The Scientific Adventure

Proceedings of the

First Glacier Bay Science Symposium

September 23-26, 1983

Glacier Bay Lodge

GLACIER BAY NATIONAL PARK & PRESERVE

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PROCEEDINGS OF THE FIRST GLACIER BAY SCIENCE SYMPOSIUM

The Scientific Adventure

September 23–26, 1983
Glacier Bay Lodge
Glacier Bay National Park and Preserve
Gustavus, Alaska 99826

Sponsored by:
Friends of Glacier Bay
National Park Service

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FOREWORD

Over 135 persons from federal and state government agencies, academia, independent research institutes and private pursuits attended the First Glacier Bay Science Symposium, held at Glacier Bay National Park and Preserve, Alaska, on September 23–26, 1983. Dedicated to the memory of William Skinner Cooper (1884–1978) and jointly sponsored by the Friends of Glacier Bay and the National Park Service, the symposium marked over a century of scientific research and achievement in Glacier Bay since John Muir's first visit in 1879. The objectives of the symposium were to:

- – Review past, present, and planned scientific research in Glacier Bay National Park and Preserve;
- – Present results of completed and ongoing research;
- – Identify gaps in knowledge;
- – Discuss new directions for future research; and
- – Formulate recommendations for improving the research and resource management programs of the Park and Preserve.

The Symposium opened on Friday, September 23rd with an informal reception and pot–luck dinner hosted by generous Gustavus and Park residents. The formal symposium presentations were given on Saturday and Sunday and were organized around four panels: (1) Geology, Glacial Activity and Climatology; (2) Terrestrial Ecosystems; (3) Marine and Aquatic Ecosystems; and (4) Resource Management. Special humanities programs describing the cultural aspects, ethnology, archaeology, and aesthetic mystic of the Glacier Bay region were given on the evenings of these two days.

At the Sunday banquet, William O. Field, Richard P. Goldthwait and Donald B. Lawrence were recognized for their longstanding research interests, scientific contributions, and dedication to Glacier Bay. They were presented with plaques honoring them for their work by Bob Howe, former Superintendent of Glacier Bay National Monument.

On Monday, the final day of the symposium, the participants boarded the MV *Thunder Bay* for a day–long cruise up the bay to the face of the Muir Glacier.

In the two days following the close of the symposium, the chairmen of the three science panels met to assemble their joint recommendations. The General Recommendations of the Science Panels were discussed with and formally presented to Superintendent Mike Tollefson by the chairmen on September 28th.

These *Proceedings* provide a record of the symposium. Included unabridged are the welcome address by Superintendent Tollefson and the keynote address by Bill Brown. The panel sections contain abstracts prepared by the panelists. Abstracts of special presentations by non–panelists are also included. A few abstracts have been edited to reduce their length. The authors did not see the edited versions prior to publication. Following the abstracts of each panel are the highlights of the panel discussions, composed from our notes and tapes of the sessions. Panelists did not have

the opportunity to review our condensations of the panel discussions prior to publication, but we have made every attempt to accurately reflect content and character. We hope we have not misrepresented anyone's ideas.

Because of the distinctively unique songs, poetry, slides and spoken word of the evening humanities programs, it was not possible to produce a detailed and aesthetically accurate written account of them. However, an introductory commentary by program coordinator Judith Aftergut and excerpts by several of the participants provide an overview of the presentations.

Each panel proceeded independently in preparing its recommendations. In all cases the final refining and editing of the panel recommendations was done by the respective chairmen following the symposium. Most panelists, therefore, have not reviewed all of the recommendations published here. The participants of the humanities programs chose to prepare two general recommendations. Additional recommendations by Robert Ackerman are also included. The numerical ordering of all recommendations does not indicate priorities.

Throughout the text we have used "GBNPP" for "Glacier Bay National Park and Preserve." In most cases where the term "Glacier Bay" appears, the context should be adequate to discern whether it refers to the specific body of water, the land adjacent to the body of water, or the geographical and administrative unit Glacier Bay National Park and Preserve. In nearly all cases where the words "Park" or "park" appear, they stand for "Park and Preserve."

These *Proceedings* only skim the surface of the countless themes and topics that arose during the four days of the symposium. However, we are confident that many of these thoughts will have set seed, germinated, and blossomed by the time of the next Glacier Bay Science Symposium, tentatively scheduled to be held in 1988.

–The Editors

ACKNOWLEDGEMENTS

The idea for this science symposium originated with Dr. William O. Field, former glaciologist (now retired) with the American Geographical Society. His support, and that of Dr. Donald B. Lawrence, Professor Emeritus of the Department of Botany, University of Minnesota, were essential in transforming the symposium from concept to reality. Dr. Lawrence was especially instrumental in raising, through personal and institutional donations, generous financial support for the symposium.

Friends of Glacier Bay co-chairman Greg Streveler, John Chapman (former Park Superintendent), and Resource Management Specialist Gary Vequist arranged co-sponsorship of the symposium. Vequist acted as symposium chairman and handled the overall planning.

Special acknowledgement must be accorded to Carolyn Elder, who worked long and hard as symposium secretary. Carolyn handled the budget, invitations, correspondence and other details, and succeeded in soliciting much-needed Alaskan institutional support.

Panel chairmen Dave Brew, Ian Worley, Dave Duggins, and Gary Vequist recruited the panelists and organized the panel agendas, discussions, and recommendations.

Special acknowledgement is given to Judith Aftergut of the Alaska Humanities Forum, who organized and coordinated the evening humanities programs. These programs were enriching and brought inspiration to many.

Special thanks and appreciation are given to Glacier Bay Lodge, Inc., for graciously offering lodging and meals at reduced rates for the participants. The Lodge also provided its cruise boat, the MV *Thunder Bay*, for an excursion up Glacier Bay and Muir Inlet to the terminus of the Muir Glacier.

Thanks also go to JoAnne Popham for her fine artwork in designing the program for the symposium and the cover for the *Proceedings*.

A special word of appreciation is also expressed to Charlene S. McLeod, editorial clerk of the NPS Science Publications Office, who diligently and competently typed and retyped the *Proceedings* to final form.

Finally, the Friends of Glacier Bay and the National Park Service wish to extend their thanks to The Alaska Council on Science and Technology; Alaska Airlines; The Alaska Conservation Foundation; The Alaska Humanities Forum; The National Endowment for the Humanities; The American Geographical Society; Carl Benson; Nancy Cooper; Bob and Doris Howe; Lynne Jensen; Paul C. Lemon; the employees of Glacier Bay Lodge and Glacier Bay National Park and Preserve; and the residents of Gustavus. All contributed importantly to the success of the symposium.

A SPECIAL NOTE OF THANKS

I would like to thank, and give recognition to, Maria Gladziszewski, Ian Worley, and Gary Vequist for their important editorial assistance with the *Proceedings*. Maria and Ian provided photographs and undertook the monumental task of transcribing and composing from tapes the highlights of the panel discussions. They also collected the abstracts and offered many suggestions for improving the manuscript. Gary lent guidance to the project and made significant editorial contributions during the preparation of the final copy.

I also want to thank Don Lawrence and William O. Field for their timely review and comments on the draft; and Mr. Field, Thomas C. Gray of the NPS Harpers Ferry Center, and John Ehrenhard of the NPS Interagency Archeological Services Division for contributing photographs.

James D. Wood, Jr.
Editor of *Proceedings*
National Park Service

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WELCOME

Mike Tollefson, Superintendent
Glacier Bay National Park and Preserve
National Park Service

Good morning. I would like to extend to you a welcome back—for most of you have been here many times before. Also, I want to extend a deep–felt "thank you" for your interest in and support for the welfare of a great national treasure, Glacier Bay National Park and Preserve.

As a newcomer to the area, I am here to learn. As a park manager, I am extremely interested in your past work and suggestions for the future of science, research, and resource management in the area. This symposium is a fantastic opportunity to assess where we have been and where we should be going in terms of research.

To begin the symposium, I would like to share a few quotes from the 1925 proclamation. The monument was established to preserve an area of significance including:

– – a number of tidewater glaciers of the first rank in a setting of lofty peaks...

– – a great variety of forest coverings...

– – a unique opportunity for the scientific study of glacial behavior and of resulting movements and developments of flora and fauna and of certain valuable relics of interglacial forests...and

– – historic interest, having been visited by early explorers and scientists since the early voyages of Vancouver in 1794...

The Alaska National Interest Lands Conservation Act further enforced the concepts of preservation, use and research in 1980. The general purposes set forth are "to preserve for the benefit, use, education, and inspiration of present and future generations certain lands and waters...that contain nationally significant natural, scenic, historic, archaeological, geological, scientific, wilderness, cultural, recreational and wildlife values."

More than most other areas, then, Glacier Bay has a mandate—responsibility—to be responsive to scientific interests. THE SCIENTIFIC ADVENTURE—THE FIRST GLACIER BAY SCIENCE SYMPOSIUM is a very significant event in carrying forward the mandate for the future of Glacier Bay.

As the schedule indicates, there were many individuals responsible for initiating and organizing this event. We are in their debt. At this time, I would like to single out one person who has devoted many, many hours of effort to get us here—Carolyn Elder.

Again, welcome back. Thank you for caring, and let's get started—A CENTURY AFTER MUIR.

Keynote Address

HISTORICAL PERSPECTIVES

William E. Brown
Alaska Regional Historian
National Park Service

I approach my task as keynoter with mingled anticipation and trepidation. I stand before an audience distinguished by deep knowledge and experience, in the vestibule of a place awesome in its beauty and magnificence.

In this place of convergent powers and processes has occurred a great cultural adventure—expressed through art, philosophy, and scientific study. Some of you have seen this scenery move before your eyes. You have recorded the passage of geologic and biologic histories that could be only inferred elsewhere. Doubtless all of you—scientists and laypersons alike—have been spiritually moved by your experiences here, transported beyond the usual objectivities and quantifications. It has always been so, for Glacier Bay is a mythic landscape, beyond all normal experience and apprehension. For peoples ancient and modern, this has been the central meaning of Glacier Bay.

World views have come and gone here, over the centuries and millennia. We of modern world view are joining the circle with those who came before us to this place—those who viewed the glacier as a living being and populated with spirits the turbulent waters under Mount Saint Elias, the giant waves of Lituya.

For is it not true that those ancient people considered the earth their home, their world—of which they were natural parts? True that they saw and experienced the world as a web of intricate interrelationships of which they, in common with all other living things—indeed everything in nature—were inseparable and connected parts?

It may seem ironic that modern science is validating the ancient myths, that such divergent systems of understanding—forced together here by the dominating scapes of mountains, ice, and the sea—should converge in their essences.

But perhaps not. A poet in this room has said:

> Maturity
> brings us ever closer
> to the spirit world
> until we blend with it,
> become it.

* * *

The early scientists who came here to observe, describe, and classify analyzed Glacier Bay with their minds while putting it back together with their emotions. Their romantic exuberance would be frowned upon in a modern monograph, but in the light of those joyous, discovering days they shamelessly joined the world as members.

Listen to Muir:

> ...the clouds began to rise from the lower altitudes, slowly lifting their white skirts, and lingering in majestic, wing-shaped masses about the mountains that rise out of the broad, icy sea. These were the highest and whitest of all the white mountains, and the greatest of all the glaciers I had yet seen. Climbing higher for a still broader outlook, I made notes and sketched, improving the precious time while sunshine streamed through the luminous fringes of the clouds, and fell on the green waters of the fjord, the glittering bergs, the crystal bluffs of the two vast glaciers, the intensely white, far-spreading fields of ice, and the ineffably chaste and spiritual heights of the Fairweather Range, which were now hidden, now partly revealed, the whole making a picture of icy wildness unspeakably pure and sublime.
>
> – John Muir, 1879

And Burroughs:

> We saw the world-shaping forces at work; we scrambled over plains they had built but yesterday. We saw them transport enormous rocks, and tons and tons of soil and debris from the distant mountains; we saw the remains of extensive forests they had engulfed and were now uncovering. We saw their turbid rushing streams loaded with newly ground rocks and soil-making material; we saw the beginnings of vegetation in the tracks of the retreating glacier; our dredgers brought up the first forms of sea life along the shore; we witnessed the formation of the low mounds and ridges and bowl-shaped depressions that so often diversify our landscapes—all the while with the muffled thunder of the falling bergs in our ears.
>
> ...great blue bergs rise up from below—born of the depths. The enormous pressure to which their particles have been subjected for many centuries seems to have intensified their color. They have a pristine, elemental look. Their crystals have not seen the light since they fell in snowflakes back amid the mountains generations ago. All this time imprisoned, traveling in darkness, carving the valleys, polishing the rocks, under a weight as of mountains, till at last their deliverance comes with crash and roar and they are once more free to careen in the air and light as dew or rain or cloud, and then again to be drawn into that cycle of transformation and caught and bound once more in glacier chains for another century.
>
> – John Burroughs, 1899

Reflected in these words conjured by the Glacier Bay wilderness are the nourishments of spiritual sustenance. Sigurd F. Olson has argued that there is a hard core of wilderness need in everyone, no matter how sophisticated, blase, or urban one might be.

He comments:

> There is far more to the spiritual values of wilderness than the beautiful music of the Psalms and the emotional release they bring. Webster, in defining the spiritual, speaks of the soul, the essence, eternal values as opposed to the worldly or carnal—the imponderables as against the tangibles. A philosophy is involved, a way of looking at life, and a perspective that goes deeply into value judgments that affect our happiness.
>
> We might argue any of these points and try to explain or analyze, as many have done before us. Volumes have been written by theologians and philosophers on their meaning...On one point all agree: that spiritual values contribute to joy and richness of living; that without them existence lacks color and warmth, and the soul itself is drab and impoverished. We accept the broad premise that such values, inspired by the contemplation of wilderness beauty and mystery, were the well springs of our dawning culture and the first significant expressions of the human mind. True in the nebulous past, it is as true today no matter how life has changed or what has happened to our environment.

As scientific work progressed in Glacier Bay, the sense of mystery did not diminish. Expression of that mystery—the unraveling of its outer layers—changed in tone, became more intellectual. But in precision and felicity these expressions are still a kind of music—classical and restrained, violins instead of harps.

May we presume to name the giants who structured the modern scientific era here? Let me say only that one has completed his work, another continues his in New Zealand, and two are joined with us today. You will recognize their words, you who have studied them before...

The first:

> A feature of unique interest in the Glacier Bay region is the presence of relics of an earlier forest which flourished prior to the last glacial advance.
>
> At one locality in Muir Inlet, the relics were found to be remarkably well preserved. The trunks, numbering at least two hundred, stood thickly together. Many still retained their bark, with mosses clinging to it. Small trees and the lower branches of large ones were many of them intact to the smallest twig. The humus layer which covered the rock surfaces was mostly thin and hard, almost skin-like, but in places there were sheets of perfectly preserved forest mosses.

The presence of these relics provides clear proof that some centuries ago the ice fields surrounding Glacier Bay were more contracted than they are today. At that time the surrounding mountains were clothed with a forest which was identical in every way with the forest of similar habitat and stage of development in southeastern Alaska today. The peaceful order of its life was suddenly disturbed by the invasion of ice tongues which descended from the higher mountains, coalesced into broad piedmont expanses, and finally united to form one huge glacier. The forest upon the upper mountain sides was swept clean away, and that upon the lower slopes and the lowlands was buried beneath hundreds of feet of sediments deposited by glacial streams during the advance. Over all poured the great ice flood, thousands of feet deep.

About 200 years ago, the glaciers began to recede, revealing the ancient forests, and opening an everwidening expanse of bare ground to renewed invasion by plants.

– adapted from William S. Cooper

The second:

Where is the gravel which once filled these extensive inlets and stretched from valley wall to valley wall? Rapid rough calculation shows that the passages of Muir Inlet, Adams Inlet, and Wachusett Inlet together comprise a length of some 80 km and an average width of 5 km, which, with an average depth of gravel of 150 m, would make 60 km^3 of gravel, most of which has been removed. Nevertheless, it is obvious that Glacier Bay, which is three times as wide, and nearly twice as deep as Muir Inlet, could receive these sediments without ever showing them. Probably they were pushed even farther south into Icy Straits.

– Richard Goldthwait

The third:

Most of the earth's glaciers have been shrinking in recent decades, but in no locality have observations revealed more spectacular recession than in the Muir Inlet arm of Glacier Bay in Southeastern Alaska...Because of the rapidity of this recession and the comparatively long record of fairly detailed observations, this area provides a unique opportunity for studying the various phenomena associated with shrinking glaciers and the emergence from under the ice of new land and marine features. Here is offered an example on a small scale of conditions which have prevailed many times in geologic history during the waning of the continental ice sheets and which in future may affect millions of square miles of the earth's surface now buried beneath glacial ice.

– William O. Field

The fourth:

> The process of vegetation development must begin with migration of mobile seeds and spores from adjacent undisturbed areas. The situation at Glacier Bay gives us a better idea, we feel, than we can get anywhere else in the world today of what probably happens following a continental glaciation...At Glacier Bay, the many square miles of new glacial till surface, exposed even in the past decade, provide great stretches of raw parent soil material lacking in nutrients necessary for rapid plant growth. The pioneer plants, small and slow-growing, have apparently without exception entered as seeds or spores blown in by wind or carried by birds and mammals in their digestive tracts or attached to the surfaces of their bodies...The seed of *Dryas*, a conspicuous plant which can grow only as a prostrate mat, arrives early as a feathery parachute transported by the gentlest breeze; it germinates promptly and rapidly covers the ground with a carpet, deep-green in spring, yellow when in flower, gray in fruit, and red-bronze in fall, which acts effectively to reduce soil erosion. Dwarf fireweed, willows, and cottonwood arrive in the same way. Occasionally, the less mobile winged seeds of alder, spruce, and hemlock arrive from the more mature vegetation on older terrain down-valley from the ice, sliding along the crusted winter snow, or shaken from the back of some roving bear, wolf, or mountain goat...
>
> – Donald B. Lawrence

There is yet another scientist here with us, erstwhile and continuing student of those others, who has found deep meanings in Glacier Bay. In the quest for knowledge and understanding, in identification with place, he has followed a course that one writer---calling it "slightly mad"---has described as follows:

> He wants to understand every natural fact
> in Glacier Bay's millions of acres...
> He wants to know Glacier Bay's biology,
> both marine and terrestrial, plant and
> animal, big and small; and its geology,
> and its climatology. He seeks total,
> cross-disciplinary knowledge of his place.

Such a description evokes both religious and scientific overtones. Of the religious it need only be said, of course.

Of the scientific it can be said that the personal quest of this person has moved another notch forward a long-standing scientific tradition here in Glacier Bay. Even cursory reading of landmark reports and papers shows the interties amongst scientific disciplines. The bibliography compiled by Doris Howe shows the broadening scope of scientific inquiry. Site or sector in-depth studies, as at Dixon Harbor and Lituya Bay, show how the generations of scientists continue that tradition begun by the heroes of the Glacier Bay scientific pantheon---often in disciplines unknown in the earlier years.

So what is next for Glacier Bay, for the assembled scientists who gather here, as at the ancient academy?

This symposium will largely tell.

Never before have so many of you gathered in the same room, had time together to devise new modes of inquiry.

And never before has Glacier Bay needed you so much.

After close analysis of the recent State of the Parks Report, Robert Cahn of the Audubon Society isolated eight urgent needs that must be addressed if the parks in the National Park System are to be preserved. Of these, five are directly related to science:

1. Increase funding and staffing for natural and cultural resource preservation.

2. Establish systems to monitor changes in the parks, and make regular reports of threats to resources, along with long-range plans to deal with them.

3. Increase scientific research in the parks and coordinate science programs with resource management.

4. Determine carrying capacities of all units in the System and devise a process for preventing excessive use.

5. Provide better protection from the impact of development or from other projects originating outside the parks.

There is mutualism between the basic science that many of you pursue and the resource management science that has become increasingly necessary in Glacier Bay and equivalent reserves throughout the world.

The basic science lays the foundations of knowledge for the understanding of natural systems. Resource management science taps this fundamental knowledge for applications that preserve the baseline environments wherein basic science can continue to be pursued.

It may be that the need for interplay between research and application is most dramatically illustrated today by the marine environment questions posed by whales, feed, and human uses in Glacier Bay.

Perhaps there is greater opportunity than ever before, during these fortunate days, to make new combinations of modes and objectives, to do something for this sacred place, to—as it were—pay an installment on what we all owe to Glacier Bay.

And—in the spirit of another tradition long-established here—may our scientific endeavor move quietly and with respect through this living landscape...protecting as it leads to protection.

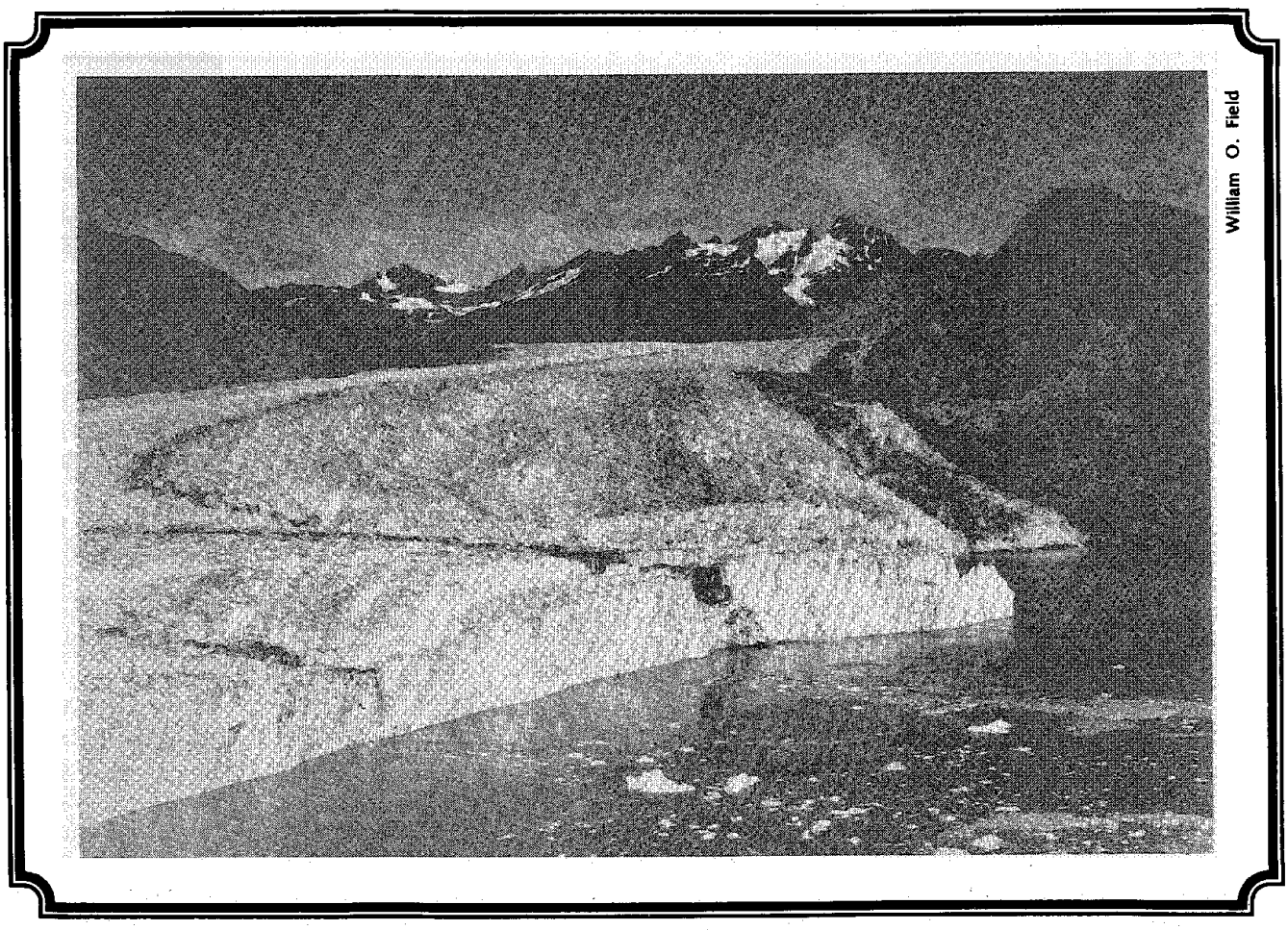
I conclude with two quotations that may add joy and inspiration to this meeting of the Glacier Bay tribal council.

One by Muir, describing an earlier conclave of scientists who visited the bay in 1899 in the steamship *Elder* during the Harriman Expedition:

> Nearly all my life I wandered and studied alone. On the *Elder*, I found not only the fields I liked best to study, but a hotel, a club, and a home, together with a floating University in which I enjoyed the instruction and companionship of a lot of the best fellows imaginable, culled and arranged like a well balanced bouquet, or like a band of glaciers flowing smoothly together, each in its own channel, or perhaps at times like a lot of round boulders merrily swirling and chafing against each other in a glacier pothole.

