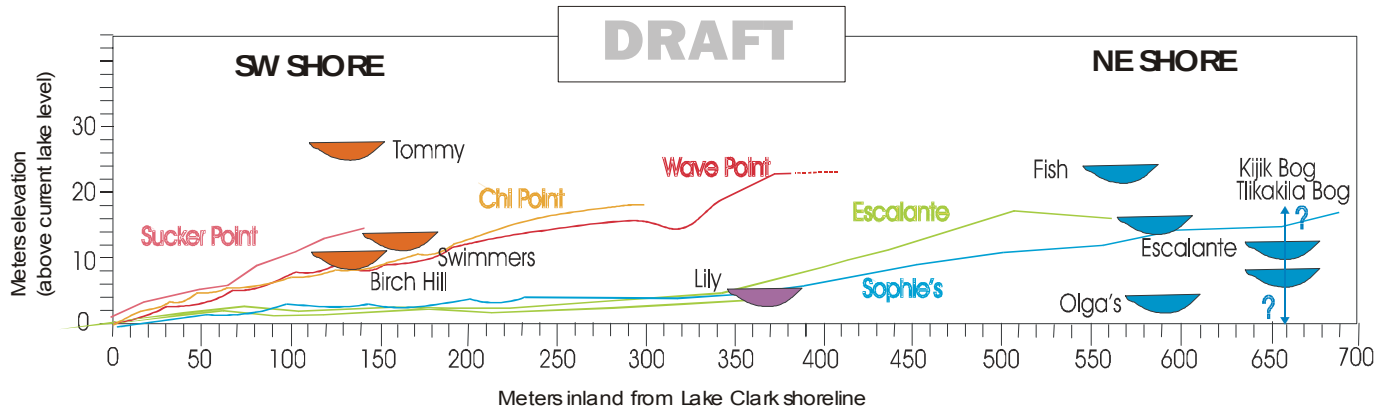
Progress: All field work has been completed. Sediment cores were retrieved from 11 small lakes, several bogs, and from exposed sections along stream banks. Topographic profiles of seven beach sequences have been reconstructed. Most laboratory analysis has been completed, with some still in progress. Lab analyses includes core description, magnetic susceptibility, organic content (loss on ignition), and radiocarbon dating.

Summary of Results: Lake Clark Valley was deglaciated sometime prior to ~13,000 years BP. This is earlier than expected and earlier than deglacial estimates in areas mapped to the south (Detterman and Reed 1973). This is likely a result of distant source area for glacial ice (Lake Clark Pass) to the northeast. Basal sediments from several small lakes around Port Alsworth indicate younger dates (based on tephra stratigraphy) and may suggest late glacial re-advance from more proximal ice sources to the east (Mt. Illiamna).

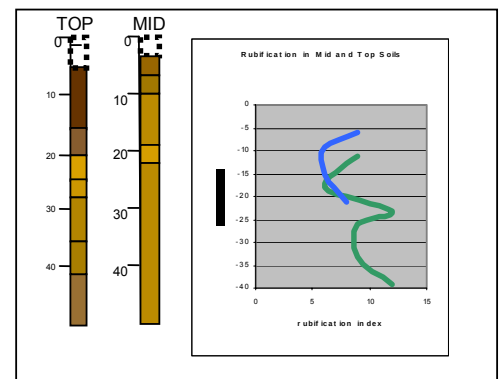
Sediments preserved in several small lakes at the lower end of Lake Clark, and in sections exposed along the Newhalen River and Tazimina River show anomalously high (by an order of magnitude) measures of magnetic susceptibility. Abandoned channels, ice margin positions, and the nature of these sediments suggest that early stages of Lake Clark likely received water from different watershed/source area. The high magnetic content suggests the source lay to the west, and may originate in the volcanic source rocks west of Nondalton, or the possibly the hydrothermally altered/gold-copper rich area of the proposed Pebble Mine.



Radiocarbon dates of the glacial-to-small lake transition in sediments suggest that Lake Clark levels dropped ~20 meters over the course of several thousand years, reaching current lake levels ~9,000 years ago. Topographic profiles from beach ridges suggest that lake level change was relatively constant, but some differences between profiles on opposite sides of the lake warrant further exploration.



