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

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Introduction

Effects of climate change are predicted to include: general tree line advance in elevation and latitude; colonization of formerly glaciated lands; transition of tree species and ecotypes (ACIA, 2004). Terrestrial vegetation type and landscape patterns are potentially important intermediaries of lake productivity. Consequently, disturbance or climate driven landscape changes influence plant community composition or abundance of certain species and may instigate changes in nutrient acquisition, retention or loss at the watershed scale (Compton, 2003).

Background

"..protect the watershed necessary for the perpetuation of the sockeye salmon in Bristol Bay, AK" (ANILCA 1980)

The Purpose 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.

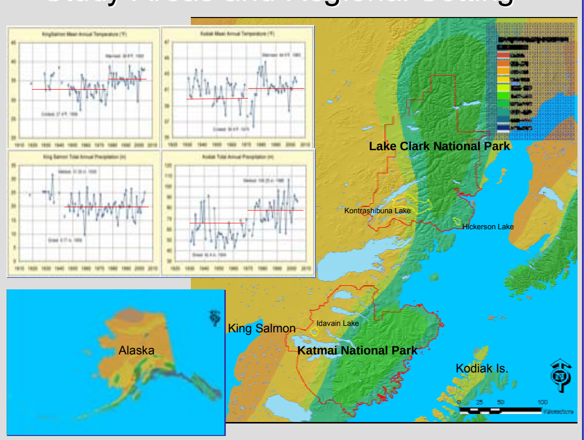
Related objectives and framework:

(1) Characterize vegetation abundance and spatial distribution, specifically alder (photographic records, landcover analyses, and pollen records)

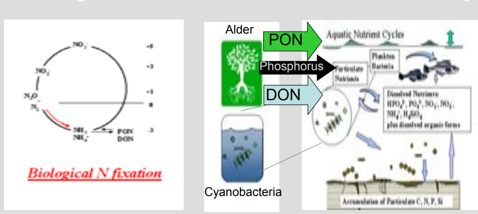
(2) Measure down core lake sediment records using nutrient and productivity indicators (C:N ratios, N:P ratios, Biogenic Opal, $\delta^{15}N$, and $\delta^{13}C$).

(3) Develop a set of watershed and lake characteristics for this region to explain the link between vegetation distribution, disturbance, and climate on the terrestrial landscape to that of the aquatic ecosystem and aquatic productivity using the results of objectives 1 and 2.

Study Areas and Regional Setting



Nitrogen Fixation and Productivity



Tree species with symbiotic N_2-fixing *Frankia* or *Rhizobium* bacteria can fix 50–200 kg nitrogen ha^{-1} y^{-1} in pure stands (Binkley et al 1994). Because nitrogen is a limiting factor for plant growth in most northern boreal forests, symbiotic N_2-fixation by alder (*Alnus*. *spp*) is an important source of nitrogen in arctic ecosystems (Chapin, 1980). The coupling of terrestrial and aquatic processes depicted above are used to help interpret the sedimentary record retrieved from lake cores.

Patterns of Rapid Vegetation Change

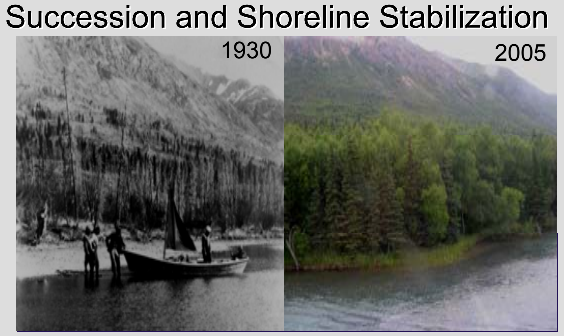
Tree and Shrub Expansion

Photographs of shrub expansion over 86 years near Grosvenor Lake in Katmai National Park within a minimal-disturbance regime. Establishment of new vegetation types and increased biomass has now covered rock outcrops. Many shrub species appear to be establishing where dwarf shrubs and prostrate shrub tundra once dominated. (Photographs courtesy of Torre Jorgenson, ABR and the National Park Service)