The second is Dave Bohn's elliptic masterpiece, which says in two lines what others have tried to say in volumes:

> But the sound lingers on when one has heard.
> Down the centuries the booming primeval thunder.



William O. Field

THE GEOLOGY, GLACIAL ACTIVITY, AND CLIMATOLOGY PANEL

David A. Brew, Chairman

Panelists: William O. Field, Carl S. Benson, Mark F. Meier, Gary D. McKenzie, Robert G. Goodwin, Ross D. Powell, and Daniel H. Mann

BEDROCK GEOLOGY AND MINERAL RESOURCES OF GLACIER BAY NATIONAL PARK AND PRESERVE, ALASKA

– – *David A. Brew, U.S. Geological Survey, Menlo Park, California*

The bedrock geology of GBNPP records a wide variety of depositional, intrusive, and tectonic events ranging in age from early Paleozoic through Tertiary. The park includes six geologic provinces designated from southwest to northeast as Lituya, Fairweather, Tarr Inlet, Geikie, Chilkat, and Muir. The Lituya province corresponds to the Yakutat or Chugach tectonostratigraphic terranes and consists of Mesozoic greenstone, phyllite, and graywacke melange together with shale, limestone, and volcanic rock of unknown thickness. These rocks are intruded by Cretaceous and Tertiary granitic rocks and are overlain by at least 3,660 m of marine and non–marine Tertiary clastic and volcanic rocks. The active Fairweather fault separates the Lituya from the Fairweather province; it may be either a plate boundary or an important intra–plate adjustment zone. The Fairweather province consists of hornblende and biotite schist and gneiss that apparently grade eastward into an unknown thickness of phyllite, graywacke, semischist, and conglomerate of Cretaceous age belonging to the Chugach terrane. They are intruded by minor granitic bodies of Tertiary or Cretaceous age and by at least four important layered gabbro complexes and several granitic bodies of Tertiary age. The Tarr Inlet suture zone separates the Fairweather from the Geikie province and is a complicated plate boundary zone with fault–bounded blocks of graywacke, volcanic rock, limestone or marble, and phyllite of possible Permian and (or) Triassic age and of phyllite, volcanic rock, and graywacke of Cretaceous age. The zone belongs in part to the Wrangell(ia) terrane and in part to the Chugach and is intruded by Cretaceous and Tertiary granitic bodies. The Geikie province belongs to the Alexander terrane and includes a diverse group of pelitic and semipelitic hornfels, marble, greenstone, and amphibolite of unknown thickness and of probably early through middle Paleozoic age. Granitic rocks of Cretaceous and (or) Tertiary age underlie most of the province. The boundary with the relatively unmetamorphosed and less intruded Chilkat province is gradational. The Chilkat consists of about 6,100–9,100 m of upper Silurian through Permian graywacke, argillite, volcanic rocks and limestone also belonging to the Alexander terrane. Cretaceous and Tertiary granitic bodies are present but are relatively uncommon. The Muir province has a gradational boundary with the Geikie and Chilkat provinces and is also part of the Alexander terrane; it is dominated by Cretaceous granitic bodies like those in the Geikie, and the intruded and hornfelsed country rocks are like those in the Chilkat. Some Tertiary (?) intrusions also occur. Its east–west structural trends contrast sharply with the northwest–southeast trends elsewhere in GBNPP.

All of the provinces contain rocks that are geologically and geochemically permissive for metallic mineral deposits of various types, and 17 areas have been identified as either containing important deposits or being favorable for their occurrence. Four deposits are especially important: (1) the Brady Glacier nickel–copper deposit in the Fairweather Range; (2) the Margerie Glacier copper deposit and (3) the Orange Point zinc–copper deposit, both in the Tarr Inlet suture zone; and (4) the Nunatak molybdenum deposit on Muir Inlet. The Reid Inlet area also contains significant undiscovered hypothetical gold resources. Coal, oil and gas, nuclear fuels, geothermal energy, and industrial minerals are probably not present in amounts of economic significance.

GLACIER–CLIMATE AND OCEANS IN GLACIER BAY

– – *Carl S. Benson, Geophysical Institute, University of Alaska*

The glaciers of Glacier Bay are part of the third or fourth largest ice mass on Earth. This Alaska–Yukon glacier system covers more than 102,000 km^2. Twelve states of the United States have smaller areas. The area is comparable in size with the area covered by glaciers in Canada's high arctic islands. The two largest masses are the Greenland and Antarctic ice sheets.

The Alaska–Yukon glacier mass has several special features: (1) A large fraction of its ice is temperate (at 0°C) in contrast to the "polar" ice (–10°C or lower) of the other large ice masses. (2) Because of its location on high mountains adjacent to the North Pacific Ocean, the Alaska–Yukon system has a higher mass flux of ice than the other large systems. (3) Storm systems that leave the North Pacific and move onto the North American continent are modified by this mountain–glacier complex which they must cross. (4) This large mass of ice is in the midst of a dynamically developing economy, instead of being remote from human concentrations as are the other large ice masses.

The glaciers of Glacier Bay contain several glacier types and the region is a natural laboratory for research on several problems. It contains one of the most dramatic and well–documented cases of retreating tidewater glaciers. Glaciological research at Glacier Bay can contribute to the knowledge of the broad regional interaction of Pacific storms with the continent. It can provide a base for study of the mass balance and dynamics of selected glaciers to contribute to our understanding of specific processes. It can contribute to our knowledge of climate on meso– and microscales within the fjords, as well as contribute to our knowledge of physical oceanography in the Bay.

The air flow in the deep fjords is influenced by cold air drainage from the glaciers. Similarly, the physical oceanography is influenced by the annual cycle in the volume of fresh water drained into the fjords and the recharge of denser sea water (mainly during the winter) over the sills at fjord entrances. The stable air masses in the surface layers (especially in upper reaches of the fjords) are controlled by topography, a cold water surface overlain by air which is 10–15°C warmer, and by the directional control of airflow provided by the gravity drainage of cold air (katabatic winds) from the glacier ice. This provides a protected environment for plant growth and a low tolerance for air pollution in the lowest 10 meters. Overall, the individual glaciological researches have direct relevance to water supply (which becomes part of the physical oceanography) and to the climatic controls. The most important climatic control is the simple presence or absence of ice because of its profound influence in the radiation balance.

A review of glaciological knowledge at Glacier Bay and surrounding areas is desired, with the goals of stating the problems which need attention and of selecting realistic, feasible approaches to their solutions. It is important that the glaciological knowledge be part of or contribute to studies of climate, oceans, and biology. The pioneering research done by Bill Field—and his active participation in planning for the future—are key factors in the next stages of research.

GLACIER TERMINI PHOTOGRAPHY SINCE 1926

– – William O. Field, American Geographical Society (ret.)

This project in Glacier Bay began in 1926 to record the changes in the terminal areas of the glaciers. There followed 13 additional visits, the latest one in June 1982, as part of a long–term project sponsored by the American Geographical Society of New York. The objective was to continue on a systematic basis the observations begun by H. F. Reid and G. K. Gilbert in the 1890s and others during the early years of this century.

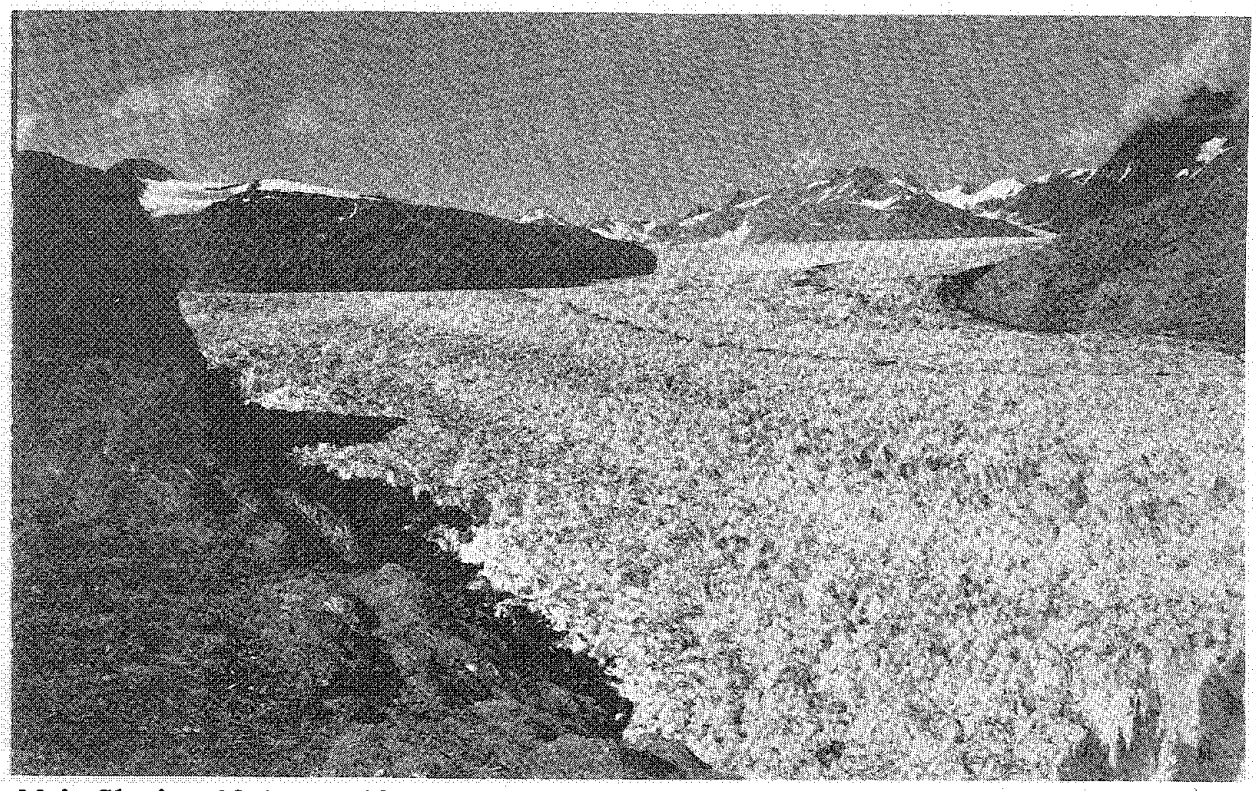
Our procedure has been to make observations and a photographic record of all the accessible termini on each visit, and to carry out simple surveys where significant changes were occurring. Photo–survey stations have been established in each inlet. Most of the early stations have become obsolete, but two stations established by Reid in 1892 are still in use. In the 1970s we occupied 43 different sites in the 10 inlets. Except for a visit to Lituya Bay in 1926 and a few aerial photo flights, we have not been active west of Glacier Bay itself.

Such observations in general provide a fairly quick and inexpensive means of determining the general trends of advance or recession, but do not usually reveal the basic causes of the changes. However, in the case of termini which calve into tidewater, conditions affecting terminal ablation appear to be one of the principal causes of advance, recession, or stability.

From 1926 to 1982, the changes in the glaciers have varied from the catastrophic recession of 30 km by the Muir Glacier, and a lowering of its ice surface by 670 m at the position of the 1982 terminus; to the other extreme, a net advance of 2.65 km at Grand Pacific Glacier. In the 1970s four valley glaciers in the Bay itself were advancing, while at least four to the west of the Bay were as far advanced as for a century or more. At least five glaciers surged in the 1960s; all had done so at least once before since the 1920s.

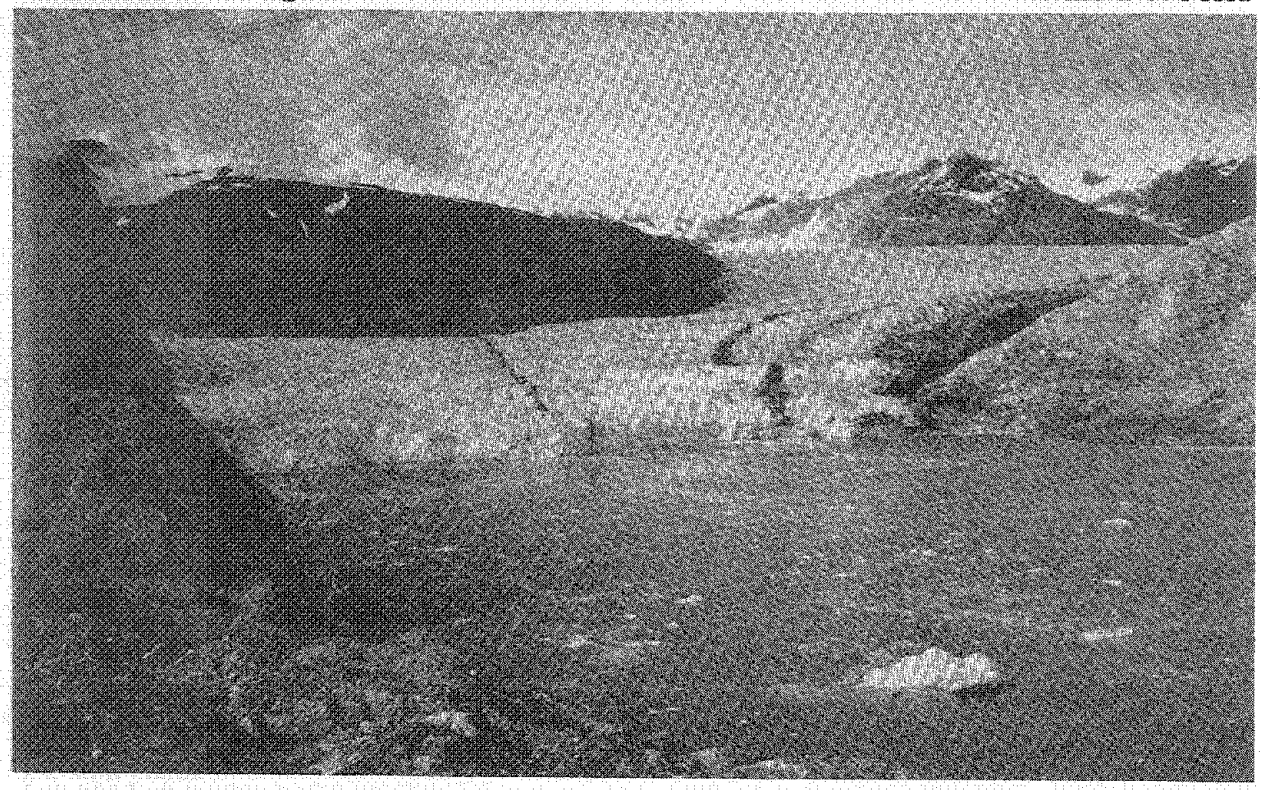
In the early 1980s, the great recession of the tidewater glaciers which began in the 18th century has apparently ended. The Muir appears to be reaching a point of stabilization in the shallower water near the head of the inlet. Some glaciers are beginning to readvance. In the Muir, Geikie, and Hugh Miller areas, the trend of recession is continuing, but to the north from the Rendu westward to the Johns Hopkins, where the neves are at higher elevations, in the last four decades there has been little net change in the area of the glaciers or in the behavior of the small hanging glaciers. This varied behavior of the glaciers within the Bay itself is matched by the glaciers outside its drainage area, which flow from common divides to the west, north, and east. Research should be encouraged into the causes of these varied responses to what appears to have been only minor changes in regional climatological parameters.

It is hoped that this program of relatively simple observations will be continued. It is also hoped that more sophisticated observations will be initiated in the upper neves to determine glacial–meteorological relationships, mass balances, and other regimen data. More research is also needed at the tidal termini, especially on the processes and rates of sedimentation.



Muir Glacier, 13 August 1941. AGS Station 4 William O. Field

Muir Glacier, 4 August 1950. AGS Station 4 William O. Field



FLUCTUATIONS OF CALVING GLACIERS IN GLACIER BAY NOT PRIMARILY DUE TO CLIMATE VARIATIONS

– – *Austin Post and Mark F. Meier, U.S. Geological Survey*

Post (1975) has shown that the fluctuations of grounded calving glaciers (those that end in the sea and discharge icebergs) depend mainly on water depth at the terminus. This thesis was developed to predict the future drastic retreat of Columbia Glacier, Alaska (Meier et al., 1980; Rasmussen and Meier, 1982; Sikonia, 1982). Critical to these predictions is a relation between calving speed and water depth, or between calving and ice thickness unsupported by buoyancy—which is related to water depth. In the course of developing the Columbia Glacier prediction, Brown et al. (1982) measured or calculated the calving speeds of Muir, Grand Pacific, Margerie, Johns Hopkins, and the 1860–79 west Glacier Bay glaciers; Rasmussen and Meier (unpublished) made a preliminary model calculation on the retreat of the Muir Glacier from 1892 to the present.

These results indicate that the fluctuations in historic times of the calving glaciers of Glacier Bay may be explained by the normal, periodic cycle of calving glacier slow advance and rapid retreat, with the timing depending primarily on fjord depth and moraine shoal development. Thus, it is incorrect to assign climatic significance to these fluctuations without first considering calving stability or instability. These stability considerations governed calving glacier fluctuations during the Holocene, and make the near–future glacier behavior pattern reasonably predictable.

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SURFICIAL GEOLOGIC STUDIES AT GLACIER BAY: DATA BASE FOR OTHER DISCIPLINES AND FOR PARK MANAGEMENT

– – *Garry D. McKenzie, Institute of Polar Studies, Ohio State University*

Unconsolidated materials, and the processes acting on them at the earth's surface, provide the substance for studies of surficial geology. In Glacier Bay the rapidly changing coastal landscape, dominated by mountain glaciers, provides an exceptional opportunity to understand the mechanisms and rates of many geologic processes and to interpret Late Quaternary and Holocene history. The potential scientific rewards and reasonably good accessibility have drawn many geologists to the area.

Since 1966 I have worked on the glacial history and processes here. Interpretation of geologic sections, best studied shortly after deglaciation, and geomorphic evidence have helped to give us the last 11,000 years of geologic history in the eastern part of the Bay. My other interests include the processes of formation of kame terraces, fan deltas, outwash, and glacier caves. Research by other members of the Institute of Polar Studies since the late '50s has also focused on interpretation of history and processes. In general, these and other surficial geologic studies have provided a base for research in other disciplines, the regional glacial geologic/climatic picture, and the geologic resource and hazard information needed for park management.

Future basic research in surficial geology should include interpretation of glacial, periglacial, lacustrine, mass movement, fluvial, eolian, coastal and submarine processes. This research will include development of more sophisticated conceptual and mathematical models to explain the processes so well displayed here. Expansion of the Quaternary history using geomorphic evidence, terrestrial and marine stratigraphy, and by mapping surficial materials in the park should be attempted, although the results may be less spectacular than those obtained to date. Through continued cooperation between NPS, public interest groups, and scientists, the objectives for basic research and management can be achieved.

MAGNETIC CORRELATION OF HOLOCENE GLACIO–LACUSTRINE SEDIMENTS, GLACIER BAY, ALASKA

– – *Robert G. Goodwin, Department of Geology, University of Nebraska–Lincoln*

Paleomagnetic analyses were carried out on 138 oriented samples (2.5 cm x 2.2 cm diam.) obtained at 25 cm intervals from vertical transects through 7 outcrops of rhythmically bedded sediment in Muir, Adams, and Wachusett Inlets. The sediments sampled record periods of ice advance down the West Arm of the Bay that resulted in glacier damming of Muir Inlet. Thickness records of rhythmite couplets failed to provide outcrop correlations. However, if the couplets are annual, they indicate that lacustrine deposition occurred for only several hundred years at any one site. All samples were measured for susceptibility on a low field susceptibility bridge, and their remanent magnetism was measured on a spinner magnetometer. Twenty samples were AF demagnetized to 70 mT in 10 mT increments. The remaining samples were

cleaned at 10 and 20 mT. Demagnetization curves, X-ray diffraction, and optical inspection indicate that magnetite is the principal magnetic component, and the NRM is interpreted as a DRM. Susceptibility is highly correlated to sample grain-size and is not regarded as a reliable correlation tool. Multiple sampling of horizons shows the natural variation of inclination to be as high as 15.5° and that of declination to be as much as 30.6°. Owing to variability and to the short length of record, average inclinations and declinations were calculated for each outcrop. Fifteen samples with low Koenigsberger ratios were excluded from averaging because their magnetization was interpreted as unstable. Results suggest that 5 outcrops can be correlated to one another. Radiocarbon dates from comparison of VGP positions calculated for averaged data with dated European magnetic records suggest two periods of ice damming. One event occurred c. 2990-2600 BP and is recorded in Muir, Adams, and Wachusett Inlets. The second took place c. 1700 BP and has been identified only in Muir and Adams Inlets.

LITHOFACIES DEVELOPMENT AT THE MARGIN OF THE CASEMENT GLACIER, GLACIER BAY, ALASKA

-- *Robert G. Goodwin and P. L. Brookner, Department of Geology, University of Nebraska-Lincoln*

The Casement is a grounded, rapidly retreating, wet-based glacier confined to a bedrock valley. The historical development of landforms related to its retreat has been documented by R. J. Price, and the physical ice-system was studied by D. N. Peterson. These studies and reconnaissance field observations made during the summer of 1983 suggest the following: A blanket of subglacial till, one to several meters thick, was deposited in low areas covered by the glacier (generally below the 300 m contour). Coarse gravel and cobbles are abundant in the till and usually show a clast supported fabric. They are well rounded due in part to their previous history as alluvial valley fill. Subglacial depositional processes were not observed, but kettles developing on the outwash train suggest that melt-out may still be occurring beneath a sediment cover. A wide band of stagnant debris-covered ice is present at the glacier margin. Clast shapes from this material are extremely angular, and the sediment is reworked and dispersed by sediment gravity flows. In exposures along valley walls, supraglacial debris is only a few to tens of cm thick. It covers subglacial till or subglacial fluvial deposits. Proglacial lakes are present along much of the glacier margin. They are floored at least in part by glacier ice. Laminated silt and fine sand are being deposited in the lakes, but they are also subject to rapid infilling by glaciofluvial sand and gravels. Eskers are emerging along the east side and at the center of the glacier margin. At some time in the past, these were preferred drainage-ways for sub- or englacial water. Most meltwater is now directed to the west side of the glacier by the asymmetric subglacial valley floor. Glaciofluvial activity on the outwash train is the dominant mechanism transporting and depositing sediment beyond the ice margin. The outwash fits the Scott fan model, and much of the sediment deposited within 2 km of the ice margin is deposited over glacier ice. Ice collapse is a major process reworking sediment and is responsible for destruction of primary sedimentary structures and fabrics. Channel migration and incision have destroyed eskers on the active valley train and have removed at least some of the till deposited in the valley. Very large rounded erratics (over 1.5 m in longest dimension) are exposed in some channels and are believed to be erosional remnants derived from subglacial till.

GLACIMARINE SEDIMENTATION BY TIDEWATER GLACIERS

– – *Ross D. Powell, Northern Illinois University*

Tidewater glaciers and iceshelves are major sources of glacimarine sediment. The unique setting and recent glacial history of Glacier Bay enables its glaciers to be used as models to describe sedimentary processes and lithofacies produced by tidewater glaciers. These models are used to interpret ancient deposits (e.g., Fraser Lowland, Maine, Africa) and for comparison with other glacimarine regimes (e.g., Antarctica).

Observed processes resulting from interaction between ice, sea and melt–water which control lithofacies production are: (1) rates of ice calving and glacier front retreat: these influence type and rates of sediment accumulated and environmental energy at a glacier front; (2) positions of debris in or on a glacier: these control where and how debris is released; (3) melt–water streams: these have seasonal and diurnal variations in discharge and produce overflows, interflows and underflows. They distribute glacial rock flour to produce glacimarine mud, and coarser–grained debris that builds ice–contact subaerial outwash deltas and submarine fan complexes; and (4) oceanic parameters: these control berg tracks, rate of ice melting, spatial distribution of turbid plumes from melt–water streams, vertical mixing of the water column and bottom current activity on the fjord floor.

Relationships of different lithofacies produced under specific conditions are described as distinctive lithofacies associations. These associations are combined into a sedimentary facies model. The model predicts that during rapid glacier retreat in deep water (Facies Association I, e.g. Muir Glacier), subglacial till may be exposed and reworked on the fjord floor. Gravel or rubble may be introduced by calving bergs and subglacial streams. An interlaminated facies is characterized by sand, silt, and mud laminae produced by sediment gravity flows, underflows and by turbid melt–water plumes. These plumes interact with tidal currents to produce cyclopels.

The high energy environment in front of a glacier stabilized at a channel constriction is characterized by coarse–grained clastic sediment on a morainal bank (Facies Association II, e.g. Riggs, Grand Pacific, Margerie, Lamplugh and Johns Hopkins Glaciers). Such banks may include subglacial stream deltas, sediment dropped by bergs and diamictons. Bank fore–slopes exhibit slides and gravity flow channels. At their toes, interlaminated facies interfingers with bergstone mud.