Soil development on different age beach ridges was also used in the study of the timing of lake level change and to observe the degree of soil formation on different age surface throughout the valley. This information could be used in other studies where surface age is of interest (e.g. archeological sites). Three soil profiles at one site, Sophie's Bay, show an increase in depth and color development on the highest and oldest beach ridges.



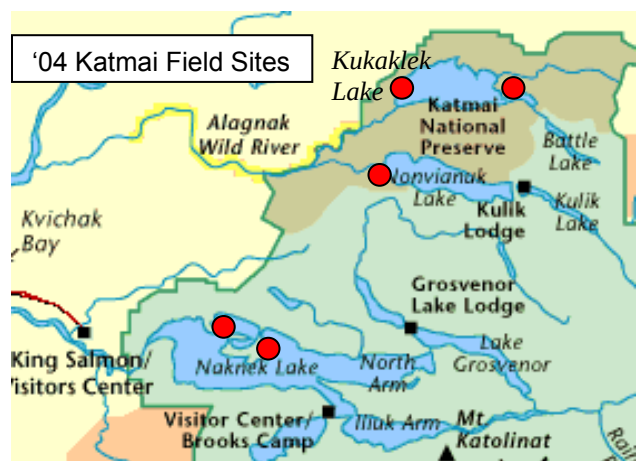
Timeline for Completion:

Field work completed, most analyses completed. Data interpretation and writing March-April 06. Completion by June 30.

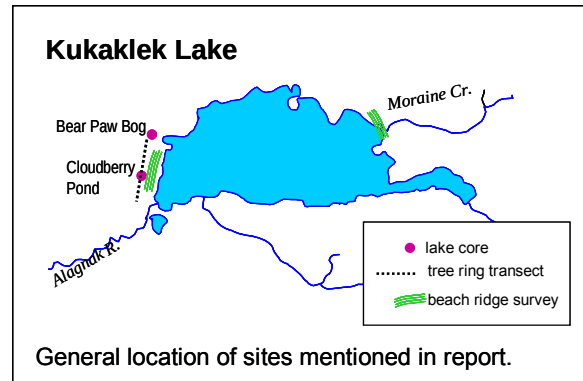
SWAN Lakes Lake Level History and Regional Comparisons:

Objective: Reconstruct lake level histories in other SWAN lakes using beach ridge elevations and isolation ponds as in Lake Clark valley. Assess the nature and timing of regional lake level changes to determine potential causes (e.g. tectonics, isostatic adjustment, downcutting).

Progress: Seven lakes were cored around Naknek, Nonvianuk, and Kukaklek lakes. Beach ridge elevations (not profiles) were obtained at Kukaklek and Naknek.



Summary of Results: Radiocarbon dates are still pending, but initial results suggest that degree and timing of lake level changes among these three systems is asynchronous. The shorelines around Naknek lake record post-glacial lake level change that was likely continuous and a result of outlet erosion. Nonvianuk lake likely had a brief high stand as a pre-glacial impoundment during ice retreat. No shorelines were observed and datable “high” lake sediments were not recovered from the one lake cored along its shores.



Kukaklek Lake showed interesting lake level history with older high shorelines present at the west end of the lake that correlate in elevation with high deltas up the Moraine Creek drainage. Lower beach ridges at the mouth of Moraine Creek, and the apparent recent/current transgression of the shoreline at the west end of the lake suggest late Holocene and possibly current lake level change or even tilting.

Timeline for Completion: One lake, near Naknek, will be cored this winter. Core analyses from other lakes are nearly complete, and radiocarbon dating is in progress. Analyses will be complete in May with interpretations and writing completed in June/July 06.

Landscape Changes and Lake Productivity:

Brian Cohn, M.S. student, Ocean Sciences, UAF (Heiser and Finney Thesis Co-Chairs)

Objectives: The objective of this study is to better understand the link between terrestrial and aquatic ecosystems to improve our ability to interpret records of landscape change and biogeochemical change in lake sediment records.

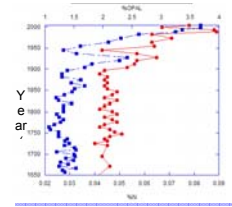
Specific Objectives:

- Characterize vegetation abundance and spatial distribution, specifically alder (Historical and Aerial Photos, GIS)
- Measure down core changes in lake sediment using nutrient and productivity indicators (C:N ratios, phosphorus, N:P ratios, $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$).
- Develop a set of watershed and lake characteristics for this region to explain the potential link between terrestrial vegetation distribution and aquatic productivity using the results of objectives 1 and 2.

