SUMMARY REPORT

Freshwater Monitoring Scoping Workshop
Southeast Alaska Network
National Park Service
Inventory and Monitoring Program

Goldbelt Hotel, Juneau, AK
February 1-3, 2005

Chiska Derr and Chris Fastie

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Freshwater Monitoring Scoping Workshop
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Workshop Objectives

1. Review and refine conceptual ecosystem models
2. Formulate potential monitoring questions for freshwater ecosystem components
3. Identify potential attributes ("vital signs") to monitor

Background

The Southeast Alaska Network (SEAN) held its first vital signs monitoring scoping workshop on freshwater ecosystem components at the Goldbelt Hotel, Juneau, February 1-3, 2005. The workshop purpose was to provide a forum for National Park Service (NPS) resource managers and invited scientists to discuss ideas for building a statistically sound, ecologically based, management-relevant, affordable monitoring program for SEAN. The network is made of Glacier Bay National Park and Preserve (GLBA), and Klondike (KLGO) and Sitka (SITK) National Historical Parks. Workshop participants included members of the SEAN technical committee and other NPS natural resource professionals, and invited scientists with expertise in fisheries biology, glaciology, hydrology, physical sciences, stream ecology, and water quality monitoring. Participants were given a notebook with background information on the national and SEAN Inventory & Monitoring (I&M) Programs, the network parks, draft conceptual ecosystem models, maps, and workshop objectives. The information and ideas generated during this workshop will help develop a long-term monitoring plan for SEAN. Workshop logistics and facilitation were provided by Arctic Research Consortium, US (ARCUS).

Introduction to SEAN Freshwater Scoping Workshop

On February 1 workshop participants (Appendix A) met between 4 and 7 pm, mingled during a social hour, and reviewed the workshop objectives and agenda (Appendix B). They received copies of the annotated bibliography compiled from various participant's input (Appendix C), and discussed the purpose and role of the two workgroups "Rivers, Lakes and Streams" and "Other Freshwater Bodies".

Presentations

During the morning of 2 February, a series of presentations were given to provide background and context for the workshop, and to review the draft conceptual ecosystem models SEAN has been developing.

National I&M Program (Sara Wesser)

Sara provided an overview of the National and Regional I&M Programs and the nationally identified core parameters for water quality and quantity monitoring.

The I&M Program in Southeast Alaska (Chiska Derr)

Chiska gave an overview of the SEAN I&M program objectives and timeline and the mandates and enabling legislation for each park in the network. She then discussed the freshwater resources and associated issues within each park.

Southeast Alaska's Ecosystem (Greg Streveler)

Greg reviewed what he referred to as the fundamental phenomena and drivers in Southeast Alaska ecology. He then discussed some specific hydric systems in each of the three SEAN parks.

Phenomena and drivers

Two factors combine to determine the character of the southeast Alaska landscape: atmospheric circulation patterns and plate tectonics. Atmospheric circulation patterns bring moist, temperate air masses ashore, resulting in a maritime climate with high precipitation and relatively warm temperatures. The active tectonic plate boundary has accreted myriad rock types over the ages, and continues to produce tectonic uplift. The resulting mountain ranges interrupt the onshore flow of moist air and redirects the air upward, where high snowfall supports the growth of mountain glaciers and ice fields.

The processes of atmospheric circulation patterns and plate tectonics interact to produce a complicated geography. This geography includes: extreme topography with great altitudinal range; high landform diversity derived from bedrock diversity and diverse glacial history; an insular geography; ubiquitous marine influences as the sea is anastomosed into the land; and a complex history of sea level changes (from tectonic and glacial-isostatic uplift and downthrow, in addition to long-term global changes in ice storage).

An example of the impact of sea level changes is the impervious nature of marine sediments deposited below an elevation of about 100 meters through much of northern Southeast Alaska. These poorly drained sediments are more susceptible to wetland formation than the sediments typical of higher elevation sites. Another example of sea level changes influencing hydric systems is the slough-like lakes formed behind beach ridges near Dry Bay.

In general, wetlands are common in Southeast Alaska because of the moist climate and layers of impervious sub-surface materials. The geographic complexity of the region results in complex and diverse watersheds and wetland habitats.

Lakes, which are relatively uncommon worldwide, are ubiquitous in Southeast Alaska in large part due to glacial processes and action. For example, lakes are formed in southeast Alaska when valleys are dammed by outwash fans or glacial ice. Tarns form where glacial scouring erodes depressions in bedrock. Abandoned channels in glacial rivers can form oxbow lakes.

Two dominant drivers, wetness and disturbance, influence the major ecological communities in Southeast Alaska. The constant wetness drives the development of plant communities and soils that are strongly influenced by autogenic processes. For example, leaching of rainwater through continuously accumulating organic soil horizons drives the development of an impervious soil horizon (paludification). Ecosystems in Southeast Alaska range from very early successional to mature. Disturbance, whether by glaciers, downslope movement of soil, rocks, snow and vegetation, or insects, creates younger, simpler systems. Early successional systems are not able to sequester as many resources as mature ecosystems, therefore nearby hydric systems receive the exported nutrients and energy. The result is more productive lakes and streams in younger, successional watersheds. Countering this temporal trend is the effect of large populations of anadromous fish, which bring marine nutrients and energy into young and old streams, lakes, and adjacent terrestrial ecosystems.

Hydric regimes of the SEAN parks

Glacier Bay National Park and Preserve

Glacier Bay is characterized by great diversity in bedrock types, topography, glacial history, and surface age, and consequently has a great diversity of hydric regimes. Dan Engstom's work relied on the large range in the age of lakes in Glacier Bay, a chronosequence that could be extended to lakes of early Holocene age near Cape Villaluenga.

Klondike National Historical Park

The Taiya Valley receives less than a quarter of the amount of the precipitation that the other two parks receive. Although this area is undergoing uplift due to isostatic rebound, it apparently does not have the history of sea level fluctuation that deposited poorly drained marine sediments in the lowlands elsewhere. The soil regime is less prone to podzolization and paludification. Consequently, wetlands are uncommon in the lowlands, except for the wetlands at the base of the valley slopes along the Taiya River. Above the cloud intercept zone at about 600 meters, the environments are moister, and wetland habitats are more similar to those in other places in Southeast Alaska.

Sitka National Historical Park

The bedrock near Sitka National Historical Park is of a single rock type, a slightly calcareous greywacke. Silt, an important erosional product of this rock, has specific influences on hydric environments. The prominent hydric feature in the park is the Indian River. This stream, while similar to streams near Glacier Bay, exists in a very different lithologic and climatic regime than other streams in the SEAN parks.

Freshwater Ecosystems (Sandy Milner)

Stream Ecosystems Conceptual Models

Sandy reviewed several conceptual models of stream ecosystems applicable to Southeast Alaska streams. One model outlines how the relative contribution of water from, snowmelt, glacial meltwater, and groundwater sources influences stream water temperature, turbidity and discharge regime, and stream channel dynamics. These variables are subsequent important drivers of stream macroinvertebrate community composition. The relative contribution from these water sources is a function of regional climate and is vulnerable to climate change.

Anotherconceptual model related to glacially influenced rivers where two major variables, water temperature and channel stability, determine much of the variability in stream benthic communities.

Sandy described the four dimensional structure of stream ecosystems: the up- and downstream continuum; the lateral gradient across the floodplain; the vertical gradient into the hyporheic zone; and the temporal gradient, which includes successional change.

Linkages between terrestrial and stream ecosystems

Sandy's research in Glacier Bay has demonstrated how stream age and the presence of a lake upstream can enhance downstream channel stability and reduce the effect of deposited sediment thereby thereby influencingbiotic community structure and increasing diversity and abundance However, Ssreams with lakes are less likely to meander or migrate across their floodplain, which reduces the recruitment of coarse woody debris (CWD) in older systems CWD from trees retains nutrients (e.g., salmon carcasses and organic carbon) and coarse benthic organic matter is associated with increased mayfly and stonefly abundance. Ongoing research includes the ecological role in aquatic and riparian food webs of nutrient pulses from colonizing anadromous fish and the linkages between the terrestrial and stream environments.

There are other strong links between stream ecosystems and adjacent riparian zones. Terrestrial vegetation along stream banks harbors terrestrial invertebrates that fall into the stream and provide food for stream organisms. Some of the riparian invertebrates (e.g., spiders, beetles) prey on aquatic insects, in turn provideing food for riparian birds and other vertebrates. Alder communities typically export more terrestrial invertebrates than young conifers.

Sandy's Stream Development Conceptual Model

Sandy presented his conceptual diagrams of the connectivity among ecosystem features of stream, lake, terrestrial, hyporheic, and marine environments. The links represented in these diagrams are not static, but vary in strength through successional processes. For example, terrestrial material falling into young streams is not retained and transported rapidly to a lake or to the ocean, but as CWD creates pools in older streams, nutrients stay in the stream longer and support more diverse floras and faunas. Links to the hyporheic zone are poorly understood in Southeast Alaska, but nutrients may be sequestered there.

Dan Engstrom's Lake Research

Dan Engstrom's research on lake succession in Glacier Bay used both a chronosequence of lakes of different ages and the stratigraphic record from sediments in individual lakes to document the development of physical and biological properties of lakes. Young lakes receive ample cations from groundwater and runoff across sparsely vegetated watersheds. As terrestrial succession covers the watershed with plants, water entering lakes carries more dissolved organic carbon, and especially where N-fixing alder is abundant, more nitrogen. Late in succession, soils become impermeable, and water flowing through only the upper, organic horizons carries more DOC and fewer cations, so lake pH is lowered. The strong links to terrestrial succession emphasize that lakes do not follow universal successional pathways but are influenced by the successional development of the particular watershed.

Water Quality Monitoring Approaches

Multimetric Water Quality Monitoring

A common multimetric approach (the Alaska Stream Condition Index [ASCI]) uses a number of biological metrics which incorporate measures of community structure. Some of these are compositional metrics which look at the percentage abundance of mayflies, stoneflies, and caddisflies. A reduction in their valuetypically indicates a decrease in water quality. . In order to infer that changes in water quality are caused by human influences, this approach requires that populations of monitored species remain stable in the absence of human influence. From long term monitoring of a number of sites in Denali National Park, Sandy's data suggests that there is considerable natural variation in in benthic macroinvertebrate populations which make compositional metrics unsuitable for water quality monitoring in some areas of Alaska.