For a glacier whose base is at tidewater, surface melting is greater than calving (Facies Association III, e.g. Lituya, North Crillon, Reid, McBride and Carroll Glaciers). Bergstone mud facies is deposited adjacent to the front and ice–marginal streamsbuild deltas along the front and into the fjord. An interlaminated facies characterizes delta bottomset beds and intertongues with bergstone mud. If the ice contains abundant debris, highly–turbid streams produce diamicton with an interlaminated matrix.

As the glacier retreats onto land, outwash deltas prograde over older glacimarine facies and intertongue with marine–outwash mud (Facies Association IV, e.g. Queen and Rendu Inlets). Eventually, coarser–grained sediment is deposited as an outwash plain.

Reference:

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PALEOGEOGRAPHY OF THE LITUYA REFUGIUM

– – *Daniel H. Mann, College of Forestry, University of Washington*

Lituya Bay, a fjord on the eastern Gulf of Alaska, has been the subject of scientific research since its discovery by LaPerouse in 1786. Recently, attention has focused on the biological refugium thought to exist since the early Pleistocene in ice–free areas on either side of the bay. Deciphering the paleogeography and biotic history of the Lituya refugium involves a multi–disciplinary approach involving entomology, palynology, and glacial geology. Distributional and taxonomic characteristics of the modern carabid beetle and spider faunae suggest that lowland forest and bog habitats are younger in age than are the subalpine and alpine habitats of the area. Similarly, pollen analysis of late Glacial and Holocene peats indicate that no tree species survived the late Wisconsin in the Lituya area.

The greatest paleogeographic puzzle of the Lituya refugium involves the ages of the raised marine terraces which presently compose most of its surface area and of the moraine systems which surround the refugium on three sides. ^{14}C dating of basal peats on the four lowest marine terraces southeast of Lituya Bay have yielded minimum limiting ages of 9200, 2400, and 700 years BP from the highest to lowest (T. Hudson, pers. comm.). Certain features of the oldest moraines on these terraces, including anomalously high surface boulder frequencies and depth of weathering pits as well as peculiarly subdued moraine morphology, suggest that several of the terraces experienced re–submergence in late Wisconsin times. It is suggested that the basal peat dates previously obtained refer only to the time of latest emergence. Regional isostatic depression is the probable cause of the late Wisconsin submergence of these terraces; supporting evidence for the re–submergence hypothesis comes from the presence of buried forest layers dating to 9,000 years BP near present sea level on the shores of Lituya Bay.

Glacial moraines resting on terraces at elevations less than 200 m have been age–correlated using pedological characteristics of clay and primary mineralogy, free iron and aluminum content, weathering rind thickness, horizon number and depth, and development of B2hir horizons. Four of the five distinguishable moraine systems on the lower four terraces are Holocene in age. Glacial drift whose topographical relationships suggest a pre–late Wisconsin age occur at elevations of at least 300 m on both sides of Lituya Bay. This drift overlies peat and forest beds dated to 40,000 years BP and yields pollen suggesting interstadial or interglacial conditions.

In summary, the preliminary glacial and terrace chronologies indicate that the Lituya ice–free area identified by earlier investigators is of middle or late Wisconsin origin and was restricted in extent (perhaps to ridge top nunataks) during the late Wisconsin by isostatic depression and local cirque glaciation. The extent of late Wisconsin glaciation and isostatic depression at Lituya Bay have important implications for the glacial history of the Gulf of Alaska's continental shelf and for the glacial and post–glacial migration and survival of biota in this region.

SPECIAL PRESENTATION: UNDERWATER ACOUSTIC EVIDENCE OF GLACIAL SEISMIC EVENTS IN GLACIER BAY

-- *Paul R. Miles and Charles I. Malme, Bolt, Beranek and Newman Inc., Cambridge, Massachusetts*

High level impulses of underwater sound occurring as frequently as 3–4 times per minute were detected in Glacier Bay during a measurement project to define the underwater acoustic environment in that region for the National Marine Fisheries Service and the National Park Service. Analysis of these impulses demonstrate signal–to–noise ratios as high as 40 dB, significant broadband energy from below 20 Hz to above 2 kHz, and the presence of pure tone components. The character of the impulses is relatively invariant with locations within the Bay area.

We hypothesize that these events are associated with the many active glaciers in the region and are the result of stick–slip action generating seismic energy at the ice/rock interface. That energy is then propagated through the bedrock and radiated as sound into the water column through the walls and/or bottom of the fjords and inlets. Acoustic instrumentation used included a sonobuoy and an omnidirectional hydrophone separated by about 4 km. Analysis of simultaneously recorded data from the two sensor systems provides some directional information relating to the source of the events.

Data are presented describing this phenomenon in detail and relating it to findings of others who used geophones on and near glaciers in other regions.

DISCUSSION HIGHLIGHTS OF THE GEOLOGY, GLACIAL ACTIVITY, AND CLIMATOLOGY PANEL

The Geology, Glacial Activity, and Climatology Panel discussion revolved around what is not known of the glaciology and climatology of the Park and Preserve. Suggestions on how to fill important gaps in knowledge included studies of refugia, glacial stratigraphy, hanging glaciers, sediment deposition, and the remote collection of contemporary climatic data.

Panelists discussed the need for background information on the dynamics of particular glaciers in the Park and a better understanding of the global context of these glaciers. They reconfirmed the belief that GBNPP is a special research site capable of providing fundamental knowledge on glacial dynamics and climatic variation.

In contrast to the limited glacial and climatological information, bedrock reconnaissance understanding now exists for all but the Preserve part of GBNPP. Thus, bedrock considerations focused on mineral deposits and the potential for mining impacts.

Wondering if criteria could be established to intensively study specific portions of the Park and Preserve, the panel held additional meetings following their formal presentations. Some results of these discussions appear in their Recommendations.

Past Climates. Several panelists cited GBNPP as a "perfect place to study" the interaction between climate and glaciers because of the knowledge accumulated about past glacial conditions from early explorers and scientists. According to Bill Field, Glacier Bay is a place "where we know so much more about what happened in the last 2 1/4 centuries than is known for most places where there has been great change [in glacial conditions]." He and others wanted to continue to know how glaciers and climate affect each other.

Throughout the geology discussion, Dan Mann championed studies of Outer Coast refugia. He spoke of the refugia as repositories of important information about past climates, Neoglacial fluctuations, and perhaps human pre-history. Mann noted that visitors to Glacier Bay hear of a few thousand years of glacial history from Park interpreters, as if nothing ever happened before the Neoglacial. "If you look past the Bay and into the rest of southeast Alaska, you're looking into a landscape that's been deglaciated for maybe 14,000 years, but at refugia you must consider tens of thousands of years. Some of the most important research that could be conducted at GBNPP would be to start looking outside of the immediate Bay at the older terrain."

Dave Brew agreed and said, "There exists no overall synthesis of glaciation in southeast Alaska...[moreover] the earlier history apparently was destroyed. If the western part of the Park has the potential of supplying that part of the geological record, then it is an extremely important area—here is the opportunity for a real contribution with the Park as representative of the older glacial history."

Ross Powell also spoke of the value of looking to the Outer Coast. "It's now fairly obvious that there weren't just the four simple glaciations as recorded in the mid-continent...offshore Pacific records show much more complicated climatic

fluctuations in the past. Perhaps we have the potential here to relate those deep-sea [sediment] records to an on-land record from the Outer Coast," Powell noted. Dan Mann added that since many Outer Coast glaciers and moraines are not at tidewater, problems associated with using tidewater glaciers as indicators of climatic change could be avoided.

In addition to studies of refugia, panelists mentioned looking at glacial stratigraphy, hanging glaciers, and sediment deposition as possible ways to retrieve data on past climates. High accumulation and melting rates for Alaskan glacial ice makes using glacial stratigraphy difficult. Mark Meier recorded 15 meters of accumulated snow during August, 1982 on the Columbia Glacier. Carl Benson drilled a 43-meter core near the top of Mount Wrangell which appeared to contain only 30 years of data. Stratigraphy is most useful, they concluded, in areas like Greenland and Antarctica where accumulation rates are not as high and melting does not complicate the stratigraphic record. Benson thought that getting several hundred years of record is possible from Glacier Bay ice, but both he and Meier doubted that thousands of years of record could be extracted.

Bill Field mentioned the possibility of studying hanging glaciers for indications of climatic change. Glaciers that end on land give a truer picture of climate change than those that end in tidewater. "That's one of the reasons to keep watching the little glaciers...Even though they don't do anything that attracts tourists here, they're extremely sensitive," Field noted.

Ross Powell suggested looking at sediment deposition in the fjords as another record of glacial fluctuation and rates of retreat. Powell, in conjunction with the USGS, ran seismic transects in front of tidewater glaciers. The data indicated that "most of the sediment deposited during the last glacial advance was flushed out...The record that is left is primarily that of retreat of the glaciers." A large ship would be required to drill through the up to 400 meters of sediment. Pockets of older sediments not scoured out by the glaciers might exist, Powell concluded, "but we don't know."

Whether data come from stratigraphy or from refugia pollen records, Mark Meier and Carl Benson continued to caution that general climatic changes cannot be inferred from changes in tidewater glaciers. These glaciers advance as fast as they can move moraine shoals forward, and retreat when they fall off those shoals; neither event is necessarily caused by climatic change. In fact, "the marine glaciers in this part of Alaska are completely asynchronous in the last few thousand years in their advances and retreats," according to Meier. Benson and Meier also cautioned that interpreting the surge of a glacier as indicative of climatic change is "another risky adventure."

Contemporary Climate. The panel (and other panels — eds.) expressed considerable concern over the absence of weather and climate data from the Park and Preserve—data which should be regularly recorded from numerous locations since there is considerable (perhaps even extreme) variation among local climates. The panel discussed the possibility of setting up a remote climatological and glaciological data collection platform. Data on wind speed and direction, air temperature, surface velocity of ice movement, thickness changes of ice, etc., could be transmitted directly to a university or research station computer. According to Meier and Benson, although

the cost of operating a remote satellite transmitting station would depend on how many elements were measured, collecting data this way is "cheaper than any other way you can get it." Some lively discussion about costs followed; Gary Vequist suggested data storage on-site with microprocessors that could be checked several times a year. Vequist added that this system would contribute less impact on the Park.

The Alaska-Yukon Cordilleran System. Panelists brought up the point several times that more is known about the Greenland and Antarctic ice caps than is known about the glaciers of the massive Alaska-Yukon system. High on the research priority list of the Committee on Glaciology of the National Academy of Sciences is the study of the Alaska-Yukon glaciers. According to Meier, this system "produces runoff [significantly] affecting the oceanography of the Gulf of Alaska—the runoff of the Alaskan coast is greater than the discharge from the Mississippi River...Storms born in the Gulf of Alaska pass across this mountain barrier, dump huge amounts of precipitation, modify the air mass, and thus affect the climate of most of the rest of North America...Yet we don't know precipitation characteristics, percentage of snow or rain at any altitude, glacier mass balance statistics, and so on...With its excellent logistic support, the interest of many researchers, and the presentation of complimentary research proposals, the best place to start gathering these data [appears to be] Glacier Bay National Park and Preserve."

Study Site Selection. The panel raised the question of criteria for study site selection. They (and the other panels -- eds.) discussed the desirability of choosing sites for concentrated, integrated studies. Could data from such areas be applied to the rest of the Park and Preserve? If picking areas for interdisciplinary study is desirable, what should be the criteria for selection? Would the impact of integrated studies at a single site possibly be significantly adverse?

The panel concluded that site-specific meteorologic studies were possible, but site selection input would be needed from glaciologists, glacial meterologists, sedimentologists, and glacial hydrologists (as well as biologists -- eds.). The selection, however, of individual glaciers, fjords, recessional systems, etc. for concentrated interdisciplinary research will likely prove most difficult and require careful deliberations.

Bedrock Geology. Dave Brew briefly summarized the very complicated geology of GBNPP based on the completed reconnaissance geologic mapping and a few detailed studies of selected areas. The area is notable for the diversity of the bedrock geology (especially the intrusive rocks of different types and ages), but perhaps the most important features relate to the four major tectonostratigraphic terranes that are clear expressions of the region's plate-tectonic history: the Yakutat "block" between the edge of the continent and the Fairweather fault, the Chugach terrane between that fault and the Tarr Inlet "suture zone," the "suture zone" itself, and the lower and upper Alexander terranes on to the east.

Mineral Deposits. Responding to audience questions, Brew mentioned some of the main findings of the 1966 USGS and 1975-1977 joint USGS-USBM mineral resource studies. GBNPP has more than its share of mineral deposits and occurrences compared with the rest of southeastern Alaska. Several areas, namely the Pacific Coast beach sands, the layered gabbros of the Fairweather Range, the complicated granitic intrusive area near

Margerie Glacier, the volcanic and sedimentary rocks near the mouth of Johns Hopkins Inlet, the altered and intruded rocks of the Muir Inlet area, and the Reid Inlet gold mining area, are more likely to attract serious economic attention than others.

Given the present economic climate along with the needs for strategic and critical minerals, Brew continued, the Brady Glacier nickel–copper deposit and the Reid Inlet gold area appear to be the most likely to receive attention. In general, mining in GBNPP is made less attractive to mining companies by law and the associated econo–politics, and by the difficulties of mining, transporting, and milling ore in a remote area. If it became necessary to exploit any of Glacier Bay's mineral resources, a mine could be constructed in an environmentally least degrading manner with the actual mine and mill site carefully controlled and later rehabilitated. Brew emphasized that it would be the support facility and community, including the power generation system, that would have the greatest impact during the mine operation and would be the most difficult to rehabilitate. He feared that if it suddenly became necessary to mine in GBNPP, the mining "would probably be helter–skelter...and not very well planned."

Ian Worley concurred with Brew and referred to his report on the Granduc Mine in British Columbia and its parallels with mining at GBNPP. This report found that the greatest impacts would be caused by the support facilities, especially the residential communities, transportation activities (e.g. multiple scheduled flights per day), harbor installations, and the power system. The report emphasized that engineered structures can be carefully regulated and monitored, but the daily activities of individuals provide considerable potential for impacts since it is neither possible nor legal to control every action of every person, nor to totally restrict their access to the Park and Preserve beyond the mining and support facilities.

THE TERRESTRIAL ECOSYSTEMS PANEL

Ian A. Worley, Chairman

Panelists: Donald B. Lawrence, Roland E. Schoenike, William Bridge Cooke, Gregory P. Streveler, James G. King, Andris Eglitis, Mark G. Noble and Fiorenzo C. Ugolini

AN OVERVIEW OF TERRESTRIAL ECOSYSTEM RESEARCH AT GLACIER BAY NATIONAL PARK AND PRESERVE

– – *Ian A. Worley, Environmental Program, University of Vermont*

The Glacier Bay terrestrial ecosystem literature reveals five periods: the early expedition period prior to the 20th century; the beginning of modern research (by William Cooper) from the 1920s to the 1940s; the diversification of research and the initiation of experimentation in the 50s; the first large scale, integrated team study (by the Institute of Polar Studies) in the 60s; the explosion of research in the 70s, in part due to human disturbance threats, including the multiple-year team studies at Dixon Harbor and Lituya Bay. The current Glacier Bay National Park and Preserve Bibliography shows that publications, reports, and theses average about one per decade, until 1950–1960 when they jump to about 10 per decade; the 70s produced over 30 items, and at the 1980–1982 rate the 1980s may produce 50–80 or more items. However, the amount or research currently underway appears significantly less than during the 1970s.

The researches can be divided broadly into those dealing with succession and those of an inventory or taxon-specific nature. More has been written about vascular plants (about 20 items) and birds (about 15 items) than any other topic; next come mammals (about 9 items), then fish, invertebrates (especially insects), non-vascular plants, and plant communities (5–7 items each). Microbiology/mycology, wetlands/aquatic systems, and soils have only about 3–4 publications each. Some topics (e.g. algae) and processes (e.g. productivity) are virtually unstudied in the Park and Preserve. To me, one report stands too quietly apart—The Natural History of Glacier Bay National Monument (Streveler and Paige, 1971); no other work so completely addresses the whole of the area (and it was done before the recent extensions of the Park and Preserve).

Research trends follow succession themes, build around "families" of researchers (e.g. Cooper, who invites Lawrence, who invites Worley, who invites Walker,...), respond to management needs, and are powered by personal curiosities. Many researchers return to Glacier Bay because it affects them in some very personal ways.

During the 1950s and 60s, research concentrated along Glacier Bay due to the work of Lawrence, Goldthwait, and co-workers. Mining threats spurred the intensive 1970s research along the Outer Coast. In the 1980s dramatic increases in visitor uses and impacts may focus the next surge of researches, especially along Glacier Bay and wherever vegetation is young or low.

In my opinion, future research should seek to more fully reach all parts of the Park and Preserve, should continue a rich enquiry of ecosystem development, should be more integrative among disciplines, should be designed so that human impacts can be better monitored and predicted, and should be useful to the interpretive and management needs of the Park Service.

VEGETATION STUDIES ON THE OUTER COAST

– – *Ian A. Worley, Environmental Program, University of Vermont*

The Dixon Harbor and Lituya Bay projects of the 1970s added considerably to the vegetation knowledge of Glacier Bay National Park and Preserve. They extended research resources, but left the researchers feeling familiar with the vegetation and in possession of a certain degree of understanding. The data as presented in the reports and herbaria should provide a good foundation for further studies. Even though the regions seemed almost impossibly large during the projects, these relatively (in contrast to most of the Park and Preserve) intensively studied areas are but a fraction of the whole of GBNPP.

Principal contributions of the vegetation studies include: annotated lists of bryophytes and vascular plants (accompanied by many voucher specimens); plant community maps of both areas; typification of a number of plant community types; recognition of at least one significant community not known before--the headland Spruce Parkland; a species biogeography of shores and beaches; the succession sequence on emergent beaches (a nice story, demonstrating that forest occupation is via copse enlargement and not advance of a forest margin, with driftwood being a most important germination substrate for the initial spruce colonization in the herbaceous meadows); and a preliminary construction of primary succession patterns in areas of river floods, catastrophic floods by released ice-dammed lakes, emergent beaches, and receding glaciers--patterns which, at least in the pre-spruce stages, are significantly different from successional patterns reported from along Glacier Bay.

ECOSYSTEM DEVELOPMENT FOLLOWING NEOGLACIAL RECESSION SINCE 1750 A.D.: AN INTRODUCTION

– – *Donald B. Lawrence, Department of Botany, University of Minnesota*

As a result of world-wide climatic oscillation over the past five centuries, glaciers advanced and receded. At Glacier Bay, recession has been a catastrophic 105 km (65 mi) since 1750. This has provided an unexcelled laboratory for testing ideas about how landscape becomes clothed with organisms and how the soil develops after melting of continental ice sheets. Ecosystem studies begun by W. S. Cooper, 1916–1935, have been continued by teams from the Universities of Minnesota and Ohio, dealing mostly with terrestrial landscapes. Freshwater studies have dealt mainly with streams. Results of these studies have altered previous concepts about how and why ecosystem development proceeds as it does.

Ecological theory has been drastically modified here. Instead of the outmoded dictum that "each stage of the development prepares the way for the next stage, thereby bringing about its own elimination," we must substitute two basic principles:

> 1. Those organisms fitted with mechanisms of greatest mobility of dispersal of spores, seeds, and fruits are most likely to arrive on new surfaces first, become established first, and attain reproductive maturity first. This principle is elementary and fairly obvious.

2. The second principle, not previously recognized, but demonstrated at Glacier Bay, is that those plants capable of fixing atmospheric nitrogen, independently (in some micro-organisms only), or symbiotically (in root nodules of higher plants), can grow and attain reproductive maturity so much faster than other plants that they rapidly can dominate the landscape. If they can grow erect as well, commanding unobstructed access to light, their prolonged success is assured. They not only grow rapidly but stimulate plants that were established earlier to grow fast also. If these neighbors can grow still taller, they can, in turn, overshadow the nitrogen fixers. When the leaf litter changes from broadleaf-blanketing to short needleleaf-sifting, mosses can carpet the forest floor deeply as they do here at Bartlett Cove on this 18th century terminal moraine. After that, it is those species capable of tolerating deepest shade, acidified substratum, reduced nutrient levels, and rising water table, that can dominate the landscape.

These are the basic principles. Other panel members will elaborate on the details regarding the sequence of organisms involved, beginning soon after ice recession and continuing through to the most changeless steady state. The latest stage, dominated by bog moss (*Sphagnum*) and dwarf shrubs of the heath family, and sedges, is beginning at Bartlett Cove. However, in order to see the final muskeg stages on relatively level ground in all their intricate beauty, dotted with pit-ponds, we need to go to nearby Pleasant Island in Icy Strait off the mouth of the Bay. I have urged that Pleasant Island be added to the National Park as a preserve, where deer harvesting may be continued but the muskeg and ancient forest remnants can be preserved for research, interpretation, and aesthetic inspiration.

THE ROLE OF *Dryas drummondii* IN PLANT SUCCESSION ON NEWLY DEGLACIATED TERRAIN AT GLACIER BAY, ALASKA

-- *Roland E. Schoenike, Department of Forestry, Clemson University*

The first plant to attain full possession of the land surface at low elevations following ice recession at Glacier Bay is *Dryas drummondii* (Richards). The remarkable vigor, rapid growth, and colonizing behavior of this mat-forming perennial is in stark contrast to the unthrifty appearance and slow growth of most pioneer species.

In 1952, D. B. Lawrence discovered *Dryas drummondii* root nodules consisting of fleshy rust-brown coralloid clusters, superficially resembling nodules on *Alnus* spp. (which have been known to fix nitrogen). Nitrogen fixation by *Dryas* was demonstrated by G. Bond. The nitrogen-fixing organisms in both *Alnus* and *Dryas*, as well as in many other non-leguminous plants, have been shown to be species of Actinomycetes.

Investigations were made on the growth rate of *Dryas* mats, their nitrogen and organic matter contents, and the influence of this species on soil characteristics and on the growth of cottonwood (*Populus trichocarpa* Torr. Gray). *Dryas* develops a centrifugal

habit of growth about the fifth year. At that time, the primary rosette has an areal coverage of about 130 cm^2. Radial extension of the lateral shoots averages 7.4 cm/yr for 15 years or more, producing a symmetrical disc on level to gently rolling terrain. The largest discs seen at Glacier Bay averaged 6.1 m in diameter and had an estimated age of 41 years. The expanding discs eventually coalesce to form a continuous blanket of vegetation.

Adventitious roots are produced annually as the disc expands, firmly anchoring the plant to the soil. *Dryas* produces asymmetrical annual growth layers of diffuse-porous wood. In many cross-sections only the first growth layer completely encircled the pith. The remaining layers were complete only on the upper surface.

Leaves, stems, and litter were sampled from the central, mid-radial, and peripheral portions of ten mats to ascertain organic matter and nitrogen content. In the center where the mat was thickest, the organic material (oven-dried) averaged 22.2 g/100 cm^2. Projecting this to complete *Dryas* cover, about 19,060 kg/ha dry matter would accumulate in only 30-40 years. Leaf nitrogen content (Kjeldahl) averaged 1.96% for green leaves and 1.47% for dead leaves. Using similiar projections, the amount of nitrogen accumulated in a complete *Dryas* cover on a surface 30-40 years old would be about 365 kg/ha.

Soil changes under the *Dryas* mat were determined by R. L. Crocker and J. Major. Bulk density in the uppermost 5 cm of soil decreases from 1.50 (bare surface) to 1.37 under the *Dryas* mat, primarily because of root concentration. Soil pH drops from 8.0 – 8.4 to 7.7 under *Dryas* in 20 years. A moderate leaching of $CaCO_3$ also occurs. Organic matter in the top 5 cm of soil increases from 650 kg/cm on bare surfaces to 1900 kg/ha under *Dryas* (exclusive of the mat) in 25 years.

Stimulation of the other plants by *Dryas* appears slight. For 11 cottonwood saplings growing in *Dryas* mats and 11 growing on *Dryas*-free sites, only in the four most recent growing seasons did *Dryas*-associated cottonwoods outgrow the controls (by about 20 percent). There were more leaves on the *Dryas*-associated plants and their nitrogen content was higher, but the relative differences were small.

The alder thicket, which succeeds the *Dryas* stage, is a much heavier producer of organic material and a more efficient nitrogen fixer, and only this plant can prepare the ecosystem for the high-forest species such as spruce and hemlock. Nevertheless, the effects of *Dryas* is not inconsiderable. By stabilizing the soil surface and providing a reservoir of nitrogen and organic matter, it would appear that the *Dryas* stage speeds up the rate of succession to high-forest by 20-30 years, and it may mean that the forest is more productive than if it had been absent.

FUNGI AT GLACIER BAY NATIONAL PARK AND PRESERVE

– – *William Bridge Cooke, Cincinnati, Ohio*

To date 635 species and species groups of fungi have been collected in Glacier Bay National Park and Preserve. To say which of these is more important is premature. Since little attention has been paid to the role of decomposer organisms in the ecosystem, the role of the individual mycorrhiza, litter, soil, wood decay, and other fungi is only broadly generalized.