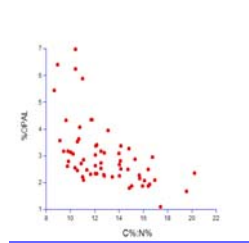
Progress: Field studies complete, most lab analyses done. Many interpretations complete and presented at national meeting of American Society of Limnology and Oceanography in Honolulu Hawaii, Feb 06.

Summary of Results: (see poster presentation provided separately)

- Vegetation change and expansion and increased biomass of American Green Alder is apparent over almost a century within the photographic record.
- Evidence for recent increases in productivity are apparent in the sedimentary records relative to the past.
- Disturbances driven by climate, glacial retreat, volcanism and other natural perturbations severely complicate assessing vegetation driven processes in lake sediment cores.
- Although it is apparent from other studies that alder fixed nitrogen is a major driver of the nitrogen cycle within aquatic ecosystems, the relative changes on the natural landscape over the last century may not be significant enough to alter the biogeochemical signatures to sufficiently elucidate its influence.
- Compound specific examination, such as determining down core NO₃ concentration using O₂ isotopes and analysis of Phosphorus (thought to be the major limiting nutrient in freshwater systems), may enhance our ability to further understand the complexities inherent in this dynamic region.



Hickerson Lake ~2% increase in OPAL (~150BP-Present). Potential drivers include increase annual temperatures (See Regional Setting Map inset) and



Hickerson Lake ~2% increase in OPAL (~150BP-Present). Potential drivers include increase annual temperatures (See Regional Setting Map inset) and shrub expansion (Left)

Timeline for Completion: Analyses and interpretation done by June 30. Writing in July. Graduation by August (?) or fall 06.

Tephra History in Lake Clark Valley

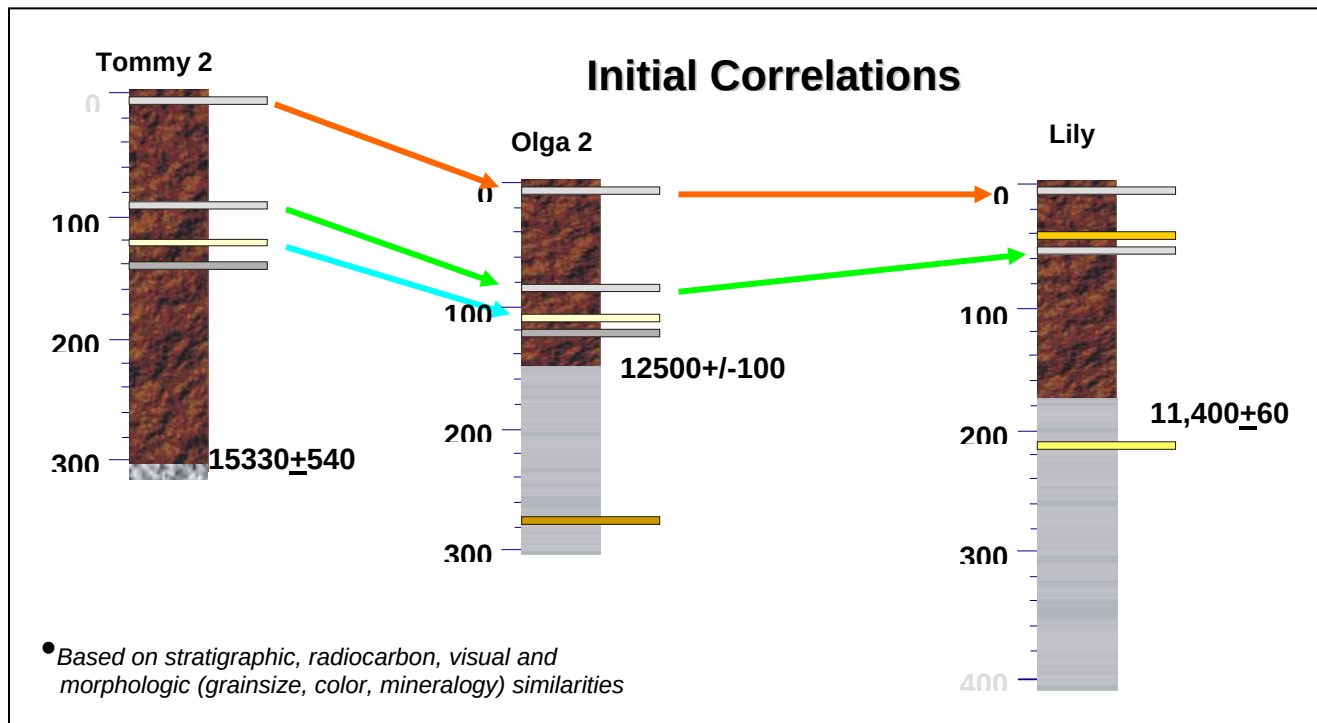
Matthew Bowes, M. S. Student, UAF Geology (P. Heiser and J. Beget Thesis Co-Chairs)