Predictive Water Quality Monitoring

Another approach involves the building the predictive models where key environmental variables are used to predict the macroinvertebrate fauna expected at a site in the absence of impairment (expected). The actual fauna is then collected (observed) and the observed is then compared to the expected to see the degree of similarity.

Water Quality Monitoring Using Fluorescence

Fluorescence spectrophotometry can quickly and accurately measure the concentration of many organic compounds in freshwaters. It can detect organic pollutants, and identify their likely sources (e.g. petroleum, animal wastes, human wastes, etc.) in a process known as fingerprinting.

Clarifying Discussions

Throughout the workshop there were a number of discussions on several aspects of the I&M program. These discussions are summarized below.

Glacier Bay Integrated Science Plan Relevance to Workshop

In late October 2004, following the Glacier Bay Science Symposium, a group of invited scientists attended a workshop to formulate the research component of an Integrated Science Plan (ISP) for the park. Several of those participants were also invited to the SEAN freshwater scoping workshop, and wondered how the two efforts were related. There was concern that the freshwater scoping workshop was attempting to "reinvent the wheel". One of the main differences between the IPS and SEAN freshwater scoping objectives was that the latter apply to two additional parks, KLGO and SITK. Another difference is that the ISP is more research oriented, where the I&M program is developing a monitoring program.

One of the ISP participants mentioned that the ISP freshwater group chose to use a long term (50-100 years) monitoring, rather than research, perspective, considered budget limitations and personnel changes, and formulated a list of relatively simple, do-able potential projects. To do this the ISP freshwater group asked themselves which monitoring questions would track the health of the park under these time and budget constraints. A list of questions generated during the ISP workshop was distributed (Appendix D). The I&M monitoring program objectives are also long term, at the 50 to 100 year scale.

Any pertinent monitoring questions generated during the ISP that apply to one or more of the SEAN parks are relevant for consideration during the SEAN scoping workshops.

Spatial Scale of SEAN Monitoring

Because some processes and influences, like the outburst flood events in West Creek (KLGO), originate outside park boundaries, there was discussion about the spatial scale of SEAN I&M monitoring. Specifically, people wondered if Alaska's monitoring program, like many programs in the Lower 48, is limited to monitoring indicators that park managers can influence through management actions. No, it is not necessarily limited to indicators that are influenced through NPS management actions. Most Lower 48 parks are small portions of larger systems with many influences coming from neighboring land owners, while most Alaska parks are much larger, and many outside influences are at much larger (ie. global) scale. Even though Alaska parks are relatively

pristine, baselines for vital signs still need to be established so changes to those vital signs can be monitored. If the network is concerned about processes or resources that originate outside of a park, and if there are park benefits to monitoring those resources or processes, then they can be considered for inclusion in the program. In those cases where there is mixed landownership, the NPS would try to work with the appropriate land owners and other partners to get pertinent information.

Monitoring Cost Considerations

There was discussion about I&M funding, how funds get allocated to science and monitoring, and if funding constraints should be a factor in during the workshop. Freshwater scoping workshop participants were encouraged not to consider cost constraints during their initial brainstorming during scoping workshops. By the time the program is implemented (after 2008), new partnerships and technologies may render once prohibitive projects more feasible. The point is to raise the monitoring questions now, but not get too specific about the sampling methods or costs at this stage. Although the SEAN is not fully funded yet, even at full funding levels the amount will never be large. The importance of collaboration and additional monitoring funding sources, such as NOAA, was discussed. Dovetailing projects with existing related research can also help stretch budgets. It was noted that NSF doesn't fund monitoring programs or projects. The utility of thinking ahead to sampling design to avoid impracticalities was mentioned.

Potential SEAN Scientific Advisory Board

Greg Streveler raised his concern about the lack of a scientific advisory body that communicates directly with the SEAN board of directors. Other scientists expressed considerable chagrin that professional and personal interest drives participation at workshops like this but that, in the end, it doesn't seem to matter what scientists say, as NPS management makes the decisions. Although it is true that park superintendents will always make the final decisions, with input from the I&M technical committees, it is the technical committee's responsibility to solicit scientific experts' input as needed. Relationships between the scientific community and SEAN are in the early stages of development, and the possibility of a regional scientific committee will be considered.

At the end of the workshop, we discussed the need for consistent scientific input throughout the process of developing the SEAN monitoring plan. It was noted that many of the scientists at the workshop were the ones likely to be asked for additional time and help. Greg Streveler suggested the use of a non-NPS person from the scientific community who would act as a liaison between the scientific community and park managers. Susan Boudreau mentioned that there is office space for visiting scientists at GLBA, and that GLBA is working toward temporary office space at the Glacier Bay Field Station in Juneau. Sandy Milner suggested that the voice of a scientific panel might be more meaningful than one voice. Susan Boudreau and Sara Wesser said they'd raise this concern at the national I&M meeting. Susan mentioned an analogous concern about the integration of local and traditional knowledge. Information must flow between the local and scientific communities and network personnel, and good working relationships are essential.

Action Item: The Technical Committee will forward the topic of a possible science advisory board to the SEAN Board of Directors.

NatureBib Database

There was a brief discussion of the NPS I&M bibliographic database, NatureBib, which includes grey literature. The intent is to make the national database available to the public, once new national-level government security issues are resolved.

Feedback on Conceptual Ecosystem Models

Discussion of the conceptual models developed for SEAN parks occurred throughout the workshop, and the important comments and suggestions are summarized here.

There was much discussion of whether climate, tectonics and glaciers, three fundamental drivers of change in Southeast Alaska, were appropriately included in the model diagrams. Dan Lawson and Roman Motyka suggested that climate and atmospheric processes were overarching drivers that should be represented as influencing all or most other drivers. They suggested that tectonics and other geological process had not been adequately incorporated. And they suggested that glacial processes should be elevated in importance because of their great influence in southeast Alaska. Much of this discussion focused on how these ideas could be incorporated into the model diagram entitled "Landscape Drivers of Change." Greg Streveler also commented that the diagram included both static (e.g., island biogeography) and dynamic (e.g., glaciers, human activity) drivers without recognizing the various rates and time frames during which the drivers changed their effects. This model will be modified to reflect these comments.

The current suite of conceptual models includes three diagrams related to resource preservation concerns. The "comprehensive" model includes both far-field and near-field drivers of change, and there are separate models of both far- and near-field drivers. This redundancy produced some confusion. The far-field drivers model illustrates how global human activity affects all of earth's environments, and therefore seemed distantly relevant to SEAN parks. For example, worldwide transformation of lands and waters has caused the loss of species, populations, and ecosystems, but Southeast Alaska remains somewhat insulated from these effects. The near-field drivers model attempts to be specific about the environmental effects of local and regional human activity, but is poorly grounded in data on these effects. Also, this model includes the distinction among human use by visitors, scientists, and developers, a distinction that some thought was unwarranted. These three models will likely be combined into one diagram that reflects these comments.

The suite of SEAN models includes five process models of ecological interactions in different habitats. One of these models, stream primary succession, is based on Sandy Milner's research in Glacier Bay National Park. At the workshop, Sandy presented a new suite of four models summarizing this research and generously offered their use to the SEAN I&M effort. The general diagram illustrating the interactions among components of the terrestrial, stream, lake, hyporheic, and marine environments will replace the stream succession model previously in the SEAN suite.

The process model and related text based on Dan Engstrom's research on lake primary succession will be modified to incorporate suggestions to better define interflow, to incorporate the results about nitrogen, and to replace "CA^{2+}" with "base cations."

A comment was made about whether the successional component of ecosystem change was adequately represented in the process models. An effective way to incorporate successional change is to draft different versions of each model for early, mid, and late successional environments, as Sandy Milner has done for his stream succession models. However, this would inflate the number of diagrams in an already growing suite of diagrams.

During the workshop two new models were generated. Dan Lawson drafted a conceptual model of the physical drivers of glaciers and icefields and their subsequent physical effects on landforms, groundwater, lakes, streams, and fjords (Figure 1). During Greg Streveler's presentation, he unveiled his new conceptual diagram of the primary factors contributing to the character of hydric environments in Southeast Alaska (Figure 2). These two diagrams will be redrafted and incorporated into the SEAN suite of conceptual models; the original versions are presented below.

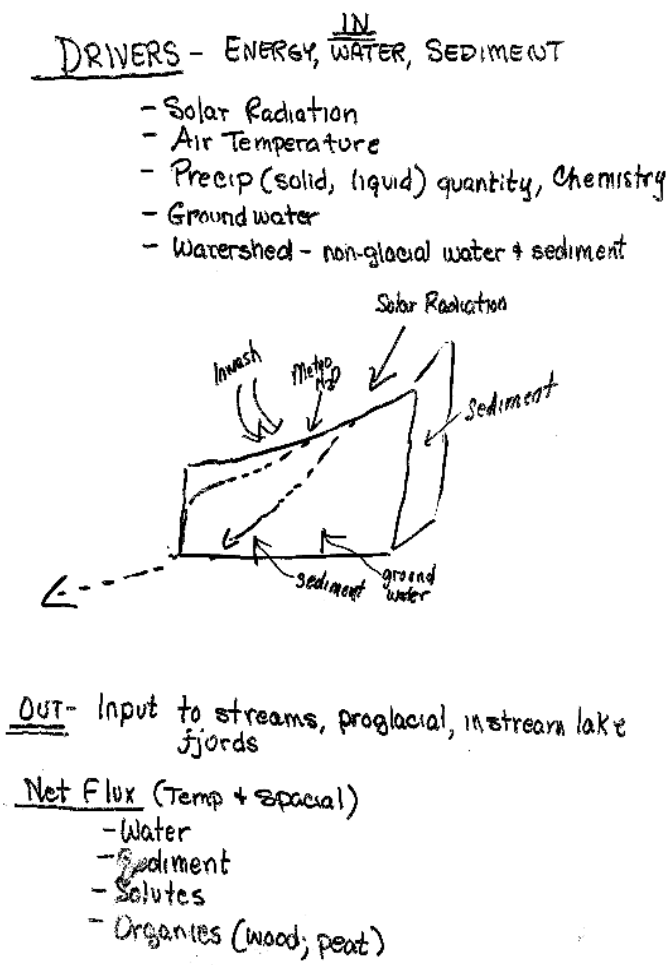

Figure 1. Draft conceptual ecosystem model of the physical drivers of glaciers and icefields, and their subsequent physical effects on landforms, lakes, streams, and fjords (Dan Lawson).