Which fungi are mycorrhizal must still be judged by observation, or by literature reference. Certain correlations may be made by sociological studies, of which only one or two have been made in North America. A series of such studies in each ecosystem and each time station chosen should be conducted. Observations should be made at least at weekly intervals, rain or shine.

Other important questions include: Of the fungi growing "on the ground," which are on litter, which are humicolous, and which are mycorrhizal? Of these, which are sugar–fungi, and which are associated with cellulose, lignin, or other food sources? One by one, what is the fundamental niche of each species, what is their realized niche, and is there an overlap? Is there exploitation competition between species in each habitat type or fungal synusium? Do marine and aquatic fungi, including aquatic hyphomycetes, occur in the Park? What are the fungal relations on the glacial ice?

A study should be made of soil fungi in each major ecosystem and in each stage of the Glacier Bay succession series, using contemporary techniques. Wood decay fungi should be studied both in down timber and in standing trees by culture techniques. Tree root and tree crown fungi should be studied. Detailed microclimatological, as well as macroclimatological, data are needed for each sampling station.

TERRESTRIAL MAMMALS IN GLACIER BAY NATIONAL PARK AND PRESERVE

– – *Gregory P. Streveler, Friends of Glacier Bay, Gustavus, Alaska*

Widespread incidental observations and three reasonably thorough surveys (of the Muir, Dixon Harbor and Lituya vicinities) have documented the presence of 28 species of terrestrial mammals, provided a few insights into rough population magnitudes and trophic relationships, and suggested a few cases of impact susceptibilities—that is all.

Five generalizations seem indicated by the present information: (1) the fauna is rather typical for mainland S.E. Alaska; (2) physical barriers introduce elements of insularity into population distributions and dynamics; (3) dynamism is very pronounced; (4) postglacial faunal development tends to be accretional, in contrast to the wavelike "succession" typical of plants and some other groups; and (5) nearshore habitats are both consistently important to mammal populations and the focus of most impact potentials.

Much research can be recommended for this neglected group. Perhaps the most important management-related topics involve construction of baselines. Other "basic" research might focus on mammals in their general ecological context and on the nature of postglacial faunal development.

NEEDS AND OPPORTUNITIES FOR BIRD STUDIES IN GLACIER BAY NATIONAL PARK AND PRESERVE

– – *James G. King, U.S. Fish and Wildlife Service (ret.)*

Future generations of wildlife scientists, struggling with conservation problems we cannot anticipate, will comb the records for baseline data on how things were in our time. We are not doing the best job we could to fill this need for our posterity. National parks could provide a continuing record of natural bird numbers and productivity. The diversity of Glacier Bay offers an outstanding place to establish a pilot project for monitoring birds. This could be achieved through a small scientific staff to provide planning and continuity and a policy to encourage university student research projects.

Bird studies we could do now include: (1) winter plot surveys of birds in the marine habitats, (2) winter aerial swan census, (3) observations of birds in migration from points on the outer coast, (4) breeding bird surveys using standard plot methods, (5) census of nesting bald eagles, (6) census of nesting swans, (7) productivity studies of seabird colonies, (8) molting and nesting habits of Canada geese, (9) sampling beached bird carcasses washed up by the tide, and (10) life history studies of all nesting species.

Fulfillment of the mandate to protect park wildlife forever may depend on knowledge gained from such studies.

THE SPRUCE BEETLE IN GLACIER BAY NATIONAL PARK AND PRESERVE

– – *Andris Eglitis, USDA Forest Service*

The bark beetle (*Dendrostonus rufipennis*) has infested Sitka spruce forests throughout the southern portion of Glacier Bay. This infestation probably began in 1977 and now covers approximately 5000 acres, including the west side of the Beardslee Islands and the mainland between Berg Bay and Ripple Cove. Additional beetle activity is evident along the Bartlett River and in patches south of Bartlett Cove. Spruce mortality has been greatest on Young Island and in an area three miles south of Berg Bay, where about 80% of the spruce have been killed since the outbreak began.

Although the spruce beetle occurs throughout the range of all spruce types, its populations rarely reach outbreak levels in Sitka spruce. Thus the Glacier Bay infestation is unique in Southeast Alaska and represents a rare opportunity to learn more about the development of the beetle in coastal forests.

Forty fifth–acre plots have been established near the infested areas and will be monitored annually to evaluate population trends and to study attack behavior of the bark beetle. In addition, the plots will serve as a means for evaluating the role of the bark beetle in secondary plant succession.

PLANT SUCCESSIONAL STUDIES IN GLACIER BAY NATIONAL PARK AND PRESERVE WITH EMPHASIS ON FOREST PALUDIFICATION

– – *Mark G. Noble, Institute of Arctic and Alpine Research, University of Colorado*

My initial investigations in Glacier Bay National Park were floristic analyses of local plant associations near the shore of Muir Point (Noble & Sandgren 1976) and in the subalpine on Mt. Wright (Sandgren & Noble 1978). At the same time (1974), observations were begun to ascertain the spatial and temporal characteristics of *Sphagnum* colonization in the post–Neoglacial spruce/hemlock forests of the lower bay (Noble et al., in review). This latter project is described below and has been carried out in collaboration with Donald B. Lawrence and Gregory P. Streveler.

Our observations, which are the first done in detail concerning *Sphagnum* colonization on the floor of a coniferous forest, are being used to evaluate the process of forest paludification. This is the process by which forest is replaced by muskeg and requires the waterlogging of the forest floor and subsequent death of the forest trees. The forest under study is dominated by *Picea sitchensis* and is located on the Neoglacial moraine near Bartlett Cove. The observations have shown that (a) *Sphagnum girgensohnii* is the first peat moss to colonize the thick moss carpet on the floor of this forest, (b) establishment occurs only where the moss carpet has been disturbed by tree falls, (c) the number of *Sphagnum* patches in this forest is increasing with time, and (d) the patches are enlarging in surface area about 2% per year.

As these changes occur on the forest floor, *S. mendocinum* and *S. squarrosum* are invading wet depressions and ponds in this forest. These colonization events seem to be a consequence of soil–formation processes which are causing the water table to rise. The rate of local paludification will be affected directly, through the rise in the water table, and indirectly, as *Sphagnum* growth is stimulated by the proximity of water.

Investigations in this forest, at other places in Glacier Bay National Park, and elsewhere in southeastern Alaska suggest that colonization by *Sphagnum* takes place from 175 to 600 or more years following the initiation of primary succession. The development of muskeg through autogenic processes may take from 800 to several thousand years, or possibly much less if allogenic factors contribute to the paludification process. On sites subject to paludification, the direction and rate of post–glacial succession is altered, the character of the vegetation gradually changes, and the appearance of the landscape is greatly modified.

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SOIL STUDIES IN GLACIER BAY NATIONAL PARK AND PRESERVE

– – *Fiorenzo C. Ugolini, College of Forest Resources, University of Washington*

I first came to Glacier Bay in 1965 as a member of a contingent of scientists organized by the Institute of Polar Studies to examine a sequence of developing ecosystems in the Muir Inlet and particularly those created by the recession of the Casement Glacier. This effort culminated in the publication of I.P.S. Report # 20. The pedological study I conducted investigated a spectrum of soils from those formed on barren till to soils developed on recessional forested moraines about 250 years old. The significance of this chronosequence was the reconstruction of the ontogenetic lines of Podzols formation. Also this study reconfirmed that soil–forming processes in southeast Alaska proceed very rapidly and that the process of podzolization is the prevailing process on the well–drained sites.

In 1977 additional chronosequences were investigated in the Lituya Bay area. These Holocene, marine terrace chronosequences offer a new insight on the interaction between soil development, plant succession, and paludification. Soil–forming processes are responsible for the development of genetic horizons on surfaces emerged from the sea. Under the impact of podzolization, sesquioxides move into the B horizon causing the formation of a placic horizon––an iron–cemented, indurated, and impermeable layer. The placic horizon initiates the deterioration of the soil's internal drainage creating anaerobic conditions and favoring the accumulation of organic matter. At this point, as seen on the mid–Holocene aged terrace, the litter layer surpasses a critical mass and becomes capable of maintaining permanent waterlogging and anaerobic condition. A muskeg is thus formed. This model suggests that pedogenically–induced bog formation may be one of the mechanisms for the paludification of southeast Alaska (Ugolini and Mann, 1979). Recent examination of other forest areas in Chichagof Island has revealed that the placic horizons favor windthrow by undermining the growth and stability of trees. Windthrows cause the formation of mounds and pits. Nearly every mound becomes colonized by trees, whereas the pits, when underlain by the placic horizon, are water–saturated and support plants that can tolerate the resulting anaerobic conditions. This microtopographic pattern of mounds and pits plays an important role in the regenerative patterns and long–term dynamics of the forest in southeast Alaska.

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BIOLOGY AND BEHAVIOR OF MOLTING CANADA GEESE (*Branta canadensis fulva*) IN GLACIER BAY, ALASKA

-- *John Calambokidis, Cascadia Research Collective, Olympia, Washington*

Gretchen H. Steiger and Robin A. Butler, The School for Field Studies, Cambridge, Massachusetts

We gathered information on the distribution, behavior, predation, and human disturbance of Canada geese in Adams Inlet during and directly following the molt in 1982 and 1983. Geese moved to Adams Inlet for approximately one month during the molt. Highest counts of geese in Adams Inlet were 985 on 13 July 1982 and 866 on 4 July 1983. The number of geese using Adams Inlet during the molt has declined from the numbers reported in the 1960s and 1970s, apparently in response to increased numbers of predators. Bald eagles and wolves frequented our study area and successfully preyed on molting geese. Molting geese reacted to potential predators (wolves and bald eagles) and human activities by escaping into the water. Molting geese reacted to vessels at significantly greater distances than post–molting geese.

Of the seven behavior categories we monitored, swimming and foraging were the most frequently seen for molting geese, accounting for 31% and 29% of behavior observations. Molt status, shoreline type, time of day, and weather significantly affected the frequency of some behaviors. Molting geese spent the largest portion of their time in the water (36%) or within 5 m of the water (28%). Molting geese spent more time than post–molting geese in the water or close to the water, apparently to provide protection from predators.

Results of this research are contained in a manuscript submitted to the Journal of Wildlife Management.

DISCUSSION HIGHLIGHTS OF THE TERRESTRIAL ECOSYSTEMS PANEL

The Terrestrial Ecosystems Panel held two discussions, each following presentations by four panelists. Responding to audience questions, the panel spent much time discussing what is known about Glacier Bay's terrestrial ecosystems. Succession dominated the conversations and included such topics as immediate post-glacial colonization, forest paludification, and beetle infestations. Biogeography was a prominent topic, with references to the preceding panel discussion of refugia. Audience interest in and concern for mammals also prompted numerous questions.

Jim King's comments about science in the Park sparked a debate that continued throughout the remainder of the symposium. The panel closed with a summary of its recommendations, which appear in detail in the Recommendations section.

Mammals. In response to a question from the audience, Greg Streveler discussed those mammals particularly susceptible to human impact. We know, he said, what species inhabit the park, we have a vague idea of their numbers, and know almost nothing of their interactions. We know almost nothing about human interactions but, he added, "many animals are being pushed to the wall by increasing human numbers." A short list of species susceptible to human impact includes wolf, wolverine, and in some contexts, goats and small mammals such as mice. Ian Worley added that during the Dixon Harbor/Lituya studies, large mammals such as wolves and bears were displaced because of the presence of the researchers.

Questions about herbivory and other animal effects upon vegetation came from both the floor and panel. Noting that no herbivory research has been done in GBNPP, Greg Streveler concluded that despite locally important instances (such as tundra vole grazing during population highs, and high-use goat meadows), herbivory likely was not a significant contributor the overall pattern of succession. Don Lawrence recalled seeing willows on Sealer's Island in 1941 that were heavily browsed by geese. Worley pointed out that from a plant point of view, sea lion haul-outs and kittiwake colonies were highly disturbed sites. He added that no exclusion research has been undertaken in the Park, but wherever such studies are done, the results are always slightly different than anticipated. Andy Eglitis thought insects might be important herbivores but knew of no data from the Park beyond his studies of the spruce bark beetle, which locally has killed up to 80% of the spruce. A question concerning the effects of sea otter re-establishment was referred to Dave Duggins, who responded that the return to former levels of this major predator likely will cause significant changes in the intertidal.

Noting that little research on mammals has been done in Alaska (except for game populations), the panel discussed ways to increase mammal research at GBNPP. Scientists must first identify key problems and then communicate these needs to both Park managers and the scientific community. Fred Dean and Ian Worley cautioned that some mammal studies require marking or otherwise disturbing animals, which may not be consistent with the concept of a national park.

Outer Coast Refugia. Responding to a question concerning evidence for refugia on the Outer Coast, panel members observed that neither the Dixon Harbor nor the Lituya Bay studies found strong evidence for refugia. Dan Mann failed to find endemic insect species; the enrichment of alpine beetle fauna, however, suggested to him the possibility of a refugium. Greg Streveler remarked that red squirrels on the Outer Coast have a color variant not seen elsewhere, but vascular plants show no evidence for refugia. Ian Worley did find a liverwort rare throughout the world, whose distribution supports a refugium concept. But, he continued, since the species also grows on youthful soils of volcanic ash near Sitka, it points out the critical problem with refugium biogeography: essentially nothing is known about the dispersal ability of most organisms. In addition to biological evidence, Worley concluded, geologic or fossil evidence is necessary to confirm the existence of a refugium.

Island Biogeography. An audience member raised the question of the applicability of island biogeography concepts to Glacier Bay National Park and Preserve, primarily with respect to animals. Streveler responded that GBNPP should be considered, especially with respect to management, as made up of many islands; thus the animals are not one "Glacier Bay population" but are separate subpopulations—for example, the west Glacier Bay and southern Outer Coast wolf populations. For many management purposes, the island–isolation is more significant than the inter–island movements. In particular, Streveler continued, the island concept is crucially important because of the possibility of local extinctions. Ian Worley agreed and stated that, in addition to lateral barriers of water and ice, Glacier Bay has vertical barriers of cliffs and steep valley walls.

Ecosystem Development (Succession). The audience and panel concurred that further succession research is needed, especially in areas other than along Muir Inlet. The panel stressed that the character and rate of ecosystem development differ substantially along Muir Inlet and the West Arm. Compared with Muir Inlet, Glacier Bay's West Arm shows a lag in the rate of lowland ecosystem development and a tendency for dominance by species characterizing drier country. Greg Streveler mentioned that the alder along Muir Inlet is a tremendously aggressive colonizer; yet along the West Arm (above Hugh Miller Inlet, for example) alder is generally restricted to moist floodplains and silty barrens. Correspondingly, more willow and soapberry grow in the West Arm region. Geikie Inlet succession "defied Cooper's predictions," Streveler added. Ian Worley pointed out that the Dixon Harbor studies have demonstrated that primary succession along the Outer Coast, especially in the early decades, differed from development reported along Glacier Bay. Different yet, said Lawrence and Worley, is the post–wave secondary succession at Lituya Bay.

Don Lawrence and Ian Worley responded to the query, "In what direction should succession research now go?" Of principal importance is the continuation of the Cooper plots with expansion of the plots to extend the information to a greater degree of generalization. Similarly, the variability of succession with respect to geo–climatic regions of the Park and Preserve, as well as substrate type, needs careful documentation. Research should extend beyond floristics and phytosociology and incorporate organic productivity, decay, and related physiological characteristics. Mark Noble concurred and said that measurements are needed of seed and spore origins and frequency; furthermore, succession studies must get away from sea level and

extend upward, well into the alpine. Bill Field asked Don Lawrence if it would be of importance to ecosystem studies to have mapped on land as well as water the dates of ice recession. Don responded with an emphatic "Yes!" (Additional thoughts on succession research appear in the panel's recommendations -- eds.)

Spruce Bark Beetles. Questions about spruce bark beetles were answered by Andy Eglitis. Large scale outbreaks in the rest of Southeast Alaska have been extremely rare, primarily due to the lack of extensive even-aged stands and a poor climate for beetle migration and survival. Since the susceptible age of 140 or so years exceeds the age of trees in even-aged managed stands, forestry practices have not led to extensive infestations. Nonetheless, any place with clearcuts, windthrows, and slash on the ground has a resident beetle population. Eglitis suggested that the dramatic decrease in the growth rate of the spruce trees in the lower Bay about 20 years ago may have meant a decrease in vigor of the trees, making them more susceptible to beetle attack than they otherwise would have been.

Peatlands (Muskeg). The panel addressed contemporary hypotheses concerning muskeg formation, focusing on current research at and applicable to Glacier Bay. Mark Noble stated that the formation of muskeg is site specific; if a particular site is well drained and if the substrate is made up of coarse material, then a muskeg will probably never form at that site. Fio Ugolini emphasized that in this climate a site must simply have impeded drainage in order for a muskeg to form; drainage could be retarded by a clay layer, bedrock, compacted till or other condition favorable for retaining water. Bernard Bormann noted that if the hypothesis that windthrow mounds prevent muskeg formation is true, more muskeg should develop in the Berg Bay area because the beetle infestation has decreased the number of windthrow mounds.

Ian Worley pointed out that peatland researchers almost universally have to interpret the character of peatland initiation by examining buried sediments several millenia old, whereas at Glacier Bay peatland initiation and the initial stages of development can be directly studied. Moreover, these may be studied not only in deglaciated terrain but also at sites emergent from the sea and at sites washed by the great waves of Lituya.

Whole-Park Studies. Expanding upon an audience question, Ian Worley recalled the completed reconnaissance of the bedrock geology of the Park, as well as the biological surveys on the Outer Coast, and then expressed the hope that similar all-Park surveys could be done for plant communities and other biological entities. Greg Streveler mentioned an ongoing avifauna study encompassing large portions of the Park and Preserve. However, it was the only such study he was aware of and it extends little beyond the checklist level. Gary Vequist emphasized the considerable amount of ground-truthing needed in community mapping from aerial photography and further observed that considerable expense would be required to achieve whole-park knowledge about any topic.

Systems and Interdisciplinary Studies. The panelists agreed that integrated, multidisciplinary studies are needed. Interspecific relationships, especially those affecting successional development and those prominent in controlling ecosystem character, are virtually unknown.

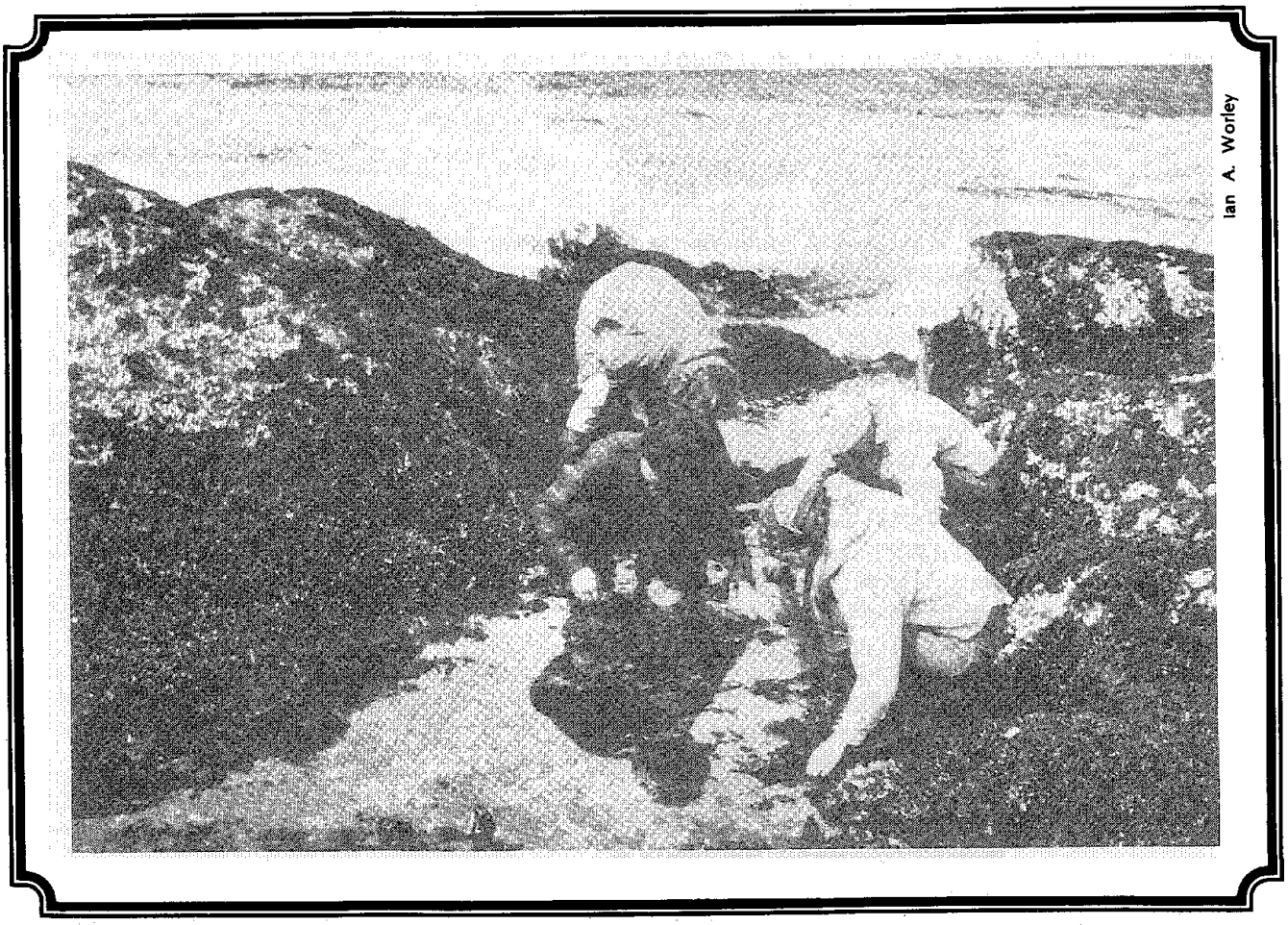
Several panelists remarked on the logistic difficulties of achieving highly detailed studies of individual taxa or of comprehensive systems studies at the level suggested by some questioners. Such research would require considerable facilities, finances, and time. Moreover, GBNPP is a very large place and is logistically difficult to encompass or even to get about within.

The influences of physical parameters likewise are little known; local climatology, biogeochemical dynamics, and groundwater and surface hydrologies were stressed. The panel strongly recommended regular meterological monitoring at a variety of sites.

Values. During the discussions (and throughout the symposium's formal and informal gatherings) topics both ethical and aesthetic arose, primarily with respect to the relationship between science and the park. Explaining his contention that "the National Park Service should recognize scientific study as perhaps the highest form of public use within a Park," Jim King stated that "scientific uses, insofar as they're not destructive to park values, probably contribute most to the long-term value of a park... Other uses are more dependent upon the success of the scientific element than the scientific element depends upon other types of use. For that reason, it is very important that the scientific be given a higher priority than it has in the past." King's comments were widely discussed during the remainder of the symposium.

Don Lawrence recommended the creation of behavior ethics for scientists and visitors as they travel and work in the Park and Preserve. Guidelines for the conduct of research and for the respect of research activities by visitors (e.g. don't dismantle cairns) should be prepared in pamphlet or booklet form.

Ian Worley added the perception that "in the early years of Glacier Bay National Monument, more was known about the place than was needed for management purposes, but in recent years, with the increases in visitors and uses, needs have surpassed knowledge...The holding of this symposium is a direct response to our recognition of this shortfall of knowledge."



THE MARINE AND AQUATIC ECOSYSTEMS PANEL

David O. Duggins, Chairman

Panelists: Lynne Z. Hale, Bruce L. Wing, A. Richard Palmer, Charles A. Simenstad, Daniel M. Bishop, Alexander Milner and C. Scott Baker

TORCH BAY BENTHIC MARINE ECOLOGY

– – *David O. Duggins, Friday Harbor Laboratories, Friday Harbor, Washington*

Studies investigating the structure of intertidal and shallow subtidal marine communities were initiated in Torch Bay in 1975. Interest in the Torch Bay ecosystem originally stemmed from the need to evaluate the potential impact of proposed large–scale mining operations in the area. Consequently, much of our work has addressed the response of benthic marine communities to disturbance. Ongoing and short term studies have been conducted by 13 investigators from several universities (primarily the University of Washington) and a range of ecological questions have been addressed.

Long term research has been along three major lines. Firstly, intertidal communities characterizing exposed and semi–exposed shores have been described qualitatively and quantitatively, and a baseline monitoring program initiated. This monitoring program concentrates on organisms we have determined to be ecologically important in structuring these communities. The baseline data should enable Park Service managers to assess future changes in local populations and ultimately, environmental quality. Secondly, from 1975–1979, subtidal kelp beds were studied in considerable detail. These marine macrophytes are an important and conspicuous element of the nearshore ecosystem because of their contribution to primary productivity and spatial heterogeneity. The work focused on (1) succession following herbivore–induced disturbance; (2) benthic primary productivity; (3) the role of benthic herbivores in determining spatial and temporal patterns of distribution, abundance, and diversity; and (4) the overriding role of high trophic status predators (primarily sea stars and sea otters) in structuring the community through their consumption of the benthic herbivores. Results from these studies have been published in articles listed in the Glacier Bay Bibliography.