Objectives: Develop a local tephrochronology, centered in LACL, which will aid in supporting the future geological, paleoenvironmental, and archeological studies in the region. Contribute to the regional tephra data base being amassed by the USGS (AVO) and NPS

- Extract lake cores for comparative analysis of changes in depositional environments and record of regional volcanic history
- Apply a multi-parametric approach to tephra correlation by Analyzing physical and chemical characteristics of tephras.
- Produce a stratigraphic and chronological framework of recorded tephra falls using morphologic, chemical, and geochronologic (¹⁴C) data.

Progress: All field work completed. All tephra samples (except 5) processed with physical and morphological data compiled. Ready for microprobe, glass shard geochemistry.

Summary of Results: Initial correlations based on stratigraphic position, gross morphology, and radiocarbon dating indicate that at least 7 of thirteen ashes appear correlative. Results to date were presented at Geological Society of America National Meeting in Salt Lake City, October 2005.



Timeline for Completion: Microprobe work March –April – May. Additional radiocarbon dating in progress. Interpretation and writing summer 06, thesis fall 06.

Paleoecology and Vegetation History In SWAN

Nancy Bigelow, Alaska Quaternary Center, UAF and P. Heiser

Objective: The objective of this component of the project is to reconstruct the vegetation history of Lake Clark valley and the Alagnak valley of SWAN. While pollen records have been obtained in the region, both of these sites are located near ecological boundaries and may contain better records of the arrival of spruce, and the timing of the establishment of the present ecosystem.

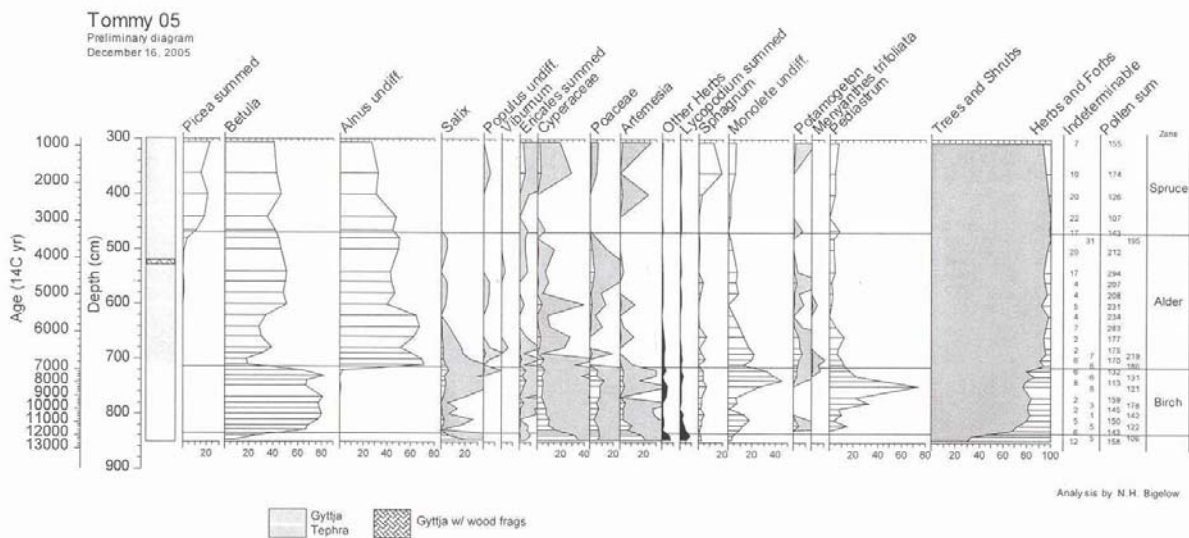
Progress: Pollen from Tommy lake has been processed with a preliminary pollen count and interpretation completed. Radiocarbon dating is in progress. Pikelet Lake pollen processing and counting is under way and initial radiocarbon dates (basal dates and major transitions) is in progress.