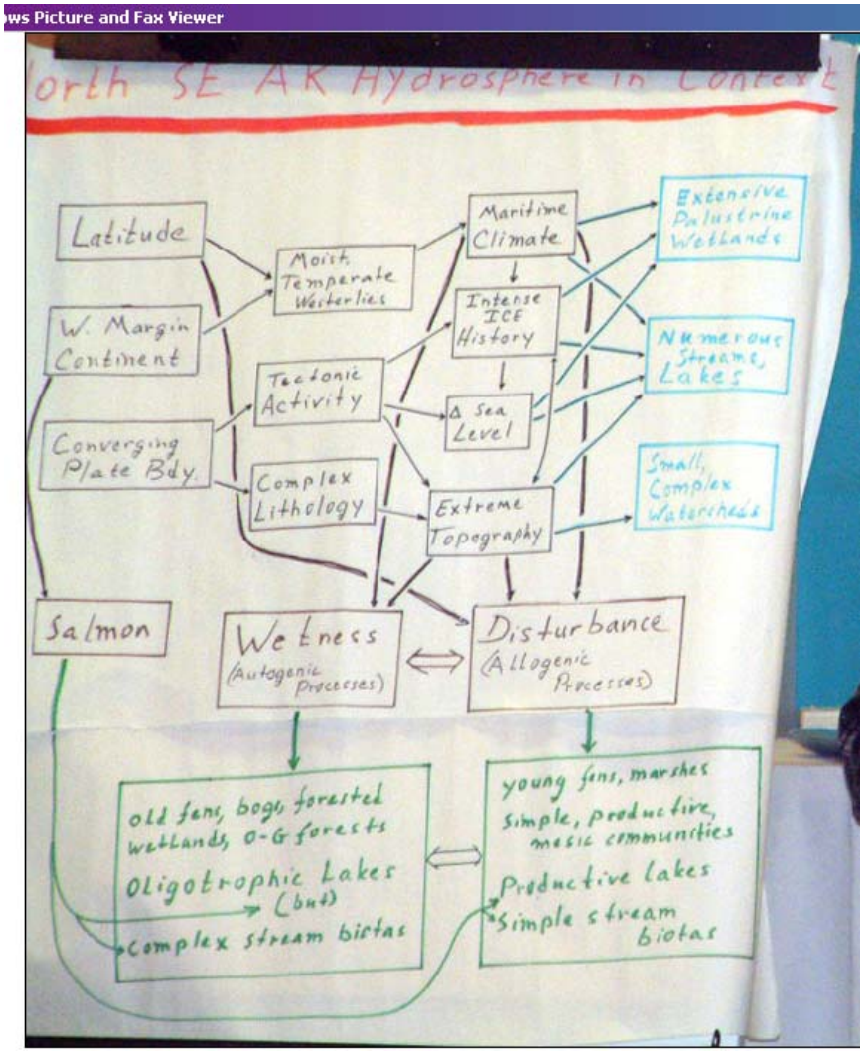

Figure 2. Conceptual model of the primary factors contributing to the character of hydric environments in Southeast Alaska (Greg Streveler).

Process for Potential Vital Sign Identification

Before this workshop, the SEAN technical committee decided to use an approach to vital sign selection that the Arctic Network (ARCN) and others have used successfully. This approach is to start by identifying data gaps, in the form of questions, about the different ecosystem components. Vital signs inherent within the questions, and appropriate measures of those vital signs, are then identified after monitoring questions had been generated. The benefit to using this approach is that workshop participants are not biased by the lists of vital signs generated by previous networks and groups. The disadvantage is that workshop participants are more or less starting from scratch, without the benefit of examples from previous efforts. As the workshop progressed, this disadvantage became clear, and examples of freshwater monitoring objectives and vital signs were brought in. The group then generated potential freshwater monitoring objectives for SEAN, which were each pertinent to one or more potential vital signs. For example: *Objective A: To understand short- and long-term changes in the physical, biological and chemical*

features of wetlands has wetlands as a vital sign. The proposed monitoring questions were ultimately nested under the appropriate objective.

Potential Freshwater Monitoring Questions

During the morning of 3 February the two work groups began to develop potential freshwater monitoring questions for SEAN. We used a database that ARCN had developed to track and summarize the questions, vital signs and measures. For ease of comparison and summarization, potential monitoring questions were grouped into categories used in the vital signs database framework, developed by the national I&M program. The groups of SEAN potential monitoring questions were formed after the workshop.

Proposed Monitoring Questions (Rivers, Streams and Lakes group)

Climate:

- ☆ What is climate doing in the SEAN?

Biotic:

- ☆ How are benthic communities changing?
- ☆ How are non-benthic aquatic communities changing?
- ☆ How are fish community compositions changing?
- ☆ What levels of harvest can small fish populations or newly colonized streams sustain?
- ☆ How are juvenile salmon densities changing over time in the Indian River?

  Vital Sign: juvenile salmon
  Stressors: water level, predation and human harvest, pollution, temperature, siltation, fisheries, food supply, genetic diversity, disease, water quality, and hatchery/fish farm influence.
  Measures: density, absolute and relative abundance, growth rates, and species composition.

- ☆ To what extent are exotic species affecting freshwater systems?
- ☆ How is amphibian distribution and abundance changing?

Glaciers:

- ☆ What are glaciers doing?
- ☆ How do glaciers affect freshwater bodies?

Possible Glacier measures:

- ☆ glacial mass balance change
- ☆ glacier growth
- ☆ glacier-related freshwater bodies
- ☆ glacier runoff

Water (Quality, Quantity & Hydrology):

- ☆ • What is the level of contaminants in freshwater systems?
- ☆ • How are water sources changing temporally and spatially (what are the relative contributions of various sources to freshwater systems)?
- ☆ • How do changing water sources influence freshwater bodies?
- ☆ • How do freshwater inputs influence near-shore marine productivity?
- ☆ • How is water quality changing?
- ☆ • How are large rivers' "health" changing?
- ☆ • How is freshwater quality changing over time, and what bodies meet state standards?

Ecosystem Processes:

- ☆ • How do marine derived nutrients affect freshwater systems?
- ☆ • How is connectivity among different freshwater bodies and other ecosystem components changing over time?

Proposed Monitoring Questions (Other Water Bodies group)

Because potential monitoring questions varied depending on the type of water body under consideration, this group listed different kinds of other water bodies and then listed a set of possible attributes.

Types of water body:

- ☆ Wetlands (bogs, fens, marshes, forested wetlands; occupied by macroscopic plants)
- ☆ Glaciers and icefields(glacier-associated water bodies: ponds, trap, supra-, en- and sub-glacial, stagnant and buried ice, proglacial lakes)
- ☆ Seasonal snow pack
- ☆ Liquid water bodies
- ☆ Ground water (minus hyporheic flow, karst hydrology)
- ☆ Permafrost (ground ice)
- ☆ Ponds (ephemeral, high-elevation bedrock, inter-morainal, kettle, dredge {amphibian habitat}, ponds on glaciers, trap lakes and ponds, supraglacial {see glaciers list})
- ☆ Permanent snow pack

Possible Attributes:

- ☆ chemistry
- ☆ location
- ☆ size and distribution
- ☆ landscape position
- ☆ water quality
- ☆ resident fish
- ☆ anadromous fish
- ☆ amphibians

Possible additional models:

- ☆ glacial hydraulics and processes
- ☆ wetlands
- ☆ ponds
- ☆ periglacial ponds
- ☆ amphibian habitat ponds
- ☆ ephemeral water bodies/streams/thermokarst ponds

Potential Freshwater Monitoring Objectives

As the final workshop exercise, the objectives and monitoring questions generated by the two work groups were written on flip chart pages, and posted on the walls. Workshop participants looked for overlap between objectives and questions, questions that should be combined or organized as subsets of others, and other patterns. The group realized that most of the questions could be fit into the eight objectives generated by the other water body group. Two more objectives, H and I, were added.

Although potential vital signs were not explicitly listed during the workshop, they were inherent within the monitoring objective statements and questions. The potential vital signs within the objectives and monitoring questions are highlighted in red.

Objective A: to understand short- and long-term changes in the physical, biological and chemical features of wetlands.

Objective B: to understand short- and long-term changes in the physical, biological and chemical features of glaciers.

• What are glaciers doing?

Objective C: to understand how glaciers influence short- and long-term changes in the physical, biological and chemical features of freshwater ecosystems.

Objective D: to understand the short- and long-term changes in the physical, biological and chemical features of permanent snow packs.

Objective E: to understand how permanent snow packs affect short- and long-term changes in the physical, biological and chemical features of freshwater ecosystems.

Objective F: to understand how park and preserve ecosystems are affected by local and regional human activities.

• What are the human uses of aquatic resources?
• What level of harvest can small fish populations or newly colonized streams sustain?
• What is the level of contaminants in freshwater systems?
• How is freshwater quality changing over time and what bodies meet state standards?

Objective G: to understand the climate in the SE Alaska Network units.

• How do changing water sources influence freshwater bodies, e.g., influence of glacial melt, snow melt, rainfall, and ground water?
• How are water sources changing temporally and spatially, i.e., what are the relative contributions of various water sources to freshwater systems (same vital signs as in previous question)?

Objective H: to understand the short- and long-term changes in the physical, biological and chemical features of watersheds, including lentic (still water) and lotic (moving water) systems.

• How are fish populations changing?
• To what extent are exotic species affecting freshwater systems?
• How are non-benthic aquatic communities changing?
• How is amphibian distribution and abundance changing?
• How are benthic communities changing?
• What is the status of the "health" of large rivers (water quality, macroinvertebrates)?
• What are the (present) conditions of freshwater bodies (water quality)?

Objective I: How is the connectivity among different freshwater bodies and ecosystems changing over time?

• How do freshwater inputs influence near-shore marine productivity?
• What is the influence of marine-derived nutrients on freshwater systems over time?

Areas of Possible Monitoring Significance that Need Further Development (and volunteers to develop objectives for these)

1. Ponds -- Geoffrey Smith
2. Climate – Susan Boudreau and Dan Lawson
3. Human uses – Meg Hahr
4. *Distinctions* among streams, rivers and lakes?
5. Rare ecosystems and taxa – Greg Streveler
6. Over-wintering conditions, i.e., ice cover: how long, how thick – Sandy Milner
7. Episodic events, i.e., ephemeral pools and streams, mass wasting, terrestrial processes – Dan Lawson

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Workshop Wrap Up: Reflections and Suggestions

To conclude the meeting, the facilitator asked the participants to step back from the science and think about the meeting process, in order to make helpful suggestions to SEAN staff for future workshops. These suggestions for future workshops were generated:

- ✰ Develop potential monitoring objectives for remaining ecosystem components (terrestrial and marine) before the workshop, and make this draft list available to participants ahead of time.