Thirdly, a series of experimental manipulations have been initiated to examine the biological processes structuring intertidal communities in moderately exposed habitats. This research deals primarily with (1) response to small scale disturbance to mussel–barnacle associations (the predominant mid–high intertidal association) and (2) the ecological role of the ubiquitous intertidal grazing chiton, *Katharina tunicata*, in the mid–low intertidal zones. The removal of barnacles and mussels from small patches results in persistent bare space, relative to replications of the experiment along the coast of Washington state, suggesting that response to disturbance may be dependent on unpredictable or infrequent recruitment events. Results of *Katharina* removals vary from site to site and year to year. Unlike many other systems, where the removal of a biological disturbance agent leads to species assemblages dominated by one or a few species, removal of *Katharina* has increased species diversity and algal abundance. The inability of a single species to dominate in the absence of disturbance may ultimately result from unpredictable species recruitment as well as high year to year variation in survival of adults and juveniles. The Torch Bay intertidal zone may therefore be characterized as exhibiting relatively low resilience stability (inability to recover from perturbations) when compared with similar communities at lower latitudes.

A CONCEPTUAL MODEL FOR THE GLACIER BAY MARINE ECOSYSTEM

– – *Lynne Zeitlin Hale, LZH Associates, Anchorage, Alaska*

The work discussed was carried out during 1978 with Dr. R. Gerald Wright, then with the National Park Service in Anchorage.

A conceptual ecological model of Glacier Bay, the major fjord system in Glacier Bay National Monument, was developed using existing data on Glacier Bay, as well as data from other Southeast Alaska fjords. The model attempted to: (1) organize and synthesize available data; (2) identify significant data gaps; (3) delineate those ecological components and processes that appear to be most significant in Glacier Bay and thus should be most closely monitored and studied; and (4) look at pathways of potential impacts on the system.

Overall models were developed for the lower and upper Bay in summer and winter, as well as major component models for primary producers, zooplankton, benthos, fish, marine mammals, birds, and detritus/nutrient regeneration. In addition, a visitor experience model was developed and the impacts of major human activities—mining, vessel traffic, sewage disposal, and commercial fishing—on system components were examined.

Existing data on the marine system components of Glacier Bay are few. Phytoplankton data are almost nonexistent, and only reconnaisance level surveys of macroalgae distribution within the Bay have been made. Until the NMFS 1981 and 1982 whale feed studies, no data were available on zooplankton or small pelagic fish. The only information available on demersal fish are some NMFS exploratory trawl surveys from 1954. Harbor seals and humpback whales have received some attention and their number and distribution within Glacier Bay are fairly well known. Much less is known about the harbor porpoises that frequent the Bay. Glacier Bay epifauna was sampled by the same 1954 NMFS survey that looked at demersal fish, while benthic infauna data are only available for Queen Inlet. The species, numbers and locations of birds within Glacier Bay are well known; however, almost nothing is known about their ecological role. The sources and importance of detritus within the Glacier Bay ecosystem have never been examined.

As is evident, much work needs to be done before the conceptual models hypothesized in this paper can be verified or new ones developed. We believe that a holistic approach is required to develop an understanding of the complex and dynamic system that is called Glacier Bay.

HUMPBACK WHALE PREY STUDIES IN GLACIER BAY AND NEARBY AREAS

-- *Bruce L. Wing and Kenneth J. Krieger, National Marine Fisheries Service, Auke Bay Laboratory, Auke Bay, Alaska*

Glacier Bay, Icy Strait, and Stephens Passage–Frederick Sound are foraging areas of the endangered humpback whale, *Megaptera noveangliae*. An apparent decline in the number of humpback whales in Glacier Bay, a concern of the National Park Service and the National Marine Fisheries Service, may be symptomatic of widespread problems involving vessel traffic and/or availability of forage for whales.

Hydroacoustic surveys and net sampling of humpback whale forage organisms have been conducted in Glacier Bay and nearby areas during the past three summers. The 1981 and 1982 survey demonstrated significant annual and areal variation in potential prey for whales, and that specific sites where whales were actively feeding had higher concentrations of prey than the mean concentrations in either Glacier Bay or the Stephens Passage–Frederick Sound study areas. In Glacier Bay, densities of prey were higher in 1981 than in 1982. In Stephens Passage, the opposite was true: densities of prey were higher in 1982. When densities are compared for the two areas, Glacier Bay had higher densities in 1981 than Stephens Passage but lower densities in 1982. The 1983 data are being processed.

Sites where humpback whales were feeding in 1982 were examined in more detail in 1983. Bartlett Cove, at the entrance to Glacier Bay, had high concentrations of capelin in 1982 and several humpback whales were consistently found there. In 1983, we did not see large schools of capelin or other forage in Bartlett Cove, and humpback whales were rarely observed in the Cove. In 1982, at Point Adolphus in Icy Strait, whales generally were observed in association with schools of herring, walleye pollock, and a complex mixture of euphausiids, amphipods and other midwater organisms. In 1983, whales feeding near Point Adolphus were most often associated with concentrations of herring. In the Stephens Passage–Frederick Sound areas, foraging whales were associated with dense concentrations of euphausiids in deep water and with schools of herring or other small fish in nearshore shallow waters.

During our hydroacoustic surveys of whale prey studies, we have found some consistent patterns in the distribution of secondary producers in Glacier Bay. Because hydroacoustic surveys can be used to document density of plankton layers and midwater fish from surface to bottom, these surveys should be used to monitor annual and seasonal changes in the abundance of forage species supporting not only the humpback whales but also seals, porpoises, and marine birds that make Glacier Bay a unique place to visit and study.

ECOLOGY OF ROCKY-SHORE GASTROPODS AND THEIR PREY ON THE OUTER COAST OF GLACIER BAY NATIONAL PARK AND PRESERVE

– – *A. Richard Palmer, Department of Zoology, University of Alberta*

Quantitative data obtained from permanent, vertical transects of rocky shores in the mouth of Torch Bay, on the outer coast of Glacier Bay National Monument, have revealed rather substantial year–to–year variation in the abundance of predatory gastropods (dogwhelks of the genus *Thais* or *Nucella*) and their prey (barnacles and mussels) over the period 1974 – 1982. These snails play a dominant role influencing the vertical distribution and local abundance of barnacles and mussels — the most conspicuous invertebrates of the mid– and upper intertidal of these rocky shores. In turn, snail abundances are tied rather closely to the recruitment of their prey each year; recruitment which appears to be regulated largely by factors external to Torch Bay (i.e., conditions in the open ocean environment). Examples of the fluctuations over this time period include: the snails *Thais lamellosa* (3–fold), *T. canaliculata* (10 to 50–fold) and *T. emarginata* (5–fold), the barnacles *Balanus glandula* (6–fold), *Semibalanus cariosus* (3–fold), and the mussel *Mytilus edulis* (6 to 15–fold in the middle intertidal, 4 to 5–fold overall). One grazing gastropod not observed from 1974 to 1980, the periwinkle *Littorina scutulata*, recruited and reached densities over 75/m^2 by 1982. The density of bladder weed, *Fucus distichus*, has also been observed to fluctuate by over 13–fold. The magnitudes of these fluctuations and the time scales over which they occur (5 to >8 yr) suggest that very long–term data (circa 20 yr.) will be required to determine reliably what the 'normal' range of variation is in this rocky shore community.

References:

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FUTURE DIRECTIONS IN GLACIER BAY RESEARCH: AN ECOSYSTEM PERSPECTIVE

– – *Charles A. Simenstad, Fisheries Research Institute, University of Washington*

A survey of the extant scientific knowledge which has resulted from over 50 years of research in the Glacier Bay National Park and Preserve (GBNPP) will readily indicate how little is known about ecosystem processes in the marine environs. While the sciences of geology, glaciology, hydrology, and terrestrial ecology have contributed considerably to the understanding of the structure and dynamics of the *terre ferme*, both aquatic and marine biotic communities have been relatively ignored and only meager oceanographic data exists. Except for studies on the Outer Coast, in only a

few isolated cases have ecological processes been coupled with the system's dynamic physical processes. Although perhaps individually excellent, such fractionated studies in the absence of a unifying concept and physical–biological couplings will continue to inhibit a functional understanding of the complex relationships which define the "Glacier Bay Ecosystem." Even though a conceptual model of ecosystem structure exists in a broad sense (Hale and Wright 1979), the rate and flux values required to couple the model's components are almost completely lacking. So, in terms of research to date relative to a holistic understanding of Glacier Bay, "you can't get there from here."

An alternative approach to organizing extant knowledge and directing future research could involve thinking of Glacier Bay in terms of discrete ecosystem functions, such as primary food processes (primary production, detritus processing) and consumption (macro–herbivory, deposit feeding, suspension feeding, predation). Biota falling into these categories would be measured as standing stocks of the various producer, decomposer, and consumer categories. Quantitative functional relationships among the structure of biotic assemblages, resources supporting and physical factors regulating these processes would define process outputs (e.g. organic carbon production, consumption, or respiration).

The fundamental need for scientific knowledge and its application to management and interpretation in the GNBPP could thus be more easily focused upon processes, habitats, and physiographic units of importance. These narrowly–defined process studies could eventually be coupled together on a higher level in order to examine ecosystem processes on more comprehensive spatial and temporal scales. Examples of specific processes which could be examined in this way might include: (1) spatial distribution of primary producers and production rates relative to neoglacial age; (2) role of the ontogenetic development of Glacier Bay in structuring important sources and pathways of organic carbon to and within the marine food web; (3) effects of marine sedimentation processes upon the community structure and trophic dynamics of benthic and epibenthic biota; and (4) flux and residence time of pelagic zooplankton and fishes originating outside Glacier Bay.

Properly designed baseline surveys, if incorporating concurrent physical and biological measurements and contemporary technological tools (i.e. $^{12}C/^{13}C$ analyses, hydroacoustic integration, side–scan sonar imagery), could measurably facilitate such an ecosystem processes approach to research in Glacier Bay National Park and Preserve.

HYDROLOGIC INVESTIGATIONS AT GLACIER BAY AND SUGGESTED FUTURE MONITORING

– – *Daniel M. Bishop, Juneau, Alaska*

Dixon River hydrologic investigations concerned proposed development of the Brady Glacier nickle–copper deposit. Reconnaissance work, qualitative in nature, concerned water chemistry and suspended sediment changes, and the possible role of glacial Bearhole Lake in receiving and periodically dumping mine waste waters into coastal stream(s). The transitional nature of glacially–fed streams and their changing morphology and sediment carrying ability were speculated upon. I concluded that mine impacts on stream and estuary might not be large; that impacts of community and power facility development would be large; and that mine development would be inconsistent with the intent of the Monument.

Investigations in 1975–76 concerned coastal streams reaching the sea between Fairweather River on the northwest and Dagelet River to the southeast, in an area with possible placer mining potential. Work characterized water chemistry of streams and identified some of the important flow characteristics. Loss of channeled flows into sand aquifer routes as streams reach foreland beach deposits, was explored and may be a significant feature of ocean beaches, affecting both stability and habitat conditions. Prominent features of these coastal streams were identified from photos and maps. Descriptive information on these streams may also apply to foreland streams ranging northwest from Lituya to Prince William Sound.

When considering future Glacier Bay studies in terms of my two decades of work with streams found in other parts of S.E. Alaska, I have reviewed three conditions:

1. Measuring abilities are greatly improved over even ten years ago. Thermographs now resolve to $0.1^{\circ}C$ for service intervals of months. Electronic field instruments allow rapid, accurate observation of some water quality parameters; others are obtainable from laboratories. Year–round work is much more feasible;

2. Investigative experience allows aquatic scientific work to be much more effectively designed; and

3. Interdependence between parts of aquatic systems is well recognized. This applies to physical–biologic units within a watershed as well as between stream and estuary, and even between the Bay and S.E. Alaska, generally.

These conditions have relevance to future aquatic studies that may be planned or carried out in Glacier Bay National Park.

Glacier Bay is usually examined in terms of its uniqueness, yet it is also very much a part of S.E. Alaska, with lands, forests, streams and estuaries at various states of ecologic development and often similar to other environments in the Panhandle. It would be useful in future work to consider the ways in which studies in the Bay may relate to and be used in the management of the region's resources.

Finally, a sustained, unified program of base-level monitoring of selected aquatic environments is needed. This program would provide research scientists with basic information needed as foundation or background for their work, and would serve other S.E. Alaskan agencies with comparative environmental or fisheries management information. Monitored features might include stream temperatures, water chemistry, flow measurements, low flow conditions, fishery escapement data, and estimates of resident fish populations. Some observations would begin intensively, with a reduced measurement interval as review of data allows. Other observations, such as water chemistry, would require only periodic monitoring once an initial period was completed. Measurement systems should be compatible with those of other agencies to the degree practical and should be computerized for ease of access, review and analysis.

RESEARCH ON FRESHWATER ECOSYSTEMS – PAST, PRESENT, AND FUTURE

– – *Alexander Milner, Fisheries and Natural Sciences, University of Alaska*

Sparse records exist from the late 1950s and early 1960s of adult salmonid fish runs in a number of streams. Johnston, a park ranger, attempted in the mid-1960s to organize and collate a stream survey where single visit measurements of general physical and biological observations were made. In the summer of 1965, collections of juvenile fish made in Muir Inlet by Merrell and Delong examined aquatic insects in a number of bodies of standing water.

My first field season in Glacier Bay occurred in the summer of 1977 as a member of the greenhorn English contingent from Chelsea College, University of London. This group undertook a general survey of eight streams of differing ages representing a progression in development with time following glacial recession. In the process of stream recolonization and development, there appeared to be three principal stream groups. Intensive investigations of one representative stream in each of these groups during 1978 and 1979 indicated that physical variables were most significant in governing stream development, particularly variations in discharge levels and effects of sediment movement and deposition.

Group A represents the first streams which typically arise as meltwater from remnant ice sheets. As extreme discharge variations are limited, stream stability and benthos production are relatively high. Low temperatures restrict macroinvertebrates to a few well adapted species of midge larvae and no salmonids are present. On ablation and disappearance of the remnant ice sheet, a clearwater stream may result if watershed catchment is able to sustain flow in the channel. Higher water temperatures enable a wider diversity of macroinvertebrates to colonize these streams together with salmonids. However, wide fluctuations in discharge and deposition of eroded sediments make these Group B streams relatively unstable and able to support only low numbers of benthos and fish. Group C streams represent stabler clearwater streams where, as a result of large lakes, discharge fluctuations and sediment effects are tempered, thereby permitting greater productivity. In the long term, Group B streams have the potential to develop increased stability and productivity through significant inputs of large organic debris, which is characteristically absent in these young streams with their developing forested watersheds.

My present involvement with stream research is in conjunction with Dr. Roy Sidle of the Forestry Sciences Lab in Juneau. We are attempting to quantify the extent of discharge fluctuations, sediment transport, and the amount of streambed movement and streambank erosion that is occurring. Also, we plan to investigate the nutrient dynamics of the watersheds, particularly in the riparian zone, and relate the findings to stream chemistry and associated biological productivity.

On a broader scale, the present undertaking of general stream surveys by Park Service personnel is extremely valuable. These record the physical characteristics of the stream, evaluate spawning and rearing habitat, and include adult salmonid escapement counts and estimates of juvenile rearing populations. This standardized baseline information will, if undertaken on a long-term basis, provide further insight into the changes that take place with time and development of terrestrial vegetation, and will identify streams that may be sensitive to visitor use, mining, or other possible uses.

In summary, the study of the dynamics of freshwater ecosystem development in Glacier Bay is of important applied value when related to other systems in southeast Alaska, because it will identify the significant environmental variables governing the recovery of streams which have been disturbed by land use.

LAKE ONTOGENY IN A CHRONOSEQUENCE AT GLACIER BAY NATIONAL PARK

-- *Daniel R. Engstrom, Limnological Research Center, University of Minnesota*

The rate and pattern of vegetational development on the landscape of Glacier Bay National Park has been a subject of considerable scientific inquiry since the early pioneering research of W. S. Cooper. While successional changes in the Park's terrestrial environment following deglaciation have been well studied, comparable developmental processes in lakes and ponds have been largely ignored. Nevertheless, aquatic and terrestrial systems are closely linked, and development changes in vegetation and soils might be expected to alter the chemistry, productivity, and biotic composition of lakes. This study, just recently initiated, investigates the early stages of lake evolution following glacial recession in the Park.

During the 1983 field season, a preliminary survey of lakes along the main bay and Muir Inlet was undertaken to select suitable sites for long-term monitoring. Ten lakes were visited that range in age from ca. 10 years at the terminus of the Casement Glacier to ca. 200 years around Bartlett and Ripple Coves. Two additional sites beyond the neoglacial ice limit on Pleasant Island were also sampled. These lakes conform to a chronosequence in which variations in water quality may be compared to site age, catchment vegetation and soils. Initial measurements of the lakes include total phosphorus and nitrogen, conductivity, apparent color, secchi-disc transparency, total chlorophyll, phytoplankton composition, depth, pH, alkalinity, and major cations and anions. Vegetational observations were also made that will be used in conjunction with infrared aerial photographs to quantify vegetation in the watershed. At the time of this writing, laboratory analyses had not been completed; however, preliminary data indicate trends of decreasing alkalinity and conductivity with increasing lake age.

Continuation of the present work will include seasonal monitoring to assess variability within lakes, and paleolimnological studies of sediment cores from Pleasant Island to connect the chronosequence of Glacier Bay with the much older landscape beyond the neoglacial limit. During these early phases of the study, water chemistry and primary production will be emphasized because these variables should respond most directly to successional changes in the terrestrial environment. The research may be expanded later to include zooplankton and benthic organisms, their patterns of colonization and associated changes in community structure and function.

HARBOR SEAL (*Phoca vitulina*) POULATION, BEHAVIOR, AND REACTION TO VESSELS IN GLACIER BAY, ALASKA

-- *John Calambokidis, Gretchen H. Steiger and Lenore E. Healey, Cascadia Research Collective, Olympia, Washington*

One of the largest known concentrations of harbor seals in southeast Alaska gives birth to young and rests on icebergs near the face of Muir Glacier. The retreat of this glacier threatens to dramatically change the availability of ice habitat. Vessels that frequent this area range from kayaks to cruise ships. We examined the population status, behavior, and reaction to vessels of harbor seals in Muir Inlet on 30 days between 17 June and 19 August 1983. We made counts at 3 hr intervals between 0600 and 2100 from an observation site 330 m above sea level and plotted the location and movements of vessels and seals with a theodolite. The research was funded and staffed by The School for Field Studies.

Our highest count of seals in Muir Inlet was 890 on 19 August during the annual molt. During the pupping season our highest count was 725, including 281 pups, on 19 June. Numbers of seals were significantly lower in July compared to June and August. Counts of seals in 1983 were generally lower than the numbers seen in 1982 and those reported by Streveler for the 1970s. Ice conditions appear to be a limiting factor to seal use of the During periods of low ice conditions in June, a high percentage of the seals were in the water and up to 71 seals were seen hauled on shore 7 km from the terminus of Muir Glacier. Numbers of seals along the east shore of Glacier Bay, between the Beardslee Islands and Adams Inlet, were higher than previously reported, with just over 1,000 seals counted at seven haul-out areas in early August. These counts indicate a change in distribution of harbor seals in Glacier Bay.

Time of day was a highly significant factor affecting the number of seals hauled out in Muir Inlet (ANOVA, $p<.01$), with highest counts around 1200 hr. Seal immigration/ emigration from the upper portion of the inlet (the primary haul-out area) was also significantly correlated to time of day ($r= -0.94$, $p<.001$) with seals arriving in the morning and leaving in the late afternoon and evening. The number of seals hauled out by time of day in August, during the molt, indicated seals were hauling for longer periods than during June and July. Seals entered the water in reaction to vessels at a mean distance of 100 m to 300 m for different vessel types. This distance was significantly affected by vessel type (ANOVA, $p<.05$).

DISCUSSION HIGHLIGHTS OF THE MARINE AND AQUATIC ECOSYSTEMS PANEL

The Marine and Aquatic Ecosystems Panel conducted two discussions, one following presentations by six marine biologists and the other following presentations by three freshwater aquatic biologists. Because of the low number of marine and aquatic studies at Glacier Bay, the panelists spent much time defining research priorities, especially the "what, where, and how" of marine studies.

Questions from the audience prompted comments on untested but likely interactions between the marine and freshwater systems and adjacent terrestrial ecosystems. The panel closed with a review of themes expressed by all three science panels, including the need for long-term baseline monitoring, the desire that future research be more integrated and holistic, and the caution that both approaches have potential problems which mandate thoughtful, careful research planning.

Research Priorities. The initial discussion began with a consideration of who should decide Glacier Bay research priorities. What research is done in Glacier Bay depends in large part upon who chooses the research and why. NPS managers can decide on priorities based on management concerns. Researchers can chose topics based on what they think is interesting enough to merit study. Some panelists thought that the Park Service should tell the scientific community what work needs to be done in Glacier Bay; others thought that the NPS should not be in the business of "dictating and assigning tasks" to scientists. Dave Duggins summed up what seemed to be the consensus when he said, "If the park uses only applied problems to attract researchers to Glacier Bay, [we] won't get the broad range of top quality scientists that we would if the scientific community helped [the park decide on research priorities]." The hope is that researchers can address both basic biological questions and questions that concern park managers.

The panelists then discussed what research they thought should be conducted in Glacier Bay. A noticeable gap exists in physical oceanographic data. The only such data from Glacier Bay were collected by the University of Alaska in the late 1960s, and those data collected in connection with the whale prey studies of the 1980s. Charles Simenstad suggested that combining physical oceanography with the study of biological processes is something that must be accomplished in intensive studies. "Someone taking one Standard (STD) cast after taking a net sample will perhaps tell them something about the water mass they're working with, but it will not tell them about the dynamics of the water mass movement in the fjord," Simenstad said. Panelists suggested that the National Oceanic and Atmospheric Administration (NOAA) is equipped to assemble such intensive studies and perhaps should be contracted to conduct such studies.

Dave Duggins talked of combining the study of physical parameters with marine ecosystem development. "The system is driven by physical parameters that vary tremendously, one assumes, as one moves up the Bay...The sorts of physical parameters that are probably important [in terms of trying to understand biological processes in marine ecosystems] may very well be the physical parameters that derive basically from the land and from the microclimate. It may be this sort of physical gradient which needs to be the focus of future studies in the marine realm," Duggins noted. For example, changes in salinity from freshwater input from the land and changes in turbidity from differences in siltation rates clearly affect the marine environment.

Succession. Dialogue about applying a successional framework to studies of marine ecosystems continued throughout the discussion. Simenstad thought ecosystem development studies would be interesting, at least in terms of production dynamics. He noted that sources of organic carbon may vary as one moves up or down the Bay. According to Simenstad, "[The] sort of particulate detrital material derived from macrophytes is an important source of carbon for estuaries and nearshore ecosystems all along this coastline...[It] may be a critically important source of carbon for Glacier Bay." According to Lynne Hale, data on benthic epifauna, fish diversity, and sediment infauna also suggest differences between the upper and lower portions of the Bay; and salinity, turbidity, temperature, and other physical parameters change as one moves up the Bay. Bruce Wing noted that there are also local variations in physical factors, but the upper portions of both arms of the Bay are likely to show similar physical characteristics.

Site Selection. Panelists then discussed where to start collecting these data. The site-to-site biological variability seems high. The following questions were raised: Should we conduct smaller-scale studies in many places, or a large-scale intensive study in one? If we study one place, will we have information that can be applied to the Bay as a whole? Should we encourage more scientists to study in Glacier Bay? Should we begin limiting studies to certain problems or places? Scientists know only very little about the marine ecosystems in Glacier Bay and do not have unlimited resources to study every area they may want to study. Richard Palmer challenged the scientists to clearly state that "we're going to have to remain ignorant, at least for a while, about some part of the system." "That's a tough position to take," he continued, "but we should take it because that will force us to identify what's really important." Nevertheless, a consensus on what to study and where to study it was not reached.

Lakes and Streams. Much of the discussion following the aquatic presentations focused on the studies of lakes and lake ecosystem development. When asked how differences in precipitation chemistry up-Bay and down-Bay might affect lake development, Dan Engstrom responded that it may be important, but it might be overshadowed because "perhaps the most important physical factor controlling the chemistry and productivity of a lake, aside from external influences by humans, is the geological setting in which the lake occurs."

Don Lawrence remarked that he was "very much concerned" about aircraft landings and other impingements upon the developing lakes. He hoped the NPS would carefully protect those lakes being studied, especially with respect to accidental introductions of organisms. Recalling the cleaning of boots, the wearing of cuffless pants, the scheduling of research from the youngest to the oldest sites, and other protective measures observed during his previous succession studies, Lawrence encouraged a prominent program guarding against the inadvertent introduction of organisms and other disturbances in and around research lakes. Dan Engstrom concurred and noted that aquatic organisms get around "quite easily," especially via the boots and equipment of researchers.