Summary of Results:

Preliminary pollen analysis from Tommy Lake (located along the shore of Lake Clark) shows the transition of vegetation from post glacial Herb Zone tundra at the bottom of the core (847-830 cm a Birch zone that encompasses more than 1 m of sediment (830- 710 cm), and likely spans a time period from about 12,000 to 7000 ¹⁴C yr BP (based on correlation with Snipe Lake core. The Birch zone transitions to an Alder zone (710-470

cm). that expand over more than 2 m of sediment, and estimated to have occurred from 7000 to 3400 ^{14}C yr BP. Alder frequencies increase rapidly from less than 5% to over 70% over the space of 10 cm. The frequencies highest at the onset of the period (ca. 80%), decreasing to about 50% by the period's end. Finally, a Spruce zone (470-300 cm) appears around 3300 ^{14}C yr BP. Spruce (*Picea*) pollen is present at low frequencies prior to this zone; the taxon may have been present in the region at this time, but probably was not growing near Tommy Lake until roughly 3300 ^{14}C yr BP.

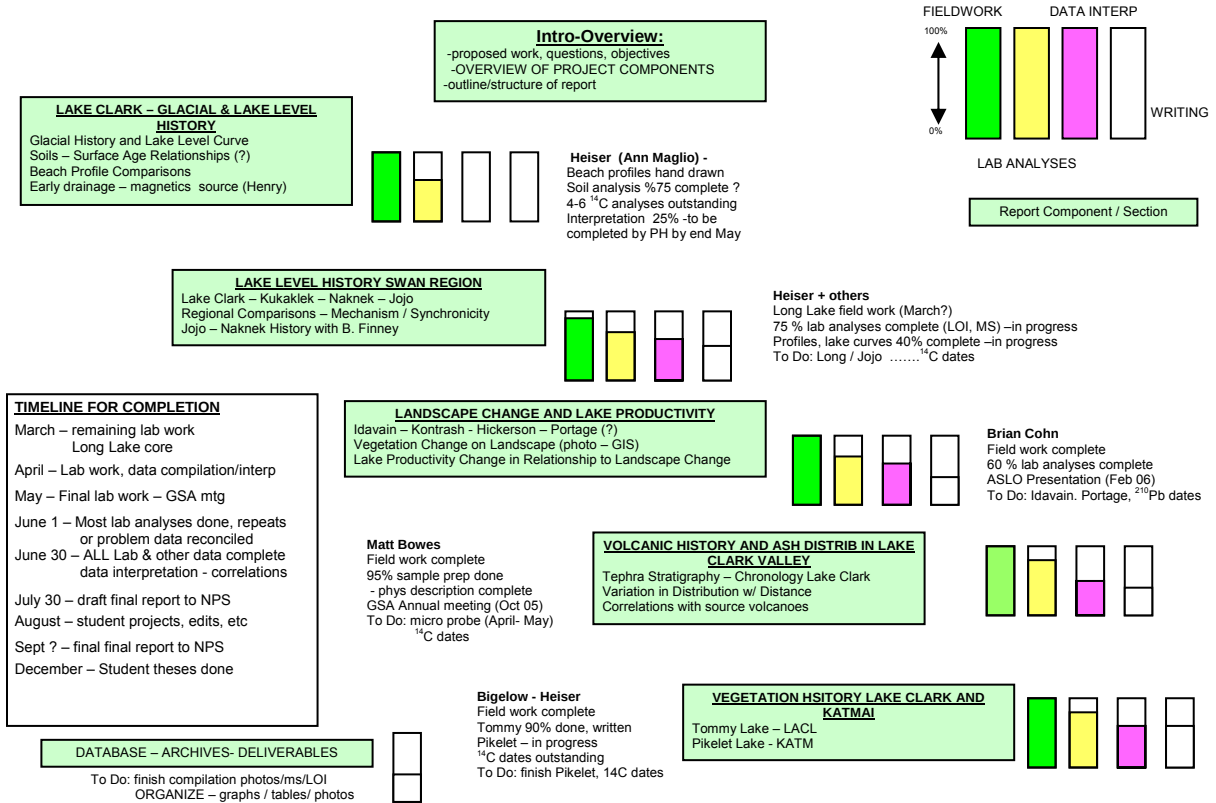
A decrease in fern pollen around 10,000 yr BP may be correlative with the “Fern Gap” attributed to Younger Dryas cooling on Kodiak Island. Detailed radiocarbon dating and final pollen counts will tighten both the record and chronology of the ecological history of the Lake Clark valley.