Provide examples of monitoring objectives, questions, vital signs and measures available to workshop participants, to help jumpstart the brainstorming. (Although some networks have provided a first list of proposed monitoring questions and vital signs, most networks do not want to bias the participants' approach. Some considerations, like weather, are similar across networks, so earlier work on these could be presented and incorporated. It was suggested that initial, big lists developed by others be provided to help the groups get started rather than having to do the whole exercise from scratch.)

- ✰ Provide the results from related science symposia, while realizing the need to think big and not fall back on favorite or familiar projects.
- ✰ Devise a one to two page "cheat sheet" for participants with examples and clarification. The workshop notebook was almost too much to digest.
- ✰ The data and maps in the notebook need to be dated and list the sources used to generate them.
- ✰ Have a facilitator and database/recorder in each small group.
- ✰ There were mixed opinions about the utility of the database. Some felt it was distracting, that the definitions and terminology was confusing, and that it was unclear what went into each box.
- ✰ Have either a scientific panel or liason help provide continuity and communication during the entire SEAN vital sign monitoring plan development process.

The facilitator asked what worked well, and responses included: thanks for the maps, the presentations as background information, the facilitator, and the small groups with their wide representation. Greg noted that the workshop took a lot of pre-work to organize, that the workshop participants had taken on a difficult task, and that everyone deserved compliments on a job well done. Thanks were expressed all 'round and the meeting was formally adjourned.

Post-Workshop Objective and Potential Vital Signs Refinement

Refined Objectives

After the freshwater scoping workshop, the SEAN technical committee reviewed the objectives and potential vital signs. Some objectives were combined, and two new ones were generated.

Objective A: to understand short- and long-term changes in the physical, biological and chemical features of wetlands.

Objective B: to understand short- and long-term changes in the physical, biological and chemical features of glaciers.

Objective C: to understand the short- and long-term changes in the physical, biological and chemical features of permanent snow packs.

Objective D: to understand how park and preserve ecosystems are affected by local and regional human activities.

• What are the human uses of aquatic resources?
• What level of harvest can small fish populations or newly colonized streams sustain?
• What is the level of contaminants in freshwater systems?
• How is freshwater quality changing over time and what bodies meet state standards?

Objective E: to understand the climate in the SE Alaska Network units.

• How do changing water sources influence freshwater bodies, e.g., influence of glacial melt, snow melt, rainfall, and ground water?
• How are water sources changing temporally and spatially, i.e., what are the relative contributions of various water sources to freshwater systems (same vital signs as in previous question)?

Objective F. Understand short and long term changes in physical, chemical and biological features of rivers, streams and other moving water (lotic) systems (watersheds, stream channel characteristics, groundwater dynamics, surface water dynamics, water quality, water chemistry, aquatic macroinvertebrates, exotic plants and animals, fish, benthic algae, benthic invertebrates).

Objective G. Understand short and long term changes in physical, chemical and biological features of lakes, ponds and other still water (lentic) systems . (same vital signs as in previous question, non-benthic invertebrates).

Objective H. Understand how the pattern and distribution of freshwater features is changing across the landscape (land cover).

Potential Vital Signs

Because some potential vital signs were common to several objectives, vital signs are listed below to reduce redundancy (Table 1).

Table 1. Potential SEAN Freshwater Vital Signs

Wetlands	Amphibians	Benthic algae
Glaciers/icefields	Exotic species	Fishes
Permanent snow packs	Water quality	Benthic invertebrates
Human activities	Water quantity	Plankton
Climate/weather	Groundwater dynamics	Marine-derived nutrients
Rivers and streams	Surface water dynamics	Terrestrial-derived nutrients
Lakes and ponds	Air quality	Permafrost
Land cover	Snow and ice chemistry	Contaminants

Vital Signs Framework

As earlier networks in the country have identified their vital signs, it became obvious that many vital signs were common among networks. To promote collaboration among networks and with other programs and agencies, and to combine results for national reporting, vital signs being monitored by the earlier parks and networks were organized into a hierarchical *Vital Signs Monitoring Framework*. Vital signs are nested within three levels, which progress from general (Level 1) to specific (Level 3). In some cases, a vital sign is worded the same as the Level 3 Category, and in some cases the vital sign is a subset of the Level 3 Category. Following the SEAN Freshwater Scoping Workshop, the potential vital signs generated during the workshop were fit to the National *Vital Signs Monitoring Framework* (Table 2). The potential vital signs (and their measures) generated during the upcoming SEAN Terrestrial and Marine Scoping Workshops will also be fit to the national framework. The list of potential vital signs will be integrated based on importance of the vital sign to multiple ecosystem components, existence of monitoring protocols, feasibility of monitoring and other criteria. The table below is a first draft of the SEAN potential vital signs.

Table 2. Potential SEAN Freshwater Vital Signs & Measures

Level 1	*Level 2*	*Level 3*	*Potential Freshwater Vital Signs*	*Potential Freshwater Vital Signs Measures*
Air and Climate	**Air Quality**	Ozone		
		Wet and dry deposition		Snow field, glacier ice chemistry
		Visibility and particulate matter		Snow field, glacier ice chemistry
		Air contaminants	Air quality	Permanent snow pack, glacier ice chemistry
	Weather & Climate	Weather and Climate	Weather and climate; Permanent snow packs, glaciers	
Geology and Soils	**Geomorphology**	Windblown features and processes		
		Glacial features and processes	Glaciers and icefields	mass balance change, glacier growth, glacier-related freshwater bodies, glacier runoff
		Hillslope features and processes	Gullies, fans, landslides, debris flows	Landform changes, features(scarps, deposits, erosional scars
		Coastal / oceanographic features and processes	Shore zone	Erosional scarps, uplift features
		Marine features and processes		
		Stream / river channel characteristics	River channel morphology	Bank erosion, migration rate, headward extension, habitat mapping, thalweg profiles, substrate size
		Lake features and	Lakes and ponds (lentic systems)	

Level 1	*Level 2*	*Level 3*	*Potential Freshwater Vital Signs*	*Potential Freshwater Vital Signs Measures*
		processes		
	Subsurface Geologic Processes	Geothermal features and processes		
		Caves / karst features and processes		
		Volcanic features and processes		
		Seismic activity		
	Soil Quality	Soil function and dynamics	Permafrost	Thermokarst formation, slope degradation, wetland and pond growth
Water	**Hydrology**	Groundwater dynamics	Groundwater dynamics	
		Surface water dynamics	Surface water dynamics	flooding regimes (KLGO), in stream flow (SITK)}
		Marine hydrology		
	Water Quality	Water chemistry	Water quality core parameters	Ph, chemistry, sediment load, temperature, dissolved oxygen, conductivity, turbidity N, P, Si, Alkalinity, Hardness, DOC, TOC, MDN, MDC
		Glacier hydrology	Discharge, stream and lake dynamics,	Outburst floods, ice thinning, ice degradation, moraine thermokarst, proglacial and supraglacial lake formation
		Toxics	Contaminants	
		Microorganisms	Microorganisms	Coliform bacteria

Level 1	*Level 2*	*Level 3*	*Potential Freshwater Vital Signs*	*Potential Freshwater Vital Signs Measures*
		Aquatic macro-invertebrates and algae	Benthic macro-invertebrates Algae	Diversity, abundance, community composition, indicator taxa, biomass
Biological Integrity	**Invasive Species**	Invasive/Exotic plants	Eurasian water milfoil Riparian Japanese knotweed	
		Invasive/Exotic animals	New Zealand mudsnail	Fishing wader felt soles
	Infestations and Diseases	Insect pests		
	Focal Species or Communities	Marine communities		
		(Coral communities)		
		Intertidal communities		
		Marsh/estuary communities		
		Wetland communities	Wetlands	
		Riparian communities		
		Freshwater Communities		
		Aquatic vegetation	*Ranunculus* in East Alsek River	
		Arctic and alpine tundra		
		Forest vegetation		
		Marine invertebrates		

Level 1	*Level 2*	*Level 3*	*Potential Freshwater Vital Signs*	*Potential Freshwater Vital Signs Measures*
		Freshwater invertebrates	Benthic and non-benthic invertebrates	
		Terrestrial invertebrates		
		Fishes	Fish distribution and population dynamics	density, growth rates, and species composition
		Amphibians (and Reptiles)	Amphibians	
		Birds		
		Mammals		
		Vegetation communities		
		Terrestrial communities		
	At-risk Biota	T&E species and communities		
Human Use	**Point-Source Human Effects**	Point source human effects	Camp sites, accidents (e.g. ship)	
	Non-point Source Human Effects	Non-point source human effects	Vessel stack emissions, small engines, ship discharges, External – global atmospheric	Air and water quality monitoring; snow and glacier ice chemistry, freshwater chemistry
	Consumptive Use	Consumptive use	Sport fishing	
	Visitor and Recreation Use	Visitor usage		
	Cultural Landscapes	Cultural landscapes		
Ecosystem	**Land Cover and Use**	Land cover and use	Freshwater body extent;	Freshwater body mapping; ice

Level 1	*Level 2*	*Level 3*	*Potential Freshwater Vital Signs*	*Potential Freshwater Vital Signs Measures*
Pattern and Processes			Glacier and icefield extent	margin surveys, ice thickness
	Extreme Disturbance Events	Extreme disturbance events	Glacial processes; outburst flooding, slope failures, earthquakes, tsunamis	Seismic sensors, terrain analysis, glacier/lake monitoring systems
	Soundscape	Soundscape	Vessels, airplanes, helicopters	Noise monitoring
	Nutrient Dynamics	Nutrient dynamics		
	Productivity	Productivity	Marine derived nutrients	

Appendix A. SEAN Freshwater Monitoring Scoping Workshop Participants

Dan Bogan
Water Quality Monitoring
Environment and Natural Resources Institute
University of Alaska Anchorage
707 A Street
Anchorage, AK 99501
Phone: 907-257-2744, Fax: 907-257-2707
bogan@uaa.alaska.edu

Susan Boudreau
Chief of Resources
Glacier Bay National Park
National Park Service
PO Box 140
Gustavus, AK 99826
Phone: 907-697-2640, Fax: 907-697-2654
susan_boudreau@nps.gov