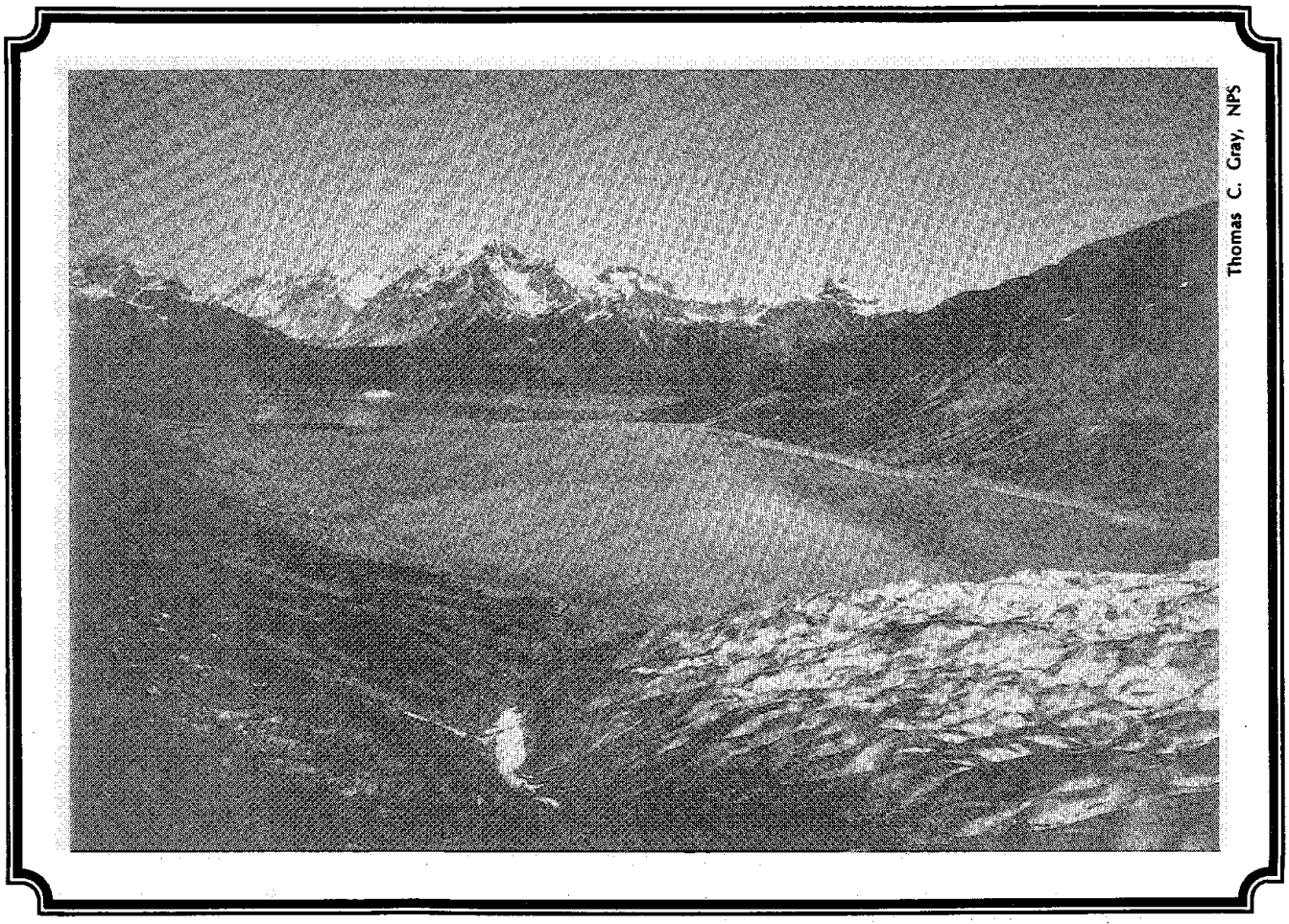
Intersystem Interactions. Agreeing with previous panel comments, Dave Duggins stressed that the panel format too artificially compartmentalized thought and "we too easily forget about the linkages and interactions [between systems]." What kinds of effects upon the landscape from lakes and streams should terrestrial ecologists be aware of? Dan Engstrom responded that surface waters provide a lot of information

about soils and soil development, and thus, at least indirectly, about vegetation. Dan Bishop stated that lakes can have not only a large effect upon local temperatures but also upon humidities, especially with respect to the timing of freeze–over and thaw. The duration of ice cover likewise affects organism behavior in and about the lakes. Greg Streveler said that land and lake biologic interactions are likely to be the greatest when lakes contain fish—organisms such as gulls and otters would go farther upland than they would if no lakes and fish were present.

Marine and terrestrial interactions are little documented, added Duggins; many terrestrial animals, for example, forage and do other things in the intertidal. "I've observed it, but we have no data at this point," said Duggins. Greg Streveler noted that of Glacier Bay's mammals, only four species have not been observed "doing something" in the intertidal. Duggins also noted that regarding other terrestrial effects on the marine ecosystem, "the nutrient influx from the land may be of critical importance in determining levels of phytoplankton and marine macrophyte production."

Top Carnivores. Scott Baker spoke on behalf of research with top carnivores, and their effects on entire food webs. Particularly interested in marine mammals in the Bay, Baker drew attention to species not so obvious as humpback whales. "Let us not find ourselves in a situation," he proposed, "when we suddenly don't recall the last time anyone saw a harbor seal; what happens, for example, when more of the tidewater glaciers ground?" With repsect to whales, Baker suggested that the "primary measure of success for any type of management program" will be the return of whales to the Bay. Only when they are back can we test the two major hypotheses for their 1978 departure: was it primarily due to a dramatic decrease in prey abundance, or was it due to an increase in human use of the Bay (especially vessel traffic)?

Overview. Duggins closed with an overview of thoughts from the three science panels. "Dismayed" that the symposium's congregation of scientists would soon be back on airplanes, split up and perhaps "never again" so assembled, Duggins called for a body of interested scientists who would continually evaluate the types of science appropriate for GBNPP and be in constant communication with the National Park Service. It was agreed that baseline monitoring and increased emphasis on more holistic and integrated studies are needed at GBNPP; however, Duggins warned that both approaches are "fraught with potential problems and disasters." Monitoring studies must be very carefully planned and the choice of parameters must acceptably span many years. Moreover, monitoring studies must be designed to maintain enthusiasm despite the "drudgery" of taking repeated measurements year after year. Here the sharing of data collection with interested residents of the Glacier Bay area may be most beneficial. Duggins further cautioned that holistic approaches may not be as productive as one thinks. It is easy to become too diffuse—"we can't start using boxes and arrows until we know what is in the boxes." Coordinated, intensive, smaller studies may prove much better at GBNPP than a massive IBP (International Biological Program) type study, he concluded.



THE RESOURCE MANAGEMENT PANEL

Gary Vequist, Chairman

Panelists: James R. Mackovjak, C. Scott Baker, Robert G. Bosworth, Darryl R. Johnson, Gregory P. Streveler, Robert Howe and Frederick C. Dean

SCIENTIFIC USE OF GLACIER BAY

– – Gary Vequist, Glacier Bay National Park and Preserve, National Park Service

The international scientific importance of glacial retreat, with rapid plant succession and animal recolonization, played an important role in the establishment of Glacier Bay National Monument in 1925. Nearly continuous documentation of terrestrial revegetation has resulted from research conducted by Dr. W. S. Cooper and Dr. D. B. Lawrence. This long sequence covering almost 70 years makes Glacier Bay one of the longest records of vegetative development in the world. Insights from these studies have greatly influenced the concept of plant successional theory.

Glacier Bay's natural resources have remained essentially unaltered by man, making it an excellent laboratory for conducting scientific research. Research projects must be well conceived to avoid compromising the important natural values.

As the number of research requests increases, it has been necessary to establish guidelines for appropriate research methods in order to prevent unnecessary impacts on the resource. Impacts must be carefully weighed against the knowledge to be gained. In evaluating research proposals, these will be some of the questions asked:

1. Does the research study interfere with other public uses? Research should be conducted in a manner that is not highly visible to park visitors.

2. Does the research provide new knowledge? Is it compatible with other ongoing research efforts?

3. Does the research address topics for which the park is uniquely suited as a study area? It is preferable that the research could not be done as well in adjacent areas outside the park boundary.

4. Will the research be useful for the management of park resources? The increased understanding of the park's natural processes should allow managers to predict and detect human–caused alterations of those processes.

The 1983 Glacier Bay Science Symposium has provided a means to assimilate existing scientific information on the Glacier Bay environment. Long–range research needs can be identified to fill critical data gaps.

RESOURCE DECISION–MAKING

– – *Gary Vequist, Glacier Bay National Park and Preserve, National Park Service*

A strong relationship should exist between research and resource management in Glacier Bay National Park. The park cannot operate without scientific information gathering, analysis and recommendations. Research plays a fundamental role in describing baseline conditions and measuring change. The ability to learn and anticipate trends will provide an understanding of how various resource uses affect the environment.

Park managers often do not have sufficient information to answer critical resource management questions. Research efforts may, instead of providing conclusive answers, give rise to a myriad of additional questions. Resource managers must analyze the resource information available and then depend on their professional judgment to develop the best management approach. But it can't stop at that. A systematic monitoring effort is needed to continue to evaluate the effectiveness of these management strategies.

The management policies of the National Park Service call for the preservation of a naturally functioning ecosystem. Park managers often find these policies difficult to implement because ecosystem processes are only partially understood by scientists. Hopefully, an adequate data base can be developed to meet the private, political, legal, and governmental challenges affecting the park.

In Glacier Bay, studies of plants, wildlife, fisheries, minerals and glaciers have established a research base for continued studies. This Science Symposium has developed a broader interdisciplinary approach for looking at Glacier Bay's environment. Emphasis will be directed toward developing new research techniques and methods to measure various ecosystem components.

COMMERCIAL HALIBUT FISHERY AT GLACIER BAY NATIONAL PARK AND PRESERVE

– – *James R. Mackovjak, Gustavus, Alaska*

A severe overcapacity problem exists in the Alaskan halibut fishery. Fishermen in 1983 in southeastern Alaska exceeded their quota by some 3,000,000 pounds, essentially doubling the predicted catch. That season was only five days long, compared to 128 days in 1975. The biological result of such a short, intense fishery is overfishing some segments of the stocks, while underfishing others.

The responsibility for the management of the halibut fishery lies with the federal government, which generally approves the recommendations of the International Pacific Halibut Commission. However, the jurisdiction which the National Park Service has over halibut in Glacier Bay is unclear. In 1983, some 100 vessels fished halibut commercially in Glacier Bay, landing approximately 300,000 – 400,000 pounds (dressed weight) of these fish.

Several options are currently being considered by the National Marine Fisheries Service to remedy the overcapacity problem in the halibut fishery. These options may result in a substantial change in the amount of halibut harvested in Glacier Bay. If the excess capacity is removed from the fishery and overcrowding ceases to be a problem, a good case might be made to eliminate commercial halibut fishing from Glacier Bay. Very simply, when fishermen's catch per unit of effort (CPUE) in surrounding areas equals that in Glacier Bay, the economic rationale for fishing in Glacier Bay ceases to exist.

To substantiate the allowance or prohibition of commercial halibut fishing in Glacier Bay, a number of values should be established. These are: (1) an idea of the economic value of the fishery; (2) the biological impact of the halibut fishery on the marine ecosystem of Glacier Bay; and (3) the effect the presence of the commercial fishery has on tourism and other park values.

With a collection of such information, the National Park Service will be prepared to deal with one of the changes which some say it is now largely ignoring.

THE IMPACT OF VESSEL TRAFFIC ON THE BEHAVIOR OF HUMPBACK WHALES

-- *C. Scott Baker, Louis M. Herman, Brooks G. Bays and Gordon B. Bauer, Kewalo Basin Marine Mammal Laboratory, University of Hawaii*

A study of the impact of vessel traffic on the behavior of humpback whales was undertaken in Glacier Bay and other areas of Southeast Alaska during the summers of 1981 and 1982. This study was funded by the National Park Service and administered by the National Marine Mammal Laboratory.

Observations of whale behavior in the presence and absence of vessels were made from shore-based observation platforms equipped with precision theodolites and microprocessor-operated time/event recorders. Acoustical monitoring of vessel noise and whale vocalizations were carried out by acoustic engineers from Bolt, Beranek and Newman, Inc. in parallel with behavioral observations. There was a clear and graded change in the behavior of whales in response to vessel traffic. Observed responses included changes in respiratory intervals, strenuous episodes of aerial behavior, movement away from the path of the vessels, and the temporary displacement of individuals from preferred feeding areas. Changes in the behavior of the whales were correlated with vessel distances, vessel speed, vessel size, and the occurrence of sudden changes in the speed or direction of the vessels.

Based on these data, two vessel avoidance strategies were suggested: (a) horizontal avoidance if vessels were between 2000 to 4000 m from the whales; and (b) vertical avoidance if vessels were less than 2000 m from the whales. The horizontal avoidance strategy involved decreased dive times, longer blow intervals, and greater speed of movement. Vertical avoidance involved increased dive times, decreased blow intervals, and decreased whale speeds.

RECREATION CARRYING CAPACITY IN GLACIER BAY MANAGEMENT

– – *Robert G. Bosworth, Alaska Department of Fish and Game*

Clearly, there is a need to accomodate recreation uses in the world's national parks while preserving the areas for the benefit of future visitors. National park management is based on the premise that this balance is attainable. In the more popular parks, such as Glacier Bay, an active management strategy is necessary to achieve this balance. Determining an appropriate or optimal level of use, and maintaining use at this level, must be the overall goal. Each set of recreation conditions sought as management objectives implicitly carries with it some limit on the kinds and amount of recreation tolerable.

There are four basic elements to a framework for management of Glacier Bay National Park and Preserve that incorporate the recreation carrying capacity concept: (1) defining specific management objectives for the park and its subunits; (2) identifying the appropriate spectrum of use demands that will be accommodated; (3) assessing and monitoring the impacts of various kinds and intensities of use; and (4) establishing correlations between appropriate use levels in different parts of Glacier Bay and acceptable levels of environmental disturbance.

None of this makes any sense without clear management objectives—objectives indicating the type of recreation experience and the level of resource use acceptable. Management objectives at Glacier Bay have never been this precise, yet maintenance of the social and environmental conditions to encourage a certain recreation experience is the basic purpose of recreation carrying capacity management.

There is not just one optimum amount of use for an area, and regulation does not always involve limiting the number of people. Design features, such as fire rings, noise limits, and activity sequencing, affect carrying capacity. Zoning commonly and effectively isolates incompatible activities with little or no effect on overall use levels.

Identifying recreation uses to be accommodated in a park (or zone of a park) first requires a regional perspective not typically found in government agency planning. The opportunity exists for managers from the National Park Service, the State of Alaska, and the U.S. Forest Service to determine which areas in northern Southeast Alaska should offer particular recreation opportunities. This regional view would allow individual managers to define more precisely uses to be accommodated in a given area. Glacier Bay then could be managed emphasizing the enjoyment of its unique features.

The effects of recreation must be identified and monitored since these impacts determine when capacity is reached. A program for monitoring social and biological effects of use assumes every area has a most sensitive social or biological component that is a limiting factor. Identification of indicators is an important step, and at Glacier Bay some research has identified useful indicators. Now the opportunity exists to integrate monitoring of these indicators into the Park's recreation management.

Recreation management requires both social and biological sensitivity; for example, one's experience may be conditioned by expectations and by appreciation of company or

isolation, while trampled vegetation influences both a visitor's experience and the integrity of the Park itself. Monitoring enables managers to recognize when a visitor's experience no longer meets the objectives for an area.

A period of phased increases in recreation use in an area, accompanied by the monitoring of key indicators, should minimize the chances of overuse. If the capacity were exceeded, returning to a prior safe level of use would be more feasible, politically and practically, than imposing sudden, severe use restrictions.

AN ERA OF CHANGE AND THE ROLE OF APPLIED SOCIAL SCIENCE

-- *Darryll R. Johnson, National Park Service, Cooperative Park Studies Unit, University of Washington*

Social science is relatively new at Glacier Bay. A review of the Park scientific bibliography, 1970 to 1982, reveals only three examples of non-anthropological social science. These are (1) a survey of backcountry users during the summer of 1978, (2) a survey of cruiseship passengers to southeast Alaska in 1979, and (3) a study relating to the determination of recreation carrying capacity of coastal and marine parks.

The 1978 backcountry survey established baseline data for the backcountry user population in relation to social and demographic characteristics, the importance of various factors in the enjoyment of backcountry trips and trip satisfaction, interaction with other backcountry parties, motorized boats and airplanes, crowding perceptions, and attitudes toward certain management policies. The cruiseship passenger study surveyed passengers scheduled for the Inside Passage and British Columbia during 1979. Questionnaires were distributed on 15 cruises the day the ships entered Glacier Bay. The objectives of the project were to describe social and demographic characteristics of the cruiseship population, to identify factors of importance in selection of the cruiseship experience, to assess knowledge of visitor attractions in Alaska and the need for additional information services, to describe passenger shore-based activity, to determine responses to the Glacier Bay experience and to the on-board interpretive programs, and to assess responses to commercial exploitation and commodity extraction. The recreational carrying capacity study is discussed in Mr. Rob Bosworth's abstract.

In addition to the above work, a study of recreationists on the Alsek River will be initiated by the Cooperative Park Studies Unit, University of Washington, during the summer of 1984. Objectives of this project are similar to the 1978 backcountry users survey applied to recreationists on the Alsek.

Contrary to the natural sciences, social science activity at Glacier Bay is almost exclusively justified from an applied perspective. That is, social science is carried out when it provides a basis to acquire information helpful for management and planning--either in protecting the resource or serving visitors. Several factors suggest social scientific analysis may be increasingly important in the management of Glacier Bay.

First, American society continues to experience social change at a rapid rate. For example, internal migration is having a significant impact upon the traditional distribution of people within the United States. This redistribution will have significant impacts upon social institutions, including those associated with outdoor recreation areas. Two states (California and Oregon) that supply a large proportion of the backcountry user population at Glacier Bay are projected to experience increases of 40 percent. Alaska's population is expected to double. It should also be noted that many of the pristine non-NPS managed lands in southeast Alaska that function as popular places for wilderness experiences will be logged or undergo some type of extractive or commercial activity in the coming decade. The combination of these two trends appears to indicate a growing demand for wilderness recreation opportunity inside Alaska's national parks.

Glacier Bay has traditionally hosted a fairly homogeneous group--largely the well-educated upper-middle class. For example, the 1978 backcountry sample averaged 17 years of formal education. Over 66 percent were professional or technical workers or managers and administrators. There were almost as many MDs (7 percent) as there were blue collar workers (9 percent). Alaska resident backcountry users do not reflect this composition. This fact means that if Alaska's population and its contribution to Glacier Bay park visitation increases faster than the balance of the U.S., then the character of the backcountry population will change and possibly the demand for services as well. Social scientific analysis by monitoring external social conditions and park visitation can put management in a pro-active position in dealing with change associated with these and similar trends.

Second, the legislation and the management tradition at Glacier Bay solidly suggest that the area should be managed for unique recreation opportunities. These obviously relate to opportunities to experience wilderness, pristine scenery and solitude. In an era of change, however, two questions immediately arise:

(1) Is this type of experience really being provided; and
(2) Is the nature of the recreation experience changing?

To understand these questions, baseline survey data and a monitoring program is needed on the nature of the Glacier Bay trip experiences.

Third, given a long-term increase in visitation--perhaps by a somewhat different clientele--the problem of human impacts upon the natural resources of the Park may increase. As this occurs, social scientists could serve on multidisciplinary teams, scientifically experimenting with ways to mitigate unacceptable impacts.

Finally, there are unique opportunities for the men, women and their families who work in areas like Glacier Bay. But there are also unique problems and challenges. We need to understand more about the Park as a working environment. Employees are important resources of the Park and the entire NPS system. The ability of the Service to efficiently manage the area is partially dependent upon their personal satisfaction and well-being.

I conclude with one suggestion. Given the broad role that science (basic and applied, natural and social) plays at Glacier Bay, and in view of realistic funding limitations and support facilities, an advisory or steering committee is needed to prioritize existing research needs and to conceptualize a science program into the intermediate future. This issue should be discussed at this conference and ground work laid for its organization.

RECOMMENDATIONS FOR A SCIENCE BOARD AT GLACIER BAY

– – Gregory P. Streveler, Friends of Glacier Bay, Gustavus, Alaska

I hope for a renaissance of research at Glacier Bay—research that is appropriate and of high quality. For this to happen, the NPS must have the means to evaluate the entire spectrum of research needs and proposals. Yet the NPS, by itself, does not have the breadth of expertise necessary for this task.

A Science Board might provide the needed vehicle. Such a Board, comprised of perhaps five scientists broadly versed in research needs and opportunities in the park, would:

- Comment on research priorities.
- Evaluate and originate research proposals.
- Act as liaison between the NPS and the scientific community.

As the first step, I recommend that the panel chairmen act as a Science Board while the concept is put into final form.

APPROPRIATE RESEARCH TECHNIQUES FOR GLACIER BAY

– – Gregory P. Streveler, Friends of Glacier Bay, Gustavus, Alaska

Park researchers are not part of a privileged "priesthood;" rather, we have a special obligation to be exemplars of a sensitive relationship between people and nature. Our techniques should reflect this sensitivity, by being:

Minimal—scaling logistics and facilities to objectives, not to comfort.

Involved—placing sufficiently few technological impediments between us and the natural world we are studying, so that our hearts as well as minds can be involved.

Respectful—leaving the dignity of our fellow organisms intact by using sampling and monitoring techniques that manipulate or kill only when necessary; and using conveyances and tools inoffensive to others in the backcountry.

HUMAN RESOURCES IN GLACIER BAY

-- Robert Howe, National Park Service (ret.)

Jim King's remarks earlier today, relative to continuity of observations, experience, and knowledge of an area and that fundamental changes will be needed in governmental agency thinking if we are to do the job necessary for the future of these areas, are important to the resource management topic which I address: the human resources of Glacier Bay--not only the scientific community and Gustavus residents interested in Glacier Bay, but more, the employees of Glacier Bay National Park and Preserve. These are the interpreters, rangers, maintenance personnel, including the seasonal employees, and the administrators. I mention the administrators last because, in general, they are the ambitious, often capable people who, with good luck, will be the Superintendents of large parks or on regional staffs. They will move through Glacier Bay regularly, some contributing to the park, and some not. However, a great deal depends upon their ability to recognize the commitment of some of their employees to Glacier Bay.

Proper land use management and "love" for the area go hand in hand, fostered by time in the area and intimate acquaintance with it. This can only come about, and is especially important in a large, remote area such as Glacier Bay, through recruitment, then through a process of elimination, encouraging those gems of love and wisdom, in any legal way, to remain for a number of years and be productive to the advantage of park resource management. This automatically results in the needed continuity of plans, research, observations, record keeping and geographic knowledge so necessary as a basis for more detailed scientific study to be carried out by individuals and institutions, when such study is needed.

To me, the failure to encourage interested and productive employees to stay and really make a contribution to the park is one of the most wasteful and short-sighted views of a most critical resource.

Fortunately, the NPS has developed a program known as Volunteers in Parks. Today many of the park's functions are carried out by these volunteers. The Glacier Bay Library, for example, is of great importance in providing references for researchers, interpreters, and other interested persons. In a park where the enabling legislation was based on the importance of research, this important tool should be well funded and encouraged.

I am encouraged by the new administration in Glacier Bay. I hope that the human resources of the area will be fully recognized.

During the course of this science symposium, I have heard many comments about what a dynamic area this recently glaciated place is. I would like to suggest that we counter this with a little less dynamism in our employee movements.

TWO ISSUES FOR CONSIDERATION BY RESOURCE MANAGERS AT GLACIER BAY

-- *Frederick C. Dean, National Park Service Cooperative Park Studies Unit, University of Alaska*

Two issues needing consideration by resource managers and scientists at Glacier Bay National Park and Preserve are the long-term maintenance of natural bear populations and the protection of wilderness as a cultural and scientific resource.

The preservation of natural bear populations requires strict avoidance of situations and conditions which tend to create links between bears and people. Human activity in bear range must be conducted with minimal impact on bears and low risk of injury to, or death of, humans. Managers should explicitly delineate much of the park-preserve area as "bear country," as well as small units of "human country" localized around developments. People in "bear country" should be required to accept the risks associated with being in such areas. They must also accept the constraints deemed necessary to prevent development of (or break existing) links between bears and humans. Failure to achieve this separation tends to cause habituation to humans and a growing series of problems. Ultimately, albeit by small increments, the bear population will be reduced as problem bears are moved or killed. In parallel, a marked change will occur in the naturalness of the population with respect to age structure, social interactions, and other characteristics. Bears must be actively excluded from "human country," preferably by methods that will result in teaching the bears to stay clear of such zones. Scientists must be particularly self-disciplined in link prevention since they are frequently among the first semi-permanent residents in bear country.