Timeline for Completion: Pikelet core should be completed by April, Tommy final pollen, dating and the core top should be completed by May. Interpretation and writing of results will be complete by late June 06.

Concept Map / Overview of Project Components, Summary of Progress, and Timeline for Completion

Conceptual Map of Project Components and Summary of Progress



Publications , Products, Deliverables submitted to date:

NPS Reports

Paleo-environmental Reconstruction and Landscape Evolution of Lake Clark National Park, Alaska: Reports submitted to Alaska Region Inventory and Monitoring Program, Southwest Area Network.

Progress Reports submitted fall 2003, 2004, 2005

Annual Reports submitted Spring 2004, 2005

Summary Final Report (this document) Spring 2006

Additional Reports

Field Report provided to Bristol Bay Native Corporation at request of NPS

NPS Meeting Presentations

Heiser, P.A. (2005) Overview of Landscape Dynamics and Paleoenvironmental Reconstruction, Lake Clark and Katmai National Parks. National Park Service Inventory and Monitoring Investigators Meeting. Anchorage AK, March 2005

Cohn, B.C. and Heiser, P. A, Finney, B. P (2005) Linking Terrestrial N Sources to Lake Productivity in Southwest Alaska: The Role of Alder (*Alnus Crispa*) Expansion and Distribution in Aquatic Productivity National Park Service Inventory and Monitoring Investigators Meeting. Anchorage AK, March 2005

P.A. Heiser (2005) Geology in Lake Clark National Park. Featured Speaker, National Park Service Western Region Geologic Scoping Meeting Anchorage AK, Feb 2005

National Presentations

Heiser, P. A. (2003) Lake Level change in large lake systems: Implications for interpreting records of salmon history in the Lake Clark Illiamna Region, AK. Geological Society of America Annual Meeting Program with Abstracts. November 2003

Fouke, B.W and Heiser, P. A. (2003) Bacterial Communities in Pleistocene and Holocene Lake Sediments, Lake Clark, Alaska, Geological Society of America Annual Meeting Program with Abstracts. November 2003

Local / Community Presentations

Alaska Science Series, Juneau Alaska January 2003

Dillingham AK, Invited Speaker, May 2004

Public / park presentations Port Alsworth, AK

Fireside Chat, Campbell Creek Science Center, March 2005



THE ROLE OF VEGETATION CHANGE, DISTURBANCE, AND CLIMATE ON SEDIMENT RECORDS OF LAKE PRODUCTIVITY: SOUTHWEST ALASKA

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Paleolimnological studies are combined with landcover vegetation analyses in selected lake ecosystems in the Southwest Alaska Network of the National Park Service in order to better understand the impacts of both rapid and recent (last century) and long-term (late Holocene) landscape changes on lake ecosystem dynamics. Evidence from previous studies suggests Alder Fixed Nitrogen (AFN) may exert an important influence on nitrogen cycling and productivity in sub arctic watersheds and lake systems. Paleo lake productivity is reconstructed from down core measurements of changes in organic carbon, nitrogen, phosphorus, and diatom accumulation as well as sedimentary $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$. Lake productivity records, ranging in age from 100 to 8000 years, have been reconstructed from at least three lakes in Southwest Alaska. Siliceous microfossils, particularly diatoms were analyzed to provide information on past and present changes in plankton abundance. Characterization of the history of vegetation abundance and spatial distribution is shown by combining pollen records retrieved from sediment cores with a suite of historical, high altitude photographs and landcover datasets. Recent vegetation change is illustrated by comparison of past and future photographic records and landcovers.