Glacial Retreat

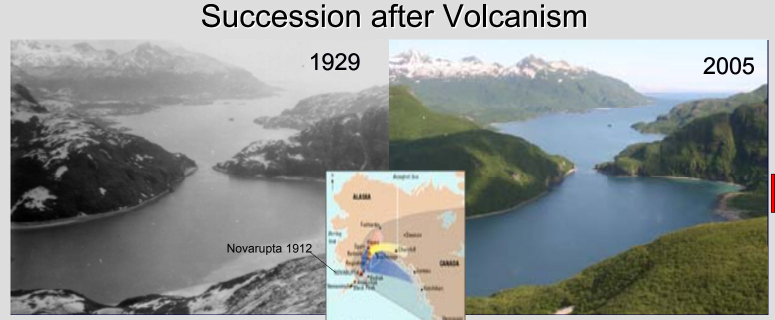
Photographs Four Peaked Glacier, Katmai National Park show evidence for ice retreat and vegetation succession from the end of the Little Ice Age to the Present. Note the alder expansion in the 2005 photo. (Photographs courtesy of Torre Jorgenson, ABR and the National Park Service)

Succession and Shoreline Stabilization



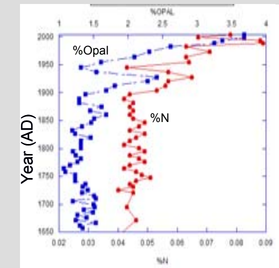
Photographs of Lake Kontrashibuna, Lake Clark National Park illustrates shoreline stabilization with the establishment of spruce and poplar forests. Alder has advanced considerably upslope in the background potentially encouraging soil development and mitigating erosion. (Photographs courtesy of Torre Jorgenson, ABR and NPS)

Succession after Volcanism



Photographs of Devils Bay, Katmai National Park depict large pockets of ash from the Novarupta Volcano eruption in 1912, the largest in the 20th century. The ash laden landscape in 1929, 17-years after the eruption was dominated by alder shrubs and shrub tundra. Alder shrubs now represent 70-90% of vegetation within coastal watersheds. Photographs courtesy of Torre Jorgenson, ABR and the National Park Service)

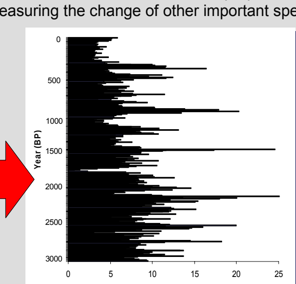
Sediment Records



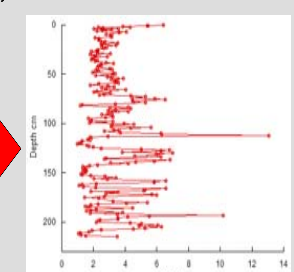
Hickerson Lake ~2% or 40% relative increase in Biogenic OPAL from150 BP to Present. Potential drivers include increase annual temperature and precipitation (A)(Right) and shrub expansion (Left)

Lake Core	Picea undiff	Picea glauca	Picea mariana	Pinus	Betula (W/ Spruce)	Betula (W/out Spruce)	Alnus (W/Spruce)	Alnus (W/out Spruce)	Salix	cf. Populus
Hickerson	200	-200	NA	200	NA	-100	5	NA	200	-200
Kontrashibuna	113	99	200	NA	48	63	-13	-17	-200	NA
Idavain	113	129	NA	200	-14	25	4	43	NA	NA

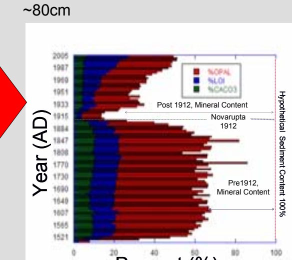
Preliminary pollen data from individual lake cores, depict the Relative Percent Change in tree and shrub species over a ~100year (~1900 to Present) Period. Note, in certain instances spruce have become very abundant on the landscape and were excluded from calculations for the purposes of measuring the change of other important species



Kontrashibuna Lake -Major disturbances from Little Ice Age (LIA) glacial activity and fires hamper the interpretation of other landscape variables, such as vegetation because of large variability in sediment inputs and turbidites in sediment core record. Hickerson Lake within the coastal zone is also subject to disturbance from the LIA.