The second matter includes the problem of allowing and encouraging the expenditure of a scarce and finite wilderness resource by individuals who may neither want to be involved with true wilderness nor be competent to travel in such country. Easy access to areas in wilderness has created levels of use and abuse that are inconsistent with the concept of wilderness. Easy access tends to erode the quality of wilderness far in excess of what is normally the result of wilderness use by individuals who are both interested in, appreciative of, and competent with respect to wilderness resources. The pattern that has developed at Glacier Bay due to the access patterns parallels (in comparatively embryonic form) what has become all too visible at Denali National Park. At Denali, levels of use and the sorts of demands made by neophyte users on the limited resource clearly have resulted in the loss of substantial wilderness quality, more through the existence of deceptively easy access than through conscious choice by the largely unaware consumers.

RESEARCH TRENDS AT GLACIER BAY SINCE 1890

– – *Garry D. McKenzie, Institute of Polar Studies, Ohio State University*

Biological and geological topics have been the main focus of studies in the Glacier Bay area since 1890, as indicated by the number of publications and reports. Since 1975, papers on resource management have become important, approaching the numbers in each of these basic sciences.

Using an incomplete draft version of a bibliography prepared for the Glacier Bay Science Symposium as a data base, references were classified into 4 groups: Biosciences, Geosciences, Resource Management, and History and Anthropology. Between 1890 and 1983, 83.5 papers had biological focus, 99.5 had geological focus, and 43 were concerned with resource management. History and anthropology were the focus of 13 works.

The references are assumed to approximate the research focus. Although unpublished work and omitted references could change the results of this analysis, the trends are expected to remain the same. The importance of the research, the person–days in the field and lab, the cost of the support by research agencies and the National Park Service are not considered here.

In Figure 1, numbers of biological, geological and management papers are shown by 10–year periods except for the first and last periods. The geosciences have led the research, probably because of the spectacular geomorphologic changes that could be studied in Glacier Bay, until the decade of the 60s. Biosciences have led since then and have nearly been matched by papers on topics related to management. The growing need for biological information to support management objectives will probably see a continuation of this trend. The total number of papers has been increasing since the 1940s, when field research may have been suppressed by activities during the war years. If the current trends continue for the 80s, there should be more than 140 new titles on the subject of Glacier Bay during this decade.

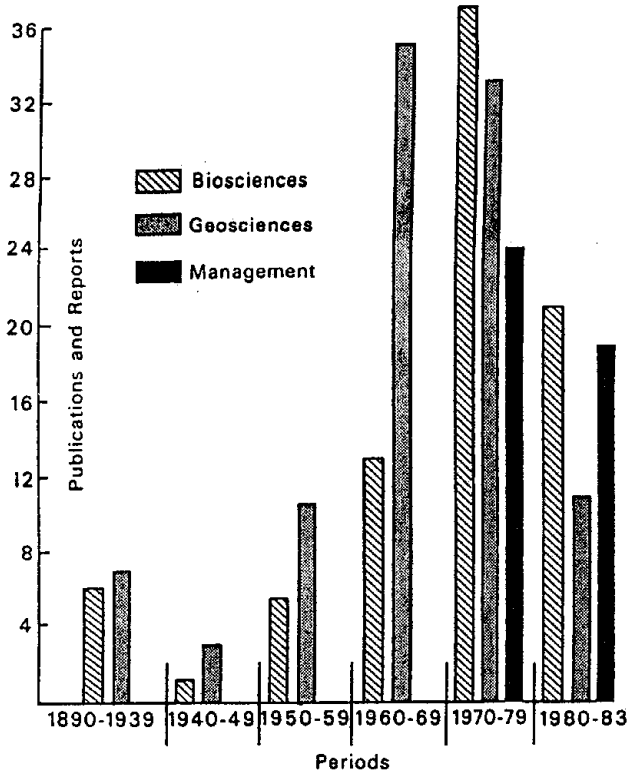


Figure 1. Titles by discipline for Glacier Bay since 1890. Total included: 226.

DISCUSSION HIGHLIGHTS OF THE RESOURCE MANAGEMENT PANEL

The final symposium panel discussion provided the opportunity to consider previous panel comments in the context of Park and Preserve management. The panel and audience touched on many topics, both specific and broadly conceptual. The topics and issues were so diverse and complex that none received a full airing and final conclusions were not achieved. The lack of consensus on most issues demonstrated that not only do different opinions exist, but that much work beyond what was possible at the symposium needs be done. Difficult themes included the fundamental character of the park and the role of science within it, problems encountered in applying the concept of carrying capacity, and the identification of indicator species.

Managers and administrators, it was stated, prefer to base decisions on useful scientific information. Relative to the years often required for collection of adequate data, resource management questions frequently demand rapid responses. Resource managers, therefore, must sometimes make decisions without as much information as they would like. Suggestions on how to increase information available to park managers included institutional arrangements (such as Biosphere Reserve status and a Science Board), the call for enriched understanding of fundamental concepts (such as regional recreational planning and carrying capacity), concrete proposals (such as interdisciplinary studies in specific, critical areas of the Park and Preserve), and ethical concerns (such as rights and responsibilities of scientists and administrators).

International Biosphere Reserve Status. During a panel–audience discussion on institutional methods to encourage funding of research at GBNPP, participants learned that GBNPP is under consideration for designation as an International Biosphere Reserve. The panel noted that designation of GBNPP as a Biosphere Reserve could help scientists gain research funding, but more importantly it would reaffirm the scientific importance and uniqueness of the area.

Science Board. The concept of a Science Board appeared in numerous contexts during the panel discussion. Most who spoke about such a board expressed support, but questions arose about the structuring of the board and what its specific functions would be. (See General Recommendation C–2 about a science board—eds.)

Carrying Capacity. The panel agreed that park managers understand the importance of determining physical, biological, and sociological carrying capacities but see difficulty establishing objective methods for measuring carrying capacities. GBNPP Superintendent Mike Tollefson expressed concern not only about backcountry and wilderness carrying capacities, but also about the carrying capacities for cruise ships in the Bay and for activities in the developed area around Bartlett Cove. Fred Dean emphasized the urgency for proper carrying capacity management, citing examples from Denali National Park where capacities have already been exceeded.

The topic of carrying capacity management proved so broad that seemingly unrelated comments flew rapidly from panel and audience alike. From the audience came the caution that managers should be aware of the "tyranny of small decisions"—incremental management in the absence of well–established conceptual frameworks. Too attractive,

it was added, is the trap of "if it is possible it is necessary"—do not slip into "management tinkering." Rob Bosworth called for careful articulation of the goals for recreation and recreation management at GBNPP, beginning with a regional perspective and proceeding with well-designed monitoring. From an ecological point of view, the changes in human activities (including carrying capacity-based management) are an integral part of Glacier Bay succession. Greg Streveler pointed out we do not know enough about choosing sites for recreational or other uses in order to prevent "unpleasant biological or aesthetic surprises."

How might the scientific community and park managers better combine efforts on carrying capacity mangement? Detailed, concrete suggestions were few, indicative of the enormity of the topic. Gary Vequist called for careful input by the scientific community on the Resource Management Plan. Some suggested that the Science Board could help. Another source of help for managers could be the review of current carrying capacity literature being conducted by the National Parks and Conservation Association.

However management proceeds, Greg Streveler concluded emphatically, it must call upon many knowledgeable and skilled persons, for "the determination of carrying capacities is so very complicated that without the accumulated expertise in this room, the concept cannot be applied adequately to a landscape like Glacier Bay."

Backcountry Drop-off Sites. Several questions arose from the audience concerning proposed changes in the location of backcountry drop-off sites. From the panel and floor came several suggestions on how to choose sites. First, said Rob Bosworth, someone has to decide what kinds of recreational opportunities exist for backcountry users in Glacier Bay, and which of these we want to provide visitors. Next, agreed the panel, places likely to be damaged by heavy use must be withdrawn from consideration.

A few participants wondered if there could be many drop-off sites, thus avoiding unnecessary "pockets of non-wilderness." A few individuals proposed that monitoring programs be set up at least a year before dropping people at a site; such monitoring would be necessary to establish baselines for comparison after campers start using an area.

Indicator Species. Gary Vequist asked for input on establishing a method for systematically monitoring human impacts to park areas, perhaps using indicator species. Some scientists expressed concern that "not only don't we know what indicators we are looking for, we don't know what we're looking to indicate." The value of indicator species, cautioned Ian Worley, is often overestimated. There is no guarantee that indicator species exist for any particular situation; furthermore, before an indicator can be selected one must know site conditions, what is to be indicated, and how the indicator species is to indicate. An indication is itself usually a disturbance, and that may be unacceptable. Other management criteria, Worley concluded, should not be abandoned in the anticipation that suitable indicators can be found because they might not exist.

Nevertheless, responded Gary Vequist, if scientists don't suggest some indicator species soon, park managers will have to select what appears to be the best indicator species using whatever resource information is currently available.

The Place of Research in GBNPP. Symposium debate on the nature of appropriate research in national parks, at GBNPP, and in wilderness areas continued during this panel discussion. Do researchers have a large impact on Glacier Bay? If so, how can they minimize their impacts? Because of the park's enacting legislation, does science have special privileges in GBNPP? Are basic and applied science projects equally appropriate or does one take precedence? Is landscape preservation and protection for or from science and other uses? Should researchers have special rights regarding motorized access or motorized equipment use in designated wilderness areas?

The topic of motor privileges (if any) in wilderness areas, the only question that time permitted a somewhat detailed treatment, exposed a basic difficulty. Ethical guidelines that are sufficiently precise to permit application need to stem from clear statements of fundamental values, be they in law, regulation, or tradition; at Glacier Bay, the fundamental values need careful examination and perhaps restatement.

Led by Don Lawrence's remarks, many individuals supported the preparation of guidelines for the ethical behavior of scientists (and other visitors) in GBNPP. Gary Vequist and others suggested that the current document, entitled "Scientific Use of Glacier Bay National Park," could be improved so that those who study in GBNPP have more specific descriptions of rights and requirements. Additional documents could also be prepared; Don Lawrence gave examples in use in Minnesota and elsewhere. Several persons expressed the hope that the Science Board would make this topic a major priority.

Funding and Other Resources. Many scientists in the audience were much interested in discovering new sources of funding and other resources. An open forum produced several ideas. For example, perhaps the NPS could offer small research grants for young scientists at Glacier Bay, anticipating that later they will return with their own grant money. By combining basic and problem-oriented research, one might be able to draw funds from more than one agency. Don't forget, said Bob Howe, to cite in research proposals the cost of support offered by the MV *Nunatak*. If researchers would be mindful of other researches when designing projects, resources could be shared and duplication of effort avoided. Could the proposed Science Board seek and distribute funds? Could the NPS staff and local residents be used in more research, especially in "off-season" monitoring?

The panel concluded that, as always, the principal responsibility for the generation of funds belongs to the individual researcher, and for most scientists conducting research in GBNPP, principal funding will come from sources other than the National Park Service.

THE HUMANITIES PROGRAMS

Judith Aftergut, Program Coordinator

Special presentations by Andrew Johnnie, Amy Marvin, and Martha Davis of the Chookaneidi tribe of the Tlingit people of Hoonah; Richard Dauenhauer, Sealaska Heritage Foundation; Robert Ackerman, Washington State University; and Dave Bohn, photographer/journalist.

THE HUMANITIES PROGRAMS

Judith Aftergut
Alaska Humanities Forum

Through a generous grant to the Friends of Glacier Bay, the Alaska Humanities Forum and the National Endowment for the Humanities made possible two evening programs for the symposium. The programs included the presentations and discussions of seven individuals: Andrew Johnnie, Amy Marvin, and Martha Davis of the Chookaneidi tribe of the Tlingit people of Hoonah; Nora Dauenhauer, anthropologist; Richard Dauenhauer, author of *Glacier Bay Concerto* and Alaska's present poet laureate; Robert Ackerman, archeologist, Washington State University; Dave Bohn, photographer and author of *Glacier Bay: The Land and the Silence;* and Judith Aftergut, author of *The Finest Musician* and coordinator of the Humanities Programs.

The purpose of the Alaska Humanities Forum's sponsorship of the Humanities Programs was to broaden the scope of the symposium to include the humanities, and to make possible the discussion of human and cultural values within the context of the conference.

The main purpose of the first evening's program, "The Cultural Context," was to provide some background on cultural history as it relates to Glacier Bay, opening a window into the human context. In particular, this program provided an opportunity and forum for the people of Hoonah to express their concerns about Glacier Bay, their connections with it, and their goals as related to both science and management.

The evening's program began as Andrew Johnnie presented an interpretive history of the Tlingit retreat from Glacier Bay in the face of advancing ice. His purpose was not simply to entertain with a story as decoration, but to interpret and editorialize as to why the land has deep personal and religious significance to the Chookaneidi people. Next, Amy Marvin sang two songs of mourning for the land, village, and people covered by the ice. These songs are sung only on rare and very serious occasions. It was a major decision of the Chookaneidi tribe of Hoonah to share these songs and the story with the participants of the symposium. Their concern was to educate and explain how they feel about the land. The final comments were by Martha Davis, who spoke of her personal attachment to the land and the events in the song and history.

Richard Dauenhauer continued the evening program with a reading of poems from his *Glacier Bay Concerto* and other works. In these he reminded us of the fundamentally different ethical contexts different peoples view a place, in particular Glacier Bay. Robert Ackerman then spoke about the artifacts and remains of past peoples in the Icy Strait – Glacier Bay region. His slides and commentary about archeological investigations showed the long period of human involvement with Glacier Bay, and how much we have yet to learn about past cultures and their participation in the landscape.

The second of the Humanities Programs was Dave Bohn's presentation of readings and slides at the conclusion of the formal sessions of the symposium. Entitled "Space and Silence," it combined readings about the Ibachs' cabin at Reid Inlet and about the role and limitations of science in natural areas with a showing of 26 slides, presented in silence.

One reason for the Alaska Humanities Forum grants is to create involvement between academic people and the public in discussions of the values involved in economic, scientific, political, and public policy issues. Glacier Bay is one place where, in my experience, people do look at the effects of their actions, which, especially when it requires limits, is no easy task. The Humanities Forum's state theme, "Changing Alaska, Land and Community," is a description of the symposium and of Glacier Bay itself on the most literal and fundamental levels.

I once asked Nora Dauenhauer about the connection which the Tlingit people had with Glacier Bay. Her response was that she had never liked to hear people speak of the Tlingit connection with Glacier Bay in the past tense. The Tlingit connection is definitely both in the past and in the present. The presence of the humanities participants is part of a dream that a broad spectrum of individuals with concerns and interests about Glacier Bay might be able to explore common ideas and differences.

The following materials are excerpts from presentations by the humanities participants or comments about issues with which they are concerned. Some materials were presented in a different form at the symposium.

WHAT IS LEFT OF OUR HOME*

Andrew Johnnie
Chookaneidi Tribe
Hoonah, Alaska

"What we see is not what we are looking at. What people are looking at now is the present. What the three of us (Andrew Johnnie, Amy Marvin, Martha Davis) see is what is left of our home. That's past tense. What we see now is a drastic change. We also see a lot of growth all over since the days we stayed here."

"Talking in a past tense, when the glacier receded, everything was bare for a while, and vegetation started coming in. We have lost not only our home. We have lost our way of living, which we cannot get back because of the nature of this national park."

"Our request for the future is that we not be turned away when we come here for food."

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* On the last day of the Science Symposium, during the trip up Muir Inlet on the *Thunder Bay*, Andrew Johnnie made these comments for the *Proceedings*.

WILDERNESS AND ETHNICITY

Richard Dauenhauer
Sealaska Heritage Foundation

Wilderness and national parks are predominantly a White American (or European–American) interest. This is not to suggest that Native Americans lack a land ethic, or are not concerned with preserving land from destruction; rather, it is to suggest that their land ethic is different, for a number of reasons. The following are some ideas about how Native American and European–American world views differ on five interrelated points.

First of all, for the Tlingit people of Hoonah, Glacier Bay is home. Each of the Tlingit speakers at the Symposium stressed and repeated the theme of coming home. There is a strong sense of homeland, and exile. In a Biblical sense, the Tlingits are strangers in a land no longer theirs.

European–Americans seem to view the land differently. Wilderness and parks are an escape from home, primarily for urban dwellers who live elsewhere and who have no historical connection to the land. Glacier Bay is a place to be alone and independent. It is undeniable that most wilderness users have a strong desire to get "back to nature" —but my main point here is that this is a movement not toward, but away from home in a historical or geographical sense.

Sacred and Secular

For the Tlingit, there is a spiritual relationship to the land of Glacier Bay. Ancestors died here; their spirits live here. There is a link of past and present, cosmic and physical. There is a presence, a dependency. In a larger sense, this reflects a major difference between sacred and secular world views.

Western civilization has become increasingly secular over the last 500 years. American society is constitutionally structured as a secular society, reflecting enlightenment and industrial revolution intellectual history. In American and Canadian literature the land is, for white settlers, a land without myth, without legend, without a past. In short, it has no spiritual tradition.

Context

The Tlingit have a highly contextualized relationship to Glacier Bay. Glacier Bay is inseparable from the human events that happened there, and from traditional uses that remember and are sanctioned by the events of the past. Glacier Bay is home and a place of historical and religious significance. For the Tlingit, Glacier Bay is personalized and perhaps even personified. People relate to the land; it is full of spirits, and human behavior is dictated by rules of the sacred.

This is in sharp contrast to scientific interests, which are, by scientific tradition, highly decontextualized and generally are not concerned with human use.

Full–Empty

There is much philosophical debate over what qualifies land as wilderness. For most European–Americans, the bottom line seems to be emptiness. The land must be empty to be wild and therefore in a state of wilderness. If it is not empty, then it must be emptied. It must be withdrawn from use—decontextualized—to be looked at. This can easily become some kind of intellectual voyeurism based on detachment rather than attachment. For land to qualify as wilderness, people must be absent.

This is the opposite of the Tlingit views and relationships as noted above; that Glacier Bay is home, is full of spirits, and is used by living people who relate to each other, to the spirits, and to the land.

Kinship–Contract

This brings us to the last point. Tlingit society, like most Native American society, is based on kinship. In contrast, European–American society is based on contract—that is, on negotiated relationships characterized by a freer entry and exit. These patterns combine especially in Alaska, where, in contrast to Natives, most non–Natives were not born here, have few if any relatives here, and are often here on contracts for short periods of time. Most non–Native Alaskans note how a circle of friends (negotiated contracts) replaces the traditional family (kinship) at such traditional times as Thanksgiving.

Conclusion

I would like to conclude by stressing that the issue is not over respect or lack of respect for the land, but of conflicting attitudes and traditions toward respect for the land.

It is interesting to note how the conflicts within the European–American tradition come from the dichotomy between destruction or preservation; the "either/or" world view that dominates Western thinking. For many traditional peoples, for many of the reasons noted in this essay, there is yet another option that seems to find no place in the Western "either/or" dichotomy. This is an option of respectful use.

As with icons as visual religious art, the best option for preservation is neither to profane the icons nor to decontextualize them in museums out of touch, but to keep them in sacred use. Sacred use is perhaps the best way to describe the traditional land ethic of the Tlingit and other Alaska Native people.

PREHISTORIC OCCUPATION OF THE GLACIER BAY REGION

Robert E. Ackerman, Department of Anthropology
Washington State University

Within Glacier Bay National Park, glacial activity has destroyed all evidence of prehistoric occupations by aboriginal populations. Archeological surveys in the park provided evidence only of a late 19th to 20th century utilization. For a more extensive record, one needs to turn to areas outside the reach of the Holocene ice advances. Such a record is available in Icy Strait in Ground Hog Bay near Point Couverden. There the record extends backward in time for 9000 years. To put the site into a proper geological perspective, the temporal range must be extended to include those events at the end of the Wisconsin glacial epoch.

Geological data from Glacier Bay National Park, Lynn Canal, Icy Strait and other locations in southeastern Alaska indicate that deglaciation began about 14,000 years ago. At this time the land was depressed 100–150 meters below present shoreline positions. With the release of the pressure of ice loading, the land in Icy Strait rose at a rapid rate until 11,500–11,000 years ago when a late Wisconsin glacial advance from Glacier Bay and Excursion Inlet again depressed the land.

Somewhat before the marine transgression, a deposit of till was laid down on the 13–meter terrace (terrace III) at Ground Hog Bay near Point Couverden in Icy Strait. Over the till, gravels and cobbles were left as an ancient beach deposit. Associated with this beach we found microblade cores and microblades, macroblade cores and macroblades, choppers, scrapers, a few bifacial point fragments, pounding stones, and fire–reddened rocks. Materials used were argillite and esite, a local rock, and exotics like chert, quartz crystal, and obsidian. The source for the obsidian was Mt. Edziza on the upper Stikine River, roughly 300 miles from Icy Strait, indicating a trade in obsidian 9000 years ago.

The land continued to rise. The forward part of terrace III at Ground Hog Bay probably sloped gradually to the modern beach with the water near its present level. Between 9000 and 5000 years ago, a marine transgression cut into terrace III, destroyed the forward part of the site associated with the early occupation, and created terrace II. Occupation continued on terrace III, marked by a similar inventory to the early occupation, until approximately 4000 years ago.

Early neoglacial advances began about 3500 years ago. This cold period lasted until about 1000 years ago. On terrace III in Ground Hog Bay, a thick layer of humus accumulated during the period 4000–1500 years ago. During this period of forest development the site was abandoned. Ice from Glacier Bay undoubtedly entered Icy Strait in massive quantities, making the region perilous to navigation. Terrace Ib was formed during this time as a result of the ice loading.

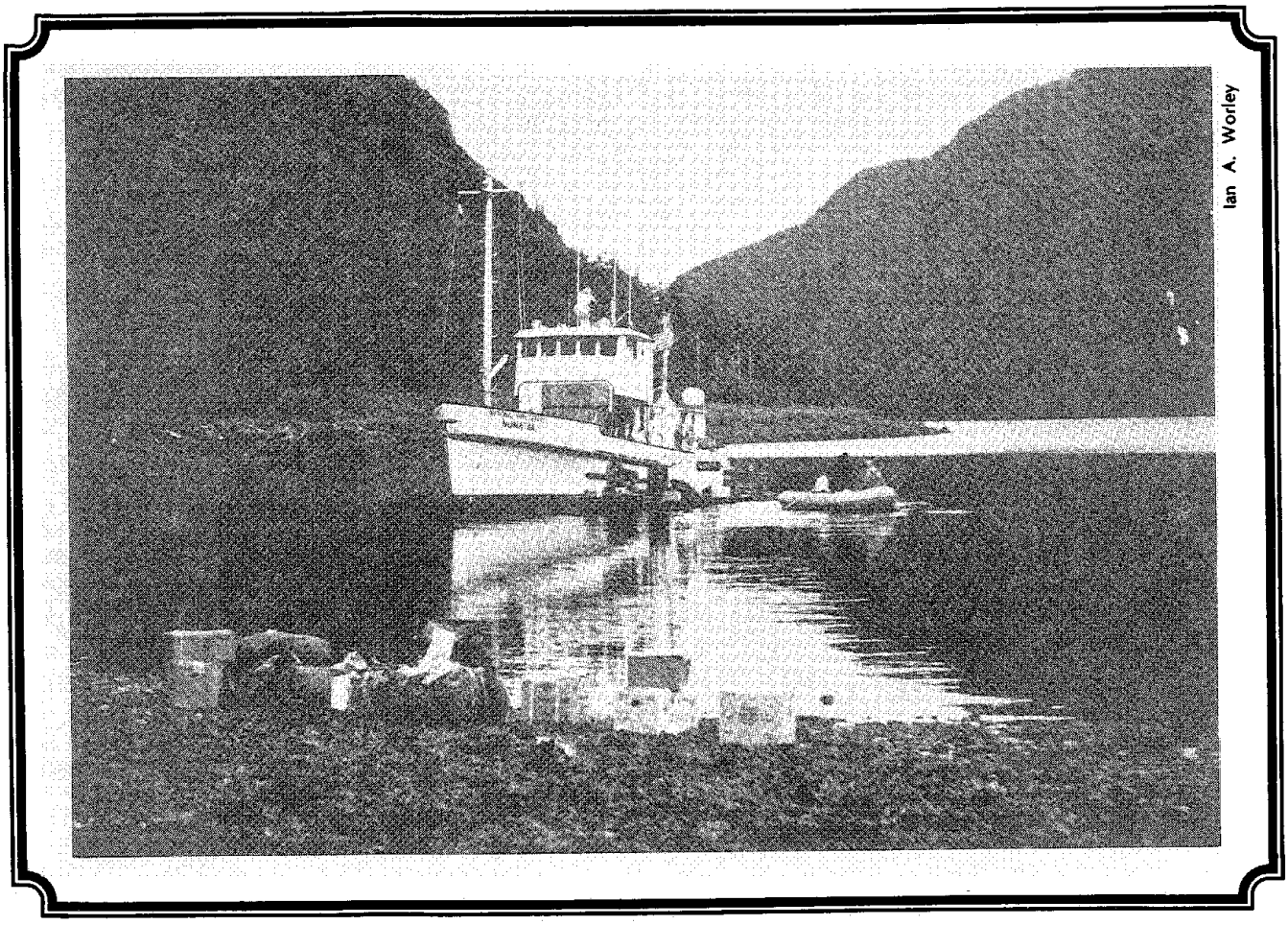
By 1000 years ago the climate had improved. This warm phase lasted to about 600 years ago. Between 900 and 450 years ago the site was reoccupied by a people that built plank houses, used ground stone tools, and made a variety of decorative designs that we associate with the Tlingit Indians of the region. A recognizable Northwest Coast cultural pattern is evident.