Results to date indicate vegetation change, namely an expansion and increased biomass of American Green Alder, is apparent over the last century as seen in the photographic record. Preliminary data suggest that recent increases in lake productivity are also apparent in the sedimentary records over the last 50 years. Disturbances driven by climate, glacial retreat, volcanism and other natural perturbations contribute to, and perhaps at times overprint, vegetation driven processes in lake sediment cores. The combined results allow for an integrated record of terrestrial and aquatic changes and evaluation of the effects of alder among aquatic ecosystems both spatially and temporally. Recent documentation that warming has accelerated over the last three decades may also allow comparisons between the climate driven 'alder rise' of the early Holocene, and the alder expansion which we observe occurring today.

CORRELATION OF TEPHRA DEPOSITS IN LAKE SEDIMENT RECORDS, LAKE CLARK NATIONAL PARK, ALASKA

BOWES, Matthew J., Geology/ Geophysics, University of Alaska Fairbanks, 900 Yukon Drive, Fairbanks, AK 99775, ftmjb@uaf.edu, HEISER, Patricia A., Geological Sciences, University Alaska Anchorage, Anchorage, AK 99508, BEGÉT, James, Department of Geology and Geophysics, University of Alaska, Fairbanks, AK 99775, and WALLACE, Kristi, Alaska Volcano Observatory, USGS, Anchorage, AK 99518

Lake Clark National Park (LACL) covers over four million acres of southwest Alaska, contains critical sockeye salmon habitat, numerous and regionally important archeological sites, and is the locus of several ongoing multidisciplinary quaternary studies (climate change, ecology glaciology, etc.). LACL is located along the northeast portion of the Aleutian Arc and adjacent to historically active Cook Inlet Volcanoes. Tephra studies are an integral part of understanding the dynamics, extent, cyclic occurrence, and hazards associated with volcanic events. Although numerous studies have cataloged tephra fall in other locations (Katmai, Anchorage, and Kenai Peninsula) the LACL region, north of many Aleutian volcanoes, remains relatively unstudied. Tephra layers represent a single instance in time and can be used to assemble a chronological framework for volcanic events as well as other studies requiring time specific information. Sediment cores obtained from eight small lakes located along a 40 mile transect (NE to SW along the Lake Clark valley) contain a sequence of visually distinguishable ashes which range from historic times to approximately 12,000 years. At least 6 of these appear to be correlative and it is likely that several can be positively correlated across the region, and in the larger lakes with additional analysis. Stratigraphic position, physical description, magnetic susceptibility, ^{14}C age, petrography, and electron microprobe analysis is used to correlate ash layers across the LACL region. This study follows protocols that will allow these data to be used in future Alaska tephra studies. Correlations and chronological framework established in this study will aid ongoing geologic and biologic research in lacustrine systems and will serve as a guide for comparison to land-based geological, archeological, and paleoecological studies. Additionally, these data may prove useful in understanding the variability in subaerial and lacustrine records while improving the confidence of correlations between the two depositional environments.

**LANDSCAPE HISTORY AND LAKE LEVEL CHANGES IN
SOUTHWEST ALASKA**

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Current research in Lake Clark National Park and other Southwest Alaskan parks combines landscape history, paleoecology, and lake system history in order to understand the formation of the present ecosystem, and its vulnerability to climatic change, geologic change, or disturbance. Landscape-scale studies (that include timing of deglaciation, volcanic history, lake level history, vegetation change, and change in drainage patterns through the Holocene) compliment ongoing studies on the archeology and salmon history of these lake systems. Lake level histories around Lake Clark and other large southwest Alaska lakes were determined using sediment cores obtained from kettle ponds located within the paleoshorelines of the larger lakes. These small lakes act as 'isolation basins' recording the change from large, glacial fed lake to small isolated pond as the lake level drops below its threshold. Studies to date show that Lake Clark gradually dropped at approximately 20 meters between deglaciation ~14,000 yBP and the early Holocene ~7,000 BP. Differences in the beach ridge profiles (gradient, and shape of profile) between the SE shore of the lake and the NW shore suggest some differences in drainage patterns and possibly indicate Holocene tectonic movement. Further radiocarbon dating may help determine the rate and nature of this difference. Kukaklek Lake and Naknek Lake (Katmai National Park and Preserve) show evidence of early Holocene lake level drop, however Nonvianuk Lake (located between the two) does not. This suggests the regional pattern of lake level change is not synchronous and most likely related to outlet changes instead of regional tectonism or isostatic rebound. Kukaklek Lake, does however, show evidence for recent (last several decades) lake level rise at it's western end, and possible regression indicated by the formation of beach ridges at it's eastern end. Continued studies at lakes surrounding Naknek Lake are expected to help us better constrain the degree and timing of lake level change in relation to salmon history, lake isolation, and archeological sites in the region.