Chiska Derr
Network Coordinator
Southeast Alaska Network
National Park Service
3100 National Park Road
Juneau, AK 99801
Phone: 907-364-2621, Fax: 907-364-1540
Chiska_Derr@nps.gov

Christopher L. Fastie
Ecologist
Department of Biology
Middlebury College
Bicentennial Hall 375
Middlebury, VT 05753
Phone: 802-352-9028
fastie@uwyo.edu

Kevin Brownlee
Fish Biologist
Sport Fish Division
Alaska Department of Fish and Game
PO Box 240020
Douglas, AK 99824
Phone: 907-465-8590
Brian_Frenette@fishgame.state.ak.us

Scott Gende
Coastal Ecologist
Glacier Bay Field Station
National Park Service
3100 National Park Road
Juneau, AK 99801
Phone: 907-364-1591, Fax: 907-364-1540
Scott_Gende@nps.gov

Meg Hahr
Wildlife Biologist
Klondike Gold Rush National Historical Park
National Park Service
PO Box 517
Skagway, AK 99840
Phone: 907-983-9228, Fax: 907-983-9249
meg_hahr@nps.gov

Kim Hastings
Tongass Monitoring Coordinator
US Fish and Wildlife Service
3000 Vintage Blvd., Suite 201
Juneau, AK 99801
Phone: 907-732-8376, Fax: 907-586-7154
kim_hastings@fws.gov

Eran Hood
Hydrologist
Environmental Sciences
University of Alaska SE
11120 Glacier Highway
Anderson Building, Room 219
Juneau, AK 99801
Phone: 907-465-8449, Fax: 907-465-6406
eran.hood@uas.alaska.edu

Daniel E. Lawson
Research Physical Scientist
Cold Regions Research and Engineering Laboratory
PO Box 5646
Fort Richardson, AK 99645
Phone: 907-232-1283, Fax: 907-384-0519
dlawson@crrel.usace.army.mil

Alexander Milner
Freshwater Ecologist
School of Geography and Environmental Science
University of Birmingham
Egbaston Birmingham, UK B15 2TT
Phone: 44-121-414-8098
Fax: +44-121-41-45528
a.m.milner@bham.ac.uk

Roman J. Motyka
Geologist
Geophysical Institute
University of Alaska Southeast
11120 Glacier Highway
Juneau, AK 99801
Phone: 907-586-1994, Fax: 907-465-6406
jfrjm@uas.alaska.edu

Geoffrey Smith
Biologist
Sitka National Historical Park
National Park Service
103 Monastery Street
Sitka, AK 99835
Phone: 907-747-0142, Fax: 907-747-5938
geoffrey_Smith@nps.gov

Chad Soiseth
Fisheries Biologist
Glacier Bay National Park
National Park Service
PO Box 140
Gustavus, AK 99826
Phone: 907-697-2659, Fax: 907-697-2654
chad_soiseth@nps.gov

Greg Streveler
Consulting Ecologist
Icy Strait Environmental Services
PO Box 94
Gustavus, AK 99826
Phone: 907-697-2287
grigori@gustavus.ak.us

Sara Wesser
Inventory & Monitoring Alaska Region Coordinator
National Park Service
240 W Fifth Avenue
Anchorage, AK 99501
Phone: 907-644-3558
sara_wesser@nps.gov

Arctic Research Consortium, US (ARCUS)
Logistical and Facilitation Support
3535 College Road, Suite 101
Fairbanks, Alaska 99709-3701
Phone: 907-474-1600
http://www.arcus.or

Appendix B. Workshop Agenda

Agenda

Freshwater Monitoring Scoping Workshop
Southeast Alaska Network
National Park Service
Inventory and Monitoring Program

Goldbelt Hotel, Juneau, AK
February 1-3, 2005

Objectives for Scoping Workshop

1. Review and refine conceptual ecosystem models
2. Formulate potential monitoring questions for freshwater ecosystem components
3. Identify potential attributes ("vital signs") to monitor

Tuesday, 1 February

4:00	Refreshments
4:30	Welcome and introductions
4:45	Discussion of workshop objectives, agenda, and preliminary notebook materials. Participants are asked to make informal comments on the notebook.
5:45	Social hour with hors d' oeuvres and cash bar
7:00	**Recess for the day**

Wednesday, 2 February

Objectives for Day Two

1. Gain familiarity with SEAN monitoring goals
2. Refine conceptual models for freshwater ecosystems and identify drivers of change

8:00	Arrival and Continental Breakfast
8:30	Welcome – Susan Boudreau, Chief of Resources, Glacier Bay National Park Review of Agenda – April Crosby, Meeting Facilitator, Crosby and Associates Overview of the Inventory and Monitoring Program – Sara Wesser, Alaska Regional Coordinator, Inventory and Monitoring Alaska
9:30	NPS Inventory and Monitoring Program in Alaska's Southeast Network – Chiska Derr, Southeast Alaska Network Coordinator
10:00	**~ ~ ~ Break ~ ~ ~**
10:15	Overview of Southeast Alaska ecosystems – Greg Streveler, Icy Strait Environmental Services
10:45	Conceptual Ecosystem Models for Southeast Alaska – Christopher L. Fastie, Middlebury College
11:15	Freshwater Ecosystem Models – Sandy Milner, U of Birmingham, UK
12:00	**~ ~ ~ Lunch ~ ~ ~**
1:00	Instructions to Working Groups
1:15	Working Groups: Each Working Group will revise and improve the draft conceptual ecosystem models. Each group can revise the model(s) as much or as little as they see fit. Creation of additional ecosystem models is encouraged. A leader for each group must report back to the larger group on revised model(s).
3:45	**~ ~ ~ Break ~ ~ ~**
4:00	Reports from Working Groups on revised conceptual ecosystem models (15 minutes per group, with questions)
4:30	Taking Stock: Issues from the day
5:00	**Recess for the day**
6:00	Participants gather at the Fiddlehead Restaurant for dinner. 429 W. Willoughby Ave. 907-586-3150

Thursday, 3 February

Objectives for Day Three

1. Identify potential monitoring questions for freshwater ecosystems
2. Develop list of priority monitoring questions for freshwater ecosystems
3. Identify possible attributes ("vital signs") for monitoring freshwater ecosystems

8:00	Arrival and Continental Breakfast
8:30	Agenda Update
8:35	Working Groups: Each Working Group will develop a comprehensive list of potential monitoring questions. A recorder for each group must record the proposed questions, and a group member must be prepared to discuss proposed monitoring questions with the whole group.
10:45	**~ ~ ~ Break ~ ~ ~**
11:00	Reports from Working Groups on potential monitoring (15 minutes for each group, with questions)
11:30	Large group discussion: Are we missing anything?
12:00	**~ ~ ~ Lunch ~ ~ ~**
1:00	Working Groups: Develop from the list of monitoring questions the five highest priority candidates for monitoring and an exhaustive list of potential "vital signs" for each of them. Write each of the five top-priority monitoring questions on a page of flip chart paper along with potential "vital signs" for each (for eventual use by the whole group).
2:00	Reports from Working Groups on priority monitoring questions and a list of potential "vital signs" (15 minutes for each group, with questions)
2:30	**~ ~ ~ Break ~ ~ ~**
2:45	Large group discussion: The whole group will identify the highest priority monitoring questions and possible "vital signs" for monitoring. Group discussion.
4:15	Reflection on the workshop: Comments and suggestions
4:30	**~ ~ ~ Adjourn ~ ~ ~**

Appendix C. SEAN Annotated Freshwater Bibliography

Amphibian Monitoring (Meg Hahr)

Carstensen, R., M. Willson, and R. Armstrong. 2003. Habitat Use of Amphibians in northern Southeast Alaska. Report to the Alaska Department of Fish and Game. Discovery Southeast, Juneau, AK. 75pp.

The Alaska Department of Fish and Game funded Discovery Southeast researchers Richard Carstensen, Mary Willson and Robert Armstrong to survey, map and describe potential breeding habitats for amphibians in the Juneau area. This report describes the results of these efforts and contains a great deal of information on features associated with amphibian occurrence and breeding in Southeast Alaska. It is the most descriptive account of amphibian habitat use for our area.
Link to PDF: http://www.discoverysoutheast.org/pdf/amphib-report-low-res.pdf

Hall, R.J. and C.A. Langtimm. 2001. The U.S. national Amphibian Research and Monitoring Initiative and the role of protected areas. The George Wright Forum 18(2):17-25.

Brief Overview. This article provides a overview of the purpose, structure and function of the USGS Amphibian Research and Monitoring Initiative. Case studies of USGS ARMI efforts in several national parks are presented.
Link to PDF: http://www.georgewright.org/182hall.pdf

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.-A.C. Hayet, and M.S. Forster. 1994. Measuring and monitoring biological diversity: Standard methods for amphibians. Smithsonian Institute Press, Washington, D.C. 364pp.

Brief Overview. This book is perhaps the most important reference available for those interested in measuring and monitoring biological diversity in amphibians. It was produced in response to the great need of the establishment of standardized methods and protocols for sampling natural amphibian populations. It covers a vast array of topics including overview chapters on the natural history of amphibians, on the essentials of standardization and quantification of study questions, randomization and bias, replication issues, and assumptions, on research design and planning. It also includes chapters on standard monitoring and inventory techniques, marking and tracking techniques, population estimation techniques, instructions for preparation of amphibians as scientific specimens, tissue collecting protocols for biochemical analysis, and instructions and recommendations for the analysis of biodiversity data.

MacKenzie, D.I., J.D. Nichols,J.E. Hines, M.E. Knutson, and A.B. Franklin. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. Ecology 84: 2200-2207.

Abstract. Few species are likely to be so evident that they will always be detected when present. Failing to allow for the possibility that a target species was present, but undetected, at a site will lead to biased estimates of site occupancy, colonization, and local extinction probabilities. These

population vital rates are often of interest in long-term monitoring programs and metapopulation studies. We present a model that enables direct estimation of these parameters when the probability of detecting the species is less than 1. The model does not require any assumptions of process stationarity, as do some previous methods, but does require detection/nondetection data to be collected in a manner similar to Pollock's robust design as used in mark–recapture studies. Via simulation, we show that the model provides good estimates of parameters for most scenarios considered. We illustrate the method with data from monitoring programs of Northern Spotted Owls (*Strix occidentalis caurina*) in northern California and tiger salamanders (*Ambystoma tigrinum*) in Minnesota, USA.
Link to PDF: http://armi.usgs.gov/MacKenzie_et_al_2003.pdf

MacKenzie, D.I., J.D. Nichols, G.B. Lachman, S. Droege, J.A. Royle, and C.A. Langtimm. 2002. Estimating site occupancy when detection probabilities are less than one. Ecology 83:2248-2255.