A final transgression of the sea, associated with glacial advances in Glacier Bay, began 500–400 years ago. Terrace Ia was formed during this period and forms the modern high beach fronting the site in Ground Hog Bay. With the onset of "Little Ice Age" conditions, the site was possibly abandoned and not reoccupied until later in the 18th or 19th centuries.

SCIENCE AS A SPECIAL INTEREST

Dave Bohn, Photographer–Journalist
Glacier Bay: The Land and the Silence

I have this concern, dating back almost twenty years now, over the fact (as I see it) that special interest groups will ultimately manage to destroy the wilderness values of all the wilderness parks, by applying, in each case, the rationalizations for more and more visitation, thence leading to devastating over–use. In other words, when self–interest becomes manifest, which does not take very long, restraint becomes non–existent, and the fact that the preservation of the Glacier Bay (or any other) wilderness system as a philosophical concept is forgotten. Thus, since scientific endeavor is a special interest, scientists need to be just as careful as anyone else not to make the rationalizations which will lead to over–use of our great natural areas.



Ian A. Worley

RECOMMENDATIONS

RECOMMENDATIONS

GENERAL RECOMMENDATIONS OF THE SCIENCE PANELS

The scientists currently studying natural phenomena in Glacier Bay National Park and Preserve (GBNPP) gratefully acknowledge the National Park Service support for and cooperation with past and present studies. These studies fit in with one of the original purposes behind the creation of Glacier Bay National Monument many years ago, namely the use of the area for scientific work.

We thank the National Park Service for their essential help as we work together in fulfillment of that purpose. We offer the following suggestions in the spirit of that cooperation and with the hope that further mutual commitments will enhance both the science done in the Park and Preserve and the interpretation and management of the Park and Preserve by the Park Service.

Many recommendations were shared by all the panels. These recommendations fall generally into five groups: (a) plans for a second symposium, (b) general conceptual frameworks for future research in all disciplines, (c) scientific volunteers, staff, and board, (d) facilities and support, and (e) catastrophic and short-lived phenomena. Note that some recommendations incorporate items already in place or proposed for GBNPP.

IT IS RECOMMENDED THAT:

A–1 the second Glacier Bay Science Symposium be scheduled tentatively for Fall 1988;

* * *

B–1 those features unique to GBNPP be more clearly identified;

B–2 there be produced more studies that are integrated among disciplines;

B–3 the scientific community, through the design of its studies, be more prepared to predict human impacts and to record human disturbances in GBNPP:

B–4 a general document be prepared for scientists, especially those new to GBNPP, that gives guidelines for research conduct in the Park and Preserve;

* * *

C–1 GBNPP identify and organize local residents wishing to voluntarily assist research projects, especially those requiring long-term data collection;

C–2 for the next year GBNPP and Friends of Glacier Bay mutually sponsor a "Science Board" made up of researchers active at GBNPP and representing the general fields of (a) geology, glacial activity, climatology/meteorology, (b) marine

ecosystems, (c) terrestrial ecosystems, and (d) sociology, anthropology, and archeology; this board to provide counsel and suggestions on scientific matters as needed, including but not restricted to:

(i) recommendations for future research,
(ii) review of science-related documents,
(iii) review, with authors' permission, research proposals,
(iv) input, as requested, on management-related topics,
(v) review of scientific impacts in the Park and Preserve,
(vi) assisting GBNPP interpreters in making the best use of scientific information;

the current board to consist of the Glacier Bay Science Symposium Science Panel chairpersons, one additional member from each panel, and two scientists from sociology/anthropology/archeology, with a chairperson chosen from among the board members; and both the concept and current board to be re-evaluated in Fall 1984;

C-3 GBNPP provide technical assistance in long-term research projects requiring repeated data collection -- this might be accomplished by NPS staff and/or volunteers and may require the addition of a part or full-time staff member;

C-4 in addition to the position of resource management specialist, GBNPP add to its staff a professional scientist who

(i) would, when appropriate, represent GBNPP as a professional scientist,
(ii) would be able to readily communicate scientific knowledge among researchers,
(iii) would have an intimate knowledge of GBNPP and thus could provide background and specific help to researchers, as well as work with researchers in the generation of ideas,
(iv) would be able to observe variation in GBNPP through all seasons and through several years,
(v) would be able to conduct significant small or timely researches in GBNPP as needed;

* * *

D-1 GBNPP provide spartan living and food preparation facilities for approximately 8-10 persons at Bartlett Cove for use by transient and visiting scientists;

D-2 GBNPP acquire, equip, maintain, place in position, and schedule the use of one or more "research barges" for the support of scientists in the Park and Preserve, and that related logistical support include a pool of kayaks, skiffs, and outboard motors (researchers are encouraged to contribute to this pool by incorporating such items in grant proposals and lending items to the pool between periods of field work);

D-3 GBNPP maintain their strong logistical support of scientific field parties with the MV *Nunatak*;

D–4 GBNPP expand the current library holdings and functions to make it into the Glacier Bay research library, including the curating of aerial photography, other imagery, herbarium specimens, and faunal collections; the library retain, as well, its usefulness to interpreters and visitors; and there be the distribution of acquisition lists at regular intervals;

D–5 GBNPP provide a simple storage facility where field gear and equipment can be stored between periods of field work;

D–6 GBNPP provide a small laboratory space (e.g. a big room with tables, benches, water) with a few general use items such as a dissection microscope;

D–7 GBNPP make available an annually updated list of current research projects, active researches, and annual research reports; and

* * *

E–1 GBNPP prepare, and be ready to execute, plans to rapidly mobilize observers/photographers/researchers to immediately visit any areas in the Park and Preserve where "catastrophic" or otherwise significant short–lived phenomena have occurred.

RECOMMENDATIONS OF THE GEOLOGY, GLACIAL ACTIVITY, AND CLIMATOLOGY PANEL

Note: Recommendations 1 and 2 are offered jointly with the Terrestrial Ecosystems Panel; Recommendation 3 is offered jointly with the Marine and Aquatic Ecosystems Panel.

1. GBNPP should take on the long–range commitment of establishing, maintaining, recording, and preserving the results of a broad fundamental climatologic/meterologic program. The design of the program should involve scientists, both biological and physical, concerned with and knowledgeable about such programs.

2. GBNPP (using the most efficient and least expensive means) should acquire at two–to five–year intervals, and care for, state–of–the–art aerial photography and/or other imagery of the Park and Preserve; the choice of materials to be made with the advice of the Science Board, incorporating input of both biological and physical scientists.

3. GBNPP should contact the National Oceanic and Atmospheric Administration (NOAA) to determine planned and potential physical oceanographic surveys in Glacier Bay. GBNPP should actively solicit a physical oceanographer from either a government agency or academia to participate in research based on those surveys.

4. GBNPP should continue and expand its efforts to reoccupy, on an annual basis, the photographic stations established by W. O. Field for glacier monitoring studies.

5. In order to further integrated and synergistic studies of natural phenomena, scientists should consider focusing their efforts and resources, insofar as practical and scientifically advisable, on a restricted number of areas in GBNPP, with those areas being selected to answer these critical questions:

   a. Can the glacial accumulation/ablation/runoff pattern in space and time be determined for this area and related to the results of studies in south–central Alaska and Washington?

   b. What controls the rate of advance of a calving glacier?

   c. What general conclusions about climate variations can be drawn from the Holocene to present–day fluctuations of glaciers?

   d. What determines regional air flow and what influences do fiords have on that flow?

   e. What is the interaction of saline oceanic water with freshwater from glaciers and other runoff? What thermal control is exerted by water surface on surface inversions?

   f. What was the cause of the Neoglacial advance?

   g. What controls the non–tidewater glaciers on the Outer Coast?

   h. What are the main processes and the rates of those processes involved in glacial and glacially–related transport and deposition on land?

   i. What are the most important mechanisms, rates, and patterns of sediment discharge?

   j. What are the relations between glacial dynamics and sedimentary facies patterns on land?

   k. What are the main processes and the rates of those processes involved in glacial and glacially–related transport and deposition in the marine environment, including consideration of: (1) factors controlling ice advance; (2) relative rates of sedimentation and variations in water physics and chemistry away from glacier termini; (3) sediment discharge and underflow from sub–glacial streams; and (4) origin patterns and dispersal of tidally influenced sediment plumes?

   l. What are the sedimentation rates throughout the whole Bay system?

   m. What are the relations between glacial dynamics and sedimentary facies patterns in the marine environment, including consideration of (1) deltaic deposition; (2) subaquatic mass movements; and (3) construction of comprehensive systems models, including the above considerations?

   For each of the above questions we have sketched out: (1) possible approaches to the question; (2) criteria for selection of field sites; and (3) the likely interdisciplinary implications.

6. GBNPP, concerned scientists, and the Friends of Glacier Bay should anticipate the acquisition of now non-existent bedrock information, through low impact, single pass bedrock geologic mapping, pertaining to the following geologic problems that can be studied only here: (1) mineralogy and petrology of the LaPerouse-Crillon layered gabbro complex; (2) structure and stratigraphy of the Tarr Inlet suture zone; (3) facies relations in Paleozoic rocks east of the Bay: and (4) first-level geologic information for the Preserve part of GBNPP.

RECOMMENDATIONS OF THE TERRESTRIAL ECOSYSTEMS PANEL

These recommendations acknowledge the significant opportunity to do long-term ecological research at GBNPP. Three topics are prominent: (1) succession (ecosystem development), most particularly post-glacier primary succession, but also succession associated with periglacial phenomena, tectonism, and great waves; (2) past ecosystems and environments spanning periods with several orders of magnitude (from the decades of Glacier Bay to the tens and hundreds of millenia along the Outer Coast); and (3) biologic insularity, corridors, and refugia. Succession dominates the recommendations, a fact which reflects the infancy of research on topics 2 and 3.

The rapid deglaciation at Glacier Bay, along with the many decades of nearly continuous research, make it one of the most valuable primary succession study sites in the world. The sediments, geomorphology, and geology of the Outer Coast are just emerging as a most important reservoir of North American ecological history.

Input to these recommendations was also given by Dan Mann, Gary Vequist, and Lars Walker. The panel felt that paleoecology, groundwater hydrology, and stream, lake, and wetland ecology should have been represented on the panel and strongly recommends they be appropriately represented on the Science Board.

Recommendations 6 and 7 are offered jointly with the Geology, Glacial Activity, and Climatology Panel.

WE RECOMMEND THAT:

1. research at GBNPP include basic science research, especially where GBNPP offers unique settings for the testing of fundamental hypotheses;

2. research at GBNPP be useful for the interpretive, nature protection, management and policy needs of the Park Service;

3. research at GBNPP provide a more uniform understanding of ecosystems throughout the entire Park and Preserve;

4. research at GBNPP include more interdisciplinary integration and systems orientation;

5. there be prepared, within the next 5 years or so, a new natural history of the entire Park and Preserve (e.g., The Natural History of Glacier Bay National Monument, Alaska by G. Streveler and B. Paige, 1971);

6. GBNPP take on the long-range commitment of establishing, maintaining, recording, and preserving the results of a broad, fundamental climatological/meteorological program. The design of the program should involve scientists, both biological and physical, concerning with and knowledgeable about such programs;

7. GBNPP (using the most efficient and least expensive means) acquire at two-to five-year intervals, and care for, state-of-the-art aerial photography and/or other imagery of the Park and Preserve; the choice of materials to be made with the advice of the Science Board, incorporating input of both biological and physical sciences;

8. GBNPP prepare documents for scientists, concessioners, boaters, campers, and other visitors giving guidelines for their activities in the Park and Preserve, emphasizing the protection of natural conditions and, as need be, care not to disturb scientific research or management activities; these materials could be modeled after documents already in existence in Minnesota (and likely elsewhere);

9. NPS request the U.S. Geological Survey (USGS) to produce a single topographic sheet of GBNPP, and there be prepared a base map of vegetation types (or some form of ecological land classification units) for the entire Park and Preserve, noting especially terrain age and type, and geomorphic/geologic dynamism; previous vegetation types, where known, could be depicted in overlays or other formats;

10. the diversity of vegetation types in the Park and Preserve be detailed sufficiently to expand and update, as appropriate, the Classification System for Vegetation of Alaska (Viereck and Dyrness 1980);

11. ecosystem impact studies include both experimentation and research on analogous situations outside the Park and Preserve;

12. ecosystem development (succession) continue to have a high research priority; in particular that:

    12a. fundamental hypotheses, especially with respect to primary succession, be richly investigated, with special emphasis on the nitrogen and other nutrient economy;

    12b. the vegetation charting and photography at the W. S. Cooper and D. B. Lawrence permanent primary succession plots be continued;

    12c. the Cooper-Lawrence permanent plot research be expanded to determine to what degree the data from the plots can be generalized;

    12d. permanent plots be established in other successional settings, particularly at wet locations and at alpine elevations;

    12e. there be a major study of organic productivity during succession--i.e., what are the rates of photosynthesis and the fates of the products of production during all stages of ecosystem development; the study should include trophic and decomposer activities, organic accumulation in and on soils, pathogens, and physical disturbances;

12f. successional researches utilize models incorporating stochastic processes, competitive (and related) interactions, life history traits, transplantation and dispersability experiments, and colonizer sources, abundances, and periodicity;

12g. ecosystem development, especially in deglaciated terrain, be examined to determine spatial and temporal variation, as well as the nature (or absence) of "stages"; the study to consider factors such as:

(i) climatic variation in the Park and Preserve;
(ii) substrate type, including geological, geomorphological, edaphic, and hydrological character;
(iii) altitude, relief, topography, aspect, exposure, etc.; and
(iv) availability of immigrants, diaspores, etc., for colonization;

and such a study to compare:

(i) primary and secondary succession;
(ii) succession at the Outer Coast, the West Arm of Glacier Bay, Muir Inlet, and Lower Glacier Bay; and
(iii) succession with increasing latitude (down–Bay to up–Bay; Icy Point to Dry Bay);

12h. establishment factors for significant organisms (e.g., alder, spruce, cottonwood, moose, wolf, earthworms, etc.) be determined;

12i. succession studies incorporate a wider array of organisms, particularly vertebrate and invertebrate fauna and non–vascular plants, especially the algae, fungi, bacteria, lichens, protonematal stages of mosses and hepatics, and gametophytic stages of ferns and fern allies;

12j. research strive to determine the initiation processes for muskeg and other wetland types;

12k. effects of aquatic and wetland systems (e.g. via salmon, black flies, water tables, etc.) upon terrestrial systems be explored; and

12l. research be conducted to determine the impacts of treading, camping, boat and kayak haulouts, introduction of exotic organisms, etc., upon various successional ecosystems.

In addition to the preceding recommendations, the panel draws particular attention to those topics about which little is known in the Park and Preserve: alpine ecosystems, pond and lake ecosystems, algae, productivity (for all terrestrial, aquatic, and marine ecosystems), invertebrates, decomposers, herbivores (including insects), pollinators, non–vascular plant communities, salt spray effects, and atmospheric pollutants. Likewise, especially deserving of continued research are these topics: mammal distributions, migrations, and responses to human disturbances; small mammal ecology; and pre–Holocene landscape development and ecology as preserved along the Outer Coast.

RECOMMENDATIONS OF THE MARINE AND AQUATIC ECOSYSTEMS PANEL

The following recommendations on future research were made by individual members of the panel:

1. When possible, more integrated studies should be encouraged. For example, specific areas of integration might include: (a) effects of sedimentation and freshwater runoff on marine benthic and pelagic communities; (b) watershed nutrient dynamics and stream productivity.

2. Large scale surveys should (a) establish complete species lists; (b) define present species ranges; and (c) map common habitat types.

3. Long-term monitoring of physical parameters (e.g., water chemistry, temperature, sediment load) should be attempted in both marine and aquatic systems. Monitoring stations must be replicated in order to sort out high site-to-site variability.

4. Studies on succession (marine and aquatic) should be strongly encouraged inasmuch as they may provide a unique focus in a glacially dynamic ecosystem.

5. The long-term monitoring of larval recruitment and adult populations of intertidal invertebrates should be continued on the Outer Coast and should be initiated on the shores of the Bay proper.

6. Monitoring of marine secondary productivity should be continued through the use of hydroacoustic measurements of standing stock. Particular attention should be given to areas of known marine mammal feeding activity.

7. Basic oceanographic (physical and chemical) data must be obtained.

8. Marine primary productivity within Glacier Bay should be examined with particular regard to the relative contribution of benthic macroalgae and phytoplankton to secondary productivity. Stable carbon isotope analyses might be an appropriate method for such an examination.

9. The repopulation of coastal areas by sea otters should be followed closely. Otter populations should be censused yearly, and, if possible, feeding observations made.

10. GBNPP should contact the National Oceanic and Atmospheric Administration (NOAA) to determine planned and potential physical oceanographic surveys in Glacier Bay. GBNPP should actively solicit a physical oceanographer from either a government agency or academia to participate in research based on those surveys. (This recommendation is offered jointly with the Geology, Glacial Activity, and Climatology Panel.)

RECOMMENDATIONS OF THE RESOURCE MANAGEMENT PANEL

1. Scientists should identify the key marine and terrestrial ecosystem components and processes that need further study. A prioritized list would allow for better allocation of Park Service assistance and support.

2. Specific monitoring procedures need to be developed that can systematically and efficiently monitor year-to-year changes in wildlife populations, plant communities, and environmental characteristics.

3. Research needs to be initiated that would help management establish a carrying capacity for backcountry sites. Backcountry use will be dispersed to locations less susceptible to human disturbance. Extremely sensitive plant communities and wildlife habitats need to be identified so that public use could be restricted during critical times.

4. Scientific use guidelines should be revised for Glacier Bay. Specific criteria should be developed for the use of helicopters, research camps, party size, permanent markers, collecting, and tagging. It is important to consider that most research will be occurring in wilderness areas.

5. Logistic support should be provided to approved research activities (see the General Recommendations).

6. Various park locations should be evaluated to determine a suitable site for detailed integrated ecological research. Independently funded research activities should continue to be encouraged and assisted.

7. Long-term monitoring of plant community and glacier changes within Glacier Bay should continue. Identification of other long-range research is needed, such as the establishment of meteorological stations.

8. The Park Resource Management Plan should be distributed to scientists, including Science Board members, for review of scientific accuracy of resource statements.

RECOMMENDATIONS FROM THE HUMANITIES PROGRAMS

General Recommendations

1. Disciplines of the humanities should be represented on the Science Board.

2. In view of the success of the Science Symposium, a humanities symposium concerned with Glacier Bay should be held before the next science symposium convenes. In this way the opportunity will exist at the next science symposium for equivalent discussions between representatives of the humanities and the natural sciences.

Recommendations from Robert Ackerman

Research is needed on man's past role in altering terrestrial and marine biomes. It is relatively easy to see changes in natural systems made by agriculturalists, pastoralists, and members of industrial nations. Man's role as a high trophic-level predatory consumer, more difficult to assess, could be tested through midden excavations, correlating archaeological sites, historic villages, and hunting and fishing camps with the presence/absence of animal and plant populations. Such data could be important in determining predation carrying capacity of natural populations. This topic could well be explored with the Hoonah Tlingit peoples.

* * *

POSTSCRIPT

Perhaps the real essence of the First Glacier Bay Science Symposium extended beyond the usual scientific objectivities and quantifications. Indeed, the prevailing mood of the gathering--among scientists and laypersons alike--was marked by a deep-seated, mutual concern about the proper relationship of science to the fundamental values of Glacier Bay *the place* and Glacier Bay *the Park and Preserve*. What is so special about the land and water and life of Glacier Bay? What is and should be the character of Glacier Bay National Park and Preserve? What role does science have here?

The symposium sharply focused on these questions during considerations about acceptable scientific activities in wilderness, whether designated or perceived. All the panels and evening programs discussed the relation of science and wilderness; Sunday evening's program centered on it; participants grappled with it at breakfast, lunch and dinner. The *Thunder Bay* trip through the tide rips of Glacier Bay, past the mountain goats on the sheer cliffs of snowy Mount Wright, to the face of the Muir Glacier confronted the participants with the stark reality of an essentially pristine yet vulnerable environment, in which science has so prominent a part.

Questions about fundamental values are seldom easily answered. The task is no easier when such a magnificent part of the nation's natural heritage is involved. But to protect this great land -- Glacier Bay, the bearer of many values -- answers must be found. Most answers lay beyond the symposium, but the seriousness of the dialogue and the recommendations calling for the development of ethical principles ensure that they will indeed be sought and, by virtue of their need, be found.

If those attending the symposium were representative of contemporary Glacier Bay scientists, the Glacier Bay tradition of careful observers treading softly on the landscape and in the waters they study will continue. That tradition, first established by John Muir a little over a century ago, must endure if we are to achieve our hopes and aspirations for the advancement of wisdom at Glacier Bay. We too must leave a legacy of caring.

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GLACIER BAY NATIONAL PARK & PRESERVE

UNITED STATES DEPARTMENT OF THE INTERIOR

NATIONAL PARK SERVICE

North

0 1 5 10 15 Kilometers

0 1 5 10 15 Miles

Glacier Bay National Park

Trail

1564 5128 Elevations are shown in meters, with feet in *Italics*

YAKUTAT GLACIER

NOVATAK GLACIER

ST. ELIAS RANGE

BRITISH COLUMBIA

ALASKA

MELBURN GLACIER

ST. ELIAS MOUNTAINS

ALSEK RANGE

GRAND PACIFIC GLACIER

CANADA

UNITED STATES

TAKHINSHA MOUNTAINS

LYNN CANAL

Dry Bay

Mt. Logan 33,19 18,523

Mt. Root 3953 12,960

Mt. Fairweather 15,300

Mt. Quincy Adams 4181 13,730

Cape Fairweather

FAIRWEATHER RANGE

NATIONAL PARK

BRADY ICEFIELD

Lituya Bay

Cenotaph Island

Mt. Lamplugh 3870 12,726

Mt. Salisbury 3368 11,050

Mt. Crillon 3879 12,726

Mt. Abbot 3572 11,720

Mt. Bertha 3040 10,000

Mt. Lituya 3147 10,320

Mt. Lamplugh 3870 10,729

BRADY GLACIER

Icy Point

Palma Bay

Dixon Harbor

Point Carolus

Grand Plateau Glacier

Carroll Glacier

Margerie Glacier

Grand Pacific Glacier

Johns Hopkins Glacier

Lamplugh Glacier

Reid Glacier

Lituya Glacier

Klotz Glacier

Gilman Glacier

Geikie Inlet

Wachusett Inlet

Tarr Inlet

Muir Inlet

Hugh Miller Inlet

Sturgis Island

Sturgis Mouse Island

Sturgis Inlet

Geikie Inlet

Scidmore Bay

Sandy Cove

NORTH MARBLE ISLAND

SOUTH MARBLE ISLAND

DRAKE ISLAND

FRANCIS ISLAND

WILLOUGHBY ISLAND

BEARDSLEE ISLANDS

Bartlett Cove

Glacier Bay Lodge

Visitor Information Services

Campground

Bartlett Cove Dock

Glacier Bay Airport

1750-1760

Gustavus

Excursion Inlet

GLACIER BAY

Gloomy Knob 3290

Dundas Bay

North Passage

South Passage

INIAN ISLANDS

ICY STRAIT

TAYLOR BAY

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Sandy Cove

NORTH MARBLE ISLAND

SOUTH MARBLE ISLAND

DRAKE ISLAND

FRANCIS ISLAND

WILLOUGHBY ISLAND

BEARDSLEE ISLANDS

Bartlett Cove

Glacier Bay Lodge

Visitor Information Services

Campground

Bartlett Cove Dock

Glacier Bay Airport

1750-1760

Gustavus

Excursion Inlet

GLACIER BAY

Gloomy Knob 3290

Dundas Bay

North Passage

South Passage

INIAN ISLANDS

ICY STRAIT

TAYLOR BAY

Cape Spencer

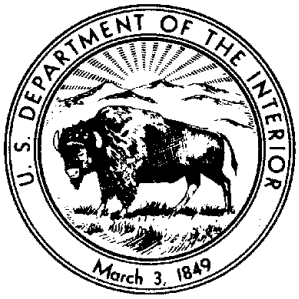
CROSS SOUND

CHICHAGOF ISLAND

GULF OF ALASKA

PACIFIC OCEAN

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE



As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.