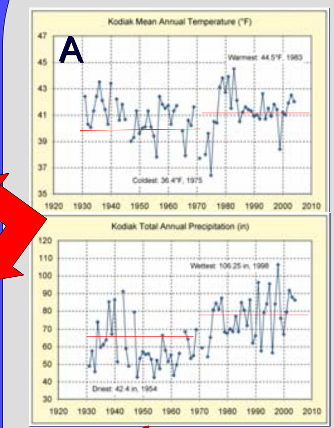


Kontrashibuna Lake – The record of Biogenic Opal is altered by turbidites. Potentially, plant succession and decreased erosion have minimized disturbance, evidenced by the stabilization in the Opal record above ~80cm

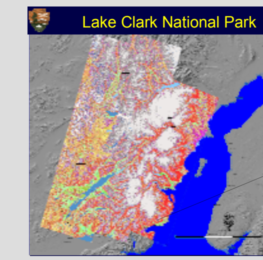


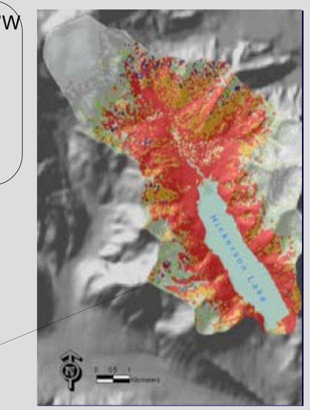
Idavain Lake -Tephra from Novarupta 1912, causes changes in sediment composition and potentially masks primary production proxy

Case Study: Hickerson Lake

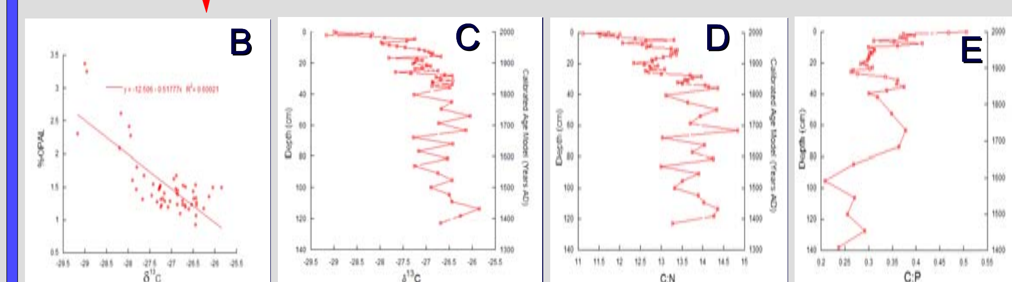


Location - 59º55.84'N,152º 55.063'W
Elevation -193m
Length of - 4.5Km
Total Watershed Area - 40km²
Maximum Known Depth– 41m
Secchi Disk Reading – 2.5m
pH – 8.3





Preliminary Results



A. Increased Precipitation and Temperatures appear to coincide with timing of changes in down core lake productivity proxy.

B. Negative correlation between $\delta^{13}C$ and %OPAL; Biogenic Opal should not be subject to dissolution or digenetic processes in freshwater systems.

C. $\delta^{13}C$ decrease may indicate increased aquatic productivity and thus enhanced contribution of algae-derived C to the sedimentary C pool. Kling and others(1992) found algae may be more depleted in terrestrial organic matter in some Alaskan lakes

D. An increase in aquatic productivity is supported by lower C:N ratios, consistent with %OPAL, the percentages of organic C and N both increase greatly near the top of the core. This is potentially because of increased production of aquatic organic matter but, may be a function of early stages of digenetic processes.

E. Decreased P relative to C; this may be caused by enhanced P recycling for primary production due to increased availability of N via N_2-fixation from Alnus species.

Preliminary Conclusions

•Evidence for recent increases in productivity are apparent in the sedimentary records relative to the past. However, completion of data analyses are necessary to more fully develop an understanding extent and causes for the increases.

•Disturbances driven by climate, glacial retreat, and volcanism severely complicate assessing the link between landscape vegetation and lake productivity.

•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 bigeochemical signatures to sufficiently elucidate its influence.

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