Abstract. Nondetection of a species at a site does not imply that the species is absent unless the probability of detection is 1. We propose a model and likelihood-based method for estimating site occupancy rates when detection probabilities are 1. The model provides a flexible framework enabling covariate information to be included and allowing for missing observations. Via computer simulation, we found that the model provides good estimates of the occupancy rates, generally unbiased for moderate detection probabilities (.0.3). We estimated site occupancy rates for two anuran species at 32 wetland sites in Maryland, USA, from data collected during 2000 as part of an amphibian monitoring program, Frogwatch USA. Site occupancy rates were estimated as 0.49 for American toads (*Bufo americanus*), a 44% increase over the proportion of sites at which they were actually observed, and as 0.85 for spring peepers (*Pseudacris crucifer*), slightly above the observed proportion of 0.83.
Link to PDF: http://armi.usgs.gov/Site_Occupancy_MacKenzie.pdf

R.D. Semlitsch, Ed. Amphibian Conservation. 2003. Smithsonian Institute Press, Washington, D.C. 324pp.

Leading amphibian biologist Raymond D. Semlitsch (Professor of biology and director of the Conservation Biology Program at the University of Missouri) brings together international amphibian experts to present the most current information on the status of amphibian populations world-wide. Threats to population viability include: disease, pesticides, climate change, habitat destruction, and human exploitation. New information suggests that observed declines in amphibian biodiversity exceed declines noted for other taxa including mammals and birds. This recently released book has been well reviewed being called both "accessible" and "informative".

Biomonitoring and Assessments (Dan Bogan)

Bailey, R.C., M.G. Kennedy, M.Z. Dervish, and R.M. Taylor. 1998. Biological assessment of freshwater ecosystems using a reference condition approach: comparing predicted and actual benthic invertebrate communities in Yukon streams. *Freshwater Biology*, **39,** 765-774.

Barbour, M.T. 1997. The re-invention of biological assessment in the U.S. *Human and Ecological Risk Assessment,* **3,** 933-940.

Barbour, M.T., W.F. Swietlik, S.K. Jackson, D.L. Courtemanch, S.P. Davies, and C.O. Yoder. 2000. Measuring the attainment of biological integrity in the USA: a critical element of ecological integrity. *Hydrobiologia,* **422/423,** 453-464.

Fore, L.S. and C. Grafe. 2002. Using diatoms to assess the biological condition of large rivers in Idaho (U.S.A.). *Freshwater Biology,* **47,** 2015-2037.

Karr, J.R. 1993. Defining and assessing ecological integrity: beyond water quality. *Environmental Toxicology and Chemistry,* **12,** 1521-1531.

Maxted, J.R., M.T. Barbour, J. Gerritsen, V. Poretti, N. Primrose, A. Silvia, D. Penrose, and R. Renfrow. 2000. Assessment framework for mid-Atlantic coastal plain streams using benthic macroinvertebrates. *Journal of the North American Benthological Society,* **19(1),** 128-144.

Climate Change (Dan Lawson)

Alley, R.B., 2004, Abrupt climate change. Scientific American, November, p. 63-69.

This article examines the geologic record of abrupt, extremely rapid changes in climate that have taken place in the past. Abrupt change is just that – many degrees C change in decades or less that have affected the climate globally, lasting hundreds or more years before climate returned to a ”normal” state. The author not only examines the environmental consequences of such rapid changes, but also explores the social and economic impacts and how they might affect modern society. This article is written by one of the most knowledgeable scientists working on paleoclimate change and it is written in layman’s terms. A good read and I highly recommend it!

National Research Council, 2003, Abrupt Climate Change: Inevitable Surprises. National Academy Press, 230pp.

Prepared by the Committee on Abrupt Climate Change, this report reviews and analyses available data on climate and paleoclimate from diverse sources on the existence in the past of rapid and sudden changes in climate. Such changes occurred over periods of several years to tens of years with significant cooling (-5 to –10 C) during this time, followed by recovery to warmer climate over a hundred or more years. They examined the paleoclimate record and concluded the inevitability of such changes, as well as the consequences for society. The Committee made recommendations for further research and urge recognition that such changes may occur in the future. This technical treatment is well written and provides an important perspective on potential global changes in climate that might in the short term affect Glacier Bay ecosystems.

Glaciers and Ice Sheets (ice dynamics, processes, environment) (Dan Lawson)

Alley, R.B., Lawson, D.E., Larson, G.J., Evenson, E.B., and Baker, G.S., 2003, Stabilizing feedbacks in glacier-bed erosion. Nature, 424, 758-760.

This article presents a hypothesis on how the configuration of the bed, and in particular the slope of overdeepenings, control glacier hydrology, erosion and deposition and in particular how glacier's are "graded" like streams.

Lawson, D.E., 1979, Sedimentological analysis of the western terminus region of the Matanuska Glacier, Alaska. CRREL Report 79-9, 121pp.

Detailed analysis of how a modern glacier erodes, transports and deposits sediment in moraines.

Lawson, D.E., 1993, Glaciohydrologic and glaciohydraulic effects on runoff and sediment yield in glacierized basins. CRREL Monograph 93-2, 122pp.

A review and synthesis of the hydrology and hydraulics of glaciers, emphasizing data and analyses of modern glaciers and ice sheets.

Ostrem, G. and Brugman, M., 1986, Glacier mass-balance measurements: A manual for field and office work. Saskatoon, Saskatchewan, Canada; National Hydrology Research Institute, NHRI Science Report No. 4, 224pp.

Everything you ever wanted to know about monitoring glaciers, including mass balance (accumulation, ablation), climate, discharge, sediment yield, surveying, data reduction and analysis, remote sensing and other techniques.

Paterson, W.S.B., 1994, Physics of Glaciers (3rd Ed.), New York, Pergamon Press.
Classic text on glacier dynamics.

<u>Glacier Monitoring (Roman Motyka)</u>

Arendt, A.A., K.A. Echelmeyer, W.D. Harrison, C.S. Lingle, and B. Valentine. 2002. Rapid wastage of Alaska glaciers and their contribution to rising sea level. *Science*, **297**, 382-386.

Fountain, A.G., Krimmel, R.M., and Trabant, D.C., 1997, A strategy for monitoring glaciers: U.S. Geological Survey Circular 1132, 19 p.

Mayo, L.R., D.C. Trabant, and R.S. March, 2004. A 30-year record of surface mass balance (1966-95), and motion and surface altitude (1975-95) at Wolverine Glacier, Alaska. *U.S. Geol. Surv. Open-File Report* 2004-1069, 105 p. plus CD.

Motyka, RJ, S O'Neel, C Connor, and K Echelmeyer, 2002. 20th Century thinning of Mendenhall Glacier, Alaska, and its relationship to climate, lake calving, and glacier run-off. *Global and Planetary Change*, ***35***(1-2) 93-112.

Neal, E.G., M.T. Walter, C. Coffeen. 2002. Linking the Pacific Decadal Oscillation to seasonal

Glacial Sediments, Landforms and Terrain (Dan Lawson)

Benn, D.I. and Evans, D.J.A., 1998, Glaciers and Glaciation. New York, Arnold, 734pp.

Extensive treatment on the glacial environment, emphasizing processes of glaciers and their landform/terrain associations.

Menzies, J.(ed.), 1995, Modern Glacial Environments: Processes, Dynamics and Sediments. Boston: Butterworth-Heinemann, 621pp.

Menzies, J.(ed.), 1996, Past Glacial Environments: Sediments, Forms and Techniques. Boston: Butterworth-Heinemann, 598pp.

The previous two books edited by John Menzies consist of multiple chapters by leading scientists in each of the fields so covered by each chapter. In the first book modern glacial and glacial marine environments are covered, with an emphasis on the processes of the glacier and its sub-environments. The second covers the various depositional environments and their products and the types of landforms develop by past glaciers and ice sheets.

Macroinvertabrate Monitoring (Alexander {Sandy} Milner)

Engstrom D.R., S.C. Fritz, J.E. Almendinger, and S. Juggins S. 2000. Chemical and biological trends during lake evolution in recently deglaciated terrain. *Nature* 408 161-166.

As newly formed landscapes evolve, physical and biological changes occur that are collectively known as primary succession. Although succession is a fundamental concept in ecology, it is poorly understood in the context of aquatic environments. The prevailing view is that lakes become more enriched in nutrients as they age, leading to increased biological production. Here we report the opposite pattern of lake development, observed from the water chemistry of lakes that formed at various times within the past 10,000 years during glacial retreat at Glacier Bay, Alaska. The lakes have grown more dilute and acidic with time, accumulated dissolved organic carbon and undergone a transient rise in nitrogen concentration, all as a result of successional changes in surrounding vegetation and soils. Similar trends are evident from fossil diatom stratigraphy of lake sediment cores. These results demonstrate a tight hydrologic coupling between terrestrial and aquatic environments during the colonization of newly deglaciated landscapes, and provide a conceptual basis for mechanisms of primary succession in boreal lake ecosystems

Flory, A.M. and A.M., Milner, 1999. Influence of riparian vegetation on invertebrate assemblages in a recently formed stream in Glacier Bay National Park, Alaska. *Journal of the North American Benthological Society*, **18**, 261-273

The influence of the development of riparian vegetation on benthic invertebrate community assemblages was analyzed in a recently formed stream in southeast Alaska. Several features of riparian interaction were documented: 1) invertebrate use of willow catkins entering streams in summer, 2) invertebrate use of submerged alder roots as a substrate for attachment and as a source of building material for caddisfly cases, and 3) retention of leaf litter by salmon carcasses. The development of riparian vegetation markedly influenced colonization of the stream by certain invertebrate taxa and thereby played an important role in the successional sequence of macroinvertebrates and overall assemblage development in this new stream.