PRELIMINARY RESULTS FOR INTERBASIN CORRELATION OF TEPHRA DEPOSITS IN LAKE CLARK NATIONAL PARK, ALASKA

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Lake Clark National Park (LACL) covers over four million acres of southwest Alaska, contains critical sockeye salmon habitat, archeological sites from pre European contact, and hosts several ongoing multidisciplinary quaternary studies (climate change, ecology glaciology, etc.). LACL is located along the northeast portion of the Aleutian Arc and adjacent to historically active Cook Inlet Volcanoes. Tephra layers represent a single instance in time and can be used to assemble a chronological framework for other significant events and/or other studies requiring time specific information. Tephra studies are an integral part of understanding the dynamics, extent, cyclic occurrence, and hazards associated with volcanic events. Although numerous studies have cataloged tephra fall in other locations (Katmai, Anchorage, and Kenai Peninsula) the LACL region has gone relatively unstudied. Therefore, a regional study is warranted by the suitability of LACL's numerous lakes and their proximity to multiple active volcanic centers. Numerous (8) lakes, separated by up to 40 miles, within LACL have been cored to obtain the paleoenvironmental record. These cores contain a sequence of visually distinguishable ashes (approx. 6 appear correlateable) which range from historic times to approximately 12,000 years and it is likely that several can be positively correlated across the region with additional analysis. Stratigraphic position, physical description, magnetic susceptibility, C14 age, petrography, and electron microprobe analysis will be used, when possible, to correlate ash layers across the LACL region. This study follows protocols that will allow these data to be used in future Alaska tephra studies. Correlations and chronological framework established in this study will aid ongoing geologic and biologic research in lacustrine systems and will serve as a guide for comparison to land-based geological, archeological, and paleoecological studies. Additionally, these data may prove useful in understanding the variability in subaerial and lacustrine records while improving the confidence of correlations between the two depositional environments.



The Role of Alder Distribution in Aquatic Productivity Linking Terrestrial Vegetation Change to Lake Primary Productivity in Southwest Alaska

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Paleolimnological techniques and landcover analysis on selected lake ecosystems in the Southwest Alaska Network of the National Park Service are utilized in this project to better understand the rapidly changing and long-term trends in their environments, with a focus on Alder Fixed Nitrogen (AFN). Although recent studies have increased our understanding of the linkages between Salmon Derived Nutrients (SDN) and the terrestrial and aquatic communities which rely on them, many questions remain regarding nutrient inputs from the terrestrial ecosystem especially when alder are present on hillslopes or within riparian areas. Evidence from previous studies suggests AFN may exert an important influence on nitrogen cycling and productivity in sub arctic watersheds and lake systems. Vegetation change in just the last half-century may be accelerating terrestrial-derived N inputs from alder. Several case studies of lakes are used to look at the influence of alder distribution and recent alder expansion. Paleoproductivity is reconstructed from down core measurements of changes in organic carbon, nitrogen, phosphorus, and diatom accumulation as well as sedimentary $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$. Data was developed to reconstruct lake productivity over the past 100 to 8000 years. This data defines the natural variability in these systems, and its relationship to past changes in climate, landscape processes, and vegetation change. Siliceous microfossils, particularly diatoms are analyzed to provide information on past and present changes in plankton abundance. Characterization of the history of vegetation abundance and spatial distribution is shown by combining pollen records retrieved from sediment cores with a suite of historical, high altitude photographs and landcover datasets. Rapid vegetation change is illustrated by comparison of past and future photographic records and landcovers. The combined results allow for an integrated record of terrestrial and aquatic changes with evaluation of the effects of alder among aquatic ecosystems both spatially and temporally. Our results suggest that a positive feedback may occur in some systems, in which increases in terrestrial nutrient input enhance lake productivity. Recent documentation that warming has accelerated over the last three decades allow comparisons between the climate driven 'alder rise' of the early Holocene, and the alder expansion which we observe occurring today.