Milner, A.M. and IT Phillips (2005) The effect of riparian vegetation and wood on the development of macroinvertebrate assemblages in streams. *Rivers: Research and Application.*

Riparian vegetation development and macroinvertebrate assemblages were studied in 16 streams formed between 35 and 230 years ago, following glacial recession in Glacier Bay National Park, southeast Alaska. Riparian vegetation established most rapidly in streams where flow variation in downstream reaches was buffered by a lake. Riparian vegetation development was positively correlated with lower bank stability, but was independent of stream age. Roots and branches of riparian vegetation trailing into streams (Trailing Riparian Habitat – TRH) were shown to be an important habitat for a number of macroinvertebrate taxa. In young and unstable streams, TRH was colonized mainly by Plecoptera whereas in more stable lake-influenced streams Simuliidae dominated. Significant coarse woody debris (CWD) accumulations were not observed until after approximately 130 years of stream development had occurred when certain channel features, such as gravel bars, were stabilised by dead wood. Where dead wood was present, opportunistic wood taxa were abundant, even in the younger streams. Canonical correspondence analysis indicated that bed stability and stream age were the most important environmental variables influencing macroinvertebrate distribution on TRH. Trailing riparian habitat was most abundant in moderately unstable streams where it facilitates invertebrate colonization. CWD contributes markedly to channel stabilisation, provides habitat for invertebrate xylophages, and confers additional habitat complexity. Maximum levels of CWD are predicted to occur in non-lake streams after approximately 300 years, but that at least a further 100 years will be required in stable streams below lakes where dead wood entrainment is not enhanced by flooding, channel migration and bank undercutting.

Milner, A.M. E. Knudsen, C. Soiseth, AL Robertson, D Schell, IT Phillips, K Magnusson. 2000. Stream community development across a 200 year gradient in Glacier Bay National Park, Alaska, USA. *Canadian Journal of Fisheries and Aquatic Sciences,* **57**, 2319-2335.

During May 1997 both physical and biological variables were studied within 16 streams of different ages and contrasting stages of development following glacial recession in Glacier Bay National Park, southeast Alaska. The number of microcrustacea and macroinvertebrate taxa, and juvenile fish abundance and diversity were significantly greater in older streams. Microcrustacea diversity was related to the amount of instream wood and percent pool habitat, while the number of macroinvertebrate taxa was related to bed stability, amount of instream wood and percent pool habitat. The percent contribution of Ephemeroptera to stream benthic communities increased significantly with stream age and the amount of coarse benthic organic matter. Juvenile Dolly Varden were dominant in the younger streams but juvenile coho salmon abundance was greater in older streams associated with increased pool habitat. Lakes significantly influenced channel stability, percent Chironomidae, total macroinvertebrate and meiofaunal abundance, and percent fish cover in downstream reaches. Stable isotope analyses indicated N enrichment from marine sources in macroinvertebrates and juvenile fish in older streams with established salmon runs. The findings are encapsulated in a conceptual summary of stream development that proposes stream assemblages to be determined by direct interactions with the terrestrial, marine, and lake ecosystems.

Milner, A.M., S.C. Conn and J.M. Ray. 2004. Development of a long-term ecological monitoring program for Denali National Park and Preserve: Design of methods for monitoring stream communities. University of Alaska report to the United States Geological Survey. 220 pp.

This report summarizes the monitoring and investigation of streams of Denali National Park and Preserve during the period 1992 to 2002 and provides the reader with data sources where more detailed information can be located. A more extensive study in 1995, when 45 streams and rivers were sampled on three occasions (spring, early summer and late summer/early fall) both north and south of the Alaska Range, was used to characterize the macroinvertebrate assemblages present. Communities were dominated by Chironomidae, which typically constituted 50 – 70 % by abundance of the community. Other Diptera, Plecoptera, and Ephemeroptera were also characteristic, but few Trichoptera and Oligochaeta were collected. Although macroinvertebrate densities were similar to more temperate areas of North America, taxa diversity was much lower. No significant difference between community structure in the streams of the Yukon hydrologic region, north of the Alaska Range, and streams of the south-central hydrologic region south of the Alaska Range was found. The 45 river sites sampled in 1995 were classified into six distinct groups supporting similar macroinvertebrate communities; (1) small stable streams, (2) groundwater-fed streams, (3) streams in the Kantishna region of the Park, (4) larger streams with some glacial influence, (5) unstable clearwater streams and (6) glacier-fed streams. Channel stability, water turbidity and altitude were the most important variables of the 19 measured that govern community structure between the six groups. Similarity coefficients indicated that the first three groups were the most distinct in terms of their community structure and difference from the other groups. Recommendations for the biological monitoring of streams include the

use of chlorophyll a, biovolume as a surrogate for macroinvertebrate biomass, and a predictive model using environmental variables as predictors of macroinvertebrate community structure.

Paleoclimate (Dan Lawson)

Bradley, R.S., 1999, Paleoclimatology: Reconstructing climates of the past. New York, Academic Press, 610pp.

The author explains the basic methods, technique and data sources of reconstructing the climate of the past, emphasizing the late Quaternary period of the last 120,000 yrs. The information provides a background on how and why "monitoring and inventorying" of paleoclimatic data are critical to understanding current climatic trends and predicting future changes in climate and how such changes may ultimately affect ecosystems.

Grove, J. M., 1988, The Little Ice Age. New York, Methuen Press, 498pp.

An extensive treatment of the Little Ice Age and in particular how the changes in climate during this recent cold period affected society and its environment. The author discusses evidence and data for the LIA from across the globe. Grove's treatment includes both measured, quantifiable data sources as well as recorded history in literature, journals, paintings and other sources. It is a most complete picture of the life and times of the Little Ice Age, and perhaps a glimpse of the future.

Mackay, A., Batterbee, R., Birks, J., and Oldfield, F. (eds.), 2003, Global change in the Holocene. London, Arnold, 598pp.

Examines changes during the Holocene period that have implications for changes within Glacier Bay that have affected glaciation, habitation and ecosystems of the last ~12,000 years.

Wiles, G., D'Arrigo, R. D., Villalba, R., Calkin, P.C. and Barclay, D.J., 2004, Century-scale solar variability and Alaskan temperature changes over the past millennium. Geophysical Research Letters, 31, paper L15203, 4pp.

Recent article on changes in temperature in south central over the past 1000 years. References cited provide links to other relevant Alaskan studies.

Fritts, H.C., 1976, Tree Rings and Climate. New York, Academic Press.

This is the standard reference for methods of tree ring analysis and its application to delineating climate.

Cook, E.R., and Kairiukstis, L.A., 1990, Methods of Dendrochronology: Applications in the Environmental Sciences. Boston, Kluwer Academic.

The chapters in this book discuss various applications of tree ring studies to environment and ecology.

Stream Ecology (Geoffrey Smith)

Allen, J. D. 1995. *Stream Ecology: Structure and Function of Running Waters*. Kluwer Academic Publishers, Bordrecht. 388 pp.

This is an excellent basic text on most aspects of stream ecology.

Hauer, F.R., and G.A. Lamberti. 1996. *Methods in Stream Ecology*. Academic Press, New York. 674 pp.

Provides a complete series of field and laboratory protocols in stream ecology for use in conducting research. Covers the areas of physical stream ecology, material storage and transport, stream biota, community interactions, and ecosystem processes. Includes detailed instructions, illustrations, formulae, and data sheets for conducting stream ecology.

Chaloner, D.T., and M.S. Wipfli. 2002. Influence of Decomposing Pacific Salmon Carcasses and Macroinvertebrate Growth and Standing Stock in Southeastern Alaska Streams. *J.N. Am. Benthol. Soc*., 21(3):430-442.

Compared macroinvertebrate growth rates and standing stock in the absence and presence of salmon carcasses in microcosm and natural stream rearing experiments in southeast Alaska. (A related article: Wipfli, M.S., J. Hudson, and J. Caouette. 1998. Influence of Salmon Carcasses on Stream Production: Response of Biofilm and Benthic Macroinvertebrates in Southeastern Alaska, U.S.A. *Canadian Journal of Fisheries and Aquatic Sciences* 55:1503-1511.)

Kline, T.C., J.J. Goering, and R.J. Piorkowski. 1997. *The Effects of Salmon Carcasses on Alaskan Freshwaters*. In *Freshwaters of Alaska* (Milner and Oswood eds.). Springer, New York. 179-204.

Another treatment of the effect of salmon decomposition in Alaskan Streams. Excellent description of process and development of a conceptual model showing the interactions of stream organisms. *Freshwaters of Alaska* (Milner and Oswood eds.) has many articles on various aspects of Alaskan aquatic habitats.

Naiman, R. J., and R. E. Bilby (eds.). 2001. *River Ecology and Management: Lessons from the Pacific Coastal Ecoregion.* Springer, New York. 705 pp.

This book is specific to the Pacific Coast ecoregion and includes sections on the Physical Environment, the Biotic Environment, Ecosystem Processes, Management, and Recommendations for the Future. Specific topics include channel dynamics, hydrology, water quality, microbial processes, primary production, fish and wildlife, riparian forest dynamics, organic matter and trophic dynamics, biogeochemical cycling, maintaining biodiversity, monitoring and assessment, economic perspectives, legal considerations, and the role of non-governmental organizations in river management. (A related article: Naiman, R. J., R. E. Bilby, and P.A. Bisson. 2000. Riparian Ecology and Management in the Pacific Coastal Rain Forest. *BioScience*. 50 (11): 996-1011.)

Wiggins, G.B., and C.R. Parker. 1997. *Caddisflies (Trichoptera) of the Yukon with Analysis of Beringian and Holarctic Species of North America* (http://www.biology.ualberta.ca/bsc/pdf/wiggins.pdf). In *Insects of the Yukon*, H.V. Danks and J.A. Downes (eds.). Biological Survey of Canada (Terrestrial Arthropods), Ottawa.

Excellent coverage of Yukon caddisflies with references to Alaskan species. Detailed account of the biogeography of northern species, particularly in relationship to the redistribution of insects in North America since the last ice age. (also see: Kavanaugh, D.H. 1988. The insect fauna of the Pacific Northwest coast of North America: present patterns and affinities and their origins. pp. 125 –149 *in* J.A. Downes and D.H. Kavanaugh (Eds.), Origins of the North American Insect Fauna. *Mem. ent. Soc. Can.* 144. 168 pp.). Coverage of mayflies, stoneflies, and other aquatic insects in *Insects of the Yukon* (H.V. Danks and J.A. Downes (eds.).) is also useful in Alaskan studies.

Surficial Processes and Landforms (Dan Lawson)

Easterbrook, D. J., 1999, Surface processes and landforms. Prentice Hall, Upper Saddle River, NJ (2nd Ed), 546pp.

This is a basic text on geologic processes and landforms that covers those physical environments common to the SEAN. The text is well written and illustrated, and is a good reference.

Appendix D. Freshwater Monitoring Questions generated during the Glacier Bay Integrated Science Plan Workshop, 28 & 29 October 2004, Juneau, Alaska

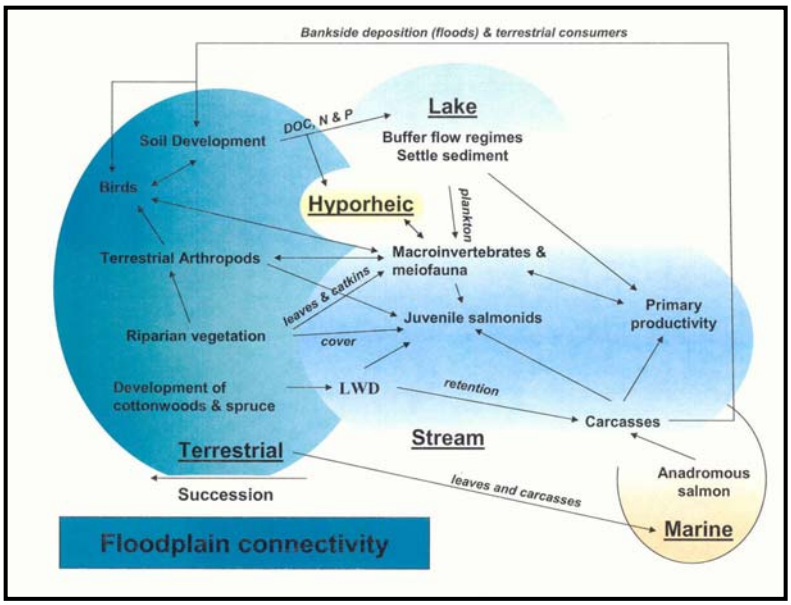
3.0 Freshwater Ecosystem Discussion

The freshwater ecosystem group framed its discussion with the following general premises:

- The goal is to be able to detect change from both natural and anthropogenic causes and ideally to discern between them. Currently, Glacier Bay is more affected by natural changes than by anthropogenic change. However, it is also important to try to position park staff and scientists to detect anthropogenic changes, especially as such changes could increase in the future.
- Once change is detected, directed research is required to discern the reason for change. (Monitoring may not be the right tool to fully understand the cause and effect of change.)
- Measuring or monitoring a biological or physical process generally is not possible. One must measure a process inferentially, by measuring a variable that is an outcome of or contributor to the process.
- A model of floodplain connectivity (below) describes the basic physical and biological processes that influence the freshwater ecosystems in Glacier Bay and illustrates the connections between the terrestrial, freshwater, and marine environments (Fastie 2004).

A. Physical and Biological Processes

The freshwater ecosystem group identified physical and biological processes that are important in modifying habitats and influencing the abundance and structure of populations and communities in freshwater ecosystems in Glacier Bay.



General physical and biological process drivers for Glacier Bay

1. Climate – solar radiation, precipitation (rain, snow), temperature, wind, altitudinal effects
2. Glaciers and glacial change
3. Tectonic processes / uplift / mountain building
4. Land cover change – vegetation and geomorphology changes
5. Air quality
6. Anthropogenic influences

<u>Specific freshwater processes, variables as surrogates of processes, and indicators of community structure and function</u>

- Flow / Discharge
- Sediment deposition, erosion, suspension
- Source of water input to freshwater system (glacial, precipitation, groundwater)
- Water temperature
- Nutrients – Total Organic Carbon (TOC), Dissolve Organic Carbon (DOC), nitrogen, phosphorus, benthic and free carbon
- pH / alkalinity
- Channel morphology changes
- Change in lake association with stream (older streams "lose" their lakes)
- Coarse woody debris recruitment and abundance
- Canopy closure / density
- Hyporheic and groundwater processes
- Primary productivity / chlorophyll-a
- Organisms – presence/ absence/ relative abundance of fish and amphibians, diatoms (lake environments), benthic species productivity and richness

B. Taxa

The group considered which taxa could provide the most accurate, sensitive, and efficient measurements to detect changes in the Glacier Bay freshwater ecosystem. These taxa were identified (below) while the group developed its representative approaches to monitoring and research.

Key organism communities to consider include:

- Benthic invertebrate abundance and diversity
- Diatoms (an important and sensitive indicator of freshwater lake ecosystem health)
- Presence / absence and relative abundance of resident or anadromous fish
- Presence / absence of amphibians

The freshwater ecosystem group identified these taxa as indicators of the relative successional stage of freshwater environments in Glacier Bay, as well as potential indicators of change in environmental conditions. The group noted that more wide-ranging organisms such as Pacific salmon would not be accurate indicators of freshwater ecosystem change, since change in salmon productivity could be result from a variety of causes (e.g., marine survival, commercial fishing) unrelated to change in the Glacier Bay environment. On the other hand, variables of life-history stages that occur within the park's ecosystems (e.g., growth of fry or parr, fry/smolt rotations,

etc.) may reflect the health of stream ecosystems because processes that affect them occur within the stream (sedimentation, stream water temperature, etc.)

C. Recommended Approaches to Monitoring and Research

The freshwater group noted that the physical and biological processes listed above resembled a basic list of ecological parameters from a freshwater limnology textbook. They questioned the usefulness of developing such a general list of variables to monitor, and the group discussed ways to focus a monitoring and research program on variables that would effectively elucidate and document changes in Glacier Bay's freshwater environments, communities, and populations.

To narrow its focus to the processes and taxa that would best detect change in the freshwater environments of Glacier Bay, the group developed three approaches to monitoring and research that could efficiently (and more affordably) be conducted at many replicate sites to increase monitoring coverage and frequency. Recommended approaches include:

1. Repeat distributed sampling in Glacier Bay streams.

Conduct repeat, distributed sampling in Glacier Bay streams, both in the bay and in other geographic areas in the park. The goal is to sample a large number of streams (40 to 50) each year, and to revisit streams over a multi-year monitoring cycle. The freshwater group reached consensus that this type of replicated distributed sampling would, if priorities were to be set, be the most valuable and effective method for detecting change and documenting the extent of change in Glacier Bay freshwater systems. The protocol defining the frequency, repeat interval and distributed locations for stream sampling should take into consideration:

- Types of streams / segregated by classification (note that Glacier Bay staff have begun a classification system for the more than 300 stream/lake systems in the park)
- Different geographic areas with the park (microclimates, other variability, accessibility, other factors)
- Accessibility and cost of sampling
- Statistical design (the group noted that it might not be cost effective to stratify sampling strictly to ensure statistical significance, due to problems of accessibility); although power to detect change should be modeled (with different effect size) to help determine minimum sampling effort
- Other relevant factors

Replicate variables that can be estimated accurately in approximately one-half day at each site visit include:

- Stream stage
- Turbidity
- Water temperature
- pH
- Chlorophyll-a
- Nitrogen, phosphorus, TOC, DOC quality (SUVA value), benthic organic carbon, free carbon
- Diatoms (essential taxa for lakes)
- Benthic organisms – biovolume Orders *Ephermeropters* (mayflies), *Plecoptera* (stoneflies) and *Trichoptera* (caddisflies) richness sensitive for water quality
- Aerial imagery – channel morphology changes, lake presence/size, wetland presence/size, coarse woody debris (size and density), canopy density/closure (affects light, temperature, litter input)
- Fish presence/absence (minnow traps in streams)
- Amphibian presence/absence (important wetland taxa)

1. **Aerial imaging of Glacier Bay stream systems to measure, monitor, and index visually observable change in freshwater streams, lakes, and wetlands.**

Through aerial imaging, measure and index (in stream miles) the following stream systems:

- with advancing glaciers
- with retreating glaciers
- with remnant ice
- with no glacier / ice
- with and without lakes

This would provide a relatively simple technique for measuring and indexing basic changes in Glacier Bay stream systems. As noted above, aerial imaging would also be a useful tool for documenting changes in land cover, channel morphology changes, lake presence/size, wetland presence/size, coarse woody debris, turbidity, and canopy density/closure.

The freshwater group noted that aerial imaging is a tool that would likely be used for a variety of monitoring purposes. They suggested that the park help coordinate the protocols for examining aerial imaging, to efficiently obtain as much information as possible to inform scientists and staff involved in monitoring and research.

2. **In-depth, long-term monitoring and research in selected reference watersheds to test the ecological processes and linkages illustrated in the floodplain connectivity model.**

Delineate selected reference watersheds within Glacier Bay, which would receive more in-depth and frequent monitoring. This would be the focus of research to test key questions related to detecting change within ecosystems, investigating the cause and effect of changes, and testing linkages between ecosystems (see Floodplain

model), and would provide locations for measuring, monitoring and research related to the more global drivers of change (such as climate and glacial change).

Knowledgeable scientists should work together to select appropriate reference watersheds. Selected watersheds should represent the various types of watersheds in Glacier Bay, and should focus on watersheds that would capture the key linkages between the freshwater, terrestrial. and marine environments that are the focus for research. These scientists would consider watersheds that are:

- of different scales, gradient, and levels of complexity (stream order)
- lakes present and absent
- active glacial input present or absent
- ice remnants present and absent
- within the bay proper and on the outer coast
- in various successional stages and pathways (e.g., N-S, and E-W, which may illustrate succession pathway with alder and without)
- where baseline data and/or a significant body of research exists

D. Linkages

The freshwater ecosystem group identified six principal types of linkages. The list was incomplete, due to time limitations. The linkages were:

1. Physical processes that affect and link all ecosystems

- Climate/weather solar radiation, precipitation (rain, snow), temperature, wind, altitudinal effects
- Tectonic forces (uplift and mountain building)
- Glacier change

2. Terrestrial to Freshwater

- Land cover changes – especially percent cover in alder, wetland/peat
- Drainage
- Surficial geology / soils

3. Freshwater to Marine

- Effects of freshwater input on the marine environment, including the delivery of carbon and nutrients, and temperature and salinity change. Note that effects would differ for subglacial streams (direct glacial to marine) than for freshwater entering the marine environment at a non-tidewater glacier setting.
- Movement of sediment/material from the watershed to the marine environment
- Successional changes of nitrogen contributions (and attendant productivity) to the marine system, with different successional stages (time) and pathways (e.g., alder, no alder).

4. Marine to Freshwater

- Marine-derived nutrients coming from the marine environment to the freshwater and terrestrial environment
- Contribution of chloride to the freshwater and terrestrial environments due to sea spray
- Evaporation, condensation, precipitation

5. Freshwater to Terrestrial

- Marine-derived nutrients
- Aquatic insects

6. Marine to Terrestrial

- Marine-derived nutrients
- Birds, mammals (vectors and pathways)